Atlantic States Marine Fisheries Commission

Atlantic Herring Management Board

October 16, 2023
9:00 – 9:30 a.m.
Hybrid Meeting

Draft Agenda

The times listed are approximate; the order in which these items will be taken is subject to change; other items may be added as necessary.

1.	Welcome/Call to Order *(M. Ware)*	9:00 a.m.
2.	Board Consent • Approval of Agenda • Approval of Proceedings from January 2023	9:00 a.m.
3.	Public Comment	9:05 a.m.
4.	Set Quota Periods for the 2024 Area 1A Fishery *(C. Starks)* **Final Action**	9:15 a.m.
5.	Update from the New England Fishery Management Council *(J. Cournane)*	9:20 a.m.
6.	Elect Vice-Chair **Action**	9:25 a.m.
7.	Other Business/Adjourn	9:30 a.m.

The meeting will be held at Beaufort Hotel (2440 Lennoxville Road, Beaufort, North Carolina; 252.728.3000) and via webinar; click here for details

MEETING OVERVIEW

Atlantic Herring Management Board
October 16, 2023
9:00 – 9:30 a.m.
Hybrid Meeting

Chair: Megan Ware Assumed Chairmanship: 08/22	Technical Committee Chair: Vacant	Law Enforcement Committee Representative: Delayne Brown (NH)
Vice Chair: Vacant	Advisory Panel Chair: Jeff Kaelin (NJ)	Previous Board Meeting: January 31, 2023
Voting Members: ME, NH, MA, RI, CT, NY, NJ, NMFS, USFWS (9 votes)		

2. Board Consent

- Approval of Agenda
- Approval of Proceedings from January 2023

3. Public Comment – At the beginning of the meeting public comment will be taken on items not on the agenda. Individuals that wish to speak at this time must sign-in at the beginning of the meeting. For agenda items that have already gone out for public hearing and/or have had a public comment period that has closed, the Board Chair may determine that additional public comment will not provide additional information. In this circumstance the Chair will not allow additional public comment on an issue. For agenda items that the public has not had a chance to provide input, the Board Chair may allow limited opportunity for comment. The Board Chair has the discretion to limit the number of speakers and/or the length of each comment.

4. Set Quota Period for the 2024 Area 1A Fishery (9:15-9:20 a.m.) Final Action
Background • Per Amendment 3 (section 4.2.3), quota periods shall be determined annually for Area 1A using bi-monthly, trimester, or seasonal quota periods. • For the current 2023 fishing year for Area 1A, the Board adopted a seasonal quota approach with 72.8% available June-September, and 27.2% available October-December. • The 2024 Atlantic herring ABC is 23,409 MT, the ACL is 19,189 M and the sub-ACL for Area 1A is 5,546 MT. This could be adjusted based on any quota overages in 2023.
Presentations • Overview of Amendment 3 quota period system by C. Starks
Board actions for consideration at this meeting • Set quota periods for the 2024 Area 1A fishery.

5. Update from New England Fishery Management Council (9:20-9:25 a.m.)
Background • Update on New England Fishery Management Council action and activity on Atlantic herring **(Briefing Materials).**

Presentations

- NEFMC update by J. Cournane

6. Elect Vice Chair

7. Other Business/Adjourn

Atlantic Herring Technical Committee Task List

Activity Level: Medium

Committee Overlap Score: Medium

Committee Task List
While there are no Board tasks for the TC at present, there are several annual activities in which TC members participate, both through the Commission and NEFMC • Participation on ASMFC PRT/PDT • Participation on NEFMC PDT • Summer/fall collection of spawning samples per the spawning closure protocol • Annual state compliance reports are due February 1

TC Members
Matt Cieri (ME DMR), Micah Dean (MA DMF), JA Macfarlan (RI DEM), Kurt Gottschall (CT DMF), Rich Pendleton (NY DEC), Matthew Heyl (NJ DEP), Jamie Cournane (NEFMC), Jonathan Deroba (NOAA NEFSC), Carrie Nordeen (NOAA)

DRAFT PROCEEDINGS OF THE

ATLANTIC STATES MARINE FISHERIES COMMISSION

ATLANTIC HERRING MANAGEMENT BOARD

The Westin Crystal City
Arlington, Virginia
Hybrid Meeting

January 31, 2023

These minutes are draft and subject to approval by the Atlantic Herring Management Board.
The Board will review the minutes during its next meeting.

TABLE OF CONTENTS

INDEX OF MOTIONS

1. **Move to approve agenda** by Consent (Page 1).

2. **Move to approve proceedings of November 7, 2022** by Consent (Page 1).

3. **Move to adopt the following specifications for the 2023-2025 fishing years for Atlantic herring as recommended by the New England Fishery Management Council, contingent on the final rule being published by NOAA Fisheries** (Page 3):

   For 2023
   • Annual Catch Limit (ACL) = 12,429 mt
   • Domestic Annual Harvest = 12,429 mt
   • Area 1A Sub-ACL = 3,592 mt
   • Area 1B Sub-ACL = 534 mt
   • Area 2 Sub-ACL = 3,455 mt
   • Area 3 Sub-ACL = 4,847 mt

   For 2024
   • Annual Catch Limit (ACL) = 19,189 mt
   • Domestic Annual Harvest = 19,189 mt
   • Area 1A Sub-ACL = 5,546 mt
   • Area 1B Sub-ACL = 825 mt
   • Area 2 Sub-ACL = 5,335 mt
   • Area 3 Sub-ACL = 7,484 mt

   For 2025
   • Annual Catch Limit (ACL) = 23,961 mt
   • Domestic Annual Harvest = 23,961 mt
   • Area 1A Sub-ACL = 6,925 mt for 2025
   • Area 1B Sub-ACL = 1,030 mt for 2025
   • Area 2 Sub-ACL = 6,661 mt for 2025
   • Area 3 Sub-ACL = 9,345 mt

   for 2025 For all three years:
   • Border Transfer = 0 mt each year
   • Fixed Gear Set-Aside= 30 mt each year
   • Research Set-Aside as % of Sub-ACLs= 0% each year

   Motion by Melanie Griffin; second by Eric Reid. Motion carried by unanimous consent (Page 3).

4. **Motion to adjourn** by Consent (Page 3).

ATTENDANCE

Board Members

Megan Ware, ME, proxy for P. Keliher (AA)
Steve Train, ME (GA)
Rep. Allison Hepler, ME (LA)
Renee Zobel, NH, proxy for C. Patterson (AA)
Doug Grout, NH (GA)
Dennis Abbott, NH, proxy for Sen. Watters (LA)
Melanie Griffin, MA, proxy for D. McKiernan (AA)
Raymond Kane, MA (GA)
Rep. Sarah Peake, MA (LA)
Conor McManus, RI, proxy for J. McNamee (AA)
David Borden, RI (GA)
Eric Reid, RI, proxy for Sen. Sosnowski (LA)
Justin Davis, CT (AA)
Bill Hyatt, CT (GA)
John Maniscalco, NY, proxy for B. Seggos (AA)
Emerson Hasbrouck, NY (GA)
Joe Cimino, NJ (AA)
Peter Clarke, NJ, proxy for T. Fote (GA)
Adam Nowalsky, NJ, proxy for Sen. Gopal (LA)
Carrie Nordeen, NMFS, proxy for Allison Murphy

(AA = Administrative Appointee; GA = Governor Appointee; LA = Legislative Appointee)

Ex-Officio Members

Renee Zobel, Technical Committee Chair
Jeff Kaelin, Advisory Panel Chair
Delayne Brown, Law Enforcement Representative

Staff

Robert Beal
Toni Kerns
Madeline Musante
Tina Berger
Kristen Anstead
Tracey Bauer
Emilie Franke

Guests

Pat Augustine, Coram, NY
Colleen Bouffard, CT DEEP
Jeff Brust, NJ DEP
Matt Cieri, ME DMR
Heather Corbett, NJ DEP
Jamie Cournane, NEFMC
Sam Duggan, NOAA
Glen Fernandes
Lauren Gaches, NOAA
Jared Flowers, GA DNR
Amalia Harrington, Univ. Maine
Heidi Henninger, AOLA
Jay Hermsen, NOAA
Jaclyn Higgins, TRCP
Pat Keliher, ME (AA)
Chip Lynch, NOAA
Jerry Mannen, NC (GA)
Sean McNally, NOAA
Jason McNamee, RI (AA)
Steve Meyers
Jeff Nichols, ME DMR
Will Poston, SGA
Rebecca Quinones MA DMF
Sam Rauch, NOAA
Gray Redding, NFWF
Mike Ruccio, NOAA
Tony Sarcoma
Erin Schletter, NOAA
David Stormer, DE DFW
ElizaBeth Streifeneder, NYS DEC
Kevin Sullivan, NH F&G
Maureen Trnka, NOAA
Jesica Waller, ME DMR

The Atlantic Herring Management Board of the Atlantic States Marine Fisheries Commission convened in the Jefferson Ballroom of the Westin Crystal City Hotel, Arlington, Virginia, via hybrid meeting, in-person and webinar; Tuesday, January 31, 2023, and was called to order at 9:30 a.m. by Chair Megan Ware.

CALL TO ORDER

CHAIR MEGAN WARE: Good morning, everyone. We are going to call the Herring Management Board to order this morning.

APPROVAL OF AGENDA

CHAIR WARE: Our first item on the agenda is Approval of the Agenda. Are there any additions or modifications to the agenda this morning? Seeing none; the agenda is approved by consent.

APPROVAL OF PROCEEDINGS

CHAIR WARE: Our next item of business is approval of the proceedings from November 2022. Are there any edits to those proceedings?

Seeing none; those proceedings are approved by consent.

PUBLIC COMMENT

CHAIR WARE: Next item of business is Public Comment. This is for topics that are not on the agenda, and I will give a minute to look for any raised hands here in the room or the webinar for Public Comment. All right, seeing none we will move along.

SET SPECIFICATIONS FOR THE 2023 TO 2025 FISHING YEARS

CHAIR WARE: Our primary objective today is to set specifications for the 2023 to 2025 fishing years. Emilie is going to provide a presentation, and then the Board will consider final action on specifications.

MS. EMILIE FRANKE: Thank you, Madam Chair. I'll provide an overview of the 2023 to 2025 specifications process for the Atlantic herring fishery. At the September meeting of the New England Fishery Management Council, the Council voted on the 2023 to 2025 specifications package.

In September the New England Fishery Management Council voted on a 2023 to 2025 specifications package, and that specifications package was based on the most recent Atlantic herring stock assessment, which was completed just last year. That assessment did include projections with an updated recruitment methodology to consider recent poor recruitment.

The specifications were also based on recommendations from the Council's Scientific and Statistical Committee, which were consistent with the biomass-based ABC Control Rule for Atlantic herring. The specifications are also consistent with the Atlantic herring rebuilding plan in Framework Adjustment 9.

This new specification's package voted on by the New England Council, reflects the most recent science and application of the rebuilding plan. Overall, the 2023 to 2025 annual catch limits for Atlantic herring remain low, sort of in the big picture, but they are an increase relative to the most recent prior years. For this timeline here you can see on the screen. The New England Council voted on the specifications package in September, which was later submitted to NOAA Fisheries for their review and approval. Today, January 31, 2023, this Atlantic Herring Management Board is considering action to set those 2023 to 2025 specifications, contingent on a Rule being published by NOAA Fisheries.

NOAA Fisheries does expect to publish a rule to implement these specifications next month in February. Again, the Board's action today would be contingent on publication of that rule by NOAA Fisheries. This is a similar timeline to what happened during the last specification setting process two years ago.

The Board at that time also met before the NOAA Rule was published, so the Board motion at that time included a statement that the specifications were contingent on a Rule by NOAA Fisheries. The next few slides show the specifications selected by the New England Fishery Management Council for 2023 through 2025, all in metric tons.

You can see that the overfishing limit acceptable biological catch and ACLs increase over the next three years from 2023 to 2025. The border transfer would be 0 metric tons each year, and a reminder about the management uncertainty buffer for Atlantic herring. If the Canadian New Brunswick fishery catch is less than its specified trigger, then 1,000 metric tons will be subtracted from that uncertainty buffer and added to the Area 1A Sub-ACL.

This slide shows those Sub-ACLs for each of the four Atlantic herring management areas. For example, in 2023 this year, the Area 1A Sub-ACL would be 3,592 metric tons. Area 1B would be 534 metric tons, Area 2 would be 3,455 metric tons, and Area 3 would be 4,847 metric tons. You can see that each of the area's Sub-ACLs would increase each year through 2025.

Then the fixed gear set aside would be 30 metric tons each year, and the research set aside would be still 0 percent each year as it has been for the most recent 2 years. On the next slide you can see a comparison of the initial 2022 total ACL and Sub-ACLs from last year, as compared to the 2023 to 2025 specifications selected by the Council.

Again, you can see that the '23 to '25 specifications are an increase, relative to last year's Sub-ACLs. For example, last year in 2022 for Area 1A, the Sub-ACL was 1,184 metric tons. For 2023 that Sub-ACL would be 3,592 metric tons. With that I am happy to take any questions on the Council's selected specifications package.

CHAIR WARE: Good, and thank you, Emilie. Are there any questions? Yes, Justin.

DR. JUSTIN DAVIS: A question about the specification's packages. Does that include the river herring bycatch caps within that package? I have a follow up.

MS. FRANKE: Yes, so the river herring and shad bycatch caps are being kept the same as recommended by the New England Council. Typically for the Commission's motions, we don't need to specify that in our motions, but the Council is recommending keeping those caps the same as they have been.

CHAIR WARE: Follow up, Justin.

DR. DAVIS: Yes, thanks. The rule that is going to be published in February, is that going to be a proposed rule, it will allow for public comment?

MS. FRANKE: That is a great question. I'm going to turn to Carrie Nordeen on the webinar from NOAA, if you are able to address that question.

MS. CARRIE NORDEEN: Right now, we're targeting to do an interim final rule to implement the specifications. Specifications are largely formulaic based on the ABC Control Rule and Rebuilding Plans. That may change, but that is our target for right now. That traditionally doesn't have the public comment period associated with the proposed rule, but comments can be made on interim final rule.

CHAIR WARE: Okay, Justin, you have a question? You're all set.

DR. DAVIS: I'm good, thank you.

CHAIR WARE: Any other questions this morning? All right, seeing none, were there any on the webinar, Emilie? No, okay. I think we would be looking for a motion today to set the specifications. I believe staff has prepared a motion, so we'll have that come up on the screen and see if we have a maker and a seconder. I think Melanie, you have your hand up.

MS. MELANIE GRIFFIN: I do, Chair, and I am happy to make the motion. I apologize the length of it, but I've had my water, so my voice shouldn't crack during it. Are you ready?

CHAIR WARE: Thank you for sacrifice, Melanie.

MS. GRIFFIN: I would move to adopt the following specifications for the 2023 to 2025 fishing years for Atlantic herring as recommended by the New England Fishery Management Council, contingent on the final rule being published by NOAA Fisheries.:

For 2023, an ACL and Domestic Annual Harvest of 12,429 metric tons, an Area 1A Sub-ACL of 3,492 metric tons, an Area 1B Sub-ACL of 534 metric tons, an Area 2 Sub-ACL of 3,455 metric tons, and an Area 3 Sub-ACL of 4,847 metric tons.

For 2024, and Annual Catch Limit and Domestic Annual Harvest of 19,189 metric tons. In Area 1A Sub-ACL of 5,546 metric tons. Area 1B Sub-ACL of 825 metric tons. Area 2 Sub-ACL of 5,335 metric tons, and an Area 3 Sub-ACL of 7,484 metric tons.

For 2025, an Annual Catch Limit and Domestic Annual Harvest of 23,961 metric tons. Area 1A Sub-ACL of 6,925 metric tons. Area 1B Sub-ACL of 1,030 metric tons, an Area 2 Sub-ACL of 6,661 metric tons, and an Area 3 Sub-ACL of 9,345 metric tons.

For all three years the Border Transfer would be set at 0 metric tons each year. The Fixed Gear Set-Aside would be set at 30 metric tons each year, and the Research Set-Aside as a percent of Sub-ACLs would be set at 0 percent each year.

CHAIR WARE: Thank you, Melanie, and we had a second by Mr. Reid. **Is there any discussion on the motion this morning? All right, seeing none; are there any objections to this motion? Any abstentions? All right, motion passes by unanimous consent.**

ADJOURNMENT

CHAIR WARE: That is our agenda this morning. Is there any other business before this Board? Seeing none; is there a motion to adjourn? So moved by Ray Kane, and seconded by Representative Peake. Thank you very much.

(Whereupon the meeting adjourned at 9:41 a.m. on Tuesday, January 31, 2023)

FOR IMMEDIATE RELEASE
October 2, 2023

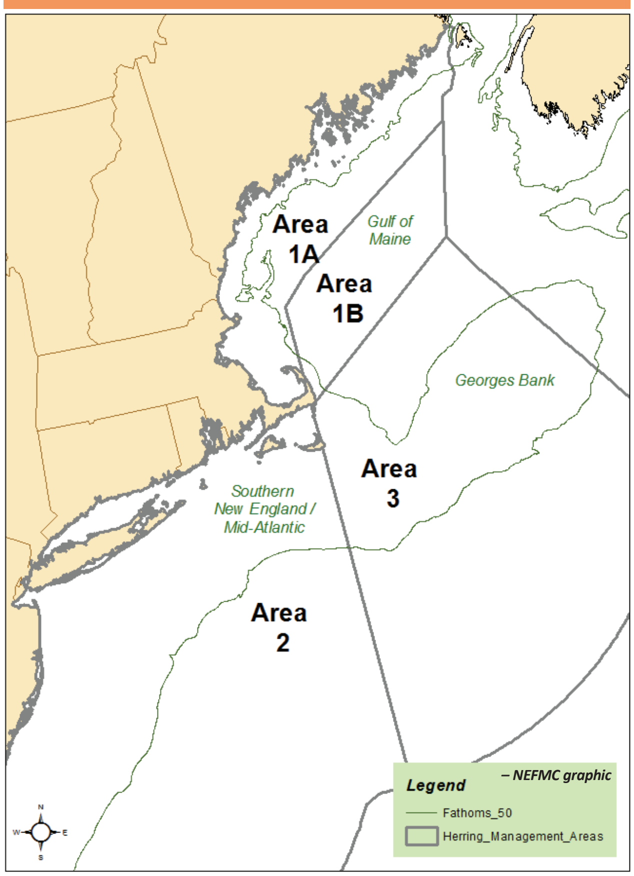
PRESS CONTACT: Janice Plante
(607) 592-4817, jplante@nefmc.org

Atlantic Herring: Council to Develop Amendment 10 to Address Fishery Issues; Launches Planning Process for Scoping Meetings

The New England Fishery Management Council has agreed to develop an amendment to the Atlantic Herring Fishery Management Plan (FMP) to minimize user conflicts in the fishery and address other issues.

In preparation for this action, the Council also agreed to develop a scoping document and schedule a series of scoping meetings to receive initial input from stakeholders on the potential range of alternatives to be considered in the amendment.

Atlantic Herring Management Units
Areas 1A, 1B, 2, and 3



HERRING AMENDMENT 10: The Council has been working on an action that previously was referred to as "revisiting the Inshore Midwater Trawl Restricted Area that was developed under Amendment 8." The restricted area was implemented but subsequently vacated by a federal court on March 29, 2022.

During its September 25-28, 2023 meeting in Plymouth, Massachusetts, the Council voted to change the title of the new action to "an action to minimize user conflicts related to the Atlantic herring fishery."

The Council already had approved a problem statement to guide this work, and it expanded the scope of the action when it met in June in Freeport, Maine.

At the September meeting, the Council took the additional step of designating the action as an amendment to, more specifically, "address spatial and temporal allocation and management of Atlantic herring at the management unit level to minimize user conflicts, contribute to optimum yield, and support rebuilding of the resource."

SCOPING MEETINGS: The Council further voted to hold scoping meetings as a first step toward identifying the full range of issues to be considered in Amendment 10. The Council tasked its Herring Committee and Herring

Plan Development Team (PDT) with developing a scoping document and scoping meeting schedule that included in-person meetings and one virtual meeting. The Council said the scoping document should:

- Be designed to solicit participation from all user groups with an interest in the herring resource; and
- Include a review of user conflict records in the Atlantic herring fishery, which should sum up previous analyses and public comments received during the development of Amendment 8 and other relevant Council actions.

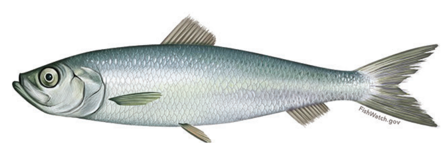
The Council indicated it wanted to review the scoping document at its late-January 2024 meeting in Portsmouth, New Hampshire.

WHAT IS SCOPING: The scoping process is an important part of the amendment development process. It marks the first and best opportunity for members of the public to raise issues and concerns for the Council to consider during the development of an amendment. Public comments received early in the amendment development process through scoping help the Council address concerns more thoroughly and ensure that an adequate range of alternatives is considered in the amendment.

WHAT'S NEXT: Future meetings of the Herring Committee and Herring Advisory Panel will be posted on the Council's herring webpage. Check in for updates. The Council will be taking final action on 2024 work priorities during its December 2023 meeting in Newport, Rhode Island. Here is the initial list of priorities the Council is working from, which will be whittled down. For herring, the Council already has a full plate of "required" actions for which it has no discretion to change. These include: (1) a fishing year 2025 through 2027 specifications package; (2) following the June 2024 Atlantic Herring Management Track Stock Assessment; (3) participating on the working group for the 2025 Atlantic Herring Research Track Assessment; and (5) coordinating with the Atlantic States Marine Fisheries Commission and the Mid-Atlantic Council on Atlantic herring and river herring and shad issues.

The Council will continue to work on Amendment 10 along with its 2024 requirements and any other adopted priorities.

Atlantic herring being salted for bait. *– NEFMC file photo*



Questions?

Contact Dr. Jamie Cournane, the Council's herring plan coordinator, at jcournane@nefmc.org. Documents used by the Council at this September meeting are posted here.

Atlantic States Marine Fisheries Commission

American Lobster Management Board

October 16, 2023
9:45 – 11:45 a.m.
Hybrid Meeting

Draft Agenda

The times listed are approximate; the order in which these items will be taken is subject to change; other items may be added as necessary.

1. Welcome/Call to Order *(J. McNamee)* 9:45 a.m.

2. Board Consent 9:45 a.m.
   - Approval of Agenda
   - Approval of Proceedings from May 2023

3. Public Comment 9:50 a.m.

4. Consider 2023 Jonah Crab Benchmark Stock Assessment and Peer Review Report **Action** 10:00 a.m.
   - Presentation of Stock Assessment Report *(J. Carloni)*
   - Presentation of Peer Review Panel Report *(R. Wong)*
   - Consider Acceptance of Benchmark Stock Assessment and Peer Review Report for Management Use
   - Consider Management Response, if necessary

5. Consider Annual Data Update of American Lobster Indices *(K. Reardon)* **Possible Action** 10:45 a.m.
   - Update on Addendum XXVII Trigger Index

6. Consider Terms of Reference and Timeline for the American Lobster Benchmark Stock Assessment *(J. Kipp)* **Action** 11:10 a.m.

7. Consider Pursuing a Management Strategy Evaluation for American Lobster *(C. Starks)* 11:15 a.m.

8. Consider Fishery Management Plan Reviews and State Compliance Reports for American Lobster and Jonah Crab for the 2022 Fishing Year *(C. Starks)* **Action** 11:35 a.m.

9. Other Business/ Adjourn 11:45 a.m.

The meeting will be held at Beaufort Hotel (2440 Lennoxville Road, Beaufort, North Carolina; 252.728.3000) and via webinar; click here for details

MEETING OVERVIEW

American Lobster Management Board
October 16, 2023
9:45 – 11:45 a.m.
Hybrid Meeting

Chair: Dr. Jason McNamee (RI) Assumed Chairmanship: 02/22	Technical Committee Chair: Kathleen Reardon (ME)	Law Enforcement Committee Representative: Rob Beal (ME)
Vice Chair: Pat Keliher (ME)	Advisory Panel Chair: Grant Moore (MA)	Previous Board Meeting: May 1, 2023
Voting Members: ME, NH, MA, RI, CT, NY, NJ, DE, MD, VA, NMFS, NEFMC (12 votes)		

2. Board Consent

- Approval of Agenda
- Approval of Proceedings from May 1, 2023

3. Public Comment – At the beginning of the meeting public comment will be taken on items not on the agenda. Individuals that wish to speak at this time must sign-in at the beginning of the meeting. For agenda items that have already gone out for public hearing and/or have had a public comment period that has closed, the Board Chair may determine that additional public comment will not provide additional information. In this circumstance the Chair will not allow additional public comment on an issue. For agenda items that the public has not had a chance to provide input, the Board Chair may allow limited opportunity for comment. The Board Chair has the discretion to limit the number of speakers and/or the length of each comment.

4. Consider 2023 Jonah Crab Benchmark Stock Assessment and Peer Review Report (10:00-10:45 a.m.) Action
Background • The first benchmark stock assessment for Jonah crab was completed earlier in 2023 (**Briefing Materials**). • The assessment was peer-reviewed virtually by a panel of independent experts in August 2023. The Peer Review Report provides the panel's evaluation of the assessment findings (**Briefing Materials**). • After reviewing the stock assessment, the Board may consider management response if warranted by the assessment results.
Presentations • Presentation of Stock Assessment Report by J. Carloni • Presentation of Peer Review Panel Report by R. Wong
Board Actions for Consideration at the Meeting • Consider Acceptance of Benchmark Stock Assessment and Peer Review Report for Management Use

5. Consider Annual Data Update of American Lobster Indices (10:45-11:10 a.m.)

Background

- An annual Data Update process between American lobster stock assessments was recommended during the 2020 stock assessment to more closely monitor changes in stock abundance. The objective of this process is to present information—including any potentially concerning trends—that could support additional research or consideration of changes to management. Data sets updated during this process are generally those that indicate exploitable lobster stock abundance conditions expected in subsequent years and include: young-of-year settlement indicators, trawl survey indicators, and ventless trap survey sex-specific abundance indices.
- This is the third Data Update and provides an update of last year's review with the addition of 2022 data. Indicator status (negative, neutral, or positive) was determined relative to the percentiles of the stock assessment time series (i.e., data set start year through 2018) **(Briefing Materials).**
- As part of this Data Update, the Technical Committee also updated the trigger index approved under Addendum XXVII. With the addition of survey indices from 2022, the combined trigger index has exceeded the threshold established in Addendum XXVII (a 35% decline from the reference period), which triggers the implementation of management measures **(Briefing Materials).**

Presentations

- Annual Data Update of American Lobster Indices and Addendum XXVII Trigger Index Update by K. Reardon

6. Consider Terms of Reference and Timeline for American Lobster Benchmark Stock Assessment (11:10-11:15 a.m.) Action

Background

- A benchmark stock assessment for American Lobster is scheduled for completion in 2025.
- The Technical Committee reviewed and recommended Terms of Reference and a timeline for the stock assessment **(Briefing Materials).**

Presentations

- Terms of Reference and Timeline for American Lobster Benchmark Stock Assessment by J. Kipp

Board Actions for Consideration at the Meeting

- Approve Terms of Reference and Timeline for American Lobster Benchmark Stock Assessment

7. Consider Pursuing a Management Strategy Evaluation for American Lobster (11:15-11:35 a.m.)
Background • In May 2021 the Board reviewed TC recommendations on a Management Strategy Evaluation (MSE) for the lobster fishery. The TC recommended the Board pursue a two-phase MSE focused on the GOM/GBK stock, with the goal of providing short-term management guidance at the stock-wide scale while concurrently building the framework to expand the MSE to provide long-term, spatially-explicit management advice. As next steps, the TC recommended a formal process to develop management goals and objectives for the future of the lobster fishery, and forming a steering committee for additional scoping and work plan development **(Briefing Materials)**. • The Board expressed interest in pursuing an MSE but postponed any action on development of an MSE in order prioritize work on Draft Addendum XXVII. This issue was last discussed by the Board in August 2021.
Presentations • Review of MSE recommendations from Technical Committee by C. Starks
Board Actions for Consideration at the Meeting • Consider pursuing an MSE for lobster

8. Consider Fishery Management Plan Reviews and State Compliance Reports for American Lobster and Jonah Crab for the 2022 Fishing Year (11:35-11:45 a.m.) Action
Background • State compliance reports for American lobster and Jonah crab were due August 1, 2023. • The Plan Review Teams reviewed state compliance reports and compiled the annual FMP Reviews for lobster and Jonah crab for the 2022 Fishing Year (**Briefing Materials**). • Delaware, Maryland, and Virginia have requested and meet the requirements for *de minimis* in the lobster and Jonah crab fisheries.
Presentations • FMP Reviews for American Lobster and Jonah Crab for the 2022 Fishing Year by C. Starks
Board Actions for Consideration at the Meeting • Approve Fishery Management Plan Reviews and state compliance reports for American Lobster and Jonah Crab for the 2022 Fishing Year • Approve de minimis requests.

9. Other Business/ Adjourn

American Lobster and Jonah Crab TC Task List

Activity level: High

Committee Overlap Score: Medium

Committee Task List
Lobster TC • August 1, 2024: Annual Compliance Reports Due • Fall 2024: Annual data update of lobster abundance indices • Spring-Summer 2024: Development of lobster stock assessment *Jonah Crab TC* • August 1, 2024: Annual Compliance Reports Due

TC Members

American Lobster: Kathleen Reardon (ME, TC Chair), Joshua Carloni (NH), Jeff Kipp (ASMFC), Catherine Fede (NY), Conor McManus (RI), Chad Power (NJ), Tracy Pugh (MA), Burton Shank (NOAA), Craig Weedon (MD), Somers Smott (VA), Renee St. Amand (CT)

Jonah Crab: Derek Perry (MA, TC Chair), Joshua Carloni (NH), Chad Power (NJ), Jeff Kipp (ASMFC), Conor McManus (RI), Allison Murphy (NOAA), Kathleen Reardon (ME), Chris Scott (NY), Burton Shank (NOAA), Somers Smott (VA), Corinne Truesdale (RI), Craig Weedon (MD)

Lobster Stock Assessment Subcommittee (SAS) Members

Jonah Crab: Tracy Pugh (MA, TC Chair), Conor McManus (RI), Joshua Carloni (NH), Kathleen Reardon (ME), Burton Shank (NOAA), Jeff Kipp (ASMFC)

DRAFT PROCEEDINGS OF THE

ATLANTIC STATES MARINE FISHERIES COMMISSION

AMERICAN LOBSTER MANAGEMENT BOARD

The Westin Crystal City
Arlington, Virginia
Hybrid Meeting

May 1, 2023

These minutes are draft and subject to approval by the American Lobster Management Board.
The Board will review the minutes during its next meeting.

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INDEX OF MOTIONS

1. **Approval of agenda** by consent (Page 1).

2. **Approval of Proceedings of January 31, 2021** by consent (Page 1).

3. **Main Motion**
Move to select under Issue 2, Option B a trigger level of 38% (Page 16).
Motion by Mr. Pat Keliher; second by Mr. Doug Grout. Motion amended (Page 16).

Motion to Amend
Motion to amend to select under Issue 2, Option B a trigger level of 35% (Page 16).
Motion by Ms. Cheri Patterson; second by Mr. Dan McKiernan. Motion passes (Roll Call: In Favor – NH, RI, CT, NY, NJ; Opposed – MA; Abstentions – DE, MD, VA, NMFS; Null – ME) (Page 18).

Motion to select under Issue 2, Option B a trigger level of 35% (Page 18).
Motion passes (10 in favor and one abstention from NMFS) (Page 18).

4. **Main Motion**
Move to select under Issue 2, Option B a modified "Measures Option 2" in which LMA3 and OCC move to a 6½ maximum gauge size in the final year of changes and do not decrease their maximum gauge size further. Initial changes to the gauge sizes for all GOM/GBK management areas should occur on June 1st in the following year. For example, if a trigger is tripped at the fall Annual meeting in 2023, a minimum gauge size change would be implemented June 1, 2024. Should a future stock assessment conclude that the GOM and GBK stocks are not a single biological stock, the Board can revisit the max gauge size decrease in OCC and LMA 3 (Page 18).
Motion by Mr. Pat Keliher; second by Ms. Cheri Patterson (Page 19).

	LMA 1	LMA 3	OCC
Initial gauge size changes (Year 1 implementation)	**Min: 3 5/16" (84mm)** Max: Status quo Vent: Status quo	Min: Status quo Max: Status quo Vent: Status quo	Min: Status quo Max: Status quo Vent: Status quo
Intermediate gauge sizes (Year 3 implementation)	**Min: 3 3/8" (86mm)** Max: Status quo **Vent: 2x5 ¾" rect; 2 5/8" circular**	Min: Status quo Max: Status quo Vent: Status quo	Min: Status quo Max: Status quo Vent: Status quo
Final gauge size (Year 5 implementation)	Min: 3 3/8" (86mm) Max: Status quo Vent: Status quo	Min: Status quo **Max: 6 ½"** Vent: Status quo	Min: Status quo **Max: 6 ½"** Vent: Status quo

Move to Amend
Move to amend that the increase in the escape vent size in LCMA 1 be implemented in year 5 after the trigger has been reached (Page 19).
Motion by Mr. Doug Grout; second by Mr. Steve Train. Motion fails (3 in favor, 5 opposed, 3 abstentions) (Page 20).

These minutes are draft and subject to approval by the American Lobster Management Board.
The Board will review the minutes during its next meeting.

	LMA 1	LMA 3	OCC
Initial gauge size changes (Year 1 implementation)	**Min: 3 5/16" (84mm)** Max: Status quo Vent: Status quo	Min: Status quo Max: Status quo Vent: Status quo	Min: Status quo Max: Status quo Vent: Status quo
Intermediate gauge sizes (Year 3 implementation)	**Min: 3 3/8" (86mm)** Max: Status quo **Vent: status quo**	Min: Status quo Max: Status quo Vent: Status quo	Min: Status quo Max: Status quo Vent: Status quo
Final gauge size (Year 5 implementation)	Min: 3 3/8" (86mm) Max: Status quo **Vent: 2x5 ¾" rect; 2 5/8" circular**	Min: Status quo **Max: 6 ½"** Vent: Status quo	Min: Status quo **Max: 6 ½"** Vent: Status quo

Motion to Amend

Move to amend that the increase in the escape vent size in LCMA 1 be implemented in year 4 after the trigger has been reached (Page 20).

Motion by Mr. David Borden; second by Mr. Steve Train. Motion passes (10 in favor, 1 abstention) (Page 21).

	LMA 1	LMA 3	OCC
Initial gauge size changes (Year 1 implementation)	**Min: 3 5/16" (84mm)** Max: Status quo Vent: Status quo	Min: Status quo Max: Status quo Vent: Status quo	Min: Status quo Max: Status quo Vent: Status quo
Intermediate gauge sizes (Year 3 implementation)	**Min: 3 3/8" (86mm)** Max: Status quo **Vent: status quo**	Min: Status quo Max: Status quo Vent: Status quo	Min: Status quo Max: Status quo Vent: Status quo
Year 4	**Vent: 2x5 ¾" rect; 2 5/8" circular**		
Final gauge size (Year 5 implementation)	Min: 3 3/8" (86mm) Max: Status quo	Min: Status quo **Max: 6 ½"** Vent: Status quo	Min: Status quo **Max: 6 ½"** Vent: Status quo

Main Motion as Amended

Move to select under Issue 2, Option B a modified "Measures Option 2" in which LMA3 and OCC move to a 6½ maximum gauge size in the final year of changes and do not decrease their maximum gauge size further. Initial changes to the gauge sizes for all GOM/GBK management areas should occur on June 1st in the following year. For example, if a trigger is tripped at the fall Annual meeting in 2023, a minimum gauge size change would be implemented June 1, 2024. Should a future stock assessment conclude that the GOM and GBK stocks are not a single biological stock, the Board can revisit the max gauge size decrease in OCC and LMA 3. The increase in the escape vent size in LCMA 1 would be implemented in year 4 after the trigger has been reached.

Motion to Amend

Motion to amend to strip the motion of the maximum size changes in OCC and LCMA 3 that are scheduled to go in this motion (Page 21).

	LMA 1	LMA 3	OCC

Initial gauge size changes (Year 1 implementation)	**Min: 3 5/16" (84mm)** Max: Status quo Vent: Status quo	Min: Status quo Max: Status quo Vent: Status quo	Min: Status quo Max: Status quo Vent: Status quo
Intermediate gauge sizes (Year 3 implementation)	**Min: 3 3/8" (86mm)** Max: Status quo **Vent: status quo**	Min: Status quo Max: Status quo Vent: Status quo	Min: Status quo Max: Status quo Vent: Status quo
Year 4	**Min: 3 3/8" (86mm)** Max: Status quo **Vent: 2x5 ¾" rect; 2 5/8" circular**		
~~**Final gauge size (Year 5 implementation)**~~	~~Min: 3 3/8" (86mm)~~ ~~Max: Status quo~~	~~Min: Status quo~~ ~~**Max: 6 ½"**~~ ~~Vent: Status quo~~	~~Min: Status quo~~ ~~**Max: 6 ½"**~~ ~~Vent: Status quo~~

Motion by Mr. Dan McKiernan; second by Mr. David Borden. Motion fails (4 in favor, 6 opposed, 1 abstention) (Page 23).

Main Motion as Amended

Move to select under Issue 2, Option B a modified "Measures Option 2" in which LMA3 and OCC move to a 6½ maximum gauge size in the final year of changes and do not decrease their maximum gauge size further. Initial changes to the gauge sizes for all GOM/GBK management areas should occur on June 1st in the following year. For example, if a trigger is tripped at the fall Annual meeting in 2023, a minimum gauge size change would be implemented June 1, 2024. Should a future stock assessment conclude that the GOM and GBK stocks are not a single biological stock, the Board can revisit the max gauge size decrease in OCC and LMA 3. The increase in the escape vent size in LCMA 1 would be implemented in year 4 after the trigger has been reached.

Motion passes 9 in favor, 1 opposed, 1 abstention (Page 23).

	LMA 1	LMA 3	OCC
Initial gauge size changes (Year 1 implementation)	**Min: 3 5/16" (84mm)** Max: Status quo Vent: Status quo	Min: Status quo Max: Status quo Vent: Status quo	Min: Status quo Max: Status quo Vent: Status quo
Intermediate gauge sizes (Year 3 implementation)	**Min: 3 3/8" (86mm)** Max: Status quo **Vent: status quo**	Min: Status quo Max: Status quo Vent: Status quo	Min: Status quo Max: Status quo Vent: Status quo
Year 4	**Vent: 2x5 ¾" rect; 2 5/8" circular**		
Final gauge size (Year 5 implementation)	Min: 3 3/8" (86mm) Max: Status quo	Min: Status quo **Max: 6 ½"** Vent: Status quo	Min: Status quo **Max: 6 ½"** Vent: Status quo

Move to approve Issue 1, sub-option B1 and sub-option B4. This combination of options will set a standard v-notch definition of 1/8" in LCMAs 3 and OCC, maintain the zero tolerance definition in LCMA1, and

establish a maximum gauge size in OCC of 6 ¾" for state and federal permit holders. It will also limit the issuance of trap tags to equal harvester trap tag allocations (Page 24).
Motion by Mr. Pat Keliher; second by Mr. David Borden. Motion separated (Page 24).

Move to Separate
Motion to separate B1 and B4.
Motion by Mr. David Borden; second by Mr. Dan McKiernan. Motion passes by consent (Page 25).

Move to approve Issue 1, sub-option B1. This option will set a standard v-notch definition of 1/8" in LCMAs 3 and OCC, maintain the zero tolerance definition in LCMA1, and establish a maximum gauge size in OCC of 6 ¾" for state and federal permit holders.
Motion passes (8 in favor, 1 opposed, 1 abstention) (Page 26).

5. **Main Motion**
Move to approve Issue 1, sub-option B4. This will limit the issuance of trap tags to equal harvester trap tag allocations (Page 26).

Motion to Amend
Move to amend to exempt the OCC from this requirement (Page 26).
Motion by Mr. Dan McKiernan; second by Mr. Pat Keliher. Motion passes (6 in favor, 5 abstentions) (Page 29).

Main Motion as Amended
Move to approve Issue 1, sub-option B4, except for OCC. This will limit the issuance of trap tags to equal harvester trap tag allocations for LCMA 1 and LCMA 3.
Motion passes (3 in favor, 1 opposed, 7 abstentions) (Page 30).

Move to approve Lobster Addendum XXVII, as modified today, with an implementation date of January 1, 2024 (Page 30).
Motion by Ms. Cheri Patterson; second by Mr. Emerson Hasbrouck. Motion passes (10 in favor and one vote in opposition from MA) (Page 31).

Move to request the Interstate Fisheries Management Policy Board approve the creation of a subcommittee to engage Canada's Department of Fisheries and Oceans to discuss transboundary issues related to the importation of lobster as it relates to different minimum gauge sizes in the two countries. The subcommittee shall be made up of up to four members of the Lobster Management Board who have license holders that fish in Area 1 and/or 3, one representative from the National Marine Fisheries Service, and the Commission's Executive Director or his designee (Page 32).
Motion by Mr. Pat Keliher; second by Mr. David Borden. Motion passes by consent with one abstention from NMFS (Page 34).

6. **Move to adjourn** by consent (Page 34).

ATTENDANCE

Board Members

Pat Keliher, ME (AA)
Stephen Train, ME (GA)
Rep. Allison Hepler, ME (LA)
Cheri Patterson, NH (AA)
Doug Grout, NH (GA)
Sen. David Watters, NH (LA)
Dan McKiernan, MA (AA)
Raymond Kane, MA (GA)
Rep. Sarah Peake, MA (LA)
Jason McNamee, RI (AA)
David Borden, RI (GA)
Eric Reid, RI, proxy for Sen. Sosnowski (LA)
Colleen Bouffard, CT, proxy for J. Davis (AA)
Bill Hyatt, CT (GA)
Jim Gilmore, NY, proxy for B. Seggos (AA)
Emerson Hasbrouck, NY (GA)
Jeff Brust, NJ, proxy for J. Cimino (AA)
Tom Fote, NJ (GA)
Adam Nowalsky, NJ, proxy for Sen. Gopal (LA)
John Clark, DE (AA)
Roy Miller, DE (GA)
Craig Pugh, DE, proxy for Rep. Carson (LA)
Mike Luisi, MD, proxy for L. Fegley (AA, Acting)
Russell Dize, MD (GA)
Dave Sikorski, MD, proxy for Del. Stein (LA)
Shanna Madsen, VA, proxy for J. Green (AA)
Jay Hermsen, NOAA proxy for A. Murphy
Mike Pentony, NMFS

(AA = Administrative Appointee; GA = Governor Appointee; LA = Legislative Appointee)

Ex-Officio Members

Kathleen Reardon, Technical Committee Chair
Derek Perry, Technical Committee Chair
Rob Beal, Law Enforcement Committee Rep.

Staff

Bob Beal
Toni Kerns
Madeline Musante
Tina Berger
Lindsey Aubart
Tracy Bauer
Julie DeFilippi Simpson
Chris Jacobs
Adam Lee
Mike Rinaldi
Caitlin Starks
Anna-Mai Christmas-Svajdlenka
Chelsea Tuohy

Guests

Dennis Abbott, NH, Leg Proxy
Max Appelman, NMFS
Mike Armstrong, MA DMF
Brendan Adams
Sydney Alhale, NOAA
Chris Batsavage, NC DENR
Alan Bianchi, NC DENR
Delayne Brown, NH F&G
Debbie Campbell
Josh Carloni, NH F&G
Beth Casoni, MLA
Barry Clifford, NOAA
Haley Clinton, NC DENR
Caitlin Craig, NYS DEC
Scott Curatolo-Wagemann, Cornell
Monty Deihl, Ocean Fleet Svcs.
Steve Doctor, MD DNR
Sam Duggan, NOAA
Bill Dunn
Julie Evans
Catherine Fede, NYS DEC
Glen Fernandes
James Fletcher
Marty Gary, PRFC
Matt Gates, CT DEEP
Diedre Gilbert, ME DMR
Angela Giuliano, MD DNR
Robert Glenn, MA DMF
Melanie Griffin, MA DMF
Bo Hale, USCG
Amalia Harrington, Univ ME
Heidi Henninger, AOLA
Jay Hermsen, NOAA
Peter Himchak, Cooke Aqua
Jesse Hornstein NYS DEC
Jeff Kaelin, Lund's Fisheries
Emily Keiley, NOAA
Tom Lilly
Chip Lynch, NOAA

These minutes are draft and subject to approval by the American Lobster Management Board.
The Board will review the minutes during its next meeting.

Guests (continued)

John Maniscalco, NYS DEC
Conor McManus, RI DMF
Kevin McMenamin, Annapolis
Nichola Meserve, MA DMF
Kyle Miller, FL FWC
Lorraine Morris, ME DMR
Allison Murphy, NOAA
Jeff Nichols, ME DMR
Scott Olszewski, RI DEM
Gerry O'Neill, Cape Seafoods
Justin Pellegrino, NYS DEC
Stephen Pickard
Chris Pickard
Nicole Pitts, NOAA
Tracy Pugh, MA DMF
Marianne Randall, NOAA
Marcel Reichert, Walhalla, SC
Paul Risi, City Univ NY
Mike Ruccio, NOAA
Somers Smott, VMRC
Renee St. Amand, CT DEEP
Jesica Waller, ME DMR
Craig Weedon, MD DNR
Angel Willey, MD DNR
Erin Wilkinson, ME DMR
Chris Wright, NOAA
Phil Zalesak
Rene Zobel, NH F&G

The American Lobster Management Board of the Atlantic States Marine Fisheries Commission convened in the Jefferson Ballroom of the Westin Crystal City Hotel, Arlington, Virginia, via hybrid meeting, in-person and webinar; Monday, May 1, 2023, and was called to order at 12:45 p.m. by Chair Jason McNamee.

CALL TO ORDER

CHAIR JASON McNAMEE: Hi everybody; I think we're going to get started here. I'm still sorting a few folks out online, but I think I've got enough to get the meeting started here. Welcome everybody to the American Lobster Management Board. We had an agenda that was published, so I'm going to start with that. Are there any changes, or additions, or anything else to the agenda that we would like for today? Yes, Pat.

MR. PATRICK C. KELIHER: Under Other Business I would like to, after we've finished with the addendum issues, I would like to raise an issue around Canada. Then a second issue would be the northern edge that the Council has just taken up.

CHAIR McNAMEE: Thank you, Pat. Any other changes to the agenda? Yes, Dan.

MR. DANIEL McKIERNAN: I'm not sure it's a change to the agenda, but when we get into the action items, I would like to take certain aspects of Addendum XXVII out of order. Is that something we can deal with when we get to that item?

CHAIR McNAMEE: Yes, thanks, Dan. I was actually thinking the same exact thing. I will be sure to highlight that. Okay, any other changes to the agenda?

APPROVAL OF AGENDA

CHAIR McNAMEE: We've had two additions under Other Business. Not seeing any other changes to the agenda, look to approve the agenda as modified. Are there any objections to approving the agenda as modified? Not seeing any; we will consider the agenda approved.

APPROVAL OF PROCEEDINGS

CHAIR McNAMEE: Next, we'll move to the proceedings from the January 2023 meeting. Are there any changes, additions, deletions to those proceedings from anybody on the Board? Okay, not seeing any hands around the table, Caitlin, anybody online with a hand up? Okay, with that are there any objections to approving the proceedings as submitted? Please, raise your hand. Seeing none; we will consider the proceedings approved.

PUBLIC COMMENT

CHAIR McNAMEE: The next agenda item is for public comment. This is public comment for things that are not currently on the agenda. Is there anyone from the public that wishes to make a comment on something, again that we're not already covering on today's agenda? Looking around the room here first, not seeing anyone. Looking over at Caitlin; nobody online either. We will consider there to be no additional public comment. I will come back to public comment in a few moments here, but we'll move past that item for now.

CONSIDER ADDENDUM XXVII ON INCREASING PROTECTION OF SPAWNING STOCK BIOMASS OF THE GULF OF MAINE/GEORGES BANK STOCK FOR FINAL APPROVAL

CHAIR McNAMEE: Next up is the main event. We're going to consider Addendum XXVII on Increasing Protection of Spawning Stock Biomass of the Gulf of Maine/Georges Bank Stock for Final Approval.

We're going to have a presentation from Caitlin Starks; both on the Addendum itself, as well as the Advisory Panel report. Then we'll come back, and then I wanted to offer a couple of comments. Dan McKiernan mentioned one of them, but I'll hit that stuff after the presentations and after you've cleared up any questions that you have. With that I will pass it over to you, Caitlin, to take us through the presentation.

REVIEW OPTIONS

MS. CAITLIN STARKS: I'll be giving a pretty quick, hopefully, presentation on Draft Addendum XXVII itself, which is again on increasing protection of the spawning stock in the Georges Bank and Gulf of Maine stock. I'll start off today with some brief background. The Addendum timeline, background information on the draft Addendum, and then go over the proposed management options that are in the document.

Then after that I'll summarize the public comments on this Addendum and present the AP report, and then we'll wrap up with the Board's actions for consideration today. This Addendum was originally initiated in 2017, and then work on the Addendum was paused for several years, as the Board had to prioritize work on right whale risk reduction efforts, and then work on this Addendum was restarted in February of 2021.

In 2021 and 2022, the Plan Development Team developed this draft Addendum document with guidance from the management board, and in January of 2023 the Board approved the draft Addendum for public comment. Our public comment period occurred earlier this year from March to April 8th of 2023, and during that time we had 8 hearings that were held from Maine to New York.

Today the Board will consider selecting a management program and final approval of draft Addendum XXVII. As I mentioned, the Board originally initiated Draft Addendum XXVII in August of 2017, and this was in response to concerns about decreasing trends in larval settlement indices for the Gulf of Maine, which have been showing declines since about 2012.

At that time the Addendum was focused on standardizing management measures across the lobster conservation and management areas, or LCMAs within the Gulf of Maine/Georges Bank stock. Then in 2021, after the Board received the results of the 2020 stock assessment and reinitiated work on this Addendum, the 2020 stock assessment highlighted some continued negative trends in the lobster stock indices in the Gulf of Maine and Georges Bank.

In the last five years settlement surveys have remained below the 75th percentile of their time series, and since the 2020 stock assessment was completed, which only included data through 2018, we've also seen some declines in the recruit abundance indices in the ventless trap survey and trawl surveys for the Gulf of Maine and Georges Bank. To give a visual of this, this slide shows the Gulf of Maine Young of Year Survey indices through 2021, sort of our last year of data that we have. The last three years of data are shown in red. You can see that there has been an overall downward trend in the settlement indices over about the past decade, with only one of the survey areas showing an increase in the last three years. Then this figure shows the Gulf of Maine recruit abundance indices from the trawl survey through 2021.

Again, the last few years of data are shown in red. You can see here that after it increased for a while in the 2000s and 2010, the recruits have also started to show declines in the last two or three years in most of the survey areas. With these trends in mind, the Board revised the objective for this Addendum, and it is now shown on the screen.

Given persistent low settlement indices and recent decreases in recruit indices, the Addendum should consider a trigger mechanism, such that upon reaching the trigger, measures would be automatically implemented to increase the overall protection of spawning stock biomass of the Gulf of Maine/Georges Bank stock.

The Draft Addendum also considers some options that would standardize some of the existing management measures within the Gulf of Maine and Georges Bank stock, which are aimed at improving or resolving some of the discrepancies between measures in different management areas within the stock.

The proposed options are expected to have benefits for the stock assessment, as well as law enforcement and interstate commerce. Next, I'm going to go over the proposed options that were included in the Draft Addendum for public comment. Our proposed options in Draft Addendum XXVII are separated into two issues.

Issue 1 addresses the standardization of a subset of management measures within LCMAs and across the stock. Then Issue 2 considers implementing biological management measures that are expected to provide increased protection of the spawning stock biomass. Before I go into the proposed changes, I want to review the relevant current measures for the areas within the stock.

You've got Area 1, Area 3 and Outer Cape Cod, just make sure everyone is on the same page for what are the measures that were considered in the status quo options. The Area 1 minimum gauge size is currently 3 and 1/4 inch. Area 3 slightly larger at 3 inches and 17/32 of an inch, and Outer Cape is at 3 and 3/8 of an inch.

V-notching is required in Area 1 and in Area 3 above the latitude of 42 degrees and 30 seconds, and then Outer Cape Cod does not have mandatory v-notching. In Area 1 there is a 0-tolerance definition for possession of v-notched lobster, and in Area 3 the definition is a notch that is 1/8 of an inch, with or without setal hairs.

In Outer Cape Cod there are two definitions. For state permitted fishermen in state waters the definition is 1/4 of an inch without setal hairs, and for federal permit holders, regardless of location, the definition is 1/8 of an inch, with or without setal hairs. Then for maximum gauge sizes, LCMA 1 is at 5 inches, LCMA 3 is at 6 and 3/4 of an inch, and Outer Cape Cod there are two maximum sizes. For state waters there is no maximum size, and in federal waters it is 6 and 3/4 of an inch. The options under Issue 1 are status quo, which is A, or B, which would implement some standardized measures upon final approval of this Addendum. Under Option B there are four sub-options that would define what those standardized measures would include. From the four sub-options the Board can select as many as desired, depending on which issues it wants to address. These are the four sub-options under B.

B1 would implement standardized measures within the Gulf of Maine and Georges Bank stock LCMAs, if there is a discrepancy within one LCMA to the most conservative measures where there are inconsistencies. This would result in the maximum gauge size in Outer Cape Cod going to 6 and 3/4 of an inch for both state and federal permit holders, and it would result in a v-notch possession definition of 1/8 inch, with or without setal hairs.

Option B2 would standardizes the v-notch requirement across LCMAs, such that v-notching would be mandatory for all eggers in LCMAs 1, 3, and Outer Cape Cod. Option B3 is to standardize the v-notch possession definition to 1/8 of an inch, with or without setal hairs for LCMA 1, 3 and Outer Cape Cod. Then Option B4 would standardize the regulations across the LCMAs, to limit the issuance of trap tags to equal the Harvester Trap Tag Allocation.

This means that no surplus tags would be automatically issued until trap losses occur and are documented. Moving on to Issue 2. These options focus on implementing management measures that would increase the protection of the spawning stock biomass. The options consider changes to the minimum and maximum gauge sizes, as well as corresponding escape vent sizes.

These are expected to increase the spawning stock biomass, and allow more lobsters to reproduce before they are harvested by the fishery. Including our status quo option, there are three total options under Issue 2. Within the options there are two approaches for implementing management changes.

The first approach is what is included in Option B, and this would establish a trigger mechanism, such that when a trigger is reached, it would result in predetermined management measures being implemented. The trigger would be based on a certain amount of decline in index, and I'll go into that in a moment. The proposed trigger index that would be used is based on multiple recruit abundance indices that are averaged over three years.

Then the second approach that we have is applied in Option C, and this would establish a predetermined schedule for future changes to the management measures. Under Option B the Board would establish a trigger mechanism to implement predetermined management measures when the trigger is reached. In this option that means the Board would need to define what the trigger level is, and what management measures would be implemented when that trigger is reached.

For selecting a trigger level, we have two options. Trigger Option 1 is that if the trigger index declines from its reference level by 32 percent, that would trigger the implementation of the management measures that are selected by the Board. Then Trigger Option 2 is a 45 percent decline in the trigger index. Just as a reminder, these two trigger levels are meant to approximate similar declines in lobster abundance. Our 45 percent trigger approximates the 75th percentile of the moderate abundance regime from the stock assessment. This figure is showing the trigger index that would be used under Option B to determine when the management measures would be implemented. This is calculated through 2021, with the available data, and the top left panel shows the combined index that would be used to determine when the trigger level is reached.

Then the three survey indices that go into that combined index are shown individually in the other three panels. These are the fall and spring trawl survey recruit indices and the ventless trap recruit index. The two horizontal lines on each graph represent the proposed trigger levels of 32 percent and 45 percent.

The reference level that the index is compared to is based on the reference abundance timeframe from the stock assessment, which was 2016 through 2018. The index is scaled to that reference level. On the Y axis one represents the reference level and that is the 2016 to 2018 average of the indices that go into the index.

Then as the index values change over time, depending on additional years of survey data, they will either decline below 1 or increase above 1. Our most recent index value, which is the 3-year average from 2019 to 2021, is 0.765, and that is about a 23 percent decline from the reference value.

If Option B is selected the Board would also need to select the biological management measures that would be automatically implemented in the Gulf of Maine and Georges Bank stock when that trigger level is reached. We have two options for management measures that were proposed in the Addendum.

Measures Option 1 would change the minimum and maximum gauge sizes, and the escape vent sizes in a single year. Then Measures Option 2 would involve a series of gradual changes to the gauge and escape vent sizes over several years. Again, these are the current gauge and vent sizes in the management areas in the Gulf of Maine and Georges Bank stock.

This table shows the measures that would change under Measures Option 1. The changes from status quo are shown in bold. Under Measures Option 1, when the established trigger level is reached for the following fishing year, the minimum gauge size for LCMA 1 would increase from the current size to 3 3/8 of an inch. The escape vent size in LCMA 1 would be adjusted, corresponding with that minimum gauge size change.

The maximum gauge size in LCMA 3 and Outer Cape Cod would decrease to 6 inches. The proposed increase to the minimum gauge size in LCMA 1 is expected to increase the proportion of the population that is able to reproduce before harvested by the fishery. This is expected to have a short-term negative impact on the Area 1 harvest, but over time the harvest in weight is expected to increase slightly with the minimum gauge size increase.

The proposed decrease to the maximum gauge sizes in LCMA 3 an Outer Cape Code are expected to enhance the stock resiliency by placing forever protections on a small proportion of the population, which includes the larger lobsters of both sexes. That change would be expected to have a small negative impact on the harvest number and weight. The proposed combinations of gauge and vent sizes are expected to maintain similar retention rates of legal-size lobsters and protection of sublegal sizes. The vent size that is proposed for Area 1 here is also consistent with the current vent size that is used in the southern New England management areas, where the minimum gauge size is also 3-3/8 of an inch.

Then this next table lists the management measures that would be implemented if Measures Option 2 is selected when the trigger point is reached. Again, the changes in each of the years are shown in bold. I want to note here that these final measures in this option in the last row are the same as what you saw in the previous option.

The difference is just that these changes occur gradually, as opposed to all at once. Under Measures Option 2, when the trigger level is reached it would start a series of gradual changes in gauge sizes for the areas in the stock, and the changes would occur every other year. The minimum gauge size in Area 1 would increase twice in increments of 1/16 of an inch.

The maximum gauge size for Area 3 and Outer Cape Cod area would decrease twice in increments of 1/4 of an inch. The escape vent size in LCMA 1 would be adjusted a single time when the final minimum gauge size is implemented in that area. Then the last option under Issue 2 is Option C, and this considers implementing gradual changes to the gauge and escape vent sizes on an established schedule, as opposed to using a trigger mechanism.

There are three steps for proposed changes in this option. This table shows the measures that would change in each of those steps in bold font. The first set of measures would be implemented no later than the 2026 fishing year. In the first step there would be an increase in the minimum gauge size in Area 1 by 1/16 of an inch to 3-5/16 of an inch, and a decrease in the maximum gauge size in LCMA 3 and outer Cape Cod to 6-1/2 inches.

Then one year following that there would be a decrease to the maximum gauge size in LCMA 3 and Outer Cape Cod to 6 and 1/4 inches, and no change in LMA 1 in that year. Then in the third and final step, which would occur one year later, it would increase the minimum gauge size in LMA 1 to 3-3/8 of an inch, and decrease the maximum gauge sizes for LMA 3 and Outer Cape Cod to 6 inches.

The vent size in LMA 1 would also be adjusted in our third and final step. As a note, for any of the proposed options for LCMA 3 measures, the Addendum specifies that whatever measures are selected would apply to all of Area 3 permit holders, including those that fish in the southern New England stock.

PUBLIC COMMENT SUMMARY

MS. STARKS: That covers all of the options in the Draft Addendum, and I am now going to go over the public comment summary. Our public comment period started in early March, and ended on April 8. During that time, we had eight public hearings that were held for Maine, New Hampshire, Massachusetts, Rhode Island and New York.

Four of those hearings were in person and four were held virtually. Across the eight hearings there were 214 public attendees. There might be some overlap in the individuals who attended multiple hearings. But in total during the comment period, we received 67 written public comments, 6 of those were letters from letters from organizations. These tables show the breakdown of the public hearing attendees and the number of comments that were provided at each of the hearings, which totaled to 159 comments provided within the public hearings, and then the breakdown of the written comments as well.

Then this larger table, I know it might be a bit hard to see, but I wanted to break down the number of comments that were in support of each option. Each of the options or sub-options that are included in the Addendum are shown in separate rows of this table, and in the far-right column are the total comments that were in support of each of those options.

The takeaway here is that the majority of comments were in support of status quo. But there were a number of comments that supported one or more of the other options. I will go into the reasons behind the support for each of those in the next slide. Across the comments that we received there were a few themes that were repeated by a significant number of people.

One of these is that there was a lot of concern about the economic impacts that could result from increasing the minimum size in Area 1, while still allowing imports of Canadian lobster that are smaller than the U.S. minimum size. Within the comments that address the options for v-notching, there were a significant number of folks that supported standardizing the v-notch definition.

However, it did seem that there was a preference among those individuals to go to a zero-tolerance definition, rather than 1/8 of an inch with or without setal hairs, because they didn't want to move backwards from the zero-tolerance definition in Area 1.

Regarding the proposed changes to the gauge sizes, a majority of the comments about this issue expressed a preference for smaller gradual changes to the measures, as opposed to implementing all of the changes at once. Then there were a lot of comments submitted, specifically about the proposed changes for the Outer Cape Cod management area.

In these comments people spoke about the unique situation of the Outer Cape fishery, and felt that it was not adequately considered in the Addendum options. In the comments that expressed a preference for status quo under Issue 1, which is to not standardize any of the management measures across or within LCMAs.

A number of people were concerned about the proposed changes would hurt the lobster industry and lobster population, specifically they referred to the increased restrictions that would go on to the commercial harvest, and the financial strain that would be caused by needing to replace or update their gear to meet the new requirements.

There were also many comments that said they were in support of the status quo option because the current measures are working and they don't need to be changed. They also thought that the proposed options for standardizing measures were not really for the benefit of the stock, but rather for the benefit of law enforcement. In the comments that supported some parts of Option B under Issue 1 to standardize some measures, there were a good number that felt that standardizing and increasing the strictness of v-notch requirements across the LCMAs will have benefits to the stock. Some people noted that it's a problem that lobsters that must be thrown back in one area can just be harvested in an adjacent area. One comment supported Sub-option B4, which would limit the trap tag issuance to the harvester allocation unless losses are documented, because they felt that this would help reduce the issue of lost and derelict gear.

Among the comments that were in support of status quo under Issue 2, that would not implement any management changes to the biological management measures to increase spawning stock protection. A lot of these comments cited market or economic concerns, and many specifically mentioned the concern about Canada gaining a market advantage over the U.S. fishery if the LCMA 1 minimum gauge size is increased. As I mentioned at the beginning, a lot of comments in favor or status quo came from fishermen in the Outer Cape Cod management area.

Their comments expressed that because of its unique situation, the Outer Cape would be disproportionately harmed by the proposed gauge size changes. They mentioned that Outer Cape has a unique catch demographic, as well as a niche market for large lobster, and that also because of the cost of living in the area, which is relatively higher than in other areas, they would face more economic hardship due to the changes than other areas would.

Then in a handful of comments that were in support of the trigger approach for implementing management changes under Issue 2, there was a majority preference for gradual changes over a single change. Supporters of Option B felt that the proposed changes would increase the overall health of the stock, that it could bring higher quality product to the market and fetch higher prices, and provide more value to the marketplace.

Some comments mentioned that they supported a minimum gauge size increase over the maximum size decreases that are proposed, because of the greater overall positive impact it is expected to have on the stock. It was also noted that decreasing the maximum gauge would result in a permanent loss of landings, but increasing the minimum size would just delay those landings temporarily.

The comments that supported Option C for scheduled changes to measures, that they preferred this option because changing the measures as soon as possible would be the best thing for the stock. They also said a minimum gauge increase is essential for the fishery to remain viable in the years ahead.

Some mentioned that they observed after the last time the gauge increased that there were benefits to the stock, and that we should act now while there is still time to reverse the negative trends that have been observed.

ADVISORY PANEL REPORT

MS. STARKS: Now I'm going to switch over to the Advisory Panel Report. Unfortunately, our AP Chair, Grant Moore, was unable to attend today so I'm going to give the AP Report on his behalf.

The AP met virtually to discuss Draft Addendum XXVII on April 10. Ten advisors were able to attend the virtual meeting and provide input. There was not consensus on a preferred set of management options that came out of that meeting. But the Advisors each provided their preferences and some comments on the proposed option. First, I want to go over the areas where the Advisors all agreed. There were a number of issues they agreed on. This includes a shared desired among them to look after the lobster resource. Some of them mentioned that they do not want to see Gulf of Maine have a similar outcome to southern New England. Many of the Advisors agree that v-notching has a positive impact on the stock, and they were supportive of standardizing the v-notch definition across the LCMAs in the Gulf of Maine and Georges Bank stock.

All of the Advisors also agreed that there could be economic impacts associated with the proposed increase to the LCMA 1 minimum gauge size, and that could create a disadvantage for the U.S. lobster fishery. Regarding the Issue 1 options, 5 Advisors supported Option B, with Sub-option B3, which would standardize the v-notch definition, and 1 Advisor also supported the other three sub-options as well.

Regarding Issue 2, 5 Advisors preferred status quo measures, stating that there is not a need to change them at this point in time. Two of the Advisors did not give a preferred option, they were expressing that they were torn between the status quo option and Option B, but they generally felt unsure if changing measures at this point is really needed, or worth the cost to the fishery.

But they don't want to see the stock end up in a bad condition. Then when asked if they had to choose one of the options other than status quo, the majority of Advisors would prefer the trigger mechanism over the scheduled changes. All right, so that wraps up the AP report and leads us to the Board's Actions for consideration today.

First, the Board would need to select a management program from the proposed options in Addendum XXVII, including Issue 1 and Issue 2, and alternatively could propose modifications to the options.

CONSIDER FINAL APPROVAL OF ADDENDUM XXVII

MS. STARKS: Then once the Board has selected a management program then the Board can consider final approval of Draft Addendum XXVII, and that says VIII, but it should say XXVII. All right, and with that I can wrap up my presentation and take any questions.

CHAIR McNAMEE: Thanks so much, Caitlin. That is what we'll start with here are just questions for now, just clarifying questions, and we'll come back around to do the deliberations after that. Any questions for Caitlin on what she just presented? I see Jim Gilmore first, go ahead, Jim.

MR. JAMES J. GILMORE: Great presentation, Caitlin. I want to just clarify I have this right. If we did go to a gradual gauge change, that all of those numbers would be predetermined, so that we don't have regulatory authority in New York, and based upon our experience with Jonah crab the last two years, we've really got to do this in one shot. If we're going to go through this we have to go through legislation. This would all be pre-prescribed, whatever and then we could do it in one event for our legislation, is that correct?

MS. STARKS: Yes, I believe that is accurate.

CHAIR McNAMEE: Next up I have Dan. No, okay, next up I have Steve Train.

MR. STEPHEN TRAIN: Thank you, Caitlin, for that that. I have a question that I think maybe Kathleen could answer it best. Sorry to put you on the spot. I was jotting down things while this was being presented. Basically, we're looking at things that show a decline, pull a trigger. We may need to increase the measure that will result in more eggs, and eventually those eggs will result in more lobsters. This is the process that we're looking at if any of this goes through, right?

MS. STARKS: Yes.

MR. TRAIN: We've had several years of declines. How many years after the trigger is pulled, did we put more lobsters back? Would those lobsters have eggs and become part of the fishery, be mature enough to be harvested or egging out?

MS. KATHLEEN REARDON: There would be an immediate… for the lobsters that are not caught there would be an immediate benefit, because those lobsters would have the opportunity to reproduce, the ones that are not caught. But the recruitment subsidy would definitely be a time lag. That recruitment subsidy is not actually considered in our simulation models. That would probably have a time lag of 6 to 8, 8 to 10 years. But there is immediate benefit for having those lobsters that are not caught to be able to reproduce, having the opportunity to reproduce rather than be caught.

MR. TRAIN: Just want to make sure I fully understand. I thought it was like 5 or 6 years. Whatever year we do this, or whatever year we actually have to trigger this, which may not be yet, probably isn't yet, will further decline until 6 to 8 years, maybe 10 until the recruit of the eggs of those lobsters can start coming into the fishery to pick it up.

MS. REARDON: If you're talking about the eggs that need to hatch and then grow large enough to then reproduce again. That is where there is a time lag. There is uncertainty around that how fast they are growing. But there is an immediate benefit by having more of those lobsters available to reproduce, if other changes are happening within the system, where not as many of those eggs are surviving. That is where we see a potential buffer to ecosystem change.

CHAIR McNAMEE: Okay, next up I have Mike Luisi.

MR. MICHAEL LUISI: Thanks, Caitlin, for the presentation. My question I guess is a simple one. From the graphs that you showed, and please correct me if I'm interpreting this wrong, but there seemed to be reasonable declines happening, which was just mentioned, as well as in the juvenile production. Was I right? Did I see the graph right on juvenile production has also been in decline over the past few years?

I guess the question that I would like to ask about that is, with everything that I saw in your presentation, declines, the status quo seems to be heavily favored. I know that you went over the public comment as to some of the reasons why. I'm just trying to understand if there are these declines, why status quo seems to be the favorite for everyone involved.

MS. STARKS: I can try to speak to the public comments that I heard during the process. I think a lot of the favor for status quo comes from concerns about economic impacts to the fishery, associated with changing the gauge sizes. I think that those impacts are to be expected whenever you potentially restrict measures in this way. I think there was a lot of concern about that, which caused people to favor status quo. But like I mentioned, there were a handful of folks that did not see status quo as an option, and felt that it is necessary to change the measures, in order to protect the stock.

CHAIR McNAMEE: Okay, two more in the queue here, David Borden.

MR. DAVID V. BORDEN: I also have a question for Kathleen. Kathleen, there was a lot of what I would characterize consternation voiced about the three surveys that are used in the index. I listened to; I think five different public hearings. In almost every single one of them it came up where members voiced concerns about it, how it was developed, how well it tracks future or predicts future landings. The question is, relative to those surveys, how well in the minds of the technical people do those surveys predict future landings? You can include the Rick Wahle survey in there, so it's four.

MS. REARDON: The combined index that Caitlin presented is actually only ventless trap, spring trawl survey and fall trawl survey from inshore Maine/New Hampshire survey as well as Massachusetts and ventless throughout the region. We are not considering part of the settlement survey from the different states as part of that trigger mechanism. It is informationally considered, but it is not part of that trigger index.

That trigger index is also focused on just one size of lobster, it's just under legal size. These are the sub-legals that we would expect to recruit into the fishery the next year. It's very close to that harvestable size, what will be legal very soon in the future. Within the conversations of the Technical Committee, we were looking at work that was done in the 2020 assessment. We wanted to create a trigger index that was related to the abundance of the whole lobster population.

In the process of the 2020 assessment, we did look at that recruit index of the 71-to-80-millimeter lobsters, and how those trends related to the abundance. We found that those trends in the surveys of those three surveys, do correlate well with the abundance. That is where we have some certainty on using those surveys between assessments as a proxy for what might be going on with abundance.

MR. BORDEN: How about with the Rick Wahle Survey? Did that also track well and predict future abundance catch?

MS. REARDON: It is not actually Rick Wahle's Survey; it is the state survey's data that is considered.

MR. BORDEN: I apologize.

MS. REARDON: We look at it as part of the data update, look at the settlement. But those lobsters are at least 6-8 years out from legal size. It is only surveying in shallow areas. We use it as kind of a red flag canary in the coal mine to say, something is changing. We did see changes since 2012, at least in Maine. We've had low levels of settlement in that survey. We were looking for trends in the recruitment indices from the trawl survey and the ventless trap since the assessment. That is one of the reasons we instituted the data update between the assessments.

CHAIR McNAMEE: Senator Watters.

SENATOR DAVID WATTERS: This is another kind of related to Steve's question, but from a different approach. I mean I can see our management technique is to do what we do to try to have increase in reproduction, and the assumption being that that will lead to abundance because of more recruitment.

But I guess my question to that though is, if the lack of recruitment is being driven by other factors, like warm air acidification or whatever it may be. I guess I had two questions. What confidence do we have then that these management methods will work, and then secondly, when might we know that they are not, and it may be these other factors that are driving the lack of recruitment?

MS. REARDON: The mechanisms for change is not something we have a lot of certainty about. We think it's changes in productivity, whether that is warmer water temperatures, survivability, larval starvation, more predation from fish. It could be any of those things.

The guidance that we got from the Board and what the Technical Committee talked about, was if we have changes in the ecosystem ahead. How could we propose management options for the Board to consider that might provide more of a buffer to that ecosystem change. Increasing the protection of spawning stock biomass was the mechanism that was focused on and proposed.

CHAIR McNAMEE: Okay, all set with that? Great. Representative Peake.

REPRESENTATIVE SARAH PEAKE: Pat Keliher at the beginning asked to have added to the end of our agenda a discussion about Canadian competition and in effect Canadian regulations. The public hearings that I attended, some of those status quo people were concerned about an increase in the minimum gauge size, that that would lead to, and the question was then raised, well will Canada have to abide by that increase in the minimum gauge size?

If not, that puts us at an economic and marketing disadvantage, because there is a market for some of those smaller lobsters. I am wondering, as you reviewed all of the options again, and many of them include either through trigger or through timing, an increase in a minimum gauge size. If we need to have a Canadian competition discussion up front, so that we can understand what the total picture is, before we start to discuss these various options and going to them.

I would like to know what the impact of a decision I'm making is, maybe in the short term if there is no change in the Canadian regulations, or long term if that is going to be a number of years, a number of months, or never that they would match what our minimum gauge size is.

CHAIR McNAMEE: They are good comments, Representative Peake. I think, and so it sounds like your concern is like with a sequence of things here. Point taken, we will have the discussion, and the folks around the table have had a chance to hear your concerns up front, so thanks. Tom Fote.

MR. THOMAS P. FOTE: I guess I always assumed that what Jersey does is what up and down the coast does, and I guess I'm wrong. We do not allow lobsters in that are below our legal-size limit, so Canadian lobsters less than our size limit cannot come in. Are we the only state that does that?

MS. STARKS: I'll say I don't know if you're the only state that does that, but it is a state decision to make the gauge sizes a possession limit as well as a harvest limit. The Commission's FMP makes it a harvest limit, but some states, such as New Jersey, have implemented that as a possession standard as well, so that those lobsters cannot be anywhere in the supply chain in the state.

CHAIR McNAMEE: Ray.

MR. RAYMOND W. KANE: A question of Kathleen. The way I heard you explain it to the Senator from Maine. This whole management action is based on previous management models, static models. We're talking about the livelihoods of lobstermen, and we hear a lot about EBFM, we hear a lot about the changing temperatures in the Gulf of Maine.

When does this all get brought to light, because the way I'm looking at this is we're trying to manage this fishery the way we have in the past, with your trawl surveys, your ventless trap. When do we start accounting for temperature changes, salinity, acidification, different predator species in the Gulf of Maine that might be consuming eggs, young of the year when it's settled to the bottom? When do we bring that into our management actions?

MS. REARDON: I'm not actually sure how to answer that question, although I think in the 2020 assessment, we did bring in more of the environmental datasets to consider as part of our Model 3 evaluation of what is going on with the stock. Looking at kind of stress indicators, temperature, other zooplankton. We looked at a number of different datasets as part of trying to understand what was going on with the lobster stock.

MS. STARKS: I just wanted to add something to that as well. During the discussions that the Technical Committee had when the PDT tasked them with trying to come up with some potential management options for this document. One of the things that the Technical Committee kept coming back to was that we don't have control over the environmental conditions.

But if we are able to have a larger spawning stock biomass, that if there is a good year, where the conditions of the environment are really good for the eggs and for recruitment, that there is a large spawning stock base there to provide that additional input into the population.

CHAIR McNAMEE: We've had one hand raised from the public, I'm going to just request, before I go to this person. We're still on the question-and-answer portion of the meeting here, so just keep that in mind. But with that I will go to Beth Casoni.

MS. BETH CASONI: I actually had my hand raised by accident; I apologize. I don't have a question at this time.

CHAIR McNAMEE: Okay, thanks, Beth, at least we know we can hear you when you do.

MS. CASONI: Right, thank you.

CHAIR McNAMEE: It looks like we've cleared up all of the questions, oh, no we haven't. Go ahead, David.

MR. BORDEN: I have one other question that relates to the issue of the impacts of the gauge increases. I talked to Kathleen briefly before the meeting. There was a lot of discussion about the impacts, at least in some of those hearings about the impacts being in a range of 20 to 30 percent decline in landings, associated with a gauge increase.

I was just wondering what, and I realize this is a really difficult issue for the technical folks to answer, because there are a lot of different moving parts in it. But what is the technical do, how much of a loss, and how much of a gain we would get out of the gauge increase?

MS. REARDON: Thanks, David, for the question. There is a difference between short term cost and long-term cost. It's more straightforward in Area 1, where it's a recruitment-based fishery. We are fishing on that first molt of lobsters coming into the fishery that is being recruited. Short term, yes there is a cost in that first year.

But when you look at it in the more long-term, that is a delayed harvest, so those lobsters that are not caught in that year have that opportunity to reproduce, but also molt again, and can be caught at a heavier size. In the long term we would anticipate a lower number of lobsters being caught, but at a higher weight in the long term.

In the short term the Technical Committee talked about this. There was a meeting summary from April of 2021, where we did put some numbers to it, based on the growth matrix, and a 32ndth of an inch would be about 8 percent proportion of lobsters that wouldn't be caught if you changed a 32ndth of an inch, and a 16th of an inch would be about a 16 percent.

But the timing of management, whether you do it January 1st or in the middle of the year, that percentage is very uncertain, depending on how that management is carried out. Many of the Technical Committee members were not as comfortable throwing those numbers around. We were focused more about the long-term benefit of increasing the spawning stock biomass, and then what that impact would be over the long term. That's where we saw a lower number but a higher weight total in the longer term.

MR. BORDEN: Follow up, Mr. Chairman. They gain in weight, Kathleen, after they molt? How does it affect the weight? I think Burton had done an analysis that indicated 6 percent increase in weight. But what I'm asking you is, what was the consensus of the Technical Committee?

MS. REARDON: In the simulation models that Burton and Jeff ran, and I will defer to Jeff if he wants to step in here. But going to 3 and 3/8, we estimated about a 5 percent increase, I believe, in weight and a decrease of 3.6. But those numbers are an estimate based on a model, and where the Technical Committee has uncertainty about where those numbers fall.

We do have some certainty about that directionality, of which direction it is likely to go. You are likely to see that benefit. We also estimated that we would have up to that size a 38 percent increase in spawning stock biomass. Those numbers are not certain, they are from a model. But the directionality, you would see, we would anticipate a big bump in that spawning stock biomass by changing that minimum gauge size.

CHAIR McNAMEE: Yes, Roy Miller.

MR. ROY W. MILLER: A quick question. Since the prevailing public sentiment at the hearings seemed to be in favor of gradual changes, as opposed to a one-year change. Refresh my memory with the options. There weren't times when more than one vent size change would occur in a fishery, was there, or was the vent size changed at most one time in the options? Which was it, Caitlin?

MS. STARKS: Yes, that is correct. The vent size is only proposed to change one time in any of the proposed management options, and that would be whenever the final minimum gauge size is implemented for the area. We're just talking about Area 1, because Area 1 is the only one where there is a proposed minimum gauge size increase.

Whenever Area 1 reaches its final minimum gauge size, the vent size would also change.

CHAIR McNAMEE: Eric Reid.

MR. ERIC REID: Just a question about the math. You said we would catch less lobsters, but they would be heavier. Why would we catch less? Is that a very short-term thing? I'm not exactly sure. It's probably short term.

MS. REARDON: You would catch less lobsters, because you have natural mortality as they are growing. You are going to lose some lobsters on an annual basis to natural mortality, plus some of those lobsters would be reproductive. But I'll defer to Jeff or Caitlin if they want to add to that.

IMPLEMENTING MANAGEMENT MEASURES

MS. STARKS: Just in general, the proposed changes would decrease the window of sizes that are available to the fishery. There would be a smaller amount of lobsters available to be caught.

CHAIR McNAMEE: Are you okay, Eric? Okay. I think that does it for questions, so let's go ahead and move into, oh, go ahead, Dan.

ISSUE 2

MR. McKIERNAN: No, not a question, but I wanted to move into the sequencing of some of our deliberations. What I would like to speak to is reversing, kind of the order that has been presented in the document, which is Issue 1, Issue 2. By taking out Issue 2 first, Issue 2 is the potential minimum size increase that's either based on a trigger or automatic.

That's where most of the resiliency is going to come. The Issue 1 tend to be more housekeeping measures or have smaller effect on the spawning stock biomass, and the resiliency, and it would be difficult to rationalize why we would do the Issue 1 actions if Issue 2 failed. I would like to see the Board Tackle Issue 2 first.

CHAIR McNAMEE: Yes, thank you, Dan. I'm in complete agreement and was going to suggest the same thing myself. Maybe I'll look around, is there anyone on the Board who does not like that idea? The suggestion is to just reverse the issues, tackle Issue 2 first and then come back to Issue 1.

The suggestion was made by Dan McKiernan and I was also contemplating making the same suggestion. Looking around the table, not seeing anyone jumping up raising their hand. We will move forward in that manner, thanks for that, Dan. One other thing I just wanted to say up front. This is simply because at least one of the options that we may take off, it's these triggers.

There are two numbers, right. They sort of bound the issue, but there is a continuum in between those two things. Over the years watching boards when they have that kind of situation, bounding back and forth a whole bunch of times on different numbers, and all of the substitutes and things like that.

I just want to say up front, I'm only going to allow one substitution at a time, so if somebody makes a motion, there is a substitution, we'll dispense with that. I don't want to layer substitutions on top of substitutions. I think that is procedurally correct anyways, I just wanted to be up front about that. One other thing I would like to attempt is, there were a couple of items in here that didn't get much discussion, so I am going to try and simplify our job here in a couple of spots, just to see if we can quickly drop out one of the multitude of options here.

When we get to those parts I'll ask the question, and see if we can simplify our job a little bit here. I just wanted to let you know what I was thinking there. I'm not trying to limit discussion or anything like that, just trying to gain some efficiencies if possible. Then finally, I will plan on at least one opportunity for public comment. I'm going to do that once we are ready to take action on some sort of a final motion on the Addendum, so before we take action on it, but once we get through all of the Board deliberations.

You know there has been a lot of comments on this Addendum already, and mostly I'm concerned about time and we don't have a lot of time on the agenda here for this, so I want to make sure we are efficient and can get done what we need to get done today. If we're doing good, I will entertain additional opportunities, but I do promise to go to the public, but probably only do that one time once we get the two issues in some semblance of final shape. All right, so with that why don't we jump right to it. The first item here that we're going to tackle is Issue 2. This is the Implementing Management Measures to Increase Protection of Spawning Stock Biomass in the Gulf of Maine and the Georges Bank Stock.

Here is the first spot where I will ask the question, is there any discussion or any need to address the potential option to adopt management changes without the institution of a trigger mechanism? That is Option C. Is there anybody who wants to speak to that Option C? Dave Borden.

MR. BORDEN: I'll keep this really quick. I favor that option, but I talked to enough people around the table to gauge the sentiment on it. I just don't think it's going to go anyplace. The reason I favor that option, and I'm going to be really brief, is that having gone through the southern New England collapse, I was basically the State Director at the time.

Having gone through that, that was a totally awful experience, not only for the industry, but for the regulators. It was just astounding what the negative consequences were for a whole group of really hard working, dedicated individuals who had generations in their families that had grown up working the water.

Anything we can do to avoid that type of situation; I think we should do. It's the main reason that I am very concerned about the triggers. It goes back to Steve Train's comment, he hit the nail on the head, the delays. If we set a trigger, we're essentially acknowledging the fact that we're going to allow the stock conditions to deteriorate until we hit that trigger.

Now I'll say right up front, I operate under no delusions here. I don't think that we can maintain the stock at historic highs. I think it's going to decline anyways. But it's a question of timing, when you react, because once we react if we get optimal conditions, it is still going to take eight years before you're going to see the recruitment in the indices.

That's a long time to allow a fishery that's worth two billion dollars, employs 30,000 people, and has particularly in eastern Maine, has coastal communities that have a 90 percent reliance on this for their economic activity. This is a really major decision on a part of the Commission. We're in a leadership position on it.

Now I'm concerned that these triggers, when we were talking about triggers originally, I was an enthusiastic supporter of the trigger, because we were talking about a trigger at 15 percent. Now we're talking about triggers at 30 percent, 50 percent, and it goes back to the question I asked Kathleen, about how well these indices track future landings.

If they do, you are essentially saying to coastal communities, you're going to lose 50 percent of your income before you recover from it. That's what my reservation is, I'm not going to make a motion, but I think it's the wrong strategy at the wrong time.

CHAIR McNAMEE: Thanks, David, words of caution are appreciated. You are not making a motion on that option, okay. Mike Pentony.

MR. MIKE PENTONY: Hi everybody, it's been quite a while since I've been able to attend a Lobster Board meeting in person, so I appreciate being here this afternoon. Yes, similar to David Borden, I'm not going to speak specifically to making a motion on the immediate or specified approach.

But I did want to offer some sort of general comments about the resiliency framework, or resiliency addendum. You know I think we all acknowledge that the lobster fishery, particularly in the Gulf of Maine is under significant existential threats, I think from three avenues, you know the effects of climate change that we're seeing on the stock and recruitment. That's what we're focused on today.

But nobody around the table is forgetting or ignoring the threats to the lobster fishery, as we try to recover North Atlantic Right Whales in a way that preserves and maintains that fishery. There is also the train that's left the station for offshore wind, that I think we all acknowledge is coming to the Gulf of Maine.

Those are all presenting extreme threats to the lobster fishery. Unless we see some statutory changes, the challenges around recovering Right Whales in your lobster fishery, that is going to be something that we continue to face. The offshore wind issue I think, we sense that coming, and that is going to remain a challenge.

Ideally, I think we would be looking at ways to preserve and ensure the resiliency of this fishery, in ways that look for synergies across those three threats, in ways that we can mitigate those threats as meaningfully as possible. You know effort reductions, effort issues, aren't on the table today. The one thing that is on the table is gauge increases, to look at promoting increased recruitment.

I encourage the Board to be as aggressive as possible. We've heard some of the concerns, the concerns that David Borden raised, the concerns we've seen in some of the public comment and letters from some states, around the need to take action sooner rather than later, because of the delayed effect we see before we're going to see increased recruitment to the fishery.

Like David Borden, I recognize that where we're going to end up is probably with some sort of trigger approach. But I just strongly encourage the Board to be as aggressive and thoughtful as possible, so that we can really ensure that we have a resilient fishery, rather than having a reactive fishery, where we are struggling to adapt or adopt to a stock in collapse. Thank you.

CHAIR McNAMEE: Thank you, Mike. Just maybe one favor for me. My ears never un-popped from the plane ride this morning, so just make sure you get that microphone up close. I did hear you, Mike, and thank you for that. But I'm just nervous that I might not hear folks, so thanks for that. You know a couple of notes of caution, but nobody looking to make a motion on Option C, so I think that kind of drops us back to, we're on Issue 2, remember. We've got Options A and B remaining. Pat Keliher.

MR. KELIHER: Back in 2017 I was the originator of the motion that started this Addendum. A lot has happened since then. I started to get gray hair; we have survived a global pandemic. I think Borden may have had more hair back then too. I think we may have set a record from delays, but those delays were needed, based on the issues that we were dealing with. I think we're at a time now, we're in a very different time in making this decision if we had of done these back in 2017.

We were at an even higher abundance. I appreciate David's words of caution here. I'm not willing to go there, but we do need to start a conversation around this trigger. I'm going to start with a motion, I think Caitlin has that. Besides the three public hearings in Maine, I've held seven zone council meetings, they were excellent conversations.

We've seen certainly an embracing of the use of a trigger, including in our easternmost areas, Zones A and B actually asking for probably the highest trigger on the coast, because they are seeing more, probably because of what they are seeing in their traps for juvenile lobsters. But as you can imagine, with a 3,000 plus mile coastline, the opinions vary greatly.

But the need for action, I think, was certainly coming to the forefront. **I would like to make a motion, and actually Caitlin, if you could change the 40 to 38, please. I would like to make a motion to select under Issue 2, Option B, a trigger level of 38 percent,** and if I get a second, I'll give additional rationale.

CHAIR McNAMEE: Thank you, Pat, second from Doug Grout. Great, so back to you, Pat.

MR. KELIHER: Thank you, 38 percent is the halfway point within the range of the trigger mechanism from 32 to 45. It certainly is going to put us below 100 million pounds from a fishery standpoint for just the state of Maine. What I've heard consistently up and down the coast was we need to act, but we're coming down from an all-time high.

I think that is why people were willing to actually push for even the 45 percent. But frankly, from a biological standpoint, and for some of the issues that have been raised already, I'm uncomfortable going that far. I know frankly, some of the members around the table are not even comfortable with 38. I'm open for discussion, but would like to start it with this motion.

CHAIR McNAMEE: Doug, do you wish to add anything?

MR. DOUGLAS E. GROUT: Yes, I would support this. I also don't believe that we can wait until we get to 42 percent. I think that would be extremely dangerous. This might be a good compromise between 32 and 42, so thank you.

CHAIR McNAMEE: Cheri.

MS. CHERI PATTERSON: While I appreciate this motion and appreciate the compromise, I am still concerned about even a 38 percent trigger level. I think that we need to continue to be a little bit more proactive than reactive. While we will likely be able to see if the trigger is tripped, we would be able to see if there is young of the year recruitment sooner than 8 years. You know we have the young of the year survey out there, we have the trawl surveys out there that would be picking up samples to determine what our recruitment will be coming into the fishery at least. But I still think that we need to be a little bit more proactive. **I would like to have a motion to amend to select under Issue 2, Option B, a trigger level of 35 percent, and if I can get a second then I can move forward with a reason.**

CHAIR McNAMEE: Seconded by Dan McKiernan, thanks, Dan. Okay, Cheri, back to you.

MS. PATTERSON: Again, this is a compromise, because I would have liked to have gone to the 32 percent, but I think this is the compromise between the 32 and the 38, and I think that this is still being on the proactive side than a reactive side.

CHAIR McNAMEE: Okay, Dan as the seconder.

MR. McKIERNAN: I endorse Cheri's comments.

CHAIR McNAMEE: Senator Watters.

SENATOR WATTERS: My question is, if our numbers are from 2021, when will we know if we may have already hit this trigger amount level?

CHAIR McNAMEE: Do you have a comment on that, Kathleen or Caitlin does, hang on one second.

MS. STARKS: Sorry, I had to move locations, but the data update would have this information in it, and we will be presenting that at the annual meeting.

CHAIR McNAMEE: Okay, other comments.

SENATOR WATTERS: I guess that it makes it a little difficult to know, you know what we're saying in terms of implementation. I think if one imagines that we're not there yet then we've set a trigger and we wait awhile. But if we find out in the fall that as a matter of fact, we are up pretty high or well beyond what is even being proposed. I guess that I am kind of affirming what Cheri has noted, that we probably need to maybe set a little more aggressive level, because we may already be beyond it.

CHAIR McNAMEE: Thank you, Senator. Ray Kane.

MR. KANE: I just have a couple of questions to the maker of the first motion, and then to Cheri on the amended motion. Pat, you said that your zones down east were more in favor of the highest trigger, which brings me back to my thought pattern that we all know that we've got this dynamic shift of all species to the east/northeast.

I can understand the lobstermen down east wanting the highest trigger. I would almost support a 40 percent trigger, but that being said, these are the motions on the table. I don't understand why we're talking about 35 percent, you just want to mediate, Cheri?

CHAIR McNAMEE: Go ahead, Cheri.

MS. PATTERSON: Yes, actually. I think that 32 percent was not very appetizing from the industry perspective, and from around this table. I wouldn't want to go above 35 percent, to be honest with you. If 38 percent is something that was presented in this motion, so I chose to take the halfway point to go there.

MR. KANE: Thank you, Cheri, thank you, Pat.

CHAIR McNAMEE: All right, so we had a motion that has been amended. Any additional discussion before we take the vote on the amended motion? All right, seeing none; why don't I give folks a minute or two to caucus, in particular if you don't have folks here at the table. I don't know, two minutes to caucus.

Okay, does anybody need a little more time? Mike is still standing up, are you okay? It looks like he's heading back. **I think we are ready to go, so we will vote on the amended motion here. This is the motion to amend to select under Issue 2, Option B, a trigger level of 35 percent. Motion made by Ms. Patterson, seconded by Mr. McKiernan. All those in favor of the motion, please raise your hand. Is it a question, Roy? Go ahead.**

MR. MILLER: Could I request a roll call on that vote?

CHAIR McNAMEE: Yes, that would be.

MR. MILLER: I have my reasons for that, we want to see how much unanimity there are among the principal lobster states to the north of us.

CHAIR McNAMEE: Yes, thank you, Roy, I think that will help too with the hybrid situation we have here as well.

MS. TONI KERNS: I can just call the states out if you have everybody raise their hand.

CHAIR McNAMEE: You said you could do it, Toni.

MS. KERNS: Yes, if everyone just re-raises their hand that said yes, I'll call our name out. Put their hands up and I'll call the states out. If everybody puts their hands up, I will call your state name, and then that will be the roll call.

CHAIR McNAMEE: Okay, got you, I got you. Let's try again. **All those in favor, please raise your hand, and then Toni will call the roll here.**

MS. KERNS: Rhode Island, Connecticut, New York, New Jersey, and New Hampshire.

CHAIR McNAMEE: Did we get the hands online as well? Okay. All right, all those opposed please raise your hand.

MS. KERNS: Massachusetts.

CHAIR McNAMEE: Okay, any abstentions?

MS. KERNS: NOAA Fisheries, Virginia, Delaware, and Maryland.

CHAIR McNAMEE: Any null votes?
MS. KERNS: Maine.

CHAIR McNAMEE: Just checking down the table. Can you give me the numbers again, either Caitlin or Toni? It was 6 to approve.

MS. KERNS: It was 5, 1, 4, 1.

CHAIR McNAMEE: Okay, thank you. The motion passes 5 to 1 with 4 abstentions and 1 null. Thank you for that. Now the amended motion is the main motion. Any discussion on this now as the main motion, before we move forward with our follow up vote? Okay, seeing no hands, we're kind of in the same spot, so I don't know if there is a need to caucus.

I'm not seeing heads shaking around the table. Why don't we move forward and take the vote. We now have a main motion. **The main motion is motion to select under Issue 2, Option B a trigger level of 35 percent.** The amended motion is still the maker and the seconder, correct?

MS. KERNS: Property of the Board.

CHAIR McNAMEE: Okay, so we can go to the vote. All those in favor of the main motion, please raise your hand, we'll call them out again, please.

MS. KERNS: Rhode Island, Massachusetts, Connecticut, New York, New Jersey, Virginia, Maryland, Delaware, Maine, New Hampshire.

CHAIR McNAMEE: All those opposed, please raise your hand. Okay, didn't see any hands there. Any abstentions?

MS. KERNS: NOAA Fisheries.

CHAIR McNAMEE: Any null votes? No nulls. All right, so the motion passes. I got 10 to approve with 1 abstention. It looks like I counted right that time. Great, okay thank you for that everyone. Let's move along here and I'll go to Pat Keliher.

MR. KELIHER: To continue on with Issue 2, I have a second motion prepared, I think staff has that. **With this motion is a creation of a table to help us kind of follow the bouncing ball here, if you will. I would move to select under Issue 2, Option B a modified "Measures Option 2" in which LMA3 and Outer Cape Cod move to a 6-1/2 minimum gauge size in the final year of changes, and do not decrease their maximum gauge size further. Initial changes to the gauge sizes for all Gulf of Maine/Georges Bank management areas should occur on June 1st in the following year. For example, if a trigger is tripped at the fall Annual meeting in 2023, a minimum gauge size change would be implemented June 1, 2024. Should a future stock assessment conclude that the Gulf of Maine and Georges Bank stocks are not a single biological stock, the Board can revisit the max gauge size decrease in Outer Cape Cod and LMA 3.**

CHAIR McNAMEE: There is a motion on the board is there a second to that motion? Cheri Patterson with a second. Go ahead, Bob.

EXECUTIVE DIRECTOR ROBERT E. BEAL: Yes, just a quick comment for the record. I think when Mr. Keliher read that into the record, I think he said minimum after 6 and 1/2, in the first sentence. I think he meant maximum.

MR. KELIHER: I did.

EXECUTIVE DIRECTOR BEAL: I just want to make sure the record is clear.

MR. KELIHER: Thank you for that clarity.

CHAIR McNAMEE: Thank you for that clarification. Pat Keliher with the motion, seconded by Cheri Patterson. Pat, as the maker of the motion, I'll come back to you.

MR. KELIHER: One thing that I heard really clear from fishermen in Maine is the fact that if this is a resiliency addendum, and that we all should be playing a part in the resiliency of the stock. Certainly, we heard from our Technical Committee Chair the bigger biological benefit being those smaller lobsters in the minimum gauge size change.

But it is clear, based on comments that I've heard that the protection of those bigger, older lobsters, it's still incredibly important when it comes to stock resiliency. After having conversations with fishermen back home, looking at the data, understanding what the potential economic impact would be.

I've created this motion to be kind of less threatening for that standpoint on the max gauge size decrease, by pushing it out to the final year of implementation, so five years out. Again, I would just reiterate that this is one stock. There is some additional tagging data that is coming in that has raised some questions about that one stock. That is why I include information or a piece of this regarding the future stock assessment, where we could revisit that and make adjustments accordingly.

CHAIR McNAMEE: Great, thank you, Pat. Cheri, as the seconder, would you like to make a comment?

MS. PATTERSON: Yes, thank you. I do agree with what Pat had indicated, as well as get back to Mr. Pentony's comment on what is going to be happening in the future with the Atlantic Large Whale Take Reduction Team, and how that might be addressing resiliency in our future. It would be aligning better to have this offshore; you know the LMA 3 and such to be a size maximum change later on.

CHAIR McNAMEE: Other comments from the Board on the motion before us. Tom Fote.

MR. FOTE: I just asked a question for everybody over here and nobody has an answer, so I figured a Mainer could tell me. How much does a 6-inch carapace lobster weigh? Steve's got it.

MR. TRAIN: Well, off the top of my head I would say 6 to 7 pounds, depending whether it's a male or female. But I'm not allowed to land them, so I'm not sure.

CHAIR McNAMEE: Doug Grout.

MR. GROUT: I will express support for this motion, although I do have one small adjustment that I would like to propose, based on some of the comments that we got in our public hearings regarding when the vent size change would take place. My motion which I sent out just recently is to **move to amend that the increase in the escape vent size in LCMA 1 be implemented in Year 5 after the trigger has been reached.** Essentially, move it down to that Year 5 implementation, as opposed to Year 3 implementation. If I can get a second, I will be glad to give my rationale before the Board.

CHAIR McNAMEE: **There is a motion to amend here, it has to do with the escape vent size.** Is there a second to the motion to amend? Seconded by Steve Train. Okay, back to you, Doug, for your reasoning.

MR. GROUT: When we were at public hearing, our lobstermen expressed more concern about having that vent size increase in the same year that we have the final gauge increase, because they already are going to be taking a hit in Year 1, and then Year 3 at least a temporary hit in their landings. They know that right now some of the current vent size, some of the legal sized lobsters are able to escape through the escape vent.

They were feeling that if we could delay the implementation of the vent size change, it would make it easier to handle the third-year increase in size. If we all remember, what we put in as vent size changes in the past, I'm pretty sure they were occurring after the gauge increases that we had.

It wasn't in the same year. That's my rationale, I'm just trying to see if there might be some support for this just waiting a couple years. Some lobstermen may end up implementing it themselves right away on their own, but I think it's reasonable to give them a little bit of a cushion, or a little bit of a breather here.

CHAIR McNAMEE: Steve, do you wish to make a comment?

MR. TRAIN: I could live without this, but I do like this idea, it kind of slows down the too much at once thing a little bit. I think Doug hit the nail on the head with, a lot of people may do it anyway. You fill that parlor up with shorts, you're not going to get many counters in it anyway. Once those things start to change, I think you'll see people voluntarily moving that vent up before it's due anyway.

CHAIR McNAMEE: Okay, further discussion? Dave Borden.

MR. BORDEN: I'm still not fully understanding why this would be Year 5 vs Year 4. I mean we did this when I worked for the state of Rhode Island, we did this a number of times. I think we went through eight-gauge changes, maybe even ten. We always tried to follow the gauge change immediately, either the same year as the gauge change or the year after it we would change the vent size. This is talking about a two-year delay. I just don't get the logic of it. These two measures work hand in hand, and that is the way they are intended to work. I could see Year 4, you know some logic in that, but not Year 5.

CHAIR McNAMEE: Okay. Additional comments from the Board. Dan McKiernan.

MR. McKIERNAN: Question on protocol. What David Borden just said, wanting to insert Year 4, do we need to vote this down consistent with your desires to only have one substitute or amended motion at a time, so that we can come back with a Year 4 implementation of that, if that is the desire of the Board, given David's logic?

CHAIR McNAMEE: Looking down the table for a little help.

MS. KERNS: Go through the motions, it's the property of the Board at this point.

CHAIR McNAMEE: Right, so yes, we have to vote up or down, and then we can sort of move on from there. Thanks. Okay, so we have an amended motion before us. Why don't we take another two-minute caucus to discuss, then we'll come back and take the vote. Two minutes, please, that seemed to work last time.

Okay, it looks like everybody is back to the table, done discussing. I think we can go ahead and call the vote here. I will follow the same procedure. I will have you raise your hands and Toni will call out the states. **All those in favor of the amended motion, please raise your hand.**

MS. KERNS: Maine, New Hampshire, Connecticut.

CHAIR McNAMEE: Okay, all those opposed, please raise your hand.

MS. KERNS: Rhode Island, Massachusetts, New York, New Jersey, NOAA Fisheries.

CHAIR McNAMEE: Any abstentions?

MS. KERNS: Virginia, Maryland, Delaware.

CHAIR McNAMEE: Any null votes? Okay, by my count the motion fails, I had 3 to approve, 5 to oppose, 3 abstentions. The motion fails. We're back to the original motion, and I have a hand up from David Borden.

MR. BORDEN: I would like to make the same motion that Doug Grout made, basically move to amend that the increase in the escape vent size in LCMA 1 be implemented in Year 4 after the trigger has been reached.

CHAIR McNAMEE: There is a new motion to amend, okay there we go. We have a new motion to amend made by David Borden, is there a second to that motion? I saw Steve Train first. Back to you, David, to make comments.

MR. BORDEN: I won't belabor the point. I made it before, so that still stands. There is a synergy between these two, and this just line that up. You want these two actions to follow each other.

CHAIR McNAMEE: Okay, Steve. Steve is good, any other discussion on the amended motion? Doug, go ahead.

MR. GROUT: I just wanted to say I support this motion, since mine failed. It sounds like a good idea.

CHAIR McNAMEE: Well, that bodes well, thank you. Okay, can anyone raise their hand if you need some time to caucus. **Okay, so we have an amended motion here. It is similar to the one that was just made, but it drops it back a year, so it would be implemented in Year 4. Let's go ahead and call the vote. All those in favor of the amended motion, please raise your hand.**

MS. KERNS: Maine, New Hampshire, Rhode Island, Massachusetts, Connecticut, New York, New Jersey, Delaware, Maryland, Virginia.

CHAIR McNAMEE: Any opposed? I don't think there is anyone left. Any abstentions?

MS. KERNS: NOAA Fisheries.

CHAIR McNAMEE: Okay, there was one person left. Any null votes? No null votes, okay so the amended motion passes. That now becomes the main motion. I'll let that get up on the board here and then we'll go ahead. Dan, go ahead.

MR. McKIERNAN: Yes, I would like to make a motion to amend to essentially strip this motion of the maximum size changes in Area 3 and Outer Cape Cod that is scheduled to go in according to this motion. Shall I give a rationale now?

CHAIR McNAMEE: Looking for a little help. We had an amended motion that passed. We didn't vote on it as the main motion, but can we entertain another amendment?

EXECUTIVE DIRECTOR BEAL: Yes, because you've cleared the slate of all the previous amendments, and now you are back to one main motion. Now, Dan is suggesting a motion that would amend the main motion again, so it's fair.

CHAIR McNAMEE: Thank you, Bob. Okay, so we've got a new motion to amend, has to do with the maximum gauge. I saw a second from David Borden, so back to you, Dan, for a rationale.

MR. McKIERNAN: I'm seeking to make the maximum size in Area 3 and Outer Cape static at the 6 and 3/4-inch size, because of the historic contributions that those areas made to the resiliency in the Gulf of Maine when the measures went in to protect the southern New England stock. We know that Outer Cape Cod and Area 3 both have portions of their fishery in the southern New England area.

For the last 15 years or so we did very little action concerning the Gulf of Maine/Georges Bank. We did a lot of activity attributable to the southern New England stock, which included aggressive trap cuts, included gauge increases. I would like to give those fleets the credit for those that have already been made.

CHAIR McNAMEE: We're still getting the motion up on the board here. But David, while that is being typed out, anything to add?

MR. BORDEN: Yes, I would just add to the points that Dan just made. You know since all the gauges were standardized in 1989, not to give everybody a history lesson. Since 1989 the minimum size in Area 1 has been 3 and 1/4. There have been 9-gauge changes in Area 3 since that period. Most of those gauge changes took place right in proximity to the southern New England collapse.

When that took place the Area 3 industry, and I would point out that this is not just a New England issue, it goes all the way down. We have Maryland boats, six New Jersey boats, three New York boats. They are all fishing in Area 3. The industry opted to implement the most conservative measures throughout Area 3, instead of applying it just to southern New England and the Georges portion of it. We've been adopting more restrictive regulations for quite a period of decades actually.

The only think I would add to Dan's point. This doesn't get implemented according to the motion for five years. I think at least in our case, we're looking at other ways to contribute to the protection of spawning stock biomass, through things like a ring size, and so forth. We've got dialogues going with the Center staff about that. We oppose it at this time, but we are going to continue to work on it. I think that the Commission can easily add it to some subsequent addendum later on.

CHAIR McNAMEE: We've got the motion up there. I'm wondering, is the table correct? Okay. Further discussion on the amended motion? Steve Train.

MR. TRAIN: With all respect to my fellow Commissioners from Rhode Island and Massachusetts, I'm going to speak against this. We are dealing with a situation that was requiring the possible rebuilding the stock through egg production, and this needs to be shared through the range of the resource in the Gulf of Maine and Georges Bank stock are currently one stock. This is their share of what we need to do. It appears this motion would do away with that.

CHAIR McNAMEE: Pat.

MR. KELIHER: I'm going to speak against the motion to amend. What I was trying to do is put some forever protections in place. It is clear that these management areas don't operate in biological isolation, so recruitment from Area 3 comes from growth of lobster within that area, and immigration of lobsters outside of that area.

The Addendum says that 70 percent of the new females in LMA 3 come from that immigration. This connectivity means that we all need to be chipping in, as far as resiliency is concerned. It's also trying to offset economic impacts here. With my original motion the addendum shows that when we do a 6-inch minimum, it would result in a 4.6 percent decrease. That was why I only made a motion to move it down a quarter of an inch, to help offset what that impact would be.

But again, I just want to stress that this is a joint stock between Area 3 and Area 1, Gulf of Maine/Georges Bank. It is one management stock. There is no isolation between these stocks as it currently exists, and I would urge the Board to support something that is in place in the future. I would also point out that the language that I included, if there is a determination that there is isolation, the Board can revisit this issue.

CHAIR McNAMEE: Cheri.

MS. PATTERSON: At this point I can't support the motion to amend. I think that since this is one stock that we are speaking of, that all need to be participating in the resiliency action. This was a very gradual, thought-out process to not have LMA 3 involved up until the fifth year, so if there is any further information in the future, then we can take action if need be.

CHAIR McNAMEE: Representative Peake.

REPRESENTATIVE PEAKE: I would like to speak in support of this motion. As we're talking about sharing responsibility, I would like to point out that status quo right now for the Outer Cape area is there is no maximum gauge size. Going from no maximum gauge to a 6 and 1/2 is a major, major contribution, on top of the contributions that have already been made towards stock resiliency by the Outer Cape lobstermen.

I can live with 6 and 3/4, for both LMA 3 and OCC. But given that already the OCC lobster area, they have a larger minimum gauge size than any of the other lobster management areas, they are contributing in that way. For all intents and purposes, they have a shortened season because of right whale protections.

As I drove to get to Boston just yesterday, driving through the Beach Point Area I could see boats ready and traps ready and buoys ready. But the right whales are still in Cape Cod Bay. It used to be May 1, May 15 for the last several years, who knows. It could be after Memorial Day. The point is, there is no fishing that is going on in Cape Cod Bay, and on the back side of the beach. I think that 6 and 3/4 is a compromise that we should go with here. Again, as I said, I would like to point out for the OCC lobstermen, whose management plan was approved, that they are going from no maximum gauge to 6 and 1/2 under the original proposal, and this is why I believe this amendment offers a fair compromise.

CHAIR McNAMEE: Looking around the table, I don't see hands for further discussion. Can you please raise your hand if anybody needs time to caucus before we call the vote. Okay, let's do a one-minute caucus on this one. We're starting to get close to Menhaden time. One minute caucus. That was the one minute, New York, are you okay? I got a thumb up, great. **Let's call the question on the amended motion. All those in favor, please raise your hand.**

MS. KERNS: Rhode Island, Massachusetts, Connecticut, New York.

CHAIR McNAMEE: All those opposed, please raise your hand.

MS. KERNS: Maine, New Hampshire, New Jersey, NOAA Fisheries, Maryland and Virginia.

CHAIR McNAMEE: Abstentions.

MS. KERNS: Delaware.

CHAIR McNAMEE: Null votes, none. The amended motion fails. That brings us back. I think that is back to the previously amended motion, which is now the main motion. Anything else before we vote on the main motion? Toni.

MS. KERNS: I just want to make it abundantly clear that the language in the motion itself plus the table, are the things that we will be implementing. Since the table has vent sizes which are not in the language of the motion, it is in the text of the options that it does say is modified, but I want to put it on record, make it clear to you, the Board and the public for transparency.

CHAIR McNAMEE: Thank you, Toni, I appreciate that clarification. I'll wait for the cleaned-up motion to get back on the board here. I believe that is the correct motion that is up before us. I see nodding heads. Does anybody need time before we take a vote? Nobody is raising their hands, so **all those in favor of the motion up on the board here, please raise your hand.**

MS. KERNS: Maine, New Hampshire, Rhode Island, Connecticut, New York, New Jersey, Delaware, Maryland and Virginia.

CHAIR McNAMEE: All those opposed, please raise your hand.

MS. KERNS: Massachusetts.

CHAIR McNAMEE: Abstentions.

MS. KERNS: NOAA Fisheries.

CHAIR McNAMEE: Null votes. None. Okay, the main motion passes, 8 with 1 opposed and 1 abstention; 9 in favor, sorry. I'm missing somebody. I must not be turning my head far enough. Thank you for that, so it was 9 to approve, 1 to oppose, 1 abstention. I believe that is it for Issue 2, I see nodding heads.

ISSUE 1

CHAIR McNAMEE: We are now back to Issue 1. Is there anybody who wishes to get a motion on the table for Issue 1? Pat.

MR. KELIHER: I think staff has a motion. Thank you. I've combined two here, so bear with me, and I'll ask the Executive Director to watch out for my dyslexia. **Move to approve Issue 1, Sub-option B1 and Sub-option B4. This combination of options will set a standard v-notch definition of 1/8 inch in LCMA 3 and Outer Cape Cod, maintain the zero-tolerance definition in LCMA 1, and establish a maximum gauge size in Outer Cape Cod of 6 and 3/4 for state and federal permit holders. It will also limit the issuance of trap tags to equal the harvester trap tag allocations.**

CHAIR McNAMEE: Okay, is there a second to the motion. Dave Borden with a second. Pat, back to you for rationale.

MR. KELIHER: Just briefly. The one thing that this Addendum was going to work to achieve was some consistency in regulations. As we all know, especially with v-notch definitions, they are all over the place. I think it doesn't bring them totally in line, but it brings them in line to a point where the LCMAs will be operating in a consistent fashion.

I've had some additional conversations with Dan McKiernan about some of the commerce issues that Dan has, which I was sympathetic to. That is one of the reasons I left them separate. Just quickly on the trap tag allocations. Maine has a very administratively heavy issue associated with ensuring that people aren't fishing 880 traps.

You have to go through a process to request trap tags if they are lost. We do not give the 880-up front. Honestly, I think we need to have equity here. There is, and Cheri has brought this up several times with the other motions. We all know we have a whale problem, so ensuring that those 880 are not fished, does help eliminate some additional endlines, which I think, be it small, it's an important step in the right direction for those conversations.

CHAIR McNAMEE: David, as the seconder.

MR. BORDEN: The only thing I would like to comment on, I think Pat summarized things well. These are really two different motions. It might make sense to take the last sentence in the motion, separate them into two motions and discuss them separately and vote on them separately, because I think if we try to do it together it's going to get a little bit confusing.

I support what Pat has suggested here, but I have a number of suggestions to make when we get to the trap issuance. I think there is going to be a lot of discussion on that. My suggestion to Pat is he just agree to a perfection and separate it into two motions, just the last line, Pat.

MS. KERNS: David, are you making a motion to split?

MR. BORDEN: Well, I was hoping he would do it by a perfection, which I would agree to.

MS. KERNS: You already seconded it. It's a motion of the Board.

MR. BORDEN: Oh, I'll make a motion to separate it into two questions.

CHAIR McNAMEE: Okay, motion to separate, is there a second to that motion? Dan McKiernan. Just to clarify, David, you are just talking about separating out the last sentence of the original motion, correct?

MR. BORDEN: Correct.

CHAIR McNAMEE: There is a motion to split, let's go ahead and vote on that. All those in favor, please raise your hand. Okay, we'll go faster. Are there any objections to the motion to split? Seeing none, thank you, you probably saved us several minutes. Okay, so now we will have two separate

motions on this, because that motion passed by consent. Dan McKiernan, go ahead.

MR. McKIERNAN: Just a point of clarification. The Addendum states that these actions, which is Issue 1, would be enacted immediately upon adoption of the Addendum, but that is subject to rulemaking, so I'm hoping that it's within the expectations of the Board should this be approved, that that would likely be 2024. For the Commonwealth to enact any of these changes, I would be going to rulemaking so we would get done by the end of the year.

CHAIR McNAMEE: Pat, did you want to add to that?

MR. KELIHER: Obviously, every state is going to have different processes by which we have to go through from a rulemaking perspective. To that point I agree with Dan McKiernan that the implementation is upon final, we may have two dates on implementation at the end. I will look to Caitlin when we get to that point. We're going to have to have time to do rulemaking, but they will have to have time to do rulemaking.

CHAIR McNAMEE: Understanding that sort of pragmatism of that, is that kind of implicit in the motion, or do we need to say something explicit in the motion?

MS. KERNS: I think you can take it up during the implementation date of the document. But if anybody is concerned, we can add it to the motion.

CHAIR McNAMEE: Excellent. We are back to now the first half of the split motion. Are we okay to move forward with this? Representative Peake, to ahead.

REPRESENTATIVE PEAKE: I would like to make a motion to amend this motion before us now, please.

CHAIR McNAMEE: Okay.

REPRESENTATIVE PEAKE: To read as follows. Move to approve Issue 1, Sub-option B1. This option will set a v-notch definition of 1/8 inch in LCMA 3, and will set a v-notch definition of 1/8 inch in OCC to be implemented upon the trigger previously voted on by this Board in Option 2 being met. Then the rest of the language stays as written.

CHAIR McNAMEE: Okay, there is a motion to amend. Is there a second to the motion to amend? Last call for a second for the motion to amend. Okay, motion fails for a lack of a second.

MS. KERNS: Sarah, is that the intent of what you said?

REPRESENATIVE PEAKE: Let me read it. What my intent was, was that the change in the v-notch definition would only be implemented when the trigger was met.

MS. KERNS: For Outer Cape only, right?

REPRESENTATIVE PEAKE: For Outer Cape only, correct.

CHAIR McNAMEE: Since the motion wasn't up there when I called for the second, I'll do one last shot at a second. Okay, so still no second for the amended motion, so it fails for lack of a second. Okay, Roy.

MR. ROY W. MILLER: Mr. Chairman, wondering if you could help me clear up a little bit. With the wording in this motion, are we consistent with what we just passed, which is no longer before us, regarding Issue 2? I think we are, at least for the OCC of 6-3/4 inches. But how about LCMA Area 3? This motion is silent, I think, for LCMA 3, is it not? In terms of maximum gauge size? It's already set at 6 and 3/4?

CHAIR McNAMEE: Correct.

MR. MILLER: Okay, thank you.

CHAIR McNAMEE: Back to the split motion here. Are we ready to call the question? Does anybody need time to caucus? All right, so let's go ahead and call the question. **All those in favor of the motion, please raise your hand.**

MS. KERNS: Maine, New Hampshire, Rhode Island, New York, New Jersey, Delaware, Maryland, Virginia.

CHAIR McNAMEE: All those opposed, please raise your hand.

MS. KERNS: Massachusetts.

CHAIR McNAMEE: Any abstentions?

MS. KERNS: NOAA Fisheries.

CHAIR McNAMEE: Any null votes? Okay, so the first half of the split motion passes 6 to approve, 1 opposed, 1 abstention. I think now the second half of the split motion, move to approve Issue 1, Sub-option B4. This will limit the issuance of trap tags to equal harvester trap tag allocations. Discussion on the motion. Go ahead, Dan.

MR. McKIERNAN: I would like to request a friendly amendment, and create an exemption for the Outer Cape lobster permit holders, and I'll tell you why. It's a very unique area, in that there are 66 permit holders fishing about 27,000 traps, and the average among these fishermen is about 420. The area is trap starved, and just about, I would say everyone is fishing to their limit.

Including many who fish single trap operations because of the challenges of the harbors that they leave, such as Nauset Inlet, where about a third of our fishery is. I would ask that the Outer Cape fishermen still be given a 10 percent extra trap tag allowance. The difference between us and Maine is that Maine is responsible for the trap tag issuance, whereas we allow the fishermen to go directly to the vendor.

If we go to this kind of a system, there is going to be inordinate delays, whereas each fisherman loses a few traps, and that's going to happen season long. They would be contacting us, and then contacting the vendor. I just don't think administratively it is worth it. I would beg for the Commission's indulgence to create an exemption for the Outer Cape Cod. Like I said, there is at least more than half of the fishermen fish less than 500 traps.

As opposed to like in Area 1, where the average might be like 5 or 600, but people are still allowed to get 800 trap tags. There are some extra trap tags, even in the Area 1 system, for those who aren't fishing up to the limit. But that is a trap limit, whereas in the Outer Cape it is a trap allocation. **I would beg the Board, or someone to give me a second on my motion to amend, to exempt the outer Cape Cod from this particular motion.**

CHAIR McNAMEE: Thanks, Dan, there is a motion to amend to exempt the Outer Cape from the rest of the motion there. Is there a second to that motion? Seconded by Pat Keliher. Dan, you gave reasoning on it, anything else? Okay, Pat, anything you want to add?

MR. KELIHER: Just concur. After I understood the issue of the fishery down there in discussions with Dan, I can see what the need is so I'm okay with it.

CHAIR McNAMEE: Steve.

MR. TRAIN: I just have a question for Dan. I think I support this. You said most of the guys fished 500 or less. But how many are fishing 800? Do you have a lot of guys from Area 1 fishing 800 that you're not going to give it to, or are you going to give the extra tags to the guys with 800 in that area?

MR. McKIERNAN: The answer is 8. Out of the 64 permit holders there are 8 of them, and they fish in the kind of the very rough area, that eastern cape shore with a lot of storm surge, and trap losses happen.

MR. TRAIN: Thank you.

CHAIR McNAMEE: Mike Luisi.

MR. LUISI: I can support this. I just thought that Dan had mentioned a percentage over an equal harvester trap tag allocation. Dan, did you say something about 10 percent? Maybe that should be in there if that is the case.

MR. McKIERNAN: Currently my state and New Hampshire issue, or allow the issuance of 10 percent additional tags over the trap limit, or in this case the trap allocation for Outer Cape. I would like status quo to allow them to continue to get 10 percent.

MR. LUISI: Okay, that clears it up, thanks.

CHAIR McNAMEE: Toni.

MS. KERNS: It's the FMP that allows for that, just as an FYI.

CHAIR McNAMEE: It is already codified, great, okay. Mike Pentony.

MR. PENTONY: Not a question to the motion to amend, but the overarching motion. You know the Addendum document just says to limit issuance until trap losses occur and are documented. I just want to ensure, because ultimately a piece of this will fall to the federal side to implement as well.

I just would like some additional information, or clarification in terms of what are the states requiring or accepting as sufficient documentation? What would be acceptable, to make sure that we've got consistency, not only in the regulations, but in the documentation standards we're using that we're applying before we issue the additional 10 percent.

Because there are a couple handfuls of permit holders that get their trap tags from us. Right now, we just issue the full 110 percent, and want to make sure that we're operating in a consistent manner. But also, because we're the Feds, we have to make sure that we're being really clear or transparent, in terms of what is required in order to do the document for the trap losses. If somebody can provide me a little bit more information, I would appreciate it.

CHAIR McNAMEE: Does anybody, I wonder, does the Commission have a comment on this, so it's kind of a state situation? Dan, go ahead.

MR. McKIERNAN: I guess I would ask that we be given time to resolve this question. I don't have a good answer, because we get so few requests now, except in a catastrophic loss situation, and we allow them to get a completely new set. But for someone to get just a small number of replacement trap tags, I agree with Mr. Pentony that we probably need consistency.

If we could do that as a committee after this meeting, consulting the state of Maine, what their standards are, because Cheri in New Hampshire and I will be doing something a little bit new, in terms of that standard. I would welcome developing that standard with our federal partners.

CHAIR McNAMEE: Okay, so it sounds like, oh David, go ahead.

MR. BORDEN: This is a question I ask out of ignorance. If somebody has an Outer Cape endorsement, and an Area 1 endorsement, are there any permit holders that have permits in both? If so, how do we handle that, because you're going to have two different rules.

CHAIR McNAMEE: Go ahead, Dan.

MR. McKIERNAN: The answer is no. We don't have any individuals who are permitted in more than one area in Massachusetts, and since the Outer Cape to my knowledge is exclusively a Massachusetts fleet, it is not an issue.

CHAIR McNAMEE: David.

MR. BORDEN: My problem with the exemption, I am supportive of the attempt here to kind of simplify the rules on this. I talked to Pat about the burden on his staff. Then when you start factoring in, as Mr. Pentony said earlier. There are a multitude of other considerations we should think about, like whales and vertical lines.

It's highly desirable to kind of start winnowing down the traps that are in the water. In my own case, in another capacity to represent the offshore guys. Most of the offshore guy's fish their full allocations. I'm not exaggerating, they've done it through a very rigorous criteria put in. To get them they had to land 25,000 pounds of lobsters over two years and so forth. The trap allocations are really tight, in the case of some of the offshore boats.

If you do this then what happens when a scalloper comes along and it clips the end of a trawl, and takes 15 or 20 pots? There is no mechanism other than catastrophic loss for them to get those tags back. I actually came to the meeting more in the mindset of supporting cutting the percent down from10 percent to say, 3 percent to move in the right direction. But also, to recognize that to try to lessen the burden on people like Pat and his staff.

CHAIR McNAMEE: Just quickly back to Mike Pentony's comments. It sounds like this sort of defined what triggers that is something that will be dealt with after the meeting, so just getting that recorded into the meeting proceedings here, so that we do in fact follow up on that is good. Go ahead, David.

MR. BORDEN: I would just like to pursue the response Dan gave. I appreciate the response, but we all have to factor in, we've got other areas. We've got Area 4, Area 5, Area 2, and I know for a fact there are lots of multi-area boats, so we have to factor those considerations into any of this. I think this is only applying to 3, but we have two 3 boats, right? If an Area 2 boat can get 10 percent and an Area 3 boat gets 0, how are we going to handle that?

CHAIR McNAMEE: I do not have an answer to that. Any response, Dan to David's questions?

MR. McKIERNAN: David is right. In Massachusetts we allow the Area 2 fishermen to also order 10 percent additional tags, because like Outer Cape, many of them are trap-starved. They took a 50 percent cut in traps, so it is very similar. He brings up a good point. I guess I don't have an answer to that.

CHAIR McNAMEE: Okay, David, one more time, and then I think we're going to need to make a motion.

MR. BORDEN: I apologize for my repeated dunks in the tank. My suggestion here is a somewhat complex issue. I think we recognize; it may make some sense to table this and just include consideration of this in a subsequent action, that's all.

CHAIR McNAMEE: Toni or Bob.

MS. KERNS: One, for all of our rules when we have two different rules, the most restrictive rule applies if you're fishing in multiple areas. That could apply. I mean if someone would ask me what I would have said to you, I would have said the most restrictive. But if it's the Board's intent to not move forward with this, then you would just vote this down and it would be status quo, you wouldn't have to table it.

CHAIR McNAMEE: Okay, so we will take the vote on this, and depending on the way the Board feels about it, it can be voted up or down. Go ahead, David.

MR. BORDEN: I had somebody whispering in my ear that the other way to solve this is to exempt Area 3 in the same motion. I think you have provided us guidance, Mr. Chairman, you don't want motions to amend. You want to deal with one motion at a time, is that correct? We have a motion to amend on the floor.

CHAIR McNAMEE: Right, so if we were to move on this motion, what you're thinking about we could make a subsequent amendment to the main motion, would that work?

MR. BORDEN: Correct.

CHAIR McNAMEE: Okay, so we have a motion to amend here, let's dispense with that motion. **I'm going to call the vote. All those in favor, please raise your hand.**

MS. KERNS: Maine, New Hampshire, Massachusetts, Connecticut, New York, New Jersey.

CHAIR McNAMEE: Okay, all those opposed.

MS. KERNS: No hands.

CHAIR McNAMEE: No hands, any abstentions?

MS. KERNS: Rhode Island, NOAA Fisheries, Virginia, Maryland, Delaware.

CHAIR McNAMEE: Any null votes? Okay. All right, so the motion to amend passes, 6 to 0 with 5 abstentions. Thank you, Jeff, I should just stop giving the numbers and just look over at Jeff's hand signals. **No null votes.** Now we have a complete motion, I'll wait for that to get crafted up on the board here. I see, except for OCC, got it. We have a main motion up on the board. I'll give folks a minute to take a look, and then David, anything to add here?

MR. BORDEN: Could I request a one-minute caucus?

CHAIR McNAMEE: Yes, in fact let's do a two-minute caucus. All right, we have a motion in front of us. Is there anything further before we go ahead and vote on this motion? Pat.

MR. KELIHER: I'm kind of in a bind because of what may come next here, but if there is a subsequent action. If this goes through, then everybody has to issue 800, minus Outer Cape Cod, right. The Outer Cape Cod would be exempt. If there is a subsequent action to exempt another area, or allow a small percentage. Then we have an equity issue between LMA 1 and any other area. I'm very cautious. It's a fairness issue, right?

Maine has done the right thing for years in a very administratively burdensome process. If we're going to go in that direction, and other areas are going to get a pass or to allow to do something different, then Maine should be given the same opportunity. I'm just a little concerned about the direction we're going to go here.

CHAIR McNAMEE: David.

MR. BORDEN: A question for Bob Beal or Toni, I guess. Do we have an option here of postponing this, while we do what Pat wants us to do, which is get together and talk about it? In other words, we approved the Addendum without this provision, but postpone this provision to a subsequent meeting?

EXECUTIVE DIRECTOR BEAL: Well, you could approve this Addendum without this, and that would be it. If you wanted to then take this issue up, you would have to initiate a new Addendum. You could pause the consideration to this Addendum right now, and not approve anything today.

Try to sort something out here and bring that back at a subsequent meeting. You couldn't approve the Addendum today, sort of hold this issue in a parking lot, and then come back and make it part of an addendum that you approved today. It's you either approve the Addendum today without this, or you pause the whole thing and try it at a subsequent meeting.

CHAIR McNAMEE: Thanks for that, Bob. Dan.

MR. McKIERNAN: I appreciate Pat's concerns, but the motion itself is even a little bit misleading, because it talks about issuance and trap tags equal to harvest or trap tag allocations. When the truth is, we talk about trap tag allocations in an area that has an effort control plan, and so that is Outer Cape, Area 2, Area 3 et cetera. Really, Area 1 has a trap limit of 800, and I think Cheri and I are both sensitive to the concerns of Gulf of Maine Area 1 fishermen with the different standards on trap tag issuance. I would be certainly willing in Massachusetts, because the plan doesn't require us to issue an extra 10 percent.

I'm certainly willing to constrain the Area 1 fishermen to 800 tags, and use a Maine-like standard, because when Maine didn't op for the 10 percent extra tags, they did it on their own volition, and they were very successful. We're kind of looking to kind of adopt that model to some degree.

But Area 3 and Outer Cape have trap limits that are license specific, and it's just really painful to squeeze down those last few trap tags out of the business, because if they loose or if they want o replace a trawl, it's nice having a few extra trap tags. But these are really trap-starved areas. I would ask that the Board approve these, and it's my intention to adopt a Maine-like approach to Area 1.

CHAIR McNAMEE: Any further discussion? I think we're ready to call the question here. **All those in favor of the motion up on the board please raise your hand.**

MS. KERNS: New Hampshire, Maine, Massachusetts.

CHAIR McNAMEE: All those opposed.

MS. KERNS: Rhode Island.

CHAIR McNAMEE: Abstentions.

MS. KERNS: Connecticut, New York, New Jersey, Delaware, Maryland, Virginia and NOAA Fisheries.

CHAIR McNAMEE: Null votes, none. Okay, I'm not going to say numbers until I see them up on the board here, but I'm fairly certain that the motion passed. **Motion passed 3 to approve, 1 opposed with 7 abstentions and no nulls.** All right, I believe that is it for Issue 1. I think we have now dealt with both issues in the Addendum, so we're ready for a final motion to approve the Addendum as modified today. Is anybody ready to make that motion? Toni.

MS. KERNS: Mr. Chair, in order to move us a little bit faster, we have suggested that you add an implementation date when you make that motion.

CHAIR McNAMEE: Okay, so when we make that motion, we would like to also add an implementation date. Cheri, did you want to make that motion, and if you would be so kind as to add the implementation date as well.

MS. PATTERSON: Yes, I would like to move to approve Lobster Addendum XXVII, as modified today, with an implementation date of January 1, 2024.

CHAIR McNAMEE: Okay, we have a motion before us, is there a second? I see Emerson with a second, Emerson Hasbrouck. Cheri, anything you want to add as the maker of the motion?

MS. PATTERSON: Dan, would that work for your rulemaking process? I mean that is several months out.

MR. McKIERNAN: Yes.

CHAIR McNAMEE: Anything else, Cheri?

MS. PATTERSON: No, I think that that would be able to address everybody's concerns to actually have it implemented in time. Thanks.

CHAIR McNAMEE: Great, thank you, Cheri. Emerson, anything to add?

MR. EMERSON C. HASBROUCK: No, but I am going to defer my time to my co-commissioner here, Jim Gilmore.

CHAIR McNAMEE: I see another hand, Representative Peake.

REPRESENTATIVE PEAKE: Just before we take a vote, I'll telegraph to the Board that I don't know how the delegation will be voting, but inside our delegation I will not be supporting this, not because I don't support conservation measures, but I feel that the economic impact and what we are asking the Outer Cape lobstermen to do in participating in this. I cannot support this motion, and the lack of support for seeking a compromise leads me to the unfortunate position, being somebody who I consider myself a conservationist, having to take a no vote for this particular motion.

CHAIR McNAMEE: Thank you, Representative. Jim Gilmore, go ahead.

MR. GILMORE: I'm not opposed to the motion, it's just as my comments were earlier. We have to do this legislatively, so we will try to make that deadline, but I will just about guarantee you we are not going to make it. For again, our history with Jonah crab. It took us two years to get that in. Secondly, we don't have a legislative commissioner right now to help us with our legislature.

We could have some challenges facing that. That being said, our fishery is extremely small. We have 9 permit holders left, and I think only 4 of them are actually fishing. If that delay does occur, I don't think it's going to have a drastic impact on the resource. Just with that caveat, we'll be supporting the motion.

CHAIR McNAMEE: Okay, further discussion? Pat.

MR. KELIHER: Just quickly. Understanding Mr. Gilmore's issues on timing. I think the biggest issue from compliance is going to be gauge. I think you would have well beyond 2024 to deal with that issue.

CHAIR McNAMEE: Okay, does anybody need time to caucus, please raise your hand. We're way over time. Thank you for not raising your hand. I did sort of promise I would go to the public. Is there anybody, we're kind of way over time, so I'm hoping there are no hands. Okay, no hands online, thank you for that.
Why don't we go ahead and call the question and get this done. **All those in favor of the motion to approve Lobster Addendum XXVII, as modified today, with an implementation date of January 1st 2024. All those in favor, please raise your hand.**

MS. KERNS: Maine, New Hampshire, Rhode Island, Connecticut, New York, New Jersey, NOAA Fisheries, Maryland, Delaware, Virginia.

CHAIR McNAMEE: Any opposed?

MS. KERNS: Massachusetts.

CHAIR McNAMEE: Any abstentions? Any null votes? All right, the motion passes 10 to approve, 1 opposed, 0 abstentions, 0 null votes. Great, thank you all very much, good job. We have a few agenda items left here.

UPDATE FROM WORK GROUP ON IMPLEMENTATION OF ADDENDUM XXIX: TRACKER DEVICES IN THE FEDERAL LOBSTER AND JONAH CRAB FISHERY

CHAIR McNAMEE: I think what we decided is we'll do the quick update on the tracker devises. We'll do a quick update on the Jonah crab assessment, but we are going to skip the Conservation Management Team roles agenda item, and we'll address that at some other point. With that, Toni, I'll turn it over to you for the update on the trackers.

MS. KERNS: I'm going to skip my slides and just quickly go through the trackers. We are well on our way in moving forward with the trackers. Massachusetts has already gotten over 200 trackers on vessels. ACCSP is seeing those tracks in the database. Things have, I think, been going pretty smoothly along the way, so it's great news. Three states have put in their implementation plans to NOAA Fisheries, two of them have been approved.

Maine is the one that has not yet, but being under consideration, and we are working on the southern states. If you see an e-mail from me, please make sure that you respond either in the affirmative or the negative from the southern states, so I can finalize that up. We, just as an FYI for the trackers. The Tracker Workgroup is going to consider a new tracker in June, so we may have another device onboard by the end of June. Any questions?

CHAIR McNAMEE: Questions for Toni? Seeing no one around the table, anyone online with questions? Any hands raised? No, okay, thank you, Toni. Appreciate that.

PROGRESS UPDATE ON 2023 JONAH CRAB BENCHMARK STOCK ASSESSMENT

CHAIR McNAMEE: Let's move on to an update from the Jonah crab assessment. Whenever you're ready, Jeff.

MR. JEFF J. KIPP: For a quick update on the Jonah crab stock assessment. The Jonah Crab Stock Assessment Subcommittee met two weeks ago in New Bedford for the Assessment Workshop. We anticipate at least two more meetings, depending on how our next goes, which will be a SAS meeting to tie up some loose ends that remain from that Stock Assessment Workshop. Then we will meet with the full Technical Committee in July, to present and hopefully have the assessment approved by the Technical Committee for peer review. Our peer review is being planned currently for slightly later than what we originally had on our timeline of July, we're planning for late August, but we still are on track to present out the assessment and the peer review to the Board at the annual meeting. That's it for my update.

CHAIR McNAMEE: Thank you, Jeff, questions for Jeff on the Jonah Crab Stock Assessment process? Not seeing any hands around the table, any hands online? No hands online. All right, thanks for that, Jeff, appreciate it.

OTHER BUSINESS

CHAIR McNAMEE: As I mentioned, we were going to skip the second to last agenda item, but we still have Other Business that was brought up at the beginning of the meeting. The first had to do with consultation with our Canadian counterparts, so Pat, I'll look to you to address that one.

MR. KELIHER: Caitlin does have a motion that I've prepared for this conversation. It was noted by several people, including Representative Peake, around the issues of uncertainty with importation of lobster. Maine in particular has our own unique problem with the gray zone, where it is disputed waters around the border between Maine and Canada.

Around Machias Seal Island, where we have roughly about 130 fishermen, who if the trigger is pulled and they are fishing under a smaller gauge, or a larger gauge at the minimum end, will be catching lobsters, throwing them back, and Canadian fishermen will be catching them and able to retain them, literally fishing right beside each other.

I think the time has come for us to address this gauge issue directly with Canada, and I would **move to request that the Interstate Fisheries Management Policy Board approve the creation of a subcommittee to engage Canada's Department of Fisheries and Ocean to discuss transboundary issues related to the importation of lobster, as it relates to different minimum gauge sizes in the two countries.**

The Subcommittee shall be made up of four members of the Lobster Management Board, who have license holders that fish in Area 1 and/or 3, and one representative from the National Marine Fisheries Service, and the Commission's Executive Director or his designee.

CHAIR McNAMEE: We have a motion on the board. The motion is seconded by David Borden. Pat, do you wish to offer anything else on the motion?

MR. KELIHER: No, I think that was offered up front. I front loaded, Mr. Chairman, I front loaded.
CHAIR McNAMEE: David, anything as the seconder?

MR. BORDEN: Nothing to add, other than the fact that these are fairly complicated issues, and I think we need to get on with the discussion.

CHAIR McNAMEE: Ray Kane.

MR. KANE: I turn to Mike Pentony. I have been told to understand these transboundary meetings are always difficult. What are your thoughts on this, Mike?

CHAIR McNAMEE: It looks like Mr. Pentony is consulting with legal counsel, so give him a minute. Mike, do you wish to answer Ray's question?

MR. PENTONY: Could I ask the indulgence of the Board to restate the question?

MR. KANE: Yes, Mike, thank you. I understand these transboundary discussions are always difficult. Can you give us your feed on this, your thoughts?

MR. PENTONY: Yes, they are difficult. I was consulting with legal counsel, because this motion, it's difficult to understand what the structure would be, in terms of a normal bilateral government to government discussion between the U.S. and Canada. My inclination is to abstain on this.

Then discuss with our International Affairs partners in the Department of State to see what might be made of this motion, should it pass. I wasn't prepared to fully comprehend and think through the implications of this, so I hope the Board will understand that I don't have any kind of definitive answer for how this might work.

CHAIR McNAMEE: Representative Peake.

REPRESENTATIVE PEAKE: Of course, as a legislator, my bias is always in favor of legislation. I know that Maine has an active federal delegation, and particularly your Senators, who care deeply about all of your fisheries that are there, but in particular the lobster fishery there. I guess a question for you, Pat is, are they in the loop on this?

Is this something that we should be speaking with our federal partners? My congressmen, my two senators, other members of the Congressional Delegation from Massachusetts, to put this on their radar screen so we have, either as a negotiating stick that federal legislation is possible, or to more fully engage them in whatever this rulemaking process might be.

CHAIR McNAMEE: Pat, go ahead.

MR. KELIHER: Thanks for that question, Representative. The Maine delegation is very informed when it comes to the gray zone issues. Senator Collins, in particular, has met with the fishermen that fish the gray zone out of Cutler. She has not, I don't believe, been brought up to speed so much on the importation issues.

But we'll certainly be having conversations with here on those. Here I'm not thinking this is a federal legislation issue, right. This is going to have to be an agreement between the countries. But I look at this as kind of a who's on first, right? The United States Marine Fisheries Commission is the primary management responsibilities for American Lobster.

Not to cut out the Agency, but the Agency is also very involved with those direct country-to-country conversations. We deal from a state of Maine perspective, directly with EFO on issues of concern one-on-one. I believe that they would engage with us on this. The gray zone this year in particular won't get resolved, unless the World Court steps in. But conversations around the inequities that are in place with them. If Canada understands that volume of lobster that may not be able to come into the United States for processing, would be significant. I would think that alone would be something that they would want to discuss with us, and how we could potentially rectify it in the long term.

REPRESENTATIVE PEAKE: Thank you.
CHAIR McNAMEE: Okay, any further discussion on this? Oh, sorry, Bob, go ahead.

EXECUTIVE DIRECTOR BEAL: Yes, I just wanted to follow up on Mike Pentony's comments, and buy him and his Agency 48 hours. Just remember this is going to go to Policy Board for consideration. I think two days from now, maybe there can be a little bit more insight from NOAA Fisheries. They probably can't fully analyze it, brought to State Department and all those other things. We can see what we can do, or they have some more insight on Wednesday.

CHAIR McNAMEE: Okay, **let's go ahead and call the question here. All those in favor of the motion, please raise your hand. Sorry, I'm going to go backwards here. Are there any objections to the motion? I will call are there any abstentions, one abstention. The motion passes by consent.**

NORTHERN EDGE SCALLOP FISHERY, NEW ENGLAND COUNCIL

CHAIR McNAMEE: All right, so Pat, I've got one more from you and that was on the interaction with the scallop fishery.

MR. KELIHER: Thank you, Mr. Chairman, I'll be quick. The New England Fisheries Management Council is considering allowing scallop access on the northern edge of Georges Bank. At their April meeting the Council initiated the action, and approved goals and objections for the action. Given the population of large female lobsters in this area, this action is likely going to be of interest to this Board, because of those interactions.

I don't think we need to task the TC with anything at this point, but I wanted to put it on the Board's radar screen. I think it's an important issue. The Lobster Board did provide comments at a previous action, the Omnibus Habitat Amendment 2 Action. That is when the scallop access to Northern Edge was considered in the past. Maybe we could just dust off those comments, and then take this issue up at the next Lobster Management Board.

CHAIR McNAMEE: Toni, go ahead.
MS. KERNS: Just to let the Board know. Michelle Bachman did reach out to Caitlin, and Caitlin has reached out to the TC. We've provided them the last report that we had, which is, I believe from 2012. Then Burton gave us some new information that we will work with Michelle to give her as well. We did engage the TC some.

CHAIR McNAMEE: Okay, great, thanks for bringing that up, Pat. Do you need anything on that beyond? Go ahead.

MR. KELIHER: Just one very quick issue. We've passed an addendum, Addendum XXVII. We still obviously have pending whale rules. Mike Pentony talked about it from a resiliency standpoint at the beginning. This probably goes without saying, but if we do see new whale rules before this trigger, before any triggers are pulled, or even in the interim between triggers. I think we as a Board and the TC need to understand what the relationship to resiliency is, and we may need to revisit that issue. But I just wanted to put that on the record.

ADJOURNMENT

CHAIR McNAMEE: Thanks for that, Pat. Okay, I think that brings us to the end of our agenda. Can I get a motion to adjourn? Motion made by Ray, second by Mike Luisi. Any objections to adjourning? Seeing no hands; we are adjourned.

(Whereupon the meeting adjourned at 3:25 p.m. on Tuesday, Monday, May 1, 2023)

Atlantic States Marine Fisheries Commission

Jonah Crab Benchmark Stock Assessment and Peer Review Report

For Review by the
American Lobster Management Board
October 16, 2023

Sustainable and Cooperative Management of Atlantic Coastal Fisheries

ACKNOWLEDGEMENTS

The Atlantic States Marine Fisheries Commission appreciates the efforts of Commission staff Jeff Kipp, Caitlin Starks, and Tina Berger in development and review of this report. The Commission thanks the numerous data providers that summarized and shared their data for this report. The Commission also recognizes Atlantic Coastal Cooperative Statistics Program staff, especially Adam Lee for support with commercial data.

Prepared by the

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A publication of the Atlantic States Marine Fisheries Commission pursuant to National Oceanic and Atmospheric Administration Award No. NA20NMF4740012.

PREFACE

The Jonah Crab Benchmark Stock Assessment and Peer Review Report is divided into two sections:

Section A – Jonah Crab Benchmark Stock Assessment Peer Review
PDF pages 4-26

This section provides a summary of the Jonah Crab Benchmark Stock Assessment results supported by the Peer Review Panel. The Terms of Reference Report provides a detailed evaluation of how each Term of Reference was addressed by the Stock Assessment Subcommittee and provides recommendations from the Panel for further improvement of the assessment in the future.

Section B – Jonah Crab Benchmark Stock Assessment
PDF pages 27-242

This section is the Jonah Crab Benchmark Stock Assessment report that describes the background information, data used, and analysis for the assessment submitted to the Peer Review Panel.

Atlantic States Marine Fisheries Commission

Jonah Crab Benchmark Stock Assessment Peer Review Report

Conducted on
August 29-31, 2023
Providence, Rhode Island

Prepared by the
ASMFC Jonah Crab Stock Assessment Review Panel

Rich Wong (Chair), Delaware Division of Fish and Wildlife, Little Creek, Delaware
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Sustainable and Cooperative Management of Atlantic Coastal Fisheries

ACKNOWLEDGEMENTS

The Review Panel gratefully recognizes the work conducted by the Jonah Crab Technical Committee in preparing the 2023 Benchmark Assessment and for the professional, open, and constructive spirit of discussion during the review workshop. The Review Panel also thanks the Science staff of the Atlantic States Marine Fisheries Commission for their role in organizing the meeting, and providing materials to the Review Panel in a timely fashion.

Acronyms

CFRF—Cooperative Fisheries Research Foundation
CPUE—Catch per unit effort
CSA—Catch Survey Analysis
CV—Coefficient of Variation
DFO—Department of Fisheries and Oceans, Canada
DRM—Direct Residual Mixture
FD—Fishery Dependent
FI—Fishery-independent
GAMS—Generalized Additive Models
IBM—Index Based Model
IGOM—Inshore Gulf of Maine
ISNE—Inshore Southern New England
LBSPR—Length-Based Spawning Potential Ratio
LOESS—Locally Estimated Scatterplot Smoothing
LPUE—Landings Per Unit Effort
M—Natural Mortality Rate (instantaneous)
MSL—Minimum Size Limit
MSE—Management Strategy Evaluation
OGOM—Offshore Gulf of Maine
OSNE—Offshore Southern New England
SAS—Stock Assessment Subcommittee
SPR—Spawning Potential Ratio
TC—Technical Committee
TOR—Term of Reference
VMS—Vessel Monitoring System
VTS—Vessel Trip/Tracking Survey/System
YOY—Young-of-the-year

EXECUTIVE SUMMARY

The Jonah Crab Stock Assessment is data-limited, preventing estimates of population size, fishing mortality rates, and determinations of overfishing and overfished statuses. The assessment explores other Status Determining Criteria (SDC), relying primarily on fishery-independent (FI) survey and fishery-dependent (FD) indices of abundance.

Despite the limited availability of current data, there is considerable urgency for the assessment due to a very steep, three-year, decline in landings. Commercial landings have declined 51% in three years, after an unprecedented 30-fold rise in landings. Although the recent decline is not well-detected in FI stock indicators, there is some evidence of declining fishery CPUE, creating substantial concern and uncertainty for the status of the stock. Given the mixed signals, the status of the Jonah Crab stock is highly uncertain.

Current conditions closely resemble early stages of the collapse of the Canada Jonah Crab fishery in the early 2000s. In the first three years of the crash, Canada landings dropped 58%. Within five years, landings fell 97%, and stock biomass could no longer support a fishery. FI trawl indicators had not fully captured the signals of a rapidly declining stock. However, declining fishery CPUE was observable preceding and during the landings crash.

Given the high level of uncertainty in the status of the Jonah Crab stock, the Panel strongly recommends close monitoring of annual stock indicators in the next few years. Annual indicators can determine whether sharply declining recent landings are signaling the start of a 'bust' phase of a boom-and-bust arc, or are due to fishery and market-related factors uncoupled with Jonah Crab abundance.

In the following report, we evaluate the assessment work by Term of Reference, and provide an Advisory section that may be useful to the Board for making decisions on future management actions, and for setting the direction of research and assessment efforts.

TERMS OF REFERENCE

1. **Evaluate the thoroughness of data collection and the presentation and treatment of fishery-dependent and fishery-independent data in the assessment, including the following but not limited to:**
    a. **Presentation of data source variance (e.g., standard errors).**
    b. **Justification for inclusion or elimination of available data sources,**
    c. **Consideration of data strengths and weaknesses (e.g., temporal and spatial scale, gear selectivities, sample size),**
    d. **Calculation and/or standardization of abundance indices.**

Data collection for the assessment was comprehensive and thoroughly assembled. The Stock Assessment Subcommittee (SAS) presented 53 fishery-independent (FI) survey indices covering four life stages (young-of-the-year, recruit, post-recruit, spawners) and five regions (IGOM, OGOM, ISNE, OSNE, Coastwide). Indices included: five young-of-the-year (YOY) indices (an additional three surveys were evaluated but not included); and 48 post-YOY indices (plus 20 evaluated but not included). Four fishery-dependent (FD), exploitable-size, male crab CPUE indices were presented covering four regions (IGOM, OGOM, ISNE, OSNE).

The SAS presented data source variance where appropriate and necessary. While error estimates were presented in tabular form for the CFRF VTS results and trawl survey estimates, having those estimates on their corresponding figures would be useful.

The inclusion (and exclusion) of all the data sources presented was well justified. In addition to tracking the mean sizes of the largest 5% of exploitable males, it would be informative to see the full-size distributions of crabs (by sex if available) from annual FI and FD collections. Continued monitoring of potential changes in size distributions may be important for detecting overfishing. Importantly, size compositions could yield initial estimates of mortality rates using length-based catch curves and estimates of spawning potential ratio (SPR) as growth parameters are further refined. Further investigation into defining the instantaneous natural mortality rate (M) will be essential for future population models and interpreting mortality rates derived from simple catch curves.

The SAS did a commendable job describing the strengths and weaknesses of the data and how they vary across the four stocks, particularly during the review workshop. The calculations and standardization of all indices were all detailed and appropriate to help interpret complex fishery-dependent data (e.g., the Direct Residual Mixture Model CPUE). Some presentation of raw vs. standardized metrics could be helpful in the future to understand the magnitude of improvements and also what factors were most influential to CPUE metrics and their interpretations. Overall, this was an impressive body of work and the Review Panel is grateful for the breadth of knowledge and attention to detail presented by the SAS.

2. **Evaluate empirical indicators of stock abundance, stock characteristics, and fishery characteristics for their appropriateness to monitor the stock between assessments.**

The Review Panel recommends continued monitoring of all current indicators of stock abundance, and stock and fishery characteristics. However, the SAS's prioritization of importance of indicators was difficult to interpret from the assessment document. Upon discussion with the SAS, opinions varied regarding the most informative indices in providing management advice. Further exploration and the accompanying rationale would be extremely useful in making the management decision process transparent and repeatable.

The utility of any indicator depends on its relationship to the true measure of abundance or underlying rate (e.g., fishing mortality). Fishery-independent data sources for Jonah crab can be difficult to interpret if the efficiency of the sampling gear is unknown or thought to be low. Similarly, fishery-dependent measures of abundance, such as commercial landings per unit effort, often require substantial analyses to isolate the effects of economic factors from measures of abundance. The Review Panel recommends additional work by the SAS to separate the essential from the desirable indicators.

Several proposed indicators of stock status were considered less useful for either measures of overall stock status or future modeling efforts. Measures of YOY settlement, while important region-wide indicators of the ecosystem, can rarely be related to the spawning biomass that produced them or their subsequent recruits to the fishery. Measures of crab biomass and length frequencies for legal and sublegal males, as well as mature females are likely to be critical for future modeling efforts.

Trawl surveys were typically the most valuable data stream since they are likely to be the only synoptic measure of relative density for most stocks. As noted elsewhere, capture efficiency was likely to be low and dependent on unobservable variations in behavior of the crabs. Collaboration with harvesters is encouraged to obtain their perspectives on changes in catchability especially with respect to seasonal factors and spatial distribution. Further development of fishing area maps (composite, not individual harvesters) could be helpful for interpreting fishery-independent surveys.

Details of the trawl survey estimates should be presented for each stock area. Over the past 15 years, the NEFSC allocated about 380 stations per year over 82 strata. Since the crab stock areas bisect some of the strata, there is a possibility that the number of stations in a stock area is very low in some years. ISNE seems to be prone to lower station numbers with consistent patterns of CV>0.70 in many years. Various model-based methods of ‘small area estimation’ may be useful, although not yet applied to NEFSC or other surveys in the crab stock areas.

Efforts should be made to document empirical sex ratios in FI and FD collections. There is also need to monitor for changes in survey-specific ‘operational sex ratios’ as potentially important early warning signals of overfishing, given the predominantly male crab fishery. In this regard, the abrupt decline of Jonah Crab in Canada (DFO 2009) suggests further collaboration with Canadian colleagues and harvesters would be useful to evaluate early warning signs that may be evident in retrospect. The post-mortem analysis should also consider evidence of recovery, or lack thereof.

In view of the potential sensitivity of the stocks to rapid collapse, the use of Kendall’s method for evaluating overall trend may not allow for detection of important short-term trends. More ‘adaptive’ measures of local trends such as LOESS smoothers or Generalized Additive Models (GAMS) should be explored.

Preliminary examination of Jonah crab prices, in conjunction with Landings Per Unite Effort (LPUE) measures, strongly suggest the need to incorporate economic factors when interpreting LPUE trends. Low CPUE when prices are at record highs may be indicative of low availability in traditional fishing areas, or reduced overall abundance. Results of a Rhode Island trip-level LPUE analysis conducted during the review meeting were informative. Continuation of such analyses is strongly encouraged for subsets of data deemed reliable.

For metrics most useful to tracking crab population dynamics, the Review Panel recommends focusing on synoptic trawl surveys with high efficiency gear (e.g., the NEFSC winter survey, 1992-2007); LPUE models informed by economics and harvester inputs; and expansion of the CFRF ventless trap survey to all harvesters, particularly if a design component could be imposed.

3. **Evaluate the methods and models used to estimate population parameters (e.g., F, biomass, abundance) and biological reference points, including but not limited to:**
    a. **Evaluate the choice and justification of the preferred model(s). Was the most appropriate model (or model averaging approach) chosen given available data and life history of the species?**
    b. **If multiple models were considered, evaluate the analysts' explanation of any differences in results.**
    c. **Evaluate model parameterization and specification (e.g., choice of CVs, effective sample sizes, likelihood weighting schemes, calculation/specification of M, stock-recruitment relationship, choice of time-varying parameters, plus group treatment).**

The SAS evaluated the utility of several data-poor methods based on rates of change in fishery-independent indicators and measures of relative exploitation. Fishery-independent (FI) indicators included one or more trawl surveys in each stock area. In OSNE, the SAS defined relative exploitation as the ratio of landings to the relative abundance from the NEFSC bottom trawl survey. The SAS conducted fishery-independent index-based methods (IBM), called 'Islope' and 'Plan B', and a relative exploitation method called 'Skate'. All of the methods rely on an adjustment of current landings in response to some measure of recent rates of change in fishery abundance index. Islope and Plan B rely on the slope of the indices. The Skate method adjusts catches in response to the ratio of recent exploitation rates to a historical period judged to be a period of stability.

The SAS concluded none of the index-based methods were applicable to Jonah crabs in any stock area. Justifications included the short duration of the time series, the high variability of survey estimates, and the wide range of catch recommendations. Perhaps most importantly, the relationship between total catch (or rates of removal) and population response has not been validated for any index or stock area. An Ensemble method, based on the median of alternative estimates, was also judged inappropriate.

The Review Panel largely agreed with the SAS's conclusions. Longer time series may improve the utility of such methods. However, the general increases in multiple indices over the period in which landings have also increased much more rapidly, suggests fishing mortality is not yet a major factor controlling stock dynamics. However, very recent declines in several fishery-dependent (FD) indicators could be early warning signals of increased exploitation. Without further analyses and the benefits of hindsight and additional data, the Review Panel concluded that further work on Index-Based Methods would not be particularly useful.

The Review Panel suggested that future work on IBMs should be subordinate to the development of other modeling approaches. Further consideration should be given to the application of Catch Survey Analyses (CSA). Such dynamic stage-based models have the advantage of being simple and readily interpretable. Initial attempts to apply these types of models were not successful, often because the size frequency data necessary to identify pre-recruits from recruits was insufficient for the range of years included in the assessment. A related concern is a general lack of knowledge on the molt increment of pre-recruit sized crabs. This is important because CSA requires information on the number of unexploited animals growing into the recruited size range between years. Further examination of existing experimental data and perhaps other experiments may be useful for improving the utility of CSA in at least some areas.

Probably the single most impactful advancement towards generating Jonah Crab population parameters is the development of an unbiased ageing method, based on a thorough examination of marine crustacean ageing research and techniques (e.g., Kilada et al. 2017, Fairfield et al. 2021). At a minimum, simple catch curves of FI and FD age compositions would be feasible, yielding highly informative mortality estimates and providing much insight into Jonah Crab population dynamics. More complex population models and operating models would naturally evolve. The Review Panel does recognize the difficulties in ageing crustaceans. Given the substantial upside of unbiased ageing for practical applications in management, we feel it is worth investigating the method further for Jonah crab.

The Review Panel was impressed with initial results from a Length Based Spawner per Recruit (LBSPR) model parameterized in response to a request from the Panel. Such models often require substantial "borrowing" of growth parameters and natural mortality assumptions from other stock areas and/or related species. Current data are insufficient to support full implementation of the LBSPR approach. However, the Review Panel recommends further development of an LBSPR model in order to guide monitoring efforts and analyze relationships among surveys and landings data. For example, the expected ratio of males to females at length under varying levels of fishing mortality could be derived and monitored routinely to derive static estimates of total mortality by sex. Alternatively, some data suggest that availability of female crabs to the fishery and fishery-independent surveys varies seasonally. If so, an LBSPR model could be useful to interpret such anomalies and distinguish seasonal migrations from changes in mortality rates.

4. **Evaluate the diagnostic analyses performed - e.g., sensitivity analyses to determine model stability and potential consequences of major model assumptions, and retrospective analysis.**

Overall, the SAS presented thorough diagnostics for the analyses they performed while balancing the length and level of detail of the report. Additional diagnostics on model selections (e.g., table of AICs) and their interpretations regarding the magnitude of various factors would have been helpful and interesting, especially in the sections on the CFRF VTS catch rates and the Direct Residual Mixture Model CPUE.

5. **Evaluate the methods used to characterize uncertainty in estimated parameters. Ensure the implications of uncertainty in technical conclusions are clearly stated.**

In general, the SAS did not formally evaluate the implications of precision of estimates, in part due to the lack of model-based approaches available to limited Jonah crab data. There was however substantial discussion of the relative merits of indices, particularly with respect to their utility for various index-based methods.

6. **Recommend best estimates of stock biomass, abundance, and exploitation from the assessment for use in management, if possible, or specify alternative estimation methods.**

The SAS was unable to develop analytical models of abundance or exploitation. Reasons included concerns about measurement error in abundance indices and insufficient knowledge of basic crab biology, particularly growth. The Review Panel agreed that a credible model could not be developed at this time. A simple catch-survey analysis model may be a useful starting point to explore the feasibility of creating a dynamic model. The Review Panel noted that static models, such as within year depletion models, would be useful for generating biomass and fishing mortality rates. Such models could be useful even when they fail, because results could indicate the relative magnitude of fishing mortality rates. Ultimately, Jonah crab models useful for management will depend on additional years of data, especially from recently initiated data collection programs.

The Review Panel noted that female Jonah crab are uncommon in the fishery, owing largely to the minimum size limit and associated trap vent sizes. In addition, selectivity of smaller sized crabs may be low in fishery-independent surveys, particularly trawls with rockhopper gear. As a result, there are relatively few data streams that would allow application of sex-based methods for mortality estimation. More importantly, there are relatively few empirical measures that could provide early warning signs of overexploitation. The Review Panel encourages further development of monitoring programs that allow for monitoring of size composition of male and female abundances, and evidence of reduced egg production. Ventless traps may be useful, particularly if the current CFRF Ventless Trap Survey could be expanded to the larger fishery. See TOR 8 for more details.

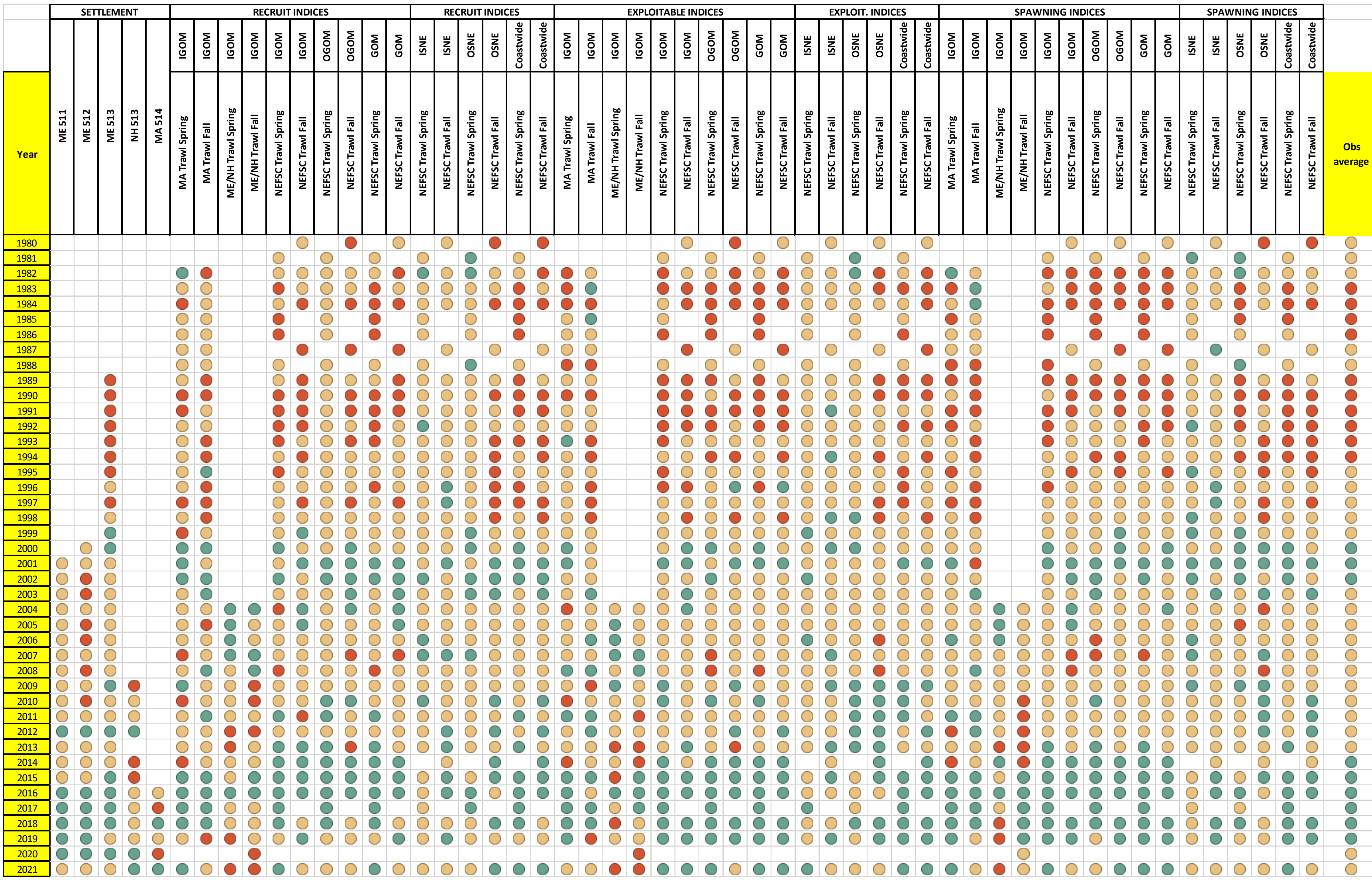
7. **Evaluate the choice of reference points and the methods used to estimate them. Recommend stock status determination from the assessment, or, if appropriate, specify alternative methods/measures.**

While exploitation-based or abundance-based reference points were not yet feasible given essential life history gaps and data constraints, the SAS was able to present numerous indicators and other important fishery and biological background that provided information about stock status. A number of favorable factors exist, such as a cohesive, coastwide, regulatory framework implementing a protective minimum size limit (MSL) that appears to conserve most mature male crabs, particularly in the region where the fishery primarily operates. Furthermore, the fishery selectivity appears to operate at even larger sizes than the MSL, given discussions with the SAS and from a preliminary, post-hoc, Panel-requested, length-based Spawning Potential Ratio (LBSPR) analysis. Importantly, the fishery also does not select female crabs, providing a significant moat to the potential depletion of female spawning biomass. The obvious danger to the stocks' reproductive potential would occur from male depletion and sperm limitation.

An evaluation of stock SPR using the LBSPR approach is a promising status determining criterion for Jonah Crab, given its minimal data requirements. For Jonah Crab, the LBSPR analysis only requires further refinement of growth parameters and natural mortality assumptions, and can be explored for both FD and FI survey size compositions for both sexes.

Fishery-Independent (FI) stock indicators, in bulk, tend to portray a population at higher levels of abundance than at the start of survey time series' (Table 1). However, the positive signals are assessed across a time span up to 42 years, and should be interpreted with caution since there appears to be a regime shift occurring circa 2010.

Table 1. Graphic depiction of ordinal measures of relative abundance indices by stock area and year. Lowest 25% quartile is coded red, interquartile range is coded in yellow, and highest quartile (>75%ile) is coded green. Each index is coded separately. Shorter time series may create bias when compared to longer time series.



Although long-term FI indicators are positive, we see a clear, sharp decline in recent fishery landings and other highly concerning, corroborating, fishery metrics. Jonah Crab landings have declined 51% in the most-recent three-year period (2019-2021) in the OSNE, even while market prices have increased. While we acknowledge other industry and market factors need to be investigated, it is highly concerning to see similar, recent, sharp declines beginning in 2019 in the fishery-dependent (FD) CFRF CPUE, the generally declining FD CPUE in the DRM analysis, and the sharp recent decline in the post-hoc, Panel-requested investigation of directed FD CPUE from RI trip level data (Figure 1). There were also large single-year drops in FI CPUE in the NEFSC OSNE trawl in Fall 2019 and Spring 2020.

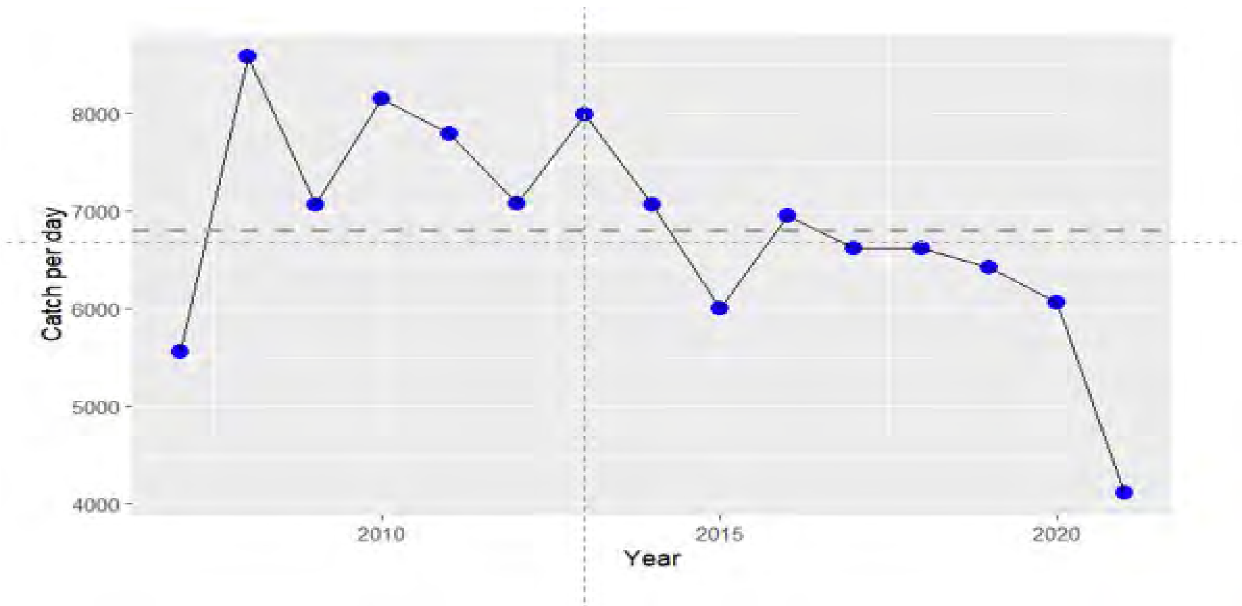


Figure 1. Rhode Island commercial Jonah Crab CPUE (harvest per fishing day) of a harvester group targeting Jonah Crab. (Analysis is preliminary)

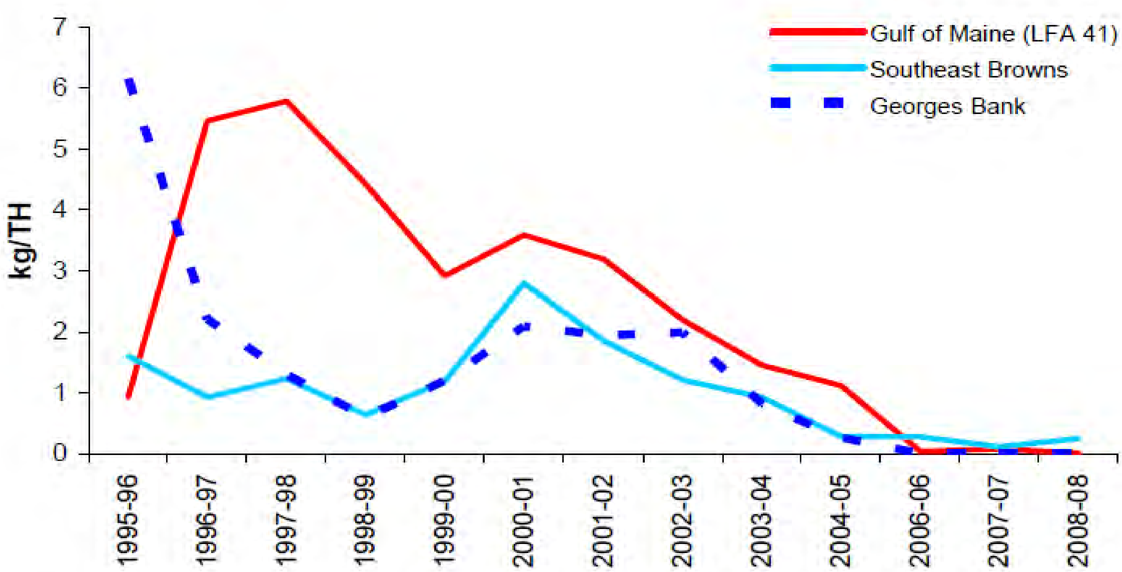


Figure 2. Commercial harvest CPUE (kg/trap) of Jonah Crab during the collapse of the Canada fishery landings that occurred primarily from 2001 to 2004.

It is very worrisome that the extremely rapid collapse of the Canada Jonah crab fishery in the early ‘00s occurred without noticeable declines in FI indicators (see Canadian Science Advisory Report 2009/034). Canada landings declined by 58% in the first three years of the fishery collapse, comparable to the current, three-year, 51% drop in OSNE landings. Although Canada Fisheries and Oceans (DFO) FI trawl indicators did not capture the deteriorating condition of the stock, declining fishery CPUE was observable preceding and during the landings crash (Figure 2).

8. **Review the research, data collection, and assessment methodology recommendations provided by the Technical Committee and make any additional recommendations warranted. Clearly prioritize the activities needed to inform and maintain the current assessment, and provide recommendations to improve the reliability of future assessments.**

The Technical Committee presented a number of research priorities in their report and, upon the Panel’s request, further refined their highest priority research recommendations to improve future Jonah crab stock assessments. The Review Panel thoroughly discussed the High Priority Short-term topics proposed by the TC. The Review Panel recommends the highest priority should be given to determining how to best interpret fishery-dependent data along with potentially new metrics (see pg 47 of Jonah Benchmark Assessment Report). In light of a new indicator brought forward (catch per trip) and the new, higher, resolution fishery dependent data streams (e.g., VMS data) this avenue of research is likely to provide the most-timely improvement in future assessments.

Additional research topics recommended by the Review Panel include: 1) potential expansion of the CFRF ventless trap sampling, 2) examination of the now defunct (ending in 2007) NEFSC Winter Bottom Trawl Survey (Terceiro 2003, NEFSC 2019), 3) more detailed evaluation of female data, and 4) development of interim measures for evaluating ‘stock health’.

1) The CFRF ventless trap research provides an intermediate design between fishery-dependent and fishery-independent data collection. Increasing its spatial extent would be valuable, especially in Southern New England (SNE) where current trawl surveys catch very few Jonah crabs. Consideration of expansion and a thoughtful design approach (e.g., stratified random within current fishing grounds) may provide an improved index of abundance through time. A broad-based program might include of one or more ventless traps deployed by <u>all</u> harvesters over the course of the regular fishing operations. While such a survey would not include random selection, ancillary data, such as historical survey, observer data, and new VMS data could be used to generate appropriate weighting factors for relative estimating abundance.

2) Crabs are scarce in the current NEFSC trawl survey in SNE. However, reasonable catches in the previously conducted NEFSC Winter Bottom Trawl Survey, suggest there may be data available to provide historical context to Jonah crab abundance, and may facilitate a small, strategic, and likely cooperative survey utilizing a gear that effectively catches crab (including females) and does not have concerns regarding behavioral interactions with lobster.

3) Similarly, a more exhaustive examination of the currently available female data (including male/female sex ratios, LBSPR) will likely prove to be an informative metric of stock health. Along with the addition of metrics on females, continued research is warranted on repeatable

and transparent methods to better summarize multiple indicators for each of the four stocks. Formalizing the methods will support decision making into the future until more quantitative methods are available.

4) Lastly, the Review Panel would like the TC to consider a more formal approach to incorporate harvesters' Local Knowledge (LK) to provide context to best interpret fishery dependent data. While we recognize fisheries agency staff have good interactions with harvesters, developing a repeatable and consistent metric(s) of local knowledge could lead to improved interpretation and "buy in" from harvesters on assessment outcomes.

9. Recommend timing of the next benchmark assessment and updates, if necessary, relative to the life history and current management of the species.

It is unlikely that sufficient research will be completed to support a stock assessment within the next five years. Up to 10 years may be needed to complete the many tasks identified by the Stock Assessment Subcommittee and Reviewers. New time series of fine-scale spatial data from the fleet should be particularly informative for future assessments. Moreover, potential new surveys, critical laboratory experiments, and more extensive analyses of existing data have been proposed. Sufficient time is needed to summarize and evaluate these projects before conducting a formal assessment.

The proposed interval for the next assessment poses problems for planning. In order to maintain a focus on the assessment, the Review Panel recommends an interim meeting within five years. The purpose of the meeting will be to summarize ongoing work and to set a date for the formal assessment. A meeting coupled with a review of ongoing status derived from indicators, will help fine tune ongoing projects, drop projects unlikely to be useful, and allow for consideration of candidate modeling approaches.

The Review Panel also expressed concerns about the lack of a decision process that will be necessary before the next assessment. Experience with other crustacean stocks suggests that rapid collapses can occur, particularly when the underlying biology of the stock and patterns of fishing mortality are not fully understood. Preliminary analyses reported at the review meeting suggest declines in catch per unit effort from a subset of directed harvesters in the Offshore Southern New England stock. To address these concerns the Review Panel emphasizes the need to:

- Identify and prioritize candidate indicators of relative abundance and fishery performance.
- Conduct a formal annual evaluation of important indicators, and
- Develop a methodology for making decisions based on ordinal data. Analyses by the SAS showed the utility of binning data into 3 bins corresponding to the first quartile, the inter quartile range, and the fourth quartile.

Ideally, the methodology would identify the probability of observing the observed trends in indicators. Simultaneous drops in multiple indicators may be indicative of true declines or coincidence. Randomization tests may be helpful for distinguishing between these alternatives.

Concomitantly the SAS, in collaboration with managers, will need to define appropriate actions in response to indicator patterns. For example, a decision rule might be to reduce catch by 10% if the probability of observing the observed trend is less than 5% due to chance alone, and to reduce catch by 25% if the probability level is less than 1%. The probability thresholds for decisions and the magnitude of management measures should not be ad hoc. Instead, simulation testing or some form of MSE will be necessary and should be considered by ASMFC. This problem is, of course, not unique to Jonah crabs. Therefore, evaluation of national and international research may be helpful.

ADVISORY REPORT

A. Status of the Stock

The Stock Assessment Subcommittee (SAS) brought forward a large assemblage of Jonah crab data in a cohesive and thorough manner. At present, the availability of data was not sufficient to estimate population parameters and biological reference points in order to determine traditional overfishing and overfished statuses. Other status determining criteria (SDC) were explored, including important fishery and biological background and trend analyses of 53 fishery-independent (FI) survey indices and four fishery-dependent (FD) indices. Interpreting stock status was difficult because longer-term trends in stock indicators appear positive, but disturbing, recent indicators signal a potentially, sharply declining stock. The conflicting indicators depicted an uncertain stock status for Jonah crab.

A number of favorable factors exist, such as a cohesive, coastwide, regulatory framework that implements an appropriate minimum size limit (MSL) that reduces harvest of immature crabs. Furthermore, the fishery selects crabs at even larger sizes than the MSL, based on discussions with the SAS and supported by a preliminary Length-Based Spawning Potential Ratio (LBSPR) analysis requested by the Review Panel. Importantly, the fishery also does not select female crabs, which provides a significant moat to the potential depletion of female spawning biomass. Given these fishery dynamics, the larger danger to population reproductive productivity would occur from male depletion/sperm limitation.

Fishery-Independent (FI) stock indicators, in bulk, tend to portray a population at higher levels of abundance than at the start of survey time series (Table 1). However, the positive signals are assessed across a time span up to 42 years, and should be interpreted with caution since there appears to be a potential regime shift occurring circa 2010, when young-of-the-year recruitment indices become conspicuously elevated in the GOM. When examining indicators over a shorter-term, post-regime-shift time span (2010-2021), there are much fewer positive (>75th percentile) index values in the terminal years (2020, 2021) across the range of indices (Table 2).

Table 2. Graphic depiction of ordinal measures of relative abundance indices by stock area and year from 2010-2021. Lowest 25% quartile is coded red, interquartile range is coded in yellow, and highest quartile (>75%ile) is coded green. Each index is coded separately. Shorter time series may create bias when compared to longer time series.

Year	SETTLEMENT ME 511	ME 512	ME 513	NH 513	MA 514	Obs average
2010	Red	Red	Yellow	Yellow		Yellow
2011	Red	Red	Yellow	Yellow		Red
2012	Green	Green	Green	Green		Yellow
2013	Yellow	Yellow	Red			Red
2014	Yellow	Yellow	Yellow	Red		Yellow
2015	Red	Yellow	Yellow	Red		Green
2016	Green	Green	Green	Red	Yellow	Green
2017	Yellow	Yellow	Yellow	Yellow	Red	Green
2018	Green	Green	Green	Yellow	Green	Yellow
2019	Yellow	Yellow	Red	Yellow	Yellow	Yellow
2020	Yellow	Yellow	Yellow	Green	Red	Yellow
2021	Yellow	Red	Red	Green	Green	Yellow

RECRUIT INDICES

Year	IGOM MA Trawl Spring	IGOM MA Trawl Fall	IGOM ME/NH Trawl Spring	IGOM ME/NH Trawl Fall	IGOM NEFSC Trawl Spring	IGOM NEFSC Trawl Fall	OGOM NEFSC Trawl Spring	OGOM NEFSC Trawl Fall	GOM NEFSC Trawl Spring	GOM NEFSC Trawl Fall
2010	Red	Yellow	Yellow	Yellow	Red	Red	Yellow	Yellow	Red	Yellow
2011	Yellow	Yellow	Yellow	Yellow	Yellow	Red	Yellow	Red	Yellow	Red
2012	Red	Yellow	Yellow	Red	Red	Yellow	Red	Red	Red	Red
2013	Yellow	Red	Red	Yellow	Yellow	Yellow	Yellow	Red	Yellow	Yellow
2014	Red	Red	Green	Yellow	Green	Green	Green	Green	Green	Green
2015	Green	Green	Green	Green	Yellow	Green	Green	Green	Yellow	Green
2016	Green	Yellow	Green	Green	Green	Green	Green	Green	Green	Green
2017	Yellow	Green	Yellow	Green	Green		Yellow		Green	
2018	Green	Green	Yellow	Yellow	Yellow	Red	Yellow	Yellow	Yellow	Red
2019	Yellow	Red	Red	Yellow	Red	Yellow	Red	Yellow	Red	Yellow
2020				Red						
2021	Yellow	Yellow	Red	Red	Yellow	Yellow	Red	Yellow	Yellow	Yellow

RECRUIT INDICES

Year	ISNE NEFSC Trawl Spring	ISNE NEFSC Trawl Fall	OSNE NEFSC Trawl Spring	OSNE NEFSC Trawl Fall	Coastwide NEFSC Trawl Spring	Coastwide NEFSC Trawl Fall
2010	Green	Yellow	Yellow	Green	Red	Yellow
2011	Yellow	Red	Green	Red	Yellow	Red
2012	Yellow	Green	Red	Green	Red	Yellow
2013	Yellow	Yellow	Yellow	Yellow	Green	Red
2014		Yellow		Yellow		Green
2015	Yellow	Green	Red	Yellow	Yellow	Green
2016	Yellow	Green	Green	Red	Green	Green
2017	Yellow		Green		Green	
2018	Yellow	Red	Yellow	Yellow	Yellow	Red
2019	Yellow	Yellow	Red	Red	Red	Yellow
2020						
2021	Yellow	Red	Yellow	Green	Yellow	Yellow

EXPLOITABLE INDICES

Year	IGOM MA Trawl Spring	IGOM MA Trawl Fall	IGOM ME/NH Trawl Spring	IGOM ME/NH Trawl Fall	IGOM NEFSC Trawl Spring	IGOM NEFSC Trawl Fall	OGOM NEFSC Trawl Spring	OGOM NEFSC Trawl Fall	GOM NEFSC Trawl Spring	GOM NEFSC Trawl Fall
2010	Red	Red	Yellow	Yellow	Yellow	Red	Yellow	Red	Yellow	Red
2011	Yellow	Yellow	Yellow	Yellow	Red	Red	Red	Red	Red	Red
2012	Yellow	Green	Yellow	Yellow	Red	Yellow	Red	Yellow	Red	Yellow
2013	Red	Red	Red	Yellow	Red	Yellow	Red	Red	Red	Red
2014	Red	Yellow	Green	Red	Green	Red	Green	Yellow	Green	Yellow
2015	Green	Green	Yellow	Green	Yellow	Yellow	Yellow	Green	Yellow	Green
2016	Green	Yellow	Green	Green	Green	Green	Green	Green	Green	Green
2017	Green	Green	Green	Green	Yellow		Yellow		Yellow	
2018	Yellow	Yellow	Red	Yellow	Green	Green	Green	Green	Green	Green
2019	Yellow	Red	Yellow	Yellow	Yellow	Green	Yellow	Yellow	Yellow	Yellow
2020				Red						
2021	Yellow	Yellow	Red	Red	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow

EXPLOIT. INDICES

Year	ISNE NEFSC Trawl Spring	ISNE NEFSC Trawl Fall	OSNE NEFSC Trawl Spring	OSNE NEFSC Trawl Fall	Coastwide NEFSC Trawl Spring	Coastwide NEFSC Trawl Fall
2010	Yellow	Yellow	Green	Yellow	Yellow	Red
2011	Yellow	Yellow	Green	Yellow	Red	Red
2012	Yellow	Yellow	Yellow	Green	Red	Yellow
2013	Yellow	Green	Yellow	Yellow	Red	Red
2014		Yellow		Yellow		Yellow
2015	Yellow	Green	Yellow	Red	Green	Yellow
2016	Yellow	Yellow	Red	Red	Green	Green
2017	Green		Yellow		Yellow	
2018	Yellow	Yellow	Green	Green	Green	Green
2019	Yellow	Green	Red	Green	Yellow	Green
2020						
2021	Green	Yellow	Red	Red	Yellow	Yellow

SPAWNING INDICES

Year	IGOM MA Trawl Spring	IGOM MA Trawl Fall	IGOM ME/NH Trawl Spring	IGOM ME/NH Trawl Fall	IGOM NEFSC Trawl Spring	IGOM NEFSC Trawl Fall	OGOM NEFSC Trawl Spring	OGOM NEFSC Trawl Fall	GOM NEFSC Trawl Spring	GOM NEFSC Trawl Fall
2010	Red	Yellow	Yellow	Yellow	Red	Yellow	Yellow	Red	Red	Red
2011	Yellow	Yellow	Yellow	Yellow	Red	Red	Red	Yellow	Red	Yellow
2012	Red	Yellow	Yellow	Red	Red	Red	Red	Red	Red	Red
2013	Yellow	Red	Red	Red	Yellow	Red	Yellow	Red	Yellow	Red
2014	Red	Yellow	Green	Red	Green	Yellow	Green	Green	Green	Yellow
2015	Green	Green	Green	Green	Yellow	Green	Green	Green	Green	Green
2016	Green	Yellow	Green	Yellow	Green	Yellow	Green	Green	Green	Green
2017	Green	Green	Yellow	Yellow	Yellow		Yellow		Yellow	
2018	Yellow	Green	Yellow	Green	Green	Green	Yellow	Yellow	Yellow	Yellow
2019	Yellow	Red	Red	Green	Yellow	Green	Red	Yellow	Yellow	Green
2020				Yellow						
2021	Yellow	Red	Red	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow

SPAWNING INDICES

Year	ISNE NEFSC Trawl Spring	ISNE NEFSC Trawl Fall	OSNE NEFSC Trawl Spring	OSNE NEFSC Trawl Fall	Coastwide NEFSC Trawl Spring	Coastwide NEFSC Trawl Fall
2010	Yellow	Yellow	Yellow	Green	Red	Yellow
2011	Green	Red	Red	Green	Red	Yellow
2012	Yellow	Red	Yellow	Green	Red	Green
2013	Yellow	Yellow	Green	Red	Yellow	Red
2014		Yellow		Yellow		Red
2015	Yellow	Green	Red	Yellow	Green	Green
2016	Yellow	Green	Green	Red	Green	Green
2017	Yellow		Yellow		Yellow	
2018	Yellow	Yellow	Green	Yellow	Green	Yellow
2019	Yellow	Green	Red	Red	Yellow	Yellow
2020						
2021	Green	Red	Yellow	Yellow	Yellow	Red

Although long-term FI indicators appear positive, we see a clear, sharp decline in recent fishery landings and other highly concerning, corroborating fishery metrics. Jonah crab landings have declined 51% in the most-recent three-year period in the OSNE, even while market prices have increased. While we acknowledge other industry and market factors should be investigated, it is highly concerning to see similar, recent, sharp declines in the fishery-dependent (FD) CFRF OSNE CPUE beginning in 2017, the generally declining FD CPUE in the inshore RI DRM analysis, and a recent decline in the post-hoc, Panel-requested, investigation of directed FD CPUE from RI trip level data (Figure 1). There were also large single-year drops in FI CPUE in the NEFSC OSNE trawl in Fall 2019 and Spring 2020.

It is particularly worrisome that the extremely rapid collapse of the Canada Jonah crab fishery in the early 2000s occurred without noticeable declines in FI trawl indicators (DFO 2009). In the first three years of the Canada fishery collapse, crab landings declined by 58%, comparable to the current, three-year, 51% drop in OSNE landings. Although Canada Fisheries and Oceans (DFO) FI trawl indicators did not fully capture the deteriorating condition of the stock, declining fishery CPUE was observable preceding and during the landings crash (Figure 2).

Given a data-limited assessment lacking population estimates and biological reference points (BRPs), generally conflicting long- versus short-term indicators, and recent, declining fishery signals, the Panel considers the status of the Jonah crab stock to be highly uncertain and recommends close, annual monitoring of stock indicators to further evaluate recent signals.

B. Data and Assessment

Data collection for the assessment was comprehensive and thoroughly assembled. The SAS presented 53 fishery-independent (FI) survey indices covering four life stages (young-of-the-year, recruit, post-recruit, spawners) and five regions (IGOM, OGOM, ISNE, OSNE, Coastwide). They included: five young-of-the-year (YOY) indices (an additional three surveys were evaluated but not included); and 48 post-YOY indices (plus 20 evaluated but not included). Four fishery-dependent (FD), exploitable-sized, male crab CPUE indices were presented covering four regions (IGOM, OGOM, ISNE, OSNE).

Given life history gaps and tempered confidence in synoptic indices, attempts to construct population models were not detailed in the assessment. Trend analyses of survey and relative exploitation indices were explored, showing mixed results between GOM and SNE regions, and were fairly inconclusive from a coastwide perspective and for the important OSNE region that supports the bulk of the fishery. Index-based methods were also explored and were not recommended for management use, given the apparent disconnect between indices and fishery removals, and concern regarding trawls as an appropriate survey gear for structure-associated Jonah crabs.

Challenges

Age and Growth

Assessing marine invertebrate fishery stocks is notoriously difficult, largely due to the prevailing lack of ageing methods for invertebrates, especially crustaceans. The inability to age individuals and characterize age distributions is particularly troublesome for assessments when the species is long-lived, without highly conspicuous life stages that can be monitored practicably and described using stage-based population models. Significant life history gaps still exist for Jonah crab, particularly with respect to modeling growth and understanding longevity, that could prove highly useful in developing length- or stage-based population models or developing other SDC such as Length-Based Spawning Potential Ratio (LBSPR) modeling. Longevity is particularly important, since maximum age is a powerful, useful predictor of natural mortality rate (M). Growth rate and M are also key elements in constructing basic yield-per-recruit (YPR) and spawner-per-recruit models that can produce fishing mortality-based reference points for Jonah crab and reveal how vulnerable the stock is to overfishing.

Surveys

The SAS did an excellent job producing a long list of FI relative abundance indices, based notably on trawl surveys for all post-young-of-the-year (YOY) FI indices. The potential ineffectiveness of mobile trawl gears for capturing benthic, structure-associated Jonah crabs was a prominent discussion point amongst the Panel and SAS. As an illustration of this potential issue, one out of every five (21.3%) annual trawl index values was zero in the assessment. Trawl ineffectiveness was especially pronounced in certain indices, particularly the Northeast Fisheries Science Center (NEFSC) trawl indices in the ISNE and OSNE (to a lesser degree than the ISNE). Such heavy reliance on trawls is a substantial concern for monitoring Jonah crab indicators.

FD indices based on passive traps and pots offer promise as stock indicators. However, the usual caveats need investigation, such as inter-specific (e.g., lobster) and intra-specific interactions, shifting bait practices, gear saturation, hyperstability in catch rates due to commercial fishing practices, regulation changes, and fluctuations in fleet composition influenced by market factors. Taking these caveats into consideration, during the Review Workshop, at the request of the Panel, the SAS produced a very promising FD catch-per-unit-effort (CPUE) indicator using Rhode Island trip-level data subset to a core group of dedicated Jonah crab harvesters. The CPUE was especially useful because it best incorporated the SAS's practical knowledge of their State fisheries as it relates to the aforementioned caveats. As seen in the Canada DFO Jonah crab assessment, FD CPUE was effective at detecting declining crab abundance during the landings crash in Canada in the early 2000s (DFO 2009).

C. Population Dynamics

The assessment provided for a better understanding of Jonah crab population dynamics that should hopefully aid future assessment efforts to estimate population parameters and biological reference points.

Growth and Reproduction

Jonah crab growth rate was described by Huntsberger (2019) across multiple approaches, including length frequency analysis of field collections, a probabilistic model based on laboratory growth, and ageing of the gastric mill, a calcified structure in the digestive system. Jonah crabs exhibited rather slow growth, taking at least four years, but most likely seven years, to reach the fishery legal size (see Figure 2.7 from Huntsberger (2019)). The slower growth rate does not imply great resiliency to fishing pressure.

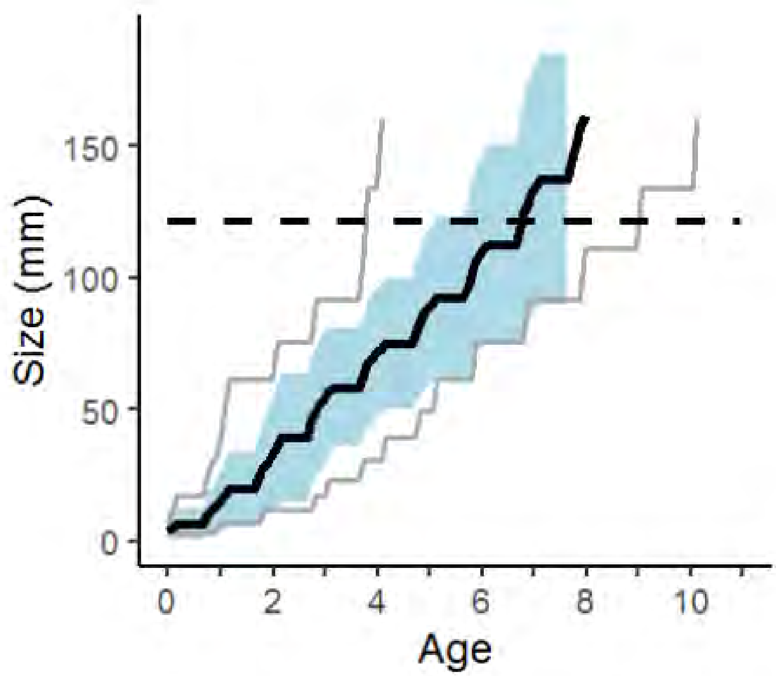


Figure 2.7 Final output of 1000 runs of the probabilistic growth model for male Jonah crabs. The average size (CW) is the solid black line with the gray lines displaying the minimum and maximum sizes and the blue shaded area as the 95% confidence interval. The dotted line is legal size.

The growth models also have value for potential length-based population modeling, YPR and spawning potential ratio models for generating fishery reference points, and SDC models such as LBSPR. Furthermore, direct ageing of individuals using the gastric mill method would enable the SAS to determine fishing mortality rates from basic catch curves of age distributions, gain insight into Jonah crab longevity, and eventually construct desired age-structured population models.

Size-at-maturity (SM50) estimates documented from a range of sources indicate the fishery minimum size limit is specified at-or-above male SM50s, and far above female size-at-maturity estimates. However, better knowledge of the Jonah crab reproductive biology, particularly maturation rates (e.g., age-at-maturity), terminal molting, spawning frequency, reproductive lifespan, operational sex-ratios, etc. would be useful to gain greater insight into crab population dynamics and vulnerability to overfishing.

Stock-Recruit Relationship

Preliminary stock-recruit (s-r) plots requested by the Panel showed a potential relationship between spawning and YOY indices. However, there are questions about the potential spatial mismatch between GOM (YOY index) and coastwide indices (spawning abundance index) (Figure 3). A s-r relationship seen between indices is encouraging for future population modeling efforts.

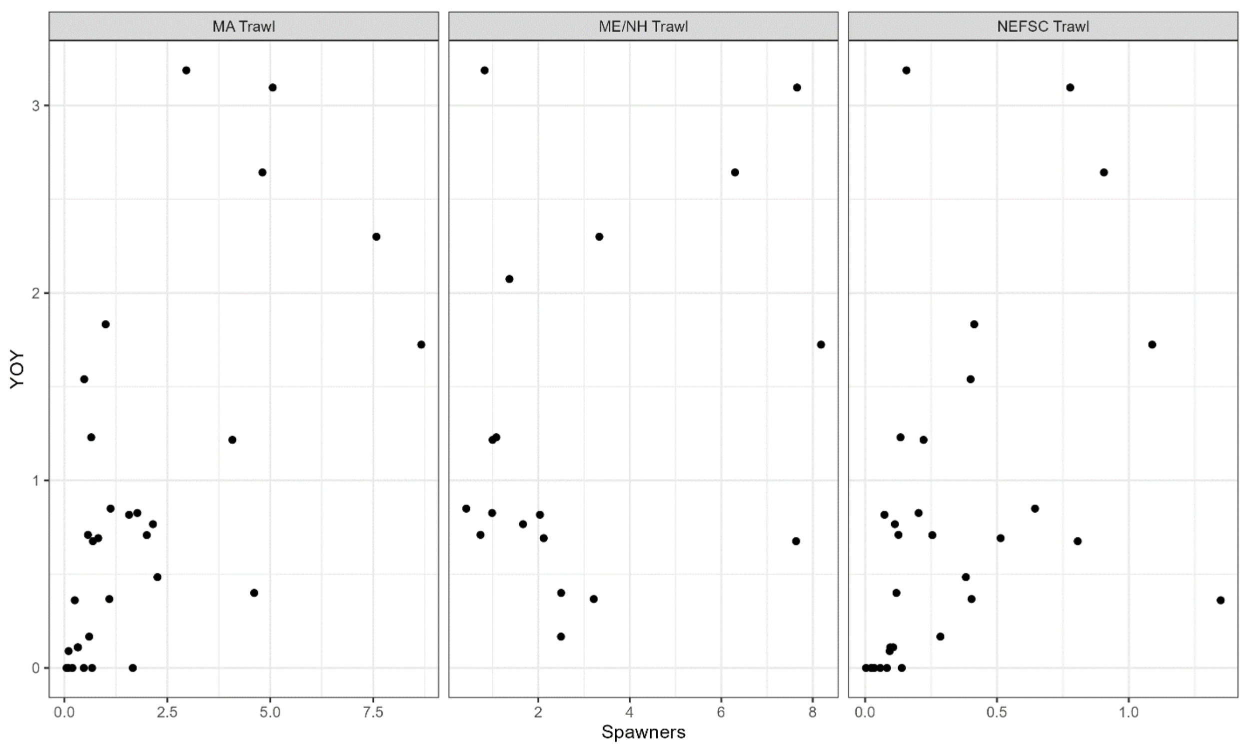


Figure 3. Stock-Recruit plots provided to the Panel during the Review Workshop. Independent axes=Spawner indices, dependent axes=GOM YOY indices (ostensibly lagged, year+1).

D. Fishery

The Jonah crab fishery is dynamic, having recently expanded and shifted towards a more targeted fishery in the past two decades, while also continuing to be strongly tied to the American lobster fishery and its markets. The stock supports a substantial fishery, with recent ex-vessel values peaking at nearly $20 million (Figure 4). Jonah crab harvest is concentrated in one particular region, in the northern area of Offshore Southern New England (OSNE), and is prosecuted mainly by the Massachusetts and Rhode Island fisheries. Considerably smaller state fisheries do operate throughout most of the Jonah crab distribution, from the Gulf of Maine to the Mid-Atlantic.

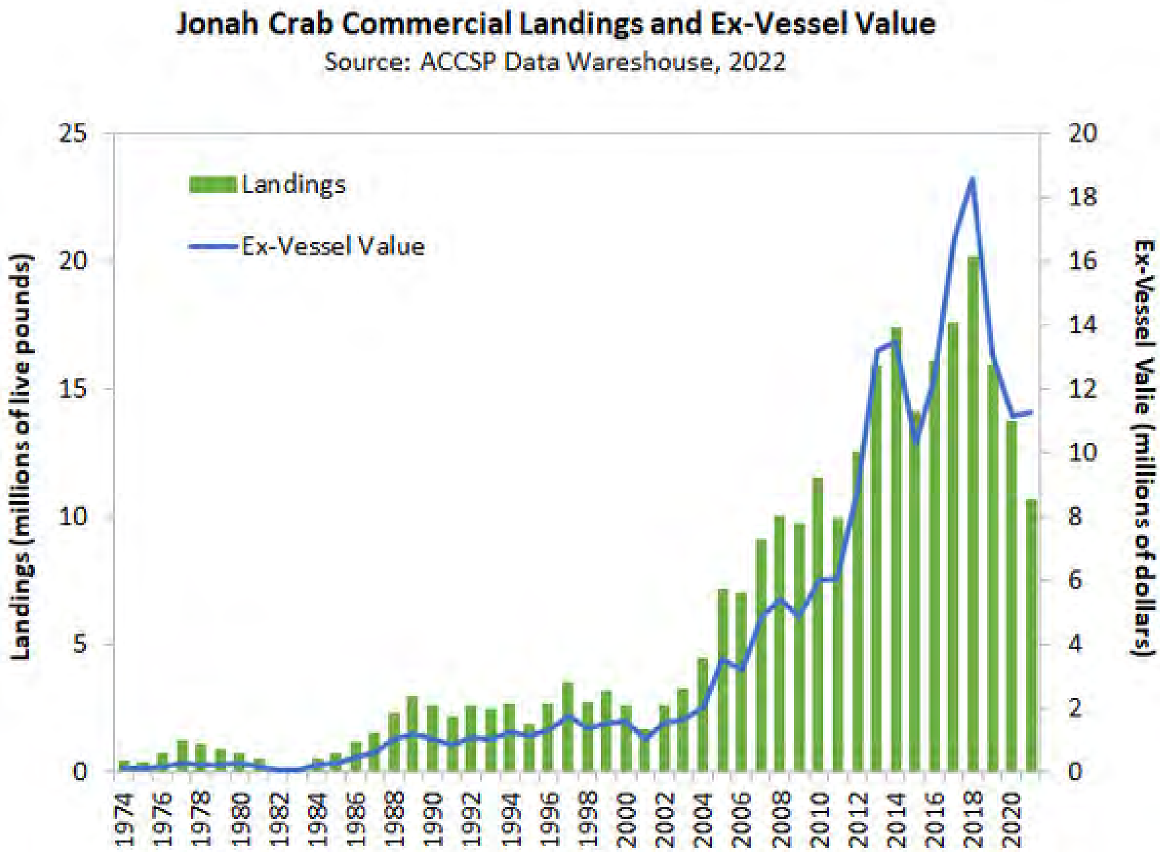


Figure 4. Jonah Crab commercial landings and ex-vessel value.

Jonah crab landings grew substantially (30-fold) in the 2000s and 2010s, and have now declined very sharply (-51%) in the three most-recent years of the assessment. The decline is similar in scope to the beginning stages of the Canada Jonah crab fishery collapse in the early 2000s. In the first three years of the Canada collapse, landings declined 58%. Within five years, landings dropped 97%. In retrospect, Canada DFO concluded that biomass had been severely overfished despite relatively low fishing pressure on a male-only fishery. The ASMFC stock assessment is occurring at a critical time, since it is imperative to determine whether the current steep decline is the start of a 'bust' phase of a boom-and-bust arc, or driven more by market factors.

The SAS brought forward two fishery-dependent (FD) CPUE indicators for the OSNE and ISNE regions in the assessment. CPUE results were mixed, as the ventless trap survey CPUE showed a three-year decline from 2017-2020 in the OSNE, while the Directed Residual Mixture Model (DRM), Rhode Island CPUE showed a declining trend in the ISNE, but no trend in the OSNE. The ventless trap survey possessed a short time-series (2015-2020) and lacked a terminal-year CPUE value for 2021. It is uncertain how well the modeled approach in the DRM performed for identifying targeted trips. After trend analyses, the SAS recommended to not use DRM indicators as measures of exploitable abundance.

Fishery-independent stock indicators, unfortunately, also provided a somewhat unclear perspective on the most-recent three-year period, largely due to the low catchability issues of trawl surveys (see Stock Status, Data and Assessment sections, and TORs for greater detail). As seen in the Canada Jonah Crab Stock Assessment, FI trawl indicators did not detect the rapidly declining stock during the fishery crash in the late 1990s and 2000s (DFO 2009). However, declining fishery-dependent CPUE was evident.

Jonah crab fishery-dependent CPUE analyses are challenging because measuring directed effort is complicated by the mixed Jonah crab and lobster fisheries, and the interplay in fishing effort for both species. Given this uncertainty, the Panel requested a fishery dependent analysis during the Review Workshop that focused on a subset of directed, core Jonah crab harvesters. Based on knowledge of the Rhode Island fishery, the SAS developed basic criteria to subset fishery data to directed Jonah crab trips (>6,000 lb landings) and to participants that were active throughout the time-series. Preliminarily, it does appear that recent fishery CPUE has declined in the OSNE. Further exploration into the directed FD CPUE should continue, with emphasis on investigating caveats typical of FD analyses (i.e., changing market factors and trends in catchability). The Panel also recommended applying the analysis to the Massachusetts fishery data, and to include both as indicators to monitor annually over the next few years, in order to understand the nature and severity of recent falling landings.

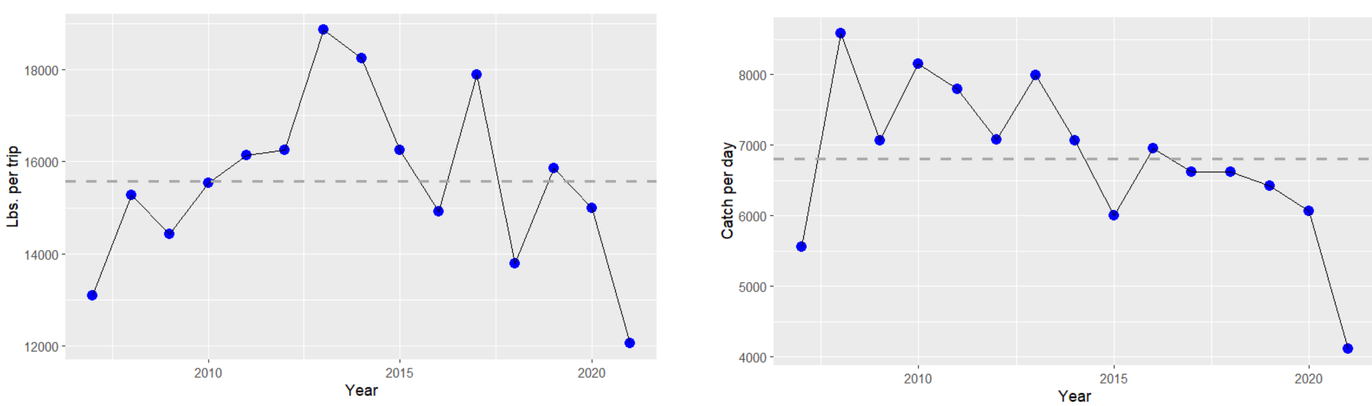


Figure 5. Preliminary analysis of Jonah Crab directed fishery commercial CPUE for select Rhode

E. Future Guidance

The greatest value in this stock assessment may be measured by how well it propels the SAS forward in generating eventual population estimates, reference points, and a clear stock status determination in the ensuing benchmark assessment. Identifying target models and related data needs should logically steer the future research and monitoring efforts of ASFMC partners.

In this assessment, the SAS did a commendable job summarizing available life history information, and constructing and vetting all possible survey and fishery indices. Looking ahead, reasonable target models to pursue would be a Catch-Survey Analysis (CSA) or surplus production model, given their simplicity and minimal data requirements. However, the main barrier to pursuing these and any other population model is the absence of a synoptic Jonah crab abundance index.

Developing a reliable index of abundance is a top priority for the next assessment. If the SAS can further develop the fishery-dependent, directed CPUE in the OSNE, it could fuel first attempts at surplus production modeling. The CPUE is useful because it leverages existing data, and will ostensibly contain a moderately duration time series over a period of substantial contrast in fishery effort and landings. Another direction is to pursue length-based models, possibly using the GMACS (Generalized Model for Assessing Crustacean Stocks) platform. This would likely require much more intensive fishery biosampling to complement the size compositions in existing FI trap and trawl surveys.

Another avenue to explore is the viability of direct ageing of individuals using Huntsberger's (2019) gastric mill method. Direct ageing of specimens would be a game-changer, as it would enable the SAS to generate first estimates of fishing mortality rates from age distributions, gain insight into Jonah crab longevity and natural mortality rate, and enable pursuit of age-structured population models. The time and effort needed to extract and age crab structures will be important factors to consider in understanding its feasibility.

Immediate Steps

The Jonah crab stock is at a pivotal junction. Fishery landings are sharply declining (-51% in the most-recent three years) following a two-decade period of unprecedented growth (30-fold increase). Although FI signals are inconclusive, it appears that fishery CPUE is declining, corroborating the fall in landings. These conditions are highly concerning because they closely resemble the early stages of the Canada Jonah crab fishery collapse in the early 2000s. There is great uncertainty in whether the very large, recent decline in landings is the beginning of a 'bust' stage of a classic boom and bust arc, or merely a short-term drop caused by markets or factors unrelated to Jonah crab abundance.

Given this uncertainty, combined with the lack of population estimates, fishing mortality rates, and reference points, the Panel recommends the SAS/TC closely monitor stock indicators on an annual basis to examine the nature and severity of the recent decline. In addition to any indicators deemed important by the SAS, we highly recommend the ASMFC monitor the directed, fishery-dependent CPUE for Rhode Island and Massachusetts fisheries. This core-fishery CPUE index was preliminarily constructed by the SAS during the Review Workshop at the request of the Panel. Continued development, exploration, and refinement to this fishery analysis are recommended. Additional, potentially-important indicators to consider are 'operational' sex-ratios in FI surveys and FD biosamples. Changes in baseline sex-ratios may signal male depletion and resulting population-level sperm limitation, and could serve as warning signals preceding a population decline.

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Atlantic States Marine Fisheries Commission

Jonah Crab Benchmark Stock Assessment Report

Prepared by the
ASMFC Jonah Crab Stock Assessment Subcommittee

And

Approved by the
ASMFC Jonah Crab Technical Committee
July 18, 2023

Sustainable and Cooperative Management of Atlantic Coastal Fisheries

EXECUTIVE SUMMARY

Stock Structure

Four Jonah crab stocks were defined during the stock assessment based on a combination of biological aspects, management considerations, fishery characteristics, and data availability. These stocks include the Inshore Gulf of Maine stock (IGOM), Offshore Gulf of Maine stock (OGOM), Inshore Southern New England stock (ISNE), and Offshore Southern New England stock (OSNE).

Data

Commercial Landings

Validated commercial landings of Jonah crab are available coastwide back to 1981, but the accuracy of the reporting and the location of where those landings were harvested is uncertain, so this assessment focused on the landings since 2010. However, it is also important to understand the context of the increases in reported landings over time and the changing structure of the fishery. Coastwide landings register a steady increase over most of the time series, but decreased from the record high in 2018 (22.8 million pounds) during the last three years of the stock assessment (2019-2021). These changes are believed to be influenced by relatively variable Jonah crab markets. Historically, Jonah crab has been a bycatch species in the American lobster trap fishery, but in the last two decades, the fishery has shifted with regional differences.

Most U.S. Jonah crab landings come from the OSNE stock which is considered a directed Jonah crab fishery in recent years. From 2010 to 2021, annual landings for this region have accounted for 70 to 85% of the total U.S. Jonah crab landings. The other three Jonah crab stocks are considered to support bycatch fisheries that are primarily targeting American lobster. Landings from the IGOM stock account for 9 to 24% of the coastwide landings from 2010-2021. The OGOM and ISNE stocks have never exceeded 5% of coastwide Jonah crab landings for any year between 2010 and 2021. Although these fisheries currently catch Jonah crab as bycatch, they represent considerable potential growth of Jonah crab fisheries if they become a target species in the future.

Commercial Size Compositions

Commercial biosample data were available from sea sampling and port sampling programs. Data are still too sparse to calculate landings-weighted stockwide statistics, but snapshots of data by stock and statistical area were evaluated for trends. Overall, trends in mean size statistics are stable over the relatively short time series. General lack of trend seen here could be a favorable indication of stock condition (i.e., stable exploitation) or it could indicate that these data are unreliable indicators of stock condition, as appeared to be the case in other crab stock assessments reviewed. These data should be revisited as potential indicators in future stock assessments when longer time series are available and, ideally, there is sufficient coverage to generate landings-weighted stockwide time series, but are not recommended at this time for stock indicators.

Fishery-Independent Indices of Abundance
Five settlement indices of young-of-year (YOY) Jonah crabs were used in the assessment as measures of year class strength. These included ME settlement surveys from three statistical areas in ME waters (statistical area 511, 512, 513), the NH settlement survey (statistical area 513), and the MA settlement survey (statistical area 514). All surveys are in IGOM waters. Indices that extend back into earlier periods in the early to mid-2000s show increasing trends over time. All available indices agree on relatively strong year classes in 2012 and 2018.

Three post-settlement abundance metrics were used as measures of relative abundance including recruit abundance, exploitable abundance, and spawning abundance. Recruit abundance is defined as male Jonah crabs 90-119mm carapace width (CW). Exploitable abundance includes all male Jonah crabs greater than these recruit sizes (120mm+ CW) and is a measure of abundance currently available to the fisheries. Spawning abundance is defined as female Jonah crabs 80mm+ CW. Three survey platforms provided these post-settlement abundance indices including the MA Trawl Survey covering the IGOM stock, the ME/NH Trawl Survey covering the IGOM stock, and the NEFSC Trawl Survey covering all four stocks (although, determined to not be of utility for ISNE stock abundance indices). All three platforms have separate surveys in the spring and fall.

Indices of each post-settlement metric across stocks generally show increasing trends over time series covering historical periods back to the 1980s and 1990s. Indices in GOM stocks show considerable, but brief pulses of abundance around the mid-2010s.

Assessment Methods
Given limitations of available data sets and poor understanding of life history characteristics needed for traditional assessment approaches, data sets were used to develop empirical indicators of stock conditions and fishery performance. These indicators provide a categorical characterization of recent condition (positive, neutral, or negative) relative to historical levels. The stock assessment terminal three years (2019-2021) are averaged to provide a smoothed measure of recent stock condition due to interannual variability reflective, in part, of observation error.

Stock abundance indicators include the YOY settlement, recruit abundance, exploitable abundance, and spawning abundance indices. Fishery performance indicators include landings, the number and proportion of pot/trap trips that landed Jonah crabs, and the number and proportion of active (i.e., reported catch during the year) lobster/crab permits that landed Jonah crab.

Stock Status
According to stock indicators, there have been declines in post-settlement abundance for the IGOM and OGOM stocks from time series highs in the mid-2010s, but conditions in the last three years of the time series are neutral or positive. The one exception is from the ME/NH Trawl survey, but this is due to the shorter time series of this survey not capturing historical lows in earlier years. Indicators for the OSNE stock also indicate neutral or positive post-

settlement abundance conditions in the last three years of the time series. Indicators agree across these stocks that abundance has not been depleted to historical lows. There are no reliable abundance indicators for the ISNE stock and inference cannot be made about condition of this stock's abundance at this time.

YOY indicators generally indicate neutral conditions and do not indicate that recruitment in GOM stocks will decline to historical lows in the near future. Settlement conditions are unknown for SNE stocks.

Landings have steadily declined in the OSNE stock which is the primary stock with targeted/mixed effort for Jonah crab and the stock accounting for the vast majority of coastwide landings. This trend is believed to be influenced by factors other than available abundance but should continue to be monitored closely. There was not sufficient information to make statements about fishing mortality or exploitation with confidence and these population parameters remain major uncertainties.

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TERMS OF REFERENCE

For the 2023 ASMFC Jonah Crab Benchmark Stock Assessment
Board Approved January 2022

Terms of Reference for the Jonah Crab Assessment

1. Characterize precision and accuracy of fishery-dependent and fishery-independent data used in the assessment, including the following but not limited to:
    a. Provide descriptions of each data source (e.g., geographic location, sampling methodology, potential explanation for outlying or anomalous data).
    b. Describe calculation and potential standardization of abundance indices.
    c. Discuss trends and associated estimates of uncertainty (e.g., standard errors).
    d. Justify inclusion or elimination of available data sources.

2. Discuss the effects of data strengths and weaknesses (e.g., temporal and spatial scale, gear selectivities, sample size) on model inputs and outputs.

3. Develop simple, empirical indicators of stock abundance, stock characteristics, and fishery characteristics that can be monitored annually between stock assessments.

4. Develop models used to estimate population parameters (e.g., F, biomass, abundance) and biological reference points, and analyze model performance.
    a. Describe stability of model (e.g., ability to find a stable solution, invert Hessian).
    b. Justify choice of CVs, effective sample sizes, or likelihood weighting schemes.
    c. Perform sensitivity analyses for starting parameter values, priors, etc. and conduct other model diagnostics as necessary.
    d. Clearly and thoroughly explain model strengths and limitations.
    e. Briefly describe history of model usage, its theory and framework, and document associated peer-reviewed literature. If using a new model, test using simulated data.
    f. If multiple models were considered, justify the choice of preferred model and the explanation of any differences in results among models.

5. State assumptions made for all models and explain the likely effects of assumption violations on synthesis of input data and model outputs. Examples of assumptions may include (but are not limited to):
    a. Choice of stock-recruitment function.
    b. Calculation of M. Choice to use (or estimate) constant or time-varying M and catchability.
    c. Choice of equilibrium reference points or proxies for MSY-based reference points.
    d. Constant ecosystem (abiotic and trophic) conditions.

6. Characterize uncertainty of model estimates and biological or empirical reference points.

7. Recommend stock status as related to reference points (if available). For example:
    a. Is the stock below the biomass threshold?
    b. Is F above the threshold?

8. Other potential scientific issues:
    a. Compare reference points derived in this assessment with what is known about the general life history of the exploited stock. Explain any inconsistencies.
    b. Explore, identify, describe, and, if possible, quantify environmental/climatic drivers.

9. If a minority report has been filed, explain majority reasoning against adopting approach suggested in that report. The minority report should explain reasoning against adopting approach suggested by the majority.

10. Develop detailed short and long-term prioritized lists of recommendations for future research, data collection, and assessment methodology. Highlight improvements to be made by next benchmark review.

11. Recommend timing of next benchmark assessment and intermediate updates, if necessary relative to biology and current management of the species.

Terms of Reference for the Jonah Crab Peer Review

1. Evaluate the thoroughness of data collection and the presentation and treatment of fishery-dependent and fishery-independent data in the assessment, including the following but not limited to:
    a. Presentation of data source variance (e.g., standard errors).
    b. Justification for inclusion or elimination of available data sources,
    c. Consideration of data strengths and weaknesses (e.g., temporal and spatial scale, gear selectivities, sample size),
    d. Calculation and/or standardization of abundance indices.

2. Evaluate empirical indicators of stock abundance, stock characteristics, and fishery characteristics for their appropriateness to monitor the stock between assessments.

3. Evaluate the methods and models used to estimate population parameters (e.g., F, biomass, abundance) and biological reference points, including but not limited to:

a. Evaluate the choice and justification of the preferred model(s). Was the most appropriate model (or model averaging approach) chosen given available data and life history of the species?
b. If multiple models were considered, evaluate the analysts' explanation of any differences in results.
c. Evaluate model parameterization and specification (e.g., choice of CVs, effective sample sizes, likelihood weighting schemes, calculation/specification of M, stock-recruitment relationship, choice of time-varying parameters, plus group treatment).

4. Evaluate the diagnostic analyses performed (e.g., sensitivity analyses to determine model stability and potential consequences of major model assumptions, retrospective analysis).

5. Evaluate the methods used to characterize uncertainty in estimated parameters. Ensure that the implications of uncertainty in technical conclusions are clearly stated.

6. If a minority report has been filed, review minority opinion and any associated analyses. If possible, make recommendation on current or future use of alternative assessment approach presented in minority report.

7. Recommend best estimates of stock biomass, abundance, and exploitation from the assessment for use in management, if possible, or specify alternative estimation methods.

8. Evaluate the choice of reference points and the methods used to estimate them. Recommend stock status determination from the assessment, or, if appropriate, specify alternative methods/measures.

9. Review the research, data collection, and assessment methodology recommendations provided by the TC and make any additional recommendations warranted. Clearly prioritize the activities needed to inform and maintain the current assessment, and provide recommendations to improve the reliability of future assessments.

10. Recommend timing of the next benchmark assessment and updates, if necessary, relative to the life history and current management of the species.

11. Prepare a peer review panel terms of reference and advisory report summarizing the panel's evaluation of the stock assessment and addressing each peer review term of reference. Develop a list of tasks to be completed following the workshop. Complete and submit the report within 4 weeks of workshop conclusion.

1 INTRODUCTION

Cooperative interstate management of Jonah crab (*Cancer borealis*) in U.S. waters was first implemented in 2015 with the adoption of the Atlantic States Marine Fisheries Commission's (ASMFC) Interstate Fishery Management Plan (FMP; ASMFC 2015). However, there has been no stock assessment of U.S. Jonah crab to date, stock status is unknown, and there has been limited science-based advice available to support management of Jonah crab fisheries.

The Jonah Crab Technical Committee (TC) met in August 2017 to review research projects and discuss data limitations. This review identified limitations on understanding of basic life history processes, but also identified several projects in progress that could help fill some information gaps in coming years. The TC met again in April 2020 and reviewed ongoing research as well as regular agency monitoring efforts. During this meeting, the TC recommended a more in-depth review of available data to better understand limitations and identify stock assessment approaches that could be supported with available data. Subsequently, the ASMFC American Lobster Management Board (Board) tasked the TC in August 2020 with conducting a pre-assessment workshop for Jonah crab and providing a report on available data and recommended assessment approaches. A series of webinars was held November 16-18, 2020, February 11, 2021, June 3, 2021, and June 29, 2021, to review and discuss available Jonah crab data sets, potential assessment approaches, and remaining data limitations.

The TC's evaluation of the data sets, findings on potential approaches for a near-term stock assessment to provide management advice, and research recommendations to advance future stock assessments were provided in a pre-assessment report in July 2021 (ASMFC 2021). In summary, the TC noted limitations in life history information, limitations with available index of abundance information such as lack of overlap with the core fishery area and poorly understood catchability, and limitations with landings data prior to 2006. Despite these limitations, the TC did acknowledge the need for a full benchmark stock assessment to provide information with which to manage the fishery as well as additional information on data needed to improve future stock assessments. The TC presented these finding to the Board and recommended conducting a benchmark assessment to be completed in 2023. The Board accepted this recommendation and initiated an assessment at the ASMFC 2021 Summer Meeting in August.

The TC and Jonah Crab Stock Assessment Subcommittee (SAS) met via webinar for a Data Workshop June 13-15, 2022 to review the available data sets and discuss data development for the assessment. The SAS than met again via webinar October 3-5, 2022 for a Methods Workshop to review updates on data development and discuss potential assessment methods. The SAS met a final time, in-person in New Bedford, MA April 18-20, 2023 to finalize assessment results which the following report covers.

1.1 Brief Overview and History of the Fishery

Until recently, Jonah crab were predominantly a bycatch species in the American lobster fishery—annual commercial Jonah crab landings were generally lower than 6 million pounds through 1996. Since then, as the lobster fishery has declined in southern New England (SNE) and the market for crab has expanded, harvesters have pivoted to target Jonah crab in addition to (or instead of) lobster. A mixed crustacean fishery now exists in which fishers seasonally adjust their fishing strategies to target Jonah crab or lobster. Harvest pressure on Jonah crab has increased substantially over the past two decades, with landings increasing steadily since around 1996 (Figure 1). Between 2010 and 2021, annual landings of Jonah crab averaged about 16 million pounds, ranging between 12.0 million and 22.8 million pounds (2018). Total Jonah crab commercial catch in 2021 was 12.2 million pounds, with a total ex-vessel value of about $12.8 million.

The Jonah crab commercial fishery occurs predominantly in SNE. Most of the U.S. Jonah crab commercial catch is landed in Massachusetts (54%, 2019-2021 average) and Rhode Island (21%), and most harvest occurs offshore in NOAA Fisheries statistical areas (hereafter, statistical area) 537 (50.6%), 526 (12.5%), and 525 (11.4%). Most Jonah crab commercial landings are reported as having been caught in traps and pots.

Coastwide, commercial landings of Jonah crab are highest in the late autumn and winter months (October to February). In an interview study, fishermen indicated that this seasonal shift was driven by the lobster fishery—lobster are less abundant in winter, so harvesters transition to target Jonah crab during these months (Truesdale et al. 2019a). Based on interviews with fifteen Jonah crab fishermen from Rhode Island and Massachusetts, the number of traps set to target Jonah crab over lobster increased by 73% in the winter compared with the summer months. Fishing strategy adjustments made to transition between Jonah crab and lobster include escape vent modifications, bait type, and fishing location changes.

A small Jonah crab claw fishery operates in Delaware, Maryland, and Virginia, wherein the claws of large Jonah crabs are removed and the animal is returned to the ocean alive. Claw harvest comes mostly from lobster vessels fishing in Lobster Conservation Management Area (LCMA) 5 and accounts for less than 1% of the coastwide commercial landings.

There is no regulatory distinction between a lobster trap and a Jonah crab trap, and a vessel's target species can often not be determined from trip reports and dealer data. Inability to identify a target species, and the recency of the development of the Jonah crab fishery makes it challenging to characterize fishing effort, and there is little literature describing the seasonal dynamics, fishing strategies, and socioeconomic aspects of the fishery. Some anecdotal information has been summarized and may provide a starting point for analyzing and characterizing the fishery (Truesdale et al. 2019a). Additionally, some model-based approaches for standardizing catch-per-unit-effort (CPUE) in mixed crustacean fisheries may serve as a path forward for estimating fishery catch rates (Maunder and Punt 2004; Okamura et al. 2018). Quantifying fishing effort for Jonah crab versus lobster remains a data need for future assessments.

1.2 Management Unit Definition

The management unit for Jonah crab includes the U.S. Atlantic states from Maine through Virginia, though the biological range of the species extends from Newfoundland, Canada to Florida.

1.3 Regulatory History

The ASMFC coordinates the interstate management of Jonah crab in state waters (from 0-3 miles offshore). The ASMFC manages Jonah crab through the FMP, which was approved by the Board in August 2015 under the authority of the Atlantic Coastal Fisheries Cooperative Management Act (1993). Management authority in the exclusive economic zone (EEZ), which extends from 3-200 miles offshore, lies with NOAA Fisheries. The FMP was initiated in response to concern about increasing targeted fishing pressure for Jonah crab, which has long been considered a bycatch species in the lobster fishery. The multi-species nature of the fishery created a challenge for managing a Jonah crab fishery completely separate from the lobster fishery without impacting the number of vertical lines and traps in state and federal waters. Furthermore, a lack of universal permitting and reporting requirements made it difficult to characterize catch and effort to the full extent in order to manage the fishery.

The goal of the FMP is to promote conservation, reduce the possibility of recruitment failure, and allow for the full utilization of the resource by the industry. The FMP lays out specific management measures in the commercial fishery to limit effort and protect spawning stock biomass in the absence of a range-wide stock assessment. These include a 4.75 inch (120.65 mm) minimum carapace width (CW) and a prohibition on the retention of egg-bearing females. To prevent the fishery from being open access, the FMP limits participation in the directed Jonah crab trap fishery to lobster permit holders or those who can prove a history of crab-only pot fishing. All others must obtain an incidental permit. In the recreational fishery, the FMP sets a possession limit of 50 whole crabs per person per day and prohibits the retention of egg-bearing females. Due to the lack of data on the Jonah crab fishery, the FMP implements a fishery-dependent data collection program. The FMP also requires harvester and dealer reporting along with port and sea sampling.

Addendum I was approved by the Board in May 2016, and states were required to implement the management measures in Addendum I by January 1, 2017. Addendum I establishes a bycatch limit of 1,000 pounds of crab per trip for non-trap gear (e.g., otter trawls, gillnets) and non-lobster trap gear (e.g., fish and whelk pots). In doing so, the Addendum caps incidental landings of Jonah crab across all non-directed gear types with a uniform bycatch allowance. While the gear types in Addendum I make minimal contributions to total landings in the fishery, the 1,000-pound limit provides a cap to potential increases in effort and trap proliferation.

Addendum II was approved in January 2017, with associated measures required by January 1, 2018. Addendum II establishes a coastwide standard for claw harvest. Specifically, it permits Jonah crab fishermen to detach and harvest claws at sea, with a required minimum claw length (measured along the bottom of the claw, from the joint to the lower tip of the claw) of 2.75” if the volume of claws landed is greater than five gallons. Claw landings less than five gallons do not have to meet the minimum claw length standard. The Addendum also establishes a definition of bycatch in the Jonah crab fishery, whereby the total pounds of Jonah crab caught as bycatch must weigh less than the total amount of the targeted species at all times during a fishing trip. The intent of this definition is to address concerns regarding the expansion of a small-scale fishery under the bycatch limit.

In response to concerns regarding deficits in existing reporting requirements, the Board approved Addendum III in February 2018, which improves the collection of harvester and biological data in the Jonah crab fishery. Specifically, the Addendum improves the spatial resolution of harvester data collection by requiring fishermen to report via 10-minute squares. It also expands the required harvester reporting data elements to collect greater information on gear configurations and effort. In addition, the Addendum established a deadline that within five years, states are required to implement 100% harvester reporting, with the prioritization of electronic harvester reporting development during that time. Finally, the Addendum improves the biological sampling requirements by establishing a baseline of ten sampling trips/year, and encourages states with more than 10% of coastwide landings to conduct additional sampling trips. The provisions of Addendum III went into effect January 1, 2019, however, implementation of the requirement for commercial harvesters to report their fishing location by 10 minute longitudinal/latitudinal square was delayed until January 1, 2021.

Federal regulations complementing the majority of measures included in the FMP and Addenda I and II became effective on December 12, 2019. Commercial measures included requiring a federal lobster permit, a minimum CW, a prohibition on retaining egg-bearing females, incidental catch limits, and federal dealer permitting and reporting requirements. Recreational measures included a daily catch limit and a prohibition on retaining egg-bearing females. The Jonah crab claw-only fishery is not directly regulated in federal waters; harvesters must abide by state requirements.

In March 2022, the Board approved Addendum IV, which expands on the Addendum III reporting improvements by establishing electronic tracking requirements for federally-permitted vessels in the American lobster and Jonah crab fisheries. Specifically, electronic tracking devices will be required for vessels with commercial trap gear area permits for LCMAs 1, 2, 3, 4, 5, and Outer Cape Cod to collect high resolution spatial and temporal effort data. The addendum requirements seek to enhance data for the stock assessment, identify areas where fishing effort might present a risk to endangered North Atlantic right whales, and document the footprint of the fishery to help reduce spatial conflicts with other ocean uses like wind energy development and aquaculture.

1.4 Assessment History

1.4.1 Previous Jonah Crab Assessments

The only stock assessments conducted for Jonah crab to date have been in Canadian waters. The most recent was conducted for Lobster Fishing Area (LFA) 41 where a directed Jonah crab fishery started in 1995. In response to the developing fishery, a total allowable catch (TAC) of 720 metric tons that was not based on scientific advice was implemented for the fishery. This TAC was fully or nearly caught in all seasons from the 1996-1997 fishing season through the 2000-2001 fishing season and was followed by a continuous decline in catch through the 2008 fishing season. Assessments were conducted in 2000 (Robichaud et al. 2000) and 2009 (Pezzack et al. 2009). These assessments provided empirically-based stock indicators developed from existing monitoring programs. Indicators included abundance indicators (fishery-independent indices of abundance, fishery CPUE, and total landings) and fishing pressure indicators (number of traps hauled and median size of Jonah crabs harvested). Indicators were categorized as positive, neutral, or negative and used to provide qualitative characterizations of stock status. In the most recent assessment, all indicators were negative relative to the previous assessment time-period (1995-1999), except for median size. Abundance indicators from surrounding LFAs where directed Jonah crab fisheries had not developed indicated no clear abundance declines over the same time-period. Although the assessment notes some uncertainty in the cause(s) of negative stock conditions, the results suggest the TAC was not sustainable and declines are due to fishing down the biomass from the start of the fishery.

1.4.2 Other Crab Species Assessments

Assessing crab stocks can be challenging, as demonstrated by other assessments reviewed to inform this assessment. Crabs generally lack age estimates, limiting the types of models that can be used. Their growth is incremental, and growth rates can vary by size, age, or maturity status. Some have a terminal molt. Further, selectivity of survey gear can be inconsistent based on substrate type, temperature, interactions with other species, and life-history characteristics. Below are summaries of selected stock assessments used to make management decisions for other crab species.

Brown Crab Stock Assessment, EIFCA, 2019

The Eastern Inshore Fisheries and Conservation Authority's (EIFCA) brown crab (*C. pagurus*) assessment uses an indicator-based model and defines stock boundaries based on pre-existing mixed-species fisheries management areas (EIFCA 2019). The primary fishery landing brown crab is a mixed-crustacean pot fishery, which also targets European lobster (*Homarus gammarus*). Unlike the Jonah crab fishery, female brown crab are regularly landed because they are of similar size to males. The main data sources used in the assessment are commercial trip reports (landings per unit of effort (LPUE)) and port sampling data. The stock is considered stable based on the stability of LPUE data (pot hauls), and recruitment is sufficient to offset harvest, though there was a slight decrease in the most heavily exploited zone. The assessment acknowledges the challenges associated with using effort data in a mixed-crustacean fishery (e.g. uncertainty in primary target species, species interactions impacting catch probability). The EIFCA is looking into the efficacy of using Length Converted Catch Curve fisheries models for future brown crab assessments but is concerned about violating assumptions of the model (e.g., recruitment and natural mortality are consistent) and the application of these models to crustaceans with incremental growth.

Snow Crab Stock Assessment, DFO Canada, 2020

Fisheries and Oceans Canada's (DFO) snow crab (*Chionoecetes opilio*) assessment (DFO 2020) uses a conditional, autoregressive, spatiotemporal model, and a logistic population model, and utilizes fisheries management areas as stock boundaries. The main data sources used in the assessment are commercial landings, commercial sea sampling, and environmental data. Sea sampling data is used to create "age" classes. The fishery is male-only and targets hard shelled-animals. Abundance is modeled using depth, substrate, temperature, and species composition as covariates. The resulting index is used with a logistic population dynamics model to estimate fishable biomass, carrying capacity, and F_{MSY}. Size composition, female recruits, sex ratios, and predator abundance are used as indicators.

Stone Crab Stock Assessment, FWC, 2011

The Florida Fish and Wildlife Conservation Commission's (FWC) 2011 Stone crab (*Menippe spp*.) assessment was conducted using the Gulf Coast of Florida as a management unit (FFWCC 2011). The stone crab fishery targets two species of stone crab, and a hybrid. Specific stone crab species abundance varies along the coast. This is a claw-based fishery where claws from male and female crabs are removed, and the crab is returned to the water. Mortality rates of de-clawed crabs is low if done properly but can be high if both claws are removed improperly. Nearly all Florida stone crab landings (~99%) come from the Gulf Coast. The assessment uses a Surplus Production model and a modified DeLury depletion model to estimate recruitment needed to offset fishing mortality (*F)* and natural mortality (*M)*. The main data sources are commercial landings, port sampling (claw size and stage), maximum age estimates, and octopus catch rates in crab traps (stone crabs avoid traps with octopus). CPUE data (per trip and per trap) are used as indicators. Assessment methods are limited due to a lack of fisheries independent data, claw size not being correlated with crab size or age, and a lack of recreational fishery data (unknown magnitude of landings).

Tanner and King Crab Stock Assessment, NPFMC, 2022

The North Pacific Fishery Management Council conducts assessments for several crab species including multiple species of tanner and king crab (NPFMC 2022). Data used in the assessments included multiple fisheries independent trawl surveys, commercial landings, bycatch from dragger fleet, sea sampling, port sampling, and pot surveys (limited in scale). The 2022 assessment used several models depending on the data available for a given species, including size and sex-based models (mature/immature, new shell/old shell), population dynamics models, random effects models, length-based models (e.g., generalized modeling for Alaskan Crab Stocks (GMACS)), and index-based models. Indicators were used for species with insufficient data to run a model (e.g., mean weight and CW of landed crabs).

Blue Crab, CBSAC, 2022

The Chesapeake Bay Stock Assessment Committee conducts annual status updates of the 2011 benchmark assessment for blue crab in Chesapeake Bay (CBSAC 2022). The main data sources used in the 2022 update were the Maryland Department of Natural Resources (MD DNR)/Virginia Institute of Marine Science (VIMS) winter dredge survey, commercial landings, and recreational landings. The assessment used a sex-specific catch, multiple survey model with four stages, age-0 males, age-0 females, age-1+ males, and age-1+ females. Reproduction was modeled using the abundance of age-1+ females in a Ricker stock-recruit model, and population density was dependent on the number of age-1+ females and males. Estimates of Bay-wide total abundance, recruits, adult female crabs, over-wintering mortality, and reference points were generated.

2 LIFE HISTORY

2.1 Migration

Catch rates of Jonah crab in traps targeting American lobster provide evidence that Jonah crab migrate to deeper water in the winter and return to shallower water in the spring (Jeffries 1966, Krouse 1980, Truesdale et al. 2019b). However, analysis of catch rates from mid-Atlantic trawl surveys indicated that Jonah crab move very little based on the consistency of Jonah crab catch rates in relation to depth and temperature (Haefner 1977).

There have been two Jonah crab tagging studies, one conducted by Rhode Island Department of Environmental Management (RI DEM; Ordzie and Satchwill 1983) and another conducted by Massachusetts Division of Marine Fisheries (MA DMF) with the Atlantic Offshore Lobstermen's Association (AOLA; Perry et al. 2019). Both studies tagged male and female crabs, but females were rarely recaptured in either study. The RI DEM study tagged 1,383 crabs in Rhode Island Sound, Block Island Sound, and mid-shelf (offshore) south of Rhode Island, and had a 1.7% return rate. All recaptures were tagged and recaptured in Rhode Island Sound. The MA DMF/AOLA study tagged 32,294 crabs on Georges Bank (GB), and the inshore and offshore regions of Gulf of Maine (GOM) and SNE, and had a 2.9% return rate. Movements in both studies were generally limited, on the scale of a few kilometers, though a few individuals from the MA DMF/AOLA study traveled between 100 and 416 km. Other *Cancer* crabs (e.g., *C. pagurus*) have been known to move similar distances, though long-distance travel is more common for female *Cancer* crabs, than male (Fahy and Carroll 2008). Movement between offshore SNE and GB was observed in the MA DMF/AOLA study as well as some small-scale seasonal movement patterns. While Jonah crab appear to be capable of moving long distances, most evidence suggests their movements are generally limited, including seasonal movements.

2.2 Growth

Jonah crab growth has been examined in several recent studies, each of which focused on different life stages of Jonah crab in distinct stock regions. A growth study including techniques for age determination was completed by Huntsberger (2019) for Jonah crabs from the GOM. Three independent methods of age determination were compared: (1) length frequency analysis of crabs sampled periodically in wild nursery populations including young-of-year (YOY) crabs, (2) building a probabilistic growth model informed with data from a laboratory growth study, and (3) applying the method of direct gastric mill band counts from crabs collected in two contrasting temperature regimes along Maine's coast. Length frequency analyses provided size-at-age estimates for the first three year classes, clear size ranges for YOY (3.8-6.6 mm CW), and showed correlation between YOY and legal size crabs four to six years later. For the laboratory growth study, 464 Jonah crabs from mid-coast Maine between 3.1 and 143mm CW were monitored in captivity for up to two years. The data collected were used to build a probabilistic molt model estimating the growth of an individual male crab until it reached legal size. Modeled growth of 1,000 crabs highlighted variability in growth, and males reached minimum legal size at an estimated four to nine years of age. Finally, while gastric mill band counts were found to have a one-to-one relationship with Jonah crab age in years, the mechanism by which annuli are formed is not yet understood. Using this method, Huntsberger (2019) estimated that Jonah crabs recruited to the fishery at four to ten years of age.

The molt increment models for males from the GOM study aligned with a laboratory-based growth study conducted at the University of Rhode Island in 2016 and 2017 (Truesdale et al. 2019a), wherein molt increments were collected for 91 male Jonah crabs ranging in pre-molt CW from 97 to 149 mm. This study also measured molt increments for 119 female Jonah crabs ranging in pre-molt CW from 73 to 113 mm, finding that there were diverging trends in the relationship between crab size and molt increment between the sexes: male molt increments increased with size, while female molt increments became smaller with increasing size. This sexual dimorphism in growth-per-molt aligns with historical growth description from Rhode Island (Ordzie and Satchwill, 1983). Considering the Rhode Island study focused on crabs above the size-at-maturity, it was hypothesized that the divergence in molt increment trends relates to somatic investment in reproduction by females (Truesdale et al. 2019a).

The Rhode Island study also examined molting seasonality for mature male Jonah crabs via year-round crab collection and observation, finding that the annual molt period was in June for the inshore Rhode Island fishery. This molting seasonality aligned with the laboratory growth observations from Huntsberger (2019), which saw a peak in molting in late spring and early summer. Additionally, the Rhode Island study found that annual molt probability decreased with increasing CW for male Jonah crabs (Truesdale et al. 2019a). A slowdown in growth with increasing size for mature individuals is evident across studies; in the MA DMF/AOLA tagging study, a few mature crabs had not molted after more than 700 days at large (Perry et al. 2019). The intermolt period for crabs larger than the legal minimum size has not yet been estimated, and the occurrence of a terminal molt for the species is not known.

2.3 Reproduction, Maturity and Fecundity

2.3.1 Reproduction

Cancer crab mating takes place immediately after the female has molted (Elner et al. 1985, Christy 1987, Orensanz et al. 1995, Tallack 2007). The female crab is cradled by the male pre- and post-copulation using his chelae and first two pairs of walking legs (Elner et al. 1985). Males attain larger sizes than females (Carpenter 1978) and use their size advantage to guard females from other potential mates and predators, as seen in other brachyurans (Christy 1987). Sexual maturity in crabs is generally described based on gonadal development, which corresponds to physiological maturity (physiologically capable of producing eggs or sperm), and morphometrically, by using changes in allometric growth patterns in a particular body part. In crustaceans, morphometric maturity is often determined by male chela length or height, and abdominal width for females (Hartnoll 1978, Lizárraga-Cubedo et al. 2008, Öndes et al. 2017). Larger males out-compete smaller males for mating opportunities (Orensanz et al. 1995), similar to other Brachyuran crabs (Sainte-Marie and Lovrich 1994, Sainte-Marie et al. 1997, Comeau et al. 1998). Gonadal maturity may not be enough for Jonah crabs to mate successfully, and morphometric maturity may be an important factor in determining reproductive ability (Conan and Comeau 1986, Comeau and Conan 1992, Stevens et al. 1993).

2.3.2 Size-at-Maturity

Jonah crab size-at-maturity studies have been conducted from the mid-Atlantic Bight through Nova Scotia, Canada (Carpenter 1978, Ordzie and Satchwill 1983, Moriyasu et al. 2002, Perry et al. 2017, Olsen and Stevens 2020, Lawrence et al. 2021, ongoing investigations – see below). Though methods and sample sizes vary over these studies, they generally show that males mature at larger sizes than females, size-at-maturity estimates increase with increasing latitude, and size-at-maturity estimates for inshore regions are generally smaller than estimates for adjacent offshore areas (Table 1 and Table 2). Some of these studies also indicate that males reach gonadal maturity before they reach morphometric maturity, whereas females reach gonadal and morphometric maturity at roughly the same time. All maturity studies conducted in the U.S. estimate Jonah crab to reach sexual maturity below the current U.S. coastwide-Atlantic minimum legal size (120.65 mm CW) except for the GOM region, where male crabs are estimated to reach maturity at 122 mm CW.

Ongoing investigations into geographic variations in size-at-maturity

Morphometric Jonah crab data collected between 2015-2021 by MA DMF, NOAA Northeast Fisheries Science Center (NEFSC), and the University of Maryland Eastern Shore (UMES, Olsen and Stevens 2020) were pooled to estimate the size at which 50% of Jonah crab reached sexual maturity (SM50), by sex and region. Samples sizes by region and data source are shown in Table 3.

We examined the performance of three different statistical models against simulated data, a broken stick model (Olsen and Stevens 2020), a two-line model with a logistic transition (Hall et al. 2006) and the hierarchical clustering method described by Somerton 1980. The Somerton method involves subjectively splitting the data into three subsets based on size (CW): immature, mature, and unknown, where "unknown" individuals are of intermediate size and span the size range where crabs are transitioning between juvenile and adult morphologies. Linear regressions are then fit to both the immature and mature portions of the data set and individuals of intermediate size are categorized as either immature or mature based on nearness to the regression models extrapolated into the intermediate range. The regression modes are then iteratively re-fit and the intermediate-sized individuals re-categorized until the model stabilizes. The simulated data were built from two-line models with logistic transitions, approximately parameterized by exploration of existing data. This model assumes that individuals displaying mature morphology was a probabilistic process around transitional sizes and appropriately recognizes that all individuals will not switch to adult morphologies at the same size due to biological and environmental variations within regions and discontinuous growth processes.

Of the three models tested, the broken-stick model consistently under-estimated SM50. The two-line logistic model, which matched the structure of the simulated data, often estimated unbiased parameters, in aggregate, but was unstable and sometimes failed to converge. The Somerton method can be sensitive to the subjective initial group classifications and produced biased logistic parameters but unbiased derived estimates of SM50. Here, we present only the results from the Somerton method and recognize additional modeling approaches need to be developed to better stabilize these models and improve performance. To derive confidence limits on the SM50 estimates, we bootstrapped the data 1,000 times for each sex and region and refit the models.

A strong geographic gradient in SM50 for female crabs was not detected. SM50 estimates varied from 89.6 to 97.5 across the regions (Table 3 and Figure 2). Bootstrapped medians were within two millimeters of estimates for all regions except SNE Inshore which was 6 mm larger than the estimate (Figure 3). Distributions of bootstrapped SM50 estimates were bi-modal for both GB and SNE Inshore, suggesting that the estimates are unstable and sensitive to anomalous observations. The maturity estimate for the GOM Offshore turned out to be highly sensitive to the assumed range of "unknown" sizes provided to the Somerton method, though this estimate is comparable to adjacent regions.

Males matured at larger sizes in offshore and more northerly regions than in inshore and southerly regions, showing strong geographical size-at-maturity gradients (Table 3 and Figure 4). A pattern of increasing size at maturity is evident for inshore habitats, increasing from 101.7 mm in the Mid Atlantic to 109.7 in inshore GOM. However, size at maturity was less variable offshore, increasing only from 119.4 mm in the offshore SNE to 121.3 mm in offshore GOM.

In general, male size of maturity is near or below minimum legal size across all regions. GOM Inshore is the only region with a history of producing high landings of Jonah crabs where crabs reach maturity at sizes much smaller than legal size. Additionally, the size of crabs generally pursued by the fishing industry is currently larger than the minimum size, suggesting that most crabs are probably reaching maturity before being captured and retained by the fishery. It is informative that the largest geographic variation in maturity occurs between inshore and offshore SNE, a difference of 16mm over about 100km, corresponds to what is probably the largest thermal gradient in bottom temperatures.

2.3.3 Fecundity

Estimated female clutch size for large female Jonah crab (105-135 mm CW) is between 400,000 and 1.8 million eggs (Hines 1991). The number of eggs per clutch increases significantly with increasing CW (Hines 1991). Though data is limited, female Jonah crab are believed to produce a maximum of one clutch of eggs per year (Hines 1991). There are four zoeal and a megalopa stage for Jonah crabs, which are morphologically identical to Atlantic rock crabs *(Cancer* *irroratus*) except for the number of setae on some appendages (Sastry 1977). This study also reported similar larval developmental times for Atlantic rock crabs at 15°C, and Jonah crabs at 20°C, which implies full larval development from hatch to megalopa would take around 25 days at 20°C for Jonah crabs (Johns 1981).

2.4 Natural mortality

Natural mortality rates for Jonah crab have not been estimated, in part due to a lack of empirical and fishery-dependent data needed for commonly applied estimation methods (Maunder et al. 2023). There are various factors known to influence natural mortality for crustaceans, including molt stage (Ryer et al. 1997), size (Canales et al. 2019), life stage (Lorenzen 1996; Vogt 2011), disease (Vogan et al. 2008), and predation (Maunder et al. 2023), which are also expected to affect Jonah crab natural mortality rates.

Epizootic shell disease has been described for the American lobster stock and is known to impact molting and natural mortality for the species (Vogan et al. 2008, Castro et al. 2012). This condition, which has increased in prevalence in lobster since 1996, occurs on a north to south gradient of increasing disease prevalence related to interacting factors of water temperature, size-at-maturity, and intermolt period (ASMFC 2020; Castro et al. 2013; Glenn and Pugh 2006). Larger lobsters and ovigerous females tend to have higher rates of shell disease, likely related to the extended intermolt duration for these groups (Castro and Angell 2000; Glenn and Pugh 2006; Castro et al. 2013; Reardon et al. 2018; DNC 2019). Lobster shell disease prevalence in the population is highest just prior to the time of molting (Tlusty et al. 2014; Groner et al. 2018) and severity has been shown to worsen more rapidly as waters warm (Barris et al. 2018).

A similar condition to lobster epizootic shell disease has been reported for Jonah crab, particularly in SNE (Haefner 1977, Truesdale et al. 2019a), attributed to chitinoclastic bacteria, including Gram-negative bacteria such as Vibrio (Sindermann et al. 1989, Austin and Alderman 1987). Prevalence of disease occurrence is not well described, but shell disease condition data have recently started being collected as part of several state sea sampling and port sampling programs. In inshore Rhode Island waters, it was observed that shell disease prevalence follows a seasonal cycle aligning with the molt season, as with lobster (Truesdale et al. 2019a). Recently, this shell disease has been reported in Jonah crabs as far north as the Bay of Fundy (Carlon et al. 2018). Like lobster shell disease, Jonah crab disease presents as dark spotting on the carapace and claws, in some cases with lesions that erode the shell's structural integrity. This presentation is similar to that of "black spot" caused by bacterial infection in the European brown crab (Stentiford 2008). The extent to which shell disease impacts internal systems and modifies mortality rates in European brown crab is not well described, but injection of bacterial species isolates was shown to lead to systemic infection and increased mortality (Stentiford 2008). Black spotting disease has been noted to be more common among older crabs, likely due to a longer intermolt duration (Ayres and Edwards 1982).

Other pathogens of Jonah crab have not been well described; however, a comprehensive review of diseases impacting the European brown crab characterized several viral, bacterial, and fungal diseases associated with increased mortality rates (Stentiford 2008). Understanding diseases as mortality drivers, including the impacts of fishing practices on disease transmission and severity (e.g., declawing practices, interspecific interactions in traps) has been emphasized as a management consideration (Stentiford 2008).

Predation on Jonah crab has also not been comprehensively described but is expected to comprise an important source of natural mortality for the species based on the available literature and diet data, which indicate that Jonah crab is a major component of the diets of several important predator species on the northeast US continental shelf. In a recent diet study, Cancer crabs were the largest component of the diets of black sea bass (*Centropristis striata*) and Atlantic cod (*Gadus morhua*) in nearshore SNE waters (Santos 2020). Jonah crab have also been found to be important prey species for skates (*Rajidae*), smooth dogfish (*Musteus canis*), spiny dogfish (*Squalus acanthias*), and longhorn sculpin (*Myoxocephalus octodecemspinosus*) in the NEFSC seasonal trawl survey (pers. comm., B. Smith, NOAA NEFSC). Given the importance of Jonah crab as a prey item, it is of interest how the shifting predator field in the region may have influenced Jonah crab mortality rates over time.

2.5 Stock Structure

Four Jonah crab stocks were defined based on a combination of biological aspects, management considerations, fishery characteristics, and data availability. These stocks (Figure 5) include the Inshore Gulf of Maine stock (IGOM), Offshore Gulf of Maine stock (OGOM), Inshore Southern New England stock (ISNE), and Offshore Southern New England stock (OSNE).

Size-at-maturity was the primary biological basis for defining the stock areas, while the available tagging information suggests limited movement of Jonah crab that would be indicative of adult connectivity throughout the population. Larval distribution and supply remain uncertainties for connectivity and stock structure. Individuals generally mature at larger sizes offshore compared to individuals inshore at the same latitudes, and individuals generally mature at smaller sizes moving south within inshore/offshore areas (Table 1 and Table 2). Inshore/offshore boundaries and the inshore GOM/SNE split were matched to existing LCMAs, where possible, recognizing these would be the likely boundaries for any future Jonah crab regulations. Assessing crab stocks at spatial scales defined in part by management and fishery characteristics is a common practice applied in other crab stock assessments (Pezzack et al. 2009, Marcussen 2022). Statistical areas were used for stock boundaries when LCMAs needed to be split because this is the finest level of spatial data available with landings.

The IGOM stock covers LCMA 1 extending from ME through central MA, while offshore stocks primarily cover LCMA 3. LCMA 3 covers offshore waters throughout the entire range of Jonah crab, so there was the need to split this area into GOM/SNE stocks using statistical area boundaries. The GOM/SNE split between offshore stocks was defined as the southern boundaries of statistical areas 521, 522, and 561. Statistical area 521 contains most of the OCC LCMA and most Jonah crab landings within this statistical area are likely to come from offshore areas in LCMA 3, so OCC was grouped with the OGOM stock. Fisheries in OGOM waters, where lobster abundance remains relatively high, target lobsters and tend to catch Jonah crab as bycatch (Section 4). This region has the potential to develop a directed Jonah crab fishery with increased and differential exploitation patterns if lobster abundance declines. These potential patterns could be masked if grouped at a broader scale with statistical areas to the south more associated with mixed crustacean fisheries and fisheries targeting Jonah crab. There is no clear separation of crabs between statistical area 562 and statistical area 525 and no evidence of connectivity between statistical area 562 and statistical area 561 according to MA DMF/AOLA tagging work (Perry et al. 2019), so statistical area 562 is grouped with the OSNE stock. Index of abundance development during the assessment showed different patterns of abundance in these areas further supporting this split (Figure 6). All Mid-Atlantic areas (LCMAs 3, 4, and 5) were grouped with the OSNE stock due to this component of the population being relatively small and located in deep canyons offshore and the expectation they would be more similar to Jonah crab populations offshore of SNE. The available maturity estimates present a more mixed picture for comparison between Mid-Atlantic crabs and those from offshore SNE proper, but the recent studies by Perry et al. 2017 and Olson and Stevens 2020 indicate similar size-at-maturity based on morphometrics for females in these two areas.

The ISNE stock primarily covers LCMA 2. LCMA 5 (Long Island Sound), which opens into LCMA 2 and accounts for minimal Jonah crab harvest, was grouped with the ISNE stock. Statistical area 537 accounts for the majority of Jonah crab harvest and extends into both inshore waters in LCMA 2 and offshore waters in LCMA 3, so there is the need to split this statistical area between SNE stocks. The northern boundary of the LCMA 2/3 overlap, which is in the middle of statistical area 537 and has more similar depths in its western section as the waters just into the LCMA 3 portion of 537 (Figure 7), was set as the boundary between ISNE and OSNE stocks within statistical area 537. The small section of LCMA 2 that extends into statistical area 521 (OGOM stock) and statistical area 526 (OSNE stock) was assumed part of these respective offshore stocks for pragmatic reasons of splitting landings data.

3 HABITAT DESCRIPTION

Jonah crabs can be found from Newfoundland to Florida at depths ranging from the intertidal to 800m but are most abundant in the northern latitudes (Haefner 1977, Stehlik et al. 1991, Pezzack et al. 2011). Limited specific information is available for the distribution as depth, season, habitat, and temperature affect the abundance of Jonah crabs (Stehlik et al. 1991, Carpenter 1978, Haefner 1977, Krouse 1980). The highest abundance of Jonah crab is found in water temperatures of 6-14^{o}C (Stehlik et al. 1991, Haefner 1977, Krouse 1980, Pezzack et al. 2011). Krouse (1980) suggests Jonah crabs have a narrower temperature range tolerance than the similar species, Atlantic rock crab, and may stay further offshore to attain more stable bottom temperatures. Laboratory studies by Lewis and Ayers (2014) found Jonah crabs thermoregulate and will move to a preferred temperature, but previously experienced temperatures significantly impacted temperature preference. At the southern end of their range, Jonah crab prefer greater depths (Jeffries 1966). In the Mid Atlantic Bight, Haefner (1977) provides evidence for an increase in size as depth increases while Carpenter (1978) suggests relative abundances of distinct size groups can be found at different depths depending on the time of year. Carpenter (1978) found female Jonah crabs are more abundant at depths less than 150m while males prefer deeper water.

Historic offshore trawl surveys and recent interviews with SNE fishermen found the highest abundance of Jonah crabs in silty sand and flat muddy habitats (Haefner 1977, Stehlik et al. 1991, Truesdale et al. 2019a), but studies, mostly in the GOM based on inshore SCUBA work, trapping, and video survey, found Jonah crabs associated with more complex cobble, boulder, and sand substrate (Jeffries 1966, Krouse 1980, Richards 1992, Palma et al. 1999, Reardon 2006). YOY and juvenile Jonah crabs are found in relatively high numbers during settlement surveys (Section 6.1) in cobble habitat. Whether offshore areas provide important settlement or nursery habitat is poorly understood. The discrepancy of observed crab habitat could be due to lower catchability of crabs by trawl surveys and commercial pot gear in complex habitat, difference of primary substrate type by life stage, or correlation of substrate with depth.

4 FISHERY CHARACTERIZATION

While landings are available coastwide back to 1981 (Figure 1), the accuracy of the reporting and the location of where those landings were harvested is uncertain, so this assessment has focused on the landings since 2010. However, it is also important to understand the context of the increases in reported landings over time and the changing structure of the fishery. The coastwide landings register a steady increase in Jonah crab landings over time. Historically, Jonah crab has been a bycatch species in the American lobster trap fishery, but in the last two decades, the fishery has shifted with regional differences. The differences in characterization are important to recognize when interpreting catch and participation data. In areas where lobsters are still abundant and available to the commercial fleet, Jonah crab remains primarily a bycatch species, but in areas where lobster abundance has decreased significantly, Jonah crab has become a directed fishery. The numbers of participants vary by states and inshore versus offshore regions. In some areas, the pounds landed per trip are significantly higher, and total landings of Jonah crab are high while the number of active harvesters is low, indicating a more directed fishery. In other areas, the number of active harvesters is significantly higher while the pounds per trip remain low, indicating a bycatch fishery. The inshore fleets tend to be bycatch fisheries while the offshore fleets are directed fisheries. In this section, we provide the characterization of the Jonah crab fishery components by state.

4.1.1.1.1 Spatial Distribution

Most U.S. Jonah crab landings come from the OSNE stock. From 2010 to 2021, annual landings for this region have accounted for 70 to 85% of the total U.S. Jonah crab landings (Figure 8-Figure 19). Landings from the IGOM stock account for 9 to 24% of the coastwide landings over the same period. The OGOM and ISNE regions have never exceeded 5% of coastwide Jonah landings for any year between 2010 and 2021.

Though Jonah crab landings are reported from a wide geographic area, most landings are concentrated in the northern portion of the OSNE stock. In recent years, more than half of the Jonah crab landed in the U.S. are caught in the offshore portion of statistical area 537 (Figure

20-Figure 31), within LCMA 3. Statistical areas 526 and 525 are also important areas. Each area often accounts for more than 10% of the annual U.S. Jonah crab landings.

4.2 State-Specific Fishery Characterizations

Maine

Jonah crab has historically been a bycatch species of the lobster fishery in Maine in LCMA 1. Misreporting is common because the fishing fleet refers to *Cancer borealis* (Jonah crab) as "rock crab" and *Cancer irroratus* (Atlantic rock crab) as numerous local names, but not "rock crab". This misidentification creates challenges in understanding the dynamics of the fishery from landings data. Anecdotally from the fishery, Atlantic rock crab is caught close to shore, predominantly in state waters in bays and rivers, while Jonah crab is predominantly caught in deeper federal waters. Most reported crabs are assumed to be Jonah crab. In the landings data, both species were often reported as "crab unclassified", prior to reporting requirements, and misreporting problems persist. The Jonah crab harvest primarily consist of whole crab, but Maine does allow a personal use exemption for Jonah crab claws. There was a pulse of very high landings of Jonah crab in the early 2000s leading to a peak of almost 10 million pounds landed, but most of that catch was reported as "crab unclassified".

Effort and landings of Jonah crab in Maine are driven by the combination of abundance of lobster, abundance of Jonah crab, and market availability. If the lobster catch is very high or markets for Jonah crab are unavailable, the fleet will actively avoid Jonah crab, even if the crabs are abundant. While poundage has been decreasing in the lobster fishery in recent years, the abundance of lobster is still high and worth much more than Jonah crab, leading to the continued preference for lobster. The bycatch fishery for Jonah crab remains at low levels characterized by low poundage per trip (Figure 32) where a majority of the trips between 2018-2021 are 100lb or less. While the poundage of the trips is low, the scale of the Maine lobster fishery compared to other regions represents high numbers of trips and permits participating in the fishery (Figure 33 and Figure 34). Since 2008, 10% or less of the Maine trap/pot trips reported harvesting Jonah crab, representing between 10,000-30,000 trips annually. Permits actively harvesting Jonah crab represent 14-25% of the active trap/pot permits, totaling 600-1,136 permits annually.

New Hampshire

In New Hampshire, Jonah crabs have historically been harvested as bycatch of the lobster fishery in both LCMA 1 and 3. The LCMA 1 fleet is made up of day boats generally fishing within 25 miles of shore, while the LCMA 3 fleet is characterized by multi-day trips to offshore GOM and GB. Vessels in both LCMAs target lobster and Jonah crab as bycatch with the magnitude of landings for crabs being driven by a number of factors, including but not limited to: 1) abundance of lobster, when lobster catch is high Jonah crabs are more apt to be thrown back, 2) markets for Jonah crab, if dealers are seeking Jonah crabs and make it easy for captains, they will be more likely to harvest crabs, 3) price per pound of Jonah crab, higher price provides more incentive, and 4) desire of captain's helper to retain crabs to sell on their own. Jonah crabs from the inshore fleet have historically been a source of additional income for helpers as they will put them aside and sell once they have enough crabs to go to market. These are the primary factors driving landings and the reason why this bycatch fishery is generally characterized by low catch per trip.

Jonah crab landings in New Hampshire from LCMA 1 averaged 36,061 from 2016-2022, whereas in LCMA 3 they averaged 77,716 pounds. In both LCMAs, Jonah crab landings comprised only 2% of total lobster/Jonah crab landings. During this same time period, 25% of vessels in LCMA 1 and 44% of vessels in LCMA 3 landed Jonah crab. Lobster is the target species for NH vessels fishing in both state and federal waters and Jonah crab makes up a very small percentage of total state landings.

Massachusetts
Jonah crab was traditionally considered a bycatch of the trap-based lobster fishery until the collapse of the SNE lobster stock in the late 1990s. The collapse of the lobster fishery forced many Massachusetts fishers to diversify. State permits that allowed for the harvest of lobster or edible crabs, and simple gear modifications, made it easy for lobster fishers to redirect effort towards Jonah crab. Increasing Jonah crab price per pound due to expanding markets and redirected effort from the lobster fishery led Jonah crab to rapidly become one of the most valuable fisheries in the state based on ex-vessel value. More Jonah crab are landed in Massachusetts than any other state.

Most Jonah crab landed in Massachusetts are caught in federal waters from statistical area 537, 526, or 525 and landed in the ports of New Bedford, Sandwich, or Gloucester. A small number of boats targeting Jonah crab are usually responsible for a large portion of the state landings, but there are numerous fishery participants targeting lobster that land smaller amounts of Jonah crab. Most trips landing Jonah crab catch less than 100 pounds per trip, but trips targeting crab often catch over 10,000 pounds (Figure 35). Some trips have reported over 100,000 pounds. The proportion trips landing Jonah crab in IGOM, OGOM, and ISNE using a Massachusetts lobster/edible crab trap permit is low (Table 4). However, about 75% of OSNE trips by those possessing a Massachusetts lobster/edible crab trap permit, land Jonah crab. The IGOM and ISNE fleet tend to be smaller vessels conducting day trips. The OGOM and OSNE fleet are larger vessels conducting multiday trips.

Crabs are landed whole, and sold to be marketed live, or processed at meat picking facilities. Nearly all the Massachusetts Jonah crab landings come from the lobster/edible crab trap fishery, and nearly all are male due to market preferences for larger crabs. The fishery targets hard-shelled crabs because recently molted crabs have little market value due to low meat yield and lower survival rates.

Rhode Island
The Rhode Island Jonah crab commercial fishery is composed of inshore and offshore fleets, with inshore vessels harvesting Jonah crab in LCMA 2 and offshore vessels harvesting Jonah crab in LCMA 3, corresponding to the inshore and offshore SNE stocks. The inshore fleet generally comprises small vessels conducting day trips, while the offshore fleet is made up of more vessels that conduct multi-day trips. As a result, Jonah crab landings per trip are higher

for the offshore fleet (Figure 36). In general, because of the price differential between Jonah crab and lobster and differences in catch rates, Jonah crab harvest per trip is often higher than lobster harvest per trip, even when lobster was the predominant target species, which warrants caution in interpretation of CPUE data. However, there appears to be a decrease in lobster landings for trips landing more than 6,000 lbs. of Jonah crab, suggesting a potential threshold for examination of trips targeting Jonah crab (Figure 37).

Historically, Jonah crab was predominantly a bycatch fishery in Rhode Island, but around 2010, harvesters pivoted to target crab in addition to, or in place of, lobster (Truesdale et al. 2019b). The fishery now comprises vessels that target either species as well as those that switch between target species based on fishing location, season, market factors, and other variables. The offshore fleet includes several vessels that have highly capitalized in the Jonah crab fishery; on average, Jonah crab make a much higher percentage of mixed-crustacean trip landings for the offshore fleet than the inshore fleet (Figure 38). Inshore trips are more frequently mixed-crustacean trips wherein Jonah crabs are retained as bycatch. Only whole Jonah crabs may be retained and sold in Rhode Island.

Overall, Rhode Island's lobster and crab commercial fleets have declined in numbers since 2007, which is attributed in part to the decline of the SNE lobster stock and related management actions over the past decade. The inshore fleet has experienced a decline in number of participants, from nearly 250 permits to just over 100 from 2007 to 2021. However, the number of vessels landing Jonah crab has been largely stable for the inshore fleet at around 35 vessels. The Rhode Island offshore Jonah crab and lobster fleet has decreased from around 30 permits in 2007 to 14 permits in 2021 (Figure 39). However, the offshore fishery accounts for the bulk of Rhode Island's Jonah crab landings; nine offshore vessels brought in more than 65% of the annual landings from 2017 to 2021, on average.

Southern States

The states of Connecticut through Virginia represent a relatively small proportion of the overall Jonah crab fishery. Since 2010, the states of Connecticut through Virginia have contributed under 10% of the coastwide total Jonah crab landings, with New Jersey and New York consistently contributing the large majority of that percentage. According to state compliance reports New York and New Jersey had 19 and 24 Jonah crab fishery participants in 2021, respectively; in Connecticut, Delaware, Maryland, and Virginia there were fewer than five Jonah crab fishery participants in each state.

In New York, the majority of participants fish in offshore SNE, though there are three to five participants that fish in the inshore SNE area, and two or fewer that fish in the GOM (Figure 40). In New Jersey, Delaware, Maryland, and Virginia, all participants fish in the offshore SNE area (Figure 41 and Figure 42).

While the majority of Jonah crab is harvested as whole crabs, fishermen from some states, particularly New York, New Jersey, Delaware, Maryland and Virginia, land Jonah crab claws. Jonah crab claws are relatively large and can be an inexpensive substitute for stone crab claws. As a result, they can provide an important source of income for fishermen. Claws can also be harvested for personal consumption; however, these landings are not well documented. A historic claw fishery takes place along the Delmarva Peninsula. These traditionally small-boat fishermen harvest Jonah crab claws because they do not have a seawater storage tank on board to store whole crabs. As a result, landing claws avoids economic inefficiencies for this small fleet. Jonah crab is also landed as bycatch in non-trap gear, such as bottom otter trawls and gillnets, and non-lobster trap gears, such as whelk pots, crab pots, and fish pots.

In Virginia, the Jonah crab claw fishery was the dominant fishery in the early 2000s and 2010s, where 100% of the catch by weight was claws. In 2015, the claw fishery declined to 1% of the total state catch by weight and whole crab landings became dominant. Since then, claws have represented 0% of the catch by weight in Virginia. In recent years Virginia's fishery in general has decreased significantly, with only one active harvester. This harvester holds a Jonah Crab Incidental Commercial Permit with Virginia, and only harvests Jonah crab as bycatch in other directed fisheries.

4.3 Market Factors

Effort and landings of Jonah crab are driven by the combination of abundance of lobster, abundance of Jonah crab, and market availability. The markets for Jonah crab are volume driven so there may be a lower threshold of volume when markets are not accessible. Markets and price may also be locally driven, or dependent on whole crab versus claw only categories. Southern states are more likely to have claw fisheries so price and pound data should be interpreted with caution.

Price per pound trends by state for states landing whole crabs have generally increased over the time period of 2010-2021 (Table 5). Rhode Island and Massachusetts prices are higher overall and track together. These are also the locations of the highest volume and likely available and consistent markets. The highest prices were experienced in 2021. The price data from Maine should be used with caution because of the misidentification issues discussed in Section 4.2. Jonah crab are typically worth more than Atlantic rock crab. While the average price is lower in Maine, it does track the same trend as Massachusetts and Rhode Island, except in 2014, when it dipped slightly.

Unlike the American lobster, there is not a species recognition for Jonah crab in the seafood consumer markets. Jonah crab is often used as a crab option and can be substituted among multiple species like the Dungeness crab, snow crab, stone crab, or king crab. Markets can be driven by demand but also may depend on the availability and cost of other crab species.

5 FISHERY DEPENDENT DATA SOURCES

5.1 Commercial

5.1.1 Landings Data Collection and Treatment

5.1.1.1 Maine

A Lobster and Crab Fishing License is required to commercially harvest Jonah crab in Maine, and it has historically been a bycatch species of the lobster fishery. A permit endorsement is also available for the drag fishery, which allows a limit of 200 pounds per day and 500 pounds of Jonah crab per trip. Traps are subject to the lobster rules including maximum size, escape vents, and trap tags. There is a recent prohibition of claw harvest, except for a personal use exemption of a 5-gallon bucket maximum. While the market has always dictated a male-only fishery, the FMP provided the guidelines for regulations on size of greater than 4.75 inches.

Misidentification of Jonah crab creates challenges in the landings data because both *Cancer irroratus* (Atlantic rock crab) and *Cancer borealis* (Jonah crab) are harvested as bycatch and have an identical common name of "rock crab". Historically, crab landings were reported on a monthly basis, but were not mandatory until 2004 and were not linked to state harvester identification numbers in the CFDERS database. In 2006, Maine shifted to using the Atlantic Coastal Cooperative Statistics Program's (ACCSP) Standard Atlantic Fisheries Information System (SAFIS) and Maine's MARVIN database for monthly mandatory reporting of landings with associated harvester identification numbers that add accountability. In 2008, the mandatory reporting was required on a trip and species level, yet there are still "crab unclassified" landings in recent years, albeit much reduced as compared to prior to 2008.

Both *Cancer* crab species were considered lower value species compared to lobster and were commonly sold for cash prior to reporting requirements; as such, landings prior to (and potentially after) 2008 should be considered an underestimate. Of the reported landings, ME DMR expects most reported volume and market demand has been for Jonah crab as opposed to Atlantic rock crab, so it is expected that historical and recent landings for Jonah crab should include the "crab unclassified" and "rock crab" landings. It may be possible to identify likely Jonah crab landings based on price (> $0.35/pound), but there is uncertainty on this threshold, especially earlier in the time series.

5.1.1.2 New Hampshire

New Hampshire lobster and crab harvesters have been reporting catch and effort from state waters since 1969 to the NH F&G. Beginning in 2006, all state licensed lobster and crab harvesters were required to report catch and effort. In 2016, with the adoption of the Jonah crab FMP, New Hampshire implemented mandatory Jonah crab harvest reporting on both monthly-summary and trip-level reports. While reporting of Jonah crab catch and effort was not mandatory prior to 2016, harvesters were provided the opportunity to report crab bycatch at the monthly level. Only commercial harvest by state lobster and crab license holders is included.

Historically, the quantity of lobsters and crabs landed in New Hampshire harvested from federal waters was derived from a combination of the NOAA Fisheries weigh out and canvas database and federal VTRs. Currently, NOAA Fisheries has mandatory reporting of harvest data for the majority of federally permitted vessels that land in New Hampshire through VTRs. Those not required to report to NOAA Fisheries are captured under NH F&G harvest reporting.

In cooperation with NOAA Fisheries, New Hampshire instituted mandatory lobster dealer reporting in 2005 and began collecting all data required under ACCSP standardized data submission standards. New Hampshire lobster dealers report transaction-level data on a monthly basis through use of paper logbooks or directly through electronic dealer reports (EDR). NOAA Fisheries mandated dealer reporting for lobster landings in 2010. Dealers report all species harvested and both state and federal dealers have been able to report Jonah crab since implementation. Jonah crab landings in New Hampshire have been reported by dealers since 1994.

In order to assign areas to the dealer report records and calculate effort estimates, VTRs and state logbooks are used to identify statistical areas and effort values as dealer reports do not contain area and effort data.

5.1.1.3 Massachusetts

Participation in the Massachusetts Jonah crab fishery has been limited to those that hold a commercial lobster/edible crab permit since 1948. Reporting of landings through Massachusetts trip level reports (MATLR) or NOAA Fisheries VTRs has been mandatory since 2010. On MATLR, fishermen are asked to report location of catch, gear type, amount of gear, soak time, number of trawls, and quantity landed.

Most Jonah crab landed in Massachusetts are caught in federal waters and reported on NOAA Fisheries VTRs. A small number of boats targeting Jonah crab are usually responsible for a large portion of the state Jonah crab landings, but there are numerous fishery participants targeting lobster that land smaller amounts of Jonah crab. Some inshore fishers will crate, or hold their catch, combining landings from multiple trips, until they reach a quantity that is deemed worth selling. Thus, dealer transactions may represent landings from multiple trips. Landings are generally in pounds, but occasionally bushels of crabs are reported. In these cases, a bushel to pounds conversion is made by multiplying the number of bushels by 65. The landing of anything other than whole crabs is prohibited. There is speculation that landings may have been under-reported prior to 2010, as Jonah crab was considered a low value species and some catch may have been sold for cash at the dock.

5.1.1.4 Rhode Island

Commercial landings in Rhode Island before 2003 are derived using NOAA Fisheries' data collection methods. Beginning in 2003, 100% electronic dealer reporting was implemented in Rhode Island through the Rhode Island Fisheries Information System, the predecessor of the SAFIS. It took a period of about three years to develop consistency in reporting among all dealers with the new trip-level system but from 2006 on, electronic dealer reports are believed to account for all Jonah crab landings. For the stock assessment, landings of Jonah crab and Atlantic rock crab were reviewed on a trip-by-trip basis, particularly for years prior to 2011, due to concerns about inconsistency in species identification. Using each vessel's full fishing history, fishing location, harvest weight, and in some cases direct consultation with harvesters, some of the landings reported as Atlantic rock crab were reassigned to Jonah crab. As a result, the time series of Atlantic rock crab landings was adjusted to be more stable over time, consistent with anecdotal reports of the Atlantic rock crab fishery's trajectory.

5.1.1.5 Connecticut

Landings are recorded in the NOAA Fisheries weigh out and general canvas database as landings at state ports. Connecticut also records landings by licensed commercial fishermen in any port (inside or outside Connecticut) by means of a mandatory logbook system that provides catch and effort information from 1979 to the present. This mandatory monthly logbook system provides detailed daily catch data by species, area, and gear as well as port landed, traps hauled, set over days, and hours trawled (for draggers). The logbook provides a means to look at fundamental changes in the operating characteristics of the lobster fishery within Long Island Sound. Since 1995, the program has required fishermen to report information on the sale and disposition of the catch, including the state or federal permit number of the dealer to whom they sold their catch. Seafood dealers are also required to report all of their individual purchases from commercial fishermen using either the NOAA form Purchases from Fishing Vessels, a Connecticut Seafood Dealer Report, Abbreviated Form for Lobster Transactions Only, or through the ACCSP's SAFIS. A quality assurance program has been established to verify the accuracy of reported statistics through law enforcement coverage and electronic crosschecking of harvester catch reports and seafood dealer reports.

5.1.1.6 New York

The commercial harvesting of Jonah crab requires a New York commercial crab permit. The crab permit has been limited entry since 6/29/1999. The limited entry stipulates that no new permits are issued, but a certain percentage of forfeited permits from the previous year are made available the following year. The limited entry permit resulted in an overall decrease in permits over time. Permit holders have until December 30th and may renew anytime during the calendar year.

New York's commercial fishery harvest data has been collected through state and federal VTRs since 2012 for food fish, lobster, and crab commercial permits. State VTR data is entered by staff into the New York Fishery Information on Sales and Harvest (NYFISH) database or entered directly by fishermen into the ACCSP's eTrips online database. New York landings reported through federal VTRs are entered by federal staff and shared with New York on a weekly basis in order to provide timely and accurate landings estimates. Landings data are reported by statistical area.

5.1.1.7 New Jersey

The commercial harvest of Jonah Crab within state waters of New Jersey does not occur, therefore data are not collected. New Jersey reported landings are obtained from NOAA Fisheries VTRs.

5.1.1.8 Delaware

The commercial harvest of Jonah Crab in Delaware requires either a Directed Jonah Crab Landing Permit issued to those who hold a valid Delaware Commercial Lobster Pot License or federal lobster permit, or an Incidental Jonah Crab Landing Permit issued by the Delaware Department of Natural Resources and Environmental Control. Delaware's commercial landings are collected through state logbooks. State logbook data are entered into a state-owned database and uploaded annually to the ACCSP data warehouse. Logbooks report daily catch and are required to be submitted on a monthly basis.

5.1.1.9 Maryland

Maryland is a *de minimis* state and all Jonah crab landings are caught in federal waters and reported on NOAA Fisheries VTRs and through SAFIS. There is no directed fishery of Jonah crab and landings are predominately claws. A small fleet of commercial fishing vessels targeting lobster harvest Jonah crab, predominately in LCMA 5, statistical area 626. In addition to the required federal lobster permit, the Maryland Limited Entry Cancer Crab License is required. The Maryland limited entry Jonah crab claw permit was eliminated by Addendum II (2017).

5.1.1.10 Virginia

Virginia data are collected via required monthly harvester reporting. The majority of landings are from a single harvester and all landings are confidential.

5.1.2 Biological Sampling Methods

5.1.2.1 NOAA Fisheries

Sea Sampling

The Northeast Fisheries Observer Program (NEFOP) has collected data from vessels engaged in the lobster fishery, including the associated Jonah crab fishery, as funding allows since 1991. Because there is no mandate under the Standardized Bycatch Reporting Methodology (SBRM) to monitor the federal lobster and Jonah crab fishery to support the management of these fisheries, the number of NEFOP sea days are allocated based on the needs to monitor bycatch of species included in SBRM, including groundfish. Thus, sampling intensity is inconsistent and varies across years. In recent years, NEFOP observer coverage peaked at 60 sea days in 2015 but coverage has since dropped to about 4 sea days per year. Data collected by NEFOP observers include CW (mm), sex, presence of eggs, kept and discarded catch weights, bycatch data (including finfish lengths and weights), gear and bait characteristics, haul locations, water depth, trip costs, and incidental takes.

Port Sampling

The NOAA Fisheries Greater Atlantic Regional Fisheries Office initiated a port sampling program for the targeted Jonah crab fishery in 2021. Annual sample requests are stratified by region, stock area, gear type, and calendar quarter and are allocated to focus on the regions where most of the Jonah crab fishery occurs and to be complementary to spatial coverage of port and sea sampling by state agencies. Port samplers select vessels for sampling based on current and historical landings data, real-time vessel tracking, and local knowledge of the fisheries. NOAA Fisheries anticipates collecting 74 port samples per year with a standard sample consisting of 40 individuals with CW measurements and gender recorded.

5.1.2.2 Commercial Fisheries Research Foundation

Sea Sampling

The Commercial Fisheries Research Foundation (CFRF) has conducted a fishery-dependent Jonah crab data collection project since 2014. The CFRF project has involved 25 vessels over the time series and offered coverage of inshore and offshore SNE, GB, and offshore GOM. Typically, three sampling sessions are conducted per month from fishermen's regular commercial catch. A sampling session consists of sampling catch from a trawl starting with the first trap hauled until 20 traps have been sampled or 50 crabs have been sampled, whichever comes first. For sampling the regular catch, fishermen decide which day(s) sampling sessions are conducted, but the trawl(s) sampled on those days is selected at random. Data collected include vessel ID, date, time, location, depth (feet), sex, CW (mm), egg-bearing status, shell hardness, and disposition (kept or discarded). Data are collected on Samsung tablets using CFRF's On Deck Data application and periodically uploaded to a database at CFRF where they are QA/QC'd and provided to ACCSP.

5.1.2.3 Maine

Sea Sampling

ME DMR does not have a formal Jonah crab sea sampling program as it has been considered a low value species as compared to lobster and is not a target species for the Maine fishery. ME DMR sampling program samples in both state and federal waters on Maine permitted boats. Some research trips were completed in 2003 and 2004 when the ME DMR was exploring experimental Jonah crab traps that would exclude lobsters yet catch Jonah crab. Those trips included subsampled biological data from both the experimental traps and standard commercial lobster traps. Since 2017, the Lobster Sea Sampling program includes an opportunistic protocol to collect Jonah crab data if they are harvested for commercial sale and the sampler has the capacity to do so. If crabs are sampled, the protocol includes collecting biological data including CW, sex, reproductive status, cull status, and shell hardness. In the future, a standardized subsampling protocol will be developed. ME DMR proposes only using data from trips with more than 20 crabs measured.

5.1.2.4 New Hampshire

Sea Sampling

Jonah crabs have been sampled by NH F&G as bycatch on lobster sea sampling trips since 2015. Samples are collected monthly from May through November at two different locations: the Isles of Shoals, and the coast (Portsmouth harbor to Massachusetts Border). Bycatch is sampled on all observed hauls (50% or more of the total hauls for the day). Data collected on Jonah crabs include sex, CW, shell condition, and cull status. Bycatch data are entered into an Access Database along with the coordinates of the trawl, number of set days, bait type, and water depth.

Port Sampling

NH F&G has conducted Jonah crab port sampling at local dealers on the New Hampshire coast since 2016. Initially, samples were collected from commercial lobster boats harvesting from several different statistical areas throughout the GOM and GB. More recently, due to a lack of fishing effort in some of the statistical areas farther offshore, samples have been obtained from dealers who purchase crabs from vessels fishing in statistical area 513, which includes both state and federal waters. Biological data (CW, sex, molt stage, shell disease, and cull status) are collected on the landed catch, and information is obtained from the dealer to determine total catch and effort where available.

5.1.2.5 Massachusetts

Sea Sampling

MA DMF does not have a formal Jonah crab sea sampling program because roughly 99% of Massachusetts landings come from federal waters, though some samples have been collected opportunistically. Jonah crab sea sampling data were collected during directed lobster trips in Cape Cod Bay (southern statistical area 514) from 2016 to 2018, and during a Jonah crab tagging project in statistical areas 537, 526, 525 from 2016 to 2017. Target species (lobster or Jonah crab) varied during the Jonah crab tagging project trips. Samplers recorded CW (mm), sex, cull status, mortalities, and presence of extruded eggs. The percent cover of shell disease (black spotting) was characterized starting in 2017. Catch was separated by trap. The start of each trawl was recorded using a handheld GPS.

Port Sampling

MA DMF began a Jonah crab port sampling program in the fall of 2013. Sampling intensity was low during 2013 (2 trips) and 2014 (4 trips). A minimum of 10 trips have been conducted annually since 2015. Starting in 2015, vessels and dealers with the most state landings were targeted for sampling. The vast majority of the sampled catch is from statistical areas 537 and 526. Statistical areas 525, 562, and 514 have been sampled with less regularity. A minimum of five crates or the entire catch, whichever is less, is sampled per trip. Data collected include: CW (mm), sex, and cull status. Shell disease and mortalities have been recorded since 2017.

5.1.2.6 Rhode Island

Sea Sampling

Rhode Island does not currently have a sea sampling program for Jonah crab as funds are not available for this purpose. In 2016 and 2017, 12 sea sampling trips did occur as part of a URI research project. These trips occurred in inshore statistical areas 539 and 537. Data collected include number of traps per trawl, soak time, bait, bottom type, depth, trap location (latitude/longitude), and trap configuration. From each sampled trawl, effort was made to sample all captured Jonah crabs—whenever this was not feasible, a systematic random sampling frame was used to census every second or third trap in a trawl. The following data were recorded for each sampled crab: CW, sex, ovigerous condition, shell disease level, molt condition, and number of claws missing.

Port Sampling

The RIDEM DMF initiated Jonah crab port sampling efforts in 2015; four trips were sampled during the initial year, before staffing and funding limitations placed this program on hold until 2019. Since the resumption of the program in late 2019, RIDEM DMF has strived to conduct ten port sampling trips for Jonah crabs per year. Most port samples have come from fishing trips taking place in offshore statistical areas 525 and 526. Port samplers reach out to captains and owners of offshore fishing vessels and coordinate with these parties to intercept a portion of their catch before it is offloaded to seafood transporters and dealers. At the trip level, samplers collect information from vessel captains on fishing area, bait, soak type, bottom type in fishing area, number of traps set, and average depth. Biological data are collected from a minimum of two totes of Jonah crab per port sample (about 200 crabs). Collected biological variables include CW, sex, shell disease level, molt condition, and cull status (number of claws missing).

5.1.2.7 New York

Sea Sampling

New York State Department of Environmental Conservation (NYDEC) sea sampling data are collected on cooperating commercial vessels in Long Island Sound (statistical area 611) and the Atlantic Ocean side of Long Island (statistical areas 612 and 613). However, Jonah crab were not included in the program until 2017, after the ASMFC Jonah crab FMP was adopted, and no Jonah crab have been sampled during the program. Much of the sea sample effort has been in statistical area 611, where few Jonah crab reside.

Port Sampling

A port sampling program began in 2005. The main objective of the program is to enhance the collection of biological data from lobsters harvested from LCMAs 3, 4 and 5. A communication network was developed with cooperating dealers and fishermen who fish these areas. This network is contacted to identify days and times of vessel landings to provide sampling opportunities. Utilizing this network of contacts allows for the sampling of lobster fishing trips landed in New York from the appropriate LCMAs. Sampling protocol adheres to the standards and procedures established in NOAA Fisheries Fishery Statistics Office Biological Sampling Manual. This program was expanded to collect data from LCMA 6 starting in 2013. Limited

Jonah crab sampling was conducted in 2014 and directed sampling was initiated in 2017. Jonah crab have only been sampled during market sampling.

5.1.2.8 Maryland

Sea Sampling

Maryland is a *de minimis* state and does not currently have a sea sampling program for Jonah crab, as funds are not available and there is no requirement to do so. However, state biologists have conducted sea sampling in previous years aboard federally permitted lobster fishing vessels in Ocean City, Maryland. Sampling occurred during calendar years 2015, 2016, 2018 and 2019 with 315 randomly selected Jonah crab caught in lobster pots from LCMA 5 (statistical area 626) sampled for CW and sex. Biologists attempt to randomly measure Jonah crab during lobster sea sampling with the goal of 100 crabs per multiday trip.

5.1.3 Trends

5.1.3.1 Commercial Landings

Coastwide dealer reported Jonah crab landings were queried from the ACCSP Data Warehouse and validated for accuracy with state partners. Additionally, landings reported as rock crabs or unclassified crabs in Maine were included due to the misidentification issues described in Section 5.1.1.1 and expectation that the majority of these landings are Jonah crabs. Stock-specific commercial landings across states were generated through a combination of applying proportions of harvest across statistical areas from harvester reports to dealer reported total landings, direct use of total harvest by statistical area from harvester reports and assigning statistical area to dealer reported landings based on port of landing. For landings from statistical areas other than 537 in RI and MA that overlap multiple stocks, landings were assigned to a stock based on expected areas fished and these assignments are in Table 6. For landings from statistical area 537 in RI and MA where the majority of Jonah crabs are harvested, landings were split between ISNE and OSNE stocks using permit LCMA data from harvester reports. Small proportions of remaining landings without statistical area information could not be assigned to a stock. These landings and proportions of the coastwide totals they make up in each year are in Table 7. Proportions range from 0.0002 to 0.0329 and average 0.0108 across years.

The start year for reliable landings identified in ASMFC 2021 was 2006. However, spatial landings are not available from the primary landing state, MA, until 2010, limiting the start of the time series for stock-specific landings to this year. The vast majority of landings have come from the OSNE stock (Table 7 and Figure 43), averaging just short of 13 million pounds over the time series, followed by the IGOM stock (averaging 2.5 million pounds), the ISNE stock (averaging 460 thousand pounds), and the OGOM stock (averaging 317 thousand pounds). Landings from SNE stocks show similar trends increasing at the beginning of the time series and declining briefly in the mid-2010s, before increasing to time series highs in the later 2010s. Landings then decline sharply in 2019. Landings inshore increase during the following two years at the end of the time series, while landings offshore continue declining to their lowest point of the time series in 2021. The two largest and distinct peaks offshore occur in 2014 and 2018, while two of largest peaks inshore, also relatively distinct, occur a year earlier than seen offshore in 2013 and 2017. Trends in GOM stocks differ both between stocks and from trends in SNE stocks. Landings inshore decline sharply at the beginning of the time series to their lowest levels in the early to mid-2010s. Landings then increase sharply to their time series highs in the later 2010s and are highly variable over the last three years of the time series. Landings offshore are variable around their highest levels in the early 2010s, then decline through the late 2010s before a slight uptick in the last two years of the time series. The peak landings offshore occur during the same year as the first peak in the OSNE stock (2014), while the peak landings inshore occur during the same year as the second peak in the OSNE stock (2018).

Seasonally, landings from the IGOM stock have shifted from being concentrated in quarter two and three to being more evenly distributed across quarters since 2016 (Figure 44). Jonah crabs from the OSNE stock have primarily been landed in quarters one and four with slightly smaller proportions in quarters two and three (Figure 45). Seasonality of landings has been more variable for the two stocks with lower landings (OGOM and ISNE), but have occurred primarily during waves one and two in the OGOM stock (Figure 46) and waves three and four in the ISNE stock (Figure 47) across the time series.

The vast majority of landings (>90%) across stocks come from pot and trap gears.

5.1.3.2 Commercial Biosampling

Commercial biosample data were compiled from all sources. Sea sampling is useful to characterize the biological attributes of the total Jonah crab catch including discarded Jonah crabs. Port or market sampling is useful to characterize the biological attributes of the landed Jonah crab catch. Biosample data through 2019 were summarized in ASMFC 2021 for some background information and are updated through 2021 and split into stock units here. The number of sea and port sampling trips conducted by year, stock, and statistical area are in Table 8 and Table 9, respectively.

Annual summary statistics, including mean size of males in the overall catch and mean size of the largest 5% males in the overall catch, were calculated from sea sampling data as measures of size structure change and potential indicators of mortality changes. Mean size of the largest 5% males was initially compared to 90% of an unpublished von Bertalanffy L_{inf} estimate (Mid-Coast, Maine males gastric mill band count analysis estimate; C. Huntsberger, personal communication, October 11, 2022) as a potential reference point, as was done by Marcussen 2022. However, there are no estimates for SNE Jonah crabs and the estimate used here appears larger than would be expected given maximum sizes of Jonah crabs observed throughout time. Therefore, only trend information was ultimately considered for these data and not the 90% of L_{inf} reference point.

Summary statistics were calculated as weighted averages across trips, weighted by the number of crabs sampled during each trip. Trips with <29 crabs sampled were excluded and strata (Stock+Statistical Area+Year+Quarter) with <2 sampling trips were excluded from the data set.

There were no strata with five years of port sampling data, so these data were not included in the analysis. Data were too sparse to calculate landings-weighted stockwide statistics, even across quarters (Figure 48), so time series by stock and statistical area were evaluated for trends. A Mann-Kendall test, which is nonparametric test for monotonic (i.e., one-way) trends, was applied to data sets to evaluate for trends. Test results with a p-value <0.05 were considered detected trends. For pragmatic reasons, time series with at least five data points were tested and the maximum time series length across data sets was eight years. Tests of these short time series should be considered with caution.

Overall, trends in mean size statistics are stable over the relatively short time series (Table 10-Table 11 and Figure 49-Figure 55). Only one significant trend was detected across data sets, an increasing trend for the ISNE stock in statistical area 539 during quarter four. Note that there were no strata with five data points for the IGOM stock. Mean sizes are typically larger for the offshore stocks. The mean sizes of the 5% largest males are well below the 90% of L_{inf} estimate in all stocks and years, highlighting concerns about the reliability of this estimate as an appropriate reference point.

General lack of trend seen here could be a favorable indication of stock condition or it could indicate that these data are unreliable indicators of stock condition, as appeared to be the case in Pezzack et al. 2009. These data should be revisited as potential indicators in future stock assessments when longer time series are available and, ideally, there is sufficient coverage to generate landings-weighted stockwide time series but are not recommended at this time for stock indicators.

5.1.4 Catch Rates

5.1.4.1 CFRF VTS

In addition to regular commercial trap (i.e., vented) sampling, CFRF provides each vessel with up to three ventless traps to use during the course of the Lobster and Jonah Crab Research Fleet project. To maintain general consistency with most configuration specifications of other ventless trap sampling programs in Rhode Island, Massachusetts, New Hampshire, and Maine, the fleet deploys ventless traps with the following configurations: 40” length x 21” width x 14” height, single parlor, 1” square rubber-coated 12-guage wire, standard mesh netting, cement runners, and a 4” x 6” disabling door. One ventless trap is typically deployed at a fixed temperature monitoring station while the others may be deployed as the lobstermen see fit. Lobstermen also decide to record a session at their discretion and can decide not to record a session after hauling the traps (e.g., poor weather conditions). Ventless trap sampling is not associated with commercial trap sampling, and thus is recorded in a different sampling session. However, harvesters can and do attach the ventless traps to strings of their commercial gear if they choose. CFRF encourages fishing vessels to record at least one ventless Jonah crab sampling session per month at the bottom temperature monitoring site.

This sampling is intended to provide information on presence of sublegal lobsters and crabs and some temperature information. It is not designed to measure size structure of the retained crabs for harvest or abundance. However, given the data limitations faced during the assessment and because this is the only non-trawl sampling of catch rates in the core area of the fishery, CPUE time series were calculated from these data to evaluate as potential measures of abundance.

Data were standardized with negative binomial generalized additive models (GAMs) using catch of male exploitable sized crabs (121+mm CW) per session as the response. Catch is not recorded to the trap level, but rather collectively at the session level. However, only 19 of 658 sessions fished more than one trap and these sessions were excluded so the response was effectively catch per trap. Factors considered in the models for both the ISNE and OSNE stocks included year, month, depth, and soak time. Additionally, statistical area was considered for the ISNE stock, but not the OSNE stock because some less-sampled areas were only sampled in one year leading to multicollinearity between area and year. Both depth and soak time were modeled with smoothers. Model selection was performed with stepwise Akaike's information criterion (AIC) and the model with the lowest AIC was identified as the final model for standardizing CPUE.

Number of sampling sessions and number of crabs sampled are in Table 12. There were only two sampling sessions for the OSNE stock in 2021, so these data were excluded from the data set. For the ISNE stock, the model with year, month, SA, depth, and soak time was identified as the final model. For the OSNE stock, the model with year, month, and depth was identified as the final model. The CPUE trends were similar between stocks, increasing in the first few years of the time series and decreasing in the latter half of the time series (Figure 56). The CPUE inshore increases slightly in 2021 and is not available offshore. Catch rates offshore are about double the catch rates inshore and the rate of change offshore is also greater during the time series.

5.1.4.2 Direct Residual Mixture Model CPUE

5.1.4.3

Fishery-dependent data can be used for deriving indices of abundance for exploited marine species when the catch per unit of effort can be interpreted as an indicator of relative population abundance. However, CPUE is influenced by numerous environmental and temporal variables, which can preclude straightforward interpretation of fishery-dependent data. Standardization techniques for catch and effort data can be used to remove the impact of these other factors on CPUE, allowing fishery-dependent data to be used in deriving an index of abundance (Maunder and Punt 2004). These methods generally comprise model-based approaches, including generalized linear models (GLMs) and GAMs.

Beyond environmental and temporal variables, fishing behavior influences catch rates of exploited species and is therefore impactful to interpretations of CPUE data for abundance indices. In mixed-species fisheries, incorporating fishing behavior into standardization procedures is particularly challenging, as it requires accounting for the fisher's target species, since fishing techniques typically vary among target species and thus impact multispecies catch rates (Stephens and MacCall 2004; Okamura et al. 2018). Several methods have been developed for standardizing catch data in mixed-species fishery to produce indices of abundance. Most commonly, these have involved applying an absolute or proportional landings threshold to identify and subset to trips targeting the species of interest (Biseau 1998; Stephens and MacCall 2004). However, such subsetting methods have been criticized because they lose information and do not allow for comparison of CPUE models before and after subsetting (Okamura et al. 2018). A recently-developed method for CPUE standardization in mixed-species fisheries, called directed residual mixture models (DRMs), allows for use of a full mixed-species fishery dataset without subsetting (Okamura et al. 2018). Here, DRMs were used to standardize Jonah crab CPUE in the Rhode Island mixed species lobster and Jonah crab fishery in inshore and offshore SNE.

The DRM includes variables related to fishing tactics (including targeted species), as well as variables that do not relate to fishing tactics. In model equation form, the DRM can be written:

$$\log\left(CPUE_{s,i}\right) = X_{s,i}^{T}\alpha_s + Z_{s,i}^{T}\beta_s + \varepsilon_{s,i}$$

where in the i^{th} fishing operation for species *s*, $X_{s,I}$ is a vector of variables excluding the variable related to fishing tactics (target species) and its interactions and $Z_{s,I}$ denotes a vector of variables that includes the variable related to fishing tactics and its interactions. The first element of $X_{s,I}$ corresponds to the intercept, and α_s and β_s are the regression parameter vectors for $X_{s,I}$ and $Z_{s,I}$, respectively. The last term, $\varepsilon_{s,I}$ denotes independently and identically distributed random variables. Because the variable related to fishing tactics is not observed, the model that is fitted to the data is:

$$\log\left(CPUE_{s,i}\right) = X_{s,i}^{T}\alpha_s + v_{s,i}$$

where $v_{s,I} \sim N(0, \eta^2)$. The residual $\widehat{v}_{s,i}$ = log(CPUE$_{s,i}$) - $X_{s,i}^{T}\widehat{\alpha}_s \approx Z_{s,i}^{T}\widehat{\beta}_{s,i} + \widehat{\varepsilon}_{s,i}$, where $\widehat{\alpha}_s$ is the maximum likelihood estimator for α_s and contains information on the variable related to fishing tactics. Essentially, if $\widehat{v}_{s,i}$ is large when species *s* is targeted, indicating a high fishing efficiency for species *s* in fishing operation *i,* then the exponentiated $\widehat{v}_{s,i}$ divided by the sum of exponentiated residuals for all species, should be large. This transformed residual is written as:

$$\widehat{p}_{s,i} = \frac{\exp\left(\widehat{v}_{s,i}\right)}{\sum_{u=1}^{S}\exp\left(\widehat{v}_{s,i}\right)}$$

It is assumed that the logit transformation of $\widehat{p}_{s,i}$ (($\hat{z}_{s,i} = logit(\hat{p}_{s,i}) = \log[\hat{p}_{s,i}/(1-\hat{p}_{s,i})]$) has a normal mixture model of linear regressions with *K* components:

$$f(\hat{z}_{s,i}) = \sum_{k} \pi_k \Phi(\hat{z}_{s,i}: u_{k,i}, \sigma_k^2)$$

where $\Phi(\hat{z}_{s,i}: u_{k,i}, \sigma_k^2)$ is normally distributed and $\{\pi_k\}$ are the missing proportions, with $\sum_k \pi_k = 1$. The parameter $\mu_{k,i} = M_{k.i}^T \omega_k$ is the expectation given the fishing tactics k, $M_{k,i}$ is a vector of explanatory variables for which the first element is 1 and the rest are related to observed variables, ω_k is the regression coefficient, and σ_k is the standard deviation of the normal distribution for fishing tactics *k.* The parameters are estimated by the expectation-maximization (EM) algorithm, producing a variable that indicates whether the individual trip was targeted or bycatch, based on the posterior probability of belonging in components of the mixture. This variable, called the "target variable" is categorical and assigns the target species for the trip.

Once the target variable has been assigned using the EM algorithm, a GLM can be fitted to the CPUE data of species s (in this case, Jonah crab), with the target variable included as a covariate. Extraction of the year effect from this GLM gives the standardized CPUE index.

Jonah crab DRM model fitting and selection

The Jonah crab DRM was fitted in R using the 'mgcv' package and the EM algorithm code from Okamura et al. (2018). Month, year, and stock region were explored as covariates for derivation of transformed residuals and for the final GLM model. Candidate models were compared using AIC and diagnostic plots (Figure 58).

Trip-level Jonah crab and lobster landings data from Rhode Island for all trips landing Jonah crab from 2007 through 2021 were queried from Rhode Island state harvester logbooks, eTrips data, and federal VTRs. Data were subsetted to the inshore and offshore SNE stock regions and to trips fishing with pot/trap gear. Data were also subsetted to trips landing more than 250 pounds of Jonah crab, as initial data analysis and model exploration indicated that inclusion of trips landing few Jonah crab had an impact on model target species assignment and model estimates. Since trips landing so few Jonah crab could be interpreted not to be targeting Jonah crab, even as a secondary target, and the catch could be highly impacted by factors unrelated to catch rates (e.g., retaining versus discarding low catch due to market factors), these trips were not included in the CPUE standardization process.

The model to derive transformed residuals for the Jonah crab fishery incorporated year and stock covariates as factors predicting log-transformed Jonah crab and lobster landings. Target species as assigned by the EM algorithm was included in the final GLM fitting process. The selected GLM for CPUE was:

```
mod<- glm(log(Jonah)~as.factor(Year)*Stock+TargetSpecies*Stock+as.factor(Month)*Stock)
```

Stock was incorporated as an interactive term with year, target species, and month (Table 14). The interaction with year was included to allow for examination of CPUE trends in the inshore and offshore stock individually. The stock interactions with target species and month align with fishery characteristics since the Jonah crab fishery has distinct inshore and offshore components with different behaviors in terms of fishing seasonality and with regard to targeting behavior (Truesdale et al. 2019).

The stock trajectories for inshore and offshore SNE Jonah crab differ in terms of scale and trend (Table 13 and Figure 57). The offshore stock appears relatively stable over the period of interest without a significant trend. For the inshore stock, there appears to be a period of higher CPUE at the beginning of the time series, with a lower CPUE period beginning around 2014.

5.1.4.4 Reference Fleet CPUE

We used commercial catch-per-trap from LCMA 3 to investigate whether there were any relationships between catch rates from a fishery-dependent “reference fleet” and fishery-independent trawl surveys throughout the GOM/GB. Only vessels landing >199lbs in a statistical area were included in this analysis, and we assessed the years 2004 through 2021 due to limitations in mining data further back than 2004. The reference fleet CPUE correlated with the ME/NH trawl survey catch for both fall males 120mm+ (see Section 6.2 for description of survey and selected size structure, Spearman’s r=0.53, P=0.0232) and spring males 120mm+ (Spearman’s r=0.49, P=0.0458), note Spearman’s was used due to skewed distributions with data. NEFSC trawl survey only showed correlation with a two year lag (Spearman’s r=0.5118 and P=0.427) fall trawl 120mm+ males. The correlation in the reference fleet and ME/NH trawl survey suggests some relationship between what was caught in trawl and traps within a year, though the NEFSC trawl takes place within the same region and there was only a correlation with a two year lag. This lag between the trawl survey and commercial catch in this region could be due to the gear selectivity of commercial harvesters and larger size of crabs being landed offshore compared to inshore, although our uncertainty around growth, catchability and incentives for harvesters to retain Jonah crabs is confounding. Nonetheless, we found general agreement between the reference fleet and trawl surveys within the GOM suggesting some spatial and temporal coherence in abundance trends between fishery-dependent and fishery-independent indices.

5.1.5 Commercial Discards/Bycatch

Although the taking of whole crabs is the current harvest practice in most areas of the Jonah crab fishery, claw-only harvesting is also practiced in other areas (e.g,. mid-Atlantic states; Seafood Watch 2014), where harvesters remove both claws from a single Jonah crab (ASMFC, 2015, ASMFC 2019) and then release it at-sea. Although at present, this harvest practice comprises only a small proportion of the overall commercial fishery effort (~ 1 %; ASMFC, 2015), given the potential expansion and growth of this fishery to other areas, it is plausible that a claw-based fishery could become more widespread. Historically, other crab fisheries utilize claw removal prior to releasing animals back to the sea with the assumption that declawed crabs will survive and continue their cycle of molting and regenerating new claws to again be harvested. This practice includes the highly valued stone crab (*Menippe mercenaria;* Duermit et al. 2015; Gandy et al. 2016; Kronstadt et al. 2018; Orrell et al. 2019), northeast Atlantic deep-water red crab (*Chaceon affinis*; Robinson 2008), European brown or edible crab (*Cancer pagurus*; Fahy et al. 2004), and fiddler crab (*Uca tangeri*; Oliveira et al. 2000). Until recently the mortality and sublethal effects of declawing Jonah crabs was unknown but recent work has helped to evaluate the impacts of declawing on harvestable Jonah crabs along with assessing the sublethal effects (e.g., mating, activity, stress, movement) on overall health and function as well (Goldstein and Carloni 2021, Dorrance et al. 2022). Goldstein and Carloni (2021) found markedly higher mortality in Jonah crabs when removing both claws (70%), compared to a single claw (51%), and mortality was significantly correlated with wound size, temperature, and shell condition. Furthermore, they found using a mechanical tool to declaw crabs where crabs would naturally autotomize reduces mortality by over 50%.

In a follow-up study Dorrance et al. (2022) investigated the sublethal effects declawing had on mating, locomotion and feeding ability. First, mating trials revealed that males with both claws removed could successfully mate with recently molted females. Second, through laboratory-based trials, crabs with claws removed were significantly less active compared to control crabs where both claws were intact; this was corroborated by a passive tagging study where declawed crabs moved about half the distance of control crabs. Additionally, declawed crabs were still able to feed, however they were unable to effectively open mussels which may influence their diet in their natural habitat. These data along with Goldstein and Carloni (2021) suggest that those Jonah crabs that do survive the claw removal process might be impaired, but should be able to forage, mate, and potentially help sustain the population.

6 FISHERY INDEPENDENT DATA SOURCES

6.1 Settlement/YOY Surveys

Settlement indices of abundance are provided for Jonah crabs <13mm CW. This size cut-off corresponds closely with size cut-offs identified by Huntsberger 2019 for YOY crabs (10mm CW). Preliminary correlation analyses applied to lagged age-specific settlement indices for ages 0-2 based on cut-offs from Huntsberger 2019 (<10mm CW for age-0, 10-19.9mm CW for age-1, and 20-40mm CW for age-2) failed to detect strong support of cohort tracking within surveys (Figure 59 and Figure 60). These analyses were likely impacted by small sample sizes but may also be indication of growth uncertainty and overlap with age. The YOY indices represent the smallest sizes that may be less affected by overlap in size-at-age and presumably would be the least mobile age class, therefore providing the best measure of year class strength.

Five settlement indices were identified as providing most utility for the assessment. These included ME settlement surveys from three statistical areas in ME waters (statistical area 511, 512, 513), the NH settlement survey (SA 513), and the MA settlement survey (SA 514). All surveys are in IGOM waters.

6.1.1 ME DMR Settlement Surveys

The ME DMR settlement survey primarily was designed to quantify lobster YOY but has also collected Jonah crab data from the sites throughout the time series. The survey was started in 1989 in a smaller regional area close to Boothbay Harbor within statistical area 513E but was expanded to statistical areas 513 W, 512, and 511 in 2000. Therefore, some indices include separate trends for areas in 513 due to the differing time series. The Maine survey currently monitors 40 sites coastwide within 1-10m in depth. The timing of this survey has shifted over time due to dive staff availability to complete the work, but it has generally occurred between September and December annually. Jonah crab information collected includes CW and location. Notations are made if small crabs carry eggs.

6.1.2 NH F&G Settlement Survey

NH F&G has participated in the American Lobster Settlement Index (ALSI) since 2008, and biological information has been collected on Jonah crabs since 2009. New Hampshire follows the standardized coastwide procedures and monitors three sites along the NH Coast.

6.1.3 MA DMF Settlement Survey

Massachusetts has conducted a juvenile lobster settlement survey since 1995. The survey begins in mid to early August, and generally runs through late September. The survey started with nine fixed stations in three regions and by 2018, had grown to include 23 fixed stations in seven different regions. The survey extent contracted in 2019 to 14 sites in five regions. The Vineyard Sound region and two of the Buzzards Bay sites were discontinued because juvenile lobsters are rarely encountered in these areas. The Cape Cod region and some South Shore stations were discontinued due to the increasing presence of white sharks at survey sites during the survey time-period.

The survey is conducted at fixed stations by a team of divers. Divers selectively place 0.5 m^2 quadrats over areas of cobble. Twelve quadrats are sampled per station, which are then immediately sorted on the boat.

Jonah crabs have been consistently identified to species in the survey since 2011. Though the survey has not always identified crabs to species, it has consistently identified *Cancer* crabs to genus over the entire time series. Jonah crabs are counted, measured (CW in mm) and sexed when possible. Crabs less than 5 mm are generally too small to sex or identify to species.

6.1.4 Other Settlement Surveys Considered

Three additional surveys were considered, but not recommended for use at this time (Table 15). These included the RI settlement survey, University of Maine Deepwater Collector survey, and Normandeau Plankton Survey. The RI settlement survey occurs in ISNE waters, but infrequently encounters Jonah crab. The University of Maine Deepwater Collector Survey, which uses collector boxes to sample across a range of depths, was useful for the assessment in that it indicates trends are tracked from shallow to deep waters (Figure 61), improving confidence that accepted settlement surveys, all occurring in shallower waters, are accurately reflecting overall settlement trends. However, settlement indices from this survey do not correlate well with the accepted state surveys which use suction sampling and may provide biased measures of interannual settlement due to the attractive nature of collectors placed in otherwise less ideal habitat. The Normandeau Plankton Survey offers a long time series in IGOM waters but does not record *Cancer* crab species to the species level.

6.2 Post-Settlement Surveys

Three post-settlement abundance metrics were identified based on biology and exploitation of Jonah crab. These metrics are intended to improve interpretation of abundance indices by filtering aggregate indices that encounter intermittent catches of small crabs, behind which the mechanisms of catchability are not well understood (e.g., catch through the trawl mesh as the bag comes into contact with the ground). Because catch rates of larger, older Jonah crabs are also low, these intermittent catches can lead to noise that has considerable impact on the abundance signal and its interpretation. Post-settlement abundance metrics include recruit abundance, exploitable abundance, and spawning abundance. Recruit abundance is defined as male Jonah crabs 90-119 mm CW. Male Jonah crabs 95mm CW are expected to grow to legal size after their next molt, on average, according to the regression equation from Truesdale et al. 2019a (PostMoltCW=1.22*PreMoltCW+5.47; expected PostMoltCW for PreMoltCW of 95mm is 121.37mm). Trawl surveys have historically measured Jonah crabs to the nearest cm, so the recruit size class was structured to include the cm bins capturing 95mm CW crabs up to the largest fully sublegal cm size bin (11cm; current minimum size is 4.75 inches or 120.65mm). Exploitable abundance includes all male Jonah crabs greater than these recruit sizes (120mm+ CW) and is a measure of abundance currently available to the fisheries. Spawning abundance is defined as female Jonah crabs 80mm+ CW. The spawning abundance size structure includes the smallest cm size bin associated with recent SM50 estimates along the coast (Table 1).

Three survey platforms were identified as providing most utility for abundance indices based on broad spatial footprints that overlap with Jonah crab habitat, long time series that cover the period of available stock-specific landings, availability of biological data that allow for filtering to the post-settlement abundance metrics, and similarities in trends measured in the respective stock. These platforms included the MA Trawl Survey covering the IGOM stock, the ME/NH Trawl Survey covering the IGOM stock, and the NEFSC Trawl Survey covering all four stocks (although, later determined to not be of utility for the ISNE stock – see Section 7). All three platforms have separate surveys in the spring and fall.

6.2.1 NEFSC Trawl Survey

The NEFSC bottom trawl survey began collecting Jonah crab data in 1979. The spring survey is generally conducted from March to May and the fall survey is generally conducted in September and October.

The NEFSC bottom trawl survey utilizes a stratified random sampling design that provides estimates of sampling error or variance. The study area, which now extends from the Scotian Shelf to Cape Hatteras including the GOM and GB, is stratified by depth (Figure 7). The stratum depth limits are < 9 m, 9-18 m, >18-27 m, >27-55 m, >55-110 m, >110-185 m, and >185-365 m. Stations are randomly selected within strata with the number of stations in the stratum being proportional to stratum area. The total survey area is 2,232,392 km^2. Approximately 320 hauls are made per survey, equivalent to one station roughly every 885 km^2.

Most survey cruises prior to 2008 were conducted using the NOAA ship R/V Albatross IV, a 57 m long stern trawler. However, some cruises were made on the 47 m stern trawler NOAA ship R/V Delaware II. On most spring and fall survey cruises, a standard, roller rigged #36 Yankee otter trawl was used. The standardized #36 Yankee trawls are rigged for hard-bottom with wire foot rope and 0.5 m roller gear. All trawls were lined with a 1.25 cm stretched mesh liner. BMV oval doors were used on all surveys until 1985 when a change to polyvalent doors was made (catch rates are adjusted for this change). Trawl hauls are made for 30 minutes at a vessel speed of 3.5 knots measured relative to the bottom (as opposed to measured through the water).

Beginning in 2009, the spring and fall trawl surveys were conducted from the NOAA ship R/V Henry B. Bigelow; a new, 63 m long research vessel. The standard Bigelow survey bottom trawl is a 3-bridle, 4-seam trawl rigged with a rockhopper sweep. This trawl utilizes 37 m long bridles and 2.2 m^2, 550 kg Poly-Ice Oval trawl doors. The cod-end is lined with a 2.54 cm stretched mesh liner. The rockhopper discs are 40.64 cm diameter in the center section and 35.56 cm in each wing section. Standard trawl hauls are made for 20 minutes on-bottom duration at a vessel speed over ground of 3.0 kts. Paired tow calibration studies were carried out during 2008 to allow for calibration between the R/V Bigelow and R/V Albatross IV and their net types. However, calibrations have not been estimated for Jonah crab. Thus, it is appropriate to treat this survey as separate time series since 2009 until a calibration can be produced.

6.2.2 Maine/New Hampshire Trawl Survey

The ME/NH Inshore Trawl Survey began in 2000 to fill a significant information gap in resource assessment surveys on approximately two-thirds of the inshore portion of the GOM. The survey is conducted in collaboration with NH F&G and its industry partner, Robert Michael, Inc. Conducted biannually, spring and fall, the survey operates on a random stratified sampling design. A goal of 120 survey stations are sampled in 20 strata that are distributed over four depths: 5-20 fathoms, 21-35 fathoms, 36-55 fathoms, and >56 fathoms roughly bounded by the 12-mile limit in five longitudinal regions (Figure 62). The survey samples a portion of 3 statistical areas, 513, 512, and 511. Jonah crab biological data were not fully collected until 2004.

6.2.3 MA DMF Resource Assessment Program Trawl Survey

Since 1978, the MA DMF Resource Assessment Program has conducted an annual spring (May) and fall (September) bottom trawl survey within state territorial waters. The survey obtains fishery-independent data on the distribution, relative abundance and size composition of finfish and select invertebrates, including Jonah crab. A random stratified sampling design is used to select stations from five bio-geographic regions and six depth zones (Figure 63). Stations are selected before each survey and drawn proportional to the area each stratum occupies within the survey area. A minimum of two stations are drawn per stratum. Stations chosen in un-towable locations are redrawn.

The F/V Frances Elizabeth conducted all surveys through fall 1981. All subsequent surveys have been conducted onboard the NOAA ship R/V Gloria Michelle. A 3/4 size North Atlantic type two seam otter trawl (11.9 m headrope/15.5 m footrope) with a 7.6 cm rubber disc sweep; 19.2 m, 9.5 mm chain bottom legs; 18.3 m, 9.5 mm wire top legs; and 1.8 x 1.0 m, and 147 kg wooden trawl doors have been used for the duration of the survey. A 6.4 mm knotless liner is used in the codend to retain small organisms. Standard tows are 20 minutes but tows of at least 13 minutes are accepted as valid and expanded to the 20 minute standard. Tows are conducted during daylight hours at a tow speed of 2.5 kts. More information on the MA DMF trawl survey can be found by visiting https://www.mass.gov/files/documents/2016/08/tm/tr-38.pdf.

Jonah crabs have been weighed collectively for each tow to the nearest 0.1 kg since 1978, and by sex since 1981. From 1978 through 2009, Jonah crab CW measurements were taken on a wooden measuring board and recorded to the nearest cm on paper logs. Starting during the 2010 spring survey, crabs were measured on electronic length boards and recorded directly in to Fisheries Scientific Computer System (FSCS) data tables. Since the fall 2014 survey, Jonah crab measurements have been recorded with digital calipers to the nearest cm and recorded directly into FSCS. The change to digital calipers was made to improve measurement accuracy, as crab legs sometimes made it difficult to measure crabs on a length board. Female crabs have been inspected for extruded eggs since the fall 2014 survey, but observations of egg bearing crabs are very rare.

Jonah crab are infrequently encountered in SNE (survey regions 1 and 2; Figure 63), so indices of abundance are only calculated for GOM strata (survey region 3-5).

6.2.4 Other Post-Settlement Surveys Considered

Several additional fishery-independent surveys that have encountered Jonah crab were considered during this assessment (Table 16). These surveys were generally more limited in the information provided, reducing their utility for the assessment. Primary limitations of these data sets included poor spatial coverage, short or discontinuous time series, relatively inefficient catchability or low catch rates, and/or lack of biological data. Most of these data sets were identified as having low utility in ASMFC 2021, including several using ventless trap gears. Ventless trap gear catchability issues impacting this gear's ability to reliably track Jonah crab abundance is further evaluated and described in Section 6.2.5.2.

There was uncertainty in the utility of the NJ Trawl survey in ASMFC 2021 and there was a new survey not considered in ASMFC 2021 but subsequently identified as a survey with relatively high encounters of Jonah crab, the Northern Shrimp Trawl Survey. These surveys were evaluated with preliminary correlation analysis to examine consistency of trends with the other trawl surveys. The NJ Trawl survey has both spring and fall surveys, while the Northern Shrimp Trawl survey has a summer survey only. Both surveys have collected limited biological data, so sex- and size-aggregate abundance indices were used in the correlation analysis. Additionally, it's important to note that there was a gear change for the Northern Shrimp Trawl survey in 2017 and gear change calibration factors are not available, so indices of abundance have not been adjusted for this gear change.

The NJ Trawl index was not correlated with the NEFSC Trawl index which has better spatial overlap with the fishery (Figure 64). This lack of correlation along with the lack of sex data until 2021 limit the utility of this survey and indices were not included in further analyses. The Northern Shrimp Survey was positively correlated with the NEFSC Trawl indices among seasons and spatial domains of indices (IGOM, OGOM and combined GOM areas; Figure 65). These results indicate that trawl surveys are tracking a consistent signal in the GOM. Unfortunately, length data has not been collected during the Northern Shrimp Trawl survey to allow calculation of the Jonah crab abundance metrics and should be prioritized given these correlation results so this survey provides more utility in future stock assessments.

6.2.5 Catchability Analyses

6.2.5.1 Temperature in Trawl Surveys

Given rapidly changing environmental conditions within the Jonah crab range and effects on catchability observed in cohabitating species like lobster (ASMFC 2020), Jonah crab catch rates and temperature time series were evaluated to identify potential temperature-driven catchability effects that may explain noise observed in indices of abundance and provide a better understanding of catchability effects. Because temperature can affect both abundance and survey catchability simultaneously, annual anomalies in catch rate and temperature from underlying trends were evaluated for relationships.

Seasonal catch rates of exploitable Jonah crabs (Figure 6) and temperature time series (Figure 66) from the NEFSC Trawl Survey were generated from adjacent statistical areas associated with high and low commercial landings. There was a period of anomalously low temperatures in the 1980s through 1990 that are not consistent with the underlying trend in other years, so data prior to 1991 were excluded from the analysis. There was a clear linear trend in temperature that was estimated with linear regression and used to calculate residuals as temperature anomalies in the analysis (Figure 67). Identifying the underlying trend in catch rates was more difficult, so two potential trends were included. The first trend was a two-year running average and the second trend was predicted with a LOESS smoother. The span was set at 0.33 to be consistent with the methodology used for the Plan B index-based method applied to Jonah crab index and landings time series (Appendix 14.1). As with the temperature time series, residuals were used as anomalies in catch rates for the analysis (Figure 68 and Figure 69). There was some change in magnitude in residuals, so Spearman's rank correlation was used in the analysis to better handle potential outliers in the relationship.

No significant correlations were detected with a Spearman's rho $\geq \pm 0.5$ in the eight data sets tested (Table 17 and Table 18, Figure 70 and Figure 71). The data for the low catch areas in the spring had a p-value<0.05, but the Spearman's rho indicated only a weak positive association while no other data sets indicated a clear relationship between temperature and catch rate anomalies. These results do not support seasonal temperature being a primary driver of Jonah crab catchability in trawl surveys.

6.2.5.2 Assessing utility of ventless trap surveys for providing Jonah crab abundance indices

The Coastwide Ventless Trap Survey (VTS) was initiated in 2006 from Maine through New York. The impetus for this survey was to track the abundance of juvenile lobster populations, particularly in areas where trawl surveys are not able to tow due to complexity of habitat (ASMFC 2006). Early in the time series, data on bycatch species were not collected on a consistent basis throughout the survey area, and although Jonah crab are now being enumerated for all cooperating organizations, questions remain as to the utility of these surveys for tracking abundance of Jonah crabs. Studies on the interactions between lobsters and Jonah crabs reveal that lobsters are both competitive dominants (Richards et al. 1983, Richards and Cobb 1986, Richards 1992), and common predators of *Cancer* crabs (Ojeda and Dearborn, 1991, Sainte-Marie and Chabot, 2002; Jones and Shulman, 2008). As a result, the presence of lobsters causes crabs to shift their activity decreasing trap entry (Richards et al. 1983). Additionally, there are other covariates that may affect Jonah crab catch rates such as depth, habitat, temperature and/or soak time. With this information in mind, we assessed two historic trap surveys to better understand the effect of soak time and lobster abundance on Jonah crab catch, with the goal of better understanding the ability of these surveys to track Jonah crab abundance over time. The two surveys were: 1) Southern New England Ventless Trap Survey (SNECVTS) conducted off the coasts of Massachusetts and Rhode Island, and 2) Normandeau Associates Inc. Ventless Trap Survey (NAI-VTS) conducted along the coast of New Hampshire.

Southern New England Ventless Trap Survey

We used trap-level data from the SNECVTS in 2018 to test the effect of a number of covariates, including lobster catch, on the catch rate of Jonah crabs. The SNECVTS program sampled 24 stations in the MA/RI wind energy area, twice per month from May to November. At each station, a 10-trap trawl was set with ventless (V) and standard (S) traps in the configuration: V-S-V-S-V-V-S-V-S-V. Target soak time was 5 nights with an acceptable range of 4 to 8 nights (Collie et al. 2019).

Jonah crab catch ranged from 0 to 130, and lobster catch ranged from 0 to 35 per trap. Both distributions were highly skewed with long tails. Jonah crab catch rate was modeled with a GLM with a negative binomial error distribution. The null model included trap type (V or S), latitude*longitude, soak time, and month. Additional candidate models tested the effects of habitat type, lobster and Atlantic rock crabs.

Based on the best-fit model, ventless traps catch more Jonah crabs than standard traps. Jonah crabs are more abundant on sand and soft sediments. Jonah crab catch rate is affected by lobsters but not rock crabs (Figure 72). Catch rate was a dome-shaped function of soak time with a peak at 6 days (Figure 72). In conclusion, Jonah crab and lobster catch rates are inversely related, after accounting for known covariates. The fitted relationship implies that the presence of two lobsters in a trap reduced Jonah crab catch by 11%. These results may account for some of the variability in Jonah crab catch rates in ventless trap surveys. They also suggest that Jonah crab catch rates could be adjusted for lobster abundance in the same traps, as has been done to Figure 72.

Normandeau Associates Ventless Trap Survey

Normandeau Associates conducted a ventless trap survey at two stations along the NH coast since the early 1980s. American lobster, Jonah crab, and Atlantic rock crab were enumerated and measured during trap hauls. Traps were hauled on two-day intervals approximately three times per week from June through November. Trawls consisted of fifteen 1" mesh single parlor traps. Data were aggregated by trawl, as trap-level data were not available. Jonah crab catch peaked during the late 1980s through early 1990s, followed by another peak in the early to mid-2000s and low catch rates from 2009 through 2021 (Figure 73). Lobster catch shows a general upward trend throughout the 40-year time series with highest catch rates being observed over the most recent twelve years (2010-2021). This period of extremely high catch of lobsters coincides with the lowest catch rates of Jonah crabs of the entire time series. Interestingly, the ME/NH trawl survey, picks up the pulse in Jonah crab abundance in the early 2000s, similar to the NAI-VTS, however the pulse picked up by the trawl survey in the mid to late 2010s is not picked up by traps, which coincides with a time period of high lobster catch, suggesting increasing numbers of lobsters within a trap may be deterring Jonah crabs from entering as documented by Richards et al. (1983).

A GAM with a negative binomial error distribution was fit to NAI-VTS data with Jonah crab catches per trawl (15 traps) as the response and year, month, station and lobster catches as covariates. Lobster catches were included as a smooth term. All covariates were retained according to AIC comparisons of reduced models with excluded covariates. Figure 74 shows the estimated effect of lobster catch on Jonah crab catches with a slight increase to catches of ≈80 lobsters per trawl, followed by a steady decrease in Jonah crab catches as lobster catches increase.

Summary

We assessed two trap-based surveys in different geographic areas to evaluate the ability of lobster centric surveys to pick up signals of abundance for Jonah crabs. The analysis of the SNECVTS data shows a positive effect of soft bottom on Jonah crab catch rates, indicating Jonah crabs are more associated with soft bottom that are towable by trawl surveys and not the complex habitat that may be more associated with ventless trap surveys. There were differences in soak times between these surveys, the SNECVTS was designed with a target soak time of 5 days, with a range between 4 and 8 days, whereas the NAI-VTS was designed with a target of 2 days, although longer sets were not uncommon. We found an increasing catch rate of Jonah crab up to six days followed by decreasing catch through eight day sets with SNECVTS. Catch rates increased in the NAI-VTS through 3 days, followed by decreasing catch with increasing soak time (NAI 2016). Although there are some discrepancies in results of catch with soak time between these two surveys, there is still general agreement between both of increasing catch for a number of days followed by decreases likely due to escapes. Similar soak-time dynamics have been observed in American lobster (NAI 2016, Clark et al. 2018). The differences we report here could be due to trap design, bait type/deterioration (Watson et al. 2019), and/or differences in species assemblage and inter and intraspecific competition.

The forty-year time series of the NAI-VTS survey provides a unique opportunity to assess trends of both lobster and crab over a long time series. It becomes even more informative when including an independent measure of crab abundance from the ME/NH trawl survey. Similar to the NAI-VTS, there was a peak in Jonah abundance in the early 2000s, however when the ME/NH trawl peaked again in the mid to late 2010s, this increase was not seen in the NAI-VTS. This time period coincides with unprecedented levels of lobster abundance in the region (ASMFC 2020) and suggests the high catch of lobsters may have deterred Jonah from entering traps, decreasing catchability to a degree that the index is not informative of Jonah crab abundance. Similarly, the models we applied to both surveys showed a decreasing catch of Jonah crabs with increasing lobster catch (Figure 72 and Figure 74), a dynamic which is in agreement with past studies (Richards et al. 1983). Our results, combined with literature on the subject, provide evidence that ventless trap surveys are not ideal for assessing abundance of Jonah crabs, largely due to lobsters being competitively dominant. As demonstrated in Figure 72, there are ways we may be able to adjust crab catch based on number of lobsters in the trap at some levels of lobster catches, though additional work is needed to apply our results to long-term surveys.

7 DATA EVALUATION

7.1 Trend and Correlation Analyses

7.1.1 Methods

After stock structure and abundance metrics were defined, data sets discussed in previous sections were evaluated with correlation analyses to identify consistencies in trends among data sets as an indication of reliability for stock indicators and trend analyses to identify signs of change over time, including:

- YOY settlement indices (<13mm CW; Table 17 and Figure 75)
- Recruit abundance indices (males 90-119mm CW; Table 21-Table 22 and Figure 76)
- Exploitable abundance indices (males 120+mm CW or fishery CPUE; Table 25-Table 27 and Figure 77)
- Spring recruit abundance indices and fall exploitable abundance indices within surveys (Figure 78)
- Exploitable abundance indices and YOY settlement indices lagged from 2-7 years
- Spawning abundance indices (females 80+mm CW; Table 29-Table 31 and Figure 79)
- Jonah crab landings (Table 7 and Figure 43)

Spring recruit abundance indices were evaluated against fall exploitable abundance indices under the assumption that recruits in the spring molt during the summer and recruit to legal-sized abundance in the fall and, therefore, share trend information. For comparisons of exploitable abundance indices and lagged settlement indices, indices from ME settlement surveys and the ME/NH and NEFSC trawl surveys were included because they occur in adjacent areas and cover relatively long time series.

Additional time series were calculated to explore exploitation signals and included:

- Ratios of spring recruit indices and fall exploitable abundance indices (Figure 80)
- Relative exploitation (landings/exploitable abundance index; Figure 81)

Data sets were structured by (1) stock, (2) with the IGOM and OGOM stocks combined due to similarities in trends during preliminary analyses (Section 6.2.4), and (3) coastwide for a perspective on the U.S. population as a whole.

Data sets were evaluated with Spearman's correlation and any results with Spearman's rho (ρ) $\geq \pm 0.5$ and a p-value<0.05 were considered detected correlations. Mann-Kendall trend analysis was applied to test for monotonic trends over time and results with a p-value <0.05 were considered detected trends. Mann-Kendall trend analysis was applied to data sets from 2010-2021 to test for trends since the beginning of the available landings time series which covers the initial ascent of coastwide landings as the fishery developed (Figure 1). However, some data sets started later than 2010 and any with at least five data points were included. Results for these shorter time series should be viewed with caution. Trend analysis was also applied to full time series to provide a historical perspective on trends. It's important to reiterate that vessel change calibration factors for the NEFSC Trawl Survey are not available and indices of abundance have not been adjusted for the vessel change in 2009.

Given limited and noisy data (low encounter rates, high CVs; Table 17-Table 32), emphasis in interpreting results was placed on patterns among all analysis results and less emphasis on individual analysis results between two data sets.

7.1.2 Results

Settlement indices showed correlation among areas in ME waters, but not correlation with indices in waters to the south that had shorter time series (NH and MA; Figure 82). Despite the lack of correlation, all available indices agree on relatively strong year classes in 2012 and 2018. No trends were detected since 2010, but there are increasing trends over the longer time series of all three ME settlement surveys (Table 33).

Recruitment indices showed some consistency between seasons within surveys in GOM and coastwide, but not in SNE stocks (Figure 83 and Figure 84). There were not correlations detected between surveys. No trends were detected in recruitment indices for any areas since 2010, but increasing trends were detected over full time series in eleven surveys covering all areas (Table 34). One decreasing trend over the full time series occurred IGOM in the ME/NH spring survey and is due to the survey beginning later than others during a pulse of abundance in the mid-2000s.

Exploitable abundance also showed consistency between seasons within surveys in GOM and coastwide, as well as some consistency between surveys in GOM (MA and ME/NH; Figure 85 and Figure 86). As with recruit indices, there was no seasonal consistency in SNE and no consistency between fishery-independent indices and fishery-dependent CPUE time series (although there was some correlation in GOM between stocks or with lags, Section 5.1.4.4). Increasing trends since 2010 were detected for the NEFSC fall indices in GOM waters (combined and inshore), while decreasing trends were detected in the ISNE stock with DRM CPUE and the OSNE stock with the NEFSC trawl spring index (Table 35). Over full time series, increasing trends were detected in ten surveys covering all stocks except ISNE. As with recruit indices, the MA/NH spring survey showed a decline from the pulse of abundance at the beginning of its time series. Additionally, the DRM CPUE for the ISNE stock had a declining trend, but this time series was only three years longer than the time series tested since 2010.

Spring recruit indices and fall exploitable abundance indices showed consistency in GOM and coastwide, but not in SNE (Figure 87 and Figure 88). An increasing trend since 2010 was detected in recruit to exploitable abundance ratios with the MA Trawl survey in the IGOM stock, but no other surveys (Table 36). No trends were detected over the full time series.

Given correlations detected among ME settlement surveys, correlation results between the trawl survey exploitable abundance indices and YOY settlement indices were similar across ME settlement indices. Therefore, only results for the central area (statistical area 512) are reported. No positive correlations were detected between the ME/NH indices and lagged settlement indices (Figure 89). However, there were correlations detected between the NEFSC indices and settlement indices lagged from 2-4 years (Figure 90). These correlations decrease as the lag increases and fall apart by a 5-year lag.

Spawning abundance indices showed similar patterns in consistency as male indices, with some seasonal consistency within surveys in GOM and coastwide, but not in SNE (Figure 91 and Figure 92). Additionally, there was some consistency between IGOM surveys. The only trend detected since 2010 was a declining trend for the OSNE stock in the fall (Table 37). During the full time series, increasing trends were detected in twelve indices covering all areas. One declining trend was detected for the ME/NH spring survey.

Landings are not correlated between stocks in GOM and no indices are positively correlated with the landings (Figure 93). In SNE, landings are correlated between stocks and CFRF VTS CPUE is correlated between stocks, while also being correlated with landings ISNE (Figure 94). Coastwide, the indices are not positively correlated with landings (Figure 95). A decreasing trend in relative exploitation was detected using both OGOM seasonal indices, while an increasing trend was detected using the OSNE NEFSC spring index, but not the fall index (Table 38).

7.1.3 Discussion

The only reliable information on settlement comes from IGOM waters. There have been increases in settlement since the 1990s and 2000s, while settlement appears to have become more stable at higher levels in about the last decade. The strong 2012 year class measured across surveys appears to have supported large pulses of abundance that show up in the IGOM and OGOM post-settlement surveys in the mid-2010s. Despite relatively limited correlations detected between surveys in the GOM and some interannual variability in when peak abundances occur, it is clear that brief pulses of increased abundance were detected in GOM waters in the mid-2010s across surveys, as well as during the early 2000s. This cohort signal tracking was measured consistently between the ME settlement surveys and NEFSC trawl survey and the strongest correlations for a two-year lag indicates a slightly shorter lag than detected by Huntsberger 2019 (four year lag between YOY and 110-120mm Jonah crabs). Post-settlement indices also show strong seasonal consistency indicating they are tracking a common signal as opposed to noise alone.

The observed pulses in abundance occur over a very short duration without any clear indication of increased exploitation. Despite the decline of the pulse near the end of the time series, there are no indications of longer-term decreasing abundance or increasing exploitation over approximately the last decade, but rather only indication of increasing abundance and decreasing exploitation.

Settlement trends are unknown in SNE stocks and there was no indication of increased recruitment in the mid-2010s in SNE post-settlement indices. Even indices at a reduced spatial scale in adjacent statistical areas of the OGOM and OSNE stocks that account for low and high magnitudes of overall landings, respectively, show very distinct abundance differences in the mid-2010s (Figure 6). It became clear during these analyses that indices from ISNE are of little utility given low sample sizes (avg. annual tows≈9), infrequency of encounters (multiple zero catch years), and considerable noise (high CVs). These indices were not considered further for information on stock abundance. Additionally, the fishery-dependent CPUE time series for both SNE stocks are not recommended as a measure of exploitable abundance. Despite a trend detected in DRM CPUE, the Mann-Kendall test provides no information on magnitude of changes and the time series shows relatively little change in catch rates despite large changes in landings. Additionally, the CFRF VTS CPUE shows similarities to the landings time series while the fishery-independent indices do not. The methodology of attaching ventless traps to commercial trap strings likely contributes to this and confounds the CPUE's refection of a true abundance trend.

The general consistencies seen in GOM, particularly seasonal consistency, fall apart in the OSNE stock where the bulk of the fishery occurs, making interpretation of these indices more difficult and reducing confidence in their ability to accurately reflect interannual changes in relative abundance. Inconsistencies lead to conflicting pictures of stock condition between seasons, with some signs of increased exploitation and decreased abundance according to spring data that are not apparent with fall data. The spring exploitable abundance index occurs after the primary landings quarters (one and four) and before incoming recruitment and should provide better information on exploitation, but encounter rates are noticeably lower during this season unlike in GOM.

The coastwide data sets present a spatial mismatch with the indices being driven by higher catch rates in GOM areas and landings being driven by the greater magnitude coming from SNE areas. This mismatch could bias true stock-specific exploitation signals.

7.2 Limitations for Assessment Methods

Some analyses of abundance index and landings time series were attempted in order to provide tactical management advice (Appendix 14.1). However, the correlation and trend analyses conducted here highlight two primary limitations for using available data sets in these traditional assessment approaches. First, there does not appear to be a clear relationship between abundance and fishery removals that assessment approaches would depend on and attempt to estimate. The observed abundance “pulse” population dynamics result in short-term, large-scale changes in abundance that appear to be driven by factors other than exploitation given there were no similar changes in landings in the bycatch-driven fisheries of GOM that would explain the rapid decline of these pulses. Another limitation is poor understanding of Jonah crab catchability and low encounter rates for available trawl survey indices. Catch rates have regularly been at or near zero and likely only provide a coarse, qualitative approximation of abundance changes between periods of time as opposed to a reliable quantitative tracking of interannual abundance changes. Therefore, estimates from the index-based methods in Appendix 14.1 are not recommended for management use. Instead, qualitative characterizations of stock status are provided in the next section with empirical stock indicators.

8 STOCK INDICATORS

Given limitations of data sets for traditional assessment approaches, data sets were used to develop empirical indicators of stock conditions and fishery performance. These indicators provide a categorical characterization of recent condition relative to historical levels. The terminal three years (2019-2021) are averaged to provide a smoothed measure of recent stock condition due to interannual variability reflective, in part, of observation error. As is done in American lobster stock assessments (ASMFC 2020), categories are defined as positive, neutral, and negative according to the 25^{th} and 75^{th} percentiles of each indicator’s time series.

8.1 Abundance Indicators

Stock abundance indicators include the YOY settlement, recruit abundance, exploitable abundance, and spawning abundance indices evaluated in the previous section. Indicators are categorized as positive if above their 75^{th} percentile, neutral if between their 75^{th} and 25^{th} percentile, and negative if below their 25^{th} percentile.

8.2 Fishery Performance Indicators

Fishery performance indicators include landings, the number and proportion of pot/trap trips that landed Jonah crabs, and the number and proportion of active (i.e., reported catch during the year) lobster/crab permits that landed Jonah crab. NH harvesters are active in the IGOM and OGOM stocks, but trip and permit data are only available for this state since 2016. Trends and conditions were compared with and without NH data and were very similar, so NH data are excluded from these indicators to maintain the time series back to 2010.

Landings provide indicators of the biomass removed from the stock due to fishing, but, as discussed in Section 4.3, are affected by factors other than available biomass and are not interpreted as an indication of stock biomass. Low landings are not favorable for fishery performance and these indicators are categorized as positive if above their 75th percentile, neutral if between their 75th and 25th percentiles, and negative if below their 25th percentile.

Trip and permit indicators are also affected by factors other than biomass that affect total landings (reduced lobster abundance/target switching, price changes). Due to these confounding factors and that these are presented as fishery performance indicators, these are interpreted similar to landings with lower levels, below their 25th percentile, interpreted as negative conditions due to lower access/participation in the fishery. Moderate levels between their 25th and 75th percentiles are considered neutral and higher levels are interpreted as positive conditions due to greater access/participation in the fishery. The lack of large changes observed in the proportion-based indicators for all stocks result in small interquartile ranges indicative of neutral conditions and conditions will be sensitive to relatively small changes.

A major caveat to the interpretation of these fishery performance indicators is that, at some point, participation in the fishery could result in more fishing pressure (i.e., exploitation) than the stocks can support. The relationship between participation and exploitation is unknown.

8.3 Results

8.3.1 IGOM

YOY settlement indicators in ME all declined in 2021 and were neutral (Table 17 and Figure 96). Indicators to the south of ME (NH and MA) were both positive in 2021. These indicators have the shortest time series but are unavailable during earlier years when low settlement was observed in ME and recent conditions likely are not inflated due to the short time series. Three-year averages are neutral for all surveys except ME 512, which is positive.

Post-settlement indicators generally agree on declines in abundance in recent years from time series highs in the mid-2010s but provide more of a mixed picture in terminal conditions across surveys (Table 21, Table 25, Table 29, and Figure 97-Figure 99). Three-year average conditions are positive across surveys and metrics for the NEFSC trawl survey, vary between positive (exploitable and spawning abundance in spring) and neutral (all metrics in fall and recruit abundance in spring) for the MA trawl survey, and are negative across surveys and metrics for the ME/NH trawl with only one exception (positive fall index of spawning abundance). The negative conditions observed by the ME/NH trawl survey are influenced by the start year of the survey. The survey began during the abundance pulse in the early 2000s and did not capture earlier years when indices observed by both the MA and NEFSC trawl surveys generally were at or near time series lows.

All fishery performance indicators are neutral (Figure 100-Figure 102). Proportional indicators indicate potential for fishery growth in this stock, with observed proportions being very low across the time series. This stock by far accounts for the highest number of trips and permits landing Jonah crabs, being an order of magnitude higher than OSNE indicators despite landings about five times lower than the OSNE stock.

8.3.2 OGOM

All settlement indicators are from IGOM, but, as seen with the data evaluation analyses, have similarities with exploitable abundance trends seen in OGOM and may be reflective of recruitment to this stock.

As with the IGOM stock, post-settlement indicators indicate declines in abundance in recent years from time series highs in the mid-2010s (Table 21, Table 25, Table 29, and Figure 103-Figure 105). Recruit abundance indicators declined to neutral conditions in both seasons, while exploitable abundance indicators remain in positive conditions in both seasons. The spring spawning abundance indicator declined to neutral while the fall indicator remains positive.

The proportion trips landings Jonah crab and both permit indicators are positive due to an upward trend at the end of the time series to the highest levels of the time series in 2021 (Figure 101 and Figure 102). The number of trips indicator is more variable during these years and neutral on average. As with the IGOM stock, proportional indicators are very low and indicate potential for fishery growth in this stock. Unlike the IGOM stock, trips and permits landings Jonah crabs through time have been the lowest observed across stocks. Landings are negative due to general decline during the time series (Table 7 and Figure 100).

8.3.3 ISNE

There are no reliable abundance indicators for the ISNE stock and abundance conditions are unknown.

The landings indicator shows an upward trend during the final three years and is neutral on average (Table 7 and Figure 100). Trip indicators and the number of permits landings Jonah crab indicator are neutral, while the proportion permits landing Jonah crab indicator is positive (Figure 101 and Figure 102). Proportional indicators indicate potential for fishery growth in this stock, but this growth may be constrained by available abundance in these more southerly, inshore waters relative to the GOM stocks.

8.3.4 OSNE

There are no settlement indicators for the OSNE stock and conditions are unknown.

Post-settlement indicators provide a mixed picture on conditions between seasons (Table 23, Table 27, Table 31, and Figure 106-Figure 108). Fall indicators generally show abundance increases to higher abundance from time series lows in the first half of the time series, while spring indicators are more variable without trend. Terminal spring indicators are neutral for all metrics, while fall indicators are positive for recruit and exploitable abundance. The fall spawning abundance indicator shows some decline to neutral conditions. It's important to note that encounter rates are considerably lower for spring indicators and the 25th percentile for the exploitable abundance indicator is actually zero due to several years when no Jonah crabs were encountered.

The landings indicator shows a consistent downward trend since 2018, with the terminal three-year average being neutral and above the terminal year value which is negative (Table 7 and Figure 100). Total count and proportional indicators show opposing trends and conditions in the terminal three years, with counts of trips and permits trending down across the times series and ending in negative (trips) or just neutral (permits) conditions while proportions trend up across the time series ending in positive conditions (Figure 101 and Figure 102). This shows a declining fishery capacity that has increasingly utilized the Jonah crab resource and could indicate shifting targeting towards Jonah crab, increasing Jonah crab abundance, or a combination of both. Greater than half of trips and active permits land Jonah crab in this fishery, contributing to the highest magnitude of landings across stocks.

9 STOCK STATUS

Inference about stock abundance condition is based on the stock abundance indicators. According to these indicators, there have been declines in post-settlement abundance for the IGOM and OGOM stocks from time series highs in the mid-2010s, but conditions in the last three years of the time series are neutral or positive. The one exception is from the ME/NH Trawl survey, but this is due to the shorter time series of this survey not capturing historical lows in earlier years. Indicators for the OSNE stock also indicate neutral or positive post-settlement abundance conditions in the last three years of the time series. Indicators agree across these stocks that abundance has not been depleted to historical lows. There are no reliable abundance indicators for the ISNE stock and inference cannot be made about condition of this stock's abundance at this time.

YOY indicators generally indicate neutral conditions and do not indicate that recruitment in GOM stocks will decline to historical lows in the near future. Settlement conditions are unknown for SNE stocks.

Landings have steadily declined in the OSNE stock which is the primary stock with targeted/mixed effort for Jonah crab and the stock accounting for the vast majority of coastwide landings. This trend is believed to be influenced by factors other than available abundance but should continue to be monitored closely. There was not sufficient information to make statements about fishing mortality or exploitation with confidence and these population parameters remain major uncertainties.

10 RESEARCH RECOMMENDATIONS

The TC recommends updating the stock indicators in five years and evaluating any new information that may allow for advanced methods to provide management advice at that time. In the meantime, the TC provides the following recommendations to improve the information base for Jonah crab. The TC strongly encourages that any prospective researchers considering projects to address these recommendations reach out to the TC to ensure project results would be of most utility for future stock assessments.

High Priority

- Surveys to track abundance in SNE during all life stages (settlement, recruitment to legal size, exploitable abundance, and spawning abundance) are essential for future stock assessments and potential management advice. Current surveys are not adequate for these goals.
- Research should be conducted to provide a more comprehensive understanding of recruitment dynamics, including tracking of spatio-temporal settlement dynamics and the source of recruitment to offshore SNE, to inform development of Jonah crab settlement surveys.
- Appropriate survey methodologies need to be researched to track abundance of Jonah crab. Trawl surveys are available, but encounter rates are very low and detection ability is uncertain. Behavioral interactions with survey gear need to be better understood. Video surveys are recommended to examine these interactions. Video surveys could also be used for snapshot estimates of total stock size (i.e., swept-area biomass) that could be used to gain a better understanding on exploitation levels.
- Female migration pathways/seasonality and distribution needs to be researched. Anecdotal information suggests seasonal aggregations in inshore areas, but research would help to understand these mechanisms and inform connectivity. Ventless trap surveys (state-run and windfarm impact) offer a potential data set to explore interannual variability in distribution
- Information on larval duration in the field, mortality, and dispersal are needed to better understand possible connectivity. Spawning female distribution information would supplement efforts to model these processes. Evaluate larval data sets for species identification and to explore abundance, seasonality, and interannual variability.
- Inter-molt duration of adult crabs is currently unknown and growth increment data for mature crabs is limited. There are no growth data from offshore SNE where the bulk of the fishery occurs and differences in growth between regions are unknown. These data will be necessary for advanced modeling methods.
- Research growth mechanisms for both sexes (e.g., potential for terminal molt, lack of growth associated with molting, high natural mortality for adults) to explain lack of exploitation signal (i.e., lack of size structure change) in available data sets. Dissection of larger crabs with old shells and evaluation of shell formation underneath external shell might help inform this research.
- Increase and improve the consistency of fisheries-dependent monitoring and biosampling. Sampling intensity by statistical area should be based on landings.

- Continue to improve accuracy of commercial reporting to improve quantification of effort in the directed and mixed-crustacean fisheries. Evaluate new spatial data (i.e., vessel tracking data) to better understand spatial dynamics of the fishery.
- Study the effect of temperature on Jonah crab behavior/activity.
- Little is known about ecosystem/environmental drivers of Jonah crab population dynamics. Studies should be done to identify and understand these drivers.
- Determine how to interpret fisheries-dependent data considering interactions between fishery response to abundance, economic drivers, and lobster fishery dynamics.

Moderate Priority

- Explore historical data sets from the scallop dredge survey and video surveys like HabCam to understand habitat use/suitability, abundance, distribution, and to inform potential covariates for catchability effects.
- Food habits data should be analyzed, with an emphasis on offshore areas, to better understand predation of Jonah crab and as a potential measure of abundance and distribution.
- Evaluate evidence for a defined stock-recruit relationship or lack thereof. If lack of evidence, identify recruitment drivers and mechanisms of population abundance change.

Low Priority

- Information should be collected to help delineate stock boundaries and understand possible connectivity, with an emphasis on the GOM/SNE boundary.
- Reproductive studies pertaining to male-female spawning size ratios, the possibility of successful spawning by physiologically mature but morphometrically immature male crabs, and potential for sperm limitations should be conducted.
- If improved abundance data with higher encounter rates becomes available, cohort tracking analyses should be conducted across and within surveys to better understand if surveys are tracking true abundance signals and provide information on growth, mortality, and other demographic factors.
- The development of aging methods or determination of the mechanism responsible for the suspected annuli formation found in the gastric mill should be explored.

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12 TABLES

Table 1. **Estimates of female Jonah crab size-at-maturity (SM50) by study, region, and type of maturity (morphometric and gonadal).**

Study	Year	Region	Morphometric	Gonadal
This Assessment	2023	GOM offshore	98	
Perry et al.	2017	GOM offshore		98
This Assessment	2023	GOM inshore	94	
This Assessment	2023	Georges Bank	97	
Perry et al.	2017	Georges Bank		93
This Assessment	2023	SNE offshore	94	
Perry et al.	2017	SNE offshore		89
This Assessment	2023	SNE inshore	95	
Perry et al.	2017	SNE inshore		86
Ordzie and Satchwill	1983	SNE inshore	40-50	40-50
This Assessment	2023	Mid Atlantic	90	
Carpenter	1978	Mid Atlantic	85	
Olsen and Stevens	2020	Mid Atlantic	88	

Table 2. **Estimates of male Jonah crab size-at-maturity (SM50) by study, region, and type of maturity (morphometric and gonadal).**

Study	Year	Region	Morphometric	Gonadal
Moriyasu et al.	2002	Nova Scotia	128	69
This Assessment	2023	GOM offshore	121	
This Assessment	2023	GOM inshore	110	
This Assessment	2023	Georges Bank	120	
This Assessment	2023	SNE offshore	119	
Lawrence et al.	2021	SNE Inshore	106	
This Assessment	2023	SNE inshore	103	
Ordzie and Satchwill	1983	SNE inshore		50-60
This Assessment	2023	Mid Atlantic	102	
Carpenter	1978	Mid Atlantic	90-100	
Olsen and Stevens	2020	Mid Atlantic	98	

Table 3. **Size-at-maturity (SM50), Boostrapped SM50, Confidence Intervals, and sample sizes by data source. The SM50 estimate for Gulf of Maine Offshore Females (*) was unstable and highly sensitive to the range of "Unknowns" assumed.**

				95% CI		Sample Size and Data Source		
Sex	Region		SM50_Boot	Lower	Upper	MassDMF	NEFSC	UMES
Fem	GOM_OFF	97.5*	97.7	94.6	99.7	161	810	0
Fem	GOM_IN	93.6	94.5	89.5	100.7	170	125	0
Fem	GB	97.3	95.7	88.6	100.2	177	340	0
Fem	SNE_OFF	93.6	93.6	87.4	97.8	250	132	0
Fem	SNE_IN	94.7	100.7	89.2	104.9	237	40	0
Fem	MAB	89.6	91.5	88.0	102.8	0	168	798
Mal	GOM_OFF	121.3	122.6	120.8	124.3	275	1222	0
Mal	GOM_IN	109.7	110.6	104.6	115.3	209	124	0
Mal	GB	120.1	120.0	117.7	122.1	251	382	0
Mal	SNE_OFF	119.4	119.1	117.0	121.3	304	165	0
Mal	SNE_IN	103.2	105.0	101.5	109.3	407	44	0
Mal	MAB	101.7	101.6	99.1	104.3	0	326	564

Table 4. **Proportion of trips landing Jonah crab using a Massachusetts lobster/edible crab trap permit by year and region.**

Year	IGOM	OGOM	ISNE	OSNE
2010	0.02	0.04	0.07	0.72
2011	0.02	0.04	0.06	0.79
2012	0.03	0.03	0.05	0.76
2013	0.04	0.03	0.11	0.82
2014	0.03	0.04	0.15	0.77
2015	0.03	0.06	0.07	0.71
2016	0.04	0.05	0.09	0.79
2017	0.06	0.05	0.11	0.81
2018	0.05	0.03	0.08	0.77
2019	0.05	0.03	0.04	0.73
2020	0.04	0.07	0.03	0.74
2021	0.05	0.07	0.06	0.83

Table 5. **Annual ex-vessel price per pound for whole body Jonah crab landings by state. Asterisks indicate confidential data.**

Year	ME	NH	MA	RI	CT	Mean	MA/RI Mean
2010	$0.34	*	$0.56	$0.52	$0.60	$0.51	$0.54
2011	$0.35	*	$0.68	$0.57	$0.54	$0.54	$0.62
2012	$0.39	*	$0.74	$0.68	$0.65	$0.61	$0.71
2013	$0.49	$0.69	$0.90	$0.72	$0.71	$0.70	$0.81
2014	$0.30	$0.71	$0.78	$0.75	$0.75	$0.66	$0.76
2015	$0.51	*	$0.76	$0.69	$0.84	$0.70	$0.72
2016	$0.51	$0.70	$0.77	$0.77	$0.61	$0.67	$0.77
2017	$0.54	$0.72	$0.98	$0.96	$0.54	$0.75	$0.97
2018	$0.59	$0.66	$0.94	$0.92	$0.81	$0.79	$0.93
2019	$0.55	$0.60	$0.84	$0.80	$0.98	$0.75	$0.82
2020	$0.54	$0.63	$0.82	$0.83	$0.97	$0.76	$0.82
2021	$0.77	$0.76	$1.20	$1.20	$1.00	$0.99	$1.20

Table 6. **Jonah crab stock assignments to statistical area-specific landings for statistical areas that overlap multiple stocks. Blanks indicate no landings in the statistical area and state combination. Proportions are the proportion of landings from the statistical area relative to coastwide landings from all known statistical areas since 2010.**

Statistical Area	ME	NH	MA	RI	CT	NY	NJ	DE-NC	Proportion
510	IGOM								0.0049
511	IGOM								0.0613
512	IGOM			OGOM		OGOM			0.0735
513	IGOM		IGOM	IGOM		IGOM	IGOM		0.0048
515	OGOM		OGOM	OGOM					0.0112
521			OGOM	OGOM			OGOM		0.0019
526			OSNE	OSNE		OSNE			0.1166
537 (for states other than MA and RI)		OSNE			Unknown	OSNE	Unknown	OSNE	0.0129
538	ISNE		ISNE	ISNE					0.0004
539	ISNE		ISNE	ISNE	ISNE	ISNE		ISNE	0.0104
611	ISNE			ISNE	ISNE	ISNE		ISNE	0.0002

Table 7. **Stock-specific Jonah crab landings and landings (total and proportion of coastwide total) that could not be assigned to a stock.**

Year	IGOM	OGOM	ISNE	OSNE	Unknown	Unknown Proportion
2010	3,296,917	495,594	251,663	10,908,252	13,656	0.0009
2011	2,573,190	431,245	292,623	8,784,679	2,336	0.0002
2012	1,805,257	301,728	306,694	11,479,530	8,360	0.0006
2013	1,542,279	431,196	716,553	14,260,261	21,538	0.0013
2014	1,981,181	560,151	400,057	16,648,366	72,590	0.0037
2015	1,890,398	422,987	387,902	13,043,052	70,085	0.0044
2016	2,168,085	393,607	460,474	14,210,751	327,863	0.0187
2017	3,397,455	233,020	912,620	14,619,539	524,715	0.0267
2018	3,673,281	83,833	782,416	17,611,400	615,568	0.0270
2019	3,164,910	55,882	284,094	13,989,900	167,475	0.0095
2020	2,038,465	187,250	299,548	11,642,200	481,767	0.0329
2021	2,944,330	205,669	428,611	8,626,968	41,035	0.0034
2019-2021 average	2,715,902	149,600	337,418	11,419,689	230,092	0.0152
25th Percentile	1,958,485	201,065	297,817	11,336,711	19,568	0.0012
75th Percentile	3,197,912	431,208	524,494	14,350,081	366,339	0.0207

Table 8. **Number of Jonah crab sea sampling trips. Colors are scaled to the minimum and maximum number of trips, with green indicating the greatest sampling intensity and red indicating the lowest sampling intensity.**

Year	IGOM				OGOM								ISNE		OSNE										
	511	512	513	514	464	465	511	512	515	521	522	561	537	539	525	526	537	562	613	615	616	622	623	626	627
2003	1	9																							
2004		2	1																						
2005				1												1									
......																									
2014													17	60	18	2	7	7	1		3				
2015					1	2		2				4	17	80	20	20	21	9	3		1			1	
2016				4	9	2		4	3			13	18	113	22	5	15	7	1					1	
2017	1	2	3	6	1	1		4	2			15	16	113	17	7	5	3	21			5			
2018	6	1	6	13	10	5		7	1			8	10	97	8	25	23	8			13	4		2	
2019	1	7	8		6	12		6	9			23	9	98	3	22	40	2			11	3	1	3	1
2020	1	1	9		9	7	1	6	1		3	16	13	90	21	30	25	2		1	16	1		1	
2021			4	6	12	3	3	5	1	1		15	9	83	15	12	8	2			2				

Table 9. **Number of Jonah crab port sampling trips. Colors are scaled to the minimum and maximum number of trips, with green indicating the greatest sampling intensity and red indicating the lowest sampling intensity.**

Year	IGOM		OGOM		ISNE		OSNE						
	513	514	521	561	537	611	525	526	537	562	612	613	616
2013					2								
2014					2					2			
2015		3						4	6				
2016							1	8	8	1	1		
2017	2		1	2			2	5	10			5	
2018	6		1		1		3	3	7	1			
2019	4					1	4	5	2	1			
2020	4	5					8	4	1				1
2021	5			1				4		1			

Table 10. **Mann-Kendall test results for mean size of males in the overall catch from sea sampling data.**

Stock	Statistical Area	Quarter	n years	tau	p-value
OGOM	561	2	5	-0.40	0.462
OGOM	561	4	6	-0.47	0.260
OGOM	464	1	5	-0.60	0.221
OGOM	464	3	5	0.20	0.806
ISNE	537	2	5	-0.20	0.806
ISNE	537	3	7	-0.62	0.072
ISNE	537	4	6	-0.33	0.452
ISNE	539	1	8	0.21	0.536
ISNE	539	2	8	0.07	0.902
ISNE	539	3	8	-0.29	0.386
ISNE	539	4	8	-0.29	0.386
OSNE	525	1	5	0.00	1.000
OSNE	525	2	7	-0.62	0.072
OSNE	525	3	7	-0.24	0.548
OSNE	525	4	5	-0.40	0.462
OSNE	526	2	8	-0.29	0.386
OSNE	526	3	7	0.62	0.072
OSNE	526	4	5	0.20	0.806
OSNE	537	1	6	0.20	0.707
OSNE	537	3	8	-0.21	0.536

Table 11. **Mann-Kendall test results for mean size of the largest 5% males in the overall catch from sea sampling data. Bold and italicized font indicates a significant trend.**

Stock	Statistical Area	Quarter	n years	tau	p-value
OGOM	561	2	5	0.00	1.000
OGOM	561	4	6	-0.20	0.707
ISNE	537	3	7	-0.52	0.133
ISNE	537	4	5	-0.20	0.806
ISNE	539	1	8	0.57	0.063
ISNE	539	2	8	0.29	0.386
ISNE	539	3	8	-0.29	0.386
ISNE	539	4	8	***0.64***	***0.035***
OSNE	525	2	6	-0.07	1.000
OSNE	525	3	6	-0.07	1.000
OSNE	525	4	5	-0.20	0.806
OSNE	526	2	7	0.14	0.764
OSNE	526	3	6	0.60	0.133
OSNE	526	4	5	0.60	0.221
OSNE	537	1	5	0.20	0.806
OSNE	537	3	6	0.20	0.707

Table 12. **CFRF VTS summary for exploitable-sized (>121mm CW) male crabs.**

Year	Inshore SNE					Offshore SNE				
	n Sessions	Proportio n Positive	n Crabs	Mean CPUE	CPUE CV	n Sessions	Proportio n Positive	n Crabs	Mean CPUE	CPUE CV
2015	42	0.95	268	7.08	0.40	57	0.89	527	9.97	0.29
2016	49	0.84	338	7.52	0.36	45	0.93	512	12.16	0.24
2017	29	1.00	251	8.82	0.30	72	0.99	1,724	17.81	0.17
2018	30	0.97	214	9.49	0.27	97	0.98	1,882	16.63	0.19
2019	39	0.97	264	7.63	0.34	34	1.00	549	15.45	0.21
2020	25	0.84	175	6.33	0.41	35	0.97	589	12.14	0.29
2021	31	0.84	190	6.71	0.39	NA	NA	NA	NA	NA

Table 13. **Directed Residual Model CPUE (catch per trip) predictions for Rhode Island Jonah crab harvest in inshore and offshore SNE in February. Predictions are in log space.**

	Inshore SNE			Offshore SNE		
Year	Number Trips	Predicted CPUE	Prediction S.E.	Number Trips	Predicted CPUE	Prediction S.E.
2007	51	8.17	0.13	525	9.65	0.06
2008	70	7.85	0.11	591	9.72	0.05
2009	89	8.10	0.10	572	9.61	0.05
2010	81	8.03	0.11	493	9.54	0.06
2011	67	7.75	0.12	414	9.52	0.06
2012	103	8.08	0.10	419	9.65	0.06
2013	328	8.02	0.07	373	9.76	0.06
2014	219	7.70	0.08	420	9.78	0.06
2015	208	7.54	0.08	386	9.80	0.06
2016	153	7.50	0.09	369	9.78	0.06
2017	212	7.71	0.08	372	9.69	0.06
2018	213	7.82	0.08	411	9.66	0.06
2019	96	7.62	0.10	375	9.84	0.06
2020	70	7.73	0.11	301	9.75	0.06
2021	101	7.32	0.10	266	9.55	0.07

Table 14. **Model summary table for DRM fitted to Rhode Island trip-level landings data.**

```
Call:
glm(formula = lCRJ ~ Year * Stock + Stock * P1 + Month * P1,
    data = alldat)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-3.2666  -0.5437   0.0224   0.5689   2.7492

Coefficients:
                Estimate Std. Error t value Pr(>|t|)
(Intercept)      6.65350    0.14977  44.425  < 2e-16 ***
Year2008        -0.32670    0.15920  -2.052 0.040187 *
Year2009        -0.07114    0.15188  -0.468 0.639523
Year2010        -0.14206    0.15456  -0.919 0.358074
Year2011        -0.42222    0.16075  -2.627 0.008642 **
Year2012        -0.09723    0.14832  -0.656 0.512148
Year2013        -0.15305    0.13020  -1.176 0.239822
Year2014        -0.47852    0.13460  -3.555 0.000380 ***
Year2015        -0.62914    0.13519  -4.654 3.31e-06 ***
Year2016        -0.66976    0.13977  -4.792 1.68e-06 ***
Year2017        -0.46667    0.13475  -3.463 0.000536 ***
Year2018        -0.35018    0.13472  -2.599 0.009357 **
Year2019        -0.55310    0.14988  -3.690 0.000225 ***
Year2020        -0.44303    0.15910  -2.785 0.005372 **
Year2021        -0.85532    0.14915  -5.735 1.01e-08 ***
Stock1           0.90913    0.12805   7.100 1.35e-12 ***
P1               1.46652    0.10128  14.480  < 2e-16 ***
Month10          0.18152    0.09364   1.938 0.052597 .
Month11          0.36240    0.09556   3.793 0.000150 ***
Month12          0.26642    0.10667   2.498 0.012521 *
Month2          -0.01692    0.17157  -0.099 0.921419
Month3           0.16735    0.14770   1.133 0.257217
Month4           0.14593    0.11497   1.269 0.204392
Month5           0.10440    0.09930   1.051 0.293086
Month6           0.09948    0.09486   1.049 0.294355
Month7          -0.07951    0.09397  -0.846 0.397537
Month8          -0.09166    0.09301  -0.985 0.324443
Month9           0.07784    0.09280   0.839 0.401599
Year2008:Stock1  0.39636    0.16739   2.368 0.017910 *
Year2009:Stock1  0.02806    0.16056   0.175 0.861294
Year2010:Stock1  0.03693    0.16379   0.225 0.821606
Year2011:Stock1  0.29547    0.17042   1.734 0.083001 .
Year2012:Stock1  0.09707    0.15877   0.611 0.540948
Year2013:Stock1  0.26762    0.14272   1.875 0.060805 .
Year2014:Stock1  0.61212    0.14599   4.193 2.78e-05 ***
Year2015:Stock1  0.78430    0.14708   5.332 9.95e-08 ***
Year2016:Stock1  0.80358    0.15168   5.298 1.20e-07 ***
Year2017:Stock1  0.50773    0.14703   3.453 0.000556 ***
Year2018:Stock1  0.36928    0.14644   2.522 0.011694 *
Year2019:Stock1  0.74128    0.16102   4.604 4.21e-06 ***
Year2020:Stock1  0.54627    0.17096   3.195 0.001402 **
Year2021:Stock1  0.75229    0.16279   4.621 3.87e-06 ***
Stock1:P1        0.56470    0.04667  12.101  < 2e-16 ***
P1:Month10      -0.84037    0.11452  -7.338 2.36e-13 ***
P1:Month11      -0.92095    0.11344  -8.118 5.40e-16 ***
P1:Month12      -0.61971    0.11926  -5.196 2.08e-07 ***
P1:Month2        0.07140    0.17994   0.397 0.691548
P1:Month3       -0.35201    0.15764  -2.233 0.025574 *
P1:Month4       -0.60371    0.12992  -4.647 3.42e-06 ***
P1:Month5       -0.70646    0.11474  -6.157 7.77e-10 ***
P1:Month6       -0.90512    0.11392  -7.945 2.20e-15 ***
P1:Month7       -0.86350    0.11732  -7.360 2.01e-13 ***
P1:Month8       -0.98593    0.11666  -8.451  < 2e-16 ***
P1:Month9       -0.90097    0.11323  -7.957 2.00e-15 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for gaussian family taken to be 0.74397)

    Null deviance: 16147.0  on 8347  degrees of freedom
Residual deviance:  6170.5  on 8294  degrees of freedom
AIC: 21277

Number of Fisher Scoring iterations: 2
```

Table 15. **Surveys encountering settling Jonah crabs considered for the stock assessment, but lacking utility for tracking abundance metrics of interest. Reasons identified for limitations of utility were lack of Cancer crab species identification (SID) and inadequate catch rates/inefficient catchability (CR).**

Survey	***Time Series***	***CWs***	***Limitations***	***Notes***
Normandeau Plankton Survey	1982-present	N	SID	
RIDEM DMF Settlement Survey	1990-present	Y	CR	
UMaine Deepwater Collectors	2007-present	Y	CR	Sampling discontinued from 2009-2015

Table 16. **Surveys encountering post-settlement Jonah crabs considered for the stock assessment, but lacking utility for tracking abundance metrics of interest. Data fields collected after the start year when Jonah crab counts were added to survey protocols are included in parentheses. Reasons identified for limitations of utility were lack of spatial overlap between the survey domain and Jonah crab population and/or small spatial domain (SS), short and/or discontinuous time series (TS), inadequate catch rates/inefficient catchability (CR), and lack of biological data (BD).**

Survey	***Time Series***	***CWs***	***Sex***	***Limitations***	***Notes***
ME Urchin Survey	2004-present	Y	Y	SS	
ME VTS	2016*-present	Y (2016)	Y (2016)	SS, CR	Counts collected prior to 2016, but ID issues render counts unreliable
NH VTS	2009-present	Y (2015)	Y (2015)	SS, CR	
Normandeau VTS	1982-present	Y	Y	SS, CR	
MA VTS	2007-present	Y	Y (2015)	SS, CR	
SMAST VTS	2019	Y	Y	SS, TS, CR	
CFRF SNE Cooperative VTS	2014-2018	Y	Y	SS, TS, CR	
RI VTS	2006-present	Y	Y	SS, CR	
NY VTS	2006-2010	N	N	SS, TS, CR, BD	
NJ Fixed Gear Survey	2016-present	Y	Y	SS, CR	
DE Structure Oriented Survey	2018-present	Y	Y (2020)	SS, TS, CR, BD	
CFRF-South Fork Wind Farm Cox's Ledge/RI Sound Trawl	2020-present	Y	Y	SS, TS	

Coonamessett Farm Foundation Scallop Dredge	2010-present	N	N	TS, BD	Data collection ceased from 2016-August 2021 and only resumed at limited stations
RI Trawl Survey	2015-present	Y	Y	CR	
URI GSO Trawl Survey	2016-present	Y	Y	CR	
CT Trawl Survey	1979-present	Y	Y	SS, CR	
NY Trawl Survey	2017-present	Y	Y	SS, TS	
NJ DFW Ocean Trawl Survey	1989-present	Y	Y (2021)	SS, BD	
NEAMAP Trawl Survey	2007-present	Y	Y	CR	
Northern Shrimp Trawl Survey	1984-present	N	Y	BD	

Table 17. **Spearman correlation results for seasonal catch rate and temperature anomalies using a two-year running average as the underlying trend in catch rates to calculate anomalies.**

Season and Areas	Spearman's Rho	p-value
Spring 521, 522, 561	0.302	0.11
Fall 521, 522, 561	0.089	0.64
Spring 537, 526, 525, 562	-0.091	0.64
Fall 537, 526, 525, 562	-0.047	0.81

Table 18. **Spearman correlation results for seasonal catch rate and temperature anomalies using a LOESS smoother fit as the underlying trend in catch rates to calculate anomalies.**

Season and Areas	Spearman's Rho	p-value
Spring 521, 522, 561	0.407	0.03
Fall 521, 522, 561	-0.119	0.53
Spring 537, 526, 525, 562	-0.044	0.82
Fall 537, 526, 525, 562	-0.034	0.86

Table 19. **Jonah crab settlement indices in GOM areas.**

Year	ME 511	ME 512	ME 513	NH 513	MA 514
1989			0.000		
1990			0.000		
1991			0.000		
1992			0.000		
1993			0.000		
1994			0.090		
1995			0.000		
1996			0.110		
1997			0.000		
1998			0.110		
1999			1.540		
2000		0.039	1.833		
2001	0.040	0.223	0.361		
2002	0.000	0.000	0.709		
2003	0.000	0.000	0.485		
2004	0.000	0.057	0.368		
2005	0.000	0.000	0.167		
2006	0.000	0.000	0.767		
2007	0.000	0.031	0.817		
2008	0.030	0.016	0.400		
2009	0.000	0.021	1.230	0.222	
2010	0.030	0.011	0.827	0.722	
2011	0.000	0.131	1.217	0.667	
2012	1.500	1.571	3.188	4.333	
2013	0.350	0.180	0.710		
2014	0.350	0.303	0.850	0.222	
2015	0.040	0.334	1.725	0.056	
2016	0.600	1.526	2.643	0.444	1.817
2017	0.470	0.450	2.300	2.389	1.033
2018	1.140	1.154	3.096	4.111	8.967
2019	0.380	0.368	0.676	2.167	1.617
2020	0.380	0.615	2.074	4.667	1.583
2021	0.057	0.119	0.692	4.222	2.417
2019-2021 average	***0.272***	***0.367***	***1.147***	***3.685***	***1.872***
25th Percentile	***0.000***	***0.017***	***0.110***	***0.389***	***1.592***
75th Percentile	***0.380***	***0.359***	***1.230***	***4.139***	***2.267***

Table 20. **Coefficient of variation for Jonah crab settlement indices in GOM areas.**

Year	ME 511	ME 512	ME 513	NH 513	MA 514
1989			0.000		
1990			0.000		
1991			0.000		
1992			0.000		
1993			0.000		
1994			0.556		
1995			0.000		
1996			1.000		
1997			0.000		
1998			0.455		
1999			0.377		
2000		1.341	0.244		
2001	1.000	0.563	0.530		
2002	0.000	0.000	0.233		
2003	0.000	0.000	0.396		
2004	0.000	1.276	0.484		
2005	0.000	0.000	1.270		
2006	0.000	0.000	0.244		
2007	0.000	2.089	0.234		
2008	1.000	2.880	0.851		
2009	0.000	1.929	0.242	NA	
2010	1.000	2.824	0.323	NA	
2011	0.000	0.663	0.210	NA	
2012	0.200	0.120	0.144	NA	
2013	0.371	0.472	0.245		
2014	0.743	0.515	0.164	NA	
2015	1.000	0.533	0.163	NA	
2016	0.450	0.138	0.089	NA	0.148
2017	0.277	0.222	0.178	NA	0.171
2018	0.494	0.221	0.211	NA	0.082
2019	0.500	0.164	0.203	NA	0.117
2020	0.368	0.316	0.146	NA	0.195
2021	1.000	0.469	0.246	NA	0.116

Table 21. **Jonah crab recruit abundance indices in GOM areas.**

Year	IGOM	IGOM	IGOM	IGOM	IGOM	IGOM	OGOM	OGOM	GOM	GOM
	MA Trawl Spring	MA Trawl Fall	ME/NH Trawl Spring	ME/NH Trawl Fall	NEFSC Trawl Spring	NEFSC Trawl Fall	NEFSC Trawl Spring	NEFSC Trawl Fall	NEFSC Trawl Spring	NEFSC Trawl Fall
1980						0.149		0.000		0.050
1981					0.065		0.029		0.041	
1982	0.410	0.060			0.033	0.032	0.075	0.025	0.050	0.026
1983	0.030	0.440			0.000	0.045	0.000	0.032	0.000	0.037
1984	0.010	0.150			0.034	0.000	0.000	0.006	0.013	0.004
1985	0.020	0.410			0.000		0.000		0.000	
1986	0.020	0.080			0.000		0.000		0.000	
1987	0.070	0.290				0.000		0.000		0.000
1988	0.020	0.220			0.183		0.000		0.054	
1989	0.090	0.000			0.017	0.000	0.000	0.032	0.016	0.020
1990	0.000	0.040			0.000	0.000	0.000	0.000	0.000	0.000
1991	0.000	0.100			0.000	0.000	0.013	0.005	0.008	0.003
1992	0.020	0.120			0.000	0.024	0.000	0.072	0.000	0.062
1993	0.080	0.030			0.000	0.100	0.009	0.000	0.006	0.029
1994	0.040	0.040			0.189	0.026	0.000	0.041	0.058	0.035
1995	0.020	0.920			0.000	0.076	0.127	0.072	0.091	0.077
1996	0.060	0.050			0.016	0.044	0.000	0.135	0.006	0.114
1997	0.000	0.030			0.045	0.026	0.036	0.000	0.042	0.009
1998	0.060	0.000			0.158	0.060	0.047	0.035	0.082	0.045
1999	0.000	0.440			0.078	0.382	0.080	0.086	0.077	0.178
2000	0.140	0.760			0.490	0.160	0.033	0.203	0.202	0.189
2001	0.270	0.260			0.216	1.593	0.186	0.458	0.206	0.859
2002	0.120	0.690			0.454	0.264	0.232	0.319	0.315	0.297
2003	0.020	0.770			0.123	0.256	0.104	0.310	0.116	0.291
2004	0.070	0.490	1.588	1.810	0.009	0.307	0.055	0.204	0.040	0.245
2005	0.100	0.070	2.580	0.782	0.053	0.616	0.061	0.029	0.057	0.198
2006	0.040	0.360	2.610	0.981	0.011	0.127	0.040	0.009	0.029	0.051
2007	0.010	0.260	0.805	1.562	0.032	0.064	0.062	0.004	0.047	0.025
2008	0.030	0.850	0.779	1.325	0.009	0.164	0.000	0.033	0.003	0.074
2009	0.120	0.230	0.574	0.286	0.210	0.152	0.079	0.053	0.128	0.079
2010	0.000	0.560	0.305	0.308	0.178	0.038	0.142	0.230	0.155	0.160
2011	0.060	0.790	0.449	0.417	0.451	0.022	0.187	0.041	0.241	0.029
2012	0.020	0.430	0.268	0.290	0.207	0.116	0.056	0.045	0.113	0.070
2013	0.040	0.160	0.203	0.417	0.376	0.283	0.532	0.000	0.481	0.098
2014	0.000	0.350	0.578	0.341	2.266	0.795	1.894	0.385	2.123	0.516
2015	0.400	2.710	0.566	5.429	0.356	0.683	0.538	0.784	0.483	0.724
2016	0.850	0.770	2.437	3.017	1.290	0.443	1.790	0.395	1.548	0.392
2017	0.150	1.210	0.491	0.616	0.825		0.484		0.596	
2018	0.160	0.910	0.304	0.482	0.592	0.064	0.146	0.050	0.270	0.051
2019	0.040	0.040	0.237	0.343	0.187	0.377	0.056	0.081	0.115	0.216
2020				0.177						
2021	0.110	0.680	0.165	0.147	0.619	0.173	0.069	0.070	0.217	0.109
2019-2021 average	***0.075***	***0.360***	***0.201***	***0.222***	***0.403***	***0.275***	***0.062***	***0.075***	***0.166***	***0.162***
25th Percentile	***0.020***	***0.075***	***0.304***	***0.316***	***0.010***	***0.030***	***0.000***	***0.008***	***0.014***	***0.029***
75th Percentile	***0.105***	***0.685***	***0.805***	***1.239***	***0.286***	***0.269***	***0.134***	***0.152***	***0.204***	***0.191***

Table 22. **Coefficient of variation for Jonah crab recruit abundance indices in GOM areas.**

Year	IGOM MA Trawl Spring	IGOM MA Trawl Fall	IGOM ME/NH Trawl Spring	IGOM ME/NH Trawl Fall	IGOM NEFSC Trawl Spring	IGOM NEFSC Trawl Fall	OGOM NEFSC Trawl Spring	OGOM NEFSC Trawl Fall	GOM NEFSC Trawl Spring	GOM NEFSC Trawl Fall
1980						0.658		Inf		0.658
1981					0.604		0.464		0.372	
1982	0.670	0.760			1.000	0.777	1.000	0.707	0.799	0.534
1983	1.000	0.260			Inf	0.604		1.000	Inf	0.597
1984	1.000	0.610			0.938	Inf	Inf	1.000	1.005	1.000
1985	1.000	0.470			Inf		Inf		Inf	
1986	1.000	0.500			Inf		Inf		Inf	
1987	0.710	0.460				Inf		Inf		Inf
1988	1.000	0.250			0.893		Inf		0.883	
1989	0.750				1.000	Inf	Inf	1.000	1.000	1.000
1990		0.750			Inf	Inf	Inf	Inf	Inf	Inf
1991		0.600			Inf	Inf	1.000	1.000	1.000	1.000
1992	1.000	1.000			Inf	1.211	Inf	1.000	Inf	0.905
1993	0.590	0.710			Inf	1.000	1.000	Inf	1.000	1.000
1994	0.720	0.710			1.000	1.000	Inf	0.741	1.000	0.610
1995	1.000	0.390			Inf	0.769	0.412	0.713	0.420	0.553
1996	0.520	0.730			1.211	0.779	Inf	0.605	1.382	0.550
1997		1.000			0.612	1.000	1.000	Inf	0.699	1.000
1998	0.580				0.382	0.672	0.583	1.000	0.346	0.602
1999		0.380			0.791	0.581	0.618	0.889	0.487	0.474
2000	0.550	0.330			0.623	0.431	0.811	0.440	0.571	0.328
2001	0.400	0.290			0.417	0.194	0.426	0.357	0.318	0.178
2002	0.330	0.510			0.291	0.420	0.443	0.342	0.258	0.270
2003	1.000	0.240			1.000	0.473	0.436	0.346	0.481	0.275
2004	0.610	0.420	0.479	0.265	1.000	0.972	0.725	0.545	0.665	0.530
2005	0.480	0.570	0.294	0.354	1.000	0.757	0.719	0.892	0.584	0.717
2006	0.710	0.400	0.471	0.666	1.211	0.546	1.467	1.000	1.223	0.517
2007	1.000	0.360	0.385	0.291	1.000	0.541	0.658	1.000	0.570	0.497
2008	0.580	0.330	0.325	0.270	1.000	0.523	Inf	0.601	1.000	0.428
2009	0.470	0.460	0.411	0.569	0.359	0.528	0.467	0.711	0.286	0.424
2010		0.190	0.527	0.554	0.507	0.670	0.865	0.628	0.540	0.582
2011	0.580	0.310	0.533	0.539	0.562	0.584	0.621	0.801	0.385	0.599
2012	1.000	0.250	0.569	0.437	0.329	0.571	0.584	0.708	0.295	0.444
2013	1.000	0.420	0.604	0.620	0.541	0.345	0.464	Inf	0.406	0.355
2014		0.340	0.684	0.539	0.290	0.218	0.209	0.299	0.174	0.198
2015	0.290	0.430	0.487	0.545	0.495	0.251	0.266	0.371	0.219	0.235
2016	0.210	0.270	0.340	0.340	0.253	0.348	0.347	0.425	0.242	0.307
2017	0.400	0.260	0.443	0.392	0.318		0.248		0.204	
2018	0.400	0.320	0.662	0.516	0.611	0.614	0.562	0.707	0.413	0.487
2019	0.500	1.000	0.879	0.498	0.641	0.300	0.722	0.554	0.465	0.279
2020				0.721						
2021	0.720	0.710	0.672	0.794	0.565	0.488	0.784	0.528	0.333	0.361

Table 23. **Jonah crab recruit abundance indices in SNE areas and coastwide.**

Year	ISNE	ISNE	OSNE	OSNE	Coastwide	Coastwide
	NEFSC Trawl Spring	NEFSC Trawl Fall	NEFSC Trawl Spring	NEFSC Trawl Fall	NEFSC Trawl Spring	NEFSC Trawl Fall
1980		0.000		0.005		0.019
1981	0.000		0.064		0.050	
1982	0.125	0.000	0.091	0.026	0.061	0.021
1983	0.000	0.000	0.000	0.059	0.000	0.044
1984	0.000	0.000	0.000	0.007	0.004	0.005
1985	0.000		0.006		0.007	
1986	0.000		0.010		0.005	
1987		0.100		0.043		0.026
1988	0.000		0.047		0.043	
1989	0.000	0.000	0.000	0.060	0.007	0.038
1990	0.000	0.000	0.000	0.000	0.000	0.000
1991	0.000	0.000	0.000	0.048	0.002	0.025
1992	0.449	0.000	0.000	0.058	0.023	0.043
1993	0.000	0.000	0.000	0.007	0.002	0.013
1994	0.000	0.000	0.000	0.002	0.018	0.012
1995	0.000	0.000	0.002	0.000	0.032	0.029
1996	0.000	0.501	0.001	0.000	0.004	0.052
1997	0.000	0.288	0.001	0.000	0.012	0.008
1998	0.000	0.073	0.009	0.008	0.041	0.020
1999	0.000	0.000	0.066	0.010	0.060	0.065
2000	0.000	0.090	0.040	0.055	0.093	0.106
2001	0.000	0.294	0.019	0.103	0.076	0.350
2002	0.147	0.090	0.086	0.134	0.149	0.183
2003	0.000	0.090	0.033	0.154	0.058	0.180
2004	0.000	0.058	0.000	0.027	0.021	0.097
2005	0.000	0.000	0.010	0.012	0.023	0.073
2006	0.159	0.000	0.010	0.051	0.016	0.044
2007	0.042	0.137	0.041	0.087	0.038	0.068
2008	0.000	0.000	0.019	0.027	0.015	0.042
2009	0.000	0.088	0.014	0.057	0.048	0.062
2010	0.021	0.058	0.009	0.163	0.063	0.142
2011	0.000	0.000	0.023	0.052	0.089	0.047
2012	0.000	0.154	0.004	0.144	0.041	0.111
2013	0.000	0.111	0.009	0.075	0.168	0.071
2014		0.064		0.117		0.224
2015	0.000	0.469	0.002	0.111	0.147	0.298
2016	0.000	0.171	0.032	0.040	0.513	0.176
2017	0.000		0.028		0.294	
2018	0.000	0.000	0.018	0.100	0.126	0.073
2019	0.000	0.128	0.000	0.021	0.038	0.087
2020						
2021	0.000	0.012	0.020	0.177	0.102	0.127
2019-2021 average	***0.000***	***0.070***	***0.010***	***0.099***	***0.070***	***0.107***
25th Percentile	***0.000***	***0.000***	***0.000***	***0.009***	***0.013***	***0.026***
75th Percentile	***0.000***	***0.103***	***0.027***	***0.090***	***0.073***	***0.107***

Table 24. **Coefficient of variation for Jonah crab recruit abundance indices in SNE areas and coastwide.**

Year	ISNE	ISNE	OSNE	OSNE	Coastwide	Coastwide
	NEFSC Trawl Spring	NEFSC Trawl Fall	NEFSC Trawl Spring	NEFSC Trawl Fall	NEFSC Trawl Spring	NEFSC Trawl Fall
1980		Inf		0.756		0.568
1981	Inf		0.361		0.256	
1982	1.000	Inf	0.304	0.597	0.276	0.429
1983	Inf	Inf	Inf	0.461	Inf	0.372
1984	Inf	Inf	Inf	0.764	1.076	0.609
1985	Inf		1.515		0.909	
1986	Inf		1.000		1.000	
1987		1.400		0.410		0.333
1988			0.492		0.459	
1989	Inf	Inf	Inf	0.468	0.781	0.418
1990	Inf	Inf	Inf	Inf	Inf	Inf
1991	Inf	Inf	Inf	0.532	1.000	0.514
1992	1.000	Inf	Inf	0.473	1.000	0.444
1993	Inf	Inf	Inf	1.000	1.000	0.770
1994	Inf	Inf	Inf	1.000	1.000	0.557
1995		Inf	1.519	Inf	0.406	0.477
1996	Inf	0.803	1.000	Inf	0.862	0.440
1997	Inf	0.783	1.000	Inf	0.632	0.625
1998	Inf	1.000	1.000	1.000	0.358	0.493
1999	Inf	Inf	0.633	1.000	0.422	0.424
2000	Inf	1.000	0.917	0.435	0.448	0.253
2001	Inf	1.000	0.956	0.285	0.302	0.149
2002	1.000	1.400	0.490	0.351	0.232	0.212
2003	Inf	1.400	0.673	0.294	0.370	0.192
2004	Inf	1.000	Inf	0.556	0.498	0.427
2005	Inf	Inf	1.000	1.000	0.507	0.608
2006	0.783	Inf	1.000	0.418	0.514	0.320
2007	1.000	1.000	0.947	0.266	0.585	0.220
2008	Inf	Inf	0.710	0.537	0.546	0.320
2009	Inf	0.638	0.708	0.334	0.267	0.247
2010	1.000	1.000	1.000	0.380	0.434	0.309
2011	Inf	Inf	0.580	0.342	0.338	0.295
2012	Inf	1.093	1.000	0.451	0.277	0.322
2013		0.661	1.000	0.479	0.345	0.296
2014		0.949		0.332		0.159
2015		1.000	1.000	0.356	0.217	0.192
2016	Inf	1.000	0.430	0.396	0.227	0.247
2017	Inf		0.560		0.282	
2018	Inf	Inf	0.828	0.262	0.302	0.231
2019	Inf	1.000	Inf	0.556	0.435	0.230
2020						
2021	Inf	0.000	0.729	0.306	0.273	0.243

Table 25. **Jonah crab exploitable abundance indices in GOM areas.**

Year	IGOM	IGOM	IGOM	IGOM	IGOM	IGOM	OGOM	OGOM	GOM	GOM
	MA Trawl Spring	**MA Trawl Fall**	**ME/NH Trawl Spring**	**ME/NH Trawl Fall**	**NEFSC Trawl Spring**	**NEFSC Trawl Fall**	**NEFSC Trawl Spring**	**NEFSC Trawl Fall**	**NEFSC Trawl Spring**	**NEFSC Trawl Fall**
10						0.087		0.025		0.045
1981					0.062		0.204		0.160	
1982	0.020	0.150			0.000	0.056	0.075	0.012	0.038	0.026
1983	0.000	0.630			0.022	0.000	0.000	0.009	0.007	0.006
1984	0.010	0.080			0.095	0.000	0.000	0.000	0.037	0.000
1985	0.120	0.680			0.088		0.000		0.023	
1986	0.040	0.310			0.000		0.000		0.000	
1987	0.090	0.430				0.000		0.033		0.021
1988	0.000	0.090			0.081		0.025		0.039	
1989	0.030	0.140			0.000	0.000	0.006	0.064	0.004	0.036
1990	0.010	0.030			0.000	0.000	0.041	0.007	0.015	0.005
1991	0.040	0.230			0.000	0.000	0.013	0.005	0.008	0.003
1992	0.100	0.210			0.000	0.000	0.012	0.036	0.008	0.028
1993	0.130	0.080			0.000	0.200	0.092	0.150	0.072	0.169
1994	0.040	0.000			0.126	0.062	0.008	0.000	0.044	0.023
1995	0.100	0.320			0.000	0.031	0.063	0.076	0.048	0.068
1996	0.100	0.040			0.000	0.000	0.026	0.321	0.019	0.261
1997	0.070	0.020			0.071	0.075	0.031	0.087	0.042	0.080
1998	0.080	0.060			0.261	0.000	0.072	0.007	0.139	0.004
1999	0.030	0.220			0.075	0.267	0.165	0.052	0.125	0.124
2000	0.130	0.440			0.269	0.295	0.314	0.186	0.314	0.224
2001	0.170	0.240			0.586	0.482	0.275	0.414	0.413	0.437
2002	0.050	0.400			0.262	0.098	0.338	0.072	0.295	0.083
2003	0.070	0.860			0.215	0.288	0.034	0.212	0.117	0.236
2004	0.020	0.350	1.173	0.864	0.083	0.349	0.203	0.069	0.160	0.187
2005	0.060	0.170	1.825	0.709	0.106	0.280	0.036	0.034	0.057	0.102
2006	0.120	0.450	1.351	0.845	0.099	0.061	0.021	0.041	0.047	0.049
2007	0.080	0.430	2.208	1.435	0.124	0.045	0.000	0.087	0.043	0.072
2008	0.210	0.680	1.305	2.195	0.036	0.050	0.000	0.071	0.025	0.072
2009	0.050	0.030	1.457	0.427	0.477	0.128	0.194	0.280	0.295	0.214
2010	0.020	0.280	0.649	0.674	0.542	0.085	0.286	0.083	0.399	0.091
2011	0.130	0.560	0.675	0.291	0.405	0.181	0.233	0.261	0.299	0.233
2012	0.080	0.620	0.704	0.316	0.318	0.224	0.139	0.282	0.208	0.259
2013	0.030	0.150	0.332	0.234	0.240	0.286	0.257	0.018	0.259	0.113
2014	0.000	0.300	0.944	0.142	2.354	0.172	1.936	0.435	2.154	0.357
2015	0.290	1.470	0.636	1.812	1.144	0.335	0.933	0.783	1.042	0.625
2016	0.710	0.380	2.310	1.535	1.459	0.449	1.466	1.166	1.446	0.907
2017	0.250	2.140	0.796	1.436	0.851		0.846		0.862	
2018	0.180	0.500	0.616	0.735	1.485	0.420	1.095	0.834	1.215	0.674
2019	0.180	0.080	0.686	0.523	0.408	0.561	0.652	0.508	0.547	0.560
2020				0.065						
2021	0.080	0.300	0.299	0.146	1.250	0.393	0.640	0.265	0.914	0.314
2019-2021 average	***0.130***	***0.190***	***0.492***	***0.245***	***0.829***	***0.477***	***0.646***	***0.387***	***0.730***	***0.437***
25th Percentile	***0.030***	***0.115***	***0.649***	***0.298***	***0.029***	***0.024***	***0.017***	***0.031***	***0.038***	***0.034***
75th Percentile	***0.125***	***0.445***	***1.351***	***1.292***	***0.407***	***0.286***	***0.280***	***0.269***	***0.307***	***0.242***

Table 26. **Coefficient of variation for Jonah crab exploitable abundance indices in GOM areas.**

Year	IGOM	IGOM	IGOM	IGOM	IGOM	IGOM	OGOM	OGOM	GOM	GOM
	MA Trawl Spring	**MA Trawl Fall**	**ME/NH Trawl Spring**	**ME/NH Trawl Fall**	**NEFSC Trawl Spring**	**NEFSC Trawl Fall**	**NEFSC Trawl Spring**	**NEFSC Trawl Fall**	**NEFSC Trawl Spring**	**NEFSC Trawl Fall**
1980						0.655		1.000		0.550
1981					0.599		0.280		0.251	
1982	1.000	0.490			Inf	0.606	1.000	1.000	1.000	0.532
1983		0.310			1.000	Inf		1.000	1.000	1.000
1984	1.000	0.520			0.819	Inf	Inf	Inf	0.732	Inf
1985	0.610	0.190			1.000		Inf		1.000	
1986	1.000	0.390			Inf		Inf		Inf	
1987	0.540	0.310				Inf		1.000		1.000
1988		0.720			1.000		1.000		0.722	
1989	0.710	0.330			Inf	Inf	1.000	0.707	1.000	0.713
1990	1.000	1.000			Inf	Inf	1.000	1.000	1.000	1.000
1991	0.710	0.430			Inf	Inf	1.000	1.000	1.000	1.000
1992	0.660	0.640			Inf	Inf	1.000	1.000	1.000	1.000
1993	0.630	0.730			Inf	1.000	0.808	0.443	0.814	0.394
1994	0.720				1.000	1.000	1.000	Inf	0.888	1.000
1995	0.470	0.290			Inf	0.758	0.718	0.467	0.719	0.423
1996	0.670	0.810			Inf	Inf	1.000	0.576	1.000	0.555
1997	0.500	1.000			0.532	0.638	1.000	0.486	0.551	0.396
1998	0.640	0.780			0.438	Inf	0.614	1.000	0.352	1.000
1999	1.000	0.270			0.821	0.372	0.648	0.663	0.559	0.304
2000	0.430	0.280			0.399	0.494	0.459	0.441	0.364	0.341
2001	0.470	0.380			0.441	0.242	0.253	0.278	0.262	0.190
2002	0.590	0.570			0.291	0.786	0.311	0.569	0.233	0.478
2003	0.500	0.220			0.474	0.470	0.728	0.444	0.387	0.325
2004	1.000	0.320	0.454	0.304	0.900	0.525	1.000	0.573	0.819	0.363
2005	0.760	0.520	0.451	0.279	0.000	0.517	1.000	0.734	0.392	0.439
2006	0.390	0.300	0.282	0.319	0.627	1.000	1.000	0.710	0.541	0.603
2007	0.440	0.310	0.363	0.335	0.698	0.713	Inf	0.500	0.720	0.420
2008	0.330	0.330	0.289	0.237	0.798	0.654	Inf	0.581	0.887	0.455
2009	0.580	1.000	0.295	0.326	0.389	0.636	0.311	0.415	0.264	0.344
2010	1.000	0.300	0.419	0.603	0.363	0.691	0.372	0.539	0.260	0.407
2011	0.560	0.320	0.415	0.502	0.346	0.511	0.543	0.785	0.281	0.685
2012	0.450	0.350	0.354	0.433	0.278	0.500	0.483	0.440	0.246	0.335
2013	0.720	0.580	0.438	0.556	0.468	0.305	0.296	1.000	0.246	0.298
2014		0.450	0.454	0.645	0.254	0.401	0.275	0.423	0.189	0.377
2015	0.500	0.250	0.432	0.424	0.314	0.251	0.278	0.283	0.194	0.226
2016	0.190	0.220	0.392	0.321	0.480	0.272	0.194	0.271	0.228	0.224
2017	0.360	0.550	0.405	0.316	0.202		0.312		0.204	
2018	0.420	0.340	0.377	0.502	0.144	0.446	0.340	0.279	0.161	0.245
2019	0.380	0.510	0.748	0.332	0.429	0.319	0.358	0.332	0.285	0.215
2020				0.905						
2021	0.510	0.450	0.590	0.708	0.226	0.334	0.464	0.272	0.273	0.225

Table 27. **Jonah crab exploitable abundance indices in SNE areas and coastwide.**

Year	ISNE NEFSC Trawl Spring	ISNE NEFSC Trawl Fall	OSNE NEFSC Trawl Spring	OSNE NEFSC Trawl Fall	Coastwide NEFSC Trawl Spring	Coastwide NEFSC Trawl Fall
1980		0.000		0.014		0.021
1981	0.000		0.059		0.093	
1982	0.000	0.000	0.123	0.006	0.073	0.011
1983	0.000	0.000	0.007	0.009	0.006	0.007
1984	0.000	0.000	0.024	0.023	0.024	0.013
1985	0.000		0.027		0.022	
1986	0.000		0.003		0.001	
1987		0.000		0.010		0.012
1988	0.000		0.000		0.017	
1989	0.000	0.000	0.000	0.009	0.006	0.018
1990	0.000	0.000	0.007	0.000	0.009	0.001
1991	0.000	0.392	0.022	0.027	0.014	0.022
1992	0.000	0.000	0.000	0.019	0.002	0.019
1993	0.000	0.055	0.000	0.010	0.016	0.061
1994	0.000	0.259	0.000	0.000	0.014	0.018
1995	0.000	0.000	0.000	0.013	0.013	0.031
1996	0.000	0.000	0.000	0.025	0.006	0.087
1997	0.000	0.000	0.000	0.000	0.013	0.027
1998	0.000	0.110	0.089	0.001	0.095	0.005
1999	0.062	0.000	0.016	0.021	0.051	0.051
2000	0.000	0.180	0.054	0.023	0.125	0.100
2001	0.000	0.052	0.024	0.019	0.153	0.156
2002	0.147	0.000	0.022	0.037	0.113	0.047
2003	0.000	0.000	0.036	0.067	0.062	0.106
2004	0.000	0.000	0.000	0.016	0.054	0.073
2005	0.000	0.000	0.010	0.014	0.023	0.041
2006	0.042	0.000	0.000	0.009	0.019	0.024
2007	0.000	0.128	0.037	0.038	0.039	0.047
2008	0.000	0.000	0.017	0.009	0.019	0.034
2009	0.000	0.167	0.091	0.147	0.151	0.148
2010	0.000	0.031	0.054	0.118	0.156	0.109
2011	0.000	0.000	0.059	0.080	0.138	0.120
2012	0.000	0.073	0.047	0.199	0.110	0.198
2013	0.000	0.184	0.047	0.125	0.112	0.118
2014		0.000		0.138		0.178
2015	0.000	0.469	0.039	0.077	0.346	0.273
2016	0.000	0.000	0.020	0.039	0.486	0.322
2017	0.042		0.030		0.303	
2018	0.000	0.000	0.108	0.163	0.489	0.313
2019	0.000	0.196	0.000	0.181	0.170	0.304
2020						
2021	0.058	0.076	0.012	0.067	0.270	0.147
2019-2021 average	***0.029***	***0.136***	***0.006***	***0.124***	***0.220***	***0.226***
25th Percentile	***0.000***	***0.000***	***0.000***	***0.010***	***0.014***	***0.021***
75th Percentile	***0.000***	***0.084***	***0.045***	***0.070***	***0.135***	***0.127***

Table 28. **Coefficient of variation for Jonah crab exploitable abundance indices in SNE areas and coastwide.**

Year	ISNE NEFSC Trawl Spring	ISNE NEFSC Trawl Fall	OSNE NEFSC Trawl Spring	OSNE NEFSC Trawl Fall	Coastwide NEFSC Trawl Spring	Coastwide NEFSC Trawl Fall
1980		Inf		0.586		0.412
1981	Inf		0.295		0.201	
1982	Inf	Inf	0.302	1.000	0.285	0.480
1983	Inf	Inf	1.000	1.000	0.727	0.790
1984	Inf	Inf	0.655	0.689	0.485	0.597
1985	Inf		0.514		0.478	
1986	Inf		1.000		1.000	
1987		Inf		1.000		0.726
1988			Inf		0.594	
1989	Inf	Inf	Inf	0.874	0.795	0.550
1990	Inf	Inf	1.613	Inf	0.868	1.000
1991	Inf	0.741	1.609	0.667	1.315	0.463
1992	Inf	Inf	Inf	0.710	1.000	0.598
1993	Inf	1.000	Inf	0.852	0.659	0.350
1994	Inf	1.000	Inf	Inf	0.884	0.609
1995		Inf	Inf	1.000	0.711	0.412
1996	Inf	Inf	Inf	0.579	1.000	0.477
1997	Inf		Inf	Inf	0.551	0.413
1998	Inf	1.000	0.546	1.000	0.322	0.622
1999	1.000	Inf	0.886	0.744	0.467	0.293
2000	Inf	0.500	0.689	0.661	0.278	0.286
2001	Inf	1.000	0.537	0.654	0.238	0.189
2002	1.000	Inf	0.649	0.783	0.216	0.403
2003	Inf	Inf	0.800	0.409	0.361	0.260
2004	Inf	Inf	Inf	0.723	0.832	0.304
2005	Inf	Inf	1.000	1.141	0.384	0.411
2006	1.000	Inf	Inf	0.874	0.490	0.495
2007	Inf	1.000	0.621	0.552	0.415	0.300
2008	Inf	Inf	1.000	1.000	0.620	0.390
2009	Inf	0.837	0.288	0.292	0.194	0.218
2010	Inf	1.000	0.529	0.284	0.230	0.212
2011	Inf	Inf	0.516	0.357	0.238	0.251
2012	Inf	0.500	0.516	0.326	0.206	0.223
2013		0.862	0.624	0.343	0.228	0.223
2014		Inf		0.311		0.199
2015		1.000	0.520	0.538	0.181	0.189
2016	Inf	Inf	0.647	0.431	0.214	0.222
2017	1.000		0.530		0.183	
2018	Inf	Inf	0.460	0.255	0.161	0.189
2019	Inf	0.756	Inf	0.227	0.278	0.155
2020						
2021	1.000	0.923	0.848	0.314	0.193	0.170

Table 29. **Jonah crab spawning abundance indices in GOM areas.**

Year	IGOM	IGOM	IGOM	IGOM	IGOM	IGOM	OGOM	OGOM	GOM	GOM
	MA Trawl Spring	**MA Trawl Fall**	**ME/NH Trawl Spring**	**ME/NH Trawl Fall**	**NEFSC Trawl Spring**	**NEFSC Trawl Fall**	**NEFSC Trawl Spring**	**NEFSC Trawl Fall**	**NEFSC Trawl Spring**	**NEFSC Trawl Fall**
1980						0.199		0.057		0.103
1981					0.345		0.045		0.134	
1982	0.970	0.610			0.000	0.073	0.000	0.020	0.000	0.032
1983	0.000	2.950			0.064	0.091	0.000	0.013	0.023	0.040
1984	0.120	2.750			0.000	0.000	0.000	0.000	0.000	0.000
1985	0.040	1.670			0.000		0.000		0.000	
1986	0.130	1.040			0.000		0.000		0.000	
1987	0.230	1.420				0.103		0.000		0.035
1988	0.000	0.430			0.000		0.111		0.070	
1989	0.040	0.050			0.000	0.041	0.000	0.032	0.000	0.035
1990	0.090	0.080			0.017	0.026	0.000	0.021	0.004	0.023
1991	0.000	0.470			0.000	0.000	0.098	0.005	0.075	0.003
1992	0.030	0.670			0.000	0.094	0.019	0.038	0.013	0.057
1993	0.150	0.190			0.000	0.133	0.031	0.073	0.020	0.083
1994	0.130	0.100			0.126	0.219	0.008	0.027	0.044	0.093
1995	0.020	1.660			0.096	0.022	0.063	0.028	0.067	0.025
1996	0.140	0.320			0.000	0.119	0.057	0.073	0.034	0.095
1997	0.030	0.090			0.197	0.221	0.049	0.083	0.094	0.139
1998	0.200	0.330			0.498	0.120	0.152	0.097	0.284	0.106
1999	0.110	0.480			0.019	0.283	0.109	0.441	0.082	0.400
2000	0.220	1.000			0.815	0.242	0.205	0.500	0.437	0.414
2001	0.650	0.250			1.486	1.375	0.647	1.191	0.978	1.349
2002	0.110	2.000			0.429	0.492	0.709	0.112	0.605	0.255
2003	0.080	2.260			0.144	0.454	0.361	0.308	0.304	0.382
2004	0.220	1.090	2.596	3.214	0.044	0.713	0.092	0.230	0.077	0.403
2005	0.240	0.600	4.553	2.498	0.159	0.694	0.242	0.110	0.204	0.285
2006	0.430	2.150	3.458	1.668	0.226	0.105	0.000	0.107	0.085	0.113
2007	0.090	1.570	1.913	2.038	0.009	0.073	0.000	0.074	0.003	0.073
2008	0.230	4.610	1.578	2.501	0.101	0.074	0.014	0.144	0.051	0.118
2009	0.130	0.650	1.315	1.083	0.331	0.259	0.216	0.055	0.261	0.134
2010	0.050	1.770	1.150	0.992	0.551	0.252	0.525	0.153	0.543	0.203
2011	0.460	4.080	1.005	1.003	0.500	0.114	0.166	0.269	0.279	0.221
2012	0.000	2.960	0.808	0.829	0.515	0.116	0.173	0.169	0.289	0.157
2013	0.060	0.570	0.529	0.739	0.681	0.154	0.485	0.096	0.546	0.126
2014	0.020	1.120	1.992	0.428	3.569	0.783	3.124	0.583	3.410	0.644
2015	0.880	8.670	1.718	8.181	1.293	0.858	1.551	1.373	1.532	1.089
2016	3.650	4.810	5.933	6.301	1.803	0.848	1.830	0.907	1.776	0.906
2017	0.880	7.580	1.291	3.335	1.211		0.598		0.815	
2018	0.540	5.060	0.751	7.657	1.307	1.303	0.358	0.480	0.691	0.778
2019	0.420	0.690	0.528	7.635	0.915	1.331	0.221	0.353	0.599	0.806
2020				1.371						
2021	0.350	0.820	0.433	2.120	1.291	0.360	0.275	0.484	0.619	0.514
2019-2021 average	***0.385***	***0.755***	***0.481***	***3.709***	***1.103***	***0.846***	***0.248***	***0.419***	***0.609***	***0.660***
25th Percentile	***0.045***	***0.475***	***0.808***	***1.023***	***0.005***	***0.093***	***0.011***	***0.036***	***0.029***	***0.069***
75th Percentile	***0.295***	***2.205***	***1.992***	***3.305***	***0.616***	***0.464***	***0.317***	***0.319***	***0.545***	***0.401***

Table 30. **Coefficient of variation for Jonah crab spawning abundance indices in GOM areas.**

Year	IGOM	IGOM	IGOM	IGOM	IGOM	IGOM	OGOM	OGOM	GOM	GOM
	MA Trawl Spring	MA Trawl Fall	ME/NH Trawl Spring	ME/NH Trawl Fall	NEFSC Trawl Spring	NEFSC Trawl Fall	NEFSC Trawl Spring	NEFSC Trawl Fall	NEFSC Trawl Spring	NEFSC Trawl Fall
1980						0.520		0.814		0.442
1981					0.407		0.369		0.328	
1982	0.740	0.520			Inf	0.664	Inf	1.142	Inf	0.639
1983		0.430			1.000	0.437		1.000	1.000	0.402
1984	0.560	0.640			Inf	Inf	Inf	Inf	Inf	Inf
1985	0.500	0.370			Inf		Inf		Inf	
1986	0.600	0.160			Inf		Inf		Inf	
1987	0.890	0.440				0.577		Inf		0.577
1988		0.180			Inf		0.430		0.475	
1989	1.000	1.000			Inf	0.757	Inf	1.000	Inf	0.673
1990	0.610	0.510			1.069	1.000	Inf	1.000	1.000	0.718
1991		0.450			Inf	Inf	0.500	1.000	0.500	1.000
1992	0.720	0.290			Inf	1.000	0.733	0.709	0.733	0.585
1993	0.790	0.420			Inf	0.792	1.000	0.740	1.000	0.523
1994	0.500	0.720			0.612	0.439	1.000	1.000	0.569	0.409
1995	1.000	0.300			1.069	1.000	0.718	1.000	0.551	0.773
1996	0.450	0.430			Inf	0.469	0.711	0.556	0.712	0.369
1997	0.720	0.580			0.515	0.435	0.733	0.671	0.412	0.340
1998	0.660	0.740			0.390	0.539	0.359	0.765	0.285	0.465
1999	0.530	0.360			0.737	0.380	0.507	0.409	0.439	0.304
2000	0.570	0.190			0.408	0.534	0.351	0.359	0.305	0.294
2001	0.420	0.300			0.251	0.311	0.258	0.275	0.185	0.218
2002	0.520	0.510			0.338	0.492	0.251	0.457	0.204	0.400
2003	0.810	0.140			0.514	0.348	0.376	0.292	0.306	0.216
2004	0.600	0.300	0.581	0.584	0.661	0.641	0.558	0.340	0.456	0.422
2005	0.750	0.420	0.348	0.457	0.538	0.737	0.522	0.443	0.410	0.554
2006	0.510	0.280	0.684	0.451	0.411	0.507	Inf	0.456	0.426	0.342
2007	0.470	0.190	0.422	0.360	1.000	0.489	Inf	0.529	1.000	0.382
2008	0.420	0.240	0.283	0.326	0.715	0.571	1.000	0.527	0.612	0.431
2009	0.330	0.470	0.310	0.422	0.410	0.644	0.333	0.660	0.259	0.434
2010	0.580	0.260	0.625	0.346	0.409	0.658	0.622	0.507	0.410	0.403
2011	0.570	0.250	0.438	0.417	0.309	0.454	0.447	0.740	0.254	0.661
2012		0.260	0.358	0.350	0.320	0.514	0.556	0.461	0.256	0.363
2013	0.820	0.240	0.556	0.324	0.397	0.399	0.339	0.511	0.255	0.346
2014	1.000	0.420	0.443	0.482	0.214	0.211	0.175	0.239	0.139	0.162
2015	0.420	0.220	0.426	0.593	0.247	0.243	0.159	0.424	0.155	0.286
2016	0.210	0.200	0.537	0.333	0.178	0.509	0.225	0.435	0.153	0.319
2017	0.240	0.290	0.340	0.293	0.335		0.348		0.251	
2018	0.400	0.220	0.368	0.416	0.502	0.568	0.364	0.414	0.286	0.389
2019	0.390	0.460	0.475	0.215	0.258	0.230	0.515	0.404	0.304	0.221
2020				0.678						
2021	0.780	0.620	0.488	0.402	0.210	0.403	0.454	0.326	0.196	0.271

Table 31. **Jonah crab spawning abundance indices in SNE areas and coastwide.**

Year	ISNE	ISNE	OSNE	OSNE	Coastwide	Coastwide
	NEFSC Trawl Spring	**NEFSC Trawl Fall**	**NEFSC Trawl Spring**	**NEFSC Trawl Fall**	**NEFSC Trawl Spring**	**NEFSC Trawl Fall**
1980		0.000		0.042		0.057
1981	0.064		0.134		0.123	
1982	0.000	0.000	0.149	0.110	0.079	0.072
1983	0.000	0.000	0.005	0.165	0.010	0.104
1984	0.000	0.157	0.000	0.078	0.000	0.049
1985	0.000		0.005		0.003	
1986	0.000		0.057		0.031	
1987		0.890		0.215		0.157
1988	0.000		0.121		0.087	
1989	0.000	0.000	0.005	0.149	0.003	0.094
1990	0.000	0.000	0.002	0.053	0.002	0.040
1991	0.000	0.135	0.000	0.063	0.015	0.043
1992	0.180	0.042	0.000	0.062	0.012	0.050
1993	0.000	0.000	0.016	0.010	0.018	0.034
1994	0.000	0.000	0.002	0.022	0.015	0.042
1995	0.064	0.000	0.036	0.035	0.061	0.038
1996	0.005	0.501	0.023	0.106	0.039	0.103
1997	0.000	0.425	0.010	0.000	0.036	0.055
1998	0.125	0.302	0.071	0.030	0.137	0.060
1999	0.062	0.058	0.084	0.216	0.081	0.236
2000	0.000	0.205	0.092	0.295	0.193	0.296
2001	0.092	0.617	0.076	0.263	0.381	0.636
2002	0.796	0.263	0.149	0.224	0.311	0.214
2003	0.010	5.155	0.027	0.605	0.147	0.561
2004	0.000	0.173	0.009	0.060	0.034	0.169
2005	0.000	0.000	0.008	0.126	0.070	0.158
2006	0.449	0.000	0.031	0.135	0.057	0.114
2007	0.042	0.000	0.055	0.314	0.030	0.200
2008	0.000	0.000	0.018	0.054	0.035	0.077
2009	0.104	0.029	0.082	0.270	0.138	0.203
2010	0.000	0.318	0.034	0.592	0.187	0.394
2011	0.010	0.000	0.026	0.377	0.110	0.319
2012	0.000	0.061	0.038	0.914	0.128	0.572
2013	0.000	0.211	0.050	0.129	0.225	0.119
2014		0.220		0.134		0.318
2015	0.000	0.979	0.020	0.230	0.491	0.475
2016	0.000	0.542	0.078	0.120	0.616	0.403
2017	0.000		0.030		0.277	
2018	0.000	0.394	0.126	0.199	0.336	0.374
2019	0.000	0.574	0.021	0.132	0.205	0.362
2020						
2021	0.030	0.012	0.045	0.173	0.247	0.273
2019-2021 average	***0.015***	***0.293***	***0.033***	***0.152***	***0.226***	***0.317***
25th Percentile	***0.000***	***0.000***	***0.009***	***0.061***	***0.030***	***0.059***
75th Percentile	***0.039***	***0.337***	***0.074***	***0.225***	***0.192***	***0.319***

Table 32. **Coefficient of variation for Jonah crab spawning abundance indices in SNE areas and coastwide.**

Year	ISNE NEFSC Trawl Spring	ISNE NEFSC Trawl Fall	OSNE NEFSC Trawl Spring	OSNE NEFSC Trawl Fall	Coastwide NEFSC Trawl Spring	Coastwide NEFSC Trawl Fall
1980		Inf		0.506		0.334
1981	1.000		0.266		0.196	
1982	Inf	Inf	0.425	0.465	0.424	0.391
1983	Inf	Inf	1.000	0.290	0.788	0.256
1984	Inf	1.000	Inf	0.370	Inf	0.331
1985	Inf		1.000		1.000	
1986	Inf		0.555		0.554	
1987		0.644		0.260		0.222
1988			0.467		0.365	
1989	Inf	Inf	1.424	0.284	1.362	0.254
1990	Inf	Inf	1.000	0.377	0.707	0.318
1991	Inf	1.000	Inf	0.341	0.655	0.298
1992	1.000	1.000	Inf	0.685	0.767	0.471
1993	Inf	Inf	0.719	0.632	0.517	0.429
1994	Inf	Inf	1.000	0.596	0.540	0.328
1995	1.000	Inf	0.501	0.592	0.284	0.400
1996	1.000	0.345	1.000	0.314	0.545	0.209
1997	Inf	0.577	1.000	Inf	0.370	0.299
1998	1.399	0.707	0.461	0.589	0.233	0.314
1999	1.000	1.000	0.395	0.215	0.279	0.177
2000	Inf	0.900	0.517	0.346	0.253	0.220
2001	1.000	1.395	0.608	0.320	0.175	0.165
2002	0.637	1.049	0.378	0.216	0.169	0.198
2003	1.399	0.797	0.581	0.172	0.274	0.183
2004	Inf	1.000	1.000	0.383	0.386	0.327
2005	Inf	Inf	1.000	0.292	0.393	0.337
2006	0.784	Inf	0.544	0.407	0.305	0.281
2007	1.000	Inf	0.611	0.197	0.580	0.173
2008	Inf	Inf	0.708	0.457	0.406	0.283
2009	1.000	1.000	0.373	0.310	0.209	0.248
2010	Inf	0.837	0.483	0.201	0.371	0.177
2011	1.000	Inf	0.489	0.272	0.224	0.257
2012	Inf	0.721	0.536	0.677	0.207	0.575
2013		0.783	0.573	0.247	0.227	0.194
2014		0.800		0.252		0.156
2015		0.481	0.915	0.316	0.155	0.217
2016	Inf	0.948	0.542	0.266	0.144	0.262
2017	Inf		0.542		0.233	
2018	Inf	0.663	0.641	0.225	0.265	0.272
2019	Inf	0.900	0.964	0.303	0.274	0.181
2020						
2021	1.000	1.000	0.710	0.244	0.193	0.181

Table 33. **Mann-Kendall results for young-of-year settlement indices.**

Stock	Survey	SA	Since 2010			Full Time Series		
			n	tau	p-value	n	tau	p-value
IGOM	ME Settlement	511	12	0.18	0.45	21	0.53	0.00
IGOM	ME Settlement	512	12	0.24	0.30	22	0.50	0.00
IGOM	ME Settlement	513	12	0.00	1.00	33	0.62	0.00
IGOM	NH Settlement	513	11	0.35	0.16	12	0.41	0.07
IGOM	MA Settlement	514	6	0.07	1.00	6	0.07	1.00

Table 34. **Mann-Kendall results for recruit abundance indices.**

Stock	Survey	Season	Since 2010			Full Time Series		
			n	tau	p-value	n	tau	p-value
IGOM	MA Trawl	Spring	11	0.31	0.21	39	0.19	0.10
IGOM	MA Trawl	Fall	11	0.02	1.00	39	0.32	0.00
IGOM	ME/NH Trawl	Spring	11	-0.20	0.44	17	-0.56	0.00
IGOM	ME/NH Trawl	Fall	12	-0.15	0.54	18	-0.31	0.08
IGOM	NEFSC Trawl	Spring	11	0.20	0.44	39	0.49	0.00
IGOM	NEFSC Trawl	Fall	10	0.24	0.37	36	0.42	0.00
OGOM	NEFSC Trawl	Spring	11	-0.13	0.64	39	0.53	0.00
OGOM	NEFSC Trawl	Fall	10	0.16	0.59	36	0.35	0.00
GOM	NEFSC Trawl	Spring	11	0.05	0.88	39	0.54	0.00
GOM	NEFSC Trawl	Fall	10	0.16	0.59	36	0.41	0.00
ISNE	NEFSC Trawl	Spring	10	-0.45	0.16	38	-0.03	0.81
ISNE	NEFSC Trawl	Fall	10	0.04	0.93	36	0.29	0.02
OSNE	NEFSC Trawl	Spring	10	0.02	1.00	38	0.15	0.19
OSNE	NEFSC Trawl	Fall	10	-0.20	0.47	36	0.37	0.00
Coastwide	NEFSC Trawl	Spring	10	0.07	0.86	38	0.47	0.00
Coastwide	NEFSC Trawl	Fall	10	0.11	0.72	36	0.50	0.00

Table 35. **Mann-Kendall results for exploitable abundance indices.**

Stock	Survey	Season	Since 2010			Full Time Series		
			n	tau	p-value	n	tau	p-value
IGOM	MA Trawl	Spring	11	0.20	0.43	39	0.32	0.00
IGOM	MA Trawl	Fall	11	0.00	1.00	39	0.22	0.05
IGOM	ME/NH Trawl	Spring	11	-0.09	0.76	17	-0.41	0.02
IGOM	ME/NH Trawl	Fall	12	-0.18	0.45	18	-0.29	0.10
IGOM	NEFSC Trawl	Spring	11	0.24	0.35	39	0.59	0.00
IGOM	NEFSC Trawl	Fall	10	0.69	0.01	36	0.53	0.00
OGOM	NEFSC Trawl	Spring	11	0.20	0.44	39	0.51	0.00
OGOM	NEFSC Trawl	Fall	10	0.42	0.11	36	0.52	0.00
OGOM	Reference Fleet CPUE	All	12	-0.15	0.54	18	-0.32	0.07
GOM	NEFSC Trawl	Spring	11	0.24	0.35	39	0.58	0.00
GOM	NEFSC Trawl	Fall	10	0.51	0.05	36	0.58	0.00
ISNE	NEFSC Trawl	Spring	10	0.47	0.12	38	0.22	0.10
ISNE	NEFSC Trawl	Fall	10	0.17	0.58	36	0.24	0.07
ISNE	DRM CPUE	All	12	-0.55	0.02	15	-0.58	0.00
ISNE	CFRF VTS	NA	7	-0.14	0.76	7	-0.14	0.76
OSNE	NEFSC Trawl	Spring	10	-0.56	0.03	38	0.16	0.18
OSNE	NEFSC Trawl	Fall	10	-0.07	0.86	36	0.51	0.00
OSNE	DRM CPUE	All	12	0.03	0.95	15	0.03	0.92
OSNE	CFRF VTS	NA	6	0.07	1.00	6	0.07	1.00
Coastwide	NEFSC Trawl	Spring	10	0.33	0.21	38	0.52	0.00
Coastwide	NEFSC Trawl	Fall	10	0.47	0.07	36	0.66	0.00

Table 36. **Mann-Kendall results for spring recruit and fall exploitable abundance index ratios.**

Stock	Survey	n	tau	p-value
IGOM	MA Trawl	11	0.55	0.02
IGOM	ME/NH Trawl	11	-0.02	1.00
IGOM	NEFSC Trawl	10	-0.11	0.72
OGOM	NEFSC Trawl	10	-0.42	0.11
GOM	NEFSC Trawl	10	-0.33	0.21
ISNE	NEFSC Trawl	6	-0.58	0.24
OSNE	NEFSC Trawl	9	0.00	1.00
Coastwide	NEFSC Trawl	9	-0.11	0.75

Table 37. **Mann-Kendall results for spawning abundance indices.**

Stock	Survey	Season	Since 2010			Full Time Series		
			n	tau	p-value	n	tau	p-value
IGOM	MA Trawl	Spring	11	0.22	0.39	39	0.29	0.01
IGOM	MA Trawl	Fall	11	0.02	1.00	39	0.30	0.01
IGOM	ME/NH Trawl	Spring	11	-0.31	0.21	17	-0.53	0.00
IGOM	ME/NH Trawl	Fall	12	0.24	0.30	18	0.03	0.88
IGOM	NEFSC Trawl	Spring	11	0.35	0.16	39	0.61	0.00
IGOM	NEFSC Trawl	Fall	10	0.60	0.02	36	0.47	0.00
OGOM	NEFSC Trawl	Spring	11	-0.02	1.00	39	0.55	0.00
OGOM	NEFSC Trawl	Fall	10	0.33	0.21	36	0.60	0.00
GOM	NEFSC Trawl	Spring	11	0.24	0.35	39	0.61	0.00
GOM	NEFSC Trawl	Fall	10	0.33	0.21	36	0.57	0.00
ISNE	NEFSC Trawl	Spring	10	0.11	0.80	38	0.02	0.87
ISNE	NEFSC Trawl	Fall	10	0.29	0.28	36	0.25	0.04
OSNE	NEFSC Trawl	Spring	10	0.16	0.59	38	0.17	0.14
OSNE	NEFSC Trawl	Fall	10	-0.38	0.15	36	0.28	0.02
Coastwide	NEFSC Trawl	Spring	10	0.33	0.21	38	0.52	0.00
Coastwide	NEFSC Trawl	Fall	10	-0.20	0.47	36	0.48	0.00

Table 38. **Mann-Kendall results for relative exploitation time series.**

Stock	Survey	Season	n	tau	p-value
IGOM	MA Trawl	Spring	10	-0.16	0.59
IGOM	MA Trawl	Fall	11	0.09	0.76
IGOM	ME/NH Trawl	Spring	11	0.20	0.44
IGOM	ME/NH Trawl	Fall	12	0.24	0.30
IGOM	NEFSC Trawl	Spring	11	-0.13	0.64
IGOM	NEFSC Trawl	Fall	10	-0.42	0.11
OGOM	NEFSC Trawl	Spring	11	-0.60	0.01
OGOM	NEFSC Trawl	Fall	10	-0.60	0.02
OGOM	Reference Fleet CPUE	All	12	-0.33	0.15
GOM	NEFSC Trawl	Spring	11	-0.27	0.28
GOM	NEFSC Trawl	Fall	10	-0.42	0.11
ISNE	NEFSC Trawl	Fall	6	-0.33	0.45
ISNE	DRM CPUE	All	12	0.36	0.11
ISNE	CFRF VTS	NA	7	-0.05	1.00
OSNE	NEFSC Trawl	Spring	9	0.56	0.05
OSNE	NEFSC Trawl	Fall	10	0.29	0.28
OSNE	DRM CPUE	All	12	0.15	0.54
OSNE	CFRF VTS	NA	6	-0.47	0.26
Coastwide	NEFSC Trawl	Spring	10	-0.29	0.28
Coastwide	NEFSC Trawl	Fall	10	-0.33	0.21

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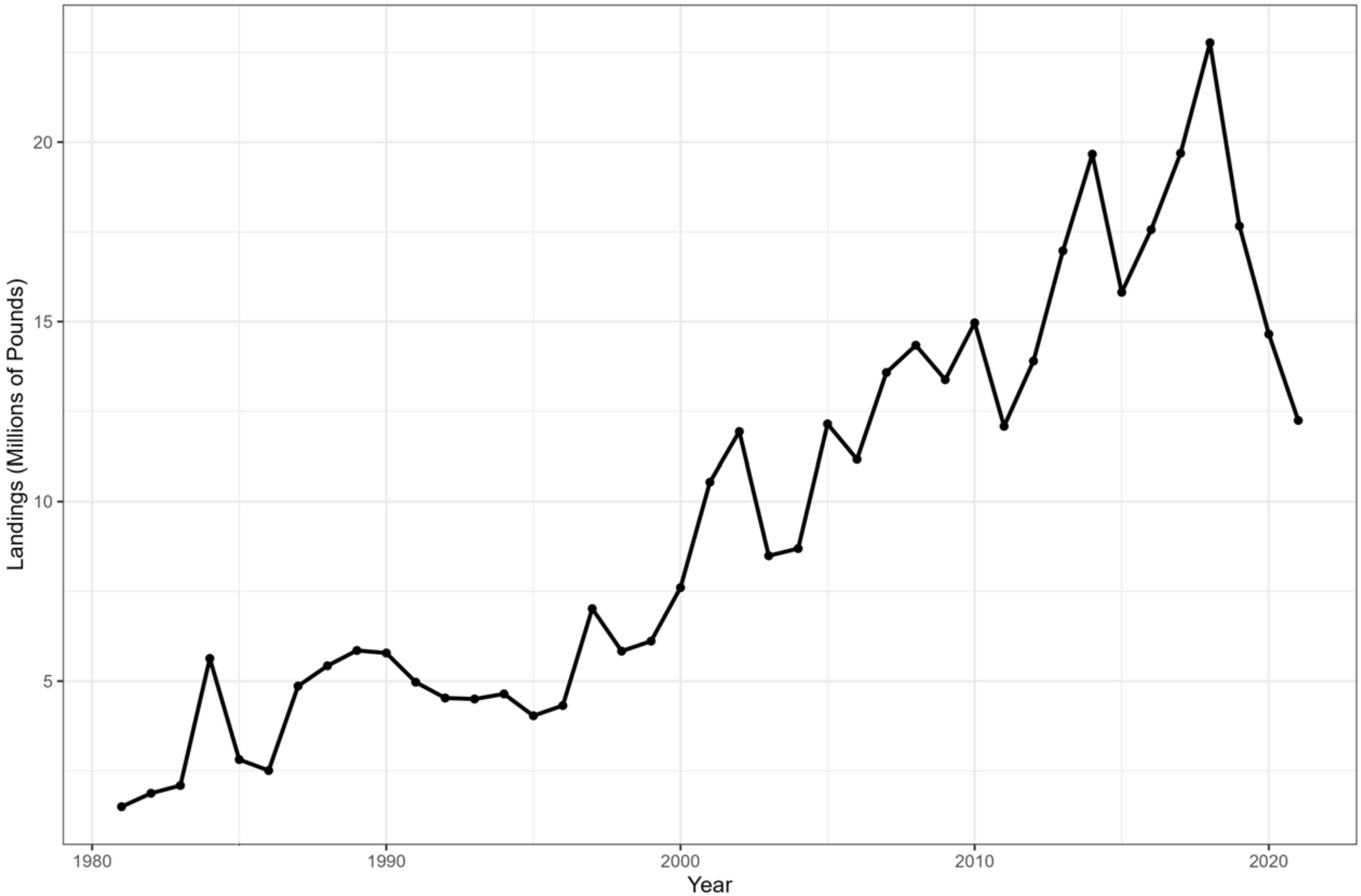

Figure 1. Coastwide landings of Jonah crab 1981-2021.

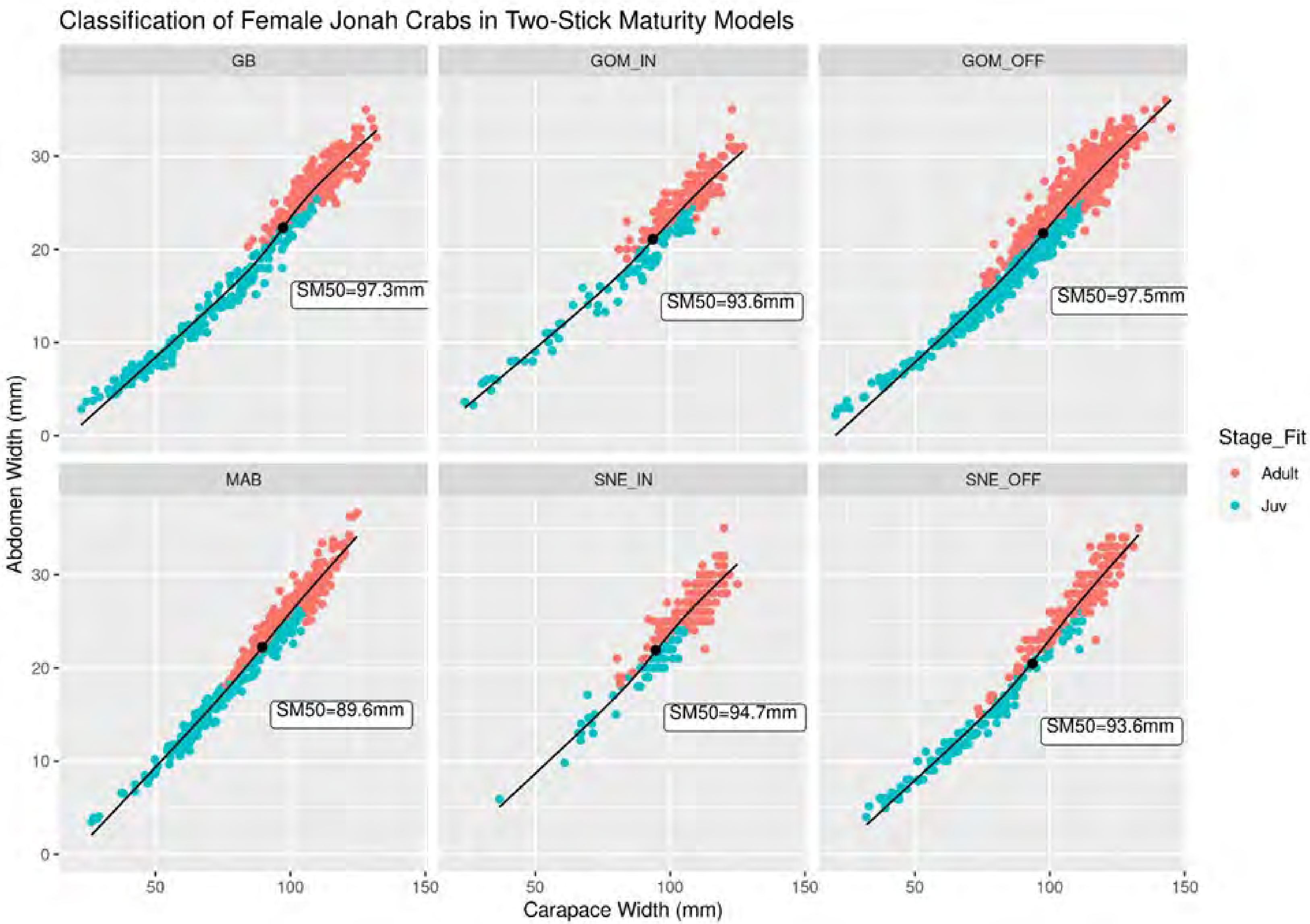

Figure 2. Relationship between abdomen width and carapace width (CW) for female Jonah crabs with fitted mean prediction at CW and estimated size-at-maturity (SM50). Color indicates predicted maturity based on Somerton method.

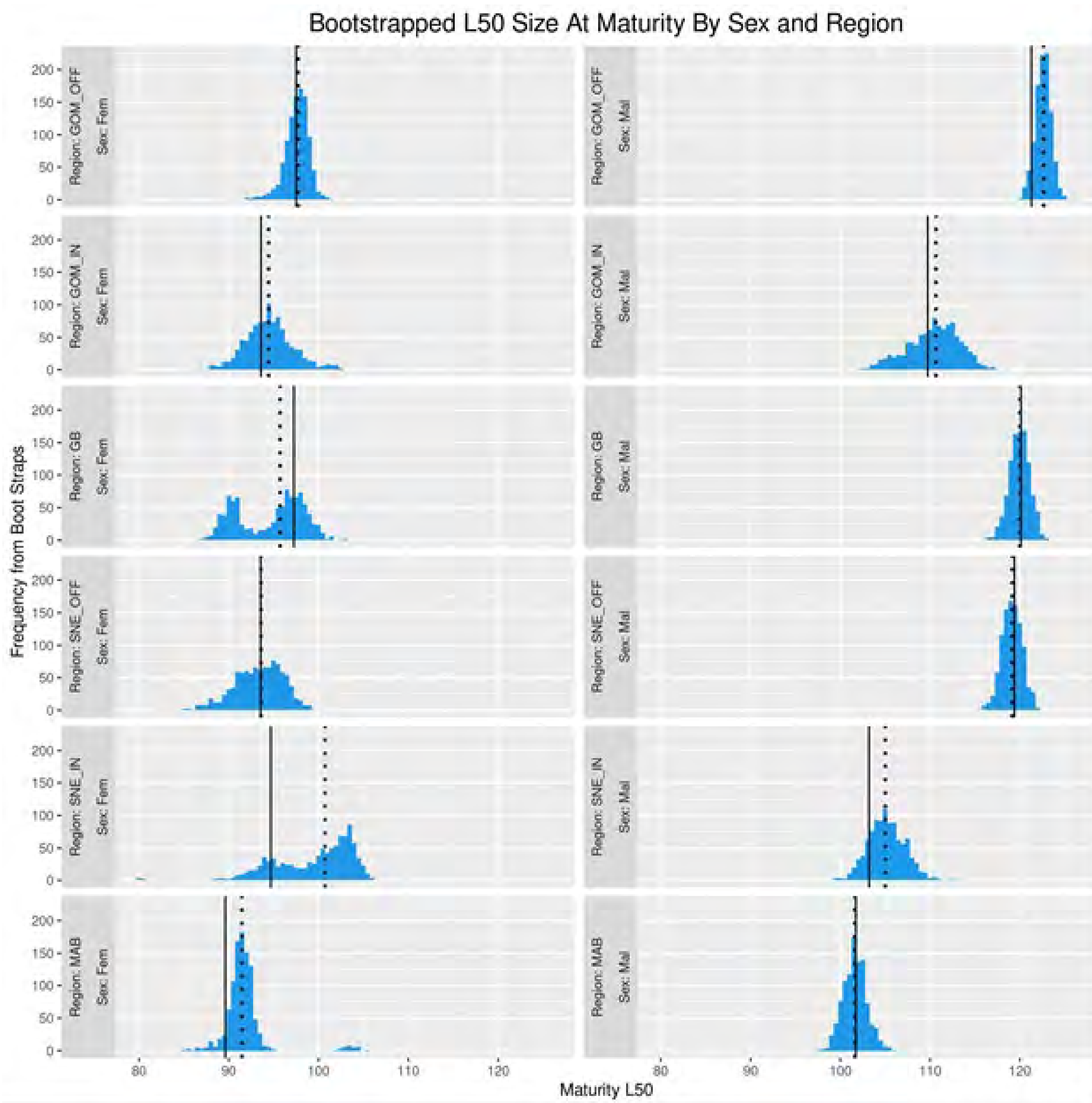

Figure 3. Bootstrapped distribution of size-at-maturity (SM50) by region and sex. Solid black line represents estimated SM50 while dotted line represents median of bootstrap.

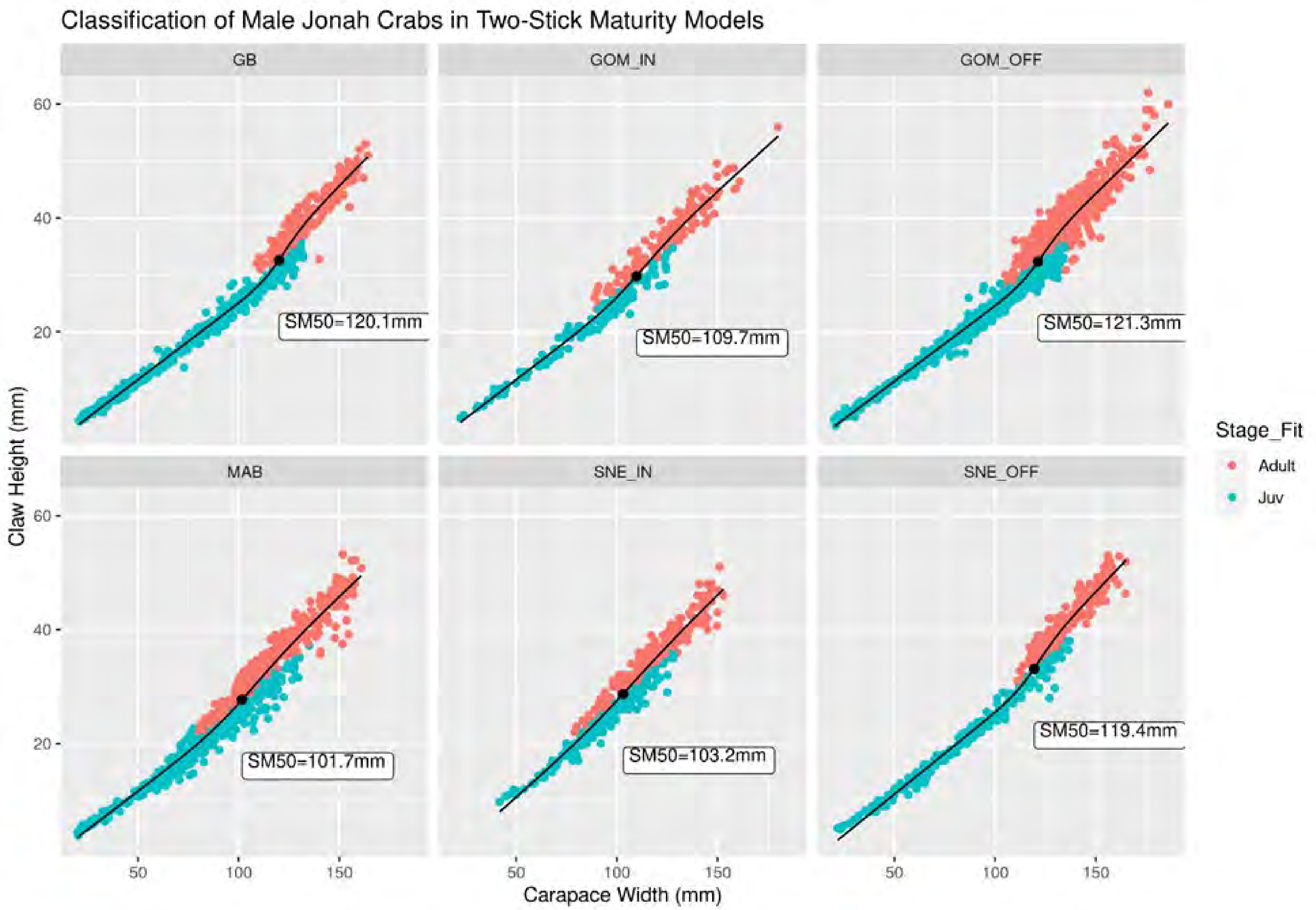

Figure 4. Relationship between claw height and carapace width (CW) for male Jonah crabs with fitted mean prediction at CW and estimated size-at-maturity (SM50). Color indicates predicted maturity based on Somerton method.

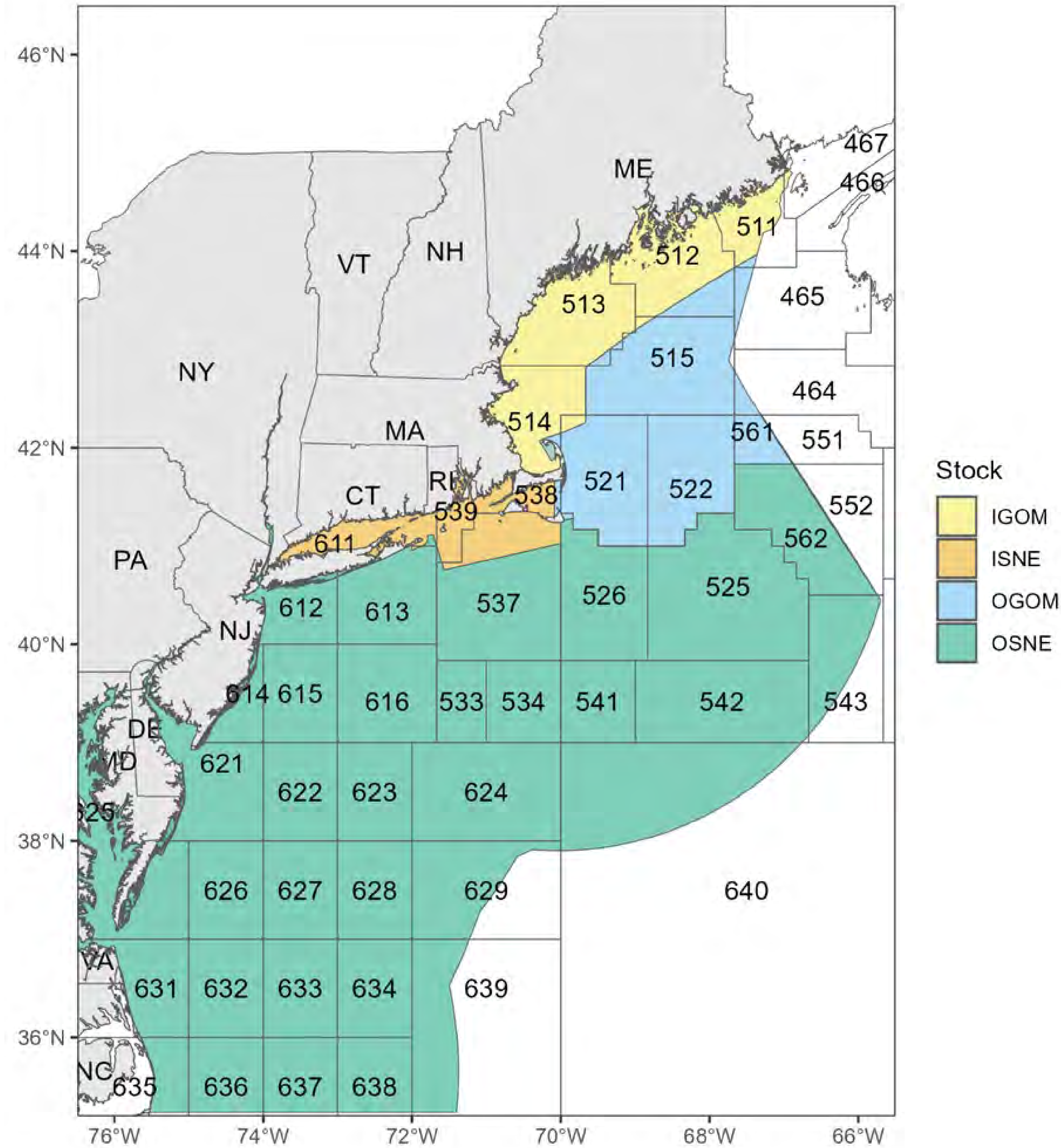

Figure 5. US Jonah crab stocks.

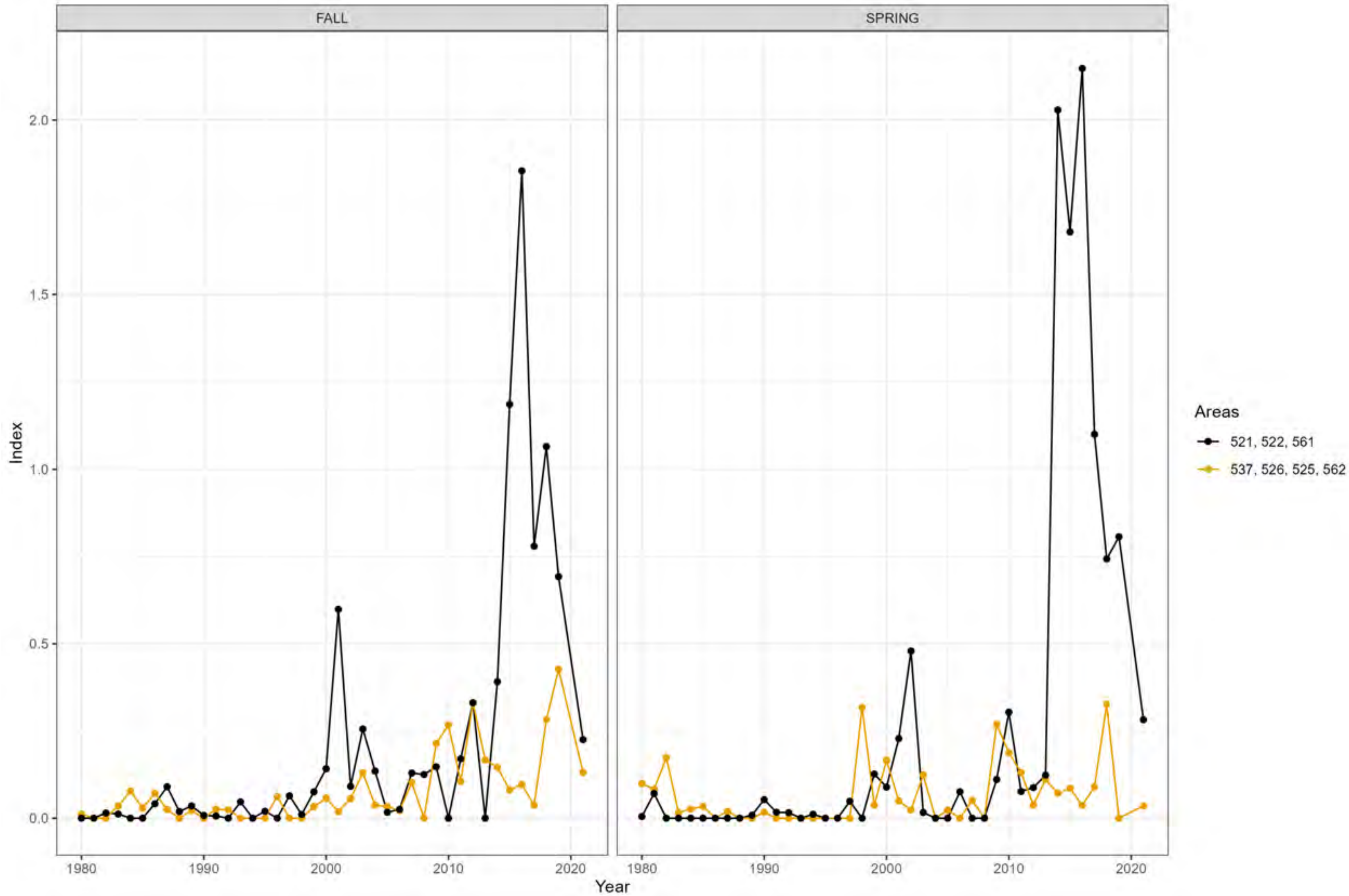

Figure 6. NEFSC Trawl Survey exploitable abundance indices (males 120mm+ CW) for adjacent NOAA statistical areas associated with high landings of Jonah crabs (Areas 537, 526, 525, 562) and low landings of Jonah crabs (Areas 521, 522, 561).

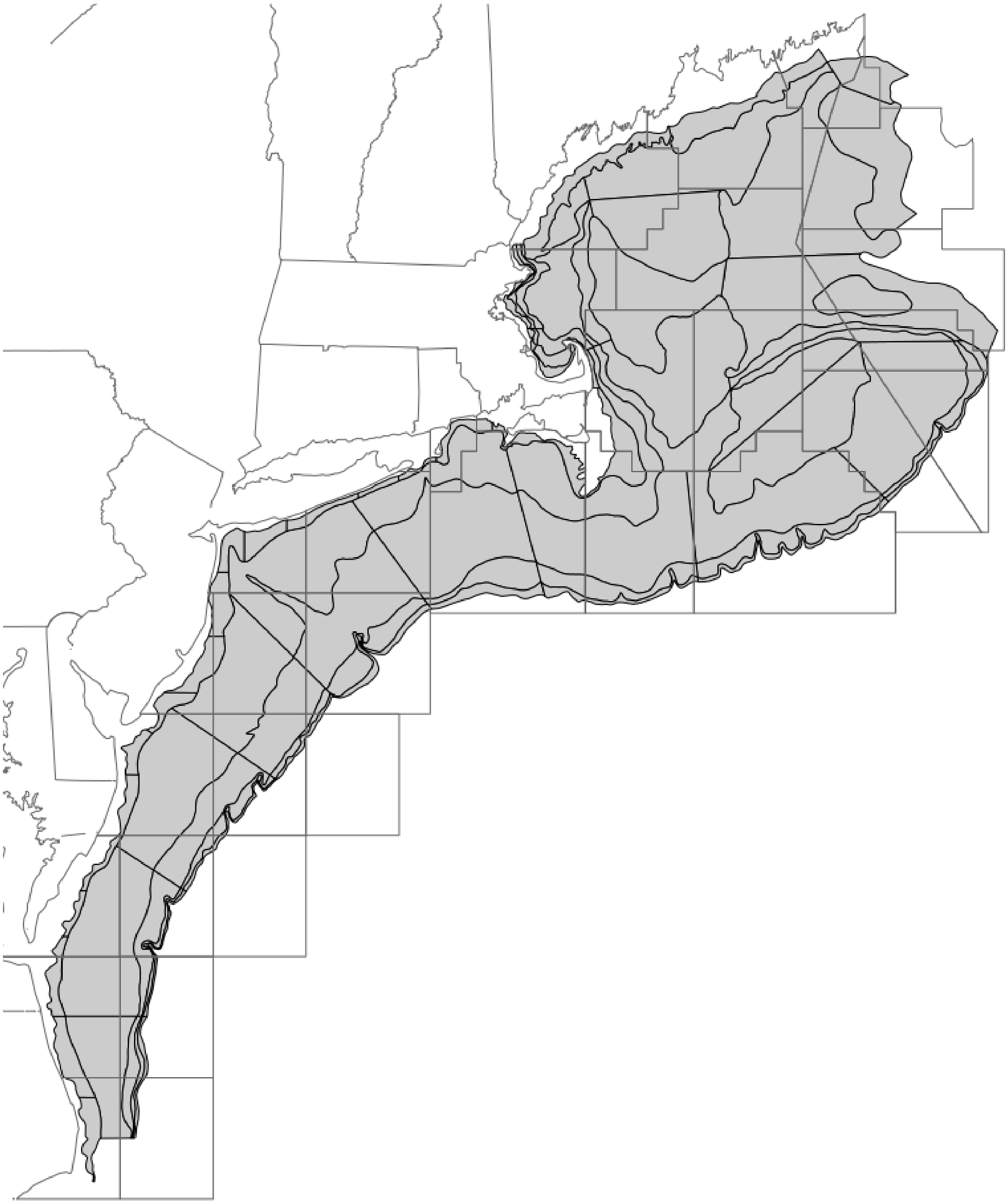

Figure 7. Survey footprint for the NEFSC Trawl Survey overlayed with NOAA statistical areas and depth contours.

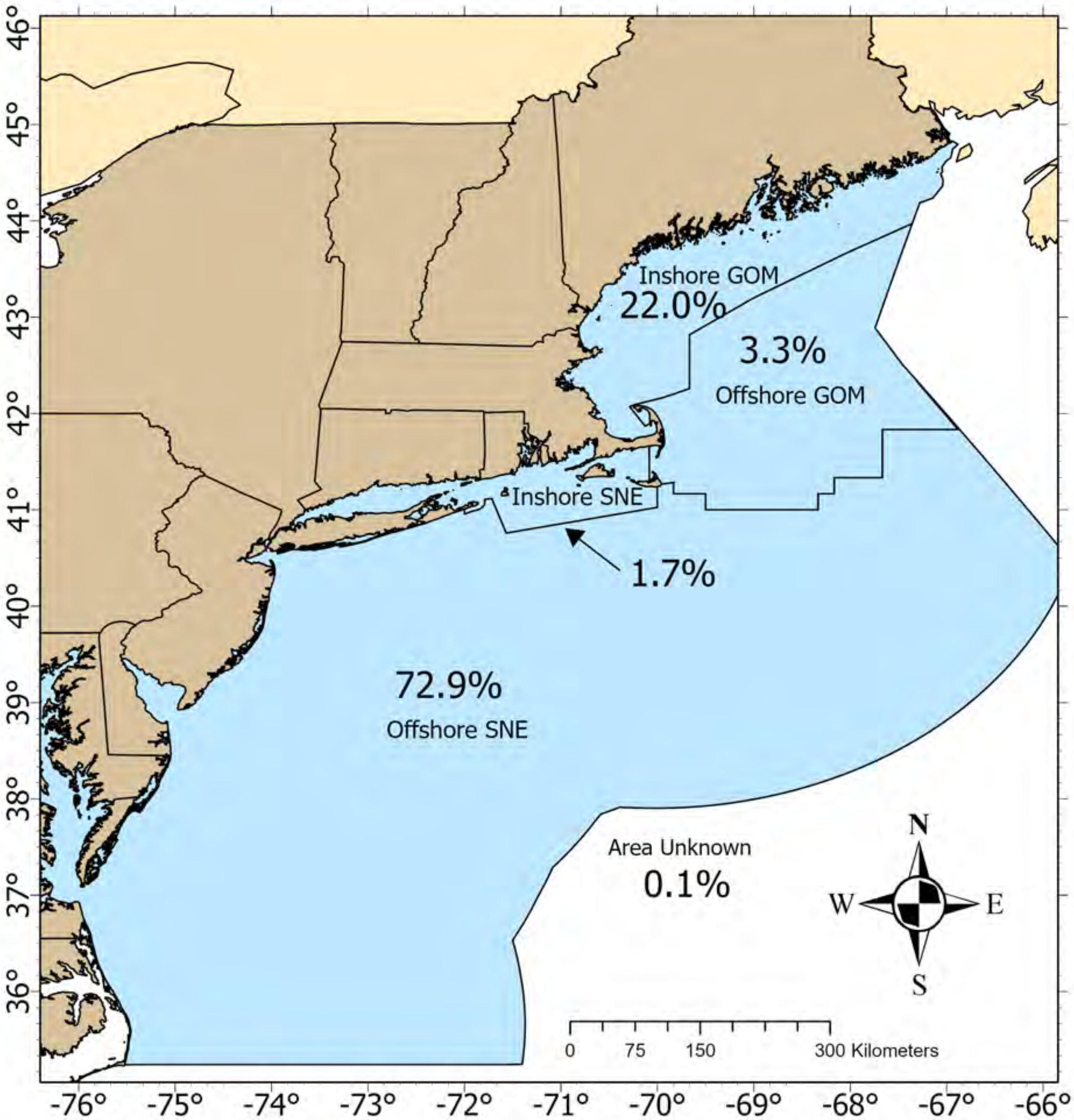

Figure 8. Percent of 2010 U.S. Jonah crab landings by stock area.

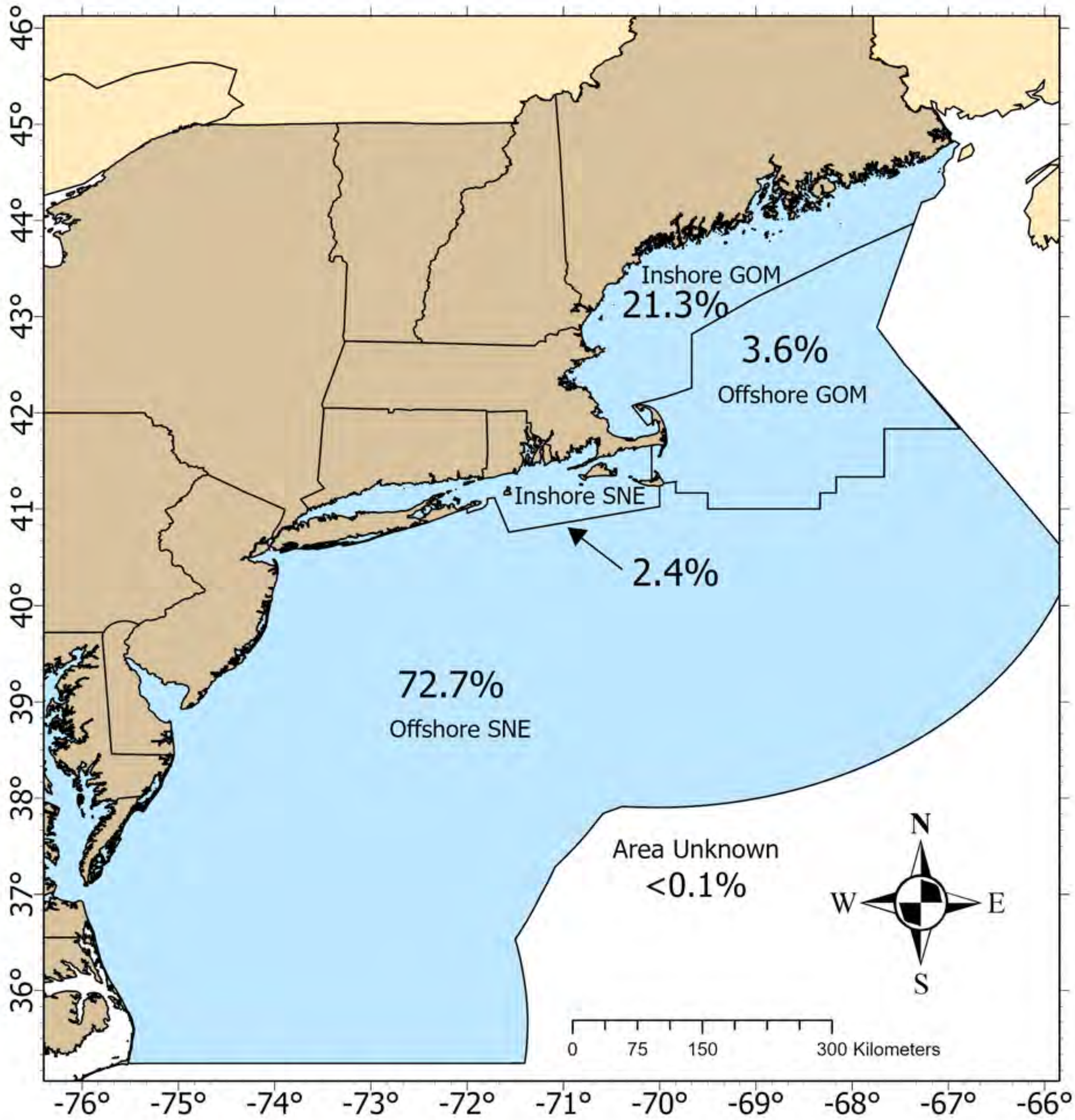

Figure 9. Percent of 2011 U.S. Jonah crab landings by stock area.

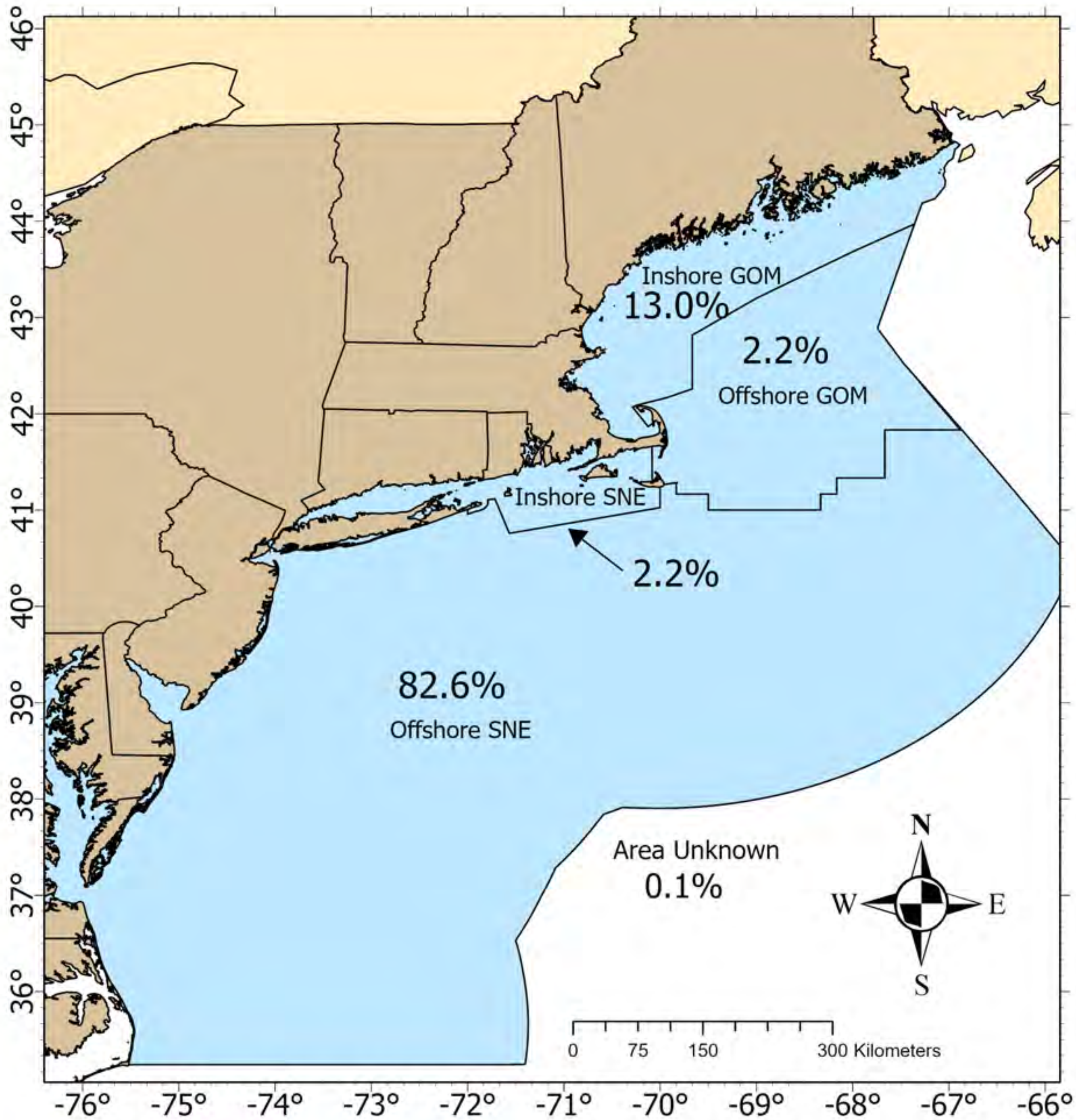

Figure 10. Percent of 2012 U.S. Jonah crab landings by stock area.

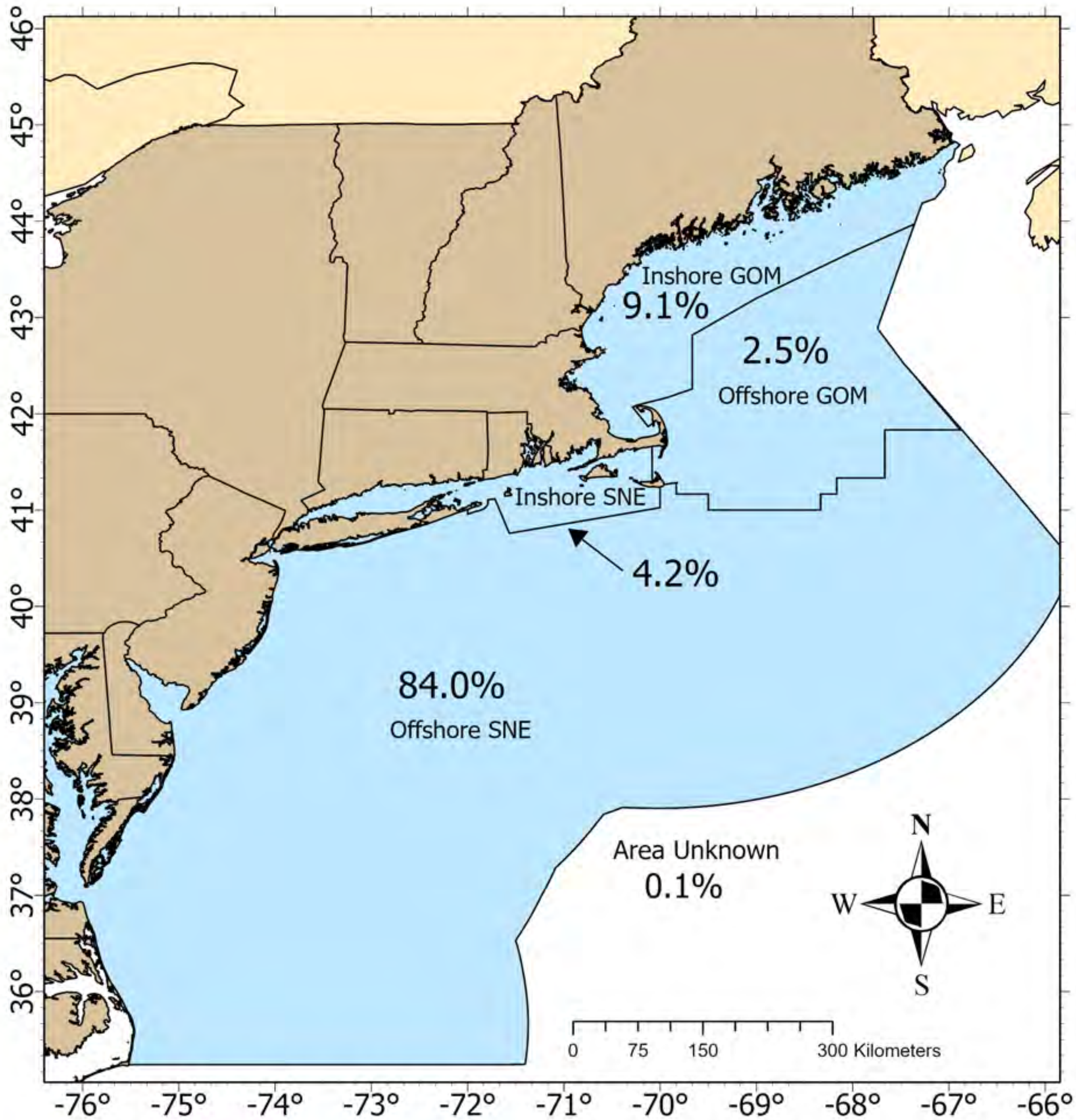

Figure 11. Percent of 2013 U.S. Jonah crab landings by stock area.

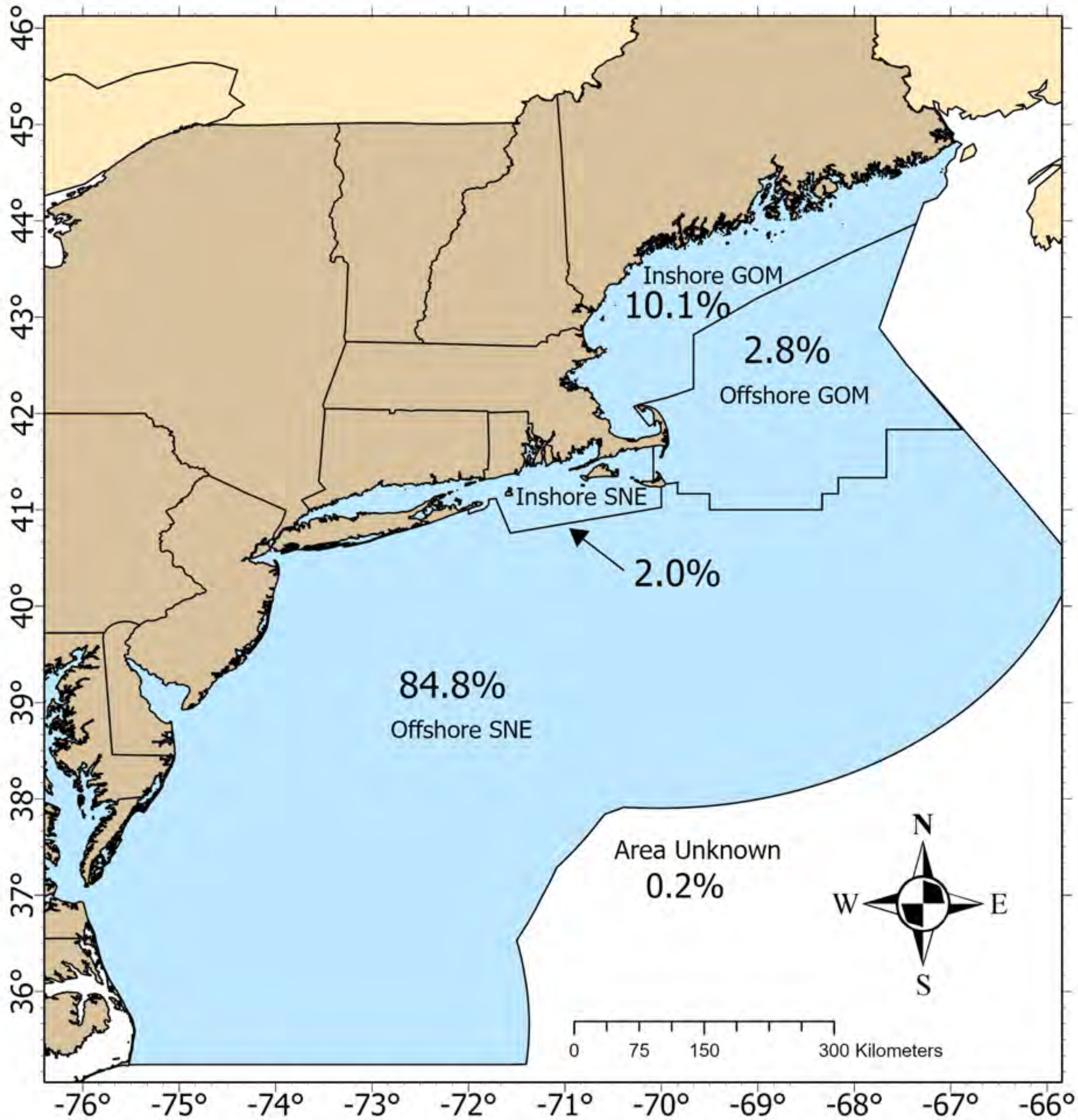

Figure 12. Percent of 2014 U.S. Jonah crab landings by stock area.

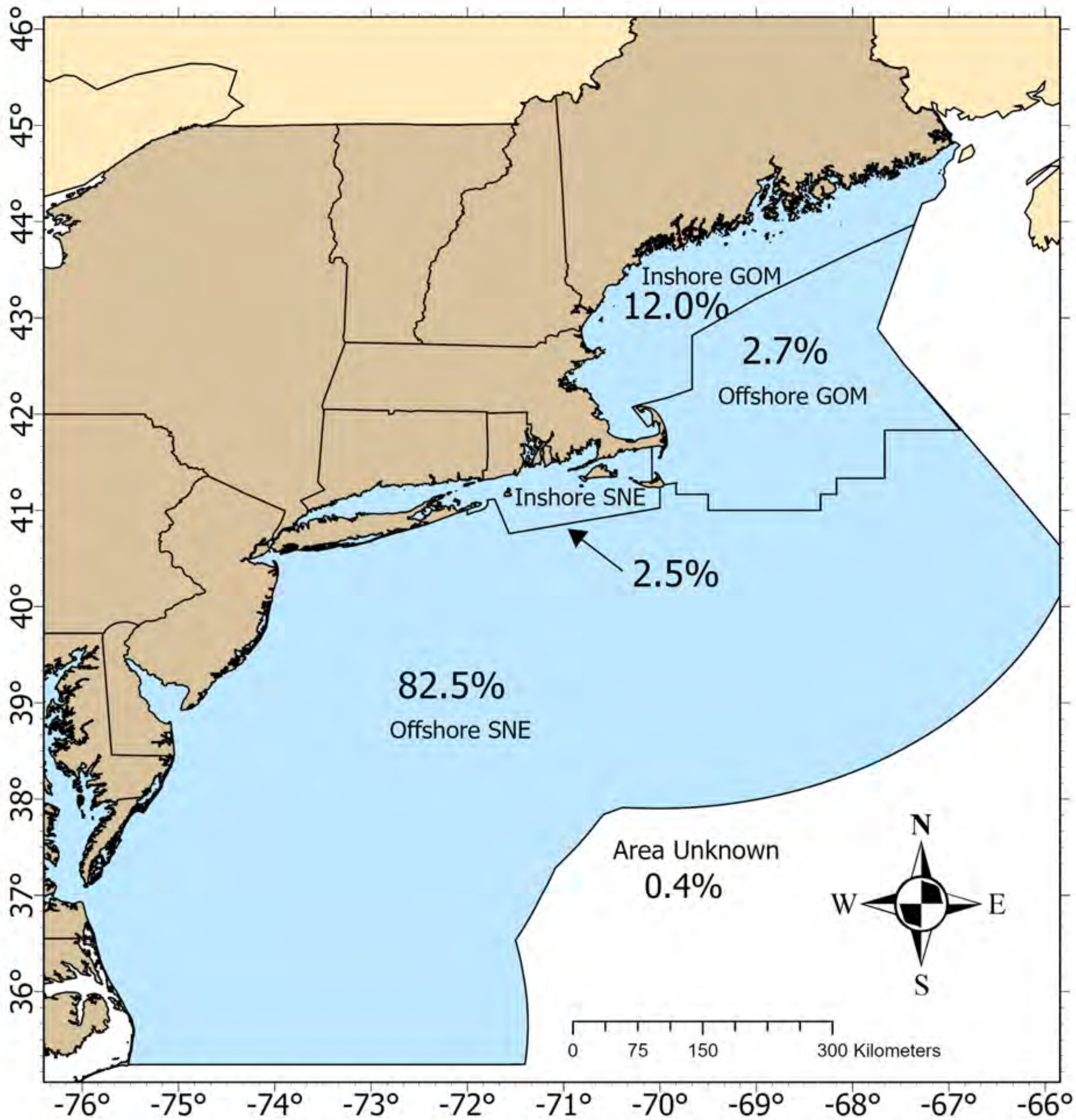

Figure 13. Percent of 2015 U.S. Jonah crab landings by stock area.

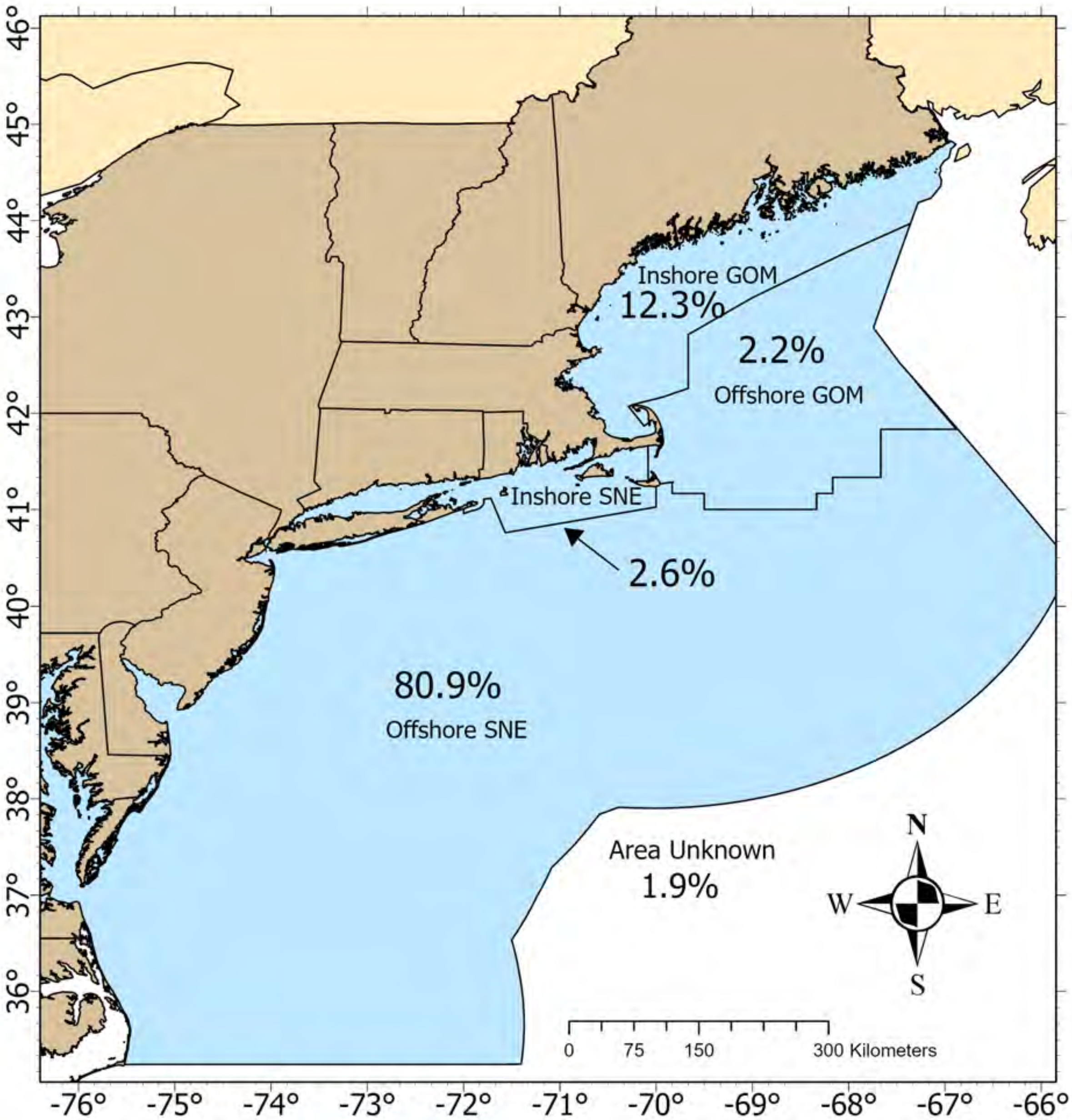

Figure 14. Percent of 2016 U.S. Jonah crab landings by stock area.

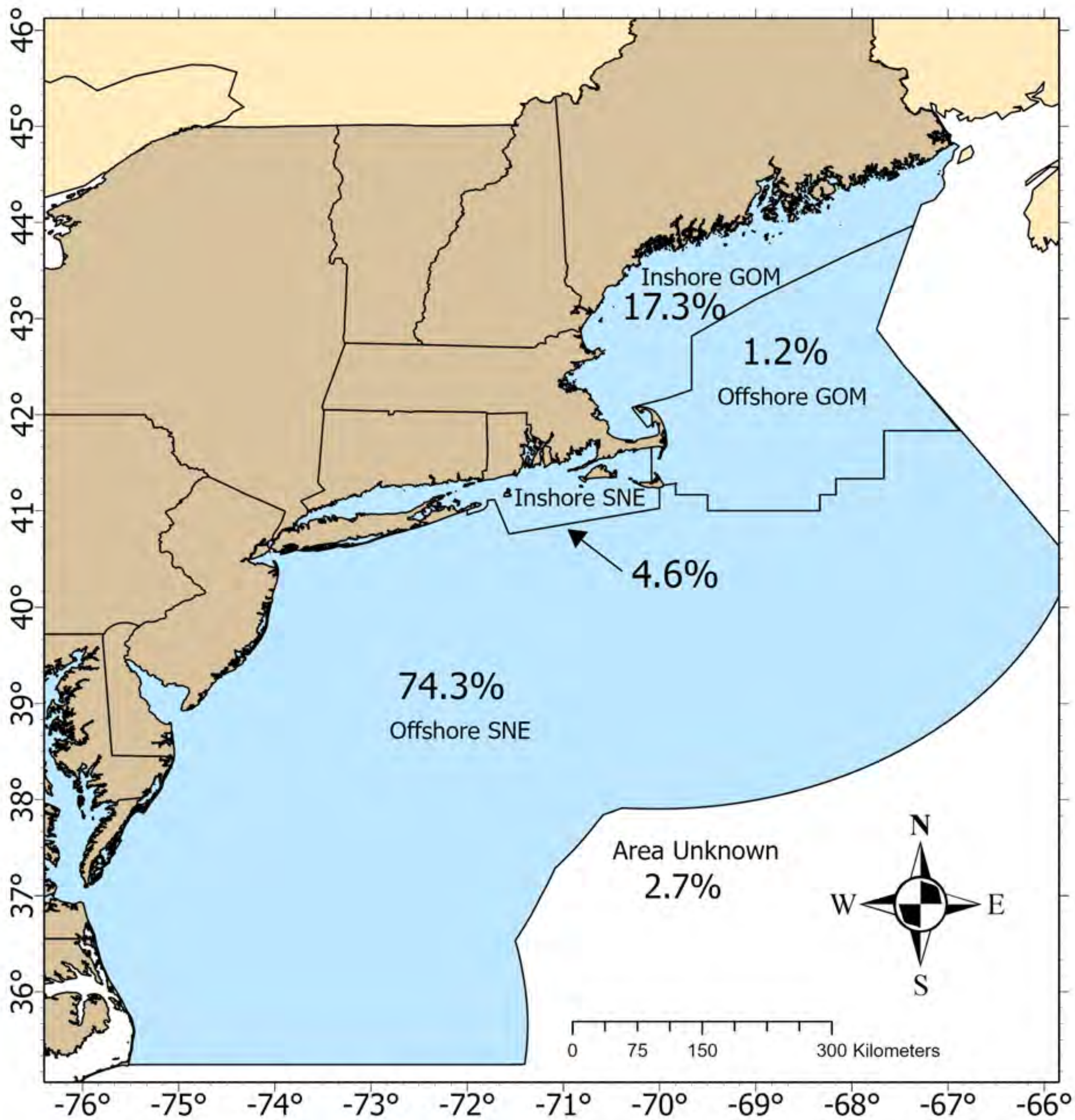

Figure 15. Percent of 2017 U.S. Jonah crab landings by stock area.

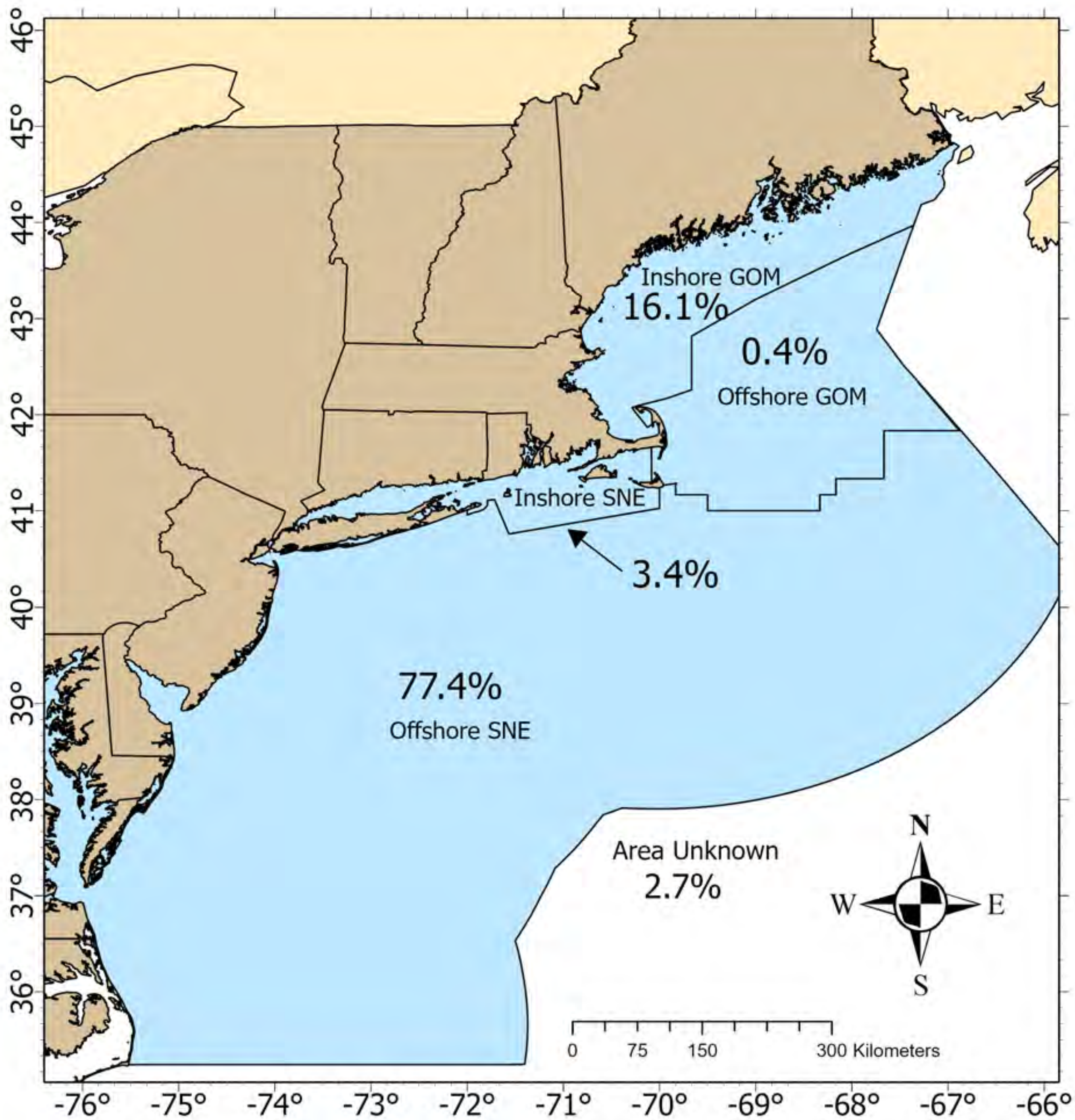

Figure 16. Percent of 2018 U.S. Jonah crab landings by stock area.

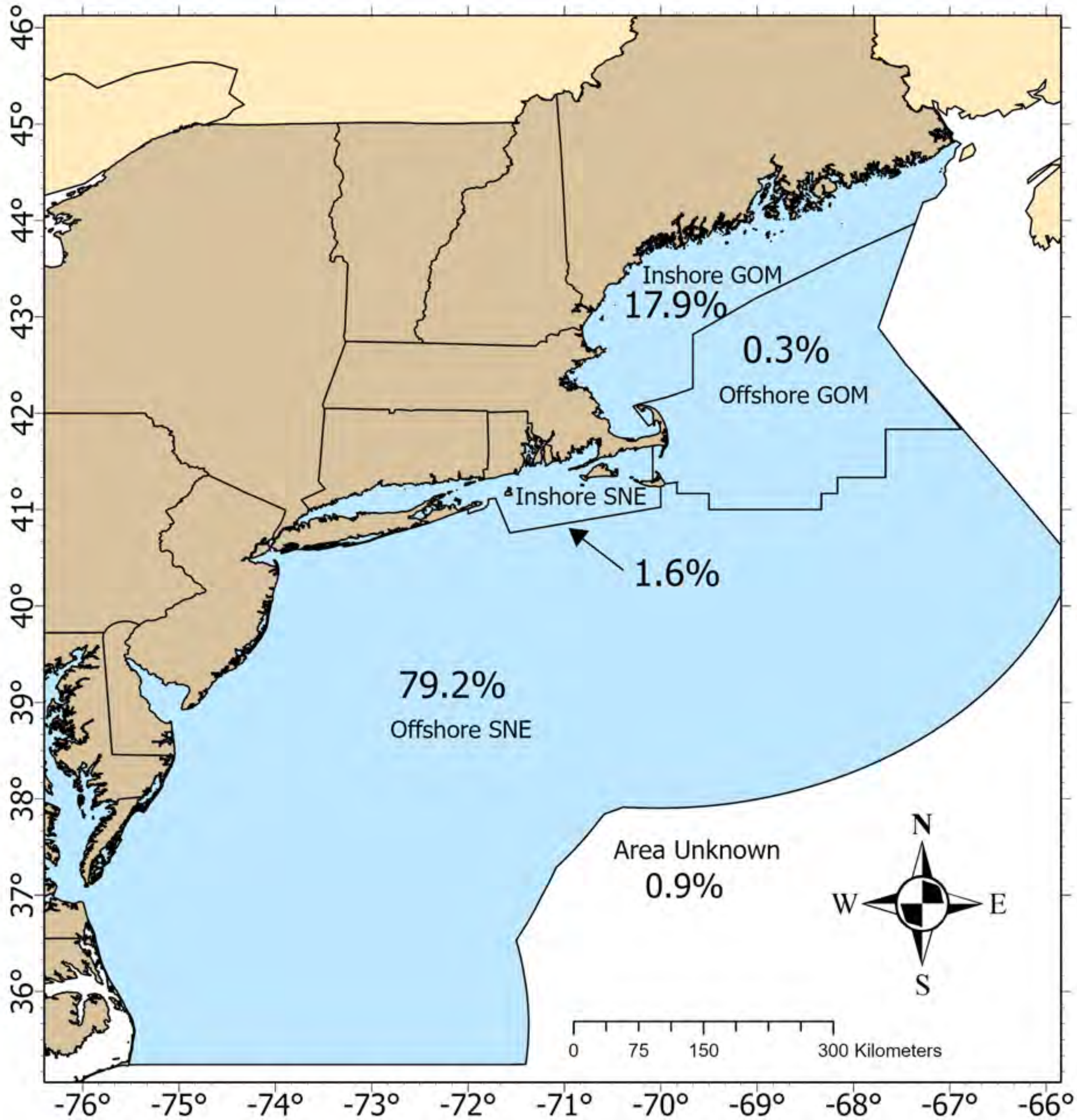

Figure 17. Percent of 2019 U.S. Jonah crab landings by stock area.

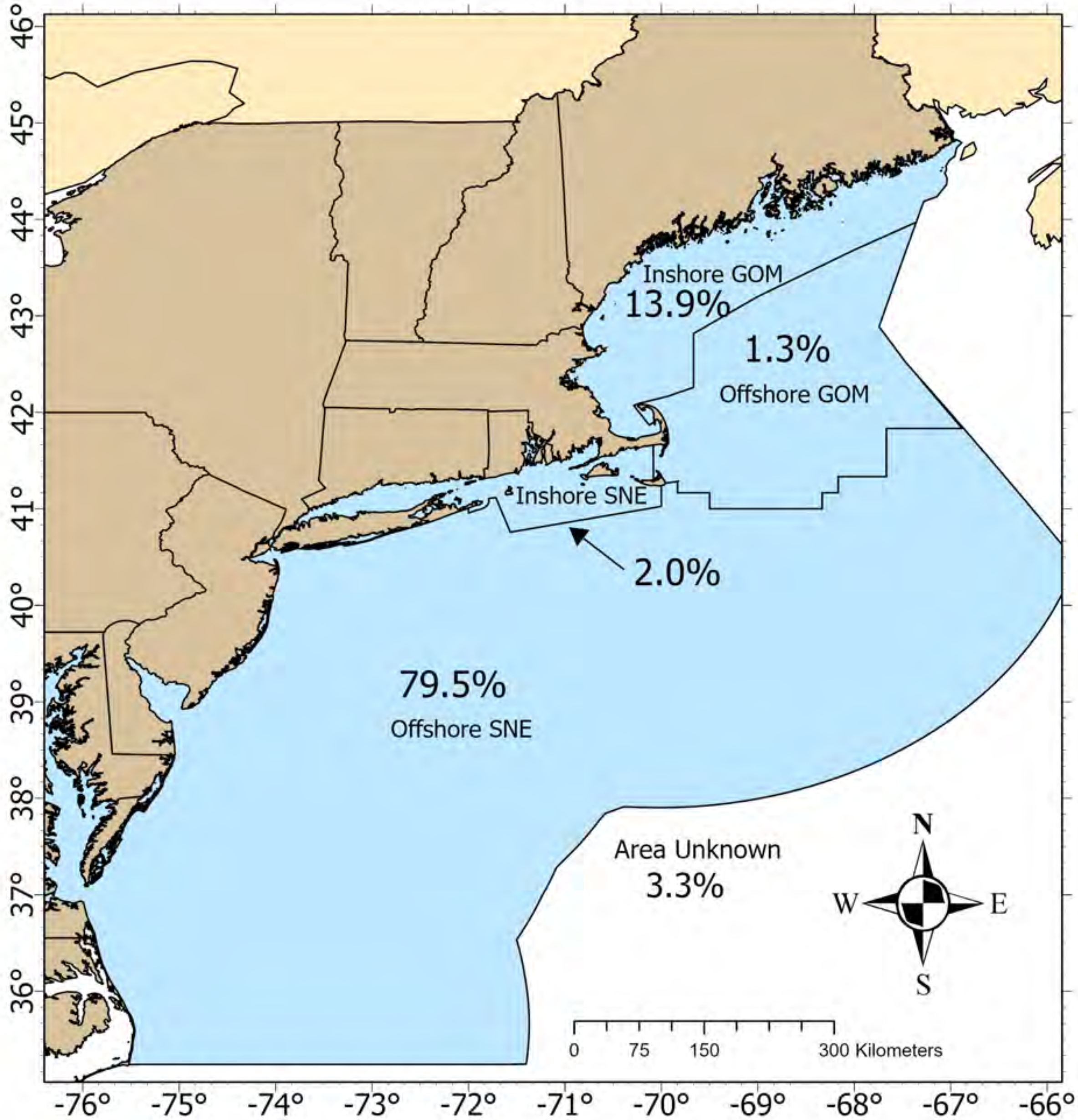

Figure 18. Percent of 2020 U.S. Jonah crab landings by stock area.

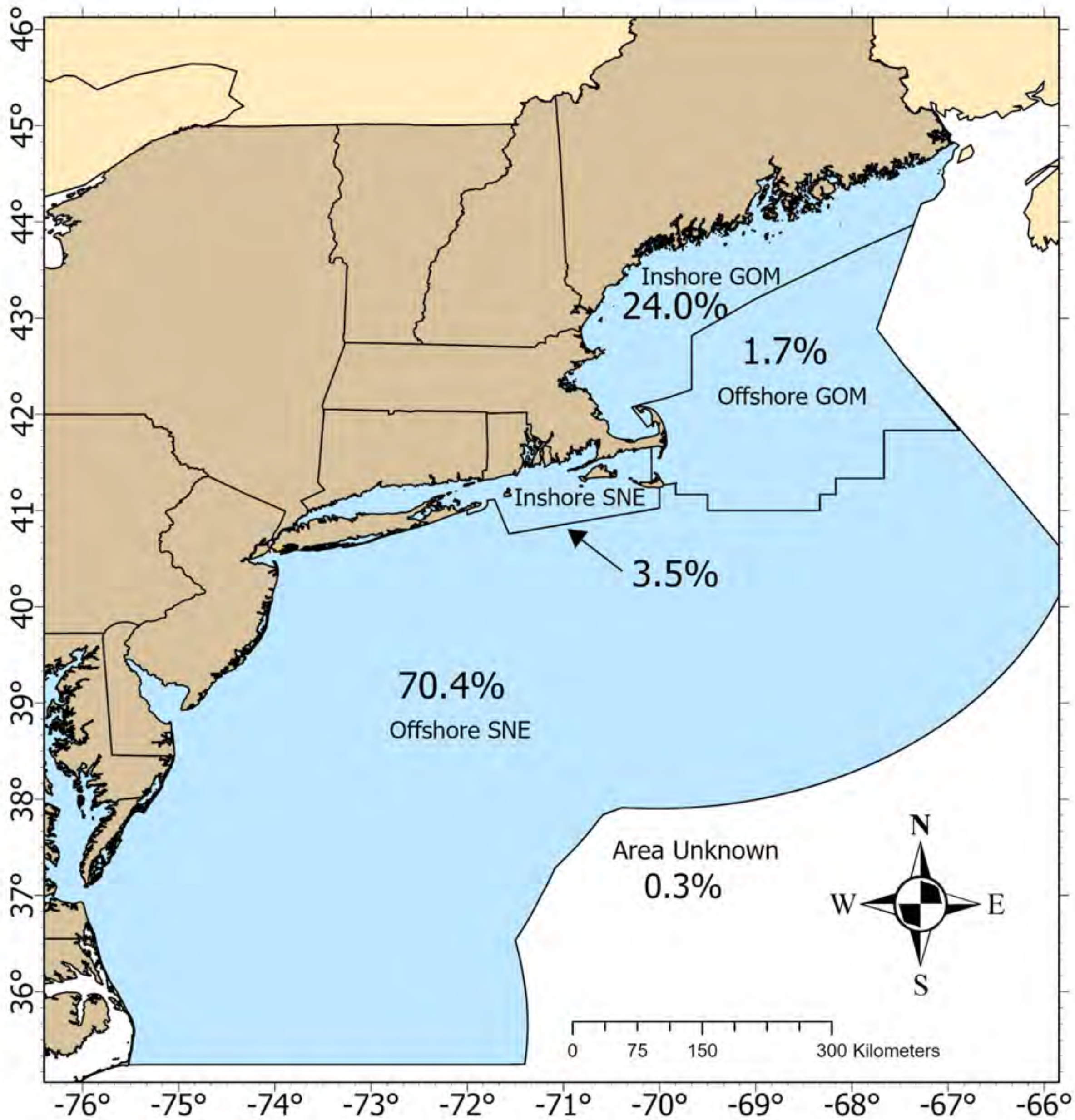

Figure 19. Percent of 2021 U.S. Jonah crab landings by stock area.

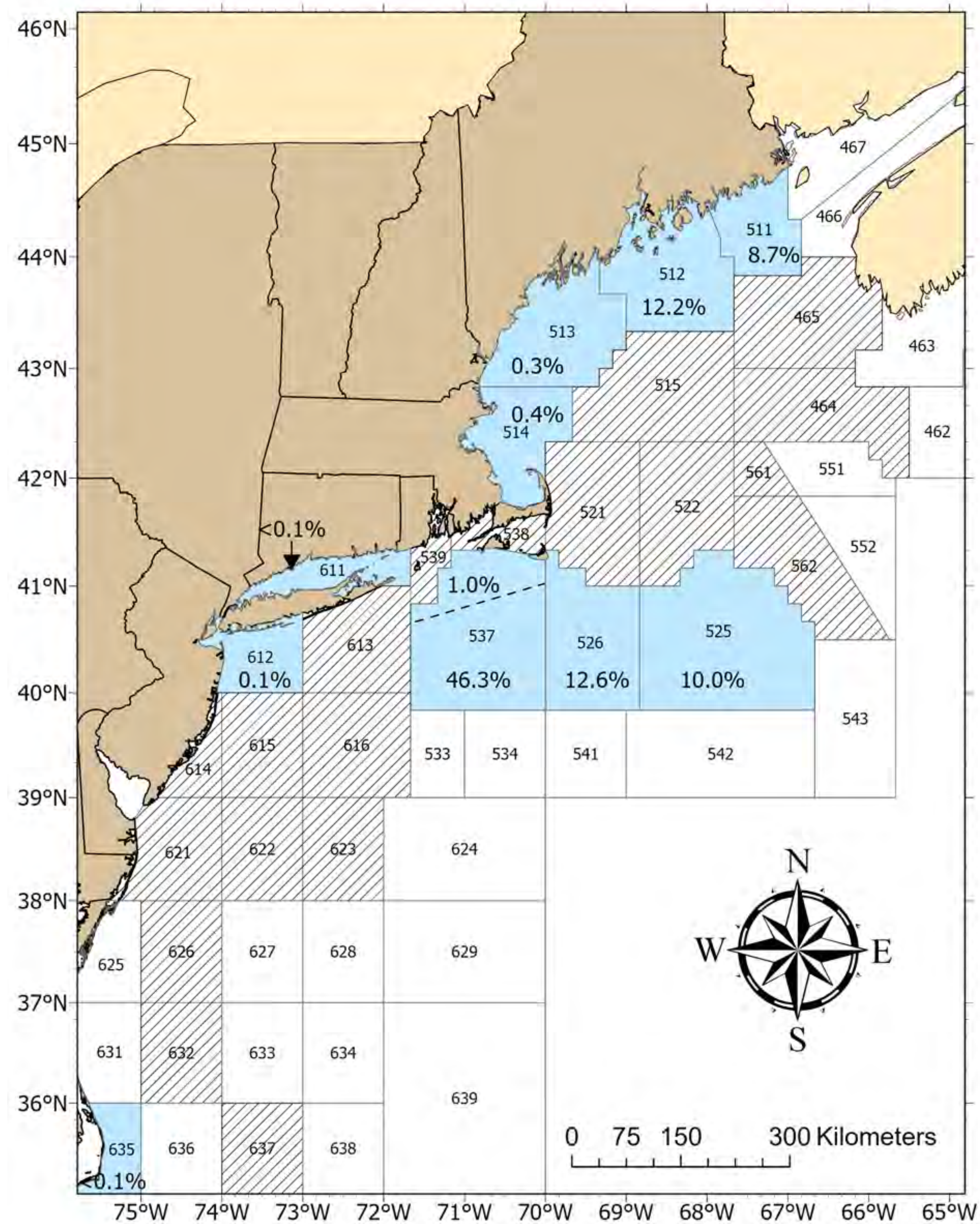

Figure 20. Percent of 2010 U.S. Jonah crab landings by NMFS statistical area. Statistical area 537 is divided (dashed line) into inshore (LMA 2) and offshore (LMA 3) regions. NMFS statistical areas with hash marks represent confidential data (fewer than three fishers reported landings). Areas with no reported landings are white.

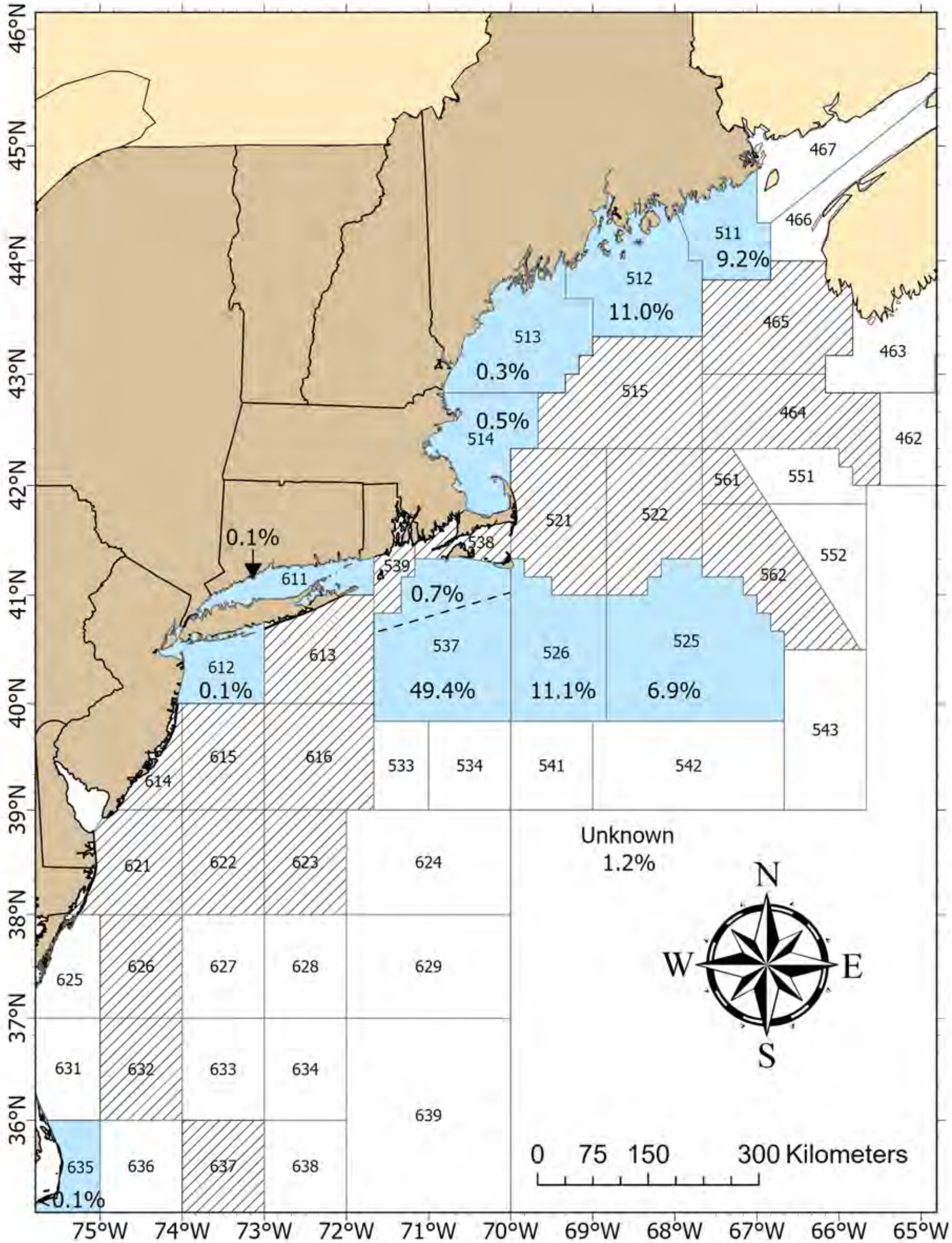

Figure 21. Percent of 2011 U.S. Jonah crab landings by NMFS statistical area. Statistical area 537 is divided (dashed line) into inshore (LMA 2) and offshore (LMA 3) regions. NMFS statistical areas with hash marks represent confidential data (fewer than three fishers reported landings). Areas with no reported landings are white.

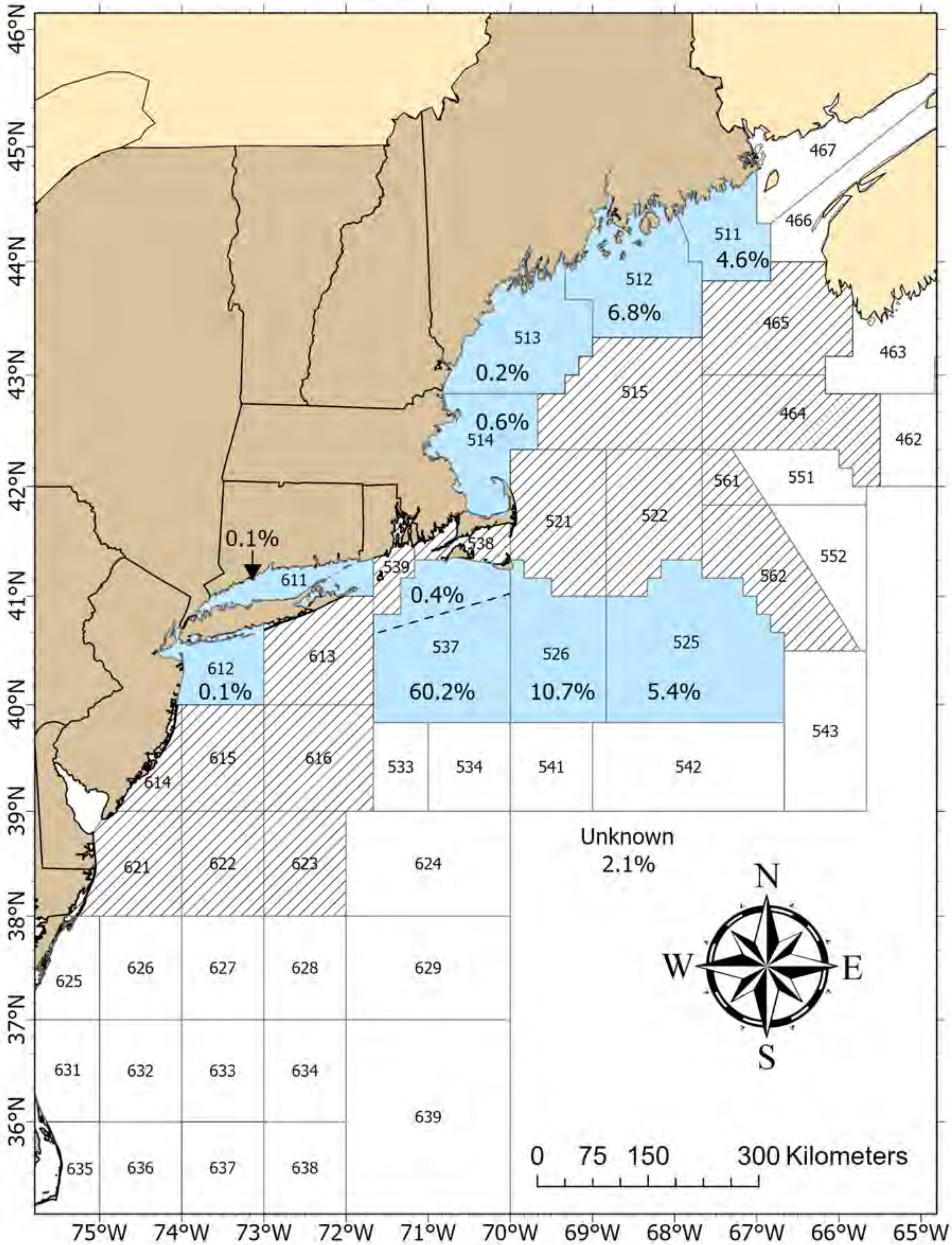

Figure 22. Percent of 2012 U.S. Jonah crab landings by NMFS statistical area. Statistical area 537 is divided (dashed line) into inshore (LMA 2) and offshore (LMA 3) regions. NMFS statistical areas with hash marks represent confidential data (fewer than three fishers reported landings). Areas with no reported landings are white.

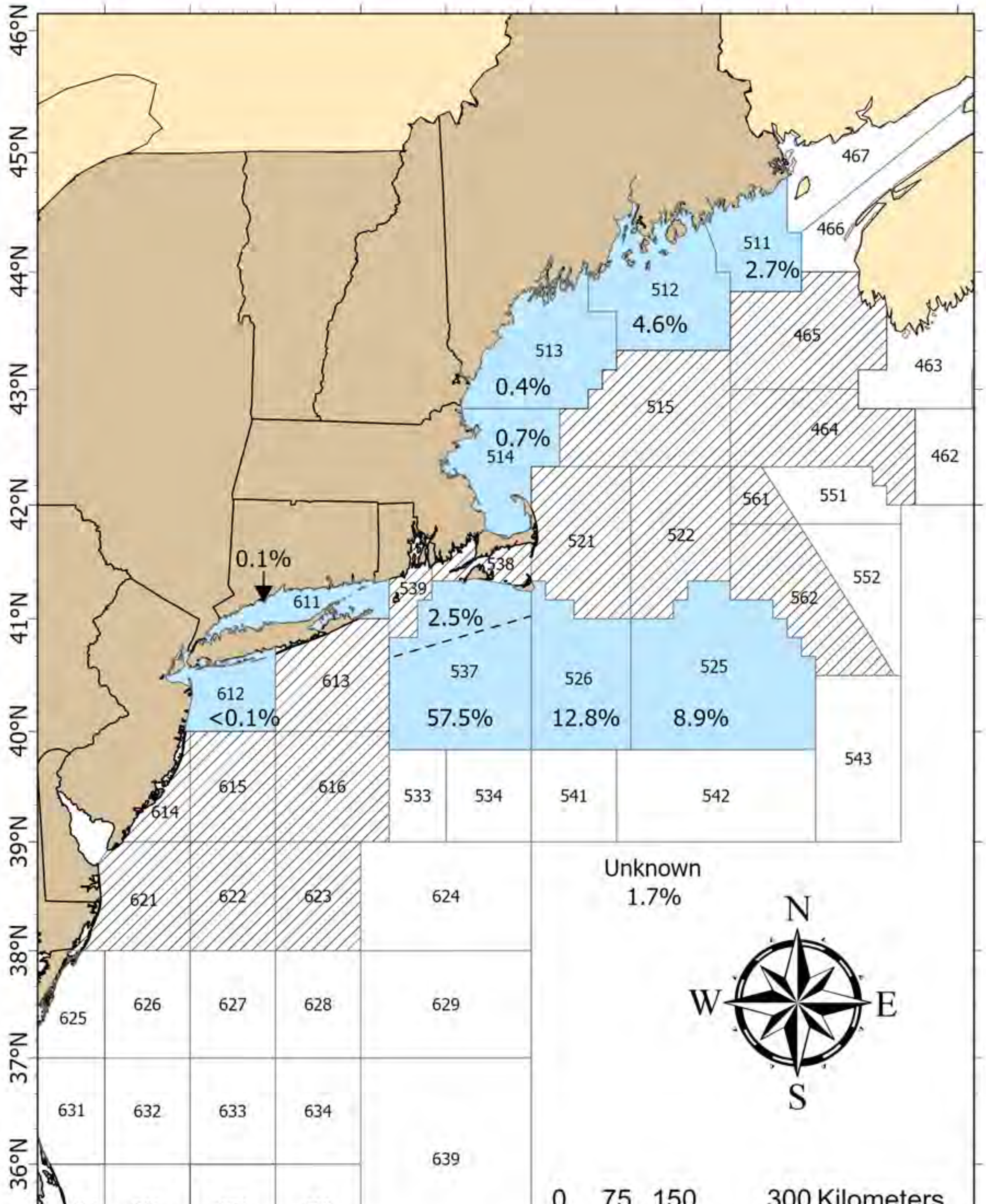

Figure 23. Percent of 2013 U.S. Jonah crab landings by NMFS statistical area. Statistical area 537 is divided (dashed line) into inshore (LMA 2) and offshore (LMA 3) regions. NMFS statistical areas with hash marks represent confidential data (fewer than three fishers reported landings). Areas with no reported landings are white.

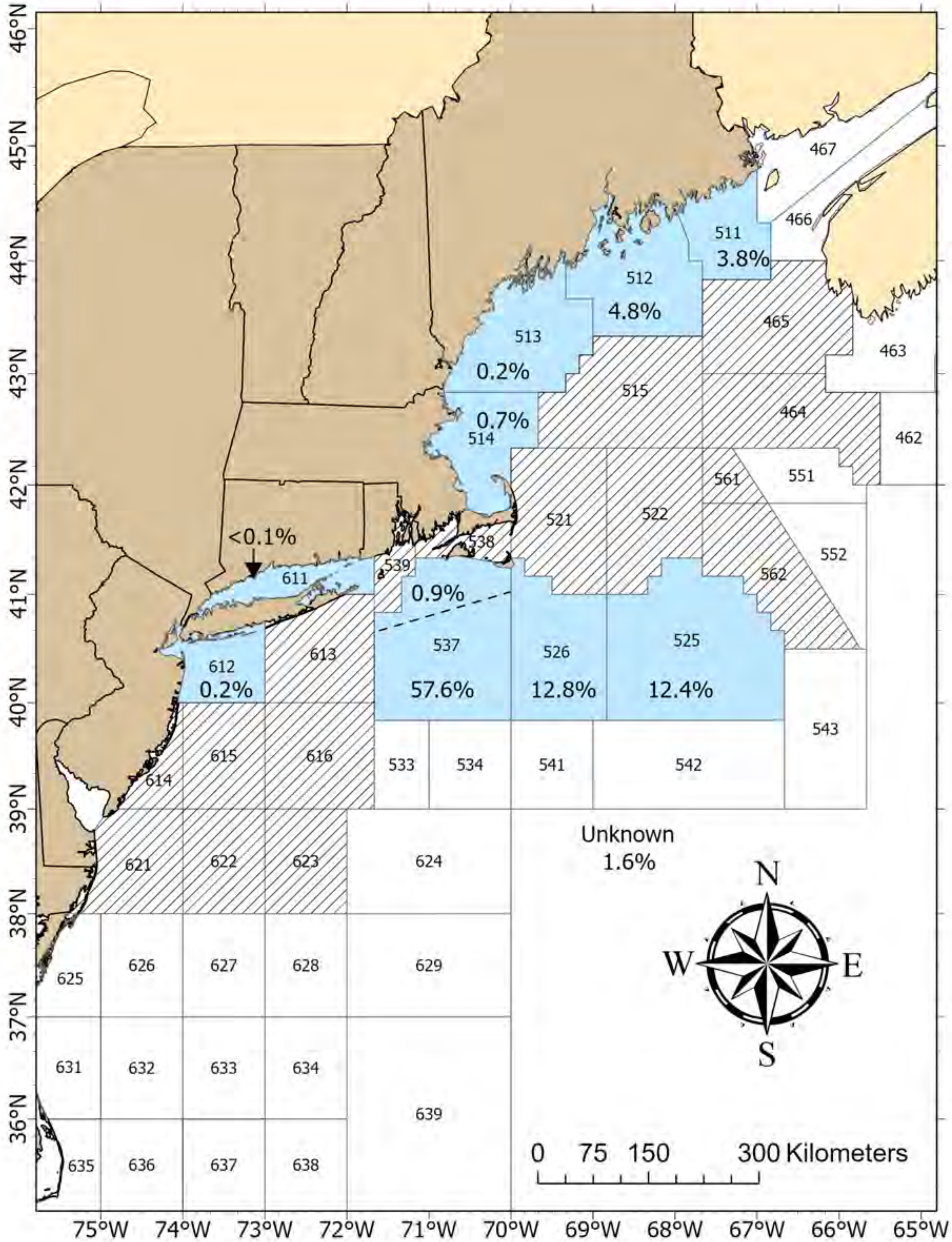

Figure 24. Percent of 2014 U.S. Jonah crab landings by NMFS statistical area. Statistical area 537 is divided (dashed line) into inshore (LMA 2) and offshore (LMA 3) regions. NMFS statistical areas with hash marks represent confidential data (fewer than three fishers reported landings). Areas with no reported landings are white.

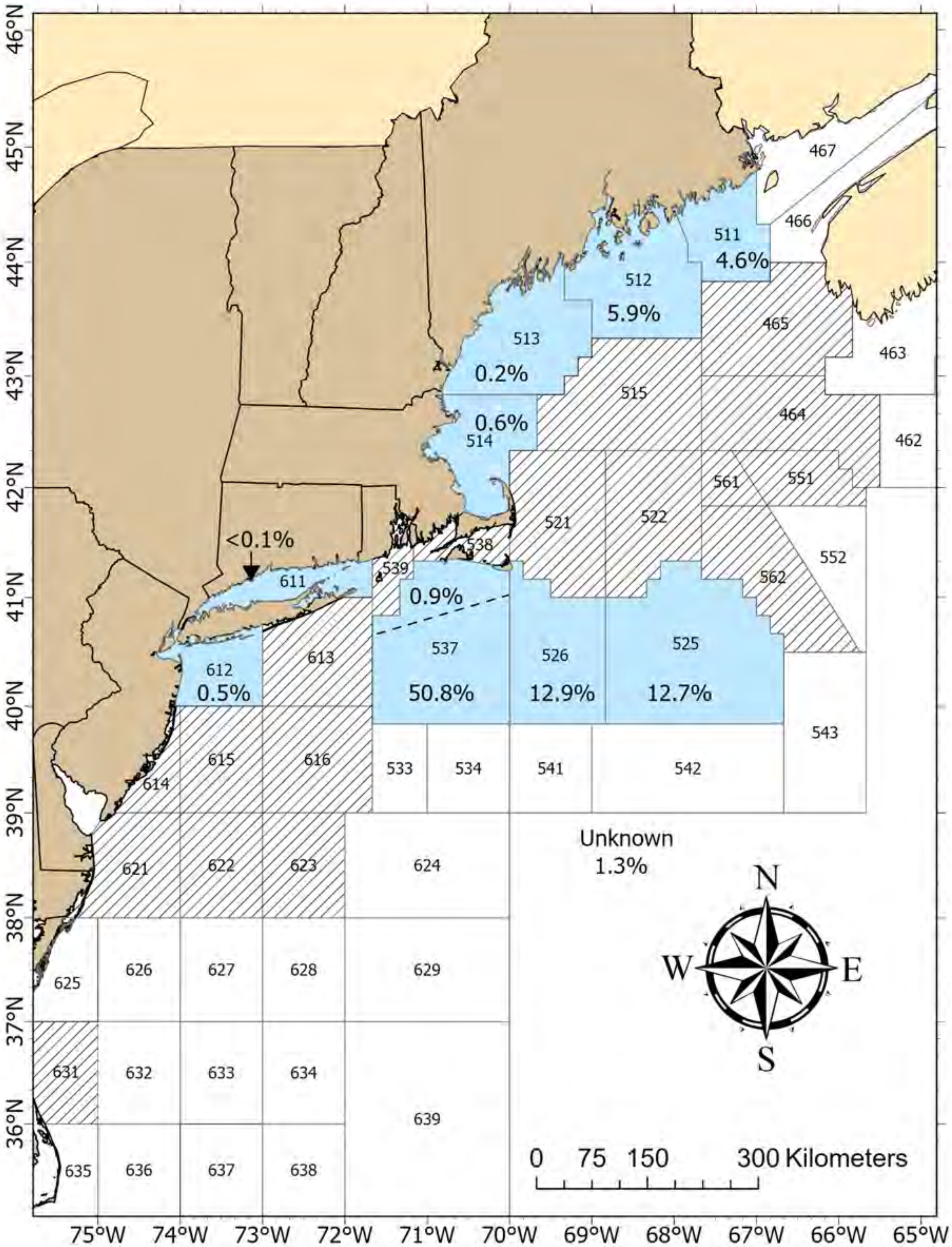

Figure 25. Percent of 2015 U.S. Jonah crab landings by NMFS statistical area. Statistical area 537 is divided (dashed line) into inshore (LMA 2) and offshore (LMA 3) regions. NMFS statistical areas with hash marks represent confidential data (fewer than three fishers reported landings). Areas with no reported landings are white.

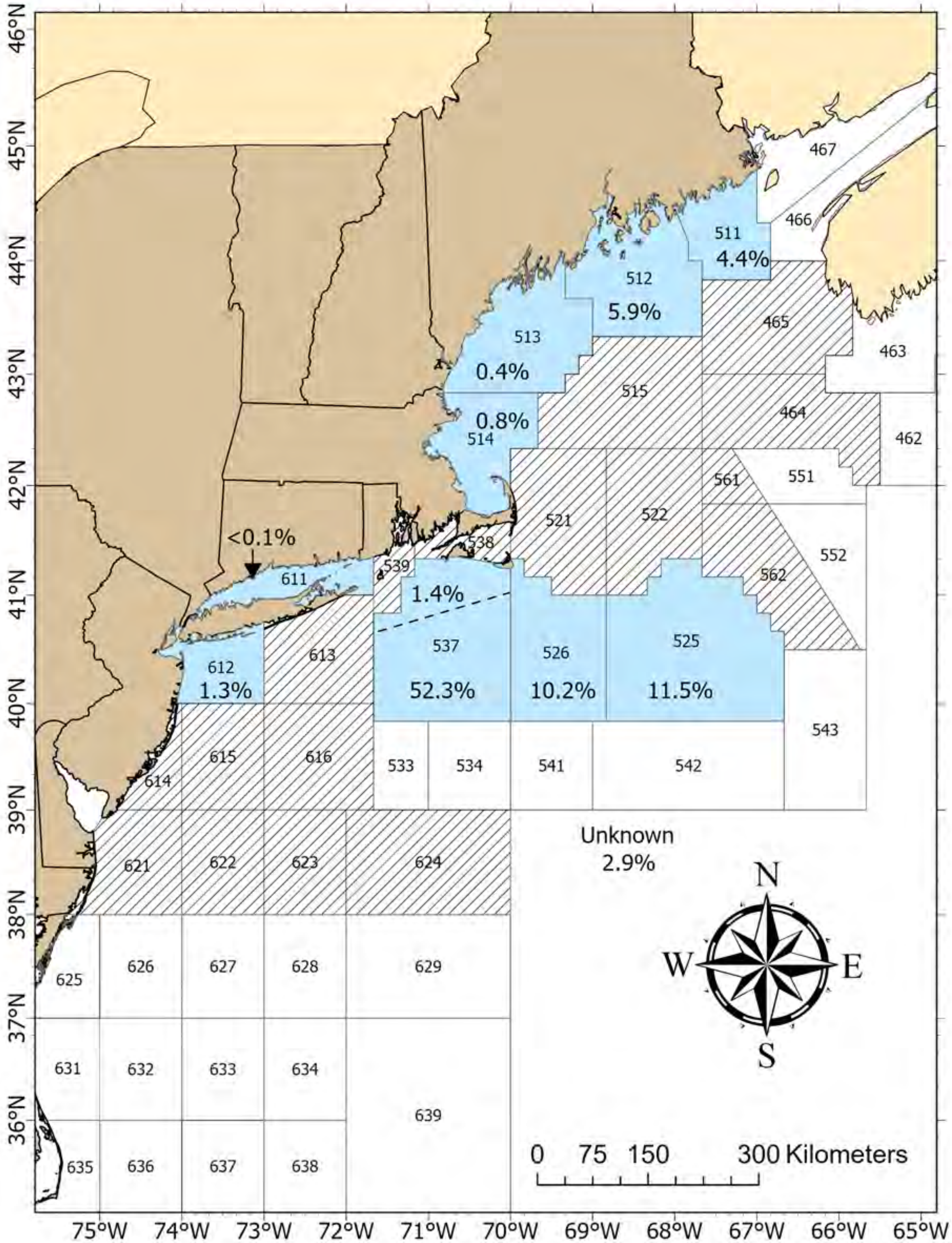

Figure 26. Percent of 2016 U.S. Jonah crab landings by NMFS statistical area. Statistical area 537 is divided (dashed line) into inshore (LMA 2) and offshore (LMA 3) regions. NMFS statistical areas with hash marks represent confidential data (fewer than three fishers reported landings). Areas with no reported landings are white.

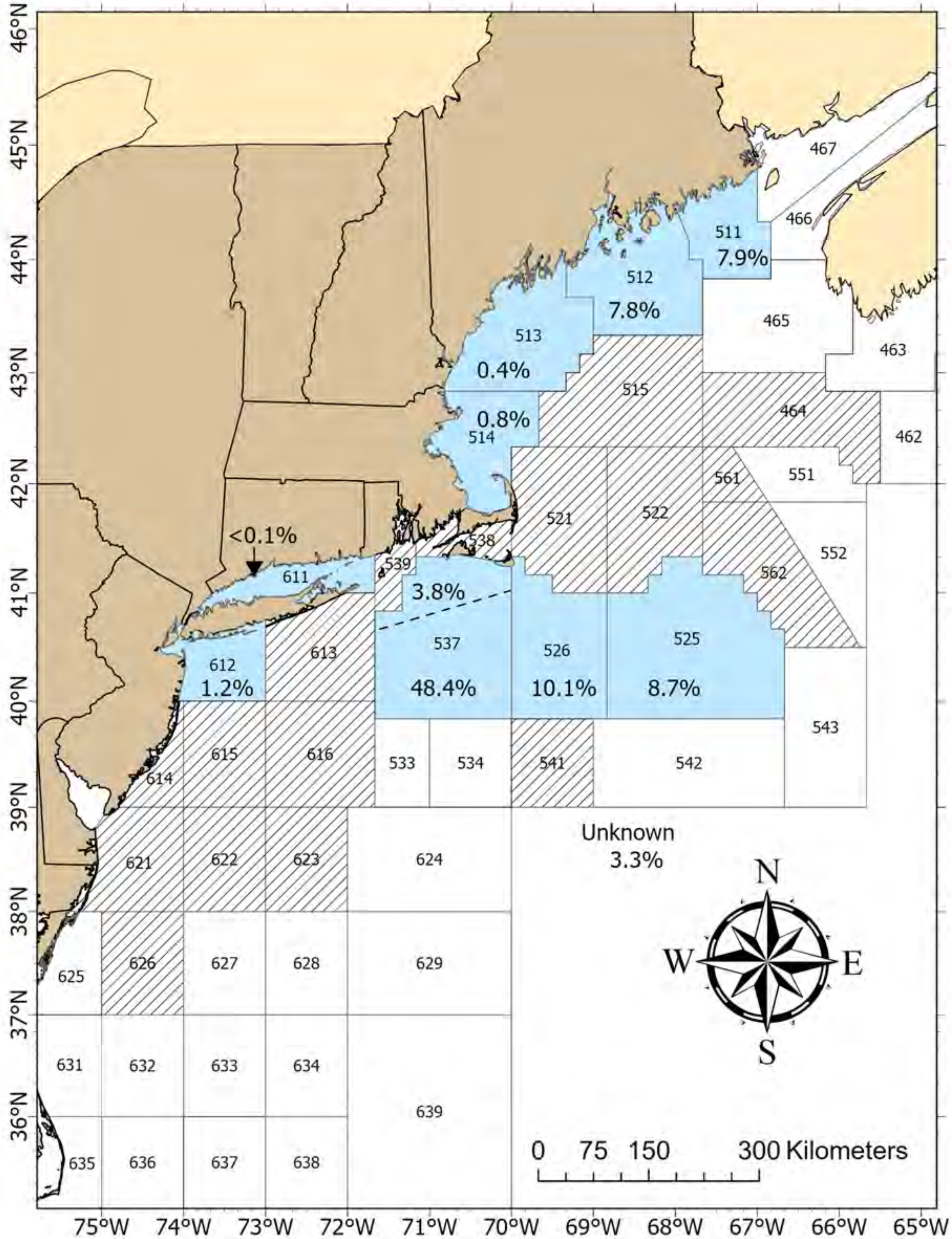

Figure 27. Percent of 2017 U.S. Jonah crab landings by NMFS statistical area. Statistical area 537 is divided (dashed line) into inshore (LMA 2) and offshore (LMA 3) regions. NMFS statistical areas with hash marks represent confidential data (fewer than three fishers reported landings). Areas with no reported landings are white.

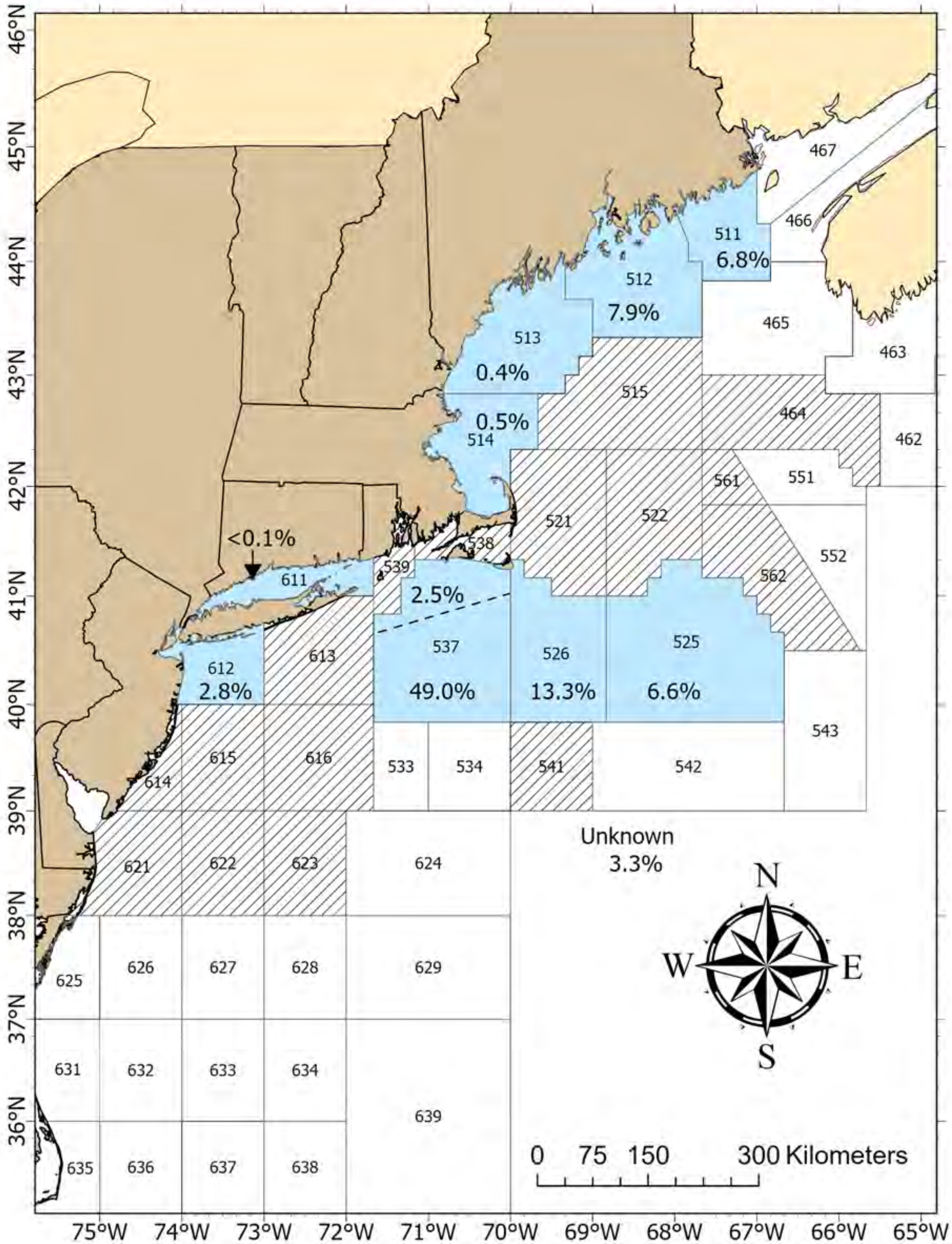

Figure 28. Percent of 2018 U.S. Jonah crab landings by NMFS statistical area. Statistical area 537 is divided (dashed line) into inshore (LMA 2) and offshore (LMA 3) regions. NMFS statistical areas with hash marks represent confidential data (fewer than three fishers reported landings). Areas with no reported landings are white.

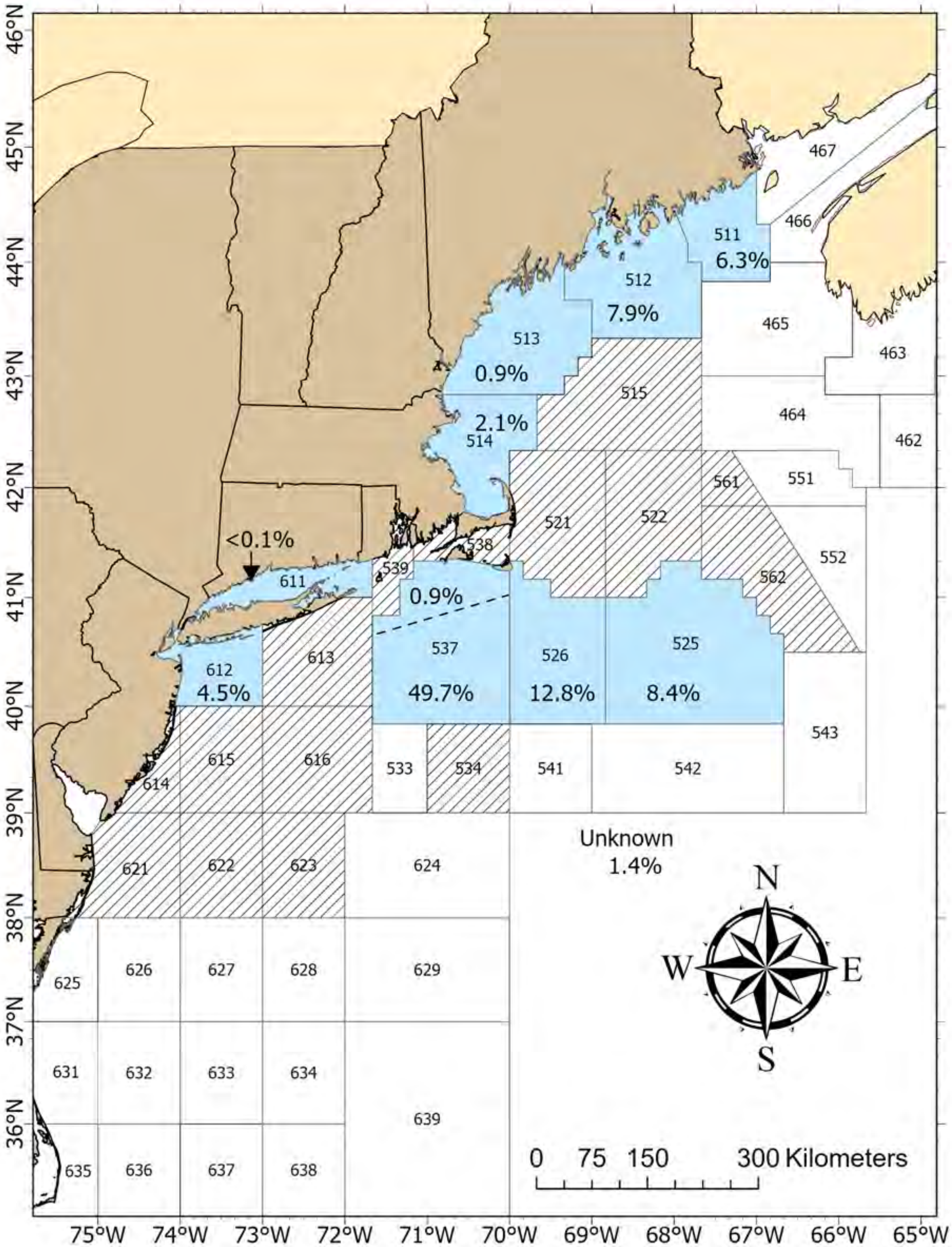

Figure 29. Percent of 2019 U.S. Jonah crab landings by NMFS statistical area. Statistical area 537 is divided (dashed line) into inshore (LMA 2) and offshore (LMA 3) regions. NMFS statistical areas with hash marks represent confidential data (fewer than three fishers reported landings). Areas with no reported landings are white.

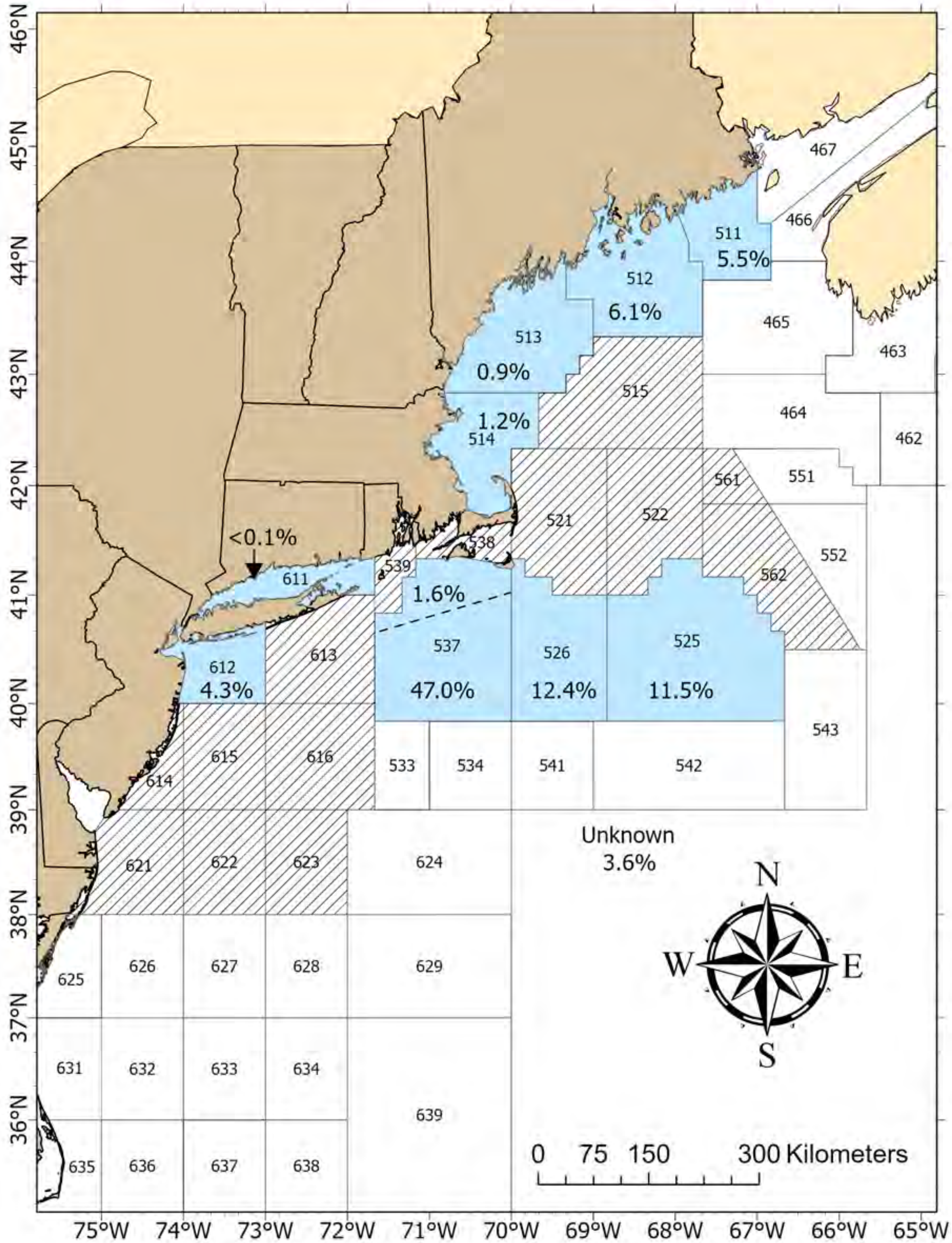

Figure 30. Percent of 2020 U.S. Jonah crab landings by NMFS statistical area. Statistical area 537 is divided (dashed line) into inshore (LMA 2) and offshore (LMA 3) regions. NMFS statistical areas with hash marks represent confidential data (fewer than three fishers reported landings). Areas with no reported landings are white.

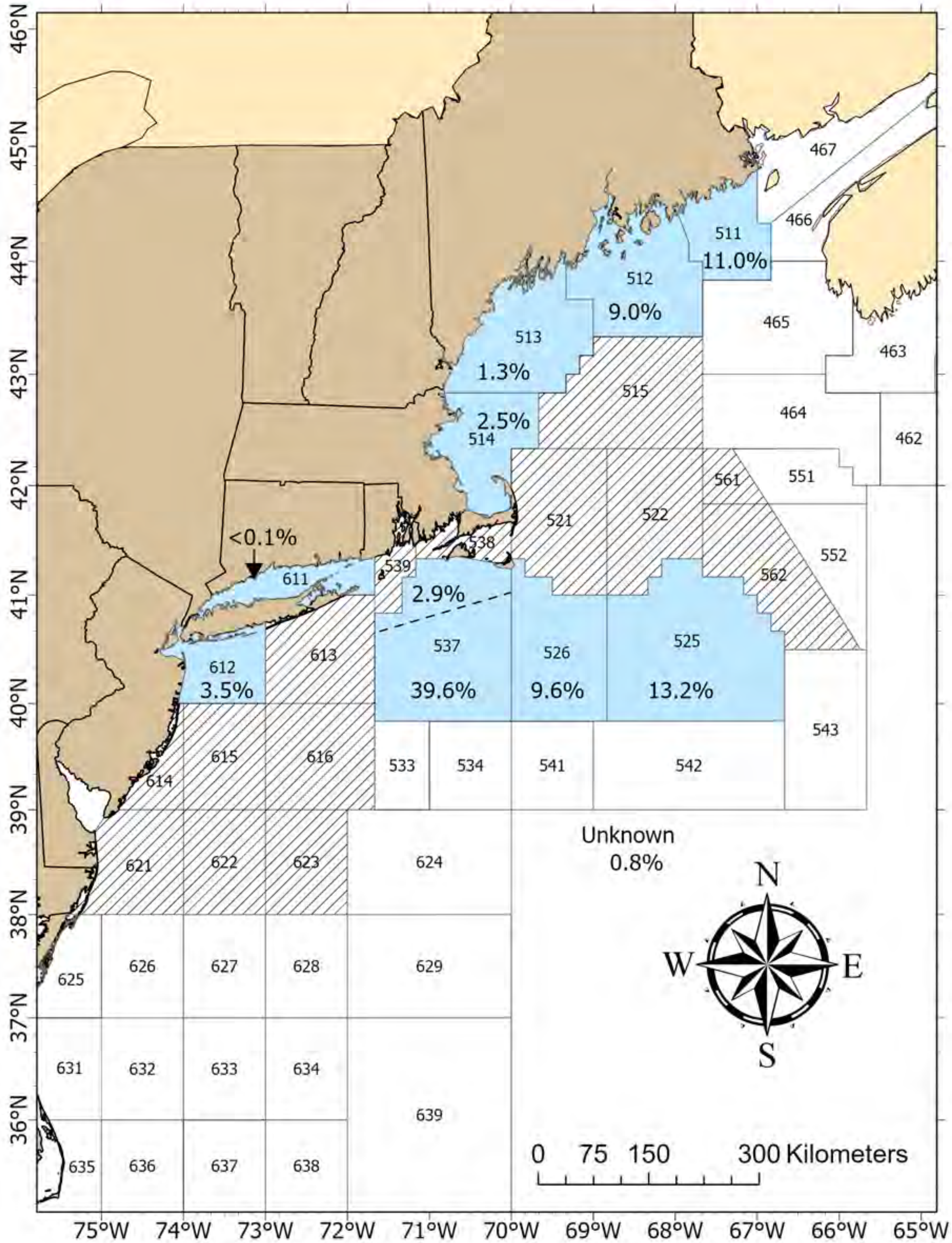

Figure 31. Percent of 2021 U.S. Jonah crab landings by NMFS statistical area. Statistical area 537 is divided (dashed line) into inshore (LMA 2) and offshore (LMA 3) regions. NMFS statistical areas with hash marks represent confidential data (fewer than three fishers reported landings). Areas with no reported landings are white.

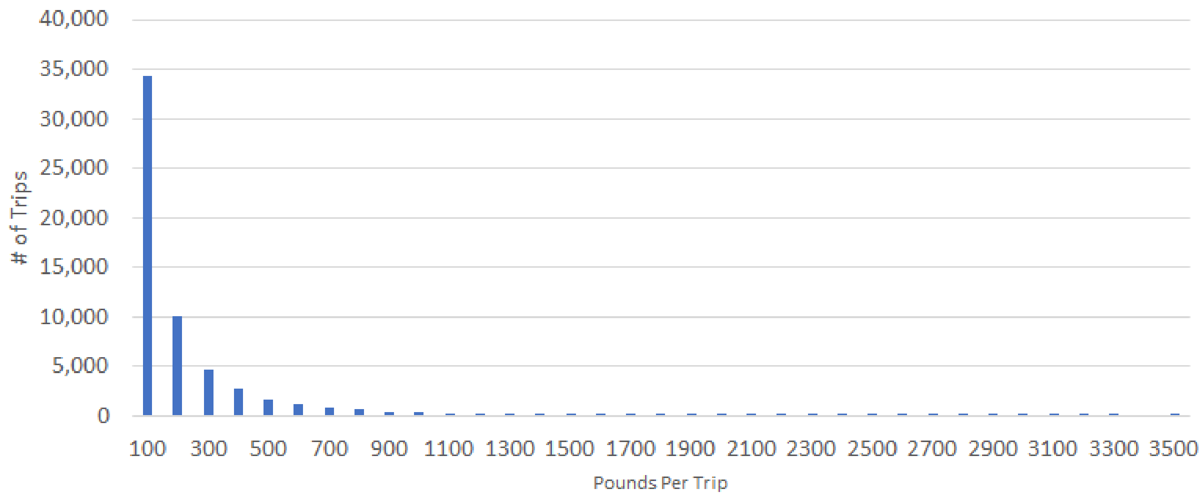

Figure 32. Landings per trip of Jonah crab for Maine trips, all ME trips landing Jonah crab, 2018-2021.

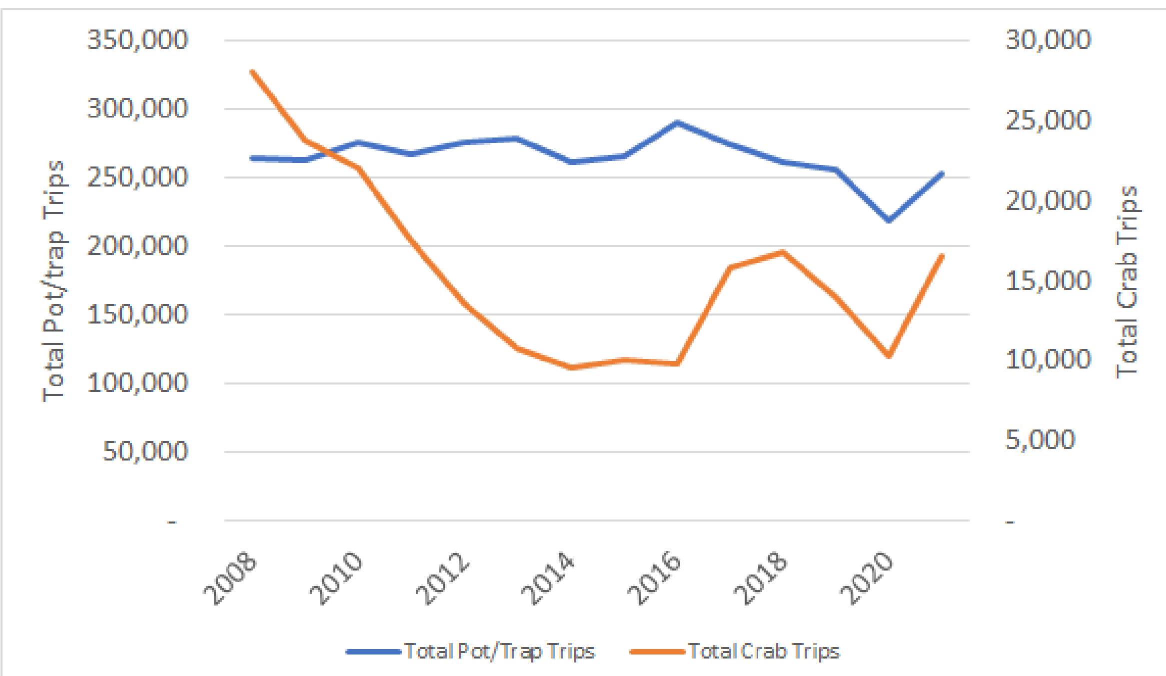

Figure 33. Total active trap/pot trips and total trips with Jonah crab 2008-2021.

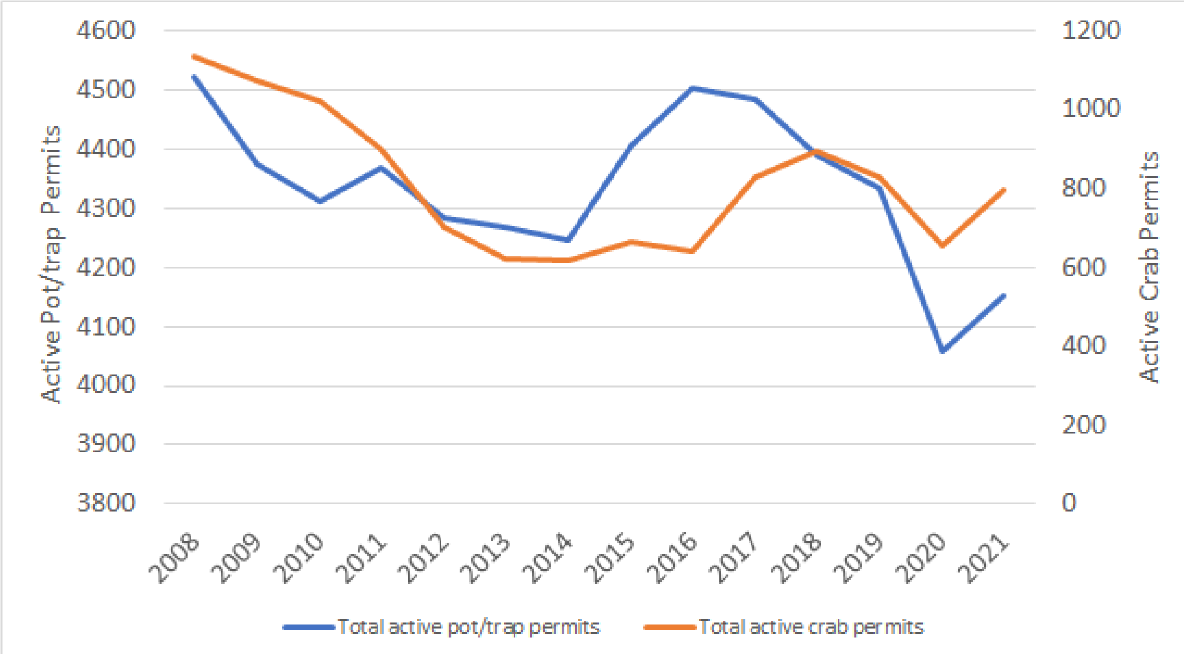

Figure 34. Total active trap/pot permits and active permits landing Jonah crab 2008-2021.

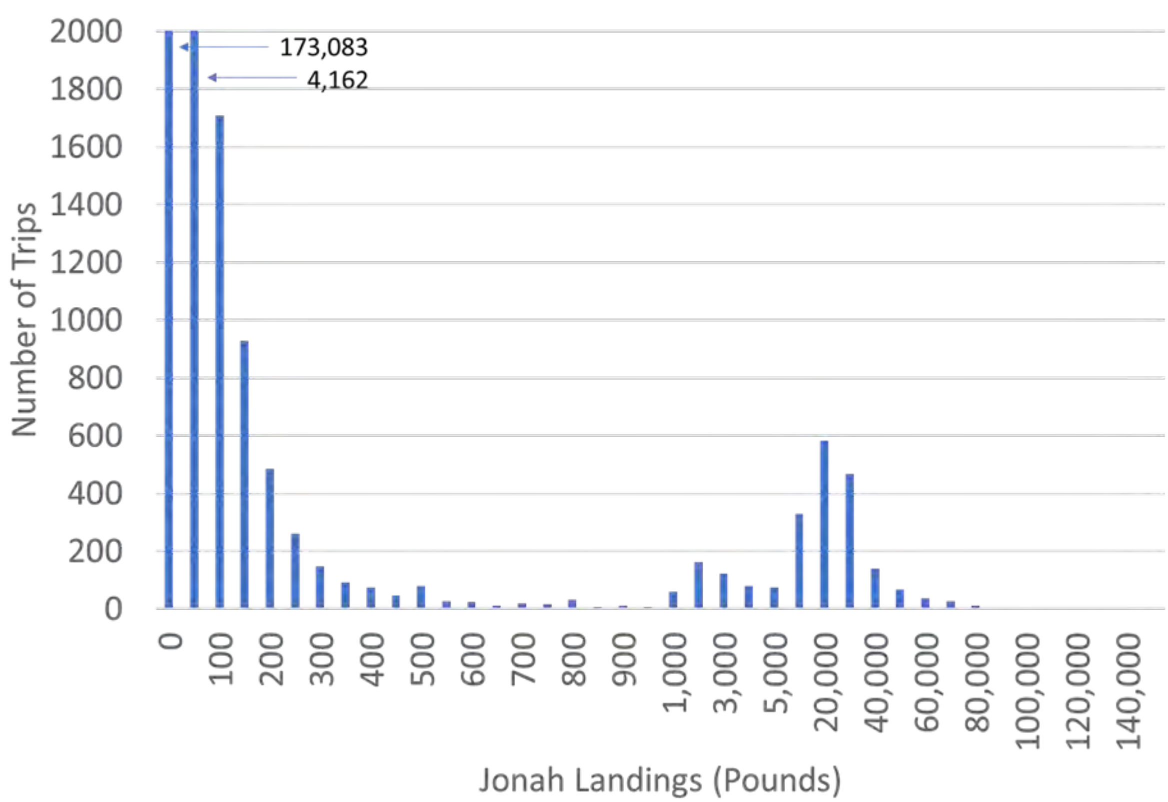

Figure 35. Number of Massachusetts lobster/edible crab pot trips landings Jonah crab pooled from 2018 through 2021. X-axis is discontinuous to account for high variability of trips with greater landings.

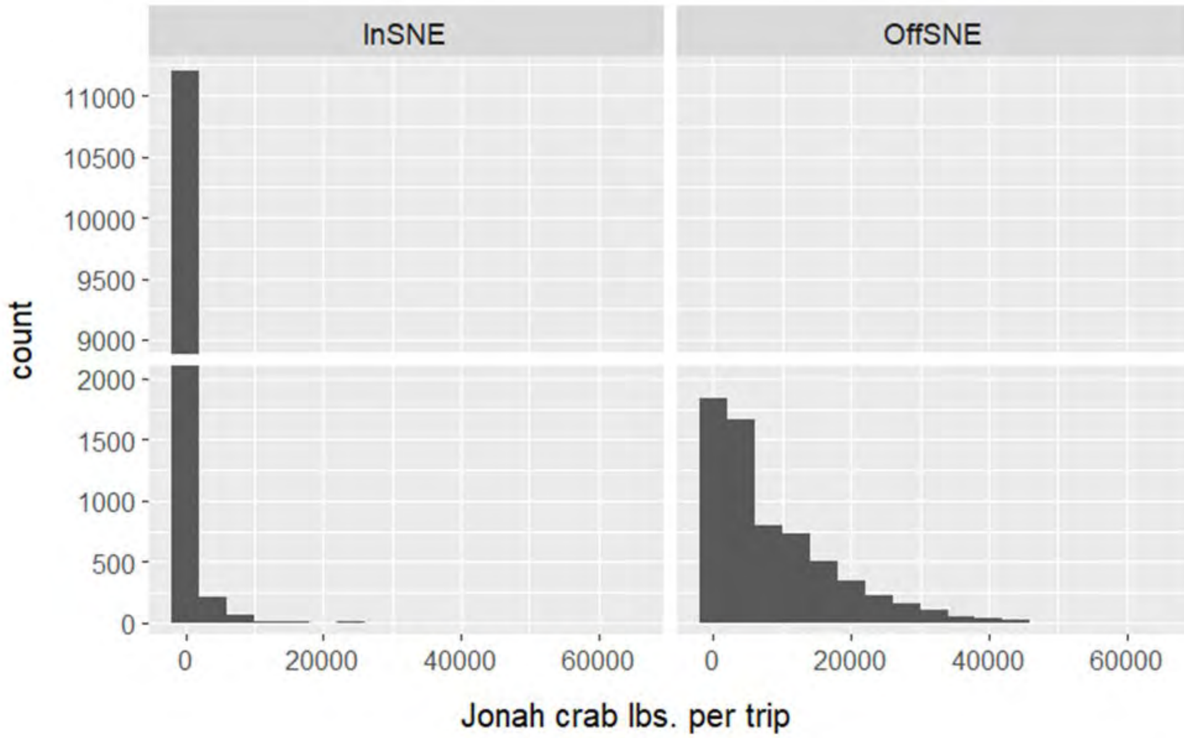

Figure 36. Histogram of landings per trip of Jonah crab for Rhode Island Inshore SNE and Offshore SNE trips, all RI trips landing Jonah crab, 2007-2021.

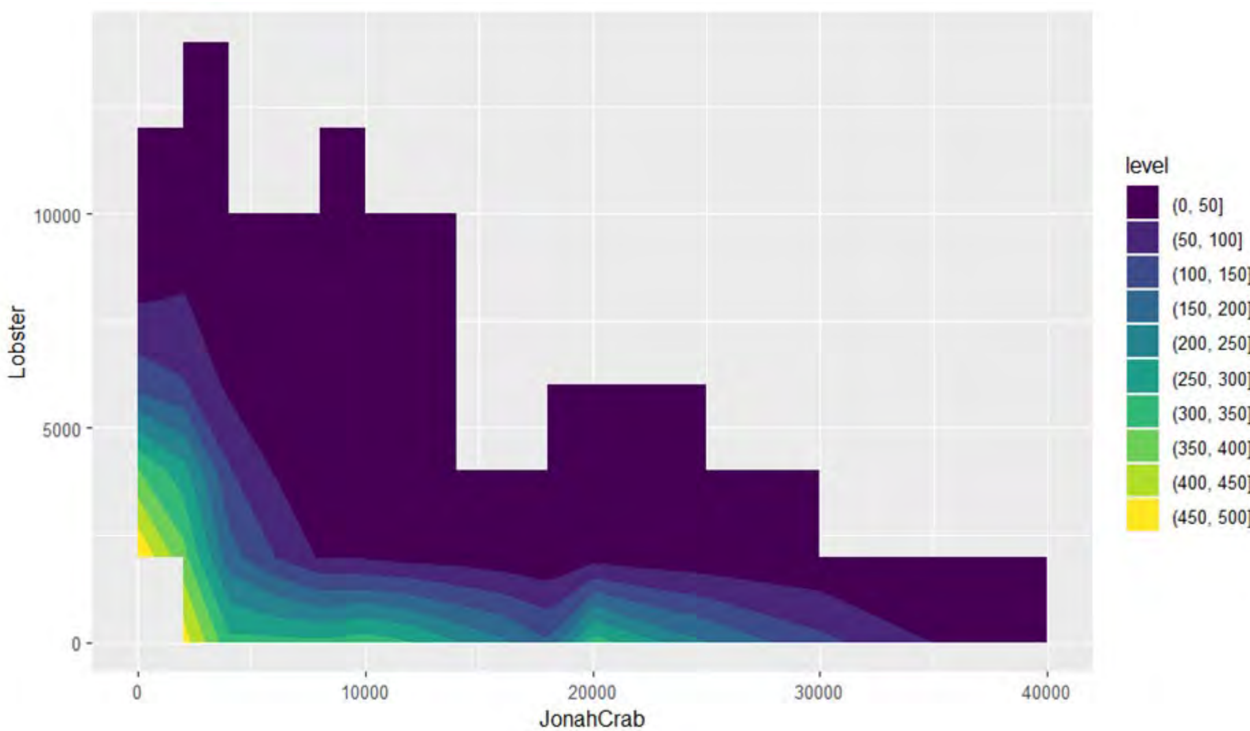

Figure 37. Density plot of Jonah crab versus lobster landings, all trips landing more than 500 lb. Jonah crab, 2007-2021.

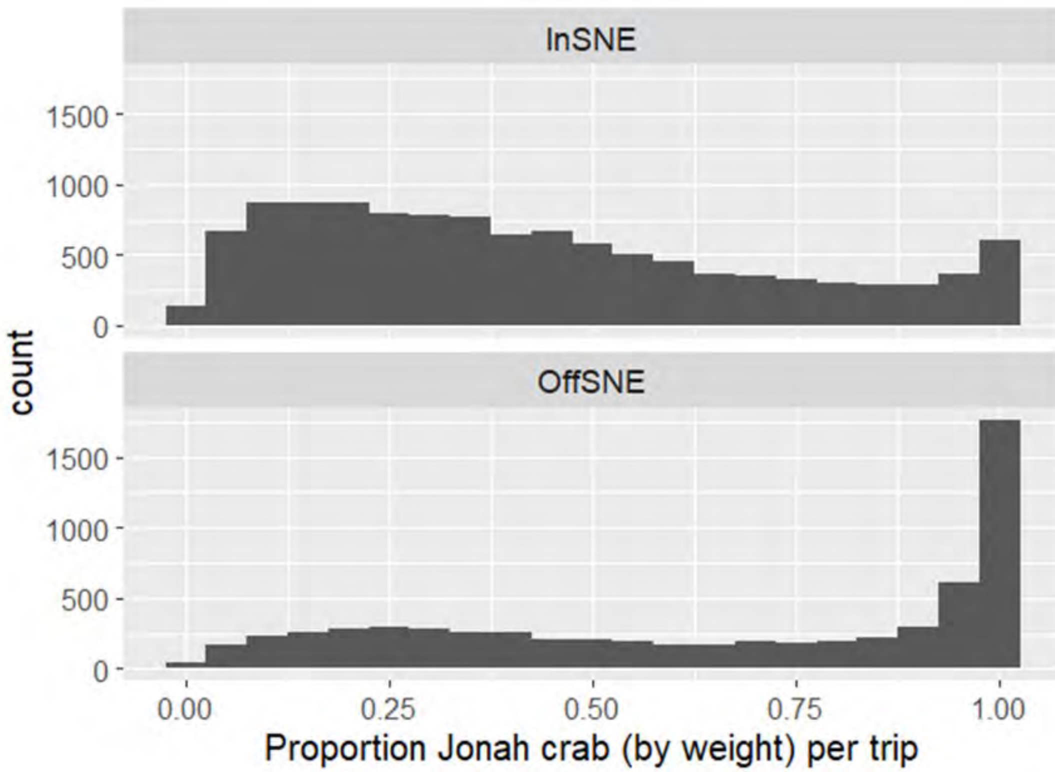

Figure 38. Histogram of Jonah crab proportion of harvest by weight (compared with lobster) for inshore and offshore SNE stocks. All RI trips landing Jonah crab, 2007-2021.

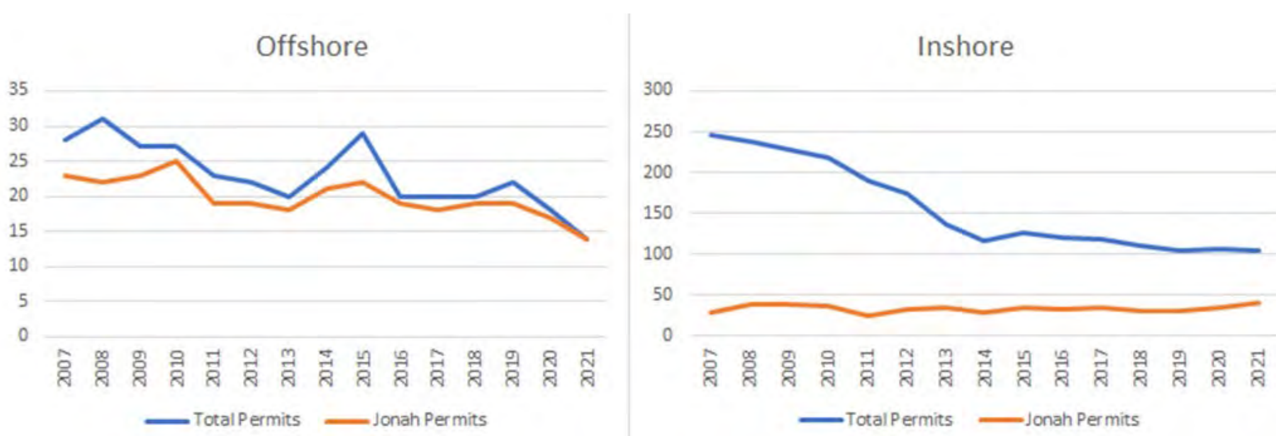

Figure 39. Number of active lobster permits and Jonah crab permits, Rhode Island Offshore SNE and Inshore SNE harvesters, 2007 to 2021.

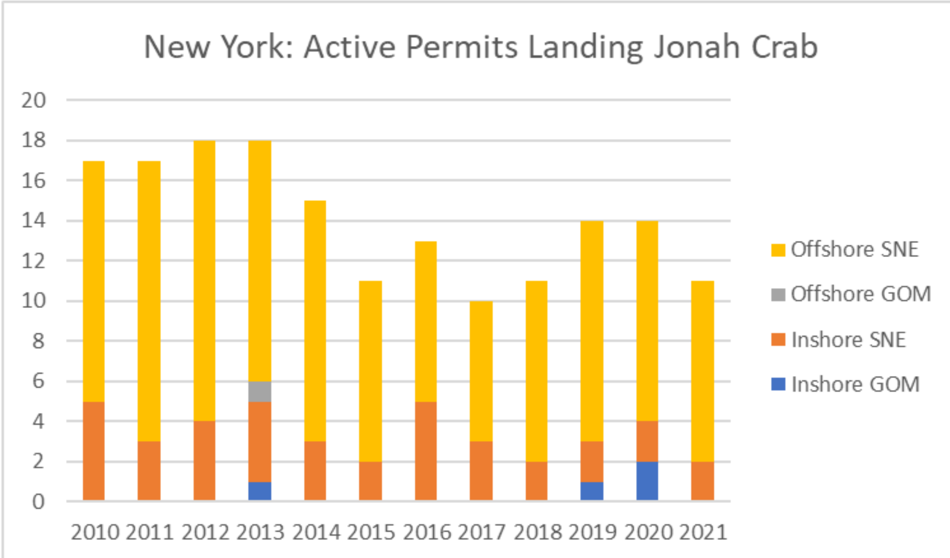

Figure 40. Active New York lobster/crab permits landings Jonah crab from each Jonah crab stock.

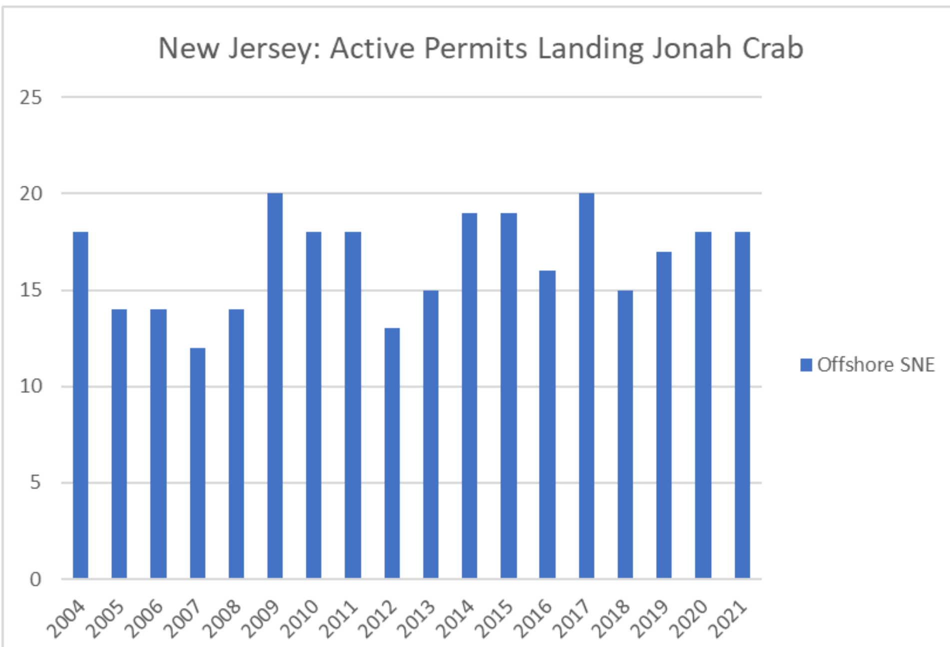

Figure 41. Active New Jersey lobster/crab permits landings Jonah crab from the OSNE Jonah crab stock.

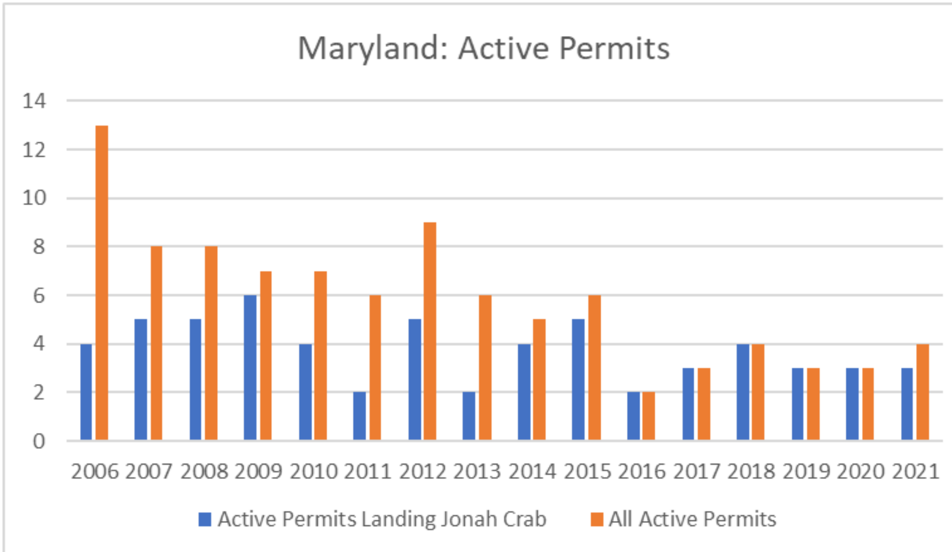

Figure 42. Maryland lobster/crab permit summary including those that have landed Jonah crab from the OSNE Jonah crab stock.

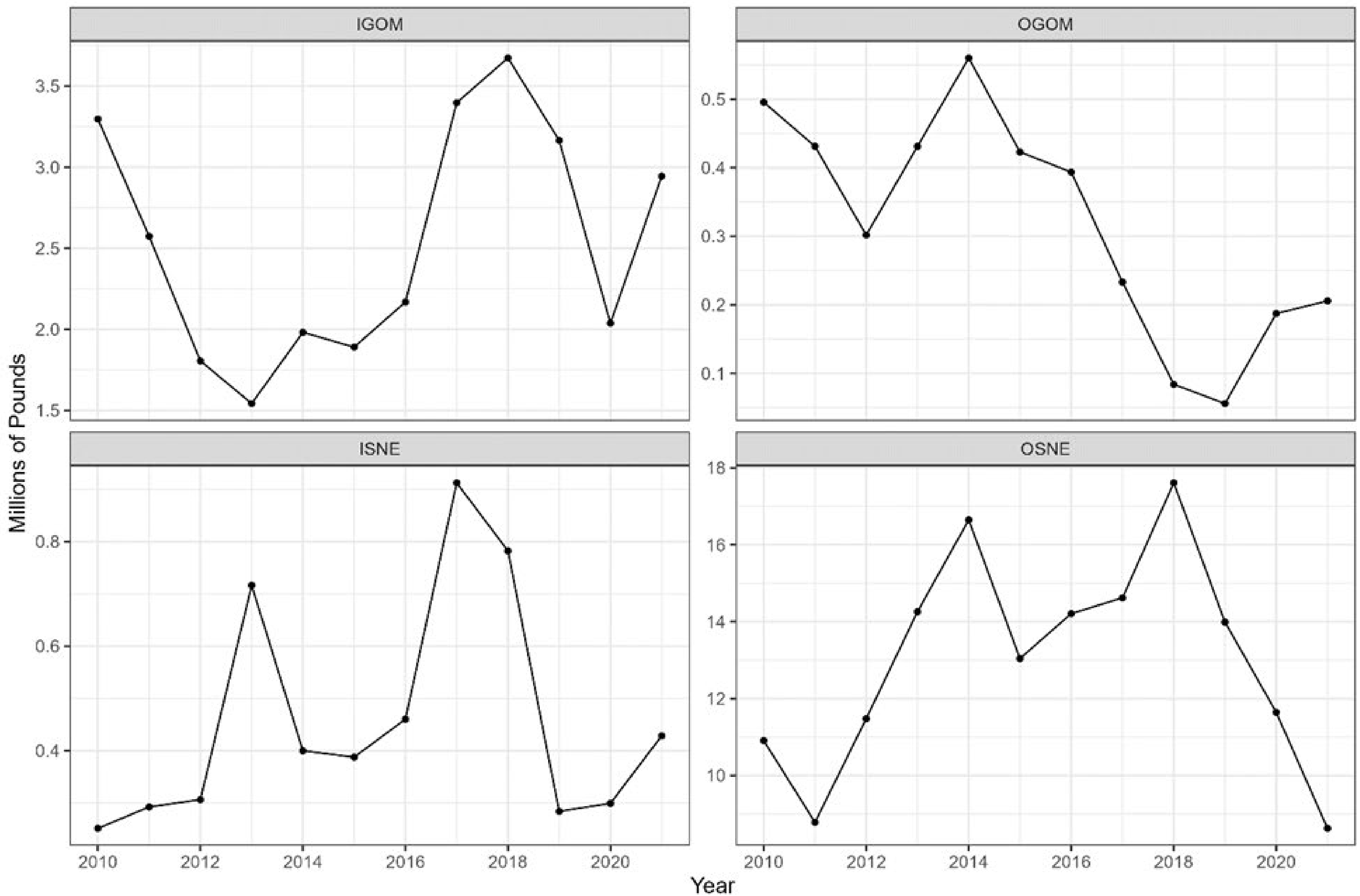

Figure 43. Stock-specific Jonah crab landings.

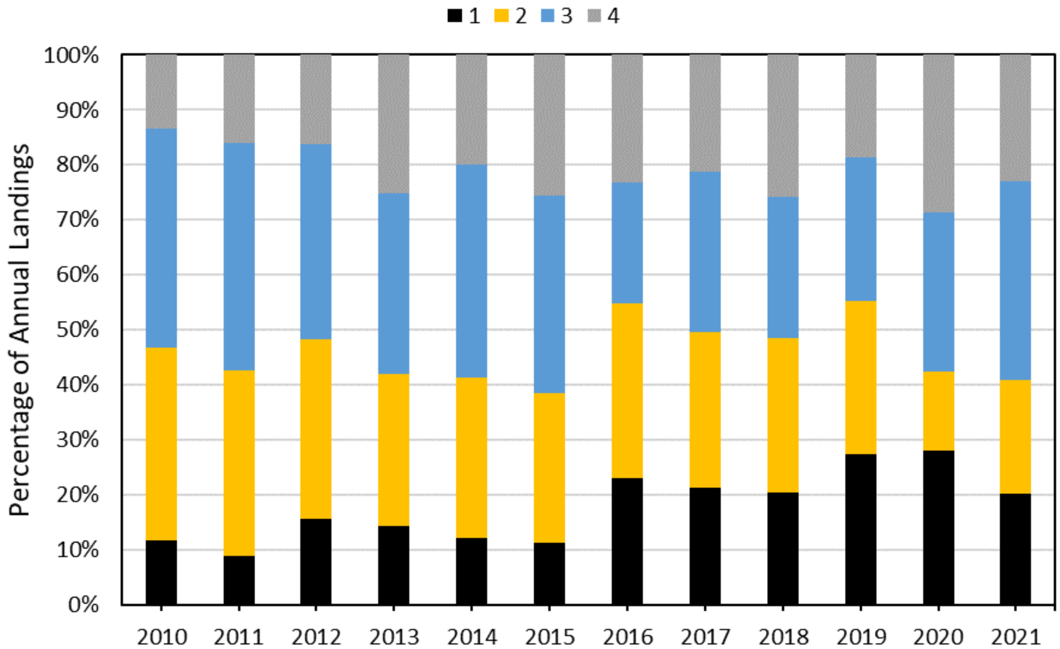

Figure 44. Quarterly breakdown of annual landings from the IGOM Jonah crab stock.

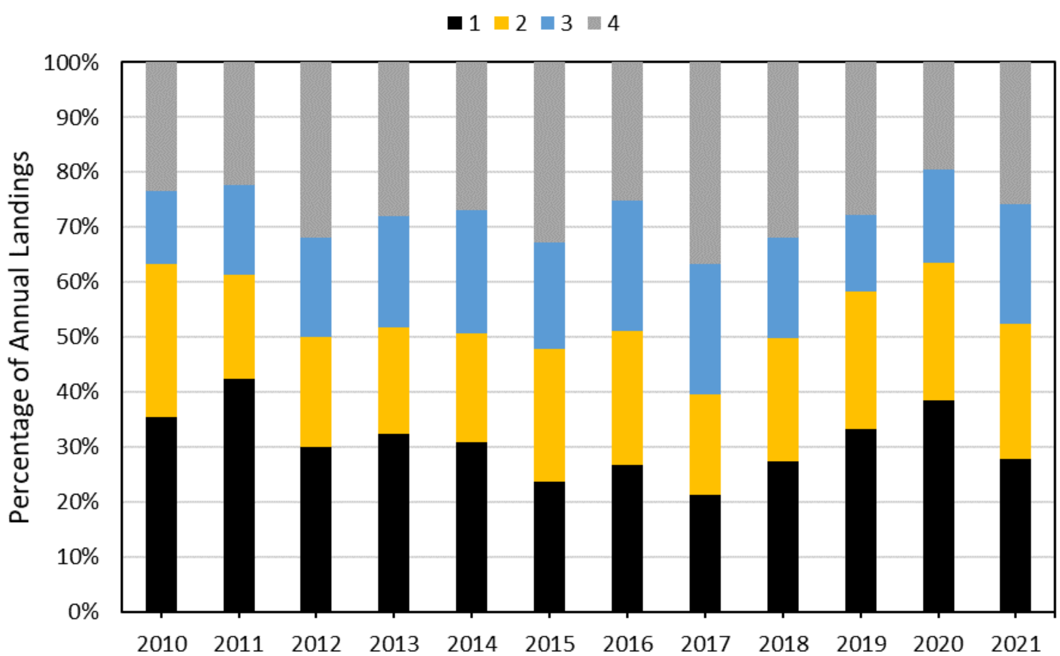

Figure 45. Quarterly breakdown of annual landings from the OSNE Jonah crab stock.

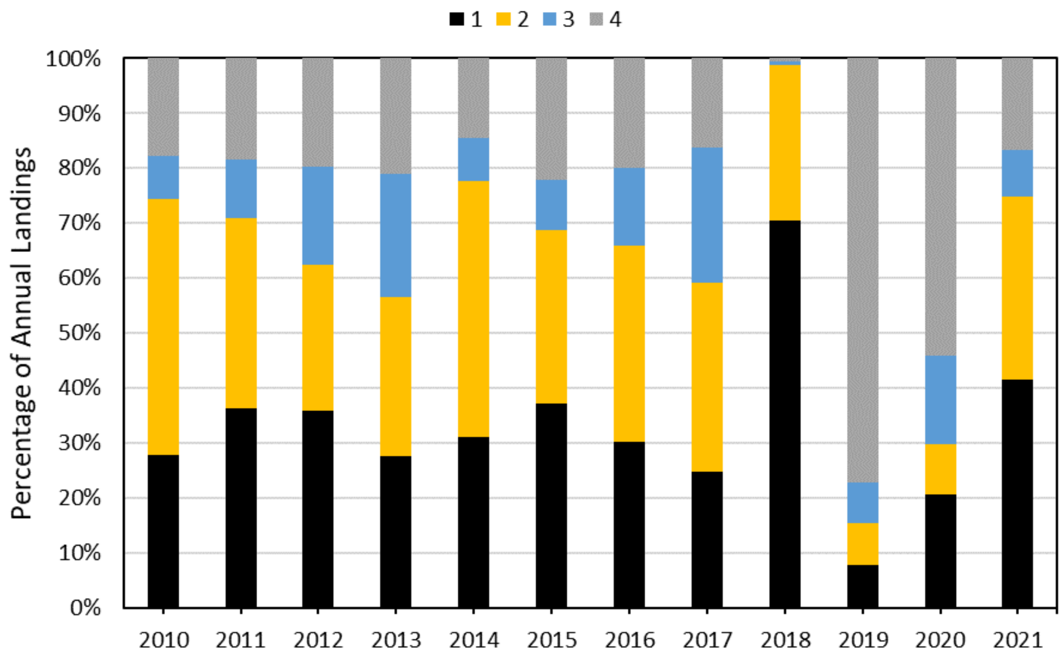

Figure 46. Quarterly breakdown of annual landings from the OGOM Jonah crab stock.

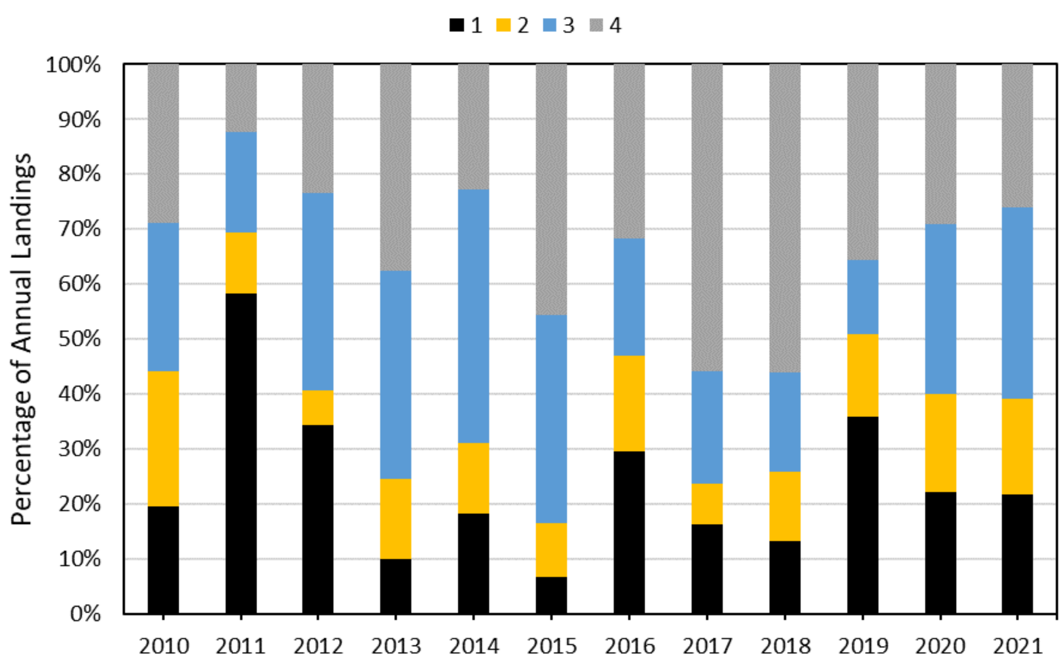

Figure 47. Quarterly breakdown of annual landings from the ISNE Jonah crab stock.

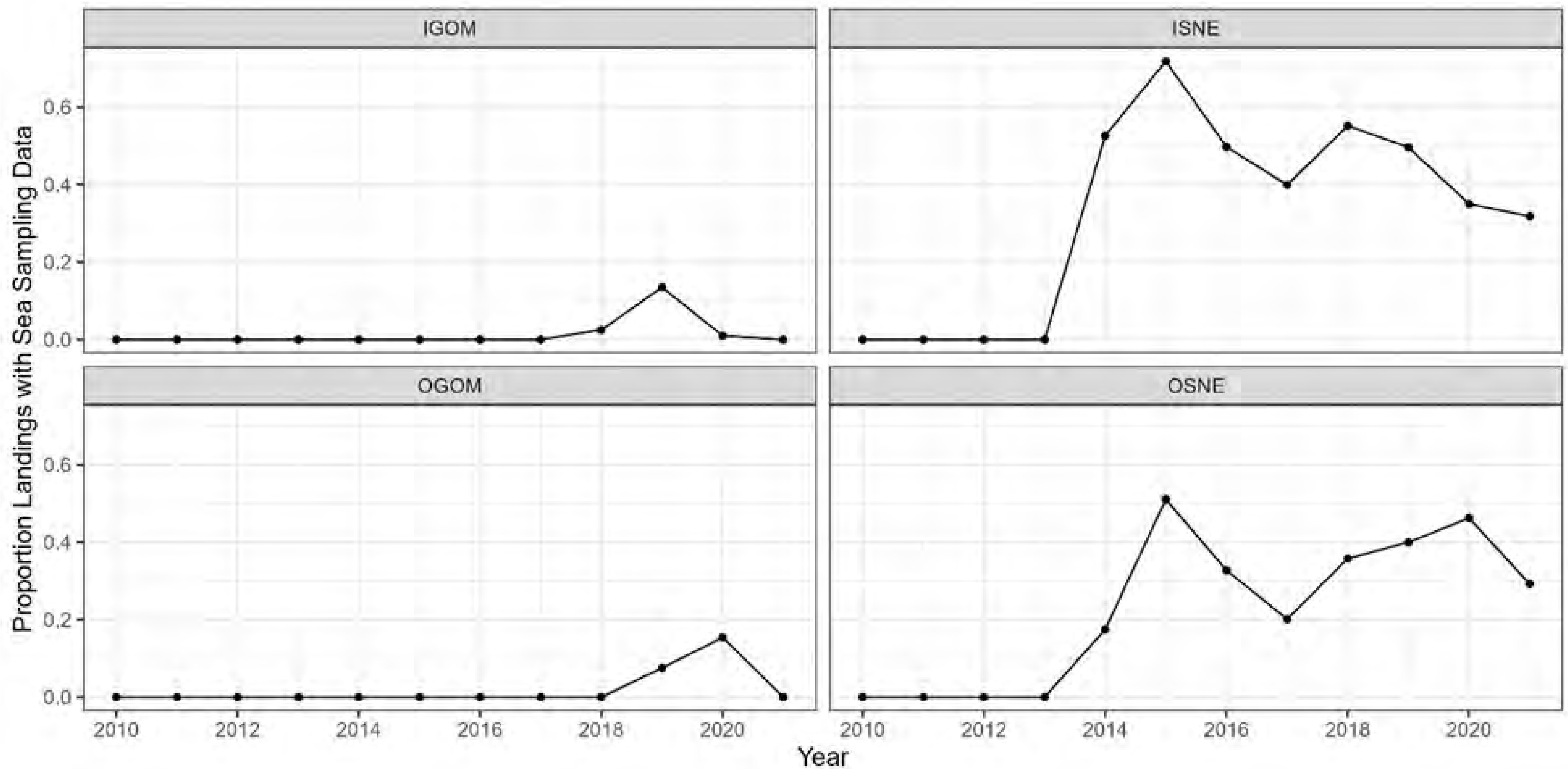

Figure 48. Proportion of landings with associated sea sampling data.

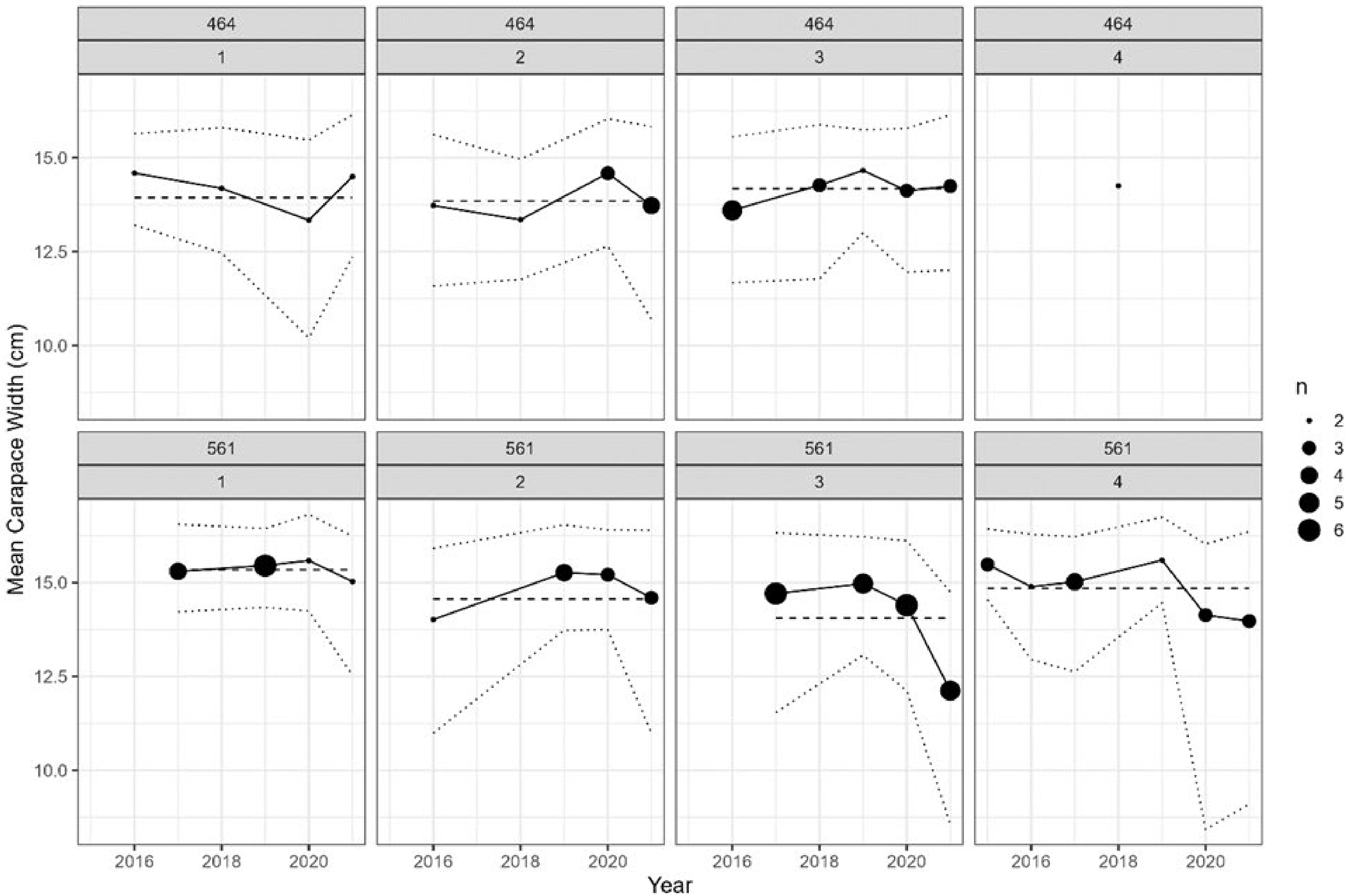

Figure 49. Mean CW (solid circles with size scaled to number of sampling trips) of males in the overall catch from OGOM sea sampling data by statistical area (top panel ribbon) and quarter (bottom panel ribbon). Dotted lines indicate the 5th and 95th percentile of CW and the dashed line indicates the mean CW across years. Data points from statistical areas 465, 511, 512, 515, and 522 are not included because there were no quarters in these statistical areas with at least five data points.

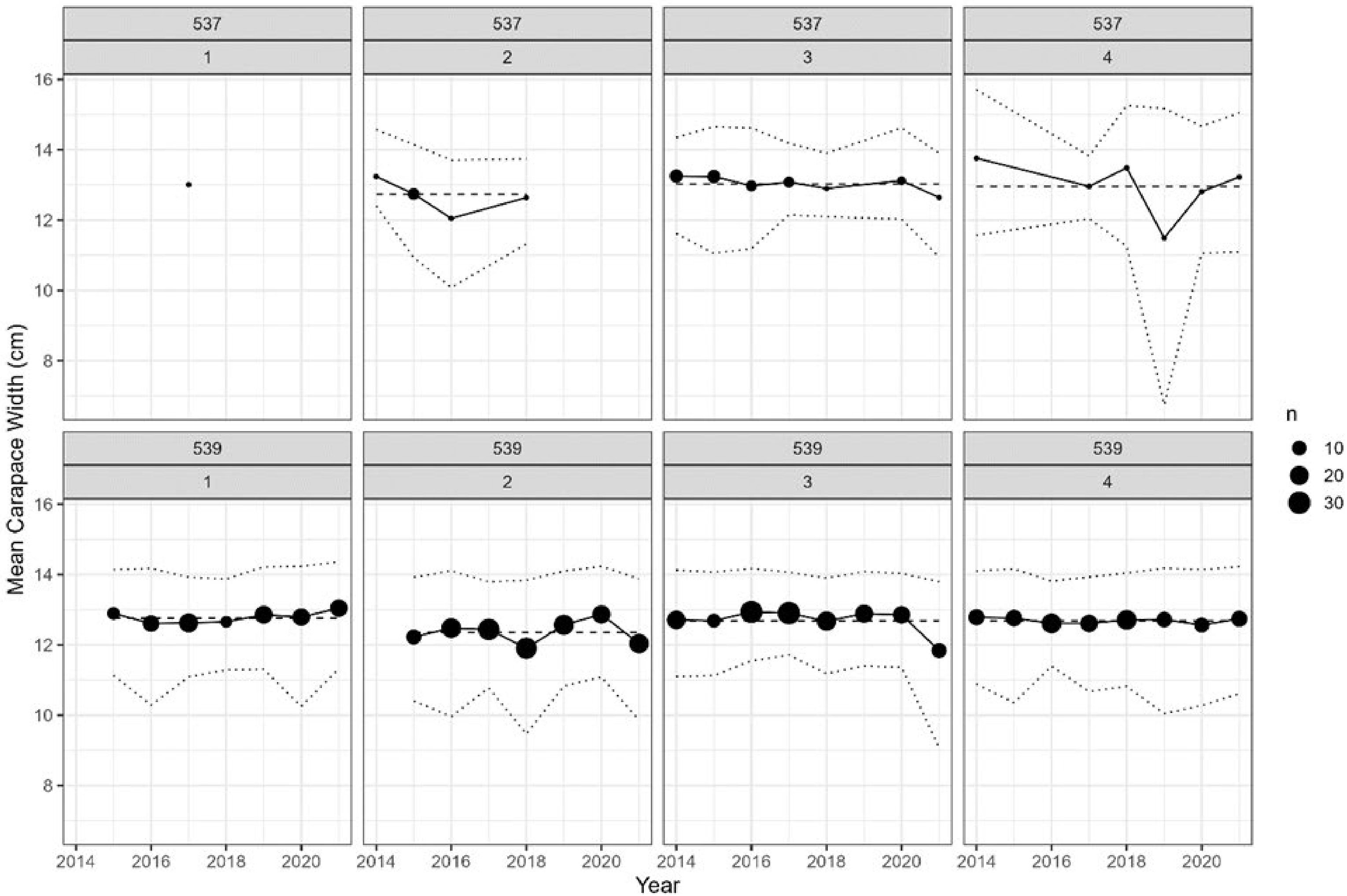

Figure 50. Mean CW (solid circles with size scaled to number of sampling trips) of males in the overall catch from ISNE sea sampling data by statistical area (top panel ribbon) and quarter (bottom panel ribbon). Dotted lines indicate the 5th and 95th percentile of CW and the dashed line indicates the mean CW across years.

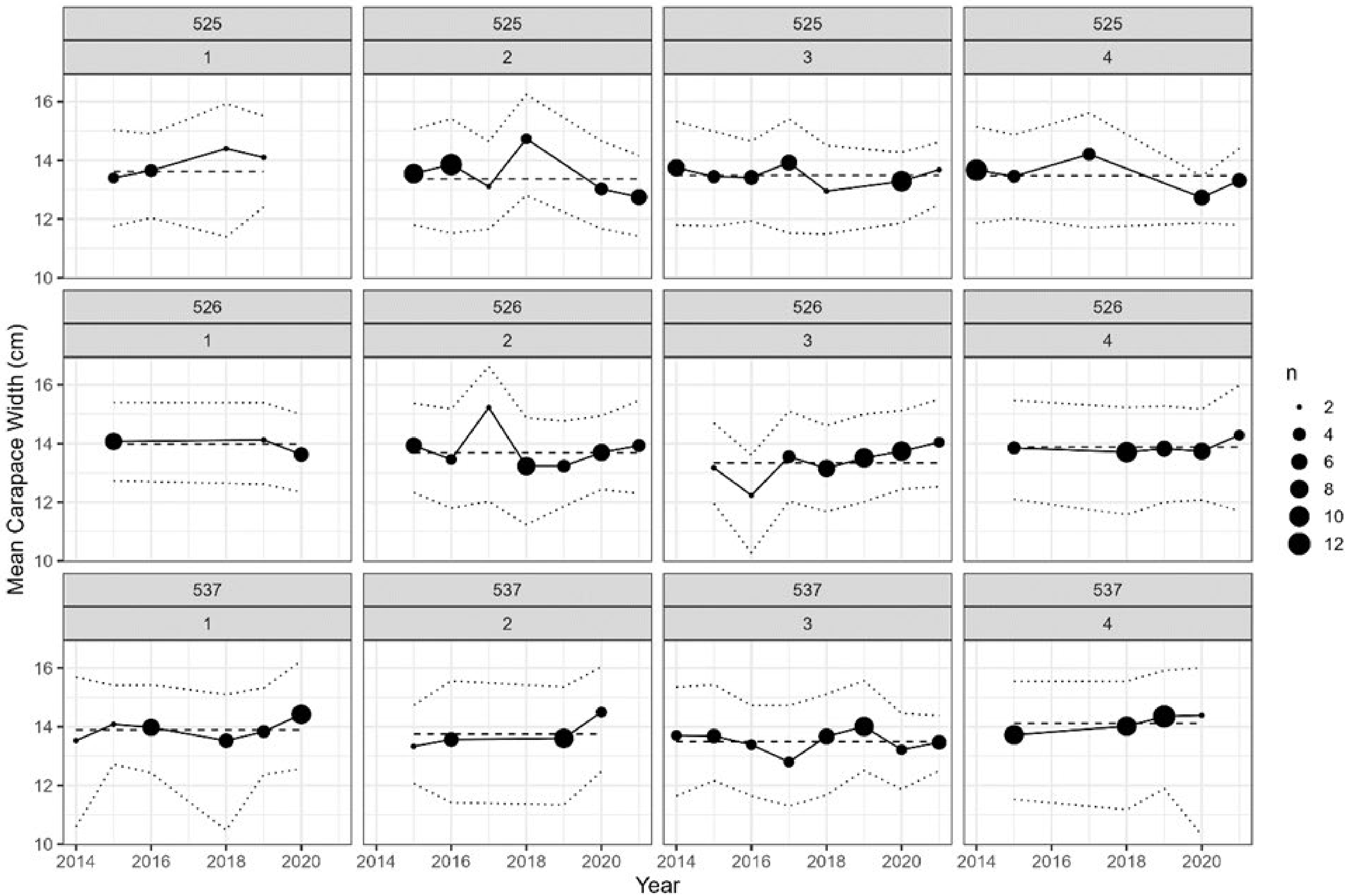

Figure 51. Mean CW (solid circles with size scaled to number of sampling trips) of males in the overall catch from OSNE sea sampling data by statistical area (top panel ribbon) and quarter (bottom panel ribbon). Dotted lines indicate the 5th and 95th percentile of CW and the dashed line indicates the mean CW across years. Data points from statistical areas 562, 613, 616, and 622 are not included because there were no quarters in these statistical areas with at least five data points.

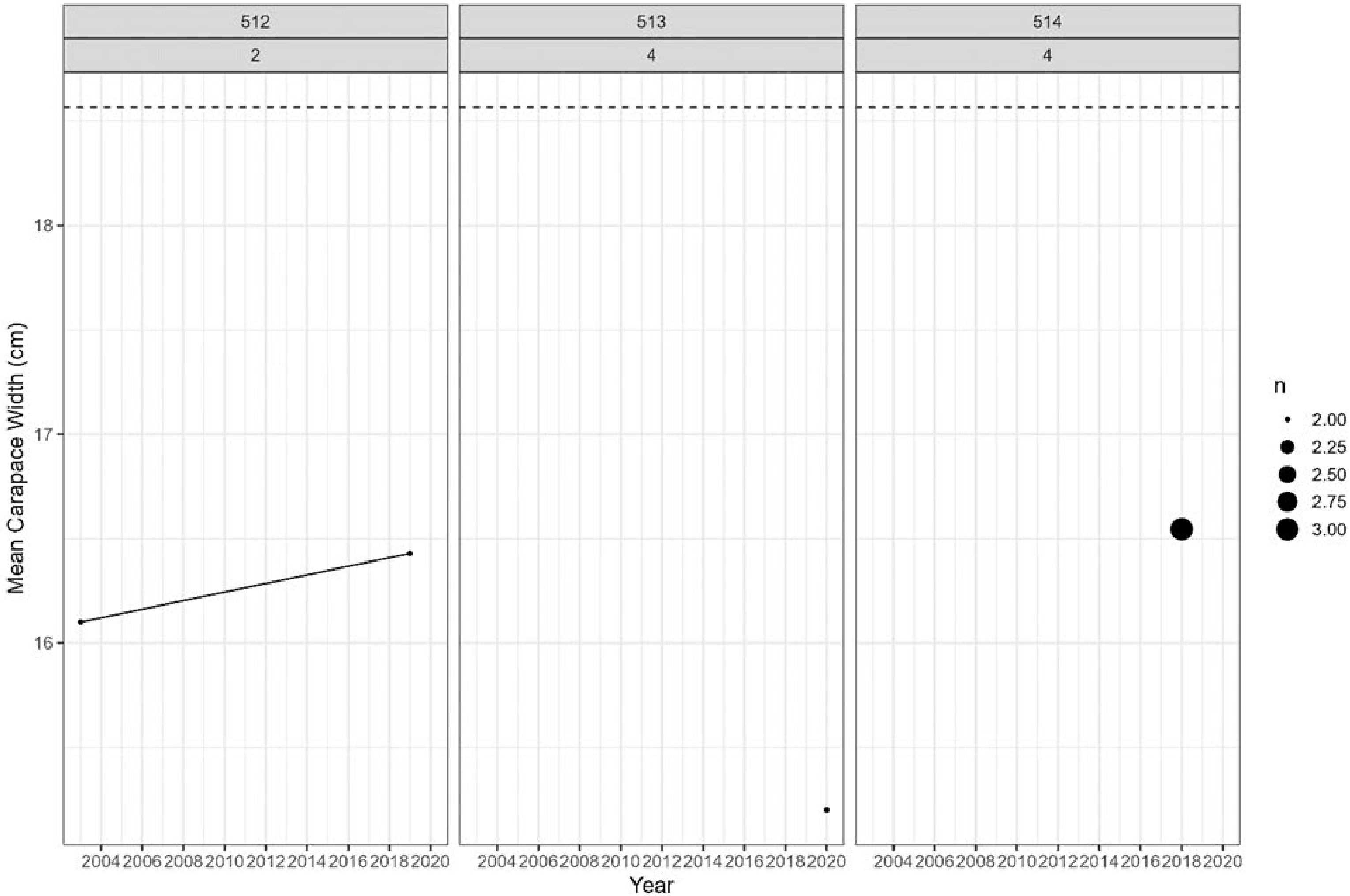

Figure 52. Mean CW (solid circles with size scaled to number of sampling trips) of the 5% largest males in the overall catch from IGOM sea sampling data by statistical area (top panel ribbon) and quarter (bottom panel ribbon). The dashed line indicates 90% of an Linf estimate for Mid-Coast, Maine males (C. Huntsberger, personal communication, October 11, 2022).

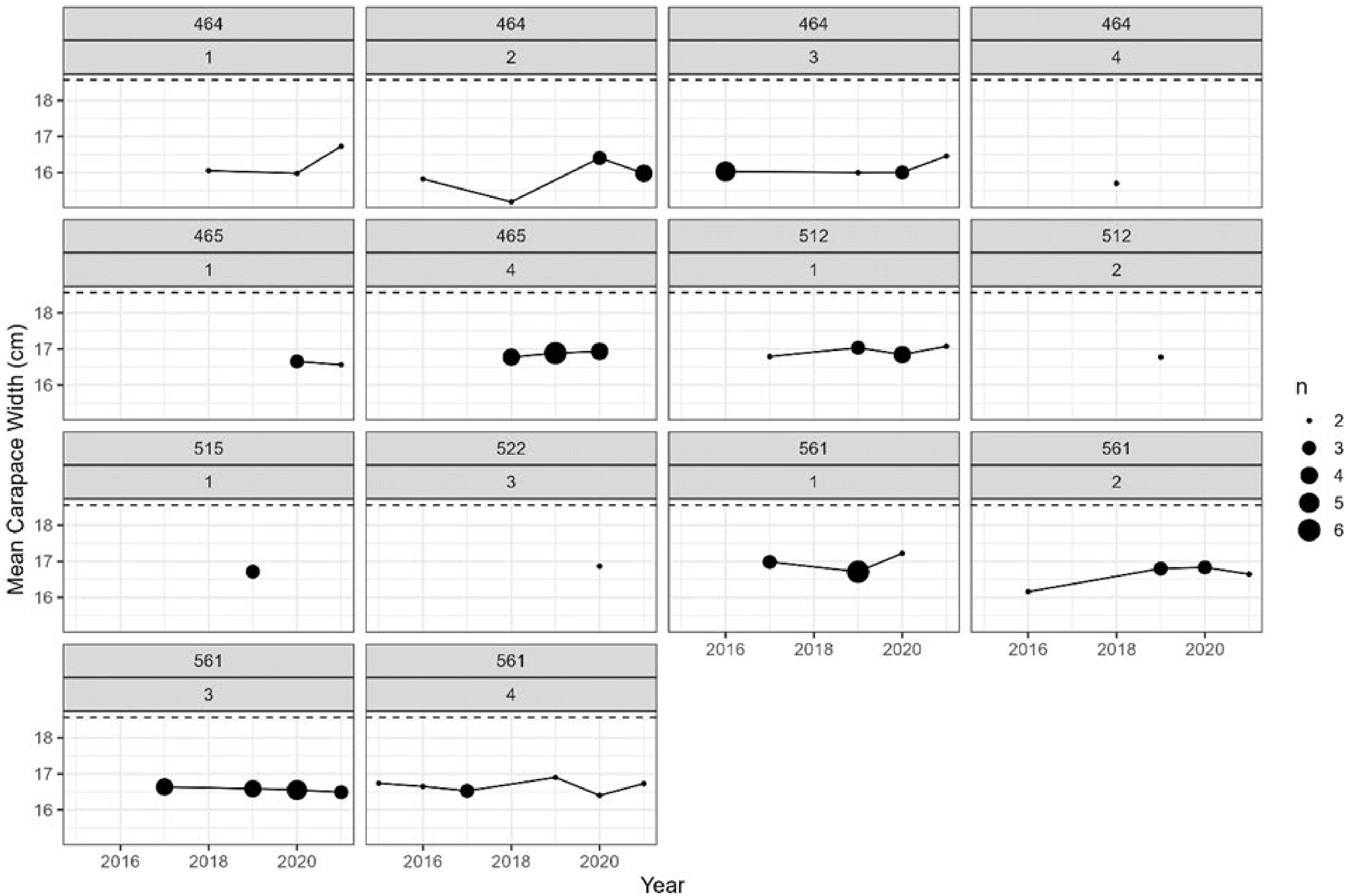

Figure 53. Mean CW (solid circles with size scaled to number of sampling trips) of the 5% largest males in the overall catch from OGOM sea sampling data by statistical area (top panel ribbon) and quarter (bottom panel ribbon). The dashed line indicates 90% of an Linf estimate for Mid-Coast, Maine males (C. Huntsberger, personal communication, October 11, 2022).

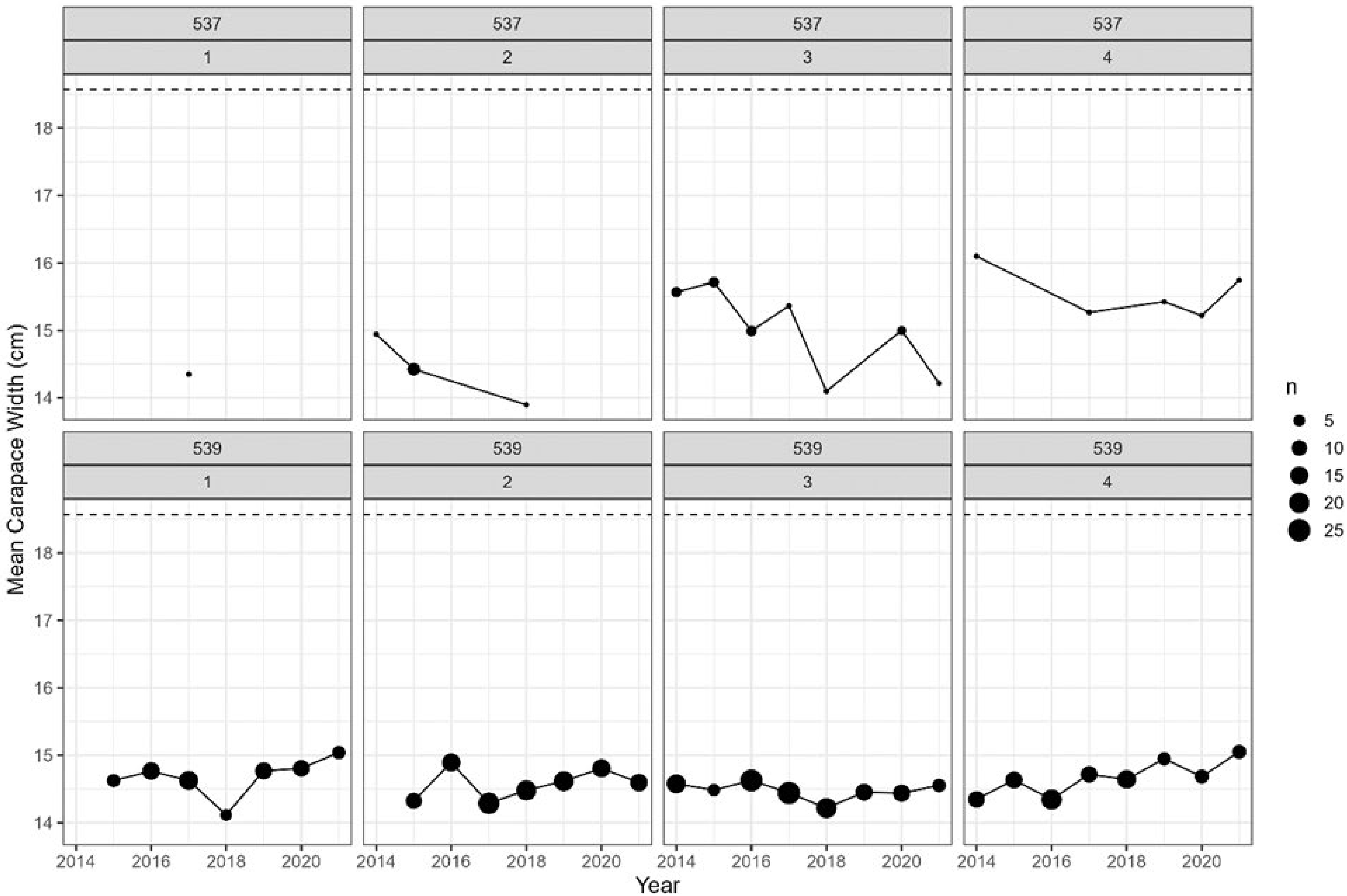

Figure 54. Mean CW (solid circles with size scaled to number of sampling trips) of the 5% largest males in the overall catch from ISNE sea sampling data by statistical area (top panel ribbon) and quarter (bottom panel ribbon). The dashed line indicates 90% of an Linf estimate for Mid-Coast, Maine males (C. Huntsberger, personal communication, October 11, 2022).

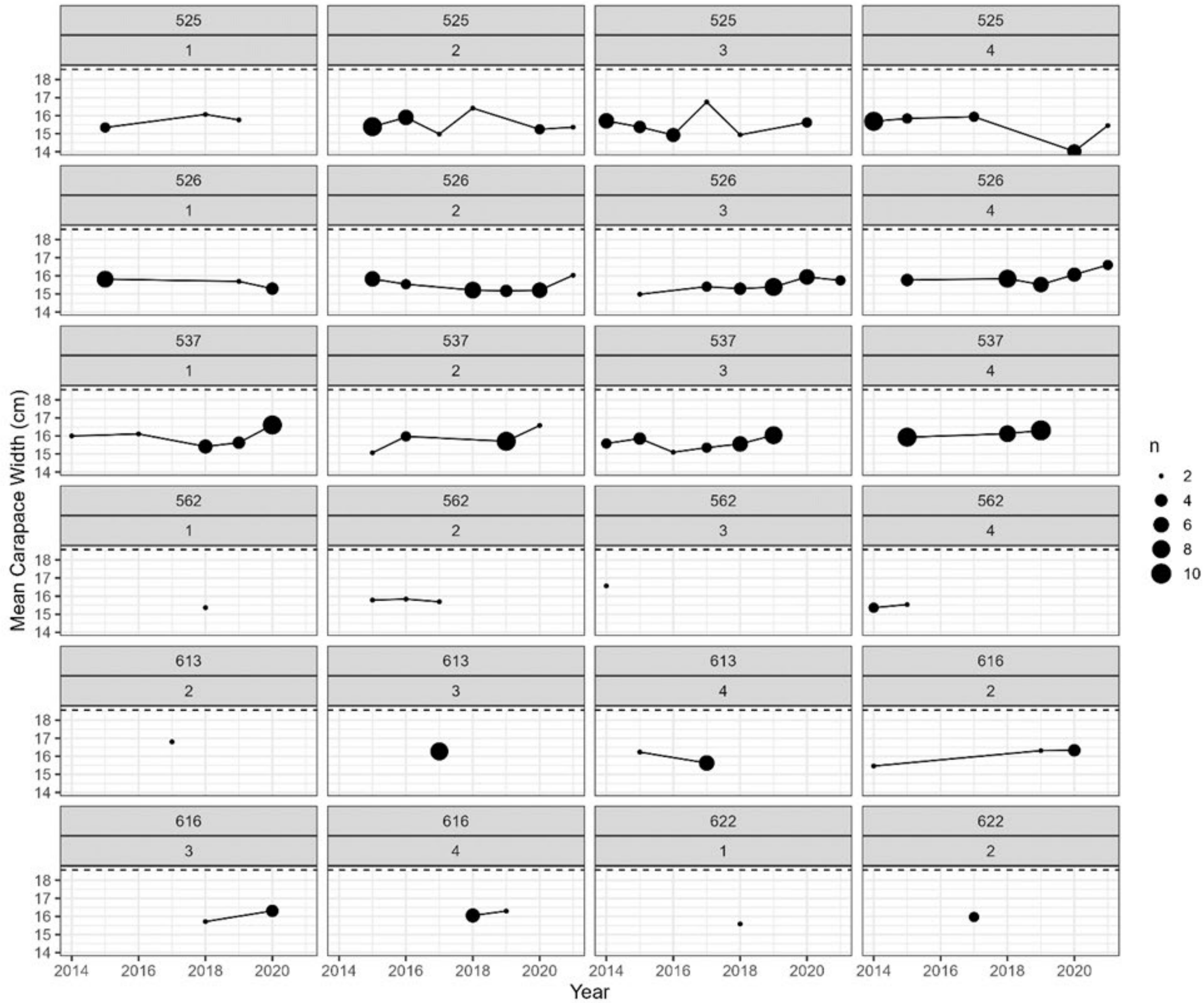

Figure 55. Mean CW (solid circles with size scaled to number of sampling trips) of the 5% largest males in the overall catch from OSNE sea sampling data by statistical area (top panel ribbon) and quarter (bottom panel ribbon). The dashed line indicates 90% of an Linf estimate for Mid-Coast, Maine males (C. Huntsberger, personal communication, October 11, 2022).

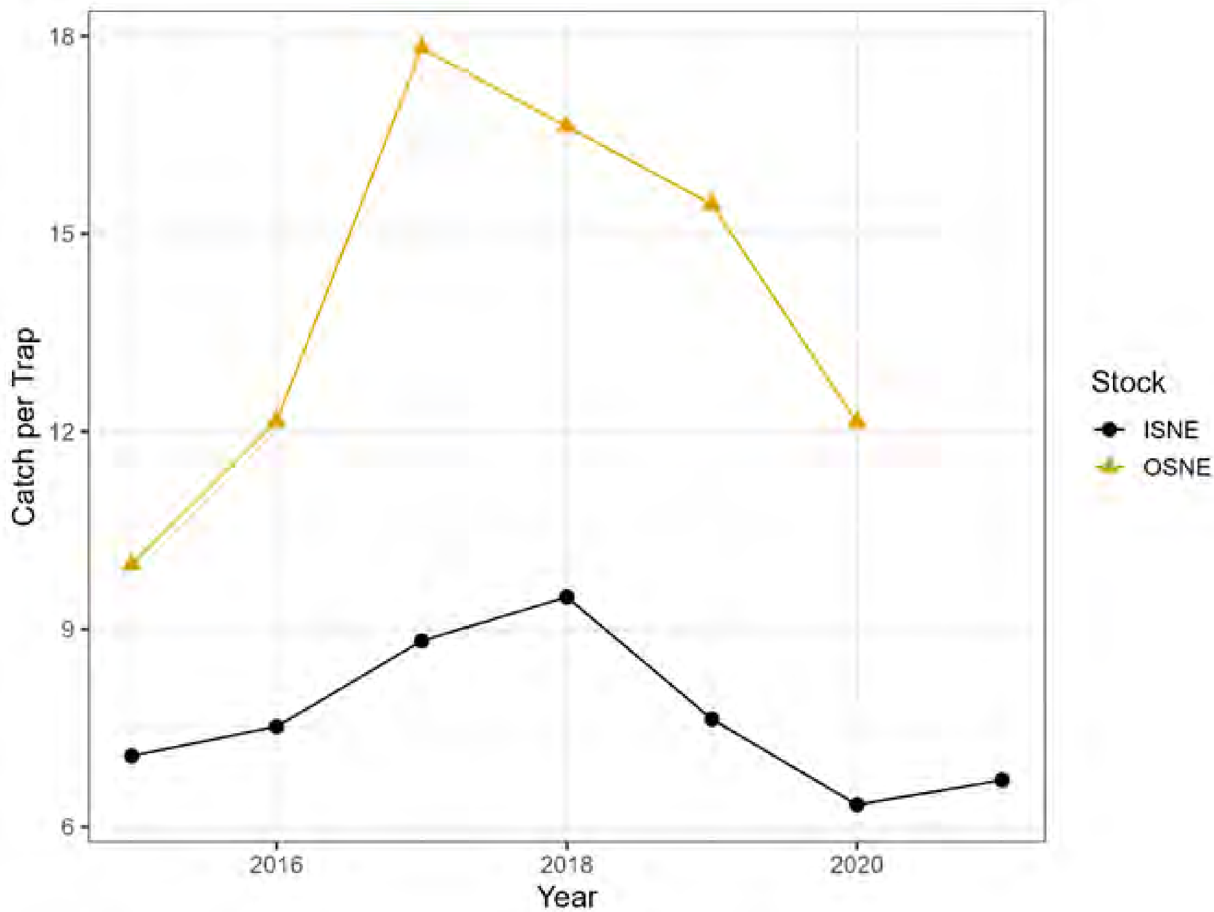

Figure 56. CFRF VTS CPUE for exploitable-sized (>121mm CW) male crabs.

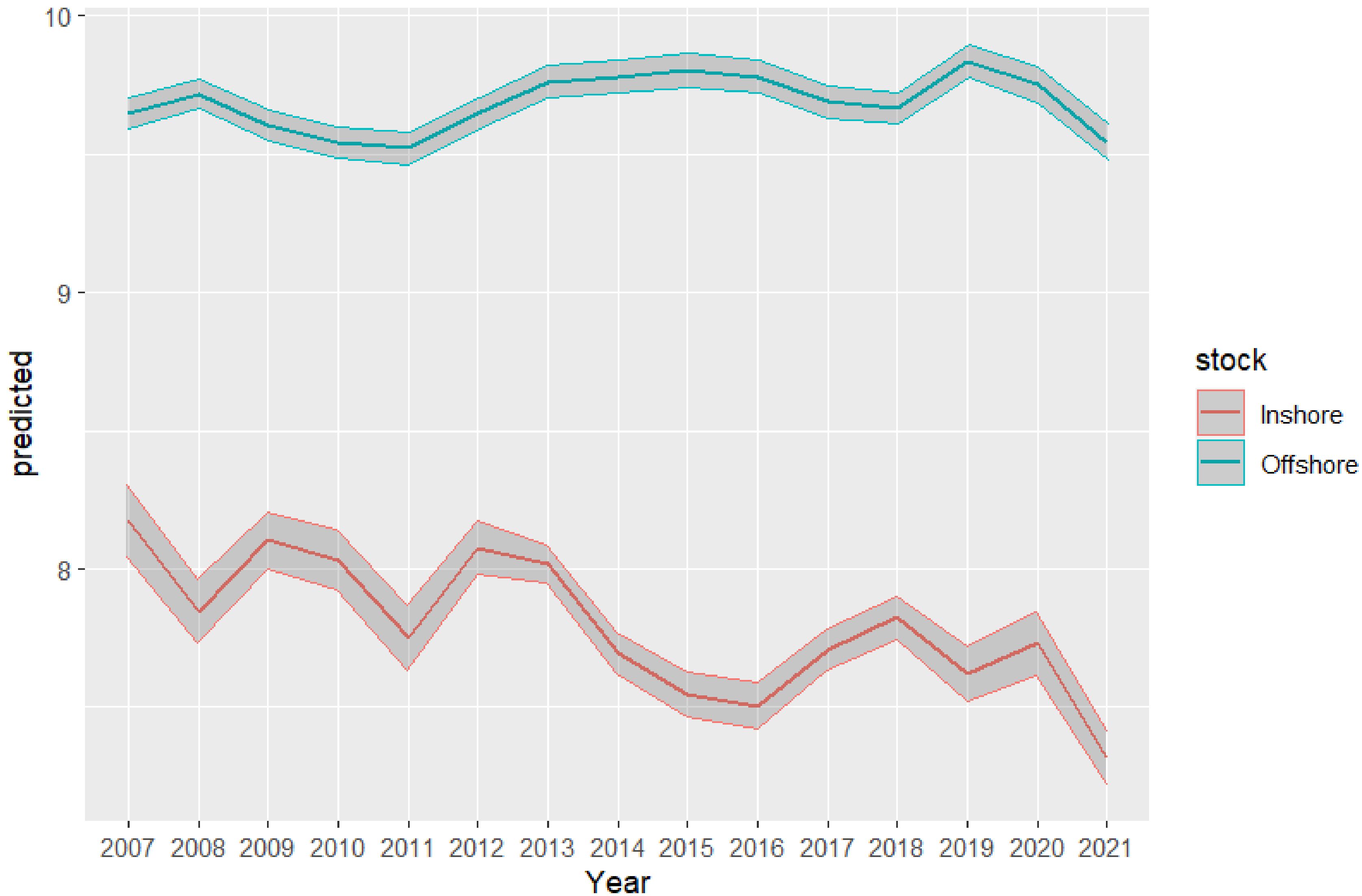

Figure 57. Jonah crab CPUE indices derived from directed residual model fitted to Rhode Island trip-level landings data.

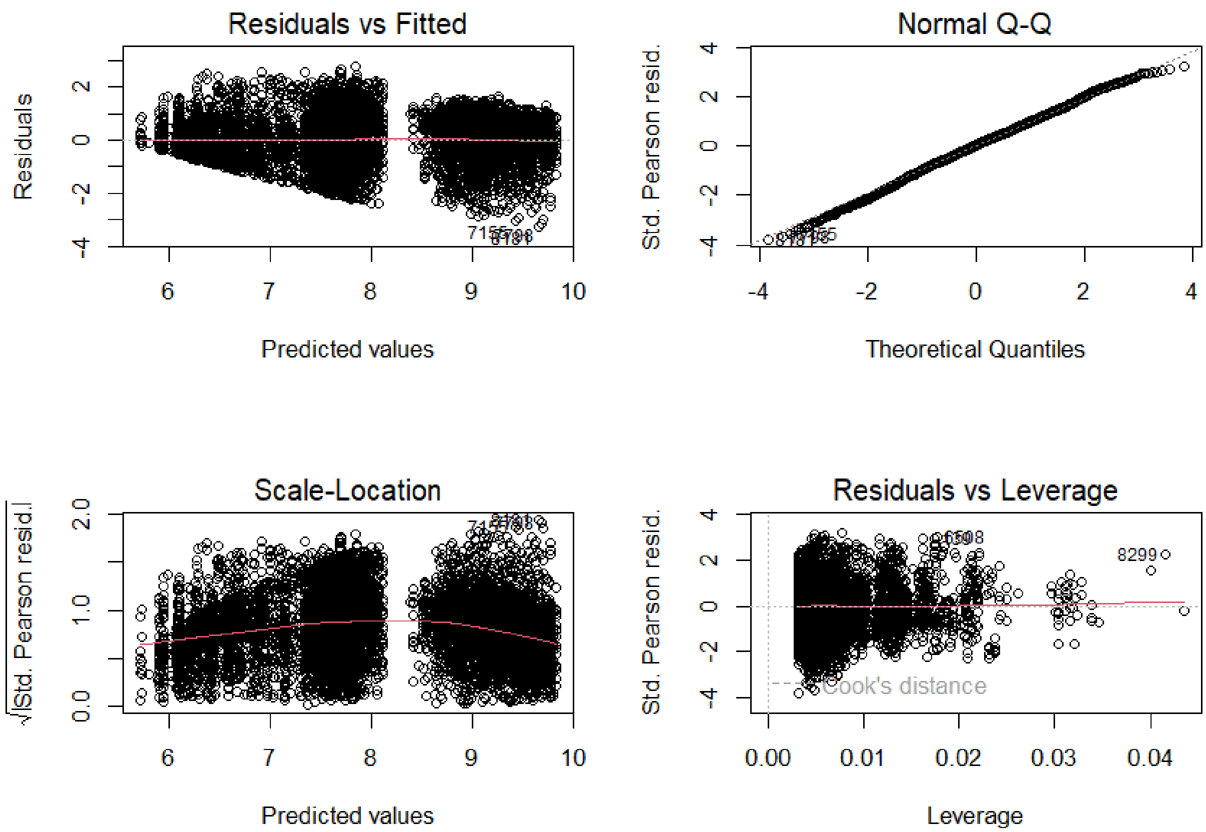

Figure 58. Diagnostic plots for selected DRM fitted to Rhode Island trip-level landings data.

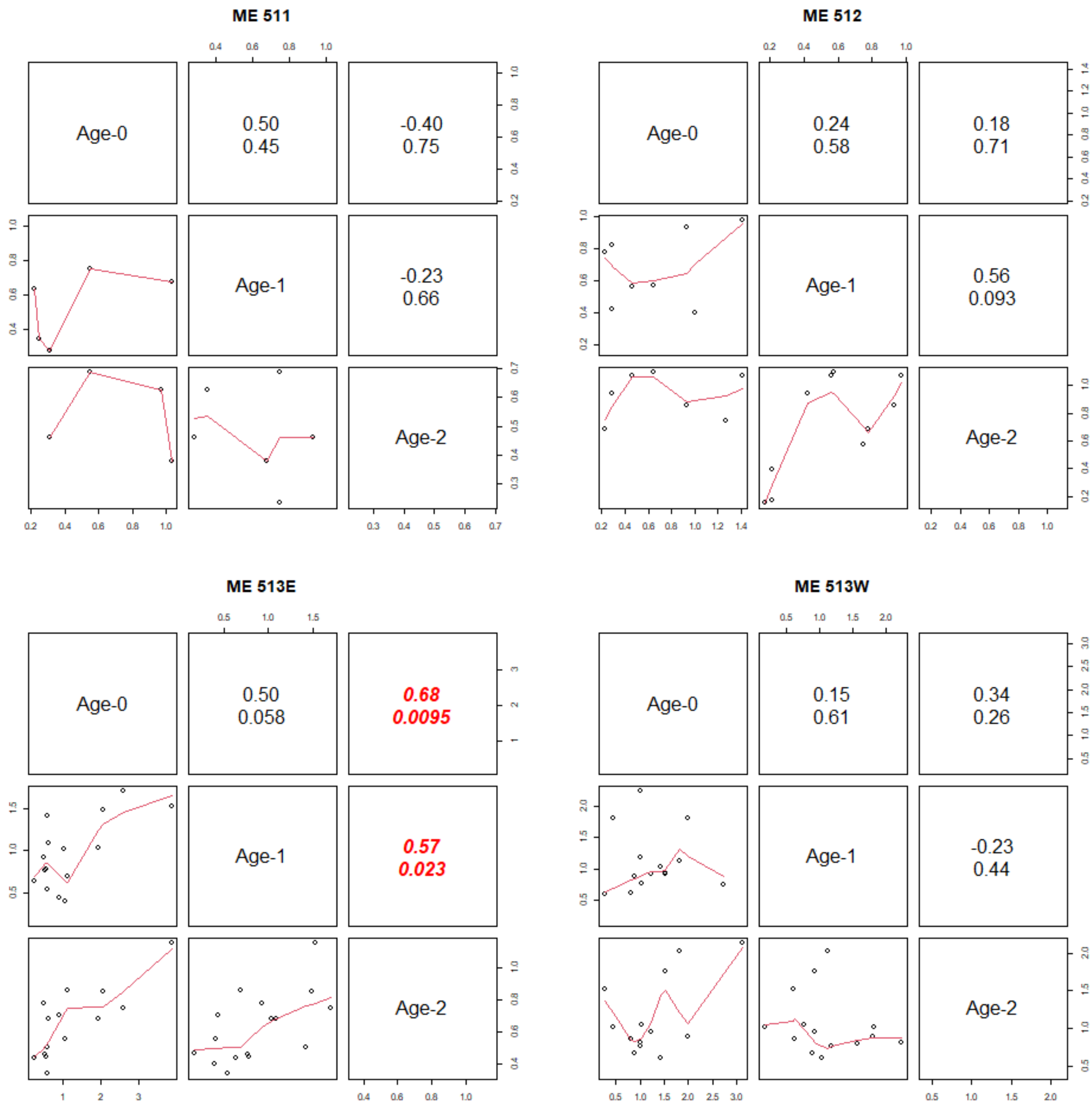

Figure 59. Spearman correlation results for age-specific settlement indices from the ME settlement surveys. Panels above the diagonal include the Spearman's ρ as the top number and the p-value as the bottom number.

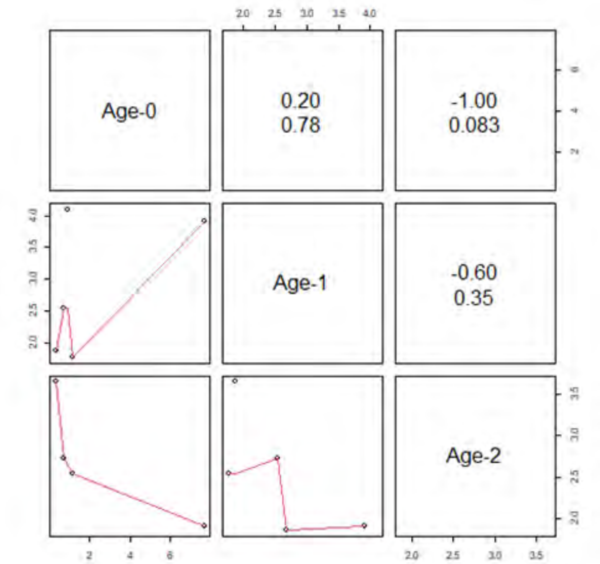

Figure 60. Spearman correlation results for age-specific settlement indices from the MA Statistical Area 514 settlement survey. Panels above the diagonal include the Spearman's ρ as the top number and the p-value as the bottom number.

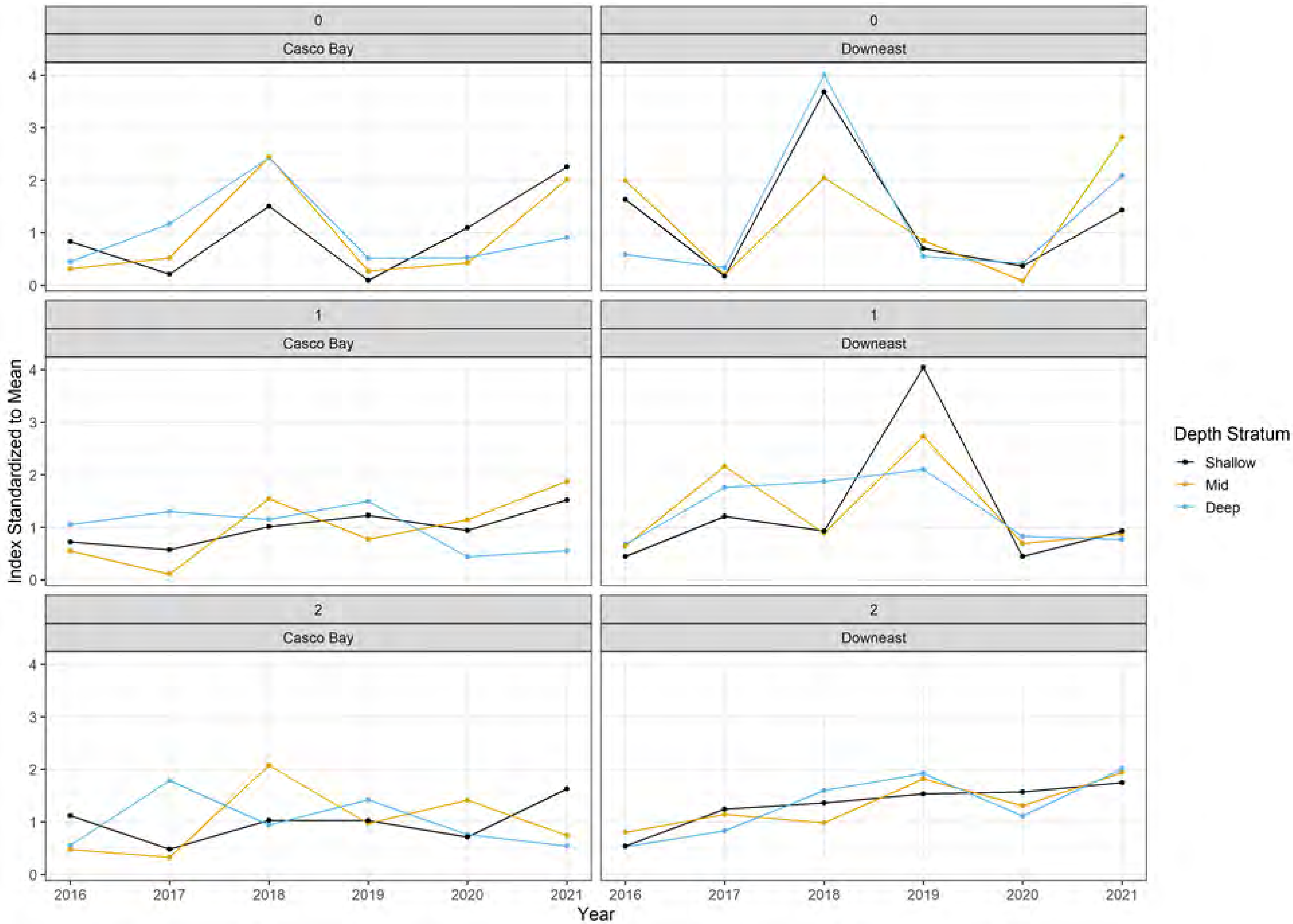

Figure 61. Comparison of depth specific indices from the University of Maine Deepwater Collector survey. Indices are age-specific (top ribbon in each panel) and region-specific (bottom ribbon in each panel).

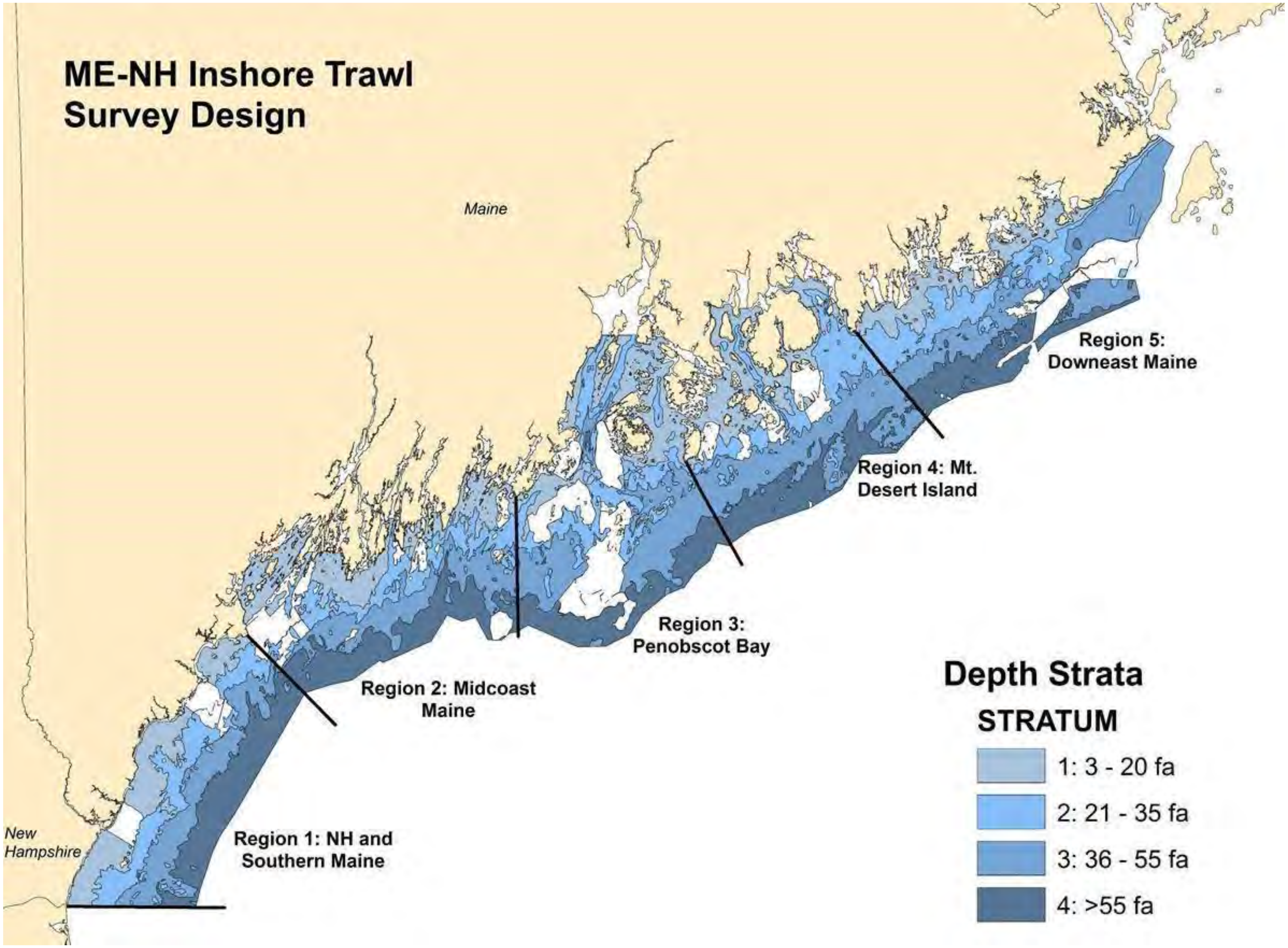

Figure 62. Sampling regions and depth strata for the Maine/New Hampshire trawl survey

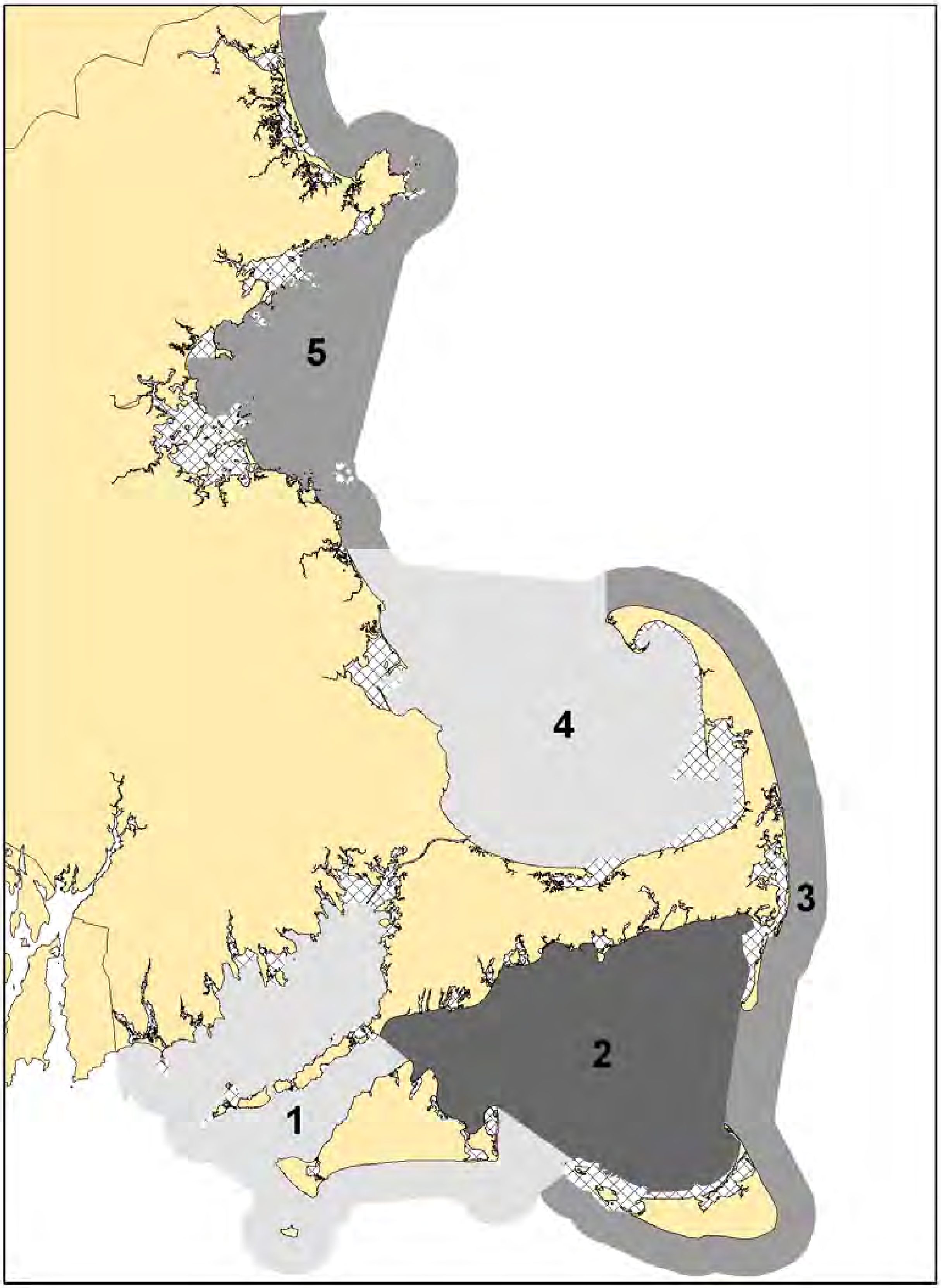

Figure 63. Sampling regions for the MA DMF trawl survey.

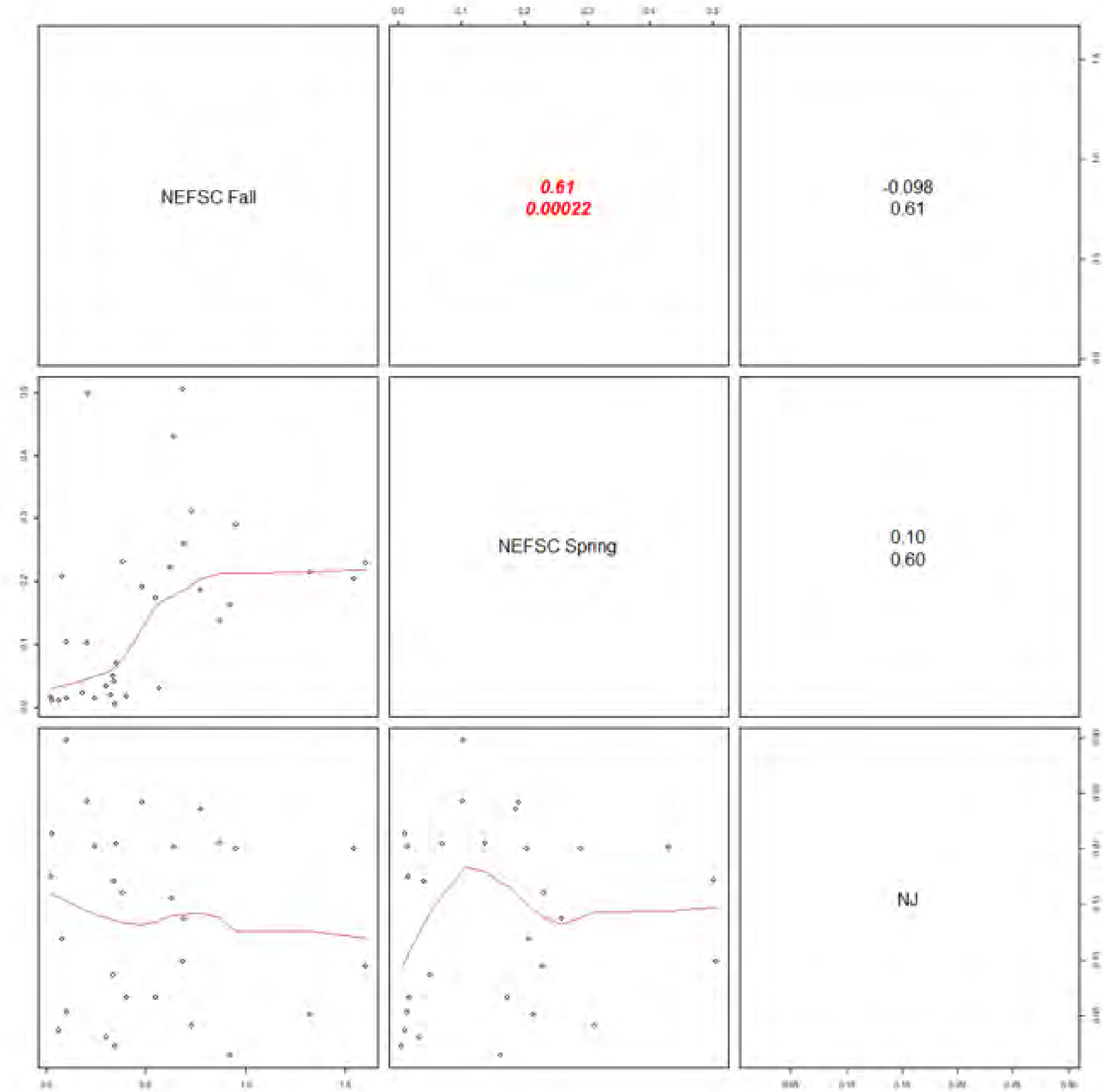

Figure 64. Spearman correlation results for sex- and size-aggregate indices from the NEFSC and NJ trawl surveys. Panels above the diagonal include the Spearman's ρ as the top number and the p-value as the bottom number. Italicized and red numbers indicate significant correlations (p-value<0.05).

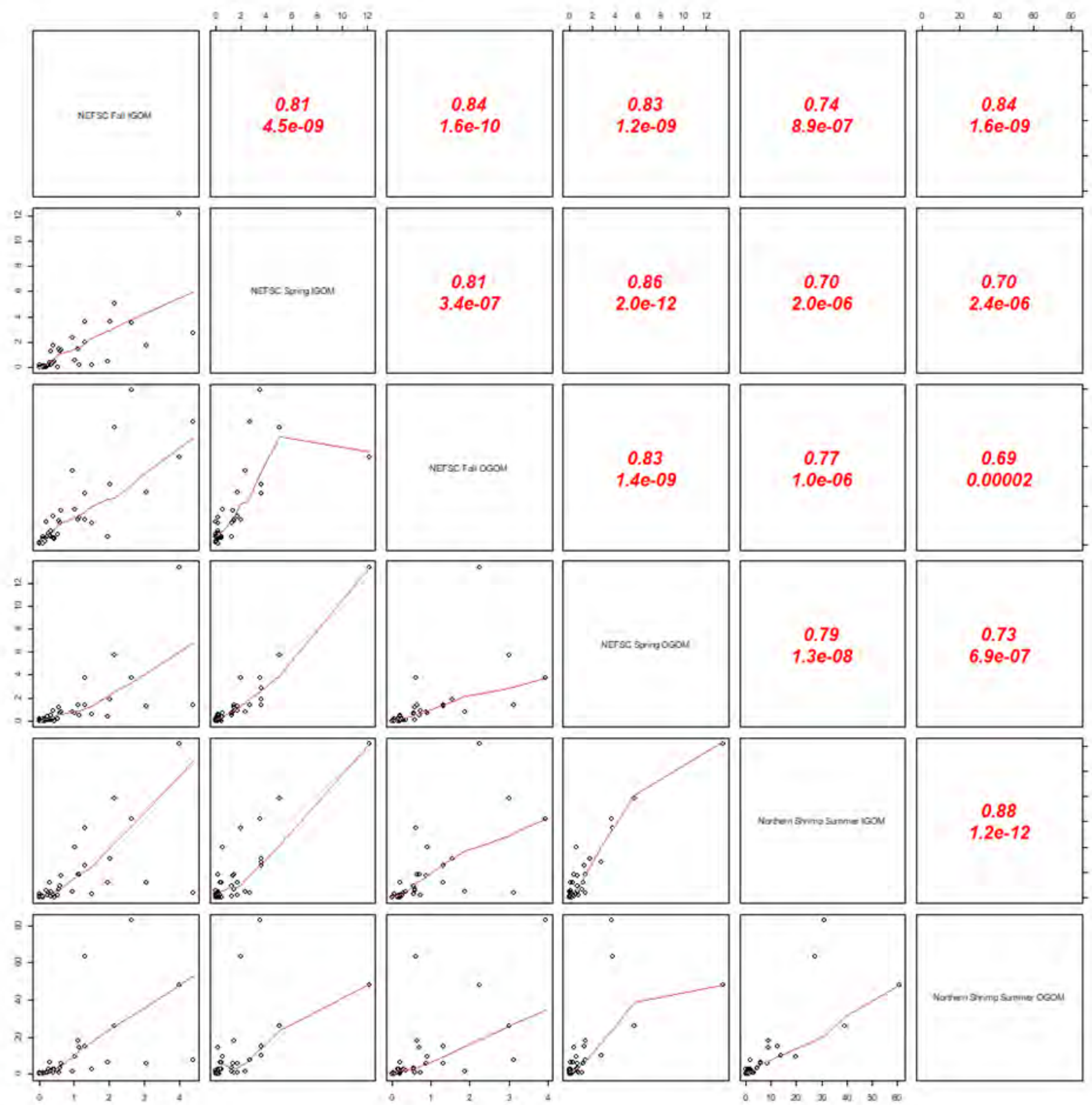

Figure 65. Spearman correlation results for sex- and size-aggregate indices from the NEFSC and Northern Shrimp trawl surveys. Panels above the diagonal include the Spearman's ρ as the top number and the p-value as the bottom number. Italicized and red numbers indicate significant correlations (p-value<0.05).

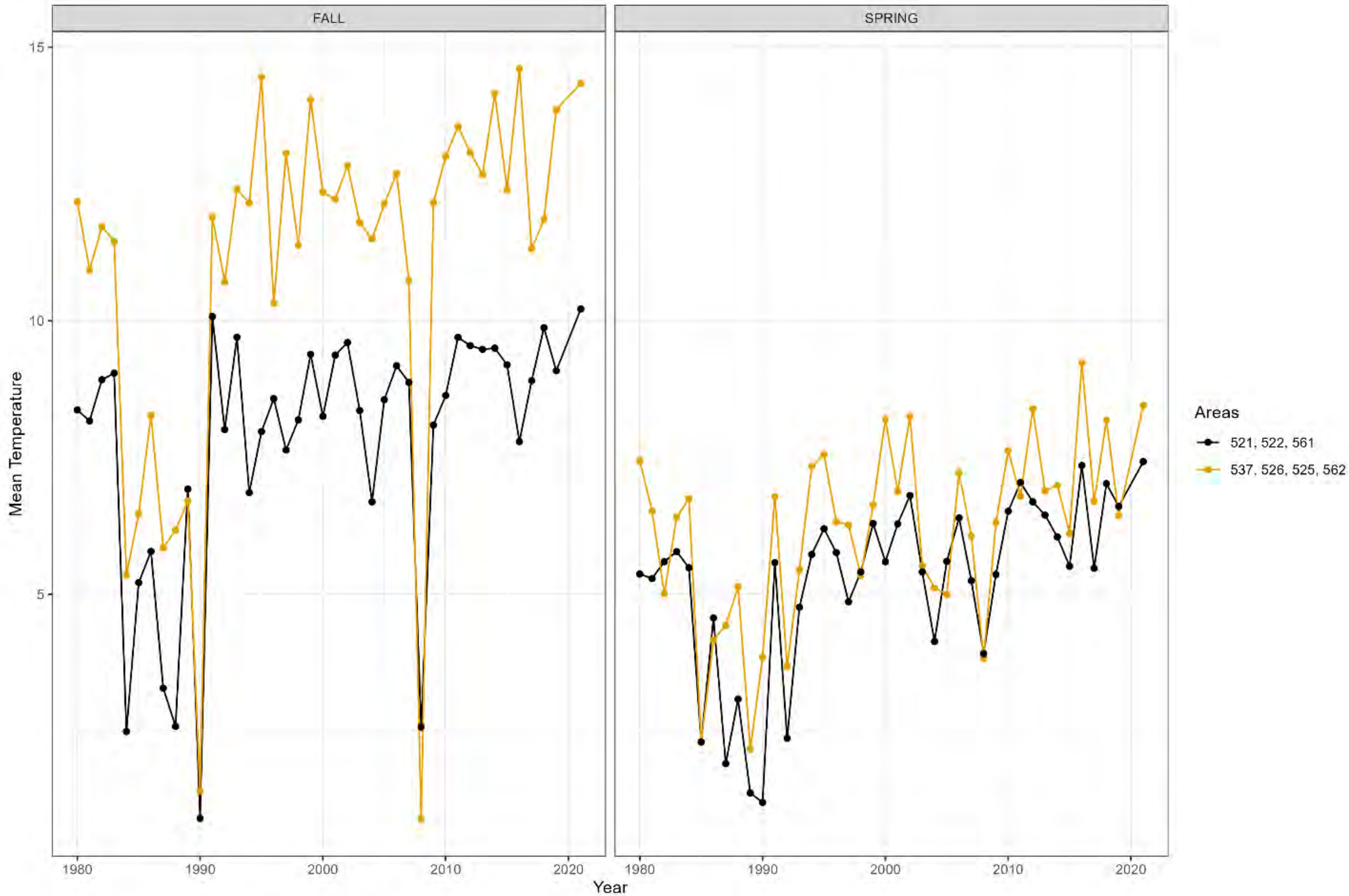

Figure 66. NEFSC Trawl Survey seasonal bottom temperature indices for adjacent NOAA statistical areas associated with high landings of Jonah crabs (Areas 537, 526, 525, 562) and low landings of Jonah crabs (Areas 521, 522, 561).

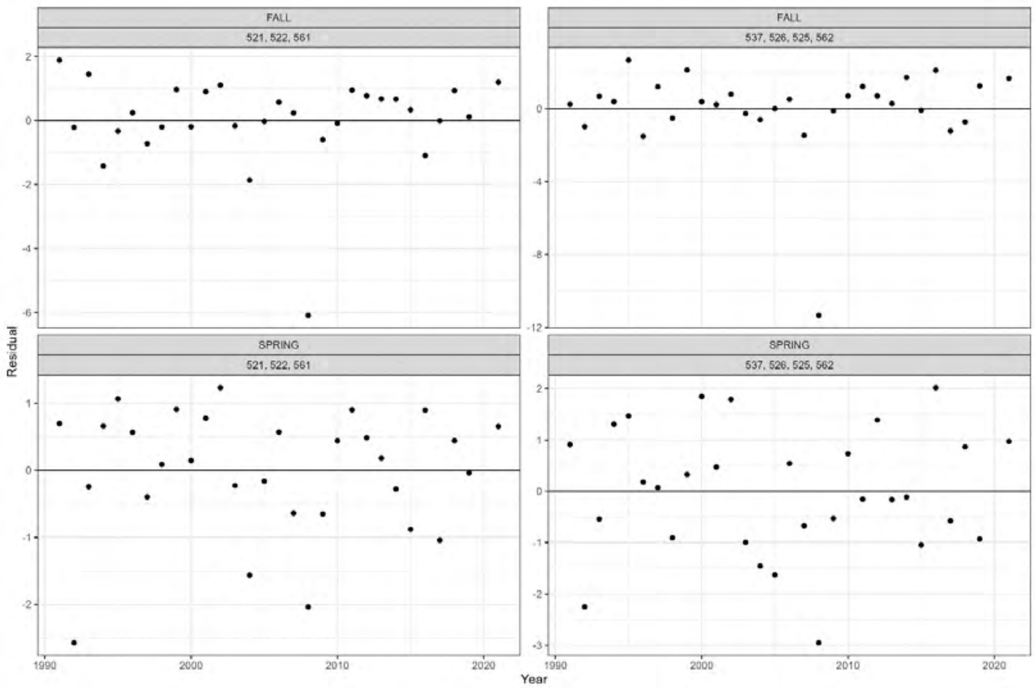

Figure 67. Residuals for linear regression fits to NEFSC Trawl Survey seasonal bottom temperature indices for adjacent NOAA statistical areas associated with high landings of Jonah crabs (Areas 537, 526, 525, 562) and low landings of Jonah crabs (Areas 521, 522, 561).

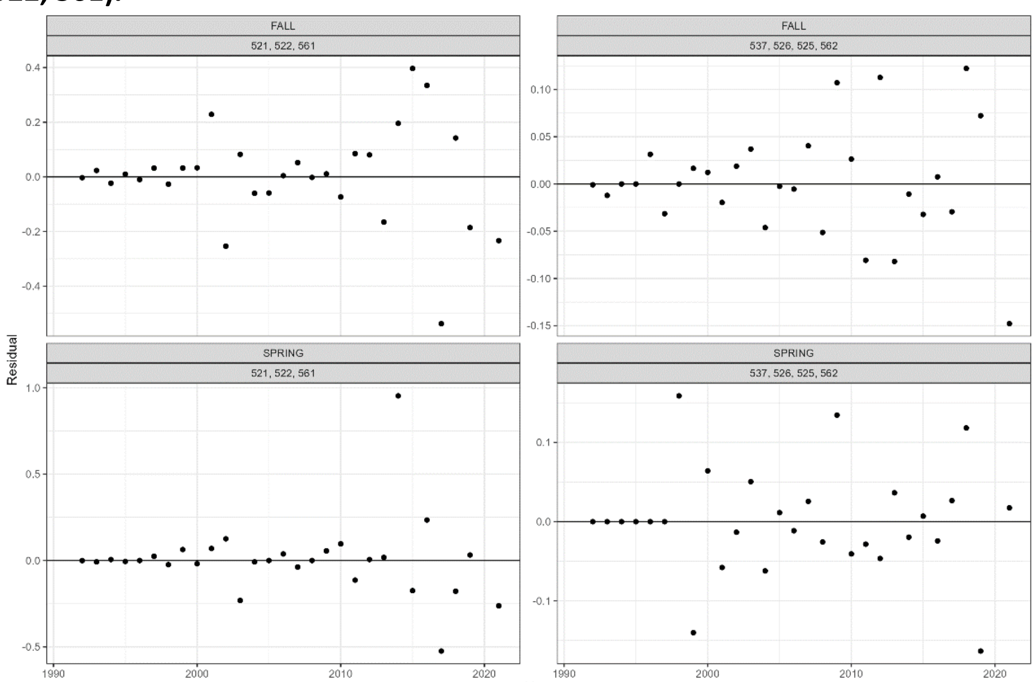

Figure 68. Residuals for two-year running average fits to NEFSC Trawl Survey seasonal exploitable abundance indices for adjacent NOAA statistical areas associated with high landings of Jonah crabs (Areas 537, 526, 525, 562) and low landings of Jonah crabs (Areas 521, 522, 561).

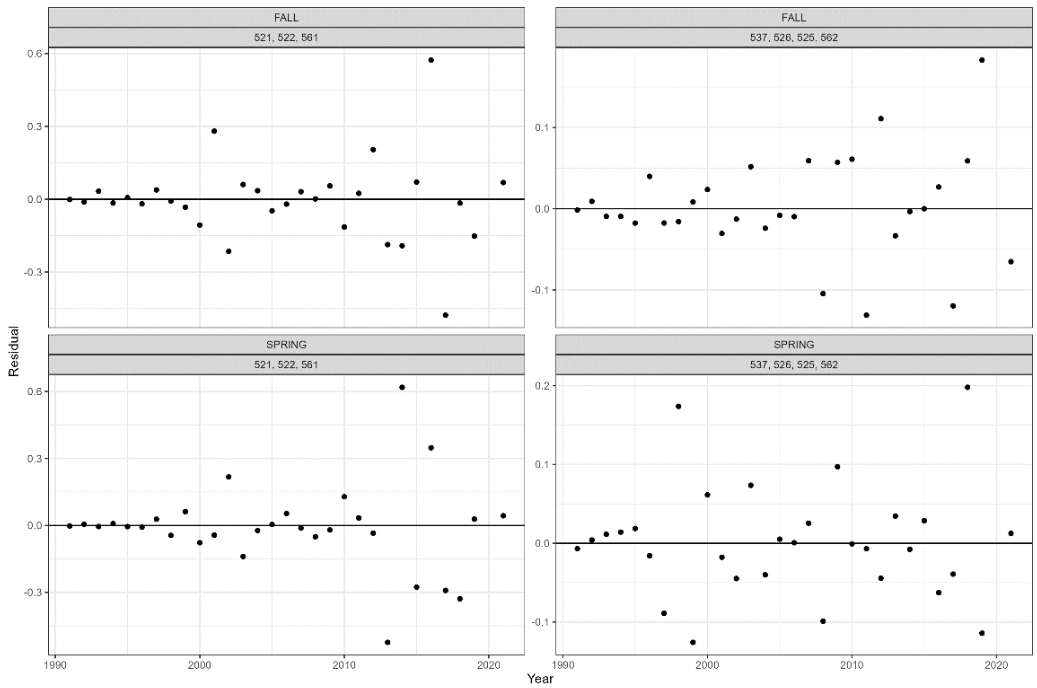

Figure 69. Residuals for LOESS smoother fits to NEFSC Trawl Survey seasonal exploitable abundance indices for adjacent NOAA statistical areas associated with high landings of Jonah crabs (Areas 537, 526, 525, 562) and low landings of Jonah crabs (Areas 521, 522, 561).

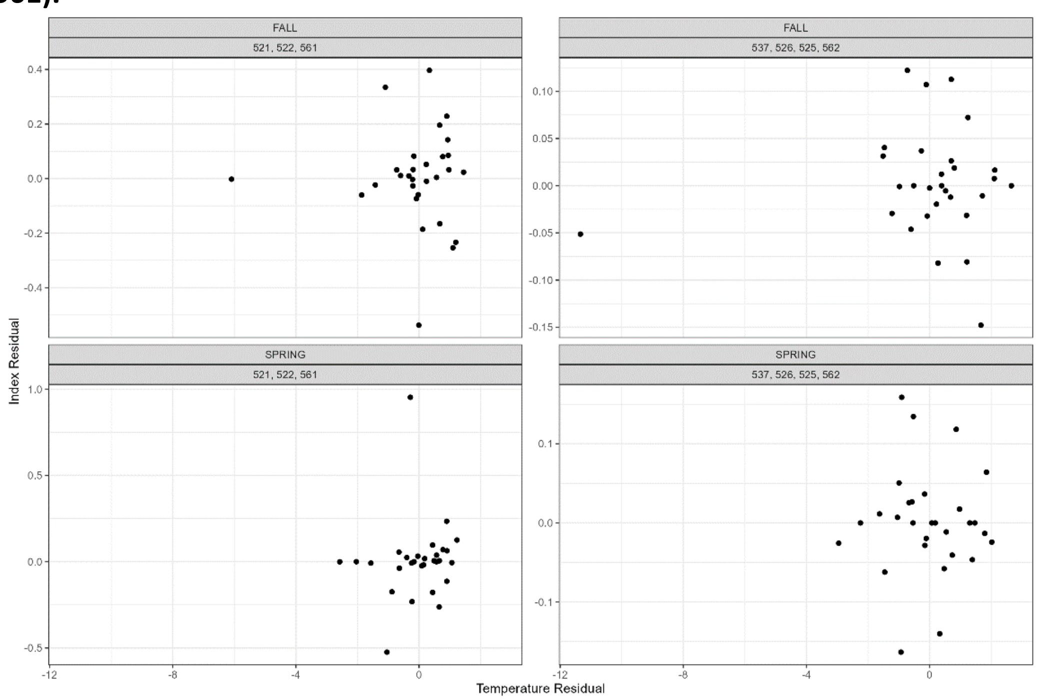

Figure 70. Residuals for NEFSC Trawl Survey seasonal exploitable abundance indices (using two-year running average fit) and temperature indices (using linear regression fit) for adjacent NOAA statistical areas associated with high landings of Jonah crabs (Areas 537, 526, 525, 562) and low landings of Jonah crabs (Areas 521, 522, 561).

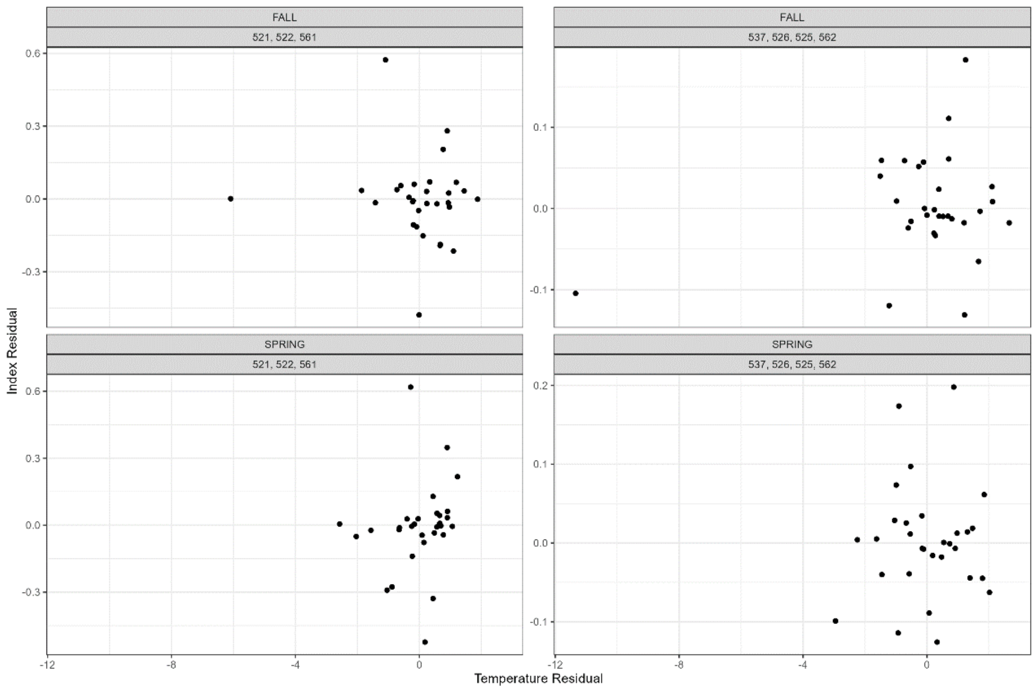

Figure 71. Residuals for NEFSC Trawl Survey seasonal exploitable abundance indices (using LOESS smoother fit) and temperature indices (using linear regression fit) for adjacent NOAA statistical areas associated with high landings of Jonah crabs (Areas 537, 526, 525, 562) and low landings of Jonah crabs (Areas 521, 522, 561).

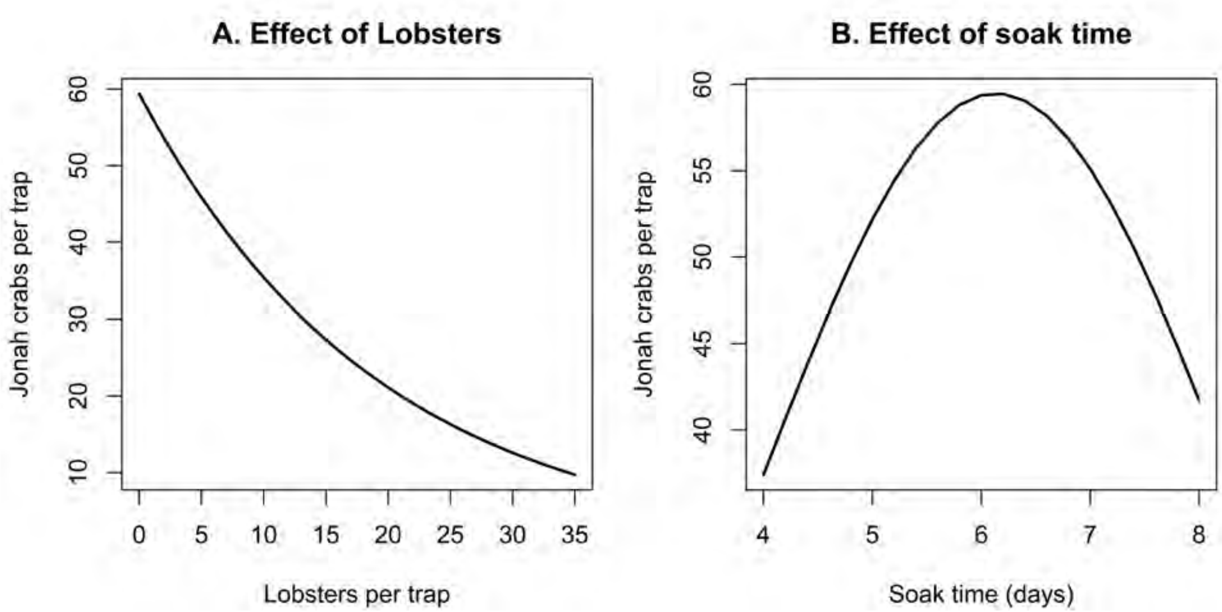

Figure 72. Results of negative binomial GLM fit to Jonah crab catch per trap. For predicting these effects, the values of other covariates were set as follows: trap_type=ventless, lat=41.2N, long=71W, habitat=sand, month=October. A. Partial effect of lobsters with soak_time=6. B. Partial effect of soak_time with lobsters=0.

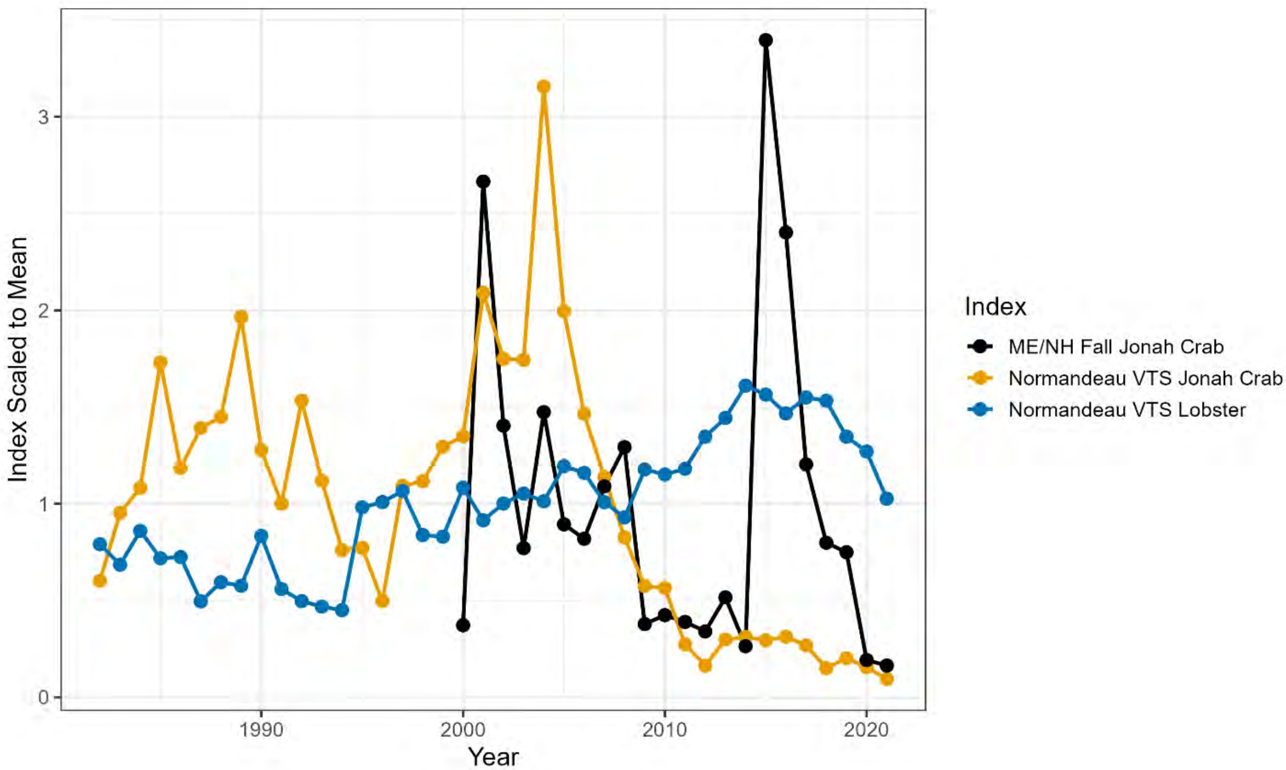

Figure 73. Comparison of nominal indices scaled to their time series mean for lobster and Jonah crab from the Normandeau Ventless Trap Survey (catch per trawl) and Jonah crab from the Maine/New Hampshire Trawl Survey (catch per tow).

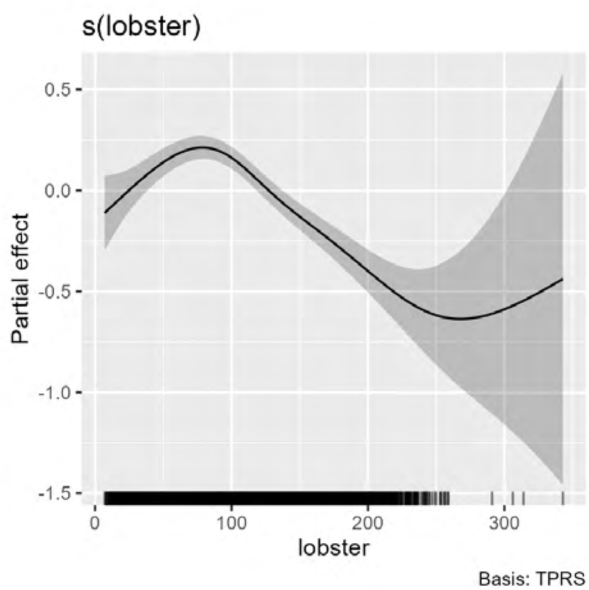

Figure 74. Estimated partial effect of lobster catch (x-axis) on Jonah crab catch (y-axis; on link scale) from generalized additive model applied to the Normandeau Ventless Trap Survey.

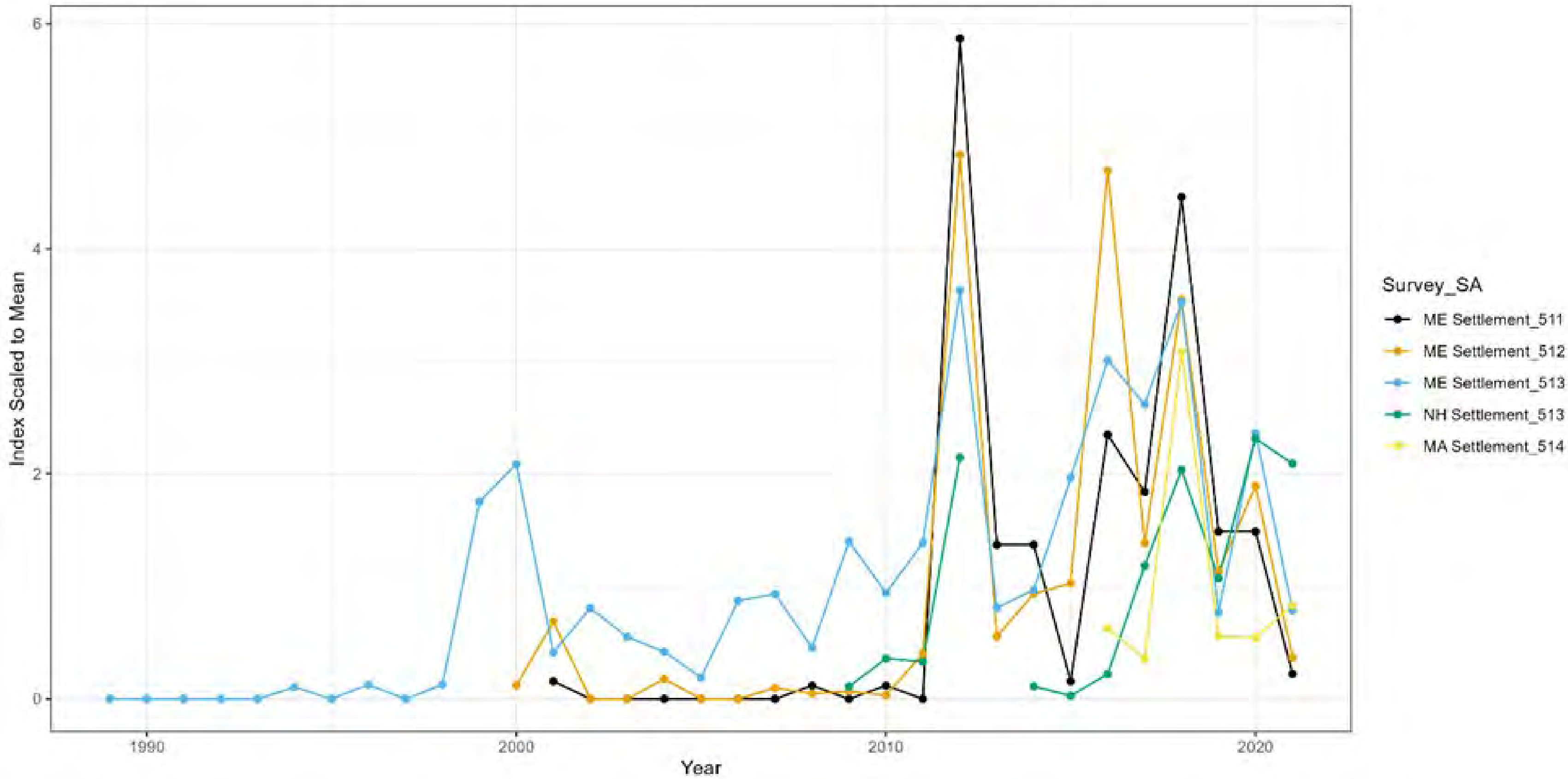

Figure 75. Jonah crab young-of-year settlement indices for the IGOM stock.

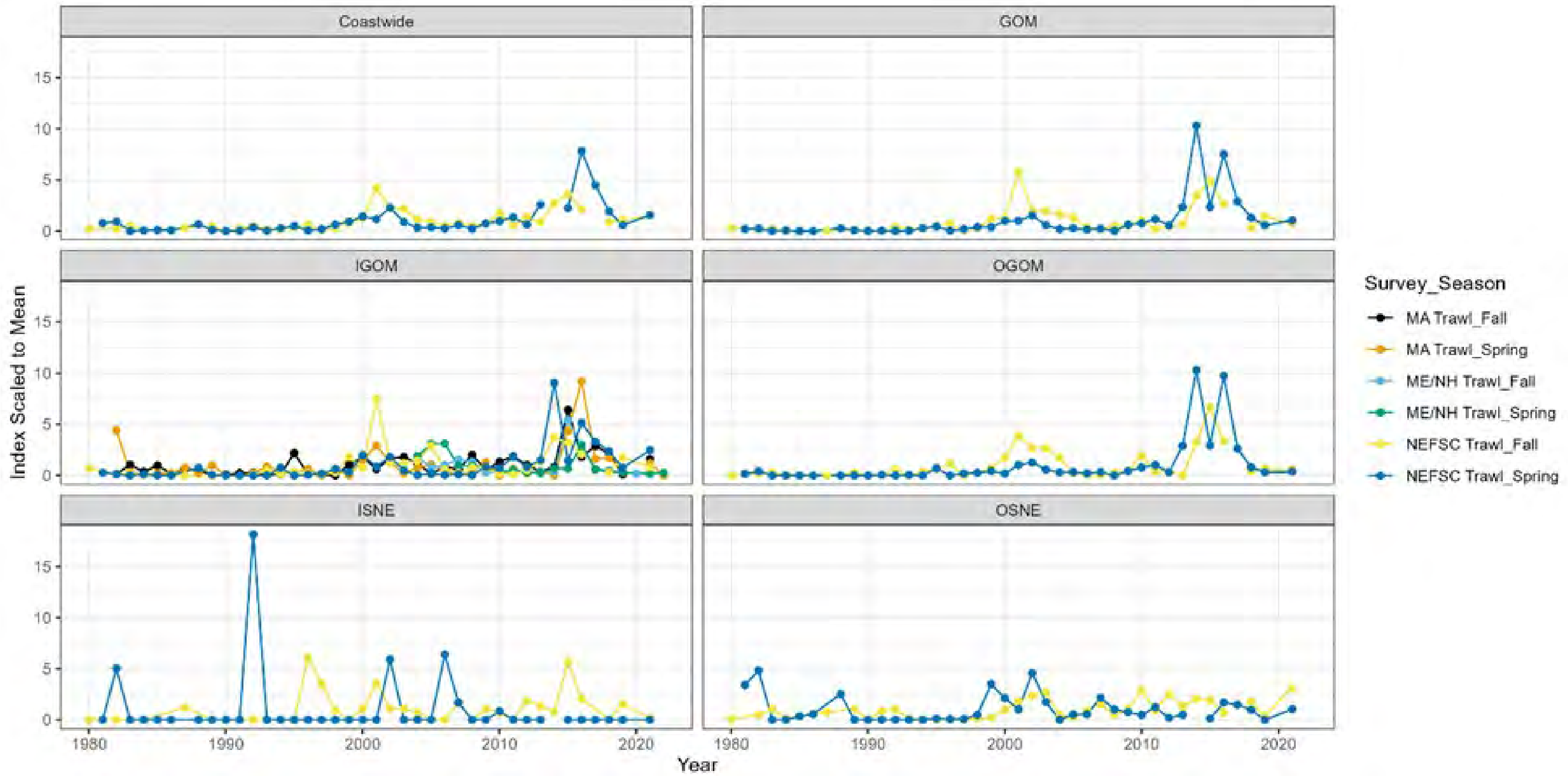

Figure 76. Jonah crab recruit abundance indices.

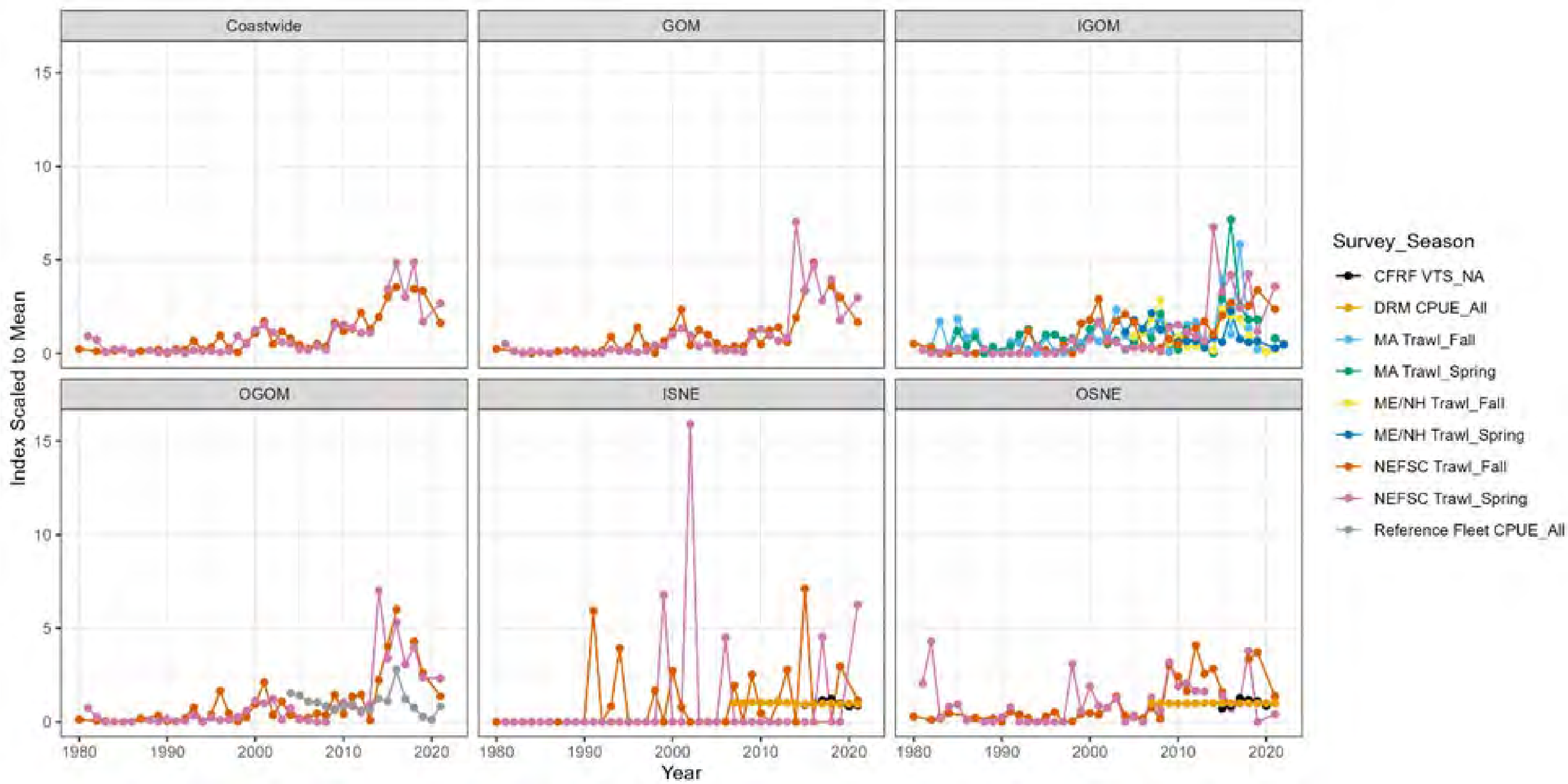

Figure 77. Jonah crab exploitable abundance indices.

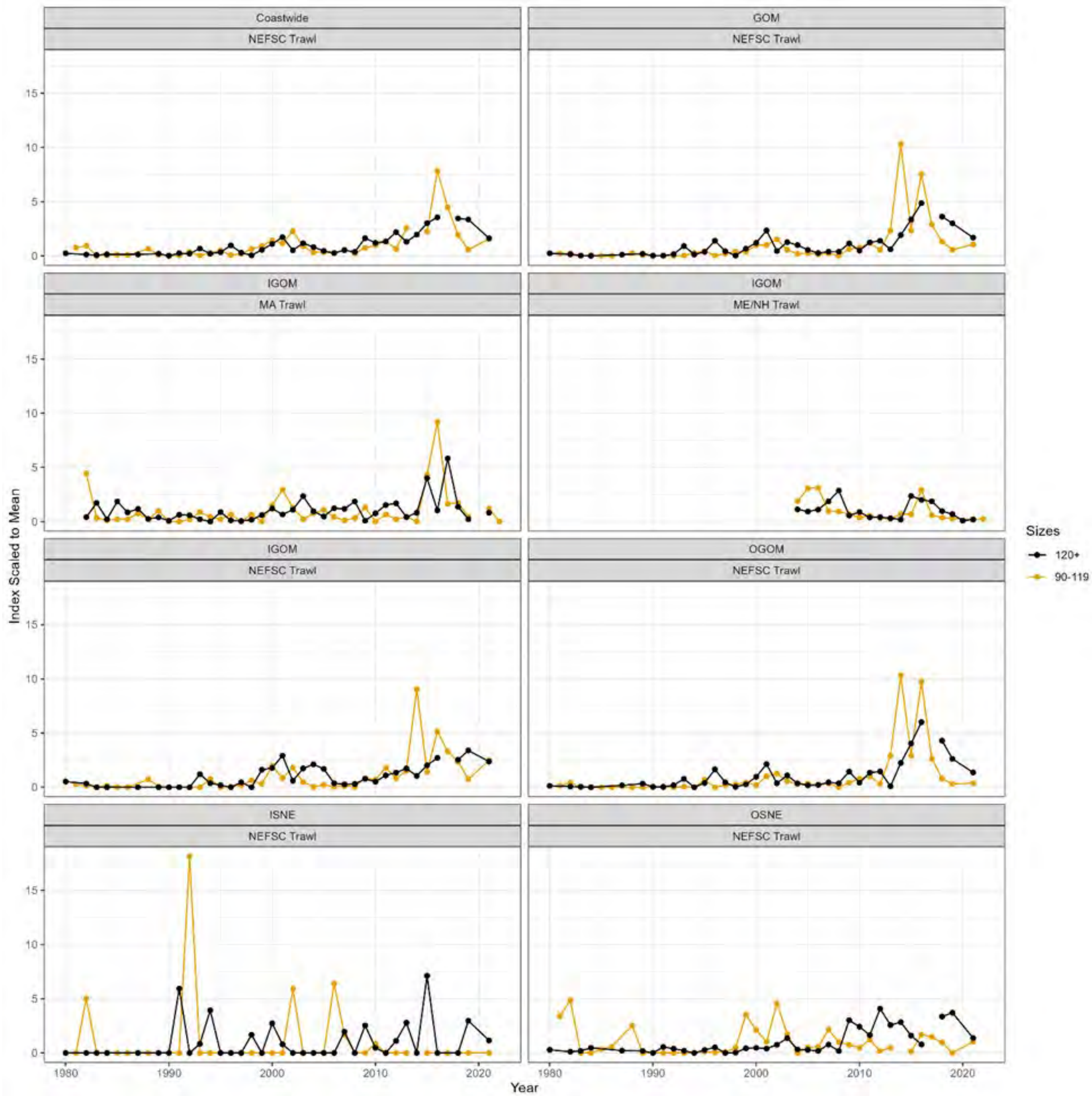

Figure 78. Jonah crab spring recruit abundance and fall exploitable abundance indices.

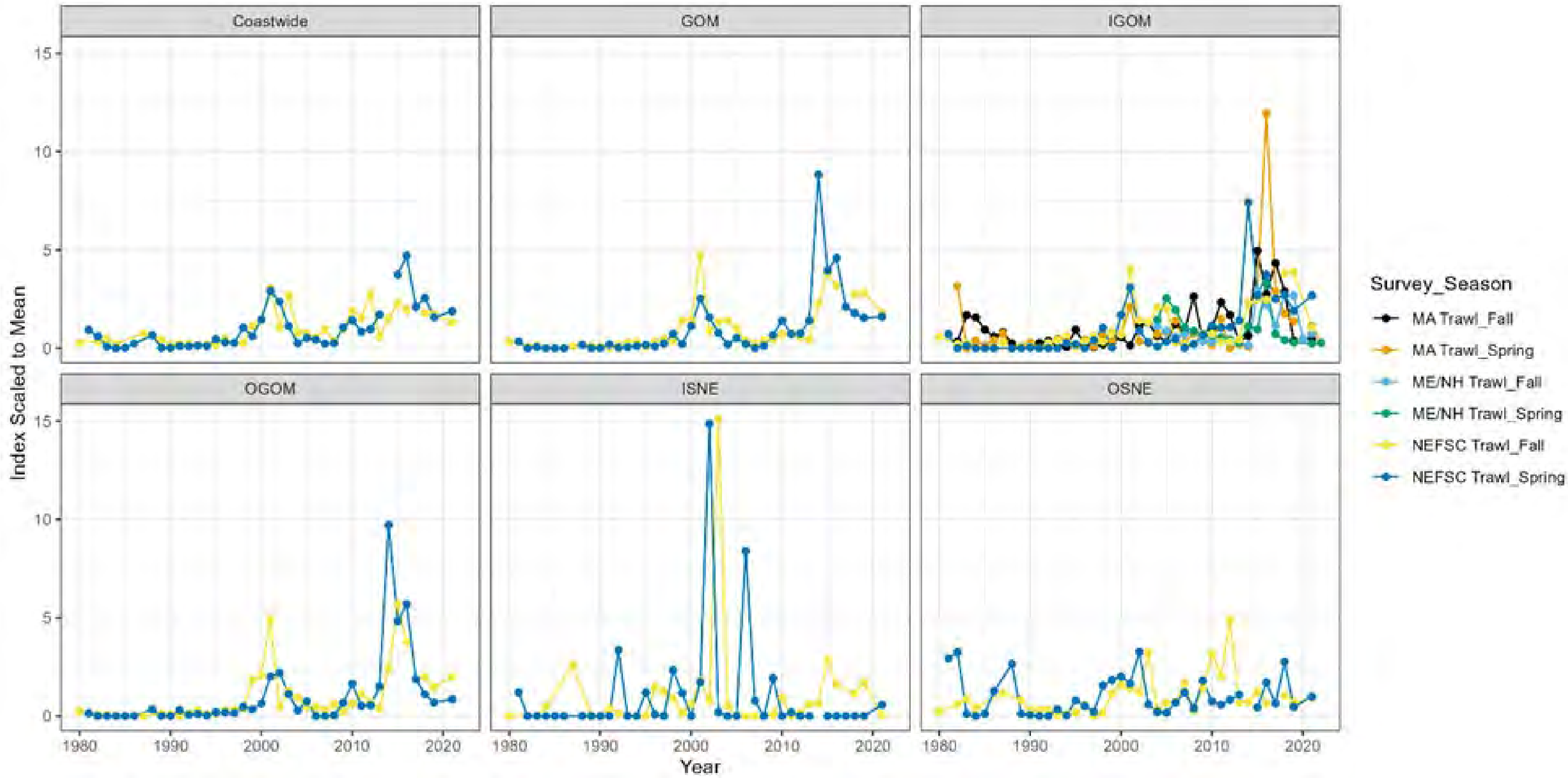

Figure 79. Jonah crab spawning abundance indices.

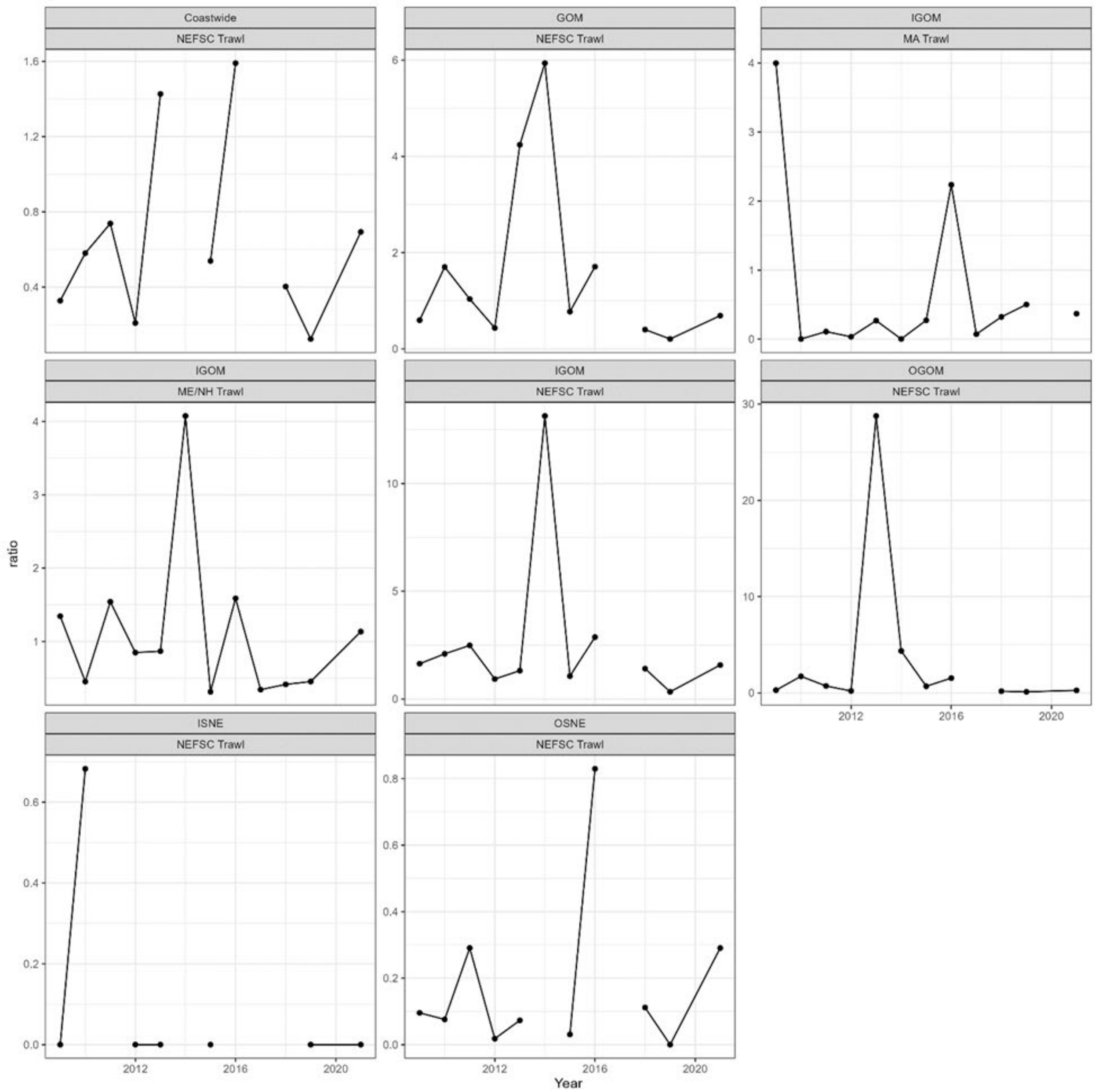

Figure 80. Jonah crab spring recruit abundance:fall exploitable abundance index ratios.

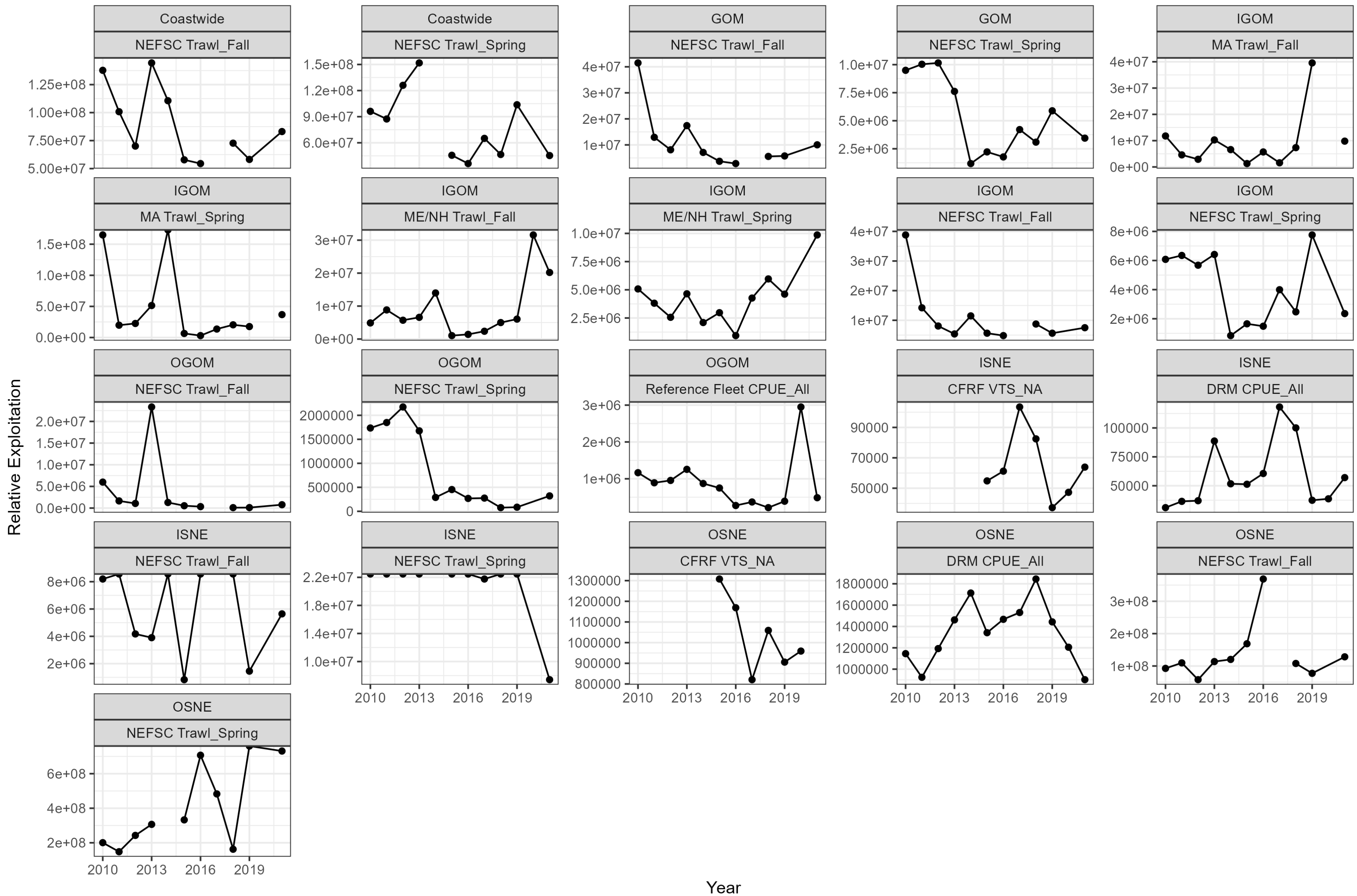

Figure 81. Jonah crab relative exploitation time series.

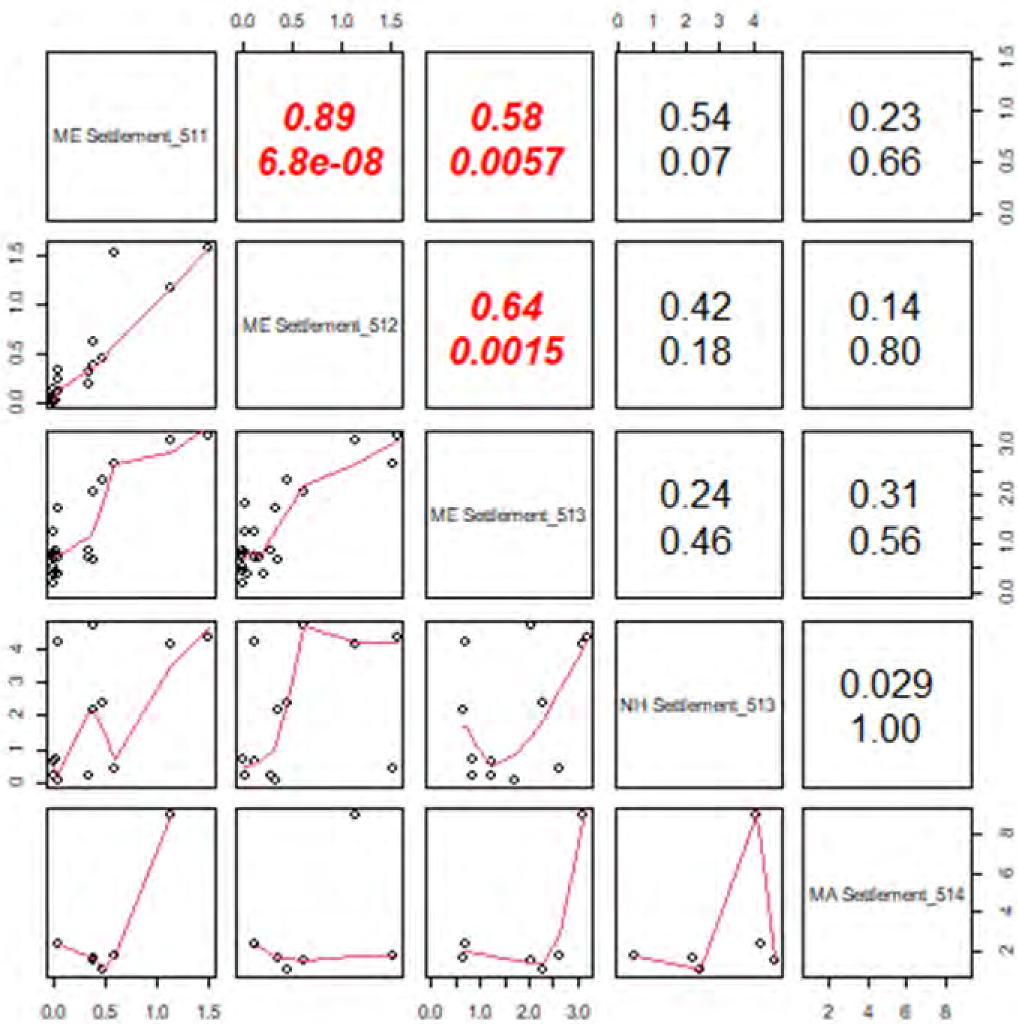

Figure 82. Spearman correlation results for young-of-year settlement indices for the IGOM stock. Panels above the diagonal include the Spearman's ρ as the top number and the p-value as the bottom number. Italicized and red numbers indicate significant correlations (p-value<0.05).

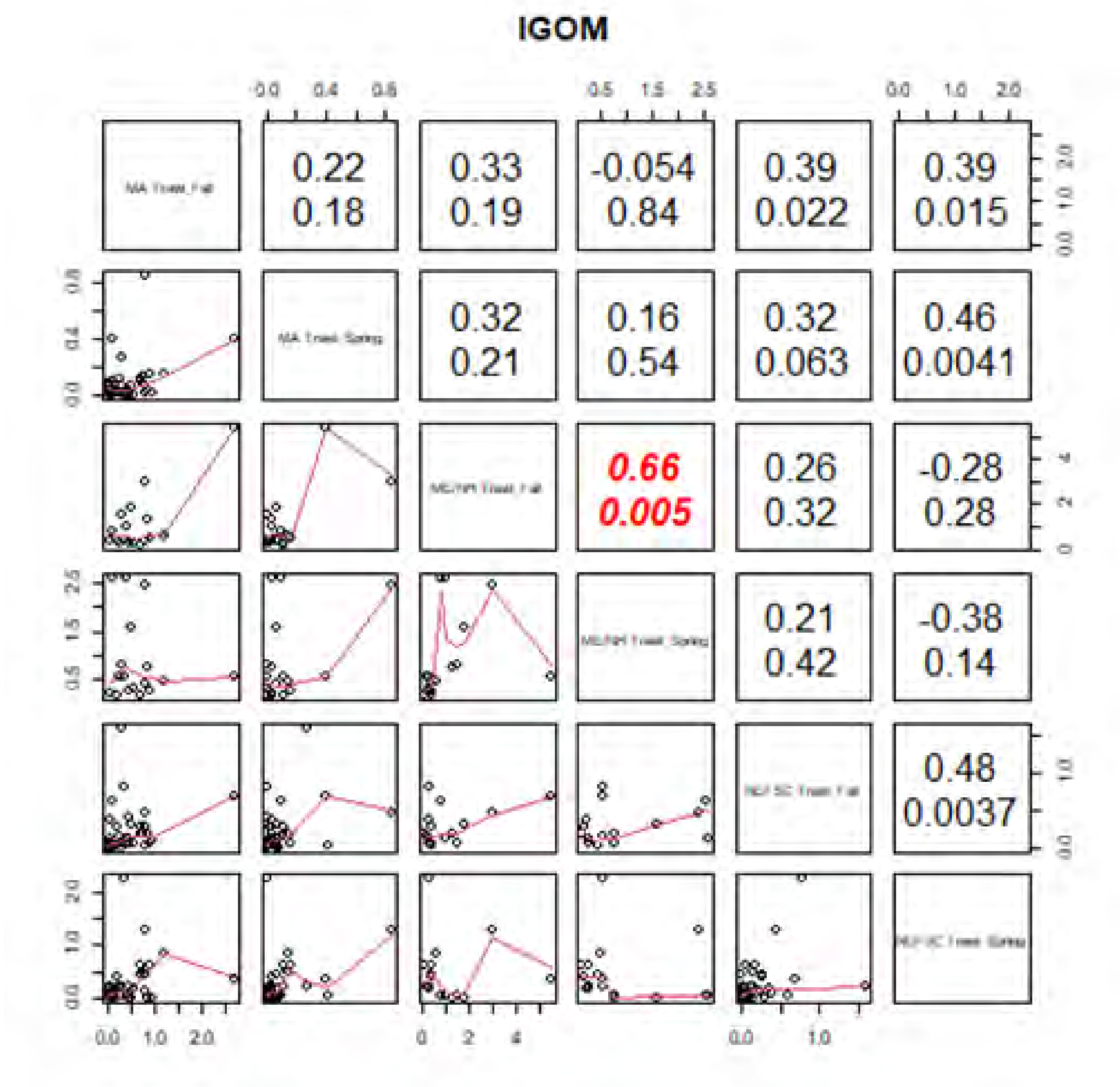

Figure 83. Spearman correlation results for IGOM recruit indices. Panels above the diagonal include the Spearman's ρ as the top number and the p-value as the bottom number. Italicized and red numbers indicate significant correlations (p-value<0.05).

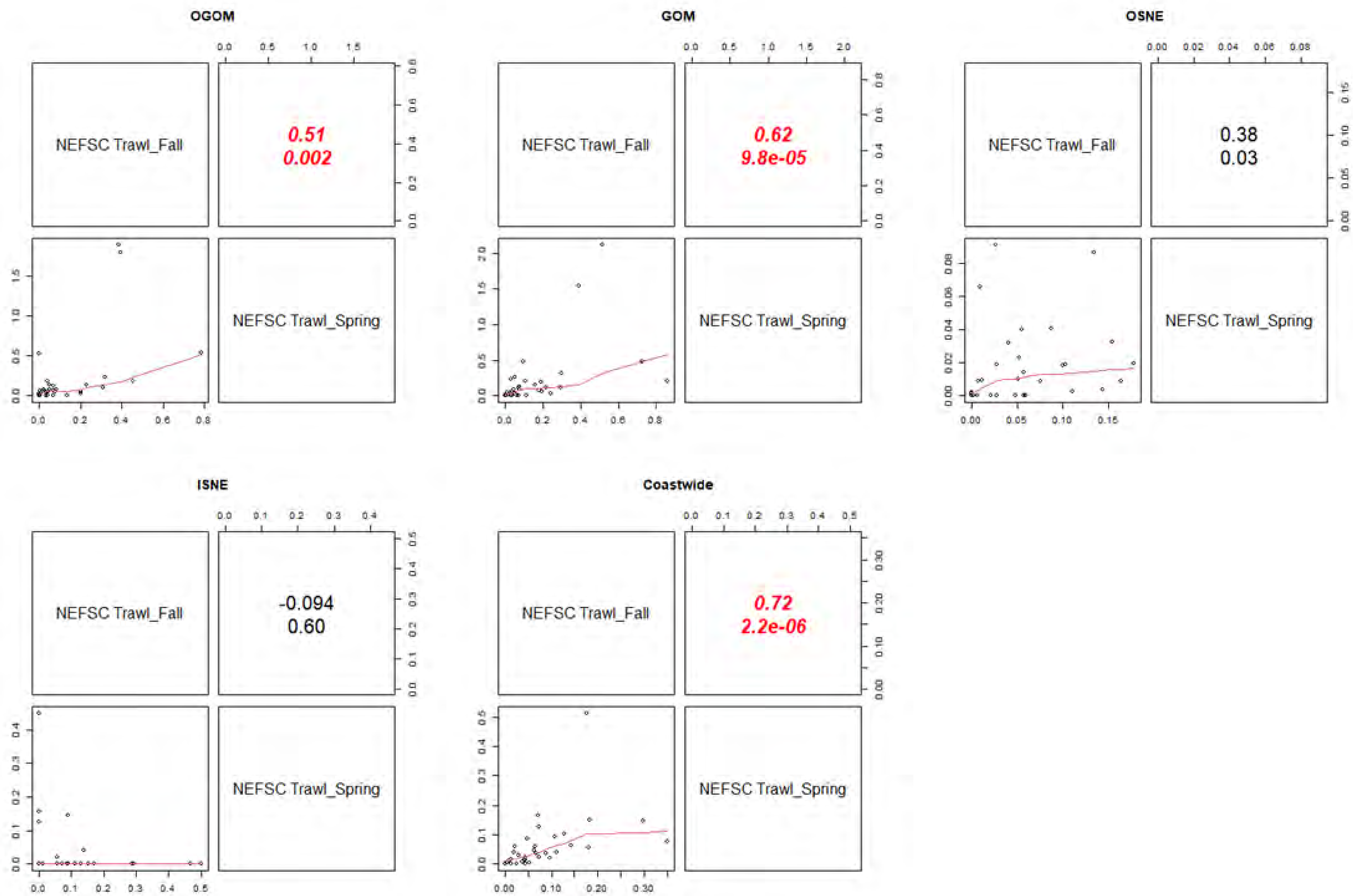

Figure 84. Spearman correlation results for OGOM, GOM, OSNE, ISNE, and coastwide recruit indices. Panels above the diagonal include the Spearman's ρ as the top number and the p-value as the bottom number. Italicized and red numbers indicate significant correlations (p-value<0.05).

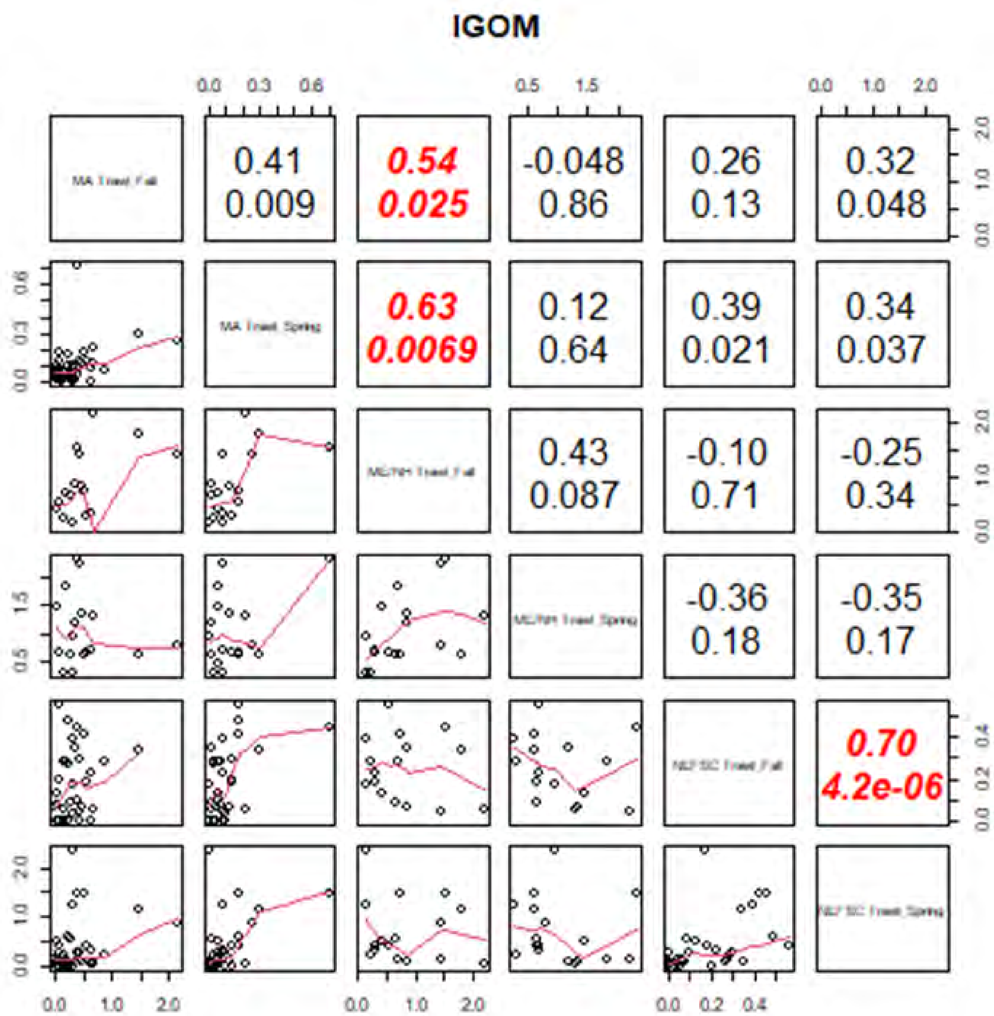

Figure 85. Spearman correlation results for IGOM exploitable abundance indices. Panels above the diagonal include the Spearman's ρ as the top number and the p-value as the bottom number. Italicized and red numbers indicate significant correlations (p-value<0.05).

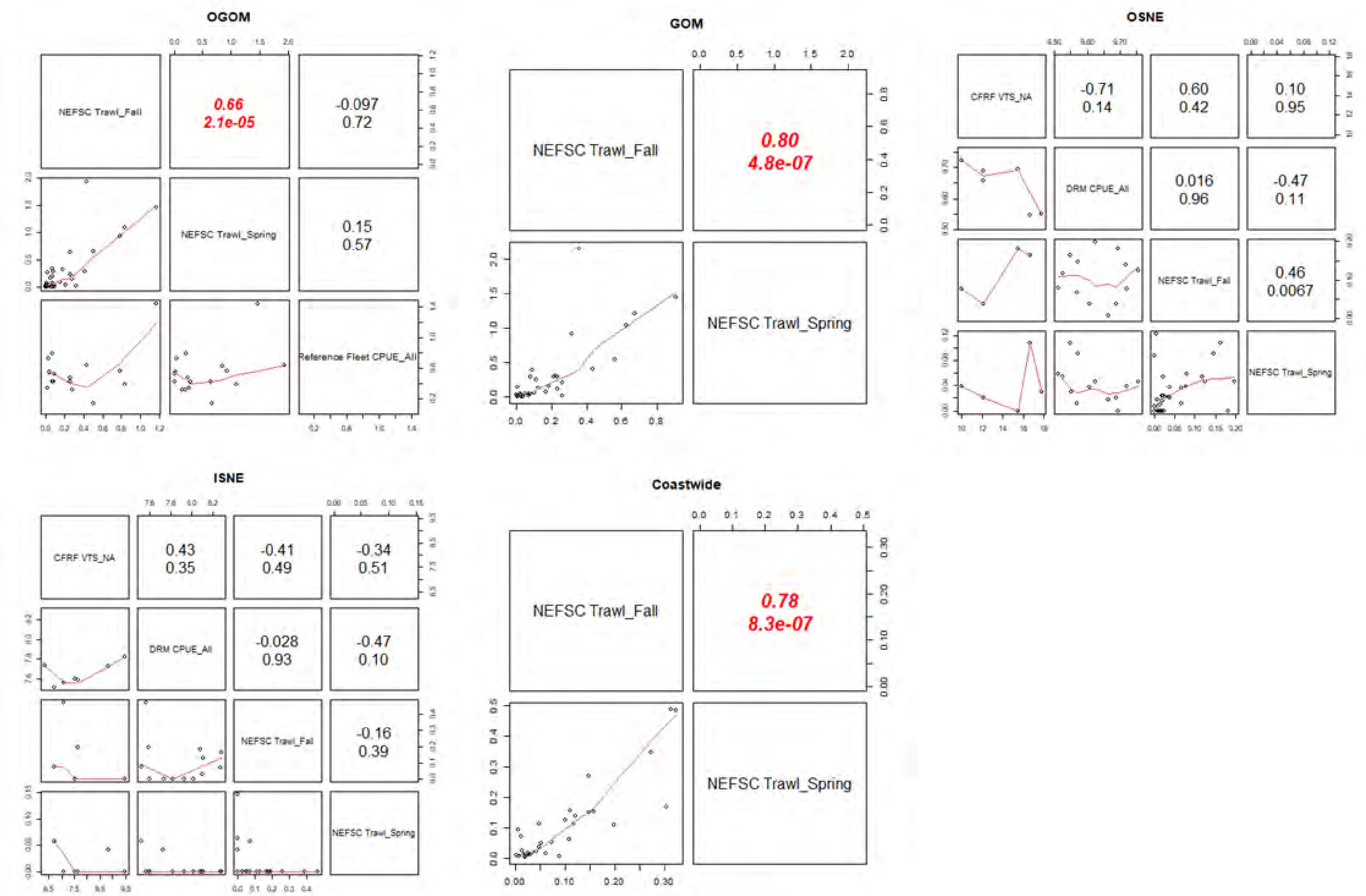

Figure 86. Spearman correlation results for OGOM, GOM, OSNE, ISNE, and coastwide exploitable abundance indices. Panels above the diagonal include the Spearman's ρ as the top number and the p-value as the bottom number. Italicized and red numbers indicate significant correlations (p-value<0.05).

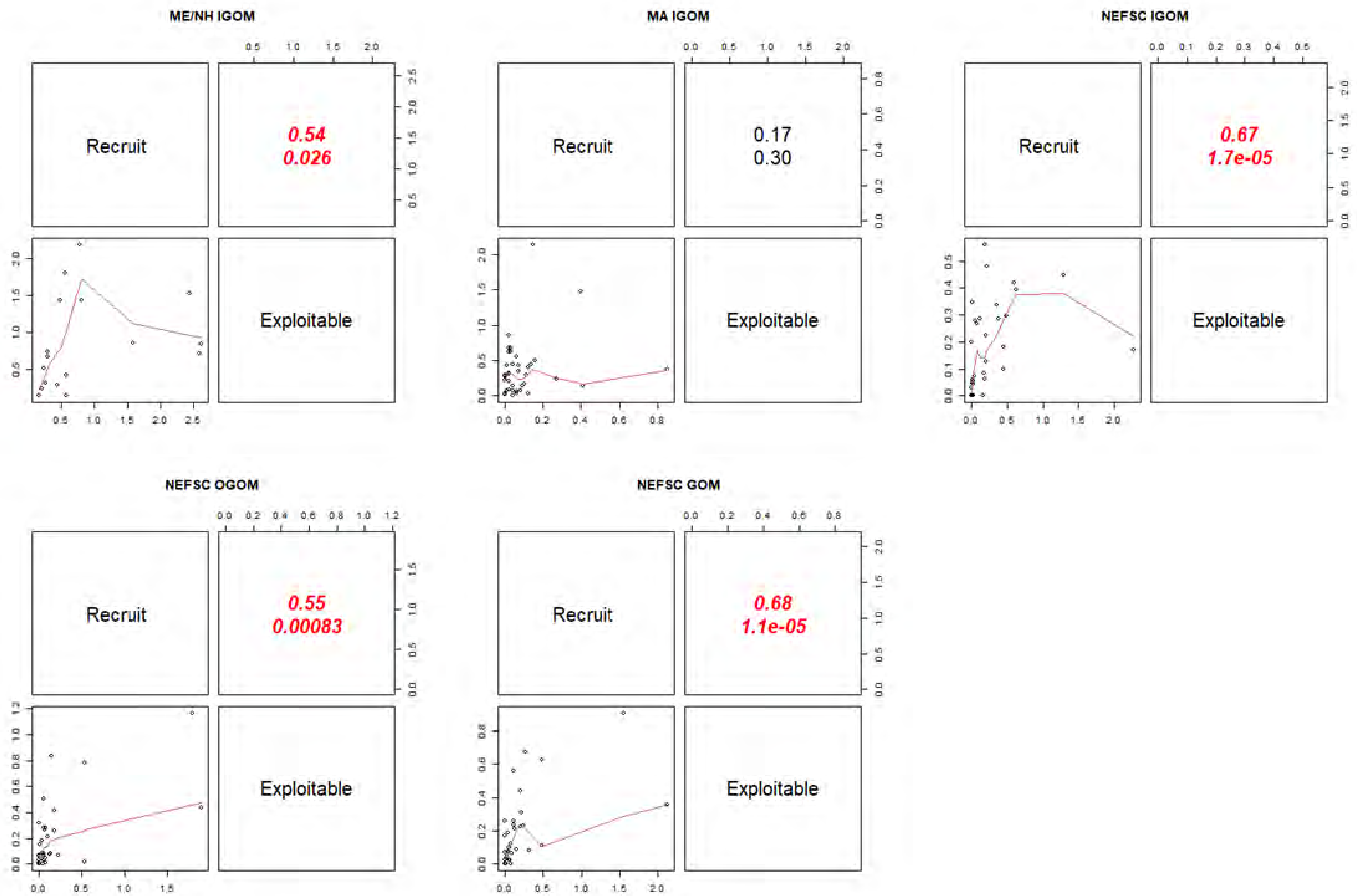

Figure 87. Spearman correlation results for IGOM, OGOM, and GOM spring recruit and fall exploitable abundance indices. Panels above the diagonal include the Spearman's ρ as the top number and the p-value as the bottom number. Italicized and red numbers indicate significant correlations (p-value<0.05).

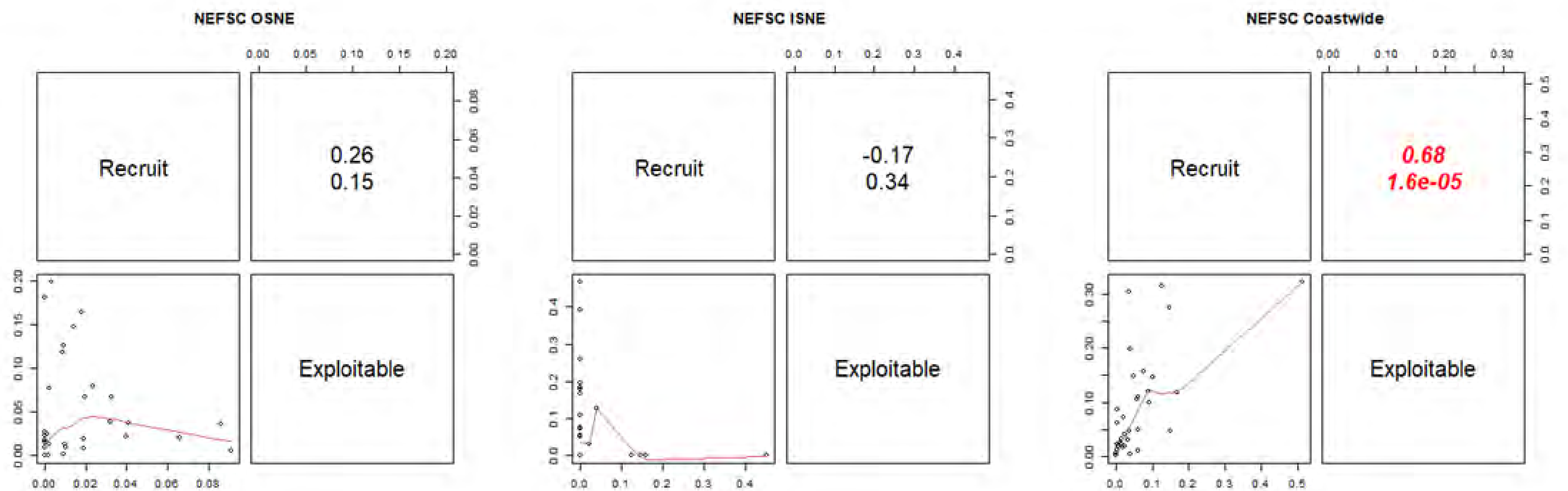

Figure 88. Spearman correlation results for OSNE, ISNE, and coastwide spring recruit and fall exploitable abundance indices. Panels above the diagonal include the Spearman's ρ as the top number and the p-value as the bottom number. Italicized and red numbers indicate significant correlations (p-value<0.05).

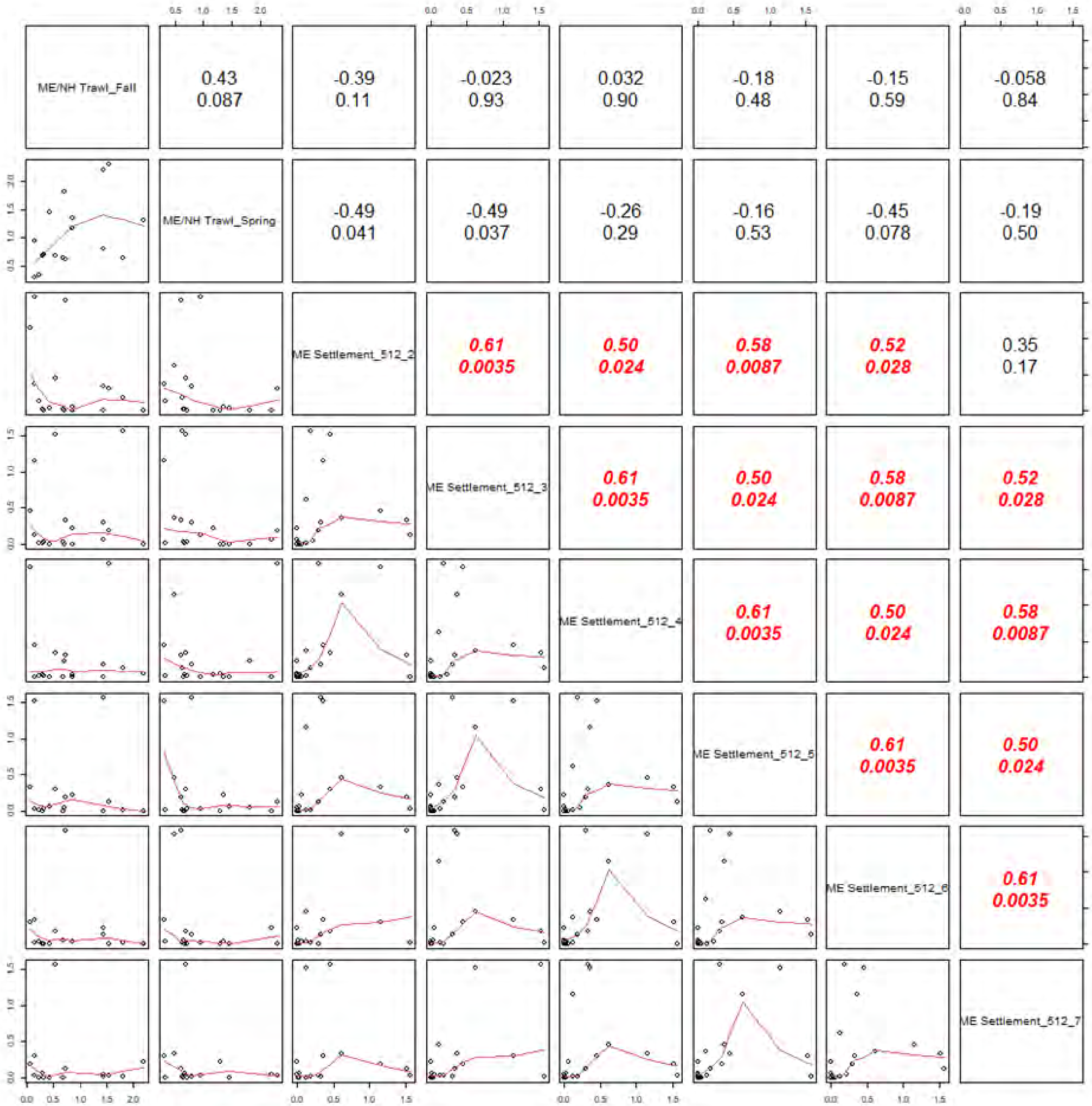

Figure 89. Spearman correlation results for ME/NH trawl survey exploitable abundance indices and lagged ME 512 settlement survey indices. Panels above the diagonal include the Spearman's ρ as the top number and the p-value as the bottom number. Italicized and red numbers indicate significant correlations (p-value<0.05).

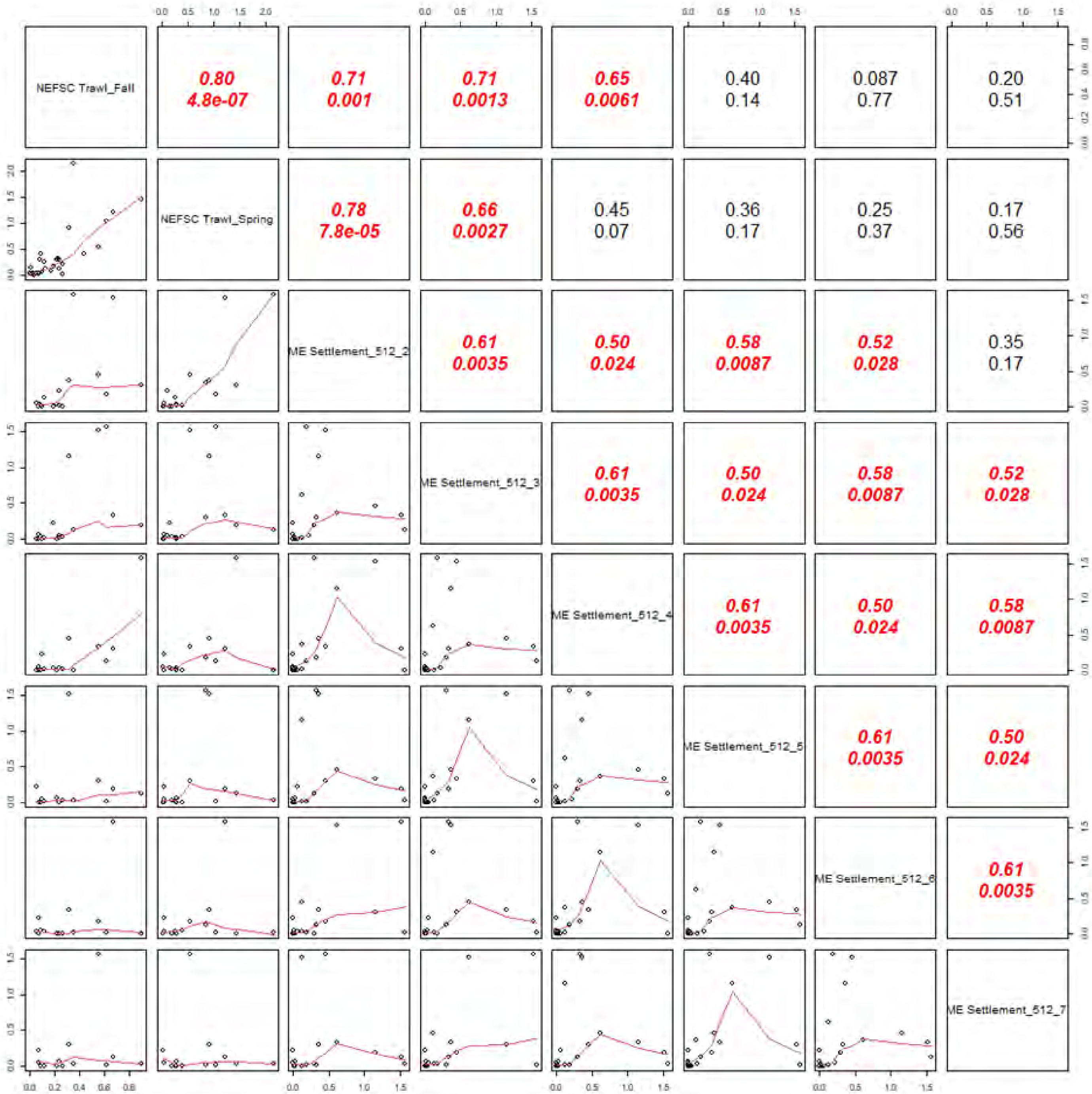

Figure 90. Spearman correlation results for NEFSC trawl survey exploitable abundance indices and lagged ME 512 settlement survey indices. Panels above the diagonal include the Spearman's ρ as the top number and the p-value as the bottom number. Italicized and red numbers indicate significant correlations (p-value<0.05).

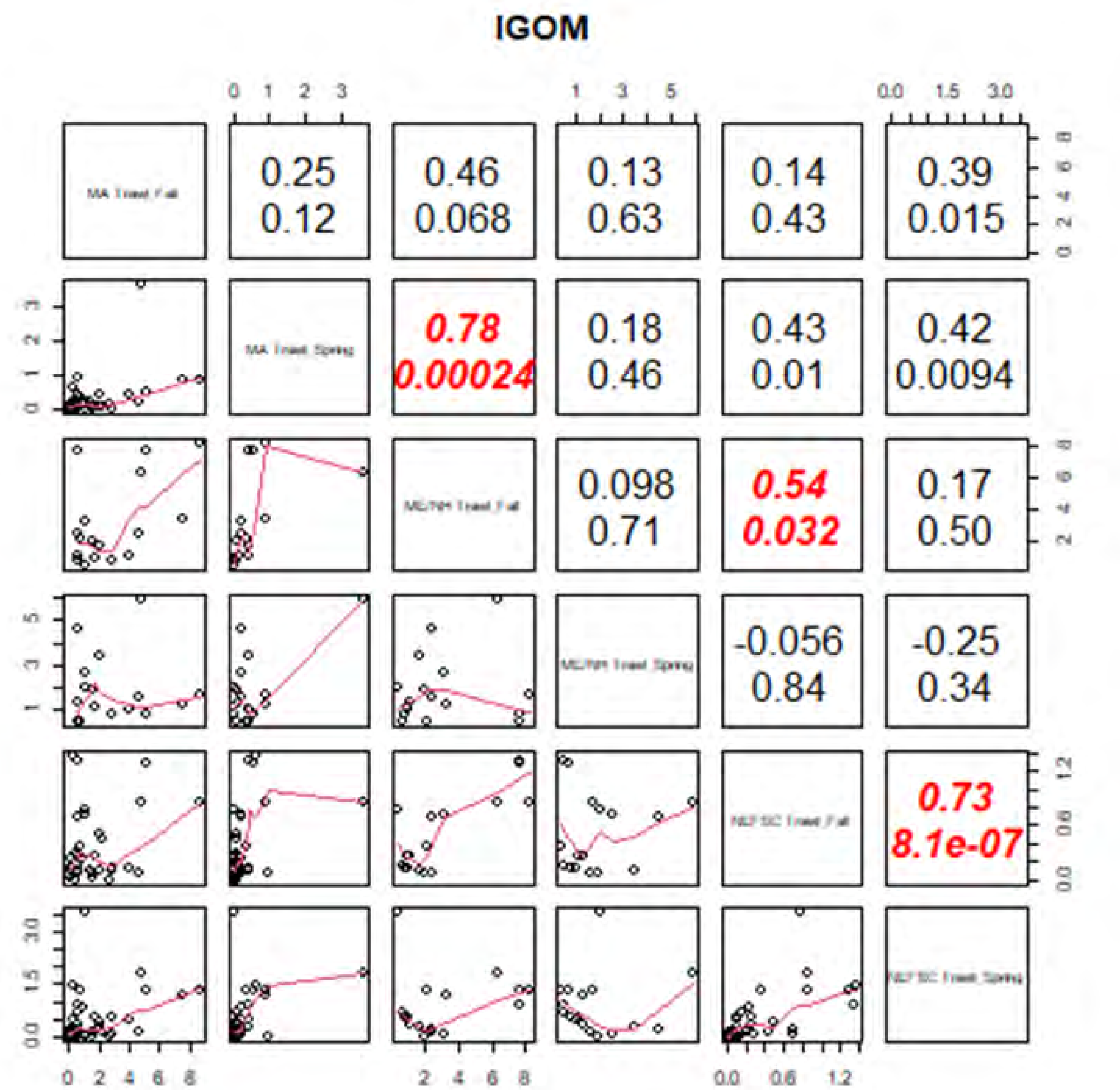

Figure 91. Spearman correlation results for IGOM spawning abundance indices. Panels above the diagonal include the Spearman's ρ as the top number and the p-value as the bottom number. Italicized and red numbers indicate significant correlations (p-value<0.05).

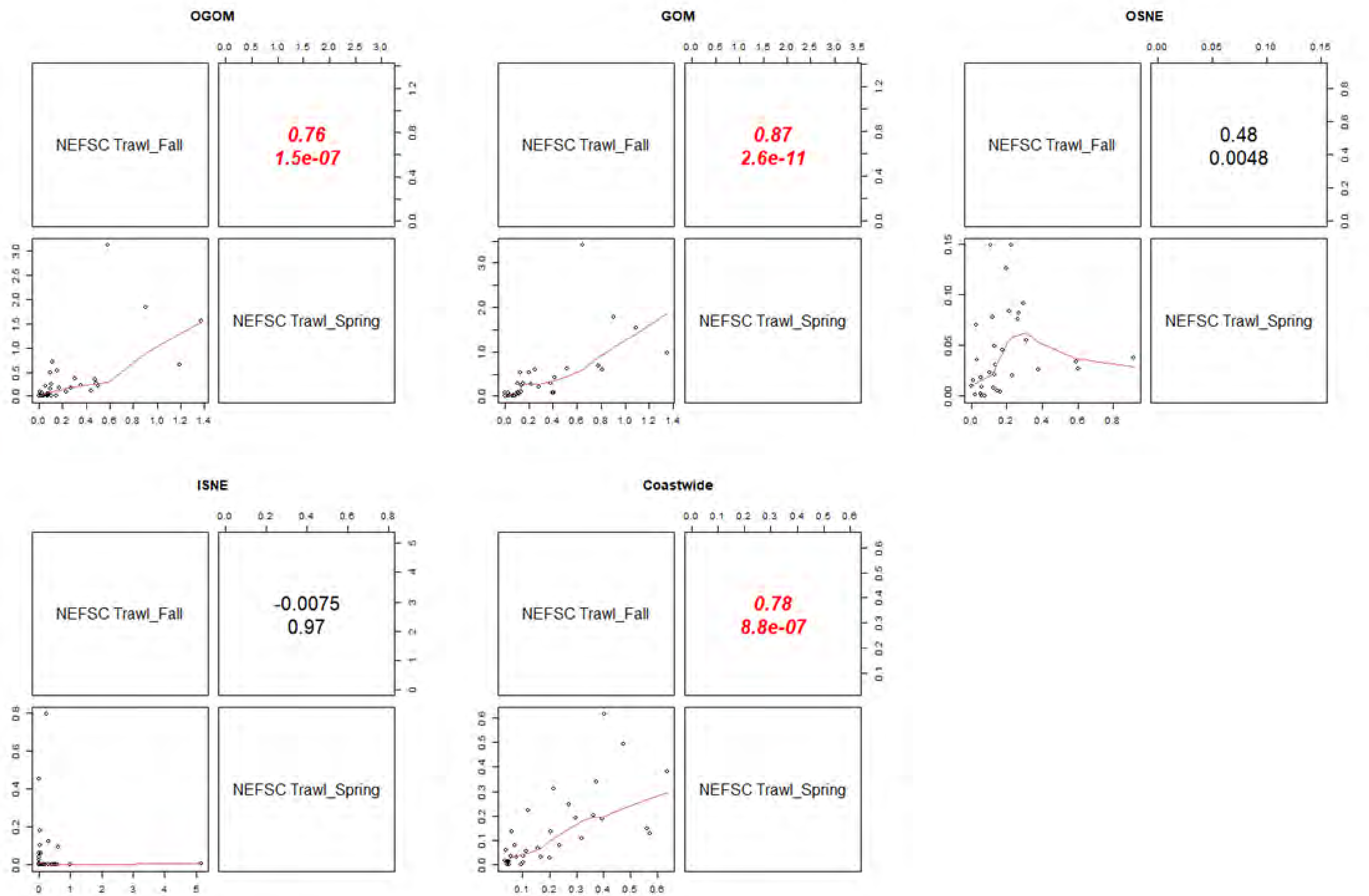

Figure 92. Spearman correlation results for OGOM, GOM, OSNE, ISNE, and coastwide spawning abundance indices. Panels above the diagonal include the Spearman's ρ as the top number and the p-value as the bottom number. Italicized and red numbers indicate significant correlations (p-value<0.05).

Figure 93. Spearman correlation results for GOM exploitable abundance indices and landings. Panels above the diagonal include the Spearman's ρ as the top number and the p-value as the bottom number. Italicized and red numbers indicate significant correlations (p-value<0.05).

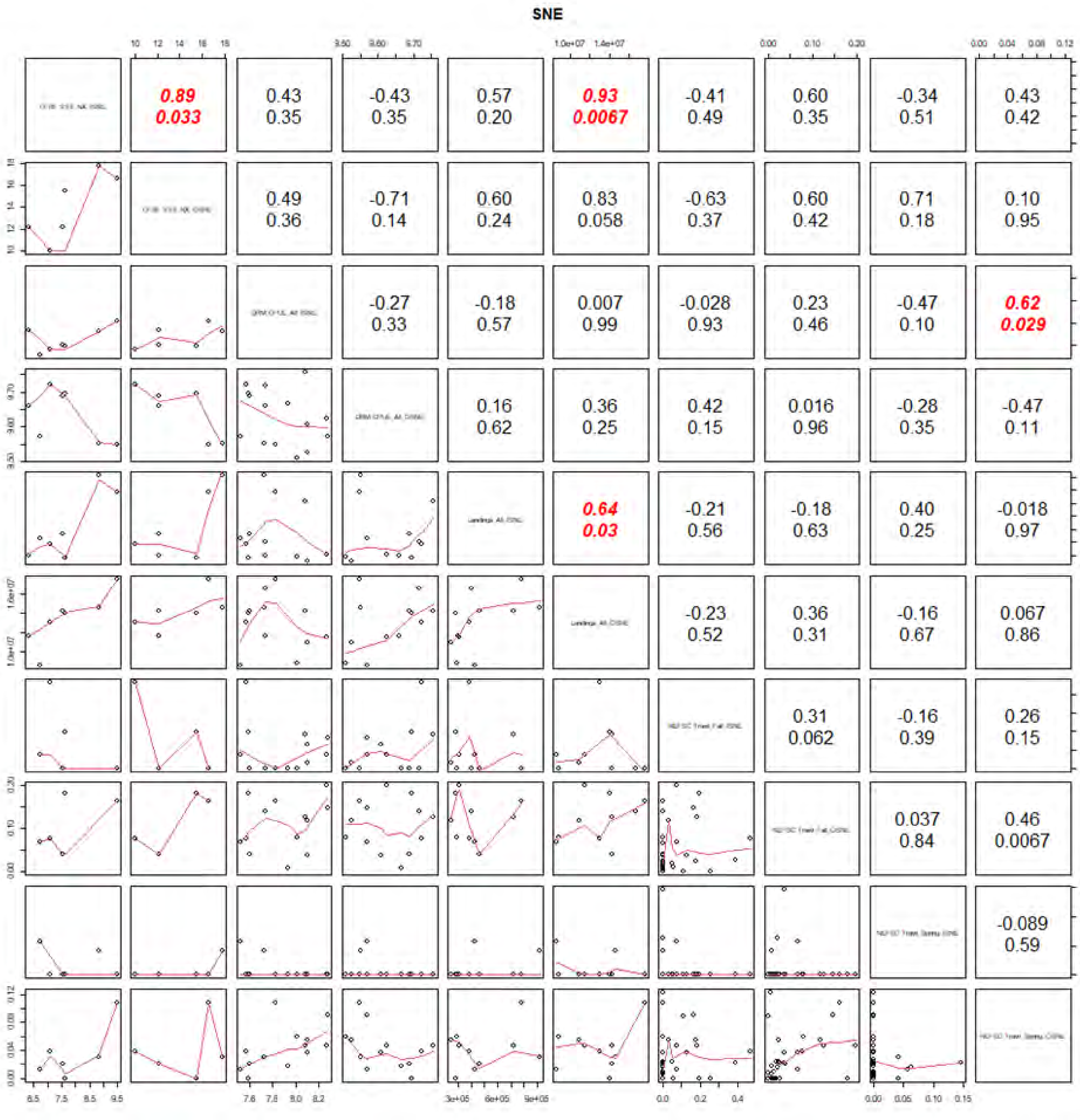

Figure 94. Spearman correlation results for SNE exploitable abundance indices and landings. Panels above the diagonal include the Spearman's ρ as the top number and the p-value as the bottom number. Italicized and red numbers indicate significant correlations (p-value<0.05).

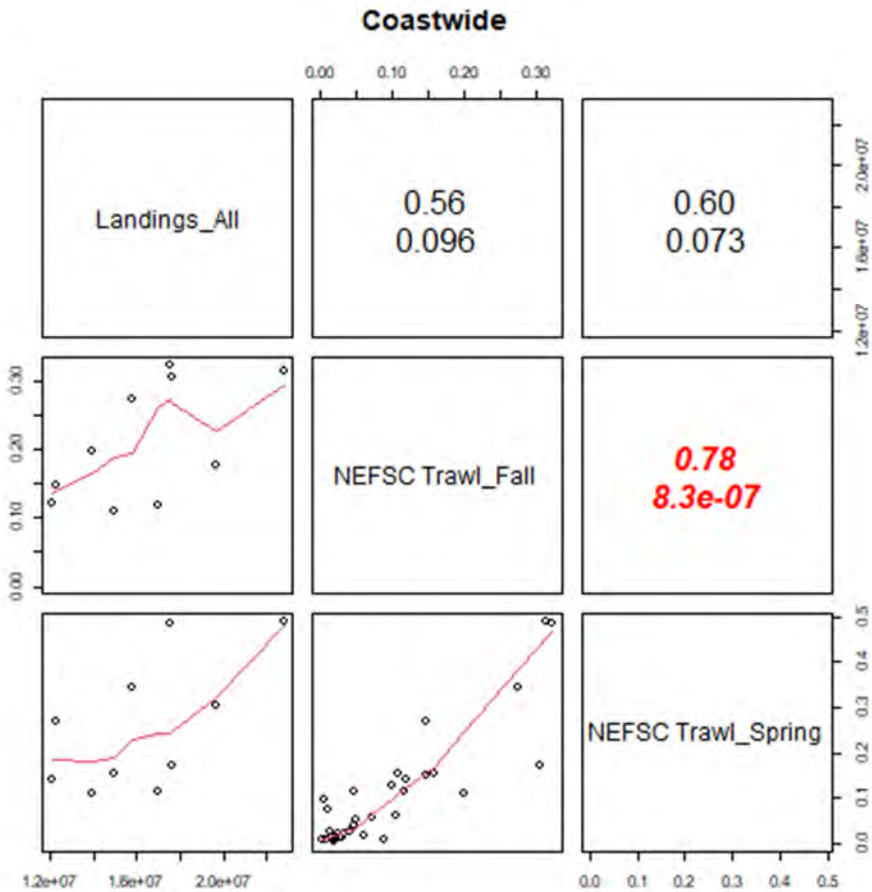

Figure 95. Spearman correlation results for coastwide exploitable abundance indices and landings. Panels above the diagonal include the Spearman's ρ as the top number and the p-value as the bottom number. Italicized and red numbers indicate significant correlations (p-value<0.05).

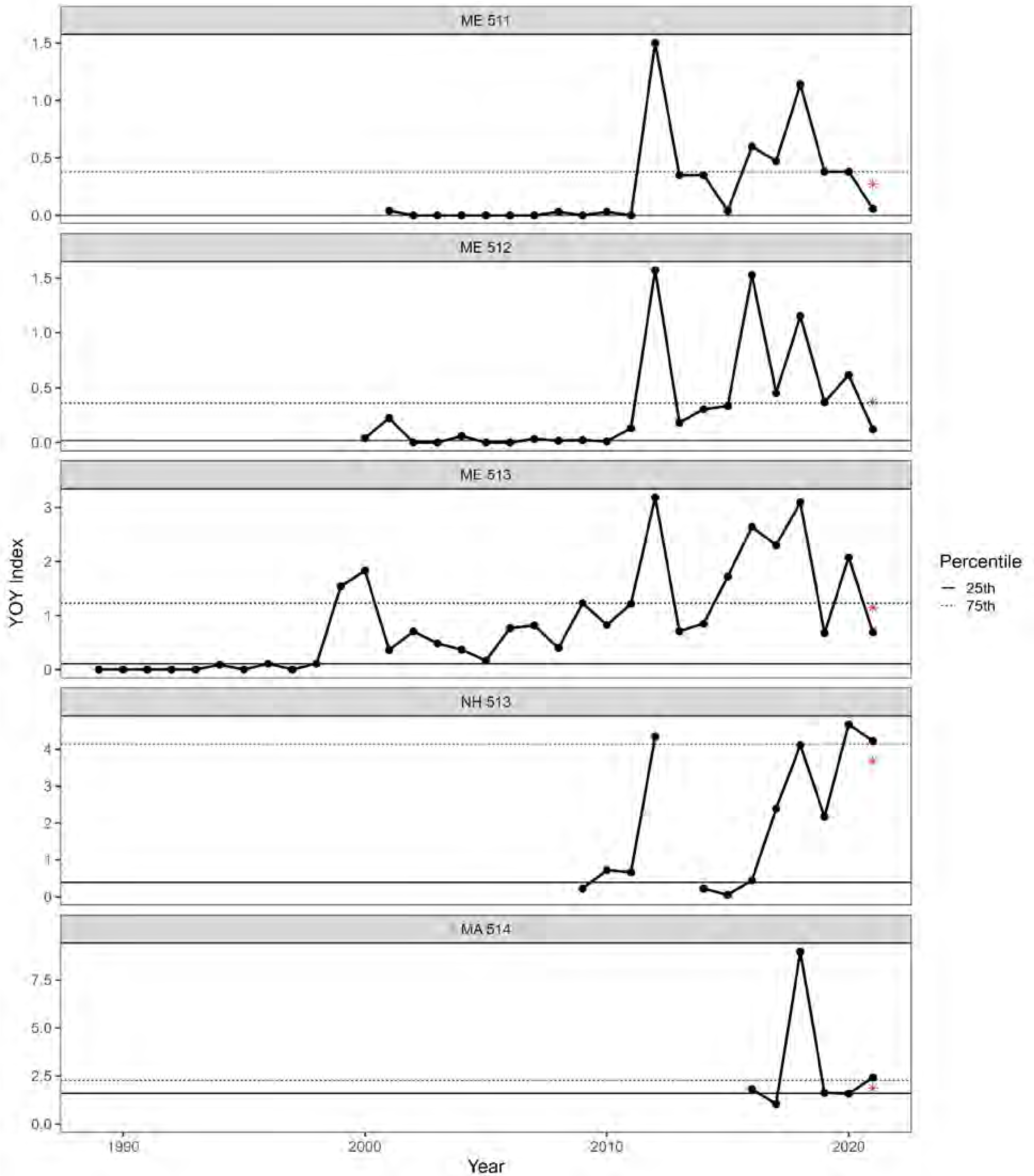

Figure 96. YOY settlement indicators for the IGOM Jonah crab stock. Red asterisks indicate the terminal three-year (2019-2021) average.

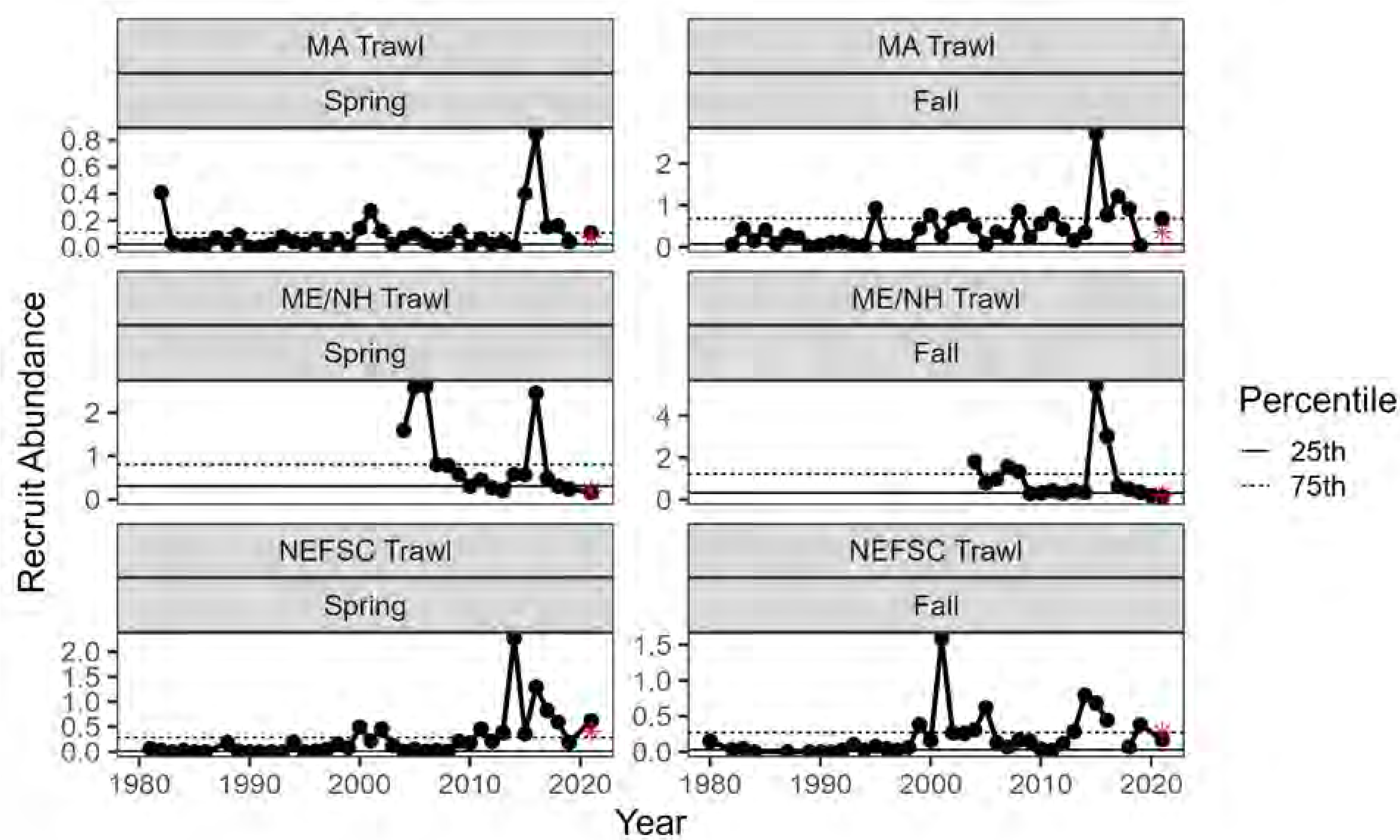

Figure 97. Recruit abundance indicators for the IGOM Jonah crab stock. Red asterisks indicate the terminal three-year (2019-2021) average.

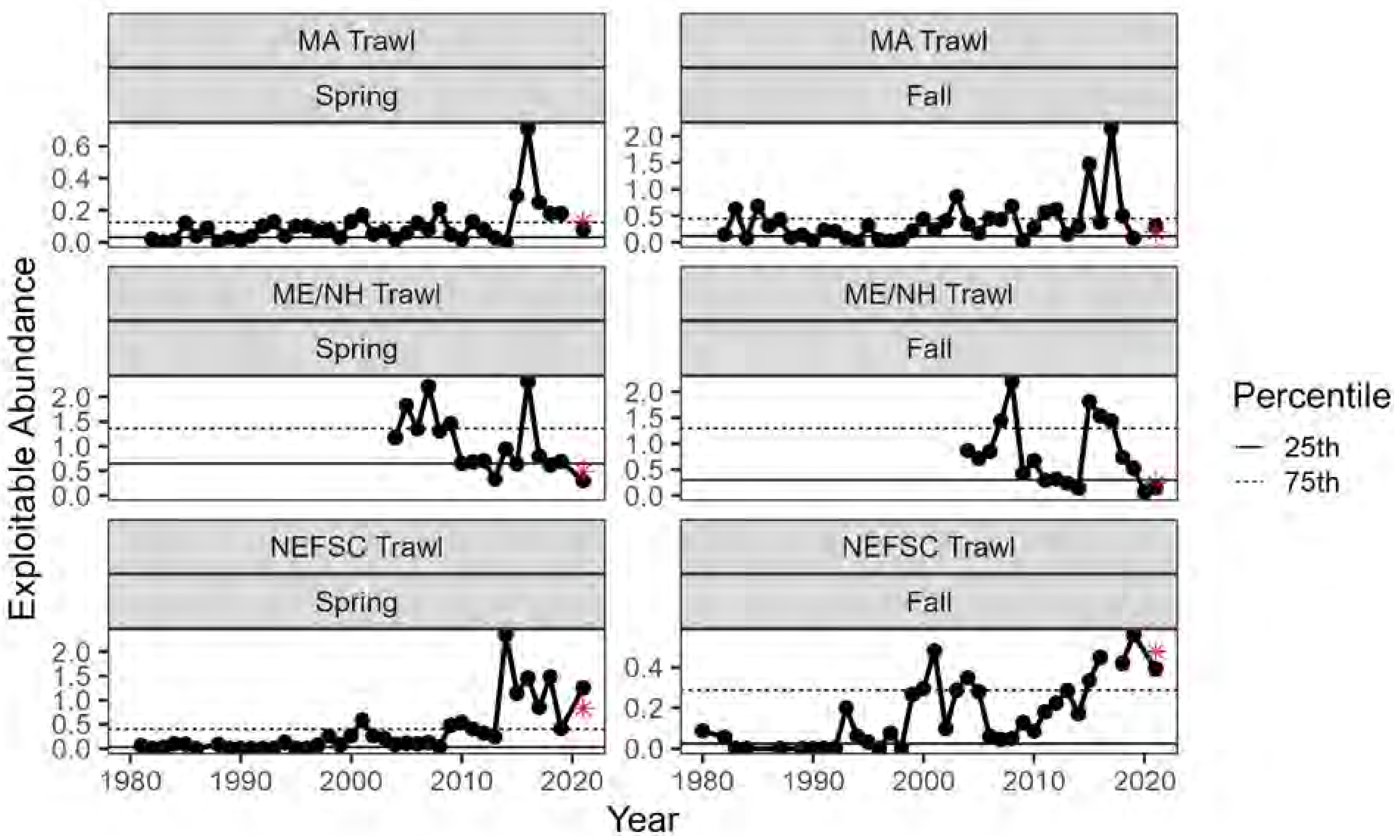

Figure 98. Exploitable abundance indicators for the IGOM Jonah crab stock. Red asterisks indicate the terminal three-year (2019-2021) average.

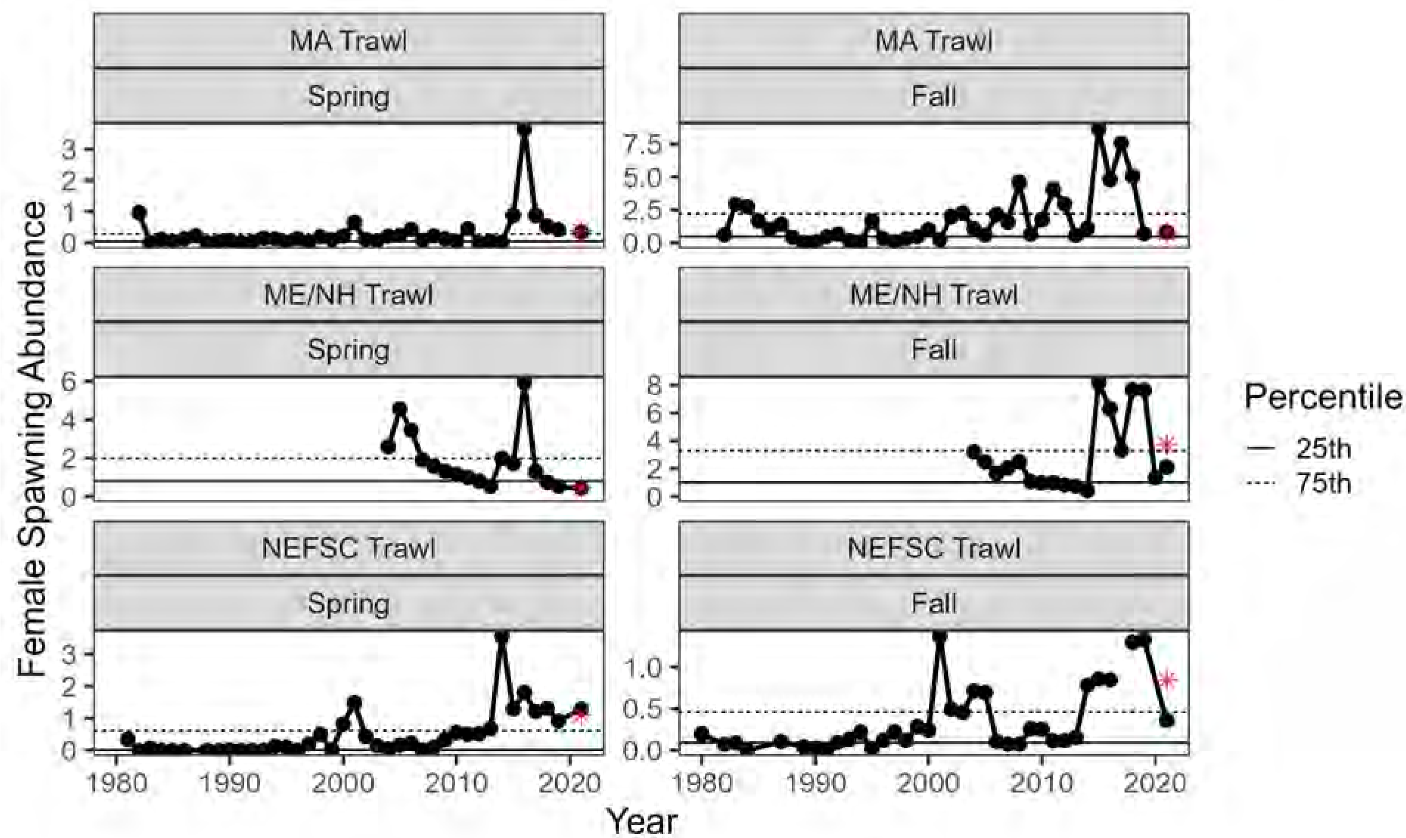

Figure 99. Spawning abundance indicators for the IGOM Jonah crab stock. Red asterisks indicate the terminal three-year (2019-2021) average.

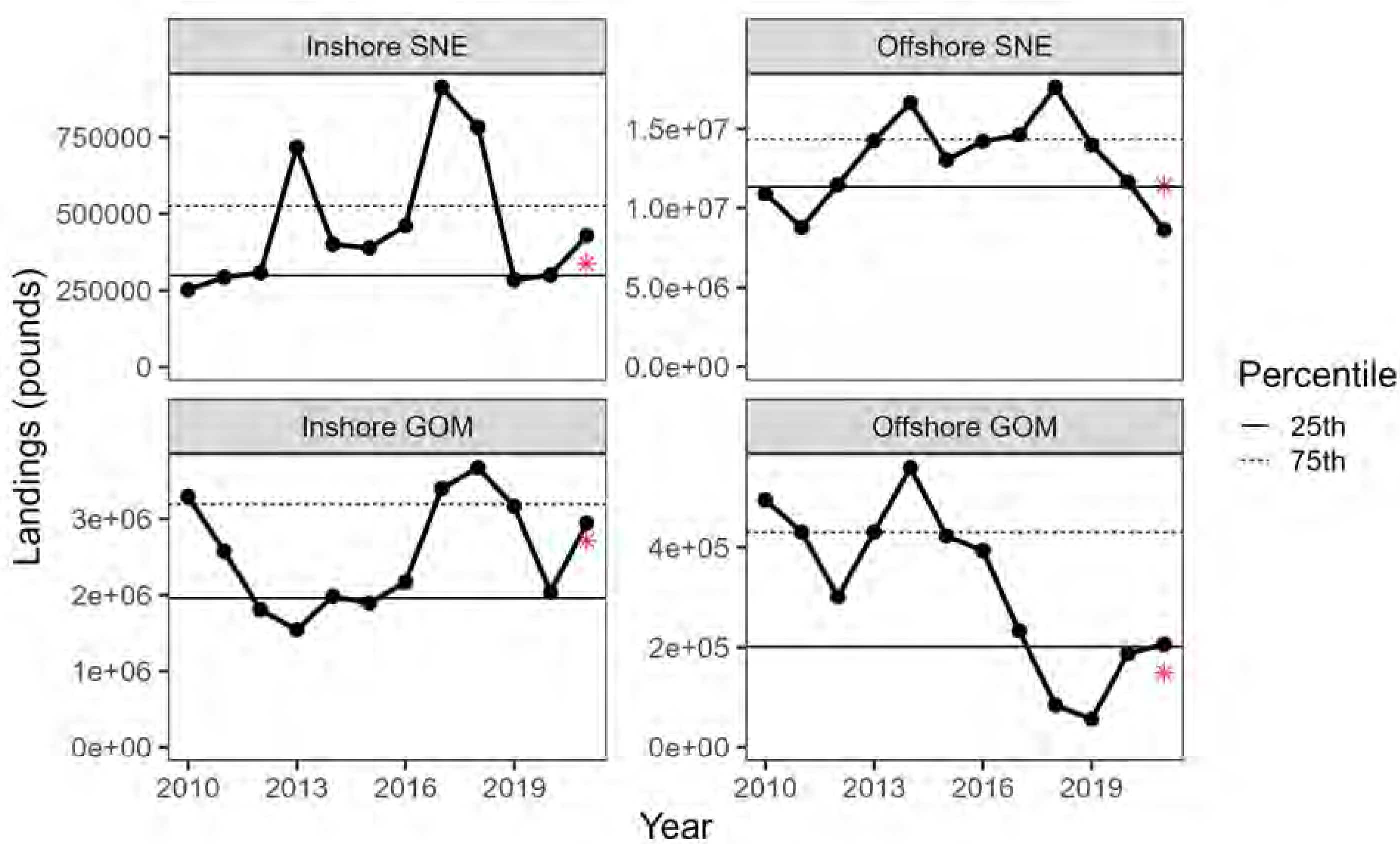

Figure 100. Landings fishery performance indicators for the Jonah crab stocks. Red asterisks indicate the terminal three-year (2019-2021) average.

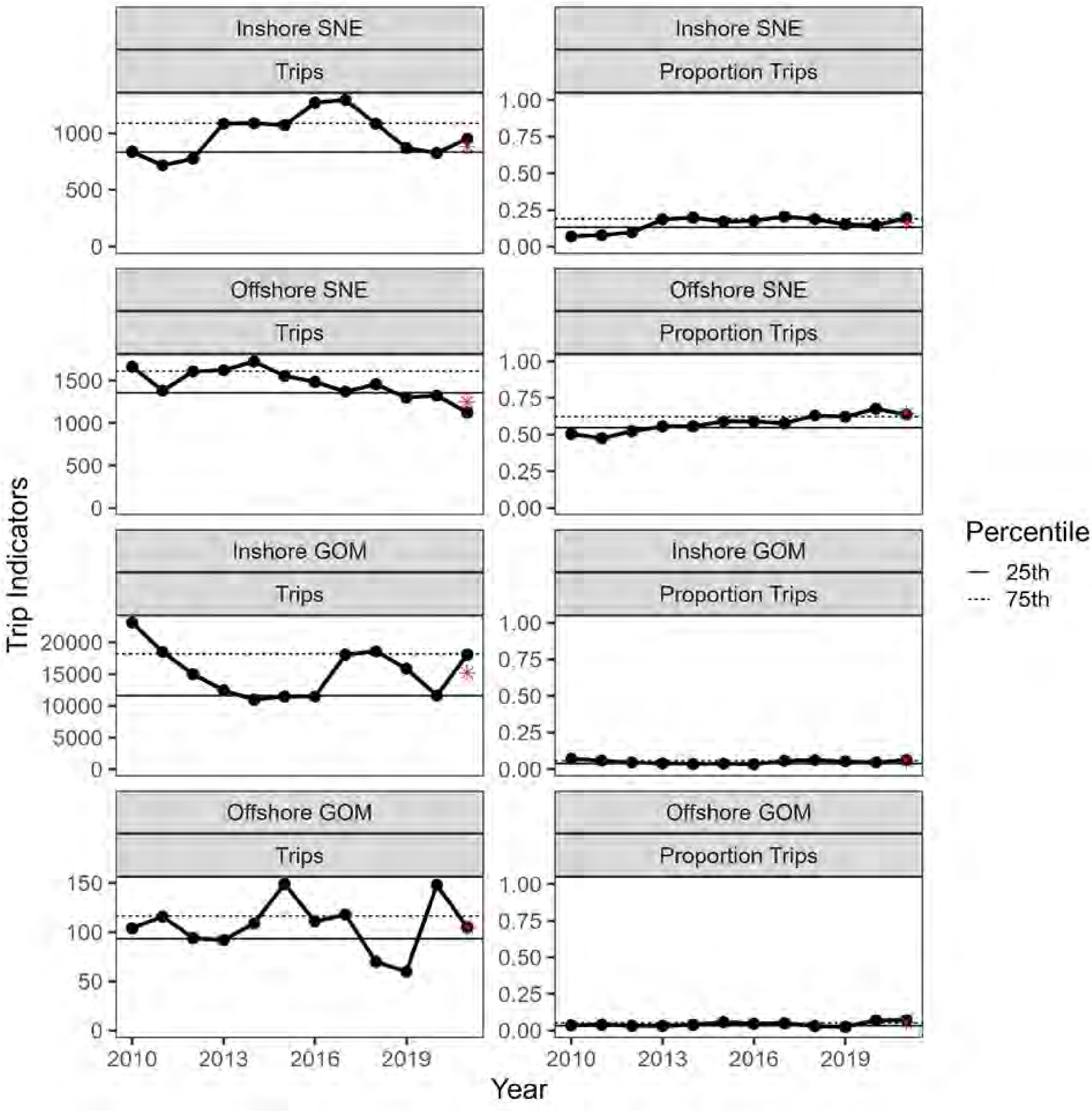

Figure 101. Trip-based fishery performance indicators for the Jonah crab stocks. Red asterisks indicate the terminal three-year (2019-2021) average.

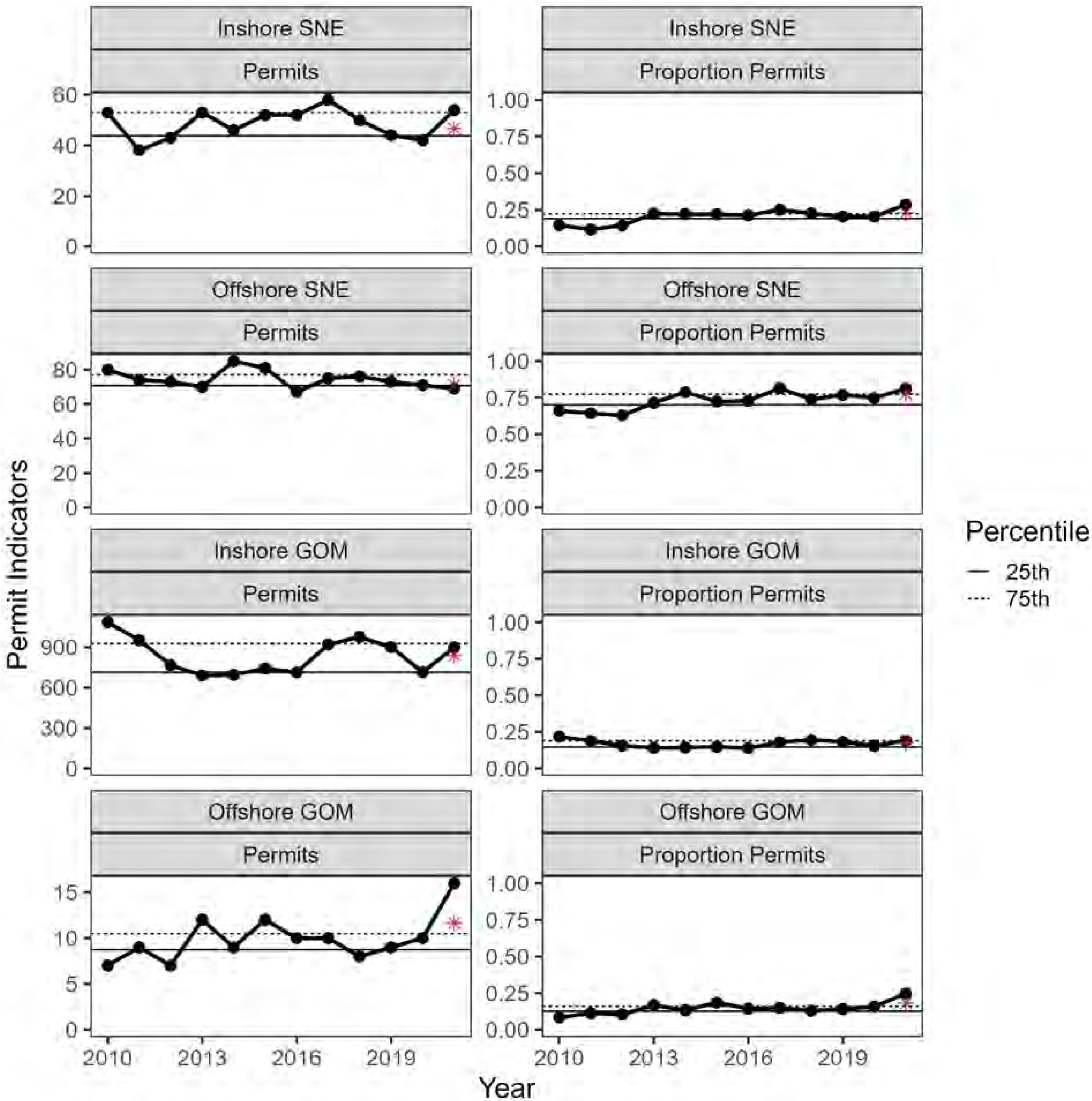

Figure 102. Permit-based fishery performance indicators for the Jonah crab stocks. Red asterisks indicate the terminal three-year (2019-2021) average.

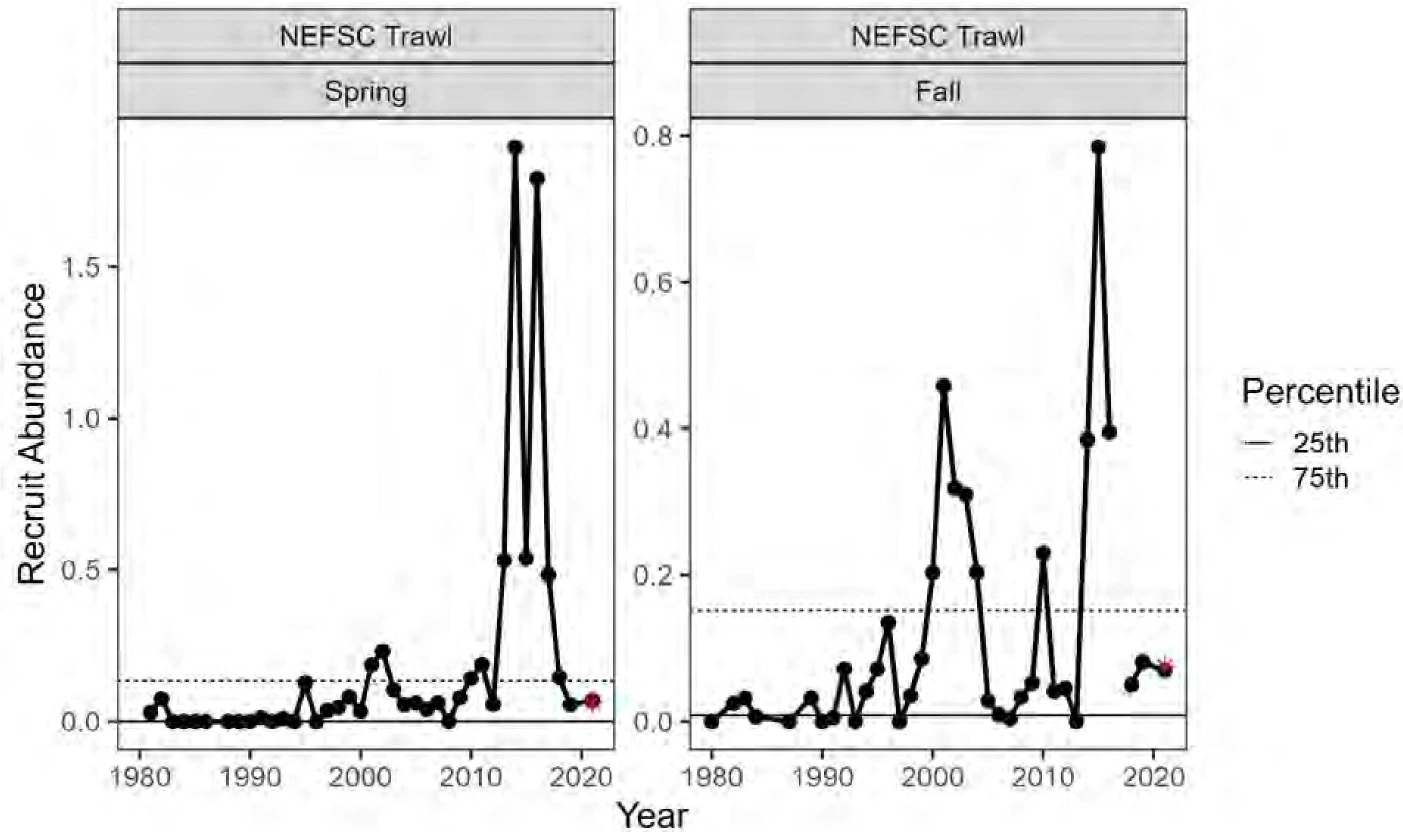

Figure 103. **Recruit abundance indicators for the OGOM Jonah crab stock. Red asterisks indicate the terminal three-year (2019-2021) average.**

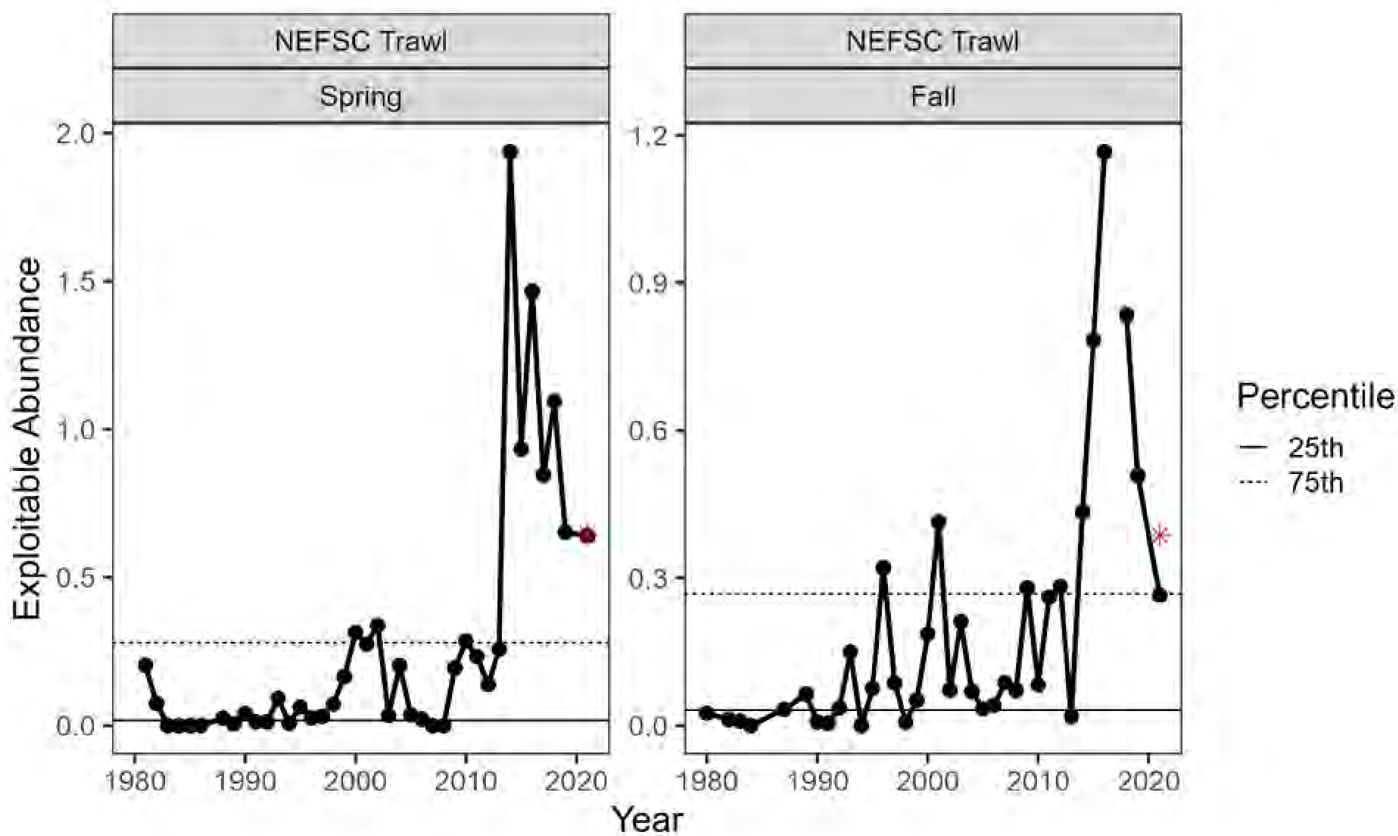

Figure 104. **Exploitable abundance indicators for the OGOM Jonah crab stock. Red asterisks indicate the terminal three-year (2019-2021) average.**

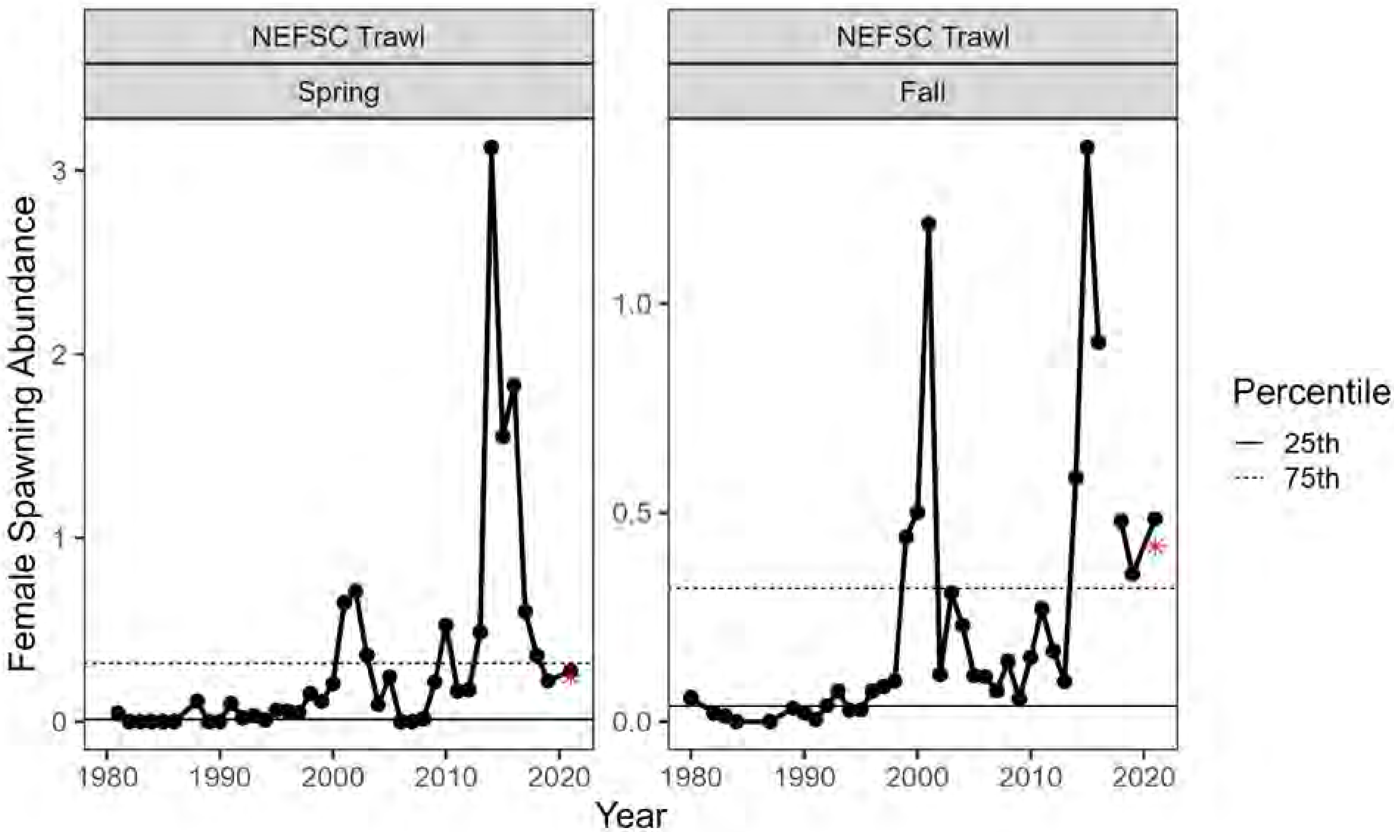

Figure 105. **Spawning abundance indicators for the OGOM Jonah crab stock. Red asterisks indicate the terminal three-year (2019-2021) average.**

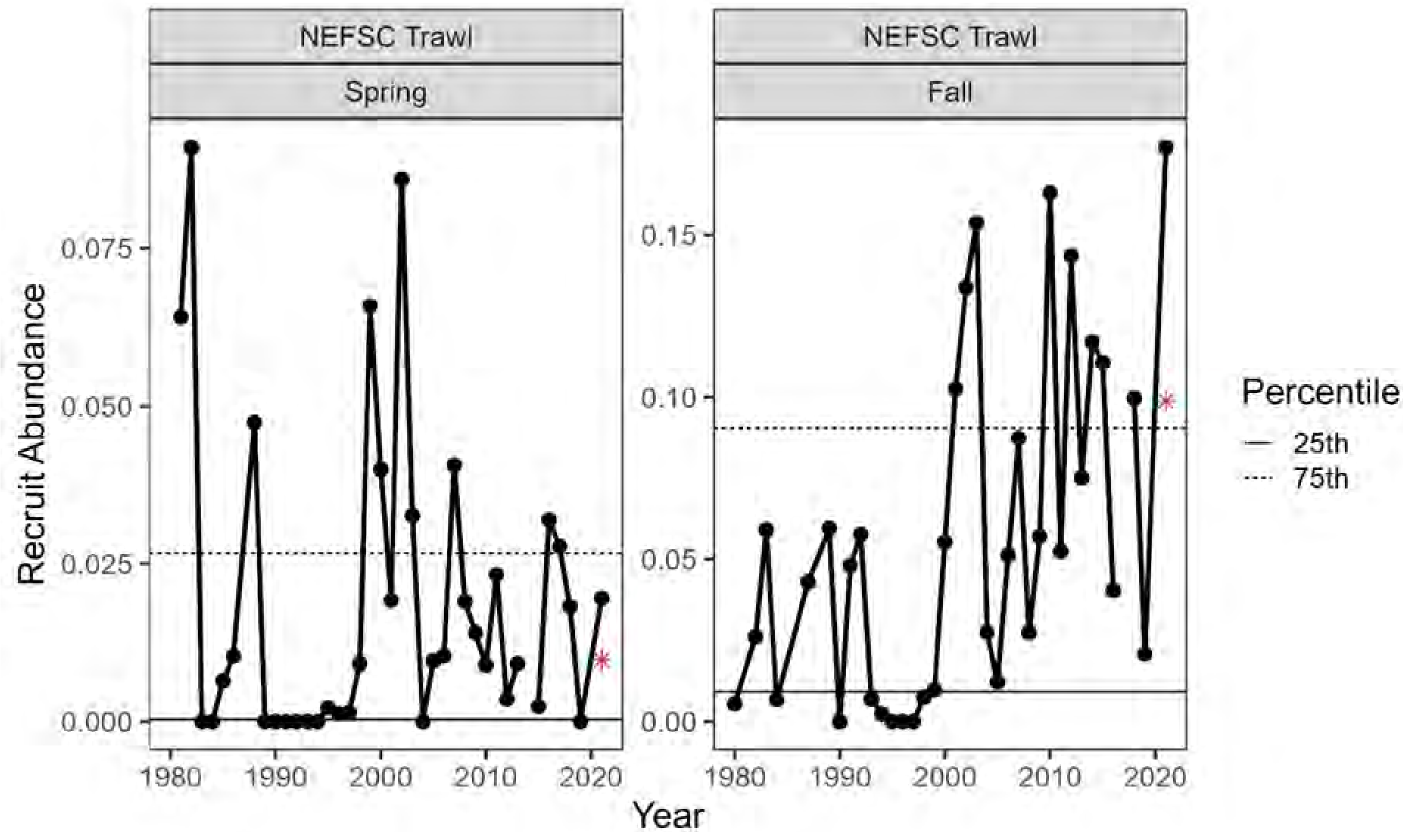

Figure 106. **Recruit abundance indicators for the OSNE Jonah crab stock. Red asterisks indicate the terminal three-year (2019-2021) average.**

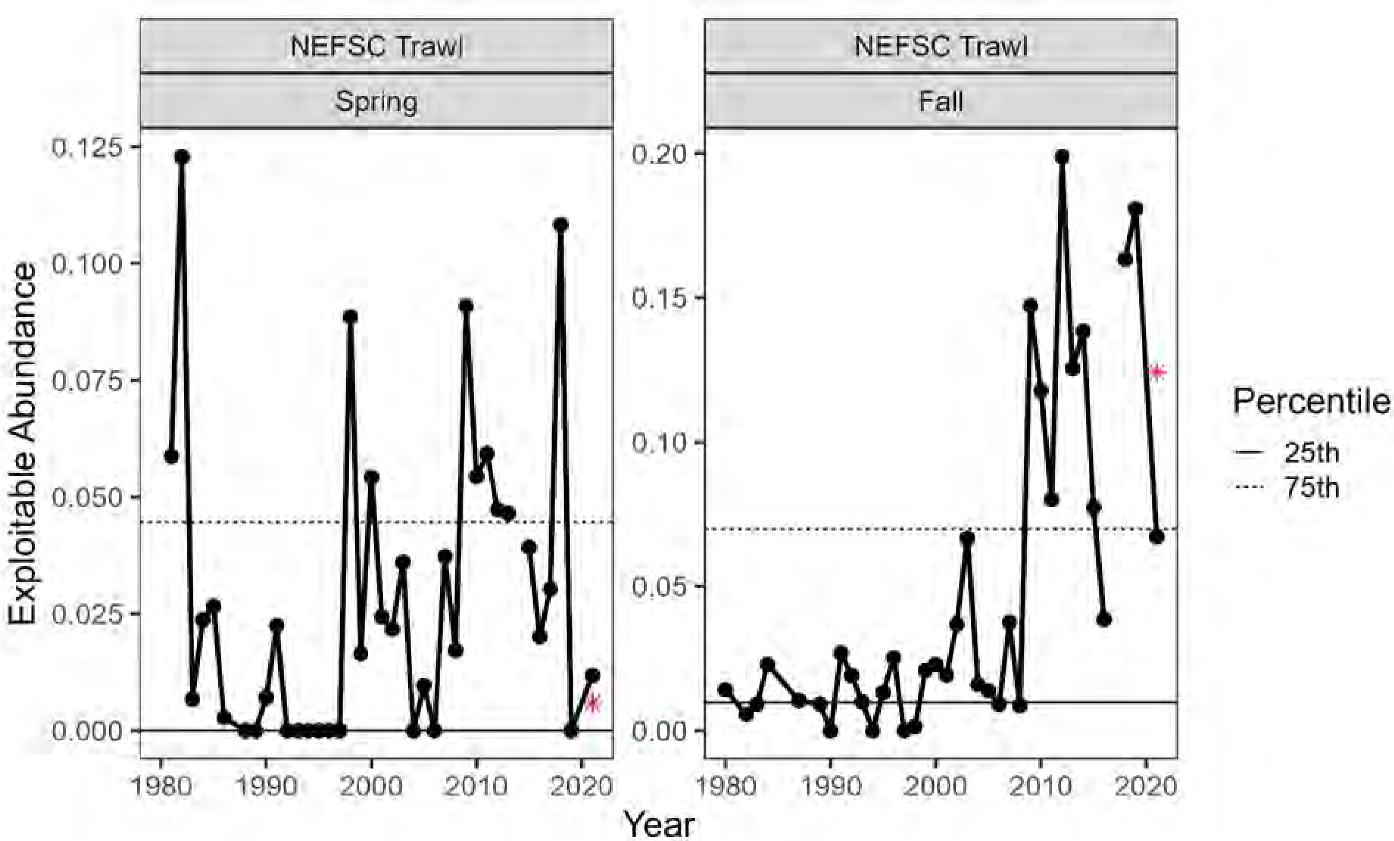

Figure 107. Exploitable abundance indicators for the OSNE Jonah crab stock. Red asterisks indicate the terminal three-year (2019-2021) average.

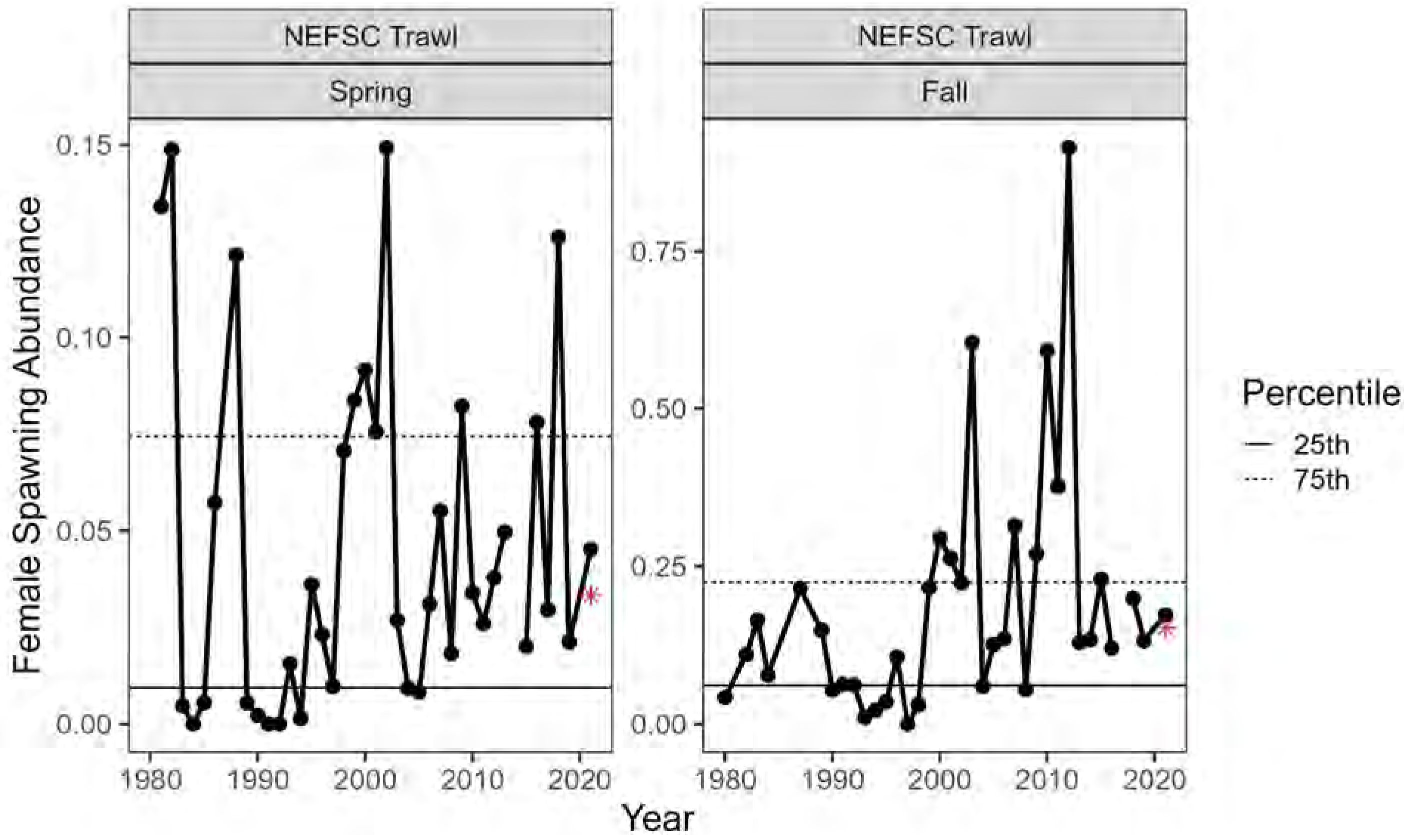

Figure 108. Spawning abundance indicators for the OSNE Jonah crab stock. Red asterisks indicate the terminal three-year (2019-2021) average.

14 APPENDICES

14.1 Index-Based Methods

Introduction

Simple index-based methods were applied to landings and exploitable abundance indices as an interim approach to generate management advice for the Jonah crab stocks until more robust data can be collected. These methods were considered ideal for Jonah crab because they rely on only a few years of data in the most recent years and do not require life history information, which is limited at this time for Jonah crab.

The typical objective of these methods is providing catch advice. However, Jonah crab and lobster fisheries are not currently managed with catch limits. Therefore, the objective of using these methods was to provide inference on exploitation levels that could be used for management advice such that catch advice that is lower than terminal year catch suggests an over-exploited stock and need for reduced exploitation, catch advice equal to terminal year catch suggests a fully-exploited stock and appropriate exploitation levels, and catch advice greater than terminal year catch suggests an under-exploited stock with potential to increase exploitation.

Three methods were evaluated including Islope, Plan B, and Skate. Islope was proposed in Geromont and Butterworth (2015) as a generic, empirical control rule using a recent abundance index trend to adjust observed catch. A log-linear regression is applied to a specified period at the end of the index time series and the estimated slope is used as a multiplier along with two additional predetermined multipliers (λ and *Cmult*) to adjust the average catch observed over the same time period. The catch advice in the form of an annual catch target (*ACT*) is calculated with equation 1:

$$Equation\ 1: ACT = Cmult * \overline{Catch} * (1 + \lambda * e^{slope})$$

where $\overline{Catch}$ is the average catch over the period selected for the log-linear regression, *slope* is the slope of the log-linear regression, and *Cmult* and λ are defined based on one of four versions proposed below ranging from least conservative (version 1) to most conservative (version 4).

$$version\ 1: \lambda = 0.4, Cmult = 0.8$$
$$version\ 1: \lambda = 0.4, Cmult = 0.7$$
$$version\ 1: \lambda = 0.4, Cmult = 0.6$$
$$version\ 1: \lambda = 0.2, Cmult = 0.6$$

Plan B was developed for and used in assessments of multiple Northeast U.S. stocks including one Atlantic cod stock and two monkfish stocks. The method is conceptually similar to Islope with a key distinction being that the abundance index is first smoothed with a LOESS smoother and the log-linear regression is then applied to the smoothed values. The *ACT* is calculated with equation 2:

$$Equation\ 2: ACT = \overline{Catch} * e^{slope}$$

Skate is a custom method developed for Northeast U.S. skate stocks. For this method, both the catch and abundance index time series are smoothed with a running average. Relative exploitation (here denoted as *F*) is estimated by diving the smoothed index by the smoothed catch and the median relative exploitation is used as a multiplier for the smoothed index in a recent period to generate a catch limit. The use of the median relative exploitation is based on the assumption that the stock has been exploited appropriately, on average, across the time series. The catch limit can then be adjusted further to account for uncertainty with a specified multiplier to generate an *ACT* with equation 3:

$$ACT = median\ Relative\ F * s\left(\overline{Index}\right) * U_{buffer}$$

where $s\left(\overline{Index}\right)$ is the smoothed average index over the selected period and U_{buffer} is the multiplier to account for uncertainty.

Skate application has also used assumptions about abundance index percentiles to generate biomass reference points and status estimates from the recent index, but these components of the method were not used due to short time series of Jonah crab abundance indices.

All of these methods assume that the index of abundance used is reliably tracking the abundance signal and that there is a relationship between catch and the index such that increased catch will result in decreased abundance. Performance of these methods was evaluated with simulation analyses in a research track assessment conducted by NOAA's NEFSC (Legault et al. 2020). These are data-limited methods and similar methods can perform differently (Legault et al. 2020). Therefore, the ensemble method evaluated in the research track assessment, simply the median of catch advice across methods, is included as an alternative method influence by all other methods applied.

Data and Methods

Both spring and fall exploitable abundance indices from the NEFSC, MA, and ME/NH trawl surveys were used in the analysis. Seasonal indices were averaged for comparison to total annual catch in these methods. The fall index from year *y* and spring index from year *y+1* were averaged and compared to catch from year *y*. This averaging is done so the average index value approximates the January 1 index from year *y+1* that would reflect the impact from catch in year *y*. Two index values were zero and these were imputed to avoid computational errors by dividing the minimum observed positive index value over the time series by ten. There were also some missing data points, primarily due to covid-19 pandemic sampling restrictions. To impute these missing values, first the ratio of year *y* fall indices and year *y+1* spring indices were calculated for each survey (Figure A1). The mean ratio over the time series was then multiplied by the observed spring index to impute a missing fall index or divided by the observed fall index to impute a missing spring index. Season-averaged indices used in the methods are compared to each seasonal index with imputed values in Figure A2. For the IGOM stock where there are multiple trawl surveys, an additional index was calculated by scaling each trawl survey's index to its time series mean and averaging across surveys (average scaled survey indices).

No modifications were necessary for the catch time series.

Each method has a few specifications that typically include defaults used for analyses elsewhere, but that can be adjusted if there is information supporting doing so. As described previously, Islope requires specification of one of the four versions defining *Cmult* and λ. Version 3 was used in the original simulation study for this method which was applied to a severely depleted stock (Geromont and Butterworth 2015). Version 2 was used in this analysis because of the relatively recent development of the Jonah crab fisheries with no indication of severely depleted stocks while still recognizing uncertainty in stock status (i.e., not selecting version 1). The default period for the log-linear regression and average catch of five years was used in this analysis.

Specifications for Plan B are the LOESS smoother span (default=9.9/n years of index data) and time period used for log-linear regression and average catch (default=three years). These defaults were maintained in this analysis and the default time period offers an alternative to that used for the Islope method.

Specifications for Skate include the time period of the running average smoother and index value for catch advice (default=three years), the moving average type (default=current and preceding years), and the uncertainty buffer multiplier for generating a catch target (default=0.25). These defaults were also maintained in this analysis. Additionally, the assumption of appropriate exploitation, on average, across the time series can be relaxed by changing the percentile of relative *F* from the median. However, there was no good information to guide this change and it was maintained. Due to this, Skate was only applied to the OSNE stock that has supported the majority of landings and not the GOM stocks because they have experienced much lower landings and are not believed to be fully-exploited across the time series.

Results

IGOM

Catch advice was highly variable among methods but similar with MA and ME/NH indices (Figures A3-A4). Advice was least conservative with the NEFSC index and also more similar between methods (Figure A5). Slopes were actually positive with the NEFSC index, resulting in catch multipliers greater than 1 and a slight increase in catch from Plan B (Table A1). Similarities between the ME/NH and MA results drive the results of the average scaled index results (Figure A6).

OGOM

Catch advice was similar from both methods, being just slightly greater from Islope (Figure A7). This catch advice was similar to the terminal three-year average catch used for Plan B (Table A1) and was lower than catches observed during the first half of the time series.

OSNE

Catch advice varied widely among methods (Figure A8). Islope estimated the highest catch at 12.6 million pounds which is only a slight reduction from the five-year average catch used for this method (13.3 million pounds, Table A1), followed by Skate (and the ensemble estimate, 8.5 million pounds) which was just slightly lower than the terminal year catch, and finally Plan B which estimates catch advice lower than any catch observed during the time series at 7 million pounds. Skate estimates increasing relative *F* over the first half of the time series followed by decreasing relative *F* from 2017-2020. There was a slight uptick in 2021.

Discussion

The longer time period of Islope generally leads to the most optimistic catch advice because it includes the peak catch years and also a period of higher index values earlier in the time series leading to a flatter slope. Based on correlation analyses of trawl surveys and lagged settlement surveys done during the assessment that found stronger correlations for shorter lag times (2-3 years), the three-year averaging period specified for Plan B may better reflect a recruitment generation time than the longer five-year time period specified for Islope and provide a more appropriate averaging period for Jonah crab. Another appealing aspect of Plan B is lack of a subjective decision on addition multipliers needed for the Islope method. The Plan B and Skate methods are also better suited for noisy data such as that available for Jonah crab because they smooth the observations first before estimating the catch multiplier.

Despite the appealing aspects of some of these methods, during deliberations about the data sets used and apparent population dynamics of Jonah crabs, advice using these methods was not recommended. In the bycatch-driven fisheries of GOM, there may yet to be a defined relationship between catch and abundance that is necessary for robust catch advice estimates from these methods. Advice, particularly for the OGOM stock, appeared unintuitive given the low magnitude of landings from this stock and presumed low exploitation. This is influenced by the decline in indices near the end of the time series from time series highs. There was no clear indication that fishing was driving this decline and, rather, it appears there are intermittent pulses of abundance that occur over short durations that are driven by unknown factors. An additional concern for all stocks is the quality of the index data. Catch rates by trawl surveys are low and have often hovered around zero. Being a species that burrows in soft bottoms, trawls may not efficiently capture Jonah crabs and indices from these surveys may only provide coarse, qualitative information on abundance changes, particularly increases when catch rates can move away from the lower bound of zero.

References

Geromont, H.F. and Butterworth, D.S., 2015a. Generic management procedures for data-poor fisheries: forecasting with few data. ICES Journal of Marine Science, 72(1), pp.251-261.

Legault, C., R. Bell, J. Cournane, J. Deroba, G. Fay, A. Jones, T. Miller, B. Muffley, and J. Weidenmann. 2020. Draft report of the index based methods working group. 59 p.

Tables

Table A1. Index-based method results for Jonah crab stocks.

Stock	Survey	Method	Slope	exp(Slope)	Catch Advice	2019-2021 Average Catch	2017-2021 Average Catch
IGOM	MA Trawl	Plan B	-0.97	0.38	1,029,669	2,715,902	3,043,688
IGOM	MA Trawl	Islope	-0.35	0.70	2,728,777	2,715,902	3,043,688
IGOM	MA Trawl	Ensemble	NA	NA	1,879,223	2,715,902	3,043,688
IGOM	ME/NH Trawl	Plan B	-0.96	0.38	1,036,612	2,715,902	3,043,688
IGOM	ME/NH Trawl	Islope	-0.43	0.65	2,684,763	2,715,902	3,043,688
IGOM	ME/NH Trawl	Ensemble	NA	NA	1,860,688	2,715,902	3,043,688
IGOM	NEFSC Trawl	Plan B	0.08	1.08	2,944,041	2,715,902	3,043,688
IGOM	NEFSC Trawl	Islope	0.05	1.05	3,026,068	2,715,902	3,043,688
IGOM	NEFSC Trawl	Ensemble	NA	NA	2,985,055	2,715,902	3,043,688
IGOM	Average Scaled Survey Indices	Plan B	-0.40	0.67	1,826,671	2,715,902	3,043,688
IGOM	Average Scaled Survey Indices	Islope	-0.18	0.84	2,844,820	2,715,902	3,043,688
IGOM	Average Scaled Survey Indices	Ensemble	NA	NA	2,335,746	2,715,902	3,043,688
OGOM	NEFSC Trawl	Plan B	-0.25	0.78	116,431	149,600	153,131
OGOM	NEFSC Trawl	Islope	-0.17	0.85	143,480	149,600	153,131
OGOM	NEFSC Trawl	Ensemble	NA	NA	129,956	149,600	153,131
OSNE	NEFSC Trawl	Plan B	-0.49	0.61	7,008,359	11,419,689	13,298,001
OSNE	NEFSC Trawl	Islope	-0.14	0.87	12,551,963	11,419,689	13,298,001
OSNE	NEFSC Trawl	Skate	NA	NA	8,482,925	11,419,689	13,298,001
OSNE	NEFSC Trawl	Ensemble	NA	NA	8,482,925	11,419,689	13,298,001

Figures

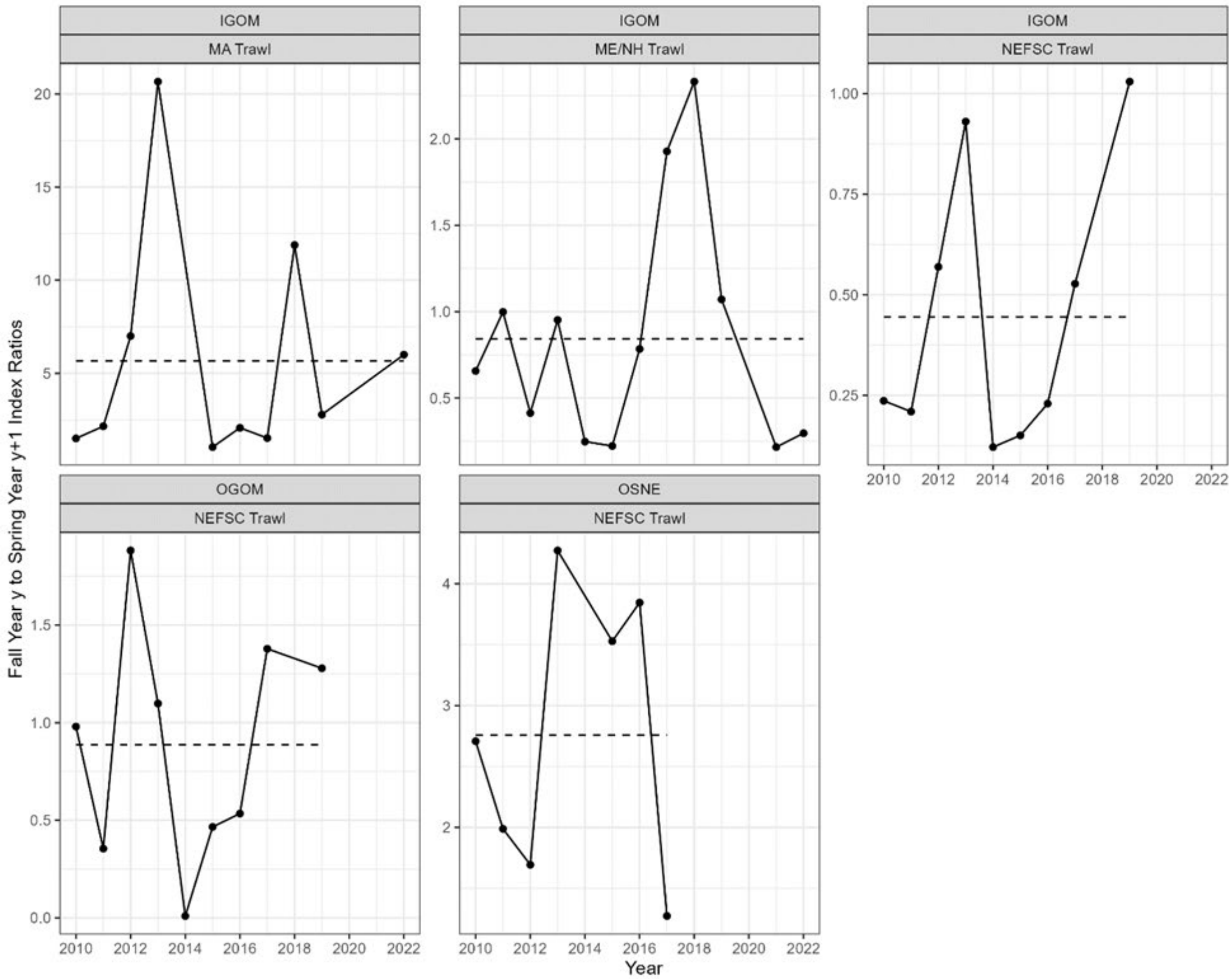

Figure A1. Ratios of fall indices in year *y* and spring indices in year *y+1.* The dashed line is the median ratio which was used to impute missing index values.

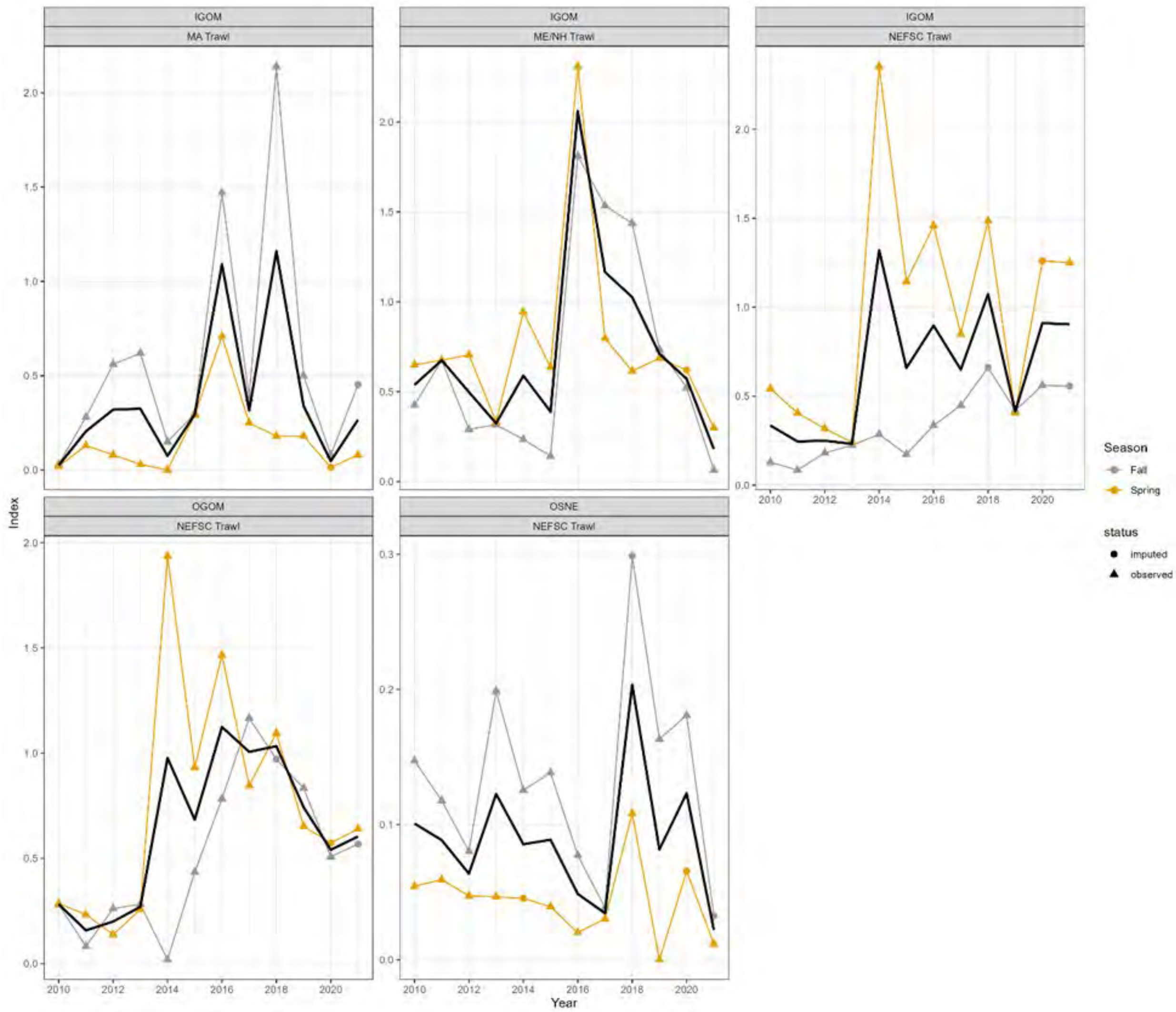

Figure A2. Final indices used in index-based methods (black line) compared to seasonal indices averaged to generate the final indices. Shapes for the seasonal index points indicate whether the value was observed or imputed.

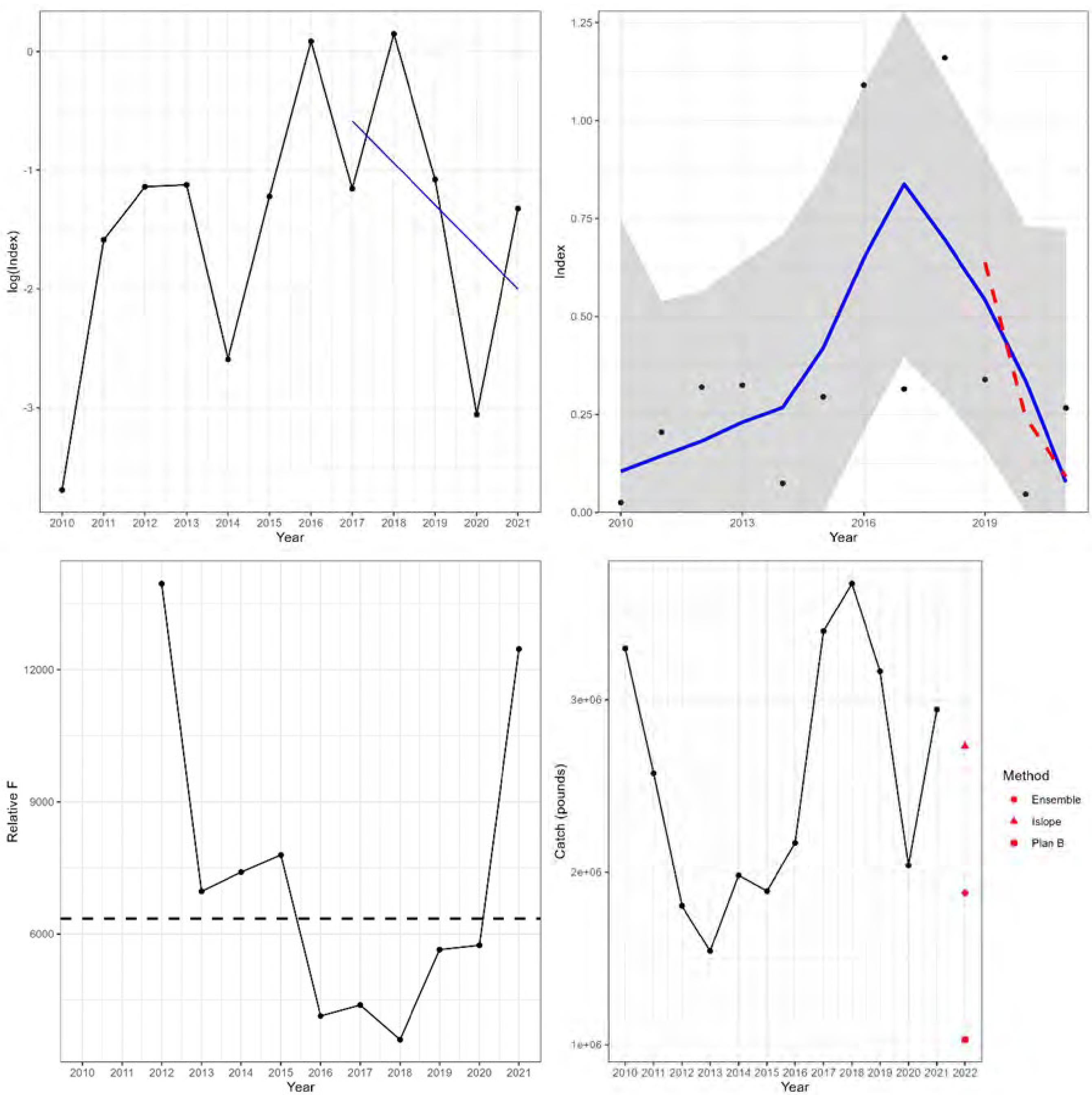

Figure A3. Index-based method results for the IGOM Jonah crab stock with the MA Trawl index including the Islope log-linear regression line and observed index on the log scale (upper left), Plan B log-linear regression line (transformed to original index scale) and LOESS smoother (blue line, upper right), Skate relative *F* time series and median (dashed line, lower left), and comparison of catch advice from all methods to the observed landings (lower right).

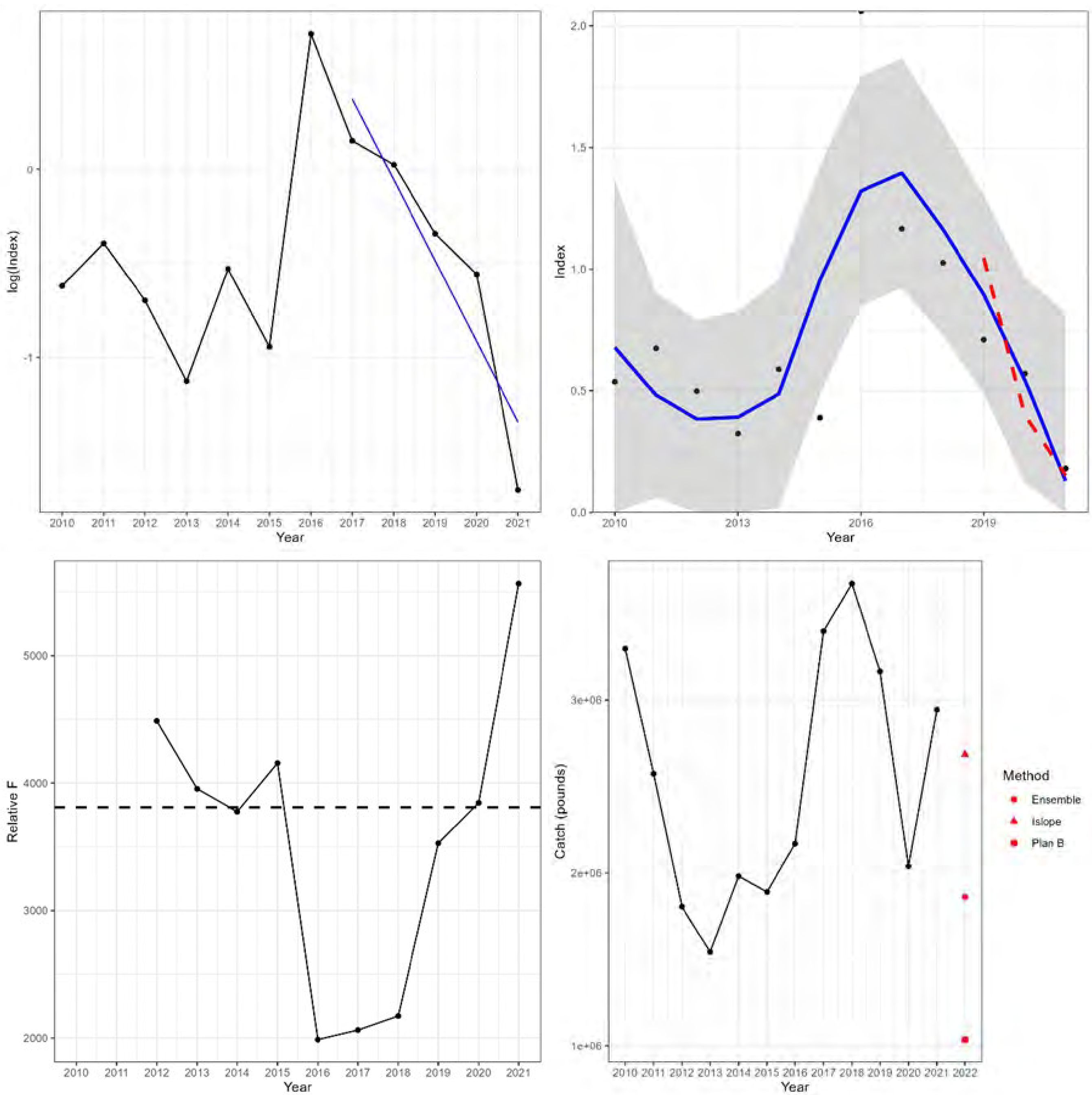

Figure A4. Index-based method results for the IGOM Jonah crab stock with the ME/NH Trawl index including the Islope log-linear regression line and observed index on the log scale (upper left), Plan B log-linear regression line (transformed to original index scale) and LOESS smoother (blue line, upper right), Skate relative *F* time series and median (dashed line, lower left), and comparison of catch advice from all methods to the observed landings (lower right).

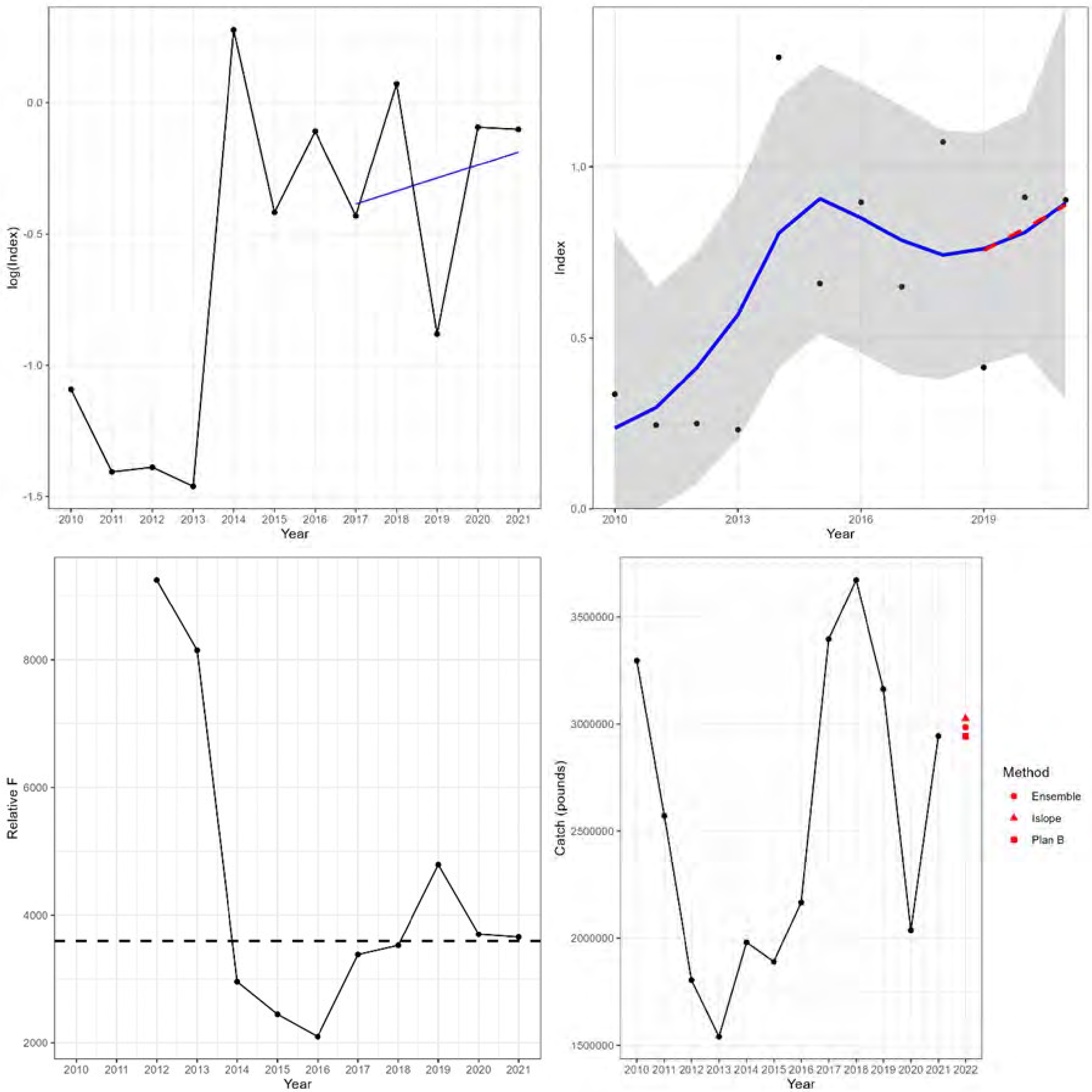

Figure A5. Index-based method results for the IGOM Jonah crab stock with the NEFSC Trawl index including the Islope log-linear regression line and observed index on the log scale (upper left), Plan B log-linear regression line (transformed to original index scale) and LOESS smoother (blue line, upper right), Skate relative *F* time series and median (dashed line, lower left), and comparison of catch advice from all methods to the observed landings (lower right).

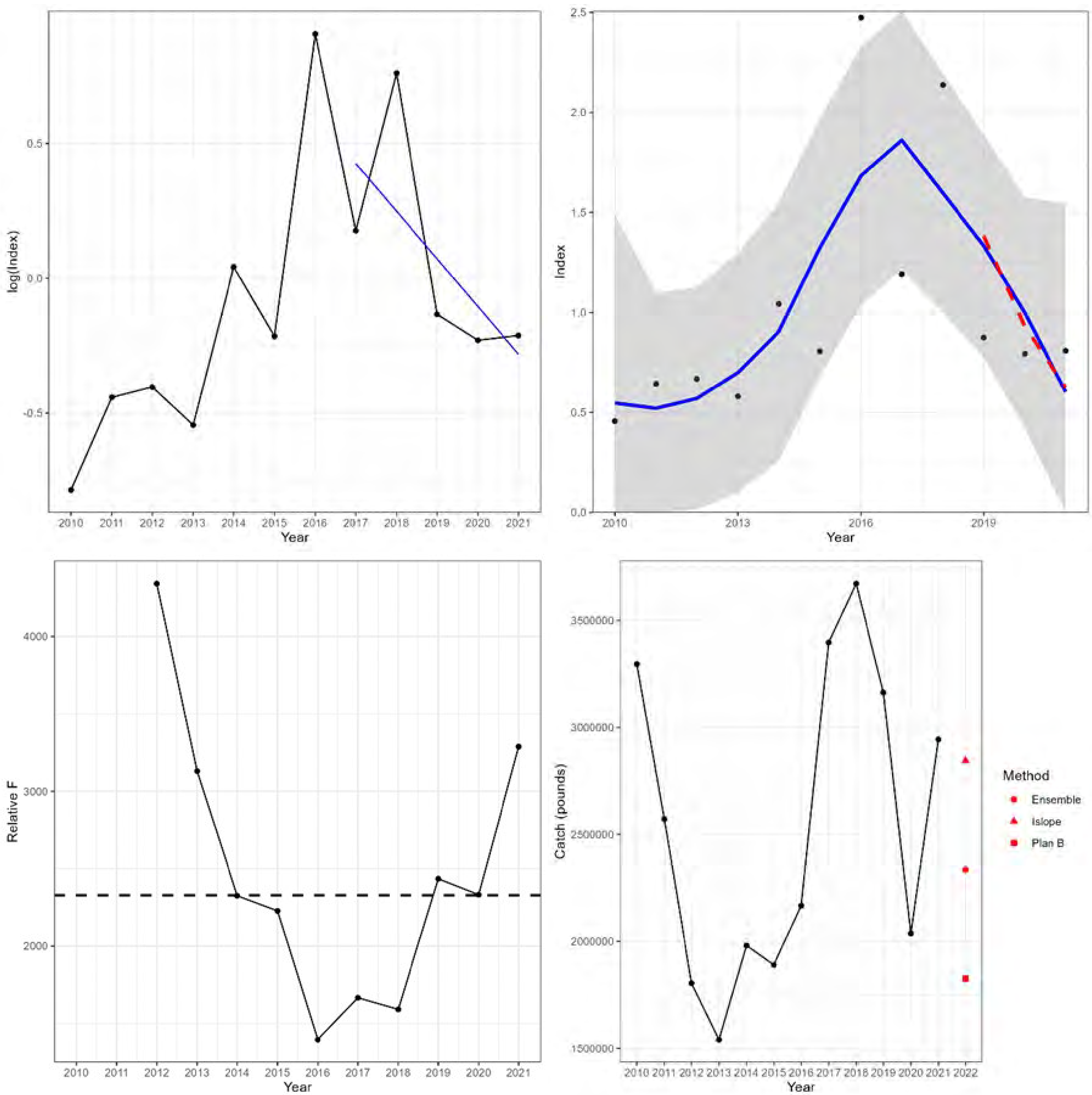

Figure A6. Index-based method results for the IGOM Jonah crab stock with the average scaled survey indices including the Islope log-linear regression line and observed index on the log scale (upper left), Plan B log-linear regression line (transformed to original index scale) and LOESS smoother (blue line, upper right), Skate relative *F* time series and median (dashed line, lower left), and comparison of catch advice from all methods to the observed landings (lower right).

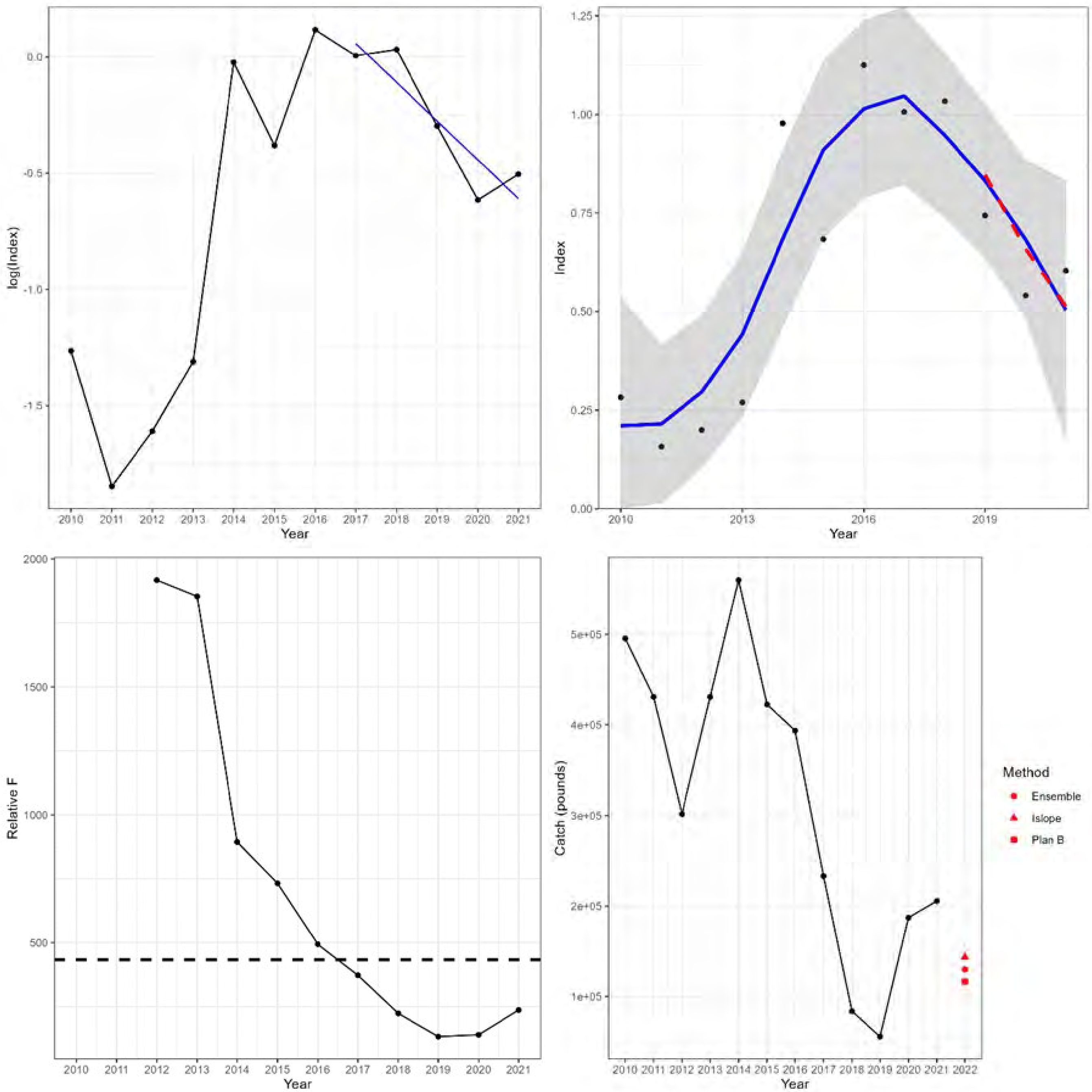

Figure A7. Index-based method results for the OGOM Jonah crab stock including the Islope log-linear regression line and observed index on the log scale (upper left), Plan B log-linear regression line (transformed to original index scale) and LOESS smoother (blue line, upper right), Skate relative *F* time series and median (dashed line, lower left), and comparison of catch advice from all methods to the observed landings (lower right).

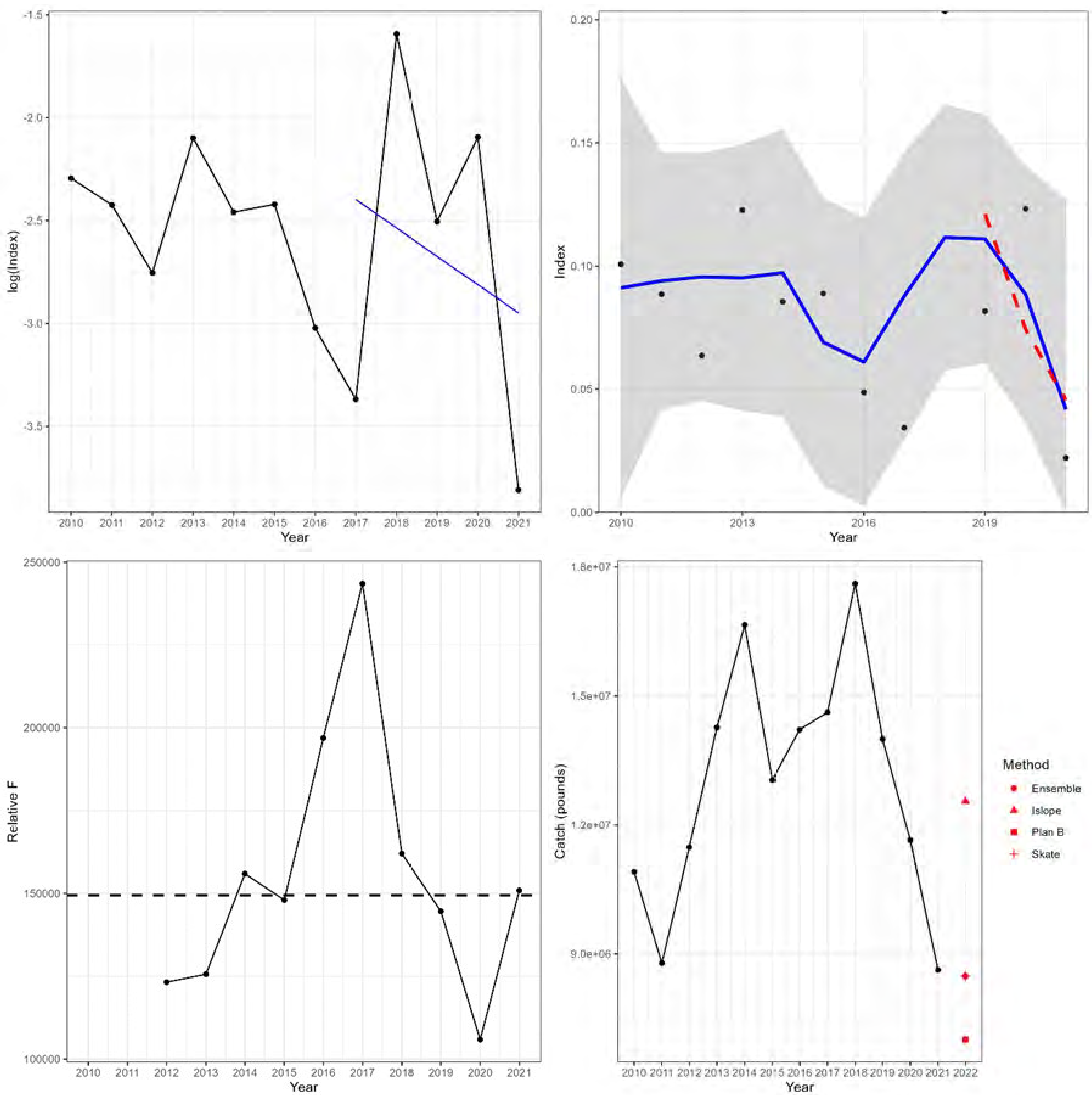

Figure A8. Index-based method results for the OSNE Jonah crab stock including the Islope log-linear regression line and observed index on the log scale (upper left), Plan B log-linear regression line (transformed to original index scale) and LOESS smoother (blue line, upper right), Skate relative *F* time series and median (dashed line, lower left), and comparison of catch advice from all methods to the observed landings (lower right).

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MEMORANDUM

TO: **American Lobster Management Board**

FROM: **American Lobster Technical Committee**

DATE: **October 2, 2023**

SUBJECT: **2023 American Lobster Data Update and Addendum XXVII Trigger Index Update**

<u>Data Update</u>

An annual Data Update process between American lobster stock assessments was recommended during the 2020 stock assessment to more closely monitor changes in stock abundance. The objective of this process is to present information—including any potentially concerning trends—that could support additional research or consideration of changes to management. Data sets updated during this process are generally those that indicate exploitable lobster stock abundance conditions expected in subsequent years and include:

- YOY settlement indicators
- Trawl survey indicators, including recruit abundance (71-80 mm carapace length lobsters) and survey encounter rate
- Ventless trap survey sex-specific abundance indices (53 mm+ carapace length lobsters)

This is the third Data Update and provides an update of last year's review with the addition of 2022 data. Indicator status (negative, neutral, or positive – see table below) was determined relative to the percentiles of the stock assessment time series (i.e., data set start year through 2018).

Indicator	**< 25th percentile**	**Between 25th and 75th percentile**	**> 75th percentile**
YOY settlement (larval or YOY)	Negative	Neutral	Positive
Trawl survey recruit abundance	Negative	Neutral	Positive
Trawl survey encounter rate	Negative	Neutral	Positive
Ventless trap survey abundance	Negative	Neutral	Positive

The five-year means provided during the stock assessment (2014-2018) for terminal indicator status determinations were also updated with new years of data. This treatment of data is consistent with stock indicators provided during stock assessments (see Section 5 in the 2020 stock assessment report for more detail). Ventless trap survey abundance indices have been added to indicators used in the stock assessment for this Data Update process. Note that updated five-year means (2018-2022) for several trawl survey-based indicators remain impacted by covid-19 data collection disruptions. Additionally, some data changes have occurred for various reasons since the stock assessment or previous year's Data Updates. Please see the appendix for details on these data changes. Below are the results of the data updates by sub-stock.

Gulf of Maine (GOM)

Overall, Gulf of Maine indicators show declines from time series highs observed during the stock assessment.

- YOY conditions showed improvements since the stock assessment, but were still not positive (Table 1 and Figure 1).
    - Updated five-year means were all neutral, indicating improvement since the stock assessment when two of the five-year means were negative (both southwest areas).
    - 2022 values showed increases from 2021 values with one exception (MA 514). Two improved from negative to neutral, two remained neutral, and one remained negative.
- Trawl survey recruit abundance indicators showed signs of decline since the stock assessment (Table 2 and Figure 2).
    - Two updated five-year means changed from positive to neutral since the stock assessment. The other four remained positive. Both indicators that declined to neutral are for inshore GOM waters.
    - 2022 values were similar to 2021 values, with three of six being neutral and three of six being positive.
    - Five of six indicators were not available for 2020 due to covid-19 sampling restrictions.
- Trawl survey encounter rates show deteriorating conditions inshore since the stock assessment (Table 3 and Figure 3).
    - All four updated five-year means for inshore indicators were neutral, whereas only one was neutral during the stock assessment. Updated five-year means for the two offshore indicators remain positive.
    - The first negative annual value since 2008 was observed in 2022.
    - Five of six indicators were not available for 2020 due to covid-19 sampling restrictions.
- Ventless trap survey indices show abundance declining since the stock assessment (Table 4 and Figure 4).
    - Six of eight updated five-year means were neutral and two were negative, compared to four positive means and no negative means during the stock assessment.
    - 2022 values were similar to 2021 values with four neutral and four negative.
    - 2022 values for both sexes in statistical areas 512 and 514 were among the lowest values observed during the time series.

Georges Bank (GBK)

Overall, Georges Bank indicators show slight improvement since the stock assessment. Note that there are no YOY or VTS indicators for this sub-stock area.

- Trawl survey recruit abundance indicators showed slight improvements (Table 5 and Figure 5).
    - One updated five-year mean changed from neutral to positive since the stock assessment, while the other remained neutral.
    - 2022 values were both positive and relatively high, as were 2021 values.
    - No indicators were available for 2020 due to covid-19 sampling restrictions.
    - These indicators tend to be noisier than some of the other abundance indicators, with high interannual variability and lack of discernible trends.

- Trawl survey encounter rates showed similar conditions since the stock assessment (Table 6 and Figure 6).
  - The updated means both remained positive.
  - No indicators were available for 2020 due to covid-19 sampling restrictions.

Southern New England (SNE)

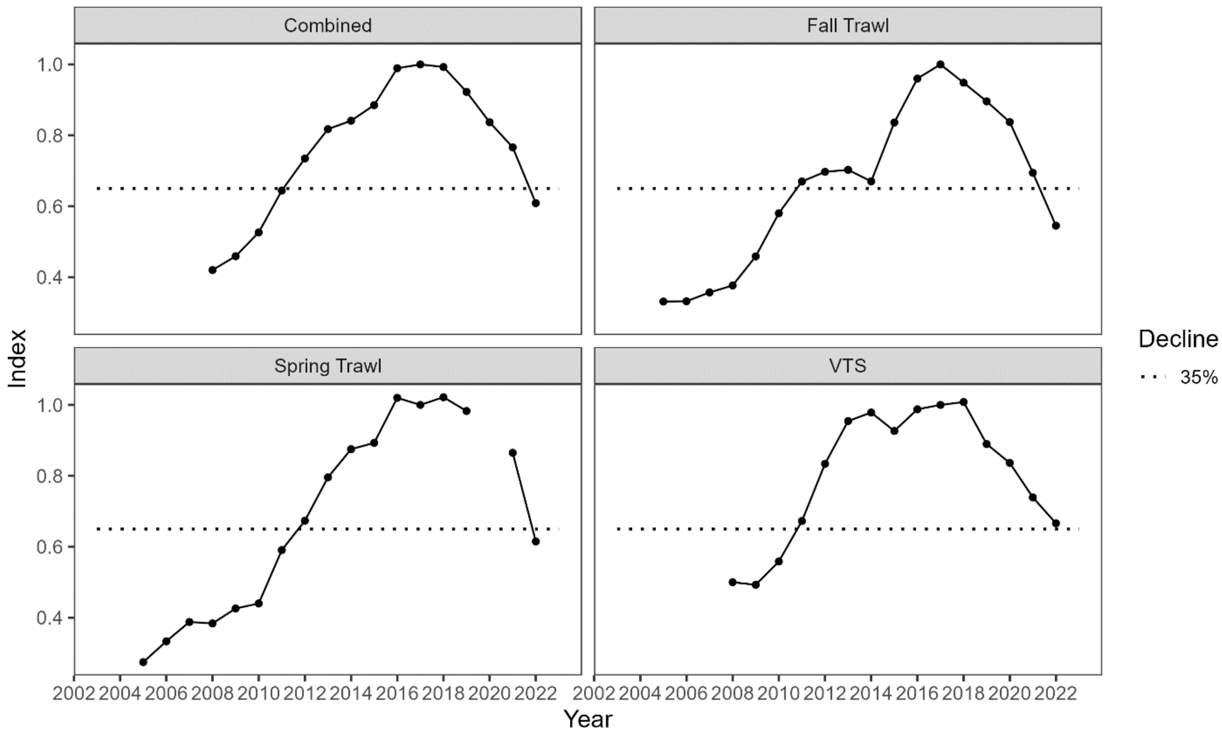
Overall, Southern New England indicators show continued unfavorable conditions with some further signs of decline since the stock assessment.

- YOY conditions were negative across the stock with some decline since the stock assessment (Table 7 and Figure 7).
  - Updated five-year means were all negative, whereas one of three was neutral during the stock assessment.
  - No YOY have been caught during the MA survey for the last eight years.
- Trawl survey recruit abundance indicators showed declines since the stock assessment (Table 8 and Figure 8).
  - The updated five-year means were all negative, with three of eight moving to negative conditions since the stock assessment.
  - All 2022 values were negative and this is the first year values have been negative across all indicators.
  - Six of eight indicators were not available for 2020 due to covid-19 sampling restrictions.
- Trawl survey encounter rates showed deteriorating conditions since the stock assessment (Table 9 and Figure 9).
  - Updated five-year means for all eight indicators were negative, with two changing from neutral to negative since the stock assessment.
  - All 2022 values were negative as was observed in 2021.
  - Six of eight indicators were not available for 2020 due to covid-19 sampling restrictions.
- Ventless trap survey indices show declines since the stock assessment (Table 10 and Figure 10).
  - Two updated five-year means changed from neutral to negative since the stock assessment. The other two remained neutral.
  - All 2022 values were negative, the second year during the time series values have been negative across all indicators.
  - It is important to note that the ventless trap survey has only taken place during depleted stock conditions coinciding with an adverse environmental regime, so interannual variability can be misleading without the context of a longer time series encompassing varying stock conditions.

Addendum XXVII Trigger Index Update

Addendum XXVII (2023) establishes a trigger mechanism to implement management measures to provide additional protection of the GOM/GBK spawning stock biomass. The trigger index is based on recruit conditions observed in three surveys used to inform the assessment model estimates of reference abundance and stock status for the GOM/GBK stock. These recruit (71-80mm carapace length lobsters) indices include: 1) combined Maine/New Hampshire and Massachusetts spring trawl survey index, 2) combined Maine/New Hampshire and Massachusetts fall trawl survey index, and 3) model-based VTS index. The management trigger is defined as a 35% decline in the combined trigger index from the reference period (average of the index values from 2015-2017).

The figure below (top left panel) shows the calculated trigger index including data through 2022 compared to the selected trigger level of 35%. Including the 2022 survey data as the terminal year, the most recent trigger index value is 0.609, which equates to a 39.1% decline from the reference period.



The TC evaluated the indices and data inputs. The TC noted that the trends across all indices are in agreement and have all been following a decreasing trend since 2018. They also noted that in 2020, several surveys did not occur due to the COVID-19 pandemic. In particular, no spring trawl surveys were completed, resulting in a missing 2020 value for the spring trawl combined index (bottom left panel). Additionally, the Massachusetts fall trawl survey was not completed in 2020, which means the 2020 value for the fall trawl index (upper right panel) is based only on the Maine/New Hampshire fall trawl survey data. Because the final index values are calculated using a three-year rolling average, the 2020, 2021, and 2022 combined index values are affected by these missing data.

Tables and Figures

Table 1. GOM abundance indicators: YOY indices.

YOUNG-OF-YEAR INDICES					
Survey	*ME*				*MA*
	511	*512*	*513 East*	*513 West*	*514*
1981					
1982					
1983					
1984					
1985					
1986					
1987					
1988					
1989			1.64		
1990			0.77		
1991			1.54		
1992			1.30		
1993			0.45		
1994			1.61		
1995		0.02	0.66		0.91
1996		0.05	0.47		
1997		0.05	0.46		0.10
1998		0.00	0.14		0.03
1999		0.04	0.65		0.43
2000	0.00	0.10	0.13	0.17	0.07
2001	0.24	0.43	2.08	1.17	0.39
2002	0.13	0.29	1.38	0.85	1.00
2003	0.22	0.27	1.75	1.22	0.75
2004	0.18	0.36	1.75	0.67	1.02
2005	1.42	1.25	2.40	1.12	1.06
2006	0.49	1.06	1.57	1.08	0.45
2007	0.59	1.11	2.23	1.30	1.27
2008	0.32	0.59	1.27	1.10	0.33
2009	0.66	0.33	1.51	0.48	0.17
2010	0.16	0.64	1.25	0.63	0.44
2011	0.41	0.98	2.33	0.90	0.58
2012	0.44	0.62	1.27	0.30	0.08
2013	0.09	0.22	0.34	0.12	0.00
2014	0.16	0.47	1.04	0.42	0.11
2015	0.15	0.22	0.42	0.03	0.00
2016	0.13	0.21	0.42	0.14	0.08
2017	0.21	0.36	0.65	0.23	0.08
2018	0.27	0.34	0.62	0.22	0.03
2014-2018 mean	0.18	0.32	0.63	0.21	0.06
2019	0.43	0.64	0.94	0.45	0.06
2020	0.29	0.51	1.06	0.33	0.19
2021	0.06	0.12	0.38	0.28	0.28
2022	0.13	0.59	0.71	0.42	0.11
2018-2022 mean	0.23	0.44	0.74	0.34	0.13

25th	0.15	0.18	0.51	0.23	0.08
median	0.22	0.34	1.26	0.63	0.33
75th	0.42	0.60	1.60	1.09	0.67

Figure 1. GOM abundance indicators: YOY indices.

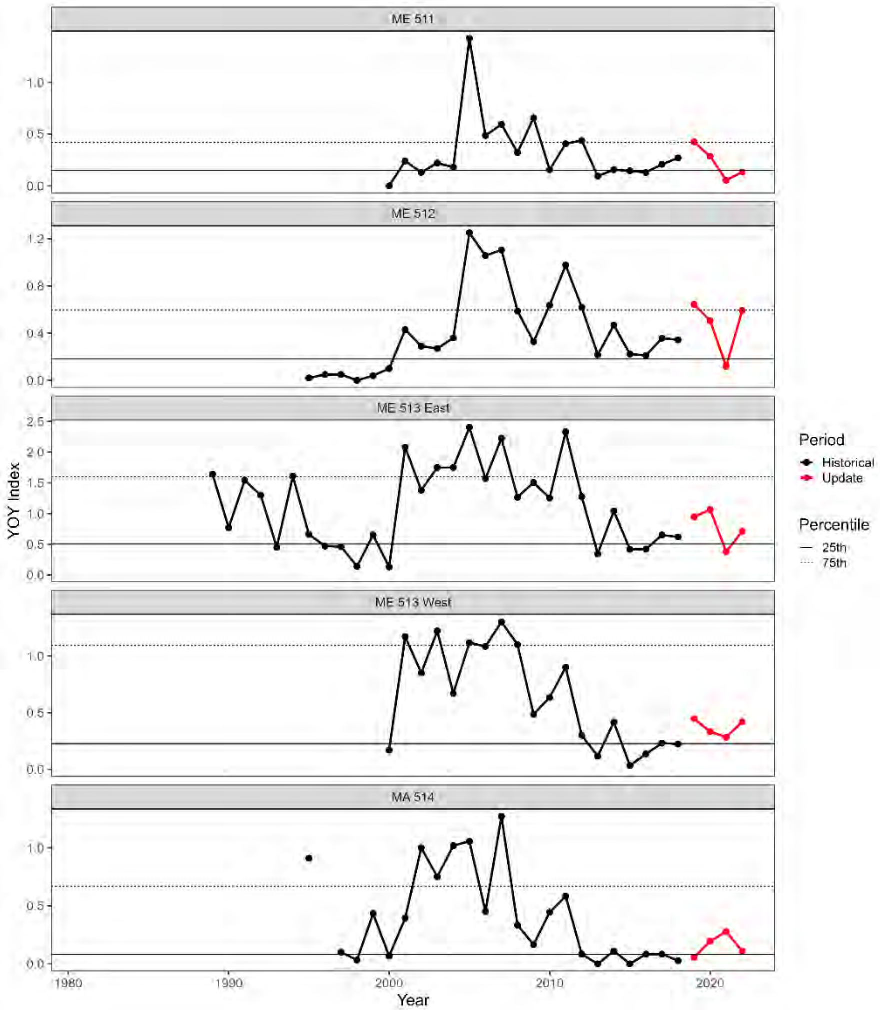


Table 2. GOM abundance indicators: trawl survey recruit abundance.

RECRUIT ABUNDANCE (SURVEY)						
Abundance of lobsters 71 - 80 mm CL (sexes combined)						
Survey	***NEFSC***		***ME/NH***		***MA 514***	
	Spring	***Fall***	***Spring***	***Fall***	***Spring***	***Fall***
1981	0.13	0.06			6.38	4.84
1982	0.29	0.42			2.74	3.85
1983	0.28	0.90			1.76	9.76
1984	0.20	0.31			2.15	6.13
1985	0.14	1.41			4.48	9.60
1986	0.27	1.29			3.01	3.80
1987	0.67	0.57			2.47	1.16
1988	0.67	1.21			2.52	4.12
1989	0.00	1.61			4.48	7.51
1990	0.27	1.76			6.11	15.36
1991	0.55	1.41			2.73	7.55
1992	0.50	1.37			4.31	8.95
1993	0.25	0.86			5.12	3.19
1994	0.15	2.75			7.59	13.77
1995	1.45	1.44			4.54	12.12
1996	0.76	4.59			3.09	12.10
1997	2.02	2.12			4.59	6.46
1998	1.59	2.16			4.50	7.47
1999	1.51	3.01			4.29	8.73
2000	4.64	3.01		24.09	4.24	8.87
2001	1.05	1.51	9.28	17.81	4.32	1.58
2002	1.08	1.91	22.00	22.41	3.43	5.00
2003	1.41	0.36	10.65	18.32	1.96	0.66
2004	0.84	2.26	7.55	12.29	2.46	1.30
2005	0.34	0.87	18.51	25.90	4.35	2.11
2006	2.17	1.27	18.07	18.30	6.09	5.30
2007	1.62	0.64	15.91	16.82	0.77	1.61
2008	0.99	2.41	17.88	31.61	2.54	6.12
2009	4.88	4.90	24.72	32.67	3.19	8.88
2010	2.98	4.53	17.66	37.35	2.22	9.39
2011	10.27	11.83	39.25	46.09	5.24	15.04
2012	11.25	6.74	36.55	37.12	3.03	11.30
2013	10.93	18.12	34.50	37.86	4.83	12.20
2014	11.66	21.54	50.79	41.95	3.35	7.06
2015	14.44	17.89	38.51	67.99	7.05	17.91
2016	13.25	22.54	50.83	60.07	13.61	17.44
2017	15.74		48.42	48.13	7.85	13.58
2018	14.15	15.87	42.77	55.84	5.25	25.69
2014-2018 mean	13.84	19.46	46.27	54.80	7.42	16.34
2019	16.69	7.62	46.37	50.85	10.69	14.59
2020				34.65		
2021	10.05	8.04	32.86	32.19	6.39	10.16
2022	11.82	8.29	22.78	24.86	8.61	6.27
2018-2022 mean	13.17	9.96	36.19	39.68	7.74	14.18
25th	0.30	1.21	17.72	20.36	2.73	4.30
median	1.07	1.76	23.36	32.67	4.30	7.53
75th	4.23	4.53	39.07	44.02	5.05	11.90

Figure 2. GOM abundance indicators: trawl survey recruit abundance.

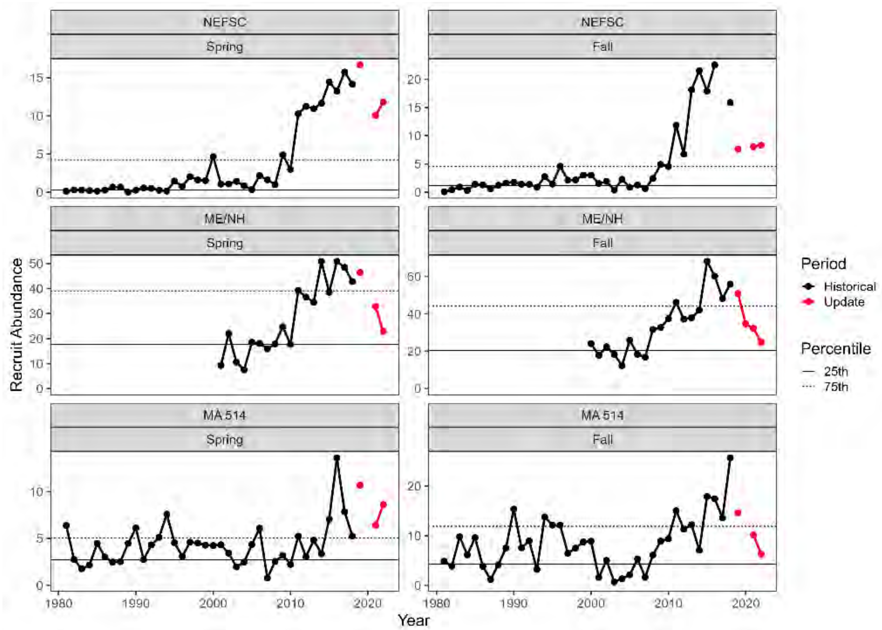


Table 3. GOM abundance indicators: trawl survey encounter rate.

SURVEY LOBSTER ENCOUNTER RATE						
Proportion of postive tows						
Survey	*NEFSC*		*ME/NH*		*MA 514*	
	Spring	*Fall*	*Spring*	*Fall*	*Spring*	*Fall*
1981	0.44	0.25			0.86	0.72
1982	0.34	0.18			0.50	0.70
1983	0.26	0.33			0.76	0.76
1984	0.28	0.36			0.76	0.76
1985	0.38	0.49			0.71	0.67
1986	0.33	0.47			0.68	0.83
1987	0.43	0.24			0.85	0.54
1988	0.31	0.30			0.76	0.58
1989	0.19	0.35			0.78	0.95
1990	0.41	0.32			0.86	0.95
1991	0.42	0.32			0.87	0.94
1992	0.40	0.24			0.93	0.77
1993	0.41	0.39			0.97	0.82
1994	0.45	0.40			1.00	0.93
1995	0.41	0.37			0.93	0.93
1996	0.54	0.54			0.91	0.95
1997	0.64	0.35			0.93	0.86
1998	0.52	0.40			0.76	0.69
1999	0.51	0.42			0.73	0.91
2000	0.63	0.42		0.94	0.93	0.98
2001	0.57	0.40	0.88	0.86	0.93	0.72
2002	0.75	0.53	0.94	0.95	0.91	0.73
2003	0.69	0.44	0.92	0.85	0.82	0.55
2004	0.87	0.31	0.89	0.86	0.84	0.56
2005	0.77	0.36	0.95	0.91	0.95	0.67
2006	0.72	0.60	0.93	0.93	0.91	0.88
2007	0.72	0.43	0.97	0.85	0.51	0.54
2008	0.84	0.49	0.92	0.86	0.83	0.75
2009	0.82	0.63	0.98	0.92	0.89	0.87
2010	0.85	0.75	0.98	0.96	0.87	0.98
2011	0.83	0.74	0.99	0.96	0.89	0.85
2012	0.86	0.78	0.98	0.98	0.91	0.95
2013	0.87	0.73	1.00	0.93	0.96	0.95
2014	0.90	0.71	1.00	0.99	0.79	0.96
2015	0.93	0.69	1.00	0.96	0.98	0.95
2016	0.94	0.75	1.00	0.96	0.96	0.97
2017	0.86		0.99	0.94	0.84	0.98
2018	0.86	0.71	0.98	0.96	0.84	0.90
2014-2018 mean	0.90	0.72	0.99	0.96	0.88	0.95
2019	0.83	0.71	0.99	0.95	0.85	0.92
2020				0.96		
2021	0.90	0.75	1.00	0.91	0.86	0.90
2022	0.79	0.76	0.98	0.90	0.78	0.85
2018-2022 mean	0.84	0.73	0.99	0.93	0.83	0.89

25th	0.41	0.35	0.93	0.89	0.78	0.72
median	0.60	0.42	0.98	0.94	0.87	0.86
75th	0.84	0.60	0.99	0.96	0.93	0.95

Figure 3. GOM abundance indicators: trawl survey encounter rate.

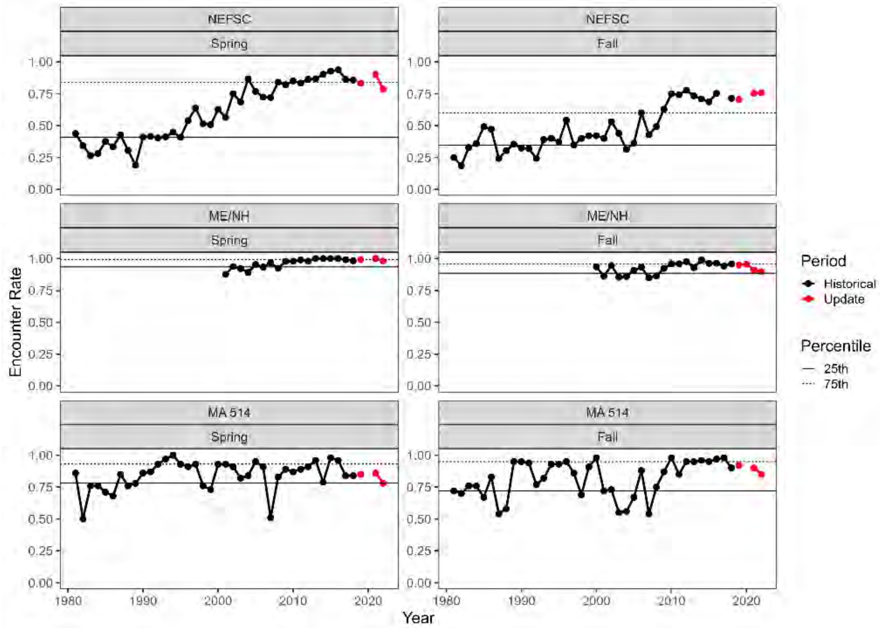


Table 4. GOM abundance indicators: ventless trap survey abundance.

VENTLESS TRAP ABUNDANCE								
Abundance of lobsters > 53 mm CL								
Survey	*511*		*512*		*513*		*514*	
	Female	*Male*	*Female*	*Male*	*Female*	*Male*	*Female*	*Male*
1981								
1982								
1983								
1984								
1985								
1986								
1987								
1988								
1989								
1990								
1991								
1992								
1993								
1994								
1995								
1996								
1997								
1998								
1999								
2000								
2001								
2002								
2003								
2004								
2005								
2006	7.65	5.34	6.87	5.38	5.73	4.37	3.10	3.40
2007	5.06	3.91	3.95	3.83	5.82	4.35	1.85	1.84
2008	4.94	3.87	5.78	4.95	5.78	4.97	2.77	2.51
2009	3.60	2.65	6.31	5.35	6.89	5.53	2.72	2.66
2010	5.66	3.90	6.95	5.69	6.61	5.27	2.49	2.22
2011	8.70	6.52	11.10	8.48	7.32	5.60	3.47	2.60
2012	10.95	7.64	12.06	9.47	11.40	7.72	5.21	4.52
2013	11.14	7.95	11.87	8.64	9.36	6.49		
2014	10.38	6.63	11.92	8.04	7.74	4.96	3.15	2.35
2015	8.47	4.63	10.39	7.70	8.54	5.48	4.01	3.16
2016	14.59	9.15	14.34	10.75	10.78	7.56	4.79	3.56
2017	11.69	7.07	11.61	8.52	8.46	5.56	3.38	2.45
2018	15.10	9.43	11.26	8.23	9.57	6.37	3.47	2.43
2014-2018 mean	12.05	7.38	11.90	8.65	9.02	5.99	3.76	2.79
2019	12.91	8.31	8.22	5.94	8.68	5.25	2.85	1.93
2020	7.66	5.47	7.91	5.96	9.29	6.61	2.50	1.69
2021	7.34	5.44	5.88	5.18	8.27	5.95	1.77	1.37
2022	6.68	4.96	4.83	4.21	7.81	6.20	1.63	0.96
2018-2022 mean	9.94	6.72	7.62	5.91	8.72	6.07	2.44	1.68
25th	5.66	3.91	6.87	5.38	6.61	4.97	2.76	2.41
median	8.70	6.52	11.10	8.04	7.74	5.53	3.27	2.56
75th	11.14	7.64	11.87	8.52	9.36	6.37	3.61	3.22

Figure 4. GOM abundance indicators: ventless trap survey abundance.

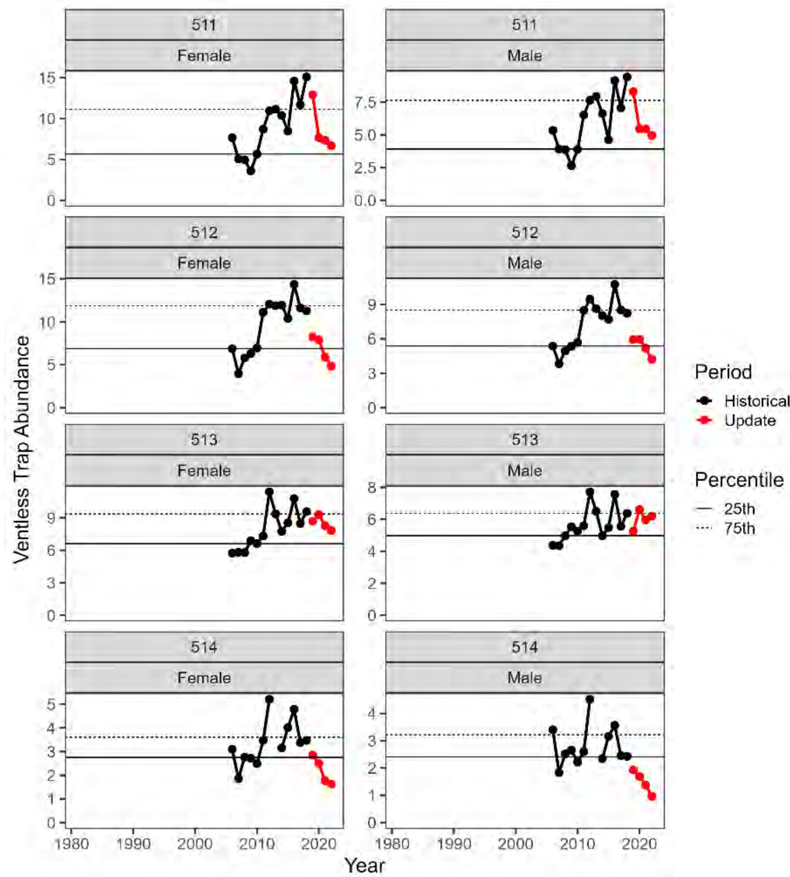


Table 5. GBK abundance indicators: trawl survey recruit abundance.

RECRUIT ABUNDANCE (SURVEY)		
Abundance of lobsters 71 - 80 mm CL (sexes combined)		
Survey	*NEFSC*	
	Spring	*Fall*
1981	0.08	0.28
1982	0.18	0.41
1983	0.16	0.33
1984	0.09	0.40
1985	0.19	0.26
1986	0.57	0.64
1987	0.43	0.54
1988	0.09	0.36
1989	0.04	0.23
1990	0.44	0.47
1991	0.08	0.34
1992	0.13	0.62
1993	0.50	0.22
1994	0.01	0.13
1995	0.03	0.14
1996	0.00	0.35
1997	0.06	0.90
1998	0.01	0.33
1999	0.07	0.29
2000	0.27	0.33
2001	0.47	0.45
2002	0.06	0.56
2003	0.29	0.16
2004	0.04	0.18
2005	0.09	0.13
2006	0.16	0.12
2007	0.03	0.23
2008	0.05	0.17
2009	0.30	0.33
2010	0.30	0.15
2011	0.09	0.35
2012	0.15	0.17
2013	0.14	0.24
2014	0.16	0.21
2015	0.06	0.44
2016	0.15	0.13
2017	0.35	
2018	0.04	0.22
2014-2018 mean	0.15	0.25
2019	0.16	0.13
2020		
2021	0.41	0.43
2022	0.42	0.62
2018-2022 mean	0.26	0.35
25th	0.06	0.18
median	0.11	0.29
75th	0.25	0.40

Figure 5. GBK abundance indicators: trawl survey recruit abundance.

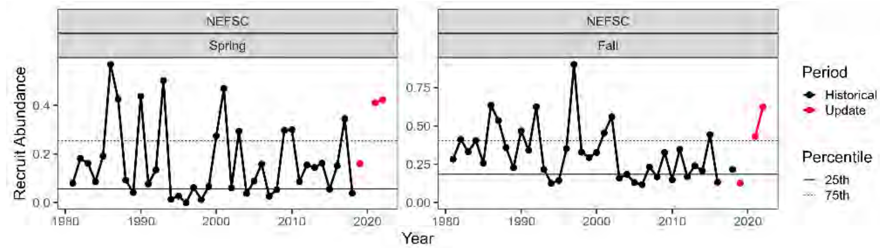


Table 6. GBK abundance indicators: trawl survey encounter rate.

SURVEY LOBSTER ENCOUNTER RATE		
Proportion of postive tows		
Survey	***NEFSC***	
	Spring	***Fall***
1981	0.23	0.52
1982	0.23	0.43
1983	0.18	0.38
1984	0.12	0.34
1985	0.19	0.35
1986	0.27	0.36
1987	0.18	0.35
1988	0.34	0.40
1989	0.14	0.38
1990	0.18	0.44
1991	0.19	0.45
1992	0.26	0.49
1993	0.22	0.36
1994	0.11	0.38
1995	0.14	0.42
1996	0.16	0.40
1997	0.10	0.48
1998	0.10	0.40
1999	0.16	0.58
2000	0.23	0.41
2001	0.23	0.49
2002	0.29	0.55
2003	0.27	0.44
2004	0.18	0.53
2005	0.16	0.58
2006	0.24	0.54
2007	0.26	0.46
2008	0.29	0.55
2009	0.34	0.54
2010	0.38	0.62
2011	0.30	0.69
2012	0.35	0.57
2013	0.33	0.65
2014	0.37	0.61
2015	0.27	0.59
2016	0.45	0.55
2017	0.40	
2018	0.29	0.59
2014-2018 mean	0.36	0.58
2019	0.36	0.57
2020		
2021	0.41	0.48
2022	0.34	0.64
2018-2022 mean	0.35	0.57

25th	0.18	0.40
median	0.23	0.48
75th	0.29	0.55

Figure 6. GBK abundance indicators: trawl survey encounter rate.

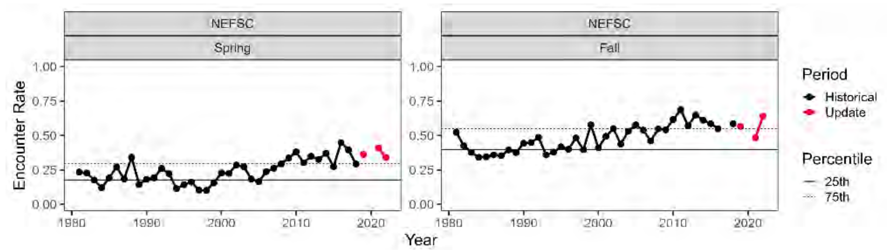


Table 7. SNE abundance indicators: YOY indices.

YOUNG-OF-YEAR INDICES			
Survey	*MA*	*RI*	*CT / ELIS Larvae*
1981			
1982			
1983			
1984			0.43
1985			0.53
1986			0.90
1987			0.78
1988			0.74
1989			0.74
1990		1.18	0.81
1991		1.51	0.55
1992		0.63	1.44
1993		0.51	1.19
1994		1.27	0.98
1995	0.17	0.34	1.46
1996	0.00	0.15	0.31
1997	0.08	0.98	0.21
1998	0.28	0.57	0.55
1999	0.06	1.03	2.83
2000	0.33	0.33	0.78
2001	0.11	0.75	0.32
2002	0.11	0.25	0.64
2003	0.00	0.73	0.25
2004	0.06	0.42	0.45
2005	0.17	0.54	0.49
2006	0.22	0.44	0.71
2007	0.17	0.36	0.37
2008	0.00	0.14	0.37
2009	0.06	0.06	0.19
2010	0.00	0.11	0.35
2011	0.00	0.00	0.26
2012	0.00	0.09	0.12
2013	0.17	0.19	0.16
2014	0.11	0.22	0.06
2015	0.00	0.17	0.19
2016	0.00	0.06	0.45
2017	0.00	0.03	0.10
2018	0.00	0.03	0.17
2014-2018 mean	0.02	0.10	0.19
2019	0.00	0.03	0.21
2020	0.00	0.14	0.10
2021	0.00	0.08	0.19
2022	0.00	0.03	0.25
2018-2022 mean	0.00	0.06	0.18

25th	0.00	0.14	0.26
median	0.06	0.34	0.45
75th	0.17	0.63	0.76

Figure 7. SNE abundance indicators: YOY indices.

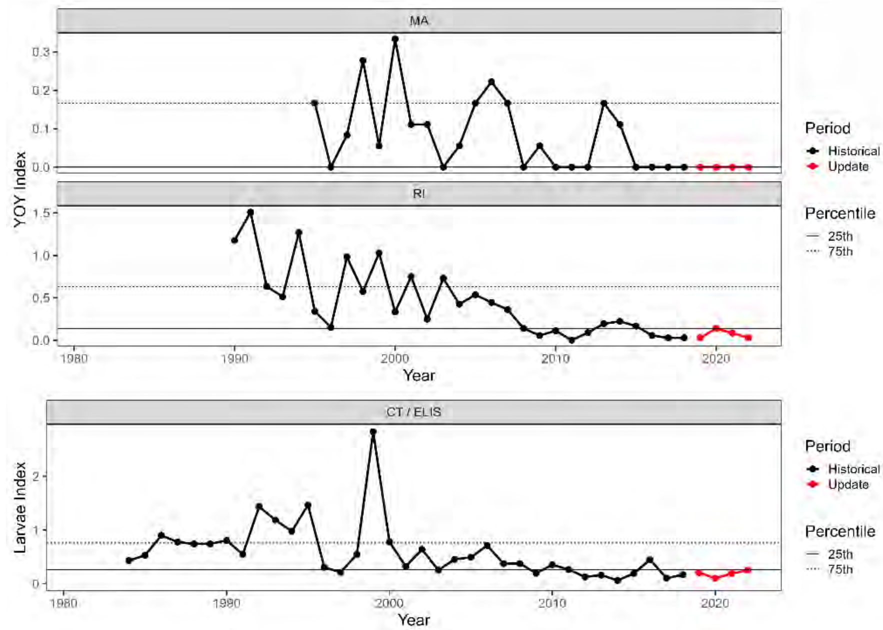


Table 8. SNE abundance indicators: trawl survey recruit abundance.

RECRUIT ABUNDANCE (SURVEY)								
Abundance of lobsters 71 - 80 mm CL (sexes combined)								
Survey	***NEFSC***		***MA***		***RI***		***CT***	
	Spring	***Fall***	***Spring***	***Fall***	***Spring***	***Fall***	***Spring***	***Fall***
1981	0.10	0.89	0.65	0.07	0.89	1.31		
1982	0.74	0.74	0.10	0.04	0.26	0.64		
1983	0.45	0.62	0.09	0.04	0.94	0.43		
1984	0.10	0.81	0.42	0.01	1.03	1.35	10.09	6.80
1985	1.99	1.01	0.34	0.09	0.28	0.97	3.08	3.93
1986	0.18	0.59	0.17	0.20	0.91	1.28	2.77	5.76
1987	1.04	0.45	0.26	0.17	0.79	3.14	2.93	6.86
1988	0.55	0.60	0.24	0.16	0.47	4.05	1.85	4.88
1989	0.09	1.65	0.14	0.43	0.90	3.26	4.86	5.28
1990	0.71	0.83	2.29	0.31	2.17	2.69	6.89	7.74
1991	0.31	0.51	1.18	0.87	4.77	3.10	10.83	10.32
1992	0.19	0.94	0.10	0.57	0.62	1.97	10.31	10.65
1993	0.59	0.42	0.25	0.52	7.81	8.29	7.78	15.18
1994	0.15	0.38	0.95	0.42	1.00	3.88	5.07	11.51
1995	0.01	0.61	1.14	0.03	1.33	4.50	12.13	11.20
1996	0.40	2.39	0.40	0.32	1.60	6.55	11.37	11.08
1997	1.64	1.60	1.45	0.12	2.58	6.10	15.42	24.99
1998	0.78	1.06	1.09	0.11	1.63	3.24	24.06	12.72
1999	2.43	0.66	0.75	0.19	1.71	2.07	24.57	12.96
2000	0.67	1.27	0.56	0.13	1.54	1.83	13.37	8.27
2001	0.39	0.45	0.18	0.03	2.97	2.17	10.77	7.41
2002	1.63	0.39	0.34	0.00	2.68	0.73	8.07	2.75
2003	0.34	0.33	0.07	0.00	0.29	0.93	3.52	4.08
2004	0.27	0.28	0.05	0.00	1.86	1.48	2.38	3.37
2005	0.11	0.24	0.08	0.00	1.07	2.53	2.26	1.54
2006	0.19	0.32	0.08	0.03	3.63	2.24	2.02	1.38
2007	0.19	0.35	0.08	0.00	0.68	2.68	2.65	1.12
2008	0.21	0.29	0.16	0.01	0.64	2.95	2.20	1.27
2009	0.15	0.35	0.16	0.05	1.14	1.36	1.20	1.33
2010	0.21	0.73	0.06	0.18	0.44	1.21	1.26	
2011	0.10	0.64	0.18	0.00	0.42	1.02	0.43	0.18
2012	0.11	0.99	0.07	0.21	0.30	0.18	0.44	0.08
2013	0.23	0.44	0.11	0.04	0.16	0.02	0.23	0.06
2014		0.67	0.04	0.00	0.02	0.14	0.15	0.05
2015	0.03	0.28	0.07	0.30	0.05	0.37	0.15	0.06
2016	0.83	0.69	0.05	0.14	0.57	0.25	0.16	0.00
2017	0.10		0.13	0.16	0.14	0.41	0.03	0.00
2018	0.08	0.38	0.02	0.01	0.18	0.68	0.00	0.01
2014-2018 mean	0.26	0.51	0.06	0.12	0.19	0.37	0.10	0.03
2019	0.06	0.32	0.01	0.02	0.52	0.50	0.03	0.00
2020					0.23	0.32		
2021	0.01	0.59	0.01	0.00	0.27	0.07	0.03	0.00
2022	0.09	0.19	0.00	0.00	0.09	0.16	0.00	0.01
2018-2022 mean	0.06	0.37	0.01	0.01	0.26	0.35	0.01	0.01

25th	0.11	0.38	0.08	0.02	0.42	0.78	1.23	1.16
median	0.23	0.61	0.17	0.10	0.91	1.65	2.93	4.48
75th	0.67	0.83	0.42	0.20	1.62	3.07	10.20	9.81

Figure 8. SNE abundance indicators: trawl survey recruit abundance.

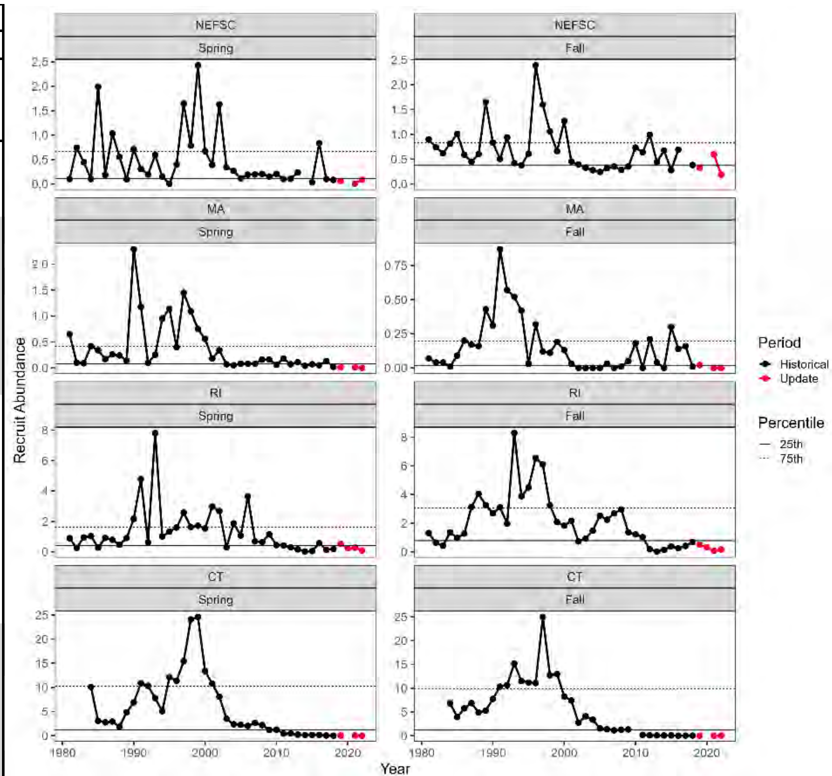


Table 9. SNE abundance indicators: trawl survey encounter rate.

SURVEY LOBSTER ENCOUNTER RATE								
Proportion of postive tows								
Survey	NEFSC		MA		RI		CT	
	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall
1981	0.18	0.47	0.38	0.15	0.49	0.41		
1982	0.26	0.35	0.28	0.21	0.30	0.43		
1983	0.14	0.26	0.21	0.16	0.46	0.37		
1984	0.08	0.32	0.40	0.18	0.59	0.44	0.63	0.76
1985	0.21	0.34	0.51	0.22	0.31	0.50	0.57	0.69
1986	0.17	0.25	0.39	0.38	0.64	0.46	0.67	0.61
1987	0.13	0.23	0.28	0.18	0.35	0.47	0.63	0.76
1988	0.09	0.28	0.39	0.21	0.49	0.55	0.65	0.66
1989	0.13	0.40	0.50	0.33	0.52	0.57	0.75	0.63
1990	0.14	0.44	0.66	0.44	0.64	0.53	0.73	0.76
1991	0.14	0.33	0.41	0.39	0.77	0.69	0.81	0.77
1992	0.22	0.34	0.51	0.23	0.40	0.57	0.77	0.68
1993	0.12	0.27	0.54	0.26	0.50	0.71	0.73	0.75
1994	0.09	0.25	0.51	0.20	0.58	0.57	0.73	0.74
1995	0.05	0.35	0.44	0.12	0.55	0.67	0.77	0.68
1996	0.10	0.39	0.30	0.16	0.79	0.76	0.66	0.78
1997	0.25	0.28	0.45	0.21	0.75	0.71	0.71	0.81
1998	0.12	0.34	0.54	0.13	0.59	0.55	0.83	0.71
1999	0.22	0.28	0.41	0.21	0.76	0.59	0.78	0.79
2000	0.13	0.31	0.45	0.15	0.68	0.63	0.81	0.73
2001	0.21	0.25	0.28	0.18	0.65	0.60	0.77	0.58
2002	0.19	0.24	0.28	0.03	0.61	0.45	0.73	0.59
2003	0.11	0.26	0.14	0.03	0.51	0.40	0.71	0.64
2004	0.10	0.19	0.28	0.03	0.54	0.50	0.61	0.66
2005	0.08	0.19	0.34	0.15	0.49	0.45	0.63	0.54
2006	0.14	0.23	0.42	0.03	0.79	0.62	0.61	0.51
2007	0.13	0.21	0.34	0.10	0.44	0.54	0.70	0.53
2008	0.10	0.22	0.32	0.10	0.55	0.52	0.63	0.65
2009	0.17	0.32	0.50	0.05	0.57	0.40	0.49	0.55
2010	0.12	0.33	0.22	0.24	0.47	0.45	0.54	
2011	0.13	0.35	0.17	0.05	0.30	0.23	0.46	0.28
2012	0.13	0.34	0.17	0.15	0.27	0.16	0.43	0.20
2013	0.10	0.28	0.18	0.08	0.20	0.09	0.28	0.15
2014		0.26	0.13	0.08	0.07	0.23	0.26	0.10
2015	0.06	0.27	0.10	0.05	0.12	0.16	0.27	0.10
2016	0.15	0.25	0.08	0.11	0.30	0.14	0.25	0.03
2017	0.08		0.07	0.16	0.16	0.23	0.08	0.03
2018	0.08	0.29	0.11	0.06	0.09	0.18	0.09	0.01
2014-2018 mean	0.09	0.27	0.10	0.09	0.15	0.19	0.19	0.05
2019	0.05	0.26	0.05	0.11	0.16	0.11	0.09	0.00
2020					0.16	0.16		
2021	0.04	0.18	0.07	0.00	0.20	0.12	0.06	0.03
2022	0.08	0.17	0.00	0.00	0.14	0.09	0.01	0.04
2018-2022 mean	0.06	0.23	0.06	0.04	0.15	0.13	0.06	0.02

25th	0.10	0.25	0.21	0.09	0.32	0.40	0.52	0.52
median	0.13	0.28	0.34	0.16	0.51	0.49	0.65	0.64
75th	0.17	0.34	0.45	0.21	0.60	0.57	0.73	0.74

Figure 9. SNE abundance indicators: trawl survey encounter rate.

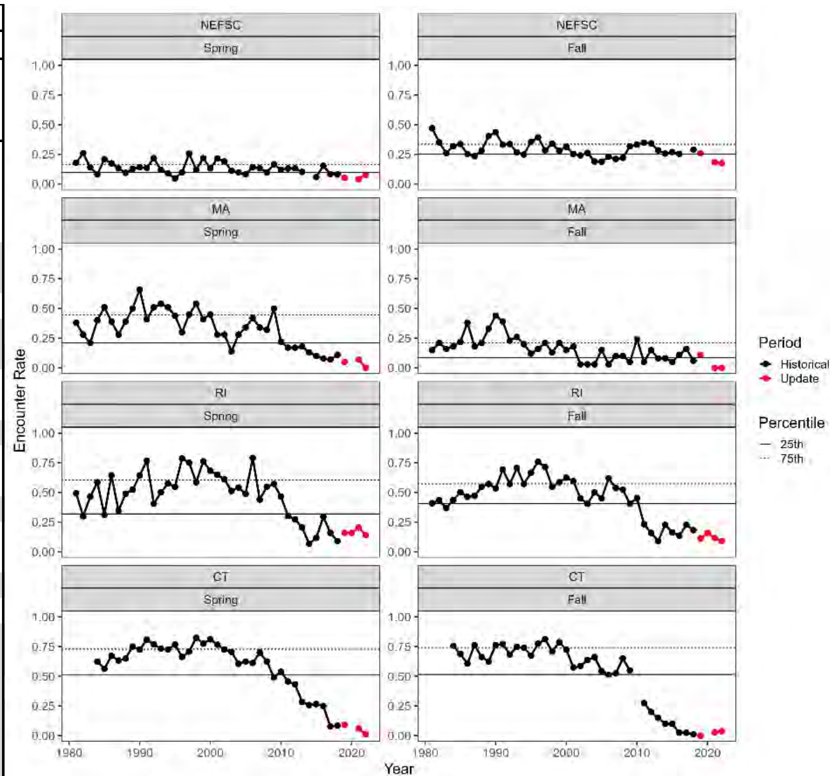
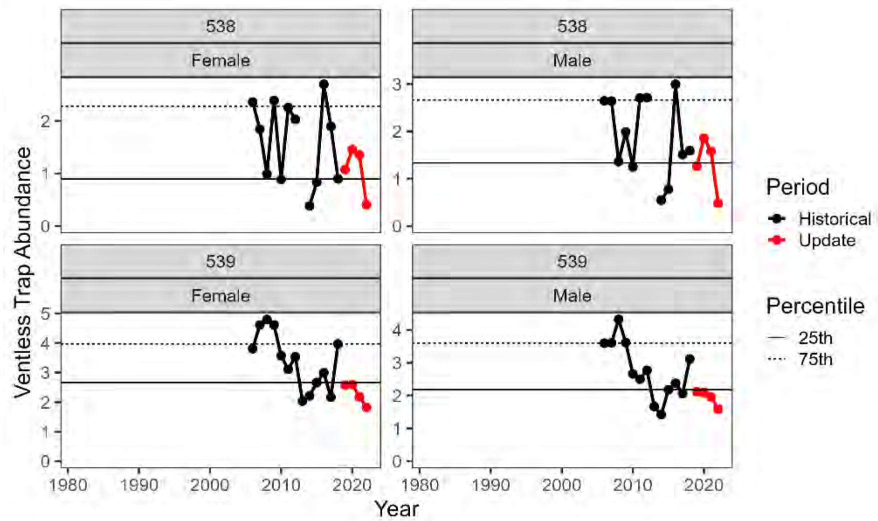


Table 10. SNE abundance indicators: ventless trap survey abundance.

VENTLESS TRAP ABUNDANCE				
Abundance of lobsters ≥ 53 mm CL				
Survey	*538*		*539*	
	Female	*Male*	*Female*	*Male*
1981				
1982				
1983				
1984				
1985				
1986				
1987				
1988				
1989				
1990				
1991				
1992				
1993				
1994				
1995				
1996				
1997				
1998				
1999				
2000				
2001				
2002				
2003				
2004				
2005				
2006	2.36	2.64	3.81	3.60
2007	1.84	2.64	4.61	3.61
2008	0.99	1.36	4.80	4.32
2009	2.39	1.99	4.61	3.62
2010	0.89	1.25	3.57	2.67
2011	2.25	2.71	3.11	2.50
2012	2.03	2.71	3.53	2.77
2013			2.03	1.67
2014	0.38	0.55	2.22	1.42
2015	0.84	0.77	2.66	2.18
2016	2.70	3.00	2.99	2.38
2017	1.90	1.51	2.17	2.06
2018	0.90	1.59	3.97	3.12
2014-2018 mean	1.34	1.48	2.80	2.23
2019	1.08	1.26	2.57	2.12
2020	1.46	1.86	2.60	2.10
2021	1.36	1.58	2.19	1.95
2022	0.41	0.48	1.82	1.59
2018-2022 mean	1.04	1.36	2.63	2.18

25th	0.90	1.33	2.66	2.18
median	1.87	1.79	3.53	2.67
75th	2.28	2.66	3.97	3.60

Figure 10. SNE abundance indicators: ventless trap survey abundance.



Appendix: Data Update Data Changes

Addendum XXVII Trigger Index

During the update of the Addendum XXVII trigger index in 2023 (terminal data year of 2022), an error was discovered in the calculation of the spring trawl index three-year average. Neither the Massachusetts or Maine/New Hampshire trawl surveys sampled in spring 2020 resulting in a missing data point. The three-year average spring index for 2021 was intended to be an average of 2021 and 2019 due to the missing 2020 data point, but was mistakenly calculated as the average of 2021, 2019, and 2018. This error affected the 2021 trigger index value published in Addendum XXVII. The 2021 value in the addendum for the spring trawl index was 0.878 and the value for the combined trigger index was 0.765. These values were corrected to 0.865 (for the spring trawl index) and 0.766 (for the combined trigger index) during the 2023 update.

Maine

During the 2023 Data Update (terminal data year of 2022), a few errors were found in the upload process where data was not uploaded correctly and treated in a consistent manner as the assessment. For the Fall 2021 ME/NH Trawl Survey, the sex of sampled lobsters did not upload correctly, leading to 7 tows being excluded in error. These data have now been corrected and included. During the 2020 assessment, the stock assessment team, in consultation with survey staff, determined that a very large outlier tow in the Spring 2014 ME/NH Trawl Survey should be excluded from the assessment. However, this outlier tow was not excluded in the 2022 Data Update. It is excluded for the 2023 Data Update, consistent with the stock assessment. For the Maine settlement survey, data for 2013 was not uploaded completely and this has now been corrected.

Massachusetts

Two changes following the stock assessment have impacted the SNE VTS Statistical Area 538 (MA) abundance indicators. Following the 2021 Data Update (terminal data year of 2020), there was a reduction in the spatial coverage of the survey due to reduced participation. This change necessitates dropping out data collected during earlier years from areas no longer sampled to calculate an index from a consistent survey footprint, resulting in changes to the indices. Note that the updated index increased slightly in scale (the reduced footprint excludes most of the interior of Buzzards Bay), but the pattern over time is generally consistent with the previous index. Additionally, following the 2022 Data Update (terminal year of 2021), an error was discovered in the data pull that did not filter the frequency of trawl hauls per month in historical data to match the reduced sampling frequency in data since the footprint reduction (reduced to 1 haul/month). This error was corrected in the data pull for the 2023 Data Update.

Rhode Island

Some changes to the SNE VTS Statistical Area 539 (RI) data occurred between the 2021 Data Update (terminal data year of 2020) and 2022 Data Update (terminal data year of 2021). Upon further QA/QC in site or sample location, strata classification for select stations over time were rectified. Data as such were updated to reflect these changes during the 2022 Data Update.

Atlantic States Marine Fisheries Commission

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MEMORANDUM

TO: American Lobster Management Board

FROM: American Lobster Technical Committee

DATE: October 2, 2023

SUBJECT: Terms of Reference and Timeline for the 2025 American Lobster Benchmark Assessment

The next American lobster benchmark stock assessment is scheduled to be completed in 2025. The American Lobster Technical Committee (TC) has recommended the Board consider the following terms of reference and timeline for the benchmark assessment and peer review panel:

Terms of Reference for the 2025 American Lobster Benchmark Stock Assessment

1. Estimate catch and catch-at-length from all appropriate fishery-dependent data sources including commercial and potential discard data.
    a. Provide descriptions of each data source (e.g., geographic location, sampling methodology, variability, outliers). Discuss data strengths and weaknesses (e.g., temporal and spatial scale, gear selectivities, sample size, confidence/uncertainty) and their potential effects on the assessment.
    b. Justify inclusion or elimination of each data source.

2. Present the abundance data being considered and/or used in the assessment (e.g., regional indices of abundance, length data, etc.).
    a. Characterize uncertainty in these sources of data.
    b. Justify inclusion or elimination of each data source.
    c. Describe calculation or standardization of abundance indices.

3. Evaluate new information on life history such as growth rates, size at maturation, natural mortality rate, and migrations.
    a. Consider any new information on growth for potential to update the growth transition matrices.

4. Identify, describe, and, if possible, quantify environmental/climatic drivers.

5. Use length-based model(s) to estimate population parameters (e.g., effective exploitation rate, abundance) for each stock unit and analyze model performance.
    a. Evaluate stability of model(s). Perform and present model diagnostics.
    b. Perform sensitivity analyses to examine implications of important model assumptions, including but not limited to growth and natural mortality.
    c. Explain model strengths and limitations.
    d. Justify choice of CVs, effective sample sizes, or likelihood weighting schemes.

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   e. State assumptions made and explain the likely effects of assumption violations on synthesis of input data and model outputs.
   f. Conduct projections assuming uncertainty in current and future conditions for all stocks. Compare projections retrospectively with model estimates.

6. Update simple, empirical, indicator-based trend analyses of abundance, exploitation, fishery performance, and environmental stress for stock or sub-stock areas. Modify or develop new indicators, if warranted.

7. Evaluate the current regime-based exploitation and abundance reference points (i.e., targets and thresholds). Recommend modifications to these reference points, if necessary.

8. Characterize uncertainty of model estimates, reference points, and stock status.

9. Perform retrospective analyses, assess magnitude and direction of retrospective patterns detected, and discuss implications of any observed retrospective pattern for uncertainty in population parameters and reference points.

10. Report stock status as related to overfishing and depleted reference points (both current and any alternative recommended reference points). Include simple description of the historical and current condition of the stock in layman's terms.

11. Address and incorporate to the extent possible recommendations from the 2020 Benchmark Peer Review.

12. Develop detailed short and long-term prioritized lists of recommendations for future research, data collection, and assessment methodology. Highlight improvements to be made by next benchmark review.

13. Recommend timing of next benchmark assessment and intermediate updates, if necessary relative to biology and current management of the species.

Terms of Reference for the Peer Review of the 2025 American Lobster Benchmark Stock Assessment

1. Evaluate thoroughness of data collection and presentation and treatment of fishery-dependent and fishery-independent data in the assessment, including the following but not limited to:
   a. Consideration of data strengths and weaknesses,
   b. Justification for inclusion or elimination of available data sources,
   c. Calculation of catch-at-length matrix,
   d. Calculation and/or standardization of abundance indices.

2. Evaluate the methods and models used to estimate population parameters and reference points for each stock unit, including but not limited to:
   a. Use of available life history information to parameterize the model(s)
   b. Model parameterization and specification (e.g., choice of CVs, effective sample sizes, likelihood weighting schemes, etc.).
   c. The choice and justification of the preferred model. Was the most appropriate model used given available data and life history of the species?

3. Evaluate the identification and characterization of environmental/climatic drivers.

4. Evaluate the estimates of stock abundance and exploitation from the assessment for use in management. If necessary, specify alternative estimation methods.

5. Evaluate the methods used to characterize uncertainty in estimated parameters. Were the implications of uncertainty in technical conclusions clearly stated?

6. Evaluate the diagnostic analyses performed, including but not limited to:
   a. Sensitivity analyses to determine model stability and potential consequences of major model assumptions
   b. Retrospective analysis

7. Evaluate the preparation and interpretation of indicator-based analyses for stocks and sub-stock areas.

8. Evaluate the current and recommended reference points and the methods used to calculate/estimate them. Recommend stock status determination from the assessment or specify alternative methods.

9. Review the research, data collection, and assessment methodology recommendations provided by the Technical Committee and make any additional recommendations warranted. Clearly prioritize the activities needed to inform and maintain the current assessment, and provide recommendations to improve the reliability of future assessments.

10. Review the recommended timing of the next benchmark assessment relative to the life history and current management of the species.

11. Prepare a Peer Review Panel TOR and Advisory Report summarizing the Panel's evaluation of the stock assessment and addressing each Peer Review Term of Reference. Develop a list of tasks to be completed following the workshop. Complete and submit the Report within 4 weeks of workshop conclusion.

Timeline for the 2025 American Lobster Benchmark Stock Assessment

- Data request: November 1, 2023
- Data deadline (data through 2022 with 2023 data to be added later in 2024): January 8, 2024
- Data Workshop: February 2024
- Assessment Workshop 1 (review continuity models through 2022): June 2024
- Assessment Workshop 2 (finalize model results/stock status determination): October 2024
- Assessment report draft finalized by Stock Assessment Subcommittee: January 2025
- Assessment reviewed by TC: February 2025
- Peer Review Workshop: May 2025
- Present Assessment and Peer Review Reports to the Board: August 2025

Atlantic States Marine Fisheries Commission

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MEMORANDUM

TO: **American Lobster Management Board**

FROM: **American Lobster Technical Committee**

DATE: **April 16, 2021**

SUBJECT: **Lobster Management Strategy Evaluation Options**

The Atlantic States Marine Fisheries Commission's Lobster Technical Committee (TC) was tasked by the American Lobster Management Board (Board) at the Commission's 2021 Winter Meeting to develop a set of prioritized options, timelines, and draft budgets to assist the Board in considering if management strategy evaluation (MSE) could be of use for management of the lobster fisheries. The TC met via webinar two times following the Winter Meeting to develop and prioritize these options. Options are outlined at the end of the memorandum, and include anticipated personnel needs, major budget line items, and timelines with milestones that would incur a substantial cost. However, the TC indicated that due to the highly interdisciplinary nature of MSE, additional perspectives are needed to provide a comprehensive work plan. Therefore, the TC has provided some recommendations for next steps for MSE development in addition to a recommended option to pursue. In addition to the line item cost estimates for each option, it is important to keep in mind that these costs do not include time and, consequently, indirect costs of several participants' time being allocated to participating in the MSE process (e.g., TC members); workloads would have to be prioritized and modified to accommodate the MSE workload. Competing workloads include the next lobster stock assessment (tentatively scheduled for 2025) and a potential Jonah crab stock assessment (tentatively scheduled for 2023), at a minimum. The details of the options provided at the end of the memorandum are considered preliminary and may change dependent on management goals and objectives (e.g., need to include anthropologists to address human dimensions objectives).

TC Recommendations on MSE Focus

<u>The TC recommends the option for a two-phase MSE of the Gulf of Maine/Georges Bank (GOM/GBK) stock.</u> The first phase of this option would provide an intermediate MSE at a coarser spatial resolution (i.e., stock level) that can be used to support a management framework in a relatively short timeframe, while also allowing time to build knowledge and tools to develop a subsequent, spatially-explicit MSE in phase two. This phased approach provides short term management guidance, while concurrently building the framework to expand to a spatially explicit approach in phase two. The extended timeframe may also allow several large-scale changes on the horizon for the lobster fishery to develop that could impact the lobster fishery and management goals, and thus better guide the cost and focus of incorporating spatial considerations explicitly into the MSE.

The TC believes MSE has potential for supporting a management framework for the Southern New England (SNE) stock, but believes a SNE-focused MSE is a lower priority option for several reasons. First, the scale of the fisheries in terms of fleet size and landings make the GOM/GBK stock a higher priority. Second, MSEs are generally focused on proactive management strategies for the future of the fishery, such as strategies intended to promote stock resilience, as opposed to reactive management strategies responding to stock conditions estimated in past stock assessments; the TC believes this further skews

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cost-benefit considerations of MSE in favor of the GOM/GBK stock. Third, the TC anticipates unique challenges that would require more complex tools to provide a successful SNE MSE. These challenges include the dominant mixed-crustacean nature of the fishery, and the degree and rate at which the lobster population and fishery have changed in response to climate change. These factors require modeling aspects of both Jonah crab and lobster population dynamics and distributions, as well as spatial dynamics of the fishery in any MSE option. There is also a high likelihood for an MSE to require customized model development and data collection by stock (e.g., socio-economic indicators), making MSE focused on one stock at a time most feasible.

TC Recommendations on Next Steps

The TC recommends two next steps for development of an MSE. First, a formal process is recommended to develop management goals and objectives for the future of the lobster fisheries. A good example is the process used by the Ecosystems Management Objectives Workshop conducted by the Commission to guide development of ecological reference points for Atlantic menhaden. Objectives developed from such a process would be used to further develop an MSE work plan for lobster. The second recommendation is to form a steering committee for additional scoping and development of a comprehensive work plan with a detailed timeline, including: outreach components that are not anticipated to incur a substantial cost but are imperative to the success of an MSE (e.g., outreach at regularly scheduled industry association meetings), identification of funding sources for the MSE costs, and identification of personnel. Representation recommended for the steering committee includes Board members, TC members, Commission staff, members of the Commission's Committee on Economics and Social Sciences, industry stakeholders (preferably those with past experience in MSE), and members of the Commission's Assessment and Science Committee or Management and Science Committee with past experience in MSE. To be effective, the number of people in the steering committee should be limited to approximately a dozen members.

The TC discussed two ongoing developments that will potentially streamline the development of a formal MSE approximately a year from now. First, University of Maine researchers have submitted a proposal to the current round of the Sea Grant's American Lobster Research Program funding; while funding is uncertain, the project is to evaluate population dynamics simulations that will incorporate environmental effects into the biological modeling framework likely to be used in a lobster MSE. Second, work towards the conceptualization of an economics model and economic data gathering is being funded by NOAA Fisheries; this will support development of an economic model within the MSE modeling framework. These developments support the TC recommendation for the formation of a steering committee, with a start date for the MSE to be determined pending the results of the steering committee's findings.

GOM/GBK MSE Option (high priority)

Phase One - Stockwide GOM/GBK MSE

Purpose: Evaluate performance of management strategies at the stock level for the GOM/GBK stock in response to changes in recruitment with biological, fishery, and other socio-economic performance metrics.

Timeline: Three years. One modeler workshop in the first year and one modeler and one stakeholder workshop in years two and three.

Personnel and responsibilities:

- ASMFC Lobster TC – Stakeholder recruitment and engagement, data gathering, guidance on technical aspects of the MSE, report writing, and training for using the MSE tools in future updates
- ASMFC Staff – Project management, data gathering, workshop coordination, and report writing/publishing
- ASMFC Lobster Board Members – Define management goals and provide guidance on the direction of the MSE based on established goals, participate in stakeholder input gathering (webinars and workshops)
- Stakeholders – Identify desired objectives and outcomes of an MSE and provide guidance on the direction of the MSE, participate in stakeholder input gathering (surveys, webinars, and workshops)
- Biological modeler – Couple existing assessment model and operating model in a closed-loop model (six months to program, six months to modify based on workshop feedback and to provide training to TC members)
- Economics modeler – Develop an economics model guided by NOAA Fisheries' economic model conceptualization and data gathering work and couple with the assessment model and operating model in a closed-loop model.
- Professional facilitator - Facilitate stakeholder webinars and workshops, assist with stakeholder input survey development and analysis

Costs:

- Facilitator - $25,000
- Travel - $37,500 for two in-person stakeholder workshops (30 people), $22,500 for three in-person modeler workshops (12 people)
- Biological model development - $85,000 (one year postdoc with ASMFC indirect cost cap)
- Economic model development - $115,000 (one year full time or two six month full time contractors)
- Total - $285,000

Phase Two - Spatially-Explicit GOM/GBK MSE

Purpose: Evaluate performance of spatially-directed management strategies for the GOM/GBK stock triggered by external forces (e.g., whale interactions, wind farm development and operation, climate change).

Costs: Estimates to be developed during phase one.

<u>Spatially-Explicit SNE MSE Option (low priority)</u>

Purpose: Evaluate performance of spatially-directed management strategies for the SNE stock in response to changes in recruitment and diversification of the fishery (targeting lobster and Jonah crab) with biological, fishery, and other socio-economic performance metrics.

Timeline: Five years. One modeler workshop in years one through five. One stakeholder workshop in years two, four, and five.

Personnel and responsibilities:

- ASMFC Lobster TC – Stakeholder recruitment and engagement, data gathering, guidance on technical aspects of the MSE, report writing, and training for using the MSE tools in future updates
- ASMFC Staff – Project management, data gathering, workshop coordination, and report writing/publishing
- ASMFC Lobster Board Members – Define management goals and provide guidance on the direction of the MSE based on those pre-defined goals, participate in stakeholder input gathering (webinars and workshops)
- Stakeholders – Identify desired objectives and outcomes of an MSE and provide guidance on the direction of the MSE, participate in stakeholder input gathering (surveys, webinars, and workshops)
- Biological modeler – Conceptualize modeling of the spatial dynamics necessary to address stakeholder objectives by integrating lobster population distribution models along with Jonah crab population distribution and the resulting fleet dynamics. Identify biological and fleet spatial dynamics and resolution of each that can and cannot be modeled with available data to guide configuration of operating and assessment model. Couple assessment model and operating model in a closed-loop model (eighteen months to program, eighteen months to modify based on workshop feedback and provide training to TC members).
- Economics modeler – Conceptualize modeling of the economic processes driven by lobster landings, and interactions between lobster and Jonah crab effort and landings. Identify processes that can and cannot be modeled with available data to guide configuration of model. Couple economics model with the assessment model and operating model in a closed-loop model.
- Professional facilitator – Facilitate stakeholder webinars and workshops, assist with stakeholder input survey development and analysis
- ***Potentially others dependent on management and stakeholder objectives (e.g., reduce whale interactions would require a whale biologist and protected resource personnel)***

Costs:

- Facilitator - $42,000
- Travel - $56,250 for three in-person stakeholder workshops (30 people), $46,875 for five in-person modeler workshops (15 people)
- Spatially-explicit closed-loop model development: $255,000 (three year postdoc with ASMFC indirect cost cap)
- Economic model development: $345,000 (three year full time or two one and half year full time contractors)
- Total - $745,125 (minimum with potential for additional costs dependent on stakeholder objectives)

ATLANTIC STATES MARINE FISHERIES COMMISSION

REVIEW OF THE INTERSTATE FISHERY MANAGEMENT PLAN

FOR AMERICAN LOBSTER
(*Homarus americanus*)

2022 FISHING YEAR

Prepared by the Plan Review Team

October 2023

Sustainable and Cooperative Management of Atlantic Coastal Fisheries

Table of Contents

1.0 Status of the Fishery Management Plan

Year of ASMFC Plan's Adoption:	Amendment 3 (1997)
Plan Addenda:	
Addendum II (2001)	Addendum XV (2009)
Addendum III (2002)	Addendum XVI (2010)
Addendum IV (2003)	Addendum XVII (2012)
Addendum V (2004)	Addendum XVIII (2012)
Addendum VI (2005)	Addendum XIX (2013)
Addendum VII (2005)	Addendum XX (2013)
Addendum VIII (2006)	Addendum XXI (2013)
Addendum IX (2006)	Addendum XXII (2013)
Addendum X (2007)	Addendum XXIII (2014)
Addendum XI (2007)	Addendum XXIV (2015)
Addendum XII (2008)	Addendum XXVI (2018)
Addendum XIII (2008)	Addendum XXIX (2022)
Addendum XIV (2009)	Addendum XXVII (2023)
Management Unit:	Maine through North Carolina
States with a Declared Interest:	Maine through Virginia (Excluding Pennsylvania and DC)
Active Committees:	American Lobster Management Board, Technical Committee, Lobster Conservation Management Teams, Plan Development Team, Plan Review Team, Advisory Panel, Electronic Reporting Subcommittee, Electronic Tracking Subcommittee, Stock Assessment Subcommittee

2.0 Status of the Fishery

2.1 Commercial Fishery

The lobster fishery has seen incredible expansion in landings over the last 40 years. Between 1950 and 1975, landings were fairly stable around 30 million pounds; however, from 1976 to 2008 the average coastwide landings tripled, exceeding 98 million pounds in 2006. Landings continued to increase until reaching a high of 159 million pounds in 2016 (Table 1). In 2022, coastwide commercial landings were approximately 121 million pounds, a 10% decrease from 2021 landings of 135 million pounds. The largest contributors to the 2022 fishery were Maine and Massachusetts with 81% and 13% of landings, respectively. The ex-vessel value for all lobster landings in 2022 was approximately $517.6 million, which is a 41% decrease from the 2021 record high value of $875 million.

Historically, Lobster Conservation Management Area (LCMA) 1 has had the highest landings, and accounted for 80% of total harvest between 1981 and 2012. This is followed by LCMA 3 which accounted for 9% of total landings during the same time period. In general, landings have increased in LCMA 1 and have decreased in LCMAs 2, 4, and 6. According to state compliance reports, in 2022, approximately 92% of the total landings came from LCMA 1, while the remaining 8% were contributed by the other LCMAs. A map of the LCMAs is found in Figure 1.

Landings trends between the two biological stocks have also changed, as a greater percentage of lobster are harvested from the Gulf of Maine/Georges Bank (GOM/GBK) stock. In 1997, 26.3% of coastwide landings came from the Southern New England (SNE) stock. However, as the southern stock declined and abundance in the Gulf of Maine increased, proportional harvest has significantly changed. In 2000, only 15.6% of landings came from the SNE stock and by 2006, this declined to 7%. In 2022, approximately 1.5% of coastwide landings came from the SNE stock.

2.2 Recreational Fishery
Lobster is also taken recreationally with pots, and in some states, by hand while SCUBA diving. While not all states collect recreational harvest data, some do report the number of pounds landed recreationally and/or the number of recreational permits issued. Recreational landings for Massachusetts are only available through 2021, and have averaged 1.1% of total Massachusetts landings over the most recent five years of data. In 2022, New Hampshire reported 6,301 pounds of lobster harvested recreationally and New York reported 1,333 pounds. Maine, Rhode Island, and Connecticut do not collect information on the number of pounds recreationally harvested. For 2022, Rhode Island issued 544 lobster licenses, and 255 lobster licenses were sold in Connecticut in 2022.

3.0 Status of the Stock
The recent 2020 American Lobster Benchmark Stock Assessment presents contrasting results for the two American lobster stock units, with record high abundance and recruitment in the Gulf of Maine and Georges Bank stock (GOM/GBK) and record low abundance and recruitment in the Southern New England stock (SNE) in recent years.

The assessment found that abundance estimates for the GOM/GBK stock show an increasing trend beginning in the late 1980s. After 2008, the rate of increase accelerated to a record high abundance level in 2018, the terminal year of the assessment. The GOM/GBK stock shifted from a low abundance regime during the early 1980s through 1995 to a moderate abundance regime during 1996-2008, and shifted once again to a high abundance regime during 2009-2018 (Figure 2). Current spawning stock abundance and recruitment and are near record highs. Exploitation (commercial landings relative to stock abundance) declined in the late 1980s and has remained relatively stable since.

The GOM/GBK stock is in favorable condition based on the new recommended reference points adopted by the Board (Table 2). The average abundance from 2016-2018 was 256 million lobster, which is greater than the fishery/industry target of 212 million lobster. The average exploitation from 2016-2018 was 0.459, below the exploitation target of 0.461. Therefore, the GOM/GBK lobster stock is not depleted and overfishing is not occurring.

In contrast to GOM/GBK, model results for SNE show a completely different picture of stock health. Abundance estimates in SNE have declined since the late 1990s to record low levels. Model estimates of recruitment and spawning stock biomass have also declined to record low levels. Analysis of these estimates indicates a declining trend in stock productivity, indicating reproductive rates are insufficient to sustain a stable population at current exploitation rates. Exploitation of the SNE stock was high and stable through 2002, declined sharply in 2003, and has remained lower and stable since.

Based on the new abundance threshold reference point, the SNE stock is significantly depleted. The average abundance from 2016-2018 was 7 million lobster, well below the threshold of 20 million lobster (Table 2, Figure 3). However, according to the exploitation reference points the SNE stock is not experiencing overfishing. The average exploitation from 2016-2018 was 0.274, falling between the exploitation threshold of 0.290 and the exploitation target of 0.257.

The assessment and peer review panel recommended significant management action be taken to provide the best chance of stabilizing or improving abundance and reproductive capacity of the SNE stock.

4.0 Status of Management Measures

4.1 Implemented Regulations

Amendment 3 established regulations which require coastwide and area specific measures applicable to commercial fishing (Table 3). The coastwide requirements from Amendment 3 are summarized below; additional requirements were established through subsequent Addenda.

Coastwide Requirements and Prohibited Actions

- Prohibition on possession of berried or scrubbed lobsters
- Prohibition on possession of lobster meats, detached tails, claws, or other parts of lobsters by fishermen
- Prohibition on spearing lobsters
- Prohibition on possession of v-notched female lobsters
- Requirement for biodegradable "ghost" panel for traps
- Minimum gauge size of 3-1/4"
- Limits on landings by fishermen using gear or methods other than traps to 100 lobsters per day or 500 lobsters per trip for trips 5 days or longer
- Requirements for permits and licensing
- All lobster traps must contain at least one escape vent with a minimum size of 1-15/16" by 5-3/4"
- Maximum trap size of 22,950 cubic inches in all areas except area 3, where traps may not exceed a volume of 30,100 cubic inches.

<u>Amendment 3 to the Interstate Fishery Management Plan for American Lobster (December 1997)</u>

American lobster is managed under Amendment 3 to the Interstate FMP for American Lobster. Amendment 3 establishes seven lobster management areas. These areas include the: Inshore Gulf of Maine (LCMA 1), Inshore Southern New England (LCMA 2), Offshore Waters (LCMA 3), Inshore Northern Mid-Atlantic (LCMA 4), Inshore Southern Mid-Atlantic (LCMA 5), New York and Connecticut State Waters (LCMA 6), and Outer Cape Cod (OCC). Lobster Conservation Management Teams (LCMTs) comprised of industry representatives were formed for each management area. The LCMTs are charged with advising the Lobster Board and recommending changes to the management plan within their areas.

Amendment 3 also provides the flexibility to respond to current conditions of the resource and fishery by making changes to the management program through addenda. The commercial fishery is primarily controlled through minimum/maximum size limits, trap limits, and v-notching of egg-bearing females.

Addendum I (August 1999)
Establishes trap limits in the seven LCMAs.

Addendum II (February 2001)
Establishes regulations for increasing egg production through a variety of LCMT proposed management measures including, but not limited to, increased minimum gauge sizes in LCMAs 2, 3, 4, 5, and the Outer Cape.

Addendum III (February 2002)
Revises management measures for all seven LCMAs in order to meet the revised egg-rebuilding schedule.

Technical Addendum 1 (August 2002)
Eradicates the vessel upgrade provision for LCMA 5.

Addendum IV (January 2004)
Changes vent size requirements; applies the most restrictive rule on an area trap cap basis without regard to the individual's allocation; establishes LCMA 3 sliding scale trap reduction plan and transferable trap program to increase active trap reductions by 10%; and establishes an effort control program and gauge increases for LCMA 2; and a desire to change the interpretation of the most restrictive rule.

Addendum V (March 2004)
Amends Addendum IV transferability program for LCMA 3. It establishes a trap cap of 2200 with a conservation tax of 50% when the purchaser owns 1800 to 2200 traps and 10% for all others.

Addendum VI (February 2005)
Replaces two effort control measures for LCMA 2 – permits an eligibility period.
Addendum VII (November 2005)
Revises LCMA 2 effort control plan to include capping traps fished at recent levels and maintaining 3 3/8" minimum size limit.

Addendum VIII (May 2006)

Establishes new biological reference points to determine the stock status of the American lobster resource (fishing mortality and abundance targets and thresholds for the three stock assessment areas) and enhances data collection requirements.

Addendum IX (October 2006)
Establishes a 10% conservation tax under the LCMA 2 trap transfer program.

Addendum X (February 2007)
Establishes a coastwide reporting and data collection program that includes dealer and harvester reporting, at-sea sampling, port sampling, and fishery-independent data collection replacing the requirements in Addendum VIII.

Addendum XI (May 2007)
Establishes measures to rebuild the SNE stock, including a 15-year rebuilding timeline (ending in 2022) with a provision to end overfishing immediately. The Addendum also establishes measures to discourage delayed implementation of required management measures.

Addendum XII (February 2009)
Addresses issues which arise when fishing privileges are transferred, either when whole businesses are transferred, when dual state/federal permits are split, or when individual trap allocations are transferred as part of a trap transferability program. In order to ensure the various LCMA-specific effort control plans remain cohesive and viable, this addendum does three things. First, it clarifies certain foundational principles present in the Commission's overall history-based trap allocation effort control plan. Second, it redefines the most restrictive rule. Third, it establishes management measures to ensure history-based trap allocation effort control plans in the various LCMAs are implemented without undermining resource conservation efforts of neighboring jurisdictions or LCMAs.

Addendum XIII (May 2008)
Solidifies the transfer program for OCC and stops the current trap reductions.

Addendum XIV (May 2009)
Alters two aspects of the LCMA 3 trap transfer program. It lowers the maximum trap cap to 2000 for an individual that transfers traps. It changes the conservation tax on full business sales to 10% and for partial trap transfers to 20%.

Addendum XV (November 2009)
Establishes a limited entry program and criteria for Federal waters of LCMA 1.

Addendum XVI: Reference Points (May 2010)
Establishes new biological reference points to determine the stock status of the American lobster resource (fishing mortality and abundance targets and thresholds for the three stock assessment areas). The addendum also modifies the procedures for adopting reference points to allow the Board to take action on advice following a peer reviewed assessment.

Addendum XVII (February 2012)
Institutes a 10% reduction in exploitation for LCMAs within Southern New England (2, 3, 4, 5, and 6). Regulations are LCMA specific but include v-notch programs, closed seasons, and size limit changes.

Addendum XVIII (August 2012)
Reduces traps allocations by 50% for LCMA 2 and 25% for LCMA 3.

Addendum XIX (February 2013)
Modifies the conservation tax for LCMA 3 to a single transfer tax of 10% for full or partial business sales.

Addendum XX (May 2013)
Prohibits lobstermen from setting or storing lobster traps in Closed Area II from November 1 to June 15 annually. Any gear set in this area during this time will be considered derelict gear. This addendum represents an agreement between the lobster industry and the groundfish sector.

Addendum XXI (August 2013)
Addresses changes in the transferability program for LCMAs 2 and 3. Specific measures include the transfer of multi-LCMA trap allocations and trap caps.

Addendum XXII (November 2013)
Implements Single Ownership and Aggregate Ownership caps in LCMA 3. Specifically, it allows LCMA 3 permit holders to purchase lobster traps above the cap of 2000 traps; however, these traps cannot be fished until approved by the permit holder's regulating agency or once trap reductions commence. The Aggregate Ownership Cap limits LCMA fishermen or companies from owning more traps than five times the Single Ownership Cap.

Addendum XXIII (August 2014)
Updates Amendment 3's habitat section to include information on the habitat requirements and tolerances of American lobster by life stage.

Addendum XXIV (May 2015)
Aligns state and federal measure for trap transfer in LCMA's 2, 3, and the Outer Cape Cod regarding the conservation tax when whole businesses are transferred, trap transfer increments, and restrictions on trap transfers among dual permit holders.

Addendum XXVI (February 2018)
Advances the collection of harvester and biological data in the lobster fishery by improving the spatial resolution of data collection, requiring harvesters to report additional data elements, and establishing a deadline that within five years, states are required to implement 100% harvester reporting. The Addendum also improves the biological sampling requirements by

establishing a baseline of ten sampling trips per year, and encourages states with more than 10% of coastwide landings to conduct additional sampling trips. Required reporting of additional data elements went into effect on January 1, 2019. The Addendum XXVI requirement for commercial harvesters to report their fishing location by 10 minute longitudinal/latitudinal square was implemented in 2021.

Addendum XXIX (2022)
Implements electronic tracking requirements for federally-permitted vessels in the American lobster and Jonah crab fisheries to collect high resolution spatial and temporal effort data. Specifically, electronic tracking devices will be required for vessels with commercial trap gear area permits for LCMAs 1, 2, 3, 4, 5, and Outer Cape Cod. Requirements will become effective in 2023.

Addendum XXVII (2023)
Establishes a trigger mechanism to implement management measures (gauge and escape vent sizes) to provide additional protection of the GOM/GBK spawning stock biomass (SSB). It also implements changes to management measures for LCMAs 1, 3, and Outer Cape Cod to improve the consistency of measures across the GOM/GBK stock.

5.0 Fishery Dependent Monitoring
The following provisions of Addendum XXVI went into effect January 1, 2019:

- Required reporting of additional data elements;
- Requirement to implement 100% harvester reporting within five years;
- Baseline biological sampling requirement of ten sea and/or port sampling trips per year.

The Addendum XXVI requirement for commercial harvesters to report their fishing location by 10 minute longitudinal/latitudinal square was not implemented until 2021. Table 5 describes the level of reporting and monitoring programs by each state. *De minimis* states are not required to conduct biological sampling of their lobster fishery.

In 2022, Rhode Island, Connecticut, New York, and New Jersey were unable to complete the ten required sea and/or port sampling trips for fishery dependent monitoring. Rhode Island completed seven out of ten trips, and New York completed eight port sampling trips. New Jersey completed zero trips and continues to have difficulty with vessel Captains accommodating an observer aboard. No fishery dependent sampling has been conducted by Connecticut since 2014 due to reductions in funding and staffing levels.

6.0 Status of Fishery Independent Monitoring
Addendum XXVI also requires fishery independent data collection by requiring statistical areas be sampled through one of the following methods: annual trawl survey, ventless trap survey, or young-of-year survey.

7.1 Trawl Surveys

Maine and New Hampshire: The Maine-New Hampshire Inshore Trawl survey began in 2000 and covers approximately two-thirds of the inshore portion of Gulf of Maine. The spring survey began May 2, 2022 in Portsmouth, NH. However, during the first day of the survey a positive covid case occurred; as a result the survey was stopped while staff and crew quarantined. During this time the decision was made to restart the survey following the current schedule due the lack of accommodations and increase issues with gear in regions 4 and 5 in mid-June, and region 3 started back up on time on May 16, 2022 and ended on June 6, 2021 off of Lubec, Maine. Regions 1 and 2 were then rescheduled after the original end date of the survey and were completed on the weeks of June 6th and June 13th, respectively. Due to covid and gear conflicts, 101 out of the 120 scheduled tows were completed leading to an 84% completion rate for the survey. A total of 10,854 lobsters were caught and sampled, with 5,133 females, 5,719 males and 2 unsexed caught and measured (Figure 4). The fall survey began on September 26, 2022 in Portsmouth, New Hampshire and finished on October 28, 2022 off of Lubec, Maine. Due to the adverse weather and gear conflicts, 87 out of the 120 scheduled tows were completed leading to a 73% completion rate for the survey. A total of 10,423 lobsters were caught and sampled, with 5,100 females, 5,319 males, and 4 unknown sexes sampled (Figure 5).

Massachusetts: Since 1978, the Division of Marine Fisheries has conducted spring and autumn bottom trawl surveys in the territorial waters of Massachusetts. For the first time since 1978, neither the spring nor fall bottom trawl surveys were conducted in 2020 due to the COVID-19 pandemic, but the survey resumed in 2021. After low levels observed in the GOM during the early to mid 2000s, relative abundance indices have increased over the last decade Legal abundance has remained high relative to the time series median since 2015, although the 2022 value was the lowest observed since 2015. Sublegal-sized abundance has been at or below the median for the past three years with data (no data in 2020). In SNE, relative abundance from the spring and fall surveys remains low. There were no lobsters observed in the SNE fall or spring surveys in 2022 (Figure 6).

Rhode Island: The Rhode Island DFW Trawl Survey program conducted seasonal surveys in the spring and fall, as well as a monthly survey. In 2022, 44 trawls were conducted in the Spring and 44 in the Fall. Monthly Survey includes monthly trawls throughout Narragansett Bay. There were 156 trawls performed as part of the Monthly program in 2022. Spring 2022 mean CPUEs were 0.07 and 0.61 for legal and sub legal lobsters (respectively), where Fall 2022 CPUE was 0.02 for legal lobsters and 0.23 for sublegal lobsters. The 2022 mean Monthly trawl CPUEs were 0.04 and 0.41 per-tow for legal and sublegal lobsters, respectively (Figure 7).

Connecticut and New York: Juvenile and adult abundance are monitored through the Long Island Sound Trawl Survey during the spring (April, May, June) and the fall (September, October) cruises all within NMFS statistical area 611. Due to the COVID-19 pandemic, the spring and fall 2020 Long Island Sound Trawl Surveys were not conducted; an estimated index is shown as the average of 2019 and 2021. The spring 2022 lobster abundance index (geometric mean = 0.01 lobsters/tow) was the lowest in the time series. Spring abundance in the last eleven years (2011-2022) remains less than 1.0. All indices from 2004-2022 are below the time series median (2.93, see figure below). The fall 2022 lobster abundance index (geometric mean = 0.03 lobsters/tow) was a slight improvement from 2019 when no lobsters were caught in September and October. The fall time series median (3.18, see figure below) has not been exceeded since 2004. Analyses of legal and sublegal size composition for the 2022 research trawl spring and fall survey catches were not available at the time of this report (Figure 8).

New York: New York initiated a stratified random trawl survey in the near shore ocean waters off the south shore of Long Island in 2018 from the Rockaways to Montauk Point and the New York waters of Block Island Sound. Seven sampling cruises were conducted in 2022 during the winter (February), spring (April, May, June), summer (August) and fall (October, November). Twenty-one stations were sampled during the winter cruise in February. Thirteen, seventeen, and twenty-three stations were sampled during the spring cruises. Thirty stations were sampled during the summer cruise in August. During the fall, 20 stations were sampled in October and eight stations were sampled in November. Ten lobsters were caught during the 2022 surveys.

New Jersey: An independent Ocean Trawl Survey is conducted from Sandy Hook, NJ to Cape May, NJ each year. The survey stratifies sampling in three depth gradients, inshore (18'-30'), mid-shore (30'-60'), offshore (60'-90'). The mean CPUE is calculated as the sum of the mean number of lobsters per size class collected in each sampling area weighted by the stratum area. Due to the COVID-19 pandemic, the survey did not take place for 2020 and 2021, but the 2022 CPUE is an increase from the 2019 value (Figure 9).

Maryland: Maryland conducted a 16-foot otter trawl survey in the coastal bays and has not encountered an American lobster in this survey (1989 - 2022).

7.2 Young of Year Index

Several states conduct young-of-year (YOY) surveys to detect trends in abundance of newly-settled and juvenile lobster populations. These surveys attempt to provide an accurate picture of the spatial pattern of lobster settlement. States hope to track juvenile populations and generate predictive models of future landings.

Maine: There are currently 40 fixed stations along the Maine coast. Of these 40 stations 38 have been sampled consistently since 2001 with two additional sites added to Zone D, off midcoast Maine, in 2005. In recent years, these sites are sampled October to December. Only 33 sites were sampled in 2022 due to staffing and weather limitations. Sites were selected based on orientation to surface winds, position in bays, water temperature during settlement period (for eastern Maine sites) and presence of suitable habitat. A new R script was developed in 2022 to pull the data directly from Maine's MARVIN archive database to create a replicable and transparent data query, but these numbers differ slightly from past data pulled. Cut-off values for YOY vary by year. This data query process is still being vetted (Figure 10).

New Hampshire: New Hampshire Fish and Game conducted a portion of the coastwide American Lobster Settlement Index (ALSI). In 2022, a total of 46 juvenile lobsters were sampled from three sites; 36 older juveniles, five young-of-year (YOY) lobster, and five one-year-old (Y+). Figure 11 depicts the CPUE (#/m2) of all sampled lobsters, YOY and Y+, for all New Hampshire sites combined from 2008 through 2022. For each of these indices, CPUE shows a general upward trend to a time series high in 2011 with sustained moderate to low levels from 2012 through 2022.

Massachusetts: Annual sampling for early benthic phase/juvenile (EBP) lobsters was conducted during August and September, 2022. Prior to 2019, sampling was completed at 21 sites spanning 7 regions in Massachusetts coastal waters. As of 2022, suction sampling is conducted in the GOM stock unit at 10 sites from Cape Ann to the South Shore area, and in the SNE stock unit at 4 sites in Buzzards Bay. In 2022 densities of YOY lobsters remained low compared to the time series average in Boston Harbor and Salem Sound (Figure 1). For the two newer sampling areas, 2022 values in Cape Ann were below the time series mean, while in the South Shore the 2022 value was at the time series mean (Figure 12). In SNE there were no YOY lobsters found in the Buzzards Bay sampling locations in 2022.

Rhode Island: In 2022, the RI DEM DMF YOY Settlement Survey (Suction Sampling) was conducted at six fixed stations with twelve randomly selected 0.5 m^2 quadrats sampled at each survey station. The survey stations are located outside of Narragansett Bay along the southern Rhode Island coast, from Sachuest Point (east) to Point Judith (west). The index represents the average annual densities for YOY (≤ 13mm) and total lobsters caught (Figure 13). The 2022 YOY Settlement Survey index was 0.03 lobsters/m^2, and with all lobsters was 0.11/m2.

Connecticut: The CT DEEP Larval Lobster Survey in western Long Island Sound was discontinued after 2012. Alternative monitoring data are available for the eastern Sound from the Millstone Power Station entrainment estimates of all stages of lobster larvae. Abundance indices in both programs are delta mean density of larvae per 1000 cubic meters of water, entrained into the power plant in the case of the Millstone program and stage 4 only captured in surface plankton samples in the CT DEEP program. Both programs show a protracted decline in recruitment following the 1999 die-off (correlation between programs: R=0.35, p=0.066) (Figure 14).

7.3 Ventless Trap Survey

To address a need for a reliable index of lobster recruitment, a cooperative random stratified ventless trap survey was designed to generate accurate estimates of the spatial distribution of lobster length frequency and relative abundance while attempting to limit the biases identified in conventional fishery dependent surveys.

Maine: The Maine Ventless Trap Survey changed strategies in 2015 to cover more area by eliminating the vented traps at each site. This change allowed the survey to double the number of sites with ventless traps and increase the sampling coverage spatially to 276 sites. Traps were set during the months of June, July, and August. The stratified mean was calculated for each area using depth and statistical area for ventless traps only. Compared to the previous years, in 2022 there were decreases in the number of sublegal (<83 mm CL) lobsters in all areas and legal sized (≥ 83 mm CL) lobsters caught in the Schoodic Point to Friendship (512). In 2022 there were increases in the number of legal sized (≥ 83 mm CL) lobsters caught in the NH-Friendship (513) and the Schoodic Pt-Cutler (511) areas (Figure 15).

New Hampshire: Since 2009, NHF&G has been conducting the coastwide Random Stratified Ventless Trap Survey in state waters (statistical area 513). A total of six sites were surveyed twice a month from June through September in 2022. Catch per unit effort (stratified mean catch per trap haul) from 2009 through 2022 is presented in Figure 16. Annual stratified mean catch per trap haul values varied without significant positive or negative trend throughout the fourteen year time series.

Massachusetts: The coast-wide ventless trap survey was initiated in 2006 and expanded in 2007 with the intention of establishing a standardized fishery-independent survey designed specifically to monitor lobster relative abundance and distribution. The survey was not conducted in 2013 due to a lack of funding; however, starting in 2014 the survey has been funded with lobster license revenues and will continue as a long-term survey.

Due to lack of interested participants in the SNE survey area (Area 538) in 2021, the SNE survey footprint was reduced, the number of hauls was reduced to one per month, and the time frame was reduced by one month to just June through August. These changes to the SNE survey necessitated re-analysis of the abundance time series to adjust to the reduced survey design. The data presented in Figure 17 and Figure 18 are the results of the new analysis. The entire SNE time series now represents June – August only, first haul of the month, and only those stations that occurred in the newly reduced footprint.

The time series of relative abundance for sublegal (< 83 mm CL) and legal-sized (≥ 83 mm CL) lobsters for Area 514 (part of LMA 1) is shown in Figure 17 as the stratified mean CPUE (± S.E.). Note that the index includes data from vented and non-vented traps, and includes all four survey months (June – Sept). The average catch of sublegal lobsters is much higher than the catch of legal-sized lobsters, and generally increased from 2006 through 2016 but has been declining since, with values from the last four years (2019-2022) falling below the time series average of 4.48 sublegal lobsters/trap. The 2022 value (2.68 sublegals/trap) was the lowest in the time series. The stratified mean catch per trap of legal-sized lobsters in 2022 was 0.50 (± 0.01), and was below the time series average of 0.56.

The time series of relative abundance (stratified mean CPUE ± S.E.) for sublegal (<86 mm CL) and legal-sized (≥ 86 mm CL) lobsters in the Area 538 (MA SNE survey area) is shown in Figure 18. The mean sublegal CPUE in 2022 was 0.47 (± 0.02), well below the time series average of 1.87 sublegal lobsters/trap haul. The CPUE of legal-sized lobsters in 2022 was 0.13 (±0.02), below the time series average of 0.33 legal lobsters/trap haul. The re-analysis of the time series to account for the reduced time period and survey area resulted in a similar trend over time for both sublegal and legal-sized lobster abundance, but a slight increase in the scale.

Rhode Island: Rhode Island conducted the 2022 ventless trap survey in June, July, and August at a total of 27 stations divided between Block Island Sound, Rhode Island Sound, and

Narragansett Bay. Over the 18 trips and 818 pots (ventless and vented) hauled, 2,695 lobsters were sampled. The depth-stratified abundance index of sublegal lobsters in the 2022 survey, 3.34 lobsters per ventless trap, remains below the time series mean of 5.87 lobsters per ventless trap. The abundance index for legal-sized lobsters was equal to the time series mean of 0.37 lobsters per ventless trap (Figure 19).

Delaware: A pilot study was initiated in 2018 to assess the population structure of structure-oriented fish in the lower Delaware Bay and nearshore Atlantic Ocean. Sampling was conducted in the lower Delaware Bay and the nearshore Atlantic Ocean using commercial-sized ventless fish pots during April through December 2022. Six American lobsters were caught in lower Delaware Bay and 610 American lobsters in the nearshore Atlantic Ocean with a ratio of 60% males, 31% female and 9% egg laden. The sampled lobsters ranged in length from 43 mm to 138 mm.

8.0 State Compliance

States are currently in compliance with all required biological management measures under Amendment 3 and Addendum I-XXIV. However, the Plan Review Team (PRT) notes that Connecticut and New Jersey and did not conduct sea/port sampling in 2022, as required by Addendum XXVI. Rhode Island and New York did conduct some sampling, but were unable to complete the ten required sampling trips.

9.0 De Minimis Requests

The states of Virginia, Maryland, and Delaware have requested *de minimis* status. According to Addendum I, states may qualify for *de minimis* status if their commercial landings in the two most recent years for which data are available do not exceed an average of 40,000 pounds. Delaware, Maryland, and Virginia meet the *de minimis* requirement.

10.0 Regulatory Changes

Maine

- In the 2022 fishing year, Maine DMR adopted rules to incorporate the measures in the 2021 Atlantic Large Whale Take Reduction Plan (ALWTRP) final rule, including requirements for 1700-pound weak link inserts, gear marking requirements, minimum trawl lengths, and the establishment of the LMA1 Restricted Area. In addition, DMR modified an existing 3-trap trawl maximum in Zone B to a 5-trap trawl maximum for compliance with the ALWTRP.
- There were two statutory changes impacting lobster management in 2022:
    - Public Law 2021, chapter 512 allowed the Commissioner of Marine Resources to adopt routine technical rules to amend the minimum and maximum lobster size and the dimensions of vents in lobster traps when necessary to comply with changes to the Atlantic States Marine Fisheries Commission Interstate Fishery Management Plan for American Lobster. It requires the Commissioner to notify the joint standing committee of the Legislature having jurisdiction over marine resources matters within 15 days of initiating such rulemaking.

- Public Law 2021, chapter 498 changed the legal start time for lobster fishing to 4:00 a.m. in the month of September.

New Hampshire

- Changes were made to weak inserts and gear marking for NH state waters to comply with the modified Atlantic Large Whale Take Reduction Plan. A copy of changes can be found in Appendix I under Fis 602.09.

Massachusetts

- Buoy line marking regulations amended to clarify that MA trap gear buoy lines shall only bear red marks.
- Requirement for all lobster traps set on or after May 1 to have current year trap tags in them for all LMAs.

11.0 Enforcement Concerns

Maine

- In 2022 Maine Marine Patrol Officers documented 336 lobster-related violations, with 67 being summonses. Marine Patrol's highest profile cases in 2022 were four individuals being charged with molesting lobster gear and two separate individuals found in possession of 13 v-notched/mutilated female lobsters. Officers documented a considerable effort inspecting lobster gear throughout the year; between gear being hauled from our fleet of large patrol vessels, and documented vessel boardings at-sea, Marine Patrol inspected an estimated 20,000 lobster traps in 2022. The majority of the violations documented by Marine Patrol were for possessing illegal lobsters, protected resource violations, and for fishing untagged lobster gear. Eighteen summonses were issued to Maine lobsterman for fishing untagged/illegally tagged lobster traps.

Massachusetts

- Aiello case – Violation of seasonal trap gear closure; buoy line marking violations; buoy line breaking strength violations; weak link violations; trap tag violations; ghost panel violation. Agreed to transfer out of the fishery and not reapply.
- D. Duhaime case – Violation of seasonal trap gear closure; buoy line breaking strength violations; maximum buoy line diameter violations; buoy line marking violations; and surface buoy and configuration marking violations. Agreed to 3-year suspension of lobster permit (2023 – 2025).
- Edwards case – Violation of seasonal trap gear closure. Agreed to 2-month annual suspension (November – December) for period of 5-years (2023 – 2027) requiring all gear to be hauled out by Oct 31 annually.
- Hamilton case – Possession of lobster in excess of gillnet trip limit. Agreed to 2-year suspension of lobster permit (2023 – 2024) and three-year probationary period following reinstatement. Criminal proceedings are ongoing.
- O'Keefe case – Violation of seasonal trap gear closure; weak link violations; buoy line breaking strength violations; maximum buoy line diameter violations; buoy line marking

violations; surface buoy marking and configuration violations. Agreed to 2-year suspension of lobster permit (2023 – 2024).
- R. Duhaime case - Violation of seasonal trap gear closure; buoy line breaking strength violations; maximum buoy line diameter violations; buoy line marking violations; and surface buoy marking and configuration marking violations. Agreed to 2-year suspension of lobster permit (2023 – 2024).
- Roche case – Impeding safe boarding by enforcement; failure to display commercial fishing permit; trap tag violations; buoy line marking violations; buoy line breaking strength violations; buoy line maximum diameter violations; surface buoy marking and configuration violations; maximum trawl length violations. Proceeded to hearing and resulted in permanent revocation of permit. Criminal proceedings are ongoing.

New Jersey
- Two summonses were issues due to failure to notify the Department before deploying lobster on an artificial reef.

12.0 Research Recommendations
The full list of research recommendations can be found in the 2020 Stock Assessment Report. Below is a summarized list of the high priority research recommendations from the 2020 Stock Assessment that were compiled by the Lobster Technical Committee (TC) and Stock Assessment Subcommittee (SAS).

Port and Sea Sampling - The quality of landings data has not been consistent spatially or temporally. Limited funding, and in some cases, elimination of sea sampling and port sampling programs will negatively affect the ability to characterize catch and conservation discards, limiting the ability of the model to accurately describe landings and stock conditions. It is imperative that funding for critical monitoring programs continues, particularly for offshore areas from which a large portion of current landings originate in SNE. Sea sampling should be increased in Long Island Sound (statistical area 611), and in the statistical areas in federal waters, particularly those fished by the LCMA 3 fleet, via a NMFS-implemented lobster-targeted sea sampling program.

Commercial Data Reporting – Finer resolution spatial data are paramount in understanding how landings align between statistical area and LCMAs. Vessel tracking is recommended for federal vessels. Once in place, the new spatial data should be analyzed for comparison to current spatial understanding of harvest. The growing Jonah crab fishery in SNE continues to complicate the differentiation of directed lobster versus Jonah crab effort. More sea sampling and landings data must be collected to better differentiate the two fisheries' activities.

Ventless Trap Survey - Calibration work to determine how catch in the ventless trap surveys relates to catch in the bottom trawl surveys remains an important and unaddressed topic of research. Ventless traps may be limited in their ability to differentiate between moderately high and extremely high abundance, and calibration with bottom trawl surveys may help to clarify how q might change with changes in lobster density.

NEAMAP Trawl Survey Protocols - The SAS recommends that the NEAMAP Trawl Survey sampling protocol be modified for all lobsters caught to be sorted by sex. If a subsample is necessary, subsamples be taken by sex for additional biological data (size, egg presence and stage, vnotch, etc.) This modification would align the biological sampling methodology with other trawl surveys used in the assessment, and perhaps allow the survey to not be collapsed by sex into survey slots.

Time Varying Growth - Growth of American lobster has been found to change through time (McMahan et al. 2016), yet the ability to incorporate this dynamic in the assessment model currently is unavailable. Accounting for interannual changes in the growth matrix, including those in increment, probability, and seasonality, is imperative for model convergence. Modification to the assessment model is needed to allow for time varying growth matrices to be used to reflect changing growth in the stocks.

Expansion of Growth Matrices - Exploration of expanding the model size structure to smaller sizes could allow the SAS to better capture changes in recruitment for the population by incorporating < 53mm lobster abundances from the surveys currently used, as well as incorporating additional surveys that currently are not model inputs for the assessment, such as those from the young of year settlement surveys. Due to decreased recruitment in SNE and some areas in GOMGBK, available survey data should be evaluated to determine whether current data sources for small sizes are sufficient for expanding the size structure and growth matrices.

Temperature-Molt Dynamics - Understanding how the timing for molting, molt increments, and probability by size vary with temperature for all stocks would allow for more accurate and realistic depictions of growth via updated annual growth matrices. The work of Groner et al. (2018) should be expanded by using the Millstone data to specifically analyze how molt frequency and increment has changed seasonally and interannually.

Larval Ecology - Spatial expansion of larval surveys and further testing is warranted, particularly in areas like the eastern GOM and GBK that lack any studies of this nature. Studies that explore greater spatial coverage of larval sampling and examine lobster larval diets, in situ development time in current conditions, larval interactions with well-mixed versus stratified water columns, and varying growth and mortality with temperature would allow for greater context on these variables' influence on recruitment.
Deepwater Settlement - There is a need to determine settlement success in habitat not currently sampled and its contribution to overall stock productivity. Research needs to explore the levels of detectability, impact of stratification, and interannual temperature effects on the indices. Additionally, it will be important to understand whether there are differences in growth and survival in these deeper habitats, particularly relative to the desire to expand the growth matrix into smaller size ranges for modeling purposes.

SNE Recruitment Failure - The direct cause of the precipitous declines in recruitment under less variable spawning stock biomass is largely unknown. Research designed to understand the causes driving recruitment failure is vital for any efforts toward rebuilding the SNE stock. In addition, being able to predict similar conditions in GOMGBK could allow management the opportunity to respond differently.

Stock Structure Working Group - The SAS recommends that a workshop on stock boundaries be convened prior to the initiation of the next assessment to review results of any new research and re-evaluate appropriate stock boundaries. Inclusion of Canadian researchers at this workshop would be beneficial to share data and knowledge on this shared resource.

Spatial Analyses of Fisheries-Independent Data – Northeast Fisheries Science Center (NEFSC) trawl survey data remains one of the richest data sources to understand abundance and distribution patterns through time for lobsters by size and sex. Formal analyses of NEFSC trawl survey and the ME/NH trawl survey and should be performed. The Ecosystem Monitoring (EcoMon) Program's larval lobster information should also be considered.

Reevaluate Baseline Natural Mortality Rate - Intensive hypothesis-driven sensitivity analyses should be conducted to evaluate the base mortality rate for both stocks by season and year. Canadian tagging data should be examined to determine how natural mortality rates derived from these data compare to the assumptions used currently in the model and sensitivity analyses. Exploration of additional time series representing natural mortality hypotheses (e.g. sea temperature, shell disease prevalence, predators) should be continued to either inform time-varying natural mortality or correlate to rates produced in sensitivity analyses.

Predation Studies - It is suspected that a given predator's role in lobster natural mortality has changed through time. Predation laboratory studies and gut content analyses would provide greater guidance on individual species' roles in lobster natural mortality. With this information, predation-indices as a function of predator annual abundances and their contribution to stock-specific lobster mortality would be immensely valuable, particularly in SNE.

Management Strategy Evaluation - Developing a true management strategy evaluation tool that can iteratively project and refit the operating model would best inform future management discussions on rebuilding the SNE stock or providing resiliency for the GOM stock and fishery.

Economic Reference Points - Economic analyses considering landings, ex-vessel value, costs, associated economic multipliers, number of active participants, and other factors are imperative to truly discern how declines in the population would impact the GOMGBK industry. The SAS strongly recommends a thorough economics analysis be conducted by a panel of experts to more properly inform economic-based reference points, and ultimately provide resiliency to both the GOMGBK stock and fishery.

13.0 Plan Review Team Recommendations

During their review of the state compliance reports, the PRT noted the following issues:

- Massachusetts was unable to provide compliance reports by the August 1 deadline. This has been a recurring issue over the last few years due to delays in data availability and limited staff resources.
- In 2022, Rhode Island, Connecticut, New Jersey, and New York did not meet the Addendum XXVI minimum requirement of ten sea/port sampling trips. Given persistent issues with states being unable to meet the sampling requirement, the Board should consider how to address this issue moving forward.

The PRT Recommends the Board approve the *de minimis* requests of DE, MD, and VA. Other than the issues noted above, all states appear to be in compliance with the requirements of the FMP.

The following are general recommendations the PRT would like to raise to the Board:

- The PRT recommends the Board consider reviewing the monitoring requirements in SNE given the status of the stock and the difficulty obtaining sea sampling trips in a fishery with reduced effort. The TC has discussed the need for additional sampling trips in federal waters as the fishery has shifted offshore.

14.0 Tables

Table 1. Landings (in pounds) of American Lobster by the states of Maine through Virginia. Source: ACCSP Data Warehouse for 1981-2021 landings; state compliance reports for 2022 landings. *C= confidential data.*

	ME	NH	MA	RI	CT	NY	NJ	DE	MD	VA	Total
1981	22,631,614	793,400	11,420,638	1,871,067	807,911	890,218	593,801	55,700	63,108	2,173	**39,129,630**
1982	22,730,253	807,400	11,265,840	3,173,650	880,636	1,121,644	846,215	90,700	64,788	4,713	**40,985,839**
1983	21,976,555	1,310,560	12,867,378	5,114,486	1,654,163	1,207,442	769,913	56,700	76,192	20,619	**45,054,008**
1984	19,545,682	1,570,724	12,446,198	5,259,821	1,796,794	1,308,023	927,474	103,800	98,876	37,479	**43,094,871**
1985	20,125,177	1,193,881	13,702,702	5,140,131	1,381,029	1,240,928	1,079,723	118,500	82,295	42,881	**44,107,247**
1986	19,704,317	941,100	12,496,125	5,667,940	1,253,687	1,416,929	1,123,008	109,000	57,593	93,105	**42,862,804**
1987	19,747,766	1,256,170	12,856,301	5,317,302	1,571,811	1,146,613	1,397,138	84,100	49,820	60,241	**43,487,262**
1988	21,739,067	1,118,900	12,977,313	4,758,990	1,923,283	1,779,908	1,557,222	66,200	22,966	53,696	**45,997,545**
1989	23,368,719	1,430,347	15,645,964	5,786,810	2,076,851	2,344,932	2,059,800	76,500	17,502	45,107	**52,852,532**
1990	28,068,238	1,658,200	16,572,172	7,258,175	2,645,951	3,431,111	2,198,867	68,300	24,941	58,260	**61,984,215**
1991	30,788,646	1,802,035	15,998,463	7,445,172	2,673,674	3,128,246	1,673,031	54,700	26,445	7,914	**63,598,326**
1992	26,830,448	1,529,292	14,969,350	6,763,087	2,534,161	2,651,067	1,213,255	21,000	27,279	753	**56,539,692**
1993	29,926,464	1,693,347	14,350,595	6,228,470	2,177,022	2,667,107	906,498	24,000	46,650	2,940	**58,023,093**
1994	38,948,867	1,650,751	16,176,551	6,474,399	2,146,339	3,954,634	581,396	8,400	7,992	460	**69,949,789**
1995	37,208,324	1,834,794	15,903,241	5,362,084	2,541,140	6,653,780	606,011	25,100	26,955	5,210	**70,166,639**
1996	36,083,443	1,632,829	15,312,826	5,295,797	2,888,683	9,408,519	640,198	20,496	28,726	C	**71,311,517**
1997	47,023,271	1,414,133	15,010,532	5,798,529	3,468,051	8,878,395	858,426	C	34,208	2,240	**82,487,785**
1998	47,036,836	1,194,653	13,167,803	5,617,873	3,715,310	7,896,803	721,811	1,359	19,266	1,306	**79,373,020**
1999	53,494,418	1,380,360	15,875,031	8,155,947	2,595,764	6,452,472	931,064	C	41,954	6,916	**88,933,926**
2000	57,215,406	1,709,746	14,988,031	6,907,504	1,393,565	2,883,468	891,183	C	62,416	C	**86,051,319**
2001	48,617,693	2,027,725	11,976,487	4,452,358	1,329,707	2,052,741	579,753	C	31,114	C	**71,067,578**
2002	63,625,745	2,029,887	13,437,109	3,835,050	1,067,121	1,440,483	264,425	C	20,489	C	**85,720,309**
2003	54,970,948	1,958,817	11,321,324	3,561,391	C	946,449	209,956	C	22,778	C	**72,991,663**
2004	71,574,344	2,851,262	11,675,852	3,059,319	646,994	996,109	370,536	13,322	14,931	27,039	**91,229,708**
2005	68,729,623	C	11,291,145	3,174,852	713,901	1,154,470	369,003	C	39,173	21,988	**85,494,155**
2006	75,419,802	2,612,389	12,090,423	3,949,299	806,135	1,252,146	470,878	3,706	26,349	28,160	**96,659,287**
2007	63,987,073	2,468,811	10,046,120	2,299,744	568,696	911,761	334,097	C	26,804	C	**80,643,106**
2008	69,910,434	2,568,088	10,606,534	2,782,000	427,168	712,075	304,479	C	32,932	C	**87,343,709**
2009	81,124,201	2,986,981	11,789,536	2,842,088	412,468	731,811	C	6,064	30,988	21,472	**99,945,239**
2010	96,244,299	3,648,004	12,772,159	2,928,688	441,622	813,513	692,869	C	29,989	16,345	**117,586,675**
2011	104,957,224	3,919,195	13,385,393	2,754,067	198,928	344,232	697,883	8,879	41,077	12,879	**126,320,059**
2012	127,464,332	4,229,227	14,486,344	2,706,384	247,857	550,441	919,351	C	65,813	10,823	**150,680,338**
2013	128,015,530	3,817,707	15,259,573	2,155,762	127,420	496,535	660,367	C	62,601	9,061	**150,604,556**
2014	124,941,312	4,374,656	15,312,852	2,412,875	127,409	222,843	526,368	26,330	57,414	11,099	**148,013,158**
2015	122,685,803	4,721,826	16,450,853	2,316,458	205,099	147,414	445,060	22,894	29,284	9,474	**147,034,165**
2016	132,750,487	5,782,098	17,784,921	2,260,335	254,346	218,846	349,880	C	29,254	2,854	**159,433,020**
2017	112,153,057	5,645,434	16,493,125	2,031,143	130,015	150,317	409,062	32,364	29,136	1,630	**137,075,281**
2018	121,226,274	6,199,365	17,697,243	1,905,689	110,580	112,685	344,547	C	24,893	2,727	**147,624,004**
2019	102,219,067	6,093,615	17,029,462	1,795,212	111,573	112,107	291,072	C	11,831	1,840	**127,665,778**
2020	97,915,188	5,014,169	15,711,853	1,695,279	159,173	111,678	309,197	11,098	10,176	C	**120,937,811**
2021	110,585,121	5,712,122	16,826,704	1,351,415	148,758	109,117	290,982	6,193	12,827	3,099	**135,046,339**
2022	98,650,231	5,262,246	15,651,988	1,176,530	66,454	82,834	258,289	C	11,144	C	**121,159,716**

Table 2. Above: Current (2016-2018) reference abundance estimates (millions), current target and threshold abundance (millions), and new recommended abundance reference points for both stocks. Below: Current (2016-2018) exploitation, current target and threshold exploitation, and new recommended target and threshold exploitation for both stocks.

Quantity	GOMGBK	SNE
Current (2016-2018 average)	256	7
Current Target	119	32
Current Threshold	58	25
Fishery/Industry Target	212	NA
Abundance Limit	125	NA
Abundance Threshold	89	20

Quantity	GOMGBK	SNE
Current (2016-2018 average)	0.459	0.274
Current Target	0.457	0.379
Current Threshold	0.510	0.437
Recommended Target	0.461	0.257
Recommended Threshold	0.475	0.290

Table 3. 2022 LCMA specific management measures

Management Measure	LCMA 1	LCMA 2	LCMA 3	LCMA 4	LCMA 5	LCMA 6	OCC
Min Gauge Size	3 1/4”	3 3/8”	3 17/32 ”	3 3/8”	3 3/8”	3 3/8”	3 3/8”
Vent Rect.	1 15/16 x 5 3/4”	2 x 5 3/4”	2 1/16 x 5 3/4”	2 x 5 3/4”	2 x 5 3/4”	2 x 5 3/4”	2 x 5 3/4”
Vent Cir.	2 7/16”	2 5/8”	2 11/16”	2 5/8”	2 5/8”	2 5/8”	2 5/8”
V-notch requirement	Mandatory for all eggers	Mandatory for all legal size eggers	Mandatory for all eggers above 42°30’	Mandatory for all eggers in federal waters. No v-notching in state waters.	Mandatory for all eggers	None	None
V-Notch Definition[1] (possession)	Zero Tolerance	1/8” with or w/out setal hairs[1]	1/8” with or w/out setal hairs[1]	1/8” with or w/out setal hairs[1]	1/8” with or w/out setal hairs[1]	1/8” with or w/out setal hairs[1]	State Permitted fisherman in state waters 1/4” without setal hairs Federal Permit holders 1/8” with or w/out setal hairs[1]
Max. Gauge (male & female)	5”	5 ¼”	6 3/4”	5 ¼”	5 ¼”	5 ¼”	State Waters none Federal Waters 6 3/4”
Season Closure				April 30-May 31[2]	February 1-March 31[3]	Sept 8-Nov 28[4]	February 1-April 30

[1] A v-notched lobster is defined as any female lobster that bears a notch or indentation in the base of the flipper that is at least as deep as 1/8”, with or without setal hairs. It also means any female which is mutilated in a manner that could hide, obscure, or obliterate such a mark.

[2] Pots must be removed from the water by April 30 and un-baited lobster traps may be set one week prior to the season reopening.

[3] During the February 1 – March 31 closure, trap fishermen will have a two week period to remove lobster traps from the water and may set lobster traps one week prior to the end of the closed season.

[4] Two week gear removal and a 2 week grace period for gear removal at beginning of closure. No lobster traps may be baited more than 1 week prior to season reopening.

Table 6. 2022 sampling requirements and state implementation. All states have 100% active harvester reporting except for Maine which has 10% harvester reporting. 100% harvester reporting will be required of all states in 2024. Sufficient sea sampling can replace port sampling. *De minimis* states (denoted by *) are not required to conduct biological sampling of their lobster fishery.

State	100% Dealer Reporting	10% Harvester Reporting	Sea Sampling	Port Sampling	Ventless Trap Survey	Settlement Survey	Trawl Survey
ME	✓	✓ (10%)	✓		✓	✓	✓
NH	✓	✓	✓	✓	✓	✓	✓
MA	✓	✓	✓		✓	✓	✓
RI	✓	✓		✓	✓	✓	✓
CT	✓	✓	[a]	[a]		[b]	✓
NY	✓	✓	✓	✓			✓
NJ	✓	✓					✓
DE*	✓	✓			✓		✓
MD*	✓	✓					✓
VA*	✓	✓					

[a] No fishery dependent sampling has been conducted by CT since 2014 due to reductions in funding and staffing levels.
[b] Larval data are available for the eastern Sound (ELIS) from the Millstone Power Station entrainment estimates of all stages of lobster larvae (Dominion Nuclear CT, Annual Report 2016).

Table 7. 2022 sea and port sampling trips and samples by state. *De minimis* states (denoted by *) are not required to conduct biological sampling of their lobster fishery.

State	Sea Sampling			Port Sampling		Market Sampling		Totals	
	Trips	Samples	Traps	Trips	Samples	Trips	Samples	Trips	Samples
ME	163	191,793	38,022	0	0	0	0	163	191,793
NH	14	6,828		11	1,074	0	0	25	7,902
MA	58	23,902	1,110	0	0	0	0	58	23,902
RI	0	0	0	7	1,353	0	0	7	1,353
CT	0	0	0	0	0	0	0	0	0
NY	0	0	0	8	839	0	0	8	839
NJ	0	0	0	0	0	0	0	0	0
DE*	0	0	0	0	0	0	0	0	0
MD*	1	230	280	0	0	0	0	1	230
VA*	0	0	0	0	0	0	0	0	0
Total	236	222,753	39,412	26	3,266	0	0	262	226,019

15.0 Figures

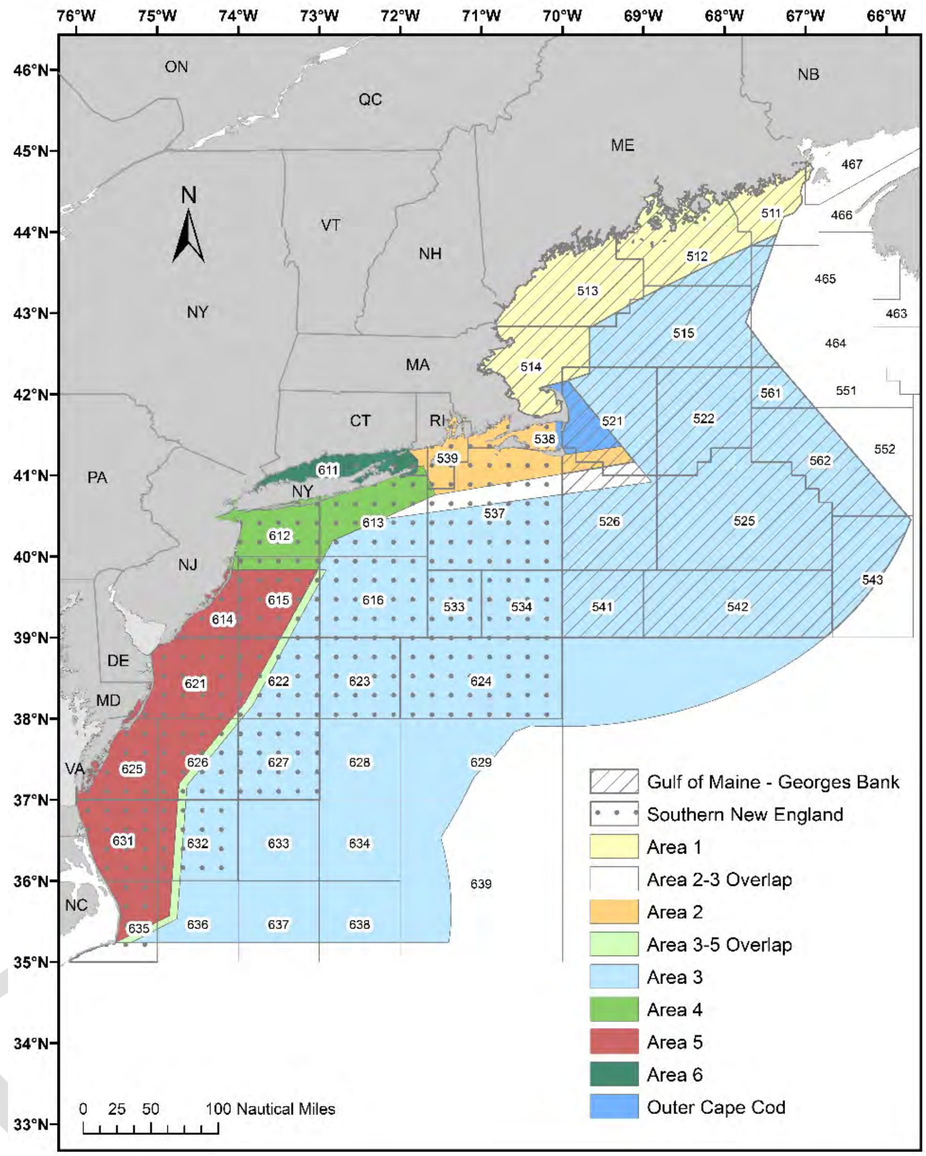


Figure 1. Lobster Conservation Management Areas (LCMAs) and stock boundaries for American lobster.

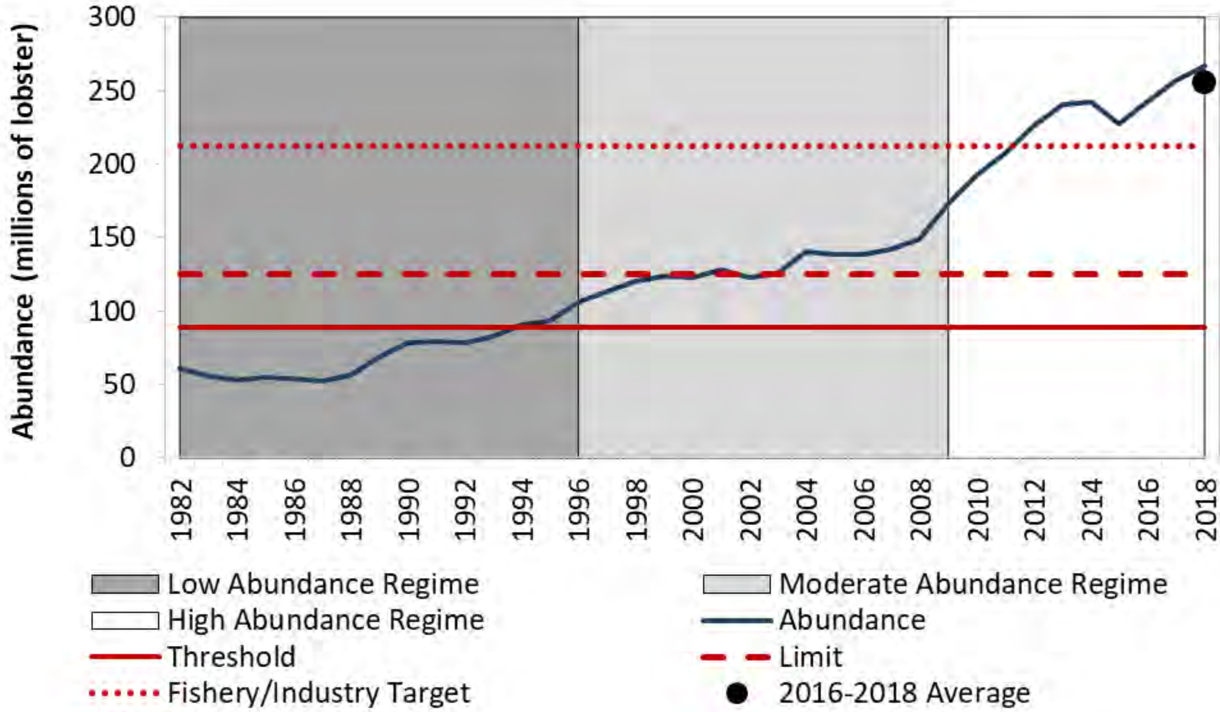


Figure 2. Abundance for GOM/GBK Relative to Reference Points. Source: 2020 Benchmark Stock Assessment for American Lobster.

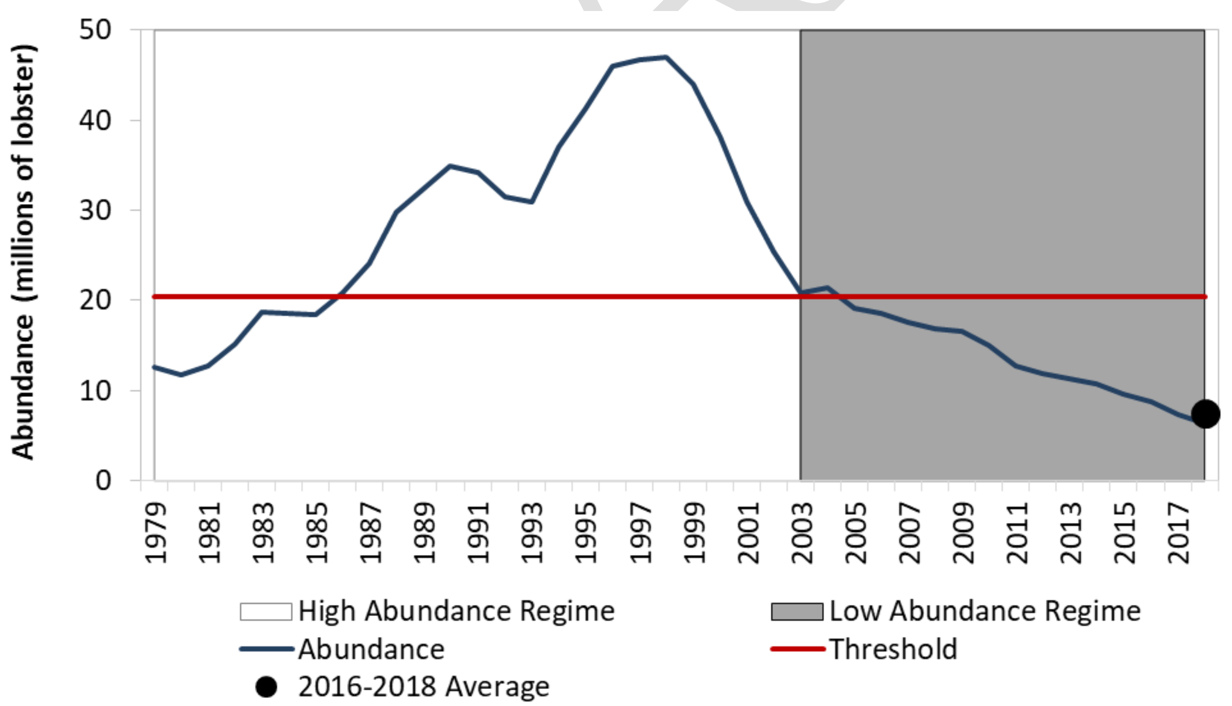


Figure 3. Abundance for SNE Relative to Reference Points. Source: 2020 Benchmark Stock Assessment for American Lobster.

Figure 4. Stratified mean catch and recruit abundance for American lobster on the Spring ME/NH Inshore Trawl Survey (2000-2022). Top: Mean catch of sublegals (<83). Middle: Mean catch of legal sized lobsters (>82). Bottom: Recruit abundance (71-80 mm lobsters).

Figure 5. Stratified mean catch and recruit abundance for American lobster on the Fall ME/NH Inshore Trawl Survey (2000-2022). Top: Mean catch of sublegals (<83). Middle: Mean catch of legal sized lobsters (>82). Bottom: Recruit abundance (71-80 mm lobsters).

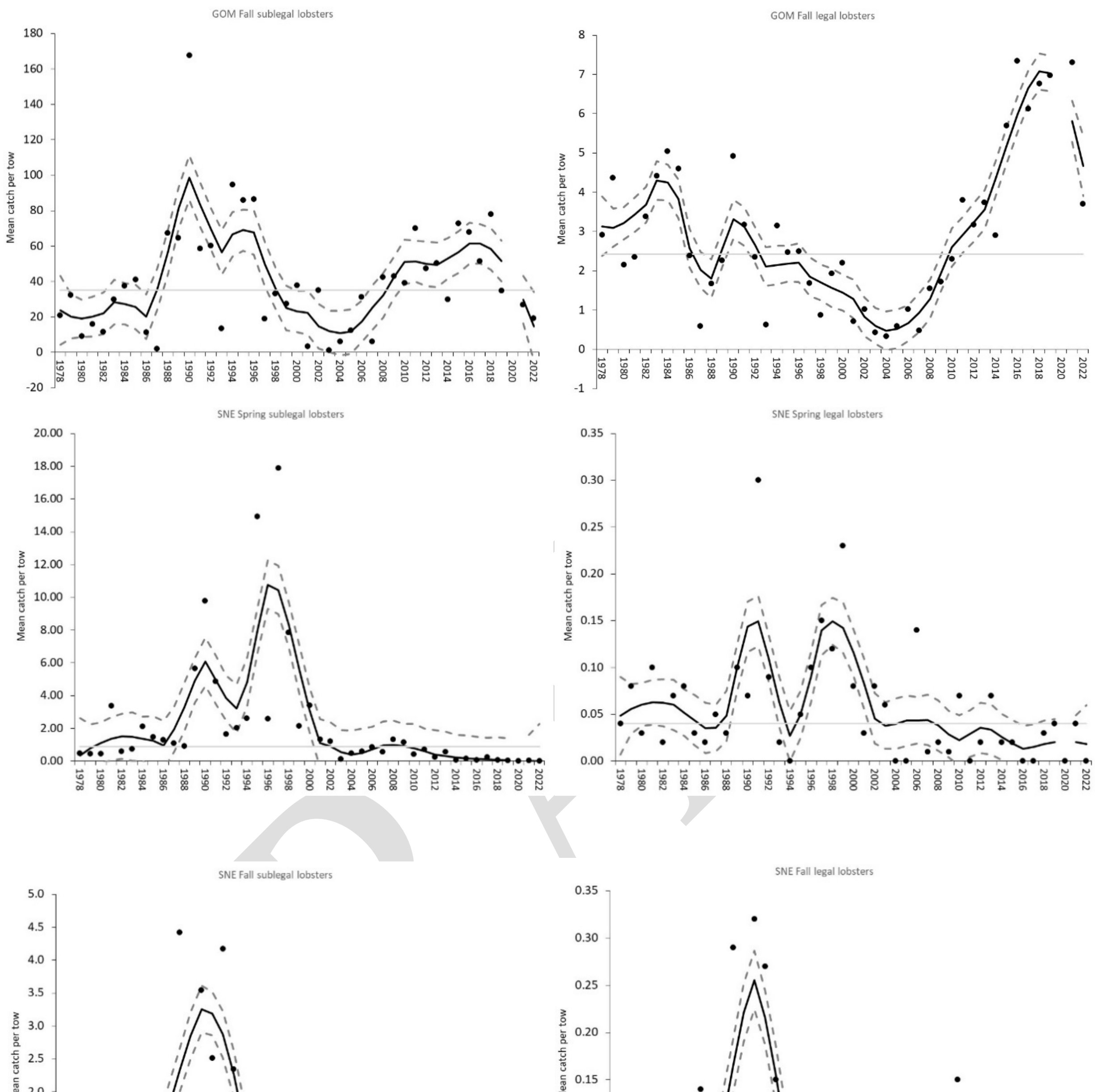
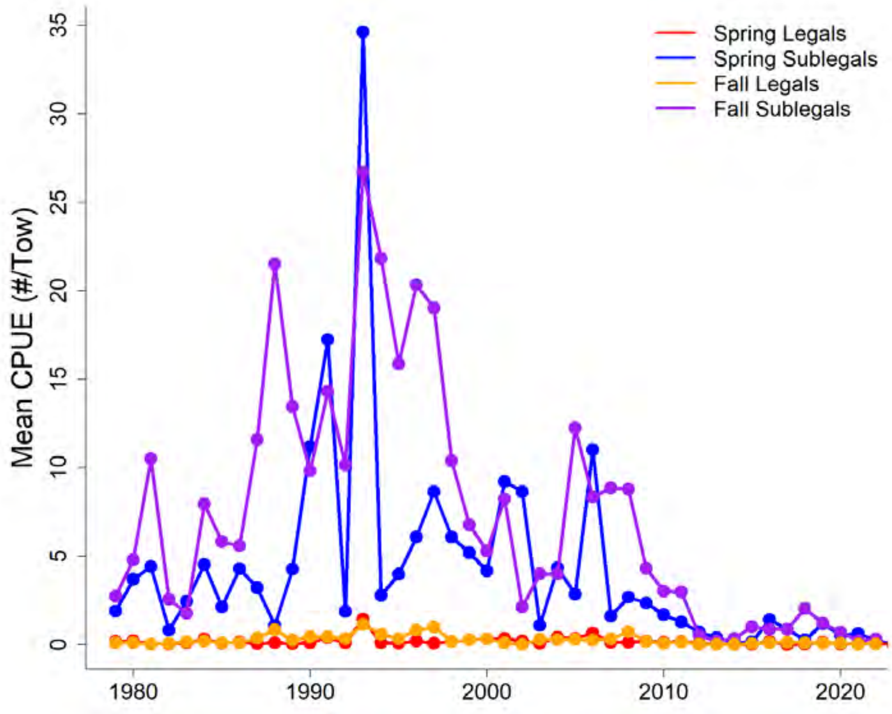


Figure 6. MADMF Fall Trawl Survey sublegal (left) and legal (right) indices from 1978-2019 sexes combined. The top two charts are from Gulf of Maine and the bottom four charts are from Southern New England.



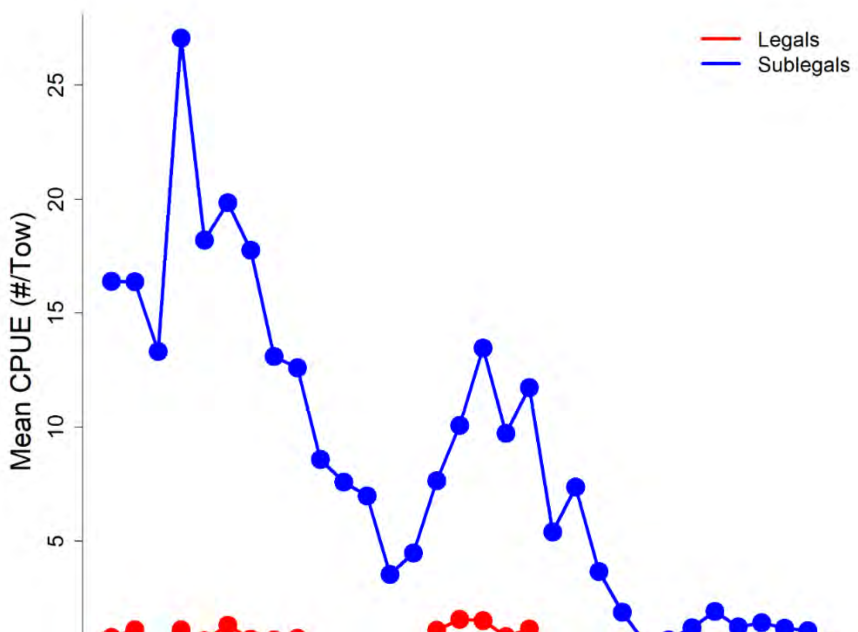


Figure 7. RIDFW Seasonal (spring and fall) Trawl lobster abundances (top) and Monthly Trawl lobster abundances (bottom). CPUE is expressed as the annual mean number per tow for sub-legal (<85.725mm CL) and legal sized (>=85.725mm CL) lobsters.

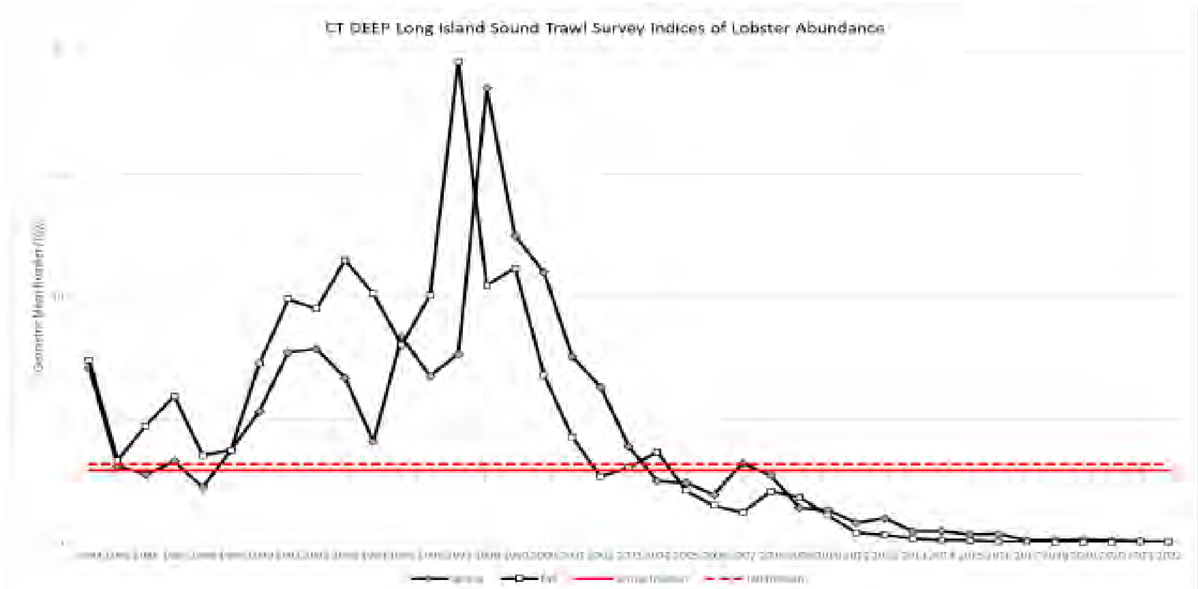


Figure 8. Results of the Long Island Sound Trawl Survey during spring (April-June) and fall (September-October) within NMFS statistical area 611.

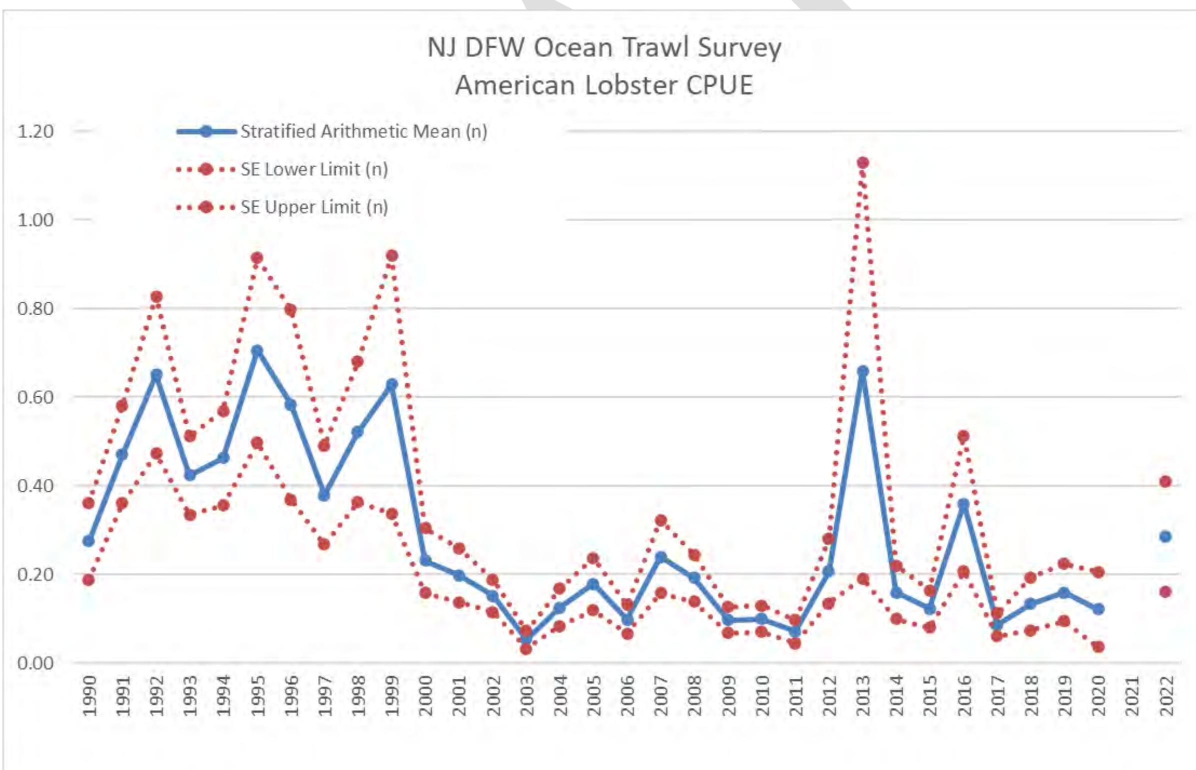


Figure 9. Stratified mean CPUE of all lobsters collected aboard the NJDFW Ocean Trawl Survey. *NOTE: No April 2019 Survey was conducted due to Research vessel mechanical issues. Due to the COVID-19 pandemic, Apr-Oct 2020 and 2021 CPUE and indices were not obtained.

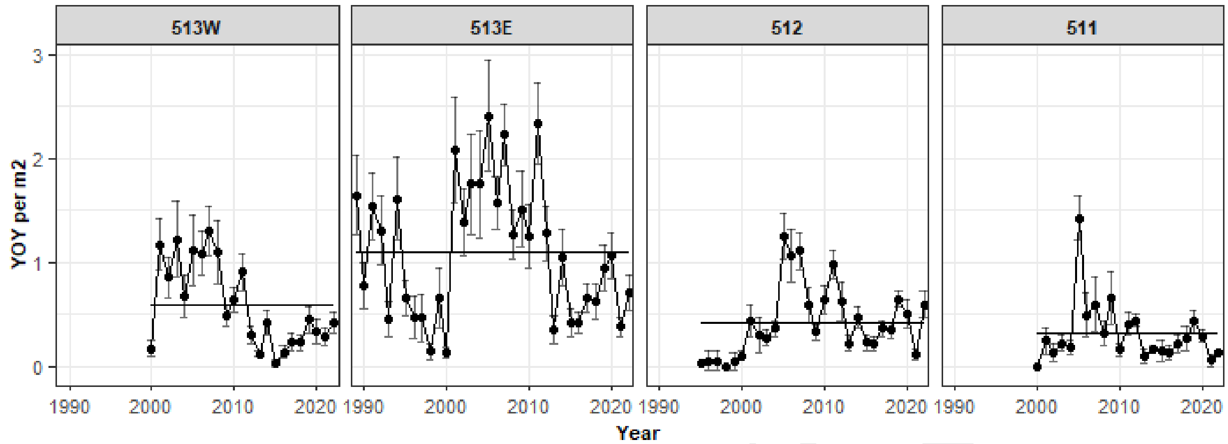


Figure 10. Maine Lobster Settlement Survey Index 1989-2022 for each statistical area with series average (solid horizonal line) for each region with standard error bars.

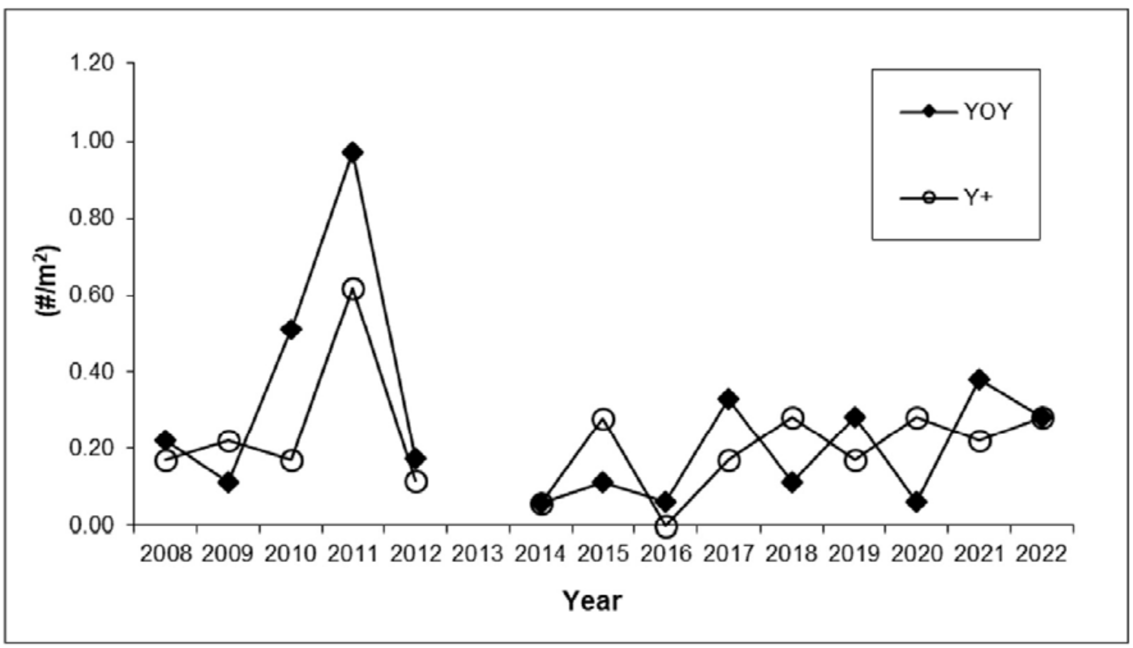


Figure 11. Catch per unit effort (#/m2) of young-of-year (YOY), one-year-olds (Y+), YOY and Y+ combined, and all lobsters during the American Lobster Settlement Index, by location, in New Hampshire, from 2008 through 2022.

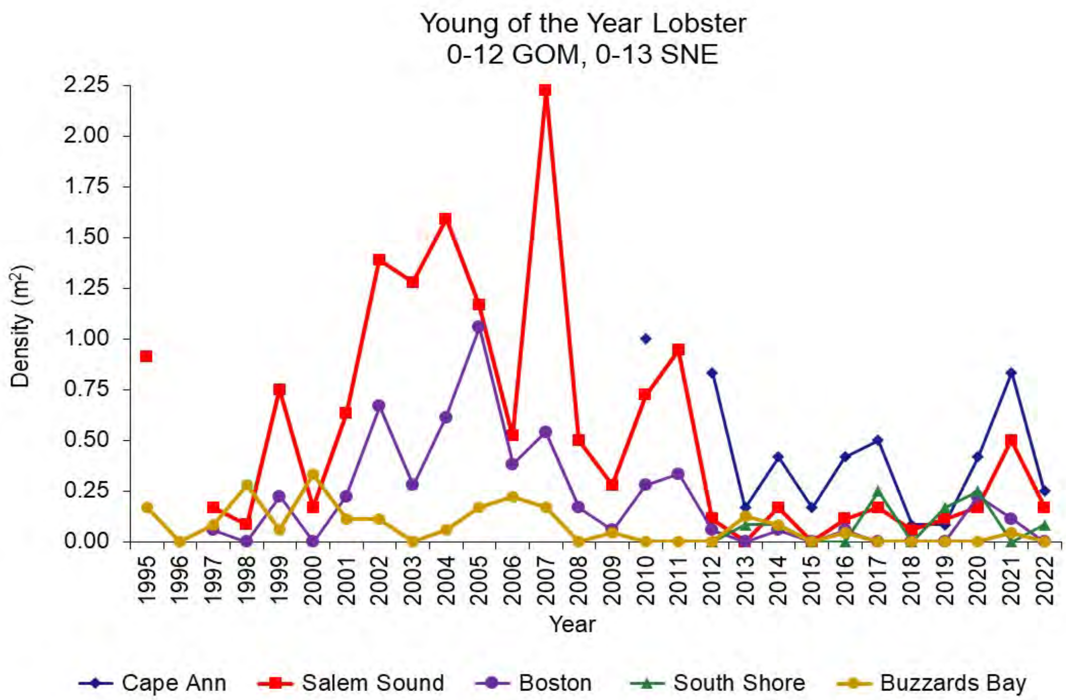


Figure 12. Young-of-year lobster density in four regions within the GOM stock unit – Cape Ann, Salem Sound, Boston, and South Shore, and one region in the SNE stock unit - Buzzards Bay. In GOM locations, lobsters ≤ 12 mm CL are considered YOY, while in SNE locations YOYs are ≤ 13 mm CL.

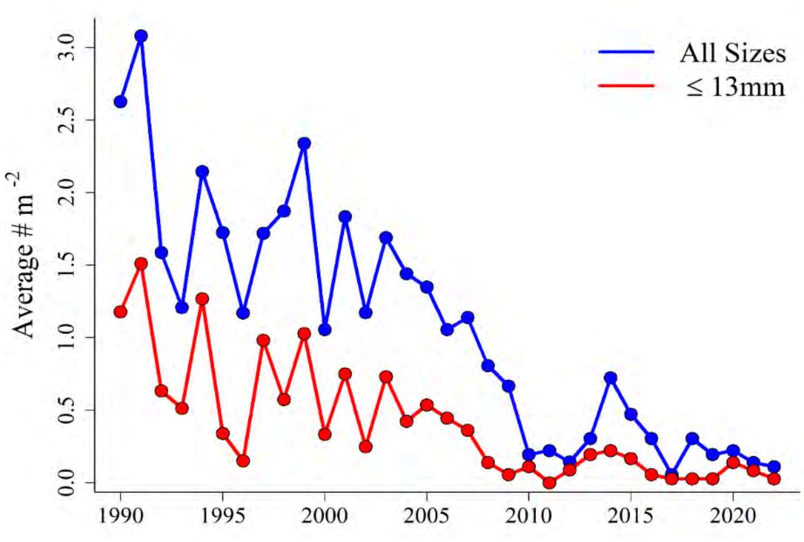


Figure 13. Average abundance of American lobster in Rhode Island suction sampling sites. Abundances are presented for YOY lobsters 13 mm or smaller (red line) and all sizes (blue line).

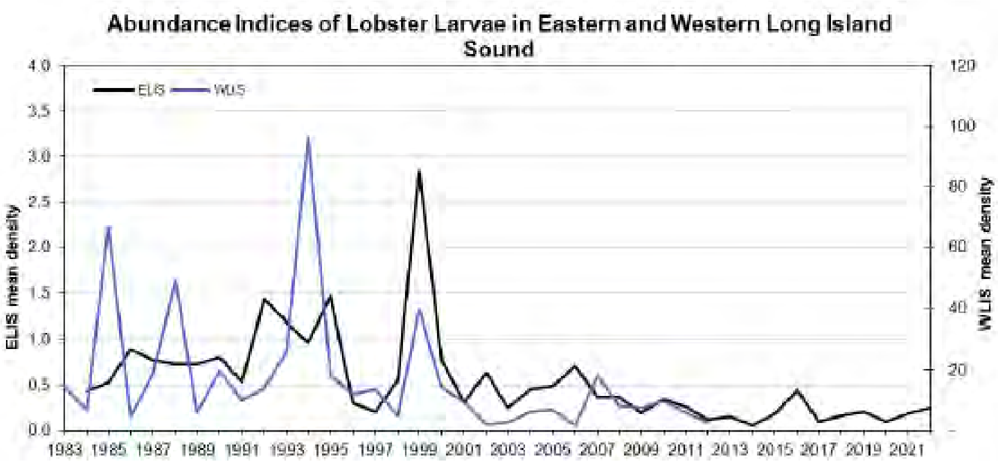


Figure 14. Abundance indices of lobster larvae from the Connecticut DEEP Larval Lobster Survey in western Long Island Sound and from the Millstone Power Station entrainment estimates in eastern Long Island Sound. The Connecticut DEEP survey was discontinued in 2013.

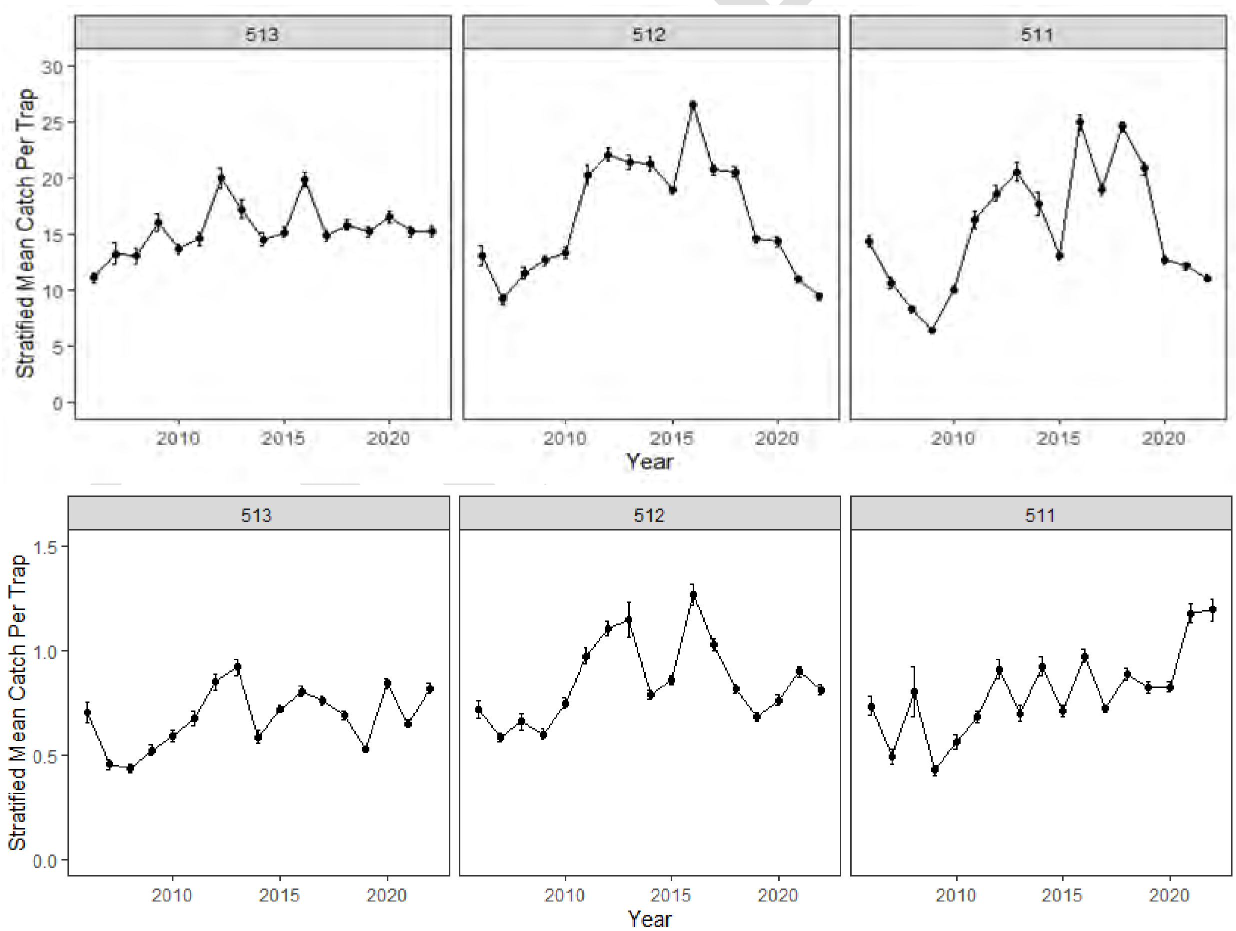


Figure 15. Stratified mean catch per trap for sublegal (top) and legal (bottom) sized lobsters from Maine's Ventless Trap Survey 2006-2022 by statistical area from ventless traps only. Standard error is shown.

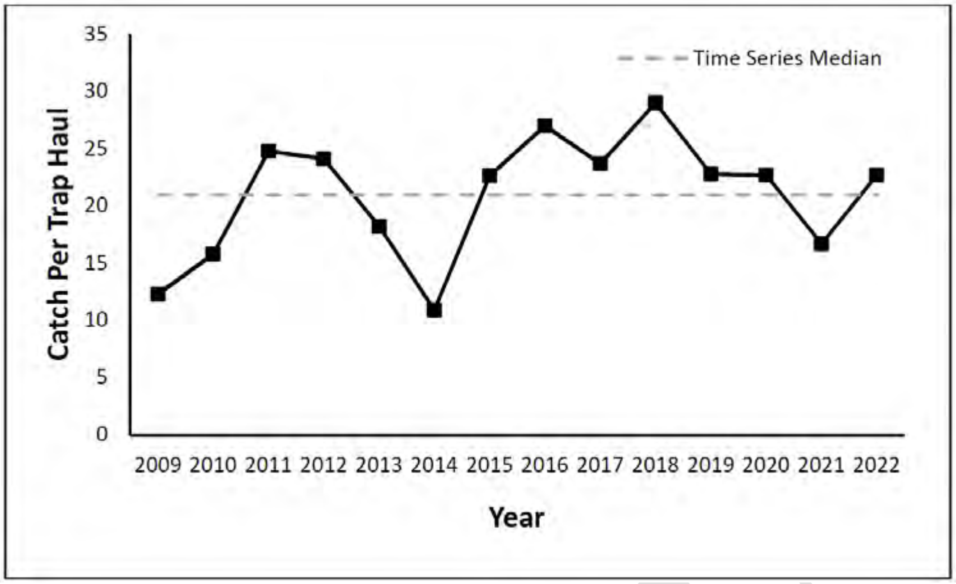


Figure 16. Stratified mean catch per trap haul (ventless traps only) for all lobsters captured during the coast-wide random stratified Ventless Trap Survey in New Hampshire state waters from 2009 through 2022.

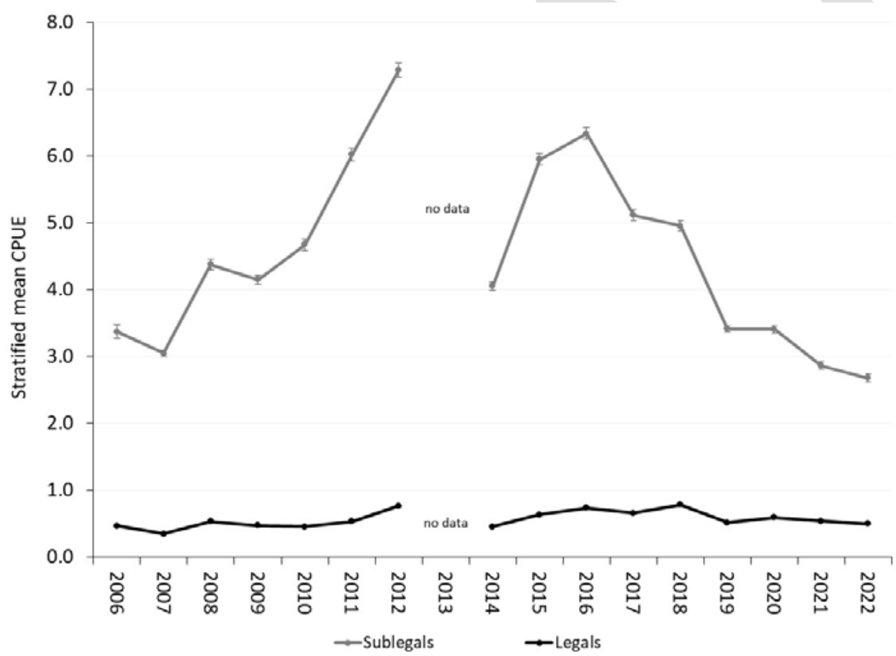


Figure 17. Stratified mean catch per trap haul (±S.E.) of sublegal (< 83 mm, grey line) and legal (≥ 83 mm, black line) lobsters in NMFS Area 514 from MADMF ventless trap survey from 2006-2022.

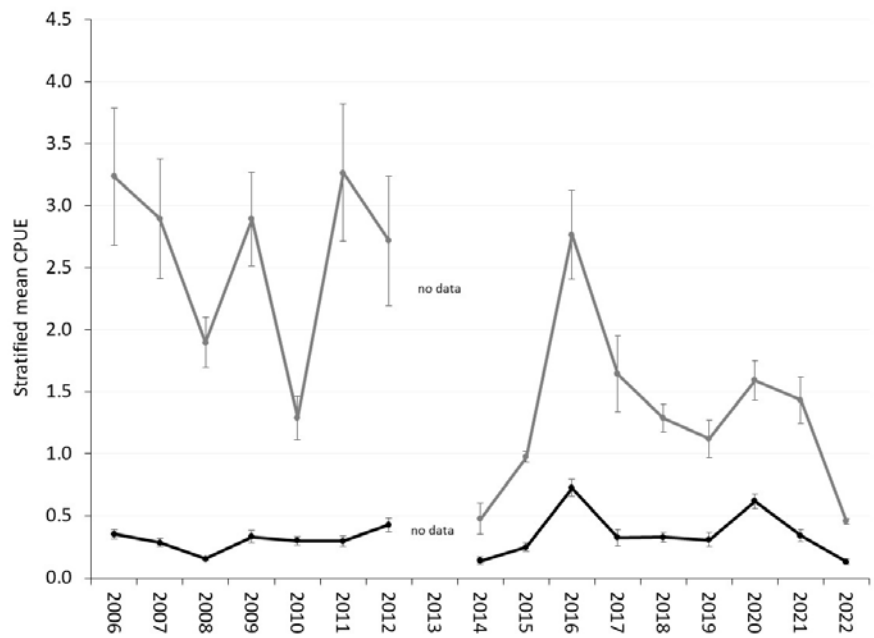


Figure 18. Stratified mean catch per trap haul (±S.E.) of sublegal (< 86 mm, grey line) and legal (≥ 86 mm, black line) lobsters in the reduced MA SNE survey area, Area 538.

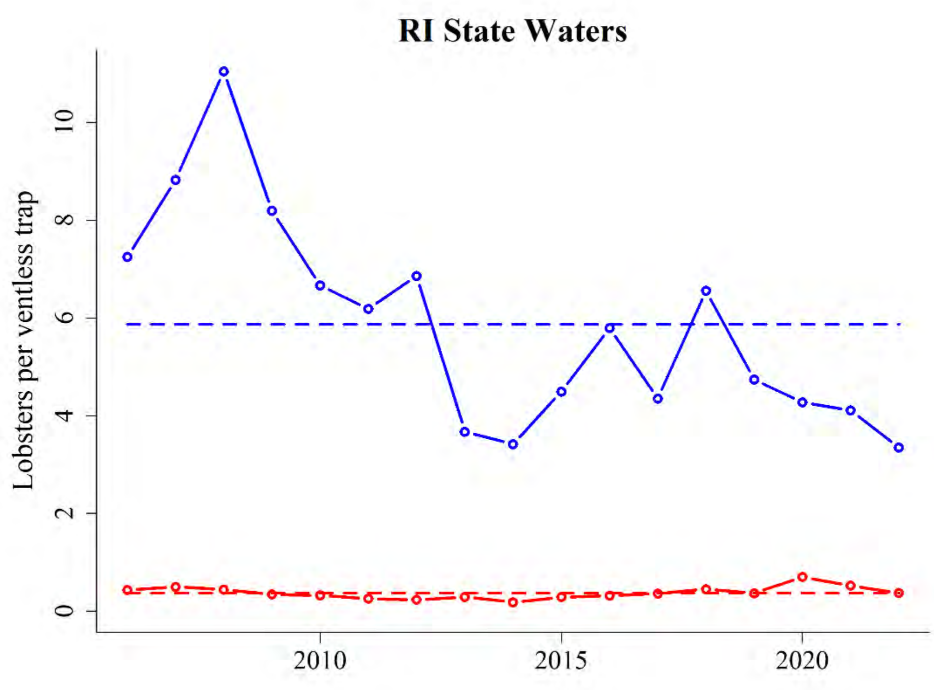


Figure 19. Depth-stratified mean catch of sublegal lobsters in the RIDEM DMF ventless trap survey, 2006-2022.

ATLANTIC STATES MARINE FISHERIES COMMISSION

REVIEW OF THE INTERSTATE FISHERY MANAGEMENT PLAN

For Jonah Crab
(*Cancer borealis*)

2022 FISHING YEAR

Prepared by the Plan Review Team

October 2023

Sustainable and Cooperative Management of Atlantic Coastal Fisheries

Table of Contents

REVIEW OF THE ATLANTIC STATES MARINE FISHERIES COMMISSION FISHERY MANAGEMENT PLAN FOR JONAH CRAB (*Cancer borealis*)

2022 FISHING YEAR

1.0 Status of the Fishery Management Plan

Year of ASMFC Plan's Adoption:	FMP (2015)
Framework Adjustments:	Addendum I (2016) Addendum II (2017) Addendum III (2018) Addendum IV (2022)
Management Unit:	Maine through North Carolina
States with a Declared Interest:	Maine through Virginia (Excluding Pennsylvania and DC)
Active Committees:	American Lobster Management Board, Technical Committee, Plan Review Team, Advisory Panel, Electronic Reporting Subcommittee, Electronic Tracking Subcommittee

2.0 Status of the Fishery

2.1 Commercial Fishery

Historically, Jonah crab was taken as bycatch in the lobster fishery; however, in recent years a directed fishery has emerged causing landings to rapidly increase. Throughout the 1990s, landings fluctuated between approximately 2 and 3 million pounds, and the overall value of the fishery was low. In the early 2000's landings began to increase, with over 7 million pounds landed in 2005. By 2014, landings had almost tripled to 17 million pounds and a value of nearly $13 million. This rapid increase in landings can be attributed to an increase in the price of other crab (such as Dungeness), creating a substitute market for Jonah crab, as well as a decrease in the abundance of lobsters in Southern New England, causing fishermen to redirect effort on Jonah crab. It should be noted that there is some uncertainty in the landings data—especially prior to 2008—due to species misidentification issues as well as underreporting of landings before the implementation of reporting requirements. Despite the uncertainty, the overall trend in landings is likely accurate.

Today, Jonah crab and lobster are harvested in a mixed crustacean fishery in which fishermen can target lobster or crab at different times of the year based on slight gear modifications and small shifts in the areas in which the traps are fished. While the majority of Jonah crab landings is harvested as whole crabs, fishermen from several states, including New York, Maryland and Virginia, land claws. Jonah crab claws are relatively large and can be an inexpensive substitute for stone crab claws. As a result, they can provide an important source of income for fishermen.

Along the Delmarva Peninsula, small boat fishermen have historically harvested Jonah crab claws because they do not have seawater storage tanks on board to store whole crabs.

In 2022, landings along the Atlantic Coast totaled approximately 14 million pounds of Jonah crab, representing $22.6 million in ex-vessel value. Landings increased 17% from 2021 landings of 11.9 million pounds, while ex-vessel value increased 76% from the 2021 value. The states of Massachusetts (55%), Maine (21%), and Rhode Island (17.5%) were the largest contributors to landings. Almost all coastwide landings came from trap gear.

2.2 Recreational Fishery
The magnitude of the Jonah crab recreational fishery is unknown at this time; however, it is believed to be quite small in comparison to the size of the commercial fishery.

3.0 Status of the Stock
Jonah crab are distributed in the waters of the Northwest Atlantic Ocean primarily from Newfoundland, Canada to Florida. The life cycle of Jonah crab is poorly described, and what is known is largely compiled from a patchwork of studies that have both targeted and incidentally documented the species. Based on tagging studies, male Jonah crab movements are generally limited to a few kilometers, though some individuals have been documented to travel over 100 km. Female movement patterns are poorly understood due to limited reported tag recaptures. Due to the lack of a widespread and well-developed aging method for crustaceans, Jonah crab size-at-age, and age-at-maturity are poorly described.

There is currently very limited information available on the status of the Jonah crab resource. The first range-wide stock assessment was completed and is scheduled for peer review in 2023. Massachusetts, Rhode Island, Maine, and New Hampshire conduct inshore state water trawl surveys, and NOAA Fisheries conducts a trawl survey in federal waters which collects data on Jonah crab abundance and distribution.

4.0 Status of Management Measures
Interstate Fishery Management Plan for Jonah Crab (2015)
Jonah crab is managed under the Interstate Fishery Management Plan (FMP) which was approved by the American Lobster Management Board in August 2015. The goal of the FMP is to promote conservation, reduce the possibility of recruitment failure, and allow for the full utilization of the resource by the industry. The FMP lays out specific management measures in the commercial fishery. These include a 4.75" minimum size and a prohibition on the retention of egg-bearing females. To prevent the fishery from being open access, the FMP states that participation in the directed trap fishery is limited to lobster permit holders or those who can prove a history of crab-only pot fishing. All others must obtain an incidental permit. In the recreational fishery, the FMP sets a possession limit of 50 whole crabs per person per day and prohibits the retention of egg-bearing females. Due to the lack of data on the Jonah crab fishery, the FMP implements a fishery-dependent data collection program. The FMP also requires harvester and dealer reporting along with port and/or sea sampling.

Addendum I (2016)
Addendum I establishes a bycatch limit of 1,000 crabs per trip for non-trap gear (e.g., otter trawls, gillnets) and non-lobster trap gear (e.g., fish, crab, and whelk pots). In doing so, the Addendum caps incidental landings of Jonah crab across all non-directed gear types with a uniform bycatch allowance. While the gear types in Addendum I make minimal contributions to total landings in the fishery, the 1,000 crab limit provides a cap to potential increases in effort and trap proliferation.

Addendum II (2017)
Addendum II establishes a coastwide standard for claw harvest. Specifically, it permits Jonah crab fishermen to detach and harvest claws at sea, with a required minimum claw length (measured along the forearm of the claw) of 2.75" if the volume of claws landed is greater than five gallons. Claw landings less than five gallons do not have to meet the minimum claw length standard. The Addendum also establishes a definition of bycatch in the Jonah crab fishery, whereby the total pounds of Jonah crab caught as bycatch must weigh less than the total amount of the targeted species at all times during a fishing trip. The intent of this definition is to address concerns regarding the expansion of a small-scale fishery under the bycatch limit.

Addendum III (2018)
Addendum III improves the collection of harvester and biological data in the Jonah crab fishery. Specifically, the Addendum improves the spatial resolution of harvester data collection by requiring fishermen to report via 10-minute squares. It also expands the required harvester reporting data elements to collect greater information on gear configurations and effort. In addition, the Addendum established a deadline that within five years, states are required to implement 100% harvester reporting, with the prioritization of electronic harvester reporting development during that time. Finally, the Addendum improves the biological sampling requirements by establishing a baseline of ten sampling trips/year, and encourages states with more than 10% of coastwide landings to conduct additional sampling trips.

Addendum IV (2022)
Addendum IV expands on reporting improvements by establishing electronic tracking requirements for federally-permitted vessels in the American lobster and Jonah crab fisheries. Specifically, electronic tracking devices will be required for vessels with commercial trap gear area permits for Lobster Conservation Management Areas (LCMAs) 1, 2, 3, 4, 5, and Outer Cape Cod to collect high resolution spatial and temporal effort data.

5.0 Fishery Monitoring
The provisions of Addendum III went into effect January 1, 2019. Specifically, Addendum III requires reporting of additional data elements, the implementation of 100% harvester reporting within five years, and the completion of a minimum of ten sea and/or port sampling trips per year for biological sampling of the lobster/Jonah crab fishery. The Addendum III requirement for commercial harvesters to report their fishing location by 10 minute longitudinal/latitudinal square was implemented in 2021. *De minimis* states are not required to conduct fishery-independent sampling or port/sea sampling.

Overviews of the states' port and sea sampling in 2022 are as follows:

- Maine: Maine conducted 163 sea sampling trips, 34 of which had Jonah crab measurements, for a total of 2,925 sampled Jonah crabs. Only 20 of the trips in 2022 measured more than 20 Jonah crabs. Types of information collected included: shell width, sex, discards, egg bearing status, cull status, shell hardness, and whether landings are whole crabs or parts. Maine's lobster port sampling program was suspended in 2011.
- New Hampshire: Staff sampled 29 Jonah crab on 14 sea sampling trips and collected information on sex, the presence of eggs, cull condition, molt stage, and carapace length. NH initiated a quarterly port sampling program in late 2016. Quarterly sampling took place at shellfish dealers, where an interview with the captain occurred and a biological sample was taken. A total of 426 Jonah crab were sampled (sexed, measured for carapace width, and weighed when feasible).
- Massachusetts: Massachusetts made 15 port sampling trips and sampled 7,103 Jonah crab from 8 different vessels. Data collected include carapace width, sex, egg bearing status, cull status, and shell hardness. No Jonah crab sea sampling trips were conducted.
- Rhode Island: Rhode Island did not conduct sea sampling for Jonah crab in 2022, due to funding and staff limitations. Five port sampling trips were conducted in 2022, measuring 971 Jonah crabs caught in four different Statistical Areas. Types of information collected included: carapace width, sex, egg bearing status, cull status, shell hardness, and shell disease condition.
- Connecticut: No sea sampling or port sampling trips were conducted for Jonah crab.
- New York: Staff conducted 7 market sampling trips, sampling 370 Jonah crab. No sea sampling trips were conducted for Jonah crab in 2022.
- New Jersey: No sea or port sampling trips were conducted for Jonah crab in 2022.
- Delaware: No sea or port sampling trips were conducted for Jonah crab in 2022.
- Maryland: No sea or port sampling trips were conducted for Jonah crab in 2022.
- Virginia: No sea or port sampling trips were conducted for Jonah crab in 2022.

6.0 Status of Surveys

The FMP for Jonah crab encourages states to expand current lobster surveys (i.e. trawl surveys, ventless trap surveys, settlement surveys) to collection biological information on Jonah crab. The following outlines the fishery-independent surveys conducted by each state.

Maine

A. Settlement Survey

The Maine settlement survey was primarily designed to quantify lobster young-of-year (YOY), but has also collected Jonah crab data from the sites throughout the survey. Jonah crab information collected includes carapace width, sex (when large enough), ovigerous condition, claw status, shell hardness, and location. The density of YOY Jonah crab increased over the past two decades with high values in 2012 and 2016, then declined slightly in recent years (Figure 1). In 2022, density of YOY Jonah crab increased from 2021 in Area 513 and 512, and decreased in 511.

B. State Trawl Survey
The ME/NH Inshore Trawl Survey began in 2000 and is conducted biannually (spring and fall) through a random stratified sampling scheme. Jonah crab data has been collected since 2003. The 2022 spring survey ran from May to June and completed 101 out of 120 scheduled tows. A total of 143 Jonah crabs were caught and sampled, with 54 females and 89 males caught and measured. The 2022 fall survey completed 87 out of 120 scheduled tows; a total of 115 Jonah crabs were caught and sampled, with 52 females, 62 males, and 1 unsexed crab caught and measured. Abundance indices for Jonah crab increased in 2022 after declining since 2016 (Tables 2 and 3).

C. Ventless Trap Survey
Maine began its Juvenile Lobster Ventless Trap Survey in 2006. Since the beginning of the survey, Jonah crab counts were recorded by the contracted fishermen, but the confidence in early years of this data is low because of the confusion between the two *Cancer* crabs (Jonah crab vs. rock crab) and similar common names. In 2016, the survey began collecting biological data for Jonah crab including carapace width, sex, ovigerous condition, claw status, shell hardness, and location. In 2022 Jonah crab catch in the survey decreased in all areas from 2021. Concentrations of Jonah crab were highest in Statistical Area 512 and lowest in 513 (Figure 2).

New Hampshire
A. Settlement Survey
Since 2009, species information has been collected on Jonah crab in the New Hampshire Fish and Game portion of the American Lobster Settlement Index. Figure 3 shows the CPUE (#/m^2) of Jonah crab for all NH sites combined, from 2009 through 2022. The time series shows a general upward trend with a time series high in 2022.

B. Ventless Trap Survey
Since 2009, New Hampshire Fish and Game has been conducting the coastwide Random Stratified Ventless Trap Survey in state waters (Statistical Area 513). A total of six sites were surveyed twice a month from June through September in 2022. Beginning in 2016, all Jonah crabs were evaluated for sex, carapace width (mm), cull condition, and molt stage. A total of 17 Jonah crab over 8 trips were measured during the 2022 sampling season.

Massachusetts
A. Settlement Survey
The Juvenile Lobster Suction Survey has consistently identified *Cancer* crabs to genus level since 1995, and Jonah crab have been consistently identified to species in the survey since 2011. The mean number of Jonah crab observed in the MA DMF Settlement Survey in the GOM region has been higher from 2016 through 2022 than it was from 2011 to 2015 (Figure 4).

B. Ventless Trap Survey
The Massachusetts Division of Marine Fisheries (MA DMF) Ventless Trap Survey is conducted in MA territorial waters of NMFS statistical areas 514 and 538. Stratified mean catch per trawl haul (CPUE) for the survey is standardized to a six-pot trawl with three vented and three

ventless traps. The index produced from the MA DMF Ventless Trap Survey has been increasing since 2012 and is approaching time series highs (Figure 5).

C. Trawl Survey
The aggregation of DMF trawl survey regions has changed compared to previous reports. Regions 1 and 2 are considered SNE, regions 3-5 are considered GOM. Previously, region 3, which extends southwards from the tip of Cape Cod along the eastern side of the outer Cape to south of Nantucket, was included with SNE. Except for the fall survey in the GOM region, Jonah crabs are infrequently caught in the MA DMF Trawl Survey. Since generally increasing in abundance since the mid-1990's, the last couple of years of the fall survey in the GOM have generally been near or below time series medians (Figure 6).

Rhode Island
A. Settlement Survey
The RI DEM lobster YOY Settlement Survey (Suction Sampling) intercepts Jonah crabs. Jonah crab catches in this survey are generally low. In 2022, the Jonah Crab Index was zero crabs per m^2, compared with the time series (1990-2022) mean of 0.18 crabs per m^2 (Figure 7).

B. Ventless Trap Survey
Since its inception in 2006, the RI Ventless Trap Survey (VTS) has recorded counts of Jonah crab per pot. Carapace width, sex, ovigerous condition, and location data have been collected for all Jonah crabs encountered in the survey since 2015; prior to this, only counts of Jonah crab were recorded. In 2022, the stratified abundance index of Jonah crabs was 2.40 crabs per ventless trap, higher than the time series mean of 1.40 crabs per ventless trap (Figure 8).

B. Trawl Survey
RI DEM has conducted spring and fall trawl surveys since 1979, and a monthly trawl survey since 1990. However, the survey did not begin counting Jonah crab specifically until 2015. Jonah crabs are rarely encountered in this survey, and abundance indices are variable yet low, averaging 0.04 crabs per tow over the time series.

Connecticut
A. Trawl Survey
Jonah crab abundance is monitored through the Long Island Sound Trawl Survey (LISTS) during the spring (April, May, June) and fall (September and October) cruises, all within NMFS statistical area 611. The survey documents the number of individuals caught and total weight per haul by survey site in Long Island Sound. The LISTS caught one Jonah crab in the fall 2007 survey and two in the fall 2008 survey. Both observations occurred in October at the same trawl site in eastern Long Island Sound. No trawl survey sampling was conducted in 2020 due to restrictions on field sampling caused by the global COVID-19 pandemic. No Jonah crabs were observed in the 2021 or 2022 spring or fall surveys.

New York

A. Trawl Survey

New York initiated a stratified random trawl survey in the near shore ocean waters off the south shore of Long Island in 2018 from the Rockaways to Montauk Point and the New York waters of Block Island Sound. Seven sampling cruises were conducted in 2022 during the winter (February), spring (April, May, June), summer (August) and fall (October, November). Twenty-one stations were sampled during the winter cruise in February. Thirteen, seventeen, and twenty-three stations were sampled during the spring cruises. Thirty stations were sampled during the summer cruise in August. During the fall, 20 stations were sampled in October and eight stations were sampled in November. A total of 256 Jonah crabs were caught. A total of 35 females were measured ranging from 18mm to 111mm with an average of 55mm; 58 males were measured ranging from 16mm to 141mm, with an average shell width of 84mm.

New Jersey

A. Trawl Survey

A fishery-independent Ocean Trawl Survey is conducted from Sandy Hook, NJ to Cape May, NJ each year. The survey stratifies sampling in three depth gradients, inshore (18’-30’), mid-shore (30’-60’), and offshore (60’-90’). The mean CPUE, which is calculated as the sum of the mean weight of Jonah crab collected in each sampling area weighted by the stratum area, has remained low throughout the time series, but increased slightly in 2019. A cruise was not conducted in April 2019. Due to the COVID-19 pandemic, 2020 and 2021 CPUE and indices were not obtained (Figure 9).

7.0 Recent and On-Going Research Projects

A. Declawing Study

NH F&G, Wells National Estuarine Research Reserve, and the University of New Hampshire have been conducting a variety of collaborative research on Jonah crabs since 2014. Two of those studies were published in 2021. Goldstein and Carloni (2021) assessed the implications of live claw removal, and Dorrance et al. (2021) conducted follow-up research on that study to better understand the sublethal effects of declawing. These manuscripts provide estimates of mortality for declawed animals, and information on the effects of claw removal on feeding, movement and mating.

In addition to the above-mentioned publications, an acoustic telemetry study was conducted in 2018 and 2019 by same collaborators to assess the movement patterns of both controls and declawed animals. These data are currently the basis for Maureen Madray’s thesis (Furey lab-UNH) and will be finalized in the coming months.

B. Growth and Fishery Dependent Data

In 2019, two collaborative studies between the University of Rhode Island and Rhode Island DEM were published. The first of these was a growth study, which described molt increments for adult females and males and molting seasonality and molt probabilities for adult males in Rhode Island Sound. The second was an interview study in which fifteen in-person interviews were conducted with Jonah crab fishermen to collect their knowledge concerning Jonah crab biology and fishery characteristics. The interviews provided insight into aspects of the species biology and life history that have not been characterized in the literature (e.g., seasonal distribution patterns); identified topics requiring further study (e.g., stock structure and spawning seasonality); and highlighted predominant concerns related to fishery management (e.g., inshore-offshore fleet dynamics).

New Hampshire Fish and Game, Wells National Estuarine Research Reserve and the University of New Hampshire conducted research on growth rates of crabs held at ambient and controlled temperatures for sizes ranging from 5 mm (YOY) to 100 mm. These data are currently being analyzed, and will be available for population assessment purposes.

C. CFRF Research Fleet

The Commercial Fisheries Research Foundation (CFRF) has expanded its lobster commercial research fleet to sample Jonah crab. Biological data collected include carapace width, sex, shell hardness, egg status, and disposition. As of July 31, 2023, 124,325 Jonah crabs have been sampled through the program.

8.0 State Compliance

All states except New York have implemented the provisions of the Jonah Crab FMP and associated addenda. The implementation deadline for the Jonah Crab FMP was June 1, 2016; the implementation deadline for Addendum I was January 1, 2017; the implementation deadline for Addendum II was January 1, 2018; and the implementation deadline for Addendum III was January 1, 2019 (with the exception of the 10 minute square reporting requirement).

- NY is in the process of implementing the full suite of management measures required under the Jonah Crab FMP or Addendum I and II. Specifically, NYSDEC has initiated a rulemaking which will limit participation in the Jonah crab directed trap fishery to those vessel and permit holders which already hold a lobster permit, or those who can prove prior participation in the crab fishery before the control date of June 2, 2015. This rulemaking will also establish a bycatch limit for Jonah crab of no more than 1,000 crabs per trip for non-trap gear and non-lobster trap gear. This rulemaking should be in effect before 2024.

9.0 De Minimis Requests

The states of Delaware, Maryland, and Virginia, have requested *de minimis* status. According to the Jonah crab FMP, states may qualify for *de minimis* status if, for the preceding three years for which data are available, their average commercial landings (by weight) constitute less than 1% of the average coastwide commercial catch. Delaware, Maryland, and Virginia meet the *de minimis* requirement.

10.0 Research Recommendations

A stock assessment for Jonah crab has been completed and is scheduled for peer review in 2023. Research recommendations will be made by the Stock Assessment Subcommittee and

Peer Review Panel.

11.0 Plan Review Team Recommendations
The following are recommendations and comments from the Plan Review Team:

- The PRT recommends the Board approve the *de minimis* requests of DE, MD, and VA.
- The PRT notes that MA has been unable to meet the August 1 deadline for compliance reports for the last several years.
- Rhode Island, Connecticut, New York, and New Jersey were not able to complete the sea and/or port sampling required by the FMP. These states have noted concerns with staff availability, funding, and lack of agreement by fishermen, which have contributed to the inability to complete the required sampling trips.

12.0 Tables

Table 1. Landings (in pounds) of Jonah crab by the states of Maine through Virginia. 2010-2021 landings were provided by ACCSP based on state data submissions. 2022 landings were submitted by the states as a part of the compliance reports and should be considered preliminary. *C= confidential data*

	ME	NH	MA	RI	CT	NY	NJ	DE	MD	VA	Total
2010	1,093,962	C	5,689,431	3,720,440	C	968,122	30,441		17,845	C	11,690,787
2011	1,096,592	C	5,379,792	3,213,119	C	69,440	27,025		92,401	C	9,947,142
2012	556,675	C	7,540,510	3,774,300	2,349	410,349	68,606		C	C	12,552,537
2013	379,073	340,751	10,117,542	4,651,796	51,462	371,713	8,143		C	C	16,075,636
2014	348,295	404,703	11,904,611	4,435,934	49,998	83,060	33,156		153,714	C	17,413,503
2015	312,063	C	9,128,876	4,298,894	C	207,424	68,116	C	39,750	C	14,253,327
2016	602,206	150,341	10,660,653	4,224,092	C	165,427	261,287	C	14,656	C	16,084,217
2017	1,043,418	114,155	11,698,342	4,111,281	C	158,231	433,132	C	23,564	C	17,594,666
2018	1,054,795	22,434	13,250,803	4,665,701	C	231,642	880,192	C	60,628	C	20,175,488
2019	763,807	70,818	9,698,145	4,222,305	C	125,391	1,061,194	C	47,829	C	15,968,414
2020	696,309	31,658	8,605,007	3,319,652	C	105,841	975,522	C	35,606	C	13,744,904
2021	1,426,959	123,729	6,539,131	2,142,424	C	72,066	1,597,748	C	34,327	C	12,345,330
2022	2,956,697	295,529	7,765,545	2,458,416	C	34,550	526,680	C	C	C	14,037,417

Table 2. Jonah crab stratified mean weight (kg/tow) for the Spring Maine-New Hampshire Inshore Trawl Survey 2001-2022 (with no 2020)

Survey	StratMean_Weight	CV_Weight	SE_Weight
SP01	0.97	0.68	0.26
SP02	0.95	0.71	0.27
SP03	0.92	0.33	0.15
SP04	1.11	0.48	0.28
SP05	1.71	0.33	0.32
SP06	1.27	0.47	0.29
SP07	1.13	0.34	0.17
SP08	0.82	0.23	0.09
SP09	0.85	0.25	0.10
SP10	0.52	0.40	0.11
SP11	0.53	0.32	0.08
SP12	0.41	0.25	0.05
SP13	0.26	0.37	0.05
SP14	0.85	0.44	0.15
SP15	0.61	0.36	0.09
SP16	2.11	0.43	0.38
SP17	0.56	0.33	0.07
SP18	0.44	0.30	0.06
SP19	0.36	0.59	0.08
SP21	0.20	0.43	0.03
SP22	0.30	0.32	0.04

Table 3. Jonah crab stratified mean weight (kg/tow) for the Spring Maine-New Hampshire Inshore Trawl Survey 2001-2022 (with no 2020)

Survey	StratMean_Weight	CV_Weight	SE_Weight
FL00	0.45	0.47	0.09
FL01	2.23	0.27	0.32
FL02	1.37	0.66	0.40
FL03	0.63	0.22	0.08
FL04	1.11	0.36	0.23
FL05	0.69	0.34	0.16
FL06	0.69	0.38	0.13
FL07	0.94	0.28	0.15
FL08	1.29	0.17	0.12
FL09	0.38	0.30	0.06
FL10	0.46	0.43	0.09
FL11	0.34	0.35	0.07
FL12	0.29	0.30	0.04
FL13	0.29	0.26	0.04
FL14	0.16	0.36	0.02
FL15	2.52	0.42	0.48
FL16	2.01	0.27	0.28
FL17	1.14	0.24	0.13
FL18	0.75	0.46	0.14
FL19	0.68	0.20	0.06
FL20	0.15	0.62	0.05
FL21	0.13	0.36	0.02
FL22	0.19	0.46	0.04

13.0 Figures

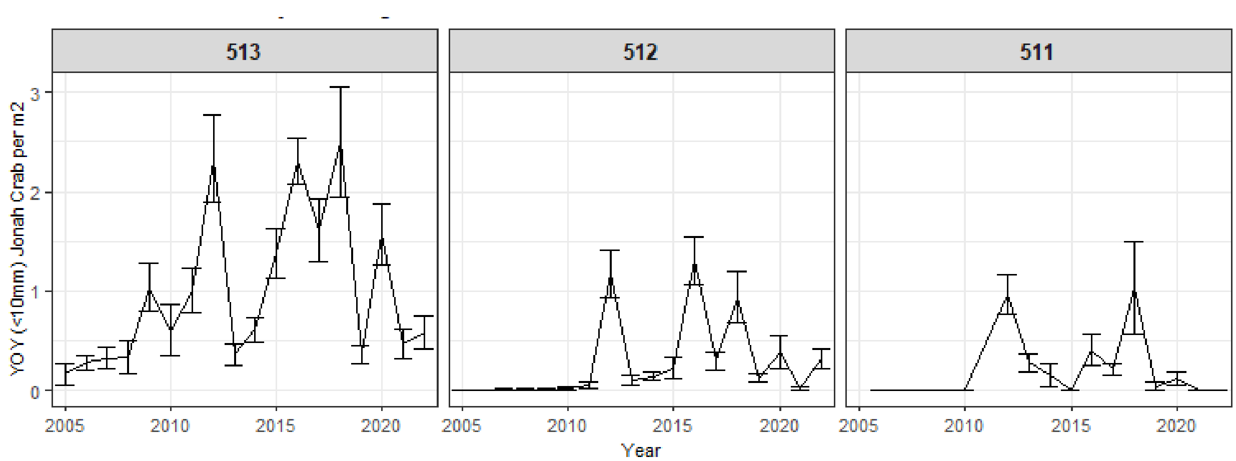


Figure 1. Density of YOY (<10mm carapace width) Jonah crab over time in the Maine Settlement Survey by statistical area.

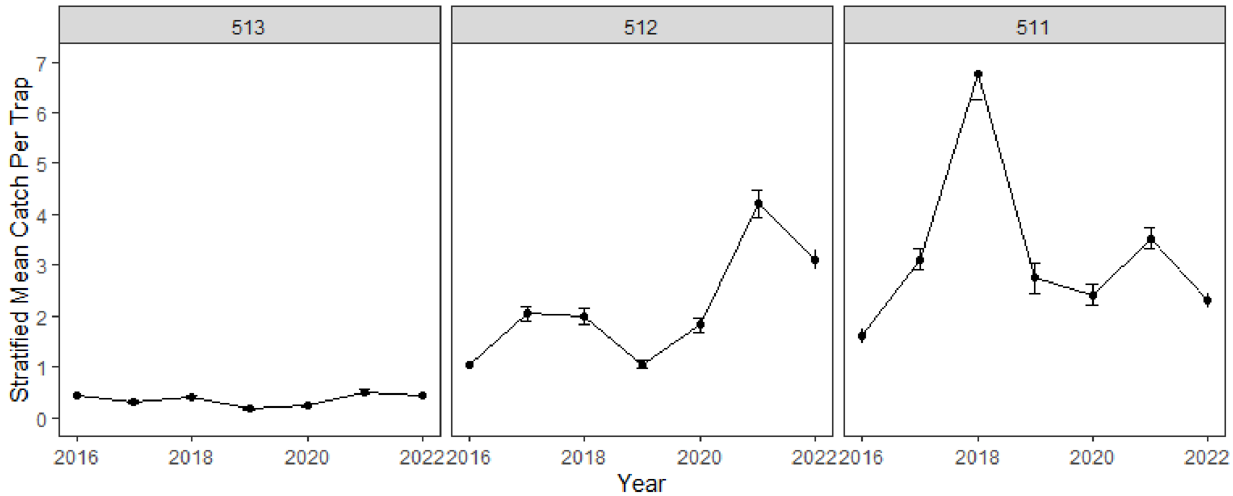


Figure 2. Stratified mean of Jonah crab from Maine Ventless Trap Survey 2016-2022. Standard error shown.

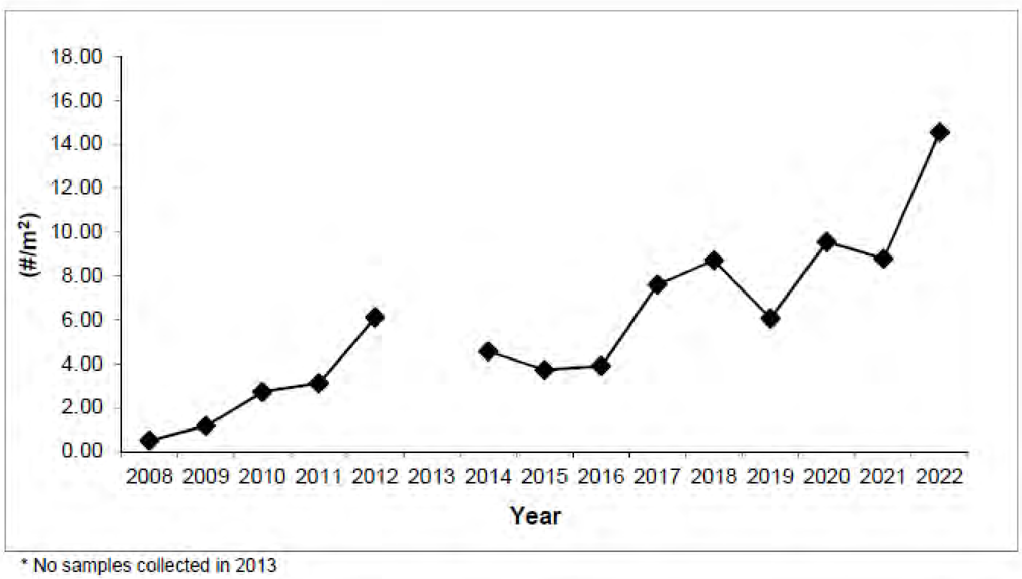


Figure 3. Catch per unit effort (#/m^2) of Jonah crab during the American Lobster Settlement Index Survey, in New Hampshire, from 2009 through 2022.

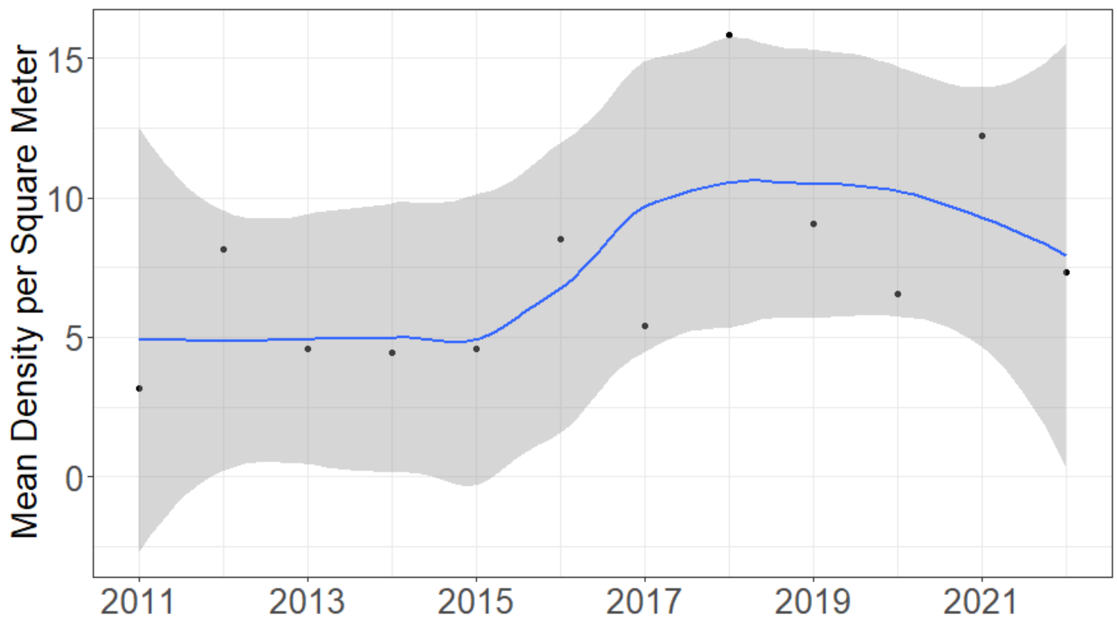


Figure 4. Mean number of Jonah crab per square meter from the MA DMF Settlement Survey from the Gulf of Maine (GOM) region. Black dots are annual means, blue line is a Loess soother, gray area is confidence interval around the Loess smoother.

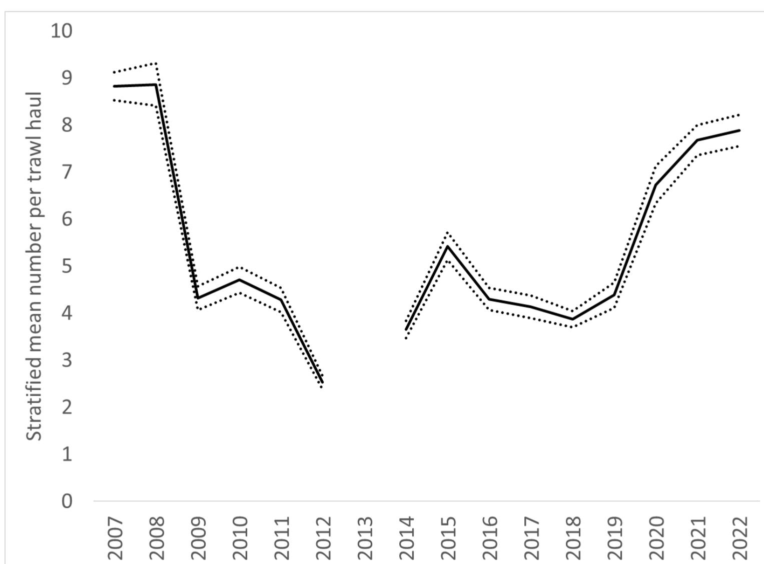


Figure 5. Mean number of Jonah crabs per trawl haul from ventless traps from GOM region of the MA DMF Ventless Trap Survey (standardized to a 6-pot trawl with three vented and three ventless traps). Error bars are two times the standard error. The survey was not conducted in 2013 due to a gap in funding.

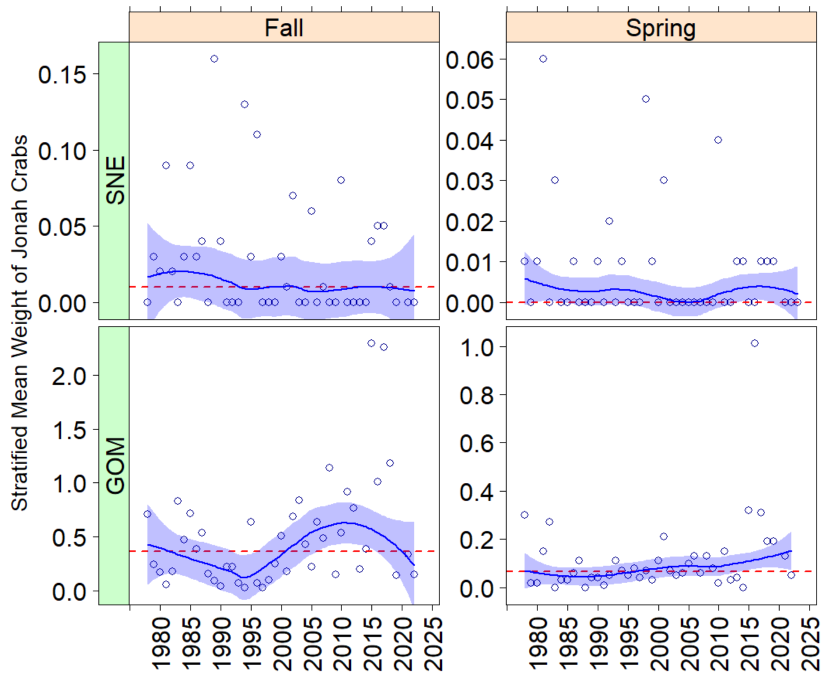


Figure 6. Stratified mean weight (kg) of Jonah crab from the MA DMF Trawl Survey. The left column shows the fall surveys, the right columns show the spring surveys. Southern New England (SNE) is on the top row, Gulf of Maine (GOM) is on the bottom. Red dashed line is the time series median. Blue line is a trend line (Loess smoother), and the blue shaded area is the confidence interval around the trend line. The survey was not conducted in 2020 due to the Covid-19 pandemic.

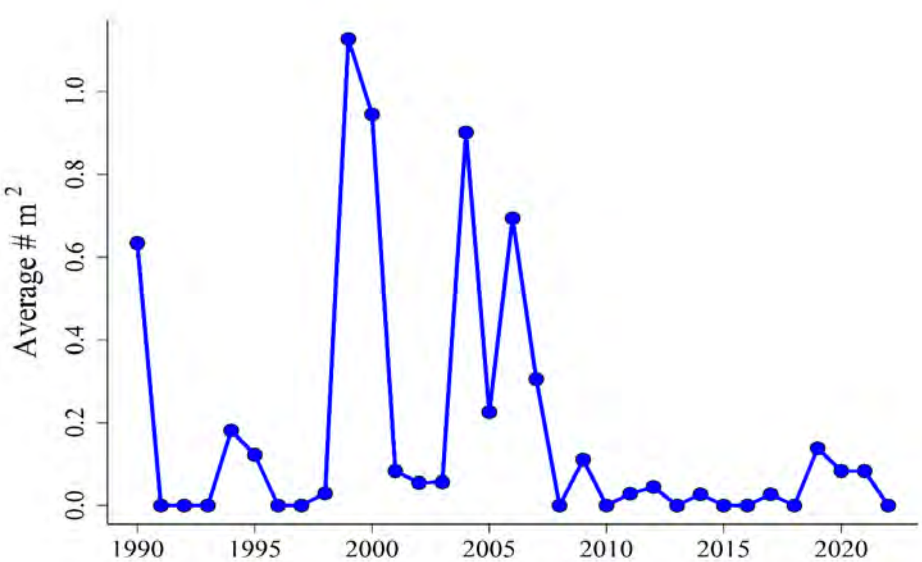


Figure 7. Rhode Island YOY Settlement Survey trend for all Jonah crabs caught per m^2, 1990-2022.

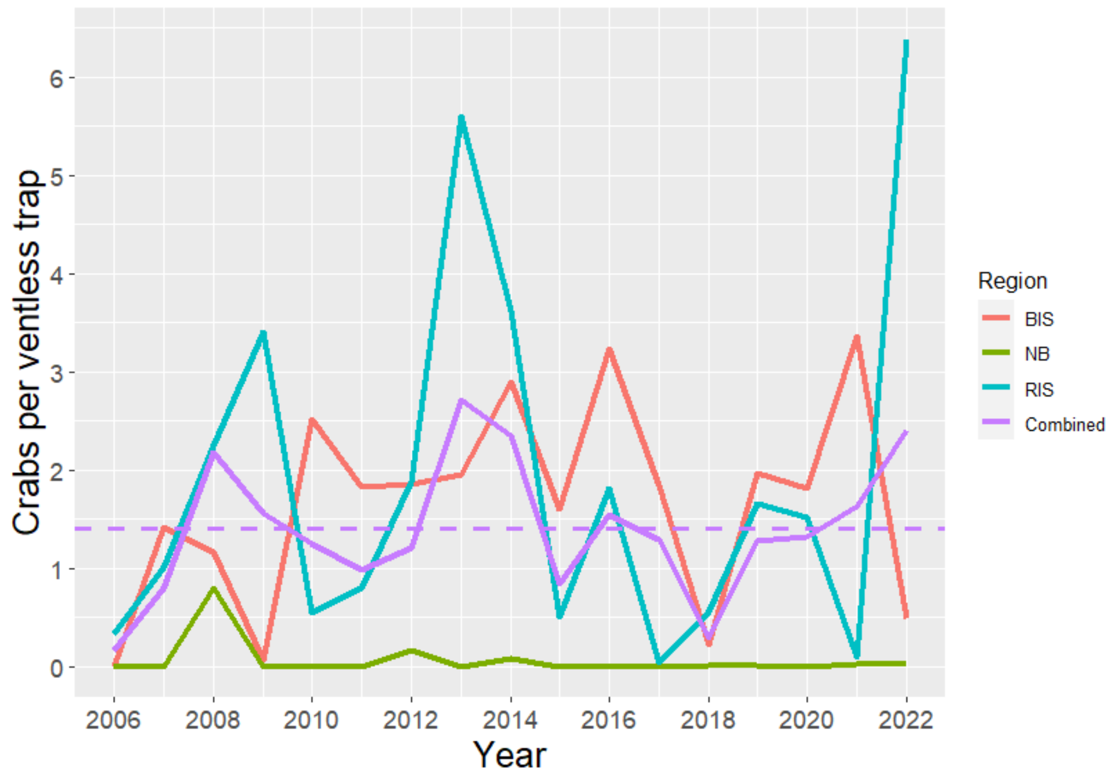


Figure 8. Rhode Island ventless trap survey index of Jonah crab abundance by region: Narragansett Bay (NB), Rhode Island Sound (RIS), and Block Island Sound (BIS). Time series mean for the combined region is presented as a dashed purple line.

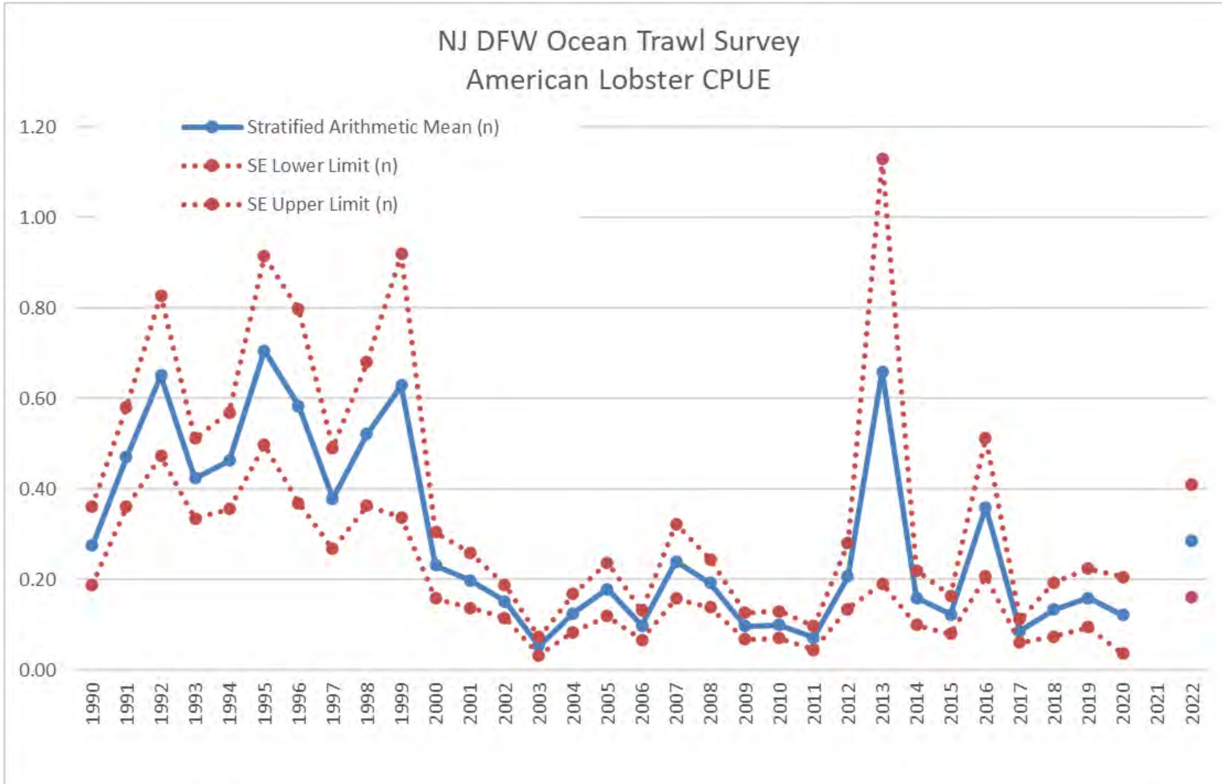


Figure 10. Stratified mean CPUE of all Jonah crab collected aboard the NJDFW Ocean Trawl Survey. The survey stratifies sampling in three depth gradients, inshore (18'-30'), mid-shore (30'-60'), offshore (60'-90'). The mean CPUE was calculated as the sum of the mean weight (in kg) of Jonah crab per size class collected in each sampling area weighted by the stratum area. ***NOTE: No April 2019 Survey was conducted due to Research vessel mechanical issues. Due to the COVID-19 pandemic, Apr-Oct 2020 and 2021 CPUE and indices were not obtained.**

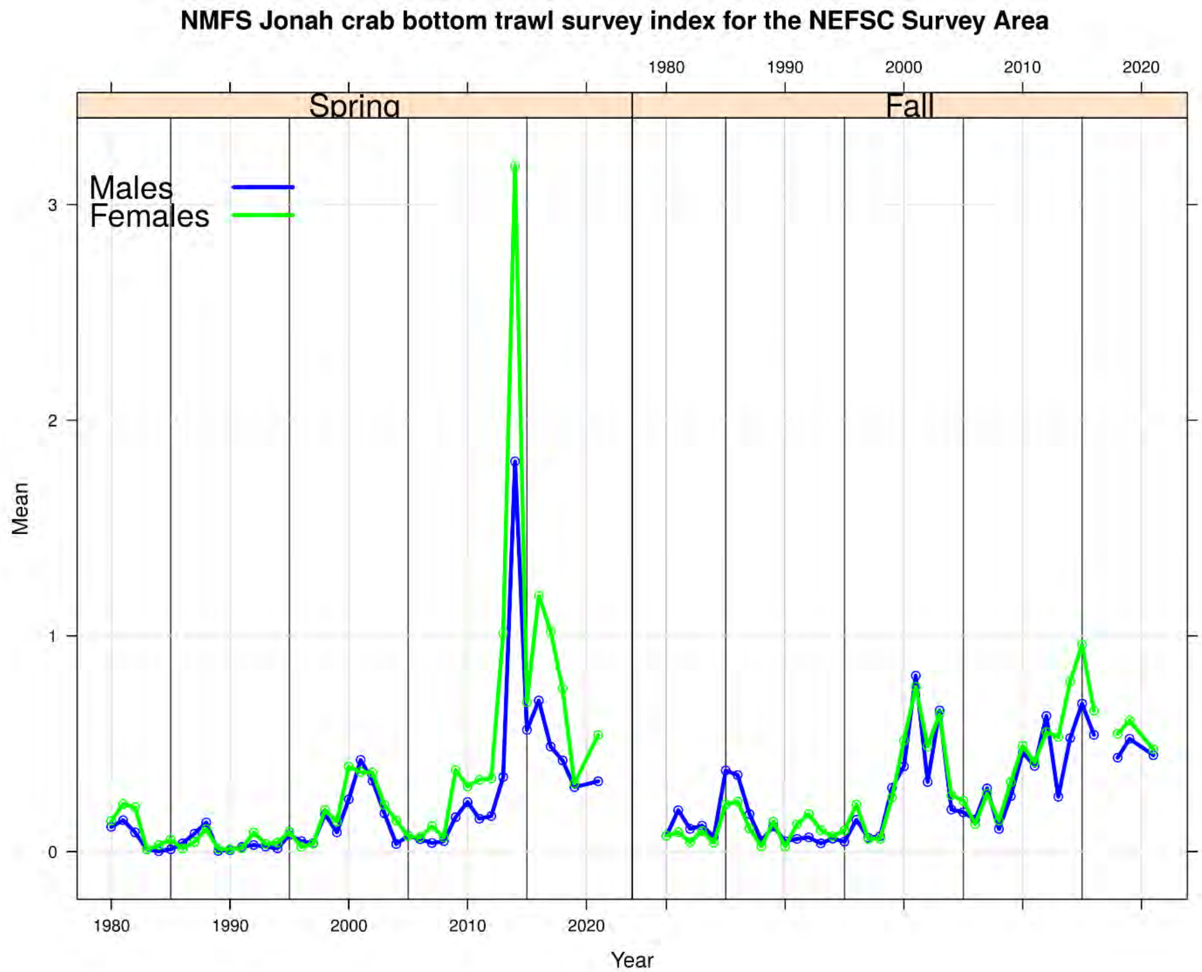


Figure 11. NMFS Jonah Crab index (mean number per tow) from the bottom trawl survey for the NEFSC Survey Area, through fall 2021 There was no survey conducted in 2020 due to the COVID-19 pandemic.

Atlantic States Marine Fisheries Commission

Tautog Management Board

October 16, 2023
1:00 – 1:45 p.m.
Hybrid Meeting

Draft Agenda

The times listed are approximate; the order in which these items will be taken is subject to change; other items may be added as necessary.

1. Welcome/Call to Order *(M. Luisi)*	1:00 p.m.
2. Board Consent • Approval of Agenda • Approval of Proceedings from August 2023	1:00 p.m.
3. Public Comment	1:05 p.m.
4. Consider Technical Committee Report on Commercial Tagging Program (*J. Boyle)* **Possible Action** • Discuss Potential Changes to the Tagging Program	1:15 p.m.
5. Other Business/Adjourn	1:45 p.m.

The meeting will be held at Beaufort Hotel (2440 Lennoxville Road, Beaufort, North Carolina; 252.728.3000) and via webinar; click here for details

MEETING OVERVIEW

Tautog Management Board
October 16, 2023
1:00 - 1:45 p.m.
Hybrid Meeting

Chair: Mike Luisi (MD) Assumed Chairmanship: 11/21	Technical Committee Chair: Craig Weedon (MD)	Law Enforcement Committee Representative: Jason Snellbaker (NJ)
Vice-Chair: Justin Davis (CT)	Advisory Panel Chair: Vacant	Previous Board Meeting: August 2, 2023
Voting Members: MA, RI, CT, NY, NJ, DE, MD, VA, NMFS (9 votes)		

2. Board Consent

- Approval of Agenda
- Approval of Proceedings from August 2, 2023

3. Public Comment – At the beginning of the meeting public comment will be taken on items not on the agenda. Individuals that wish to speak at this time should use the webinar raise your hand function and the Board Chair will let you know when to speak. For agenda items that have already gone out for public hearing and/or have had a public comment period that has closed, the Board Chair may determine that additional public comment will not provide additional information. In this circumstance, the Board Chair will not allow additional public comment on an issue. For agenda items that the public has not had a chance to provide input, the Board Chair may allow limited opportunity for comment. The Board Chair has the discretion to limit the number of speakers and/or the length of each comment.

4. Consider Technical Committee Report on Commercial Tagging Program (1:15-1:45 p.m.) Possible Action
Background • The commercial harvest tagging program was fully implemented by all states in 2021. • In response to a Board request at the August meeting, the Technical Committee (TC) discussed potential alternative tags and how to evaluate them **(Briefing Materials)**.
Presentations • Technical Committee Report by J. Boyle

5. Other Business/Adjourn

Tautog

Activity level: Low

Committee Overlap Score: High (Menhaden, BERP, Summer Flounder, Scup, and Black Sea Bass)

Committee Task List
• TC – May 1, 2023: compliance reports due

TC Members: Craig Weedon (Chair, MD), Alexa Kretsh (VA), Coly Ares (RI), Linda Barry (NJ), Sandra Dumais (NY), Scott Newlin (DE), David Ellis (CT), Sam Truesdell (MA), Alexei Sharov (MD), Joshua McGilly (VA), James Boyle (ASMFC Staff)

SAS Members: Coly Ares (RI), Linda Barry (NJ), Alexei Sharov (MD), Sam Truesdell (MA), Jacob Kasper (UCONN), Katie Drew (ASMFC Staff), James Boyle (ASMFC Staff)

DRAFT PROCEEDINGS OF THE

ATLANTIC STATES MARINE FISHERIES COMMISSION

TAUTOG MANAGEMENT BOARD

The Westin Crystal City
Arlington, Virginia
Hybrid Meeting

August 2, 2023

These minutes are draft and subject to approval by the Tautog Management Board.
The Board will review the minutes during its next meeting.

TABLE OF CONTENTS

INDEX OF MOTIONS

1. **Approval of agenda** by consent (Page 1).

2. **Approval of Proceedings of January 25, 2022** by consent (Page 1).

3. **Move to approve the Fishery Management Plan Review, state compliance reports, and *de minimis* requests for DE and MD for the 2022 fishing year** (Page 3). Motion by Emerson Hasbrouck; second by John Clark. Motion passes by unanimous consent (Page 3).

4. **Move to task the Technical Committee with evaluating the feasibility of using the smaller tag and any tag that has not been previously tested that may meet the goals and objectives of the tagging program** (Page 12). Motion by Jesse Hornstein; second by John Clark. Motion passes by unanimous consent (Page 12).

5. **Move to approve Nicholas Marchetti of NY to the Tautog Advisory Panel** (Page 14). Motion by Jesse Hornstein; second by Jason McNamee. Motion passes by unanimous consent (Page 14).

6. **Move to nominate Dr. Justin Davis as Vice-Chair of the Tautog Board** (Page 14). Motion by John Clark; second by Raymond Kane. Motion passes by consent (Page 14).

7. **Move to adjourn** by consent (Page 14).

These minutes are draft and subject to approval by the Tautog Management Board.
The Board will review the minutes during its next meeting.

ATTENDANCE

Board Members

Dan McKiernan, MA (AA)
Raymond Kane, MA (GA)
Sarah Ferrara, MA, proxy for Rep. Peake, MA (LA)
Jason McNamee, RI (AA)
Eric Reid, RI, proxy for Sen. Sosnowski (LA)
Justin Davis, CT (AA)
Bill Hyatt, CT (GA)
Jesse Hornstein, NY, proxy for B. Seggos (AA)
Emerson Hasbrouck, NY (GA)
Joe Cimino, NJ (AA)
Jeff Kaelin, NJ (GA)
Adam Nowalsky, NJ proxy for Sen. Gopal (LA)
John Clark, DE (AA)
Roy Miller, DE (GA)
Michael Luisi, MD, proxy for L. Fegley (AA)
Russell Dize, MD (GA)
David Sikorski, MD, proxy for Del. Stein (LA)
Pat Geer, VA, proxy for J. Green (AA)
Shanna Madsen, VA, proxy for Sen. Mason (LA)
Bryan Plumlee, VA (GA)
Chris Wright, NOAA

(AA = Administrative Appointee; GA = Governor Appointee; LA = Legislative Appointee)

Ex-Officio Members

Craig Weedon, Technical Committee Chair

Staff

Bob Beal
Toni Kerns
Madeline Musante
Tina Berger
Jeff Kipp
Tracy Bauer
James Boyle
Caitlin Stark
Katie Drew
Geoff White
Kurt Blanchard
Kristen Anstead
Chelsea Tuohy

Guests

Max Appleman, NOAA
Mike Armstrong, MA DMF
Pat Augustine
Alan Bianchi, NC DMF
William Brantley, NC DMF
Jeff Brust, NJ DEP
Margaret Conroy, DE DNREC
Heather Corbett, NJ DEP
Jeff Deem, VMRC
Alexa Galvan, VMRC
Lewis Gillingham, VMRC
Angela Giuliano, MD DNR
Joseph Grist, VMRC
Yan Jiao, Virginia Tech
Kris Kuhn, PA F&B
Joshua McGilly, VMRC
Brandon Muffley, MAFMC
Brian Neilan, NJ DEP
Thomas Newman
Bryn Pearson
Nicole Pitts, NOAA
Bob Pride, MAFMC
Tara Scott, NOAA
McLean Seward, NC DMF
Chad Thomas, NC Marine & Estuary Foundation
Sam Truesdell
Mason Trumble, CT DEEP
Tor Vincent
Mike Waine, ASA
Paul Wolfe
Erik Zlokovitz, MD DNR

These minutes are draft and subject to approval by the Tautog Management Board.
The Board will review the minutes during its next meeting.

The Tautog Management Board of the Atlantic States Marine Fisheries Commission convened in the Jefferson Ballroom of the Westin Crystal City Hotel, Arlington, Virginia, via hybrid meeting, in-person and webinar; Wednesday, August 2, 2023, and was called to order at 4:00 p.m. by Chair Michael Luisi.

CALL TO ORDER

CHAIR MICHAEL LUISI: Welcome everyone. I would like to call this meeting of the Tautog Management Board to order. My name is Mike Luisi; I am an Administrative Proxy for the state of Maryland. I'm your current chair, so I'll be chairing the meeting today. With me to my left, I have the Technical Committee Chair, Craig Weedon, also from Maryland. Joining me to my right is James Boyle, who is our FMP Coordinator, as well as Dr. Drew, who will be providing information to us today.

APPROVAL OF AGENDA

CHAIR LUISI: With that let's go ahead to our first item on the agenda, which is the Approval of the Agenda. Does any member of the Board have any modifications they would like to see made to the agenda? Are there any objections to the approval of the agenda? Seeing none; consider the agenda approved.

APPROVAL OF PROCEEDINGS

CHAIR LUISI: Our next item on today's agenda is Approval of Proceedings from the January 25, 2022 meeting. It seems like an awful long time ago, and I guess it is. It's been a while since this Board has been together. Are there any additions, edits, anything to report regarding the proceedings? Okay, seeing none; are there any objections to approving the proceedings? Seeing none; let's consider the proceedings approved.

PUBLIC COMMENT

CHAIR LUISI: The next item on our agenda is Public Comment. This Board will entertain public comment on items that are not on today's agenda from any member of the public. I don't see any in the crowd, Tor. No, I'll come to you during the tagging discussion that we plan to have in just a bit. This would be for items that are not on the agenda.

Do we have anyone online? Okay, no one is online, so we'll go ahead and move past public comment to our first item on today's agenda.

CONSIDER APPROVAL OF FISHERY MANAGEMENT PLAN REVIEW AND STATE COMPLIANCE FOR 2022 FISHING YEAR

CHAIR LUISI: For presentation purposes, we're here to Consider Approval of Fishery Management Plan Review and State Compliance for the 2022 Fishing Year. I'm going to turn that over to James for the FMP Review presentation, so take it away.

MR. JAMES BOYLE IV: Good afternoon, everyone, I'll be presenting the Tautog FMP review for 2022 fishing year. On the screen is an overview of the sections of the report that I'll be reviewing briefly. There is the status of the FMP, status of the stock, status of the fishery, before getting into the compliance requirements like biological sampling requirements, and an update on the commercial tagging program. Tautog has been managed under Amendment 1 since its approval in 2017, which established a commercial tagging program and delineated a stock into four regions, each with individual spawning stock biomass and mortality targets.

The only reported regulatory change for 2022 was in Rhode Island, which implemented a maximum size to their recreational regulations, such that only one fish of the bag limit may be above 21 inches. Their possession limits and minimum size remain unchanged, and the document notes that Massachusetts has implemented a complementary change for 2023.

The status of the stock has not changed since the previous review for Fishing Year 2021. It is based on the 2021 stock assessment update, which found improvements in most regions from the 2017 assessment. Overfishing was no longer occurring in any region as of 2020, with only the New Jersey/New York Byte Region remained overfished, although the spawning stock biomass did trend upward in that region between those two assessments.

For historical context, since 1981 total coastwide harvest peaked at 22.5 million pounds in 1986. Since then, harvest has declined significantly, starting even before state restrictions were implemented. Total harvest has averaged approximately 7.8 million pounds per year, since 1996, when the FMP was first approved.

In 2022, nonconfidential commercial landings amounted to approximately 541,950 pounds, which is about a 28 percent increase from 2021, and accounted for approximately 6 percent of the total coastwide harvest. On a state level, New York had the most commercial landings of tautog in 2022, with 73 percent of the coastwide total, and Massachusetts landed the second most with approximately 13 percent of the coastwide total.

Additionally, Massachusetts and Rhode Island commercial landings both exceeded their state quotas by 15 percent and 1 percent respectively, and the states have adjusted their 2023 quotas to account for these overages. Tautog is predominantly taken by the recreational fishery, about 96 percent on average by weight.

Coastwide anglers harvested historic highs of over 20 million pounds of tautog in 1986 and 1992. Since then, harvest has declined, fluctuating between 3.4 million pounds and 13.2 million pounds, which was in 2021. The 2022 harvest is estimated at 8.8 million pounds, which was an approximate 33 percent decrease from that high in 2021.

For biological sampling, the only note was that Virginia was unable to meet the 200-age sample requirement in 2022, due to the dispersed and inconsistent nature of the fishery in the state. Virginia was able to collect 181 samples. In light of the small difference, the PRT recommends the Board find all states in compliance with the sampling requirements of the FMP.

For de minimis status, Maryland and Delaware both continue to request de minimis status, and meet the criteria based on their commercial landings, and the PRT is recommending approval of their requests. For the commercial tagging program, 2022 was the second year where every state participated, and state by state tagging information is summarized more thoroughly in the document. Overall coastwide, the percentage of issued tags that were returned vary between 17 percent and 66 percent, and the coastwide return rate was 31 percent. The PRT noted that preliminary estimates show there were just under 13,000 tags unaccounted for coastwide, which is about 5.1 percent of tags issued. These are primarily in Rhode Island and New York, and although it is a 30 percent decrease from 2021 unaccounted for tags, which is just a little over 18,000.

While there is a notable improvement, the PRT is still recommending that states work to reduce the number of tags unaccounted for, and more information on the tagging program will follow in upcoming presentations from the Technical Committee and Law Enforcement Committees. With that, the Board action for consideration today is to approve the 2022 Tautog FMP Review and the de minimis requests for Delaware and Maryland, and with that I will accept any questions.

CHAIR LUISI: Any questions? Emerson Hasbrouck.

MR. EMERSON C. HASBROUCK: I don't have any questions, but when you're ready for a motion to accept the review, I'll make that motion.

CHAIR LUISI: Okay, let me see if anyone has any questions first. Seeing no hands; I think staff have prepared a motion. We can get that up and then I'll come to you, Emerson.

MR. HASBROUCK: Move to approve the Fishery Management Plan Review, state compliance reports and de minimis requests for Delaware and Maryland for the 2022 Fishing Year.

CHAIR LUISI: We have a motion, second by John Clark. Discussion on the motion? **Is there any discussion? Is there any objection to the motion? Seeing none; the motion carries by consent**, thank you very much, James for the presentation.

CONSIDER COMMITTEE REPORTS ON COMMERCIAL TAGGING PROGRAM AND POSSIBLE CHANGES TO THE TAGGING PROGRAM

CHAIR LUISI: We're going to go ahead and move on to the next item on the agenda. It is the item To Consider Committee Reports on the Commercial Tagging Program and Possible Changes to the Tagging Program. There is possible action being considered here today.

TECHNICAL COMMITTEE REPORT

CHAIR LUISI: I'm going to go ahead and turn things over to our Technical Committee Chair, Mr. Craig Weedon, for that presentation, so Craig, whenever you're ready.

MR. CRAIG WEEDON: Thank you, Mr. Chair, Members of the Board. I only have seven slides. Everything I'm going to cover is in the supplemental and in your handouts as well. The TC met three times in April, May and July, to discuss the reported live market fish quality and mortality issues presumed associated with the commercial tagging requirements.

In April, we developed survey questions to standardize and distribute to the fishery participants. We wanted to drill down and focus on the market, specifically with damage and mortality and not discuss applicator issues and other things that were corrected by previous states, other states, and the learning curve over a year. We also discussed the best practice recommendation for tagging tautog in the left operculum, which was included in the Technical Guidance Document, but not mandated in the FMP. Furthermore, the TC noted that a previous study conducted by New York, used a smaller version of the current tag. It was the Dash-4 versus the 681-tag. It's a strap tag, but it's a little bit smaller. The Board went ahead and used the larger tag, to accommodate for all the serial numbers and accountability the state, the year, and everything else that needed to go on that.

The survey results, we condensed these. We have breakouts in your handouts, and backup slides for each state. This is a regional summary. Of the 176 harvesters, and there were dealers that responded, 52 percent used live storage, 44 percent reported lesions and excess damage due to the tags, and 43 percent reported fish mortality associated with the tags in the live market.

The most concerning problems were associated with the live market in New York, but other states had similar issues with the tags as well, just not at a very big scope. We're going to talk about the New York tag study that they were given the go ahead from the Policy Board. We had really high hopes for the cinch tag that they put on the tail.

They had 10 fish they held for 2 weeks, and they put the cinch tag around the tail in all the fish. These fish also had the standard operculum tags in them, and they also applied that tag and the smaller version of the tag to fins and the tail. After 15 days they realized that there was damage to the fish, so they stopped the study.

It was going to go on for 30 days and do some live market testing. They reported that to us. The next slide shows the results of the study. Basically, the damage was equal to the current tagging system, basically. It was kind of not successful and it was upsetting. We had some really productive meetings and covered some old ground, and rediscussed some situations from the market and from the tagging program.

The possibilities of using different tags for live market fish versus the unalive market fish, tradeoffs between the security of the tag design, and trying to come up with a more workable tag. We also, the merits of the program were discussed, and it was noted that the New York landings in the commercial sector went up quite a bit from ’21 to ’22. Originally, I thought it was 20 percent, but it was higher than that. I think it was around 40 percent. That was good, and we think that it was probably from better reporting.

We did reach a consensus that the tagging program should remain in place in various new studies to focus on changing the tagging location, tag size or tag type may provide relief to harvesters. Our recommendations, after discussing the potential methods to reduce the unique characters needed on each tag, the TC is recommending to the Board to consider tasking the TC with evaluating the feasibility of converting to the smaller tag.

If feasible, New York plans to conduct a study with industry to evaluate the effectiveness of the tag in the current commercial holding tanks, and possibly present this at the annual meeting. Other states are encouraged to replicate this research. Alternative tag types such as the T-Bar tag may provide a compromise with easy application and minimal impact to the marketability of the fish. But these will be offset with less security and a higher cost. That concludes my briefing.

CHAIR LUISI: Okay, thanks, Craig. Let me see if any members of the Board have any questions for Craig. John Clark.

MR. JOHN CLARK: Thank you for the presentation, Craig. Just curious as to with the tags, were all the fishermen using the actual applicator that the National Tag Company supplies, or were some of them using pliers instead, and did that make any difference?

MR. WEEDON: I’m not positive, but I think they used the proper applicator, because if you don’t you have a lot of issues with tags misfiring or bending. They are $25.00, I think most people have them by now, or they should, because the tags don’t really work well without the proper applicator.

CHAIR LUISI: Dan McKiernan.

MR. DANIEL McKIERNAN: To John’s point. I think the problem is that the applicator doesn’t hold up to salt water so well, and that could be part of the challenge. But I wonder in the long term, when we made the decision to go to the bigger tag, because we needed more information on the tag. I wonder if we could go back to how much information needs to be on the tag. I know Toni was instrumental in helping us figure that one out as we were ordering those tags.

Massachusetts buys the tags, and we hand them out for free. I’m not really interested in the more expensive tag. What is different about these tags, or the management of this program is, my state like other states that don’t have an IFQ, we need a lot of tags. Instead of giving everybody their amount of tags totally commensurate with their allocation. When you have kind of a fishery where any individual fisherman can exceed last years catch. Everybody needs surplus tags. We do our best to get them back.

But getting back to my recommendation, I wonder if we could do a combination of alpha numeric characters, to get back to that smaller tag, because that smaller tag seemed to be superior. In other words, instead of MA, maybe we could go with just one letter, because when you use letters, as we know with RM being license plates, letters help you get a hold of a lot of extra options.

CHAIR LUISI: Toni Kerns.

MS. TONI KERNS: Mike and Dan, we can definitely do that. Another thing that James and I have been talking about is the actual number of tags being ordered is becoming significantly less, I believe.

Whether or not it is few enough for every state to need to switch over to a letter to represent their state or not, I'm not sure. But several states are not ordering as many tags as we originally thought they would need.

CHAIR LUISI: Jason McNamee.

DR. JASON McNAMEE: Thanks, Craig, good job getting through that quickly and efficiently. First, like this discussion was interesting. I wonder if there is even a simpler way to code it, where each state gets the first number is the state, so we just assign 1 to Rhode Island and 2 to Connecticut, and then whatever other numbers you need. Just thinking out loud, but the idea of revisiting how to make the tags, keep the accountability but make them simpler, I think is a good way to go. Then the other way, I thought you could probably shrink the tag. I wonder if there is like any like chip tags that exist, they are probably more expensive than these metal ones, but maybe not by a lot.

All of our key cards for the hotel all have little chips in them. They are not like super expensive. We have to give all of our enforcement officers little wands or something to read them, but they'll just add more stuff onto their utility belts. Just throwing ideas out there for the TC to kind of investigate and think on.

MR. WEEDON: I did bring the tags with me, and the year and the state are in much smaller size than the actual number. We might be able to just go with smaller numbers. Then we did talk about the letters, because there are 26 combinations with a letter, versus 10 with a number. I believe we only have to shave off maybe one numeral. But we discussed this at the TC and the accountability of having tags with multiple letters is painful. Some states have more tags than others. I think that New York wanted to have the capacity for 200,000 tags. That's a lot.

CHAIR LUISI: I'm going to go to Toni, Eric Reid, I know your hand is up online, and then I'll go to John Clark after that. Go ahead, Toni.

MS. KERNS: Just a reminder to the Board as we try to think of new ideas that the tag has to be non-tamperable. That aspect of it, it can't be easy to use easily.

CHAIR LUISI: Yes, that's a good point, Toni, and I think in a minute I'm going to go to the public, where I received a demonstration prior to the meeting regarding the re-usableness of the tag that we currently use. Stay tuned for that. But also, be thinking about how you would like to task the TC in moving forward with this, given the recommendation from the TC to provide a tasking job for them between now and our next meeting. Dan, I want to come back to you in a second, let me go to Eric Reid and then John, and then I'll come over to you, Dan. Eric Reid.

MR. ERIC REID: I appreciate the presentation. On your slide, and you don't have to pull it up, about testing the two different size tags. Did I hear you right when you said there was not much difference between the size of the tags and the outcome? Was that right?

CHAIR LUISI: Craig.

MR. WEEDON: Well, the hope was that the cinch tag on the tail was going to be successful. But previously in 2016, New York did a study with Stonybrook, using a smaller tag in pretty good conditions, and they were successful without much or any fish damage. Then the test that they did recently was in a little bit harsher condition, and they had damage from all the tags.

MR. REID: Okay thanks, that's what I thought I heard you say, which honestly leaves me to believe that maybe it's the tank that is causing the damage. You know if they're using mesh rectangular tanks, you know the mesh is reasonably luff, let's say, and fish tend to swim into the corner and they get stuck in the corner, as foolish as that may sound. But a round tank with smooth hard sides might solve the problem. The fish will swim around in circles, they won't get hung up on the mesh. It's just a thought, but maybe it's not the tag, maybe it's the tank.

CHAIR LUISI: John Clark.

MR. CLARK: Just wanted to follow up some on the T-Bar tags, Craig, because I mean T-Bars are really simple to use. I was surprised to hear that they cost more, because they are usually fairly inexpensive, and they are very easy to teach people how to apply them. Do they have good retention rate in the Tog, and if so, I mean you can get a lot of information on the standard T-Bar too. Just curious.

MR. WEEDON: They've been used for a long time. New York was ready, they told me they were ready to go with that, but they weren't supposed to use that based off law enforcement guidance, because it's too easy to pull them out of the fish and put them in another fish. They didn't think it was secure enough. I think the applicator short term the cost is like $50.00, and I think it does cost a little bit more than the band tag.

Then the control is a little less, because we have one company that manufactures these. I think if we're looking at getting rid of the tagging program, I think it's a good idea, because originally, supposedly recreational fishermen were selling their fish, and I don't think someone would go through that much effort to get their own counterfeit tags and all that. But they may, I don't know.

MR. CLARK: With T-Bars, I mean the gun, once you pay the $50.00, they are plastic, so they don't have any problem. You can replace the needles. It's really simple that way, and the tags themselves, usually if you pull those out of a fish, you are usually going to bend the T-Bar hard enough so that it's not going to work that well on another fish.

CHAIR LUISI: Dan McKiernan.

MR. McKIERNAN: Craig, how many characters need to go on the tag? Did you guys look at that? Is it six?

MR. WEEDON: Well, right now we have the state and the year in small letters, taking up one column, and then we have a letter and four numbers. I believe we have to get rid of just one number, hopefully. It might be two, I think it's just one.

MR. McKIERNAN: We order like 30,000 tags, so getting back to Jason's point. If the state could be a one-character designation and the year could be a one-character designation, we need 30,000, so I need five numbers sequential, there is seven. Then maybe New York, if they need that extra character could just have a second state designation, so they can get a second set.

Would that help? I kind of feel bad. I know it was a successful trial with that smaller tag, and then at the eleventh hour we said, oh shoot, we need a bigger tag for more information. But maybe there is a creative way to reduce the amount of information.

MR. WEEDON: Right, yes sir. The band company will put the prefix, the state and a year on the opposite side as well, so maybe you could have the numbers on the inside of the mouth. I know that there was some concern from New York that the law enforcement wants to be able to read the state and the year when they're in the tank. But yes, there are some possibilities. I think they want to go ahead and test the smaller tag first, before we really get in the weeds with it.

CHAIR LUISI: Okay, any other questions for Craig? My last experience with a T-Bar tag and the very easily used applicator, it was probably 15 years ago and I was standing there in front of the Governor of Maryland with his son watching me tag a flounder, to throw back over in the coastal bays. I pushed so hard on the flounder I put the gun into the cooler that I was tagging on. Blood was going everywhere. It was a total disaster and like media event.

I'm sorry I kind of tuned that whole part of that discussion out. I have some reoccurring nightmares with that one from a long time ago. Okay, before we get to taking some action and providing guidance to the Technical Committee, and given some of the questions that have come up. I'm going to go to the public. Tor Vincent it is, right?

Yes, if you want to step up to any of the microphones here, please introduce yourself. We do have a little bit of time on the agenda here today, but if I could ask you to provide your comment regarding the tagging program. Provide your comments to me directly, and not to any individual on the Board, and to keep your comments to just a few minutes. We do appreciate you coming down.

MR. TOR VINCENT: Thanks, Mike. I showed you before that the tag you've been using has an external locking mechanism, which is easily straightened out and reused. It could go about five times generally before it breaks. That means your tags are good for five uses. The design is not nearly the tags that you originally tested, but the vendor sold you these tags.

I see what happened here is you got lost in this, we need our digits and whatever, and you forgot, you are not supposed to harm the fish, and you were supposed to have a secure tag. You blew it on both of those. Neither of those are even close to being qualified. What I also want to bring up is when you talk about tanks.

You talk about harsh conditions, whatever. The New York test was done in well water. Well water is basically sanitized water that has been sanitized in the pathogens, and it's flowing through the system and being dumped. It's a hospital set. It's the absolute cleanest thing you can create in a tank. That is not valid for testing.

A closed system is based on bacteria being in the system. It's a Petrie dish of bacteria. That's how it works. That is what takes care of the nitrates and everything in the system. Everybody knows this. You cannot tell me good conditions and bad conditions, you have to use a closed system that has all the bacteria, and we know from the history of holding fish.

You cannot put a damaged fish in there, it will get infected. This is also known in the aquarium world. When you talk about tanks, you cannot have a sharp edge in a tank. It will cut the fish. The first scratch in a fish is most likely where it becomes infected and dies. This is known. This is known science. You've created this illusion that you didn't know this. When you harm that fish and we bring a perfect fish. We cannot sell a damaged fish to the live market. We bring a perfect fish and we mutilate it with this tag, and watch these infections happen. That's on you. You absolutely should have known better, and for you to say good tank/bad tank is silly, absolutely silly.

You are responsible for what you've done here. As you get into your security issues, you have to harm the fish. Security issue, I don't even understand this bit about the T-Tag, because I've used them. They come in a rack that fits in the gun. How are you going to reuse a single tag? You can't put it in the gun by itself.

You're going to take a piece of plier and stick it in? I don't know. I mean but you already have a tag that has been able to be reused five times, and if you haven't found any. If you've had any conservation effect, I don't know that you have. I don't agree that there was a reason for this in the same way. I don't think there is enough talent around to fill all the tags that are out there, quite honestly in New York.

I don't know the states where you don't have the amount of tags, that is probably more likely where they are being reused. What happened in New York was you created this thing where oh, if you don't have a history. New York went out there and just handed out the tags with no financial, you didn't have to show any proof of commerce, just say, I caught this many fish.

There are people throwing those tags in a dumpster everywhere, and you say New York landings are up. I don't believe that is legitimate, I really don't. My landings used to be something like 3 or 4 percent of New York landings. Now they're down to like 1.5, 2 percent. The fishing hasn't changed. Those guys aren't out there. I don't see them.

A lot of the stuff you got so lost here, but the biggest thing is you need to understand what a tank is, what a commercial holding facility tank is, and all the bacteria that are involved, because if you don't, you are going to continue to fail and you are going to continue to cause economic harm like you already have.

You are definitely responsible for the economic harm you have caused, and I want to see what you do about it. I hope we don't need a legislative fix to come and look at how wrong you've got this and got away with it, because you have to figure out how you are going to take care of that damage. That should absolutely be a priority.

CHAIR LUISI: Yes, thank you very much for your comment, appreciate that. Before I turn to the Law Enforcement presentation, does anyone have any other questions for Craig? Roy Miller.

MR. ROY W. MILLER: Mike, I seem to recall a study some time ago using the T-Bar tags. I have a vague recollection of tautog were inclined to pluck them off other tautog in the tank. Does that ring any bells? Am I right in my recollection of that?

CHAIR LUISI: Again, you're bringing up the T-Bar tag, Roy. No, it doesn't. My memory is not as good as it once was. I don't remember that discussion. Maybe somebody else around the table may, but I don't, personally. Jason.

DR. McNAMEE: I don't remember it super well, but I'm pretty sure that the T-Bar tag was one of the tags that was tested in the original work that was done, where we ended up with this kind of cowier tag. Toni is saying no, but.

MS. KERNS: It might have been one of the tags that we looked at, but the only tag that we ended up water testing, I believe was the small tag. I think we put a bunch of tags out, Law Enforcement Committee said that the small tag was the least tamperable. I think Kurt is giving the report, but let Kurt discuss the non-tamperable-ness of the T-Bar tag, and then you guys can evaluate whether or not you want New York to go ahead and test that or not, based on what Kurt tells you guys about that T-Bar tag. I don't think we actually water tested it.

DR. McNAMEE: Yes, that could be right. I just was suggesting that we looked at all of your kind of standard tagging approaches.

CHAIR LUISI: You don't play poker do you, Toni? Good. As soon as you say something, you can see it all over Toni's face if you're right or wrong as you're speaking. Dan McKiernan, we'll go to you last, and then I'm going to turn to Kurt.

MR. McKIERNAN: I look forward to Kurt's report, because we were assured by Law Enforcement that when the tag was removed it became somewhat mangled, and it was kind of a dead giveaway that such a tag would have been reused, because of the distortion of the metal. I look forward to hearing from Law Enforcement on that issue.

CHAIR LUISI: Okay, with that, that is a good segue into the Law Enforcement Committee Report, and Kurt, if you could hold on, I've got one more hand waving in the air, Chris Wright.

MR. CHRIS WRIGHT: My experience of tagging fish, in the research setting and working in a wet lab, anything you put through the flesh you're going to have an infection, even if you have a clean system, like our comment had. If you're going to be holding those fish for any period of time, there is going to be an infection, and it's going to get damaged for market purposes.

Is there any other tag that you evaluated that goes through the mouth and then through the gill, or like a zip tie type of application where once it's zipped it can't be taken out unless it's cut? That would be the only thing that I can think of that wouldn't damage the fish in some way, and would still keep them marketable. Was there any evaluation of that type of a tag?

CHAIR LUISI: I think I can maybe answer this. Not that I'm aware of through the mouth and the gill, but the tag that Craig presented on that after 15 days showed some wear and tear, was a zip tie type of tag placed around the tail. I think what ended up happening is it probably just wore away the protective barrier on the fish, and then in a confined setting it became infected. But that is the only one I'm aware of, Craig, was there any other work done on anything through the mouth into the gills?

MR. WEEDON: Like our striped bass tags through the unalive market? No, not that I'm aware of.

LAW ENFORCEMENT COMMITTEE REPORT

CHAIR LUISI: Okay, let's turn to Kurt Blanchard, who is going to provide us a Law Enforcement Committee Report. Kurt, are you with us?

MR. KURT BLANCHARD: I am, thank you, Mr. Chairman. The LEC conducted a virtual meeting on July 19, 2023 to discuss the current status of the back tagging program. We were brief by staff on both the state harvester survey that the TC completed, as well as the New York assessment.

In an effort to update the January, 2022 LEC Report to the Tautog Management Board, staff proposed the following questions to the LEC for consideration. The first is, is the program working to reduce illegal harvest, and is there a quantitative or qualitative way to evaluate? The consensus was the tautog tagging requirement is effective in reducing illegal sale of unreported fish.

The rationale for the opinion is that officers are seeing fewer fish and violations in the live market, which is attributed to the reduction of illicit sale of recreationally caught fish. The tagging program has closed a path for illegal distribution, and provided a means of accountability with dealers and fishermen.

Officers still pursue and document the illegal so called back door sales of fish, but the main path for distribution has been reduced. The group also discussed the possibility that increased penalties, as implemented in New Jersey, and/or potential decrease in consumer demand, are possible explanations for reduction of fishing violations.

These finding are subjective in nature, and most states do not collect species-specific data. The inability to have consistent data points across all jurisdictions, creates a false narrative in our deliberations. Many states can provide the number of citations and/or warnings issued for documented violations, but not all states can show the number of inspections for license checks, either commercially or recreationally specific to a species.

Question Number 2, what are the areas of concern for compliance, and are these outweighing the benefit of the program? The main concern for compliance was a specific time of tagging of fish. The issue is not new to the tautog tagging requirement, and was considered at the time of implementation of this program.

Most regulations have identified that commercially caught fish must be tagged at the time of offload. This was in consideration of having a fisherman required to tag a fish at time of take. While in the middle of handling gear and/or navigating weather conditions. This becomes problematic when an inspection is being conducted at-sea or nearshore, and the fish are not required to be tagged.

Rhode Island recently changed their law to fish needed to be tagged at the time of landing. There was some discussion about shore-based fishery, where neither offload nor landing applied, and how time of possession should be considered. It was an additional comment that dealer tagging versus fisher tagging should be considered. The striped bass fishery was used as an example. The consensus was that any compliance concerns did not outweigh the benefit of this program. The third and final question was, are the tag issues causing noncompliance?

The LEC does not think the tag issues are causing noncompliance. A small amount of noncompliance that has been observed, is based on fishermen not respecting the rules. In both New York and New Jersey, officers witnessed untagged fish at dealers, with matching tags adjacent to respected fish, but not on the fish.

An additional violation was documented by Rhode Island of a dealer who was in possession of untagged fish. The belief was that this was a three-day limit of fish sold at one time. With a lack of tags, officers had difficulty in tracing the fish back to the fisherman. There was also one comment made that officers are not seeing the level of damage to fish that are being reported by the industry.

That was one comment. Mr. Chairman, that is all I have for this summary. There were a couple points brought up about the tag and consideration of what Law Enforcement feels on what we need. The two points that we wanted to make or have made in the past on the tags, are they need to be tamper-proof, and we need to have traceability. I was not involved in the original assessments of the different respective tags.

I do know that the small tag that has been referenced, I believe by Toni and others, was the one we were recommending, and willing to support. As far as the T-Bar tag, I don't have information on that. I do know it has been alleged that they are tamper-proof and they don't hold up to this type of fishery. I would suggest that if that is a tag that is being considered, that maybe we do test it, water test it and get some better information on that before we would comment. That's all I have at this time, thank you.

CHAIR LUISI: Thanks, Kurt, and I will say that given the presentation I got from Tor before the meeting started, those tags that we're currently using, he was able to demonstrate the bendability of the tip of the tip of the tag. I don't see any reason why it couldn't be used more than once. It didn't even require a lot of bending. It was just a simple twist of the wrist with a wrench. All right, so I'm going to come back for Board consideration of tasking the TC with moving forward, with some direction given. I'll start with Dan on this.

MR. McKIERNAN: I would like to just to make an observation that it was really our last-minute decision to go to the next larger tag. That was kind of a wild card in this situation, and it was demonstrated to me four or five years ago, when we first started this, that the tag that was tested, the smaller tag. You know when you do cinch it on the fish, to get it off that fish you really have to do some pretty serious bending on the tag.

I am not convinced that if we couldn't come up with a more creative, sequential marking system with the year and et cetera, that going back to what was originally tested wouldn't bring about the solution that we need. As far as whether a live tautog can be kept for long periods of time in closed system, I concede to that. But on the other hand, 95 percent of the landings of tautog are recreational, and we had a serious poaching problem. In my mind, if the commercial fishery can't figure this out, then I don't know what we would do. I would love to see us go back to that original tag and try to work with that which was developed, and see if that wasn't the answer. Maybe we veered off by going to that next larger tag.

CHAIR LUISI: Any other thoughts? Chris.

MR. WRIGHT: One of the things I did for my Master's degree was marking juvenile Atlantic salmon. One of the tagging things, which wasn't a tag, I freeze branded the juveniles, and I kept them live in a box or whatever. Did you ever consider freeze branding? We used the basically typewrite key type of things and liquid nitrogen, that would freeze them, would keep them alive.

I didn't have any mortalities from that, and it doesn't damage the fish, it just leaves it like a tattoo type of mark. That is also a possibility. There has to be something there that helps out the fisherman, and they don't lose their market, but doesn't damage the fish. But we can still enforce it, so that is the conundrum. But that might be another option.

CHAIR LUISI: All right, thanks for those thoughts, anyone else? John.

MR. CLARK: Just a practical question. If we do go back to the smaller tag, we would have to get new applicators, right? The applicator for the bigger tag, does it work with the smaller tag?

CHAIR LUISI: You need a different applicator. Dan.

MR. McKIERNAN: But that's a cheaper tag, it's a cheaper applicator. You could buy two or three of them. You're right though, but it's I don't know $25.00.

CHAIR LUISI: Forty.

MR. McKIERNAN: Small expense.

CHAIR LUISI: Let me go to Jesse, and then I'm going to ask the question to the Board as to whether or not you are supportive of the direction mentioned, at least a few times now today about continued follow up work by the Technical Committee. Go ahead, Jess.

MR. JESSE HORNSTEIN: I'm ready to make that motion, whenever you're ready.

CHAIR LUISI: It's all you.

MR. HORNSTEIN: I will move to task the Technical Committee with evaluating the feasibility of the smaller tag and any other tag that has not been previously tested, which may meet the goals and objectives of the tautog tagging program.

CHAIR LUISI: Okay, I have a motion, let me get it on the board first, Jesse, then I'll ask for a second. John, you're going to second that, okay? While they're working to get that onboard, any discussion on that motion? Jason.

DR. McNAMEE: Yes, I mean I think a good starting point, and maybe the Technical Committee has done this recently. But to go back to that, like we put a report together with the original kind of testing of the tags. I think starting there, and then kind of working their way to a potential new solution. I think it aligns with what Jesse just offered as well, but just to offer a little more guidance.

CHAIR LUISI: Dan McKiernan.

MR. McKIERNAN: I don't want to make it too open ended. I would like to get the report back from the Technical Committee about the smaller tag, without them going off into new directions. Can we get a report on that first tag, and then if they think they need to pursue a second, third and fourth tag, maybe that could be a second exercise.

CHAIR LUISI: That seems reasonable to me. I think, Craig, you mentioned that there would be a follow up at the annual meeting.

MR. HORNSTEIN: Right, yes, Mr. Chair. The timeline is pretty tight, in order to implement a new tag by the next fishing season. We're looking at October, coming back with the smaller band tag. Is the T-Bar tag authorized in this motion? I don't know if it's been tested before or not. I know that there has been a lot of success with that tag in research.

MR. WEEDON: It has.

CHAIR LUISI: Dan, I think what we can do is we can task the Technical Committee with coming back to us, even though it's a quick turnaround, coming back to us with what they can find between now and then. Then if we feel satisfied with the work they've done, we can start working towards implementing any new type of tag that is being considered, or test them further before we see that we all like the results of the work. We have a motion before us. Does anyone need any time to caucus on the motion before I call the question? I don't see any other hands being raised. Jason.

DR. McNAMEE: Just 30 seconds, I just have to ring up Eric here.

CHAIR LUISI: All right, 30 second caucus.

MS. KERNS: I do have a quick question for the Board members, especially those of you that have earlier fisheries than others. When do your fishermen order the tags? I know it's soonish, but I don't know when that is. Are the Bay states the earliest?

MR. HORNSTEIN: I think November was probably the latest. October/November was.

MS. KERNS: Okay, I just want to make sure we're thinking about that, in terms of next year. Luckily, in this case, the annual meeting is earlier.

MR. HORNSTEIN: It would be a heavy lift though, for everyone to get a new applicator.

MR. CLARK: That sounds about when we ordered them too, Toni, was around that time. They were really fast, but we don't order many. I mean a few hundred is all we ordered.

MR. LUISI: They probably dropped that order off free to you on the way down to Maryland.

MR. CLARK: I wish!

MR. LUISI: Shanna Madsen.

MS. SHANNA MADSEN: Yes, we actually order our tags pretty soon, so October might be rough for us, unless we're definitely switching over in October to the new tags, because we let people pick them up by December 1st. We actually usually order our tags sometime in about September. We can stretch it.

I think they could probably turn it around quickly, if that is the route that we intend on taking. It's also not a problem for Virginia. Frankly, we don't have a live market. We have maybe one guy who used to live tag tautog, but he hasn't done it in a long time. If worse comes to worse, and we're stuck using the old tags, it's really not a problem for Virginia.

CHAIR LUISI: Yes, I think those hurdles will be things that we will just have to deal with as states. But I think the information that we can gather from the work, from the Technical Committee work will be important in deciding how we improve this program moving forward. I'll leave it with that. Seeing no other hands; I'm going to go ahead and read the motion into the record, and then I'll call the question.

Move to task the Technical Committee with evaluating the feasibility of using the smaller tag and any tag that has not been previously tested, that may meet the goals and objectives of the tagging program. Motion made by Mr. Hornstein, seconded by Mr. Clark**. Is there any objection to the motion? Seeing no objection; the motion carries by consent.**

Thank you very much, and Craig and Kurt, thanks for the information, we look forward to your report in October.

PROGRESS UPDATE ON THE 2025 TAUTOG STOCK ASSESSMENT UPDATE

CHAIR LUISI: Moving on, we're going to go ahead to the next item on the agenda this afternoon. It's a progress update on the 2025 tautog stock assessment, and we've got Dr. Katie Drew is going to give us some information about that.

DR. KATIE DREW: The last stock assessment, as we covered in the FMP Review, was conducted in 2021 with a terminal year of 2020. We recommended that the next update be in 2024, which could be the three-year average to calculate F, and that would get us three years past the last point.

However, 2024 is an extremely heavy year for the Commission, in terms of stock assessments. We talked with the Tautog Technical Committee, and they agreed that shifting the assessment back one year to be completed in 2025 instead of 2024 would make the most sense, in terms of balancing everyone's workload, without having serious repercussions, given the status of the stock was generally favorable during the last assessment update.

That is the current plan is to conduct a stock assessment update in 2025, with a terminal year of 2024. In addition, the Technical Committee recommended putting a benchmark on the schedule for tautog. It's been a while since we've done a benchmark for this species. We have several new surveys that will have enough time to come online by a 2028 benchmark, as well as some new additional modeling tools.

We can sort of explore moving from the current ASAP framework into something more like BAM or stock synthesis, as well as kind of reevaluating the stock structure context. There is a number of improvements that can be made, and a benchmark would be beneficial, and so we recommend actually formally scheduling one of those for tautog for 2028, after the next assessment update. I'm happy to take any questions on that, but that is kind of the recommendation from the TC to make that change for our stock assessment schedule.

CHAIR LUISI: Let's see if anyone has any questions, and then I'll look for support of the recommendation on delaying the assessment a year. John Clark.

MR. CLARK: Katie, I was just curious as to whether we're going to be looking into the affect on catchability of the prevalence of spot lock now, that recreational fishermen can use to hold themselves right over good tautog fishing areas. It seems to really have increased the number of tog that recreational fishermen catch.

DR. DREW: We can definitely look into that. It's not something we've discussed. I think it would probably be, we would have to do some additional work on trying to link what we see in the MRIP intercept data with things like, who is using what, who is not, things like that. But it is definitely something we can look into as a potential change in catchability over time, for what is an important index for us.

CHAIR LUISI: Jason.

DR. McNAMEE: Thanks, Katie, and like completely support what you guys are trying to do. Just to offer additional support for investigating platforms that have more integration for the spatial aspects, I think is super important and needs some time. That is all good. I wonder if there is an ability. I'm a little nervous, it's like a little way off.

Is there like a chance somewhere between now and then, to kind of just investigate indices or, I don't know just see if there is any. Maybe you guys have done this. Are there any negative signals out there? I think harvest has been fairly steady, or what we saw. I just would love for somebody to look at something that said no, things seem normal, between now and then.

DR. DREW: You mean between now and 2025, essentially? I think we did look at harvest removals as part of this, and recreational catch has gone up a little bit in all these in compared to where it was in 2020. Before that, 2020 obviously a weird year. It's gone up a little bit. I think we haven't looked at the indices.

But we could definitely maybe do some kind of traffic light approach or something, not a formal traffic light approach. But like in the sense of, you know where we pull the indices together and take a look at them sometime in the next year, to kind of see if there is any strong signal there. If the Board is interested in checking in on that beforehand.

CHAIR LUISI: Yes, it sounds like Jason wants a little fuzzy little blanket, to kind of tell him everything is okay, you know to hold on to. Okay, any other questions for Katie? Okay, seeing none, thank you for your report. Well, let me ask. I'll just make sure to put it on the record. Is there any objection to moving forward with the recommendation for the delay of the assessment?

Seeing no objection around the table, we'll consider that an approval. Thank you very much. We are getting close to the end here this afternoon.

REVIEW AND POPULATE ADVISORY PANEL MEMBERSHIP

CHAIR LUISI: The next item on the agenda is a Review and Populate the Advisory Panel Membership. Tina Berger is going to provide us with a presentation.

MS. TINA BERGER: I present to you for your approval, Nicholas Marchetti, a commercial rod and reel fisherman and trapper from New York. You received the nomination in your main meeting materials.

CHAIR LUISI: Okay, do we have anyone that would like to make a motion to populate the seat on the Advisory Panel? Jesse Hornstein.

MR. HORNSTEIN: I would like to **move to approve Nicholas Marchetti of New York to the Tautog Advisory Panel.**

CHAIR LUISI: Thank you very much for that, Jesse. Second by Jason McNamee. Get a good Italian on the Panel there, good stuff. **Any objection to the motion? Okay, seeing no objection, congratulations, Nicholas, if you're listening. You are now a member of the Advisory Panel.**

ELECT VICE-CHAIR

CHAIR LUISI: The last item on today's agenda is the election of a Vice-Chair. Does anyone have any motions they would like to make regarding the election of a Vice-Chair? John Clark.

MR. CLARK: I hope it doesn't come as a surprise, but **it is my pleasure to nominate our esteemed colleague from Connecticut, Dr. Justin Davis to be the Vice-Chair.**

CHAIR LUISI: Okay, is there a second. Ray Kane seconds the motion. **No discussion on the motion. No objection to the motion. I didn't see that, Justin. Okay, motion carries by consent.** I think the way that will work, Justin, we spoke of it, last night. I will serve as Chair through the annual meeting, and then you will take over.

Try not to leave it too messy for you, since we only met once in two years. I think I did okay.

ADJOURNMENT

CHAIR LUISI: Okay, that concludes our business on the agenda today. Is there any other business to come before the Tautog Management Board this afternoon? Okay, seeing no hands, thank you for your time and participation today. Thanks, Craig, Kurt, James and Dr. Drew for your presentations. This meeting stands adjourned, thank you.

(Whereupon the meeting adjourned at 5:00 p.m. on Wednesday, August 2, 2023)

Atlantic States Marine Fisheries Commission

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MEMORANDUM

August 11, 2023

Tautog Technical Committee (TC) Meeting Summary

TC Attendees: Craig Weedon (MD, Chair), Sam Truesdell (MA, Vice Chair), Lindy Barry (NJ), Sandra Dumais (NY), Josh McGilly (VA), and Coly Ares (RI)

Staff: James Boyle and Katie Drew

Other Attendees: Jesse Hornstein and Rachel Sysak (NY DEC)

The Commission's Tautog Technical Committee (TC) met via conference call on Friday, August 11th, in response to a task from the Management Board to evaluate the feasibility of using the smaller version of the current commercial tag and any tag that has not been previously tested that may meet the goals and objectives of the tagging program.

Identify Potential Alternative Tags and Discuss Methods for Evaluation

The TC discussed a number of tag options and how to study the effectiveness of those tags both within and beyond the timeframe to the Annual Meeting. The TC noted that conducting a study in time for the Annual Meeting in October limited the duration of the study, as well as the number of different tag types that could be included. Rachel Sysak presented the format for the potential study where New York would distribute 50 tags each to a number of participating dealers and harvesters, who would then provide daily survey responses and semiweekly photos to document any possible health outcomes to the fish. NY noted that if results are needed for the Annual Meeting, then it would only be possible to study the smaller version of the current tag, and the study could last no longer than two weeks. The TC decided that if results are needed for October, then they would proceed with studying the smaller tag, but that it should consider studying the T-Bar and Petersen tags over a longer period in 2024.

Atlantic States Marine Fisheries Commission

Horseshoe Crab Management Board

October 16, 2023
2:00 – 4:00 p.m.
Hybrid Meeting

Draft Agenda

The times listed are approximate; the order in which these items will be taken is subject to change; other items may be added as necessary.

1.	Welcome/Call to Order *(J. Clark)*	2:00 p.m.
2.	Board Consent • Approval of Agenda • Approval of Proceedings from May 2023	2:00 p.m.
3.	Public Comment	2:05 p.m.
4.	Consider Results of Stakeholder Survey on Delaware Bay Management Objectives *(C. Starks)* **Possible Action**	2:15 p.m.
5.	Set 2024 Delaware Bay Bait Harvest Specifications **Final Action** • Review Horseshoe Crab and Red Knot Abundance Estimates and Model Results from the Adaptive Resource Management Framework *(J. Sweka)* • Set 2024 Specifications *(C. Starks)*	3:15 p.m.
6.	Consider Approval of Fishery Management Plan Review and State Compliance for 2022 Fishing Year *(C. Starks)* **Action**	3:45 p.m.
7.	Report on Status of Synthetic Endotoxin Testing Reagents *(C. Starks)*	3:50 p.m.
8.	Review and Populate Advisory Panel Membership *(T. Berger)* **Action**	3:55 p.m.
9.	Other Business/Adjourn	4:00 p.m.

The meeting will be held at Beaufort Hotel (2440 Lennoxville Road, Beaufort, North Carolina; 252.728.3000) and via webinar; click here for details

MEETING OVERVIEW

Horseshoe Crab Management Board Meeting
October 16, 2023
2:00 – 4:00 p.m.
Hybrid Meeting

Chair: John Clark (DE) Assumed Chairmanship: 1/22	Horseshoe Crab Technical Committee Chair: Vacant	
Vice Chair: Justin Davis (CT)	Horseshoe Crab Advisory Panel Chair: Brett Hoffmeister (MA)	Law Enforcement Committee Representative: Nick Couch (DE)
Delaware Bay Ecosystem Technical Committee Chair: Wendy Walsh (FWS)	Adaptive Resource Management Subcommittee Chair: John Sweka (FWS)	Previous Board Meeting: May 3, 2023
Voting Members: MA, RI, CT, NY, NJ, DE, MD, DC, PRFC, VA, NC, SC, GA, FL, NMFS, USFWS (16 votes)		

2. Board Consent
- Approval of Agenda
- Approval of Proceedings from May 2023

3. Public Comment – At the beginning of the meeting public comment will be taken on items not on the agenda. Individuals that wish to speak at this time must sign-in at the beginning of the meeting. For agenda items that have already gone out for public hearing and/or have had a public comment period that has closed, the Board Chair may determine that additional public comment will not provide additional information. In this circumstance the Chair will not allow additional public comment on an issue. For agenda items that the public has not had a chance to provide input, the Board Chair may allow limited opportunity for comment. The Board Chair has the discretion to limit the number of speakers and/or the length of each comment.

4. Consider Results of Stakeholder Survey on Delaware Bay Management Objectives (2:15-3:15 p.m.) Possible Action
Background • In May 2023 the Board formed a work group to develop a survey that will be distributed to stakeholders to guide the Board in evaluating management objectives for the Delaware Bay horseshoe crab bait fishery, and whether to consider future changes to management. • The survey targeted stakeholders from the Delaware Bay region including bait harvesters and dealers, fishermen who use horseshoe crab as bait, biomedical fishery and industry participants, and environmental groups. • The survey was sent to recipients on August 22 and the survey window was closed on September 25. • Survey responses were analyzed and compiled in a report of the results (**Briefing Materials**).
Presentations • Delaware Bay Stakeholder Survey Results by C. Starks

Board actions for consideration at this meeting

- Consider management response to survey results

5. Set 2024 Delaware Bay Harvest Specifications (3:15-3:45) Final Action

Background

- In September 2023, the Delaware Bay Ecosystem TC (DBETC) and Adaptive Resource Management (ARM) Subcommittee met to review results of the horseshoe crab and red knot population abundance surveys in the Delaware Bay region (**Briefing Materials**).
- The ARM model was run using three fishery-independent surveys for horseshoe crabs, various sources of horseshoe crab removals, and the estimated population of red knots to provide a recommendation for harvest specifications for Delaware Bay states in 2024 (**Briefing Materials**).

Presentations

- Horseshoe Crab and Red Knot Abundance Estimates and 2023 ARM Model Results by J. Sweka

Board actions for consideration at this meeting

- Consider ARM harvest recommendations and set 2024 specifications for states in the Delaware Bay region

6. Consider Approval of Fishery Management Plan Review and State Compliance for the 2022 Fishing Year (3:45-3:55 p.m.) Action

Background

- State Compliance Reports were due July 1, 2022.
- The Plan Review Team reviewed each state report and compiled the annual FMP Review (**Briefing Materials**).
- South Carolina, Georgia, and Florida have requested and meet the requirements of *de minimis* status.

Presentations

- FMP Review of the 2022 Fishing Year by C. Starks

Board actions for consideration at this meeting

- Accept FMP Review and State Compliance Reports for the 2022 Fishing Year.
- Approve *de minimis* requests.

7. Report on Status of Synthetic Endotoxin Testing Reagents (3:55-4:00 p.m.)

Background

- In May, The Board requested information on the efficacy of the synthetic alternatives to LAL, the endotoxin testing reagent derived from horseshoe crab blood.
- Recently, an expert committee of the US Pharmacopeia (USP) proposed a new standard, Chapter <86>, that provides additional techniques for bacterial endotoxin testing using non-animal derived reagents. The new chapter includes methods for using several reagents, including recombinant Factor C (rFC) and recombinant cascade reagents (rCR), and provides information for manufacturers of new and existing biopharmaceuticals on how to incorporate them into their quality testing.
- The USP developed a fact sheet to answer frequently asked questions on this topic (**Briefing Materials**).

• The official open comment period on the proposed standard will run from Nov. 1, 2023 through Jan. 31, 2024.
Presentations • Report on Status of Synthetic Endotoxin Testing Reagents by C. Starks

8. Other Business/Adjourn

Horseshoe Crab

Activity level: Medium

Committee Overlap Score: Low

Committee Task List
• TC – July 1st: Annual compliance reports due • ARM & DBETC – Fall: Annual ARM model to set Delaware Bay specifications, review red knot and VT trawl survey results • Stock Assessment Subcommittee – Winter, Spring, Summer: Assessment analyses and report

TC Members: Katie Rodrigue (RI), Jeff Brunson (SC), Derek Perry (MA), Deb Pacileo (CT), Catherine Fede (NY), Samantha Macquesten (NJ), Jordan Zimmerman (DE), Steve Doctor (MD), Ingrid Braun (PRFC), Ethan Simpson (VA), Jeffrey Dobbs (NC), Eddie Leonard (GA), Claire Crowley (FL), Chris Wright (NMFS), Joanna Burger (Rutgers), Kristen Anstead (ASMFC), Caitlin Starks (ASMFC)

Delaware Bay Ecosystem TC Members: Wendy Walsh (USFWS, Chair), Samantha MacQuesten (NJ), Katherine Christie (DE), Jordan Zimmerman (DE), Steve Doctor (MD), Ethan Simpson (VA), Jim Fraser (VA Tech), Eric Hallerman (VA Tech), Yan Jiao (VA Tech), Kristen Anstead (ASMFC), Caitlin Starks (ASMFC)

ARM Subcommittee Members: John Sweka (USFWS, Chair), Linda Barry (NJ), Henrietta Bellman (DE), Jason Boucher (DE), Steve Doctor (MD), Wendy Walsh (USFWS), Conor McGowan (USGS/Auburn), David Smith (USGS), Jim Lyons (USGS, ARM Vice Chair), Jim Nichols (USGS), Kristen Anstead (ASMFC), Caitlin Starks (ASMFC)

Stock Assessment Subcommittee Members: Katie Rodrigue (RI, Chair), John Sweka (USFWS), Derek Perry (MA), Linda Barry (NJ), Margaret Conroy (DE), Jeffrey Dobbs (NC), Daniel Sasson (SC), Kristen Anstead (ASMFC)

DRAFT PROCEEDINGS OF THE

ATLANTIC STATES MARINE FISHERIES COMMISSION

HORSESHOE CRAB MANAGEMENT BOARD

The Westin Crystal City
Arlington, Virginia
Hybrid Meeting

May 3, 2023

These minutes are draft and subject to approval by the Horseshoe Crab Management Board.
The Board will review the minutes during its next meeting.

TABLE OF CONTENTS

INDEX OF MOTIONS

1. **Move to approve Agenda** by consent (Page 1).

2. **Move to approve Proceedings of November 10, 2022** by consent (Page 1).

3. **Move to accept the draft BMP document as final and publish it on the ASMFC website** (Page 10). Motion by Dan McKiernan; second by Mel Bell. Motion approved by consent (Page 11).

4. **Move to pursue option 1 from the memo dated April 17, 2023 with the intent to include a wide range of stakeholders in a survey formulated by a workgroup of board members** (Page 18). Motion by Shanna Madsen; second by Rick Jacobson. Motion carried by consent (Page 19).

5. **Motion to adjourn** by consent (Page 20).

ATTENDANCE

Board Members

Dan McKiernan, MA (AA)
Raymond Kane, MA (GA)
Rep. Sarah Peake, MA (LA)
Jason McNamee, RI (AA)
Eric Reid, RI, proxy for Sen. Sosnowski (LA)
David Borden, RI (GA)
Justin Davis, CT (AA)
Rob LaFrance, CT, proxy for B. Hyatt (GA)
Jesse Hornstein, NY, proxy for B. Seggos (AA)
Emerson Hasbrouck, NY (GA)
Jeff Brust, NJ, proxy for J. Cimino (AA)
Adam Nowalsky, NJ, proxy for Sen. Gopal (LA)
John Clark, DE (AA)
Roy Miller, DE (GA)
Craig Pugh, DE, proxy for Rep. Carson (LA)
Mike Luisi, MD, proxy for L. Fegley (AA) (Acting)
Dave Sikorski, MD, proxy for Del. Stein (LA)
Russell Dize, MD (GA)
Shanna Madsen, VA, proxy for J. Green (AA)
Chris Batsavage, NC, proxy for K. Rawls (AA)
Mel Bell, SC (AA)
Malcolm Rhodes, SC (GA)
Chris McDonough, SC, proxy for Sen. Cromer (LA)
Spud Woodward, GA (GA)
Carolyn Belcher, GA, proxy for Rep. T. Rhodes (LA)
Erika Burgess, FL, proxy for J. McCawley (AA)
Gary Jennings, FL (GA)
Marty Gary, PRFC
Chris Wright, NMFS
Rick Jacobson, US FWS

(AA = Administrative Appointee; GA = Governor Appointee; LA = Legislative Appointee)

Ex-Officio Members

Brett Hoffmeister, Advisory Panel Chair
John Sweka, ARM Subcommittee Chair
Nicholas Couch, Law Enforcement Representative

Staff

Robert Beal
Toni Kerns
Madeline Musante
Tina Berger
Tracey Bauer
Emilie Franke
Chris Jacobs
Jeff Kipp
Adam Lee
Caitlin Starks

Guests

Max Appelman, NMFS
Pat Augustine, Coram, NY
Russell Babb, NJ DEP
Meredith Bartron, US FWS
Alan Bianchi, NC DENR
Nora Blair, Charles River Labs
Jeff Brunson, SC DNR
Melissa Chaplin, US FWS
Haley Clinton, NC DENR
Margaret Conroy, DE DFW
James Cooper
Deborah Cramer
Ben Dyar, SC DNR
Chiara Eisner, NPR
Jacob Espittia, FL FWC
Julie Evans
Catherine Fede, NYS DEC
Angela Giuliano, MD DNR
Shirley Goffigon, Fuji Film
Shari Heller
Berlynna Heres, FL FWC
Jay Hermsen, NOAA
Alexandria Hoffman, DE DFW
Brett Hoffmeister, AP Chair
Blaik Keppler, SC DNR
Wilson Laney
Christina Lecker, Fuji Film
Ben Levitan, Earth Justice
Samantha MacQuesten, NJ DEP
Nichola Meserve, MA DMF

These minutes are draft and subject to approval by the Horseshoe Crab Management Board.
The Board will review the minutes during its next meeting.

Guests (continued)

Steve Meyers
Allison Murphy, NOAA
Deborah Murray, SELCVA
John Pappalarado, Cape Cod Fishermen
Michael Pierdinock
Tracy Pugh, MA DMR
Zoe Read, WHYY
Allen Reneau, Fuji Film
Paul Risi, City Univ, NY
Daniel Sasson, SC DNR
Chris Scott, NYS DEC
McLean Seward, NC DENR
Jennifer Slovinski, Fuji Film
Brian Sparrow, Fuji Film
David Stormer, DE DFW
Yoshihiro Takasuga, Fuji Film
Wendy Walsh, US FWS
Megan Ware, ME DMR
Craig Weedon, MD DNR
Kristoffer Whitney, RIT
Angel Willey, MD DNR
Jordan Zimmerman, DE DFW
Renee Zobel, NH F&G

The Horseshoe Crab Management Board of the Atlantic States Marine Fisheries Commission convened in the Jefferson Ballroom of the Westin Crystal City Hotel, Arlington, Virginia, a hybrid meeting, in-person and webinar; Wednesday, May 3, 2023, and was called to order at 1:10 p.m. by Chair John Clark.

CALL TO ORDER

CHAIR JOHN CLARK: Welcome everybody; I'll be chairing the meeting. I'm John Clark from the state of Delaware.

APPROVAL OF AGENDA

CHAIR CLARK: Let's get right into this. Our first item is Approval of the Agenda. Does anybody have any questions or concerns about the agenda, any additions? Seeing none; the agenda is approved by unanimous consent.

APPROVAL OF PROCEEDINGS

CHAIR CLARK: The second question is the Approval of the Proceedings from the November, 2022 meeting. Does anybody have any comments about the proceedings? Seeing none; those are approved by unanimous consent.

PUBLIC COMMENT

CHAIR CLARK: Now we move on to Item 3, which is Public Comment. Do we have anybody signed up for public comment? Okay, is there anybody in the room that would like to make a comment about an item that is not on the agenda? Seeing none; we will move on then. Excuse me, we have an online, and Ben Levitan would like to make a comment about an item that is not on the agenda.

CHAIR CLARK: Okay, you are free to speak, Mr. Levitan.

MR. BEN LEVITAN: This is Ben Levitan from Earth Justice, and I'm speaking on behalf of New Jersey Audubon and Defenders of Wildlife. In a letter that we submitted into the supplemental materials for this meeting, we conveyed our appreciation for the Board's decision last fall to acknowledge significant public concern about red knots, and maintain a zero female bait harvest for Delaware Bay origin horseshoe crabs.

We also ask the Board to resolve an obstacle to future public participation. Specifically, going forward the public won't know in a given year whether the Board intends to maintain the zero female bait harvest, or adopt the recommendation of the new ARM model, which is expected to consistently recommend a substantial female harvest.

We're asking the Board to resolve this uncertainty by committing to provide advanced notice if it will consider authorizing a bait harvest of female horseshoe crabs. For example, the Board could commit to notifying the public no later than its summer meeting if at the annual meeting in the fall, the Board will consider authorizing a female harvest for the following fishing year.

If the Board provides that notice, concerned members of the public can submit comments and demonstrate their continued opposition to a female harvest, and if the Board doesn't provide that notice, the public will have assurance that a female bait harvest is not a live issue for the next fishing year. Without this sort of process in place, the public may feel compelled to organize against a female harvest every year, which would just waste time and resources for both the public and the Commission. But with a process like the one I just described; the Board could safeguard public participation by enabling the public to make informed choices about when to engage in the Board's decision making. Thank you.

CHAIR CLARK: Thank you, Mr. Levitan, and I believe with one of our agenda items we will at least partially address your concerns there. That was it for public comment.

CONSIDER THE WORK GROUP REPORT ON BIOMEDICAL BEST MANAGEMENT PRACTICES

CHAIR CLARK: We will now move on to Agenda Item 4, which is to Consider the Work Group Report on

Biomedical Best Management Practices, and this is an action item. Take it away, Caitlin.

MS. CAITLIN STARKS: I'll just give a presentation on the Work Group's recommendations on the Biomedical Best Management Practices. To start off with some background. As a reminder, at the August, 2022 meeting the Board agreed to form a Work Group to review the Best Management Practices for handling biomedical catch, and suggest options for updating and implementing the BMPs.

This was based on a recommendation from the Plan Development Team that no action was needed related to the Biomedical Mortality Threshold that's in the FMP, but that the Board could continue to annually review estimated biomedical mortality levels, and also form a work group to address and improve upon the Biomedical Best Management Practices.

The Work Group members are listed on the slide here, and they included state and industry representatives, who are technical experts in horseshoe crab biology at biomedical blood collection processes. The Work Group was tasked with looking at the original BMPs, which were developed in 2011, and included recommendations for best management practices for each of the steps in the biomedical process, from the point of capture to the point of release.

These BMPs are recommended but are not required by the Commission's FMP. The FMP does include some requirements that relate to biomedical collections, including the states. States are required to issue a special permit or other specific authorization for harvest for biomedical purposes, and that horseshoe crabs taken for biomedical purposes must be returned to the same state or federal waters from which they were collected.

Then additionally, the FMP requires states to report the number of biomedical horseshoes crab collected, the number bled, the number of observed mortalities, and the number of horseshoe crabs that are released alive on an annual basis. This 2023 Work Group met five times this winter and spring, and they reviewed the BMPs from 2011. The product of these meetings, which was included in your Board materials, is an updated draft BMP document.

This updated version includes additional context and background information on the biomedical industry and fishery, the purpose of the BMPs, the relevant FMP requirements and a modified list of BMPs that were recommended by the Work Group, as well as additional research recommendations. The Work Group also recommended changes to the flow chart that shows the steps in the biomedical process. On this screen is the old chart from the 2011 document, and then this is the modified chart that is recommended by the Work Group. The changes here are getting at trying to more accurately describe the process, and include the process of in-water holding of horseshoe crab between the point of capture and being transported to the facility, which was not previously recognized in the BMPs from 2011. Just to walk through this. We start at the point of collection of the horseshoe crab, and then there is the possibility that they might be held in water for a short period of time before being transported to the facility, where their blood would be collected.

At the facility they are held and inspected for bleeding, so there are some crabs that are accepted, and they would get their blood collected, and then other crabs that are rejected for reasons such as looking damaged or unhealthy would go back into holding until they can be released. All of the crabs that are bled also go into holding, and then all of the crabs together are released alive to the state or federal waters where they were collected.

All right, I'm not going to go through the recommended changes that the Work Group proposed to the BMPs themselves. I want to start by saying that the recommended changes were mostly to reorganize and streamline the BMP document. The main changes that are in the document are that the overarching BMPs that apply across the process were moved up to the top, since these are pretty important for general handling practices.

Similarly, some of the BMPs were recognized or moved to different sections, to better align with the biomedical process. As mentioned, the Work Group also added a section related to in-water holding BMPs. In general, though most of the 2011 BMPs were maintained in this document, sometimes two BMPs that were covering similar issues were combined to reduce redundancy. There were some cases where edits were made to reduce specific details like temperature ranges, in order to make the BMPs more applicable across the states or regions.

This means there is not as much detail in these BMPs as some folks might have been looking for, but the Work Group agreed that because of the range of different environmental conditions and regulations across the states, it would be difficult to specify some of these aspects in the BMPs, because what is best in one state may not be best in another state.

In the next set of slides, I'm going to go over each section of the BMPs, and highlight some of the more major changes. The first section of BMPs covers the overarching practices that apply to the whole process. In the first bullet, language was added about avoiding anoxic conditions, which was not previously addressed.

Then in the next bullet, which is avoid prolonged exposure of gills to fresh water. This was moved into this section from a different section, to make it clear that this should be avoided at all points in the process. The last two highlighted bullets were also moved up to this section from other sections.

The first of those was modified from the previous version. The 2011 version read, return to the water as soon as possible. If not being returned to the area of capture, ensure that conditions, salinity, water temperature et cetera are similar to those found at the harvest site, and the revision, which is highlighted here states, return horseshoe crabs taken for biomedical purposes to the same state or federal waters from which they were collected. This change was intended to be consistent with the language in the FMP requirement. One bullet was removed from this section, because the Work Group thought it was redundant, which was generate written procedures for all handlers of horseshoe crabs, covering all steps in the process from collection to release. There is another bullet in this section about written agreements, with outlying practices and expectations.

The next section covers the collection of biomedical horseshoe crabs. The first change is in the first bullet, which now reads, minimize tow times for targeted horseshoe crab trawl tows. The Work Group recommended removing specific tow times, which were previously defined as 20 to 30 minutes, because the Work Group felt that there was not sufficient data or information to substantiate this number.

In the second bullet on proper care and handling of horseshoe crabs while sorting and placing into bins, the Work Group recommended changes to highlight certain practices to minimize injury to crabs, so we have, avoid dropping/tossing horseshoe crabs, et cetera. Then in the fourth bullet on night collections, language was added to say, when permitted by state regulation.

This recognizes that some states do not allow collection of horseshoe crab at night. More details were added to the next bullet about not collecting or returning soft shelled or undersized horseshoe crabs, in addition to those that appear unhealthy. The last bullet was moved from a later section to this one, because the Work Group wanted to recognize that crabs that have been marked as being bled already in the last year, should be returned as soon as possible, rather than be collected and brought into a biomedical facility at all.

This whole section on in-water holding is a new addition that the Work Group recommended. In their discussions the Work Group recognized that this practice does not occur everywhere, and that there are not yet a lot of technical studies to provide guidance that could be included in the BMPs. But they did want to add the section, and provide some general guidance.

The recommendations here are to include minimized holding time, avoid overcrowding, monitor water conditions, temperature dissolved oxygen salinity, and minimize exposure to stressful conditions, as well as follow state guidelines on holding conditions where applicable. In the transport to facility section there was a minor change to add that transport containers should also be protected from heat as well as sunlight.

Then there were a few BMPs from the 2011 Work Group that the Work Group recommended be removed from this section. The first of those was a BMP that said, to maintain temperature between approximately ambient water temperature at the time of collection and 10 degrees Fahrenheit below ambient water temperature.

The Work Group discussed this at length, and they ultimately decided that the range of normal temperatures and environmental conditions and the range of states that have biomedical collections are variable, and they wanted to have BMPs that could apply across the board. They couldn't determine a temperature range that would be the same for all areas. They also recommended removing the BMP to maintain good ventilation while stacked in bins. This is because the Work Group thought there could be room for confusion with this BMP, because on one hand the horseshoe crabs need oxygen, but on the other, too much airflow could dry out the gills, and that would negatively affect respiration. To address this issue, the Work Group added language to the overarching section about avoiding anoxic conditions. In the Holding at Facility/Blood Collection section, the changes were pretty minor.

The word ideally was added to the first bullet. That recognizes that sometimes unforeseen circumstances can cause the holding time to exceed 24 hours, but the goal is to always hold the crabs for less time. Then in the third to last bullet, the Work Group suggested this edit so that it now reads, cease blood collection once blood flow rate slows, instead of the previous wording, which was bleed until the rate slows down, so that excessive bleeding is prevented.

This change was really intended to make it clear that blood collection should stop immediately at the point that the blood flow slows down. Then these are the last two sections of the BMPs. Under post blood collection holding in our last bullet, the Work Group recommended changing it from keeping crabs in the dark to keeping them in low light areas.

This is because they didn't want to give the impression that the best practice is to keep them in complete darkness. A few of the BMPs that were in this section were also moved up to the overarching section. Then lastly, there were no changes recommended for the Return to Sea section. In addition to the BMPs that were recommended, the Work Group came up with a list of research recommendations that they believe would enhance our understanding of the impacts of the biomedical process on horseshoe crabs.

They recommended studying survival rates over time, when kept in water holding ponds or pens. They recommended studying the impacts of biomedical collection processes on spawning of horseshoe crabs, comparing mortality rates across different collection methods, and estimating horseshoe crab discard mortality associated with trawling collection.

They also recommended summarizing the findings of current literature on horseshoe crab mortality associated with blood collection, and comparing those across experiments that more closely reflect the BMPs versus those that do not reflect the BMPs. They also recommend quantifying mortality rates of horseshoe crabs post blood collection, applying the BMPs in other standard biomedical industry practices, and studying conditions that minimize movement and injury of horseshoe crabs during biomedical processes such as light and density.

During their meetings there were a few other issues that the Work Group discussed, which didn't really fit into this BMP document, but the Work Group thought they were worth raising to the Board. First, the Work Group recommends that the management board task the Technical Committee with reevaluating the calculation or the coastwide biomedical mortality estimates that are presented in Commission documents.

The Work Group discussed the possibility that with our current calculation process, which adds the observed mortalities to a 15 percent estimated mortality of bled crabs. This could result in double counting of some horseshoe crab mortalities, so they would like to see this looked into, to clarify that. The Work Group also recommends the Commission's FMP be modified to use language that accurately reflect the practices used by the biomedical industry. One example here is the use of the word collection rather than harvest in the context of biomedical, because of the requirement that those crabs be released alive. Another example is the use of the word shipping in the FMP versus transport, which the Work Group thought could be misleading about the distance or time it takes to move crabs.

Then lastly, the Work Group discussed that while there are five biomedical operations along the Atlantic Coast that are licensed by the U.S. and Drug Administration, there are some other operations along the coast that are not licensed by the FDA, but are still permitted by the states to collect blood from horseshoe crabs for other purposes such as health or medical research.

They just thought it would be good to get a better understanding of these operations, so the Work Group recommends that each state provide a report back to the Board on those activities and the permitting and reporting requirements associated with them. Thanks for hanging in there through a lot of information. This is my last slide. Today, the action before the Board is to consider approving the recommended changes to the BMPs that were proposed by the Work Group. With that I can take any questions.

CHAIR CLARK: Thank you very much, Caitlin. Before we get to questions, in my cake-addled state, I rudely did not introduce that presentation. An excellent presentation was given by Caitlin Starks, who is the FMP Coordinator for Horseshoe Crab, and I'm also joined by Kristen Anstead, who as you know is our expert on all things ARM related or modeling for Horseshoe Crab. Sorry about that, too much cake. Now, on to questions. Who has questions about this? First, I have Rob LaFrance. Go ahead, Rob.

MR. ROBERT LAFRANCE: Thank you, Caitlin, for a great presentation. I guess my question now is, what is the next step? In other words, do we take this document, and does it go for public review like we would with other amendments or addenda, or is this it?

MS. STARKS: Thanks for that question. I think that is a little bit up to the Board. The 2011 BMP document did not go out for public review. It was simply this process where a Work Group was formed, they recommended BMPs, brought those back to the Board. The Board approved that list of BMPs, and it was posted on the Commission's website. Again, these are recommendations that the Commission is posting, but it is not something that is required by our FMP. If there is an intent for that to be different, then I would need guidance from that.

MR. LAFRANCE: From my own point of view, just in response to that, I would love to see this actually, because there was a fair number of people commenting on this, you know slightly differential. I think there was a lot of information provided about future research. My sense is, both of those things would be worth another go around, if you will, with some of the public who are interested, very interested in the species.

I think you're making headway, but I think there are some still, I would describe them as perhaps slightly not quite coordinated elements of what was written by this Horseshoe Coalition letter, as well as what was put together by the Working Group. My sense is it would be helpful, I think, from both people's understanding of the horseshoe crab issue, to do a little bit more outreach to the public, and perhaps spend a little time allowing people to comment on all elements of what you put together, which I think has been some really good work. Thank you.

CHAIR CLARK: Next, we have Chris Wright online.

MR. CHRIS WRIGHT: Yes, I have a couple of questions. In the one slide you added, or the group added on the word observe. Who is going to be doing the observation? Is that going to be the state law enforcement folks? That was not clarified in the edit.

MS. STARKS: Yes, thanks for that question. The Work Group did discuss that it made sense to them that it should be up to the states to decide who was doing these types of audits or observations, since they have different processes within facilities and state's regulations. They did not clarify who would be responsible for those.

MR. WRIGHT: Okay, and then the second question, that helps me, the second question was that a lot of times they tag the bled crabs, but as far as my recollection is. But for those rejected crabs, do they also tag those so we can get the mortality rate on those that are actually released?

MS. STARKS: I do not believe so.

MR. WRIGHT: They're just tagging those bled crabs.

MS. STARKS: That is my understanding.

MR. WRIGHT: I'm just wondering, because I know they were talking about recommendations regarding, you know mortality rates for those released crabs, but if we tag a proportion of those, we might be able to get some information if we tag those also, if they are already in the facility. Anyway, those are my two questions. Thank you.

CHAIR CLARK: The next question is from Dan McKiernan. Dan will pass. Any other questions? I see Justin and then Jeff. Go ahead, Justin.

DR. JUSTIN DAVIS: I guess I'll return back to Rob's earlier comment about public comment. I think I agree with Rob that there might be some benefit in sending this out for public comment. I can't see any harm in that, given that we're not up against, as I understand it, some sort of deadline to complete this.

We're probably not likely to take a look at it again anytime soon, since it's been quite a while since we updated these. But I do think, if you are interested in hearing opinions about that around the table, then we would have to think about, what do we do with that public comment? What would be the next step?

Would that public comment go back to the Working Group? And then they would have to decide if they want to make any changes to the document in response to that comment. I think that would have to be worked through. But I guess I'm just interested in hearing opinions around the table, and expect to hear something from Toni here on that.

CHAIR CLARK: Toni, do you want to take that?

MS. TONI KERNS: Just quickly in follow up, Justin, just as the Board comments on that to understand the intention. These currently are recommendations; they are not requirements of the FMP. Typically, we don't go out for public comment on things that are recommendations. Would it be the intention of the Board to ask the states to make this a requirement in some way, shape or form?

I don't know if that would be in order to get the permit this would be a requirement of the companies or not. Just as you are commenting on that, to try to have a better understanding, because what are we asking of the public on these recommendations?

CHAIR CLARK: Thanks, Toni, thank you, Justin, and next we have Jeff Brust and then Ray Kane.

MR. JEFFREY BRUST: I guess before I get to my question, I just wanted to respond to Justin. I don't really see any issue taking it to public comment, other than how you finished with, what would we do with that? To Toni's point, they are just recommendations. I appreciate that clarification, because that was going to be one of my questions.

What would we do with that public comment? I would hope that we can keep these as recommendations. I agree with a lot of the things that are in this document. I think there is enough variability across the coast and across the different collection facilities, that there is a one-size-fits-all that makes these requirements.

I would hope that we could give each facility the flexibility to work within these recommendations to use what fits their operation most appropriately. Notwithstanding that certain states can take any one of these recommendations and make them regulatory in their own state. But I don't think we're ready to make these essentially compliance criteria for all operations equally at the same time. I guess that's my response to your question.

I guess I just had one other question, maybe to Caitlin or to Kristen. There is a bullet in there that said, review current literature on biomedical collection practices, especially those that are following the BMPs to reevaluate the mortality rate. Is there any new research, or are we just going back to the studies that have already been reviewed back in what, one and a half, two decades ago? I would be just curious to know if there is anything new, or we've just got the same list that we've had for a while now. Thank you.

MS. STARKS: I believe there is one newer study that was not used, but this is something that we would be looking at through the Horseshoe Crab Assessment Update process. Regardless of what happens coming out of this meeting, it is something that would be looked at throughout that process as well.

As you remember in the 2019 benchmark, they reevaluated that estimated mortality number by doing a metadata review of all the research that is out there. But I think the thing to focus on for what the Work Group is recommending is really honing in on the experiments that followed the BMP versus those that did not. Because I think right now the 15 percent, there is a perception that this is based on all of the studies and not necessarily just those that follow the practices that are actually used.

CHAIR CLARK: Did you have follow-up, Jeff?

MR. BRUST: I thought about it, but no, I think I'm good.

CHAIR CLARK: Next, we have Ray Kane.

MR. RAYMOND W. KANE: I've never studied the physiology of a horseshoe crab, but it has come to my attention by both captains of otter trawlers and deep pickers. Is there a better way, a more appropriate way of marking a horseshoe crab that has had blood drawn, as opposed to painting a stripe on it? Because according to these harvesters that paint fades rapidly. I was wondering if there was a more appropriate way of marking the crab.

MS. STARKS: I don't think I have an answer for the most appropriate way to mark. I know that the facilities do use different methods, and the methods that they use are because they think that they are working well. I'm not sure I can answer that question for you.

CHAIR CLARK: Next, we have Roy Miller, and then Chris McDonough.

MR. ROY W. MILLER: This question is for either you, Mr. Chair, or for Caitlin. Can you refresh my memory what happens, or what you are allowed to do with a crab that succumbs as a result of the bleeding process? Can it be entered into the bait market, or are these bait market and bled crabs kept entirely separately at all times?

MS. STARKS: Thanks for the question, Roy. I can answer that. To be as clear as possible, there are crabs that are collected under a bait permit, and there are crabs that are collected under a biomedical permit. The biomedically collected crabs under a biomedical permit, may not be entered into the bait market, even if they die during the process.

The bait crabs, there are a few instances where states allow those crabs to first be bled by the biomedical facilities, in order to kind of kill two birds with one stone, in effect, and then go back to the bait market. But those crabs are always counted against the bait quota, and they are always assumed to have the 100 percent mortality rate applied to them that would apply to a bait crab.

MR. MILLER: Do you know what happens to the crabs that succumb, what their eventual distribution is?

MS. STARKS: I do not. I assume that they are put back into the environment, but I am not sure.

CHAIR CLARK: Next up we have Chris McDonough.

MR. CHRIS McDONOUGH: Yes, Caitlin, I'm just curious. On the new section in the recommendations, the in-water holding. You guys have under monitoring water conditions, you guys aren't really recommending any minimum environmental standards, and I'm assuming that is covered under the last bullet, follow state guidelines on holding conditions, because then it would depend on the location and the state.

MS. STARKS: Yes, that is correct. There are differences in the in-water conditions that these crabs are being held in. Just generally from my understanding through these Work Group discussions, there are some cases where they are held in a harbor, and some cases where they're held in a coastal bay. Those are two very different environments, and the Work Group did not have numbers to put on these things like temperature dissolved oxygen for that reason.

CHAIR CLARK: Are there any other questions? Rob Lafrance.

MR. LAFRANCE: I just wanted to follow up on Roy Miller's question having to do with those crabs that are taken in the bait market, versus those crabs that are actually utilized for biomedical purposes. When I was reading the material, I did not get a sense of what the volume of that is. I am very interested to know what percentage overall is actually being done that way. I mean there was discussion of like the 15 percent versus 100 percent. But if you could help me understand that better that would be a big help from my perspective.

MS. STARKS: Yes, I can try to clarify. A portion of the bait crabs, the total bait crabs that are taken on an annual basis, and this is again only occurring I think in one state or two. Those states have quotas for those bait crabs, and if they choose to allow some of those crabs to go to the biomedical facility first, they still are counted under their bait quota. Does that clarify it?

MR. LAFRANCE: It does, and this may be a silly question, but I want to understand. Those bait crabs, when they are going to the facility. Do they have to be treated under the same processes that would be otherwise required for those crabs that will be returned to the ocean or not?

MS. STARKS: Again, these are not requirements in the BMPs in the first place, so I would say no they are not required to be treated in a certain way. But the Work Group did discuss that these BMPs are targeted at the crabs that are intended to be released alive. If there are facilities that are doing dual use, which is bleeding of bait crabs before they go back to the bait market, then I think it is up to them how to handle those. But my understanding is that they typically follow the same processes that they use for the biomedical crabs.

MR. LAFRANCE: Thank you, that is very helpful. My concern is, if they are not, how would you know the difference when they are at the facility, right? You bring one in, it came that it's going to be tagged ultimately to be used as bait, and another one that is going to be returned to the ocean. How do you know if you are actually looking at that whether they were actually complying with that, so it's a concern?

MS. STARKS: If I could just follow up on that. My understanding is that the crabs that are brought in from the bait market are batched together, and they are not intermingled with the biomedical crabs.

MR. LAFRANCE: But that's not included in the BMPs, correct?

MS. STARKS: Accurate, yes.

MR. LAFRANCE: Again, that is one small issue that I would like to see, why I would like to be able to go out to the public on some of these smaller things, recognizing that BMPs are not requirements. But they will be looked at, I believe, as documents that the Atlantic States Marine Fisheries Commission has looked at, and will be looked to as best management practices across the industry. That is why I would like to see them reviewed publicly.

CHAIR CLARK: Thank you, and I see we have a question from Craig Pugh.

MR. CRAIG PUGH: Yes, and Mr. Lafrance's comments. These BMPs seem to be quite micro managerial as the fishery conducts itself, as far as I can point to one example right now. The tow times of the dredge are generally dictated by depths and bottom structure, you know dictating the time. If you're going to regulate that and put it into like a regulatory program that would be certainly hard to enforce.

I think if you're going to look at this, we have to take a much, much deeper and harder look at these managerial micromanaging points that they've explained in here. I would take issue with some of those, maybe because I'm not so sure that most people in this room are aware of that type of fishing and what it takes to get that part of it done.

MR. LAFRANCE: If I might respond, Mr. Chair.

CHAIR CLARK: Go right ahead, Rob.

MR. LAFRANCE: Thank you for those comments, I wouldn't disagree. I guess part of what I'm trying to say is, I'm not just looking for one side to make comment. I would also be interested to hear from the industry on what their concerns may be or not be, in terms of I understand there were representatives there. But sometimes representatives don't represent the entire industry. Again, I'm looking at this more from a transparency perspective for what the Board does on a document that ultimately will be looked at as the Board's work thing.

CHAIR CLARK: Are there any other questions? I'm not seeing any hands. Anybody remotely? Chris Wright, you have another question?

MR. WRIGHT: No, sorry. I didn't put my hand down from prior.

CHAIR CLARK: All right then, we've had a discussion here, a good amount of questions. Our next step on this, this is an action item, so because these are just recommendations, are we moving to approve them or accept them, or what's the deal here?

MS. STARKS: Yes, so I think that the Board could choose to approve the modifications that were made by the Work Group or recommended by the Work Group. If that is the route that the Board were to go today, we would post that new document online in place of the old one. If there is a desire to do something different, other than approve these, then I would need some kind of guidance. Thanks.

CHAIR CLARK: Bob.

EXECUTIVE DIRECTOR ROBERT E. BEAL: Just a question or comment. If the Board approves these recommendations as Caitlin commented, they remain that. They are still recommendations. They are not binding on the states or on the industry, they are just recommended best management practices by the Atlantic States Marine Fisheries Commission, and we'll publish them on our website and those sorts of things. I just want to be clear; they don't become binding if the Board approves them today.

CHAIR CLARK: Just to clarify also, because I know Rob brought up the question of public hearings about it or doing some sort of outreach about this. Is approving it and putting it on the website, would that preclude doing any further outreach on this? Go right ahead, Bob.

EXECUTIVE DIRECTOR BEAL: Well, you know we don't really have a mechanism to do public hearings on a suite of recommendations, recommended best management practices. You know I'm not sure where the Board is on this, but if we wanted to open up a whatever, 30-day public comment opportunity or something like that, that could be done. But again, back to maybe Justin's question of then what. What are you going to do with that feedback that you get? You could do that, I'm just not sure where we go with that.

CHAIR CLARK: Thanks, Bob. Just to maybe summarize. The Board can either approve, these will be posted as the recommendations put on the website, maybe a press release done about it, or if as you mentioned there. If the Board preferred to have like a 30-day comment period, or something to that effect, the Board could move to do something like that at this point, or that would work. We have a couple options here. Does anybody want to put forward a motion? Dan McKiernan.

MR. DANIEL McKIERNAN: Yes, I would move that we accept the draft document as final, and publish it on the ASMFC website.

CHAIR CLARK: Do we have a second? I see Mel Bell. Okay, we have a seconded motion. Once it's on the board if anybody would like to make a comment, speak to it. Of course, after you, Dan.

MR. McKIERNAN: I can speak to it, it's a pretty simple motion. Just to assure everyone that we have in Massachusetts, I'll speak for my own agency, you know a close oversite and a close working relationship with the companies involved with this. We have permit conditions on their permits that we place that are largely based on this, but in some cases are more restrictive. We will continue to work these issues, not only with the processing firms or the biomedical firms, but also with the harvesters, because there has been a shift in the harvesting makeup, or the makeup of the harvest is where more and more of our crabs are being harvested by otter trawlers, you know more than three miles from shore in some pretty productive areas. We are evolving our management strategies to accommodate that. This is a good document. You know the team put their heads together. We do recognize that there are differences among the companies, but in the locations relative to temperature and the like in salinity. I'm comfortable with the document, but it doesn't mean that we're not going more restrictive on some of the conditions.

CHAIR CLARK: Thanks, Dan. Mel, as the seconder, did you have any comments you would like to add?

MR. BELL: No, other than I think you had a good group of folks here, in terms of their experience level and they were the folks that gave this a lot of thought and input, so you got some good recommendations. I will say as Dan mentioned, we do permit this fishery, and we already have things in place that are more restrictive or more detailed than some of these. I think I'm satisfied with them.

CHAIR CLARK: Thanks, Mel, anybody have any comments? I see Rob Lafrance. Go right ahead, Rob.

MR. LAFRANCE: I was very satisfied with a notion of a 30-day comment period, allowing for people to comment. I'm not looking for digestion of that. I mean my sense is if people have a concern, they could write it in and we would record it. I don't know whether that needs to be added to this, but if it were something that was just left open, where staff could review and just send to this Board any comments that came in from the public.

I do not believe that we're going to get into the minutia of trying to deal with it. But I do think it would be helpful for all of us to understand if there are concerns. I guess I'm looking to what Bob had recommended, and wondering if we can just ask that be posted on the web, and if people want to comment they are given 30 days. I'm not looking for anything else.

MS. KERNS: Rob, I guess a question back would be, if we do post them for comment but you are approving them today, what are we doing with those comments?

MR. LAFRANCE: I think that is for the next go around, right? I mean at some point in time people are going to say they either liked them or they didn't like them and why they did or they didn't. But you're adopting them today based upon the work of the Working Group. I guess all I'm saying is, it's almost like taking an exception to a decision. You are able to put on the record why it is you didn't like it.

MS. STARKS: If I could just respond to that quickly. I think that the Work Group, first of all, did discuss that these BMPs are meant to evolve over time. The original Work Group that put them together in 2011 wrote that into the document, and this Work Group maintains that and does expect that there could be future changes to the BMPs. If we're posting it online and folks want to send in comments, we will definitely record those and keep them in our records, and send them to the Board. Next time the Board wants to revise or review these BMPs, it would just need to initiate a new process.

MR. LAFRANCE: Well, that satisfies me, so thank you.

CHAIR CLARK: Any further discussion of the motion? Seeing none; is there any need for the Board to caucus on this motion? Yes, okay why don't we take two minutes to caucus. Okay, before we call the question, we did have another comment from Chris Wright, and Chris, you are reminded to please mute yourself after you make your comment, thanks.

MR. WRIGHT: I have a question just clarifying on the motion. Is this just on the BMP document, or are we going to discuss the recommendations later that the group had?

CHAIR CLARK: This is just on the BMP document.

MR. WRIGHT: All right, are we going to have a discussion on the recommendations then?

CHAIR CLARK: Are you referring to the next agenda item? Sure, we could discuss those after we take the vote.

MR. WRIGHT: All right, thank you.

CHAIR CLARK: Okay, we've had time to caucus. I guess before we do a vote, is there any opposition to the motion? Okay, seeing none; I think we can have the motion approved by consent. Before we move on from the subject then, as Chris just brought up. He wanted to speak to the recommendations, right? Okay, I guess at this point then, since Chris, you brought it up. Would you like to make a comment?

MR. WRIGHT: Yes, I would like to just have a little discussion on the recommendations. The one recommendation that I was interested in, and we might be able to take action on now is the other non-FDA organizations that are part of the industry that are still bleeding, but we're not tracking those. I'm a little bit confused. Are we just not tracking those in the state reporting? If not, I think we might be able to get that resolved today, because in my mind we should be tracking those folks also.

MS. STARKS: I can try to respond. The conversation that happened at the Work Group level was that some of the Work Group members believe that there are other operations that are not one of the five FDA licensed biomedical facilities that do collect and bleed horseshoe crabs.

It is unclear what those facilities are and what their permitting requirements are, and that's why this came up. I do think we would need input from the states to understand if there are crabs that are being collected and bled that are not being reported by the Commission, we would need to understand that.

MR. WRIGHT: Great, and so can we at least ask the states to either report on that informally or put them in their state reports? I don't know which way the process is for that. But I would like to get an idea about that too, because I didn't know that there were other operations that were bleeding crabs, and I don't know if they are under state permit or what have you. I've been on the Horseshoe Crab Board for quite a while, and that's the first I've heard of it.

MS. STARKS: I think talking with Toni, it seems like it would be a good idea to send a questionnaire out to the Board by e-mail after this meeting, to try to get at some of these questions.

MR. WRIGHT: Yes, that sounds fair.

CHAIR CLARK: Thanks, Chris, any further comment about the recommendations? I'm not seeing any hands.

MS. STARKS: I guess I want to ask for guidance on this first recommendation about tasking the Technical Committee with reevaluating the mortality estimates. Is it something the Board would like the

TC to work on more immediately? If so, we can have that conversation.

CHAIR CLARK: Yes, Shanna.

MS. SHANNA MADSEN: Maybe this is just a clarification. I thought that when Jeff asked his question regarding this, it was clear that the biomedical mortality would be looked at when you do the stock assessment update, which is coming up.

MS. STARKS: Thank you. These are two separate issues. I know it's a little nuanced, but there is the 15 percent estimate of bled crabs that are assumed to die. That is what we are referring to with the stock assessment, where they would review all the literature related to that. Then this question is more specifically about when we calculate the number of total biomedical mortality in our Commission documents, are we double counting any mortalities? Right now, when I get reports to me from the states, that includes the number of mortalities. They have a column usually of observed mortalities, where the crabs are at some point, but from collection to release observed to die. Then we also have a 15 percent applied to any crabs that are bled. The question is getting at whether there is any double counting there.

CHAIR CLARK: Do you need further input on that, Caitlin, or Shanna, do you have a follow up?

MS. MADSEN: Well, I think Caitlin's question now I understand, is when we might want to do that. Is there something that we can roll into the stock assessment update? Like, is it necessary that we tackle that right now? I feel like we're tasking you guys with a lot of stuff, and we're talking about potentially tasking with you more things at our next decision point. I'm trying to figure out what works best.

MS. STARKS: I do believe that this is something that the Stock Assessment Subcommittee could tackle. When we do the stock assessment, we will want to validate the data on biomedical mortalities, and so I think this would fall into that.

CHAIR CLARK: That makes sense. Okay, so a new task has been added then. Okay, now is that the end of the discussion of this item, or is there anything else that anybody wants to bring up about the BMP? Oh, Mr. Beal.

EXECUTIVE DIRECT BEAL: Just back to the 30-day comment period. I'm not clear if that was a consensus of the Board. Rob brought it up. Are we doing that or not? You know if the Board wants to do it, we can do it. If there is consensus that we don't need to revisit these or have additional public comment right now. We could do it; you know obviously public comment at a later date before we update BMPs the next time. It just wasn't clear on the record of whether we're doing it now or not.

CHAIR CLARK: Well, that makes two of us, Bob. Let's see, I've got a couple of hands here. Mike Luisi and then Jeff Brust.

MR. MICHAEL LUISI: I'll just say that in my experience, I think that is more frustrating for an individual who wants to make comment to something like this, to make that comment with no expectation that the Board is going to consider making any changes at this time, as kind of what was discussed with Caitlin's idea about when this is revisited again, perhaps we could fold in some of the information we hear from the public.

I think that even if you don't open a public comment period for 30 days, you're going to get comment based on the actions that were taken as a result of the press release that goes out, that states that the Board approved these best management practices. If you're engaged in this discussion, you are going to go online.

You are going to read the BMPs, and someone is going to get an e-mail about it, probably Caitlin and John, as well as all the shark collection permits that you'll be getting soon. But that is just my take. I think you are going to hear what you're going to hear. I don't know that 30-day comment period with no action on top of that is necessary at this time. Thanks, John.

CHAIR CLARK: Jeff and then Rob Lafrance.

MR. BRUST: I think I agree completely with what Mike just said. I don't understand why we need to put a time certain on the review period. We're going to get comments. We get comments on all our other completed actions as well. It will be on the web; people can comment on it.

At some point, yes, I think that those comments should come back to the Board. You know it's been 10 years since we looked at these the last time, 12 years, maybe. Perhaps if we get a substantial number of comments, the Board hears about that and reconsider when the next update comes. But again, I don't see any need to put a time certain review period on this.

CHAIR CLARK: Thanks, Jeff, and Caitlin, you have a response.

MS. STARKS: Yes, I just kind of want to add on to something that Jeff said. Our typical process with receiving comments, outside of a specific comment period, is that if those comments come into our comment's inbox or to staff directly, we save those and we put them in the materials for the next Board meeting. Those comments would come back to you in the following meeting after they're received, and we can certainly compile them all and save them in our records for the next time the BMPs come up as well.

CHAIR CLARK: Rob, you had a comment?

MR. LAFRANCE: Yes, I did not know that was the process, so in many ways I guess I was trying to maybe simplify it, so you would only keep those for 30 days. But I mean again, to the extent that there are comments, and I think the comments are not only on the BMPs, but they are on some of your other research recommendations. I think we will get comments, and as a member of the Board I would love to see them. Since they are going to be in the next materials, I am satisfied by that as well.

CHAIR CLARK: Mel Bell, you had a comment?

MR. BELL: Yes, I was just going to say, I mean Rob is right, we'll get comments and we will see the comments, and Mike is absolutely right. My fear is having a process set up where you are actually asking for comments on something that you've already made a decision on. That wouldn't sit well with me if I was commenting. I think we've got it set up properly.

CHAIR CLARK: Was the idea that we would have that in the press release would say, if you have comments send them to the comment box? No? I'm full of good ideas. The comments will come in regardless, got it.

Are there any further comments on this subject? All right, seeing none; we are going to move on to Item Number 5, which is to Review Potential Processes and Resources Required for Evaluating Management Objectives for the Delaware Bay Bait Fishery. Caitlin, you have another presentation on this.

REVIEW POTENTIAL PROCESSES AND RESOURCES REQUIRED FOR EVALUATING MANAGEMENT OBJECTIVES FOR THE DELAWARE BAY BAIT FISHERY

MS. STARKS: Yes, you have to listen to me again. All right, so I am going to go through this pretty briefly. This is in your materials. There was a memo on this. This is just to summarize what's in that memo, to provide the Board with some ideas for thinking about evaluation of the management objectives for the Delaware Bay Horseshoe Crab bait fishery. In November, 2022, the Board adopted the revised ARM Framework with Addendum VIII, and it set specifications for 2023 for Delaware Bay bait harvest.

That was set at 475,000 males and 0 females. At this time the Board discussed forming a Work Group to evaluate the current goals and objectives for the management of the Delaware Bay horseshoe crab fishery. That is why we're bringing this back today. What we did as staff was come up with a couple of options for ways that the Board could go about evaluating these management objectives.

I'm just going to run through those really quick. The first one is a stakeholder survey, the second is a

Board/Work Group process, and the third is a more in-depth process that would look like an Ecosystem Management Objectives Work Shop, similar to the one that was done for menhaden. The stakeholder survey idea concept is that this would be our lower end of resource requirement intensity. For personnel we would be looking at ASMFC staff, along with 5 or 6 Board members to develop the survey.

We expect this would take about 4 to 6 months to put the survey together, send it out to a specific set of stakeholders, and receive those responses, and then analyze them and bring the results back to the Board. Major budget items, this is not expected to cost much, unless we want to do an in-person Work Group meeting, so that is the main thing there. Then the next suggestion is a Board/Work Group process, and this would be a more medium level resource requirement. Our personnel needs would be again, ASMFC staff, and then we would look for Board members to serve on the Work Group, as well as some Advisory Panel members and Technical Committee and stakeholder representatives to advise the Work Group, not necessarily to participate on it, but to actually bring some information to that group to help them.

We are imagining this process taking from 6 to 9 months, in which we would set up that Work Group, form the Work Group. Have a couple of meetings with the Work Group, and maybe either at or between those meetings have some consultations with the stakeholders that I mentioned, to try to help develop recommendations for potential management objectives, or changes to the management objectives for the Delaware Bay.

That group would then be responsible for producing a report that would include those recommendations and information, and bring that back to the Board. For this we would plan on having in-person Work Group meetings, in order to have a more effective conversation. That would be the major budget item.

Then the last suggestion is this type of Ecosystem Management Objectives Workshop. This is expected to be a pretty big lift, and some higher resource requirements, in terms of staff and money. For personnel we would need ASMFC staff as well as Board members and Advisory Panel members and some technical and stakeholder representatives to attend the workshop or workshops, as well as either a Workshop Chair or a hired facilitator to run that.

For this we would expect a longer timeline somewhere from 9 to 12 months. That takes a lot of planning to put something together like this. On the front end we would need more time to set up that workshop, and then the workshop would occur and we would use that to develop a report that would come back to the Board with some potential recommendations for management objectives or changes to those. As you could guess, our major budget items here would be actually having that in-person workshop with stakeholders and a facilitator.

The next steps for the Board today are to discuss what your intentions are with evaluating the Delaware Bay Management Objectives. I think it would be helpful to hear today what questions you are specifically hoping to answer through any of these processes, and maybe once we have some discussion on that we can consider if you would like to move forward with one of these or multiple of these processes today or put this on hold for now and come back to it later. With that I can take any questions.

CHAIR CLARK: Thank you, Caitlin, and as the Board remembers, the impetus for this item was the brilliant new ARM Model, which we approved in Addendum VIII. Of course, it did show that female horseshoe crabs could be harvested again, and in fact even the old ARM Model would have allowed that. The Board at the time, because of the huge amount of public consternation about that, decided male-only harvest.

We decided to move ahead with this item, to see what we want to do in the future, because of course if there is no desire for female harvest that is a whole different way to manage those species. With that, why don't we get some discussion going. The first hand I saw up was Mike, and then I've got Shanna.

MR. LUISI: I guess this is a question for either you or maybe Caitlin, perhaps even Bob or Toni. You know the way I saw the three options laid out; they were focused on resources. I just wonder if you have all given some thought about the cost benefit, the tradeoff between spending more and getting more, or spending less and having it drawn out over a longer period of time with more steps and layers, as to which one is, at the end of the day, going to be something that is most useful. What is the better bang for the buck, you know as far as taking next steps?

CHAIR CLARK: Do you want to respond to that, Toni?

MS. KERNS: I'll try, I guess. One of the things that I've been thinking about is for the Delaware states. One of the things that we talked about, I think two meetings ago, was you guys going home and talking to your fishermen, to find out if they want to harvest females or not. If the answer is no, then do we need to even do any of these things, and the Delaware Bay states could make a recommendation to the Board that you don't want to harvest females anymore.

We could do an addendum to do so, and then provide the ARM Model to address that new direction. That is how we have also thought about it, but this is what the Board had asked us to provide, so there is that thought back to you, in terms of, I guess that would be less work maybe on both ends. Not that the outcome would be similar, but similar end point.

MR. LUISI: All right, thank you.

CHAIR CLARK: Shanna.

MS. MADSEN: Thank you Caitlin and Toni for working to put these options together. I know it's a pain to have to come back and have workgroups suggested to you, so I really appreciate it. The thing I kind of wanted to start off saying is, I was a part of the original EMO Workshop. I was staffing it at that time. I don't think that we're at that point just yet.

To Toni's point, I think that the very first thing that we need to consider doing is asking that tough question, because that question is really what forms the objective statement that we have for the ARM right now. The thing that I think that I would most likely want to recommend, and I don't know if we're going to do this by motion or just by Board consent, but I would like to see us start with Option 1, which is putting together a survey to ask that very direct question.

Do our constituents want us to harvest female horseshoe crabs? If the answer is no, then I think that really helps us outline what that objective statement is. I think it might still lead us to potentially going to Option 2, because we still really as a Board need to define what our objective statement is, to help you define as the Stock Assessment Subcommittee, the ARM Workgroup.

What exactly we're asking you for, because I remember being stuck in that back and forth of being a scientist, not exactly knowing what my managers wanted. I want to make sure that we're giving you the best and most clear information possible. From my standpoint, I think that we start with Option 1, put together some very pointed questions to our stakeholders, from the Delaware Bay states, and ask exactly what they are looking for. Then we come back and reevaluate, and see what our next steps are.

But I just did want to make clear that I do not think that we are at the level of Option 3 just yet, and I do not want to put my foot on that gas pedal right now, especially given the conversation that we've just had at our last meeting, with Dr. Drew looking at that stock assessment schedule, looking at how busy all of our staff are. Let's start simple, get some answers to questions, and move forward from there. Don't overcomplicate it yet.

CHAIR CLARK: Thanks, Shanna, good suggestion. I see Rick Jacobson.

MR. RICK JACOBSON: I want to thank the Chair and the staff of ASMFC for bringing forward these three options for the Board to consider. It is exactly the kind of thing we were looking for when we first put this charge together last fall, so again, thank you very much for that. I agree too with the previous speakers that we do have a fundamental question that we need to ask ourselves first. What is the public appetite for the harvest of female horseshoe crabs from Delaware Bay?

It is a critical question, and if the answer to that question is no, it greatly simplifies all of our work moving forward, and it will define what our next steps are. The second part is, however, if we take the alternate path, and the public does in fact support the harvest of horseshoe crabs, that we will need to explore the broader array of how public sentiment needs to be factored into the ARM. Whether it's Option 1 or it's some combination of Option 2, with a survey as called for in Option 1, I'm not altogether clear. But I don't think we're at the point of Option 3 at this point.

CHAIR CLARK: Do we have any other comments? Rob Lafrance.

MR. LAFRANCE: Yes, we've had some discussions around the table about this outside and prior to today's meeting. I think I speak with Bill Hyatt, who is my Governor's Appointee, and one of the things he wants to make certain is whatever we're doing we're doing it with ecological basis. I think in his preliminary evaluation of this, he thought the Ecosystem Management approach was a good one.

But in my conversations with other folks around the table about this, the notion that we understand whether or not we're going to move forward with a female harvest or not, is a key and important question. I think once we come to some semblance of that, I just don't want to see us not think about Option 3, in the event that we get there.

In other words, even if we have females off the table, what does that mean, I mean in terms of an ecological perspective? But in parsing it out, moving from one maybe to some semblance of two makes sense? From what I've heard thus far from a technical perspective, we're probably not ready for 3, but I don't think we can forget about 3.

CHAIR CLARK: I don't believe that starting with Option 1 would preclude us moving to either of the second or third option, and Caitlin and Kristen are both nodding in agreement to that. At this point, is there anybody else who would like to make a comment? Craig Pugh.

MR. PUGH: I'm in a bit of precarious situation here. I've become one of the old new guys in our commercial fishery in Delaware, so I still remember the collection and usage of female horseshoe crab. However, just during the closure of that we have a lot younger group of commercial fishermen now that don't really realize what benefit that is.

Do we use that as a benefit here is a question that kind of conflicts me, because I grew up with the usage of that. But knowing that most of my younger generation is not aware of that experience, and have become accustomed to what we have today, the female horseshoe crab appetite, I believe has waned off in our commercial industry.

That's as honest and as truthful as I can be. I would like, however, to somehow hold on to the ability or the language to some extent, in case things were to change. Do we have that option? The sustainability and feasibility of those fisheries if become available, do we continue with that option? In some fashion I would like to see that.

But I can tell you that the overall arching that even though our commercial fishery is such a small, miniscule part of our population, would not hold water in our legislature, damn sure. More than likely, even if we allowed it here today, it would probably more than likely, legislation would be passed to eliminate that option. But how do we do this? That is my question. Maybe that is the staffs? Can we still withhold some of this, even though knowing that the appetite at this point in time is not there?

CHAIR CLARK: Caitlin, did you have a response to that?

MS. STARKS: Yes, just in general, if the Board were to go down a path that the appetite is not there, you do not want to harvest females at this time, so you were to initiate an addendum and approve that addendum that says we're only going to harvest males. The Board could always do another addendum in the future if that appetite came back.

There is always the opportunity to modify a management program in that way. Then the situation that you're in right now seems to be that you have the option to harvest females, but there is not an appetite there, so you have used the specifications process to only harvest males in the Delaware Bay. Those are kind of two different alternatives, but both have the same answer, which is not harvesting females and potentially being able to harvest them in the future.

CHAIR CLARK: Do we have any other commentors online? We do not. Based on what we've discussed here, the view of the Board seems to be to move ahead with Option 1, trying to survey if the stakeholders. I agree with Craig. You know I know in our state that even though the ARM would allow female harvest, the Board of course did not allow female harvest. We are moving ahead with just a male-only harvest. But even just the possibility of female harvest has really brought out a lot of opposition to any horseshoe crab harvest. It's definitely going to be a fraught issue, but I think the survey would be a good place to start. Do we need a motion on that, or is the Board comfortable with just moving ahead with the survey by assent? Oh, Toni.

MS. KERNS: Not a motion, I just want to make it clear that it's not our intention to send this survey to the world. We intend to hit the major stakeholders. We would like the states to make sure that their industry members are a part of that survey, and we can work with you, the four Delaware Advisory states, to make sure either we get those e-mail addresses or you guys facilitate that. But I just want to make it clear that it is not the entire public that we are sending this out to.

MR. PUGH: That lengthy process would be, I think of some benefit to those stakeholders that we have. It would, I guess sort of it may dampen hopes, but it's information I think that could be extended out, and should kind of lower the seas. I would appreciate that and welcome that.

CHAIR CLARK: Justin Davis.

DR. DAVIS: Just to follow up on Toni's comments. Would it include a broad variety of stakeholders? I mean, how is it going to work though if you send it to somebody and they send it to somebody? I mean, you can set it up somehow so it can't be distributed broader than who you distribute it to?

MS. KERNS: It will be a single-source survey, where you can't share the link.

CHAIR CLARK: Sure thing, Justin, follow up.

DR. DAVIS: Who is going to make the determination about who it gets sent to?

MS. STARKS: The Work Group. This process, Process Number 1, does still involve a Work Group of the Board being formed to develop the survey and to discuss the participants in the survey.

MS. KERNS: Just follow up, Justin, we're not trying to exclude the public, but we have just done a management document where we received 34,000 comments, and we heard from the general public on their intentions. We still want to make sure we're capturing all the stakeholders here, but we're also not looking for that many comments to have to summarize in order to provide feedback to this Board.

CHAIR CLARK: Roy Miller.

MR. MILLER: Craig and I were just discussing who constitutes a stakeholder in this particular case. Does a non-harvester like an Audubon Society member, could they be considered a stakeholder?

MS. STARKS: Yes, I think the general stakeholder groups that we discussed are the fishery, the commercial fishery for bait harvest, the biomedical fishery as well that occurs in the Delaware Bay, and then environmental groups that are also involved with the Delaware Bay ecosystem, and have been involved through the process of the development of the ARM. Those are, I think, our three main general stakeholder groups.

CHAIR CLARK: We actually have ecotourism for horseshoe crab spawning now, so something else to think of. Dan.

MR. McKIERNAN: Good luck with this. I have two recommendations, one is I think you need to broaden the stakeholder consideration from the commercial side, and not just talk to harvesters, because then you might not talk to dealers, you might talk about the users of bait. If you don't have a horseshoe crab fishery in Delaware Bay, that puts more pressure on states that do. I just want that to be understood.

Even if you don't put people from Massachusetts on that list. But I would recommend, when you do this survey you hire a facilitator, and maybe bring some of the principals together, and see if people can stop talking past one another. I think there needs to be some mediation to get some common ground.

CHAIR CLARK: Thanks Dan, and Rick you had a comment?

MR. JACOBSON: Am I correct in assuming that the array of people that will be surveyed under Option 1 will be equally broad, if not more broad, than those who would be engaged under Option 2, and that that group would be as broad or more broad than those who would be engaged in Option 3?

I ask that question, because if we're thinking the array of stakeholders that would be engaged is at its broadest at Option 1, and a subsequent action, depending on what we learn from Option 1, may lead us to further engagement through Option 2 or Option 3, then we will not have missed anyone in that first step. That is Item 1.

Since we were so clear last fall about our intent to engage the public in how we might look at the ARM Model that was adopted, and perhaps even change some of the criteria elements within the model to reflect that. It seems to me we do need to take some formal action here, as a follow up to last fall's direction to the staff, but perhaps I'm wrong.

CHAIR CLARK: Rick, you're suggesting that we need a motion. We've heard that we could do this by assent, but I don't think it hurts to have a motion. We can just go ahead and do it as a motion. Would somebody like to make that motion? Go right ahead, Shanna.

MS. MADSEN: I'm going to do this one off the cuff here. I guess I would move to pursue Option 1 from the memo dated April 17, 2023, with the intent to capture a wide range of stakeholders in a survey formulated by a workgroup of Board members. I think it was just Board members, right Caitlin? Okay, good. Then, so that we're clear, because I want to make sure that I'm taking everyone's thoughts into account. This does not preclude the Board from later pursuing Options 2 or 3 following the survey.

CHAIR CLARK: That is a most impressive motion off the cuff there, Shanna, great. Do we have a second? Rick Jacobson is second. We'll wait until that motion is up there. Okay, is that looking like what you thought it would look like? Hey Ray, go ahead.

MR. KANE: Just a friendly to the maker and the seconder. With the intent to survey a wide range of stakeholders in a formulation by a workgroup of Board members, as opposed to the way it reads now.

CHAIR CLARK: Oh, instead of to capture, to survey, is that okay with you, Shanna?

MS. MADSEN: That's fine, and then at the end of this motion I did say, not to preclude the Board from later pursuing Options 2 or 3 in the memo, just to get that up there as well. We don't need it?

CHAIR CLARK: It's not necessary. We've got two surveys in there don't we? Everything is on the fly here. How about to include in the first place, instead of survey, in the first instance of survey change to include. How does that look? Okay, Rob Lafrance.

MR. LAFRANCE: I guess I just want to understand, I think some of the dialogue here for the Board was that we weren't going to preclude Options 2 and 3. I just don't understand why we can't put that up. I mean, is it just left unsaid because of the record? I mean my sense is this may be the first step of future steps.

CHAIR CLARK: Yes, I'm leaving that to Bob.

EXECUTIVE DIRECTOR BEAL: It's obviously part of the record here, and the intent of the Board to move forward with that, depending on the results of the survey. It's fair game and it's not precluded, but it doesn't need to be necessarily in this motion.

MR. LAFRANCE: Fair enough, I just wanted to get that clarified on the record, thank you.

CHAIR CLARK: Is there any further discussion of this motion? No seeing any, I don't believe there is a need to caucus. Is there any opposition to this motion? Seeing none; let's consider it approved by consent. That ends this item.

OTHER BUSINESS

CHAIR CLARK: Oh yes, we just have Other Business. Is there any other business to come before this Board? Because we do have other business, but it's not Horseshoe Crab Board business. Chris Wright, go right ahead.

MR. WRIGHT: I have a question. Are we going to get the Board members for the Work Group now or later?

CHAIR CLARK: We're going to do that later, Chris.

MR. WRIGHT: Okay, thank you.

CHAIR CLARK: Malcolm, you have your hand up, Malcolm Rhodes. You can go right ahead.

ALTERNATIVE TO LAL SPEAKER

DR. MALCOLM RHODES: Mr. Chairman, I was trying to get in on the first discussion, and I really wanted to thank Caitlin and her Working Group for that job on the BMP. In these days we're getting into more and more multiple resistant organisms to test for sterility is vitally important.

It's much easier to not catch a disease than have to treat it, and especially as we're getting into more resistant ones. I applaud that and what this industry has done. The one thing I was wondering, if at some point, and it may be a year from now, if we could get some experts in to discuss the recombinant/synthetic LAL efficacy versus, you know the one derived from the horseshoe crabs.
More and more we see this being thrown out, and the U.S. Pharmacopeia has not allowed that for a lot of products, and especially for vaccines, because our current LAL made from horseshoe crab is the gold standard. It's hard to find any up-to-date information that I feel is acceptable, and I think it would help the Board, you know at some point, just to put a marker in, to have someone address the Board on that one issue.

CHAIR CLARK: Thank you, Malcolm, is there any response to that?

MS. STARKS: I'm not sure I'm entirely clear on the question, so I just want to ask a follow up. Is it your intent to have an external presenter come and provide information? Is that what you're asking for?

DR. RHODES: Whether it's external or internal who could do it. We've had, it may have been a decade ago, it may have been longer. The Board was addressed by someone discussing LAL and the recombinant alternatives to it. Whenever we get letters, or when you're reading the newspaper press clippings, you know, you are kind of inundated.

Well, use the synthetic, use the synthetic. I think it would be good for us to know if it is as effective, and where we are of this substance versus the recombinant alternatives. I don't know if that would come from someone in the industry, if someone in one of our groups has the expertise to go through the literature and find appropriate peer reviewed studies. But just to inform us fully about LAL. (Recording faded out)

CHAIR CLARK: Okay, thanks, Malcolm, and I think Caitlin and Bob were just discussing this, and I believe the idea was to get outside, so get an outside expert on that and definitely have that at a future Board meeting. Thank you. I see Dan has got his hand up.

MR. McKIERNAN: Yes, just a point of clarification. There is a lot of competition in that line of work. Could it be someone from an impartial party like the FDA? You know National Institute for Health, NIH, something? I hate to see some up-and-coming biomedical firm come in here and say, oh yeah, it's perfect. Do away with the wild harvest, we don't want that. It's the position of the government that it hasn't been approved on that scale, so why not the FDA?

CHAIR CLARK: Makes sense to me. I think it's something to explore all these options in the future.

MR. McKIERNAN: I appreciate Malcolm's point; I want to thank him for making that.

CHAIR CLARK: Right, it's great, obviously a very germane topic to what we've been discussing here today.

ADJOURNMENT

CHAIR CLARK: Is there anything else, any other hands out there? Not seeing any; do we have a motion to adjourn? Mike Luisi, seconded by Ray Kane. We are adjourned.

(Whereupon the meeting adjourned at 2:40 p.m. on Wednesday, May 3, 2023)

EARTHJUSTICE

September 25, 2023

Horseshoe Crab Management Board
Atlantic States Marine Fisheries Commission
1050 N. Highland Street, Suite 200 A-N
Arlington, VA 22201
comments@asmfc.org

VIA ELECTRONIC MAIL

Re: Use of the Adaptive Resource Management Model to Recommend Horseshoe Crab Bait Harvest Quotas

Dear Members of the Horseshoe Crab Management Board:

New Jersey Audubon and Defenders of Wildlife urge the Horseshoe Crab Management Board ("Board") to maintain the prohibition on harvesting female Delaware Bay-origin horseshoe crabs for bait. These comments present extensive new technical analysis by Dr. Kevin Shoemaker demonstrating that the adaptive resource management ("ARM") model[1] does not accurately represent the impact of the horseshoe crab harvest on red knots or horseshoe crabs. As a result of the ARM model's flaws—many of which are intrinsic to its core structure and functionality—utilizing the model to inform management decisions will not safeguard against "limiting the red knot stopover population or slowing recovery"[2] or violating the Endangered Species Act ("ESA"). These comments also explain why the Board must not use the ongoing stakeholder survey to initiate a resumption of the female harvest.

The ARM model ostensibly represents the connection between horseshoe crabs and red knot shorebirds (*Calidris canutus rufa*). Each year, red knots fly from as far south as Tierra del Fuego to the Arctic Circle, where they breed—a round trip that can span 19,000 miles. At a critical point in their northbound migration, after depleting much of their energy, most red knots stop at Delaware Bay as horseshoe crabs emerge from the water to spawn on the beach. By feasting on a superabundance of horseshoe crab eggs, red knots can double their body weight in under two

[1] Unless otherwise stated, in these comments, the "ARM model" refers to the version approved by the Horseshoe Crab Management Board in 2022.
[2] ASMFC, *Revision to the Framework for Adaptive Management of Horseshoe Crab Harvest in the Delaware Bay Inclusive of Red Knot Conservation (Draft for Board Review)* 25 (2021) ("ARM Report") (providing the objective statement for the ARM Framework).

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weeks.[3] With their energy restored, red knots have an improved likelihood of completing their migration and breeding successfully.[4]

In the late twentieth century, horseshoe crabs were severely overharvested. As their numbers fell, eggs on the beach grew scarcer, with devastating impacts on red knots. In 2015, the U.S. Fish and Wildlife Service ("USFWS") listed red knots as threatened under the ESA, citing "[r]educed food availability in Delaware Bay due to commercial harvest of the horseshoe crab . . . [as] a primary causal factor in red knot population declines in the 2000s."[5] The Atlantic States Marine Fisheries Commission ("ASMFC"), through its Horseshoe Crab Management Board, has regulated the harvest of horseshoe crabs for use as bait since 1998, but both red knots and horseshoe crabs remain perilously depleted compared to historical levels. Last year, the Board approved the use of a revised ARM model to process data about horseshoe crab and red knot demographics and recommend horseshoe crab bait harvest quotas.[6] The ARM framework's objectives include "ensur[ing] that the abundance of horseshoe crabs is not limiting the red knot stopover population or slowing recovery."[7]

In advance of the Board's decision to approve the revised ARM model, New Jersey Audubon and Defenders of Wildlife submitted analysis by independent consultant Dr. Kevin Shoemaker demonstrating that the model falls far short of that objective. Among other deficiencies that Dr. Shoemaker identified, the model recognizes scarcely any correlation between the abundance of horseshoe crabs and red knots. Despite the historical role of horseshoe crab overharvest in the decline of red knots, the model predicts red knot abundance will increase even if all horseshoe crabs vanish entirely from Delaware Bay. This deficiency heavily influences the harvest quotas that the model recommends. While the previous model never recommended allowing a bait harvest of female Delaware Bay-origin horseshoe crabs, the revised model is nearly certain to recommend a significant female harvest every year. Citing public concern, the Board maintained a male-only bait harvest for 2023. That is, the Board approved the ARM model but did not immediately adopt its recommended harvest quotas.[8]

The numerous flaws in the ARM model that Dr. Shoemaker previously identified thoroughly demonstrated that the model is unfit for recommending horseshoe crab harvest levels. That conclusion was evident even though Dr. Shoemaker could analyze only one component of the model because the rest was being withheld from public review. New Jersey Audubon and Defenders of Wildlife cautioned that additional flaws may emerge when the public gained access to the entire model and urged the Board to abstain from voting on the model until that time. The

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[3] New Jersey Department of Environmental Protection, *Wildlife Populations: Red Knot* 1-2 (2020), https://dep.nj.gov/wp-content/uploads/dsr/trends-red-knot.pdf.
[4] Sjoerd Duijns et al., *Body Condition Explains Migratory Performance of a Long-Distance Migrant*, 284 Proceedings of the Royal Society of London B 20171374, at 4-6 (2017).
[5] FWS, "Endangered and Threatened Wildlife and Plants; Final Threatened Status for the Rufa Red Knot," 79 Fed. Reg. 73,706, 73,707 (Dec. 11, 2014).
[6] ASMFC, Press Release, "Horseshoe Crab Board Sets 2023 Specifications for Horseshoe Crabs of Delaware Bay-Origin & Adopts ARM Framework Revision via Addendum VIII" (Nov. 10, 2022), http://www.asmfc.org/uploads/file/636d41cepr33_HSC2023DEBaySpecs_AddendumVIII_Approval.pdf.
[7] *See* ARM Report 25.
[8] See ASMFC, *supra* note 6.

entire model was finally released the evening before the Board approved it, and Dr. Shoemaker has now performed a comprehensive review.

Dr. Shoemaker's new analysis paints an even starker picture of the ARM model's unsuitability for managing the horseshoe crab bait harvest. Collectively, his two analyses make abundantly clear that the ARM model does not accurately represent the relationship between horseshoe crabs and red knots or the population status and trajectory of either species individually. As a result, the model cannot anticipate the consequences of its own harvest recommendations. Implementing the model's recommendations—especially its recommendation to resume a female horseshoe crab bait harvest—would place red knots at extraordinary risk and potentially destabilize the horseshoe crab population as well.

While red knots face a variety of threats, including beach development and climate change, the availability of horseshoe crab eggs is a key determinant of their survival and reproductive success. The Board cannot use the existence of other threats to deflect its responsibility to ensure that horseshoe crab levels do not limit the Delaware Bay stopover population or slow the recovery of red knots. To the contrary, the existence of other threats should impel the Board to exercise more precaution when setting harvest quotas.

These comments present Dr. Shoemaker's analysis and other material to make four principal points, all of which support the overarching conclusion that the Board cannot defensibly use the ARM model to set bait harvest quotas for Delaware Bay-origin horseshoe crabs:

1. **The availability of horseshoe crab eggs on the beach, not trawl survey data, is the most direct and meaningful determinant of red knot survival.**

    - The ARM model entirely ignores the most important source of data—the number of horseshoe crab eggs per square meter of beach (referred to as egg "density"). Egg density is the most direct measure of whether there are enough horseshoe crabs to fulfill the nutritional needs of red knots. Dr. Shoemaker shows that *egg density is strongly correlated with red knot survival*.
    - The ARM model's cornerstone is the relationship between two factors that bear virtually no relation: female horseshoe crab abundance data derived from trawl surveys and red knot abundance. The absence of a meaningful correlation between these data likely results from the difficulty of collecting and evaluating horseshoe crab abundance data using trawl surveys. It does not indicate that no significant correlation exists between the two species. But the ARM model mistakenly concludes that red knot population trajectories are not strongly related to horseshoe crab populations and thus that increasing the horseshoe crab harvest would scarcely impact red knots, even as it ignores egg density data that strongly show the opposite.
    - By failing to recognize the dependence of red knots on horseshoe crabs, the ARM model predicts the abundance of red knots will increase even if all horseshoe crabs suddenly disappear from Delaware Bay. By contrast, the correlation between egg density and red knot survival reveals a grave threat: if horseshoe

crab egg density stagnated at the lowest recently observed level (to say nothing of entirely disappearing), red knots would quickly plummet to near-zero levels.

2. **<u>The ARM model overestimates and misrepresents the health and resilience of red knots and horseshoe crabs at Delaware Bay.</u>**

- In order to serve as a legitimate basis for managing the ecosystem, the ARM model would need to accurately characterize the demographics of red knots and horseshoe crabs. In many key respects, the model misrepresents these demographics. As a result, its recommended harvest quotas are largely untethered from the actual condition of red knots and horseshoe crabs and would have dangerous impacts that the model cannot predict.

Red Knots

- The ARM model inaccurately concludes that the red knot lifespan is roughly three times what the data show (15 years instead of 5 years). Thus, the model assumes that red knots have many more breeding opportunities than they actually do. The model seriously underestimates the impact that one or two poor breeding years—due to a scarcity of horseshoe crab eggs, for example—can have on lifetime reproductive success and, by extension, the persistence of the species.
- When estimating red knot abundance, the ARM model draws a large number of conclusions from a very small dataset of population counts. This causes the model to falsely detect trends in the data even when no trends are present. Dr. Shoemaker tested the model with 50 sets of random, white-noise data that lacked any trend; the model spuriously detected a non-negligible trend in red knot abundance more than 80% of the time.
- The component of the model that estimates the red knot population fails standard "goodness-of-fit" tests, meaning that it does not conform to the empirical data. This failure further suggests that the model does not represent actual ecological processes. Thus, the recommended harvest quotas are unsubstantiated numbers bearing minimal connection to the condition of the ecosystem.

Horseshoe Crabs

- The ARM model estimates horseshoe crab abundance by processing data from three trawl surveys. The data from these surveys are not significantly correlated, suggesting that they largely reflect random fluctuations rather than meaningful biotic signals. By consolidating these results into a single, Delaware Bay-wide population estimate, the model manufactures a veneer of certainty that conceals the underlying prevalence of random noise.
- Beyond the inherent limitations of the trawl survey data, the model fails to adjust for confounding factors, such as water depth and temperature, that impact the survey results. When Dr. Shoemaker adjusted for these factors and reanalyzed the data, there was no conclusive trend in horseshoe crab abundance, undercutting the ARM model's claim of a modest positive trajectory.

- Dr. Shoemaker's new analysis supplements the extensive analysis submitted last year that explained how the model generates highly overoptimistic horseshoe crab population projections.

3. **<u>Implementing the ARM model's recommendations would pose a profound risk of violating the Endangered Species Act.</u>**

- ASMFC would violate the ESA by authorizing horseshoe crab harvest at levels that would "take" red knots, a federally protected species. Taking a species includes harming it, which in turn includes "significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavioral patterns, including breeding, feeding or sheltering."[9] The ESA's "take" prohibition extends to governmental authorizations to third parties to undertake actions that result in the incidental take of ESA-listed species because those authorizations "solicit" or "cause" prohibited take.[10]
- The ARM model is not informative as to whether any particular horseshoe crab harvest level would result in an unlawful take of red knots. The model does not accurately represent the status of horseshoe crabs and red knots, and it is oblivious to the dependence of red knots on horseshoe crabs. Since the model does not represent ecological conditions, the Board cannot rely on it to assess ecological impacts or ensure compliance with the law.
- USFWS's evaluation of the ARM framework provides no meaningful information about the likelihood of an ESA violation. In stating that the model's harvest recommendations would "pose[] negligible risk to red knot recovery and negligible risk of take," USFWS merely characterized the model's own outputs. Since the model claimed that its recommended harvest quotas would be harmless, the agency concluded that no take would be likely. USFWS's statement hinges on the accuracy of the model, which is deeply flawed.

4. **<u>The ongoing stakeholder survey cannot justify a resumption of the female horseshoe crab harvest.</u>**

- The Board must make management decisions based on the best available science and legal requirements. The vulnerability of red knots and horseshoe crabs, together with the ARM model's inability to generate accurate predictions of the effects on red knots of horseshoe crab harvest levels, mandate that the Board take a risk-averse approach and, at a minimum, maintain the prohibition on harvesting females and refrain from increasing male harvest quotas.
- To the extent that the Board also considers public opinion, the public has already spoken on this issue. When the Board accepted public comment last year on whether to adopt the new ARM model, more than 34,000 people expressed their opposition, compared to only 5 who expressed support. The overwhelming

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[9] 16 U.S.C. § 1532(19) (defining take); *id.* § 1538(a)(1)(B) (take prohibition); 50 C.F.R. § 17.3 (defining harm).
[10] *Strahan v. Coxe*, 127 F.3d 155, 163 (1st Cir. 1997); 16 U.S.C. § 1538(g).

message was clear: female Delaware Bay-origin horseshoe crabs should not be harvested for bait.

- The Board has since decided to conduct a stakeholder survey to gauge the level of support for the bait harvest of female horseshoe crabs. Unlike the public comment solicitation, this survey is open only to an undisclosed, hand-selected group of respondents.
- Whatever the survey's outcome, it cannot justify reauthorizing a female bait harvest. The Board must not discount public comments and scientific and legal imperatives through opaque engagement with its selected survey respondents.

The remainder of these comments elaborate upon each of those four points. Dr. Shoemaker's new analysis immediately follows these comments. These comments and analysis supplement the comments that New Jersey Audubon and Defenders of Wildlife submitted prior to the adoption of the ARM model (the "Addendum VIII comments"). The Addendum VIII comments—including expert reports by Dr. Shoemaker and Dr. Romuald Lipcius—are incorporated by reference and attached.

Respectfully submitted,

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Technical Comments

I. THE AVAILABILITY OF HORSESHOE CRAB EGGS ON THE BEACH, NOT TRAWL SURVEY DATA, IS THE MOST DIRECT AND MEANINGFUL DETERMINANT OF RED KNOT SURVIVAL.

The ARM model is irreparably distorted by its core finding that the abundance of female horseshoe crabs has virtually no impact on red knots. That finding defies both historical observation and empirical data, and it subverts the very purpose of utilizing a model to inform horseshoe crab harvest quotas. By contrast, the density of horseshoe crab eggs on the beach correlates strongly with red knot survival. The Board must fully account for the vital correlation between the two species when making management decisions.

A. Horseshoe Crab Eggs Are Critical to the Survival of Red Knots at Delaware Bay.

The relationship between horseshoe crabs and red knots is an extraordinary example of the interconnectedness of life on Earth. Each year, red knots fly from as far as the southern tip of South America to breed in the Arctic Circle. For most red knots, this epic journey coincides with another ecological marvel: the emergence of horseshoe crabs from the waters of Delaware Bay to spawn on the beach. Historically, an enormous population of horseshoe crabs has produced a vast resource of eggs. This bounty of eggs serves as a critical food source for red knots. Having already flown thousands of miles at significant physiological expense, red knots can consume enough eggs in less than two weeks to double their body weight and gain the energy to complete their migration and breed successfully.[11] Horseshoe crab eggs may be especially important for the most southern-wintering red knots, whose migrations are the longest and most energy-intensive.[12] Only with a superabundance of horseshoe crabs can red knots access the eggs: horseshoe crabs lay their eggs too deeply in the sand for red knots to reach, but successive waves of spawning crabs churn the sand, elevating a portion of the eggs toward the surface.[13]

The importance of horseshoe crab eggs shapes red knots' migratory paths, and the plethora of crabs has historically drawn red knots to Delaware Bay.[14] USFWS has labeled the overharvest of horseshoe crabs in Delaware Bay a "primary causal factor" in red knots' decline.[15] A key objective of the ARM framework is to "ensure that the abundance of horseshoe crabs is not limiting the red knot stopover population or slowing recovery."[16]

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[11] Lawrence Niles et al., *Effects of Horseshoe Crab Harvest in Delaware Bay on Red Knots: Are Harvest Restrictions Working?*, 59 BioScience 153, 154 (2009); New Jersey Department of Environmental Protection, *Wildlife Populations: Red Knot* 1-2 (2020), https://dep.nj.gov/wp-content/uploads/dsr/trends-red-knot.pdf; Duijns, *Body Condition Explains Migratory Performance* at 4-6.
[12] *See* FWS, *Draft Recovery Plan for the Rufa Red Knot* 13-14 (May 2021).
[13] Niles, *Effects of Horseshoe Crab Harvest* 155.
[14] The utilization of other horseshoe crab-rich stopover sites in South Carolina further bolsters the importance of horseshoe crabs to red knots.
[15] 79 Fed. Reg. at 73,707.
[16] ARM Report 25. More information about the role of horseshoe crab eggs in red knot migration is available in New Jersey Audubon and Defenders of Wildlife's comments on Addendum VIII (attached).

In light of the well-established reliance of red knots on horseshoe crabs, achieving the ARM framework's objective requires the restoration of adequate horseshoe crab egg resources. But instead, the ARM model concludes—contrary to decades of observation and belying the ARM framework's own objective statement—that red knot abundance bears almost no connection to the abundance of horseshoe crabs.[17] The model would predict that red knot numbers would most likely increase even if horseshoe crabs disappeared entirely.[18] According to the model, horseshoe crabs, including the egg-laying females, could be harvested in large numbers, and red knots would barely notice the difference.

The ARM model is wrong. As described below, and building on decades of observation, the fate of red knots is significantly correlated with the fate of horseshoe crabs. The model's contrary—and counterfactual—conclusion does not represent the dynamics of the ecosystem and results from flaws in how the model is structured and processes data.

B. The density of horseshoe crab eggs on the beach strongly correlates with red knot survival and demands central consideration in management decisions.

The ARM model entirely ignores the most direct measure of whether there are enough horseshoe crab eggs for red knots: the density of eggs at or near the surface of the beach. Data on egg density have reliably and consistently been collected for decades. Peer-reviewed, published research shows that egg density has declined by an order of magnitude since the 1980s.[19]

Building on that peer-reviewed research, Dr. Shoemaker found a significant positive correlation between egg density and red knot survival. The data show that higher egg density has historically tracked with higher red knot survival rates. The reverse is also true: projecting forward from this correlation, multiple years of low egg density would likely decimate the red knot population.[20]

Instead of using egg density data, the ARM model uses data that are, at best, a remote proxy of food availability for red knots: the abundance of female horseshoe crabs, as estimated from trawl surveys conducted in the open sea. The ARM model illogically assumes that the ecosystem is meeting the needs of red knots based on horseshoe crab trawl surveys, even as horseshoe crab egg densities on the beach languish at low levels. Thus, a model with the stated purpose of protecting red knots is erroneously being used to assert that red knots hardly need protection after all.

As described above, Dr. Shoemaker previously explained that the ARM model would project a likely increase in red knot abundance even if horseshoe crabs vanished entirely from Delaware

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[17] *See, e.g.*, ARM Report 86.
[18] *See* Kevin Shoemaker, *Review of 2021 ASMFC ARM Revision* 6-12 (Sept. 2022), *in* Addendum VIII comments (attached) ("Shoemaker 2022 Analysis").
[19] *See* Joseph A. M. Smith et al., *Horseshoe Crab Egg Availability for Shorebirds in Delaware Bay: Dramatic Reduction After Unregulated Horseshoe Crab Harvest and Limited Recovery After 20 Years of Management,* Aquatic Conservation: Marine and Freshwater Ecosystems 1, 8 (2022), https://doi.org/10.1002/aqc.3887.
[20] *See* Kevin Shoemaker, *Review of the Atlantic States Marine Fisheries Commission's (ASMFC) Adaptive Resource Management (ARM) framework for regulating Horseshoe Crab bait harvest in Delaware Bay* 19-27 (Sept. 2023) ("Shoemaker 2023 Analysis").

Bay.[21] He has now supplemented that finding with a projection based on the correlation between red knot abundance and horseshoe crab egg density (Figure 1).[22] The contrast between the two projections is stark and highlights the recklessness of accepting the ARM model's representation of the ecosystem. Notably, the projection based on egg density—unlike the projection based on horseshoe crab abundance—does not assume that horseshoe crabs vanish entirely but incorporates the less extreme scenario that egg density stagnates at the lowest historically observed level. Yet even under that relatively modest and more plausible scenario, the consequences for red knots would be dire.

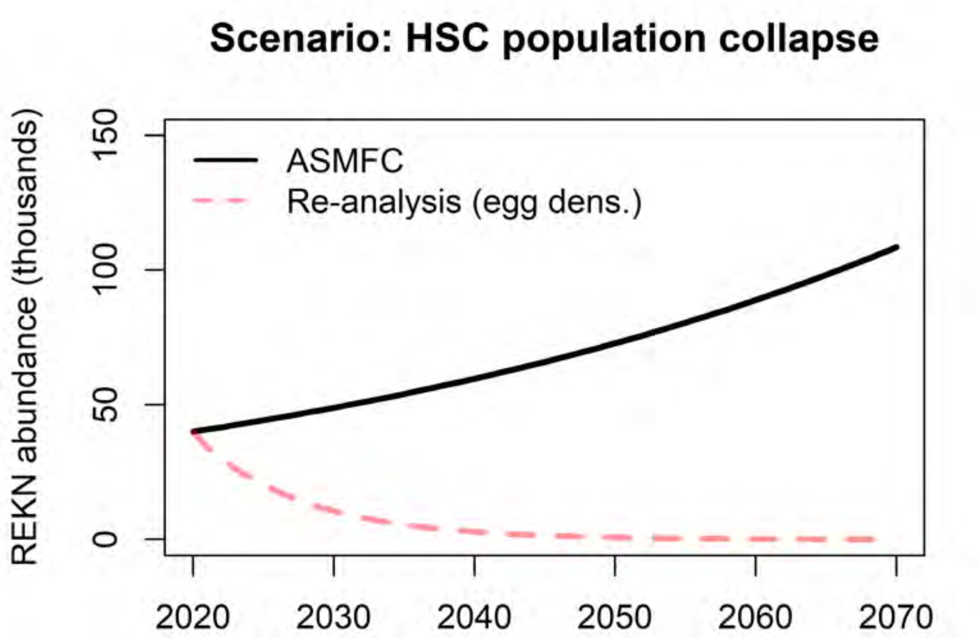

Figure 1 (appears as Figure 6 in Dr. Shoemaker's analysis). The solid black line represents the ARM model's weak correlation between red knot abundance and horseshoe crab abundance (as estimated from trawl surveys) and depicts a scenario in which horseshoe crabs completely disappear from Delaware Bay. The dashed red line represents the correlation between red knot abundance and egg density and depicts a scenario in which egg density stagnates at the lowest historically observed level.

Figure 1 shows that persistently low egg density would cause the abundance of red knots at Delaware Bay to plummet toward near-zero levels. It further undercuts the ARM model's implausible expectation that red knot abundance would increase even in the total absence of horseshoe crabs.

It bears emphasis that, while egg density is the best indicator of resource adequacy for red knots, there is almost certainly a positive correlation between the abundance of horseshoe crabs and red knots. The model's failure to find such a correlation may be attributable to trawl surveys' inaccurate measurements of horseshoe crab abundance. Section II.B, *infra*, presents Dr. Shoemaker's finding that the trawl survey data are likely more reflective of random noise than

[21] *See* Shoemaker 2022 Analysis 6-12.
[22] *See* Shoemaker 2023 Analysis 25.

horseshoe crab demographics. If the horseshoe crab abundance estimates are inaccurate, then the strength of their correlation with red knot abundance is meaningless.

Management decisions that affect a threatened species like the red knot, including by causing prohibited take, demand a precautionary approach. Basing management decisions on the ARM model would be risk-prone and invite calamity for red knots.

II. <u>THE ARM MODEL OVERESTIMATES AND MISREPRESENTS THE HEALTH AND RESILIENCE OF RED KNOTS AND HORSESHOE CRABS AT DELAWARE BAY.</u>

In addition to disregarding the connection between horseshoe crabs and red knots, the ARM model contains fundamental errors and deficiencies that prevent it from accurately representing the status of either species individually. As a result, its recommended harvest quotas do not reflect ecological conditions. Implementing the model's recommendations would have adverse outcomes that the model cannot accurately predict and put both red knots and horseshoe crabs at greater risk, in sharp contrast to the precautionary approach that managing an imperiled ecosystem demands.

A. <u>The ARM model's evaluation and projections of red knot demographics are not reliable.</u>

i. *The model artificially inflates the red knot survival rate.*[23]

The ARM model incorrectly estimates that red knots' lifespan is roughly three times as long as similarly sized shorebirds—nearly 15 years compared to 5 years. The lifespan estimate is derived from the annual survival rate, which the model estimates at 93%. Most other estimates of the survival rate for red knots (and similarly sized shorebirds) are closer to 80%.

Overestimating the survival rate results in the model underestimating the vulnerability of red knots to a single unsuccessful breeding year. To maintain a stable population, each female needs to replace herself at least once (on average) during her lifetime. For example, a female that is reproductively active for 14 years may be relatively unaffected by one or two poor breeding years. But for a female that is reproductively active for 4 years, the same conditions would significantly reduce her likelihood of reproductive success, even if, on average, she produces more offspring per year.

The model's erroneous survival rate flows from its method of tabulating red knot resightings. Researchers have long affixed leg bands to red knots, with each band having a unique, three-character code. By reading the codes from red knots that are banded and then return to Delaware Bay in subsequent years, researchers acquire data about what proportion of red knots survive from year to year.

The difficulty of reading codes from leg bands means that researchers need to account for two types of misread errors. The ARM model accounts for one type by ignoring a reading if the code

[23] This finding is presented at Shoemaker 2023 Analysis 8-14.

was never actually used on a leg band. But it does not account for codes that are mistaken for other existing codes. For example, assume that in year 1 of the study, a red knot is assigned the code 1AB, and in year 7, a red knot is assigned the code 7AB. In year 8, a researcher may misread "7AB" as "1AB," even though the bird assigned 1AB may have died years earlier.

To minimize misread errors, researchers can weed out codes that are sighted only once in a season. Uncorroborated by additional readings, these codes are more likely to be misreads. Dr. Shoemaker recalculated red knots' survival rate after weeding out these uncorroborated potential misreads. The resulting estimated survival rate dropped to approximately 80%, which is much more consistent with most other estimates.[24]

For further verification, Dr. Shoemaker also calculated the survival rate using readings only from red knots that were captured after previously having been banded—upon capture, the codes could be read at close range. These close-range readings constitute a much smaller data-set but would be expected to include minimal misreads. This subset of readings yielded an estimated survival rate of approximately 79%, consistent with Dr. Shoemaker's corrected overall estimate and estimates from other researchers.

The enormous overestimate of red knot survival is indicative of how profoundly the ARM model fails to represent even the basic lifecycle of the species it is supposed to protect—and why the model should not be used to make existential decisions affecting that species.

ii. The ARM model misrepresents trends in red knot abundance.[25]

The ARM model has a strong tendency to detect false trends in red knot abundance, even when no trend exists. Thus, the model cannot be trusted to assess one of the most important factors: whether and to what degree the red knot population is increasing or decreasing.

This problem results from a design flaw in a key component of the model that estimates abundance and recruitment. The component, called a "state-space" model, uses annual red knot population counts to estimate various metrics related to red knot demography (all of which feed into abundance estimates). These metrics, or "parameters," include estimates of initial red knot abundance, annual recruitment, and the effect of horseshoe crab abundance on red knot recruitment. But the initial dataset is far too small to support the large number of parameters estimated from it.

More concretely, this component of the model draws from just 14 datapoints: the peak count of red knots in Delaware Bay for each of the years 2005-2018. From that limited dataset, the model estimates at least 18 different parameters. As models become "overparameterized," they bear a decreasing relationship to the truth. Dr. Shoemaker analogizes this phenomenon to a parachutist

[24] Allan J. Baker et al., *Rapid population decline in red knots: fitness consequences of decreased refuelling rates and late arrival in Delaware Bay*, Proceedings of the Royal Society of London, Series B: Biological Sciences 271(1541), 875-882 (2004); Theunis Piersma et al., *Simultaneous declines in summer survival of three shorebird species signals a flyway at risk*, Journal of Applied Ecology 53(2), 479-490 (2016); Verónica Méndez et al., *Patterns and processes in shorebird survival rates: a global review*, Ibis 160(4), 723-741 (2018).
[25] This finding is presented at Shoemaker 2023 Analysis 34-39.

connected to a parachute with suspension cords. As the number of suspension cords declines, the parachutist and parachute become increasingly untethered. Similarly, with insufficient datapoints, the parameters lose a strong connection to the truth. Instead, the model is likely to conclude that false, or "spurious," trends exist, even when the data indicate no such thing.

Dr. Shoemaker's tests revealed that the ARM model is highly likely to find spurious trends. To test this, he generated 50 sets of random, white-noise population count data that lacked a trend in either direction. Feeding those 50 random datasets into the model, he found that the model contrived a significant, spurious trend 42 times. That is, working from a dataset of white noise, the model was more than 80% likely to project that red knot abundance was on a trajectory to increase or decrease significantly by the year 2100.

This flaw in the model is unlikely to be resolved through the accumulation of more data in future years. While the acceptable ratio of datapoints to parameters varies, Dr. Shoemaker explains that 30-to-1 is sometimes used as a rule of thumb. The affected component of the ARM model has less than 1 datapoint per parameter. Even though one additional datapoint of red knot abundance is collected each year, it would take decades before the dataset grew large enough to support the demands that the model places up on it.

iii. The model bears little resemblance to real-world data.[26]

Based on the information that ASMFC has released, the ARM model has not undergone sufficient goodness-of-fit testing. As Dr. Shoemaker explains, such "testing is a critical validation step . . . [for] ensuring that key assumptions made during the modeling process are reasonable and justified."[27]

To fill this gap, Dr. Shoemaker performed four goodness-of-fitness tests for various aspects of the ARM model, focusing on the open robust design component of the integrated population model—a portion of the model that measures red knot survival among other parameters. Each of the four tests assessed different parameters in order to test different aspects of the model.

The model failed each of the goodness-of-fit tests by a wide margin. Dr. Shoemaker explains that these failures "cast[] additional doubt on conclusions generated from this model."[28] Basing management decisions on a model that bears so little resemblance to real data would be an exercise in arbitrary and risk-prone decision-making.

B. Properly evaluated, the horseshoe crab trawl surveys do not indicate a positive trend in horseshoe crab abundance.

As discussed in Section I, the ARM model is centered around the correlation between red knot abundance and female horseshoe crab abundance as measured by trawl surveys. This overreliance on trawl survey data is inherently inappropriate because the data do not correlate with red knot abundance, and the model ignores data on horseshoe crab egg density that correlate

[26] This finding is presented at Shoemaker 2023 Analysis 39-41.
[27] *Id.* at 39.
[28] *Id.* at 41.

strongly with red knot outcomes. That problem is compounded by several flaws in how the model uses and processes the trawl survey data. Upon correcting some of those flaws, it becomes clear the trawl surveys do not support the ARM model's optimistic assessment of the horseshoe crab population trajectory. In fact, the trawl surveys reveal no conclusive trend in either direction, bolstering the need to make precautionary management decisions for this overexploited species, especially considering that the species remains depleted relative to historical levels.

To assess the horseshoe crab population, the ARM model processes data from three different trawl surveys using a catch multiple-survey analysis ("CMSA"). While the goal is to derive a meaningful signal from the three surveys collectively, the survey data seem to be heavily influenced by random fluctuations, rendering any collective signal meaningless. In fact, there is virtually no correlation among the horseshoe crab abundance data from the three surveys.[29] The resulting unified abundance estimate provides a false veneer of certainty, masking an underlying reality of random noise.

In addition, the CMSA does not adjust for confounding factors that skew the survey data. The number of horseshoe crabs counted in the surveys can be impacted by seasonality, water temperature and depth, and other factors. But the CMSA does not adjust for these impacts, allowing the data to remain skewed.

By adjusting for these confounding factors and reanalyzing the data, Dr. Shoemaker made two striking findings: first, in contrast to the ARM model's finding that horseshoe crabs are recovering, the trawl surveys do not indicate any upward trend in the population of female horseshoe crabs in Delaware Bay.[30] And second, the three surveys are even less correlated with each other—and more likely to reflect random noise—than they previously appeared.[31]

This new analysis supplements the analysis that Dr. Shoemaker performed prior to the approval of Addendum VIII, detailing serious deficiencies in the CMSA's evaluation of horseshoe crab data. For example, Dr. Shoemaker previously showed that:

- The CMSA does not properly account for uncertainty in its horseshoe crab abundance projections.[32] It treats the potential for inherent biases—which could persistently skew the model's projections too high or too low—as if they were year-to-year variations that would cancel each other out over time. If the CMSA properly accounted for uncertainty, it would show that horseshoe crabs face a realistic risk of falling to extremely low levels even in the absence of any harvest (bait or biomedical) or discard mortality.

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[29] *See id.* at 17-19.
[30] *See id.* at 28-33.
[31] *See id.* at 17-19. While Dr. Shoemaker adjusted the trawl survey data for confounding factors, the trawl surveys remain unsuitable for quantifying the correlation between horseshoe crabs and red knots. Even with adjusted data, the surveys appear inherently random and vastly inferior to egg density data as a corollary to red knot survival. Instead, Dr. Shoemaker's analysis reveals that the trawl survey data are completely uncorrelated, and, even using the ARM model's preferred data source, horseshoe crab abundance is not increasing.
[32] *See* Shoemaker 2022 Analysis 12-18.

- For years when horseshoe crab recruitment data were not available, the CMSA filled in numbers that are absurdly higher than the estimates from any year with empirically observed data, resulting in significantly inflated long-term abundance projections.[33]

The Addendum VIII comments also presented analysis by Dr. Romuald Lipcius highlighting many worrying trends in the trawl survey data from Virginia Polytechnic Institute (which collects the most detailed demographic information on horseshoe crabs in Delaware Bay). For example, the Virginia Tech survey data indicate that the body size of female horseshoe crabs in Delaware Bay is decreasing, the ratio of females to males is decreasing, and the number of newly mature females is disturbingly low, among other troubling developments.[34] As Dr. Lipcius explained, these are not the trends that one would expect to find in a recovering population, especially one in which females have been protected from harvest.[35]

The prior analyses, together with Dr. Shoemaker's new analysis, strongly suggest that horseshoe crabs are not recovering in Delaware Bay. They require protection for their own sake, as well as for the nourishment that their eggs provide to red knots and other species. They certainly should not be harvested at levels recommended by a model that misrepresents the condition and trajectory of both of the species that it considers.

III. IMPLEMENTING THE ARM MODEL'S RECOMMENDATIONS WOULD POSE A PROFOUND RISK OF VIOLATING THE ENDANGERED SPECIES ACT.

In their Addendum VIII comments, New Jersey Audubon and Defenders of Wildlife cautioned that, by utilizing the ARM model, ASMFC would risk violating the Endangered Species Act. The ESA prohibits any person from "tak[ing] any [endangered] species within the United States or the territorial sea of the United States."[36] Such prohibited "take" includes actions that "harm" listed species, including "significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavioral patterns, including breeding, feeding or sheltering."[37] The ESA's "take" prohibition extends to governmental authorization to third parties to conduct activities that themselves result in unauthorized incidental take, thus "solicit[ing]" or "caus[ing]" an offense.[38] By virtue of a regulation in effect at the time the red knot was listed as threatened, the statutory take prohibitions apply to the take of many USFWS-listed threatened species, including the red knot.[39]

The Addendum VIII comments explained that ASMFC would likely commit a take by authorizing a harvest of female horseshoe crabs, impairing red knots' ability to feed. While the Board did not accept the model's recommendation to authorize a female harvest for 2023, that

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[33] *See id.* at 22-24.
[34] *See* Romuald Lipcius, *Expert Report* 6, 10 (Sept. 2022), *in* Addendum VIII comments (attached).
[35] *See id.* at 4-5.
[36] 16 U.S.C. § 1538(a)(1)(B).
[37] 50 C.F.R. § 17.3.
[38] *Strahan v. Coxe*, 127 F.3d at 163; 16 U.S.C. § 1538(g).
[39] 50 C.F.R. § 17.31(a) (applying the provisions of § 17.21 (addressing endangered species) to threatened species listed on or prior to September 26, 2019, unless USFWS has promulgated a species-specific rule); *id.* § 17.21(a), (c) ("[I]t is unlawful . . . to solicit another to commit or to cause to be committed" the taking of an endangered species.).

remains a threat for future years due to the ARM model's proclivity for recommending a substantial female harvest quota.

Because the model does not accurately represent the relationship between horseshoe crabs and red knots, it offers no useful guidance on whether *any* particular harvest level amounts to a take. Notably, while much of the discussion around the ARM model has addressed the risk of a female horseshoe crab harvest, the model is similarly unable to assess the risk posed by a male harvest. In this information void, allowing any horseshoe crab harvest is a roll of the dice.

The Endangered Species Act requires a precautionary approach. As the Supreme Court has stated, "Congress has spoken in the plainest of words, making it abundantly clear that the balance has been struck in favor of affording endangered species the highest of priorities, thereby adopting a policy which it described as 'institutionalized caution.'"[40] In line with that principle, the ARM framework's stated objective includes "*ensur[ing]* that the abundance of horseshoe crabs is not limiting the red knot stopover population or slowing recovery."[41] It would be inconsistent with Endangered Species Act requirements (and the ARM framework's objective) to utilize a model that, among other deficiencies:

- by virtually disregarding the correlation between red knots and horseshoe crabs, fails to appreciate the importance of the very resource that it is managing for;
- takes no account of egg density on the beach surface—the one datapoint that directly measures whether the horseshoe crab population is providing adequate nutrition for red knots;
- significantly misapprehends the life cycle of red knots, vastly overestimating their lifespan;
- through an overparameterized model, incorrectly concludes that there are trends in red knot abundance even when no trends exist;
- generates horseshoe crab abundance estimates from trawl surveys that are heavily influenced by random noise; and
- produces erroneously optimistic projections of horseshoe crab abundance while disregarding multiple, persistent negative trends in horseshoe crab demographics.

Without a clearer understanding of the impact of the horseshoe crab harvest, the only lawful, precautionary, and ecologically defensible approach is for the Board to set conservative (if any) bait harvest levels. Certainly, no reauthorization of a female bait harvest could be defensible under these circumstances.

Moreover, as explained in the Addendum VIII comments, ASMFC cannot rely upon USFWS's statement that the ARM model's harvest recommendations would "pose[] negligible risk to red knot recovery and negligible risk of take."[42] USFWS's evaluation was based entirely on the model's own outputs and thus harbors all of the flaws inherent in the model itself. In particular, the evaluation accepts that the correlation between horseshoe crab abundance and red knot success is minimal without considering other evidence of a correlation (like egg density).

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[40] *Tenn. Valley Auth. v. Hill*, 437 U.S. 153, 194 (1978).
[41] ASMFC, *ARM Report* 25 (emphasis added).
[42] FWS Evaluation 3.

Unsurprisingly, it concludes that “there is a very small probability (<1%) ARM management will result in a lower abundance of red knots.”[43]

By merely repackaging the ARM model’s findings, the USFWS evaluation never provided significant additional information about the effects of implementing the model’s recommendations. Dr. Shoemaker’s new analysis highlights additional flaws in the model and, by extension, in the USFWS evaluation, demonstrating that the evaluation is even less informative than previously known. The USFWS evaluation lends no independent factual or legal support for the Board’s reliance on the ARM model.

IV. THE ONGOING STAKEHOLDER SURVEY CANNOT JUSTIFY A RESUMPTION OF THE FEMALE HORSESHOE CRAB HARVEST.

It is imperative that the Board base horseshoe crab harvest quotas “on the best scientific information available”[44] and the requirements of the ESA. As detailed extensively in the comments above and the attached analyses and comments, the ARM model does not provide a firm scientific basis for setting horseshoe crab bait harvest quotas and cannot predict the impact of its recommended quotas. Implementing those quotas would therefore imperil the ecosystem in ways that the Board cannot foresee. In the absence of reliable information about what harvest levels the ecosystem can sustain, the only scientifically defensible approach is to set highly conservative harvest quotas—continuing the prohibition on harvesting females and certainly not increasing male harvest quotas from current levels.

The results of a stakeholder survey cannot alter the Board’s obligation to make scientifically grounded and legally sound management decisions. But to the extent that the Board also considers public opinion, the Board must respect the overwhelming opposition to a female horseshoe crab bait harvest expressed in the comments submitted on Addendum VIII last year. The Board’s comment solicitation yielded 34,631 submissions, all but 5 of which opposed the adoption of the new ARM model—a tally that reflected the public’s “[o]pposition to female horseshoe crab harvest.”[45] Although the Board approved the new ARM model, it appropriately rejected the model’s recommendation to authorize a female harvest, “[a]cknowledging public concern about the status of the red knot population in the Delaware Bay.”[46] Shortly after the Board’s decision to adopt the revised ARM model but decline to adopt its recommendation for 2023, the chair of the subcommittee responsible for the ARM model wrote:

> [T]here is absolutely no appetite for female harvest from any stakeholder. Not only were the shorebird advocates strongly against any resumption of female harvest, but it appears that the bait industry is completely satisfied with male only harvest. . . . [W]hen ASMFC is asked by NGOs in the media where the pressure for female harvest is coming from, it’s really coming from us scientists in our

[43] *Id.*
[44] ASMFC, *Interstate Fisheries Management Program Charter* § 6(a)(2) (Aug. 2019).
[45] *See* Memorandum from Caitlin Starks on Public Comment on Draft Addendum VIII to the Horseshoe Crab Fishery Management Plan 1 (Oct. 20, 2022), *in* ASMFC, Materials for the 2022 Annual Meeting of the Horseshoe Crab Management Board, http://www.asmfc.org/files/Meetings/2022AnnualMeeting/HorseshoeCrabBoard_Nov2022.pdf.
[46] ASMFC, *supra* note 6.

> desire to find an optimal solution to the problem statement. Perhaps our problem statement is no longer applicable in this situation.[47]

While the Board maintained protections for female horseshoe crabs in 2023, it did not resolve whether those protections would extend to future years. Instead, the Board expressed interest in a process "with stakeholders and managers and scientists, to try to help better inform future goals and objectives and modeling approaches" and "to really start to talk about what our goals and objectives are for both the fishery and the ecosystem."[48] In a subsequent meeting, Board members repeatedly conveyed that the primary objective of the stakeholder engagement was to determine whether any public appetite exists for a female bait harvest—and if not, to adjust the management framework accordingly.[49] After reviewing options for stakeholder engagement, the Board opted to proceed with a survey. Unlike the public comment period, however, this survey would seek the perspectives only of hand-selected respondents, not all interested members of the public.[50]

The public has already spoken on this issue. Whatever the outcome of the stakeholder survey, the Board must respect the overwhelming opposition to a female harvest expressed in the public comments on Addendum VIII. The entire public, including everyone invited to participate in the stakeholder survey, had the opportunity to weigh in during the public comment period, but only a small fraction of commenters were invited to complete the survey. ASMFC appears to be denying requests for additional stakeholders—even longtime horseshoe crab advocates—to complete the survey, and it has denied a request to disclose the list of people who received the survey.[51] This method of secretive, restricted engagement falls far short of ASMFC's obligation to "provide adequate opportunity for public participation."[52] Public transparency is essential

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[47] Email from John Sweka to Conor McGowan, David Smith, James Lyons, Clinton Moore, Anna Tucker, Richard Wong, Kristen Anstead, Caitlin Starks (additional recipients redacted) re Kristen's presentation to the HSC board (Nov. 17, 2022) (obtained via FOIA).

[48] Comments of Shanna Madsen 28, *Draft Proceedings of the Horseshoe Crab Management Board Hybrid Meeting: November 2022* (as approved at the May 2023 meeting), https://www.asmfc.org/files/Meetings/2023SpringMeeting/May3/HorseshoeCrabManagementBoard_May2023.pdf.

[49] *See, e.g.*, *Horseshoe Crab Board Proceedings May 2023*, at 1:00:21, https://www.youtube.com/watch?v=QFw9N1LJF-A, Comments of John Clark ("We decided to move ahead with this item to see what we want to do in the future 'cause of course, if there is no desire for female harvest, that's a whole different way to manage the species."); *id.* at 1:03:47, Comments of Shanna Madsen ("I'd like to see us start with option one, which is putting together a survey to ask that very direct question: do our constituents want us to harvest female horseshoe crabs? And if the answer is no, then I think that really helps us outline what that objective statement is."); *id.* at 1:05:48, Comments of Rick Jacobson ("I agree, too, with the previous speakers that we do have a fundamental question that we need to ask ourselves first: what is the public appetite for the harvest of female horseshoe crabs from Delaware Bay? It is a critical question.").

[50] *See id.* at 1:12:21, Comments of ASMFC Fisheries Policy Director Toni Kerns ("I just want to make it clear that it's not our intention to send this survey to the world. We intend to hit the major stakeholders. . . . We're not trying to exclude the public, but we have just done a management document where we received, how many, 34,000 comments, and we heard from the general public on their intentions, and we still want to make sure we're capturing all the stakeholders here, but we're also not looking for that many comments to have to summarize in order to provide feedback to this Board.").

[51] *See* email from Caitlin Starks to Susan Linder denying request for survey (Aug. 24, 2023); email from Toni Kerns to Susan Linder denying request for list of survey recipients (Sept. 13, 2023). The stated rationale for withholding the list of survey recipients was to preserve the anonymity of responses, but no information about responses was requested.

[52] ASMFC, *Interstate Fisheries Management Program Charter* § 1(c).

when setting harvest quotas for a public resource. The Board must not discount public comments based on feedback from a limited, undisclosed group of hand-selected survey recipients.

V. CONCLUSION

Independent analysis powerfully demonstrates that the ARM model is not suitable for managing the bait harvest of Delaware Bay-origin horseshoe crabs. The ARM model entirely fails to accurately represent what scientific study of the relationship between red knots and horseshoe crabs has already incontrovertibly established—that robust horseshoe crab populations capable of generating a superabundance of eggs on red knot stopover beaches are critical for the red knot's survival and reproduction. The model is oblivious to the strong correlation between red knots and horseshoe crabs and misconstrues data about each species, creating an unbridgeable chasm between its harvest recommendations and actual ecological conditions. Consistent with the Endangered Species Act and its own stated objective to protect red knots, as well as its obligation under the Interstate Fisheries Management Program Charter to base its decisions about horseshoe crab harvest quotas on the best available scientific information, the Board must not implement the model's recommendations. The Board's obligation includes, at a minimum, maintaining the zero-harvest bait quota for female horseshoe crabs and not increasing male-only harvest quotas from current levels.

Review of the Atlantic States Marine Fisheries Commission's (ASMFC) Adaptive Resource Management (ARM) framework for regulating Horseshoe Crab bait harvest in Delaware Bay

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September 2023

This is an expert review of the Atlantic States Marine Fisheries Commission (ASMFC)'s Adaptive Resource Management (ARM) framework – which has been approved for use in managing the Horseshoe Crab fishery in Delaware Bay – performed by Kevin Shoemaker, Ph.D. This document is intended to supplement the review of the ARM completed by Dr. Shoemaker in Fall 2022.

Dr. Shoemaker holds a Ph.D. and an M.S. in Conservation Biology from SUNY-ESF in Syracuse, NY, and a B.S. degree in Biology from Haverford College. He was a Postdoctoral Fellow in the Department of Ecology and Evolution at Stony Brook University and has served as Senior Scientist at Applied Biomathematics, an ecological research and development company located in Setauket, NY. Dr. Shoemaker is currently an Associate Professor at the University of Nevada, Reno, where he uses quantitative models to inform wildlife conservation and management. He has over 15 years of experience as a wildlife ecologist and conservation modeler and has authored over 50 peer-reviewed scientific articles and book chapters on topics in ecology and conservation. He has expertise in Bayesian inference, population ecology, population viability analysis (PVA) and ecological modeling.

OVERVIEW

This report reviews the scientific merits of the Adaptive Resource Management (ARM) framework that has been approved for use by the Atlantic States Marine Fisheries Commission (ASMFC) as a tool for guiding management of the horseshoe crab (HSC) fishery in Delaware Bay and protecting the Federally Threatened *Rufa* Red Knot (*Calidris canutus rufa*; REKN). In Fall 2022

I completed an initial review of the ARM, in which I pointed out five major areas of concern: (1) the fitted relationship linking HSC abundance to REKN survival was functionally insignificant as a driver of REKN population dynamics, (2) the HSC simulation model did not correctly address parameter uncertainty, (3) the statistical model used to estimate HSC demographic processes (Catch Multiple Survey Analysis, or CMSA) exhibited poor fit to the data, (4) the CMSA results were compromised by a 4-year period during which a key source of data was not collected, and (5) the ARM lacked performance benchmarks (null models) to ensure that key model components (e.g., the effect of HSC abundance on REKN survival) meaningfully improved predictive performance versus simpler approaches. The purpose of this follow-up report is to evaluate components of the ARM for which the source code was unavailable for evaluation in my initial review. In particular, I focus on the Integrated Population Model (IPM) approach used by ASMFC for estimating REKN demographic parameters and for quantifying the influence of HSC abundance on the REKN population.

Delaware Bay is a critical stopover site used by REKNs and other shorebirds as they migrate to breeding grounds in the high arctic from their wintering grounds as far south as Tierra del Fuego (USFWS 2021). In particular, HSC eggs deposited on coastal beaches provide a necessary high-calorie food resource for REKNs and other migrating shorebird species as they replenish fat reserves depleted from their long migration and prepare for breeding. At the heart of ASMFC's ARM framework is a set of 'harvest functions' for setting HSC harvest recommendations on the basis of annual estimates of HSC and REKN abundance. In theory, these harvest functions are calibrated to maximize HSC harvest yields while causing minimal risk to the HSC or REKN populations. Optimization of the harvest functions is accomplished by running numerous alternative harvest scenarios using a two-species (HSC and REKN) demographic simulation model and weighing the benefits (harvest) and costs (population risks to HSCs and REKNs) of the simulated outcomes. The cornerstone of this two-species demographic simulation model is a weak (but statistically conclusive) positive effect of female HSC abundance on REKN survival, which serves as a formal, quantitative linkage between the two species. Therefore, the validity of the ARM framework depends upon proper specification of each species' demographic rates (e.g., survival and recruitment) and the degree to which the modeled HSC-REKN interaction is an appropriate representation of the real-world biotic interaction between these species.

Building on the issues raised in my initial review, this report identifies six additional areas of concern (see below). Based on these concerns, I conclude that the ARM framework is not useful for managing risk to the REKN population due to HSC harvest. Furthermore, my results suggest that the revised ARM misrepresents the importance of HSCs to the REKN population and thereby underestimates both the existential risk to the REKN population posed by female HSC harvest and the potential for promoting REKN recovery through increased regulatory protections and conservation efforts aimed at promoting HSC population increases in the Delaware Bay region. The six primary areas of concern are summarized below, with technical details provided in the "supporting evidence and analyses" section.

(1) **Estimates of REKN survival used in the ARM appear to be artificially inflated, likely resulting in falsely optimistic estimates of population resilience**. The majority of previously reported estimates of annual survival for REKNs and similar shorebirds are in the neighborhood of 80%, corresponding to an average lifespan of approximately five years. In contrast, ASMFC reported a mean annual REKN survival estimate of 0.93, which corresponds to an expected lifespan of nearly 15 years. By nearly tripling the expected REKN lifespan *vis-a-vis* previous estimates, ASMFC is effectively classifying the REKN as a uniquely long-lived species among medium-sized shorebirds. Since individual females must only replace themselves once during their lifetime (on average) for a population to be stable, longer-lived species can afford a higher per-capita failure rate in breeding attempts than shorter-lived species. Therefore, long-lived species are expected to be more resilient to short-term fluctuations in recruitment. However, my findings strongly indicate that ASMFC's estimate of REKN survival is biased high due to the presence of misread errors (by which a flag code is mistaken for a code previously deployed on a different bird). The potential for misread errors in the study system has been previously acknowledged (Tucker et al. 2019). After correcting for potential misread errors, REKN survival estimates fall to approximately 80% annually – a rate more consistent with previous estimates for REKN and similar species. The apparent positive bias in ASMFC's survival estimates is likely to result in falsely optimistic estimates of population resilience to short-term environmental fluctuations, raising

concerns about the adequacy of the ARM framework for assessing population-level risks to this federally Threatened species.

(2) **Trawl-based indices of HSC abundance are inadequate for detecting robust links to REKN demography**. ASMFC documented a very weak (and not ecologically meaningful; see attachment) positive effect of female HSC abundance on REKN survival. This relationship is the cornerstone of the revised ARM framework, as it represents the primary functional link between the two focal species. The effect of HSC abundance on REKN survival was estimated using the output from a Catch Multiple Survey Analysis (CMSA) as a proxy for annual HSC abundance in Delaware Bay. The CMSA in turn was trained using data from three trawl-based surveys, conducted by Virginia Tech, New Jersey, and Delaware, respectively (in addition to data on known sources of HSC mortality). However, my reanalysis of the available data uncovered no conclusive relationship between REKN survival and any trawl-based index of HSC abundance. Notably, after including several additional years of REKN mark/resight data (I used REKN banding and resighting data from 2003 through 2022, whereas ASMFC's used data from 2005 to 2018), the effect of HSC abundance on REKN survival became negative (lower REKN survival with more female HSCs) when using the code and data provided by ASMFC. This result underscores the frailty of the foundational relationship on which ASMFC's two-species ARM is based. Trawl-based surveys are necessarily imperfect snapshots of the abundance of HSCs occupying Delaware Bay, obscured by differing survey methodologies and poorly understood aspects of HSC ecology, including seasonal and daily activities, habitat preferences, and degree of clustering on the seafloor. Moreover, the functional link between HSC abundance and REKN demographic rates is eroded by additional, poorly understood processes that govern the availability of HSC eggs for shorebirds, including variation in the timing of HSC egg deposition and the factors that dislodge eggs from their clusters, rendering them accessible to shorebirds. Therefore, the lack of a demonstrable effect of trawl-based HSC indices on REKN vital rates likely reflects the weakness of these indices and not the weakness of the underlying biotic interaction.

(3) **REKN survival is strongly sensitive to HSC egg-density, indicating that persistent**

degradation of the HSC egg resource could have dire consequences for the REKN population. Intuitively, surveys of HSC egg densities measured on the same beaches used by foraging shorebirds during their spring migration should more directly capture the biotic interaction between these two species. Although researchers have been consistently measuring the surface density of HSC eggs at multiple beaches across Delaware Bay (NJ side only) since 2000, ASMFC chose to rely on trawl-based surveys instead of egg-density surveys as a proxy for the HSC resource available to REKNs. My reanalysis of the Delaware Bay mark-resight database indicates that REKN survival is strongly and positively influenced by annual fluctuations in HSC egg density. Unlike the weak relationship documented in the ARM, the fitted relationship between HSC egg-density and REKN survival implies severe risks to the REKN population under a scenario of sustained low HSC egg densities. In contrast to ASMFC's two-species ARM, this alternative characterization of the HSC-REKN interaction is capable of explaining the observed decline in REKN populations during the late 20th century, which is widely attributed to unregulated harvest of HSCs in Delaware Bay. These new results strongly suggest that ASMFC's ARM framework misrepresents the importance of HSCs to the REKN population. As a result, the ARM not only severely underestimates the consequences of HSC population declines on the REKN population, but it severely underestimates the critical role that a rebound of the HSC population could play in the recovery of this federally Threatened species.

(4) **The ARM exaggerates the evidence for an increasing trend in the number of female HSCs in Delaware Bay.** Based on my reanalysis, neither the trawl-based surveys used by ASMFC nor the egg-density surveys (recently used to document an increasing trend in the HSC population) show strong evidence for increasing abundance of female HSCs in Delaware Bay over the last 20 years. As a case in point, the raw data (catch-per-unit-effort; CPUE) from New Jersey's ocean trawl survey (one of the data sources used by ASMFC for documenting a positive trend in HSC abundance) appears to indicate increasing female HSC abundance over time (statistically significant at alpha=0.05); however, when the raw CPUE numbers are adjusted for strong effects of seasonality, water temperature, depth and dissolved oxygen on HSC captures in Delaware Bay (NJ ocean trawl survey), the apparent positive trend in

HSC CPUE becomes inconclusive. Notably, the trawl-based indices used by ASMFC in their CMSA model did not control for these confounding factors. Therefore, the increasing trend in the HSC population reported by ASMFC and used in the ARM may be an artifact of differing survey conditions (e.g., differences in trawl depth or water temperature) rather than evidence of recovery of the HSC population over time. Furthermore, regression models combining the CPUE estimates (both adjusted and unadjusted) from all three trawl-based surveys showed no conclusive evidence for a trend in HSC abundance over time. Similarly, when the egg-density data were adjusted for known differences in survey methodologies, the apparent positive trend (reported in Smith et al. 2022) became inconclusive (note that this adjustment did not impact the estimated relationship between REKN survival and HSC egg-densities). Overall, my reanalysis suggests that the ARM framework exaggerates the potential for recovery of the female HSC population under present conditions, and thereby likely underestimates the risk of harvest to the HSC (and REKN) populations in Delaware Bay.

(5) **The statistical model (IPM) used for estimating REKN population parameters is over-parameterized and likely to yield spurious results**. The IPM framework used to train the REKN population model comprises two integrated sub-models: (1) a "state-space" model for estimating abundance and recruitment on the basis of population counts over time, and (2) a "capture-recapture" model for estimating survival rates from observation records of uniquely marked individuals. Whereas the data available for fitting the capture-recapture model (over 100,000 resighting records of tens of thousands of unique REKN individuals) was information-rich and well-suited for training complex models, the data available for training the state-space model was sparse by any standard, comprising 14 unique data points (one count per year from 2005 to 2018). In fact, the number of parameters estimated in the state-space model appears to exceed the number of data points. As an analogy, consider a parachute whose canopy is attached to its user with suspension cords. A minimum of three cords is necessary for the parachute to have any chance of operating correctly, yet many more cords are typically incorporated to ensure robust performance. Similarly, a free parameter (an "unknown") must be tethered to the truth using data points

as suspension cords. A model's claim to truth strengthens as the ratio of data points to free parameters increases; statisticians often recommend a ratio exceeding 30 or more for robust model performance. With less than 1 data point per parameter, the IPM's state-space model is occupying a danger zone statisticians refer to as "over-parameterization", or "over-fitting". Over-parameterized models have a strong tendency to produce spurious results (results that fail to replicate when confronted with new data). To confirm the tendency of the REKN IPM to yield spurious results, I generated artificial REKN count data under a model with no underlying trend (a white-noise process) and assessed how often the IPM erroneously detected a trend. After running 50 replicates (iteratively replacing the peak-count data with newly simulated white-noise), the IPM falsely detected an ecologically meaningful temporal trend (increase or decline in abundance over time) over 80% of the time. Among the unknown quantities estimated from the 14 peak-count data points are several terms critical for understanding and forecasting REKN population dynamics, including initial abundance, population trends (growth or decline), mean recruitment, and the effect of HSC abundance on recruitment. Lacking sufficient data for parameter estimation, the REKN recruitment and population trend estimates used in the ARM model are more likely to reflect random noise in the peak count data rather than the demographic reality of the REKN population. Therefore, the REKN demographic simulations used in the ARM should not be considered a robust representation of the real-world population of *Rufa* Red Knots that uses Delaware Bay each year.

(6) **The IPM exhibits poor fit to the observed REKN data**. Goodness-of-fit (GOF) testing is a critical validation step in any model-fitting workflow, ensuring that key assumptions made during the modeling process are reasonable and justified. For example, the results from a linear regression or ANOVA test can only be interpreted once the analyst confirms that important assumptions are satisfied (e.g., that model residuals are approximately normally distributed). Although the REKN IPM is much more complex than a linear regression model, assessing goodness-of-fit is no less important. In the context of hierarchical Bayesian analysis (the paradigm used by ASMFC to fit the REKN IPM), a commonly used approach is to run a Posterior Predictive Check (PPC), in which data are repeatedly simulated under the

fitted model and compared to the actual data. If a model is unable to generate data resembling what was actually observed, the model is determined to be an inadequate representation of the true processes that generated the data. In their ARM report, ASMFC mentions (but does not further document) two PPCs that were performed to assess goodness-of-fit. One of these tests – the only test included in the publicly shared IPM code – uses a PPC to assess the degree to which the state-space model adequately represented the 14 peak-count data points. However, this test has been shown to be an insufficient gauge of model adequacy. The second and final goodness-of-fit test mentioned in the ARM report (for which the result suggests moderate lack of fit) is absent from the version of the IPM code shared publicly, so it is not possible to assess what test was actually run. However, I ran three additional PPCs to assess the degree to which the IPM adequately represented the REKN resighting data from 2003 to 2022. These tests, which were applied and reported in an earlier version of the open-robust-design (ORD) model for estimating REKN survival and stopover use (Tucker et al. 2021), indicated poor fit to the data, suggesting that the IPM is an inadequate representation of key processes operating in the REKN population – including survival. The failure of the IPM to pass rigorous goodness-of-fit tests casts additional doubts on the conclusions generated from this model.

SUPPORTING EVIDENCE AND ANALYSES

The remainder of this report supplies supporting details for the six major areas of concern identified above, including results and figures from re-analyses of the data presented in the ARM report. I report additional findings in the “supplemental analyses” section located at the end of this report.

1. Estimates of REKN survival used in the ARM appear to be artificially inflated, resulting in falsely optimistic estimates of population resilience

The majority of published survival estimates for REKNs and other medium-sized shorebirds indicate a mean annual survival of approximately 80% (Baker et al. 2004; Piersma et al. 2016; Mendez et al. 2018), corresponding to an expected lifespan of approximately five years. In contrast, ASMFC reported a mean adult REKN survival rate of 0.93 on the basis of the REKN IPM, corresponding to an expected lifespan of nearly 15 years. By nearly tripling the expected REKN lifespan (versus previous estimates), ASMFC is effectively classifying the REKN as a longer-lived species than other similar-sized shorebirds (Mendez et al. 2018). Since a stable population requires only that individual females replace themselves once during their lifetime, longer-lived species can afford to fail in more of their breeding attempts than shorter-lived species. Therefore, longer-lived species are expected to be more resilient to short-term fluctuations in breeding success and juvenile survival than species with a shorter lifespan (Lovich et al. 2015). ASMFC argues that their characterization of the REKN life history is accurate, and that previously reported estimates may be biased low (ASMFC 2021). In contrast, my findings strongly indicate that ASMFC's estimate of REKN survival is biased high, most likely due to the presence of misread errors in the REKN resighting database.

The presence of potential misread errors in the study system has been previously acknowledged (Tucker et al. 2019). Studies with simulated and real-world data have shown that misread errors can induce biases in survival estimates (Tucker et al. 2019; Rakhimberdiev et al. 2022). Because the data used to fit the REKN IPM was adjusted for one type of potential misread error (i.e., any observed flag codes that were never deployed in Delaware Bay were discarded), the only type of misread error that ASMFC did not account for was the possibility that a flag code was mistaken in the field for a different previously deployed code (effectively ascribing that observation to a bird that may no longer be alive). This type of misread error (if present in sufficient numbers) is known to falsely inflate survival, especially for the early years of a long-term mark-resight study (Tucker et al. 2019). Tucker et al. (2019) showed that this source of bias can be corrected by discarding observations for which a flag code was sighted only once (i.e., by a single observer during a single sampling occasion) in a given season. Although this technique necessarily discards some correct observations (only a fraction of these 'singlet' observations are likely to be in error) and thereby reduces the precision of the resulting estimates (Tucker et al. 2019; Rakhimberdiev et al. 2022), Tucker et al. (2019) demonstrated that this method was effective in removing biases induced by this class of misread error. Furthermore, Tucker et al. (2019) demonstrated that, when applied to the flag-resighting data from Delaware Bay, REKN survival estimates from early in the study period dropped from 87% to 81%, suggesting that these survival estimates were artificially inflated due to misread errors.

The number of leg-flag codes that can be manufactured is necessarily limited by the number and type of symbols and colors used. Notably, given the very large number of leg flags that have been deployed on REKNs in Delaware Bay since 2003, shorebird biologists have cycled through all possible flag code permutations for the flag color (lime green) most commonly deployed in Delaware Bay. Therefore, any leg-flag codes that are read or transcribed in error are more likely to be falsely attributed to a different bird in the database than to be discarded (as it would be if there were no match in the database). Furthermore, the risk of this type of error is likely to increase substantially as the years pass and as a greater fraction of flag code permutations are deployed in the field. Coupled with the fact that longer time series are likely to manifest increasingly strong biases due to misread errors (Tucker et al. 2019) the risk of biased survival estimates and spurious trends is likely to increase markedly as the database continues to grow (e.g., in future iterations of the ARM model if potential misread errors continue to be ignored).

To assess whether ASMFC's survival estimates were biased due to the inclusion of misread errors, I used REKN banding and resighting data from Delaware Bay to estimate annual REKN survival using two different statistical frameworks: Cormack-Jolly-Seber (CJS; a standard approach to survival estimation using capture-recapture data) and the open-robust-design (ORD) framework for survival estimation used by ASMFC. First, I ran standard CJS models to estimate annual survival rates as a function of the banding data only (Cooch 2008) (i.e., ignoring all flag-resighting data). This model generated separate estimates of survival and detection probability for each year, and included additional terms for transience and 'trap-response' (Pradel and Sanz-Aguilar 2012). The banding data were much less information-rich than the re-sighting observations, with far fewer observations and a much lower re-capture rate. However, misread errors should be virtually absent from the banding records (as captured birds can be examined at close range). I trained this model (and all models presented in this section) using Markov Chain Monte Carlo (MCMC) in a Bayesian framework using JAGS (Plummer 2012), which was called from R using 'JagsUI' (Kellner et al. 2019). The 'band-only' models yielded an estimated mean annual REKN survival of 79% (Fig. 1). Based on a posterior predictive check (PPC), the Bayesian p-value for this model was 0.1, indicating reasonable fit, with the observed data slightly over-dispersed relative to the fitted model (Fig. 1).

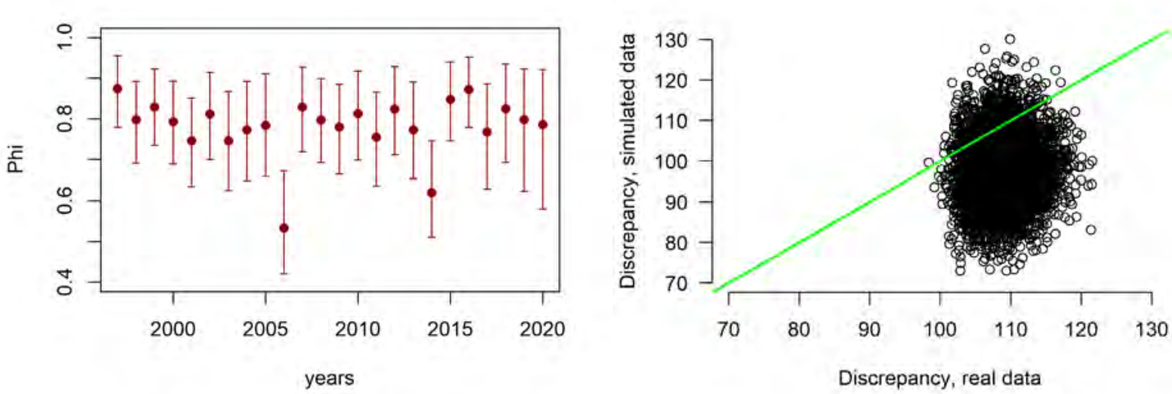

***Figure 1**. Left: mean annual (apparent) REKN survival (y axis) based only on banding data (no resighting data) from Delaware Bay from 1997 to 2022, using a Bayesian CJS model. Mean estimated apparent survival was 0.79, much lower than ASMFC's estimate of 0.93. Apparent survival (Phi) is a compound parameter indicating the probability of surviving and remaining within the study area. This model accounts for the presence of transients, which can bias survival estimates low. Right: Goodness-of-fit plot for the Bayesian CJS model using only banding data from Delaware Bay. This model exhibited reasonable fit to the data, with a Bayesian p-value of 0.1.*

Next, I fitted CJS models that incorporated the resighting data along with the banding data. When potential misread errors (flag codes observed only once by a single observer in a given season) were retained for analysis, mean apparent survival across all years was ~88%, with a steady decline in survival observed over the period from approximately 2005 to 2015 (Fig. 2). When potential misread errors were removed, mean REKN survival estimates dropped to ~80% annually – a rate more consistent with previous estimates for REKNs and other similar-sized shorebirds (Fig. 2). After correcting for potential misread errors, no temporal trend in survival was apparent across the study period (Fig. 2). This pattern is consistent with the known effects of misread errors, which tend to induce a spurious negative trend in survival (more positively biased estimates going further back in time) for long-term studies (Tucker et al. 2019).

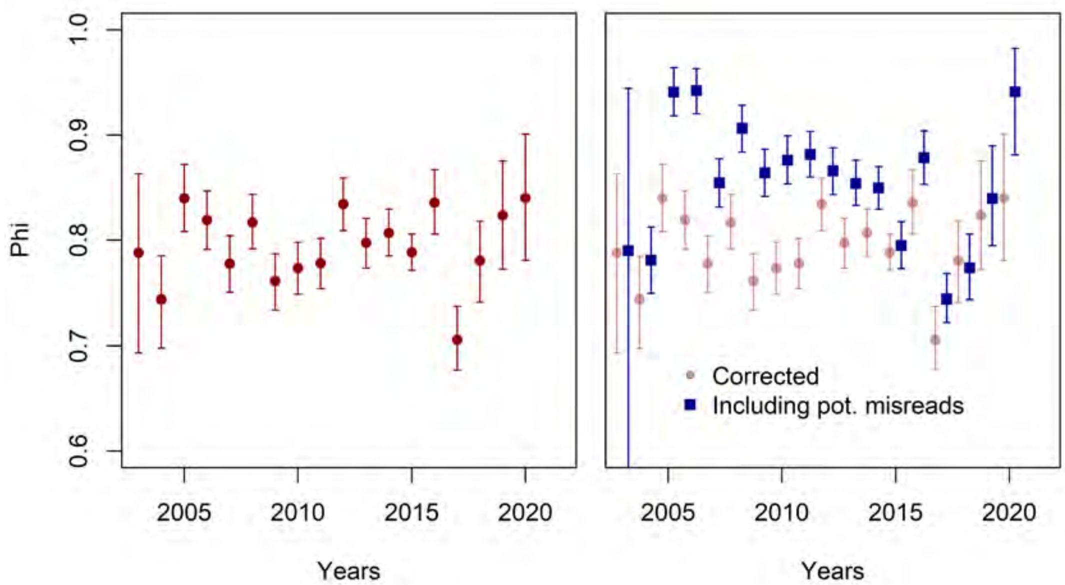

Figure 2*. Left: REKN annual apparent survival estimates (Phi; error bars indicate Bayesian 95% credible intervals) based on banding and resighting records from Delaware Bay, using a Bayesian CJS model with inter-annual process variance in survival, accounting for potential transients and 'trap response' (whereby individuals are more likely to be resighted if they were resighted in the previous year). This analysis uses only birds first banded in Delaware Bay (resighting observations of birds first captured elsewhere were discarded prior to analysis, following ASMFC 2021). To correct for misread errors, only birds resighted more than once in a particular year were considered to have been resighted that year. After correcting for potential misread errors, the estimated average apparent survival (Phi) was 0.80 annually, much lower than ASMFC's estimate of 0.93. Right: Comparison of REKN apparent survival with potential misreads (blue squares, including individuals resighted only once in a given year) versus the corrected version of the data with single-resight observations removed (transparent red; same results reported in left panel). As noted by Tucker et al. (2019), misread errors are more likely to bias survival estimates high in the early years of long time series- we see this effect here, especially in the period from 2005 to 2015.*

Finally, I used ASMFC's open robust design (ORD) framework to estimate annual REKN survival rates. This model, described by Tucker et al. (2022), is capable of estimating survival in addition to temporary emigration and the timing of arrival and departure from the stopover site each year. When potential misread errors are retained in the data set, the ORD model indicated a mean REKN survival rate of 0.9 (somewhat lower than ASMFC's estimate of 0.93, but similar to the survival rate reported in Tucker et al. 2022), with survival rates generally declining across the study period, as expected for data sets with misread errors (Tucker et al. 2019) (Fig 3). When potential misread errors were removed following the methods of Tucker et al. (2019), mean apparent survival rates dropped to ~80% or below throughout most of the 20-year study period, with no apparent trend over time (Fig. 3).

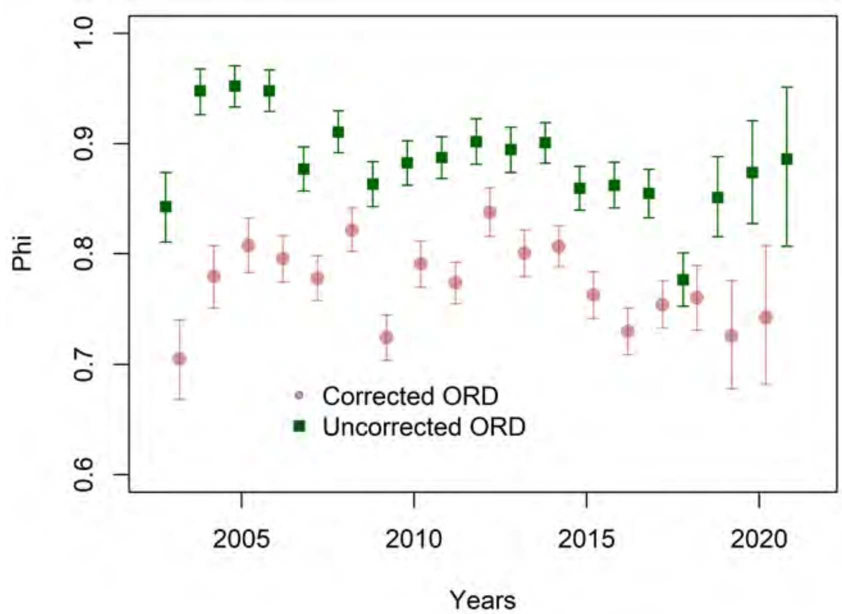

***Figure 3**. Annual apparent survival (phi; y axis) estimates from the open robust design (ORD) model used by ASMFC, fitted to REKN banding and resighting data from Delaware Bay from 2003 to 2022. Red circles and confidence intervals represent estimates from the model after correction for potential misread errors (i.e., by removing instances in which a REKN was re-sighted only once in a season). Estimated survival from the uncorrected ORD model (green squares; without correction for potential misread errors) are nearly always substantially higher than the corresponding estimates after accounting for potential misread errors. In addition, the uncorrected time series (green squares) displays the characteristic (spurious) negative trend in survival typically associated with survival estimates from long time series that include misread errors (Tucker et al 2019).*

Overall, these tests strongly indicate that the REKN survival rates used by ASMFC's ARM framework are artificially inflated and do not accurately reflect the real-world population of *Rufa* Red Knots. This artificially exaggerated longevity is likely to result in falsely optimistic estimates of REKN population resilience to short-term environmental fluctuations. In reality, the REKN population is likely to be much more vulnerable to one or two bad breeding years than the ARM model would suggest. The misspecification of the REKN demographic model raises serious concerns about the adequacy of the ARM framework for assessing population-level risks to this federally protected species.

2. Trawl-based indices of HSC abundance are inadequate for modeling the biotic interaction between REKNs and HSCs

ASMFC's IPM indicated a weak (and not ecologically meaningful; see attachment) positive effect of female HSC abundance on REKN survival. This relationship is in many ways the cornerstone of the ARM framework, as it represents the primary functional interaction between the two focal species. In the IPM, the effect of HSC abundance on REKN survival was trained using output from a Catch Multiple Survey Analysis (CMSA) as a proxy for female HSC abundance in Delaware Bay. In the CMSA, the HSC population was estimated on the basis of data from three trawl-based surveys (in addition to known sources of HSC mortality), conducted by Virginia Polytechnic Institute and State University (VT), New Jersey (NJ), and Delaware (DE), respectively.

I was able to obtain the survey records from each of the three Delaware Bay trawl surveys for reanalysis up to and including data from 2022. For my reanalysis, I only analyzed data on female HSCs due to their unique importance for REKNs. For each trawl survey, I generated a 'raw' annual catch-per-unit-effort (CPUE; often used as an indicator of abundance) by dividing the total number of female HSC captures by the total survey effort (generally reported as the length of seafloor surveyed). However, raw CPUE values do not control for other factors that can affect the number of expected HSC captures, such as time of year (seasonality), water temperature, salinity, depth, and dissolved oxygen. Therefore, comparing raw CPUE estimates across years can be misleading if (for example) the surveys were conducted at different seasons, or under disparate water temperatures or depths. To control for these unwanted effects, I used generalized linear models (GLM) and generalized additive models (GAMs) to model the number of female HSCs captured in each trawl survey as a function of seasonality (Julian date), water temperature, dissolved oxygen, salinity, and depth, using an offset term to account for differences in survey effort (tow length) among surveys (e.g., Fig. 10). Nonlinear responses were accommodated with quadratic terms or spline fits. All models assumed a negative binomial error distribution and a log-link. Models were fitted in R using the package 'glmmTMB' (Brooks et al. 2017), with goodness-of-fit assessed using the 'DHARMa' package (Hartig and Hartig 2017).

In my reanalysis I attempted to replicate the biotic interaction reported by ASMFC using trawl-based indices of female HSC abundance. Specifically, I used the REKN banding and resighting records from 2003 to 2022 (including 6 years of additional data relative to the ASMFC model, which only used data from 2005 to 2018) to model REKN apparent survival as a function of HSC several trawl-based indices of HSC abundance: (1) the CMSA results reported by ASMFC, (2) raw (unadjusted) and adjusted indices of HSC abundance from the DE, NJ and VT trawl surveys, and (3) design-based estimates of HSC abundance derived from the VT trawl survey (Wong et al 2022). In my reanalysis, I used conventional capture-recapture methods (Cormack-Jolly-Seber; CJS) in addition to the open-robust-design (ORD) framework used by ASMFC to estimate the effect of these indices on REKN survival.

Despite running multiple analyses with alternative trawl-based indices, my reanalysis efforts have uncovered no conclusive link between REKN survival and any trawl-based index of HSC abundance (including the CMSA-based indices used by ASMFC) (Table 1). Neither classical capture recapture methods (CJS) nor ASMFC's ORD method yielded evidence for a positive HSC-REKN relationship. Notably, the model that most closely resembled ASMFC's model – using the ORD framework for parameter estimation and the CMSA results as a proxy for HSC abundance – indicated a statistically significant *negative* effect of HSC abundance on REKN survival (Table 1). This surprising result is likely to be a spurious correlation, and should not be interpreted to suggest that higher HSC abundance in Delaware Bay leads to lower REKN survival (higher mortality). Critically, this result demonstrates that ASMFC's documented relationship between REKN survival and HSC abundance (upon which this two-species ARM framework is based) is unstable, underscoring the tenuousness and uncertainty of this critical relationship. Interestingly, this relationship could not be replicated even after (1) using the ORD parameter estimation framework and the code provided by the ASMFC modelers (2) reducing the dataset to cover the same period analyzed by ASMFC (2005 through 2018), (3) using the same CMSA-based estimates of female HSC abundance used by ASMFC, and (4) including the other time-varying covariates used in the ASMFC model (arctic snow cover and spawn timing). The instability of the HSC-REKN relationship reported by ASMFC suggests both that it is unlikely to be meaningful reflection of reality and that it is a poor foundation upon which to base a two-species risk assessment framework.

***Table 1**. Tests of alternative HSC abundance indices as drivers of REKN survival. Gray shading reflects non-significant results (95% CI overlaps zero, suggesting coefficient could plausibly be positive or negative), green shading reflects significant positive coefficients (more HSC implies higher REKN survival), light green shading represents weakly (marginally) significant positive coefficients, and red shading reflects significant negative coefficients (more HSC implies lower REKN survival).*

HSC Abundance index	HSC survey type	Survival coef, CJS	Survival coef, ORD
CMSA (uses DE, NJ and VT), 2005-2018	Ocean Trawl	0.02 (-0.18 to 0.22)	-0.18 (-0.31 to -0.06)
Virginia Tech (VT), abundance estimate	Ocean Trawl	-0.03 (-0.21 to 0.23)	-0.24 (-0.45 to 0.00)
Virginia Tech, CPUE	Ocean Trawl	0.23 (-0.01 to 0.54)*	-0.19 (-0.37 to -0.02)
Virginia Tech, CPUE adjusted	Ocean Trawl	0.01 (-0.18 to 0.18)	0.08 (-0.12 to 0.26)
DE trawl, CPUE**	Ocean Trawl	0.01 (-0.14 to 0.18)	-0.14 (-0.31 to 0.04)
DE trawl, CPUE adjusted**	Ocean Trawl	-0.02 (-0.17 to 0.17)	-0.10 (-0.27 to 0.09)

NJ trawl, CPUE	Ocean Trawl	-0.05 (-0.31 to 0.15)	-0.16 (-0.32 to 0.10)
NJ trawl, CPUE, adjusted	Ocean Trawl	-0.07 (-0.28 to 0.09)	0.09 (-0.16 to 0.28)
Delaware Bay Spawning Survey	Beach survey	0.02 (-0.18 to 0.27)	-0.09 (-0.26 to 0.12)
NJ Surface Egg Density	Beach survey	-0.08 (-0.24 to 0.06)	-0.09 (-0.29 to 0.09)
NJ Surface Egg Density (NJ REKN data only)***	Beach survey	0.29 (0.07 to 0.52)	0.32 (0.01 to 0.58)

*This relationship has weak statistical support but could be interpreted as evidence for a positive effect of HSC abundance on REKN survival.

*** Data provided on Aug 10, 2023. This work does not represent the opinions of the State of Delaware, Delaware Department of Natural Resources and Environmental Control or Delaware Division of Fish & Wildlife

*** This analysis used REKN capture and recapture records from the NJ side of the bay, since surface egg density was only collected on the NJ side of the bay.

The lack of a demonstrable effect of trawl-based HSC indices on REKN survival (Table 1) likely reflects the weaknesses of these indices rather than the weakness of the underlying biotic interaction. Trawl-based surveys are highly imperfect snapshots of the population of HSCs inhabiting Delaware Bay, obscured by differing survey methodologies and poorly understood aspects of HSC ecology, including seasonal and daily activities, habitat preferences, and degree of clustering on the seafloor. Furthermore, trawl-based surveys ignore that REKNs and other shorebirds do not feed on HSCs directly, but instead use their eggs to fuel their northward migration; therefore, the utility of trawl-based indices may be further eroded as a useful metric by additional, poorly understood processes such as annual variation in the timing of HSC egg deposition and the processes that dislodge eggs from their clusters and thereby render the eggs accessible to shorebirds.

To assess the degree to which the Delaware Bay trawl survey results reflected signal about true annual fluctuations in HSC abundance versus random noise (likely driven by unmodeled variations in survey conditions, HSC clustering and seasonal movements and other poorly understood aspects of HSC ecology), I tested for pairwise correlations of the raw and adjusted CPUE estimates. Pearson correlations among the raw and adjusted CPUE results ranged from 0 to 0.45 (Fig. 4). The only statistically significant correlation among the three surveys was between the unadjusted CPUE estimates for the NJ and DE trawl surveys. However, this relationship weakened to 0.16 and became inconclusive after controlling for seasonality and site conditions (Fig. 4). Overall, the correlation tests indicated that the results from the three trawl surveys are largely uncorrelated with one another (Fig. 4). Therefore, it is likely that the trawl survey results (and the resulting indices and estimates of HSC abundance) largely reflect factors unrelated to variation in the underlying HSC population.

If annual trawl-based estimates (and estimates derived from these surveys, like the CMSA) are largely uncorrelated with the underlying dynamics of the HSC population, REKN survival could conceivably be strongly correlated with true HSC abundance yet show little correlation with trawl-based HSC indices (Table 1). In this way, the use of trawl-based indices as a proxy for HSC abundance (e.g., in models of REKN survival) may severely misrepresent the true nature of the interaction between these two species. Overall, the results of my reanalysis indicate that trawl-based indices of HSC abundance are a noisy and unreliable indicator of annual fluctuations in the HSC population, and are likely an inadequate metric for quantifying the biotic interaction between REKNs and HSCs in Delaware Bay.

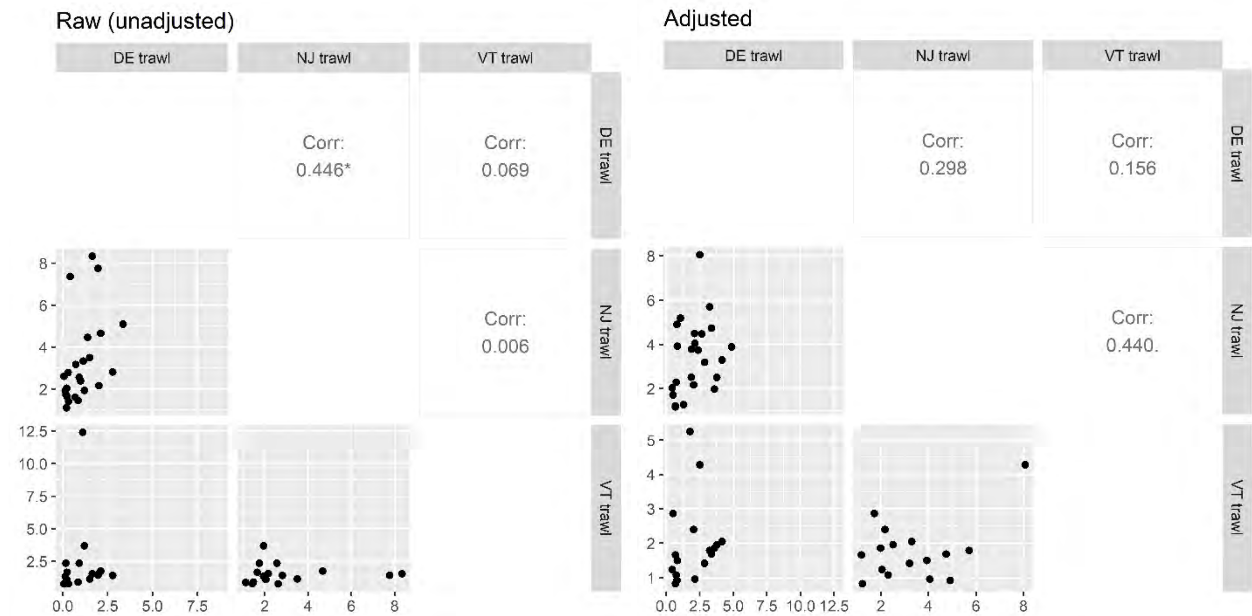

***Figure 4**. Scatterplot matrices (lower diagonals) and Pearson correlation tests (upper diagonals) for raw (left) and adjusted (right) catch-per-unit-effort (CPUE; HSC abundance indices) from three trawl-based surveys conducted in the Delaware Bay area from 1990 to 2022. Pearson correlations among the different trawl surveys ranged from 0 to 0.45. The only statistically significant correlation among the three surveys was between the unadjusted CPUE estimates for the NJ and DE trawl surveys. This relationship weakened to 0.16 after controlling for seasonality and site conditions. DE trawl data were provided on Aug 10, 2023. This work does not represent the opinions of the State of Delaware, Delaware Department of Natural Resources and Environmental Control or Delaware Division of Fish & Wildlife. Note that fulfillment of data requests does not constitute endorsement by the NJ Marine Resources Administration of any analyses or end products derived from the requested data.*

3. REKN survival is strongly sensitive to HSC egg-density, indicating that persistent degradation of the HSC egg resource could have dire consequences for the REKN population

In contrast to trawl-based HSC survey data, surveys of HSC egg densities measured directly on the beaches used by REKNs and other shorebirds are likely to be a far more direct representation of the functional ecological link between these two species. Fortunately, such data are available: researchers have been consistently measuring the shallow-depth (0 to 5 cm) density of HSC eggs in Delaware Bay (NJ side only) since 2000. While beach surveys (like all ecological data) are subject to sources of error that can obscure underlying signals, there are far fewer intermediate processes that may compromise the signal of the ecological relationship between these species. Although HSC egg surveys and spawning counts have been conducted in Delaware Bay for many years, ASMFC chose to use trawl-based surveys instead of surface egg density surveys to represent the HSC resource available to REKNs in their models (although they also used information on the timing of HSC spawning). To explain this decision, ASMFC has stated (1) that HSC abundance in Delaware Bay (CMSA model and results) has a clearer nexus with their management directive (ASMFC manages the HSC stock rather than the density of eggs deposited on beaches), and (2) that the egg data are highly variable across both space and time (seemingly making a case, without strong evidence, that the surface egg density surveys may be unreliable). Whatever their rationale for ignoring the long-term surveys of HSC surface egg-densities, it is misguided if it misrepresents the true nature of the underlying biotic interaction.

To evaluate the HSC surface egg density data as a proxy for the HSC egg resource available to migrating REKNs, I first reanalyzed the raw data to ensure that comparisons were valid across years for which survey methodologies differed. Overall, three different survey methodologies were used for measuring surface egg density during the period from 2000 to 2023. Although egg densities were always measured in the top 5 cm of the surface, the total area of beach surface measured per sample differed substantially among survey periods. To correct for these differences (effectively putting all samples on an even playing field) I used a modified version of the methods described in Smith et al. (2022) that included an offset term in the linear model formula. Briefly, I used generalized additive mixed models (GAMM) to model the number of eggs counted in each sample as a function of year (fixed effect) and seasonality (Julian day, using a smoothing spline to accommodate a non-linear functional response), with a random intercept term to accommodate for among-site variation, using an offset term (log of surface area sampled) to account for differences in survey effort (surveyed area) among samples. Following Smith et al. (2022), I assumed a negative binomial error distribution and a log link. Also following Smith et al. (2022), models were fitted in R, using the package 'glmmTMB' (Brooks et al. 2017), with goodness-of-fit assessed using the 'DHARMa' package (Hartig and Hartig 2017).

To assess the annual estimates of HSC surface egg density as a proxy for HSC egg resource availability in the REKN survival models, I used the annual adjusted surface egg density estimates as a covariate in the CJS and CMSA models. Since the HSC egg data were only collected on the NJ side of the bay, I only used REKN banding and resighting data from NJ for this analysis. The results of this analysis indicated a strong, positive effect of HSC density on REKN survival (Fig. 5). Years with high HSC egg densities were associated with mean REKN survival rates approaching 85%, whereas survival was reduced to approximately 65% in years with low HSC egg densities. Although these results were based on a standard Cormack-Jolly-Seber model for survival estimation, the open-robust-design model used by ASMFC yielded similar results, although with a wider range of parameter uncertainty (Table 1, section 2).

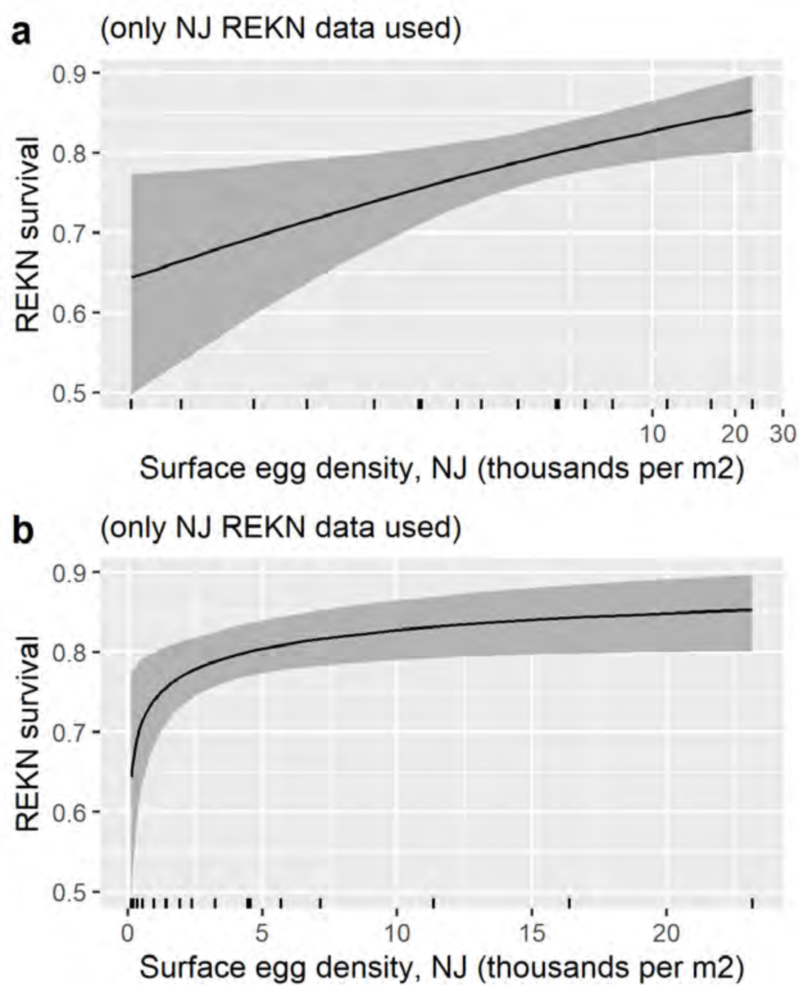

Figure 5*. REKN survival as a function of the observed surface density of HSC eggs (thousands of eggs per m2, top 5 cm) on the NJ side of Delaware Bay. The top panel shows this relationship on the log scale (the scale at which the relationship was modeled), and the bottom panel shows the same relationship on the raw, untransformed scale. These results are derived from a Cormack-Jolly-Seber (CJS) model fitted to REKN banding and resighting data from 2003 to 2022. The rug (additional tick-marks along the x-axis) represents the observed egg densities during the study period. Since egg density data was not collected on the DE side of Delaware Bay, only birds resighted in NJ were used for this analysis.*

In contrast to the HSC-REKN relationship used by ASMFC, under which the REKN population would be expected to increase even under the complete elimination of the HSC population in Delaware Bay (see attached), the effect of HSC egg density on REKN survival (Fig. 6) forecasted a steep decline in the REKN population under sustained low densities of HSC eggs (held constant at the lowest observed levels from 2000 to 2022), resulting in near-extinction of the REKN population after 2-3 decades (Fig. 6). The magnitude of this relationship suggests that even 5 years of low HSC egg densities could result in a 50% decline of the REKN population. The strength of the estimated relationship between HSC egg densities with REKN survival is much more consistent (in comparison with the ARM framework) with the observed decline in the REKN population during the late 20th century, which is widely attributed to unregulated HSC harvest. Also in sharp contrast to the ASMFC model, the estimated relationship between REKN survival and HSC egg density indicate that sustained high HSC egg densities (held constant at the highest observed levels) can potentially promote the rapid recovery of the REKN population (Fig. 7).

It is important to recognize that the relationship between HSC abundance and HSC surface egg densities, which is critical for assessing the link between HSC harvest (which affects abundance) and REKN population persistence (which depends upon surface egg densities) remains unclear. Notably, surface egg densities are uncorrelated (in many cases, weakly negatively correlated) with the CMSA results and other trawl-based indices of HSC abundance (Fig. 8). Although knowledge of the link between HSC abundance and egg densities is clearly critical for managing the HSC stock in Delaware Bay, the true HSC abundance in Delaware Bay remains poorly characterized (see part 2, above), and the relationship between HSC abundance and the density of eggs accessible to shorebirds remains poorly understood. Therefore, caution should be used in interpreting any direct comparisons between models using HSC abundance versus egg density as a predictor variable (Figs. 6, 7), as these covariates are not strictly comparable. However, common sense dictates that there is a relationship between HSC egg availability and HSC abundance. Furthermore, the dependability of the egg resource year after year (and ultimately, the recovery of the REKN population) may require a “superabundance” of horseshoe crabs in Delaware Bay, ensuring an adequate supply of eggs available to REKNs even in years where environmental processes may be unfavorable to horseshoe crabs, the timing of their spawning, or the processes that dislodge eggs and make them available to foraging shorebirds. Finally, given the limited state of knowledge about the relationship between surface egg densities and HSC abundance, it is precautionary to assume a strong direct relationship whereby lower HSC population numbers (e.g., via harvest or other anthropogenic sources of mortality) can reduce the number of HSC eggs available for shorebirds during the critical stopover period.

Finally, the results of this reanalysis strongly argue for continued rigorous monitoring of HSC surface egg densities at multiple beaches across Delaware Bay (on both the DE and NJ sides), as these data are critical for assessing the ecological link between HSCs and REKNs. By ignoring this source of data, ASMFC's revised ARM framework misrepresents the importance of the HSC egg resource to the REKN population and thereby underestimates the risk posed by HSC harvest to the long-term viability of the REKN population. By recommending harvest of female horseshoe crabs each year, the ASMFC's ARM framework has the potential to impede both the survival and the recovery of the REKN population.

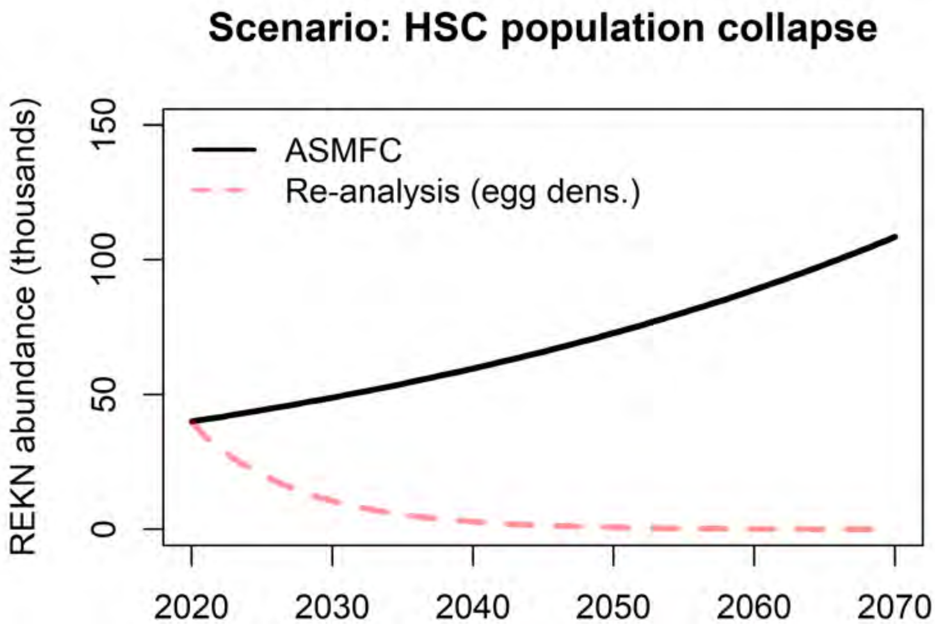

Figure 6*. Results from 'back of the envelope' calculations of REKN population growth under scenarios with a depleted HSC population. The solid black line represents REKN abundance from 2020 through 2070 under the HSC-REKN relationship described in the ASMFC ARM framework, which was trained using the CMSA model as a proxy for the HSC egg resource in Delaware Bay. The numbers used for this calculation reflect the mean survival and fecundity values assuming a HSC population of zero. The dashed red line represents REKN abundance from 2020 through 2070 under a reanalysis in which the HSC-REKN relationship was trained using surface egg density data as a proxy for the HSC egg resource in Delaware Bay. In sharp contrast to the ASMFC model, the relationship fitted to the HSC egg density data indicate that collapse of the HSC population (here defined as the lowest observed annual surface egg density values) could easily drive the collapse of the REKN population in Delaware Bay. Note that this figure is based on a simple age-structured population model and does not incorporate a density-dependence mechanism (the revised ARM includes a density ceiling that prevents the REKN population from growing above ~150k).*

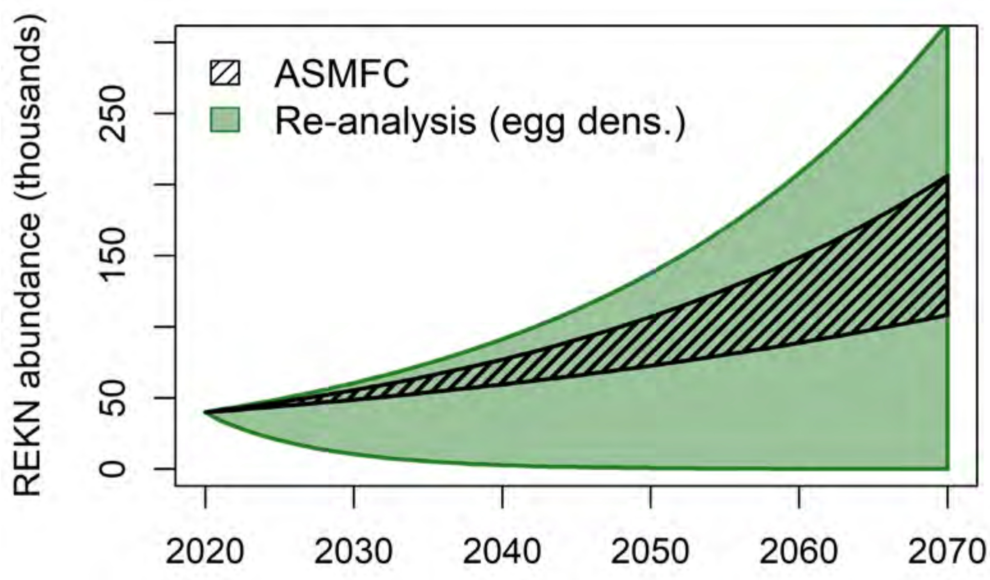

***Figure 7**. Results from 'back of the envelope' calculations of REKN population growth under scenarios ranging from a worst-case scenario of HSC population depletion (see Fig. 6) to a favorable scenario with constant HSC abundance/egg density at the highest levels observed from the early 2000s to present. The black hashed polygon (with diagonal lines) represents REKN abundance from 2020 through 2070 under the HSC-REKN relationship described in the ASMFC ARM framework, which was trained using the CMSA model as a proxy for the HSC egg resource in Delaware Bay. The light green polygon represents REKN abundance from 2020 through 2070 under a reanalysis in which the HSC-REKN relationship was trained using surface egg density data as a proxy for the HSC egg resource in Delaware Bay. In sharp contrast to the ASMFC model, this reanalysis indicates that HSC egg densities can strongly impact whether the population thrives (under consistently high surface egg densities) or declines to extinction (under consistently low egg densities). Note that this figure is based on a simple age-structured population model and does not incorporate a density-dependence mechanism (the revised ARM includes a density ceiling that prevents the REKN population from growing above ~150k).*

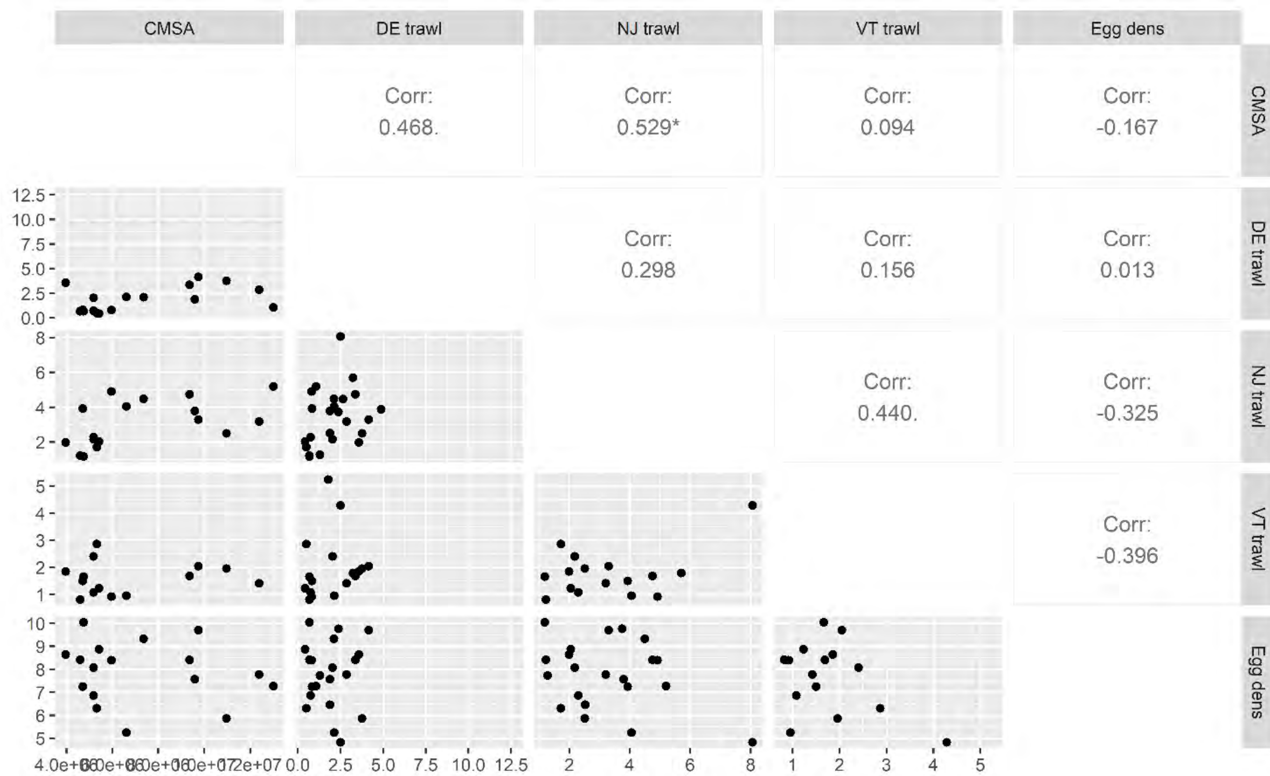

Figure 8*. Scatterplot matrices (lower diagonals) and Pearson correlation tests (upper diagonals) for HSC abundance indices derived the CMSA model (used as an estimate of HSC abundance in the ARM framework), three trawl-based surveys conducted in the Delaware Bay area from 1990 to 2022 (used for training the CMSA model; adjusted for seasonality and survey conditions), and surface egg densities (NJ side only). The only statistically significant correlation among these five indices was between the CPUE estimates from the NJ trawl survey and the CMSA results. There was no apparent correlation between surface egg density measurement and any trawl-based index of HSC abundance (including the CMSA results). In fact, surface egg density had a weakly negative relationship with most trawl-based indices of HSC abundance. DE trawl data were provided on Aug 10, 2023. This work does not represent the opinions of the State of Delaware, Delaware Department of Natural Resources and Environmental Control or Delaware Division of Fish & Wildlife. Note that fulfillment of data requests does not constitute endorsement by the NJ Marine Resources Administration of any analyses or end products derived from the requested data.*

4. The ARM exaggerates the evidence for an increasing trend in the number of female HSCs in Delaware Bay

ASMFC used their CMSA model (which used the DE, NJ and VT trawl surveys as primary data sources) to claim that the HSC population in Delaware bay has been undergoing a recovery (population increase) during the period from 2003 to 2018 (ASMFC 2001). Furthermore, Smith et al. (2022) documented evidence for an increase in HSC surface egg densities during the same period. However, after controlling for potentially confounding factors like seasonality, water temperature, and differences in survey effort and methodology, neither the trawl-based surveys used by ASMFC nor the egg-density surveys show strong evidence for increasing abundance of female HSCs in Delaware Bay over the last 20 years.

The NJ trawl data provides an interesting case-in-point. The raw catch-per-unit-effort (CPUE) from New Jersey's ocean trawl survey (one of the major data sources used by ASMFC for documenting a positive trend in HSC abundance) appears to indicate increasing female HSC abundance from 2003 to 2022 (statistically significant at alpha=0.05; Fig. 9). However, when raw CPUE numbers are adjusted for strong effects of seasonality, water temperature, depth and dissolved oxygen on HSC captures in Delaware Bay (Fig. 10) the apparent positive trend in HSC CPUE disappears, becoming statistically inconclusive on the basis of a linear regression weighted by the inverse of sampling variance (Fig. 9). The values used by ASMFC to represent the NJ trawl data values in their CMSA model (which used only trawl data from April and August; ASMFC 2021) match closely with the unadjusted CPUE numbers (Fig. 9; results are similar using all months instead of only April and August trawl results), indicating that ASMFC's estimates of HSC population dynamics failed to control for differences in season and survey conditions. This result was consistent whether or not all NJ trawl results were used for model fitting or whether the data were filtered to include only the months used by ASMFC (April and August). Therefore, the increasing trend in the HSC population reported by ASMFC and used in the ARM may (at least in part) be an artifact of differing survey conditions (e.g., differences in trawl depth or water temperature) rather than evidence of recovery of the HSC population over time.

Similarly, when the egg-density data were adjusted for known differences in survey methodologies (primarily, differences in sampled area), the apparent positive trend in HSC surface egg densities (Smith et al. 2022) became weak and inconclusive (note that this correction did not impact the estimated relationship between REKN survival and HSC egg-densities) (Fig. 11). Thus, my reanalysis of both the trawl-based surveys (Figs. 9, 10) and the egg-density surveys (Fig. 11) indicates that perceived positive trends in HSC population indices may reflect sampling differences and not trends in the underlying HSC population. Although these findings suggest the trend estimates reported by Smith et al. (2022) may be in error, this finding does not call other findings from Smith et al. (2022) into question, as these findings do not strictly depend upon the comparability of surface egg density samples collected during the study period.

Finally, I tested whether the aggregate evidence from the three trawl-based surveys (both adjusted and unadjusted; see part 2 of this report) showed evidence for HSC population recovery. Specifically, I ran linear regression models combining the CPUE estimates (both adjusted and unadjusted) from all three trawl surveys to assess evidence for an aggregate trend in abundance over time. Neither the raw HSC capture efficiencies (CPUE) from the trawl surveys nor the adjusted CPUE estimates showed conclusive evidence for a trend in HSC abundance over time (Fig. 12). With little correlation in inter-annual variation among trawl surveys (Figs 4, 8), years in which one trawl-based survey tended to indicate a large HSC population were rarely reinforced by the other surveys, resulting in a regression to the mean (Fig. 12).

Overall, the above results suggest that the ARM framework exaggerates the evidence for an increasing trend in female HSC abundance over the first two decades of the 21st century. In so doing, the ARM framework predicts recovery of the HSC population in Delaware Bay under a *status quo* scenario whereby HSC harvest regulations and other protections are maintained at current levels. In contrast, the results from my reanalysis suggest that the recovery of the female HSC population may require additional safeguards – including possibly decreasing harvest and continuing to improve and restore habitat at spawning beaches. Furthermore, by overstating the evidence for recent increases in the HSC population, ASMFC thereby likely underestimates both the vulnerability of the HSC population to harvest pressures in Delaware Bay and the potential carryover impacts on the REKN population.

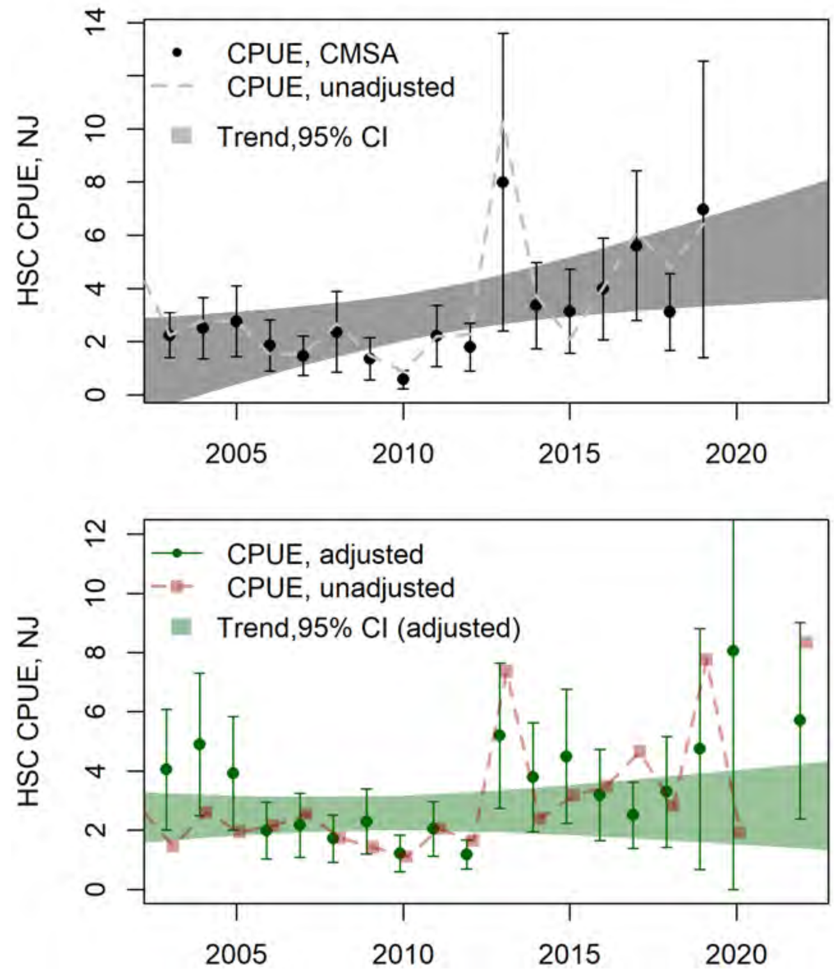

Figure 9*. Annual HSC catch-per-unit-effort (CPUE; a type of abundance index) for trawl surveys conducted by the state of New Jersey from 1999 to present. The top figure compares the numbers used by ASMFC for their Catch Multiple Survey Analysis (CMSA) model (black), compared with the unadjusted, raw CPUE computed from the raw data (for comparison, only surveys conducted in April and August were used to compute CPUE; however, results look similar with raw CPUE for all months combined). The gray polygon represents the 95% confidence interval for the linear regression of the unadjusted CPUE against time in years. The bottom panel displays CPUE estimates adjusted for the effects of seasonality, water temperature, depth, and dissolved oxygen, with the dashed gray line and points again representing the (unadjusted, all months combined) CPUE computed from the raw data. Error bars represent 95% credible intervals. The green polygon represents the 95% confidence interval for the linear regression of the adjusted CPUE against time in years, showing no substantive trend over time.*

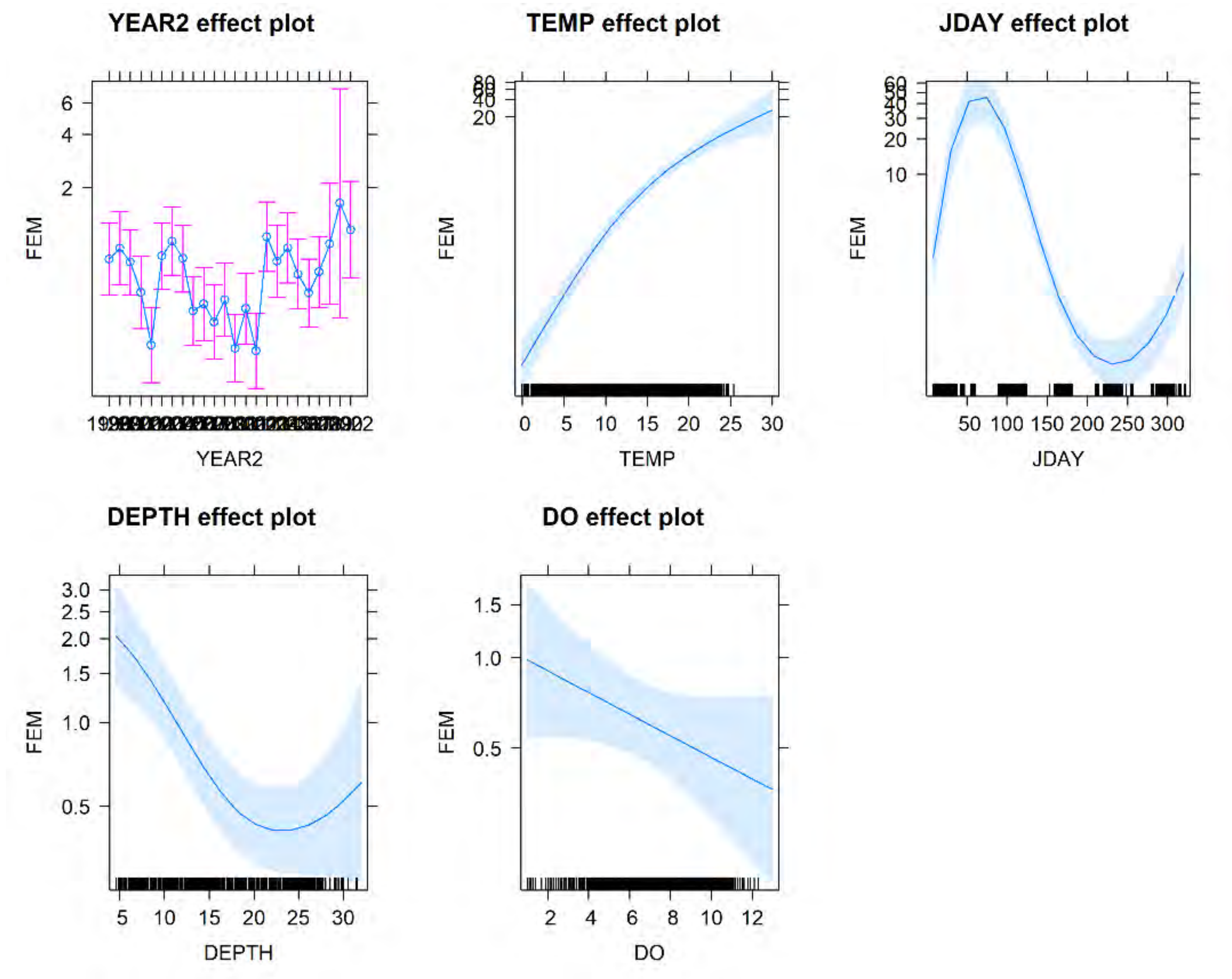

Figure 10. *Effects plots illustrating strong, non-linear effects of season and environmental covariates (from top left to bottom right: year, temperature, Julian day, trawl depth, and dissolved oxygen) on the results of the ocean trawl surveys conducted in the Delaware Bay region by the state of NJ. These figures are predictions from a generalized linear model (GLM) using a negative binomial error distribution, quadratic terms to represent non-linear relationships, and an offset term to accommodate differing effort among surveys (amount of seafloor surveyed). The 'rug' on each plot illustrates the distribution of data for each quantitative covariate. Each panel represents the expected effect of a single predictor variable (indicated by the x-axis label), holding all other predictor variables at their mean or most frequent value. Therefore, although temperature and dissolved oxygen (DO) are closely linked, the DO effect plot illustrates the effect of DO after factoring out the effect of temperature.*

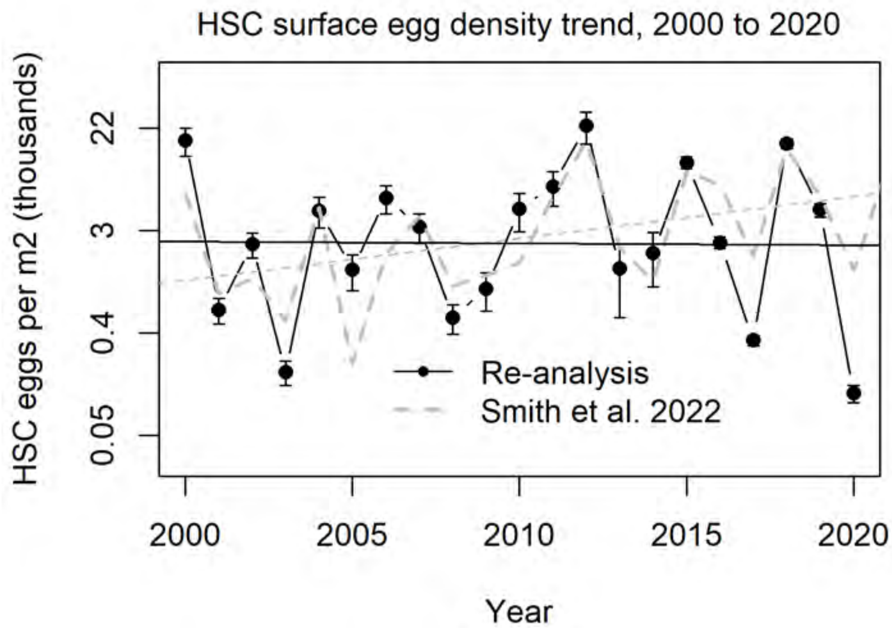

***Figure 11**. Reanalysis of the evidence for a temporal trend in long-term surface egg density data from 2000 to 2020. Although the original analysis (Smith et al. 2022) detected a weak but non-negligible positive trend over time (dashed grey line), this regression relationship became inconclusive after accounting for differences in survey methodology across the 20 year study period (area represented by each sampling unit). Therefore, the increasing trend reported in Smith et al. (2022) appears to be an artifact of differing sampling methodologies used during this time frame.*

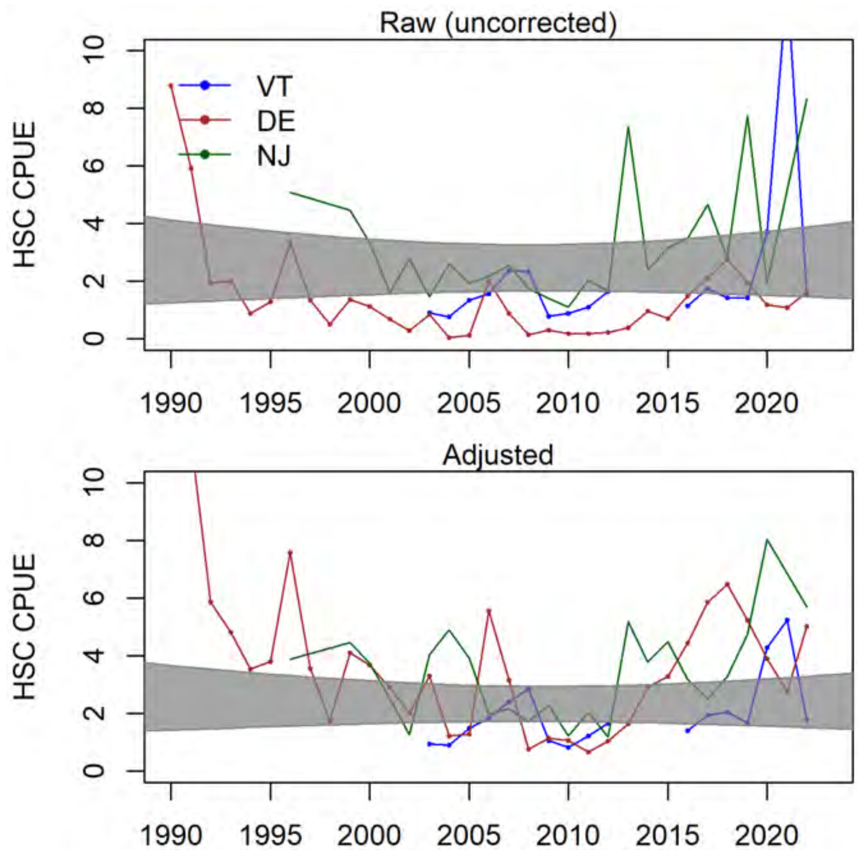

Figure 12. *Raw and adjusted HSC catch-per-unit-effort (CPUE, which serves as an index of abundance) from three trawl surveys conducted in the Delaware Bay area from 1990 to 2022. Transparent gray polygons represent the 95% confidence region for a linear regression of CPUE (aggregated across the three surveys) across time. Top panel represents raw CPUE, whereas CPUE values in the lower panel are adjusted for the effects of seasonality, water temperature, salinity, dissolved oxygen, and depth. Taken in aggregate, the trawl data indicate an uncertain and variable population that is neither increasing nor decreasing over time. DE trawl data (Delaware Division of Fish & Wildlife, Delaware Department of Natural Resources and Environmental Control) were provided on Aug 10, 2023. This work does not represent the opinions of the State of Delaware, Delaware Department of Natural Resources and Environmental Control or Delaware Division of Fish & Wildlife. Note that fulfillment of data requests does not constitute endorsement by the NJ Marine Resources Administration of any analyses or end products derived from the requested data.*

5. The statistical model (IPM) used for estimating REKN population parameters is over-parameterized and likely to yield spurious results

Like many Integrated Population Models (IPMs), ASMFC's Red Knot IPM comprises two sub-models: (1) a "state-space" model for estimating abundance and recruitment on the basis of population counts over time, and (2) a model for estimating survival on the basis of capture-recapture data (history of observation records for all uniquely marked individuals) (Schaub and Kery 2021). In the REKN IPM, the state-space model is trained using annual 'peak count' data (total number of REKNs observed during annual aerial and ground surveys), and the capture-recapture model is trained using REKN banding and resighting records from Delaware Bay. Whereas adult REKN survival (capture-recapture model) can be estimated directly from available capture-recapture records (banding and re-sighting data from Delaware Bay), recruitment of juvenile REKNs into the adult population (state-space model) is not directly estimable from the peak-count data. Instead, the IPM estimates annual recruitment rates indirectly, as the offsets required to match the observed dynamics of the peak-count data while accounting for expected losses to mortality (the latter estimated from the capture-recapture sub-model).

While the data sources for training the capture-recapture model are information-rich (tens of thousands of banding records and hundreds of thousands of resighting observations), the peak-count data used by ASMFC to train the state-space model comprised a total of 14 data points: one for each year from 2005 to 2018. Mathematically, this implies that these data could be used to assign values to a maximum of 14 unknown parameters. However, with several sources of 'noise' present in the data (sources of variation that obscure the important underlying signals), these data are likely to support far fewer than 14 parameters. Some statisticians informally recommend a rule of thumb of 30 data points per parameter for robust parameter estimation; however, the optimal ratio differs depending upon many factors, including the signal-to-noise ratio in the system as well as the risk tolerance of the researcher (Muthen and Muthen 2002). Nonetheless, the REKN IPM treats the peak-count dataset as a much richer source of information than it actually is. In fact, the number of parameters estimated by the state-space model exceeded the number of data points, resulting in a highly over-parameterized model that is inherently prone to generating spurious results. Table 2 (below) enumerates the unknown parameters estimated in the REKN IPM on the basis of the REKN peak-count dataset.

***Table 2**. Free parameters ('unknowns') estimated using the peak-count data (n = 14) in the REKN IPM*

Description	Number of free parameters
Initial abundance	1
Annual recruitment	2 to 12*
Effect of HSC abundance on recruitment	1
Observation error, ground counts	1
Observation error, aerial counts	1
"Availability" parameters	12**
TOTAL	18 to 28

* Random effect
** Strong priors assigned

Taken together, the state-space model used in the REKN IPM estimated between 18 and 28 free parameters on the basis of 14 data points (Table 2). There are two reasons why it is not possible to pinpoint the exact number of free parameters estimated in this model. First of all, the state-space model includes a 'random effect' (representing annual recruitment of new REKNs into the breeding adult population) whereby 12 separate estimates of annual recruitment (12 parameters) are generated on the basis of a two-parameter Gaussian ('normal') distribution (mean and variance; known as 'hyperparameters'). Therefore, the number of free parameters used to estimate annual recruitment could be as high as 12 (number of annual recruitment estimates) or as low as 2 (number of 'hyper-parameters' used for generating the 12 annual estimates); the "truth" lies somewhere between those two extremes. Secondly, several parameters in the state-space model (notably, the 12 'availability' parameters, representing the fraction of the stopover population observable in the aerial and ground counts) were assigned relatively strong priors (in Bayesian inference, parameter estimates combine prior knowledge with additional knowledge inferred from the data). These strong prior distributions were assigned to the 'availability' parameters on the basis of comparisons between the peak-count data and REKN abundance estimates generated annually as part of the ARM (Lyons 'superpopulation' models). Therefore, one could argue that the 12 'availability' parameters were not strictly 'free parameters' (or 'unknowns') since they were constrained by previous information from the Lyons models. However, my tests indicate that the 'availability' parameters remained sensitive to the peak-count data, and therefore it is more correct to treat these terms as free parameters ('unknowns') rather than as fixed parameters. Nonetheless, even in the most generous interpretation (~8-10 free parameters), the number of unknowns in the state-space model is far greater than the peak-count data (n = 14) could reasonably support, resulting in an over-parameterized model.

Models that fit more parameters than the data can support have a strong tendency to produce spurious results (results that fail to replicate when challenged with new data). Statisticians call such models "over-parameterized", or "over-fitted", and this problem is widely understood by quantitative researchers and statisticians (McNeish 2015). Among the free parameters estimated from this over-fitted model are several terms vital for understanding and simulating REKN population dynamics, including initial abundance, population trends (growth or decline), mean recruitment rate, and the effect of HSC abundance on recruitment. Due to over-fitting, these key parameters in the ARM model are likely to reflect random noise in the peak count data rather than the demographic reality of the REKN population.

To confirm the tendency of the REKN IPM to generate spurious results, I simulated artificial 'peak-count' data under a 'white noise' process (with no underlying trend) and assessed how often the IPM detected a spurious trend. To do this, I ran the IPM 50 times, each time replacing the REKN peak count data with random "white noise" generated using the same mean and variance as the observed peak-count data. Using the REKN abundance estimates from each of the 50 replicates, I ran a linear regression model with log transformed median REKN abundance as the response variable and time (year; 2003 to 2022) as a continuous predictor variable. For each replicate, I recorded whether the temporal trend of abundance over time was "significant" at alpha=0.05, along with the sign and magnitude of the inferred trend. As a second test, I ran 100 80-year projections (one set of projections for each of the 50 replicates) using the time-varying survival and recruitment estimates from the IPM to project REKN abundance from 2023 to 2100 (propagating uncertainty using standard Bayesian demographic modeling techniques; Goodman 2002). Since the 'peak-count' data in these replicates were simulated with no underlying trend, the final abundance should match the initial abundance on average.

The results demonstrated that the IPM more often than not detected spurious temporal trends in REKN abundance (increases or declines in abundance over time) during the study period (Fig. 13). In fact, linear regressions (n = 50) fitted to the estimated log-median abundance from 2003 to 2022 indicated a non-negligible spurious temporal trend for 84% (42 of 50) of replicates at alpha = 0.05. Consequently, the results from projecting abundance forward to the year 2100 showed a strong tendency to erroneously produce estimates of final REKN abundance either much lower or much higher than the initial abundance (Fig. 14). Surprisingly, spurious negative trends were more common in my analysis than spurious positive trends in my analysis (Fig. 14). However, it is likely that this result is an artifact of the particular data simulation methods, model specification and initial values I used, and I caution against using this result to infer a systemic bias in the REKN IPM results. The apparent biases in my test results may be sensitive to many aspects of model specification, from the distribution and transformations used for simulating the peak-count data, to the prior distributions specified, to the initial values used for Markov-chain Monte Carlo (MCMC) simulations. Lacking access to the full modeling workflow used by ASMFC, I specified many of these parameters somewhat arbitrarily (lacking the bandwidth to complete a full sensitivity analysis). In addition, I modified the capture-recapture data to account for potential misread errors (see above), and this change could have potentially changed or even reversed any apparent biases in the modeling framework used by ASMFC. Therefore, additional sensitivity tests would be necessary to understand the conditions under which systemic biases may manifest in this modeling framework.

Due to over-parameterization, the REKN IPM is unstable and has a strong tendency to produce spurious results. Therefore, the REKN demographic simulations used in the ARM framework are unlikely to accurately capture the dynamics of the real-word population of *Rufa* Red Knots inhabiting Delaware Bay each Spring. Overall, the tendency of the REKN IPM to produce spurious results suggests that this model should not be used for assessing REKN conservation status, running scenario tests, or guiding recovery efforts for a federally Threatened species.

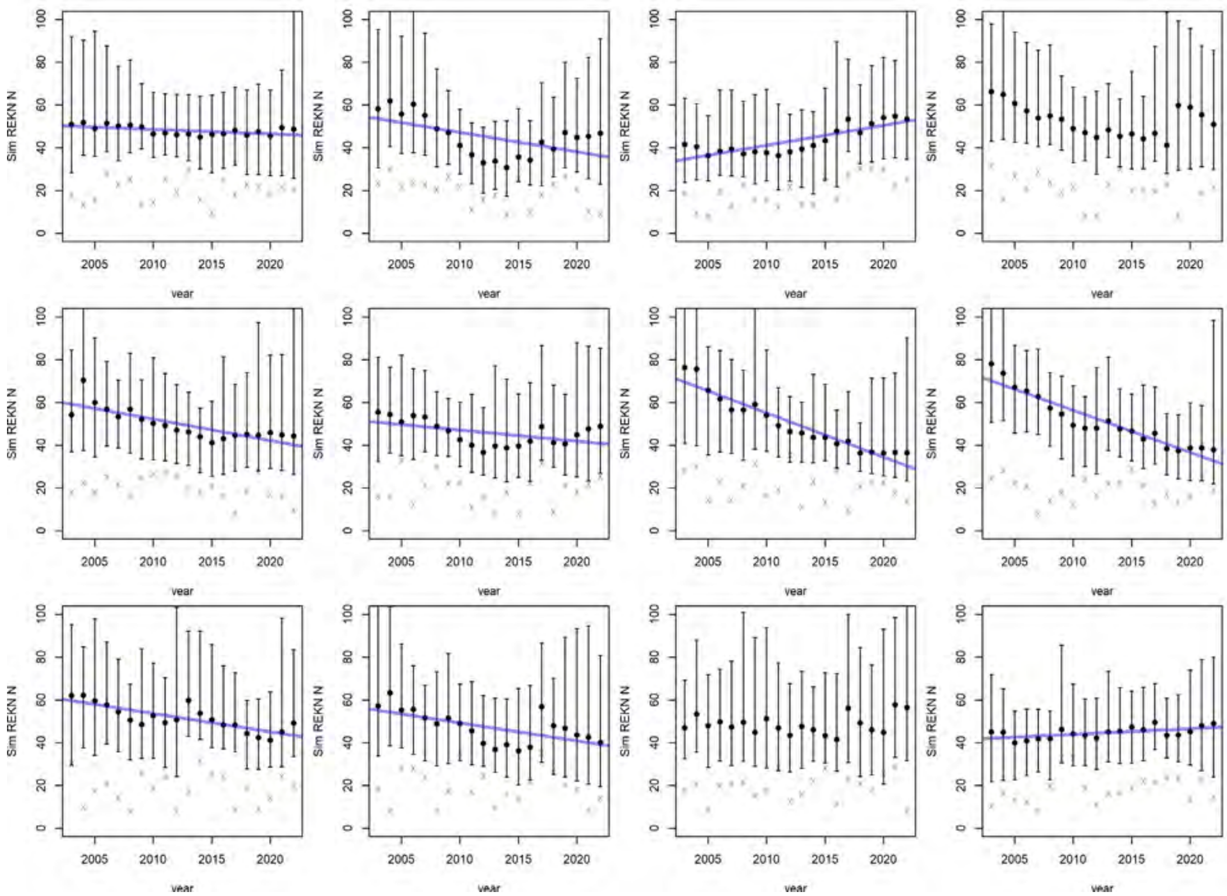

***Figure 13**. Simulated REKN abundance (in thousands) over time for 12 replicates (randomly chosen from among 50) of the REKN IPM from 2003 to 2023 in which the peak-count data were replaced with random noise with no underlying trend (simulated data are represented by "X" symbols in the above panels). In many of these replicates, the IPM results detected a spurious trend over time (regression lines in the above panels) despite the lack of a trend in the count data.*

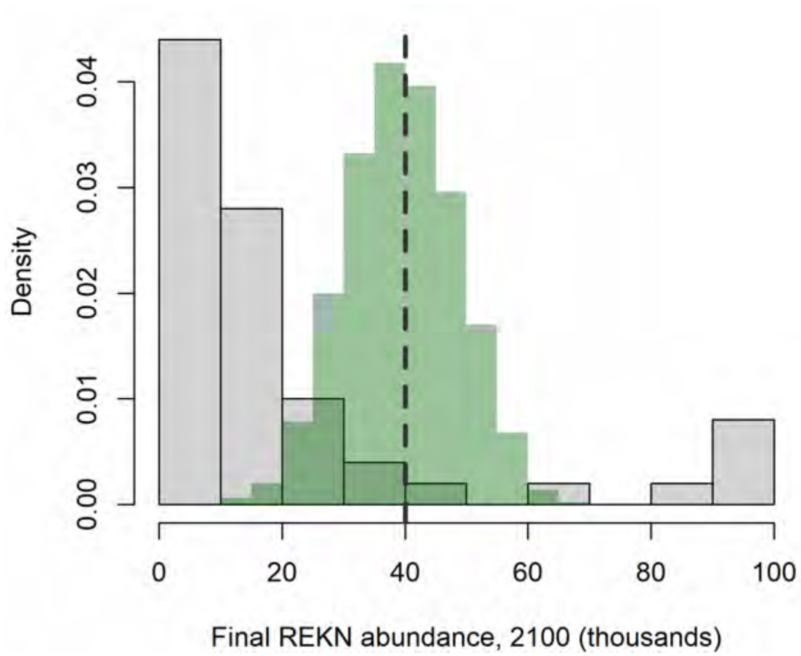

***Figure 14**. Histogram of median simulated REKN abundance at year 2100, based on the results from 50 replicates of the REKN IPM whereby the 'peak-count' data were iteratively replaced by randomly generated white noise with the same mean and standard deviation as the observed peak-count data (bars with gray fill). The vertical dashed line represents the initial abundance for the simulations (40,000 REKNs). Since the peak-count data were simulated with no trend, the final simulated abundance should match the initial abundance on average – which in this case would imply a single peak centered on the initial abundance (green histogram). However, the peaks at abundances near zero and 100 indicate that many of these simulations (fitted to white-noise) spuriously projected either near-extinction or a full recovery of the population after 80 years. The fact that more replicates projected spurious declines versus spurious growth is likely to be an artifact of the simulations rather than a systematic bias inherent to the REKN IPM.*

6. The IPM exhibits poor fit to the available data

Goodness-of-fit (GOF) testing is a critical validation step in any model-fitting workflow (e.g., assessing the normality of residuals in linear regression), ensuring that key assumptions made during the modeling process are reasonable and justified (Conn et al. 2018). In the case of IPMs, simulation studies have indicated that indirect estimates of latent parameters (like recruitment rates in the REKN IPM) can be highly sensitive to model assumptions, and can produce biased and nonsensical results if key assumptions are violated (Riecke et al. 2019; Schaub and Kery 2021). Therefore, it is critical to assess model goodness-of-fit (GOF) to assess whether IPM assumptions are reasonable (Conn et al. 2018). If an IPM fails to exhibits a reasonable fit to the data, key model parameters (like recruitment rates in the REKN IPM) should be used with extreme caution (Riecke et al. 2019).

In the context of hierarchical Bayesian analysis (the paradigm used by the ASMFC modelers), a commonly used approach is to run a Posterior Predictive Check (PPC), in which data are repeatedly simulated under the fitted model and compared to the actual data (Kery and Schaub 2011; Schaub and Kery 2021). If a model is unable to simulate data resembling the real-world observations, the model is determined to be an inadequate representation of the true processes that generated the data. 'Bayesian p-values' are often used to summarize GOF for IPMs, and represent the fraction of simulated datasets whose variance from expected values exceeds that of the true observations (Kery 2010). Whereas statisticians have noted that Bayesian p-values tend to understate a model's lack of fit (Conn et al. 2018), and research on assessing GOF for IPMs is ongoing, Bayesian P-values remain the most commonly used and reported GOF statistic for models like the REKN IPM (Schaub and Kery 2021).

In their ARM report, ASMFC mentions (but does not further document) two PPCs that were performed to assess goodness-of-fit for the IPM. One of these tests – the only test included in the publicly shared IPM code – uses a PPC to assess the degree to which the state-space model adequately represented the peak-count data. However, this test has been previously demonstrated to be an insufficient gauge of model adequacy (Schaub and Kery 2021). Furthermore, the over-parameterization of the state-space model (see above) virtually guarantees that the state-space model will pass this test (over-parameterized models tend to exhibit excellent fit to the observed data, although they tend to perform poorly in other contexts). The second and final goodness-of-fit test mentioned in the ARM report (which suggests mild lack of fit) is not included in the version of the IPM code shared publicly, so it is impossible to assess what test was actually run. However, I ran three additional PPCs to assess the degree to which the IPM (specifically, the open robust design component of the IPM) adequately represented the REKN resighting data from 2003 to 2022. These tests, which were used and reported in an earlier version of the open robust design (ORD) model for estimating REKN survival and stopover use (Tucker et al. 2021), indicated poor fit to the data (Figure 15), suggesting that the IPM is an inadequate representation of key processes operating in the REKN population – including survival and recruitment. The failure of the IPM to pass rigorous goodness-of-fit tests casts additional doubt on conclusions generated from this model.

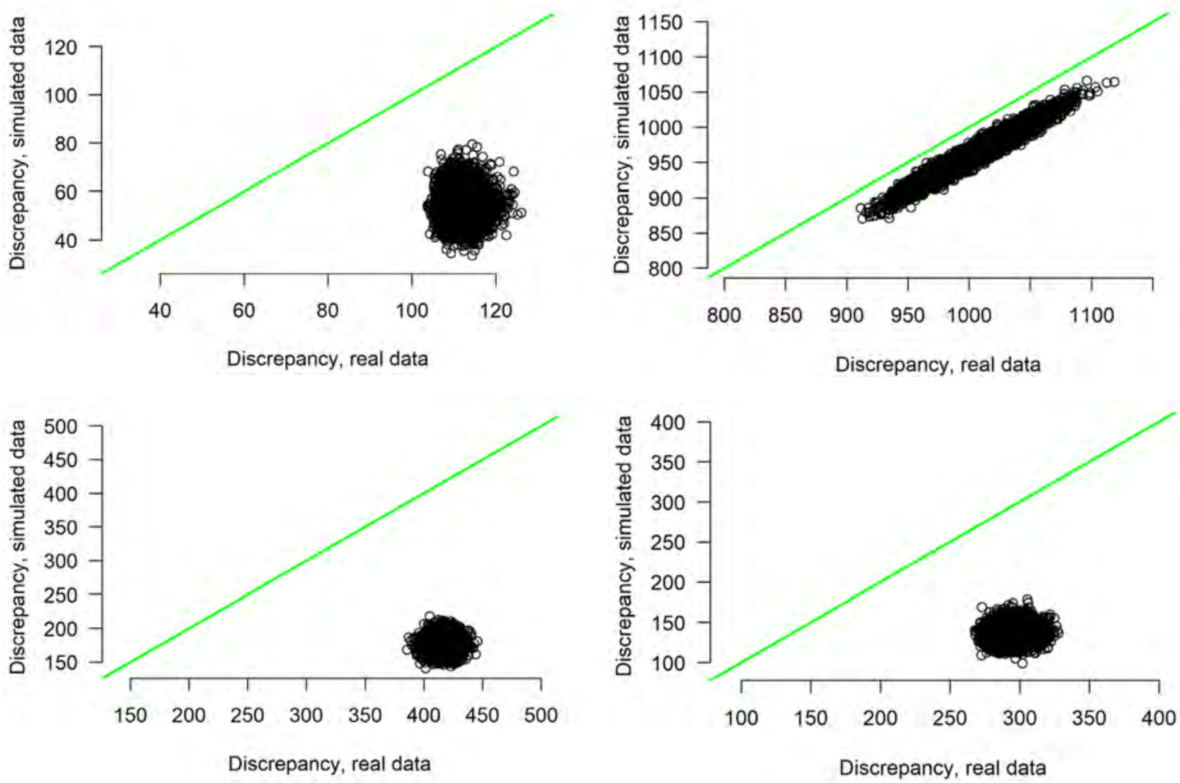

***Figure 15**. Four goodness of fit (GOF) tests for the open robust design (ORD) component of the REKN IMP. GOF test #1 (upper left) assesses the adequacy of the survival and temporary emigration parameters, and is therefore the most directly relevant to the REKN population model. The remaining tests assess model fit to the timing of arrival within each year (upper right), numbers of 'transients' observed during each 3-day survey period (lower left), and recaptures of non-transients during each 3-day survey period (lower right). Bayesian p-values for all tests are equal to 1, indicating severe over-dispersion of the data relative to model predictions.*

CONCLUSION

Building on the issues identified in my 2022 review of this ARM framework, I have outlined six additional concerns about the validity of ASMFC's revised ARM framework as a tool for assessing and managing the risks to the *Rufa* Red Knot posed by the horseshoe crab harvest in Delaware Bay. First, I demonstrated that a major component of the Integrated Population Model (used for modeling REKN population dynamics) is severely over-parameterized and prone to generating spurious results. Second, I presented evidence that ASMFC's estimates of REKN survival were biased high due to failure to account for misread errors, thereby artificially inflating the resilience of the REKN population to short-term fluctuations in recruitment. Third, my reanalysis showed that trawl-based indices of HSC abundance – and the CMSA model used by ASMFC for estimating HSC abundance dynamics – have no conclusive relationship with REKN survival. Fourth, I showed that HSC surface egg density has a strong relationship with REKN survival, suggesting that ASMFC is strongly underestimating the strength of the biotic interaction and the dependency of REKNs on HSC eggs for population survival and recovery. Fifth, I show that the ARM exaggerates the evidence for an increasing trend in the number of female HSCs in Delaware Bay, thereby likely over-estimating HSC population resilience to harvest pressure. Finally, I present evidence that ASMFC's model of REKN population dynamics exhibits poor fit to the data, casting additional doubts on the validity of the ARM's model of REKN population dynamics. Based on these concerns, I conclude that this ARM framework is not useful for managing risk to the REKN population due to HSC harvest. Furthermore, my results suggest that the revised ARM misrepresents the importance of HSCs to the REKN population and thereby underestimates both the existential risk to the REKN population posed by female HSC harvest and the potential for promoting REKN recovery through increased regulatory protections and conservation efforts aimed at promoting HSC population increases in the Delaware Bay region.

Acknowledgments

I am thankful to numerous people and organizations for sharing data for reanalysis in this project. First, Lena Usyk and bandedbirds.org were extremely helpful in providing access to the Red Knot banding and resighting data from Delaware Bay. Thanks to the many agencies, biologists and volunteers who contribute time and expertise to these data collection efforts. I thank Linda Barry, Jeff Brust, and the New Jersey Marine Resources Administration (NJ DEP Fish and Wildlife) for sharing data on female horseshoe crab captures from the NJ ocean trawl surveys from 1999 through 2022. Note that fulfillment of data requests does not constitute endorsement by the NJ Marine Resources Administration of any analyses or end products derived from the requested data. Similarly, I thank Jordan Zimmerman and the Delaware Division of Fish & Wildlife, Delaware Department of Natural Resources and Environmental Control, for sharing horseshoe crab capture data from the Delaware 30 ft. Trawl Surveys from 1990 to 2022 (data provided on Aug. 10, 2023). Note that this work does not represent the opinions of the State of Delaware, Delaware Department of Natural Resources and Environmental Control or Delaware Division of Fish & Wildlife. Finally, I thank Joseph A.M. Smith for sharing data on surface densities of horseshoe crab eggs, and everyone involved in collecting these data from 2000 to present.

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SUPPLEMENTAL ANALYSES

Note on the incorrect specification of the "pi" parameter in the REKN IPM

Although not directly related to any of the six primary critiques in this report, it is nonetheless important to note here that the "*pi*" parameter in the REKN IPM, which represents the fraction of the flyway population that is present at the stopover site at any given 3-day time window, is incorrectly specified in the ARM model. This parameter is used internally within the IPM for adjusting the total estimated flyway abundance to reflect the number of REKNs using the stopover at the time of the peak count surveys. Therefore, this parameter provides a critical link between the open robust design model and the state-space model within the IPM, helping to refine estimates of REKN abundance and population trends.

In the REKN IPM, the computation of *pi* follows two steps. First, for each 3-day occasion during the stopover period each year, the probability of being present in the stopover (conditional on using the stopover at least once that year) is computed using the *delta* (arrival) terms, the *tau* (stopover residency) and the *psi* (stopover retention/persistence) parameters. This derived term, which appears to be performed correctly, is called *alpha* in ASMFC's IPM code. To compute *pi* (proportion of the entire flyway present at the stopover site during each period) from *alpha* (the proportion of stopover users present at the stopover site each period) we just need to multiply alpha by a factor representing the fraction of flyway individuals using the stopover each year (we will call this factor "*z*"). ASMFC computed '*z*' as the sum of two parameters from the open-robust-design (ORD) model: '*gammaII*' and '*gammaOI*', which represent the probability of returning to the stopover (conditional on having been there last year), and the probability of returning to the stopover (conditional on having NOT been in the stopover last year), respectively. Importantly, the '*gammaII*' and '*gammaOI*' parameters are conditioned on two distinct segments of the flyway population; these parameters have no meaning when added together. For 'gammaII' and 'gammaOI' to have meaning at the level of the flyway population, we would need to know the fraction of the flyway population that used the stopover last year, which we call '*f*'. With this information, we could compute *z* and *pi* as:

z = gammaII(f) + gammaOI*(1-f)* (Correct formulation)

*pi = z * alpha*

Multiplying this term (*z*) by *alpha* would yield the appropriate estimate of *pi*. However, ASMFC computed the *z* parameter as:

z_i *= gammaII + gammaOI* (Incorrect formulation)

$pi_i = z_i * alpha$

Since z_i does not have meaning as a probability (this quantity can theoretically exceed 1), the resulting estimate of *pi* has no discernible meaning. Since *pi* is used to make the link between the annual peak counts and true flyway abundance, this error may introduce another source of bias in the estimates of REKN abundance and growth rate derived from the IPM. Although this is an important error, likely to have implications for the IPM results and the ARM framework, I consider this issue secondary in importance to the over-parameterization of the state-space model.

Note on over-parameterization of ASMFC's REKN survival model

In contrast to the ORD model, the 'classical' Cormack-Jolly-Seber (CJS) framework yielded estimates of the REKN-HSC relationship that were neither positive nor negative (inconclusive; Table 1). The increased tendency of the ORD model to yield conclusive (but negative) relationships may be a consequence of the increased complexity of the ORD model versus the CJS models, as more complex models have a greater tendency to generate spurious results. Furthermore, there is reason to suspect that the ASMFC model of REKN survival tried to estimate more parameters than the data could support. With 14 years of data used for training the ASMFC model (2005 to 2018), there are 13 years for which survival is theoretically estimable (one fewer than the years of data; Cooch 2008). In the IPM, these 13 estimable rates represent the degrees of freedom (independent information used for parameter estimation) needed for modeling annual variation in REKN survival. In ASMFC's IPM, these 13 data points are used to estimate no fewer than five parameters: (1) the effect of HSC abundance on REKN survival, (2) the effect of spawn timing on REKN survival, (3) the effect of arctic snow cover on REKN survival, (4) an interaction between HSC abundance and spawn timing, and (5) a temporal process variance that allows survival to vary among years. Fitting five parameters using 13 degrees of freedom (a ratio of 2.6 data points per free parameter) suggests that this model (like the model of REKN recruitment; see above) is prone to over-fitting and thereby producing spurious results (see above).

The model instability that is characteristic of over-fitted models is apparent in the estimation of the effect of trawl-based HSC indices on REKN survival. Notably, when I specified the ORD model with the full set of time-varying covariates used by ASMFC – including HSC abundance derived from the CMSA model, the fraction of HSCs spawning in May, arctic snow cover, and an interaction between HSC and HSC spawn timing -- the previously significant (and nonsensical) negative relationship between HSC abundance and REKN survival disappeared (B= -0.04, 95% CI: -0.20 to 0.08). This relationship remained inconclusive regardless of whether potential misread errors were included in the model training set.

Potential biases due to over-representation of Mispillion harbor in the REKN resighting dataset

Tabular summaries of the number of observations by site and by state exposed a strong over-representation of a single study site (Mispillion harbor, in DE) in the REKN resighting dataset, raising concerns that patterns in the REKN survival results used for the ARM framework may represent the idiosyncrasies of a single site rather than general patterns across Delaware Bay

(Fig. S1). In fact, some Delaware Bay shorebird experts indicated to me that Mispillion harbor likely has a greater concentration of HSC eggs than many other sites and tends to support rapid weight gain in REKNs, which could induce lower mortality rates. To test this, I ran multiple models of REKN survival – including the ORD formulation used by ASMFC in addition to simpler Cormack-Jolly-Seber (CJS) models – using data sets excluding Mispillion harbor and including only data from Mispillion harbor. Overall, I found that mean REKN survival estimates were very similar for birds captured inside and outside of Mispillion harbor. However, patterns in survival among years showed some marked differences that could potentially indicate different drivers of survival inside and outside of Mispillion harbor (Fig. S2). In particular, survival for birds captured and resighted in Mispillion harbor was more stable across years, yet showing a slight declining trend. In contrast, survival for birds captured and resighted outside of Mispillion harbor was more variable (showing a strong reduction in 2010 and 2017), with no apparent trend over time.

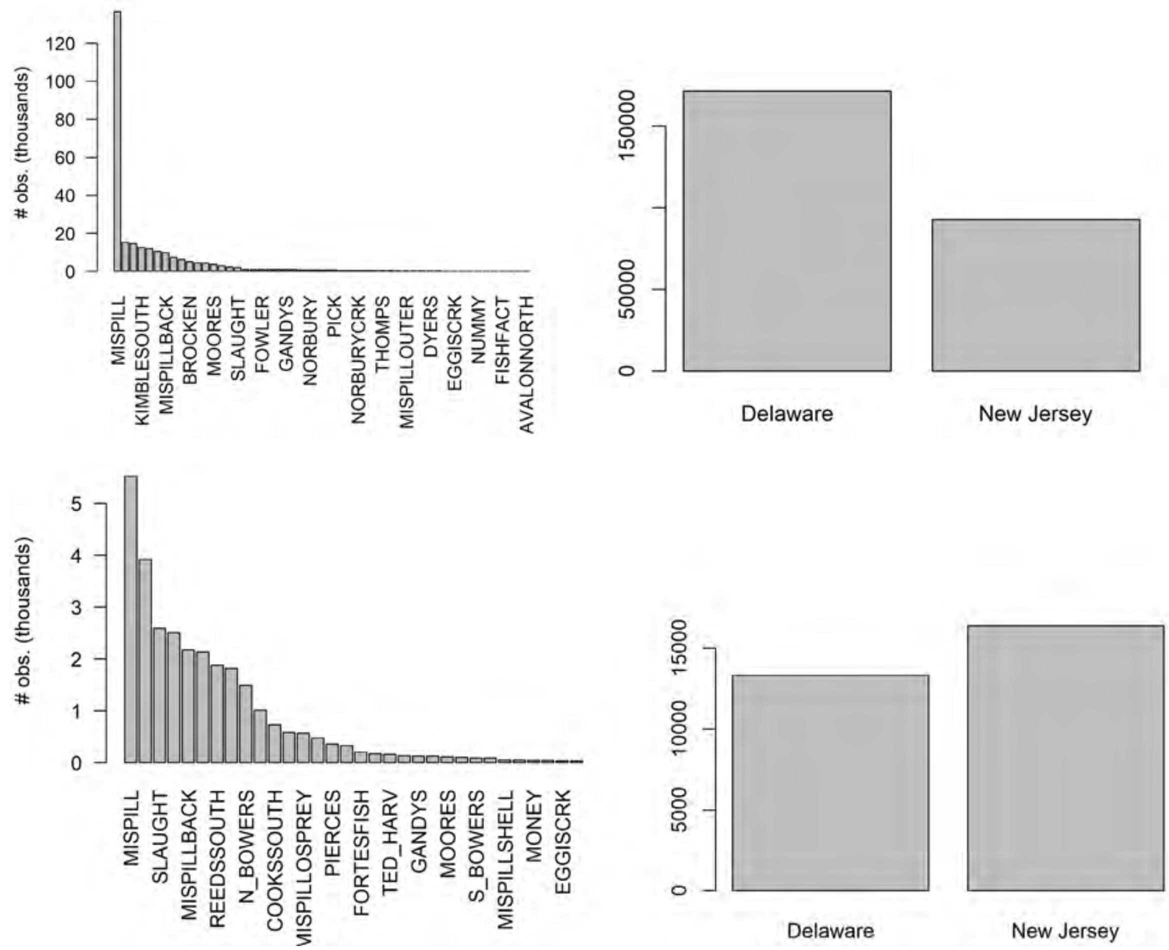


Figure S1*. Top panels: number of resighting observations per site and by state. Note that resighting observations within Mispillion harbor ("MISPILL" in the above figures) far outweigh all other sites, leading to some concern that analysis results may be biased if this site differs from other sites. Delaware (which is dominated by Mispillion harbor data) has about 2x the number of resighting observations than NJ. Bottom panels: banding data summary by site and by state. As opposed to the resighting data, there are more banding records from New Jersey, and Mispillion harbor does not dominate the banding records to the same degree as it does the resighting data*.

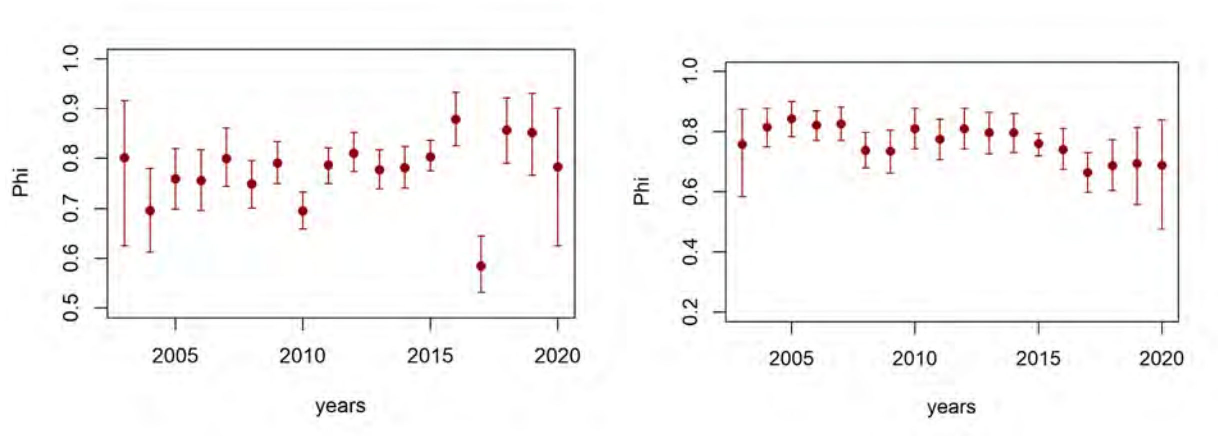


Fig. S2*. Comparison of annual REKN apparent survival estimates using (left) only birds marked and re-sighted outside of Mispillion harbor, and (right) only birds marked and re-sighted inside Mispillion harbor. Only birds first captured in Delaware Bay were included in the analysis, following ASMFC's stated data protocols. This figure illustrates different temporal patterns in survival, with REKN survival showing little trend outside of Mispillion harbor and decreasing slightly for birds captured and resighted inside Mispillion harbor. Outside of Mispillion harbor, estimated apparent survival was particularly low for two years: 2010 and 2017. Both models indicated reasonable goodness of fit.*

Trawl-based indices of HSC abundance

The figures below are a supplement to section 5 of this report, which documents that the evidence for a recent increase in the HSC population in Delaware Bay may be overstated. The figures below illustrate my efforts to generate adjusted indices of HSC abundance from trawl surveys to control for factors known to influence HSC capture rates: seasonality, trawl depth, salinity, and temperature (note that dissolved oxygen also emerged as an important factor in the New Jersey trawl surveys; Fig. 10).

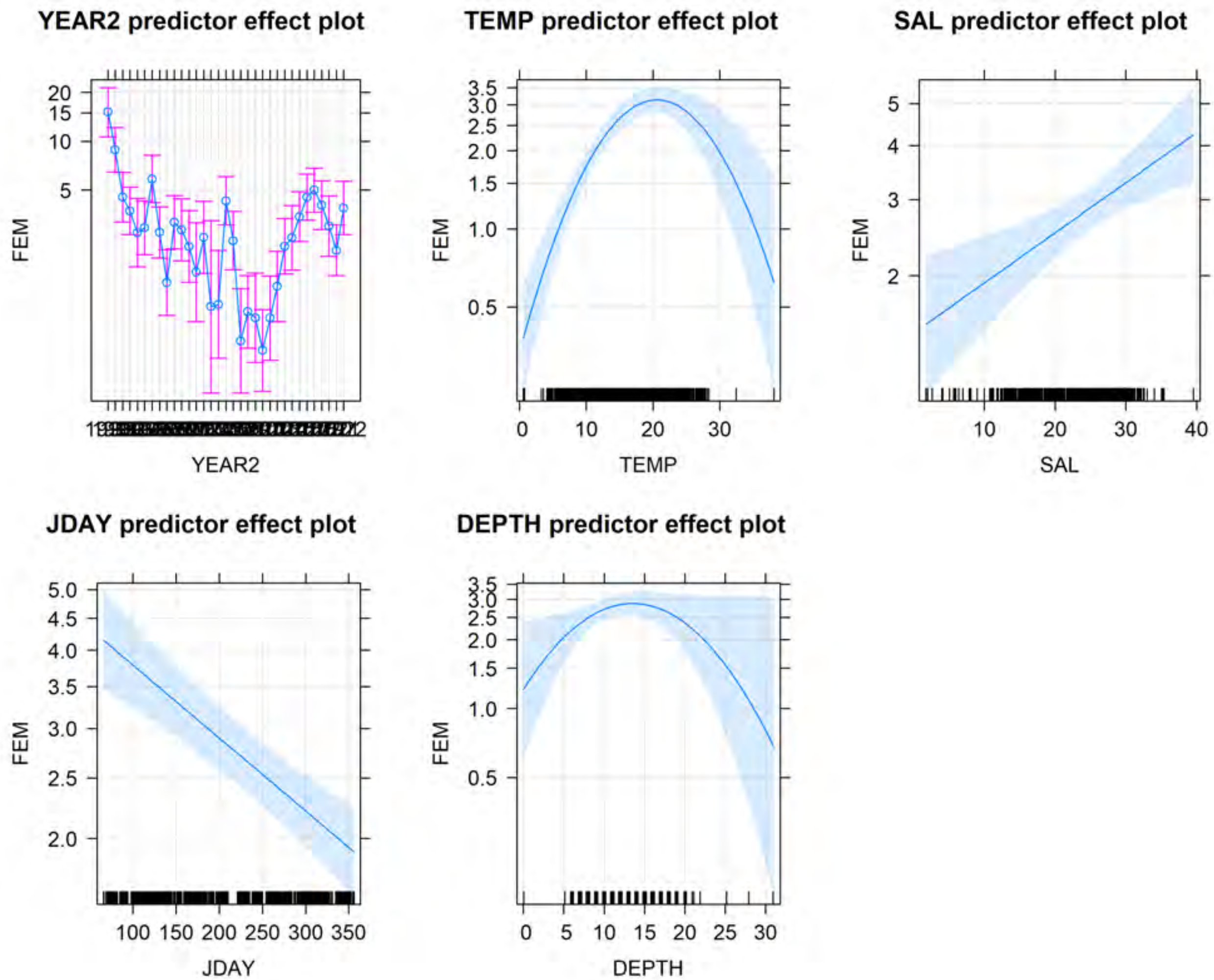


Figure S3. *Effects plots illustrating strong linear and non-linear effects of season and environmental covariates (from top left to bottom right: year, temperature, salinity, Julian day, and trawl depth) on the results of the Delaware Bay trawl surveys conducted by the state of DE. These figures are predictions from a generalized linear model (GLM) using a negative binomial error distribution, quadratic terms to represent non-linear relationships, and an offset term to accommodate differing effort among surveys (amount of seafloor surveyed). The 'rug' on each plot illustrates the distribution of data for each quantitative covariate. DE trawl data were provided on Aug 10, 2023 by Delaware Division of Fish & Wildlife, Delaware Department of Natural Resources and Environmental Control. This work does not represent the opinions of the State of Delaware, Delaware Department of Natural Resources and Environmental Control or Delaware Division of Fish & Wildlife*

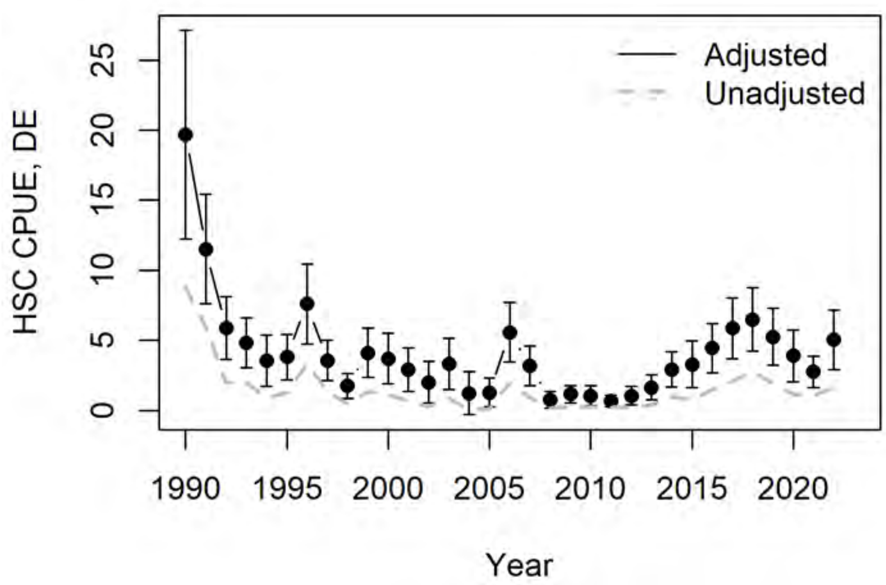


Figure S4. *Annual HSC catch-per-unit-effort (CPUE; a type of abundance index) for trawl surveys conducted by the state of Delaware from 1990 to present. Solid black dots are adjusted for the effects of seasonality, water temperature, depth, and salinity, while dashed gray line represents the unadjusted CPUE. Error bars represent one standard error on either side of the adjusted CPUE estimate. Unlike for the NJ data, the correction does not alter the general pattern of HSC abundance versus the unadjusted CPUE. DE trawl data were provided on Aug 10, 2023 by Delaware Division of Fish & Wildlife, Delaware Department of Natural Resources and Environmental Control. This work does not represent the opinions of the State of Delaware, Delaware Department of Natural Resources and Environmental Control or Delaware Division of Fish & Wildlife*

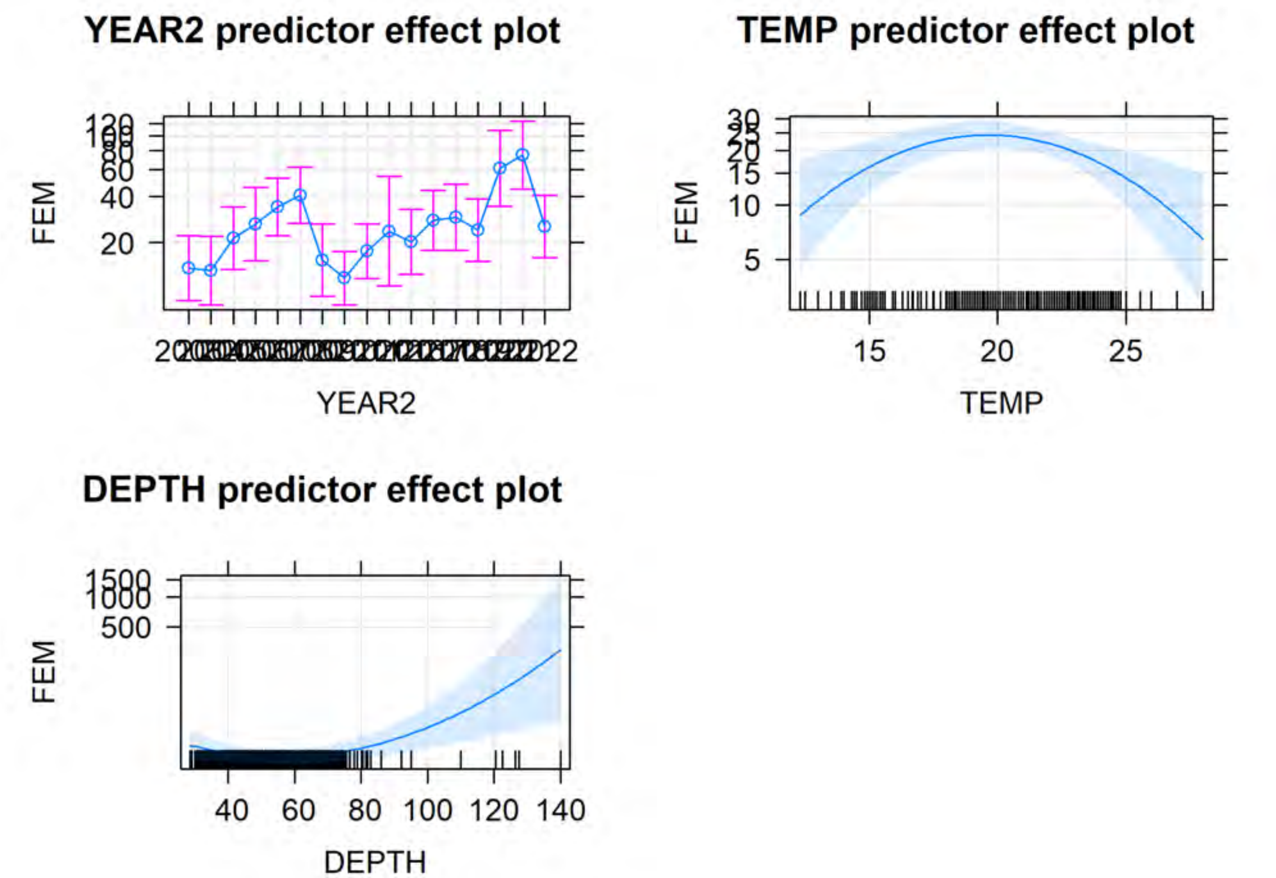


Figure S5*. Effects plots illustrating strong effects of year and environmental covariates (temperature and trawl depth) on the results of the Delaware Bay trawl surveys conducted by Virginia Tech (VT). These figures are predictions from a generalized linear model (GLM) using a negative binomial error distribution, quadratic terms to represent non-linear relationships, and an offset term to accommodate differing effort among surveys (amount of seafloor surveyed). The ‘rug’ on each plot illustrates the distribution of data for each quantitative covariate.*

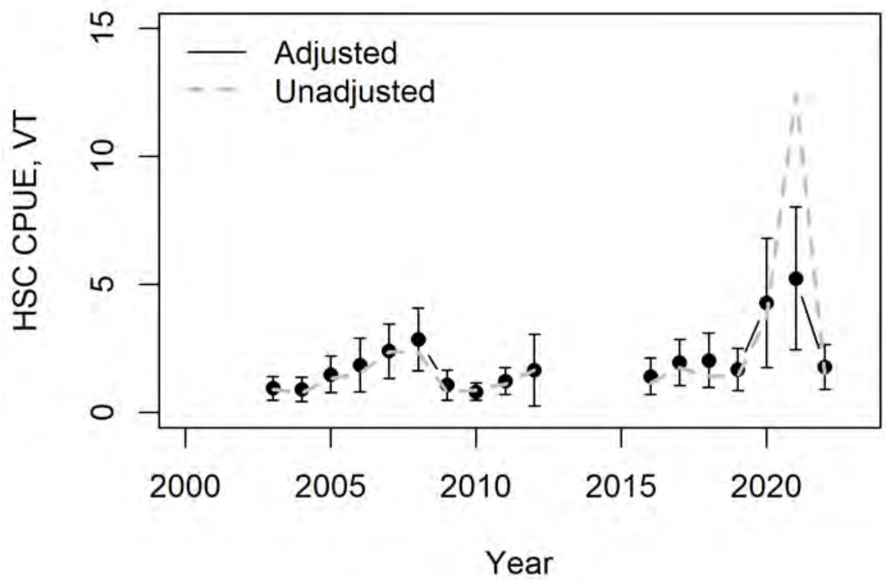


Figure S6. *Annual HSC catch-per-unit-effort (CPUE; a type of abundance index) for trawl surveys conducted by Virginia Tech from 2003 to present. Solid black points are adjusted for the effects of seasonality, water temperature, and depth, while dashed gray line represents the unadjusted CPUE. Error bars represent one standard error on either side of the adjusted CPUE estimate. Unlike for the NJ data, the correction does not generally alter the pattern of HSC abundance versus the unadjusted CPUE.*

Open robust design (ORD) validation tests

In this section, I report validation tests for assessing the ability of the open robust design (ORD) model to estimate the known values of key parameters (like survival) from simulated band-resighting data. In general, the ORD model successfully recovered the true parameters used to simulate the data, indicating that this model was correctly specified and capable of estimating parameters correctly. Overall, the ORD model was able to estimate many parameters related to survival, temporary emigration, the timing of stopover arrivals and departures, and detection probability (Figs S7-10). However, while the ORD model appears to perform well in simulation tests, recall that goodness of fit (GOF) tests showed that this model was not an adequate representation of the observed REKN data from Delaware Bay (see section 6, above). In addition, issues with potential misread errors further compromised the validity of the results (see above).

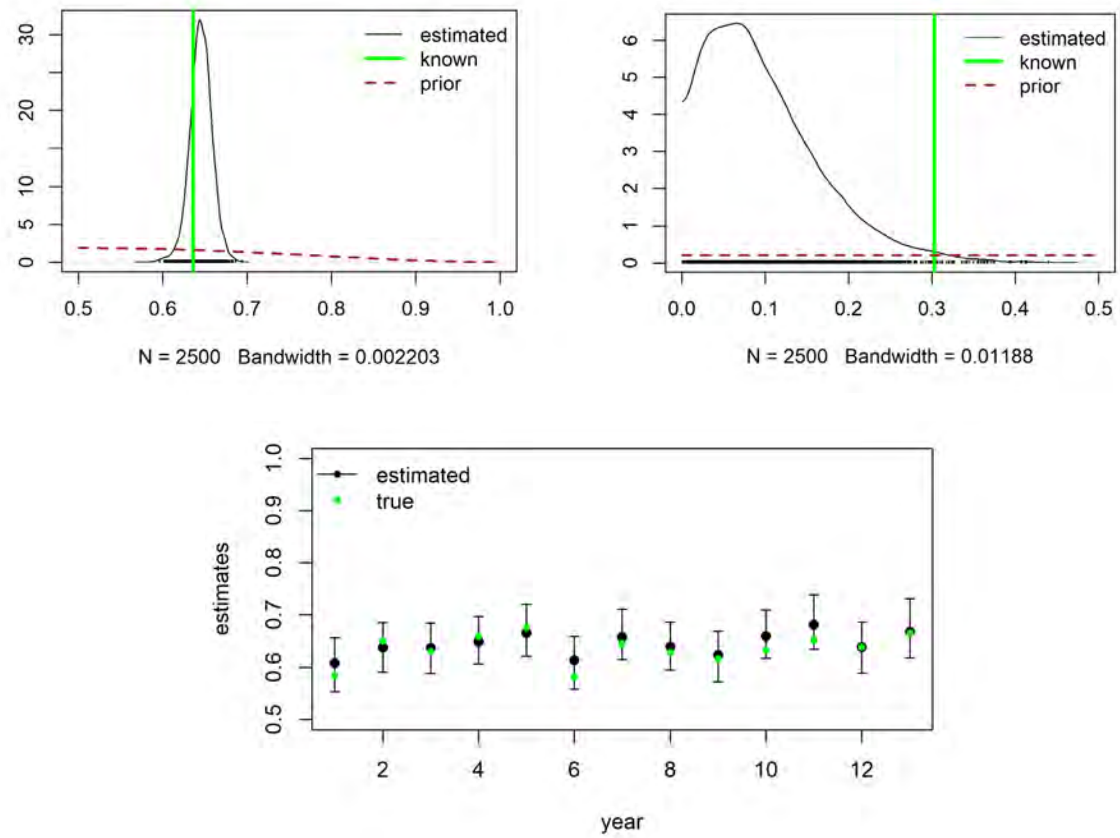


Figure S7. *In simulation tests, the ORD model seems to do a good job of recovering true mean survival (top left) from simulated data. The ORD model frequently fails to capture the true variance in survival (top right), leading to some concern about its ability to model annual variation in survival. However, the model performs well in capturing true annual survival values (bottom). Green dots and vertical lines represent the true values used in simulations, black curves, points, and confidence intervals represent parameter estimates from the ORD model, and dashed brown curves represent the prior probability distributions used for Bayesian model fitting.*

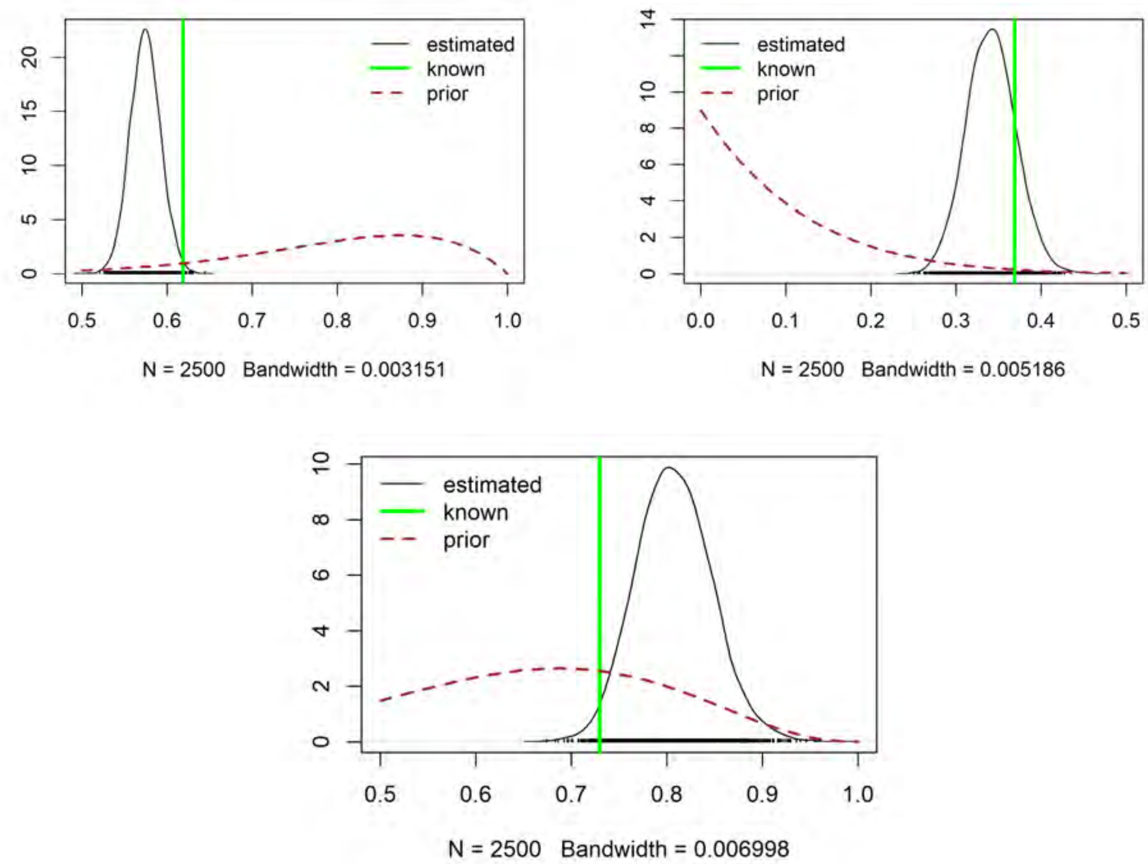


Figure S8*. In simulation tests, the ORD model tended to perform moderately well at recovering the true gammaII term (temporary emigration- prob of returning to the stopover after using it last year) from simulated data (top left), GammaOI term (temporary emigration- prob of returning to the stopover after skipping last year) (top right) and Tau (stopover residency probability) (bottom panel). Green dots and vertical lines represent the true values used in simulations, black curves, points, and confidence intervals represent parameter estimates from the ORD model, and dashed brown curves represent the prior probability distributions used for Bayesian model fitting.*

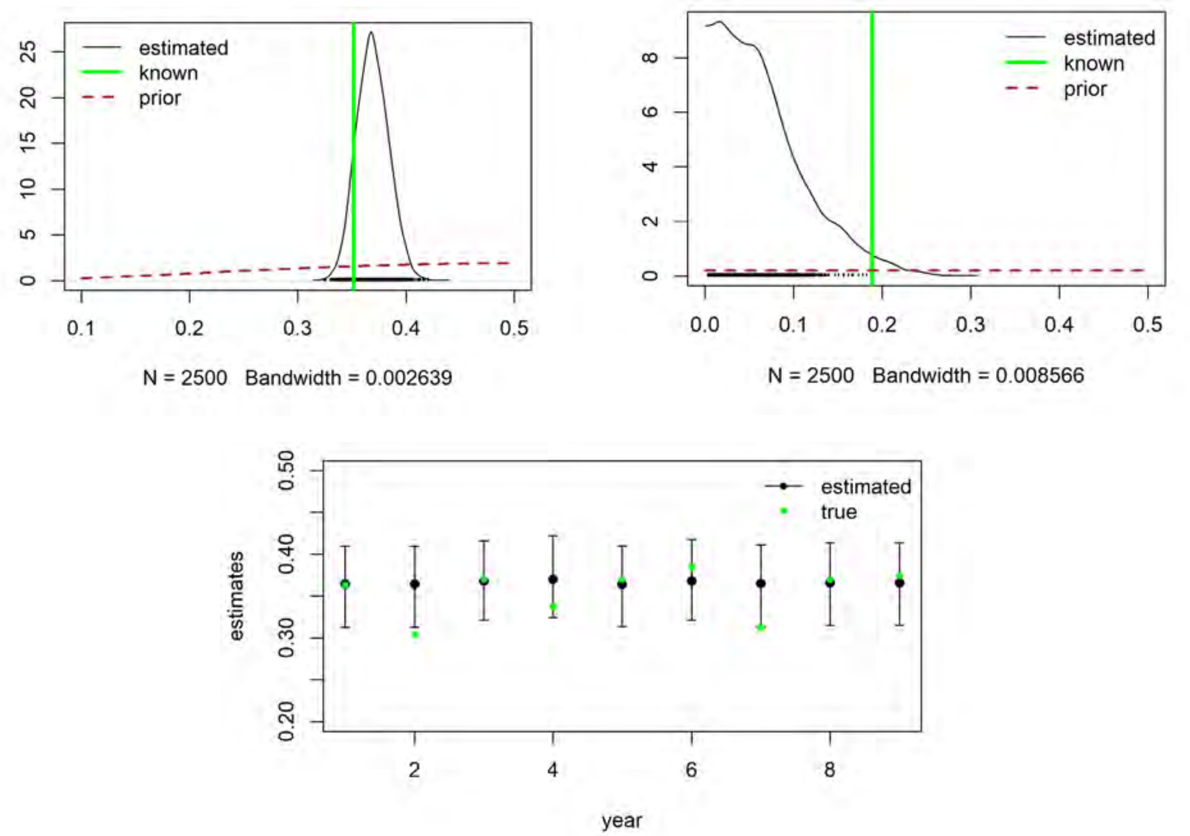
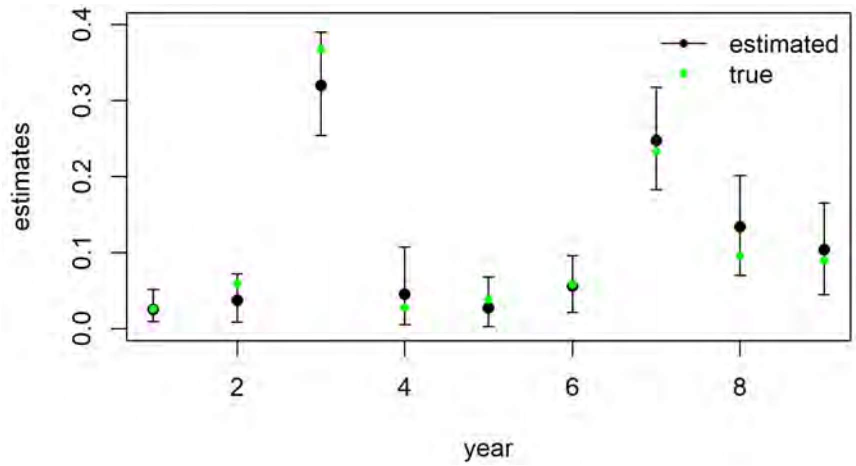


Fig. S9. *In simulation tests, the ORD model tended to perform moderately well at recovering the true temporal mean detection probability (top left). However, the ORD model performed somewhat poorly at recovering the temporal process variation in p (variation across both primary and secondary occasions); this parameter doesn't seem to fit well, and the chains exhibited very slow mixing. The bottom panel indicates detection probability per 3-day sampling occasion; the model appears to be underestimating variation among secondary occasions. Green dots and vertical lines represent the true values used in simulations, black curves, points, and confidence intervals represent parameter estimates from the ORD model, and dashed brown curves represent the prior probability distributions used for Bayesian model fitting.*



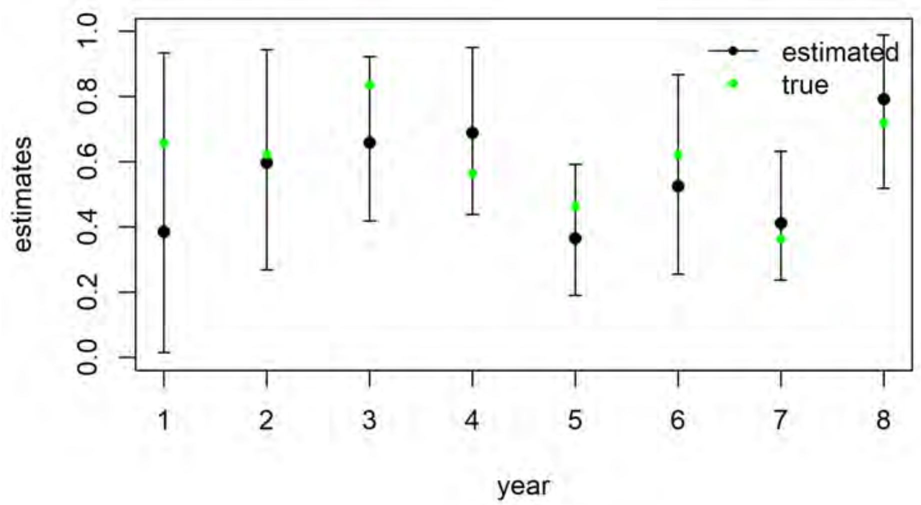


Fig. S10. *In simulation tests, the ORD model tended to perform moderately well at recovering the 'Delta' parameter (entrance probabilities) (top panel)— here, estimated from simulated data for year 8 (selected randomly from among years). The ORD model also performed well in recovering information about the 'Psi' parameter (probability of stopover persistence) (bottom panel). The green dots and vertical lines represent the true values used in simulations, while black curves, points, and confidence intervals represent parameter estimates from the ORD model.*

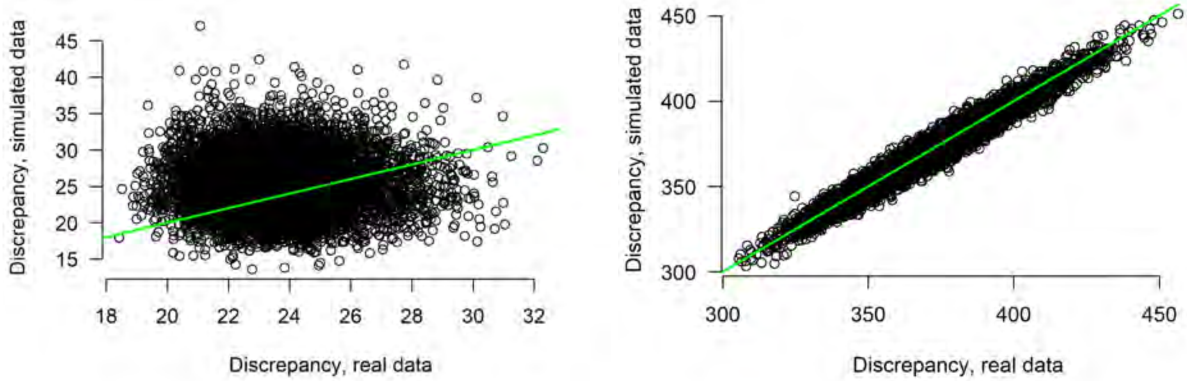


Fig. S11*. In simulation tests, the open-robust-design (ORD) model exhibited adequate goodness of fit, demonstrated here through posterior predictive checks (PPCs) involving the among-year survival process (L1; left panel) and the timing of first entry to the stopover each year (L2; right panel). The ORD model passed all four GOF tests when data were simulated using the same model assumptions used for model fitting (two tests not shown). In contrast, when the real REKN mark-resight data were used for model fitting, these tests indicated poor model fit (see section 6, above).*

ATTACHMENT

The following materials were submitted in September 2022 to inform the ASMFC Horseshoe Crab Management Board's consideration of Addendum VIII to the Horseshoe Crab Fishery Management Plan. They are included here for reference.

September 30, 2022

Horseshoe Crab Management Board
Atlantic States Marine Fisheries Commission
1050 N. Highland Street, Suite 200 A-N
Arlington, VA 22201
comments@asmfc.org

VIA ELECTRONIC MAIL

Re: Draft Addendum VIII to the Horseshoe Crab Fishery Management Plan for Public Comment

Dear Members of the Horseshoe Crab Management Board:

I write on behalf of New Jersey Audubon and Defenders of Wildlife to urge you to reject Addendum VIII to the Horseshoe Crab Fishery Management Plan. Since the Board instituted the Adaptive Resource Management ("ARM") Framework in 2012, red knot[1] abundance at Delaware Bay has fallen to historically low levels, and the U.S. Fish & Wildlife Service ("FWS") has listed the species as "threatened" under the Endangered Species Act ("ESA"). Horseshoe crabs, too, remain severely depleted compared to historical benchmarks. These circumstances demand greater protections and a precautionary strategy. But Addendum VIII would instead weaken the protections currently in place. Among other harmful outcomes, the Addendum almost certainly would reinitiate the female horseshoe crab bait harvest. Recognizing that neither red knots nor horseshoe crabs have recovered, the ARM Framework, until this proposal, has prohibited female harvest to protect the eggs on which the red knots rely.

Horseshoe crab eggs are critical to the red knot's ability to survive its 9,000-mile migration from as far south as Tierra del Fuego and to breed successfully in the Arctic Circle. The importance of horseshoe crab eggs to red knot success has long been recognized by scientists, government agencies, and the Atlantic States Marine Fisheries Commission ("ASMFC" or "Commission"), and the overharvest of horseshoe crabs has been a primary cause of the red knots' decline over the past three decades.

Nevertheless, despite the well-established link between horseshoe crab eggs and red knot survival and reproduction, Draft Addendum VIII proposes a starkly different version of reality. Through a combination of modeling defects and risk-prone decision-making, the revised ARM Framework now determines that the relationship between these species is scarcely perceptible, and that red knots would be virtually indifferent to the renewed harvest of female horseshoe crabs.

[1] In this document, "red knot" refers to the *rufa* subspecies.

As detailed in these comments and the attached expert reports by Dr. Kevin Shoemaker and Dr. Romuald Lipcius, this depiction of the relationship between horseshoe crab eggs and red knot demography is deeply flawed. Contrary to the conclusions represented in Draft Addendum VIII, adopting a new management approach that would enable resumption of the harvest of female horseshoe crabs at this juncture, when both red knots and horseshoe crabs are depleted, would harm red knots and present risks to the horseshoe crab population itself. Accordingly, the revised ARM Framework is not suitable for recommending horseshoe crab bait harvest quotas.

More specifically, the Board should reject Addendum VIII for reasons including but not limited to:

- **<u>The revised ARM Framework errs in concluding that red knots are not highly dependent on horseshoe crabs at Delaware Bay.</u>**
    - After flying thousands of miles, red knots arrive at Delaware Bay to renourish on horseshoe crab eggs. Under ideal conditions, red knots can double their body weight in less than two weeks. In the late 20th century, the peak count of red knots at Delaware Bay usually exceeded 40,000 and sometimes exceeded 90,000.
    - Horseshoe crabs were overharvested in the 1990s. In 2015, FWS listed red knots as "threatened" under the ESA and called horseshoe crab overharvest and corresponding egg depletion a "primary causal factor" in red knot decline. The peak red knot count has stayed below 13,000 for each of the past two years.
    - Despite this strong evidence of the importance of horseshoe crab eggs to red knots, the revised ARM Framework posits a weak link between the two species. By so doing, the revised ARM Framework subverts the premise of ASMFC's management regime for the horseshoe crab fishery, which is to manage the horseshoe crab harvest for red knot recovery.

- **<u>New analysis reveals significant technical flaws that make the revised ARM Framework unsuitable for managing the horseshoe crab harvest.</u>**
    - The revised ARM Framework abandons the well-established understanding of the importance of horseshoe crab eggs to red knots in favor of an extreme, contrary reconstruction of the ecosystem that defies history and reality. Even if horseshoe crabs vanished entirely today, the revised ARM Framework's computer model predicts that red knot abundance would remain stable on average or even increase over the next 50 years. The model clearly would not have predicted the decline of red knots that resulted from horseshoe crab overharvest in the 1990s, which discredits its usefulness in making projections that could help both species recover.
    - The revised ARM Framework also undermines sustainable management of horseshoe crabs. By miscalculating uncertainty, the horseshoe crab projection model generates artificially stable horseshoe crab population projections, when there actually exists a significant threat of decline.
    - The horseshoe crab population projections are significantly influenced by nonsensically high recruitment rates that were plugged in for years when recruitment was not measured empirically, thus further undermining the reliability of its projections.

- The horseshoe crab population model bears very little correlation even to the data that the model is based upon, raising significant additional doubt about its predictive power and usefulness.

- **The revised ARM Framework's risk-prone assumptions and decisions are inappropriate, especially when a threatened species is at stake.**
    - Horseshoe crab demographic information, including size and sex ratio, strongly suggests that the species is not recovering and that a risk-averse management approach is required.
    - The Framework does not consider the availability of horseshoe crab eggs, which is the most direct measure of food resources for red knots. Analysis of horseshoe crab demographic trends indicates that egg production may be declining more than abundance estimates suggest.
    - The model finds a weak relationship between horseshoe crabs and red knots partly because it is based on data from years when both species had already declined rather than when the ecosystem was flourishing. Modeled projections of a depleted ecosystem offer no guidance on managing to achieve recovery of either red knots or horseshoe crabs.
    - The Framework does not assess whether Delaware Bay provides adequate food for Southern wintering red knots, which are especially dependent on horseshoe crab eggs.
    - The Framework would eliminate protective population thresholds that must be met prior to any female harvest, creating risks to red knots and horseshoe crabs and contravening stakeholders' precautionary intent.
    - For population estimates, the model equally weights three surveys, despite stakeholders' express preference—and ASMFC's practice until now—to rely exclusively upon the model that is purpose-designed for counting horseshoe crabs. This results in artificially inflated horseshoe crab population estimates.

- **ASMFC has repeatedly excluded input from stakeholders and the broader public.**
    - In addition to its other flaws, the revised ARM Framework is based on a model that has never been released to the public. Analysis of even the limited information made available to the public to date indicates significant problems with the model, as discussed above. If the Board approves Addendum VIII now and the model is subject to public evaluation, new concerns and critiques will inevitably arise after the revised ARM Framework is already in use.
    - The ARM Subcommittee failed to solicit formal stakeholder input in this proceeding, in violation of its own procedures and past practice.
    - By designating Addendum VI the "No Action" alternative, the Board artificially narrowed its options to two addenda that would reinitiate the female horseshoe crab harvest, thus deciding the most important issue before the public comment period even began.

- **<u>The flaws in the revised ARM Framework must be addressed now.</u>**
    - The authority of ASMFC to deviate from the ARM Framework's harvest quotas in the future is not a rationale for approving Addendum VIII based on a flawed modeling framework now. Prematurely approving Addendum VIII would set the stage for contentious and arbitrary decisions about annual quotas for years to come.
    - The authority of states to set lower quotas than ASMFC provides does not lessen the Board's obligation to ensure that the revised ARM Framework is fully vetted and reflects stakeholder values.
    - Updating the revised ARM Framework's model as new data become available will not correct its fundamental flaws, many of which—as explained in these comments—are apparent from expert reviews of even the limited data made publicly available to date.

- **<u>Approving Addendum VIII would likely lead to a violation of the Endangered Species Act by ASMFC.</u>**
    - The ESA requires a precautionary approach to protecting threatened species.
    - By reinitiating the bait harvest of female horseshoe crabs, ASMFC would commit "take" of red knots. ASMFC is responsible under the ESA for harvests conducted pursuant to the quotas it sets.
    - FWS's purported "evaluation" of the revised ARM Framework merely repackages ASMFC's modeling, with all of its flaws, and uses it to generate an unreliable conclusion regarding the impact of red knots. It therefore sheds no new light on the Board's stewardship responsibilities or the Commission's legal obligations.

The objections listed above are elaborated in the comments and expert reports that follow. Each objection is an independently sufficient reason to reject Addendum VIII. Collectively, they demonstrate that Addendum VIII is incompatible with the Board's mandate to maintain the ecosystem integrity of Delaware Bay and to comply with the Endangered Species Act.

Respectfully submitted,

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I. THE REVISED ARM FRAMEWORK ERRS IN CONCLUDING THAT RED KNOTS ARE NOT HIGHLY DEPENDENT ON HORSESHOE CRABS AT DELAWARE BAY.

Each year, a population of red knots completes one of the most epic migrations in the animal kingdom. Starting from Tierra del Fuego at the southern tip of South America, the red knots fly more than 9,000 miles to their breeding grounds in the Arctic Circle. For most red knots, the final staging area before the Arctic Circle is Delaware Bay, where their stopover coincides with another ecological marvel: the spawning of millions of horseshoe crabs that emerge from the water and lay clusters of approximately 4,000 eggs, with the potential for an individual to lay more than 100,000 eggs over the course of several nights.[2] For red knots that have already flown thousands of miles at enormous physiological expense, the eggs provide essential replenishment, enabling a doubling of body mass in fewer than 14 days, versus 21 to 28 days at comparable stopovers where they eat clams and mussels.[3] This unique resource fuels the duration of their journey and enhances breeding success in the Arctic.[4]

The abundance of red knots and horseshoe crabs at Delaware Bay as recently as the 1990s is almost unimaginable today. From 1981 to 2002, the peak red knot count in Delaware Bay usually exceeded 40,000 and twice surpassed 90,000.[5] One participant in an aerial survey of shorebirds during that period described "lines of deposited horseshoe crab eggs set like mineral veins in smooth white marble, virtually an unlimited food supply."[6] In a single day, his survey tallied 62,000 red knots and 318,000 total shorebirds on just the New Jersey side of Delaware Bay.[7]

In the 1990s, increasing and unregulated horseshoe crab harvest by the bait and biomedical industries crashed the population of horseshoe crabs.[8] Red knots, no longer able to rely on the irreplaceable horseshoe crab eggs, declined in tandem. ASMFC adopted a fishery management plan for horseshoe crabs in 1998 and instituted adaptive management in 2012. Since then, the female bait harvest has been prohibited. But the fate of horseshoe crabs remains highly uncertain, and red knots have continued to decline. Red knot peak counts that previously topped 90,000 have, for the past two years, languished below 13,000, including a record low of 6,800 in 2021. Twenty years have passed since the population topped a modest 33,000.[9] Instead of these peak

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[2] NOAA Fisheries. *Horseshoe Crabs: Managing a Resource for Birds, Bait, and Blood* (July 31, 2018), https://www.fisheries.noaa.gov/feature-story/horseshoe-crabs-managing-resource-birds-bait-and-blood.

[3] Lawrence Niles et al., *Effects of Horseshoe Crab Harvest in Delaware Bay on Red Knots: Are Harvest Restrictions Working?*, 59 BioScience 153, 154 (2009); New Jersey Department of Environmental Protection, *Wildlife Populations: Red Knot* 1-2 (2020), https://www.nj.gov/dep/dsr/trends/wildlife-redknot.pdf.

[4] Sjoerd Duijns et al., *Body Condition Explains Migratory Performance of a Long-Distance Migrant*, 284 Proceedings of the Royal Society of London B 20171374, at 4-6 (2017).

[5] FWS, *Rufa Red Knot Background Information and Threats Assessment* 100 tbl. 12 (2014) (excluding 1984-1985, when the survey was not conducted).

[6] Pete Dunne, *Tales of a Low-Rent Birder* 10 (1986).

[7] *Id.* at 13-14.

[8] FWS, *Rufa Red Knot Background Information and Threats Assessment* 232 ("Evidence that commercial harvests caused horseshoe crab population declines in recent decades comes primarily from a strong temporal correlation between harvest levels . . . and population levels.").

[9] *Id.* at 100 tbl. 12 (for years 1981-2014); ASMFC, *Revision to the Framework for Adaptive Management of Horseshoe Crab Harvest in the Delaware Bay Inclusive of Red Knot Conservation (Draft for Board Review)* 155 tbl.

counts, the revised ARM Framework uses modeled estimates of the total number of red knots passing through Delaware Bay. While these modeled estimates face criticism for overrepresenting red knots' use of Delaware Bay, they have fallen as well, from as high as 152,900 in 1989, to an average of 77,000 per year for 1998-2001, to numbers in the 40,000s over the past several years.[10]

In 2015, FWS formally listed the red knot as a threatened species under the Endangered Species Act.[11] At the time of the listing, FWS cited several studies indicating that red knot abundance had declined, "probably sharply," since the 1980s.[12] FWS found that "[r]educed food availability in Delaware Bay due to commercial harvest of the horseshoe crab . . . is considered a primary causal factor in red knot population declines in the 2000s."[13] Reduced food availability is a particular threat for the Southern wintering population of red knots, which is disproportionately reliant on the Delaware Bay staging area and which FWS views as "a bellwether for the subspecies as a whole."[14] According to FWS, "[R]educed food availability at just one key migration stopover area (Delaware Bay) is considered the driving factor behind the sharp decline in the Southern wintering population in the 2000s."[15]

As FWS has stated, "Studies have shown red knot survival rates are influenced by the condition (weight) of birds leaving the Delaware Bay staging area in spring."[16] Research has also shown that, while red knots arriving relatively late to Delaware Bay were able to compensate by gaining weight at a higher rate, that was not the case in years with low horseshoe crab egg availability.[17]

Until now, the well-established link between horseshoe crabs and red knots has been the cornerstone of ASMFC's management of the horseshoe crab fishery at Delaware Bay. Addendum VIII would subvert that regime. While the proposed model nominally bases harvest quotas on red knot and horseshoe crab abundance estimates, it assigns an extremely weak correlation between the abundance of the two species. It thereby concludes that red knots would be essentially unaffected by the resumption of the female horseshoe crab bait harvest.

As explained below, Addendum VIII's baseline assumption—that increasing the horseshoe crab harvest would only marginally impact red knots at Delaware Bay—is unsupported. It relies on evaluating a limited dataset that omits years when the ecosystem flourished. (For example, its dataset about horseshoe crab abundance is drawn entirely from the last 20 years, after the crash

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12 (2021) ("ARM Report") (for years 2011-2020); Larry Niles, "2022 Delaware Bay Stopover Project Final Update-5 June 2, 2022," *A Rube with a View* (June 15, 2022), https://www.arubewithaview.com/2022/06/15/2022-delaware-bay-stopover-project-final-update-5-june-22022/ (for years 2021-2022).

[10] FWS, *Rufa Red Knot Background Information and Threats Assessment* 101 tbl. 13; ASMFC, *ARM Report* 155 tbl. 12.

[11] FWS, "Endangered and Threatened Wildlife and Plants; Final Threatened Status for the Rufa Red Knot," 79 Fed. Reg. 73,706 (Dec. 11, 2014). The listing became effective on January 12, 2015. *Id.* at 73,706.

[12] FWS, *Rufa Red Knot Background Information and Threats Assessment* 85. While FWS primarily analyzed red knot population trends within individual regions, it "note[d] a temporal correlation between declines at Tierra del Fuego and Delaware Bay." *Id.* at 84.

[13] 79 Fed. Reg. at 73,707.

[14] FWS, *Draft Recovery Plan for the Rufa Red Knot* 13 (May 2021).

[15] *Id.* at 14.

[16] *Id.* at 25; FWS, *Rufa Red Knot Background Information and Threats Assessment* 254.

[17] FWS, *Rufa Red Knot Background Information and Threats Assessment* 253.

of the horseshoe crab population and during a period when red knot abundance has been comparatively low.) And it suffers from modeling defects that, among other things, erroneously overstate the size and stability of the horseshoe crab population.

For these reasons and others detailed below, Addendum VIII is not a pathway for sustaining red knots, much less restoring a thriving ecosystem, nor does it honor the precautionary approach required when a threatened species is at stake. Instead, it risks a violation of ASMFC's legal obligations, including its obligation to avoid "take" of red knots under the ESA. The Board therefore should reject Addendum VIII and instead adopt adequate protections for horseshoe crabs and red knots at Delaware Bay.

II. NEW ANALYSIS REVEALS SIGNIFICANT TECHNICAL FLAWS THAT MAKE THE REVISED ARM FRAMEWORK UNSUITABLE FOR MANAGING THE HORSESHOE CRAB HARVEST.

As detailed in the following sections, the parties to this letter solicited independent expert reviews of the revised ARM Framework. These reviews reveal significant technical and methodological flaws that render the Framework unreliable for ASMFC management decisions.

For the first expert review, Dr. Kevin Shoemaker conducted an independent analysis of the horseshoe crab abundance and projection model that informs the revised ARM Framework. Dr. Shoemaker demonstrates that the Framework contains significant flaws that make it unsuitable for managing the horseshoe crab harvest. These flaws are especially alarming given the implications of the Framework for a threatened species such as the red knot. This section details many of Dr. Shoemaker's key findings, all of which are explained in more detail in the attached expert report.

At the outset, it is important to note that most of the components of the revised ARM Framework's model still have not been made available to the public. As a result, Dr. Shoemaker was unable to evaluate the components that link horseshoe crab abundance to red knot abundance or generate horseshoe crab harvest recommendations. Although Dr. Shoemaker was able to draw some conclusions about those aspects of the model, most of the analysis below necessarily focuses on the horseshoe crab model. As these comments proceed to discuss, the analysis that Dr. Shoemaker was able to conduct reveals severe issues concerning the reliability of the modeling. Nevertheless, Dr. Shoemaker's focus on the publicly available modeling information should not be interpreted to suggest that the unreleased components do not also contain significant flaws. To the contrary, given the flaws that are apparent in the information released to date, it is vital that *all* components of the model be subject to public evaluation before the Board takes any action to approve Addendum VIII.

A. <u>The revised ARM Framework Is an Inappropriate Tool for Helping to Reverse the Decline and Promote the Recovery of Red Knots.</u>

Considering that adaptive management is premised on the link between horseshoe crabs and red knots, the weakness of that link in the revised ARM Framework is breathtaking. By way of illustration:

- Dr. Shoemaker shows that, even if the horseshoe crab population in Delaware Bay completely collapsed to zero, the revised ARM Framework would predict that red knot abundance would remain stable or even increase over the next 50 years on average.[18]
    - Furthermore, "This simulation exercise makes it very clear that the REKN model used in the revised ARM would not be able to predict or explain the decline in the REKN population observed during the 1990s."[19] In other words, the model could not even have diagnosed the problem that it is supposed to solve.
- The data informing the revised ARM Framework actually show a negative correlation between female horseshoe crab abundance and red knot recruitment.[20] That is, according to the model, as female horseshoe crab abundance *increases*, red knot recruitment *decreases* on average.
- Due to the weak relationship between red knot and horseshoe crab abundance, it is not implausible that, with future updates to the revised ARM Framework, the relationship will disappear entirely or even become negative. Dr. Shoemaker observes that "[t]his outcome would pose an existential problem for the ARM framework . . . . There does not appear to be a contingency plan for this outcome."[21]
- Whatever weak signal the model has detected in historical data appears to be overwhelmed by random noise. As Dr. Shoemaker explains, it is highly likely that the model's "information about the HSC/REKN relationship would explain little if any of the variation in independent validation data."[22]

Due to the weak relationship between red knots and horseshoe crabs represented in the revised ARM Framework, it is unlikely that the model would outperform—much less significantly improve upon—a "null" model that entirely omits any effect of horseshoe crab abundance.[23] Yet it was impossible for Dr. Shoemaker to explore this key issue further because of the limitations on the materials made publicly available to date. Nevertheless, the concerns raised by the analysis that Dr. Shoemaker was able to perform are profound and call into question the revised ARM Framework's utility to guide any decision-making about the status or management of the affected species.

In sum, while the revised ARM Framework nominally recommends harvest quotas based on the relationship between horseshoe crabs and red knots, it effectively decouples the fates of the two species, unjustifiably transforming the methodology and philosophy that underlie the management of this fishery. This is an independently sufficient reason for the Board to reject Addendum VIII.

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[18] Kevin Shoemaker, *Review of 2021 ASMFC ARM Revision* 6-9 & fig. 1 (Sept. 2022) ("*Shoemaker Expert Report*").
[19] *Id.* at 8.
[20] *Id.* at 9 fig. 2.
[21] *Id.* at 10.
[22] *Id.* at 26.
[23] *Id.* at 25-26.

B. The Horseshoe Crab Population Simulation Model Does Not Properly Account for Uncertainty, Resulting in Artificially Stable Abundance Projections.

The revised ARM Framework profoundly underestimates uncertainty in the horseshoe crab recruitment rate, thereby calling into question its projections concerning the impact of harvest. As Dr. Shoemaker explains, the rate at which new recruits join the reproductive population "is the most consequential empirically fitted component of the HSC simulation model."[24] Other components of the model, such as natural and biomedical mortality, are fixed values, but the recruitment rate is calculated based on data.

Dr. Shoemaker shows[25] that the model errs by conflating two distinct types of uncertainty: (i) natural, year-over-year variation and (ii) the potential that the model incorporates incorrect parameters (most importantly, the mean horseshoe crab recruitment rate). The model treats both types of uncertainty as natural, year-over-year variation, with the consequence that the abundance estimates regress to a mean. In other words, the variations cancel each other out, making the projected population appear highly stable. But if evaluated properly, parameter uncertainty would likely compound over time, yielding a very different picture of the population. For example, if average recruitment is actually lower than the rate used in the model, that uncertainty would *not* cancel out over time. Instead, the horseshoe crab population could be headed for a one-way decline. Notably, the revised ARM Framework accounts for the two types of uncertainty separately in the *red knot* projection model, suggesting that the modelers recognized the importance of that approach, but nevertheless they did not implement it when projecting horseshoe crab abundance.

The consequences of this error are significant for estimates of the population's trajectory. Properly accounting for uncertainty, Dr. Shoemaker found that the horseshoe crab population faces a very real threat of declining well below levels acknowledged by the revised ARM Framework's projection model. Notably, he used the same estimates of uncertainty as the revised ARM Framework (as well as the same values for natural mortality, biomedical mortality, etc.). All that changed in his analysis was the method of evaluating uncertainty. Dr. Shoemaker's analysis[26] reveals that:

- Even under a scenario with *no* bait harvest, *no* biomedical mortality, and *no* discard mortality, the female horseshoe crab population has a 17.4% probability of declining below 4 million, and a 3.8% probability of declining below 3 million, over the next 50 years.
  - For comparison, 4 million is the lowest female abundance estimated for any year from 2003 to 2019 (the years upon which the model was based).
  - In contrast, by incorrectly accounting for uncertainty, the revised ARM Framework's model does not project female abundance values below 4 million within the 95% confidence interval under optimal harvest scenarios, *including* bait harvest, biomedical mortality, and discard mortality.[27]

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[24] *Id.* at 12.
[25] The information in this paragraph is drawn from *Shoemaker Expert Report* 12-18 & figs. 3-4.
[26] Except where noted, these findings are presented in greater detail at *Shoemaker Expert Report* 15, 18 fig. 4.
[27] ASMFC, *Supplemental ARM Report* 35 fig. 15.

- Under a scenario in which horseshoe crabs are harvested for bait under the maximum quotas of 500,000 males and 210,000 females but are still *not* subject to biomedical or discard mortality, the female population has a 33% probability of declining below 4 million, an 11% probability of declining below 3 million, and a 2% probability of declining below 2 million, over the next 50 years.

Dr. Shoemaker concludes that, "if sources of error in the recruitment process are properly accounted for, the outlook for the HSC population in Delaware Bay is uncertain even in the absence of any harvest pressures."[28] If the Board approves Addendum VIII, it would increase harvest pressure through a model that fails to properly account for the risk of a declining horseshoe crab population.

C. The Horseshoe Crab Projection Model's Recruitment Estimates Are Strongly Influenced by Nonsensical, Unverified Estimates from the Virginia Tech Gap Years.

The revised ARM Framework's conclusions are further undermined by its reliance on fantastical recruitment projections to fill in a key gap in actual population-monitoring data for horseshoe crabs. Of the three trawl surveys that inform the catch multiple survey analysis ("CMSA") component of the framework, only the Virginia Tech survey measures primiparous (i.e., newly mature) females to provide an empirically based estimate of recruitment. Thus, the CMSA does not incorporate any direct measurement of recruitment during the 2013-2016 period when the Virginia Tech survey was not conducted. Instead, it indirectly estimates annual recruitment rates, but two of these estimates are many times higher than any estimate from years with direct observations. Since the average recruitment rate in the population projection model treats all of the estimates as equally valid—whether or not they were based on empirical observations or hypothetical estimates—the model's estimated annual recruitment rate is heavily influenced by the nonsensical estimates from the Virginia Tech gap years.

To understand the impact of the nonsensical gap year estimates, first consider the years with empirically derived recruitment estimates. The average annual estimated recruitment for 2003-2012 was 1.2 million primiparous females. The average annual estimated recruitment for 2017-2019 was 1.9 million. Now consider the non-empirically derived gap year estimates. In 2013, the estimate was *9.6 million*—roughly eight times larger than the average over the previous ten years, and four times larger than the maximum annual estimate from that period.[29] In 2014, the estimate dropped to only two primiparous females across all of Delaware Bay, but the estimate is so uncertain that the upper limit of the confidence interval approaches infinity.[30] All told, the *average* estimate for the four Virginia Tech gap years was 4.2 million primiparous females, which is nearly *2 million* higher than the *maximum* ever estimated for any year with empirical observations.[31]

[28] *Shoemaker Expert Report* 17.
[29] ASMFC, *Supplemental Report to the 2021 Revision to the Adaptive Resource Management Framework* 16 tbl. 3 (2022) ("*Supplemental ARM Report*").
[30] *Id.* at 25 fig. 5.
[31] *Id.* at 16 tbl. 3.

The nonsensical estimates from the Virginia Tech gap years compromise the horseshoe crab projection model because they significantly affect its recruitment estimate. As Dr. Shoemaker shows,[32] in the original ARM report, the ARM Subcommittee based the recruitment rate exclusively on data from 2013 to 2019, which relied overwhelmingly on estimates from the gap years and generated an annual recruitment estimate of 3.1 million primiparous females. Following criticism from the Peer Review Panel, the Subcommittee expanded the dataset to include 2003-2019, which reduced the recruitment estimate to 1.67 million. But if the nonsensical data from the gap years were excluded, this estimate would fall to 1.26 million. Dr. Shoemaker illustrates how the difference in these estimates has huge implications for the model's projection of future horseshoe crab abundance.

Dr. Shoemaker concludes that "the inflated estimates of recruitment during the VT gap years are likely to be an artifact of the CMSA model specification (and the lack of data on recruitment for those years) and are unlikely to be reflective of true HSC recruitment rates. . . . [A] conservative (precautionary) approach would be to exclude the VT gap years when computing recruitment for the HSC population simulations."[33] Doing so would yield a substantially lower recruitment estimate with a commensurately lower capacity to withstand a resumption of female harvest.

D. The Horseshoe Crab Population Model Has a Poor Correlation to Existing Data.

The CMSA's usefulness is cast further into doubt by its failure to correlate with any source of data about horseshoe crab abundance. As Dr. Shoemaker shows from an analysis of female horseshoe crab abundance estimates, the model does not correlate even with the data sources upon which it was based, much less any independent validation data.

For the years 2003-2019, the CMSA's correlation with the Delaware Adult Trawl Survey is extremely weak, and any correlation that exists is entirely attributable to the model's apparent ability to predict that horseshoe crab populations rose during 2013-2016, when the Virginia Tech survey was not conducted.[34] For the years before and after the Virginia Tech gap—that is, for the vast majority of years evaluated—the coefficient of determination (R^2) between the CMSA model and the Delaware Survey was *negative*, meaning that the model performed worse than a null model. The CMSA performs almost as poorly against data from the New Jersey Ocean Trawl Survey, with a weak positive correlation for the years prior to the Virginia Tech gap and a negative R^2 for the years after. The CMSA's worst performance comes when measured against the Virginia Tech survey, with a negative R^2 across the full time series for which data are available. To test the CMSA against independent validation data, Dr. Shoemaker compared it to the results of Delaware Bay spawning surveys and found no detectable relationship whatsoever between the results.

As this summary makes clear, the CMSA's modeled outcomes bear little relationship to actual data on the Delaware Bay horseshoe crab population. For this reason, Dr. Shoemaker recommends comparing the CMSA's horseshoe crab estimates to a null model that omits all information about horseshoe crab harvest from the model fitting process. Given its poor fit to

[32] The data discussed in this paragraph can be found at *Shoemaker Expert Report* 22-24 & fig. 7.
[33] *Id.* at 23.
[34] The findings in this paragraph are presented in greater detail at *Shoemaker Expert Report* 19-22 & figs. 5-6.

existing data, the CMSA's horseshoe crab projection model is "unlikely to outperform" even a relatively simple null model.[35] Dr. Shoemaker concludes, "If the HSC simulation model fails to outperform a model in which population dynamics are driven by noise instead of harvest, it should prompt managers to acknowledge that our current understanding of the effects of harvest on HSC populations remains insufficient for robust forecasting."[36] Absent a sound basis for robust forecasting, adoption of Addendum VIII and its attendant resumption of the female harvest cannot be justified.

III. THE REVISED ARM FRAMEWORK'S RISK-PRONE ASSUMPTIONS AND DECISIONS ARE INAPPROPRIATE, ESPECIALLY WHEN A THREATENED SPECIES IS AT STAKE.

In addition to its technical flaws, the revised ARM Framework incorporates risk-prone assumptions and decisions that further render it unsuitable as a management tool. It neglects important variables related to horseshoe crab demography and egg density that cast doubt upon the recovery of horseshoe crabs and their ability to provide adequate food resources for red knots. It draws conclusions from data collected when both red knots and horseshoe crabs were already depleted and therefore does not understand how the species would interact in a healthy ecosystem. It also reverses precautionary decisions made by stakeholders in the original ARM Framework—without soliciting renewed stakeholder input—in order to eliminate protections against the female horseshoe crab harvest and utilize previously-rejected surveys that inflate horseshoe crab abundance estimates.

The findings in this section draw heavily from an independent analysis of the revised ARM Framework and related materials conducted by Dr. Romuald Lipcius, as well as the analysis of Dr. Shoemaker. Both expert reports are attached.

A. <u>Demographic Trends Indicate that the Horseshoe Crab Population Is Not Recovering.</u>

Despite the Subcommittee's assertion that horseshoe crab abundance is increasing in Delaware Bay, Dr. Lipcius has identified troubling indicators that are inconsistent with a recovering population. The revised ARM Framework ignores these trends and treats abundance estimates as a comprehensive indication of population health. That would be a risk-prone approach even if the abundance estimates were fully reliable (which they are not).

As shown in Dr. Lipcius's report, the mean size (prosomal width) of female horseshoe crabs has recently declined. In the most recent three years of available data (2018-2020), adult female horseshoe crabs recorded the lowest mean sizes of any year since data collection began in 2002.[37] The same is true for newly mature females over the most recent two years of available data.[38]

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[35] *Id.* at 25.
[36] *Id.*
[37] Romuald Lipcius, *Expert Report* 6 (Sept. 2022) ("*Lipcius Expert Report*").
[38] *Id.*

Dr. Lipcius explains that, given constant recruitment, a prohibition on female harvest would typically lead to an increase in size due to reduced harvest pressure on older, larger females.[39] The declining size of female horseshoe crabs is inconsistent with the premise that the female segment of the population has recovered.[40] It is further evidence that the revised ARM Framework does not properly account for the population dynamics of horseshoe crabs.

A female harvest prohibition would also be expected to decrease the ratio of males to females in the population. But the data indicate that the male-to-female ratio increased between 1999 and 2019, suggesting *fewer* females for every male.[41] This is another warning sign that the population has not recovered, and the harvest of female horseshoe crabs should not resume.[42] Resuming such harvest would only further deplete a critical component of the population that has failed to show expected signs of recovery even under the female harvest prohibition.

Abundance data for immature and newly mature females raise additional concerns about the recovery of the female population. In 2019 and 2020, the Virginia Tech survey estimated the lowest abundance of newly mature female horseshoe crabs since data collection began in 2002, "indicating low influx of young mature females into the spawning stock."[43] Moreover, abundances of immature females and males for 2016-2020 were similar to those before 2013, when there was no female harvest prohibition in place. That is again contrary to expectations, since a prohibition on harvesting females should correlate to an increase in younger individuals.[44]

Dr. Lipcius explains that estimates of abundance can be less sensitive to serious problems in a population than variables including female size, female size structure, spawning stock biomass, and sex ratio. But the revised ARM Framework relies on abundance estimates to the exclusion of these other important variables. That is a risk-prone strategy and is not suitable for protecting horseshoe crabs or the threatened red knots.

B. The Revised ARM Framework Fails to Consider Horseshoe Crab Egg Density, the Most Direct Measure of Food Availability for Red Knots.

Another critical omission in the revised ARM Framework is its exclusion of data about the most direct measure of the adequacy of food resources for red knots: the availability of horseshoe crab eggs on the beach. As explained above, for red knots arriving at Delaware Bay after flying thousands of miles, horseshoe crab eggs provide energy-rich, easily digestible nutrition as the birds prepare to complete their journey northward and breed in the Arctic Circle. Red knots flying from South America shrink their digestive organs for the journey, and no other food source can replace easily digestible horseshoe crab eggs in enabling red knots to quickly rebuild their organs and muscles.[45] When conditions permit, a red knot at Delaware Bay can double its

[39] *Id.*
[40] *Id.*
[41] *Id.* at 10.
[42] *Id.*
[43] *Id.* at 6, 7 fig. 1.
[44] *Id.*
[45] Niles et al., *Effects of Horseshoe Crab Harvest* 154.

body mass in as little as 12 days by feasting on horseshoe crab eggs.[46] Research indicates that the red knots that have flown the farthest, from Tierra del Fuego, are particularly dependent on the density of horseshoe crab eggs (i.e., the number of eggs per square meter of beach).[47] Nevertheless, the revised ARM Framework has failed to consider actual data on egg density in the Delaware Bay region. Whatever concerns may have existed about such data at the time the original ARM Framework was developed, egg density should now be considered in light of new scholarship (discussed below) and the importance of horseshoe crab eggs for red knots. The revised ARM Framework's failure to do so represents another key flaw.

1. Egg density is the most direct measure of food availability for red knots.

Scientific studies link food availability at Delaware Bay to red knot survival and fecundity. Under favorable conditions including abundant horseshoe crab eggs, red knots at Delaware Bay roughly double their body mass from 90-120 grams to 180-220 grams before departing for the Arctic.[48] Individual red knots can gain up to 15 grams per day, "probably when horseshoe crab eggs are superabundantly available," allowing even late-arriving red knots to gain adequate mass in a brief period.[49] Researchers have observed that red knots experience "striking fitness consequences . . . correlated with the amount of nutrient stores accumulated in Delaware Bay."[50] Specifically, research has found a positive correlation between the mass of birds leaving Delaware Bay in the spring and the speed at which they complete their migration to the Arctic, reproductive success, and survival to the autumn.[51]

A superabundance of horseshoe crab eggs is required to meet the nutrition needs of red knots, other shorebirds, and the many other species that rely on this unique resource. Horseshoe crabs lay eggs too deep in the sand for red knots to access. But as more horseshoe crabs spawn on the beach, they disturb the sand, churning some of the eggs closer to the surface.[52] It is this churning, as well as wave action, that makes horseshoe crab eggs accessible to red knots.[53] The system depends on the successive spawning of large numbers of horseshoe crabs.[54]

2. Egg Density Has Declined Dramatically in Recent Decades, Correlating with the Decline in Red Knots.

Research strongly demonstrates that the abundance of horseshoe crab eggs near the beach surface (where the eggs are accessible to red knots) used to be at least ten times greater than the

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[46] New Jersey Department of Environmental Protection, *Wildlife Populations: Red Knot* 1-2.
[47] FWS, *Species Status Assessment Report for the Rufa Red Knot* (Version 1.1) 9 (Sept. 2020) ("*Species Status Assessment Report*").
[48] Allan J. Baker et al., *Rapid Population Decline in Red Knots: Fitness Consequences of Decreased Refuelling Rates and Late Arrival in Delaware Bay*, 271 Proceedings of the Royal Society of London B 875, 876 (2004).
[49] *Id.* at 876.
[50] *Id.* at 881.
[51] Duijns et al., *Body Condition Explains Migratory Performance* 5-6.
[52] Niles et al., *Effects of Horseshoe Crab Harvest* 155.
[53] *Id.*
[54] *Id.*

abundance in recent years.[55] Measurements from 1985 to 1987 conservatively indicate that egg density averaged 156,000 eggs per square meter of beach. In recent years, egg density averaged only around 10,000 eggs per square meter of beach.[56]

This decline in egg density correlates with the dramatic decline of migratory shorebirds, especially red knots. The trends mirror each other over decades but also converge on smaller timescales. Among years when measurements were taken, the nadir for horseshoe crab egg density appears to have been the early 2000s, shortly after the unregulated overexploitation of horseshoe crabs in the 1990s.[57] This corresponds to a "changepoint" for red knots when the peak count dropped from more than 43,000 to fewer than 16,000.[58]

3. Horseshoe Crab Abundance Is Not an Adequate Proxy for Egg Availability.

Notwithstanding the research documenting a dramatic decline in the availability of horseshoe crab eggs, the revised ARM Framework posits that the abundance of female horseshoe crabs is increasing. That is a dubious claim, as explained in section III.A of these comments. But even assuming for the sake of argument that it were correct, it would not necessarily result in more eggs for horseshoe crabs. To the contrary, demographic trends suggest that the production of eggs per horseshoe crab is likely decreasing.

Dr. Lipcius describes how egg production is directly proportional to the weight of horseshoe crabs, such that heavier crabs produce more eggs.[59] Data from the Virginia Tech Horseshoe Crab Trawl Survey indicate that the average prosomal width of female horseshoe crabs has fallen considerably, with an especially marked drop in the largest crabs over the past few years (2018-2020). Weight is an exponential function of prosomal width, meaning that even a modest decline in crab width could signify a very significant decline in weight and therefore in egg production. The trend toward smaller female horseshoe crabs may partially explain the low egg density numbers in recent years. Dr. Lipcius concludes that "total reproductive (egg) output has likely not improved, which hampers recovery of the HSC and RK populations."[60]

4. The ARM Report Presents No Compelling Reason to Ignore Egg Density.

There is no defensible rationale for completely excluding from the revised ARM Framework any direct measure of the most direct indicator of the adequacy of the red knot food supply: egg density. None of the ARM Subcommittee's reasons for excluding data about food availability withstands scrutiny.

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[55] Joseph A.M. Smith et al., *Horseshoe Crab Egg Availability for Shorebirds in the Delaware Bay: Dramatic Reduction After Unregulated Horseshoe Crab Harvest and Limited Recovery After 20 Years of Management*, Aquatic Conservation: Marine and Freshwater Ecosystems (2022) (in press) ("*Horseshoe Crab Egg Availability*").
[56] *Id.*
[57] *Id.*
[58] *Id.*
[59] The information in this paragraph is drawn from *Lipcius Expert Report* 7-10 & figs. 2-6.
[60] *Id.* at 10.

First, the Subcommittee asserted that the protocol for measuring egg density over the years was too variable to provide reliable comparisons.[61] Even if that was previously a legitimate concern, scientists have now demonstrated a long-term reduction in the surface availability of horseshoe crab eggs based on multiple studies using similar methods and sampling from comparable or even identical locations.[62] More fundamentally, in the context of a threatened species, major warning signs should not be disregarded on the basis of uncertainty in the data, especially when the data that exist point strongly in the same troubling direction. As Dr. Lipcius explains, "Lack of use of HSC egg density data, as a proxy for RK food availability, amounts to a failure to incorporate all available scientific information into the analysis to guide management decisions in a risk-averse manner."[63]

The Subcommittee next asserted that habitat loss had not been "adequately rule[d] out" as the cause of declining egg density. This argument is equally misplaced. Recent research demonstrates that egg density has declined even where habitat continues to be suitable, such as where sand depth exceeds 40 centimeters.[64] Moreover, habitat loss does not provide a basis for disregarding the availability of horseshoe crab eggs for red knots. As Dr. Lipcius explains, while the Board does not have control over all sources of stress on horseshoe crabs, the existence of multiple stressors demands a *more* risk-averse approach with respect to factors such as harvest quotas that are fully within the Board's control.[65]

In addition, the Subcommittee denied the ability to link horseshoe crab egg abundance with red knot nutrition or survival.[66] However, as shown above, there is a strong correlation between declining egg density and declining red knot abundance.

Regardless of the Subcommittee's concerns that egg density data are not sufficiently conclusive, or that habitat loss is a contributing factor, multiple studies over several decades uniformly point in the same direction: egg density has declined to an alarming degree, as have the red knots that consume the eggs. At a minimum, the Commission must recognize that plentiful eggs are a necessary and critical element of red knot recovery and solicit formal stakeholder input on incorporating that principle into harvest decisions in light of recent research.

C. <u>The Revised ARM Framework Finds a Weak Relationship Largely Because It Relies on Data from Years When Both Red Knots and Horseshoe Crabs Were Already Depleted.</u>

In contrast to all of the scientific information discussed above demonstrating a critical connection between horseshoe crabs and red knots, the revised ARM Framework finds a weak link between these species partly because it is based entirely on data from after the ecosystem

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[61] ARM Subcommittee, *Majority Response to Niles and Justification for Why Opinion Not Adopted* (in *ASMFC, ARM Report*) 105-06.
[62] Smith et al., *Horseshoe Crab Egg Availability*.
[63] *Lipcius Expert Report* 12.
[64] Smith et al., *Horseshoe Crab Egg Availability*.
[65] *Lipcius Expert Report* 13.
[66] ARM Subcommittee, *Majority Response to Niles* 104.

crashed in the late 1990s.[67] The most the model can do is interpret the interaction between two perilously depleted species, without any concept of how a healthy ecosystem would function. In defiance of historical and scientific evidence, the revised ARM Framework seems to assume that a supposedly minimal correlation between horseshoe crabs and red knots when both species are degraded is indicative of how the ecosystem would operate when both species are plentiful. Rather than viewing its finding of a weak link appropriately as a symptom of an ailing ecosystem, the revised ARM Framework leverages it to justify greater exploitation.

As one example of why recent data may not represent the historic relationship between the two species, consider the population of red knots migrating from southern South America. These birds travel the farthest to reach Delaware Bay and need to rebuild their digestive organs upon arrival, making them particularly dependent upon easily digestible horseshoe crab eggs.[68] Even more than other red knots, this Southern wintering population has suffered "sharp and well-documented declines" in recent decades due to reduced food availability at Delaware Bay.[69] As a result, the relatively small number of red knots that pass through Delaware Bay may be increasingly skewed toward birds that winter farther north, with fewer of the birds that most heavily depend upon horseshoe crab eggs. The revised ARM Framework would interpret these conditions to mean that red knot abundance is less affected by horseshoe crab abundance and that greater exploitation is acceptable. It would thus ignore the impact of egg scarcity on the most vulnerable population of red knots.

While the revised ARM Framework may necessarily be limited by the years from which data are available, it should not draw overbroad conclusions from a constrained dataset. As Dr. Shoemaker explains, these constraints give the model a "limited scope of historical variation . . . . Using these models to forecast system dynamics under conditions outside the range of values used to fit the model (e.g., lower HSC abundances, higher REKN abundances) therefore requires extrapolation, which can be highly uncertain (and often inaccurate)."[70] Based on Dr. Shoemaker's expert judgment, "[I]t does not seem prudent to implement management 'experiments' that could potentially imperil a threatened or endangered species (TES), even under the rubric of adaptive management."[71]

D. The Revised ARM Framework Would Arbitrarily and Unjustifiably Remove Abundance Thresholds Below Which the Harvest of Female Horseshoe Crabs Is Prohibited.

The revised ARM Framework would arbitrarily lift the protective abundance thresholds intended to preserve the availability of food for red knots. Specifically, under the existing Framework, the female harvest quota is zero until the estimated abundance of female horseshoe crabs exceeds 11.2 million or the estimated abundance of red knots exceeds 81,900 in Delaware Bay.[72] These

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[67] *E.g.*, *ARM Report* 156 tbl. 13 (illustrating that the catch multiple survey analysis for horseshoe crabs uses data starting from 2003). Compounding the chronological limitations on the data informing the model, the revised ARM Framework also imposes geographic constraints by including only data from Delaware Bay.
[68] FWS, *Species Status Assessment Report* 9.
[69] *Id.* at 28; FWS, *Draft Recovery Plan for the Rufa Red Knot* 14.
[70] *Shoemaker Expert Report* 11.
[71] *Id.*
[72] ASMFC, *ARM Report* 21.

thresholds reflect stakeholders' desire to take a precautionary approach to managing the delicate relationship between horseshoe crabs and red knots. Because neither species has reached its threshold since the original ARM Framework was implemented, the model has never recommended a female harvest. Under the revised ARM Framework, the model could (and likely would) recommend a significant female harvest even when neither red knot nor female horseshoe crab abundance has exceeded its protective threshold. Indeed, the Subcommittee's calculations show that the model would have recommended a female harvest of approximately 150,000 for 2017-2019, years when the original ARM Framework recommended a female harvest of zero.[73]

1. ASMFC Has Provided No Defensible Rationale for Removing the Protective Thresholds.

Removal of the protective thresholds received significant criticism in the minority opinions submitted by ARM Subcommittee members.[74] In rejecting these critiques, the Subcommittee relied on two primary arguments, neither of which is defensible.

First, the Subcommittee stated, "The presence of these threshold constraints in the utility function was criticized during this revision for not being consistent with adaptive management and optimization procedures and therefore they were removed from the utility functions."[75] But the Subcommittee's argument assumes that stakeholder values have no role in adaptive management, and that adaptive management is inconsistent with any constraint that arises from something other than an optimization model. This view squarely defies the adaptive management process as described in Addendum VII, which highly values stakeholder input, as explained in section IV.B of these comments. Moreover, the Subcommittee's view is internally inconsistent, as the revised ARM Framework appropriately maintains precautionary limits on the maximum harvest of male and female horseshoe crabs,[76] which represents a constraint on the model in deference to precautionary values. Thus, the revised ARM Framework is arbitrarily selective about its willingness to consider precautionary constraints.

Second, the Subcommittee described the thresholds as a "knife-edge utility function[]" and stated that, once the thresholds were exceeded, the existing ARM Framework would immediately recommend the maximum harvest package, with its female quota of 210,000.[77] According to the Subcommittee's calculations, the model is unlikely to ever select the interim harvest package, with a female quota of 140,000.[78]

The Subcommittee's argument misses the mark. The immediate issue is whether female harvest is allowed *below* the thresholds. The Subcommittee may have concerns about what

[73] ASMFC, *Supplemental ARM Report* 21 tbl. 11.
[74] *E.g.*, Wendy Walsh, *Walsh Minority Opinion* (in ASMFC, *ARM Report*) 113-14.
[75] ARM Subcommittee, *Majority Response to Niles* 107.
[76] ASMFC, *ARM Report* 81 ("[O]ne feature from the packages used in the original ARM version was retained: the maximum harvest for females was set to 210,000 and for males 500,000."). The Subcommittee pointed to these limits as an example of maintaining an "earlier decision[] made by stakeholders." ARM Subcommittee, *Majority Response to Walsh and Justification for Why Opinion Not Adopted* (in ASMFC, *ARM Report*) 125.
[77] ARM Subcommittee, *Majority Response to Walsh* 124.
[78] *Id.*

recommendations the current model would make in the unprecedented event that the thresholds were exceeded, but that is a separate question. In addition, if the current model would catapult over the interim harvest package and immediately recommend the maximum harvest package in the event that red knots or female horseshoe crabs met their abundance threshold, that would seem to indicate a defect in the existing model. A more reasonable correction would be to adjust the existing model to facilitate a gradual increase in female harvest recommendations once an abundance threshold is met. It is not at all clear why removing the thresholds altogether is a necessary or logical solution. Regardless, a potential defect in the current model's response to the achievement of protective thresholds for horseshoe crabs or red knots cannot offer any justification for eliminating the thresholds well before they are met. At the very least, the Subcommittee should have made its decision in consultation with stakeholders, not unilaterally.

2. The Elimination of the Protective Thresholds Illustrates the Improper Exclusion of Stakeholder Input.

In section IV.B, these comments detail why the exclusion of formal stakeholder input from the development of the revised ARM Framework was inappropriate and violated the requirements for adaptive management. This section explains why excluding stakeholders from decisions about the protective thresholds was particularly improper and contravened the views of the Commission's own experts and peer review panel.

During the Board's early consideration of developing Addendum VIII, the ARM Subcommittee Chair explained what process would be required to change (much less eliminate) the protective thresholds:

> [M]oving forward with this new Population Dynamics Model, where that threshold is at 11.2 million, you know that could change. It is a possibility to have a different utility function. *That is something that would have to be discussed amongst stakeholders* and among the ARM Workgroup members.[79]

Despite the Chair's acknowledgement that changing the female horseshoe crab threshold would require stakeholder input, the revised ARM Framework would eliminate the threshold even in the absence of stakeholder input.

The exclusion of stakeholders and elimination of the thresholds was criticized in the minority opinion of Subcommittee member (and Chair of the Delaware Bay Ecosystem Technical Committee) Dr. Wendy Walsh, the national lead for red knot recovery at FWS. Dr. Walsh meticulously detailed the role of stakeholder input in adaptive resource management and observed that the ARM Subcommittee had "failed to consult a broad array of stakeholders in the reinterpretation of previously agreed-upon objectives."[80] With respect to the abundance thresholds, Dr. Walsh explained:

[79] Comments of John Sweka, ARM Subcommittee Chair, *Proceedings of the Atlantic States Marine Fisheries Commission Horseshoe Crab Management Board* 5 (Oct. 29, 2019) (emphasis added), https://www.asmfc.org/uploads/file/5fb2ea02HorseshoeCrabBoardProceedingsOct2019.pdf.
[80] *Walsh Minority Opinion* 113.

> These threshold values act as a constraint on female harvest, which was the express intent of the stakeholders. . . . [T]he formulation of these values as a constraint was an explicit and clear choice in the development of the existing framework. . . . [T]he high risk-aversion to female crab harvest by the stakeholders is clear, and thus it can be presumed that the new utility function . . . would be of considerable concern to those same stakeholders.[81]

The ASMFC-convened Peer Review Panel echoed these concerns. Recognizing that the Subcommittee had not convened stakeholders for this proceeding, the Panel tentatively stated that it "does not disagree" with the revised modeling functions, "as long as they truly reflect the objectives related to HSC harvest and REKN recovery and the risk associated with the HSC harvest."[82] The Panel reiterated its concern in its list of recommendations:

> The new utility and harvest functions are a representation of values, and the Panel understands that convening a group of stakeholders for this revision was not possible. Therefore, the Panel recommends the WG fully consider whether the new utility and harvest functions represent stakeholder values as articulated in 2009.[83]

The rejection of Dr. Walsh's minority opinion indicated a troubling misunderstanding of the Subcommittee's assignment. The Subcommittee wrote that retaining the threshold values "is more consistent with a simple harvest control rule" and "would not be adaptive management and would not require the Framework developed in this assessment."[84] By this statement, the Subcommittee revealed that it viewed stakeholder input as an impediment to adaptive management—an obstacle to the Framework the Subcommittee had already devised. But as explained in more detail below in section IV.B, stakeholder input has consistently been recognized as the foundational step of adaptive management. There is no adaptive management without stakeholder input, and the revised ARM Framework is therefore not an exercise in adaptive management.

E. <u>The Horseshoe Crab Population Estimates Are Improperly Based, in Large Part, on Two Surveys that Stakeholders Have Rejected.</u>

The omission of stakeholder input was particularly harmful because it obscured stakeholder objections to new survey data upon which the revised ARM Framework extensively relies. Since its inception, the ARM Framework has based horseshoe crab abundance estimates entirely on data from the Virginia Tech Horseshoe Crab Trawl Survey, which reflected the original stakeholders' greater confidence in that survey compared to other surveys of horseshoe crabs in Delaware Bay. The Virginia Tech survey is purpose-designed to count horseshoe crabs, as opposed to general surveys that count horseshoe crabs just incidentally, and FWS has called it

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[81] *Id.* at 113-14.
[82] ASMFC, *Horseshoe Crab Adaptive Resource Management Revision Peer Review Report* (in ASMFC, *ARM* Report) 10 (277 of PDF) ("*Peer Review Report*"). Significantly, the Peer Review Panel's tentative approval of the revised ARM Framework was uninformed by independent expert reviews such as those offered by Drs. Shoemaker and Lipcius in this comment process.
[83] *Id.* at 12.
[84] ARM Subcommittee, *Majority Response to Walsh* 122.

"the best benthic trawl survey to support the ARM."[85] Yet the revised ARM Framework would drastically downgrade the model's reliance on the Virginia Tech survey, rendering it one of three equally weighted surveys.[86] The two additional surveys that would comprise the abundance estimates—the New Jersey Ocean Trawl Survey and the Delaware Adult Trawl Survey—are general trawl surveys and not purpose-designed to count horseshoe crabs.

In her minority opinion, Dr. Walsh explained (as the Subcommittee acknowledged) that the revised approach would generate significantly higher abundance estimates,[87] which will lead to higher harvest recommendations for female horseshoe crabs. Dr. Walsh urged that, if the Subcommittee determined to rely upon all three surveys, it should at least accord greater weight to the Virginia Tech survey based on its "technical rigor and deliberate design" and "the high level of confidence that stakeholders have expressed in" it, among other reasons.[88] As Dr. Walsh noted, using all three surveys generates such high estimates that it would sometimes have resulted in female harvest recommendations even under the existing ARM Framework.[89]

The original decision to rely exclusively on the Virginia Tech survey reflected explicit stakeholder input. By introducing two additional surveys that stakeholders previously disfavored, and weighting all three surveys equally, the revised ARM Framework alters yet another stakeholder-driven component of the model without soliciting formal stakeholder input.

IV. ASMFC HAS REPEATEDLY EXCLUDED INPUT FROM STAKEHOLDERS AND THE BROADER PUBLIC.

The development of Draft Addendum VIII omitted input from stakeholders and the public throughout the process. The Atlantic Coastal Fisheries Cooperative Management Act of 1993 requires the Commission to "provide[] adequate opportunity for public participation in the [fishery management] plan preparation process."[90] ASMFC has violated legal requirements and its own guidelines by severely limiting public participation in this proceeding. Specifically, the Commission held a public comment period before essential information was publicly available, failed to solicit formal stakeholder input, and decided to artificially limit its range of options to adopting Addendum VIII or reverting to Addendum VI—both of which would lead to resuming the female horseshoe crab harvest—without any public input whatsoever.

[85] FWS, *Rufa Red Knot Background Information and Threats Assessment* 247.
[86] ASMFC, *ARM Report* 55.
[87] Walsh Minority Opinion 111; ARM Subcommittee, *Majority Response to Walsh* 123 ("[I]t was noted in the 2019 assessment that equally weighting the surveys resulted in higher population estimates and that characterization by Walsh is accurate."); ASMFC, *Supplemental ARM Report* 21 tbl. 11 (for a comparison of abundance estimates under the current and proposed methodologies).
[88] *Walsh Minority Opinion* 111.
[89] *Id.* at 111-12.
[90] 16 U.S.C. § 5104(a)(2)(B).

A. <u>ASMFC Held the Public Comment Period Before the Revised ARM Framework's Core Model Was Publicly Available.</u>

The public comment period for Addendum VIII occurred while crucial, material information was being withheld from the public. Specifically, the public still has not been allowed to see the model that generates bait harvest recommendations for horseshoe crabs in Delaware Bay.

New Jersey Audubon and Defenders of Wildlife requested the model on February 23, 2022, in FOIA requests submitted to the U.S. Geological Survey ("USGS") and FWS, as well as a record request submitted to ASMFC. While ASMFC provided certain components related to the horseshoe crab estimates, USGS controls the core component that links horseshoe crabs and red knots to generate harvest recommendations. In a letter prior to the Board's August 2022 meeting, New Jersey Audubon and Defenders of Wildlife explained that USGS had not yet released the model and urged the Board not to initiate the public comment period on Draft Addendum VIII until the public could access the model that underlies the revised ARM Framework.[91] At the Board meeting, several members expressed concern about the unavailability of the model, noted USGS's stated intent to release the model following internal review,[92] and asked to be kept apprised of developments in the public's access to the model.

As of September 30, 2022—the close of the public comment period on Draft Addendum VIII—USGS has still not released the model. As a result, the public's ability to submit substantive technical comments has been severely constrained. As this comment letter demonstrates, public evaluation is essential for identifying significant issues for the Board's consideration. Indeed, many of Dr. Shoemaker's critiques were enabled by the limited model components released by ASMFC. But the preponderance of the model underlying the revised ARM Framework still has not been subject to public evaluation. Dr. Shoemaker listed several questions that he could have investigated more thoroughly if that model were available,[93] including:

- Does the red knot projection model outperform a null model that excludes any effect of horseshoe crab abundance?
- How much variation in apparent survival in the red knot IPM model is explained by the horseshoe crab effect compared to random among-year variation?
- Would an index of horseshoe crab egg density explain more variation in red knot survival and fecundity than the CMSA-derived estimate of horseshoe crab abundance?

While the Board should resolve the issues that have already been raised before further considering Addendum VIII, it is impossible to anticipate all of the additional questions that will

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[91] Letter from Benjamin Levitan, Earthjustice, to ASMFC Commissioners re *Consideration of Draft Addendum VIII on the Implementation of Recommended Changes from 2021 Adaptive Resource Management Revision and Peer Review Report for Public Comment* (July 26, 2022).
[92] In an email accompanying its denial of a Freedom of Information Act Request for the model, a U.S. Geological Survey representative wrote, "We have withheld the two USGS models, but they and their associated use publications will be published following the required USGS Fundamental Science Practices reviews." Email from Janis Wilson, USGS, to Benjamin Levitan, Earthjustice, re: *FOIA: DOI-USGS-2022-002312 – Response* (July 28, 2022). On August 15, 2022, New Jersey Audubon and Defenders of Wildlife administratively appealed the denial of access to the model, but USGS has not yet responded.
[93] *Shoemaker Expert Report* 26-27.

be identified once the model is released. New issues will inevitably arise. The proper time to address those questions is before the Board approves Addendum VIII. Enabling the public to identify additional questions only after the revised ARM Framework has been approved would subject red knots and horseshoe crabs to unacceptable risk and raise difficult administrative questions about how to limit the harm even as the Framework is in place.

B. The Subcommittee Violated ASMFC's Procedures by Failing to Solicit Formal Stakeholder Input.

The ARM Subcommittee's failure to solicit formal stakeholder input in this proceeding violated the principles and process of adaptive management. When the Board first approved the ARM Framework in Addendum VII more than a decade ago, stakeholder input was integral to the process. The *first sentence* of the "ARM Framework" section of Addendum VII was, "A goal of the ARM Framework is to transparently incorporate the views of stakeholders along with predictive modeling to assess the potential consequences of multiple, alternative management actions in the Delaware Bay Region."[94] The ARM Subcommittee expressed the same sentiment about the "ARM approach" in the current proceeding: "First, there is a great emphasis on complete elicitation of objectives and management actions from a full range of stakeholders."[95] The Subcommittee took that sentence verbatim from the Commission's Framework for Adaptive Management from 2009,[96] demonstrating how consistently stakeholder input has been acknowledged as the cornerstone of adaptive management.

The Board formalized the role of stakeholder input when it approved Addendum VII, which implemented an adaptive management framework for the Delaware Bay horseshoe crab fishery. Addendum VII required that the ARM Framework's "[i]mplementation *shall* be comprised of two cycles."[97] The *first step* of the "Longer Term Cycle," which was to occur "every 3 or 4 years," was to "[s]olicit formal stakeholder input on ARM Framework to be provided to the relevant technical committees."[98]

The ARM Subcommittee's failure to convene stakeholders in preparing Addendum VIII violated the Board's express requirements, as well as the principles underlying the adoption of adaptive management. And if the Board approves Addendum VIII, the exclusion of stakeholders is unlikely to be rectified anytime soon. Addendum VIII sets forth a default period of "every 9 or 10 years" for revising the ARM Framework, which "should incorporate" soliciting "formal stakeholder input."[99] Pursuant to that schedule, if the Board approves Addendum VIII in 2022—which it should not do—the ARM Framework will be due for a revision in the early 2030s. Assuming that stakeholders are formally consulted at that time (unlike this time), roughly *20*

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[94] ASMFC, *Addendum VII to the Interstate Fishery Management Plan for Horseshoe Crabs for Public Comment: Adaptive Resource Management Framework* 2 (2012), https://www.asmfc.org/uploads/file/hscAddendumVII_Feb2012.pdf ("*Addendum VIII*").

[95] ASMFC, *ARM Report* 21.

[96] ASMFC, *Stock Assessment Report No. 09-02 (Supplement B): A Framework for Adaptive Management of Horseshoe Crab Harvest in the Delaware Bay Constrained by Red Knot Conservation* 1 (2009), https://www.asmfc.org/uploads/file/2009DelawareBayARMReport.pdf.

[97] ASMFC, *Addendum VII* at 4 (emphasis added).

[98] *Id*.

[99] ASMFC, *Horseshoe Crab Draft Addendum VIII for Public Comment* 8 (Aug. 2022).

years will have elapsed between such consultations, a striking contrast to the "3 or 4 year[]" interval required by Addendum VII. That would also mean that stakeholders would not be formally consulted for roughly *17 years* after FWS's 2015 determination to list red knots under the Endangered Species Act. While it is impossible to know all the ways that soliciting stakeholder input would have affected the current proceeding, the revised ARM Framework's elimination of the protective abundance thresholds (described above in section III.D.2) demonstrates that this concern is not merely theoretical.

It bears repeating how significantly the revised ARM Framework departs from the paradigm that the stakeholders accepted in preparation for Addendum VII, which instituted harvest recommendations based on the relationship between horseshoe crabs and red knots. The revised Framework would weaken that relationship almost to the point of nonexistence and recommend quotas accordingly. While presented as a technical update, the revised ARM Framework cannot plausibly be considered a reflection of the stakeholders' articulated values. At the very least, stakeholders should have been involved in designing a revised approach. Failure to involve them represents another reason for rejecting the current proposal.

C. <u>Even Before the Public Comment Period, ASMFC Purported to Limit Its Options to Those that Would Reinitiate the Female Horseshoe Crab Harvest.</u>

In addition to the inaccessibility of crucial information and the exclusion of stakeholder input, there was no public notice or comment for arguably the most critical decision presented by Draft Addendum VIII, which ASMFC now presents as a foregone conclusion: designating a reversion to Addendum VI as the "No Action" alternative if the Board does not approve Addendum VIII.[100] Addendum VI would increase the Bay-wide horseshoe crab harvest quota and *allow for the resumption of the female harvest* in Maryland and Virginia. Thus, the Board has effectively foreclosed public comment on the pressing question of *whether* to resume female harvest for this fishery. Under the terms of draft Addendum VIII, whichever option the Board selects—and regardless of any information that might surface during the public comment period—that decision is preordained.

On the merits, selecting Addendum VI as the "No Action" alternative was arbitrary, unnecessary, and misleading. Addendum VI would completely transform the management framework. The transition from Addendum VI to Addendum VII was arguably the most significant event in ASMFC's management of the horseshoe crab fishery, and reverting to Addendum VI would be equally significant.

To justify the selection of Addendum VI, Draft Addendum VIII indicates that Addendum VII is unavailable as the "No Action" alternative because the model underlying it was built on obsolete software and can no longer be utilized.[101] Even if the software is obsolete, that does not back the Board into a corner with no option but to adopt an addendum with a female harvest. The current ARM Framework has generated the same harvest quota for ten consecutive years, and the legitimate "No Action" alternative would be to apply the same quota to the 2023 fishing season. In fact, Addendum VII contains two "fallback option[s]" for when the data required to run the

[100] *Id.* at 5.
[101] *Id.*

ARM model are not available: use the quotas from Addendum VI *or* use the same quotas as the previous year.[102] It is unclear why the Board would have fewer options when the Addendum VII model cannot be run. The natural understanding of "No Action" would be to maintain the current status quo—i.e., the current addendum and current quotas—not to revert to an addendum and quotas that mark a major departure from the status quo.

At the August 2022 Board meeting, ASMFC staff explained that simply reusing last year's quotas is not appropriate because that would not qualify as "adaptive resource management."[103] Even if that were so, the solution should not be to reinstate the 12-year-old static quotas from Addendum VI. If the Board has authority to impose such a drastic change, then surely it has authority to continue relying on the most recent outputs of the current ARM Framework. It may be that neither option offers a satisfactory long-term solution, but the question now is what to do while questions about the revised ARM Framework are being addressed. The Board is not required to rush through a new (or old) addendum. It can temporarily maintain the current Framework to allow for thorough consideration of the appropriate next step, which clearly does not include accepting Addendum VIII as currently proposed.

V. THE FLAWS IN THE REVISED ARM FRAMEWORK MUST BE ADDRESSED NOW.

The Board's decision on Addendum VIII is highly consequential and could determine the course of the horseshoe crab fishery for many years to come. It is vital that the revised ARM Framework be subject to full vetting, and that foreseeable flaws be identified, prior to implementation by the Board. There will not be realistic opportunities to remedy defects in the revised ARM Framework in the future—at least not without imposing large burdens on both the Board and the public.

A. Flaws in the Revised ARM Framework Cannot Realistically Be Remedied at the Quota-Setting Stage.

At the Board's meeting in August 2022, some speakers observed that Addendum VIII will not, in itself, set binding quotas because the Board will retain discretion to deviate from the ARM Framework's harvest recommendations, and states will retain discretion to set quotas below those set by the Board.[104] But that is not a valid rationale for approving an addendum that has not been fully vetted and has been demonstrated to be flawed based on even the limited amount of information that has been made publicly available.

The purpose of the ARM process is to generate harvest recommendations based on rigorous science and sound policy.[105] As these comments detail, the revised ARM Framework incorporates many substantive and procedural flaws, and additional flaws are likely to emerge

[102] ASMFC, *Addendum VII* at 6.
[103] ASMFC, *Horseshoe Crab Management Board Proceedings Aug2022*, at 5:11, https://www.youtube.com/watch?v=OZvpdTTPj8c.
[104] *E.g.*, *id.* at 28:00, 1:12:57.
[105] 16 U.S.C. § 5104(a)(2)(B) (requirement in the Atlantic Coastal Fisheries Cooperative Management Act of 1993 for ASMFC to follow "standards and procedures to ensure that . . . [fishery management] plans promote the conservation of fish stocks throughout their ranges and are based on the best scientific information available.").

when the underlying model is released to, and evaluated by, the public. Regardless of the Board's or states' ability to deviate from those recommendations, the Board must ensure that the Framework represents the best available—and properly vetted—science and policy. To do otherwise would call into question the purpose of the ARM process and the harvest recommendations.

It would also not be practical for the Board or states to resolve the flaws in the revised ARM Framework at the quota-setting stage. If Addendum VIII were approved and the Board were unable to rely upon the Framework's flawed harvest recommendations, there would be no clear criteria or guidelines for establishing quotas, leading to a confusing, burdensome, and arbitrary quota-setting process. Similarly, if the Board approved Addendum VIII and adopted the revised ARM Framework's flawed harvest recommendations, states would need to determine the proper course in the absence of reliable information or direction from ASMFC. That would undermine the Horseshoe Crab Fishery Management Plan's purpose of creating "[a] coordinated and consistent management strategy."[106]

B. Flaws in the Revised ARM Framework Cannot Be Addressed Through Updates to the Model.

While the revised ARM Framework can be "updated based on the annual routine data collected in the region,"[107] updates will not remedy its flaws. Many of the defects identified in these comments cannot be addressed by new data but rather demand a deeper restructuring of the model. For example, the model's miscalculation of the uncertainty in horseshoe crab abundance projections will persist despite new data. The same is true for all of the variables that are omitted from the model but indicate an unstable horseshoe crab population: egg density, prosomal width, sex ratio, etc.

Other defects would theoretically be alleviated by new data, but not on any relevant timescale. For example, the effect of the nonsensical horseshoe crab recruitment rates from the Virginia Tech gap years will gradually be diluted as new data are added, but they will continue to have perilously high influence for many years—realistically, for as long as Addendum VIII will be in effect. And even if, for the sake of argument, the estimated recruitment rate will slowly become more accurate over the years, that does not justify neglecting to fix a clear defect before implementing the revised ARM Framework.

Finally, some defects may be compounded by the addition of more data. As explained above in section III.C, the model is based entirely on data from when both horseshoe crabs and red knots had already crashed. It does not reflect the dynamics of a properly functioning ecosystem. As more data from the post-crash years are added, the model may only grow more confident that the current state of the ecosystem represents the norm. As Dr. Shoemaker observes, additional data may even yield a negative relationship between the abundance of horseshoe crabs and red knots, which would pose an existential problem for the Framework.[108]

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[106] ASMFC, *Fishery Management Report No. 32 of the Atlantic States Marine Fisheries Commission: Interstate Fishery Management Plan for Horseshoe Crab* 1 (1998).
[107] ASMFC, *Draft Addendum VIII* at 8.
[108] *Shoemaker Expert Report* 10.

VI. APPROVING ADDENDUM VIII WOULD LIKELY LEAD TO A VIOLATION OF THE ENDANGERED SPECIES ACT BY ASMFC.

In addition to the other bases for rejecting Addendum VIII discussed above, the Endangered Species Act provides a powerful further reason: adopting Addendum VIII would threaten to violate the federal prohibition against "taking" a threatened species. The ESA prohibits any person from "tak[ing] any [endangered] species within the United States or the territorial sea of the United States."[109] Such prohibited "taking" includes actions that "harm" listed species, including "significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavioral patterns, including breeding, feeding or sheltering."[110] The ESA's "taking" prohibition extends to governmental authorization to take protected species that facilitates such harm by "solicit[ing]" or "caus[ing]" an offense.[111] By regulation, that prohibition extends to the taking of most threatened species, including the red knot.[112]

A. The Endangered Species Act Requires a Precautionary Approach.

In the Endangered Species Act, Congress adopted a precautionary approach. As the Supreme Court has stated, "Congress has spoken in the plainest of words, making it abundantly clear that the balance has been struck in favor of affording endangered species the highest of priorities, thereby adopting a policy which it described as 'institutionalized caution.'"[113] This principle is echoed in the ARM Framework's objective statement, which calls for "*ensur[ing]* that the abundance of horseshoe crabs is not limiting the red knot stopover population or slowing recovery."[114] Within the context of the ESA's legal framework, to ensure against such harms means taking a precautionary approach of "giv[ing] the benefit of the doubt to the species."[115] By setting ASMFC on a path to harm a threatened species whose population shows no sign of recovery, the revised ARM Framework would fall far short of ESA requirements and ASMFC's own objective.

As shown above, in many instances, Addendum VIII would enshrine a risk-prone approach instead of the risk-averse, precautionary approach required under the ESA. Even as it would allow the renewed harvest of female horseshoe crabs, Addendum VIII would utilize a model that, among other risky decisions:

- rejects the significant connection between horseshoe crabs and red knots,

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[109] 16 U.S.C. § 1538(a)(1)(B).
[110] 50 C.F.R. § 17.3.
[111] *Strahan v. Coxe*, 127 F.3d 155, 163 (1st Cir. 1997); 16 U.S.C. § 1538(g).
[112] 50 C.F.R. § 17.31(a) (applying the provisions of § 17.21 (addressing endangered species) to threatened species); *id.* § 17.21(a), (c) ("[I]t is unlawful . . . to solicit another to commit or to cause to be committed" the taking of an endangered species.).
[113] *Tenn. Valley Auth. v. Hill*, 437 U.S. 153, 194 (1978).
[114] ASMFC, *ARM Report* 25 (emphasis added).
[115] *See, e.g., Roosevelt Campobello Int'l Park Comm'n v. U.S. Envtl. Prot. Agency*, 684 F.2d 1041 (1st Cir. 1982) (quotations and citation omitted); *see also Defs. of Wildlife v. U.S. Dep't of the Interior*, 931 F.3d 339, 351 (4th Cir. 2019) (same regarding scientific determinations).

- neglects egg-density data, which provide the most direct measure of the adequacy of food for red knots,
- rejects protective populations thresholds that were essential to the only group of stakeholders that ASMFC ever formally consulted about this matter,
- assumes that horseshoe crabs are recovering despite negative demographic trends, and
- uses horseshoe crab projections that fail to account for uncertainty and are scarcely more accurate than a null model.

The exclusion of public input at multiple stages of this proceeding exacerbates the risk of an ESA violation because ASMFC has evaded the public scrutiny that would be appropriate for such a consequential proceeding. A risk-averse approach would be to welcome public input in order to identify and address weaknesses that create unacceptable risk for the red knot. But the Board has taken a different, risk-prone approach: hastening a vote on Addendum VIII even as the underlying model continues to be withheld, despite record requests submitted more than seven months ago. The Board will therefore make a decision without the benefit of crucial public input and the important considerations such input would raise.

Both ASMFC and FWS suggest that the model will be improved by future updates.[116] As shown above in section V.B, updates cannot remedy the flaws in the revised ARM Framework. But even if they could, relying on future updates is not appropriate when an ecosystem is dangerously degraded and a threatened species hangs in balance. Future updates are likely to come too late.

B. By Utilizing the Revised ARM Framework, ASMFC Would Harm Red Knots.

Like any other association or governmental entity, ASMFC is subject to the ESA taking prohibition.[117] Under the Atlantic Coast Fisheries Cooperative Management Act of 1993,[118] ASMFC's fishery management plans are legally binding upon affected states. Once the Commission issues a plan, states "shall implement and enforce the measures of such plan within the timeframe established in the plan."[119] Because ASMFC's quotas cannot be exceeded, states have been prohibited from authorizing female horseshoe crab bait harvest in Delaware Bay under the existing framework. States may authorize a female bait harvest only if ASMFC sets a non-zero female harvest quota.[120]

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[116] ASMFC, *Draft Addendum VIII* at 8; FWS, *U.S. Fish and Wildlife Service Evaluation of the Atlantic States Marine Fisheries Commission Horseshoe Crab/Red Knot Adaptive Resource Management Revision* at 3 of PDF (2022) ("*Evaluation*"), https://www.fws.gov/sites/default/files/documents/service-evaluation-of-atlantic-states-marine-fisheries-commission-horseshoe-crab-red-knot-adaptive-resource-management-revision.pdf.
[117] The ESA applies to any "person," which is broadly defined. 16 U.S.C. § 1532(13) ("The term 'person' means an individual, corporation, partnership, trust, association, or any other private entity; or any officer, employee, agent, department, or instrumentality of the Federal Government, of any State, municipality, or political subdivision of a State, or of any foreign government; any State, municipality, or political subdivision of a State; or any other entity subject to the jurisdiction of the United States.").
[118] Atlantic Coastal Fisheries Cooperative Management Act of 1993, Pub. L. 103-206, 107 Stat. 2419, Tit. VIII (codified at 16 U.S.C. § 5101 *et seq.*).
[119] *Id.* § 5104(b)(1).
[120] *Cf. Defs. of Wildlife v. U.S. Envtl. Prot. Agency*, 882 F.2d 1294, 1301 (8th Cir. 1989) (EPA's registration of pesticide effected a taking because the pesticide could not be used without such registration).

ASMFC's fishery management decisions therefore have a direct causal connection to the ultimate bait-harvesting actions that impact horseshoe crabs and red knots.[121] Indeed, the connection between the Board's management decisions and red knot demographics is the premise and intent of the ARM Framework's objective statement:

> Manage harvest of horseshoe crabs in the Delaware Bay to maximize harvest but also to maintain ecosystem integrity, provide adequate stopover habitat for migrating shorebirds, and ensure that the abundance of horseshoe crabs is not limiting the red knot stopover population or slowing recovery.[122]

Draft Addendum VIII shows that, if the revised ARM Framework had been utilized in 2017-2019, it would have allowed for the harvest of around 150,000 female horseshoe crabs each year,[123] compared to the actual quota of zero for each of those years. Going forward, allowing such an increase in the harvest of female horseshoe crabs, upon which egg abundance depends, threatens significant degradation and modification of red knot habitat at Delaware Bay that would kill or injure red knots by significantly impairing breeding and feeding activities that are essential to the continued existence of the species.[124]

As explained above, the revised ARM Framework raises serious questions that the Board has not answered or publicly considered. After 24 years of ASMFC management, including 10 years under an ARM Framework, neither red knots nor horseshoe crabs are on a trajectory to recover. There are serious reasons to doubt even the modest increase in the horseshoe crab population that ASMFC reports. ASMFC's red knot abundance estimates are essentially flat at low numbers, while other estimates based on direct counting have shown a dangerous decline in recent years.

Now, in the Board's first addendum since red knots were listed as threatened, Addendum VIII would result in the increased harvest of horseshoe crabs, including the resumed harvest of females, thus magnifying the factors imperiling red knots. This poses an enormous risk to the ecosystem, which is precisely the wrong response to a species being listed under the ESA.

C. FWS's "Evaluation" Does Not Offer Independent Support for Addendum VIII.

Recent statements from FWS do not bolster the credibility of the revised ARM Framework. When FWS listed red knots as threatened under the ESA, it stated, "[A]s long as the ARM is in place and functioning as intended, ongoing HSC bait harvests should not be a threat to the red knot."[125] In her minority opinion raising concerns about the revised ARM Framework, Dr. Walsh

[121] *E.g.*, *Sierra Club v. Yeutter*, 926 F.2d 429, 438-39 (5th Cir. 1991) (holding that government agency violated ESA taking prohibition by authorizing logging that destroyed habitat and thereby impaired essential behavioral patterns of listed woodpecker species); *Loggerhead Turtle v. County Council of Volusia County*, 896 F. Supp. 1170, 1181-82 (M.D. Fla. 1995) (holding that county that regulates vehicular access to beaches is liable under ESA for taking of sea turtles caused by nighttime beach driving).
[122] ASMFC, *ARM Report* 25.
[123] ASMFC, *Draft Addendum VIII* at 12 app'x A tbl. 1 (showing annual female harvest quotas ranging from 144,803 to 154,483).
[124] 50 C.F.R. § 17.3 (defining "[h]arm").
[125] 79 Fed. Reg. at 73,709.

wrote that "[i]mmediate resumption of female harvest by the means described in the draft report may prompt the USFWS to reconsider if the ARM is functioning as intended."[126]

In contrast to Dr. Walsh's minority opinion, the document that FWS released on August 16, 2022, styled as an "evaluation" of the revised ARM Framework, did not offer any independent assessment of the revised ARM Framework. Rather, it repackaged the revised ARM Framework's modeling with all of its flaws detailed above, at times appearing to copy and paste figures directly from the Subcommittee's materials, and stated that the revision "poses negligible risk to red knot recovery and negligible risk of take under the Endangered Species Act."[127] Nowhere did FWS question the validity of the revised ARM Framework or any of the underlying assumptions or decisions, including on any of the bases discussed in these comments and accompanying expert reports.

With its complete deference to ASMFC's flawed modeling, assumptions, and conclusions, FWS unsurprisingly reached the same flawed result but did not bolster its validity. As these comments have shown, the revised ARM Framework incorporates numerous erroneous methodologies and assumptions. In its document, FWS propagated the same errors and replicated the same flaws as ASMFC. Moreover, since FWS relied on ASMFC's non-public model, its assertions are effectively unverifiable. The revised ARM Framework is unreliable for the reasons demonstrated in these comments. The Framework also still needs a legitimate, thorough, independent review based on all underlying information—not just the information released publicly to date. FWS's imprimatur does not resolve the defects of Addendum VIII.

VII. CONCLUSION

The window to save red knots is closing rapidly, especially for Southern wintering birds that fly the farthest and are most reliant upon horseshoe crab eggs at Delaware Bay. The revised ARM Framework would increase the pressure on this species, which is already vastly diminished on the beaches that once hosted its extraordinary migration. The Framework does not appreciate the importance of horseshoe crabs to red knots or the fragility of the horseshoe crab population itself. The weak relationship that it perceives between red knots and horseshoe crabs may well become a self-fulfilling prophecy, as the computer model continues to run while the ecosystem around it fades away.

The Horseshoe Crab Management Board has an obligation to restore red knots and horseshoe crabs at Delaware Bay. Just as importantly, it has a real—and maybe a final—opportunity to do so. For the reasons described above and in the attached expert reports, the Board should reject Addendum VIII.

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[126] *Walsh Minority Opinion* 117.

[127] FWS, *Evaluation* at 3 of PDF. While the document is dated January 18, 2022, it was not released to the public until August 16. For an example of a copied figure, compare ASMFC, *Supplemental ARM Report* 30-31 figs. 10-11, with FWS, *Evaluation* at 5 of PDF fig. 1.

Review of 2021 ASMFC ARM revision

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September 2022

This is an expert review of the Adaptive Resource Management plan (ARM) proposed by ASMFC to guide management of the Horseshoe Crab fishery in Delaware Bay, performed by Kevin Shoemaker, Ph.D.

Dr. Shoemaker has a Ph.D. in Conservation Biology, a Master of Science degree in Conservation Biology, both from SUNY-ESF in Syracuse, NY, and a Bachelor of Science degree in Biology from Haverford College. He is a former Postdoctoral Fellow in the Department of Ecology and Evolution at Stony Brook University and a former Senior Scientist at Applied Biomathematics, an ecological research and development company located in Setauket, NY. Dr. Shoemaker is currently employed as an Associate Professor of Population Ecology at the University of Nevada, Reno. He has over 15 years of experience as a wildlife conservation scientist and has authored over 45 peer-reviewed scientific articles and book chapters on topics in wildlife ecology and conservation. He has expertise in Bayesian inference, machine learning, population ecology, and ecological modeling.

OVERVIEW

This report presents my review of the Adaptive Resource Management plan (ARM) proposed for use by the Atlantic States Marine Fisheries Commission (ASMFC) as a tool for guiding management of the horseshoe crab (HSC) fishery in Delaware Bay and protecting the Federally Threatened *Rufa* Red Knot (*Calidris canutus rufa*; REKN). Delaware Bay is a critical stopover site for REKN in their spring migration to breeding grounds in the high arctic from wintering grounds as far south as Tierra del Fuego (USFWS 2021). Specifically, HSC eggs deposited on coastal beaches provide a necessary high-calorie food resource for REKNs and other migrating shorebird species as they replenish fat reserves depleted from their long migration and prepare for breeding. At the heart of the proposed ARM framework is an optimization model that provides harvest recommendations for female and male HSC, conditional on current estimates of HSC and REKN abundance. These recommendations are calibrated to maximize HSC harvest while causing minimal risk to the REKN population. The optimization model is based on a linked two-species simulation model (comprising a HSC and a REKN simulation model) that incorporates a one-way biotic interaction in which annual REKN survival and recruitment depend on female HSC abundance in Delaware Bay (among other covariates). While the stated objectives of the revised ARM are sensible, my review identified several concerns that suggest the revised ARM framework is not an appropriate tool for managing risk to HSC or REKN populations. Specifically, this report identifies six main areas of concern:

(1) **The fitted relationship between HSC abundance and REKN vital rates (survival and fecundity) is of insufficient magnitude to forecast a decline in mean projected REKN population growth even under a total collapse of the HSC population**. The extremely weak REKN/HSC relationship used in the revised ARM is inconsistent with previous research documenting HSC eggs as a critical food resource for migrating REKN and with the documented decline of the REKN population over recent decades, which experts have linked to increases in HSC bait harvest during the 1990s (Niles et al. 2009; USFWS 2014). If the REKN population model is inconsistent with what has been observed in the recent past, it seems unlikely to yield robust forecasts of future risk to the REKN population (or recovery of this population) from which to base management decisions. The inclusion of a REKN population model within the ARM framework (both the initial and revised versions) presupposes that HSC harvest could put REKN populations at risk, at least under some scenarios. As it stands, the apparent inability of the revised ARM model to predict a decline of the REKN population even under a total collapse of the HSC population seems to violate this premise, and practically guarantees that the REKN population model will play an insignificant role in setting optimal HSC harvest rates.

(2) **The HSC population simulation model fails to correctly propagate uncertainty about mean recruitment rates**. In specifying the bivariate normal distribution used to generate

annual male and female HSC recruitment rates (the most consequential empirically fitted parameters of the HSC simulation model), the proposed ARM framework treats incertitude about annual recruitment rates as representative of temporal process variance (natural year-to-year fluctuations) rather than as a mixture of parameter uncertainty and process variance (Link and Nichols 1994; Regan et al. 2002; McGowan et al. 2011). This subtle but significant shortcoming will tend to manifest in simulation replicates that closely resemble one another, since key sources of uncertainty "regress to the mean" (good years cancel out bad years) instead of propagating over time. The importance of this distinction is magnified for long-lived iteroparous species like HSC, since these populations tend to be resilient to short-term fluctuations in reproduction or recruitment (Lovich et al. 2015). When this issue is corrected (using the same Bayesian approach used to treat process variation and uncertainty in the REKN simulation models in the revised ARM framework), preliminary simulation results suggest a highly uncertain outlook for the HSC population in Delaware Bay, especially when faced with harvest pressures. In sharp contrast to the ARM report and supplement, the population of HSCs in Delaware Bay appears to have a substantial (17.5%) probability of falling below the lowest previously estimated levels even in the absence of all direct anthropogenic sources of mortality (bait harvest, biomedical bleeding and discard mortality) over the next 50 years. Furthermore, a scenario in which HSCs are harvested annually at the current maximum allowable rates is accompanied by a severe risk of decline (33.45%) and disruption to the population age structure (lower multiparous/primiparous ratios than previously observed). Finally, an extreme harvest scenario in which two million male and female HSCs are harvested each year results in near-certain catastrophic population collapse over the 50-year time horizon, in contrast to the (original) ARM report, which suggests a relatively stable HSC population even under this extreme scenario (which greatly exceeds current maximum allowable rates).

(3) **The Catch Multiple Survey Analysis (CMSA) exhibits poor fit to training and independent data, raising concerns about its use in projecting future HSC abundance**. Aside from being able to explain the apparent difference in mean HSC abundance before and after the "VT gap years" (see below; higher HSC abundance is both predicted and observed after the

period 2013-2016), the CMSA model explains very little, if any, of the observed variation in the primary data sources (three trawl surveys conducted in and around Delaware Bay). The CMSA results exhibit relatively good fit ($R^2 > 0.5$) to the recruitment data (primiparous abundance); however, this is unsurprising since there is only one source of data (VT swept area surveys) for estimating annual primiparous abundance versus three sources for estimating adult (multiparous) and total abundance. Given the overall lack of fit to training data, the HSC simulation model is unlikely to perform well for predicting independent validation data (data not used to fit the model). Indeed, when the CMSA results are challenged against the HSC spawning surveys – an independent estimate of HSC abundance for this region – there is no detectable relationship between these two independent estimates of HSC abundance. This lack of fit to both training and validation data raises concerns about the utility of the CMSA model, which informs all aspects of the proposed ARM, including the REKN IPM (where it represents the abundance of female HSC each year), the HSC projection model, and the annual harvest recommendation.

(4) **The "gap years" in the VT trawl survey data raise concerns about HSC recruitment estimates from the Catch Multiple Survey Analysis (CMSA)**. As noted above, the CMSA is fundamental to all aspects of the proposed ARM framework. For the HSC population simulation models, the primary role of the CMSA is to parameterize HSC recruitment rates (which are the most consequential empirically derived inputs for the HSC simulation model). Unfortunately, of the three trawl surveys used to fit the CMSA models, the only survey that provides information for estimating recruitment – the Virginia Tech (VT) trawl surveys – was not conducted during a critical four-year period from 2013 to 2016 (hereafter referred to as the "VT gap", during which no direct information was available for estimating annual HSC recruitment rates). The CMSA results suggest that the HSC population underwent a substantial state transition during the VT gap years in which the population was small but stable prior to the gap, and larger and more variable after the gap. More concerningly, the CMSA predicts much higher average recruitment rates during the VT gap (for which no data are available for estimating recruitment) than at any single year before or after. The inflated average recruitment rates during the VT gap period are subsequently used for estimating

mean HSC recruitment rate for the HSC simulation models (thereby increasing estimated population resilience to harvest) – but unfortunately these high recruitment rates cannot be verified empirically. If average recruitment rates were computed from only those years in which recruitment could be verified empirically (i.e., excluding estimates from the VT gap years) the expected resilience of the HSC population to harvest would be substantially reduced.

(5) **The proposed ARM framework lacks 'null model' benchmarks and independent performance validation**. Null models are simplified representations of a system that lack many or all the proposed mechanisms that may help to explain the system dynamics; the typical null model in statistics assumes all observed variation is the result of a single random error process. By comparing complex models such as those used in the revised ARM with one or more null-model benchmark(s), researchers can determine whether the more complex models represent useful learned knowledge about a system (Koons et al. 2022). If a complex model fails to outperform a null model in terms of bias or precision (typically using independent validation data), the complex model is likely to be improperly specified or "overfitted" (whereby parameters are fitted to "noise" rather than true signal; Radosavljevic and Anderson 2014) and therefore not useful for prediction. The CMSA model fails to outperform even the simplest statistical null model (single intercept term with sampling error) for at least one data source (the VT swept-area estimate of female multiparous abundance). For the REKN component of the revised ARM, it would be informative to compare the performance of the REKN simulation model against a null model that omits any effect of female HSC abundance. It was recently demonstrated (Koons et al. 2022) that the ARM framework for guiding North American mallard harvest was unable to outperform a null model, and it would be instructive to pose a similar challenge to the REKN simulation model. If either model fails to outperform a null model, it should prompt managers to acknowledge that our current understanding of the effects of harvest on HSC populations remains insufficient for robust forecasting (Dietze 2017), and that a more precautionary approach may be warranted.

(6) **Lack of transparency**. The public still has no access to the data and code used for estimating

REKN population parameters, simulating REKN and HSC population dynamics, and running optimization routines (the CMSA code and data were made available). Without this data and code, it is difficult to fully assess the proposed ARM framework and to run scenario tests. If granted access to the code and data, there are a number of important null model tests (see above) and scenario tests that can be run, including (1) developing and testing the HSC and REKN models against a "null model" benchmark, (2) determining the 'optimal' female HSC harvest rates from the "canonical" versions of the HSC and REKN models in the absence of defined harvest limits, and (3) running the REKN simulation model under a scenario representing near-total collapse of the HSC population. The concerns identified above, which arise from analysis of the limited data and code made available to date, demonstrate, at a minimum, that such further testing is warranted. It seems prudent to delay implementation of the new ARM framework until the public and outside experts have had adequate time to scrutinize the statistical and simulation models that play such a central role in this proposed decision-making framework.

SUPPORTING EVIDENCE AND ANALYSES

The remainder of this report provides additional supporting details for the six major areas of concern identified above, including results and figures from re-analyses of the data presented in the ARM report.

1. The fitted relationship between HSC abundance and REKN vital rates (survival and fecundity) is of insufficient magnitude to forecast a decline in mean projected REKN population growth even under a total collapse of the HSC population

Including a model of REKN population dynamics as part of the previous and revised versions of the ARM framework implicitly acknowledges that reduction of the HSC population could, under some circumstances, have a negative impact on REKN populations. This assumption has a strong empirical basis, as multiple lines of evidence suggest that HSC eggs are an extremely important resource for migrating REKNs during their spring migration (e.g., Karpanty et al. 2006; Niles et al. 2009; USFWS 2014; USFWS 2021). Therefore, it is surprising that the fitted relationship between HSC abundance and REKN survival used in the revised ARM is very weak and appears to be overwhelmed by random among-year variation (Fig. 47 from ARM Report; Fig. 9 from Supplemental Report; hereafter, I will use the notation 'ARM Fig. 47/9'). In fact, it appears from the ARM report that estimated REKN survival rates have generally decreased weakly over time despite an estimated increase in HSC abundance (ARM Fig. 44/7). Years with the lowest HSC abundance in the study period (at or near the lowest HSC abundances ever recorded in Delaware Bay) are coincident with the highest estimated REKN survival rates (ARM Fig. 47/9). Given this weak fitted relationship, simulated REKN abundance based on this model seems unlikely to be very sensitive to changes in HSC abundance. Indeed, a 'back of the envelope' calculation based on the REKN vital rates presented in the ARM report (and the slightly modified numbers presented in the Supplement) shows that the mean population growth rate (Lambda) of the REKN population is likely to remain at or above replacement levels (Lambda ≥ 1) even at HSC population size equal to zero (Fig. 1). This calculation was produced by using the mean survival from Supplemental Table 8, mean recruitment estimated from Supplemental Fig. 7b, and the standardized logistic regression coefficients from Supplemental Table 9 (effect size = 0.37 for survival and -0.14 for recruitment) to model REKN survival and recruitment as a function of HSC abundance. As a brief aside, the regression coefficients presented in the ARM report (e.g., effect of HSC on survival) are standardized and are on the logit (log-odds) scale, making them difficult to interpret. A quick example may help to aid interpretation of the effect size of this relationship: given a coefficient of 0.37 (the mean regression coefficient for the relationship between HSC abundance and REKN survival from the ARM Supplement, Table 8), a loss of 1 million female horseshoe crabs from Delaware Bay would result in REKN survival rate declining by only 0.004 (from 0.93 to 0.926). This is consistent with visual inspection of ARM Fig. 47/9.

Although I did not have access to the code and data used to fit the relationships between HSC abundance and REKN survival and recruitment, the relationships I used to generate Fig. 1 closely match the relationships presented in ARM Fig. 46/8 (Fig. 2). Interestingly, the value for mean recruitment provided in Supplemental Table 8 (ρ_{mean} = 0.063) yields a declining REKN population (Lambda = 0.99) even under average conditions from 2005 to 2017. Since this result is inconsistent with the reported Lambda of 1.04 during that same period from ARM Table 25 (and the generally increasing population trajectories indicated in ARM Fig. 58/15), I chose to use the mean annual recruitment estimated from Supplemental Fig. 7b, which I calculated to be 0.109 (or geometric mean of 0.099). Using these mean recruitment values resulted in a Lambda of 1.035 (for arithmetic mean) or 1.027 (for geometric mean), more closely resembling but still below the reported baseline Lambda of 1.04 from the ARM report; setting baseline Lambda to 1.04 would only make a stronger case that REKN populations would not be expected to decline under an HSC population collapse (Fig. 1). This simulation exercise makes it very clear that the REKN model used in the revised ARM would not be able to predict or explain the decline in the REKN population observed during the 1990s, which has been attributed to unregulated harvest of HSCs in Delaware Bay (Niles et al. 2009; USFWS 2014). If this framework is unable to explain the decline of the REKN population in the first place, it does not appear to be an appropriate tool for helping to reverse the decline and promoting the recovery of this threatened subspecies.

Note that the population vital rates used to generate Fig. 1 represent point estimates. Because there was uncertainty associated with the estimate of Lambda (CI from 1.00 to 1.06; ARM Table 25), and with the effect size of HSC abundance on survival rate (CI from 0.12 to 0.63; ARM supplemental Table 9), some simulation runs (i.e., those with small Lambda and larger effect size sampled randomly from the joint posterior distribution) are likely to indicate REKN population decline at low HSC abundances. It is likely that these (probably rare) simulations drive the shape of the REKN "harvest function" yielded by the approximate dynamic programming algorithm. However, without access to the IPM and simulation code, I am not able to formally test the behavior of the REKN simulation model under scenarios of HSC population decline or collapse.

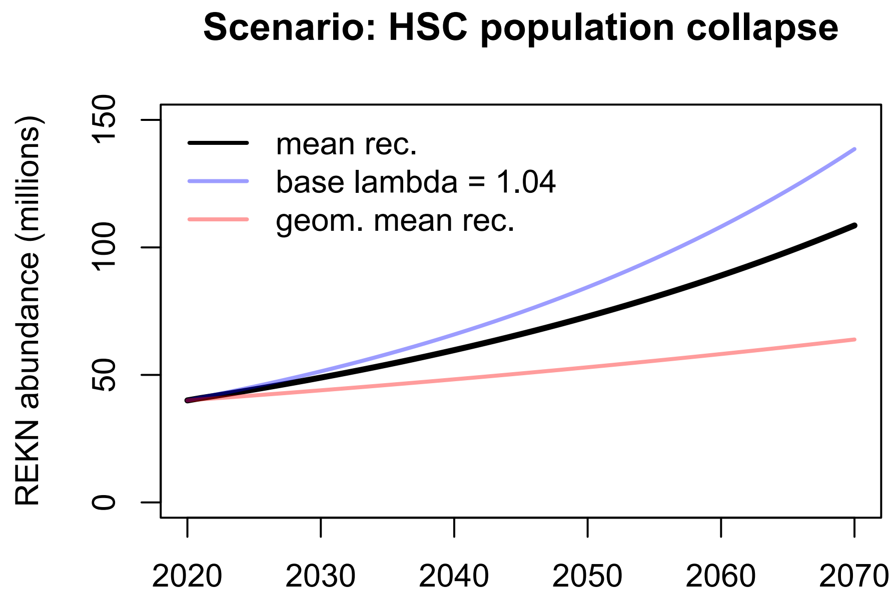

Figure 1. *Results from a 'back of the envelope' calculation of REKN population growth under a scenario with depleted HSC population (female HSC abundance = 0 based on numbers presented in the ARM report. Mean recruitment rate was computed in three ways: arithmetic mean of values from ARM Supplemental Fig. 7b ("mean rec"), the geometric mean of these same values ("geom. mean rec."), and a value fitted to ensure a population growth rate (Lambda) of 1.04, as indicated in the ARM report. Although somewhat simplistic, this figure illustrates that the reduction in REKN survival due to the collapse of HSCs in Delaware Bay appears to be insufficient to induce a meaningful REKN population decline. This figure is based on a simple age-structured population model and does not incorporate a density-dependence mechanism (the revised ARM includes a density ceiling that prevents the REKN population from growing above ~150k).*

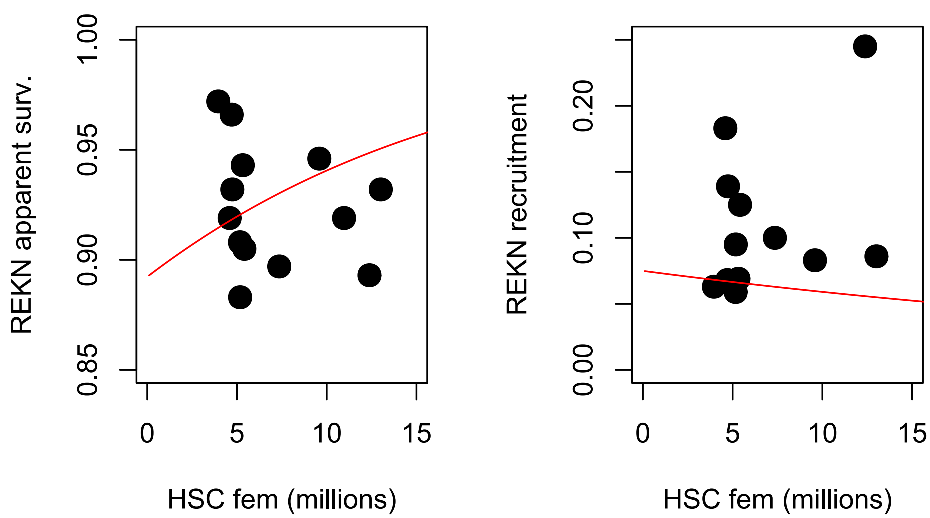

Figure 2. *Relationships between female HSC abundance and REKN survival (left panel) and recruitment (right panel), recreated from information in the ARM supplemental report for the purpose of calculating the expected REKN population response to changes in the HSC population. Solid black dots represent annual vital rates estimated from ARM Supplement Fig. 9, and the red lines represent the fitted relationships presented in ARM Supplement Table 9.*

Due to the weakness of the HSC/REKN relationship used in the revised ARM, and due to the complexity of the Integrated Population Model (IPM) framework used to represent the REKN population in the revised ARM, the relationship between HSC abundance and REKN population vital rates are likely to be unstable (sensitive to new data and alternative model specifications). Therefore, it is not implausible that the fitted relationship may disappear (become "non-significant") – or even flip sign to become a negative relationship – when the IPM is fitted to additional observations. This outcome would pose an existential problem for the ARM framework, decoupling the two-species framework and rendering the REKN model unusable in the context of management. There does not appear to be a contingency plan for this outcome. More generally, the REKN IPM appears to have gone through several distinct versions before researchers settled on a final set of decisions to incorporate into the final model (there are several important differences between an earlier version of the IPM presented in Tucker [2019] and the ARM report). Ideally, the results from alternative representations of the REKN system should be considered in aggregate to better represent structural uncertainty about this system (Williams 2011).

The linked two-species modeling framework in the revised ARM assumes the relationship between REKN and HSC is independent of REKN densities (i.e., it assumes a prey-dependent functional response). Under this assumption, larger REKN populations do not require larger abundances of HSC females (i.e., more HSC eggs deposited) to support adequate per-capita weight gain; in other words, the ARM model assumes that a REKN population of 40k would experience the same per-capita survival and fecundity as a population of 400k for a given abundance of female HSC. Implicitly, this assumes a lack of interference among REKN individuals, and no decline in the mean quality or accessibility of HSC egg resources at elevated REKN abundances (Karpanty et al. 2011). Some researchers have argued convincingly that a ratio-dependent functional response – in which per-capita prey consumption depends on the ratio between prey and predator abundances – is likely to be more realistic for simulation models with discrete time steps that span the entire reproductive periods of predator and prey (Abrams and Ginzburg 2000), such as the linked two-species model used in the revised ARM.

The previous ARM framework used data gathered from multiple sources of data outside

Delaware Bay to parameterize the simulation models. The revised ARM attempts to use Delaware Bay data sources wherever possible – which is a significant advance in many ways, as the revised ARM is “fine-tuned” for the system and can be updated relatively easily as new data are collected. However, this modeling decision also limits the analyses to a small geographic area over a short period of time, potentially ignoring relevant evidence from other regions and/or time periods. Furthermore, the time frame over which data are available for fitting the population models used in the revised ARM represents a limited scope of historical variation during which populations of REKN and HSC were relatively small in comparison with earlier estimates. Using these models to forecast system dynamics under conditions outside the range of values used to fit the model (e.g., lower HSC abundances, higher REKN abundances) therefore requires extrapolation, which can be highly uncertain (and often inaccurate). Since both the HSC and REKN simulation models tend to produce forecasts that differ from current conditions (e.g., larger numbers of both species), and because the optimization routine relies on these simulated results, the management recommendations emerging from the revised ARM rely on highly uncertain extrapolations about HSC and REKN population dynamics and about how these two species may interact (analogous to extrapolations of species and community distributions under climate change; Araujo and Rahbek 2009). On one hand, the ARM framework is designed to be able to refine management policies as new data become available and as sources of uncertainty are reduced (Nichols et al. 2007). On the other hand, it does not seem prudent to implement management “experiments” that could potentially imperil a threatened or endangered species (TES), even under the rubric of adaptive management.

In summary, the relationship between HSC abundance and REKN survival appears to be too weak to induce a decline in REKN abundance (Fig. 1). If all HSCs in Delaware Bay disappeared today, the model would continue to predict a generally stable or increasing population of REKN over the next 50 years. Therefore, the revised ARM model would be unable to predict the decline of REKNs that was observed in recent decades, and which has been attributed in part to the decline in the HSC population (Niles et al. 2009; USFWS 2014). This lack of consistency between the revised ARM model and recent historical observations raises significant doubts about the ability of this model to accurately reflect future risks to the REKN population or to guide HSC harvest decisions in a way that promotes REKN survival and recovery. Furthermore, the decision to include a REKN population model as part of the ARM framework (in both the original and revised versions) presupposes that HSC harvest could result in risk to the REKN population; the apparent inability of the ARM model to predict a decline in REKN abundance under a total HSC population collapse violates this premise and undermines the apparent purpose of the model.

2. The HSC population simulation model fails to propagate uncertainty about mean recruitment rates

The HSC recruitment process is the most consequential empirically fitted component of the HSC simulation model. Other elements of the HSC simulation model are not fitted to data – for example, natural mortality rate, the biomedical mortality rate, and bait harvest rates are fixed by the modelers. In the revised ARM, the recruitment process is fitted to data indirectly via the CMSA model; annual male and female recruitment estimates were used to fit a bivariate log-normal distribution (defined by a mean and standard deviation for each sex, along with a covariance between sexes – all on a logarithmic scale), which was then used to represent annual recruitment in the simulation model. The only other parameter fitted in the CMSA model – initial abundance – is not directly used in the simulation model. Recruitment is critical for any assessment of population resilience to harvest, since (in the absence of immigration, which is not included in the revised ARM), it is the only process that enables the population to overcome sources of mortality. Therefore, it is not surprising that the HSC simulation model is highly sensitive to changes in mean (log) fecundity (ARM Fig. 33; note that when I omit any reference to the supplemental report, I am referring to the primary ARM report). Given the high sensitivity of the HSC simulation model to the (log) mean HSC recruitment for males and females, it is critical that uncertainty about these parameters is properly represented in simulation models. However, the revised ARM framework incorrectly treats incertitude about annual recruitment rates as representative of temporal process variance (natural year-to-year fluctuations) rather than as a mixture of parameter uncertainty and process variance (Link and Nichols 1994; Regan et al. 2002; McGowan et al. 2011). This is a subtle but consequential error, as sources of uncertainty will tend to "regress to the mean" (with good years cancelling bad years) instead of propagating over time.

To estimate the parameters for the log-normal recruitment process in the revised ARM, the following steps were taken: (1) log-normal distributions were separately fitted to each estimate of primiparous abundance (separately for each year and sex), based on estimates of parameter uncertainty (95% confidence intervals) derived from the CMSA results, (2) this collection of lognormal distributions (representing parameter uncertainty) was used to simulate annual male and female primiparous abundance for the years represented in the CMSA model (confusing parameter uncertainty with temporal process variation), and then (3) data from these simulations were used to fit a bivariate lognormal distribution (via maximum likelihood) for representing annual HSC recruitment in the ARM model. In general, parameter uncertainty should be represented in simulation models by drawing a single sample per replicate from a distribution of values representing parameter uncertainty (or by running replicates with "worst-case" and "best case" values for key parameters). However, the "canonical" version of the HSC projection model fails to address parameter uncertainty – most notably, uncertainty about the mean HSC recruitment rate, to which the HSC projection model is highly sensitive (ARM Fig. 33). Therefore, there is more uncertainty about the future of the HSC population in Delaware Bay than the revised ARM acknowledges. It is important to note that a sensitivity analysis was run in which expected recruitment was allowed to vary across simulation replicates within ca. 5% or 10% of the median recruitment value. This sensitivity test demonstrates an appropriate method for modeling parameter uncertainty; however, this test fails to represent the extent of uncertainty about the median HSC recruitment, which extends far beyond 10% of the mean estimated value (Fig. 3). Furthermore, this treatment of uncertainty was only run as a scenario test and was omitted from the 'canonical' version of the ARM that is proposed for use in managing the HSC harvest in Delaware Bay.

Interestingly, the REKN projection model in the revised ARM appears to represent parameter uncertainty appropriately. The key parameters of the REKN model were estimated using an Integrated Population Model (IPM), which were fitted in a Bayesian framework. In this framework, parameter uncertainty is represented by a joint posterior distribution that embodies the set of values that are consistent with the observed data. Furthermore, temporal process variation in the REKN population model is treated by explicitly modeling annual variability in key vital rates (survival and recruitment) via annual random effects fitted with hyperparameters (Kery and Schaub 2011). This Bayesian hierarchical approach enables parameter uncertainty and process variation to be interpreted and modeled separately in a straightforward and intuitive manner. Specifically, parameter uncertainty is incorporated by running multiple replicates with different values drawn from the joint posterior distribution, and temporal process variation is included by sampling from the hyperparameters across years within each replicate (Goodman 2002).

To enable sensible propagation of parameter uncertainty in the HSC simulation model (analogous to the REKN model in the ARM), I constructed and fitted a hierarchical Bayesian version of the CMSA model. This model was fitted using the same data and model structure as the CMSA model included in the revised ARM. However, instead of estimating annual recruitment separately for each year and sex, the Bayesian CMSA model included an explicit representation of temporal process variance in recruitment (i.e., a "random effect" describing inter-annual variation in recruitment). This temporal process model was specified using a bivariate lognormal distribution exactly analogous to the HSC simulation model included in the ARM model, which included "hyperparameters" for male and female (log) mean recruitment, male and female (log) standard deviation, and a correlation term. By estimating temporal process variation directly, the Bayesian CMSA closely mirrors the HSC simulation model (analogous to the direct relationship between the IPM and the REKN simulation model), circumventing the multi-step process used in the ARM to generate the bivariate lognormal distribution from the CMSA results, and (most importantly) enabling the parameters of the bivariate lognormal distribution to be estimated directly from the data. To simulate HSC abundance over time, parameters for each replicate were drawn from the joint posterior distribution (representing parameter uncertainty), and temporal process variation within each replicate was simulated by sampling from the bivariate lognormal distribution. For the simulations, I incorporated the same restrictions in the stock-recruitment relationships indicated in the ARM report (driven by abundance and sex ratios for the years in which recruits were expected to have hatched).

Results from the Bayesian CMSA model indicate substantial uncertainty around mean HSC recruitment rates for both males and females (Fig. 3). Simulations (50 year time horizon) from this model in the absence of any direct anthropogenic sources of mortality (no bait harvest, biomedical mortality or discard mortality) indicate that the future of the HSC population in Delaware Bay is uncertain; the population has a 17.4% chance of declining below 4 million females (combined multiparous and primiparous abundance) at least once in the next 50 years, equivalent to the lowest abundances estimated from 2003 – 2019 (period for which the CMSA model was fitted) (Fig. 4). This no-harvest scenario also had a 3.8% probability of falling below 3 million females over the 50-year simulation, well below any estimate from the VT swept area surveys. In contrast, the HSC projection model in the revised ARM indicates a large and sustainable HSC population under a scenario with no bait harvest but including other anthropogenic sources of mortality including biomedical harvest and discard mortality (ARM Fig. 30; note that this figure does not reflect changes in mean HSC recruitment following peer review—the Supplement does not update this figure but contains other figures indicating a sustainable HSC abundance even with a bait harvest; Supplemental Fig. 15). Simulations from the Bayesian CMSA also indicate a much higher probability of decline under a scenario in which males and females are harvested at their respective maximum allowable rates (but are not subject to biomedical and discard mortality); this scenario had a 33% probability of declining below 4 million females over the next 50 years, 11% probability of declining below 3 million females, and a 2% probability of declining below 2 million females (Fig. 4). This scenario also appeared to disrupt the age structure in many simulations, resulting in fewer multiparous adults than primiparous adults. In contrast, the HSC simulation model in the revised ARM suggests a stable or increasing HSC population even under maximum allowable harvest scenarios that also include biomedical and discard mortality (ARM Fig. 31; see above caveat). Finally, a scenario in which both female and male HSCs were harvested at a rate of 2 million per year (much higher than the current maximum rate) results in a high probability of decline or even extirpation over the 50-year simulation; there was a >99% probability of declining to below 3 million females, a 92% probability of declining below 1 million females, and a 12% chance of falling below 10k females (Fig. 4). In contrast, the HSC simulation model in the revised ARM predicted a relatively sustainable population of HSC even under this extreme scenario, with no risk of population collapse (ARM Fig. 32; note that the HSC simulation model in the supplemental report may not sustain this level of harvest due to the reduced mean recruitment rate relative to the model used to generate ARM Fig. 32).

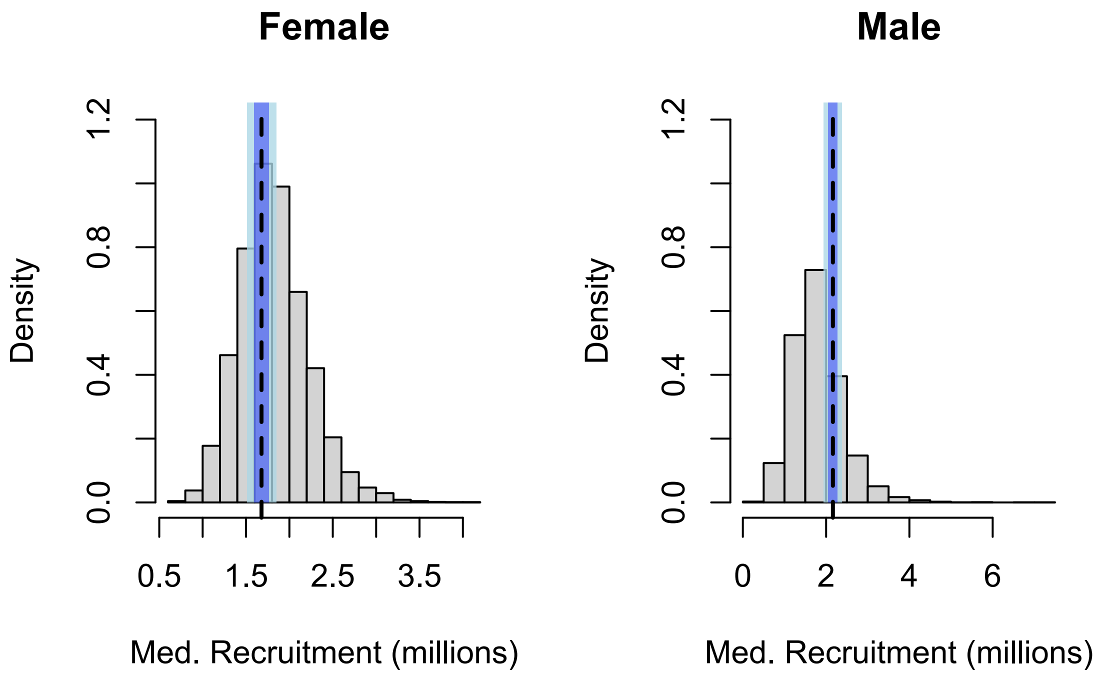

***Figure 3**. Posterior distributions representing parameter uncertainty for median female and male HSC recruitment rates, fitted using a Bayesian reanalysis of the CMSA model from the revised ARM (same data and model structure used to fit the CMSA model). Vertical dashed lines denote the median HSC recruitment values used in the base HSC projection model in the revised ARM. Light and darker blue shaded polygons represent the "added variation in expected recruitment" sensitivity tests from the ARM report (e.g., Fig. 69, 70). Note that the true range of parameter uncertainty falls well beyond the bounds of these sensitivity tests.*

This critique is focused primarily on uncertainty about the annual HSC recruitment (primiparous abundance) parameters since they represent the ultimate source of projected resilience (or non-resilience) to harvest pressures and are therefore the most consequential fitted parameters in the CMSA simulation model. However, there are several other sources of uncertainty that should be accounted for in the HSC simulations. For example, natural mortality of HSC is set at exactly 0.3 (30%) across all sexes and age classes (primiparous and multiparous) in the revised ARM model, whereas there is substantial uncertainty about this parameter. The value of 0.3 was based on tag recovery data (assuming negligible harvest), but other lines of evidence seem to suggest natural mortality may be closer to 20% or even lower (as noted in the ARM report). Lower estimates of mortality (higher survival and greater longevity) could imply lower resilience to harvest of adults (Midwood et al. 2015). Interestingly, natural mortality is an estimable parameter in the CMSA model; when modeled as a free parameter in the Bayesian CMSA, the model suggests that natural mortality is lower than 30%, but higher for females than males (note that Figs 3 and 4 are based on a model with natural mortality set at 30%, to match the ARM models). Other sources of uncertainty in the HSC population model include discard mortality (where 5% mortality was assumed for trawl and dredge surveys, while 12% mortality applied for gill nets) and biomedical mortality (assumed to be 15%). Although the ARM report documents a limited set of sensitivity analyses that were designed to test the degree to which key results changed under alternative parameter values (including mortality; ARM Table 18, 19), the relatively small set of sensitivity tests does not appear to comprehensively address these sources of uncertainty and seem inadequate for characterizing uncertainty about this system. Furthermore, uncertainty about these processes is not propagated through the HSC projection models.

In summary, if sources of error in the recruitment process are properly accounted for, the outlook for the HSC population in Delaware Bay is uncertain even in the absence of any harvest pressures. Based on a reanalysis of the existing data (using the same model specification used in the CMSA and HSC projection model), I found that harvest at the current maximum allowable rates has a high risk (11%) of causing the female HSC population to decline below the lowest levels ever recorded (3 million females). The HSC population models presented in the ARM report and supplement are not useful because they mis-characterize the risk of harvest pressures to the HSC population in Delaware Bay.

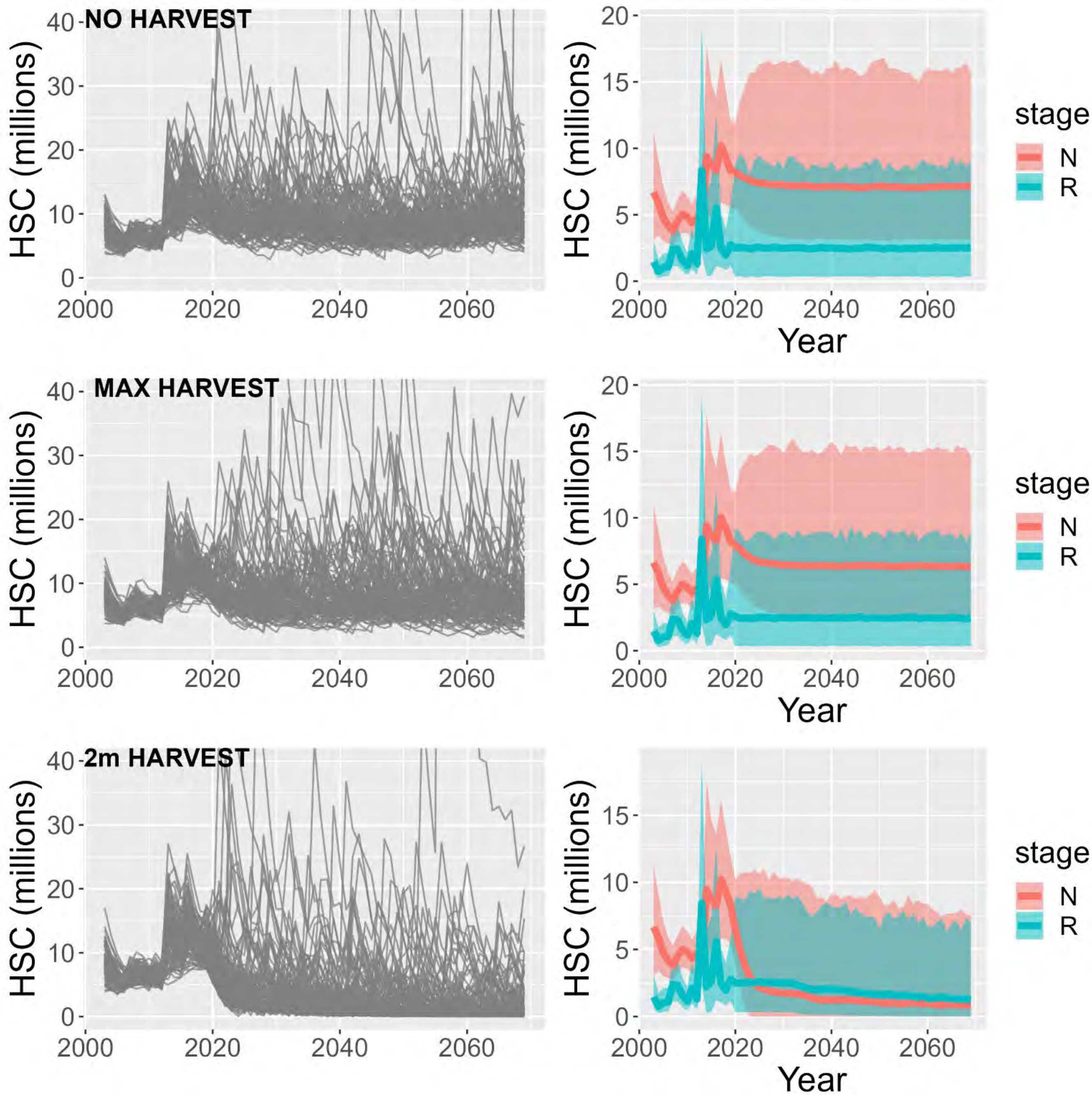

Figure 4. *Female HSC population simulations run using fitted parameters (joint posterior distribution) from a Bayesian CMSA model, with uncertainty propagation performed in a manner analogous to the REKN projection model. The top row depicts simulations run under a no exploitation scenario (no bait harvest nor biomedical/discard mortality), the middle row depicts maximum allowable harvest rates (but also without biomedical and discard mortality), and the bottom row depicts an extreme harvest scenario (2 million females, 2 million males harvested annually). The left-hand panels depict trajectories of total abundance (primiparous and multiparous) for individual simulation replicates. Right-hand panels depict the 95% credible intervals for primiparous abundance (R) and multiparous abundance (N). None of these scenarios include biomedical or discard mortality.*

3. The Catch Multiple Survey Analysis (CMSA) appears to exhibit poor fit to both training and independent data, raising concerns about its use in projecting future HSC abundance

The CMSA model explains little (and, in at least one case, none) of the variation in the data sources used to train this model (comprising three different trawl surveys conducted in and around Delaware Bay; here I present results for the female CMSA only) (Fig. 5). Notably, the CMSA performs worse than a statistical null model (all variation is assumed to be random "noise") for predicting the multiparous female abundance estimated from the VT trawl surveys, with R^2 of -0.42 for the full time series (negative R-squared value indicates the CMSA model performs worse than the null model). In contrast, the CMSA results appear to exhibit relatively good fit ($R^2 > 0.5$) to the recruitment data (primiparous abundance) from the VT trawl surveys (Fig. 5; ARM Fig. 21). However, this is not a fair test; with only one source of data for estimating annual primiparous abundance (the VT trawl surveys) – and with a separate recruitment parameter fitted for each year – the CMSA recruitment results are practically guaranteed to resemble the observed recruitment data.

For the remainder of the datasets used to train the CMSA (DE and NJ trawls), it is instructive to note that the majority of the observed variance 'explained' can be attributed to the apparent difference in mean HSC abundance before and after the period 2013-2016 (during which the Virginia Tech trawl surveys were not conducted and therefore no estimates of recruitment were available; hereafter, "VT gap", see below). Indeed, for the DE surveys the R-squared value drops to negative values for the periods before (R^2 = -0.07) and after (R^2 = -0.03) the VT gap period (versus R^2 = 0.14 for the full time series). Similarly, for the NJ trawl survey, the R-squared value drops to 0.11 for the period before the gap and falls below zero for the period after the VT gap (R^2 = -0.05; compared to R^2 = 0.57 for the full time series). More concerningly, the CMSA can "explain" the apparent increase in the HSC population after the VT gap period only by estimating extremely high recruitment during the VT gap period (during which no recruitment information was available; see below for more details). Because no data were available for fitting recruitment (primiparous abundance) during the VT gap, the CMSA model was free to "fill in" whatever recruitment estimates produced the best match to available data (DE and NJ surveys were the only available data sources during this period)—even if these recruitment estimates were unrealistically high or low (with no data available for comparison, there was no penalty for producing unrealistic estimates). If the CMSA is only able to fit the training data via unrealistic estimates of recruitment (see below), this strongly suggests a poorly specified model and raises serious doubts about using the CMSA results to represent and forecast the HSC population in Delaware Bay.

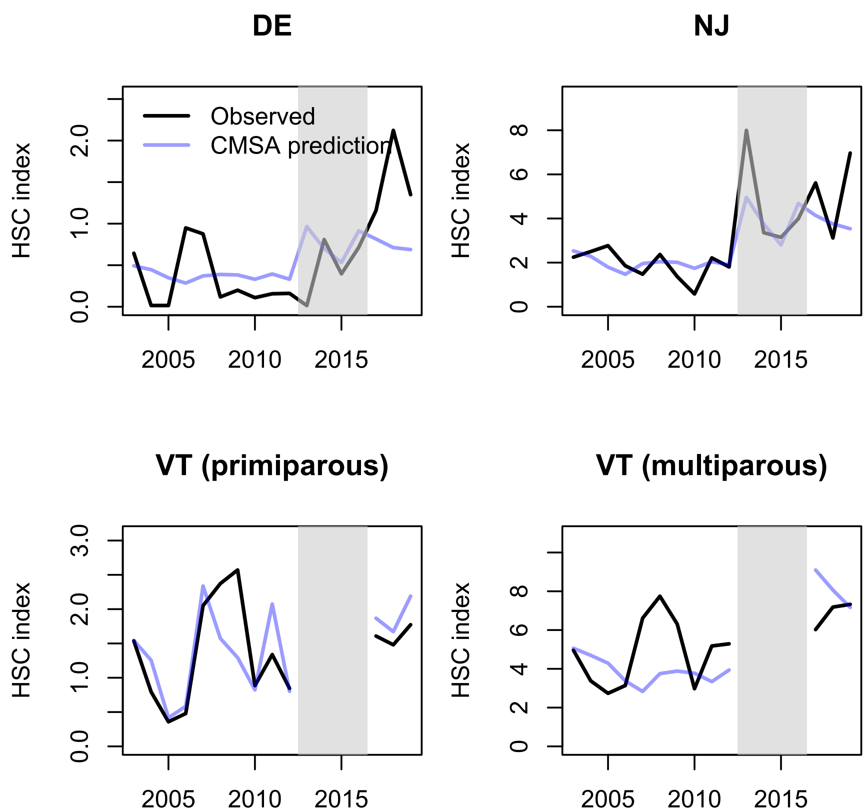

***Figure 5**. Illustration of the fit of the CMSA model to data on female HSC abundance derived from three trawl surveys: DE, NJ, and VT (the same sources of data that were used to fit the CMSA model). This figure presents the same information as ARM Fig. 21/4. The CMSA model performs well in predicting primiparous abundance (bottom left) but exhibits poorer performance for predicting adult (multiparous) abundance (bottom right) or total abundance (top row). The CMSA predicts little to no variation in adult/total abundance besides the difference in apparent mean abundance before and after the "VT gap years" (gray regions).*

Given the lack of fit to training data, the HSC simulation model is unlikely to perform well when predicting to independent validation data (data not used to fit the model). Indeed, when the CMSA results are challenged against the Delaware Bay HSC Spawning Surveys (e.g., Zimmerman et al. 2020; https://www.delawarebayhscsurvey.org/), which provides an independent estimate of relative HSC abundance for this region, there is no detectable relationship between these two independent estimates of HSC abundance (Fig. 6). This lack of fit to both training and validation data raises doubt about the utility of the CMSA results, which are central to all aspects of the proposed ARM, from fitting the HSC/REKN relationship to forecasting HSC abundance, to guiding annual decisions about HSC bait harvest.

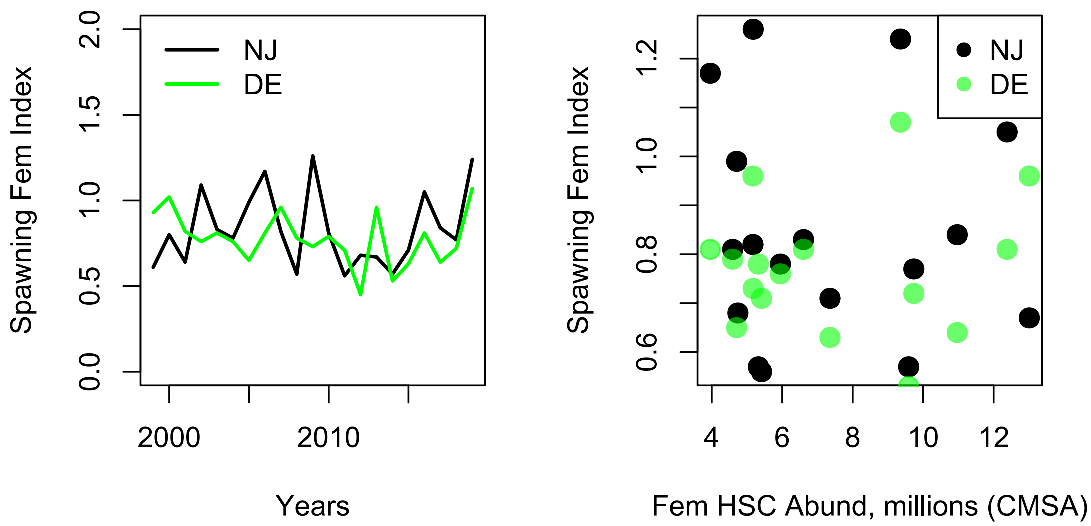

***Figure 6**. Comparisons of standardized HSC spawning female counts from DE and NJ beaches (an index of relative female HSC abundance analogous to trawl surveys) with (left) each other and (right) with the CMSA estimates of female HSC abundance in Delaware Bay (in millions). The two spawning surveys exhibit very little correlation between the NJ and DE sides of Delaware Bay from 1999 to 2018 (left panel; correlation = 0.25). In addition, there is no detectable relationship between spawning counts (on either the NJ or DE sides) and CMSA estimates of female HSC abundance (right panel).*

In summary, the CMSA model does not perform well when predicting to the training data (the three sources of data used to fit the model). Although the model can explain some of the apparent difference in mean HSC abundance before and after the 'VT gap years', this 'ability' is driven by inflated recruitment rate estimates during the VT gap years that cannot be verified empirically (see below). Furthermore, the CMSA model explains virtually none of the observed variation in HSC spawning abundance from the same period, which represents an independent index of HSC population size. The poor performance of the CMSA model in predicting observed variations in HSC abundance in Delaware Bay calls into question the utility of this model – which is central to all aspects of the ARM model – as a robust system for characterizing and predicting the HSC population in Delaware Bay.

4. The "gap years" in the VT trawl survey data raise concerns about HSC recruitment estimates from the Catch Multiple Survey Analysis (CMSA)

As noted previously, the CMSA is fundamental to the proposed ARM framework. For the HSC population simulation models, the primary role of the CMSA is to parameterize HSC recruitment rates (which are the most consequential empirically derived inputs for the HSC simulation model). Unfortunately, of the three trawl surveys used to fit the CMSA models, the only survey that provides information for estimating recruitment – the Virginia Tech (VT) trawl surveys – was not conducted during a critical four-year period from 2013 to 2016 (referred to in this report as the "VT gap", during which no direct information was available for estimating annual HSC recruitment; note that the missing survey years were actually 2012-2015, but the VT results were lagged forward within the CMSA to ensure comparability with the DE and VT trawls). The lack of information on primiparous abundance during the VT gap years leads to several nonsensical results in the CMSA model. For example, in one year (2013; the first VT gap year) the estimated number of new female recruits is near 10 million – approximately 8 times larger than the average estimated recruitment rate from the 10-year period from 2003 to 2012 and 4 times larger than the maximum estimate during this 10-year time frame (ARM Supplemental Table 3). The following year (2014), the point estimate for primiparous abundance goes down to 2, i.e., 2 primiparous female individuals across Delaware Bay. Furthermore, the standard error estimates for primiparous abundance during the VT gap years are very large – in fact, the upper bound on the confidence intervals approaches infinity for one year (2014).

The CMSA results suggest that the HSC population underwent a substantial state transition during the VT gap years in which the population was small but stable prior to the gap, and larger and more variable after the gap. In the fitted CMSA model, this state transition appears to be driven by extremely high recruitment rates during the VT gap years. Concerningly, the CMSA model (including the Bayesian version of the CMSA model described above) predicts much higher mean annual recruitment rates during the VT gap (for which no data are available for estimating recruitment) than at any single year before or after (Fig. 7). Specifically, mean annual recruitment during the VT gap years was estimated at 4.2 million (using the arithmetic mean, per the ARM report), versus 1.2 million before the gap and 1.9 million after the gap (using the geometric mean to represent the median of a lognormally distributed sample, per the ARM report). The inflated mean recruitment rates during the VT gap period are subsequently used for estimating the average HSC recruitment rate for the HSC simulation models (thereby increasing estimated population resilience to harvest) – but unfortunately these high recruitment rates cannot be verified empirically.

In summary, the CMSA model estimates abnormally high annual recruitment rates during the VT gap years (Fig. 7). These very high estimates are unverifiable, as no data on HSC recruitment was collected during these years. In the original ARM report, the average annual recruitment used in the HSC simulation model relied heavily on the inflated estimates of recruitment during the VT gap years, discounting the pre-gap years entirely. After peer-review, the ARM was altered to consider all years instead of discarding lower estimates from the pre-gap years. Nonetheless, the revised ARM model continues to treat the mean recruitment rate during the VT gap as reliable, allowing these inflated estimates to contribute to the estimate of average annual HSC recruitment used for the HSC simulation models (which are highly sensitive to the estimate of average recruitment; ARM Fig. 33). If the extremely high recruitment estimates during the VT gap years were to be excluded from this estimation process out of precaution, the average annual HSC recruitment rate would drop substantially (Fig. 7), further reducing the expected resilience of this population to harvest pressures. Ultimately, the inflated estimates of recruitment during the VT gap years are likely to be an artifact of the CMSA model specification (and the lack of data on recruitment for those years) and are unlikely to be reflective of true HSC recruitment rates. However, there remains no way to verify HSC recruitment rates during this period. Given this uncertainty, a conservative (precautionary) approach would be to exclude the VT gap years when computing recruitment for the HSC population simulations (Fig. 7).

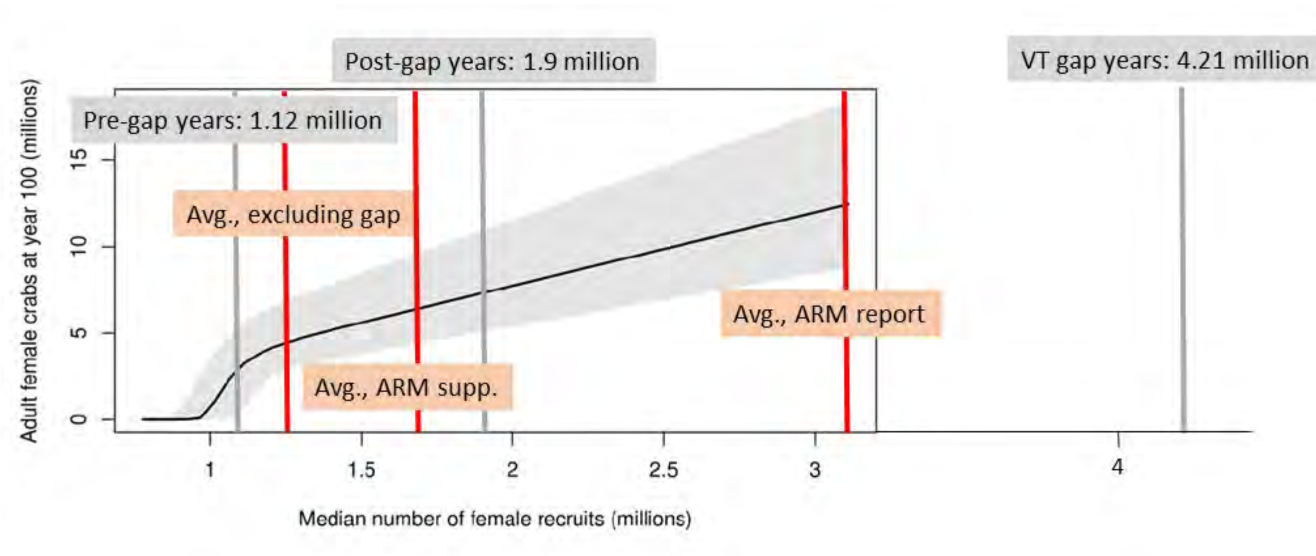

Figure 7. *Annotated version of ARM Fig. 33, which (in its original form) illustrates the sensitivity of HSC simulation results to changes in average HSC recruitment rates. Annotations reflect the average female recruitment before, after and during the VT gap years (in gray), the average recruitment value used in the original 2021 ARM report (red, far right), the value used in the supplemental report produced after peer-review (red, middle) and the analogous estimate computed by excluding the VT gap years (red, left). Average recruitment estimated for the VT gap years (arithmetic mean of 4.21 million based on the latest CMSA results) falls well outside the range of estimates during years for which recruitment was an observable process (and well outside the range of the x-axis of the original figure). The ARM report ignored recruitment estimates from the pre-gap years, giving very high weight to the inflated estimates during the VT gap years. Based on the peer-review, which suggested that the pre-gap years should not be excluded from the estimation of average recruitment rates, the current proposed value (described in the ARM supplement) is much lower than the value used in the ARM report (1.67 million vs. 3.1 million). However, the new proposed value continues to include unverifiable estimates from the VT gap years. If the VT estimates were excluded out of precaution, the average annual HSC recruitment would drop to 1.26 million, perilously close to the sustainability threshold identified in this figure (i.e., ARM Fig. 33).*

5. The proposed ARM framework lacks 'null model' benchmarks and independent performance validation

Null models are simplified representations of a system that lack many or all the explanatory mechanisms hypothesized to operate in the system. In statistics (e.g., linear regression analysis) the typical null model assumes all system variation is a result of unexplained variance in the form of random noise (often a single random error process). In other contexts, null models may include additional processes/mechanisms but omit a key focal mechanism, enabling researchers to test whether that focal mechanism contributes usefully to predictive performance. In the context of adaptive harvest management, a null model would at least omit consideration of the impacts of harvest processes on system dynamics, which ultimately informs management decisions (Koons et al. 2022). By comparing complex models such as those used in the revised ARM with one or more null-model benchmark(s), researchers can determine whether the more complex models represent useful learned knowledge about a system (Koons et al. 2022). If a complex model fails to outperform a null model in terms of bias or precision (typically using independent validation data), the complex model is likely to be improperly specified or "overfitted" (whereby parameters are fitted to "noise" rather than true signal; Radosavljevic and Anderson 2014) and therefore not useful for prediction.

In the context of the HSC fishery in Delaware Bay, it would be informative to compare the performance of the HSC simulation model against a null model that omits all information about HSC harvest from the model fitting process; this would enable assessment of our current understanding of how estimated rates of harvest affect the HSC population. Given the poor fit of the HSC simulation model to training and validation data (see above), the HSC simulation is unlikely to outperform simpler null models. In fact, the CMSA model fails to outperform the simplest standard null model (single intercept term with sampling error) for at least one data source (the VT swept-area estimate of female multiparous abundance) despite its complexity (~20 parameters for the CMSA vs 1 parameter for describing expected abundance each year). If the HSC simulation model fails to outperform a model in which population dynamics are driven by noise instead of harvest, it should prompt managers to acknowledge that our current understanding of the effects of harvest on HSC populations remains insufficient for robust forecasting (Dietze 2017).

For the REKN component of the revised ARM, it would be informative to compare the performance of the REKN simulation model against a null model that omits any effect of female HSC abundance. It was recently demonstrated (Koons et al. 2022) that the ARM framework for guiding North American mallard harvest was unable to outperform a null model, and it would be instructive to pose a similar challenge to the REKN simulation model. Given that all the deterministic processes (fixed effects) included in the IPM model were very weak (i.e., the HSC effect on survival and fecundity; see above) or "non-significant", it is already apparent that random noise overwhelms most signal in the training data regarding how the HSC population affects REKN population dynamics. Therefore, it is likely that information about the HSC/REKN relationship would explain little if any of the variation in independent validation data. Furthermore, the lack of a relationship between the HSC model (CMSA) and the number of spawning females observed on coastal beaches (see above) makes it even more unlikely that the current REKN population model would outperform a null model that excludes any effect of HSC abundance (since the HSC/REKN relationship is based on the consumption by REKNs of HSC eggs deposited by spawning females).

In summary, null model benchmarks should be incorporated into the ARM framework to ensure that effective learning is occurring and that managers acknowledge uncertainty about how their decisions affect the populations they are charged with managing (Koons et al. 2022). If one or both simulation models that form the core of the revised ARM framework fail to outperform null models, it would strongly suggest that the ARM framework's current level of understanding about how management decisions are likely to affect the HSC and REKN populations is insufficient for robust forecasting of population-level risk to either species from HSC harvest. Although the ARM process is designed to treat management actions as opportunities for learning – updating harvest recommendations as new data become available (Nichols et al. 2007) – the fact that one of these species is federally threatened (USFWS 2014) justifies a more precautionary approach for risk management.

6. Lack of transparency

The public still has no access to the data and code used for (1) estimating REKN population parameters via a Bayesian integrated population model (IPM), (2) simulating REKN and HSC population dynamics, and (3) running the optimization routines via approximate dynamic programming (ADP). The CMSA code and data were made available, which enabled me to re-analyze the HSC survey data and run informative scenario tests (see above). Without the data and code for other components of the ARM model, it is not possible to re-analyze the data, test key assumptions, or simulate population dynamics under different hypothetical scenarios. Given the substantial concerns generated by the data and code that has been made publicly available to date (discussed above), such further re-analysis, testing, and simulation is warranted. If granted access to the code and data, there are several important questions that could be addressed more thoroughly, including but not limited to:

1) How would HSC abundance projections change – and how would harvest functions change – under the lower mean recruitment estimate produced by excluding anomalous estimates from the VT gap years?
2) What would happen to the REKN population projections if female HSC abundance were set to zero?
3) Does the REKN projection model outperform a null model that excludes any effect of HSC abundance?
4) In the REKN IPM, does the effect of HSC abundance disappear (or flip sign to become a negative relationship) under alternative plausible model specifications?
5) What proportion of variation in apparent survival in the REKN IPM model is explained by the HSC effect vs. random among-year variation?
6) Does an index of HSC spawning or HSC egg densities explain more variation in REKN survival and fecundity than the CMSA-derived estimate of HSC abundance?

CONCLUSION

In this report I have outlined six major concerns about the revised ARM. First, the modeled relationship between REKN vital rates and HSC abundance does not appear to be strong enough to induce an expected decline in the REKN population even under a catastrophic collapse of the HSC population. The apparent inability of the model to predict a major population response of REKNs to the depletion of the Delaware Bay HSC stock invalidates the premise of including a REKN population model within the ARM framework, which implicitly assumes that (1) HSC eggs are a critical resource for REKN populations and (2) HSC harvest could inhibit or slow the recovery of the REKN population, at least under some circumstances. The apparent inability of the ARM model to show a strong population-level effect of HSC harvest on REKN populations is inconsistent with the observed decline of the REKN population in recent decades, which many researchers have attributed to increased HSC harvest rates in the 1990s. Therefore, the REKN model included as part of the revised ARM does not appear to be a useful tool for assessing and managing risks to the REKN population from HSC harvest – or for promoting recovery of the REKN population.

In addition, I have identified several concerns about the HSC data analysis and simulation models. First, the HSC model in the revised ARM does not appropriately address key sources of uncertainty – particularly with respect to HSC fecundity (the source of potential harvest resilience). When these sources of uncertainty are addressed, the outlook for the HSC population is more uncertain than indicated in the ARM report. My analyses indicate that harvest at the maximum allowable levels could put the population in jeopardy (~11% risk) of decline below 3 million females – well below the minimum level previously recorded – within the next 50 years. In addition, the Catch Multiple Survey Analysis (CMSA), which is central to all aspects of the ARM, appears to exhibit poor fit to both training and independent data. I was unable to detect any correlation between the CMSA estimate of female HSC abundance and the estimated number of spawning females on coastal beaches in Delaware Bay. Finally, the estimate of HSC recruitment (which determines harvest resilience in the projection models) used in the revised ARM incorporates questionable (and highly inflated) estimates from a four-year period during which direct information on HSC recruitment was not available. Taken together, the above concerns strongly suggest the ARM model is not a valid tool for managing risk to the HSC population in Delaware Bay.

My final concerns are more general. First, I suggest that both the REKN and HSC models should be subjected to more rigorous evaluation, including tests for whether these models are able to outperform "null model" benchmarks that assume no useful learned knowledge about population dynamics and population response to harvest and harvest management. Ecological null models provide a useful benchmark for gauging the degree to which knowledge is accrued through the adaptive management process, and a mechanism for keeping modelers and managers "honest" by acknowledging an incomplete or inadequate understanding of the systems they are charged with managing. My analysis demonstrates that the CMSA model fails to outperform the simplest statistical null model for at least one data source. Finally, I was not provided access with much of the data and code used to generate the models used in the revised ARM (except for the CMSA code and data). Given the concerns that are apparent based on analysis of the limited code and data made available to date, it seems prudent to, at a minimum, delay implementation of this framework until the public and outside experts have had adequate time to scrutinize the statistical and simulation models that play such a central role in this proposed decision-making framework.

Despite the lack of transparency, I was able to run several informative re-analyses and scenario tests with the information provided in the ARM report and supplement, and with the CMSA code and data. Based on my analysis, there is sufficient evidence to conclude that the ARM framework is not useful for assessing the resilience of the HSC population to harvest pressures, nor for managing risk to the REKN population due to HSC harvest.

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EXPERT REPORT

Romuald N. Lipcius, Ph.D.

29 September 2022

Contents

1 Scope of Work

I was asked by representatives of EARTHJUSTICE to evaluate the Atlantic States Marine Fisheries Commission's Report and Supplemental Report to the 2021 Revision to the Adaptive Resource Management (ARM) Framework dealing with horseshoe crab (*Limulus polyphemus*) fishery management and implications for red knot (*Calidris canutus*) conservation. The red knot (RK hereafter) has been listed as "threatened" under the Endangered Species Act, and relies on horseshoe crab eggs buried along beaches of Delaware Bay to feed as it migrates along North and South America. The conclusions in the ARM report relate to an amendment proposed through the Atlantic States Marine Fisheries Commission (ASMFC) that would likely allow female horseshoe crab (HSC hereafter) harvest in Delaware Bay for the first time since 2012 and thereby potentially reduce food provisions (HSC eggs) needed by migrating RK. My primary goal is to evaluate the evidence in favor of the amendment objectively and determine if the amendment is justified.

In forming my opinions, I reviewed and considered various data sources regarding the HSC fishery and RK conservation along the Mid-Atlantic coast, with emphasis on Delaware Bay. My opinions are also based on my extensive experience conducting research and providing technical advice on fishery management and conservation of various marine species (see Section 8). My compensation is not contingent upon the conclusions or outcome of my review.

2 Summary Opinion

Based on my analysis and my expertise in conservation, fisheries and fishery management, I conclude to a reasonable degree of scientific certainty that:

The proposed amendment that would allow harvest of female horseshoe crabs is not justified by the available scientific evidence, due to various *risk-prone* decisions and assumptions that underlie the Adaptive Resource Management framework and model. The proposed amendment thereby poses a significant risk both to the Horseshoe Crab population and Red Knot recovery.

3 Abbreviations and Definitions

ARM: Adaptive Resource Management framework
HSC: Horseshoe Crab (*Limulus polyphemus*)
RK: Red Knot (*Calidris canutus*)
VTS: Virginia Tech HSC survey
DES: Delaware HSC survey
NJS: New Jersey HSC survey
Risk-prone: Conservation or management actions based on overly optimistic assumptions about the status of a population. The assumptions may be about data sources, observations or data, and often involve ignoring information to the contrary of optimistic conclusions about population status. For endangered or threatened species, a risk-averse, rather than risk-prone, strategy based on the precautionary principle is critical for population recovery, population conservation, and sustainable resource management.

4 Opinions

The following specific opinions describe various lines of evidence indicating that the HSC population is not in a healthy state and has not fully recovered despite a prohibition on female harvest since 2012. The different lines of evidence are effectively "red flags" leading to the conclusion that the current and proposed management strategies are risk-prone, such that harvest restrictions should not be relaxed at present. To the contrary, further management actions or improvements to the current management plan are necessary to stimulate HSC recovery. Furthermore, due to the lack of *substantial* improvement of the HSC spawning stock (i.e. mature females), the existing HSC management strategy has not significantly enhanced food availability for the threatened RK and therefore its recovery. A shift to risk-averse management based on the precautionary principle is essential for HSC and RK recovery.

4.1 Low Newly Mature Female, Recruit and Spawning HSC Abundance

An expectation from the female harvest prohibition is a rebound in young mature females and recruitment of immature males and females into the HSC population. In 2019 and 2020, abundance of newly mature females was at an all-time low; recruitment of immature females and males was extremely low and unchanged since before the prohibition; and female abundance in the spawning survey dropped sharply in 2019. These are warning signs that the HSC population has not fully recovered and may even be declining. Thus, female harvest should not be raised.

4.2 Smaller Body Size of Mature Female HSC

An expectation of the female harvest prohibition is that female body size would increase, given constant recruitment, which is a typical response in fisheries worldwide when harvest pressure on older, larger females is reduced. On the contrary, mean size of mature female HSC was smallest in the last 3 years (2018 to 2020) and of newly mature females in the last 2 years of the time series from 2002 to 2020, despite the prohibition on female harvest since 2012. These data are inconsistent with the previous expectation and the premise that the female segment of the HSC population has rebounded.

4.3 Loss of Large Mature Female HSC and Lower Egg Production

Population egg production is a function of spawning stock (= mature females) biomass (i.e. weight). Hence, changes in size distribution of mature females will affect total egg production, particularly the loss of large HSC females which contribute disproportionately to total egg production. Consequently, using only HSC abundance to estimate reproductive output and egg production is ignoring main biological drivers of population egg production–size structure and biomass–of the HSC spawning stock. Size distribution of mature females has shifted to smaller females. Abundance of females larger than 300 mm prosomal width (i.e. females with the highest egg production) has dropped recently, particularly from 2018 to 2020. Recent low recruitment means that smaller mature females are not compensating for the loss of larger mature females. Consequently, total reproductive (egg) output has likely not improved, which hampers recovery of the HSC and RK populations.

4.4 HSC Sex Ratio

When HSC harvest has been restricted to males, the ratio of males to females should have decreased. In contrast, male:female sex ratios have actually increased from 1999 to 2019. This represents another warning sign that the current management strategy has not been effective, that population dynamics are not well understood, and that harvest of females should not be increased.

4.5 High Mature Female HSC Mortality

The combination of discard mortality and bait harvest mortality for females has increased substantially in recent years and is comparable to levels before the prohibition. Assuming that the prohibition has worked is therefore risk-prone. The collective bait harvest and discard mortality is not being controlled effectively and inhibits HSC recovery.

4.6 Reliance on HSC Density as the Indicator of HSC Population Status

Female density (catch per unit area) is a primary variable used in HSC surveys and the ARM framework model. Reliance solely on HSC density or abundance ignores other variables that commonly produce warning signs about the status of a stock, such as female size, female size-frequency distribution, spawning stock biomass and female:male sex ratio. These variables are often more sensitive indicators of problems in a population, meaning that they can detect problems more effectively than abundance estimates. Hence, the current management strategy is risk-prone by ignoring these more sensitive indicators.

4.7 Low HSC Egg Density

Recent data indicate that HSC egg densities in HSC spawning habitats and RK feeding grounds remain an order of magnitude below densities when RK and HSC were relatively abundant. The ARM process has decided to ignore patterns in HSC egg density because of methodological "uncertainty" in the data. Under conditions where a population is not in danger, this may be acceptable, but absolutely not when it represents a potential warning sign about a population in danger, such as the RK. Thus, lack of use of HSC egg density data, as a proxy for RK food availability, amounts to a failure to incorporate all available scientific information into the analysis to guide management decisions in a risk-averse manner.

4.8 Lack of Correlation of HSC Surveys

Data from the DES and NJS of HSC in Delaware Bay are assumed to be correlated with the VTS and used to fill in survey gaps in the VTS. Survey data when all three surveys were conducted are not correlated, and data from the DES and NJS were relatively higher than that from VTS. These results lead to an overestimation of HSC abundance during VTS gap years, which is indicative of a risk-prone assumption.

4.9 Degraded HSC Spawning Habitat and RK Feeding Grounds

Spawning habitat (e.g. beaches) for HSC and feeding grounds for RK have been lost throughout the stopover range of RK in the Mid-Atlantic. Loss of habitat is an additional stress that demands risk-averse management of mortality sources (e.g. fishing) which management can control. There may be variables that are beyond ASMFC's control, but that means they should be more precautionary with variables they can control, and it's certainly not a valid basis for ignoring warning signs like reduced HSC egg density and abundance.

5 Evidence for Opinions

The VTS is based on robust experimental design principles, and is the only spatially widespread survey that includes the coastal zone along Delaware and New Jersey, as well as Delaware Bay. In addition, the VTS collects much more comprehensive demographic data, which enables more types of analysis. Thus, the VTS serves as a robust and independent measure of HSC population status. The remainder of the analysis therefore focuses on data from the VTS and other published information on horseshoe crabs and the red knot. All analyses were conducted using the statistical software package R, version 4.1.2 (2021).

5.1 Low Newly Mature Female, Recruit and Spawning HSC Abundance

An expectation from the female harvest prohibition is a rebound in young mature females and recruitment of immature males and females into the HSC population. In 2019 and 2020, abundance of newly mature females was at an all-time low; recruitment of immature females and males was extremely low and unchanged since before the prohibition; and female abundance in the spawning survey dropped sharply in 2019. These are warning signs that the HSC population has not fully recovered and that female harvest should not be raised.

Data from the VTS on abundance of newly mature female HSC in 2019 and 2020 were at the lowest levels in the time series since 2002, indicating low influx of young mature females into the spawning stock (Figure 1). Similarly, abundance of immature female and male HSC, representing future recruitment to the adult segment and spawning stock of the population, were at extremely low levels and unchanged from those before 2013 (Figure 1). Moreover, female abundance in the Delaware Bay Horseshoe Crab Spawning Survey dropped sharply in 2019 (Figure 2), despite the prohibition of female harvest since 2012.

5.2 Smaller Body Size of Mature Female HSC

An expectation of the female harvest prohibition is that female body size would increase, given constant recruitment, which is a typical response in fisheries worldwide when harvest pressure on older, larger females is reduced (Beverton and Holt, 1956; Gedamke and Hoenig, 2006). On the contrary, mean size of mature female HSC was smallest in the last 3 years (2018 to 2020) and of newly mature females in the last 2 years of the time series from 2002 to 2020, despite the prohibition on female harvest since 2012. These data are inconsistent with the previous expectation and the premise that the female segment of the HSC population has rebounded.

VTS data were examined in two ways (mean and mode of size-frequency histograms) to evaluate this expectation. First, the time series of mean size in the VTS (Figure 3) indicated that mean sizes of mature female HSC and of newly mature females from 2016 to 2020 were the smallest in the time series from 2002 to 2020, despite the prohibition of female harvest since 2012.

Given that the mean of a sample can be influenced by outliers, the size data were also examined using a non-parametric statistic, the mode. The median could not be calculated because the raw data were unavailable for this analysis. The mode for each year was visually estimated from the size-frequency histograms of mature females (Appendix Figures 10 and 11). As with the mean, modal sizes of mature females from 2018 to 2020 were the lowest in the time series (Figure 4). In contrast, modal sizes of mature males were relatively unchanged (Figure 4).

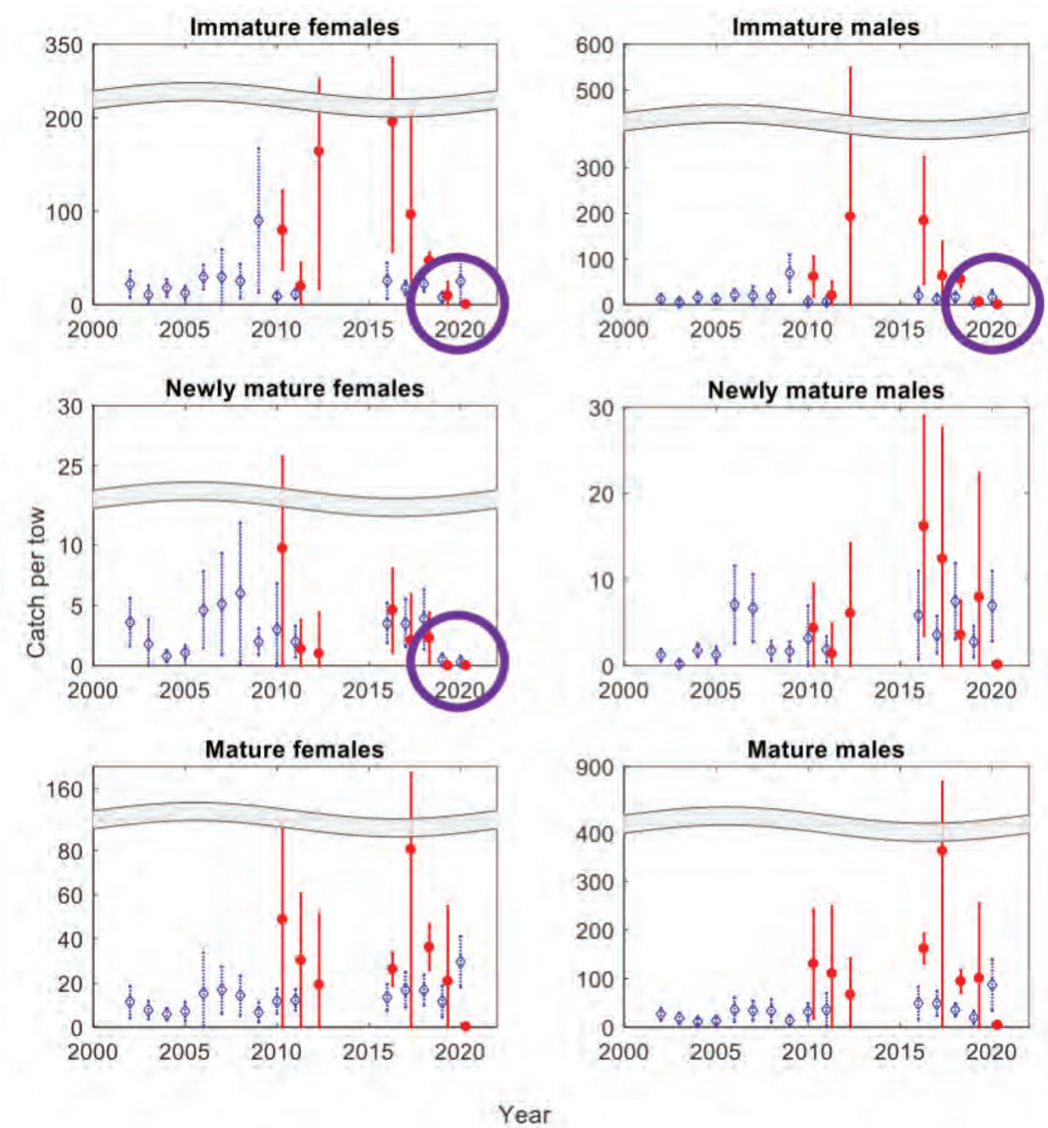

Figure 1: Densities of HSC males and females from Figure 3 of the VTS report (Hallerman and Jiao, 2021). Purple circles have been added to highlight the warning signs that the HSC population has not fully recovered.

Mean body size of spawning females could decrease over time if there was high recruitment of smaller, newly mature females shifting down the average size. However, the opposite (weak recruitment) appears to be the case, as described in section 5.1.

5.3 Loss of Large Mature Female HSC and Lower Egg Production

Population egg production is a function of spawning stock (= mature females) biomass (i.e. weight). Hence, changes in size distribution of mature females will affect total egg production, particularly large HSC females which contribute disproportionately to total egg production. Consequently, using only HSC abundance to estimate reproductive output and egg production is ignoring the main biological drivers of population egg production–size structure and biomass–of the HSC spawning stock. Size distribution of mature females has shifted to smaller females. Abundance of females larger than 300 mm prosomal width (i.e. females with the highest egg production) has dropped recently,

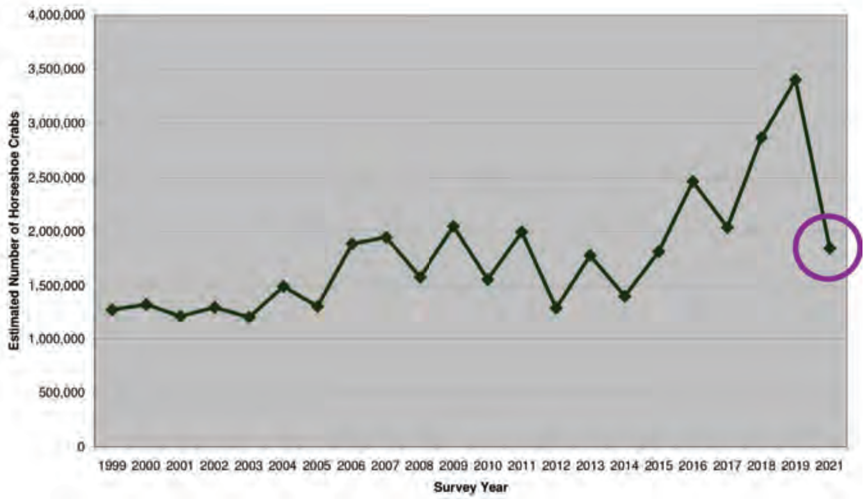

Figure 2: Spawning horseshoe crab survey data, highlighting low abundance of spawning horseshoe crabs in 2021 Swann and Hall (2019).

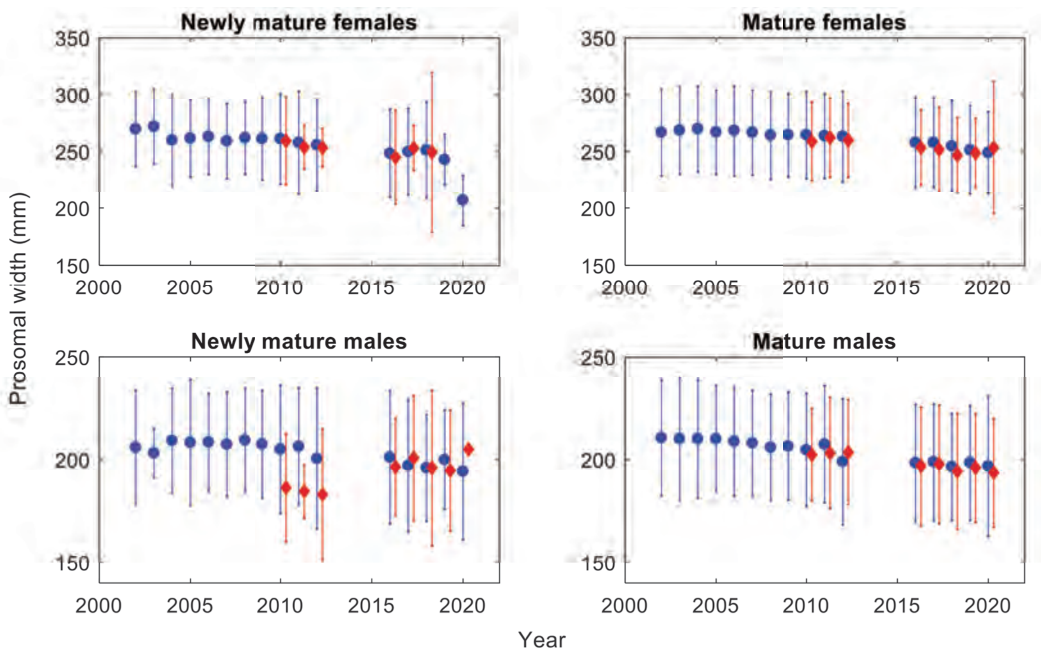

Figure 3: Mean sizes of newly mature and mature female and male horseshoe crabs over 2010 to 2020, with gap years from 2012 to 2015, from the VT survey in the coastal Delaware Bay area (Hallerman and Jiao, 2021).

particularly from 2018 to 2020. Recent low recruitment means that smaller mature females are not compensating for the loss of larger mature females. Consequently, total reproductive (egg) output has likely not improved, which hampers recovery of the HSC and RK populations.

For an individual HSC female, her egg production is directly proportional to individual weight, which is an exponential (not linear) function of prosomal width (Figure 5), as in other species of horseshoe crabs (Chatterji, 1995) and marine species in general (Barneche et al., 2018).

Changes in size distribution of mature females, particularly large HSC females which contribute disproportionately to total egg production due to the exponential increase in weight with size (Figure 6), will reduce population egg production. This was validated for an HSC population by

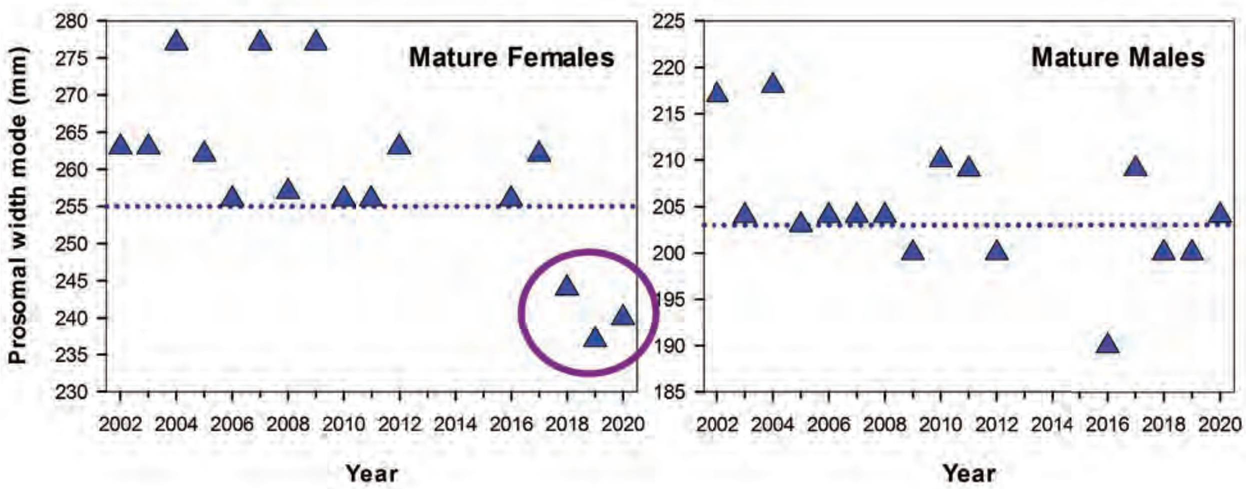

Figure 4: Size modes of mature female and male horseshoe crabs over 2002 to 2020 (gap years from 2013 to 2015) from the VTS in the coastal Delaware Bay area. Mode sizes were estimated from Figures 10 and 11.

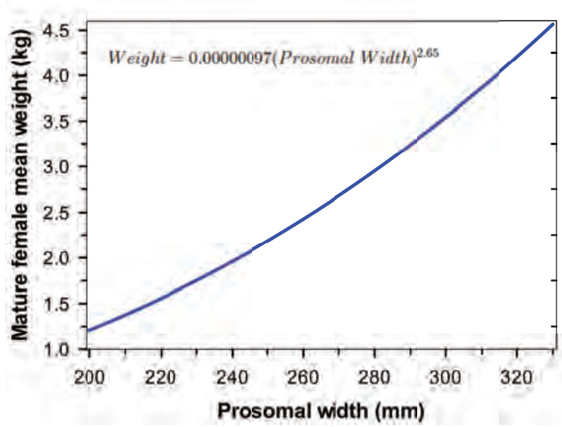

Figure 5: Exponential relationship between mature female HSC weight (kg) and prosomal width (mm) derived from Table 3 in Graham et al. (2009).

Leschen et al. (2006), who concluded that "larger females held a larger number of eggs (63,500) than smaller females (14,500) [and] laid a higher percentage of the eggs they contained. Thus they not only contain more eggs, but are more effective at laying them as well."

Using only HSC abundance to estimate reproductive output and egg production is ignoring the main biological drivers of population egg production–size structure and biomass (weight)–of the HSC spawning stock. Abundance is a reliable proxy of HSC egg production only if size structure of the spawning stock is unchanged over time, which is not the situation with the HSC spawning stock. Size distribution of mature females has shifted to smaller females (Figures 3 and 4), and recruitment does not account for the recent shift in size distribution because abundance of newly mature and immature females in the past few years has been well below average (Figure 1).

Abundance of females larger than 300 mm prosomal width (i.e. females with the highest egg production) has dropped recently, particularly from 2018 to 2020 (Appendix Figures 10 and 11), which has substantially reduced egg production. Note in Figures 10 and 11 that females larger than 300 mm prosomal width were apparent in 6 of 8 years from 2002 to 2009 (Figure 10), but only in 1 of 8 years from 2010 to 2020 (Figure 11). Moreover, the recent low recruitment means that

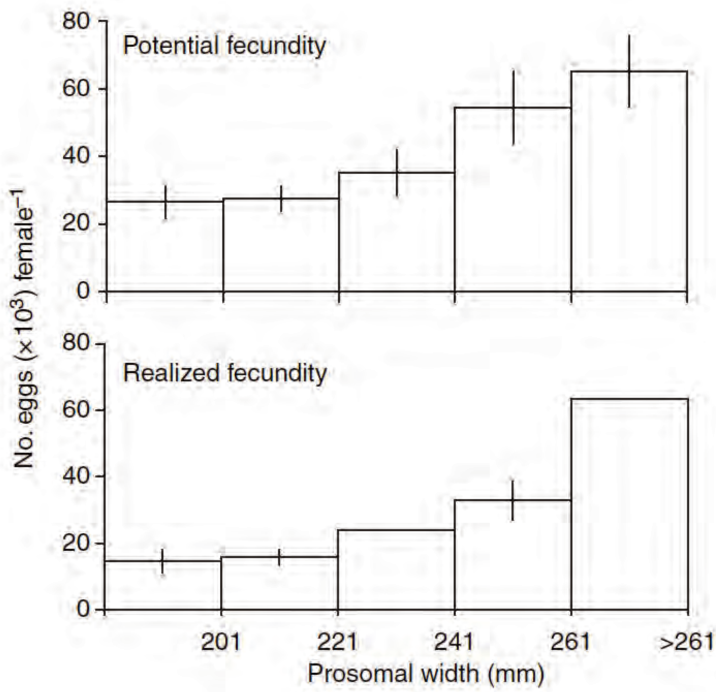

Figure 6: Positive relationship between HSC female fecundity and prosomal width (Leschen et al., 2006).

smaller mature females are not compensating for the loss of larger mature females. Consequently, total reproductive (egg) output has likely not improved, which hampers recovery of the HSC and RK populations.

5.4 HSC Sex Ratio

When HSC harvest has been restricted to males during the prohibition, the ratio of males to females should have decreased. In contrast, male:female sex ratios have actually increased from 1999 to 2019. This represents another warning sign that the current management strategy has not been effective, and that harvest of females should not be increased.

To assess HSC sex ratio over time, particularly since the prohibition on female harvest, I examined sex ratio data from the 2019 Delaware Bay Horseshoe Crab Spawning Survey, Table 5 (Figure 7). The time series shows an initial drop in the ratio of males to females during 2013, shortly after the prohibition on female harvest began. However, the ratio of males to females has increased since 2014 and even reached the highest ratios in the time series during 2018 and 2019.

5.5 High Mature Female HSC Mortality

The combination of discard mortality and bait harvest mortality for females has increased substantially in recent years and is comparable to levels before the prohibition. Assuming that the prohibition has worked is therefore risk-prone. The collective bait harvest and discard mortality is not being controlled effectively and inhibits HSC recovery.

Total mortality of females due to the bait fishery and its discards has increased substantially in recent years and is comparable to levels before the prohibition (Figure 8). Note that there is still a small amount of direct mortality due to the bait fishery (Figure 8), possibly due to inaccurate identification of female HSC by fishers. Thus, the prohibition on female harvest has not been

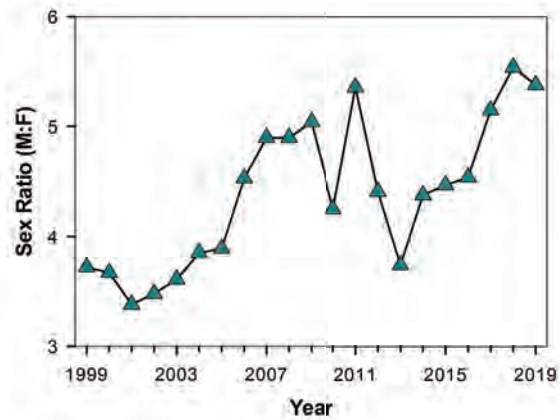

Figure 7: Sex ratio from the Delaware Bay Horseshoe Crab Spawning Survey Swann and Hall (2019).

effective in reducing female HSC mortality, and any further increase in female harvest is risk-prone and a danger to the HSC population and RK recovery.

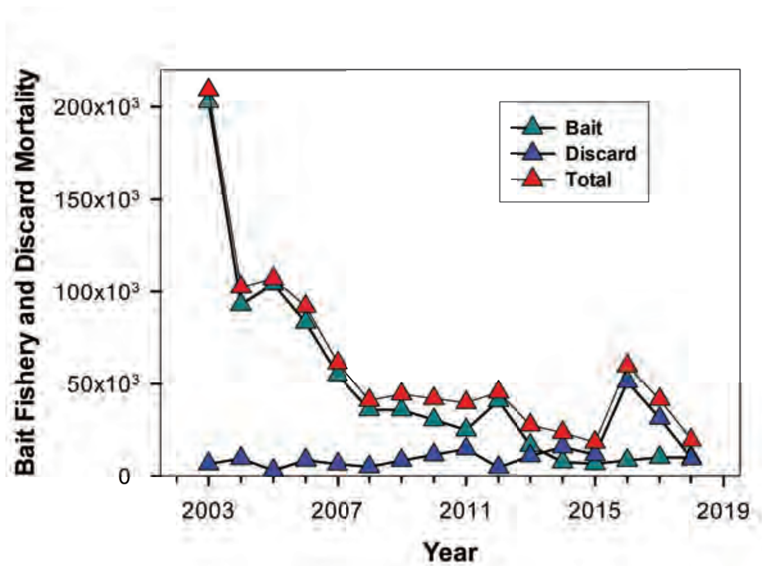

Figure 8: HSC mortality due to the bait fishery and discards (Adaptive Resource Management Subcommittee, 2022).

5.6 Reliance on HSC Density as the Indicator of HSC Population Status

Female density (catch per unit area) is a primary variable used in HSC surveys and the ARM framework model. Reliance solely on HSC density or abundance ignores other variables that commonly produce warning signs about the status of a stock, such as female size, female size-frequency distribution, spawning stock biomass and female:male sex ratio (Free et al., 2020; Punt et al., 2020). These variables are often more sensitive indicators of problems in a population, meaning that they can detect problems more effectively than abundance estimates alone. Hence, the current management strategy is risk-prone by ignoring these more sensitive indicators.

5.7 Low HSC Egg Density

Recent data indicate that HSC egg densities in HSC spawning habitats and RK feeding grounds remain an order of magnitude below densities when RK and HSC were relatively abundant. The ARM process has decided to ignore patterns in HSC egg density because of methodological "uncertainty" in the data. Under conditions where a population is not in danger, this may be acceptable, but absolutely not when it represents a potential warning sign about a population in danger, such as the RK. Thus, lack of use of HSC egg density data, as a proxy for RK food availability, amounts to a failure to incorporate all available scientific information into the analysis to guide management decisions in a risk-averse manner.

To assess changes in HSC egg density over time, I compared data for egg density before the peak of HSC harvest during 1985, 1986, 1988 and 1990 with data after the peak of HSC harvest from 1999 to 2021 (Smith et al., 2022). While the time series from 1999 to 2021 shows egg density increasing from an average of about 3,000 eggs per m^2 in 2000 to 9,000 eggs per m^2 in 2021 (Figure 6), egg density remains over an order of magnitude lower than that before the peak of HSC harvest during 1985 to 1990 (Figure 6).

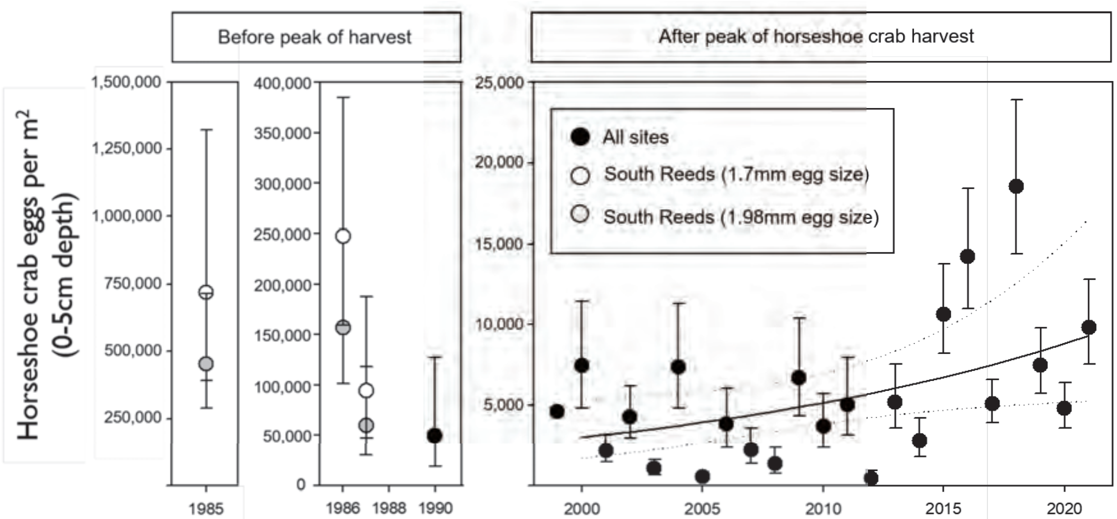

Figure 9: HSC egg density from spawning beaches, emphasizing the order of magnitude lower egg densities in recent years relative to historical levels in the spawning beaches. Note the different range of values in the left and right graphs. Figure from Smith et al. (2022).

5.8 Lack of Correlation of HSC Surveys

Data from the DES and NJS of HSC in Delaware Bay are assumed to be correlated with the VTS and used to fill in survey gaps in the VTS. Survey data when all three surveys were conducted are not correlated, and data from the DES and NJS were relatively higher than that from VTS. These results lead to an overestimation of HSC abundance during VTS gap years, which is indicative of a risk-prone assumption.

To evaluate the assumption of coherence between the three surveys, and justification for use of the DES and NJS in the four years when VTS data were unavailable, correlation between the three surveys was investigated. Data used in the analysis are those in Tables 1 and 2 from Adaptive Resource Management Subcommittee (2022) for indices VTS Multiparous Females, DES Adult and

NJS Ocean Trawl from 2003 to 2012, when indices were available for all three surveys prior to the 2012 prohibition.

Data for female and male HSC abundance from the three surveys were not correlated (Table 1), such that the use of data from two surveys (NJS and DES) to estimate data from the VTS survey during gap years when the VTS did not collect data is invalid. Furthermore, the NJS and DES produced data that were relatively higher than data from the VTS (positive intercepts in Table 1), indicating that the replacement data for the VTS using DES and NJS overestimate HSC abundance from the VTS.

Table 1: Correlation analysis for mature female HSC from VTS, NJS and DES.

Parameter	Estimate	Standard Error	t value	P
Females				
DES as a function of VTS: $r^2 = 0.01$				
Intercept	0.23	0.37	0.61	0.56
Slope	0.02	0.07	0.28	0.79
NJS as a function of VTS: $r^2 = 0.001$				
Intercept	1.96	0.67	2.91	0.02
Slope	-0.01	0.13	-0.07	0.95
Males				
DES as a function of VTS: $r^2 = 0.12$				
Intercept	0.03	0.23	0.12	0.91
Slope	0.02	0.02	1.03	0.34
NJS as a function of VTS: $r^2 = 0.03$				
Intercept	2.25	0.71	3.15	0.02
Slope	-0.03	0.06	-0.52	0.62

5.9 Degraded HSC Spawning Habitat and RK Feeding Grounds

Spawning habitat (e.g. beaches) for HSC and feeding grounds for RK have been lost throughout the stopover range of RK in the Mid-Atlantic. Loss of habitat is an additional stress that demands risk-averse management of mortality sources (e.g. fishing) which management can control. There may be variables that are beyond ASMFC's control, but that means they should be more precautionary with variables they can control, and it's certainly not a valid basis for ignoring warning signs like reduced HSC egg density.

A major threat to horseshoe crab population involves habitat degradation and loss, and is expected to worsen in the future due to sea level rise (Botton et al., 2022). Spawning habitat loss has been significant due to various factors such as shoreline management (e.g. bulkheading), coastal disturbances and sea-level rise (Smith et al., 2017, 2020). In some cases, whole beaches have been lost (Smith et al., 2017). Given that habitat loss is not under control by ASMFC, precautionary management demands consideration of such stressors to the population by control of fishery harvest to compensate for external stressors.

5.10 Appendix Figures

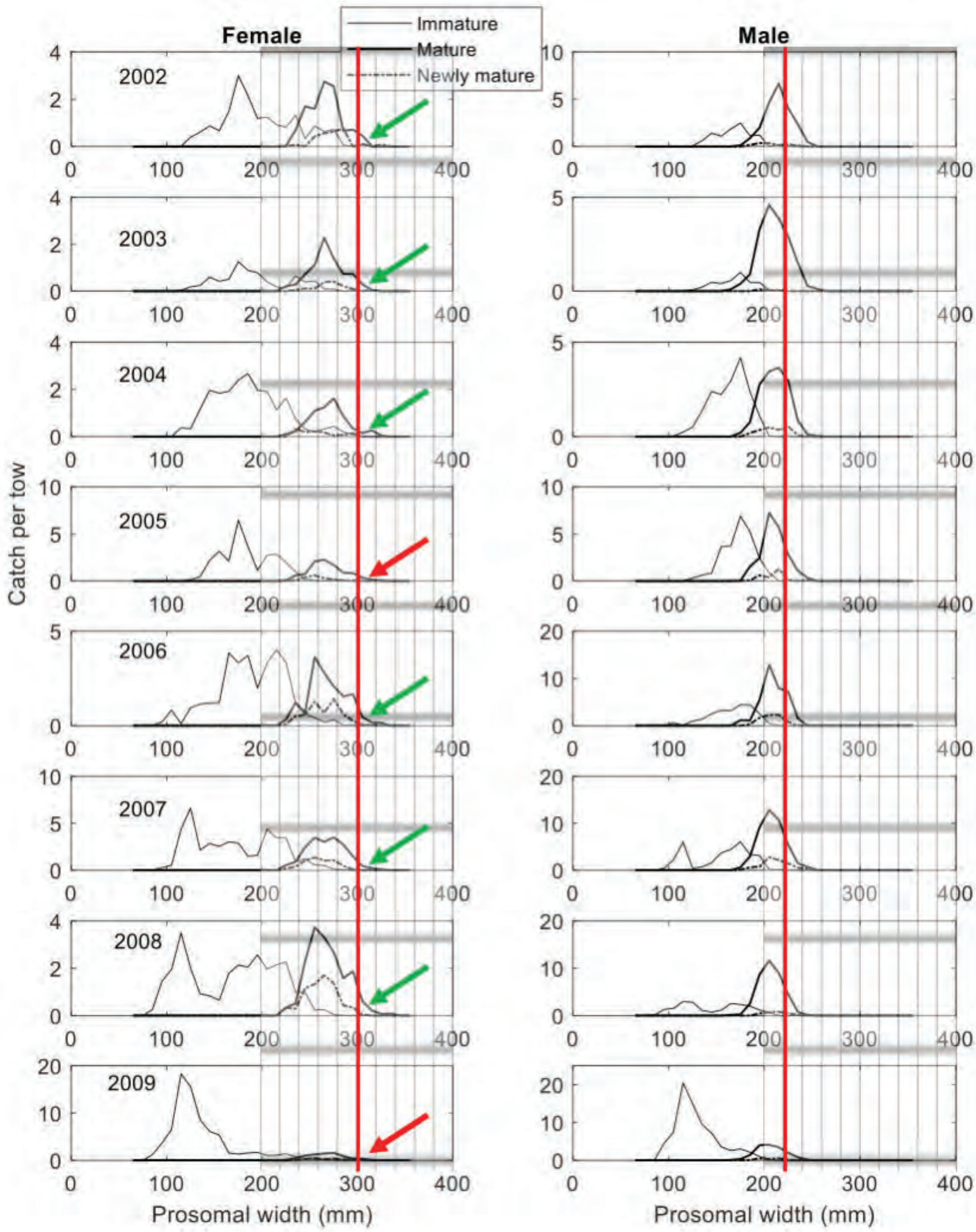

Figure 10: Size frequencies of mature female and male horseshoe crabs over 2002 to 2009 from the VT survey in the coastal Delaware Bay area (Hallerman and Jiao, 2021). Vertical red lines and grid cells were added for reference. Green arrows indicate years when mature females larger than 300 mm prosomal width were apparent, and red arrows when not.

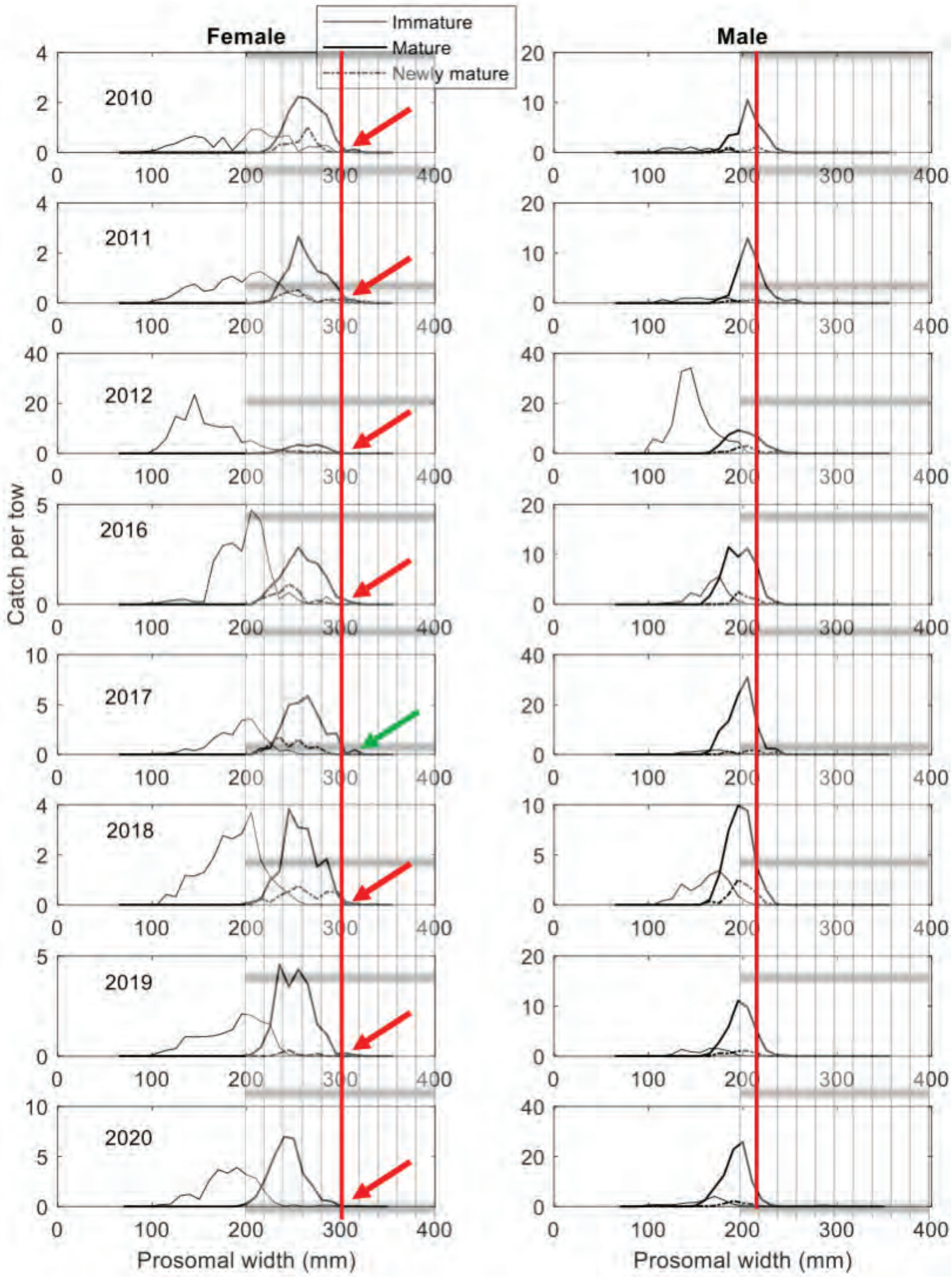

Figure 11: Size frequencies of mature female and male horseshoe crabs over 2010 to 2020, with gap years from 2013 to 2015, from the VT survey in the coastal Delaware Bay area (Hallerman and Jiao, 2021). Vertical red lines and grid cells were added for reference. Green arrows indicate years when mature females larger than 300 mm prosomal width were apparent, and red arrows when not.

6 Acknowledgements

I am extremely grateful to Dr. John Hoenig for his ideas and comments which greatly improved this report.

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8 Qualifications & Credentials

The qualifications, experience and scientific recognition that allow me to provide an informed, expert opinion on this matter are described below. My academic and professional credentials include: Professor (2000-present), Associate Professor (1993-2000), and Assistant Professor (1986-1993) of Marine Science, Virginia Institute of Marine Science, William & Mary, Department of Fisheries Science; Senior Postdoctoral Fellow, Smithsonian Institution (1997-1999); Postdoctoral Fellow, U.S. National Research Council (1985-1986); Adjunct Professor, Anne Arundel Community College (1984-1985); Postdoctoral Fellow, Smithsonian Institution (1984-1985); and Assistant Professor, Florida A & M University (1981-1984; while Ph.D. student at FSU). I received my Ph.D. from Florida State University in 1984 (major: Biological Science; minor: Statistics).

My scientific expertise and research specialties include Marine Conservation Ecology, Fisheries Management, Mathematical Biology, Ecological Statistics, and Ecology and Management of Crustaceans and Molluscs. Over the span of my career, I have 121 publications in peer-reviewed scientific journals, numerous technical reports, and 80 research grants totaling over $20 million from agencies including the National Science Foundation, National Oceanic and Atmospheric Administration, U.S. Army Corps of Engineers, National Undersea Research Program, Department of Defense, and various others.

I have 45 years of experience with eastern oyster, blue crab, Caribbean spiny lobster, queen conch, Nassau grouper and various marine bivalves; 36 years experience as the Commonwealth of Virginia's expert on blue crab ecology and fishery management; provision of formal opinions to Virginia Marine Resources Commission, Chesapeake Bay Commission, Chesapeake Bay Stock Assessment Committee, and Chesapeake Bay Program Fisheries Goal Implementation Team; 18 years experience as scientific advisor on oyster restoration to U.S. Army Corps of Engineers, NOAA Chesapeake Bay Office, and Chesapeake Bay Program Fisheries Goal Implementation Team; 33 years as Chief Scientist of the Blue Crab Winter Dredge Survey; Co-Principal Investigator of the Blue Crab Stock Assessment in Chesapeake Bay; and member of technical teams for Gulf of Mexico and Chesapeake Bay oyster and blue crab stock assessment, conservation and restoration.

Scientific honors, recognition and awards include: (i) Coastal America Partnership Award from the Executive Office of the President of the U.S., (ii) Kavli Fellowship from U.S. National Academy of Sciences, (iii) Aldo Leopold Leadership Fellow Award, (iv) Outstanding Faculty Award for Advisory Service, Virginia Institute of Marine Science, and (v) Outstanding Faculty Award for Research, Virginia Institute of Marine Science.

From:	Robert E. Rutkowski
To:	info; Comments
Cc:	Keith Abouchar
Subject:	[External] Expert Analysis Reveals Fatally Flawed Horseshoe Crab Model Threatens Red Knots in Delaware Bay
Date:	Tuesday, September 26, 2023 11:26:55 AM

Horseshoe Crab Management Board
ASMFC
1050 N. Highland St., Suite 200 A-N
Arlington, VA 22201
703-842-0740
Fax: 703-842-0741
info@asmfc.org, comments@asmfc.org

Re: Expert Analysis Reveals Fatally Flawed Horseshoe Crab Model Threatens Red Knots in Delaware Bay

Dear Members of the Horseshoe Crab Management Board:

A new technical analysis from University of Nevada, Reno Associate Professor Dr. Kevin Shoemaker finds that a computer model used by the Atlantic States Marine Fisheries Commission does not accurately represent the impacts of a horseshoe crab bait harvest in Delaware Bay. As a result of the model's intrinsic flaws, relying on it to justify management decisions would further imperil the rufa red knot, a shorebird listed as threatened under the Endangered Species Act. Citing this analysis, Earthjustice sent comments to the ASMFC on behalf of New Jersey Audubon and Defenders of Wildlife, urging it to exercise precaution when setting bait harvest quotas and to maintain the prohibition on harvesting female horseshoe crabs from Delaware Bay. At its annual meeting in October, the ASMFC will set the Delaware Bay horseshoe crab bait harvest quota for 2024.

This new analysis makes it abundantly clear that red knots remain at risk in Delaware Bay. While the ASMFC did not authorize a female crab harvest for 2023 in response to overwhelming public concern, it also approved a fatally flawed computer model that is nearly certain to recommend a substantial female harvest in future years, which could have devastating impacts. Implementing the model's recommendations would pose a profound risk of violating the Endangered Species Act.

The full adaptive resource management model was withheld from the public until the evening before the ASMFC's horseshoe crab management board approved it in November 2022. Dr. Shoemaker has since reviewed the full model, finding irremediable flaws intrinsic to its core structure and functionality. Among other deficiencies, the model fails to acknowledge the correlation between the abundance of horseshoe crabs and red knots. Despite the historical role horseshoe crab overharvest has played in the decline of red knots, the model predicts red knot abundance would increase even if all horseshoe crabs vanished from Delaware Bay. The model does not account for the number of horseshoe crab eggs on the beach—a critical food source metric that is necessary for red knot survival.

Dr. Shoemaker's review and reanalysis of the ASMFC's adaptive resource management framework makes it clear that the models used by this agency to manage horseshoe crabs must be revamped. The ASMFC's stated responsibility is to manage horseshoe crabs populations to ensure the long-term viability of red knot populations. The premise put forward by the ARM model outputs suggesting that the relationship between horseshoe crab and red knot populations are weak is an outcome of using the wrong metric to measure the relationship. Clearly, horseshoe crab eggs, which have been ignored by the ASMFC since the inception of the ARM framework, have the greatest influence on the trajectory of red knot populations.

The ASMFC has prohibited the bait harvest of female horseshoe crabs in Delaware Bay for more than a decade, but the status of both horseshoe crabs and red knots remains precarious. Instead of delivering much-needed additional protections, the ARM model's recommended harvest quotas would increase pressure on these species.

Management decisions for public resources such as horseshoe crabs must be based on verifiable science, not inaccurate assumptions only loosely tethered to reality. The ASMFC is charged with conserving Atlantic coastal fishery resources based on the best scientific information available. The ARM model, however, is too fundamentally flawed to conserve depleted horseshoe crabs and protect threatened red knots that depend on horseshoe crab eggs to survive their epic migration and successfully reproduce.

Conservation groups have repeatedly sounded the alarm over the potential of an Endangered Species Act violation on impacts to red knots if the ASMFC moves forward with a female horseshoe crab bait harvest. Red knots make one of the most epic migrations in the animal kingdom, which begins as far south as Tierra del Fuego and journeys more than 9,000 miles to their breeding grounds in the Arctic Circle. For most red knots, Delaware Bay is a critical resting point to replenish and renourish with horseshoe crab eggs that enable a rapid doubling of their body mass before they complete their journeys.

Letter:
https://earthjustice.org/wp-content/uploads/2023/09/nj-audubon-defenders-of-wildlife-2023-comments-to-hsc-board.pdf

Yours sincerely,
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Delaware Bay Horseshoe Crab Management Stakeholder Survey Report

October 2023

Sustainable and Cooperative Management of Atlantic Coastal Fisheries

Delaware Bay Management Objectives Work Group

Joe Cimino, New Jersey Department of Environmental Protection
John Clark, Delaware Department of Natural Resources and Environmental Control
Michael Luisi, Maryland Department of Natural Resources
Shanna Madsen, Virginia Marine Resource Commission

EXECUTIVE SUMMARY

The Atlantic States Marine Fisheries Commission (Commission) has maintained primary management authority for horseshoe crabs in state and federal waters since it adopted the Interstate Fishery Management Plan for Horseshoe Crabs (FMP) in 1998. The Delaware Bay population of horseshoe crabs has been managed under the Adaptive Resource Management (ARM) Framework since 2012. The ARM Framework considers the abundance levels of horseshoe crabs and shorebirds in determining the optimal harvest level for the Delaware Bay states of New Jersey, Delaware, Maryland, and Virginia (east of the COLREGS). Since 2013 the Horseshoe Crab Management Board (Board) has set bait harvest limits for the Delaware Bay region based on the ARM Framework recommendations.

In 2023 the Board undertook an effort to better understand stakeholder values regarding horseshoe crab management in the Delaware Bay region. This initiative was in response to widespread public concern about the adoption of the 2021 ARM Revision, which updated the ARM model to include additional data on shorebirds and horseshoe crabs and advancements in modeling software and techniques. In large part this public concern was focused on the potential for female horseshoe crab harvest under the Revised ARM and its impact on the rufa red knot, which is listed as threatened under the Endangered Species Act, and depends on horseshoe crab eggs as a major food source in the Delaware Bay during its migration.

A survey was developed by a work group of Board members from the Delaware Bay states and distributed to Delaware Bay stakeholders, including bait harvesters and dealers, fishermen who use horseshoe crab as bait, biomedical fishery and industry participants, environmental conservation groups, and researchers. The survey results reflect diverging values across stakeholder groups. Commercial industry participants indicated they still value the harvest of female horseshoe crabs, though it has not been permitted in the region since 2012. Researchers and environmental groups tended to value the protection of female horseshoe crabs and the ecological role of horseshoe crabs as a food source for shorebirds over the fishery.

The survey results will be considered by the Board to provide guidance on whether to consider future changes to horseshoe management for the Delaware Bay region.

Table of Contents

1. INTRODUCTION

The Delaware Bay population of horseshoe crabs has been managed under the Adaptive Resource Management (ARM) Framework since 2012 in recognition of public concern regarding the horseshoe crab population and its ecological role of horseshoe crabs in the Delaware Bay. The Framework considers the abundance levels of horseshoe crabs and shorebirds in determining the optimal harvest level for the Delaware Bay states of New Jersey, Delaware, Maryland, and Virginia (east of the COLREGS). Since 2013, the Board has annually reviewed recommended harvest levels from the ARM model, and specified harvest levels for the following year in New Jersey, Delaware, Maryland, and Virginia.

In 2021, a revision to the ARM Framework was completed. The revision updated the ARM model with an additional decade of data on shorebirds and horseshoe crabs in the Delaware Bay region, and advancements in modeling software and techniques. Changes to the ARM Framework are described in detail in the 2021 Revision to the Adaptive Resource Management Framework and Peer Review Report, and include:

- Catch multiple survey analysis (CMSA) to estimate male and female horseshoe crab population estimates using all quantifiable sources of mortality (i.e., natural mortality, bait harvest, coastwide biomedical mortality, and commercial dead discards) and several abundance indices from the Delaware Bay Region
- Integrated population model (IPM) to quantify the effects of horseshoe crab abundance on red knot survival and recruitment based on data collected in the Delaware Bay
- Transition to new modeling approach which can be implemented through readily available R software and incorporates uncertainty on all life history parameters for both horseshoe crabs and red knots
- Harvest recommendations based on a continuous scale rather than discrete harvest packages as in the previous Framework
- Female harvest decoupled from the harvest of males

Following the recommendations of the ARM Revision independent peer review panel that endorsed the ARM Revision as the best and most current scientific information for the management of Delaware Bay horseshoe crabs, the Horseshoe Crab Management Board (Board) reviewed and accepted the ARM Framework Revision in January 2022. The Board adopted use of the ARM Revision for management under Addendum VIII, approved in November 2022. During the public comment period on Addendum VIII, there was significant public concern about the status of the red knot population in the Delaware Bay. Over 30,000 comments were submitted by the public opposing the adoption of the ARM Revision, in large part due to the fact that the revised model allowed for a limited amount of female horseshoe crab harvest by the bait fishery. In response to the widespread public concern, the Board elected to implement a zero female horseshoe crab harvest for the 2023 season, despite the 2022 ARM model run recommending a female harvest limit of 125,000 horseshoe crabs for the 2023 season.

The Board expressed interest in evaluating the current goals and objectives for the Delaware Bay horseshoe crab fishery and ecosystem, given the apparent differences in stakeholder opinions on female harvest. After reviewing information on available resources and possible approaches, in May of 2023 the Board agreed to form a work group to develop a survey that would be distributed to stakeholders including bait harvesters and dealers, biomedical fishery and industry participants, and environmental groups. The goal of the survey is to provide insight into stakeholder perspectives to help inform the Board on whether to consider future changes to horseshoe management for the Delaware Bay region.

2. METHODS

Survey Development

The Delaware Bay Management Objectives Work Group (DBMO WG) met via webinar four times between June and September 2023 to develop the survey questionnaire. The WG members identified the following overarching research questions:

- Is there demand for harvest of female horseshoe crabs?
- Under what conditions would stakeholders be comfortable allowing female harvest?
- What management goals for the Delaware Bay region are important to stakeholders?
- Should the Board consider changes to the management program for setting Delaware Bay bait harvest specifications?

A survey questionnaire was developed to provide insight into these research questions. The questionnaire was reviewed by an external social science researcher to identify potential sources of bias and recommend changes. The final survey was created using online SurveyMonkey software. Survey logic was incorporated into the survey design to present certain questions to a respondent based on a previous response. Specifically, one set of questions was only administered to those who indicated their field of work was commercial fisheries. A copy of the final survey questionnaire is provided in Appendix A.

Survey Dissemination

This survey effort was aimed at better understanding stakeholder values regarding the Delaware Bay horseshoe crab fishery and population; therefore, the survey participants were limited to stakeholders from the Delaware Bay region. The DBMO WG aimed to survey individuals from various stakeholder groups with an interest in horseshoe crab management, including environmental conservation groups, commercial fishermen and dealers, biomedical industry, academics and researchers, and coastal community members.

The WG members identified specific individuals from New Jersey, Delaware, Maryland, and Virginia to participate in the survey representing the various stakeholder groups. Contacts were also collected from organizations that submitted public comments to the Management Board on Addendum VIII. A total of 107 individuals with available contact information were identified to receive the survey. Table 1 details the number of contacts provided by each state, and by stakeholder group.

Table 1. Survey contacts provided by states and stakeholder groups.

Group	Harvesters	Dealers	Other Fishermen	Environmental NGO	Biomedical	Towns	Other
#	26	4	39	25	4	3	6
State	**NJ**	**DE**	**MD**	**VA**			
#	53	15	18	17			

Using SurveyMonkey, the survey was disseminated via email to the recipients on August 22, 2023 and two reminder emails were sent to those that had not completed the survey (September 11 and 18, 2023). Each survey recipient was informed their responses would be anonymous.

3. RESULTS

Response Rate

Of the 106 individuals who received the survey invitation, 83 opened the survey (78.3%), 17 did not open the survey (16.0%), and 4 email invitations bounced (3.8%). A total of 40 responses to the survey were received, resulting in a 38% response rate.

The following sections provide the results of the survey, grouped by sets of related questions. Open-ended responses are provided in Appendix B, and additional figures are provided in Appendix C.

3.1 Questions 1-2. State of Residence and Occupation

The first two questions of the survey asked the respondents to indicate which state they lived in, and their primary field of work. The majority of respondents identified New Jersey as their state of residence (22 of 40, 55%), followed by Delaware (7, 18%), Virginia (6, 15%), and Maryland (3, 8%). One respondent each answered New York and Pennsylvania.

Of 11 possible multiple-choice options, the 40 respondents represented five occupational groups. The groups in descending order by number of respondents are: Commercial fisheries (harvesters and dealers) (21, 53%), Environmental conservation (8, 20%), Biomedical industry (4, 10%), Academia or research (4, 10%), and Unemployed or retired (3, 8%).

3.2 Questions for Harvesters and Dealers

Questions 3-7 in the survey was only administered to respondents who answered that their primary field of work is “Commercial fisheries (harvesters and dealers).” These questions were targeted at the fishing industry to better understand the makeup of the fishery and value of horseshoe crabs by sex. A total of 19 individuals responded to these questions.

Question 3. What are the horseshoe crabs that you harvest or sell used for?

The possible responses to this question were: bait, biomedical, both bait and biomedical, I do not know, and I do not harvest horseshoe crabs. Ten respondents harvest or sell horseshoe crabs for bait, five for both bait and biomedical, three do not harvest horseshoe crabs, and one does not know what the horseshoe crabs are used for. No respondents indicated that they only harvest or sell horseshoe crabs for biomedical purposes.

Question 4. Have you ever harvested or sold female horseshoe crabs for bait in the past?
The majority of respondents to this question indicated that they have harvested or sold female horseshoe crabs in the past (74%). Five responded that they have not (26%).

Question 5. How important is it to you to be able to harvest/sell female horseshoe crabs for bait in the future?
The possible responses to this question included: Not Important at All, Of Little Importance Of Average Importance, Very Important, and Absolutely Essential. Respectively, these responses were selected by 1, 1, 6, 7, and 4 individuals. The most common responses were "Very Important" (37%), "Of Average Importance (32%), and "Absolutely Essential" (21%) (Figure 1). By applying a numeric value to each of the above responses from one to five (1=Not Important at All, 5=Absolutely Essential) the average response across the 19 respondents is equal to 3.63. This indicates that on average, more commercial fishermen and dealers do think it is important to harvest/sell female horseshoe in the future than do not.

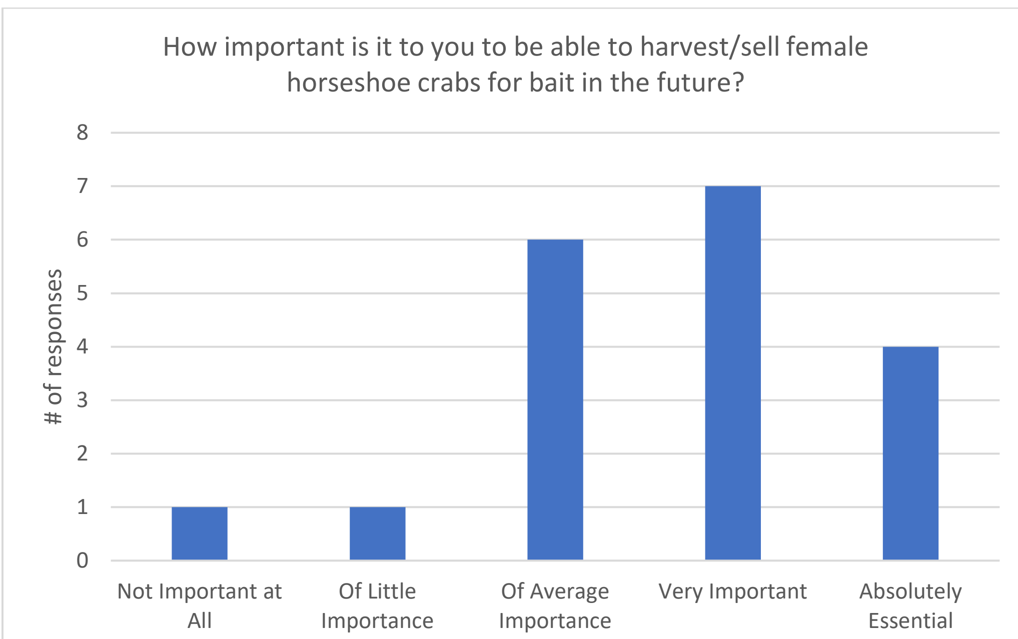

Figure 1. Importance of future female harvest.

Question 6. Value and demand for female horseshoe crabs
Question 6 asked respondents to express their level of agreement to two separate statements: "Female horseshoe crabs are worth more money than male horseshoe crabs" and "There is no market demand for female horseshoe crabs." Responses were given on a scale of 1 to 5, where 1 is "strongly agree" and 5 is "strongly disagree." The responses to each statement were significantly skewed, with the large majority in agreement that female horseshoe crabs are worth more money than males, and in disagreement that there is no market demand for female

horseshoe crabs (Figure 2). A single respondent disagreed with the first statement, and one respondent agreed with the second statement.

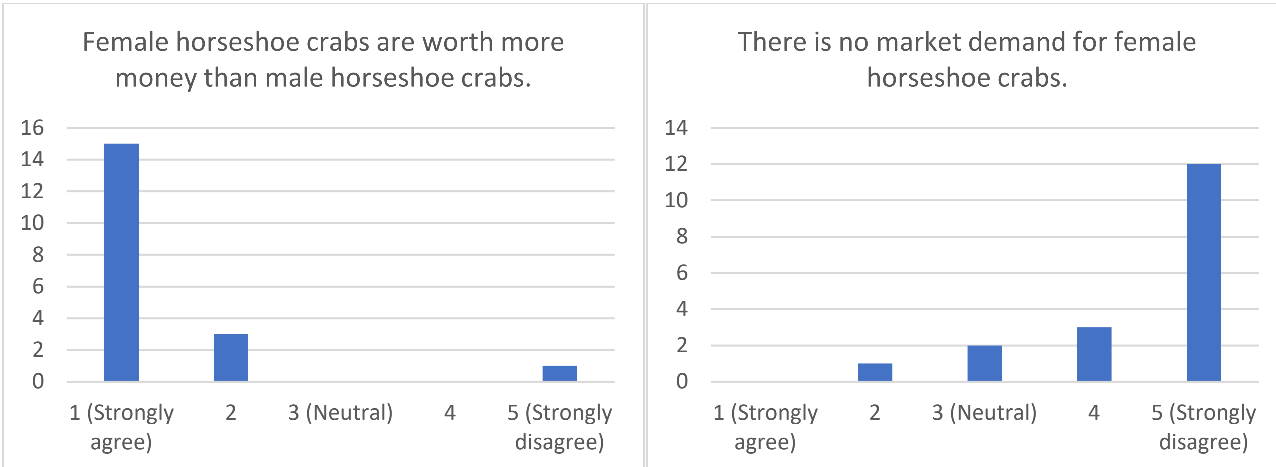

Figure 2. Perceived value (left) and demand for (right) of female horseshoe crabs.

Question 7. Preferences for female versus male harvest

Question 7 aimed to further understand the value of female harvest. Respondents were asked "Of the following two options, which do you prefer?" and only two possible choices were provided: 1) A larger overall quota of all male horseshoe crabs, or 2) A smaller overall quota including some female horseshoe crabs. The responses to this question were evenly split, with nine responses for each choice.

When the responses were broken down by state, two notable results are that all of the respondents from Virginia (n=4) prefer a smaller quota including some females, and the majority (70%) of respondents from New Jersey (n=10)—which currently has a moratorium on bait harvest—prefer a larger overall quota of all males. Table 2 provides responses by state.

Table 2. Question 7 responses by state.

State	A larger overall quota of all male horseshoe crabs	A smaller overall quota including some female horseshoe crabs
Delaware	2	1
Maryland		1
New Jersey	7	3
Virginia		4
Total	**9**	**9**

3.3 Perspectives on the Delaware Bay system

Question 8. Delaware Bay Perceptions

Question 8 was designed to elicit information on how stakeholders perceive different components of the Delaware Bay ecosystem, including the horseshoe crab population, bait fishery, and interactions with red knots. Participants were asked to respond to six statements with their level of agreement on a scale of 1 to 5, where 1 is "strongly agree" and 5 is "strongly disagree." The six statements are listed below:

A. The Delaware Bay population of horseshoe crabs is healthy.
B. The horseshoe crab bait fishery is negatively impacting the Delaware Bay population of horseshoe crabs.
C. The number of horseshoe crabs in the Delaware Bay population is increasing.
D. The horseshoe crab bait fishery is negatively impacting red knots in the Delaware Bay.
E. Fishermen should be allowed to harvest female horseshoe crabs from the Delaware Bay population if it is at a healthy level.
F. Fishermen should not be allowed to harvest male horseshoe crabs from the Delaware Bay population if it is at a healthy level.

There were 36 responses to this question. The responses to each statement tended to show bipolar trends, where the largest number of responses were divided between the two extremes, and fewer responses fell in the middle of the range. This seems to be primarily explained by diverging perspectives among different stakeholder groups (Table 3).

Table 3. Average responses to Question 8 by occupational group. Cells are color coded such that averages falling on the side of agreement are shaded in green, and averages falling on the side of disagreement are shaded in red, and averages in the neutral range are white.

Statement	Commercial fisheries (harvesters and dealers) (n=18)	Environmental conservation (n=7)	Unemployed or retired (n=3)	Biomedical industry (n=4)	Academia or research (n=4)
A	1.22	4.43	3.00	1.00	4.00
B	4.61	1.57	1.00	5.00	2.00
C	1.65	3.40	3.00	2.00	3.00
D	4.29	2.83	1.00	4.33	2.25
E	1.44	5.00	3.33	3.00	3.25
F	4.88	2.83	2.33	3.67	4.00

Question 9. Impacts on Horseshoe Crab Population

This question asked respondents to rank three issues by the level of impact they are thought to have on the Delaware Bay population of horseshoe crabs: climate change, horseshoe crab harvest, and human development of the shoreline.

There was a total of 35 responses to this question. The responses varied across occupational groups. When all responses from each occupational group were averaged, the ranking order of the three issues varied from group to group (Table 4, Figure 3). Higher average values equate to a higher level of perceived impact on the horseshoe crab population.

Table 4. Average rank value of horseshoe crab threats by occupational group. Higher value = higher impact.

Occupational Group	Average of Climate change	Average of Horseshoe crab harvest	Average of Human development of the shoreline
Academia or research (n=3)	2.00	2.25	1.75
Biomedical industry (n=4)	1.75	1.25	3.00
Commercial fisheries (harvesters and dealers) (n=18)	1.89	1.33	2.78
Environmental conservation (n=7)	1.50	2.50	2.00
Unemployed or retired (n=3)	1.67	2.00	2.33
Average of all responses (n=35)	1.80	1.69	2.51

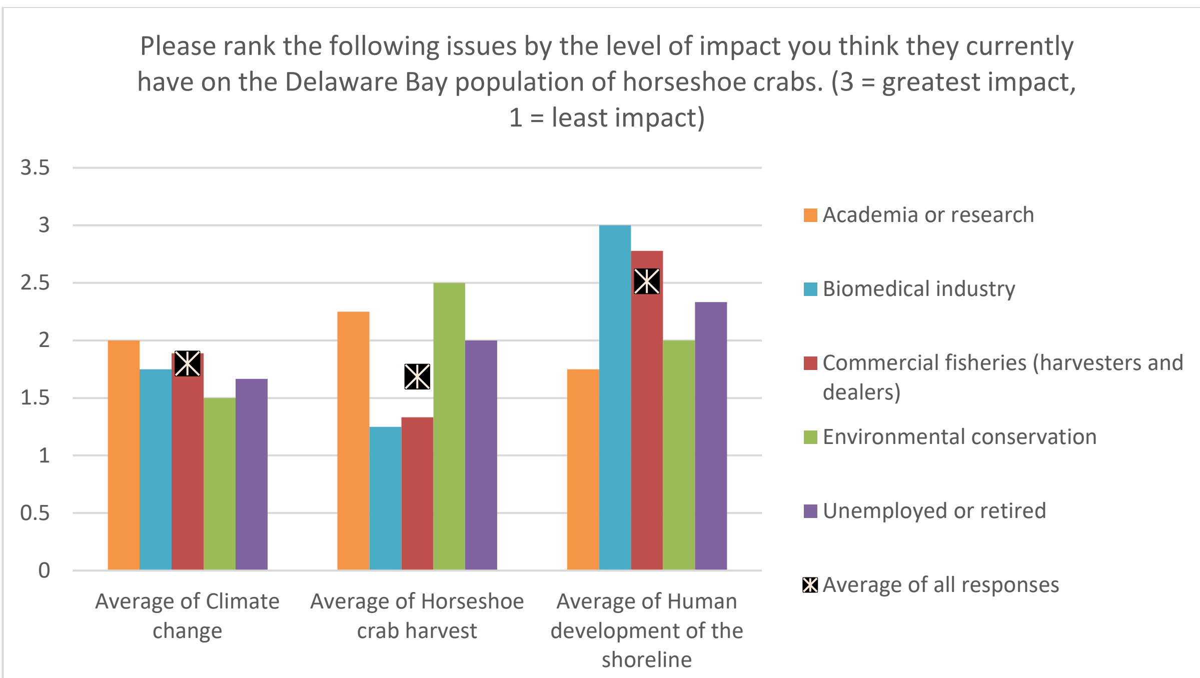

Figure 3. Perceived impacts of individual threats to horseshoe crab population. Higher average values equate to a higher level of perceived impact on the horseshoe crab population.

Question 10. Impacts on Red Knot Stopover Population

This question asked respondents to rank three issues by the level of impact they are thought to have on the red knots that stopover in the Delaware Bay during their migration: climate change, reduced food availability (horseshoe crab eggs) due to horseshoe crab harvest, and human development of the shoreline.

Similar to Question 9, there was substantial variation in the responses across different occupational groups (Table 5, Figure 4). Higher average values equate to a higher level of perceived impact on the red knot stopover population.

Table 5. Average rank value of red knot threats by occupational group. Higher value = higher impact.

Occupational Group	Average of Climate change	Average of Reduced food availability (horseshoe crab eggs) due to horseshoe crab harvest	Average of Human development of the shoreline
Academia or research (n=3)	2.00	2.33	1.67
Biomedical industry (n=4)	2.00	1.00	3.00
Commercial fisheries (harvesters and dealers) (n=18)	2.28	1.11	2.61
Environmental conservation (n=7)	1.43	2.57	2.00
Unemployed or retired (n=3)	2.00	2.00	2.00
Average across all responses (n=35)	2.03	1.57	2.40

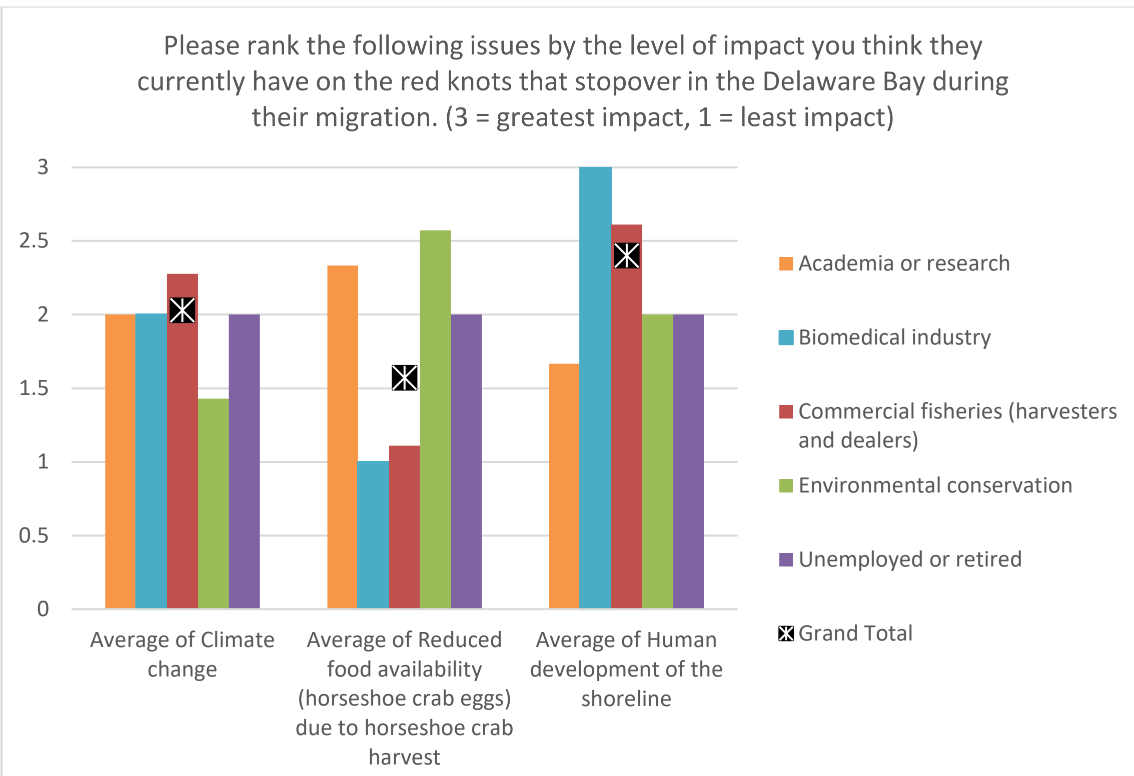

Figure 4. Perceived impacts of individual threats to red knot stopover population. Higher average values equate to a higher level of perceived impact on the red knot population.

Question 11. Importance of Management Objectives

Question 11 was designed to provide insight into the importance to stakeholders of various management objectives for the Delaware Bay horseshoe crab fishery. Participants were asked to indicate the level of importance of seven different management objectives. Possible responses included: Not Important at All, Of Little Importance, Of Average Importance, Very Important, and Absolutely Essential. The seven management objectives presented are listed below:

1. Maintaining a healthy population of horseshoe crabs
2. Maximizing forage (horseshoe crab eggs) for migrating shorebirds
3. Maximizing horseshoe crab bait harvest
4. Allowing horseshoe crabs to be used in the biomedical industry for human health
5. Protecting female horseshoe crabs
6. Using the best available science to inform management
7. Using a multi-species management approach that uses data on horseshoe crabs and shorebirds to recommend harvest levels

Thirty-four responses were received. For analysis, the responses were weighted as follows: Not Important at All = 1, Of Little Importance = 2, Of Average Importance = 3, Very Important = 4, and Absolutely Essential = 5. The average importance of each management objective was calculated across all responses and by occupational group (Figure 5, Table 6). Average values above 3.00 indicate that a management objective is perceived as above average importance, while average values below 3.00 indicate that an objective is perceived as below average importance.

Across all groups, Objective 1, Maintaining a healthy population of horseshoe crabs, was consistently considered to be above average importance (> 4.00) by all five groups. Maximizing forage (horseshoe crab eggs) for migrating shorebirds was considered above average importance for four of the five occupational groups. Maximizing horseshoe crab bait harvest was considered above average importance for two of the five groups ("commercial harvesters" and "unemployed or retired") and below average importance for the other three. Allowing horseshoe crabs to be used in the biomedical industry for human health was considered above average importance for four of five groups, with values generally falling closer to 3 (average importance) and showing greater variance than the responses for the other objectives (range: 2.57-5). For the last three objectives, all five groups considered them to be above average importance on average (> 3), but there was variation in the degree of importance across groups.

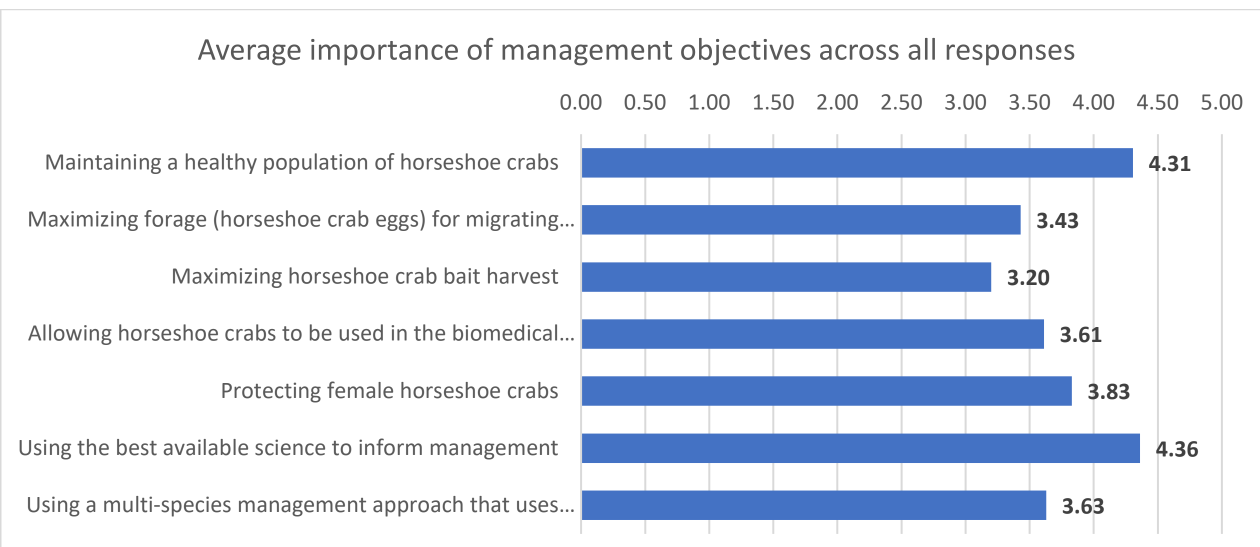

Figure 5. Average importance of management objectives across all responses.

Table 6. Average responses to Question 11 by occupational group. 1=Not important At All, 5=Absolutely Essential. Cells are color coded by column to indicate levels of importance assigned to each objective by each group, where the highest importance is shaded green and the lowest importance is shaded red.

Management Objectives	**Academia or research (n=4)**	**Biomedical industry (n=3)**	**Commercial fisheries (harvesters and dealers) (n=18)**	**Environmental conservation (n=6)**	**Unemployed or retired (n=3)**
Maintaining a healthy population of horseshoe crabs	5.00	4.75	4.00	4.43	4.33
Maximizing forage (horseshoe crab eggs) for migrating shorebirds	4.25	3.25	2.78	4.67	4.00
Maximizing horseshoe crab bait harvest	2.00	2.75	4.24	1.14	4.33
Allowing horseshoe crabs to be used in the biomedical industry for human health	3.25	5.00	3.78	2.57	3.67
Protecting female horseshoe crabs	4.50	3.33	3.28	5.00	4.00
Using the best available science…	4.75	3.33	3.17	4.00	4.33
Using a multi-species management approach…	4.75	3.33	3.17	4.00	4.33

Question 12. Ranking management goals

To provide additional insight into stakeholder priorities, Question 12 asked respondents to rank the first five management goals from the previous question by their level of importance. For analysis, responses were weighted with the most important item assigned a value of 5, and the least important assigned a value of 1. Consistent with the previous question, the results indicate that on average across all responses (n=36), maintaining a healthy population of horseshoe crabs is viewed as the most important management objective (Figure 6). Similar to previous issues, there is more variation among the responses when broken down by occupational group (Table 7).

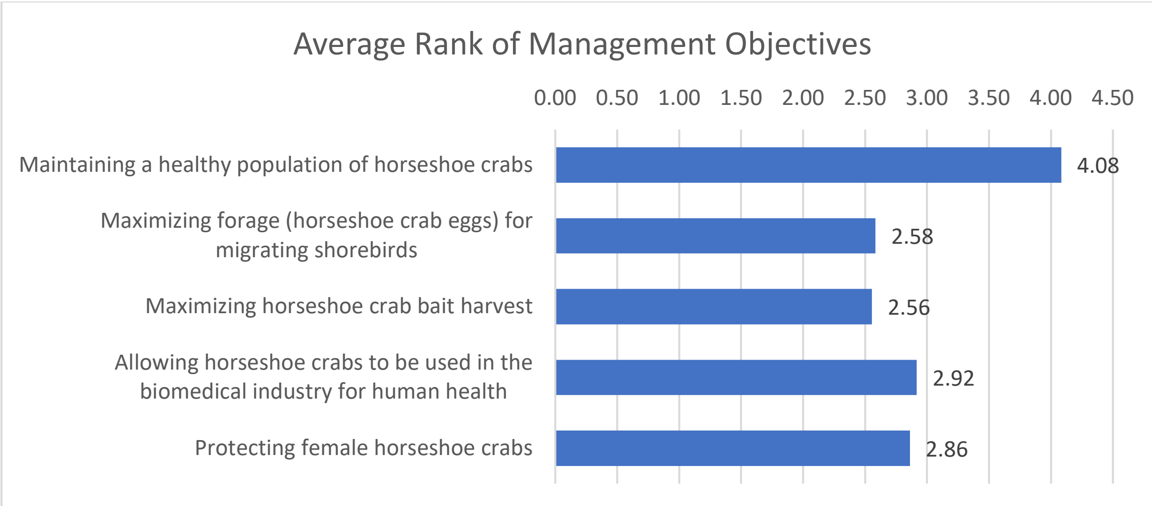

Figure 6. Average rank of management objectives based on importance across all responses. Higher value = higher rank.

Table 7. Average rank of management objectives based on importance, by occupational group. Cells are color coded by column to indicate average ranks assigned to each objective by each group, where the highest rank is shaded green and the lowest rank is shaded red.

Management Objectives	**Academia or research (n=4)**	**Biomedical industry (n=3)**	**Commercial fisheries (harvesters and dealers) (n=18)**	**Environmental conservation (n=6)**	**Unemployed or retired (n=3)**
Maintaining a healthy population of horseshoe crabs	4.75	4.25	4.17	4.00	2.67
Maximizing forage (horseshoe crab eggs) for migrating shorebirds	4.00	1.75	1.61	4.14	4.00
Maximizing horseshoe crab bait harvest	1.00	1.25	3.56	1.29	3.33
Allowing horseshoe crabs to be used in the biomedical industry for human health	2.00	4.25	3.39	2.00	1.67
Protecting female horseshoe crabs	3.25	3.50	2.28	3.57	3.33

3.4 Perspectives on the Adaptive Resource Management (ARM) Model and Female Harvest

Questions 13-14. Should the ARM model be modified?

Question 13 specifically asked survey participants if they think the ARM Model, as revised in 2021, should be modified. Of the 36 responses, 47% said yes, 20% said no, and 33% said "I don't know" (Figure 7). Among most occupational groups, there was not a clear tendency toward any particular response.

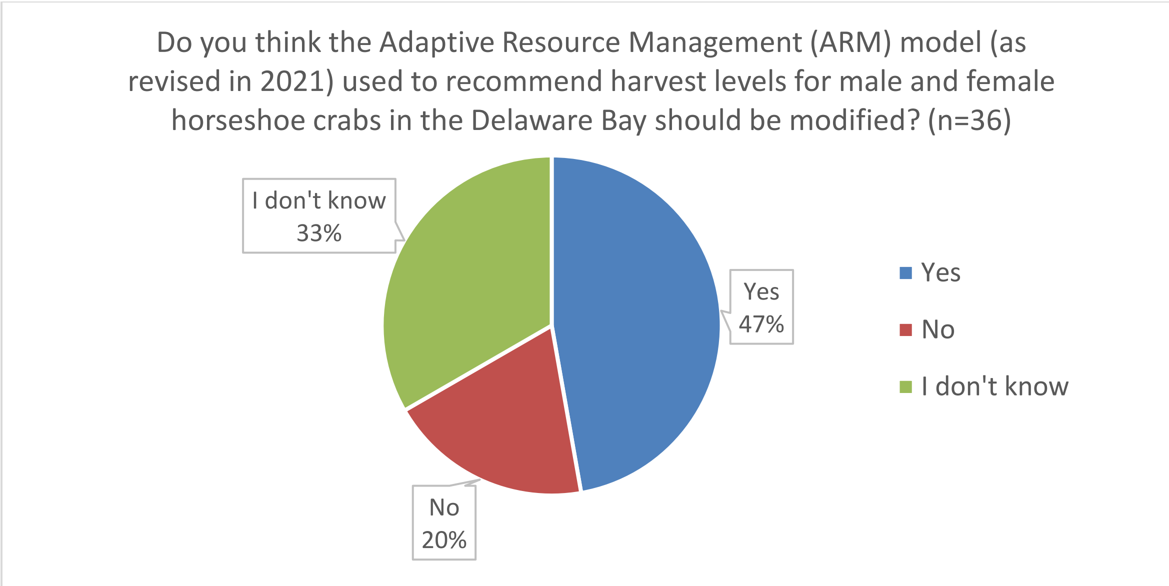

Figure 7. Opinion on whether the current ARM Model should be revised.

Respondents who answered “Yes” to Question 13 were presented with another question: “Why do you think ARM model used to recommend harvest levels for male and female horseshoe crabs in the Delaware Bay should be modified?” Sixteen open-ended responses were provided. Among the commercial fishery members who responded, a prevailing theme in the responses is that there are more horseshoe crabs than what is estimated in the ARM. A few responses stated that New Jersey should be given some opportunity for harvest. One commercial industry member advocated for Delaware Bay horseshoe crabs to be used only for biomedical purposes and not for bait because of the low mortality rate and the greater value of biomedical crabs. Seven responses, mostly from academic or environmental conservation respondents, referenced issues with the model and the built-in assumptions in the framework. For example, some stated that the model underestimates the relationship between horseshoe crabs and red knots, that the model population estimates do not accurately reflect the conditions of either species, and that it underestimates the impact of biomedical removals. Two comments stated that there should be a larger horseshoe crab population before increased harvest is allowed. All open-ended responses to this question are provided in Appendix B.

Questions 15-16. Should a limited amount of female harvest be allowed?

Question 15 specifically asked survey participants if they think a limited amount of female horseshoe crab bait harvest should be allowed at this point in time. Of 35 total responses, 49% said yes (n=17), 37% said no (n=13), and 14% said “I don’t know” (n=5). The distribution of responses varied between occupational groups. For the “academia and research” group responses were split evenly between “No” and “I don’t know.” The majority (14 of 18) of commercial fisheries group answered “Yes,” while 100% of the environmental conservation group answered “No.” The “biomedical industry” group responses included two “Yes” and one “I don’t know.” The responses from the “unemployed or retired” group were split evenly among all three answers (Figure 8).

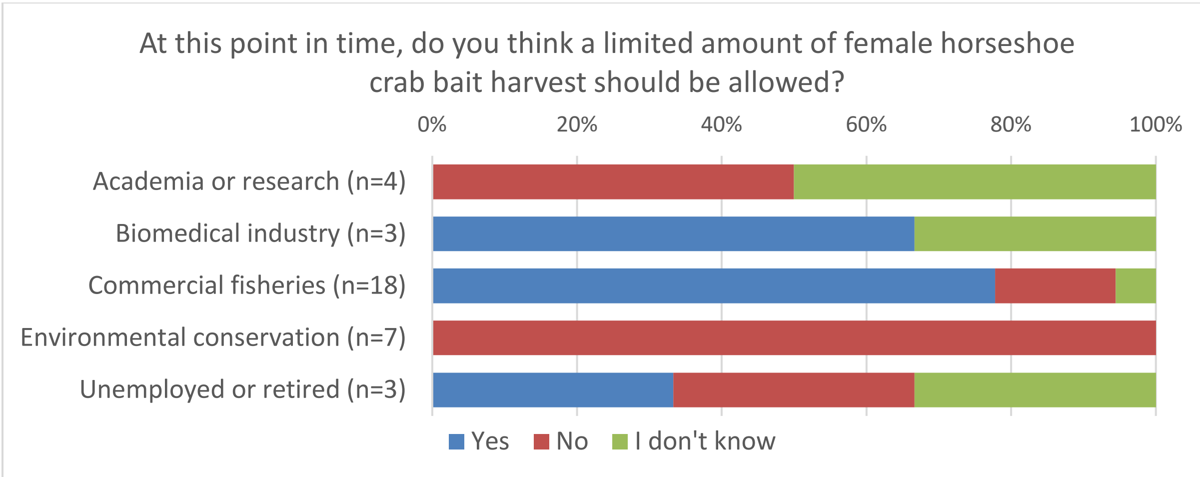

Figure 8. Opinion on allowing female bait harvest within occupational groups.

Participants that answered "No" to Question 15 were presented with another question: "Under what conditions should harvest of female horseshoe crabs be allowed?" Eleven open-ended responses were provided. Three responses indicated that female harvest of horseshoe crabs should not be allowed under any conditions, and another said that female harvest is not necessary. One response said that females should only be used for biomedical purposes. Three responses stated that female harvest should only be allowed once horseshoe crab and/or red knot populations have rebounded to near historic levels. One response argued that females should be harvested according to the original ARM framework until the current framework has been evaluated by multiple stakeholders. All open-ended responses to this question are provided in Appendix B.

Question 17. Use of female horseshoe crabs by the biomedical industry

This question aimed to understand stakeholder opinions about whether female horseshoe crabs should be collected for biomedical purposes. Thirty-five responses were given, and 46% said "Yes," 43% said "No" and 11% said "I don't know". Occupational groups responded differently to this question (Figure 9).

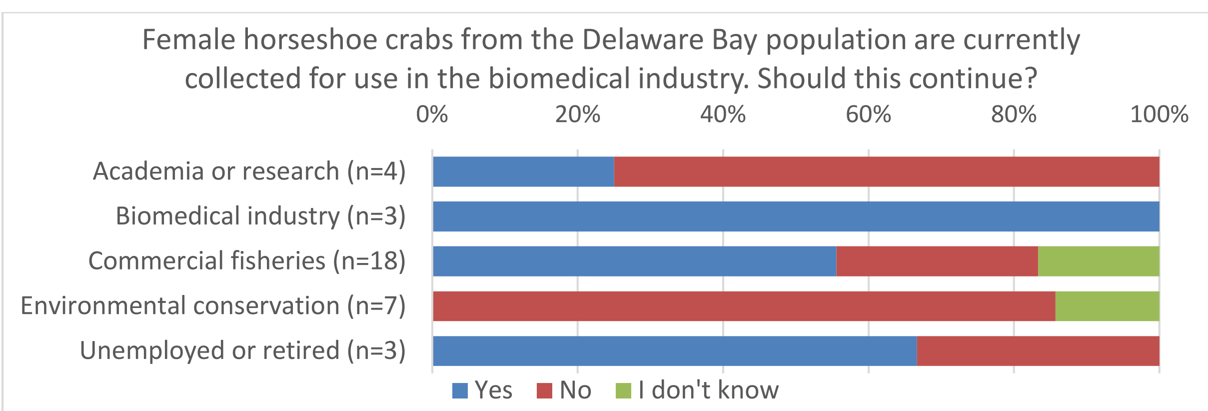

Figure 9. Opinion on biomedical use of female horseshoe crabs within occupational groups.

3.5 Question 18. What do you think is most important for managers to consider when making decisions about the management of the Delaware Bay horseshoe crab population?
The final survey question aimed to allow respondents to add additional information that may not have been considered in the other survey questions. Thirty-two open ended answers were submitted describing what the respondent thinks is the most important issue for managers to consider relative to this issue. A wide variety of topics and perspectives were addressed in these responses. The two most commonly mentioned issues were the health of the horseshoe crab population (n=9), and basing management decisions in robust science (n=5). Four responses focused on allowing sufficient bait harvest, and three responses emphasized the importance of impacts on fishermen and coastal communities. Two responses highlighted the importance of the greater ecosystem, including the role of horseshoe crabs and other species. Two responses specifically mentioned supporting shorebird recovery. Two responses highlighted allowing for biomedical use of horseshoe crabs, while two other responses advocated for switching to synthetic alternatives for bait and limulus amebocyte lysate (LAL). One response focused on the importance of maintaining adequate spawning beaches. One response emphasized the need to improve the data used for management. All open-ended responses to this question are provided in Appendix B.

4. DISCUSSION

The responses to this survey reflect one of the prominent challenges of managing the Delaware Bay horseshoe crab population, of which the Board has long been aware: a variety of stakeholders have an interest in the Delaware Bay population of horseshoe crab, but these stakeholder groups have diverging and sometimes contradictory management goals. The survey results provide some insight on the values and objectives of certain stakeholder groups.

The results clarify that within the commercial industry, including horseshoe crab harvesters and dealers, and fishermen who use horseshoe crab as bait, there is demand for female horseshoe crabs and they are considered more valuable than males. The majority of the commercial industry respondents have harvested females in the past, and indicate that harvesting females in the future is important to them. The majority of commercial industry respondents think a limited amount of female harvest should be allowed at present, but a few do not. Among the biomedical and academic stakeholders there is less certainty on allowing female harvest, and for environmental conservation respondents the unanimous opinion is that no female harvest should be allowed at this time. Among the respondents who do not think any female harvest should be allowed, there is a divide between individuals who think female harvest could be allowed once horseshoe crab and red knot populations have rebounded to near historic levels, and individuals who think it should never be allowed.

Regarding management goals, the results are mixed on which goals are perceived as most important. Researchers and environmental groups tended to value the protection of female horseshoe crabs and the ecological role of horseshoe crabs as a food source for shorebirds over the fishery. Commercial fishery participants attribute greater importance to bait harvest.

One area where almost all stakeholder groups agree is on the importance of maintaining a healthy horseshoe crab population. Across stakeholder groups this remains a top priority for management. However, there are differing opinions on the current state of the Delaware Bay population and the impacts of the bait fishery. While the commercial fishery participants tend to have a more positive perception, the environmental and academic participants tend to disagree with the idea that the Delaware Bay population is healthy, and think the bait fishery is having a negative impact on the horseshoe crab population.

A significant proportion of survey respondents think the ARM Model should be revised. Those respondents belong to various stakeholder groups and have a number of reasons for their opinions. Most commercial fishery respondents think the ARM should be revised because it is underestimating the numbers of horseshoe crabs, whereas other stakeholders argue it is overestimating the populations of horseshoe crabs and red knots. Nevertheless, the survey results are clear that stakeholders highly value the use of the best available science to inform management.

Appendix A. Survey Questionnaire

Delaware Bay Horseshoe Crab Management Survey

The Horseshoe Crab Management Board of the Atlantic States Marine Fisheries Commission (Commission) is seeking input from stakeholders regarding management of the Delaware Bay population of horseshoe crabs. As a stakeholder with an interest in horseshoe crab management, you have been selected to participate in this survey because of the valuable perspective you can provide on this issue. The purpose of the survey is to better understand the value of horseshoe crabs to stakeholders and guide the Board in evaluating the management objectives established in the fishery management plan.

All survey responses will be anonymous, and the results will be generalized such that individual responses will not be discernable. Your participation and engagement in the management process by completing this survey are greatly appreciated.

Delaware Bay Horseshoe Crab Management Survey

Participant Information

* 1. In what state or U.S. territory do you live?

* 2. What is your primary field of work?

- Commercial fisheries (harvesters and dealers)
- Fisheries management
- Environmental conservation
- Biomedical industry
- Academia or research
- Legislature
- Tourism industry
- State government
- Federal government
- Unemployed or retired
- Other (please specify)

Delaware Bay Horseshoe Crab Management Survey

Questions for Commercial Harvesters and Dealers

3. What are the horseshoe crabs that you harvest or sell used for?

- Bait
- Biomedical
- Both bait and biomedical
- I do not know
- I do not harvest horseshoe crabs
- Other (please specify)

4. Have you ever harvested or sold female horseshoe crabs for bait in the past?

- Yes
- No

5. How important is it to you to be able to harvest/sell female horseshoe crabs for bait in the future?

- Not Important at All
- Of Little Importance
- Of Average Importance
- Very Important
- Absolutely Essential
- This does not apply to me

6. On a scale of 1 to 5, where 1 is "strongly agree" and 5 is "strongly disagree," express your level of agreement with the following statements:

	1. Strongly agree	2	3. Neutral	4	5. Strongly disagree
Female horseshoe crabs are worth more money than male horseshoe crabs.	○	○	○	○	○
There is no market demand for female horseshoe crabs.	○	○	○	○	○

7. Of the following two options, which do you prefer?

- ○ A larger overall quota of all male horseshoe crabs
- ○ A smaller overall quota including some female horseshoe crabs

Delaware Bay Horseshoe Crab Management Survey

The questions in this survey ask about the Delaware Bay horseshoe crab population, and the management of the fishery in the Delaware Bay region. The Delaware Bay population includes horseshoe crabs within the state waters of New Jersey, Delaware, Maryland, and Virginia and adjacent federal waters.

Horseshoe crabs from the Delaware Bay region (New Jersey-Virginia) have been of particular concern due to their relationship with red knots, a shorebird species currently listed as Threatened by the US Fish and Wildlife Service. The red knot is one of the many shorebird species that feed on horseshoe crab eggs in the Delaware Bay region during their annual migration from South America to the Arctic.

For the purposes of this survey, a "healthy" horseshoe crab population is considered to be one with enough horseshoe crabs to supply enough food for the shorebirds and sustain fishery harvest.

8. On a scale of 1 to 5, where 1 is "strongly agree" and 5 is "strongly disagree," express your level of agreement with the following statements:

	1. Strongly agree	2	3. Neutral	4	5. Strongly disagree
The Delaware Bay population of horseshoe crabs is healthy.	○	○	○	○	○
The horseshoe crab bait fishery is negatively impacting the Delaware Bay population of horseshoe crabs.	○	○	○	○	○
The number of horseshoe crabs in the Delaware Bay population is increasing.	○	○	○	○	○
The horseshoe crab bait fishery is negatively impacting red knots in the Delaware Bay.	○	○	○	○	○
Fishermen should be allowed to harvest female horseshoe crabs from the Delaware Bay population if it is at a healthy level.	○	○	○	○	○
Fishermen should not be allowed to harvest male horseshoe crabs from the Delaware Bay population if it is at a healthy level.	○	○	○	○	○

9. Please rank the following issues by the level of impact you think they currently have on the Delaware Bay population of horseshoe crabs. (1 = greatest impact, 3 = least impact)

☐ Climate change

☐ Horseshoe crab harvest

☐ Human development of the shoreline

10. Please rank the following issues by the level of impact you think they currently have on the red knots that stopover in the Delaware Bay during their migration. (1 = greatest impact, 3 = least impact)

- [ ] Climate change
- [ ] Reduced food availability (horseshoe crab eggs) due to horseshoe crab harvest
- [ ] Human development of the shoreline

Delaware Bay Horseshoe Crab Management Survey

11. How important to you is each of the following management objectives for the Delaware Bay population of horseshoe crabs?

	Not Important at All	Of Little Importance	Of Average Importance	Very Important	Absolutely Essential
Maintaining a healthy population of horseshoe crabs	○	○	○	○	○
Maximizing forage (horseshoe crab eggs) for migrating shorebirds	○	○	○	○	○
Maximizing horseshoe crab bait harvest	○	○	○	○	○
Allowing horseshoe crabs to be used in the biomedical industry for human health	○	○	○	○	○
Protecting female horseshoe crabs	○	○	○	○	○
Using the best available science to inform management	○	○	○	○	○
Using a multi-species management approach that uses data on horseshoe crabs and shorebirds to recommend harvest levels	○	○	○	○	○

12. Rank these management goals for the Delaware Bay region by their level of importance to you. (1 = most important, 5 = least important)

- ☐ Maintaining a healthy population of horseshoe crabs
- ☐ Maximizing forage (horseshoe crab eggs) for migrating shorebirds
- ☐ Maximizing horseshoe crab bait harvest
- ☐ Allowing horseshoe crabs to be used in the biomedical industry for human health
- ☐ Protecting female horseshoe crabs

Delaware Bay Horseshoe Crab Management Survey

In 2012, the Commission adopted the use of the Adaptive Resource Management (ARM) Framework for setting harvest levels for horseshoe crabs of Delaware Bay-origin given the important ecological role horseshoe crab eggs play in the food web for migrating shorebirds in that region. The ARM Framework considers the abundance levels of horseshoe crabs and red knots, as well as values previously expressed by stakeholders, in determining the optimal harvest level for horseshoe crabs from the Delaware Bay population. The ARM Framework was revised and peer reviewed in 2021.

Abundance surveys are used for both red knots and horseshoe crabs to estimate population sizes. The ARM Revision uses fishery-dependent data for horseshoe crabs from the commercial bait fishery, dead discard estimates from other fisheries, and mortality estimates from the biomedical industry. Based on these population estimates, and stakeholder values, the Framework recommends the appropriate number of male and female horseshoe crabs that can be harvested for the commercial bait fishery without limiting the population growth of red knots.

13. Do you think the Adaptive Resource Management (ARM) model (as revised in 2021) used to recommend harvest levels for male and female horseshoe crabs in the Delaware Bay should be modified?

- ◯ Yes
- ◯ No
- ◯ I don't know

Delaware Bay Horseshoe Crab Management Survey

14. Why do you think ARM model used to recommend harvest levels for male and female horseshoe crabs in the Delaware Bay should be modified? Answer below.

Delaware Bay Horseshoe Crab Management Survey

15. The current management framework allows for the possibility of limited commercial harvest of female horseshoe crabs from the Delaware Bay population based on the number of horseshoe crabs and red knots. At this point in time, do you think a limited amount of female horseshoe crab bait harvest should be allowed?

- ◯ Yes
- ◯ No
- ◯ I don't know

Delaware Bay Horseshoe Crab Management Survey

16. Under what conditions should harvest of female horseshoe crabs be allowed?

Delaware Bay Horseshoe Crab Management Survey

17. Female horseshoe crabs from the Delaware Bay population are currently collected for use in the biomedical industry. Should this continue?

- ◯ Yes
- ◯ No
- ◯ I don't know

Delaware Bay Horseshoe Crab Management Survey

18. What do you think is most important for managers to consider when making decisions about the management of the Delaware Bay horseshoe crab population?

Delaware Bay Horseshoe Crab Management Survey

Optional Demographic Information

19. What is your age?

- ◯ 17 or younger
- ◯ 18-20
- ◯ 21-29
- ◯ 30-39
- ◯ 40-49
- ◯ 50-59
- ◯ 60 or older
- ◯ Choose not to answer

20. What is your gender?

- ◯ Female
- ◯ Male
- ◯ Other
- ◯ Choose not to answer

21. Which race/ethnicity best describes you? (Select all that apply)

- ☐ American Indian or Alaskan Native
- ☐ Asian / Pacific Islander
- ☐ Black or African American
- ☐ Hispanic
- ☐ White / Caucasian
- ☐ Choose not to answer
- ☐ Multiple ethnicity / Other (please specify)

Delaware Bay Horseshoe Crab Management Survey

Thank you for completing this survey!

The Commission's Horseshoe Crab Management Board greatly appreciates your perspective on this topic. The Management Board will review the results of the survey at its next meeting.

Appendix B. Open-Ended Survey Responses

Question 14. Why do you think ARM model used to recommend harvest levels for male and female horseshoe crabs in the Delaware Bay should be modified?
The horseshoe crab levels should be a lot stronger than they have been because the harvesting have been restrictive.
The ARM model vastly underestimates the importance of horseshoe crabs to red knots and thus recommends dangerously high harvest levels. It also generates estimates and projections of horseshoe crab and red knot abundance that do not accurately reflect the conditions of either species. Considering the precarious state of the ecosystem, ASMFC should take a risk-averse approach.
More crabs now then 2007.
I believe it underestimates the levels of impacts to both horseshoe crabs and shore birds
I think NJ should be allowed to harvest
I feel that female horseshoe crabs should be exclusively utilized for bio-medical purposes. The value per crab and the very low mortality rate by live return to sea, far outweighs the value of females for bait and far outweighs 100% bait mortality. Female survival is essential to sustaining a healthy stock biomass.
Because it sucks
We need more harvest and mortality data from the pharmaceutical industry. They should not be exempt from supplying data. In addition, the model should be giving more weight to the horseshoe crab / shorebird recourses in the Delaware Bay. The bait harvest industry while a worthwhile endeavor should not trump the resources. Female horseshoe crabs should not be harvested until the population recovers to near historic levels.
I feel that there are many more crabs than they think
The numbers of crabs in the Delaware Bay are not yet at a sustainable level. I believe we need a few more years of significant increase not occurring using the current ARM model
Puts too much emphasis on allowing HSC harvest before the populations number have fully rebounded. Also underestimates negative effect of crab bleeding.
You are not taking in consideration the use of one female horseshoe crab for bait will save millions of eggs. We are using the horseshoe crabs to catch everything that is eating the eggs in the water. For instance one horseshoe crab could catch 10 pounds of eels how many eggs do you think 10 pounds of eels can eat in a year?
Crabs are more plentiful and NJ moratorium in place 16 years lifted and NJ and Delaware should be alternate. 1 state every other year to be more equitable
It should be modified to include harvest impacts in a diversity of species, not just red knots.
Many assumptions of the model are problematic and unsupported, likely affecting the inferences being made by model developers with respect to the status of the horseshoe crab populations and their relationship to Red Knot population viability.
Because it doesn’t allow for female harvest of local population of female’s that are not from the Delaware Bay population

Question 16. Under what conditions should harvest of female horseshoe crabs be allowed?
Given the importance of female horseshoe crabs to the ecosystem and the harm that their removal has caused, it is difficult to imagine a scenario when harvesting them would be justified. At a minimum, both horseshoe crabs and red knots would need to have recovered to their pre-overharvest abundance levels, with enough of a buffer to ensure that a female harvest would not precipitate another decline. Those conditions seem very remote today.
Under no conditions should female horseshoe crabs be harvested
It isn't necessary
Bio-Medical use only
none
After the population recovers to near historic levels.
When fishermen needed them just like it was.
When HSC populations number and egg densities on the spawning beaches are up to earlier documented levels.
ABSOLUTELY NONE
As proposed in the original ARM framework. However, interpretation of the existing data and the outputs of the current ARM framework must be scrutinized and evaluated by multiple stakeholders. To date, this has not been done.
On all occasions

Question 18. What do you think is most important for managers to consider when making decisions about the management of the Delaware Bay horseshoe crab population?
Healthy population so you can have enough for the biomedical research
Managers should prioritize the critical and unique role of horseshoe crabs in the ecosystem, including the many species and processes that depend on them.
The health of the horseshoe crab population, utilizing the best available horseshoe crab population data and ensuring that horseshoe crabs can continue to be collected for the Limulus Amebocyte Lysate (LAL) test that is critical to human health
Make a decision on future harvest or buy the few licenses that are left. People make a living off the water!
Increasing the population of horseshoe crabs and supporting shore bird migration and populations.
I'm in MD there management is working fine
Not sure
In New Jersey the harvest method should be addressed. Many horseshoe permit holders have the ability to harvest crabs in other fisheries that do not require a hand harvest on the beach during the spawn of the horseshoe crab. If a permit holder can harvest horseshoe crabs in another legal fishery it will eliminate the interaction of harvesters and horseshoe crabs spawning on the shoreline as our current regulation requires that method to collect them. As an example such as a winter dredge fishery or spring Gillnet, the horseshoe crab that could be harvested in that manner would not be pulled from the sandy shorelines during the time when the crab spawns. The beach collection is not favorable due to the fact that that crab is there to

spawn. If it's harvest in another fishery other than hand/beach harvest it's not collecting a spawning crab which may or may not make it to the shoreline due to other environmental reasons or threats.
Whether horseshoe crabs have the ability to change sex depending on the lesser of one or the other sex
The use of existing alternative to HSC blood is now possible HSC should be phased out Bait alternatives also exist
Keeping the resource strong and robust. Create the greatest use benefit to human population in mortality estimates and calculations. The Red Knot need for the eggs is essential, although should not be arbitrary in reasoning to limit Horseshoe Crab usage. How will having a Wind Energy Farm located on top of the Schuster Sanctuary, effect the long-term viability of the resource?
Ecological interrelationships between horseshoe crabs and other species including shorebirds
That Delaware's season is after the bulk of the crabs have already laid their eggs.
Use scientifically-robust data and models, including analyses and interpretation by scientists not affiliated with affected states.
Maintain a balance of both the female and male population to their percentage so they can reproduce sufficiently. We do not want to overharvest to prevent their reproduction. Our main goal is to not only preserve the red knots but also the horseshoe crabs also.
Current population and collection data is extremely important, especially data from the pharma industry. Without this data the current model does not work as well as it could.
Having real science done and not made up science like all the science in the past for the birds..!!
The stock of the crabs
When making the decisions managers should take the actual science for what it's worth and not change the method once it doesn't meet their agenda.
I think they need to push for additional use of synthetic baits for the fishing industry and synthetic blood substitutes for the medical industry. They need to look at overall impacts, not just horseshoe crab population size.
Data. Full stop.
Make a reasonable amount of horseshoe crabs available for bait.
That HSC population numbers haven't fully rebounded and is not producing an overabundance of eggs needed to sustain shorebird foraging needs.
Recovery of the Red Knot
Using horseshoe crabs for bait and catching what is eating their eggs we help the population. Less predators more prey Simple
NJ license permit holders should be the ones to harvest these biomedical crabs currently NJ has established monopoly should be ivestigated anti trust violations
Horseshoe crab population
The current population of horseshoe crabs is just a fraction of its historic numbers. Any management decisions should be to increase their population numbers not just maintain current levels.

Use ecological endpoints for recovery of horseshoe crab populations.   Consider the importance of horseshoe crabs as a keystone species in near shore inter tidal communities, not only for migratory shorebirds, but fishes and other marine organisms.
The fisherman
Financial and cultural impact on small coastal communities.
It is very important to keep the spawning beaches from becoming over developed and not having anywhere for the Horseshoe Crabs to spawn

Appendix C. Additional Figures

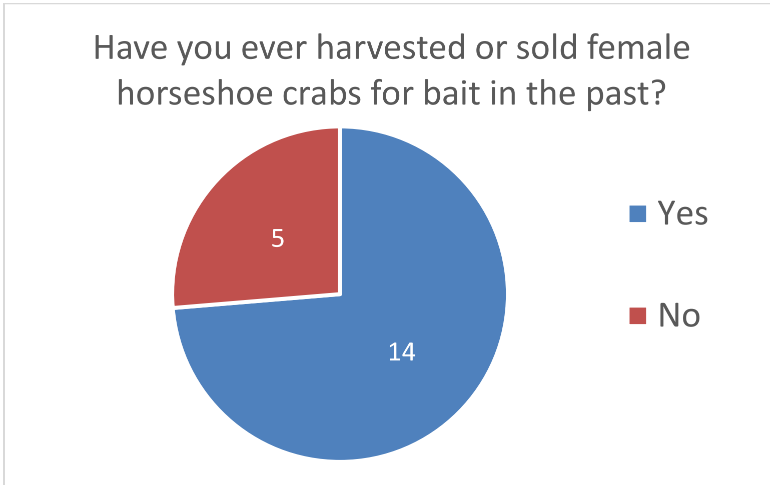

Figure A1. Past female horseshoe crab harvest.

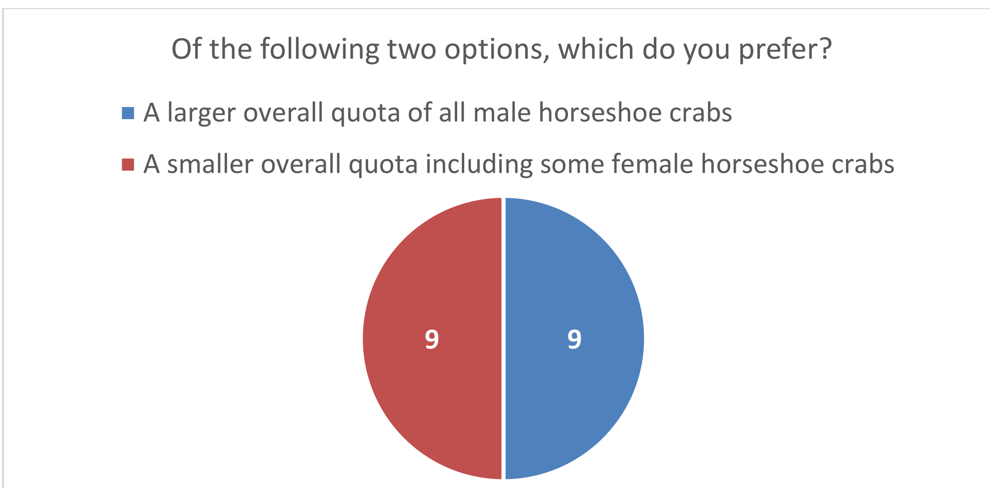

Figure A2. Preferences for harvest quota makeup.

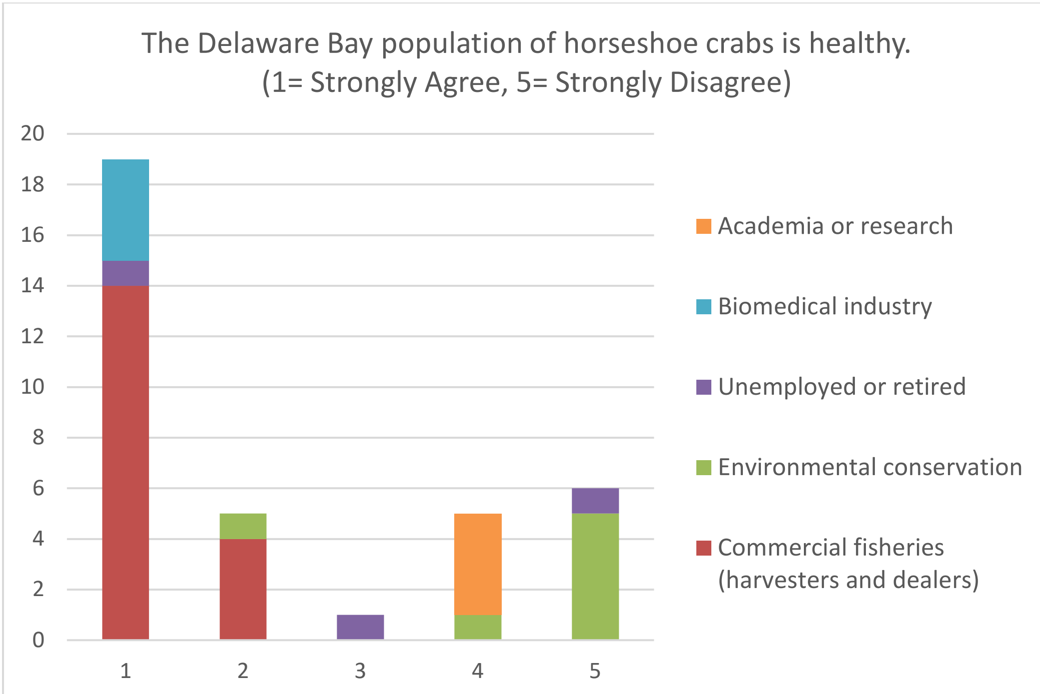

Figure A3. Perception of Delaware Bay horseshoe crab population health.

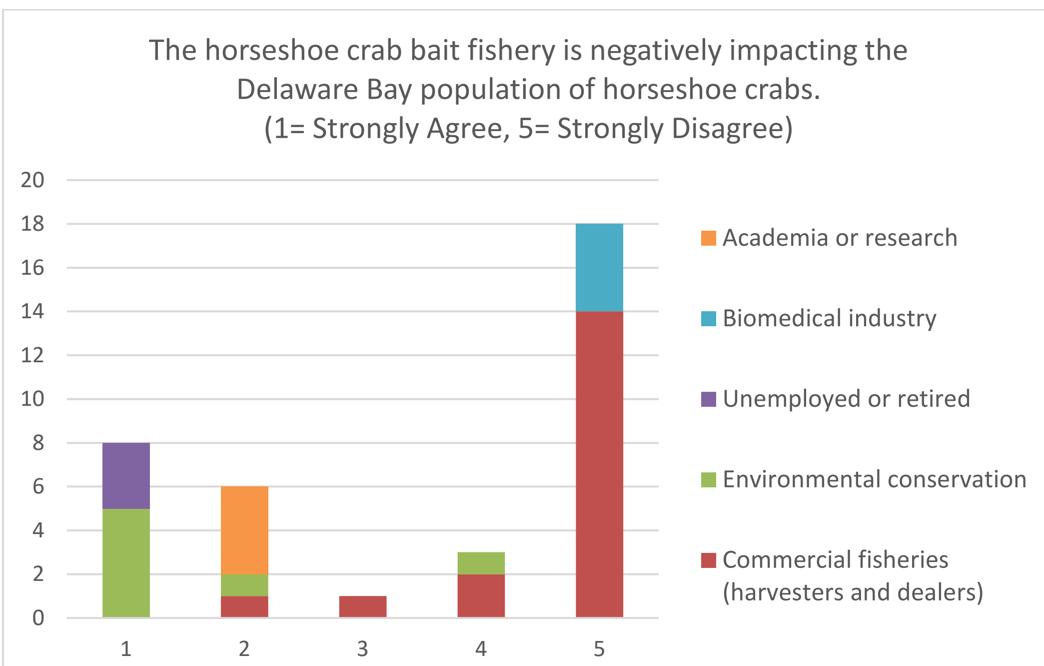

Figure A4. Perception of bait fishery impacts on horseshoe crab population.

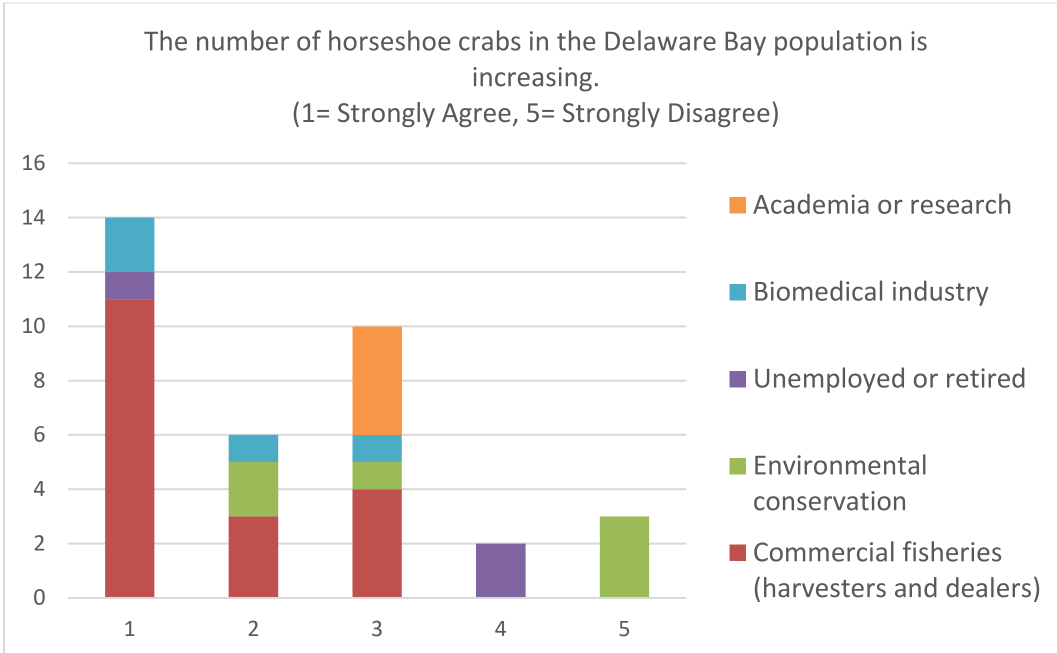

Figure A5. Perception of Delaware Bay horseshoe crab population growth.

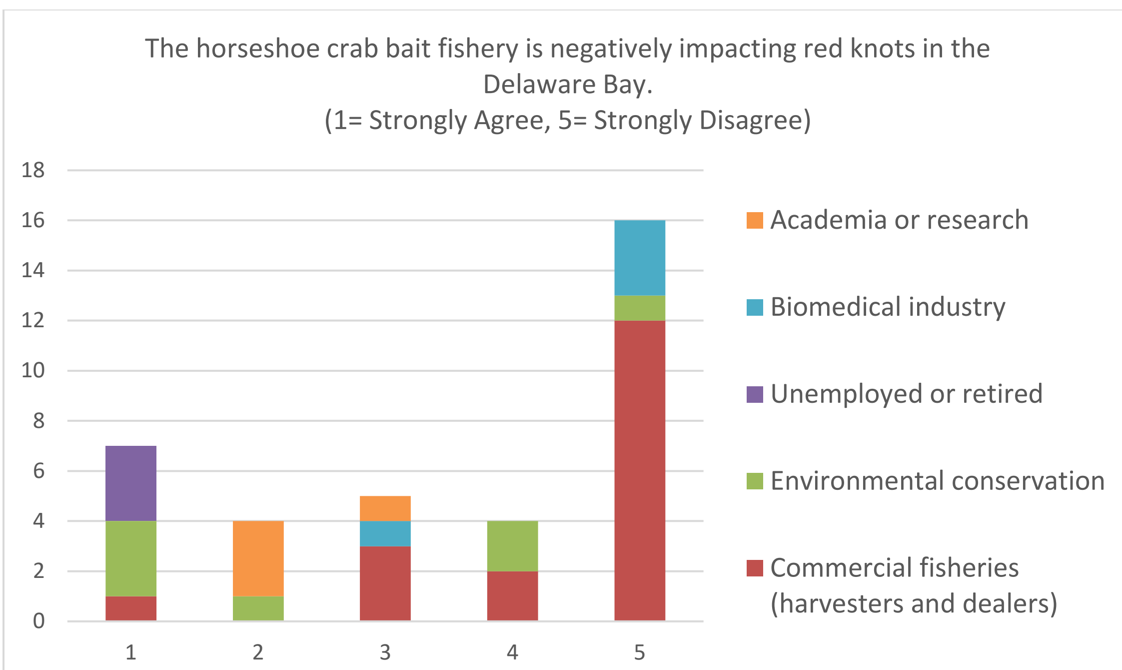

Figure A6. Perception of bait fishery impacts on red knots.

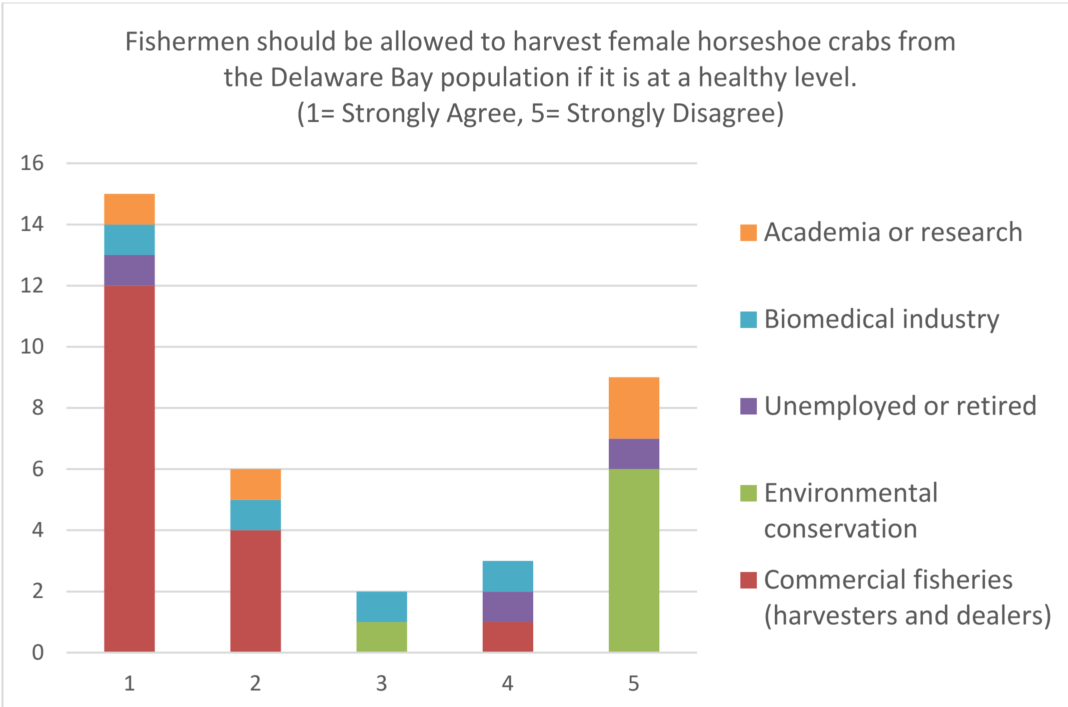

Figure A7. Opinion on female harvest allowance.

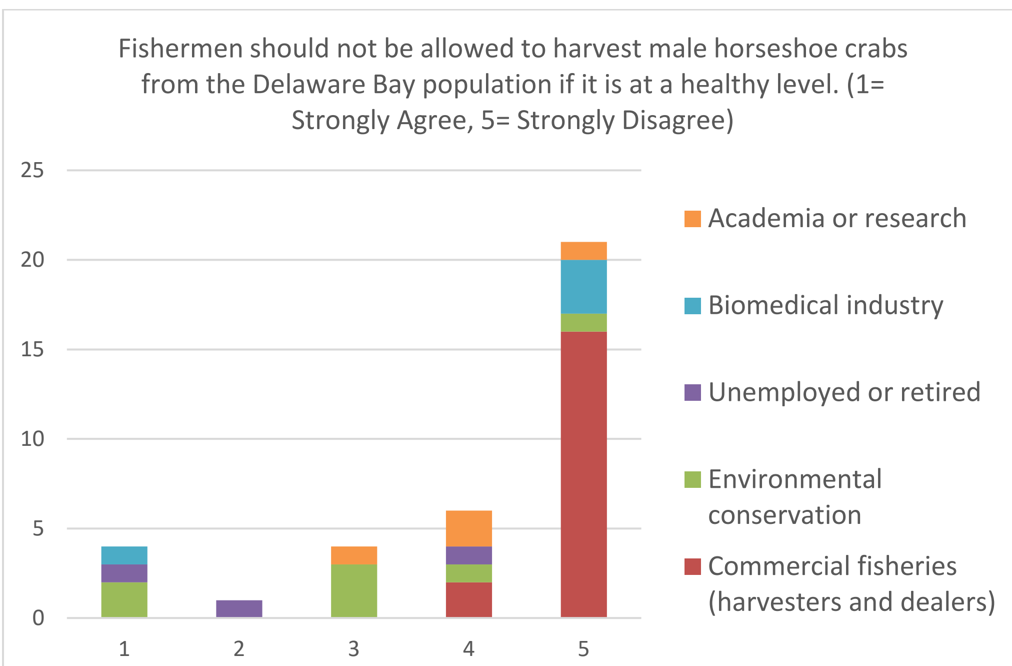

Figure A8. Opinion on male harvest allowance.

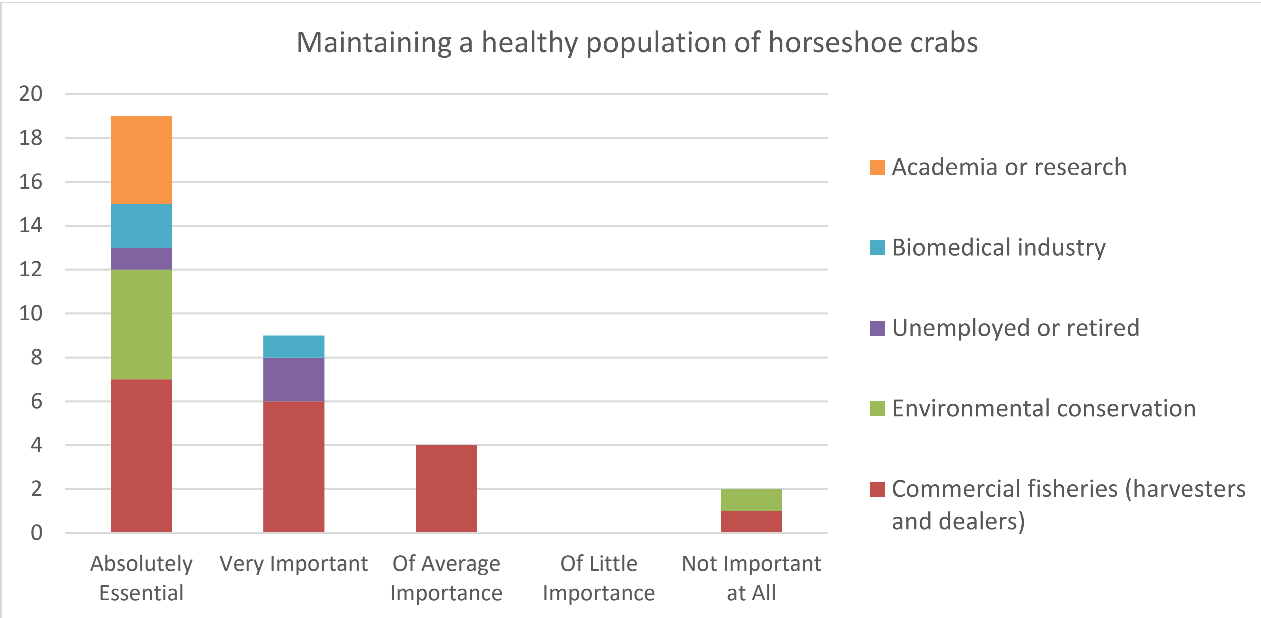

Figure A9. Importance of maintaining a healthy population of horseshoe crabs.

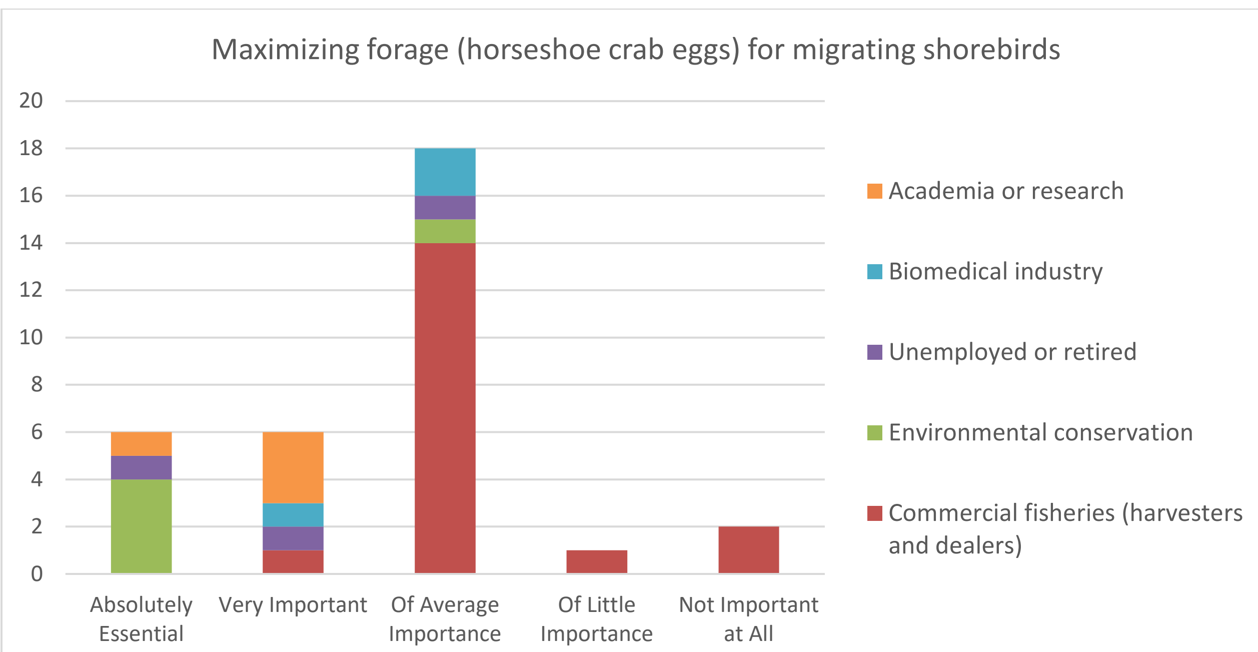

Figure A10. Importance of maximizing forage (horseshoe crab eggs) for migrating shorebirds.

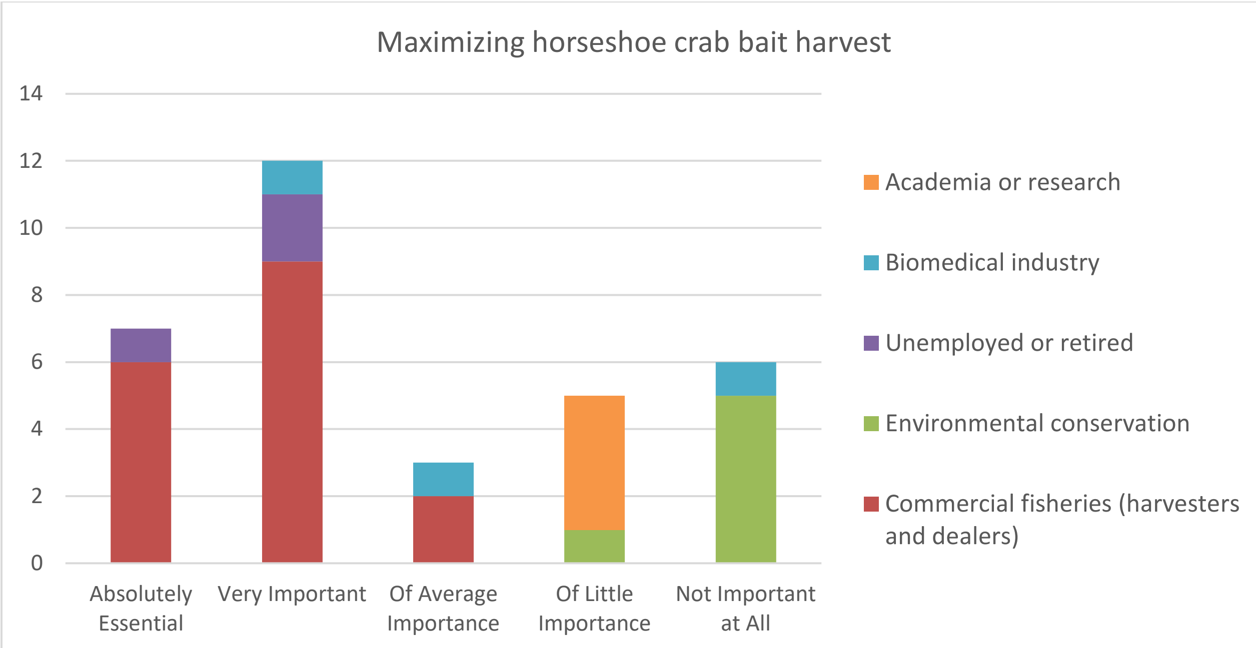

Figure A11. Importance of maximizing horseshoe crab bait harvest.

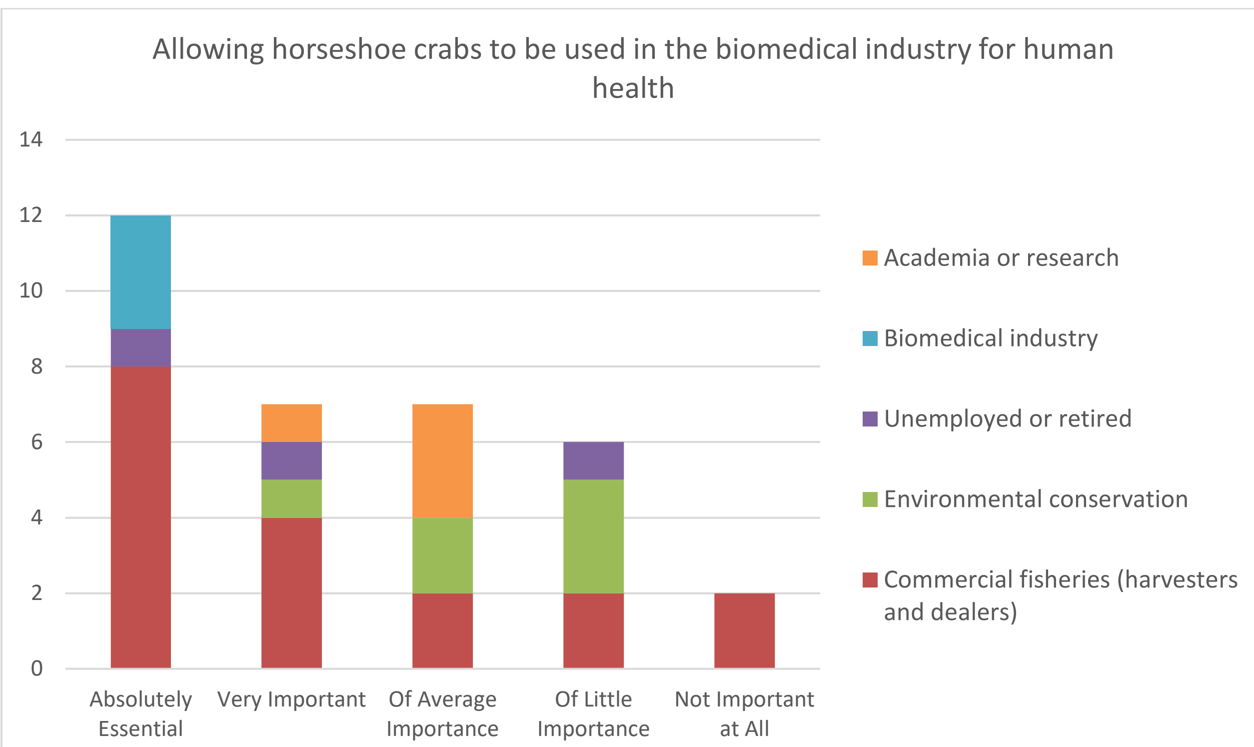

Figure A12. Importance of allowing horseshoe crabs to be used in the biomedical industry.

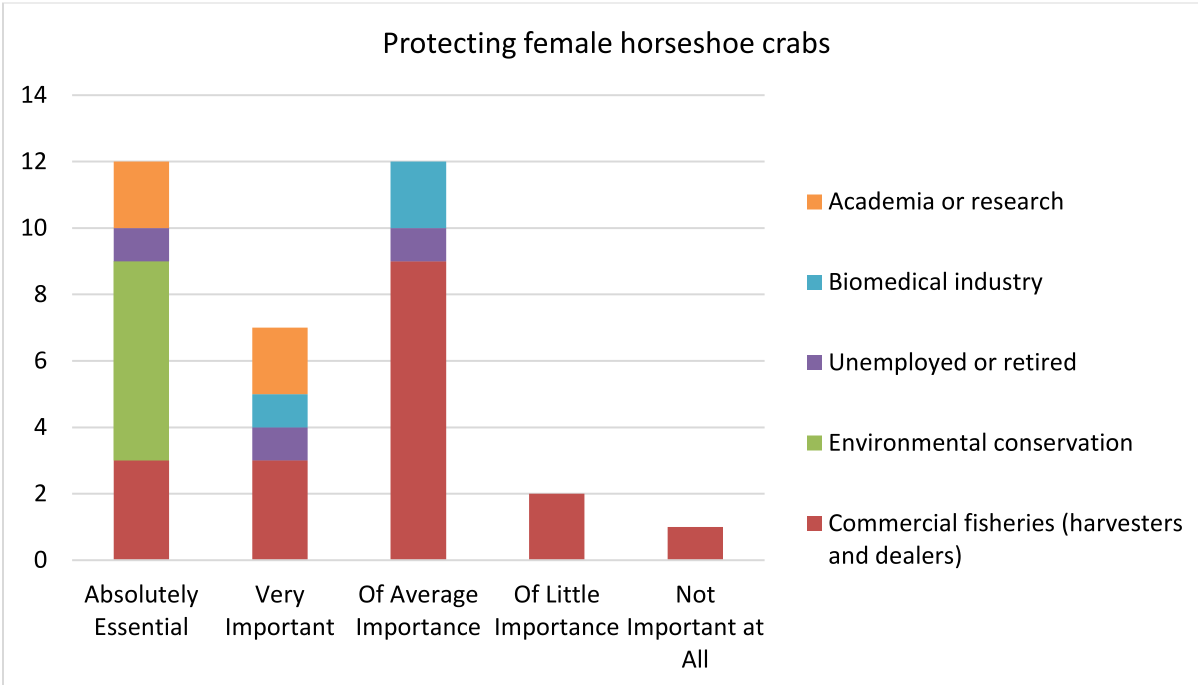

Figure A13. Importance of protecting female horseshoe crabs.

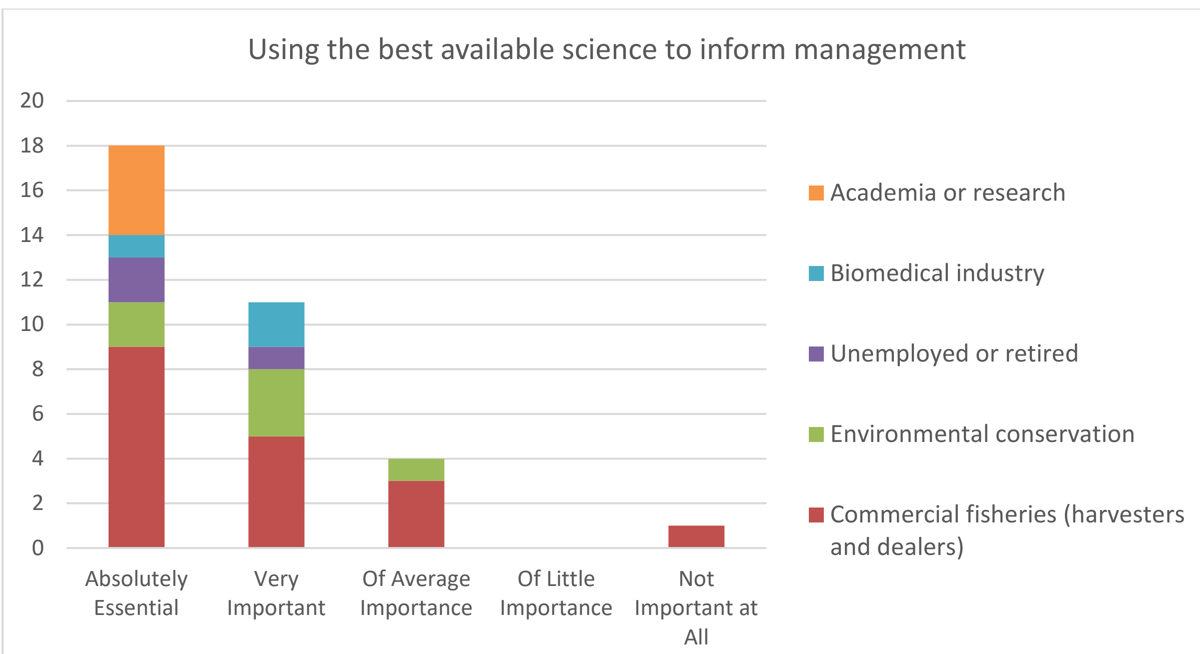

Figure A14. Importance of using the best available science to inform management.

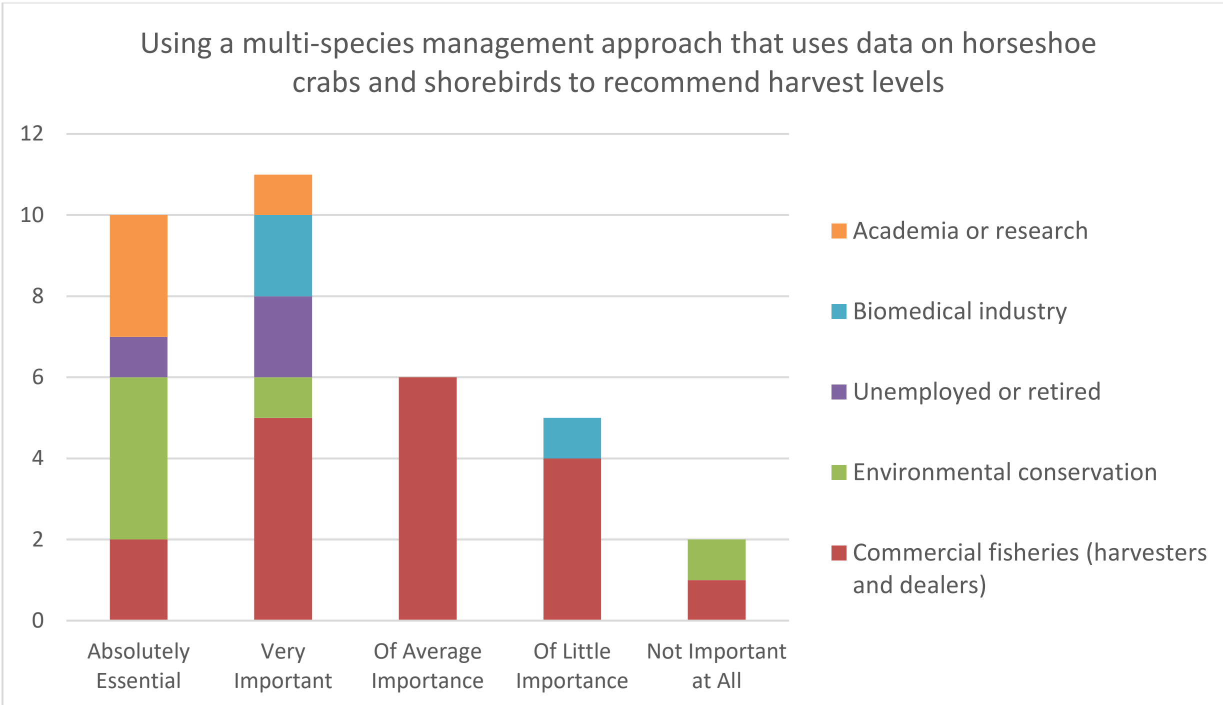

Figure A15. Importance of using a multi-species management approach.

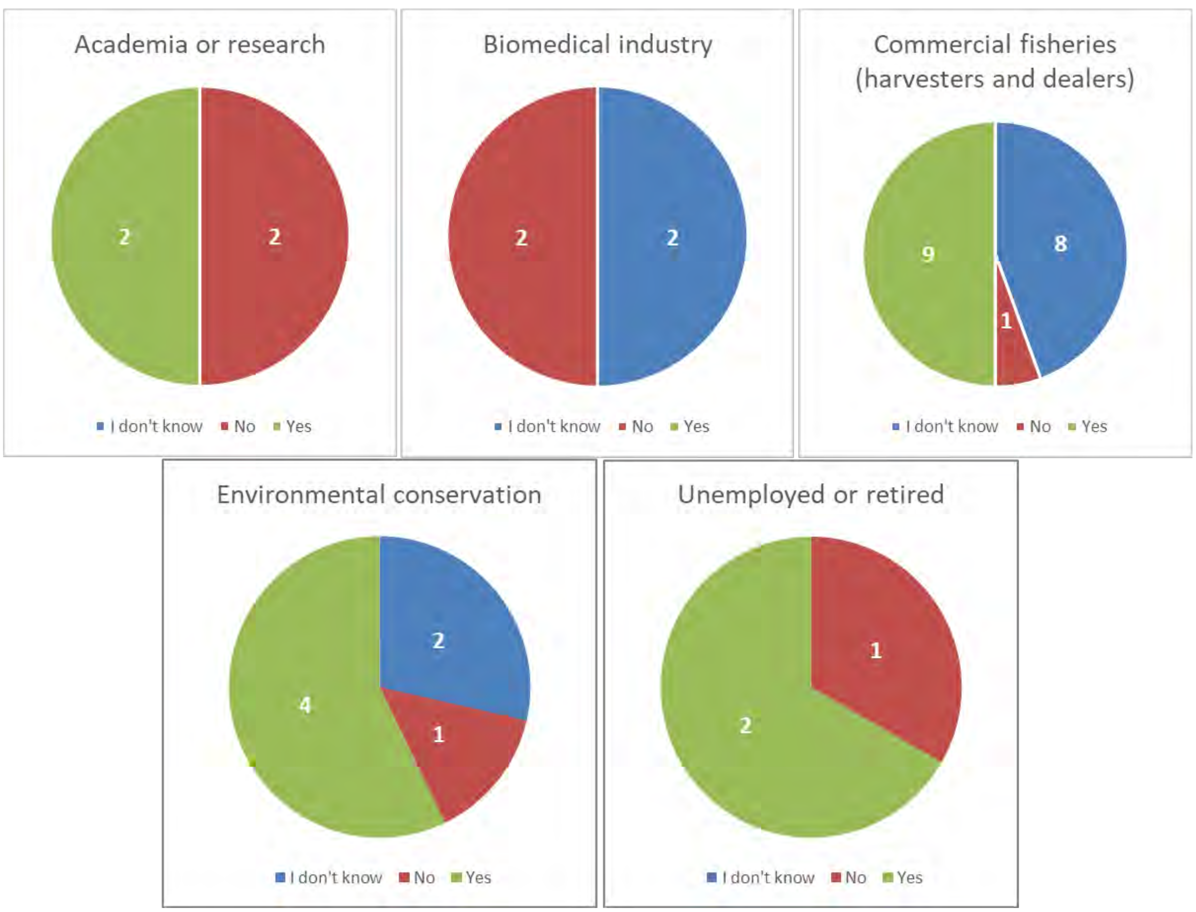

Figure A16. Opinion on whether the current ARM Model should be revised by occupational group.

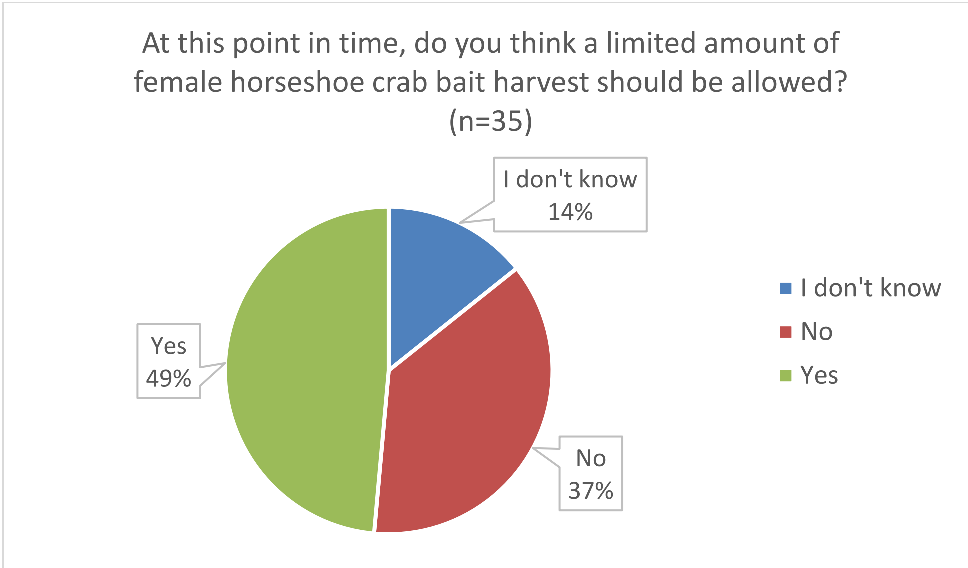

Figure A17. Opinion on allowing female bait harvest.

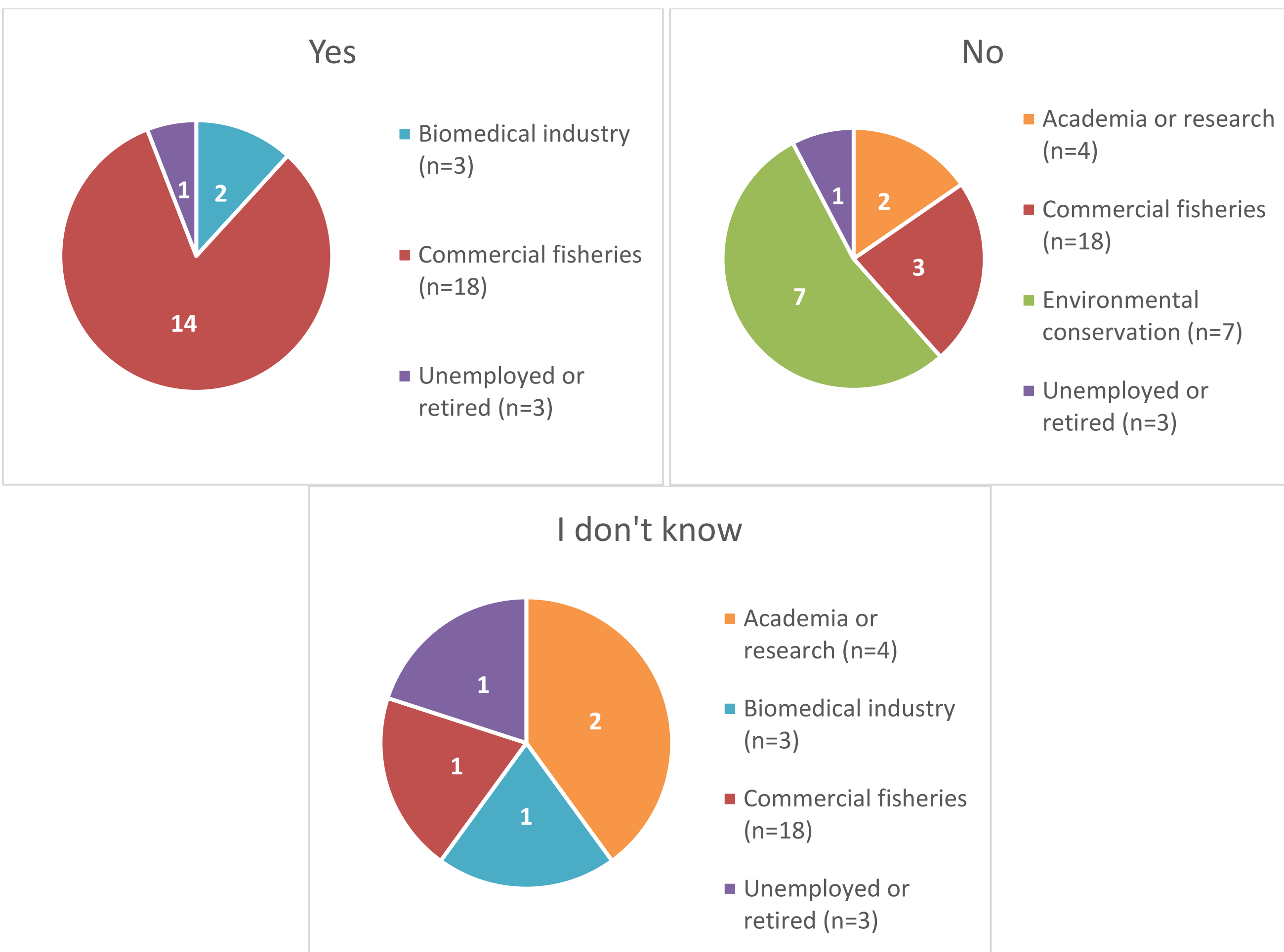

Figure A18. Makeup of respondents to Question 15 by answer provided.

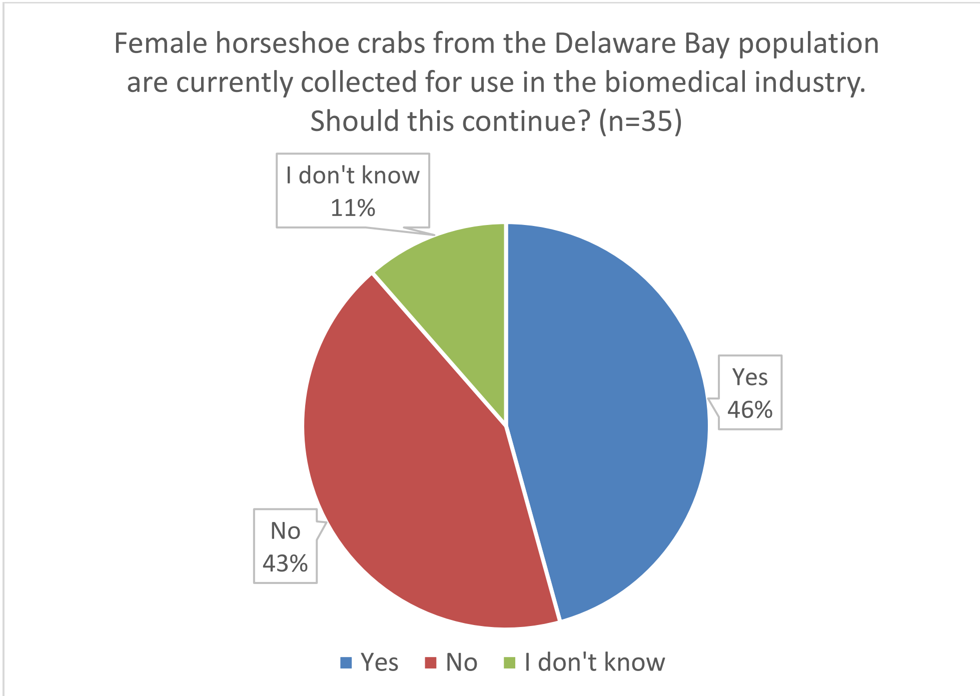

Figure A19. Opinion on use of female horseshoe crabs in the biomedical industry.

Atlantic States Marine Fisheries Commission

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MEMORANDUM

TO: **Horseshoe Crab Management Board**

FROM: **Delaware Bay Ecosystem Technical Committee and Adaptive Resource Management Subcommittee**

DATE: **October 2, 2023**

SUBJECT: **Delaware Bay Horseshoe Crab Harvest Recommendation for 2024**

This memo describes the 2024 harvest recommendation for Delaware Bay region horseshoe crabs using the methods from the Adaptive Resource Management, or ARM Framework (ASMFC 2022a). Since 2013, horseshoe crabs in the Delaware Bay Region (New Jersey, Delaware, Maryland, and Virginia) have been managed under the ARM Framework to set harvest levels with consideration of the needs of migratory shorebirds. The ARM was developed jointly by the Commission, U.S. Fish and Wildlife Service, and U.S. Geological Survey in recognition of the importance of horseshoe crab eggs to migratory shorebirds stopping over in the Delaware Bay region. In particular, horseshoe crab eggs are an important food source for the *rufa* red knot, which is listed as threatened under the Endangered Species Act.

Under Addendum VIII (ASMFC 2022b), the 2022 ARM Revision is used to annually produce bait harvest recommendations for male and female horseshoe crabs of Delaware Bay-origin based on the abundance of horseshoe crabs and red knots. The maximum number of male and female horseshoe crabs the ARM Revision can recommend is 500,000 males and 210,000 females. The ARM Revision was used for the first time to set harvest for the 2023 fishing year and the recommended harvest levels were 475,000 male and 125,000 female horseshoe crabs. Acknowledging public concern about the status of the red knot population in the Delaware Bay, the Board elected to implement harvest limits of zero female and 475,000 male horseshoe crabs for the 2023 season. To make up for the lost harvest of female crabs, the Board agreed to increase Maryland and Virginia's male harvest quotas with an offset ratio of 2:1 males to females.

1. Objective Statement

Manage harvest of horseshoe crabs in the Delaware Bay to maximize harvest but also to maintain ecosystem integrity, provide adequate stopover habitat for migrating shorebirds, and ensure that the abundance of horseshoe crabs is not limiting the red knot stopover population or slowing recovery.

2. Population estimates

Red knot abundance estimates used to make harvest recommendations under the ARM Revision are based on mark-resight total stopover population estimates (Figure 1; Lyons 2023). The 2022 red knot population estimate was 39,800.

In the ARM Revision, all quantifiable sources of mortality (i.e., bait harvest, coastwide biomedical mortality, and commercial dead discards; Figure 2 - Figure 3) were used in the catch multiple survey analysis (CMSA) to estimate male and female horseshoe crab population estimates. Population estimates for horseshoe crabs were made using the coastwide biomedical data or no biomedical data which provide upper and lower bounds for the public. The harvest recommendation is based on the results using confidential biomedical data from the region. The Virginia Tech Trawl Survey estimates are used in the CMSA along with the New Jersey Ocean Trawl and the Delaware Fish and Wildlife Adult Trawl Surveys (ASMFC 2022a; Wong et al. 2023; Figure 4 -Figure 5).

In 2021, the number of newly mature female horseshoe crabs estimated in the Virginia Tech Trawl survey was zero (Table 1). This data point is lagged forward to represent 2022, the terminal year of the current model, and poses an issue for the CMSA. The CMSA is a simple, stage-based model that essentially sums the newly mature and mature crabs, subtracts harvest and accounts for natural mortality, and predicts the next year's population. The model will not run with an estimate of zero newly mature horseshoe crabs and has struggled to reconcile the high mature female horseshoe crab population estimates in the Virginia Tech Trawl Survey with the low newly mature population estimates for the last few years. The ARM Subcommittee and Delaware Bay Ecosystem Technical Committee (DBETC) previously discussed three hypotheses for the low newly mature horseshoe crabs in the Virginia Tech Trawl Survey: 1) a catchability issue where newly mature crabs are not in the same location as mature crabs, 2) a multi-year recruitment failure beginning in 2010 that began to show up 9 years later (the length of time to maturity) in 2019, the first year of low newly mature crabs, or 3) an identification issue where the onboard technicians since 2019 have been misclassifying newly mature horseshoe crabs as mature or immature.

To gap-fill the newly mature female horseshoe crab time series so there are no zeros, the ARM Subcommittee and DBETC decided to use an average ratio of newly mature to mature females from previous years. For 2002-2018, newly mature female horseshoe crabs comprised 19.9% of the total mature crabs (newly mature plus mature) in the Virginia Tech Trawl data. Additionally, the Delaware Adult Trawl Survey is used in the CMSA as an index of abundance and has been collecting staged data since 2017 (Figure 6). While the Delaware Adult Trawl has fewer years of stage data, the two stages have tracked each other also with an average of 19.9% of the female horseshoe crabs being newly mature for 2017-2022 (Figure 7). Using the average of 19.9%, the years of 2019-2022 in the Virginia Tech Trawl were adjusted where the observed newly mature and mature female horseshoe crabs were added together and then 19.9% were attributed to the newly mature stage. This method did not increase the number of total female horseshoe crabs in the model, but rather re-proportioned them between the two stages of newly mature and mature. This approach is supported by the biology of horseshoe crabs since it is hard to reconcile the high number of mature female and low newly mature female horseshoe crabs in recent years given the single year time step. This approach also resulted in CMSA estimates of total females that were closer to swept area estimates from the Virginia Tech trawl survey. If the trend of low newly mature female horseshoe crabs continues in the future, the ARM and DBETC will re-evaluate gap-filling methods as needed.

No adjustments had to be made for the male horseshoe crab model.

Using the CMSA model, there were approximately 40.3 million mature male and 16.1-16.2 million mature female horseshoe crabs in the Delaware Bay region in 2022, depending on the use of coastwide or no biomedical data (Figure 8 - Figure 9). The Virginia Tech Trawl population estimates were 44.9 million male and 15.5 million female mature horseshoe crabs for comparison (Table 1).

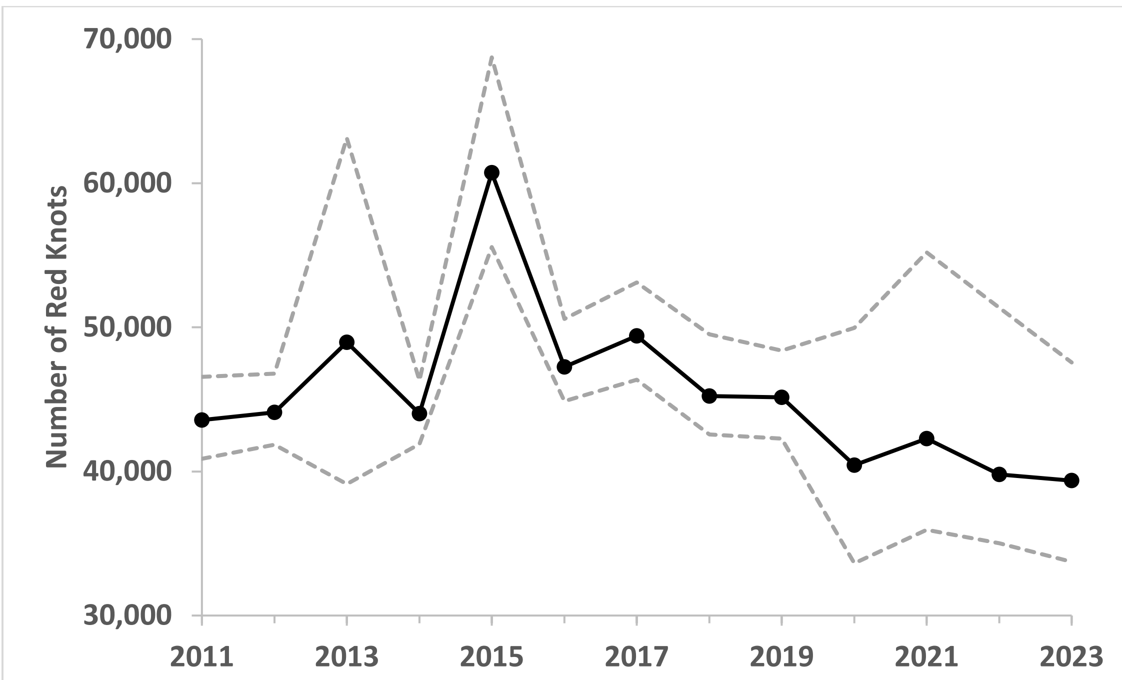

Figure 1. Mark-resight abundance estimates for the red knot stopover population with 95% confidence intervals, 2011-2023.

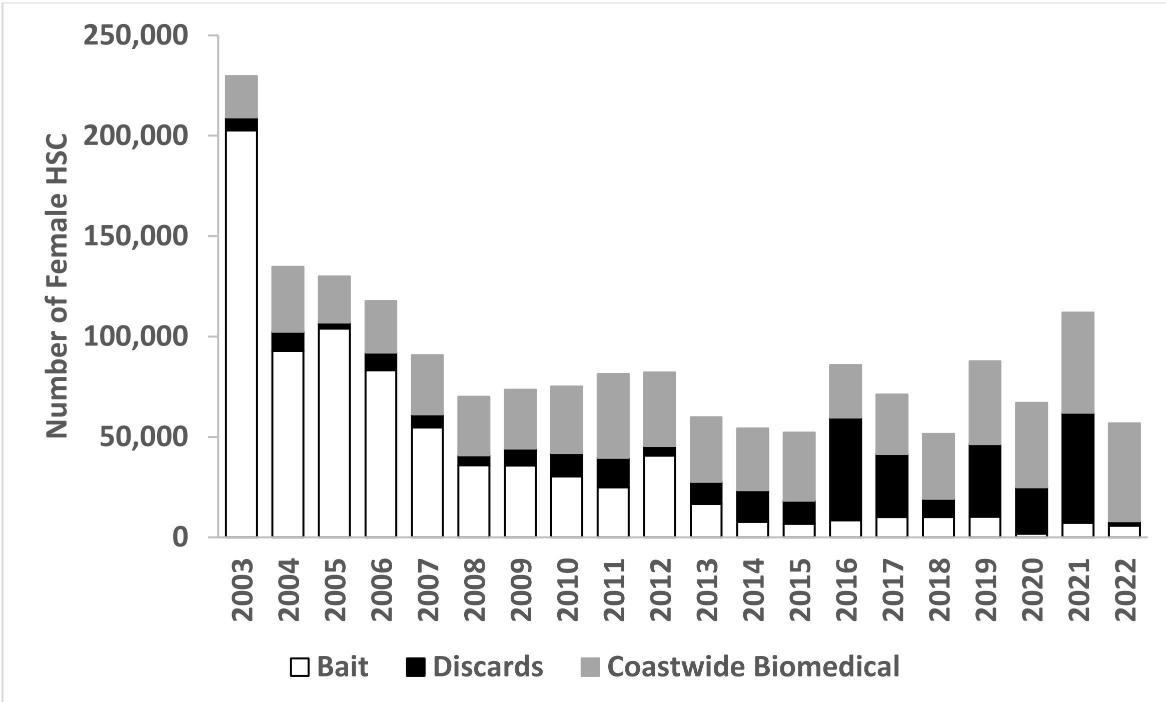

Figure 2. Total female horseshoe crab harvest by source in the Delaware Bay, 2003-2022.

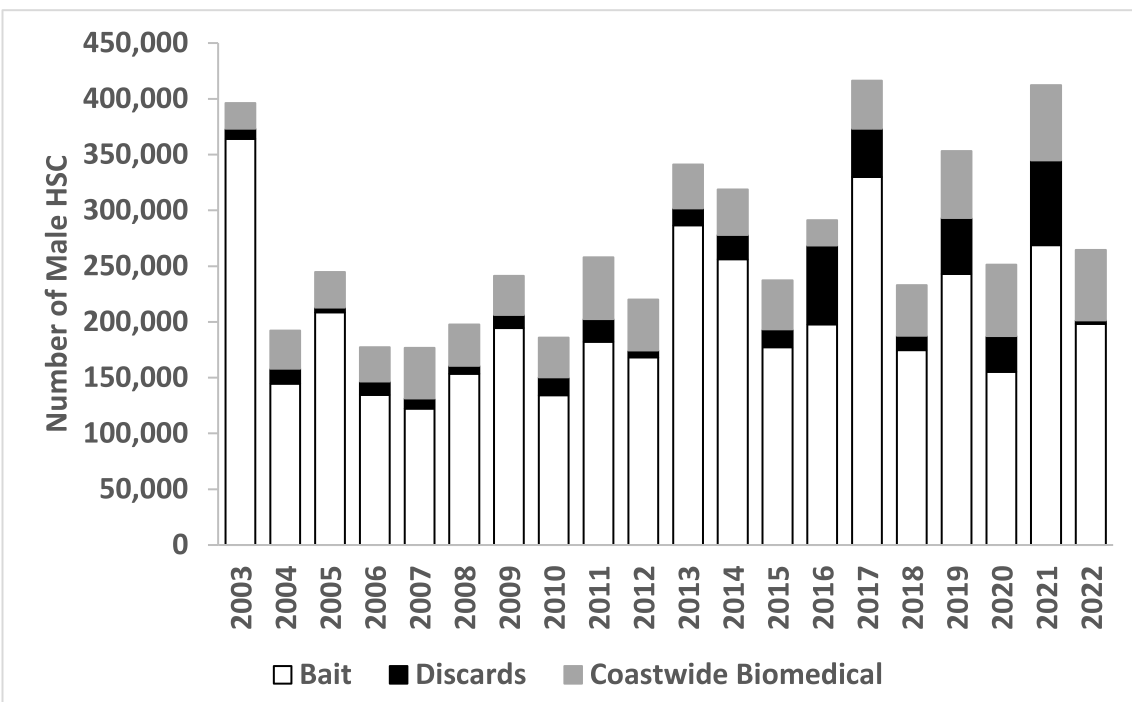

Figure 3. Total male horseshoe crab harvest by source in the Delaware Bay, 2003-2022.

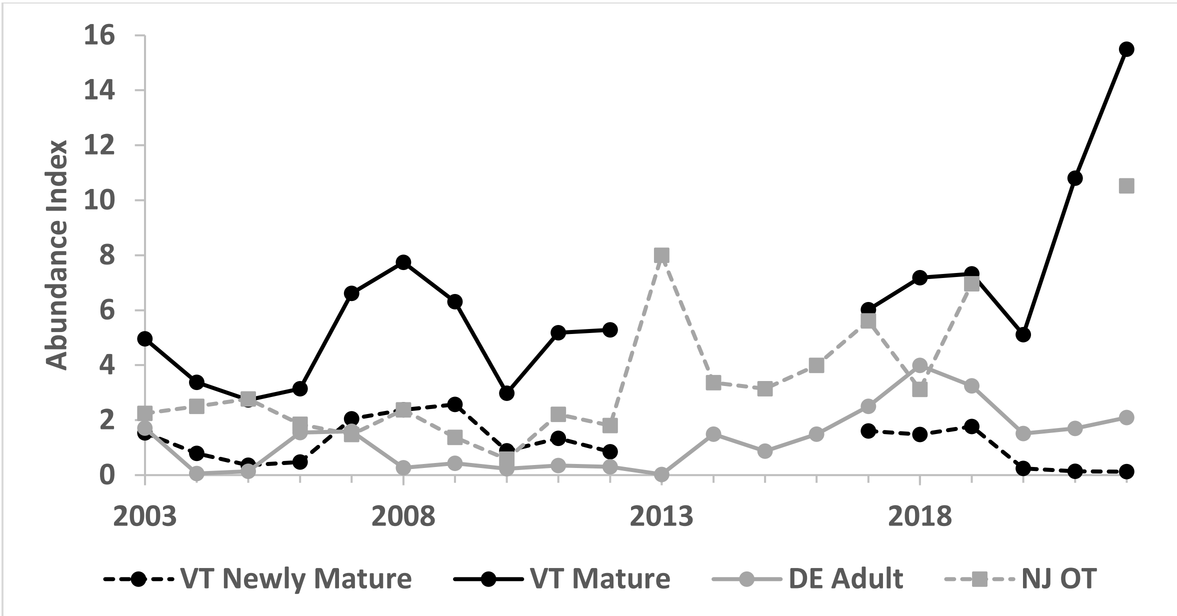

Figure 4. Female horseshoe crab abundance indices used in the CMSA. The Virginia Tech (VT) indices are in millions of newly mature and mature crabs while the Delaware Adult (DE Adult) and New Jersey Ocean Trawl (NJ OT) are in catch-per-tow.

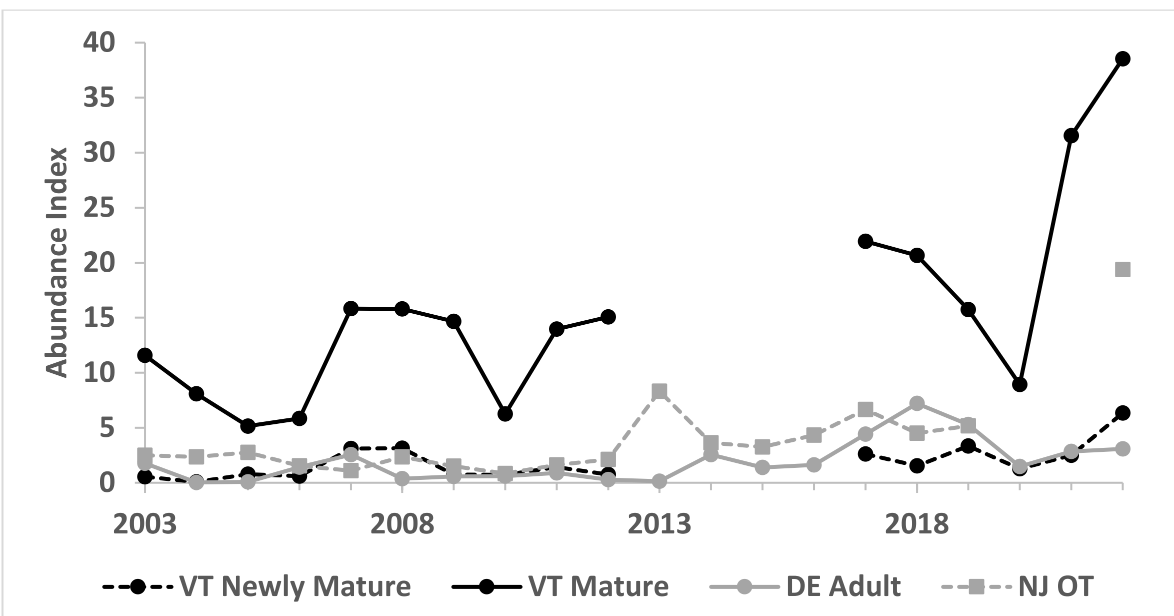

Figure 5. Male horseshoe crab abundance indices used in the CMSA. The Virginia Tech (VT) indices are in millions of newly mature and mature crabs while the Delaware Adult (DE Adult) and New Jersey Ocean Trawl (NJ OT) are in catch-per-tow.

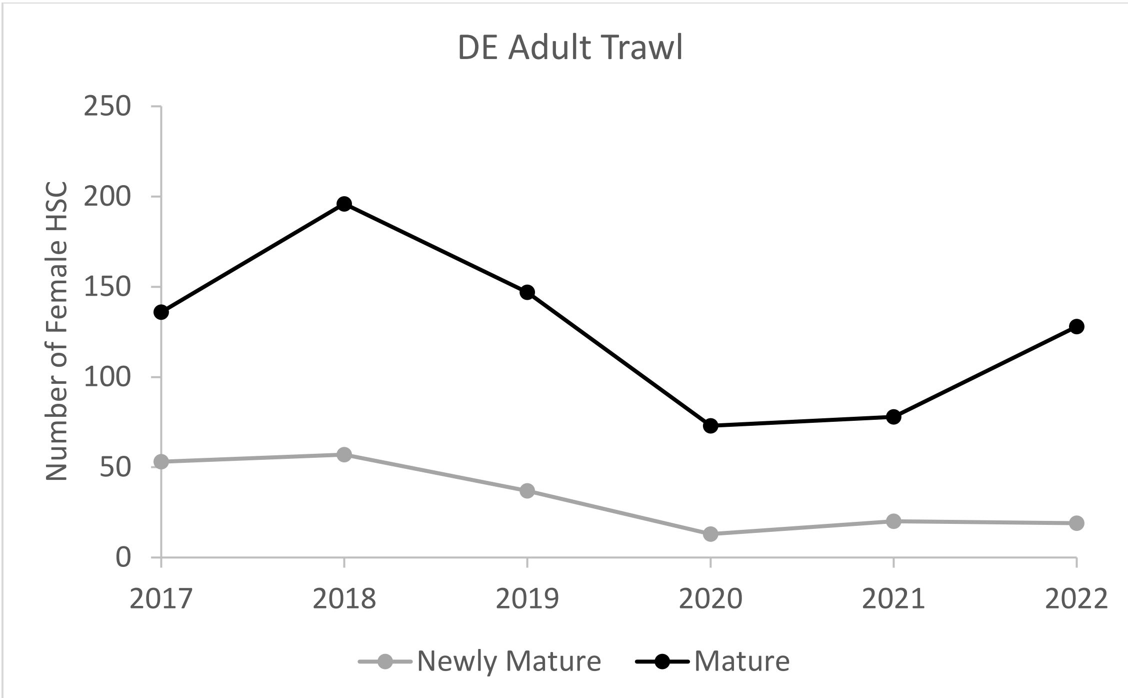

Figure 6. **Mature and newly mature female horseshoe crabs caught in the Delaware Adult (30 foot) Trawl, 2017-2022.**

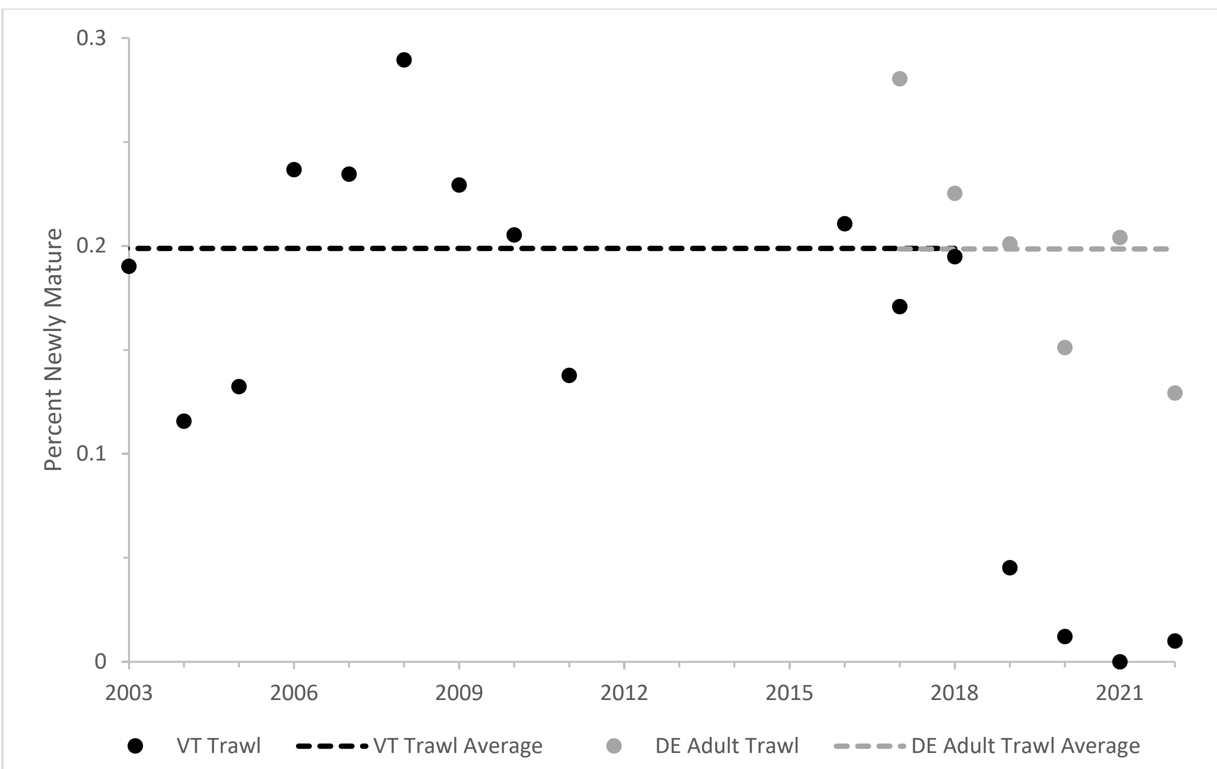

Figure 7. **Percent of newly mature female horseshoe crabs in the Virginia Tech and Delaware Adult Trawls. The low years of newly mature female horseshoe crabs (2019-2022) were not included in the average for the Virginia Tech Trawl.**

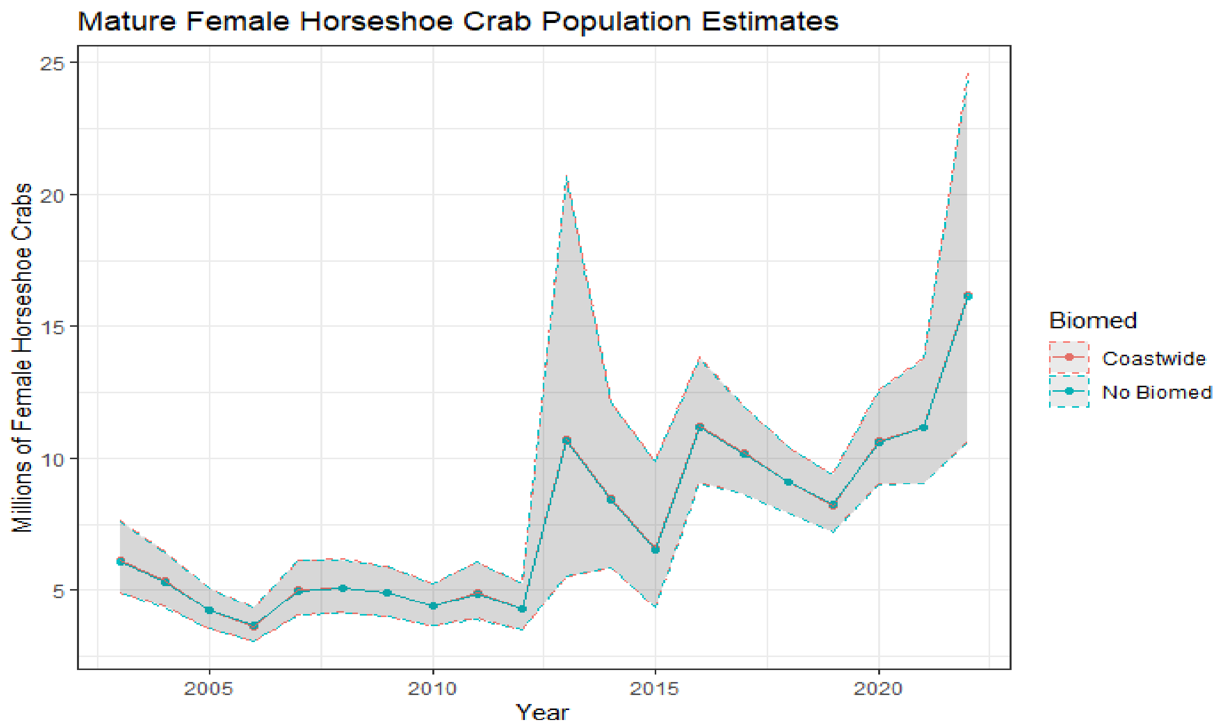

Figure 8. Population estimates from the CMSA for mature female horseshoe crabs with 95% confidence intervals. Delaware Bay biomedical data is confidential so population estimates using coastwide and zero biomedical data provide upper and lower bounds, although there is very little difference between the two and the time series overlap on the figures.

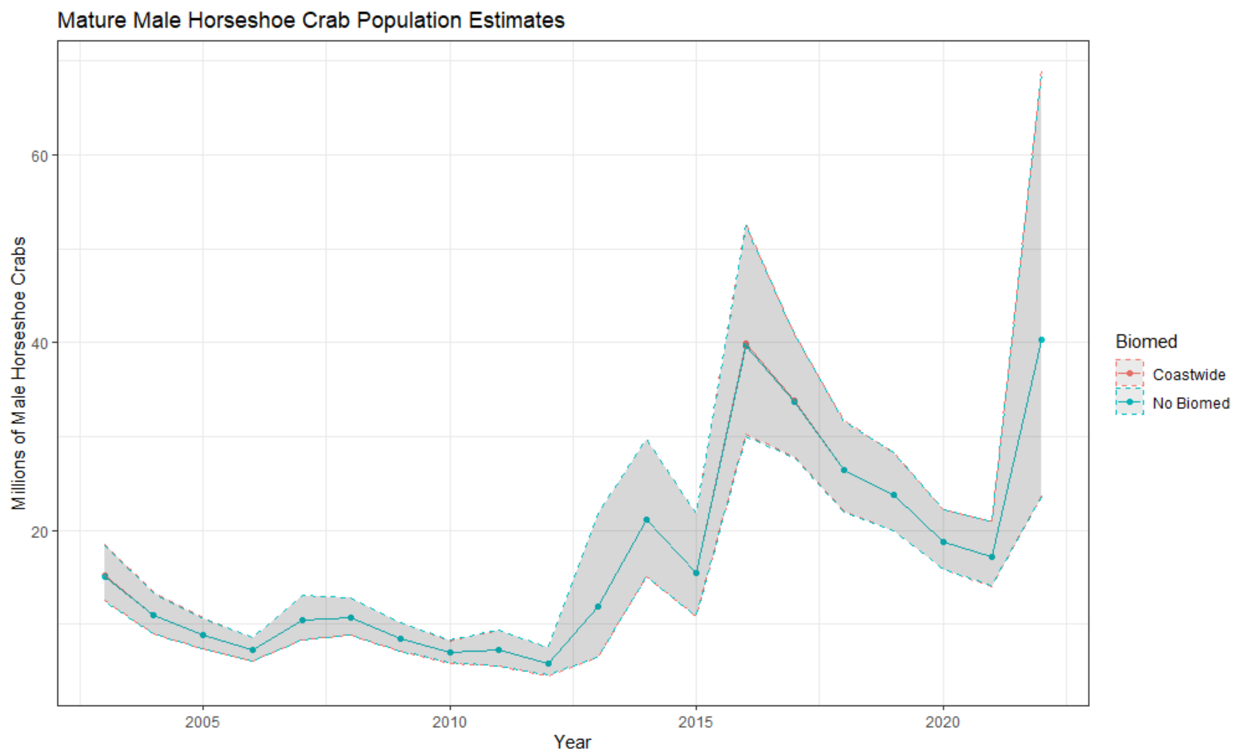

Figure 9. **Population estimates from the CMSA for male horseshoe crabs with 95% confidence intervals. Delaware Bay biomedical data is confidential so population estimates using coastwide and zero biomedical data provide upper and lower bounds, although there is very little difference between the two and the time series overlap on the figures.**

Table 1. Total mature (newly mature plus mature) horseshoe crab population estimates in millions by sex and estimation method (catch multiple survey model or Virginia Tech Trawl Survey), 2003-2022.

	Females (in millions)			Males (in millions)		
Biomedical Data:	**Zero**	**Coastwide**	**N/A**	**Zero**	**Coastwide**	**N/A**
Estimation Method:	**CMSA**		**VT Trawl**	**CMSA**		**VT Trawl**
2003	6.1	6.1	6.5	15.1	15.2	12.1
2004	5.3	5.3	4.2	11	11	8.1
2005	4.2	4.2	3.1	8.9	8.9	5.9
2006	3.7	3.7	3.6	7.3	7.3	6.4
2007	5	5	8.7	10.4	10.5	18.9
2008	5.1	5.1	10.1	10.7	10.7	18.9
2009	4.9	4.9	8.9	8.5	8.5	15.4
2010	4.4	4.4	3.9	7	7	7
2011	4.9	4.9	6.5	7.2	7.3	15.4
2012	4.3	4.3	6.1	5.9	5.9	15.8
2013	10.7	10.7		11.9	11.9	
2014	8.4	8.5		21.1	21.2	
2015	6.5	6.6		15.4	15.4	
2016	11.2	11.2		39.7	39.9	
2017	10.2	10.2	7.6	33.7	33.8	24.5
2018	9.1	9.1	8.7	26.4	26.4	22.2
2019	8.2	8.2	9.1	23.7	23.8	19.1
2020	10.6	10.7	5.4	18.8	18.8	10.2
2021	11.2	11.2	10.9	17.2	17.2	34
2022	16.1	16.2	15.5	40.3	40.3	44.9

3. Harvest Recommendation

Harvest recommendations for the 2024 fishing year made using the ARM Revision are based on CMSA estimates of horseshoe crab abundance and the red knot mark-resight abundance estimates. ARM harvest recommendations are based on a continuous scale rather than the discrete harvest packages in the previous ARM Framework. Therefore, a harvest number up to the maximum allowable harvest could be recommended, not just the fixed harvest packages. Harvest of females is decoupled from the harvest of males so that each is determined separately. The maximum possible harvests for both females and males are maintained from the previous ARM Framework at 210,000 and 500,000, respectively.

The annual recommendation of allowable Delaware Bay horseshoe crab harvest is based on current state of the system (abundances of both species in the previous calendar year) and the optimal harvest policy functions from the ARM Revision. Annual estimates of horseshoe crab and red knot abundances are used as input to the harvest policy functions, which then output the optimal horseshoe crab harvest to be implemented. As per Addendum VIII, the optimal recommended harvest is rounded down to the nearest 25,000 crabs to uphold data confidentiality.

The harvest recommendation based on the ARM Framework for 2024 is 175,000 female and 500,000 male horseshoe crabs.

4. Quota Allocation

Allocation of allowable harvest was conducted in accordance with the methodology in Addendum VIII (Table 2).

Table 2. Delaware Bay-origin and total horseshoe crab quota for 2024 by state. Virginia total quota only refers to the amount that can be harvested east of the COLREGS line.

State	Delaware Bay-Origin Quota		Total Quota	
	Male	Female	Male	Female
Delaware	173,014	60,555	173,014	60,555
New Jersey	173,014	60,555	173,014	60,555
Maryland	132,865	46,503	126,410	44,243
Virginia	21,107	7,387	40,667	20,331
TOTAL	500,000	175,000	513,106	185,684

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Results of the 2022 Horseshoe Crab Trawl Survey:

Report to the Atlantic States Marine Fisheries Commission Horseshoe Crab and Delaware Bay Ecology Technical Committees

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10 May 2023

Abstract

With the continued growth of the mid-Atlantic horseshoe crab (*Limulus polyphemus*) fishery, annual analyses of the population dynamics of key demographic groups are needed for defensible, science-based management. We conducted a trawl survey within the lower Delaware Bay and along the coast of the Delaware Bay area (DBA – Virginia to New Jersey), quantified mean catch per 15-minute tow, and compared relative abundance of demographic groups with those of prior years. Due to time constraints, no trawls were performed in the lower Delaware Bay this year. Mean catch-per-tow of all demographic groups were similar to last year's analysis, with the exception of the increase in newly mature females, which were not caught in the previous survey. Mean stratified catch-per-tow for all demographic groups continues to be highly variable, although mature females appear to show a positive trend over the study period. Newly mature males also appear to exhibit an increasing trend in recent years. Prosomal widths of all demographic groups, except immature individuals, show decreasing trends over the time-series in the DBA. Our findings will be used to parameterize the Adaptive Resource Management model used to set annual harvest levels for horseshoe crabs.

Introduction

To effectively manage the mid-Atlantic horseshoe crab (*Limulus polyphemus*) fishery, accurate information on relative abundance levels and trends is needed. The Adaptive Resource Management model (McGowan et al. 2011) adopted by the ASMFC requires annual, fishery-independent indices of newly mature recruit and adult abundances. Since its inception, the ARM Framework has used the VT trawl survey's swept area-based population estimates of horseshoe crab numbers and a theoretical population model developed primarily from literature-derived values. With more data collected in the region in recent years and other sources of mortality that can now be quantified, Anstead et al. (in press) developed a catch multiple survey analysis (CMSA) for Delaware Bay horseshoe crabs to provide robust population estimates for harvest management. The CMSA provides the best and most comprehensive population estimates of horseshoe crabs in the region and will improve modeling efforts within the ARM Framework going forward. The purpose of this project was to conduct a horseshoe crab trawl survey along the Mid-Atlantic coast in order to: (1) determine horseshoe crab relative abundance, (2) describe horseshoe crab population demographics, and (3) track inter-annual changes in horseshoe crab relative abundance and demographics. Here, we report our cumulative results through the fall 2022 trawl survey.

We have provided the Adaptive Resource Management (ARM) Subcommittee relative abundance estimates of horseshoe crabs in the DBA and LDB surveys to inform the ARM model runs. Herein, we present the population estimates through the 2022 survey. Gear catchability has not been evaluated for these estimates, so they should be considered conservative.

Methods

The Virginia Polytechnic Institute and State University horseshoe crab trawl survey is traditionally conducted in two areas (Figure 1). The coastal Delaware Bay area (DBA) survey extended in the Atlantic Ocean from shore out to 22.2 km (12 nautical miles), and from 39º 20' N (Atlantic City, NJ) to 37º 40' N (slightly north of Wachapreague, VA). This area was previously sampled from 2002 to 2011, and again from 2016 to 2022. The lower Delaware Bay (LDB) survey area, which extends from the Bay mouth to a line between Egg Island Point, New Jersey and Kitts Hummock, Delaware, was not sampled this year due to budget and time constraints. The LDB was previously sampled from 2010 to 2012 and 2016 to 2021. The surveys were conducted between 2 August to 12 October 2022.

The DBA survey area was stratified by distance from shore (0-3 nm, 3-12 nm) and bottom topography (trough, non-trough) as in previous years. The LDB survey area was stratified by bottom topography only, as in previous years. Sampling was conducted aboard a 16.8-m chartered commercial fishing vessel operated out of Ocean City, MD. We used a two-seam flounder trawl with an 18.3-m headrope and 24.4-m footrope, rigged with a Texas Sweep of 13-mm link chain and a tickler chain. The net body consisted of 15.2-cm (6-in) stretched mesh, and the bag consisted of 14.3-cm (5 5/8-in) stretched mesh. Tows were usually 15-minutes bottom time, but were occasionally shorter to avoid fishing gear (e.g., gill nets, crab and whelk pots) or vessel traffic. Start and end positions of each tow were recorded when the winches were stopped and when retrieval began, respectively. Bottom water temperature was recorded for each tow. We sampled 41 stations in the DBA survey. Two of these trawls were shorter in duration than average, one being a six-minute tow within our inshore/non-trough stratum and the other being a one-minute trawl in the offshore/trough stratum. Data from this latter one-minute trawl was not included in our data analysis as there were net malfunctions that resulted in the loss of the net. We included the six-minute inshore/non-trough trawl in our analysis as it did not involve net malfunction and hence provides useful data. Additionally, due to the high variance in CPUE and density of HSCs in each stratum (Figure 2), a larger sample size will help better explain variability.

Horseshoe crabs were culled from the catch, and either all individuals or a subsample were examined for prosomal width (PW, millimeters) and identified for sex and maturity. Maturity classifications were: immature, newly mature (those that are capable of spawning but have not yet spawned), and mature (those that have previously spawned). Newly mature and mature males are morphologically distinct and are believed to be classifiable without error. However, some error is associated with distinguishing newly mature from immature females. All examined females that were not obviously mature (i.e., bearing rub marks) or immature (too small or soft-shelled) were probed with an awl to determine presence or absence of eggs. Females with eggs but without rub marks were considered newly mature. Females with both eggs and rub marks were considered mature. Initial sorting classifications were: presumed adult males (newly mature and mature), presumed adult females, and all immature. Up to 25 adult males, 25 adult females, and 50 immatures were retained for examination. The remainder were counted separately by classification and released. Characteristics of the examined subsamples were then extrapolated to the counted portions of the catch

In each stratum, the mean catch per 15-minute tow and associated variance were calculated using two methods, i.e., either assuming a normal-distribution model or a delta-lognormal distribution model (Pennington, 1983). Stratum mean and variance estimates were combined using formulas for a stratified random sampling design (Cochran, 1977). The approximate 95% confidence intervals were calculated using the effective degrees of freedom (Cochran, 1977). Annual means were considered significantly different if 95% confidence limits did not overlap. Stratified means calculated using the delta-lognormal distribution model are not additive - i.e., means calculated for each demographic group do not sum to the mean calculated using all crabs. Means calculated using the normal-distribution model are additive, within rounding errors.

Annual size-frequency distributions, in intervals of 10-mm prosomal width, were calculated for each sex/maturity category by pooling size-frequency distributions of all stations (adjusted for tow duration if necessary) in a stratum in a year to determine the relative proportions for each size interval. Those proportions then were multiplied by the stratum mean catch-per-tow that year to produce a stratum size-frequency distribution. Stratum size-frequency distributions then were multiplied by the stratum weights and added in the same manner as calculating the stratified mean catch per tow. Areas under the distribution curves represent the stratified mean catch per tow at each size interval.

Within the DBA, excluding the one shorter trawl, the average tow distance for a 15-min tow was 1.50 kilometers at a speed of 4.80 KPH. No net-spread measurement device was used during sampling. Instead, net-spread was calculated using the net-spread regression relationship, *net spread* (*S,* in meters)/tow speed (*C,* in KPH), developed from previous trawl *surveys* ($S = 13.84 - 0.858 \times C$). From our combined 40 tows, the average net-spread was 8.68 meters.

For each tow, catch density (catch/km^2) was calculated from the product of tow distance (in km) and estimated net-spread (converted from meters to km) assuming that all fishing was done only by the net, and that there was no herding effect from the ground gear (sweeps):

$$\text{catch/km}^2 = \text{catch}/[\text{tow distance (km)} \times \text{net-spread (km)}].$$

Within each stratum, the mean catch per square-kilometer and associated variance were calculated assuming a normal-distribution model and a lognormal delta-distribution model. Stratum mean densities and variance estimates were combined to produce a stratified mean density ($\bar{X}_{st}$) using formulas for a stratified random sampling design as with the catch-per-tow estimates described above. Population totals were estimated by multiplying stratified mean density ($\bar{X}_{st}$) by survey area (DBA = 5127.1 km^2; LDB = 528.4 km^2):

$$\text{Population total} = \bar{X}_{st} \text{ x } (5127.1 \text{ or } 528.4 \text{ km}^2)$$

Results

Delaware Bay Area

For all demographic groups other than newly mature males, mean stratified catch-per-tow values have remained relatively consistent between 2016 and 2018. Since then, there has been a substantial increase in variation over the past four years among newly mature and mature individuals (Tables 1 and 2; Figure 3). While the mean stratified catches-per-tow for newly mature males and mature individuals decreased compared to last year, means for newly mature females and immature individuals all exhibited an increase. No estimates were significantly different from last year, besides newly mature females, as none were caught last year.

There is a significant correlation between stratified mean catches of mature males and mature females ($r = 0.94$; $p < 0.001$; $T = 10.81$; $n = 17$) when considering all data since 2002. This is also true for immature males and females ($r = 0.98$; $p < 0.001$; $T = 19.36$; $n = 17$), but not for newly mature individuals. Previously, there was a significant positive correlation between newly mature individuals between 2002 – 2018. However, this correlation was lost with the addition of data from 2019 and 2022, likely due to the low number of newly mature females trawled in recent years compared to newly mature males. For example, newly mature females were caught in only 15% of all trawls performed in 2022 for a total of 8 measured individuals. Newly mature males were caught in 40% of the forty trawls performed this year for a total of 82 measured individuals.

<u>Lower Delaware Bay</u>

No samples were collected within the Delaware Bay in 2022 as with rising operating costs, time became limiting. Since 2016, there has been a relative decrease in the mean relative abundances of almost all demographic groups in the LDB except newly mature females, which have remained consistently low. The mean stratified catch-per-tow in 2021 increased significantly from 2020 for immature females, immature males, and mature females (Tables 3 and 4; Figure 4). No newly mature females have been trawled in the LDB since 2018, and in 2021, no newly mature males were caught. 2021 presented the lowest mean value for newly mature males in the time series. Mean catches of mature males were significantly correlated with mean catches of mature females ($r = 0.91$; $p < 0.001$; $T = 5.9831$; $n = 9$). This was also present among immature males and immature females ($r = 0.97$; $p < 0.001$; $T = 11.513$; $n = 9$).

<u>Size distributions</u>

Similar to results in last year's report, size-frequency distributions remained highly variable (Figure 5). There were no distinct modal groups simultaneously in both sexes other than in 2009 for immature individuals. However, this modal group did not continue into the following years and was not found within previous year of sampling in the lower Delaware Bay (Figure 6).

We had previously reported that mean prosomal widths of mature and newly mature and mature male and female crabs in the DBA survey displayed slight, but detectable, decreases over time (Table 5, Figure 7) (Hata and Hallerman 2017, 2019, Hallerman and Jiao 2020). This trend appears to have continued this year within the Delaware Bay area. The negative correlation between years and mean prosomal width of newly mature and mature individuals strengthened compared to last year and remained statistically significant. The LDB portion of the table has been retained for comparison but has not changed from our previous analysis as no new data were added. A similar trend is present within the LDB amongst newly mature females and mature individuals.

Sex ratios

Overall, mature males were generally twice as common as mature females throughout the sampling period. Sex ratios (M:F) from mean catch-per-tow within the DBA ranged from 1.72 in 2019 to 3.64 in 2016, with an average of 2.38 over the time series. Male to female sex ratios in newly mature individuals have been highly variable, ranging from 0.11 in 2003 to 47.7 in 2022, with a new overall average of 5.70 over the time-series. This may reflect sampling effects, temporal variability in recruitment to the newly mature class relative to survey period, or differences in year-class abundance because females are believed to mature a year later than males.

Compared to the coast, the lower Delaware Bay continues to have a much higher male-to-female sex ratio in mature individuals. These values for mature individuals have ranged from 2.60 in 2018 to 20.5 in 2020, with an average of 5.98. This relationship between the coast and bay has been historically similar for newly mature individuals, with a low of 0.45 in 2010 and high of 6.10 in 2012. Excluding 2019 and 2020 — where newly mature males were caught but no newly mature females — led to an average of 3.09. The higher sex ratios within Delaware Bay may reflect a tendency for male horseshoe crabs to remain near the spawning beaches.

Population estimates

Annual population estimates of immature crabs in the DBA survey mirror trends observed in the catch-per-tow estimates and have been variable over time, with a large peak in 2009 (Tables 6 and 7). Compared to the previous year, estimated mean population total decreased for mature individuals and newly mature males, while newly mature females and immature individuals have increased. Assuming the normal distribution, the significance found in catch-per-tow estimates is mirrored in population total estimates. These mean population total estimates are similar to those seen since 2016 for immature individuals. Newly mature-males and mature individuals appear to have a recent increasing trend, while newly mature females appear to show a recent decreasing trend. There is a significant correlation between population estimates for mature males and females (r = 0.92; p < 0.001; T = 9.18; n = 17) and immature males and females (r = 0.99; p < 0.001; T = 32.571; n = 17), as observed in mean catches per tow above. There is no significant correlation amongst newly mature individuals in the DBA.

Lacking new data, population estimates for immature crabs in lower Delaware Bay in 2022 are not available. The estimates in 2021 were consistent with coastal estimates since the LDB survey began in 2010 (Tables 8 and 9). Despite the LDB representing only 9.3% of the entire sampling area, 19.4% of immature males and 15.3% of immature females were collected in this area over the time-series. In 2021, only 5.2% of immature males and 3% immature females were collected within the lower Delaware Bay. Proportions of newly mature crabs within the LDB compared to the DBA in 2021 are most similar to what one would expect based on the sample area that the LDB represents within the total available sampling area. Newly mature females from the LDB on average represent only 4.8% of the total population during the time series, along with newly mature males representing only 7.3%. No immature males or females were caught inside the LDB in 2021. On average, only 16% of mature males and 11% of mature females occurred within the lower Delaware Bay. In 2021, less than 1% of mature males, and mature females, were caught in the LDB. This low representation of mature individuals within the lower Delaware Bay is likely due to grown, mature individuals moving offshore towards the continental shelf, away from nursery grounds.

Effects of sampling period

Sampling in the Delaware Bay Area occurred primarily during September and early October, with the last trawls occurring October 12th. This time frame is similar to those in sampling years prior to 2019, as trawls between 2019 – 2021 were performed earlier in August and September. Although the water temperature was lower than last year, it was similar to the higher average water temperature seen in the past six years compared to sampling prior to 2016 (Table 10; Figure 8). This more consistent temperature within the Delaware Bay Area is in contrast to the lower Delaware Bay, where average water temperature is more directly inversely proportional to the ordinal date.

When comparing water temperature and the time of our sampling period, there appears to be a correlation within the DBA of mean catches-per-tow of immature males and females with both water temperature ($p = 0.026$, $p = 0.028$) and ordinal date ($p = 0.016$, $p = 0.019$) (Table 11). This is also seen in mature males ($p_{temp} = 0.014$, $p_{date} = 0.001$) and females ($p_{temp} = 0.020$, $p_{date} = 0.002$). For newly mature males, there appears to be a correlation only among newly mature females and ordinal date ($p = 0.036$).

Key Findings

1. Mean catches-per-tow among all demographic groups was similar to last year, with the exception of newly mature females, which were caught this year unlike the previous year.
2. Mean catch-per-tow of immature male and female horseshoe crabs in the coastal Delaware Bay area have remained variable since 2002 and have no apparent trend.
3. Mean catch-per-tow of newly mature male horseshoe crabs in the coastal Delaware Bay area remained highly variable, with newly mature males showing a weak positive trend since 2016, while newly mature females have remained relatively low since 2019.
4. Mean catch-per-tow of mature male and female horseshoe crabs in the coastal Delaware Bay area continue to be highly variable, with their highest points in 2021, with mature-females appearing to show a positive trend since 2016.
5. Mean catch-per-tow of all demographic groups except newly mature males in the DBA may be correlated with ordinal date. Mean catch-per-tow of immature and mature individuals may be correlated with temperature.
6. Annual mean prosomal width appears to still be decreasing in mature and newly mature males and females in the DBA.

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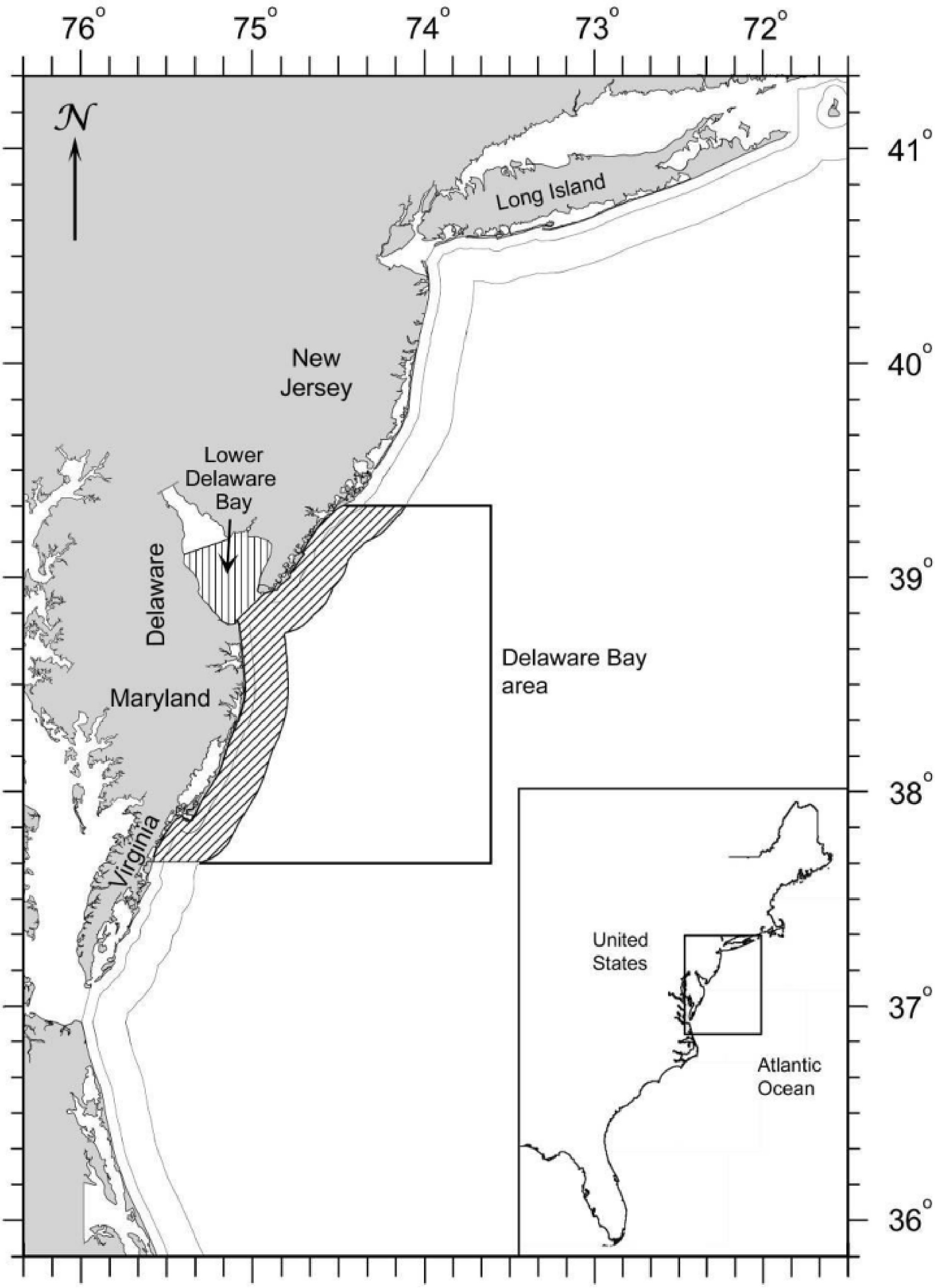


Figure 1. Fall 2022 horseshoe crab trawl survey sampling area. The coastal Delaware Bay area (DBA) and Lower Delaware Bay (LDB) survey areas are indicated. Mean catches between years were compared using stations within the shaded portions of the survey areas.

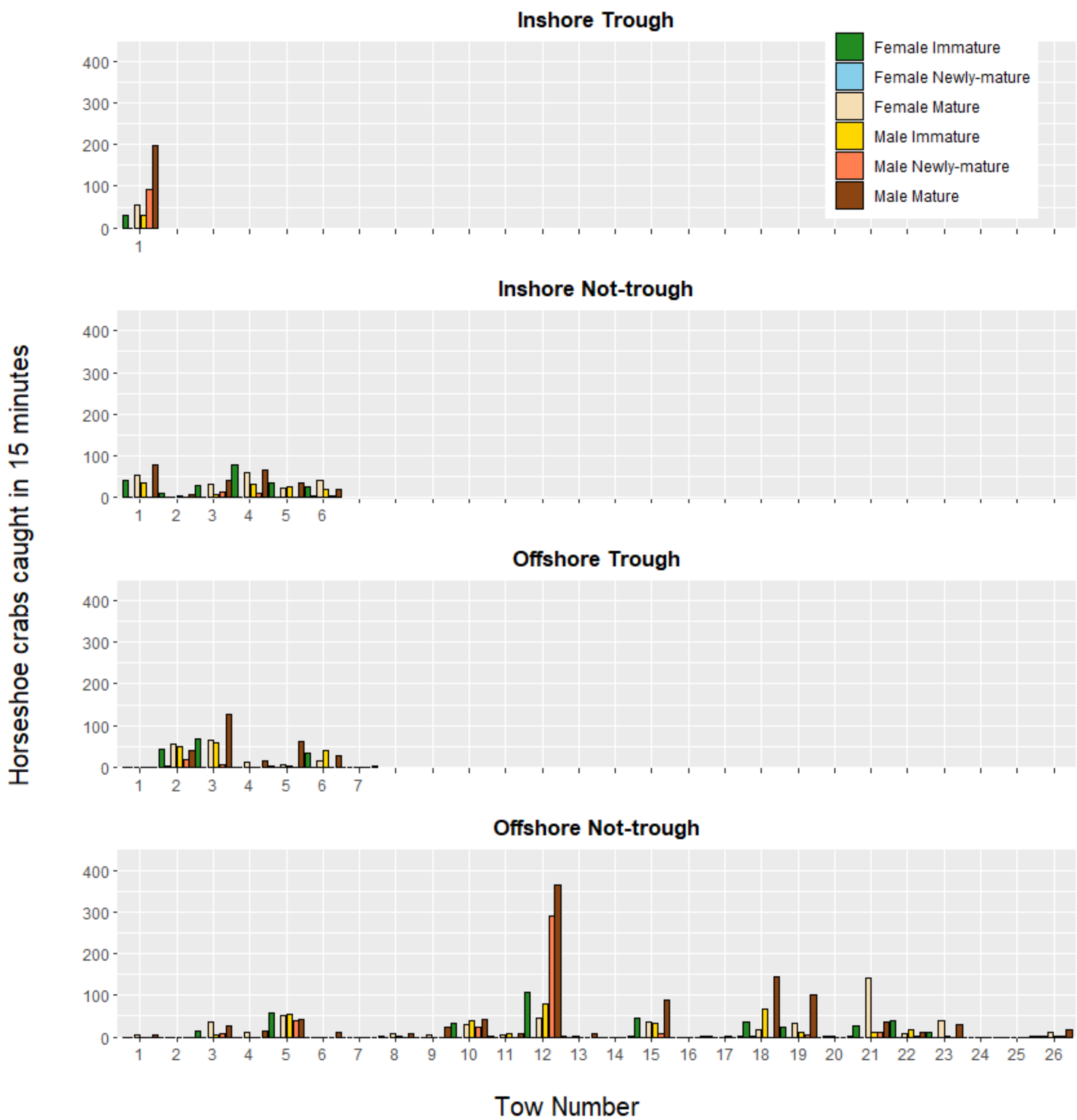


Figure 2. Plots showing high variability of relative abundances of horseshoe crabs of different demographic groups caught within the same strata in fifteen-minute tows in 2022.

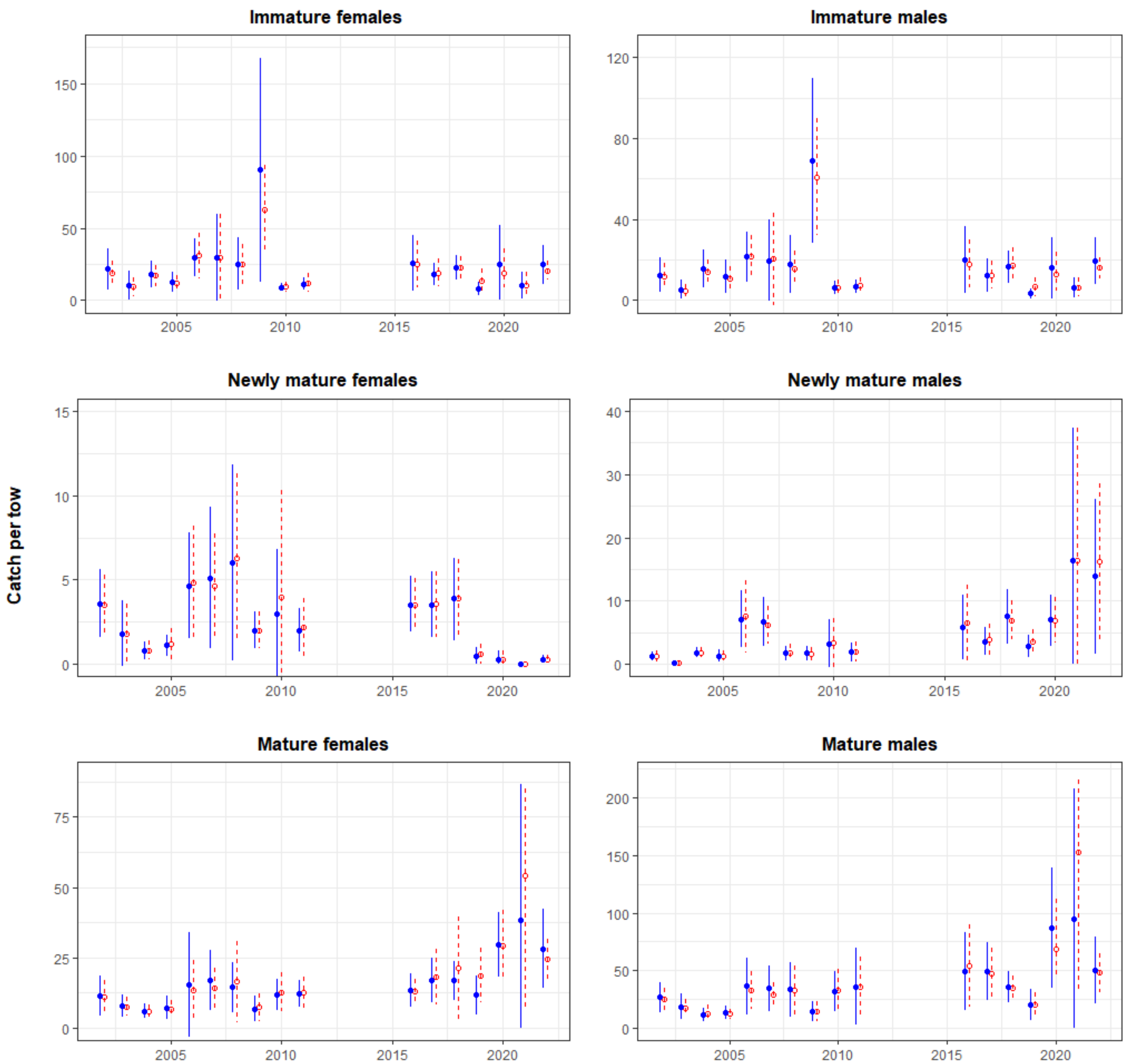


Figure 3. Plots of stratified mean catches per 15-minute tow of horseshoe crabs in the coastal **Delaware Bay area** survey by demographic group. Vertical lines indicate 95% confidence intervals. Solid blue symbols and lines indicate the **delta distribution** model. Open red symbols and dashed lines indicate the **normal distribution** model. Data are from Tables 1 and 2. Note the differences in the *y*-axis scales.

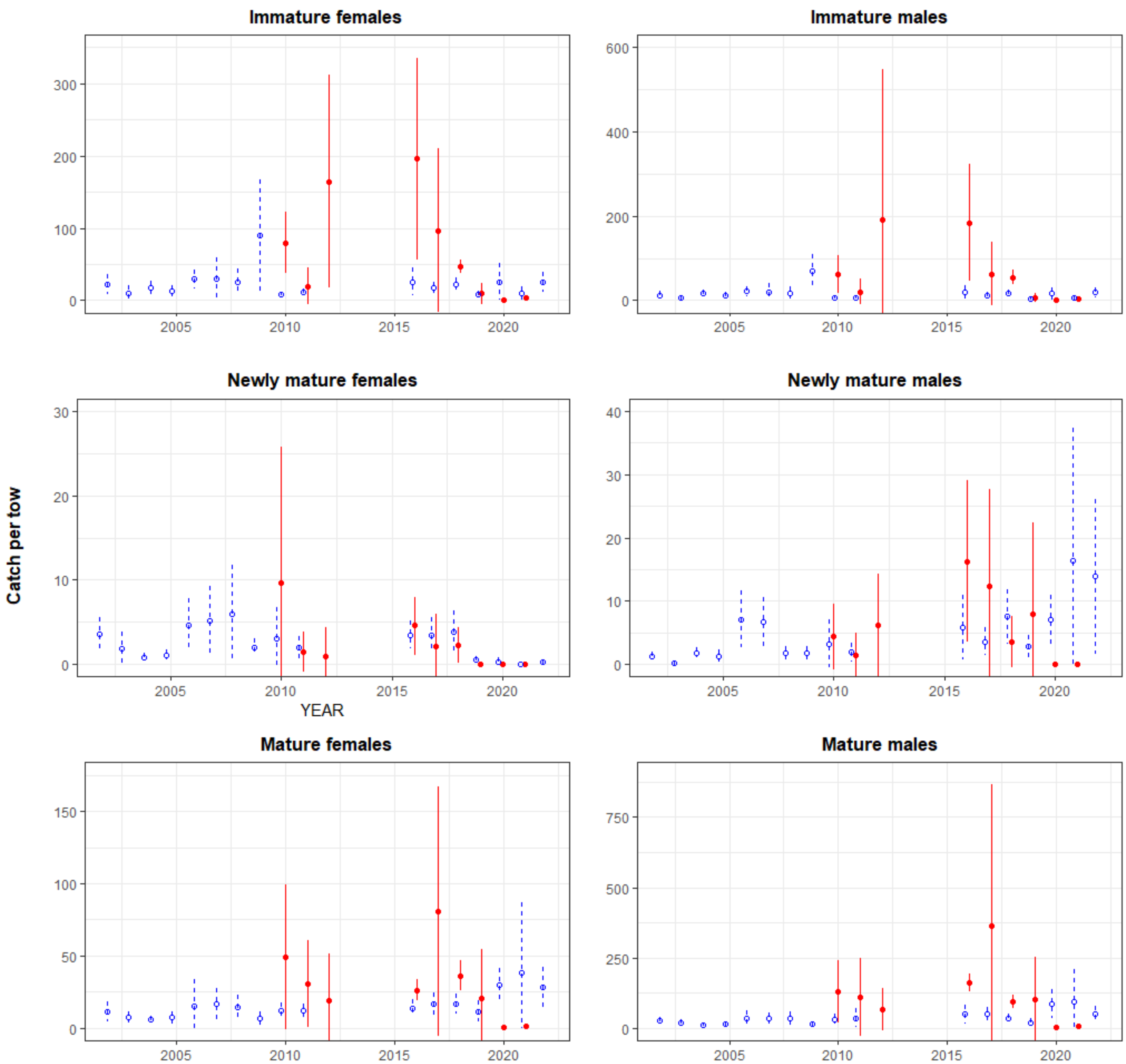


Figure 4. Plots of stratified mean catches per 15-minute tow of horseshoe crabs in the **lower Delaware Bay** survey by demographic group, with coastal **Delaware Bay area** survey means for comparison. Vertical lines indicate 95% confidence limits. Only the **delta distribution** model means are presented for clarity. Solid symbols and lines indicate **the lower Delaware Bay survey**. Open symbols and dashed lines indicate the coastal **Delaware Bay area** survey. Note differences in y-axis scales.

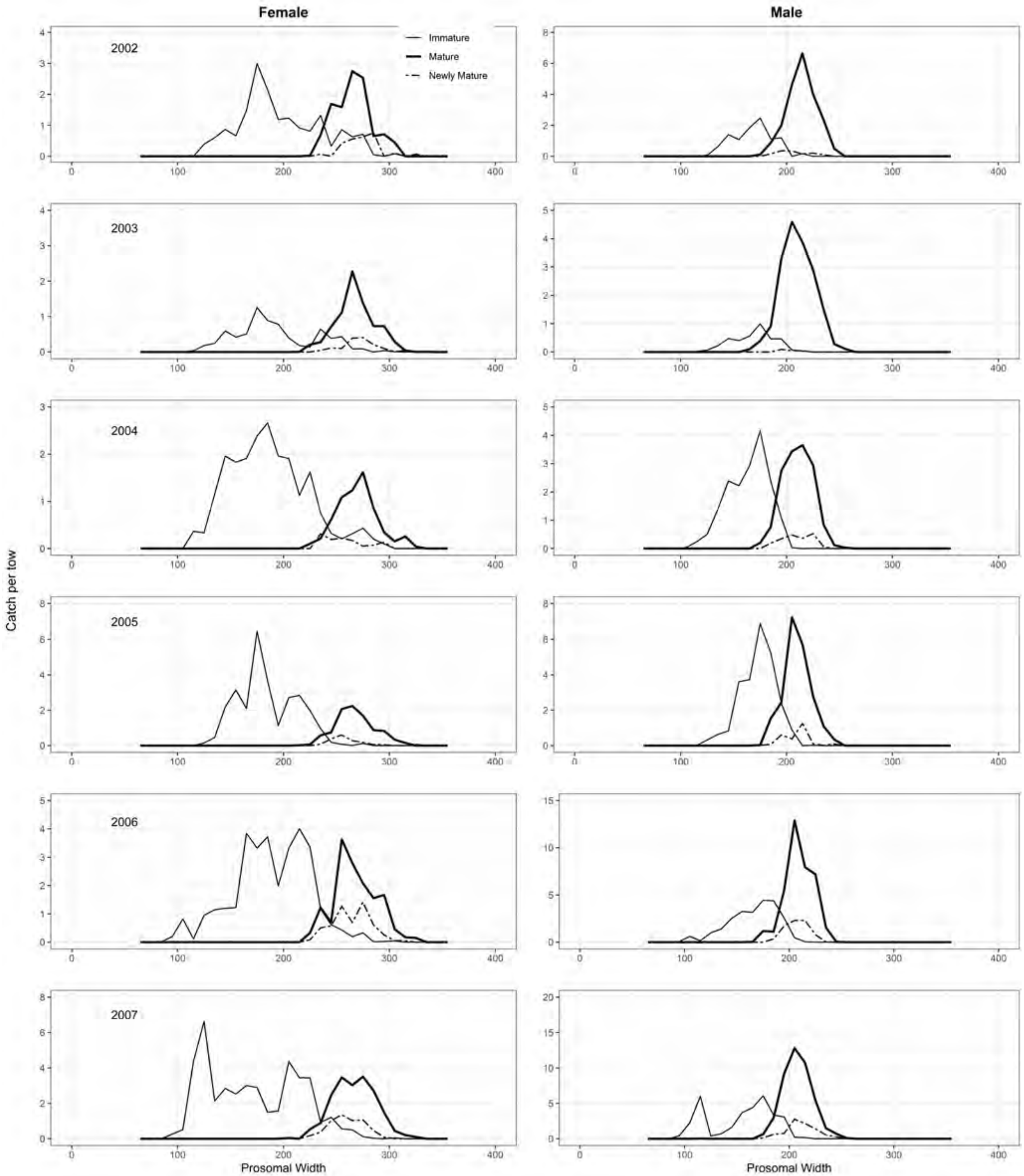
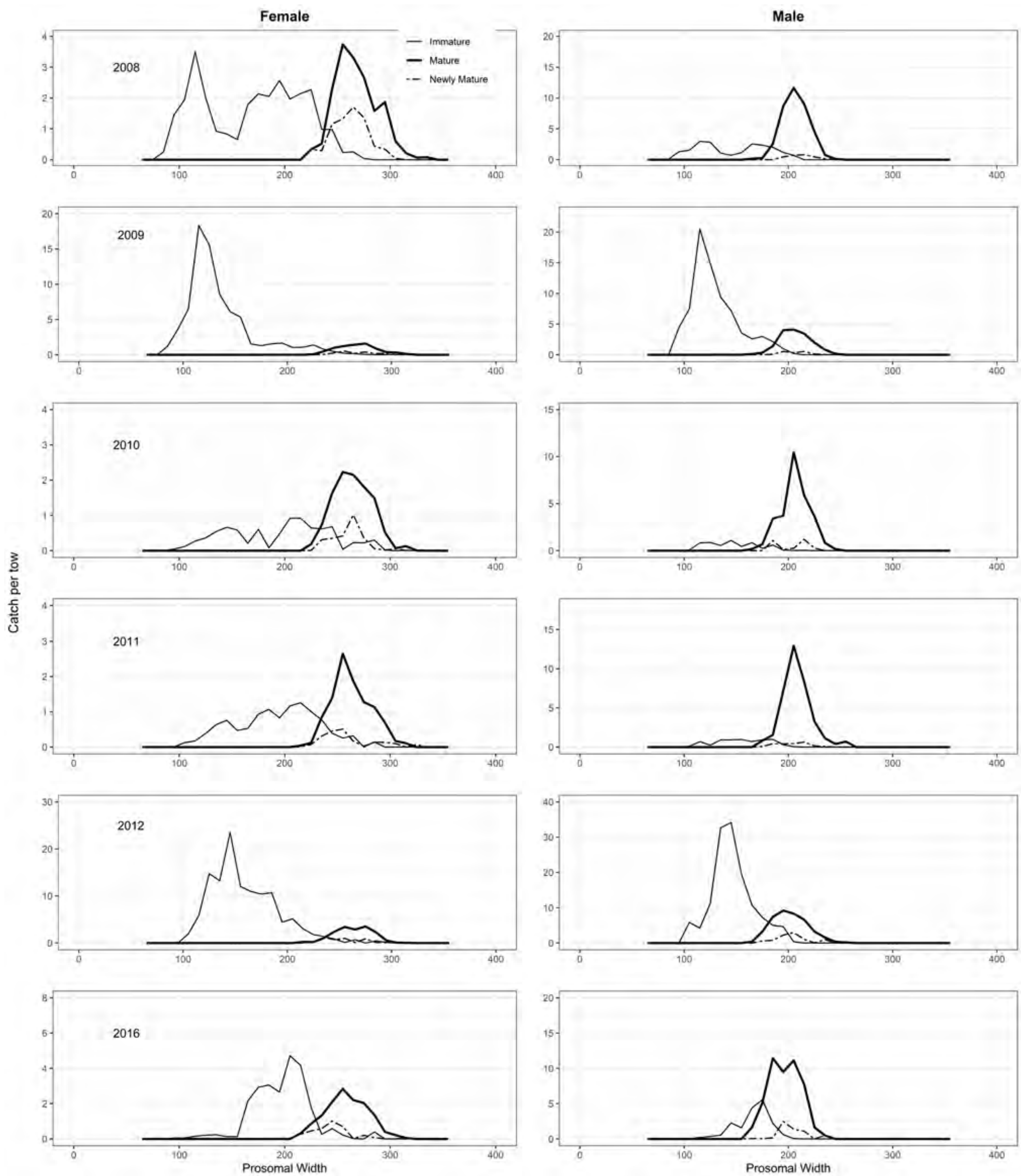


Figure 5. Size-frequency distributions of horseshoe crabs by demographic group and year in the coastal **Delaware Bay area** trawl survey. Relative frequencies are scaled to represent stratified mean catches in Table 1.



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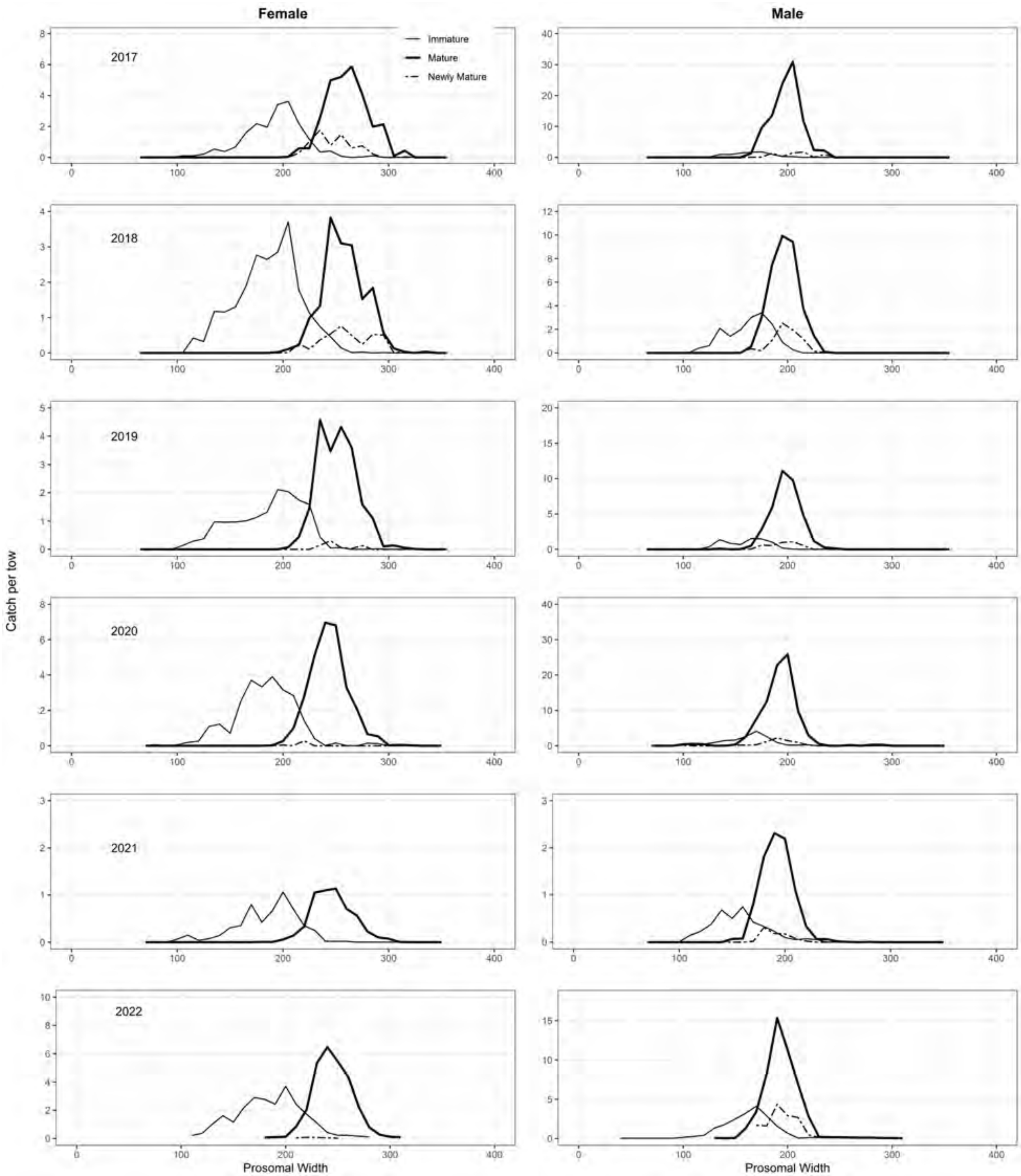

Figure 5. continued.

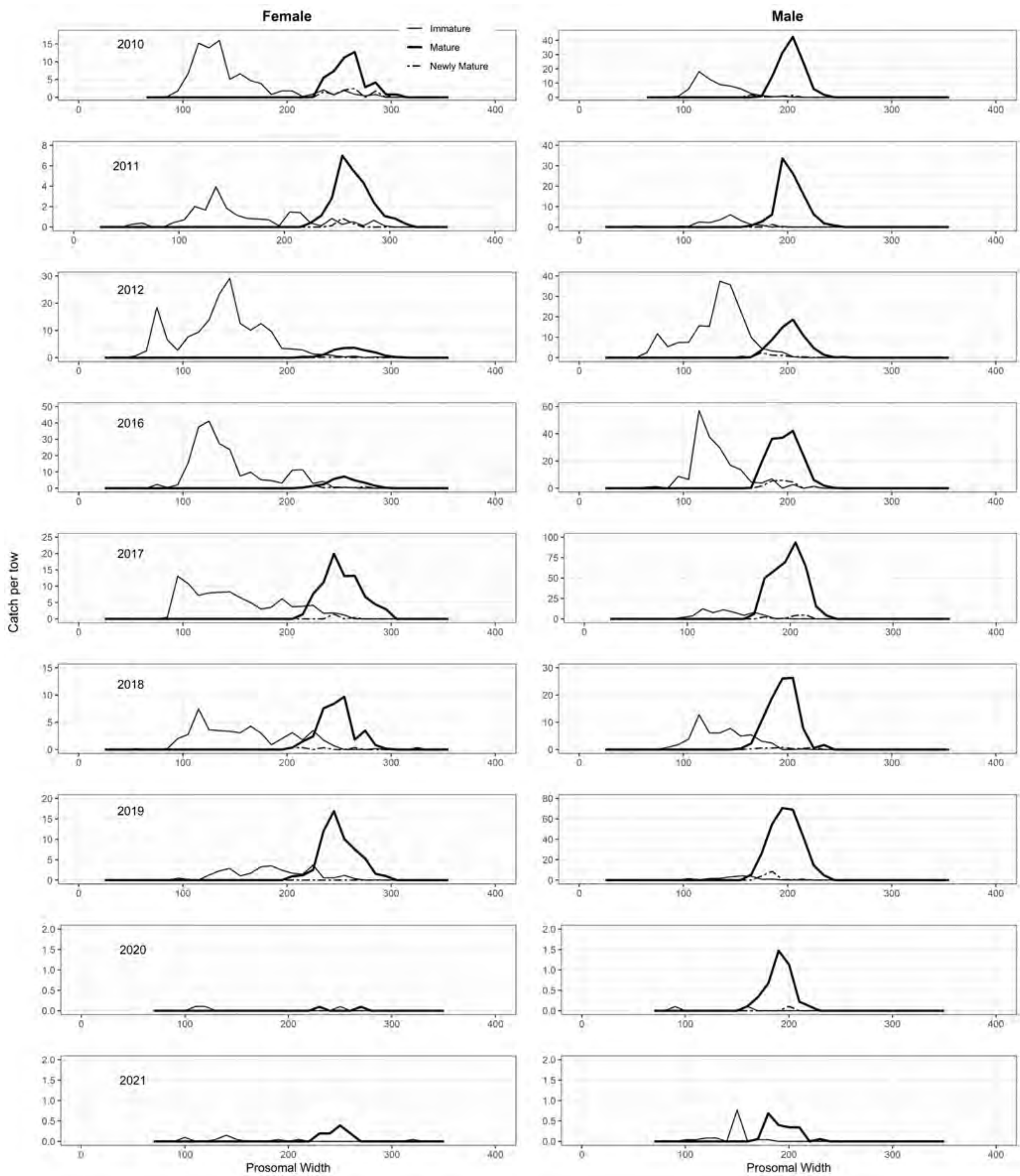

Figure 6. Relative size-frequency distributions of horseshoe crabs by demographic group and year in the **lower Delaware Bay** trawl survey. Relative frequencies are scaled to represent stratified mean catches in Table 3.

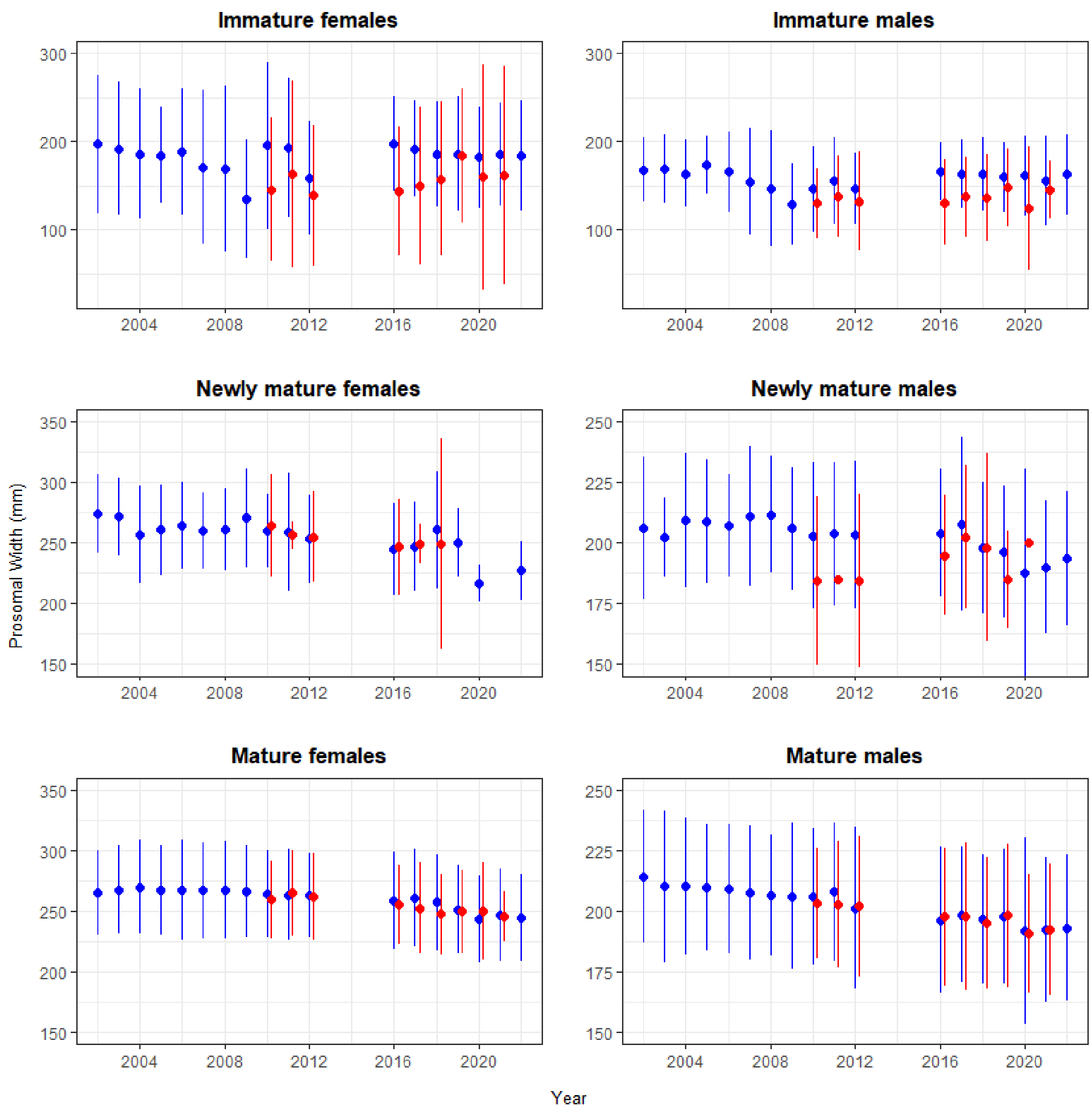

Figure 7. Mean prosomal widths (mm) (± 2 standard deviations) of mature and newly mature female and male horseshoe crabs in the Delaware Bay area (blue symbols and lines) and lower Delaware Bay (red symbols and lines) surveys.

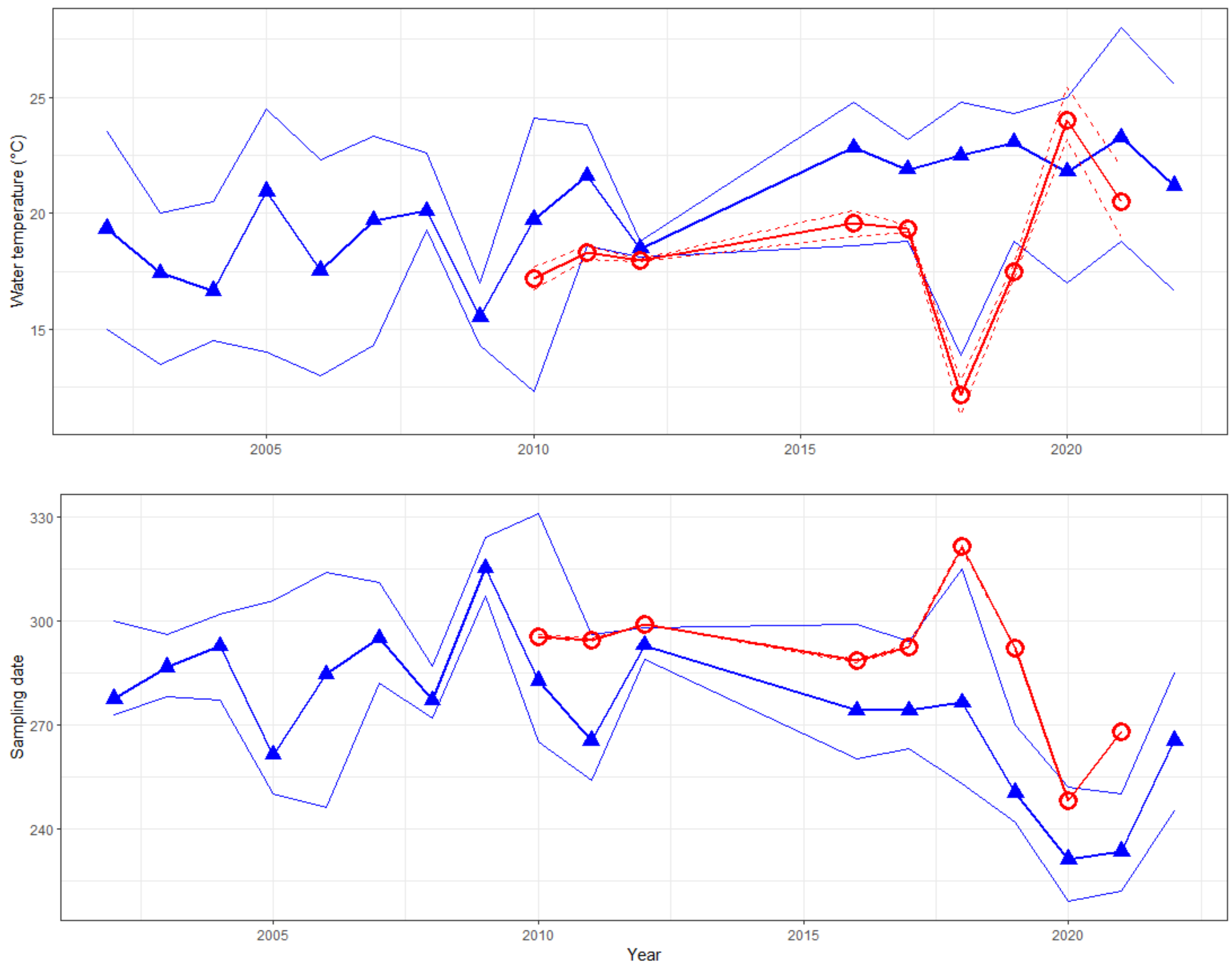

Figure 8. Plots of bottom water temperatures and ordinal sampling dates (days since 1 January) in the coastal Delaware Bay area and lower Delaware Bay trawl surveys. Solid symbols and blue lines indicate coastal Delaware Bay area. Open symbols and red lines indicate lower Delaware Bay. Points indicate mean values. Thinner lines indicate maximum and minimum values. Approximate calendar dates are indicated by gray horizontal lines for reference (ordinal dates are shifted by one day for leap years).

Table 1. Stratified mean catch-per-tow of horseshoe crabs in the coastal **Delaware Bay area** survey, 2002-2022, with the mean, standard deviation (sd), and coefficient of variation (CV), calculated using the **delta distribution** model by demographic group. Also included are the estimated upper and lower 95% confidence limits (UCL, LCL).

YEAR	MEAN	UCL	LCL	CV	SD	YEAR	MEAN	UCL	LCL	CV	SD
Immature Females						**Immature Males**					
2002	21.9	36.1	7.6	0.31	6.8	2002	12.6	21.4	3.9	0.33	4.2
2003	10.5	20.4	0.7	0.43	4.6	2003	5.4	9.9	0.9	0.39	2.1
2004	17.9	27.2	8.6	0.25	4.5	2004	15.7	25	6.4	0.29	4.5
2005	12.7	19.9	5.5	0.28	3.5	2005	11.9	20	3.8	0.33	3.9
2006	29.5	42.8	16.3	0.21	6.3	2006	21.6	33.9	9.2	0.25	5.4
2007	29.6	59.4	-0.2	0.41	12.2	2007	19.5	39.6	-0.6	0.42	8.2
2008	25.3	43.7	6.9	0.33	8.3	2008	18	32.4	3.6	0.35	6.3
2009	90.2	167.4	12.9	0.39	35.5	2009	69	109.7	28.3	0.29	19.8
2010	9	11.9	6.1	0.16	1.4	2010	6.1	9.5	2.8	0.27	1.6
2011	11.4	15.9	6.9	0.19	2.2	2011	6.9	10.1	3.7	0.23	1.6
2016	25.8	45.1	6.5	0.36	9.2	2016	20	36.6	3.5	0.39	7.9
2017	17.9	25.4	10.4	0.19	3.4	2017	12.3	20.5	4.2	0.27	3.3
2018	22.5	31.2	13.9	0.18	4.1	2018	16.5	24.4	8.7	0.22	3.7
2019	8	12.7	3.2	0.3	2.4	2019	3.5	6	1	0.35	1.2
2020	25.3	51.9	0.1	0.6	15.2	2020	16	31.3	0.8	0.56	9.1
2021	10.4	19.8	1.1	0.52	5.5	2021	6.4	11.5	1.3	0.46	3
2022	**24.6**	**38.5**	**10.8**	**0.33**	**8.1**	**2022**	**19.3**	**30.8**	**7.7**	**0.36**	**6.9**
Mature Females						**Mature Males**					
2002	11.4	18.5	4.2	0.3	3.4	2002	26.6	39.7	13.4	0.24	6.3
2003	7.7	11.7	3.7	0.25	1.9	2003	18.4	29.6	7.3	0.28	5.2
2004	5.9	8.6	3.3	0.21	1.3	2004	11.4	17.1	5.7	0.24	2.8
2005	7.2	11.4	3	0.27	2	2005	13.2	19.1	7.3	0.21	2.8
2006	15.3	33.8	-3.2	0.44	6.7	2006	36.2	60.9	11.4	0.28	10.1
2007	16.9	27.5	6.2	0.3	5.1	2007	34.3	54.4	14.3	0.28	9.7
2008	14.4	23.3	5.4	0.29	4.2	2008	33.5	57.2	9.8	0.33	11.2
2009	6.7	11.2	2.3	0.32	2.1	2009	14.1	22.8	5.3	0.3	4.2
2010	11.8	17.3	6.3	0.22	2.6	2010	31.5	49.2	13.8	0.27	8.6
2011	12.3	17.1	7.6	0.18	2.2	2011	36	69.8	2.2	0.41	14.7
2016	13.5	19.5	7.6	0.21	2.9	2016	49.2	83.1	15.2	0.29	14.3
2017	16.9	24.8	9	0.23	3.9	2017	48.9	74	23.9	0.25	12.2
2018	16.8	23.7	9.9	0.2	3.3	2018	35.7	48.9	22.5	0.17	6.2
2019	11.6	18.7	4.5	0.3	3.5	2019	20	33.3	6.8	0.33	6.6
2020	29.6	41.2	18.1	0.23	6.9	2020	87	139.4	34.5	0.36	31.1
2021	38.2	86.5	0	0.72	27.4	2021	95	207.8	0	0.67	64.1
2022	**28.2**	**42.3**	**14.1**	**0.29**	**8.3**	**2022**	**50**	**79.1**	**20.9**	**0.34**	**17.2**
Newly Mature Females						**Newly Mature Males**					
2002	3.6	5.6	1.6	0.26	0.9	2002	1.3	2	0.5	0.28	0.4
2003	1.8	3.8	-0.1	0.49	0.9	2003	0.2	0.5	-0.1	0.84	0.2
2004	0.8	1.3	0.3	0.3	0.2	2004	1.8	2.6	1	0.21	0.4
2005	1.1	1.7	0.5	0.28	0.3	2005	1.3	2.3	0.4	0.33	0.4
2006	4.6	7.8	1.5	0.3	1.4	2006	7.1	11.6	2.6	0.36	2.7
2007	5.1	9.3	0.9	0.39	2	2007	6.7	10.6	2.8	0.28	1.9
2008	6	11.8	0.2	0.44	2.7	2008	1.8	2.9	0.6	0.32	0.6
2009	2	3.1	0.9	0.26	0.5	2009	1.7	2.8	0.5	0.34	0.6
2010	3	6.8	-0.7	0.59	1.8	2010	3.2	7	-0.5	0.55	1.8
2011	2	3.3	0.7	0.31	0.6	2011	1.9	3.4	0.4	0.37	0.7
2016	3.5	5.2	1.9	0.23	0.8	2016	5.9	11	0.7	0.42	2.5
2017	3.5	5.5	1.6	0.27	0.9	2017	3.6	5.8	1.5	0.29	1
2018	3.9	6.3	1.4	0.3	1.2	2018	7.5	11.9	3.1	0.27	2.1
2019	0.5	1	0	0.46	0.2	2019	2.8	4.6	1	0.32	0.9
2020	0.3	0.8	0	0.85	0.3	2020	7	11	2.9	0.35	2.4
2021	0	NA	NA	NA	0	2021	16.4	37.3	0	0.69	11.3
2022	**0.29**	**0.52**	**0.05**	**0.46**	**0.13**	**2022**	**13.8**	**26**	**1.7**	**0.52**	**7.2**

Table 2. Stratified mean catch-per-tow of horseshoe crabs in the coastal **Delaware Bay area** survey, 2002-2022, with the mean, standard deviation (sd), and coefficient of variation (CV), calculated using the **normal distribution** model by demographic group. Also included are the estimated upper and lower 95% confidence limits (UCL, LCL).

YEAR	MEAN	UCL	LCL	CV	SD	YEAR	MEAN	UCL	LCL	CV	SD
Immature Females						**Immature Males**					
2002	19.1	27.6	10.5	0.22	4.1	2002	11.7	18.3	5	0.27	3.2
2003	9.5	15.9	3	0.32	3.1	2003	4.9	8.1	1.8	0.3	1.5
2004	17	24.5	9.5	0.21	3.6	2004	14	20.3	7.6	0.22	3.1
2005	11.5	17	6.1	0.23	2.6	2005	10.6	16.7	4.4	0.28	2.9
2006	31.1	46.9	15.3	0.24	7.5	2006	21.5	32	11.1	0.23	5
2007	29.8	59.6	0	0.41	12.2	2007	20.5	43.2	-2.3	0.45	9.3
2008	24.6	38.9	10.3	0.27	6.6	2008	15.9	24.2	7.6	0.24	3.8
2009	63.1	93.8	32.4	0.24	14.9	2009	61	89.8	32.1	0.23	14
2010	9.4	13	5.7	0.19	1.8	2010	6.4	10.1	2.6	0.29	1.8
2011	12.2	18.5	6	0.25	3	2011	7.3	11.2	3.3	0.26	1.9
2016	25.1	41.1	9	0.31	7.7	2016	18.1	29.9	6.3	0.31	5.7
2017	19.1	28.7	9.6	0.24	4.6	2017	12.4	19.3	5.5	0.26	3.3
2018	22.5	30.6	14.5	0.17	3.8	2018	17.2	25.9	8.6	0.24	4.1
2019	13.7	21.9	5.5	0.3	4.1	2019	6.6	11.1	2	0.34	2.2
2020	18.8	35.4	8.7	0.32	6	2020	12.7	24	4.7	0.37	4.75
2021	10.14	19.20	1.54	0.50	5.05	2021	6.39	10.99	1.83	0.42	2.66
2022	**20.7**	**27.2**	**14.2**	**0.18**	**3.83**	**2022**	**16.0**	**21.4**	**10.7**	**0.20**	**3.2**
Mature Females						**Mature Males**					
2002	11	17	4.9	0.26	2.8	2002	24.6	34.4	14.8	0.19	4.7
2003	7.5	10.9	4.1	0.22	1.6	2003	17	24.7	9.4	0.21	3.6
2004	6	8.3	3.7	0.19	1.1	2004	12.6	20.2	5.1	0.29	3.6
2005	6.8	10	3.5	0.22	1.5	2005	12.3	16.7	7.8	0.17	2.1
2006	13.5	24.2	2.7	0.31	4.2	2006	32.8	49.5	16.1	0.22	7.4
2007	14.2	21.3	7.1	0.24	3.4	2007	28.4	39.9	16.8	0.2	5.6
2008	16.5	31	2	0.41	6.8	2008	32.7	53.7	11.7	0.31	10
2009	7.3	12.3	2.2	0.33	2.4	2009	14.2	22.9	5.5	0.29	4.1
2010	12.7	19.7	5.7	0.26	3.3	2010	32.5	50.9	14.1	0.27	8.8
2011	12.6	18.1	7.2	0.2	2.6	2011	35.4	61.4	9.5	0.32	11.5
2016	12.8	17.4	8.2	0.17	2.2	2016	53.9	90	17.8	0.3	16.2
2017	18.2	28	8.4	0.26	4.8	2017	47.2	69.3	25.1	0.23	10.8
2018	21.1	39.6	2.5	0.41	8.7	2018	34.9	44.9	24.9	0.14	4.8
2019	18.7	28.4	9	0.26	4.8	2019	19.7	31	8.4	0.28	5.6
2020	29.4	41.8	17.3	0.25	7.2	2020	68.8	111.7	44.1	0.21	14.7
2021	54.03	85.27	6.79	0.50	26.82	2021	152.63	215.49	30.01	0.46	69.66
2022	**24.3**	**31.5**	**17.1**	**0.18**	**4.3**	**2022**	**47.8**	**64.7**	**31**	**0.21**	**9.90**
Newly Mature Females						**Newly Mature Males**					
2002	3.5	5.3	1.7	0.24	0.9	2002	1.3	2.2	0.4	0.31	0.4
2003	1.8	3.6	0.1	0.45	0.8	2003	0.2	0.5	-0.2	0.84	0.2
2004	0.8	1.4	0.3	0.33	0.3	2004	1.8	2.6	1	0.21	0.4
2005	1.2	2.1	0.3	0.35	0.4	2005	1.3	2.1	0.5	0.29	0.4
2006	4.8	8.2	1.4	0.33	1.6	2006	7.5	13.2	1.8	0.36	2.7
2007	4.6	7.7	1.5	0.32	1.5	2007	6.1	9.1	3.2	0.23	1.4
2008	6.3	11.3	1.3	0.37	2.3	2008	1.8	3.1	0.5	0.34	0.6
2009	2	3.1	0.9	0.26	0.5	2009	1.6	2.6	0.6	0.3	0.5
2010	4	10.3	-2.3	0.74	3	2010	3.3	7.2	-0.6	0.56	1.9
2011	2.2	3.9	0.5	0.38	0.8	2011	1.9	3.5	0.4	0.38	0.7
2016	3.5	5.1	1.9	0.22	0.8	2016	6.6	12.6	0.6	0.43	2.9
2017	3.6	5.5	1.6	0.27	1	2017	3.8	6.4	1.3	0.32	1.2
2018	3.9	6.2	1.6	0.28	1.1	2018	6.9	10	3.9	0.21	1.5
2019	0.6	1.2	0	0.48	0.3	2019	3.5	5.5	1.5	0.29	1
2020	0.3	0.8	0	0.84	0.28	2020	6.9	10.6	3.3	0.31	2.1
2021	0.00	NA	NA	NA	0.00	2021	16.33	37.39	0.00	0.69	11.31
2022	**0.29**	**0.53**	**0.04**	**0.46**	**0.13**	**2022**	**16.2**	**28.6**	**3.8**	**0.45**	**7.2**

Table 3. Stratified mean catch–per-tow of horseshoe crabs in the **lower Delaware Bay** survey area in 2010-2022, with the mean, standard deviation (sd), and coefficient of variation (CV), calculated using the **delta distribution** model, by demographic group. Also included are the estimated upper and lower 95% confidence limits (UCL, LCL).

YEAR	MEAN	UCL	LCL	CV	SD	YEAR	MEAN	UCL	LCL	CV	SD
Immature Females						**Immature Males**					
2010	79.7	122.2	37.3	0.21	16.5	2010	61.2	105.5	16.9	0.3	18.1
2011	19.7	45.2	-5.9	0.47	9.2	2011	20.2	50.7	-10.4	0.55	11
2012	164.3	311.8	16.9	0.32	53.1	2012	192.6	548.4	-163.3	0.43	82.7
2016	196	335.5	56.6	0.29	57	2016	184.2	322.9	45.5	0.32	58.7
2017	96.7	210	-16.7	0.46	44.1	2017	62.9	137.6	-11.7	0.46	29
2018	47.2	56.2	38.1	0.08	3.8	2018	55.1	71.8	38.4	0.12	6.8
2019	9.5	24.3	-5.3	0.6	5.7	2019	5.7	15.8	-4.5	0.7	4
2020	0.3	0.8	0	0.97	0.3	2020	0.2	0.6	0	0.97	0.2
2021	3.1	NA	NA	0.99	3.1	2021	3.3	NA	NA	0.78	2.6
2022	**NA**	**NA**	**NA**	**NA**	**NA**	**2022**	**NA**	**NA**	**NA**	**NA**	**NA**
Mature Females						**Mature Males**					
2010	48.8	98.9	-1.2	0.4	19.5	2010	130.3	242.6	18.1	0.34	43.7
2011	30.3	60.4	0.2	0.36	10.8	2011	110.2	249	-28.6	0.45	50
2012	19.1	51.6	-13.4	0.4	7.6	2012	66.8	141.1	-7.4	0.35	23.3
2016	26.3	33.9	18.7	0.12	3.2	2016	161.7	192.5	131	0.08	13.3
2017	80.6	167.1	-5.8	0.39	31.1	2017	362.7	868.5	-143.2	0.5	182.2
2018	36.2	46.6	25.8	0.12	4.3	2018	94.3	117.9	70.7	0.11	10
2019	20.8	54.7	-13	0.63	13.2	2019	100.4	254	-53.2	0.59	59.7
2020	0.2	0.5	0	0.97	0.2	2020	4.1	8.8	0	0.67	2.7
2021	1.6	NA	NA	0.99	1.5	2021	8.7	NA	NA	0.72	6.3
2022	**NA**	**NA**	**NA**	**NA**	**NA**	**2022**	**NA**	**NA**	**NA**	**NA**	**NA**
Newly Mature Females						**Newly Mature Males**					
2010	9.7	25.8	-6.3	0.64	6.2	2010	4.4	9.5	-0.8	0.46	2
2011	1.4	3.8	-0.9	0.58	0.8	2011	1.4	4.9	-2.2	0.94	1.3
2012	1	4.4	-2.3	0.76	0.8	2012	6.1	14.2	-2	0.48	2.9
2016	4.6	8	1.1	0.31	1.4	2016	16.2	29	3.5	0.3	5
2017	2.1	5.9	-1.7	0.65	1.4	2017	12.4	27.6	-2.7	0.44	5.4
2018	2.3	4.4	0.2	0.35	0.8	2018	3.6	7.6	-0.5	0.44	1.6
2019	0	0	0	NA	0	2019	8	22.3	-6.4	0.7	5.6
2020	0	0	0	NA	0	2020	0.1	0.3	0	0.97	0.1
2021	0	NA	NA	NA	0	2021	0	NA	NA	NA	0
2022	**NA**	**NA**	**NA**	**NA**	**NA**	**2022**	**NA**	**NA**	**NA**	**NA**	**NA**

Table 4. Stratified mean catch-per-tow of horseshoe crabs in **the lower Delaware Bay** survey area in 2010-2022, with the mean, standard deviation (sd), and coefficient of variation (CV), calculated using the **normal distribution** model by demographic group. Also included are the estimated upper and lower 95% confidence limits (UCL, LCL).

YEAR	MEAN	UCL	LCL	CV	SD	YEAR	MEAN	UCL	LCL	CV	SD
Immature Females						**Immature Males**					
2010	79.5	116.5	42.6	0.19	15.1	2010	60.4	95.7	25.1	0.25	15.3
2011	21.3	54.2	-11.5	0.55	11.8	2011	21.5	57.2	-14.3	0.6	12.9
2012	165.5	287.6	43.4	0.3	49.9	2012	183.9	360.1	7.8	0.34	63.4
2016	186.5	284.7	88.3	0.22	40.1	2016	167.9	249.7	86	0.21	34.6
2017	90.8	176	5.6	0.37	33.2	2017	58.2	109	7.5	0.36	20.7
2018	47.1	55.6	38.6	0.08	3.6	2018	54.9	69.6	40.2	0.11	6.2
2019	16	30.4	1.5	0.35	5.6	2019	10.7	21.7	-0.4	0.4	4.3
2020	0.3	0.8	0	0.97	0.3	2020	0.2	0.6	0	0.97	0.2
2021	3.1	NA	NA	0	0	2021	3.3	NA	NA	0	0
2022	**NA**	**NA**	**NA**	**NA**	**NA**	**2022**	**NA**	**NA**	**NA**	**NA**	**NA**
Mature Females						**Mature Males**					
2010	49.1	99.8	-1.7	0.4	19.7	2010	128	227.9	28.2	0.3	38.9
2011	28.6	49.9	7.4	0.27	7.7	2011	100.3	187.7	13	0.31	31.5
2012	18.7	46.2	-8.9	0.34	6.4	2012	65.3	111.7	18.8	0.28	18.1
2016	26.2	33.4	19	0.11	3	2016	161.8	192.4	131.1	0.08	13.3
2017	80.5	165	-4	0.38	30.4	2017	303.4	531.7	75.2	0.27	82.2
2018	36.2	47.2	25.1	0.12	4.3	2018	94.7	120.3	69	0.11	10.8
2019	29.3	54.8	3.8	0.34	9.9	2019	49.9	90	9.9	0.31	15.6
2020	0.2	0.5	0	0.97	0.2	2020	4.1	8.8	0	0.67	2.7
2021	1.6	NA	NA	0	0	2021	8.7	NA	NA	0	0
2022	**NA**	**NA**	**NA**	**NA**	**NA**	**2022**	**NA**	**NA**	**NA**	**NA**	**NA**
Newly Mature Females						**Newly Mature Males**					
2010	9.6	24.9	-5.7	0.62	5.9	2010	4.3	9.1	-0.5	0.43	1.9
2011	1.4	3.8	-0.9	0.58	0.8	2011	1.4	4.9	-2.2	0.94	1.3
2012	1	4.4	-2.3	0.76	0.8	2012	6.1	14.1	-1.9	0.47	2.9
2016	4.5	8	1.1	0.3	1.3	2016	16	27.2	4.9	0.27	4.3
2017	2.1	5.9	-1.7	0.65	1.4	2017	12.4	25.7	-1	0.42	5.2
2018	2.3	4.3	0.3	0.34	0.8	2018	3.6	7.6	-0.5	0.44	1.6
2019	0	0	0	NA	0	2019	8.5	22.9	-5.9	0.66	5.6
2020	0	0	0	NA	0	2020	0.1	0.3	0	0.97	0.1
2021	0	NA	NA	NA	0	2021	0	NA	NA	NA	0
2022	**NA**	**NA**	**NA**	**NA**	**NA**	**2022**	**NA**	**NA**	**NA**	**NA**	**NA**

Table 5. Results of correlation analyses of mean prosomal width (mm) and survey year for mature and newly mature males and females from the Delaware Bay area and lower Delaware Bay surveys. Statistics presented are number of years included: *n*; *T-score*; probability, *p*; and correlation coefficient, *r*. A negative correlation coefficient indicates a decreasing regression slope.

Maturity Group	n	T	p	r
Delaware Bay Area 2002 - 2022				**p**
Mature females	17	-8.51	<0.001	-0.905
Newly mature females	17	-5.07	0.001	-0.794
Mature males	17	-16.45	<0.001	-0.972
Newly mature males	17	-4.81	<0.001	-0.769
Lower Delaware Bay 2002 - 2021				
Mature females	9	-6.78	<0.001	-0.932
Newly mature females	9	-3.98	0.016	-0.894
Mature males	9	-6.32	<0.001	-0.922
Newly mature males	9	2.28	0.063	0.681

Table 6. Estimated population (in thousands) of horseshoe crabs in the coastal **Delaware Bay area** survey, 2002-2022, with the mean, standard deviation (sd), and coefficient of variation (CV), calculated using the **delta distribution model** by demographic group. Also included are the estimated upper and lower 95% confidence limits (UCL, LCL).

YEAR	MEAN	UCL	LCL	CV	SD	YEAR	MEAN	UCL	LCL	CV	SD
Immature Females						**Immature Males**					
2002	9470	15665	3275	0.31	2936	2002	5483	9284	1683	0.33	1809
2003	4585	8848	321	0.43	1972	2003	2303	4217	390	0.39	898
2004	7774	11770	3778	0.25	1944	2004	6810	10895	2725	0.29	1975
2005	5630	8856	2404	0.28	1576	2005	5260	8839	1681	0.33	1736
2006	12928	18691	7164	0.21	2715	2006	9327	14554	4100	0.24	2238
2007	13684	27486	-118	0.41	5610	2007	8966	18246	-314	0.42	3766
2008	10933	18650	3216	0.32	3499	2008	7841	13917	1766	0.35	2744
2009	39032	72868	5197	0.39	15222	2009	29864	47269	12460	0.28	8362
2010	3954	5220	2688	0.16	633	2010	2686	4144	1229	0.26	698
2011	4965	6945	2985	0.2	993	2011	3092	4547	1637	0.23	711
2016	11699	20462	2935	0.36	4212	2016	9102	16649	1555	0.39	3550
2017	7505	10708	4302	0.19	1426	2017	5091	8465	1717	0.27	1375
2018	10173	14285	6061	0.19	1933	2018	7507	11173	3842	0.23	1727
2019	3397	5516	1279	0.31	1053	2019	1487	2614	360	0.38	565
2020	9475	19779	0	0.65	6159	2020	5925	11967	0	0.61	3614
2021	4,174	7,947	400	0.53	2218	2021	2,574	4,634	513	0.47	1,199
2022	**9,930**	**15,493**	**4,366**	**0.33**	**3282**	**2022**	**7,652**	**12,192**	**3,112**	**0.35**	**2686**
Mature Females						**Mature Males**					
2002	4959	8084	1834	0.3	1488	2002	11584	17335	5834	0.24	2780
2003	3379	5160	1599	0.25	845	2003	8069	13029	3110	0.29	2340
2004	2735	4043	1426	0.23	629	2004	5150	7788	2511	0.25	1288
2005	3138	4942	1333	0.27	847	2005	5844	8461	3228	0.22	1286
2006	6611	14330	-1108	0.42	2777	2006	15825	26060	5589	0.27	4273
2007	7746	12704	2789	0.31	2401	2007	15795	25104	6487	0.28	4423
2008	6311	10202	2419	0.29	1830	2008	14647	24995	4299	0.33	4834
2009	2975	4971	979	0.32	952	2009	6240	10197	2283	0.3	1872
2010	5178	7616	2740	0.23	1191	2010	13963	21910	6015	0.28	3910
2011	5290	7282	3297	0.18	952	2011	15060	29000	1120	0.4	6024
2016	6024	8635	3413	0.21	1265	2016	21941	37216	6665	0.29	6363
2017	7185	10525	3844	0.23	1653	2017	20664	31208	10119	0.25	5166
2018	7326	10520	4131	0.21	1538	2018	15749	21880	9619	0.18	2835
2019	5110	8454	1767	0.32	1635	2019	8924	15202	2646	0.35	3108
2020	10803	15359	6247	0.25	2706	2020	31546	51050	12042	0.36	11583
2021	15,498	35,873	0	0.75	11,568	2021	38,538	85,949	0	0.7	26,925
2022	**11,421**	**17,179**	**5,662**	**0.30**	**3380**	**2022**	**19,921**	**31,447**	**8,395**	**0.34**	**6,806**
Newly Mature Females						**Newly Mature Males**					
2002	1537	2400	675	0.26	400	2002	548	869	227	0.28	153
2003	794	1633	-45	0.49	389	2003	78	221	-65	0.84	66
2004	358	575	141	0.29	104	2004	789	1127	451	0.21	166
2005	479	753	206	0.27	129	2005	597	1002	191	0.33	197
2006	2051	3509	594	0.31	636	2006	3113	5113	1113	0.31	965
2007	2373	4339	408	0.4	949	2007	3129	4972	1287	0.28	876
2008	2571	4984	158	0.43	1106	2008	757	1254	261	0.31	235
2009	885	1361	410	0.26	230	2009	725	1240	210	0.34	247
2010	1338	2990	-314	0.59	789	2010	1422	3070	-226	0.55	782
2011	845	1360	331	0.3	254	2011	749	1335	164	0.36	270
2016	1608	2357	860	0.23	370	2016	2608	4884	331	0.42	1095
2017	1480	2274	687	0.26	385	2017	1523	2392	654	0.28	426
2018	1773	2923	622	0.31	550	2018	3341	5367	1316	0.29	969
2019	242	472	12	0.47	114	2019	1271	2154	389	0.34	437
2020	133	330	0	0.87	117	2020	2492	4030	953	0.37	914
2021	0	NA	NA	NA	NA	2021	6,333	14,328	0	0.68	4309
2022	**115**	**207**	**23**	**0.46**	**53**	**2022**	**5,487**	**10,293**	**681**	**0.52**	**2,835**

Table 7. Estimated population (in thousands) of horseshoe crabs in the coastal **Delaware Bay area** survey, 2002-2022, with the mean, standard deviation (sd), and coefficient of variation (CV), calculated using the **normal distribution** model by demographic group. Also included are the estimated upper and lower 95% confidence limits (UCL, LCL).

YEAR	MEAN	UCL	LCL	CV	SD	YEAR	MEAN	UCL	LCL	CV	SD
Immature Females						**Immature Males**					
2002	8222	11875	4568	0.21	1727	2002	5076	7998	2155	0.28	1421
2003	4089	6860	1317	0.32	1308	2003	2114	3462	766	0.3	634
2004	7376	10616	4135	0.21	1549	2004	6033	8786	3281	0.22	1327
2005	5104	7521	2687	0.23	1174	2005	4673	7414	1932	0.28	1308
2006	13714	20988	6439	0.25	3429	2006	9378	13971	4786	0.23	2157
2007	13692	27335	48	0.41	5614	2007	9350	19735	-1035	0.45	4208
2008	10595	16578	4612	0.26	2755	2008	6897	10443	3350	0.23	1586
2009	27375	40519	14232	0.23	6296	2009	26435	38730	14140	0.23	6080
2010	4102	5706	2497	0.19	779	2010	2781	4423	1139	0.29	806
2011	5426	8433	2420	0.27	1465	2011	3301	5219	1382	0.28	924
2016	11292	18441	4144	0.3	3388	2016	8185	13512	2858	0.31	2537
2017	7948	11818	4077	0.23	1828	2017	5082	7829	2335	0.26	1321
2018	10115	13839	6391	0.18	1821	2018	7768	11653	3882	0.24	1864
2019	14855	15027	14682	0.33	4902	2019	66	236	-104	1.27	84
2020	6832	10559	3106	0.32	2213	2020	4610	7540	1679	0.38	1740
2021	4053	7670	436	0.51	2064	2021	2548	4389	707	0.42	1074
2022	**8,328**	**11,016**	**5,639**	**0.19**	**1580**	**2022**	**6,359**	**8,461**	**4,257**	**0.20**	**1243**
Mature Females						**Mature Males**					
2002	4779	7431	2128	0.26	1243	2002	10711	14972	6450	0.19	2035
2003	3308	4851	1764	0.22	728	2003	7454	10827	4082	0.21	1565
2004	2767	3919	1615	0.2	553	2004	5586	8875	2297	0.28	1564
2005	2957	4323	1592	0.22	651	2005	5408	7322	3494	0.17	919
2006	5867	10517	1218	0.31	1819	2006	14461	21734	7188	0.23	3326
2007	6553	9864	3243	0.25	1638	2007	13100	18506	7694	0.2	2620
2008	7172	13336	1008	0.4	2869	2008	14244	23240	5247	0.3	4273
2009	3230	5523	936	0.33	1066	2009	6319	10255	2383	0.29	1833
2010	5588	8698	2478	0.26	1453	2010	14396	22600	6192	0.27	3887
2011	5388	7629	3147	0.2	1078	2011	14858	25890	3825	0.33	4903
2016	5735	7770	3700	0.17	975	2016	24017	40197	7837	0.3	7205
2017	7785	12033	3537	0.27	2102	2017	19985	29245	10724	0.23	4597
2018	9463	18463	464	0.44	4164	2018	15264	19849	10680	0.15	2290
2019	6420	6506	6334	0.32	2054	2019	11660	11824	11497	0.37	4314
2020	10927	16014	5840	0.28	3021	2020	25200	34983	15416	0.23	5810
2021	21766	40665	2867	0.49	10750	2021	61879	109880	13877	0.45	27576
2022	**9,839**	**12,836**	**6,842**	**0.18**	**1770**	**2022**	**19,032**	**25,588**	**12,475**	**0.20**	**3859**
Newly Mature Females						**Newly Mature Males**					
2002	1509	2278	741	0.24	362	2002	561	925	196	0.31	174
2003	787	1547	26	0.45	354	2003	78	222	-66	0.84	66
2004	367	613	120	0.32	117	2004	786	1120	452	0.2	157
2005	531	908	154	0.34	181	2005	580	927	233	0.29	168
2006	2122	3705	540	0.33	700	2006	3377	6076	678	0.38	1283
2007	2129	3584	674	0.33	703	2007	2841	4214	1468	0.23	653
2008	2697	4780	613	0.36	971	2008	776	1315	237	0.33	256
2009	883	1366	399	0.26	230	2009	708	1157	259	0.31	219
2010	1770	4532	-992	0.74	1310	2010	1464	3180	-252	0.56	820
2011	882	1495	269	0.34	300	2011	766	1343	190	0.36	276
2016	1583	2304	863	0.22	348	2016	2939	5588	290	0.43	1264
2017	0.00	NA	NA	NA	NA	2017	1590	2623	557	0.32	509
2018	1780	2866	695	0.29	516	2018	3064	4466	1663	0.22	674
2019	77	225	-70	0.94	73	2019	112	267	-43	0.68	77
2020	134	330	0	0.87	117	2020	2430	3676	1184	0.3	740
2021	0	NA	NA	NA	NA	2021	6308	14299	0	0.68	4307
2022	**115**	**212**	**18**	**0.46**	**53**	**2022**	**6,370**	**11,143**	**1,597**	**0.44**	**2795**

Table 8. Estimated population (in thousands) of horseshoe crabs in the **lower Delaware Bay** survey area in 2010-2022, with the mean, standard deviation (sd), and coefficient of variation (CV), calculated using the **delta distribution** model by demographic group. Also included are the estimated upper and lower 95% confidence limits (UCL, LCL).

	YEAR	MEAN	UCL	LCL	CV	SD		YEAR	MEAN	UCL	LCL	CV	SD
Immature Females							**Immature Males**						
	2010	3510	5199	1822	0.2	702		2010	2632	4476	788	0.29	763
	2011	870	1931	-191	0.44	383		2011	881	2160	-397	0.52	458
	2012	8021	15084	958	0.32	2567		2012	9381	21965	-3204	0.42	3940
	2016	9046	15558	2534	0.29	2623		2016	8429	14813	2044	0.32	2697
	2017	4536	10029	-956	0.47	2132		2017	2920	6458	-618	0.47	1372
	2018	2211	2803	1619	0.1	221		2018	2597	3516	1678	0.15	390
	2019	525	1278	-229	0.56	294		2019	308	816	-201	0.64	197
	2020	12	33	0	0.97	12		2020	8	22	0	0.97	8
	2021	130	NA	NA	0.99	129		2021	140	NA	NA	0.78	109
	2022	**NA**	**NA**	**NA**	**NA**	**NA**		**2022**	**NA**	**NA**	**NA**	**NA**	**NA**
Mature Females							**Mature Males**						
	2010	2117	4260	-25	0.39	826		2010	5657	10247	1067	0.32	1810
	2011	1348	2599	96	0.33	445		2011	4829	10570	-912	0.43	2076
	2012	938	2522	-646	0.39	366		2012	3263	6864	-338	0.35	1142
	2016	1274	1710	837	0.15	191		2016	7735	9709	5761	0.1	774
	2017	3674	7501	-153	0.38	1396		2017	16794	40517	-6929	0.51	8565
	2018	1771	2588	953	0.18	319		2018	4616	6600	2631	0.18	831
	2019	1148	3011	-715	0.63	723		2019	5746	14583	-3092	0.6	3448
	2020	7	19	0	0.97	7		2020	152	332	0	0.68	103
	2021	65	NA	NA	0.99	64		2021	365	NA	NA	0.72	262
	2022	**NA**	**NA**	**NA**	**NA**	**NA**		**2022**	**NA**	**NA**	**NA**	**NA**	**NA**
Newly Mature Females							**Newly Mature Males**						
	2010	414	1087	-260	0.63	261		2010	187	409	-35	0.46	86
	2011	65	170	-40	0.58	38		2011	58	208	-93	0.94	55
	2012	50	214	-114	0.76	38		2012	301	710	-109	0.49	147
	2016	206	357	55	0.3	62		2016	727	1268	186	0.29	211
	2017	88	249	-73	0.66	58		2017	542	1100	-16	0.4	217
	2018	115	220	9	0.36	41		2018	148	290	7	0.4	59
	2019	0	0	0	NA	0		2019	361	1022	-299	0.71	257
	2020	0	0	0	NA	0		2020	4	11	0	0.97	4
	2021	0	NA	NA	NA	NA		2021	0	NA	NA	NA	NA
	2022	**NA**	**NA**	**NA**	**NA**	**NA**		**2022**	**NA**	**NA**	**NA**	**NA**	**NA**

Table 9. Estimated population (in thousands) of horseshoe crabs in the **lower Delaware Bay** survey area in 2010-2022, with the mean, standard deviation (sd), and coefficient of variation (CV), calculated using the **normal distribution** model by demographic group. Also included are the estimated upper and lower 95% confidence limits (UCL, LCL).

YEAR	MEAN	UCL	LCL	CV	SD	YEAR	MEAN	UCL	LCL	CV	SD
Immature Females						**Immature Males**					
2010	3503	5155	1851	0.18	631	2010	2588	4056	1120	0.24	621
2011	938	2311	-435	0.53	497	2011	935	2437	-567	0.58	542
2012	8125	14222	2027	0.31	2519	2012	9023	17690	356	0.35	3158
2016	8618	13190	4046	0.22	1896	2016	7725	11638	3812	0.21	1622
2017	4325	8829	-178	0.41	1773	2017	2731	5408	53	0.38	1038
2018	2209	2780	1638	0.1	221	2018	2595	3529	1661	0.15	389
2019	852	868	836	0.01	9	2019	566	566	566	0	0
2020	12	33	0	0.97	12	2020	8	22	0	0.97	8
2021	130	NA	NA	0	0	2021	140	NA	NA	0	0
2022	**NA**	**NA**	**NA**	**NA**	**NA**	**2022**	**NA**	**NA**	**NA**	**NA**	**NA**
Mature Females						**Mature Males**					
2010	2124	4340	-91	0.41	871	2010	5600	9916	1285	0.3	1680
2011	1290	2239	340	0.27	348	2011	4479	8332	625	0.31	1388
2012	915	2242	-412	0.34	311	2012	3188	5456	921	0.28	893
2016	1264	1647	880	0.13	164	2016	7727	9570	5883	0.1	773
2017	3654	7307	2	0.36	1315	2017	13805	23702	3908	0.26	3589
2018	1782	2666	898	0.19	339	2018	4647	6901	2393	0.19	883
2019	1932	1948	1916	0	0	2019	8356	8356	8356	0	0
2020	7	19	0	0.97	7	2020	152	332	0	0.68	103
2021	65	NA	NA	0	0	2021	365	NA	NA	0	0
2022	**NA**	**NA**	**NA**	**NA**	**NA**	**2022**	**NA**	**NA**	**NA**	**NA**	**NA**
Newly Mature Females						**Newly Mature Males**					
2010	418	1097	-260	0.63	263	2010	185	391	-22	0.43	80
2011	65	170	-40	0.58	38	2011	58	208	-93	0.94	55
2012	50	214	-114	0.76	38	2012	302	719	-114	0.5	151
2016	205	355	55	0.28	57	2016	716	1176	256	0.25	179
2017	88	249	-73	0.66	58	2017	541	1090	-9	0.4	216
2018	114	226	3	0.35	40	2018	149	296	1	0.41	61
2019	0	0	0	NA	0	2019	401	408	394	0	3
2020	0	0	0	NA	0	2020	4	11	0	0.97	4
2021	0	NA	NA	NA	NA	2021	0	NA	NA	NA	NA
2022	**NA**	**NA**	**NA**	**NA**	**NA**	**2022**	**NA**	**NA**	**NA**	**NA**	**NA**

Table 10. Mean, minimum (min), and maximum (max) bottom water temperature (C°) and ordinal sampling date (numerical calendar date from 1 January) for survey collections in the Delaware Bay area and Lower Delaware Bay. For reference, 1 September is ordinal date 243 in non-leap years.

	Water Temperature			Ordinal Date		
	mean	max	min	mean	max	min
Delaware Bay Area						
2002	19.33	15	23.5	277.41	273	300
2003	17.41	13.5	20	286.60	278	296
2004	16.67	14.5	20.5	292.74	277	302
2005	20.94	14	24.5	261.23	250	306
2006	17.53	13	22.3	284.53	246	314
2007	19.69	14.3	23.3	294.96	282	311
2008	20.09	19.3	22.6	277.02	272	287
2009	15.54	14.3	17	315.24	307	324
2010	19.72	12.3	24.1	282.68	265	331
2011	21.60	18.6	23.8	265.44	254	296
2012	18.47	18.1	18.8	292.92	289	298
2016	22.82	18.6	24.8	274.02	260	299
2017	21.89	18.8	23.2	274.05	263	294
2018	22.48	13.9	24.8	276.41	253	315
2019	23.05	18.8	24.3	250.38	242	270
2020	21.79	17	25	231.15	219	252
2021	23.25	18.8	28	233.44	222	250
2022	**21.18**	**16.7**	**25.6**	**265.42**	**245**	**285**
Lower Delaware Bay						
2010	17.18	16.7	17.7	295.36	295	296
2011	18.32	18	18.6	294.27	294	295
2012	17.96	17.9	18	299.00	299	299
2016	19.56	19	20.1	288.40	288	289
2017	19.35	19.2	19.5	292.30	292	293
2018	12.16	11.3	12.8	321.44	321	322
2019	17.50	17.2	17.8	292.00	292	292
2020	24.00	23.2	25.4	248.00	248	248
2021	20.50	19	22	268.00	268	268
2022	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**

Table 11. Correlations between annual mean catches-per-tow of horseshoe crabs with mean bottom water temperature and ordinal sampling date in the Delaware Bay area survey and the lower Delaware Bay survey, by demographic group. The Delaware Bay area surveys included 15 years, and the lower Delaware Bay surveys included 8 years. Statistics presented include correlation coefficient, *r*; *T-score*; and probability, *p*. Data are from Tables 1, 3, and 10.

	Water Temperature			Ordinal Date		
Delaware Bay Area 2002 - 2022	***r***	***T***	***p***	***r***	***T***	***p***
Immature females	-0.531	-2.43	0.028	0.563	2.64	0.019
Immature males	-0.539	-2.48	0.026	0.578	2.74	0.015
Mature females	0.556	2.59	0.020	-0.692	-3.71	0.002
Mature males	0.581	2.76	0.014	-0.714	-3.95	0.001
Newly mature females	-0.164	-0.64	0.529	0.512	2.31	0.036
Newly mature males	0.452	1.96	0.068	-0.475	-2.09	0.054
Lower Delaware Bay 2002 - 2021						
Immature females	-0.116	-0.31	0.767	0.346	0.98	0.362
Immature males	-0.154	-0.41	0.692	0.36	1.02	0.341
Mature females	-0.371	-1.06	0.325	0.537	1.69	0.136
Mature males	-0.153	-0.41	0.694	0.37	1.05	0.327
Newly mature females	-0.273	-0.75	0.477	0.318	0.89	0.405
Newly mature males	-0.086	-0.23	0.826	0.303	0.84	0.428

Red Knot Stopover Population Size and Migration Ecology at Delaware Bay, USA, 2023

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Abstract

Red Knots (*Calidris canutus rufa*) stop at Delaware Bay on the mid-Atlantic coast of North America during northward migration to feed on eggs of horseshoe crabs (*Limulus polyphemus*). We conducted a mark-recapture-resight investigation to estimate the passage population of Red Knots at Delaware Bay in 2023. The 2023 passage population size was estimated at 39,361 (95% credible interval: 33,724–47,556). Although there is broad overlap in the credible intervals for population estimates from 2020–2023, the population estimate for 2023 was below 40,000 birds for only the second time since 2011. Horseshoe crabs have been harvested for use as bait in eel (*Anguilla rostrata*) and whelk (*Busycon*) fisheries since at least 1990. In the late 1990s and early 2000s, the number of Red Knots counted during aerial surveys at Delaware Bay declined from ~50,000 to ~13,000 and some avian conservation biologists hypothesized that horseshoe crab harvest levels in the 1990s prevented sufficient refueling for successful migration to the Arctic breeding grounds, reproduction, and survival for the remainder of the annual cycle. Since 2013, the harvest of horseshoe crabs in the Delaware Bay region has been managed using an Adaptive Resource Management (ARM) framework. The objective of the ARM framework is to manage sustainable harvest of Delaware Bay horseshoe crabs while maintaining ecosystem integrity and supporting Red Knot recovery with adequate stopover habitat for Red Knots and other migrating shorebirds. For annual harvest recommendations, the ARM framework requires annual estimates of horseshoe crab population size and the Red Knot stopover population size. We used a Bayesian analysis of a Jolly-Seber model, which accounts for turnover in the population and the probability of detection during surveys to estimated the passage (stopover) population. The 2023 population size estimate will inform harvest recommendations in the next management cycle for decision making by the Atlantic States Marine Fisheries Commission.

1. Introduction

Red Knots (*Calidris canutus rufa*) stop at Delaware Bay during northward migration to feed on eggs of horseshoe crabs (*Limulus polyphemus*). The northward migration of *C. c. rufa* coincides with the spawning of horseshoe crabs, whose eggs are an excellent food resource for a migrating Red Knots because they have a high energy content and are easily digestible (Karpantyet al. 2006, Haramis et al. 2007). Horseshoe crabs are therefore an important food resource for Red Knots as well as other shorebirds at Delaware Bay.

Horseshoe crabs have been harvested since at least 1990 for use as bait in American eel (*Anguilla rostrata*) and whelk (Busycon) fisheries (Kreamer and Michels 2009). In the late 1990s and early 2000s the estimated number of Red Knots counted at Delaware Bay declined from ~50,000 to ~13,000 (Niles et al. 2008). The number of horseshoe crabs harvested peaked in the late 1990s and then declined in the early 2000s. Avian conservation biologists hypothesized that unregulated harvest of horseshoe crabs from Delaware Bay in the 1990s prevented sufficient refueling during stopover for successful migration to the breeding grounds, nesting, and survival for the remainder of the annual cycle (Baker et al. 2004, McGowan et al. 2011).

The Atlantic States Marine Fisheries Commission (ASMFC) has managed the horseshoe crabs in the Delaware Bay region since 1998 and in 2012 adopted an Adaptive Resource Management (ARM) framework, which explicitly incorporates shorebird objectives in horseshoe crab (hereafter "crab" or "crabs") harvest regulation (McGowan et al. 2015b). The ARM framework was designed to constrain the harvest so that the number of spawning crabs would not limit the number of Red Knots stopping at Delaware Bay during migration. To achieve multiple objectives simultaneously, the ARM framework requires an estimate each year of both the crab population and the Red Knot stopover population size to inform harvest recommendations (McGowan et al. 2015a). Therefore, we estimated the stopover population size in 2023 using mark-resight data on individually-marked birds and a Jolly-Seber model for open populations, as we have each year since 2011.

2. Methods

Red Knots have been individually marked at Delaware Bay and other locations in the Western Hemisphere (e.g., Argentina, Brazil, Canada, Chile) with engraved leg flags since 2003. Each leg flag is engraved with a field-readable, unique 3-character alphanumeric code (Clark et al. 2005). Mark-resight data (i.e., sight records of individually-marked birds and counts of marked and unmarked birds) were collected on the Delaware and New Jersey shores of Delaware Bay in 2023 according to the methods for mark-resight investigations of Red Knots at Delaware Bay (Lyons 2016). This protocol has been used at Delaware Bay since 2011.

Surveys to locate leg-flagged birds were conducted on 20 beaches (Appendix 1) in 2023 according to the sampling plan, i.e., every three days in May and early June (Table 1). During these resighting surveys, agency staff and volunteers surveyed the beach and recorded the field- readable alphanumeric combinations detected on leg-flagged birds.

As in previous years (Lyons 2022), all flag resightings were validated with physical capture and banding data available in the data repository at http://www.bandedbirds.org/. Resightings without a corresponding record of physical capture and banding (i.e., "misread" errors) were discarded and not included in the analysis. However, banding data from Argentina are not available for validation purposes in bandedbirds.org; therefore, all resightings of orange engraved flags were included in the analysis without validation using banding data. We also omitted resightings of 12 flagged individuals in 2023 whose flag codes were accidentally deployed in both New Jersey and South Carolina (Amanda Dey, New Jersey Division of Fish and Wildlife, pers. comm., 31 May 2017) because it is not possible to confirm individual identity in this case. Section 4 "Summary of Mark-resight and Count Data Collected in 2023" describes additional quality control procedures and the potential for other types of errors in the mark- resight dataset.

While searching for birds marked with engraved leg flags, observers also periodically used a scan sampling technique to count marked and unmarked birds in randomly selected portions of Red Knot flocks (Lyons 2016). As part of the scan sampling protocol to estimate the marked-unmarked ratio (Lyons 2016), observers checked a random sample of birds for marks (leg flags), and recorded 1) the number of individually-marked birds, and 2) the number of birds checked for marks in each sample.

To estimate stopover population size, we used the methods of Lyons et al. (2016) to analyze 1) the mark-resight data (flag codes), and 2) data from the scan samples of the marked-unmarked ratio. Lyons et al. (2016) relied on the "superpopulation" approach developed by Crosbie and Manly (1985) and Schwarz and Arnason (1996). The superpopulation is defined as the total number of birds present in the study area on at least one of the sampling occasions over the entire

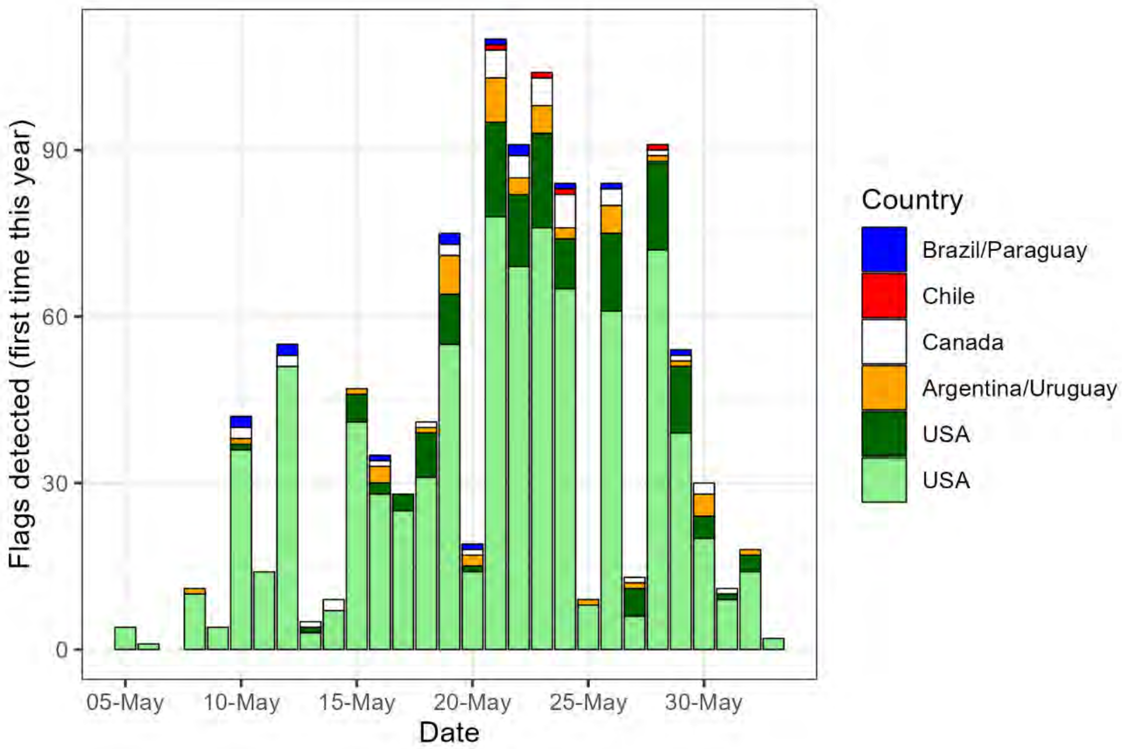

Figure 1 Number of flags detected for the first time in 2023 by flag color.

study, i.e., the total number of birds present in the study area at any time between the first and last sampling occasions (Nichols and Kaiser 1999). In this superpopulation approach, passage population size is estimated each year using the Jolly-Seber model for open populations, which accounts for the flow-through nature of migration areas and probability of detection during surveys.

In our analyses for Delaware Bay, the days of the migration season were aggregated into 3-day sampling periods (a total of 10 sample periods possible each season, Table 1). Data were aggregated to 3-day periods because this is the amount of time necessary to complete mark-resight surveys on all beaches in the study (a summary of the mark-resight data from 2023 is provided in Appendix 2).

With the mark-resight superpopulation approach, we first estimated the number of birds that were carrying leg flags, and then adjusted this number to account for unmarked birds using the estimated proportion of the population with flags. The estimated proportion with leg flags is thus an important statistic. We used the scan

Table 1. Dates for mark-resight survey periods (3-day sampling occasions) for Red Knots (*C. c. rufa*) at Delaware Bay in 2023. The same sampling periods have been used at Delaware Bay since 2011. Data from survey period 10 were not used in the 2023 analysis because the mark-resight data were sparse in this period.

Survey period	Dates	Survey period	Dates
1	≤10 May	6	23-25 May
2	11-13 May	7	26-28 May
3	14-16 May	8	29-31 May
4	17-19 May	9	1-3 June
5	20-22 May	10	4-6 June

sample data (i.e., the counts of marked birds and the number checked for marks) and a binomial model to estimate the proportion of the population that is marked. To account for the random nature of arrival of marked birds at the study area and the addition of new marks during the season, we implemented the binomial model as a generalized linear mixed model with a random effect for the sampling period. More detailed

Table 2. Number of Red Knot (*C. c. rufa*) flags detected at Delaware Bay from 2019–2023 by banding location (flag color).

	No. of flagged individuals detected				
Banding location (flag color)	2019	2020	2021	2022	2023
U.S. (lime green)	2,368	1,255	1,292	1,281	843
U.S. (dark green)	351	161	118	118	141
Argentina (orange)	216	89	81	66	48
Canada (white)	156	52	78	62	41
Brazil (dark blue)	35	21	17	14	14
Chile (red)	10	9	5	5	4
Total	3,136	1,587	1,591	1,546	1,091

methods are provided in Lyons et al. (2016) and Appendix 3.

3. Summary of Mark-resight and Count Data Collected in 2023

3.1 Mark-resight encounter data

The 2023 Red Knot mark-resight dataset included a total of 1,091 individual birds that were recorded at least once during mark-resight surveys at Delaware Bay in 2023; these birds were originally captured and banded with leg flags in five different countries (Table 2). This total is ~30% lower than the total detected at Delaware Bay in 2020 (1,587) and 2021 (1,591), and 2022 (1,546; Table 2).

There was sufficient data for analysis in 9 of the 10 sampling periods in 2023 (≤10 May to 3 June; Table 1). In 2023, data beyond 3 June were too sparse for analysis and were not included.

One assumption of the mark-resight approach is that individual identity of marked birds is recorded without error (see Lyons 2016 for discussion of all model assumptions). As noted above, some field-recording errors are evident when sight records are compared to physical capture records available from bandedbirds.org. Again, any engraved flag reported by observers that did not have a corresponding record of physical capture was omitted. Field observers submitted 3,379 resightings in 2023; 34 were not valid (i.e., no corresponding banding data), for an overall misread read of 1.1%. These invalid resightings were removed before analysis, but a second type of "false positive" is still possible, i.e., false positive detection of flags that were deployed prior to 2023 but were not in fact present at Delaware Bay in 2023. It is not possible to identify this second type of false positive with banding data validation or other quality assurance/quality control methods (Tucker et al. 2019).

3.2 Marked-ratio data ("scan samples")

In 2023, 504 marked ratio scan samples were collected: 326 and 178 samples in Delaware and New Jersey, respectively (Appendix 4). In 2020, 2021, and 2022, there were 734, 564, and 541 marked-ratio scan samples collected, respectively.

Table 3. Number of Red Knots (*C. c. rufa*) detected during aerial and ground surveys of Delaware Bay in 2023. Data were provided by W. Pitts, New Jersey Department of Environmental Protection, Division of Fish and Wildlife.

	Total
Aerial survey	
2023-05-16	5,029
2023-05-22	12,713
2023-05-26	11,785
Ground/Boat Surveys	
2023-05-22	22,266
2023-05-26	21,448

3.3 Aerial and ground count data

Aerial surveys of the Delaware and New Jersey shore were conducted on 16, 22, and 26 May 2023 (Table 3; data provide by W. Pitts, New Jersey Department of

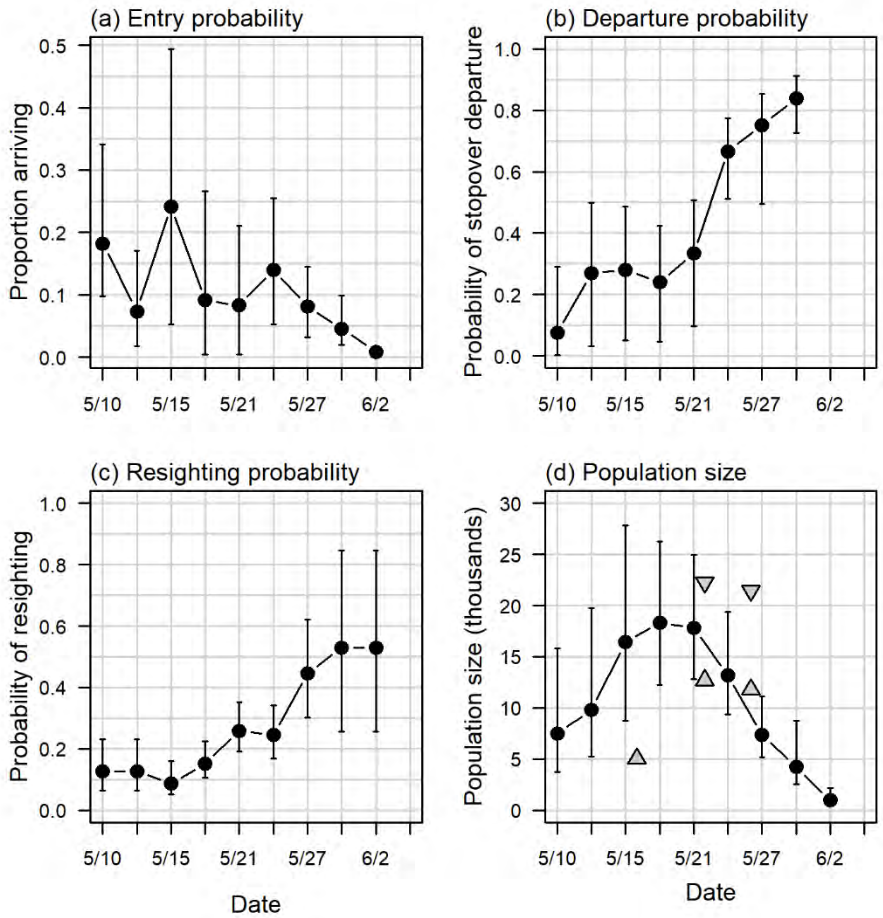

Figure 2 Estimated Jolly-Seber (JS) model parameters from a mark-resight study of Red Knots (*C. c. rufa*) at Delaware Bay in 2023: (a) proportion of stopover population arriving at Delaware Bay, (b) stopover departure probability, (c) probability of resighting, and (d) time-specific stopover population size. Dates on the x- axis represent sampling occasions (3-day survey periods, Table 1). Triangles in (d) are aerial survey (triangle point up) and ground counts (triangle point down).

Environmental Protection, Division of Fish and Wildlife). Ground and boat surveys of the Delaware and New Jersey shore also were conducted on 22 and 26 May 2023.

4. Summary of 2023 Migration

A substantial number of Red Knots arrived early in 2023, with ~20% of all birds that stopped in the bay this year arriving by 10 May (Fig. 1a). This is a larger proportion of early arrivals than last year: in 2022, <10% arrived before 14 May. Arrivals in 2023 peaked around 15 May, with another ~25% of all birds arriving between 13 and 16 May 2023. Approximately 50% of all birds in the 2023 stopover populations thus had arrived by 16 May, which is slightly earlier than the long-term pattern of arrivals; in many years the peak of arrivals has been closer to 18 May.

Stopover departure probability is the probability that a bird present at Delaware Bay during sampling period *i* departs before sampling period *i*+1. In 2023, departure probability was relatively high early in the season, indicating substantial turnover in the stopover population (Fig. 1b). In many years, departure probability is often ≤10% early in the season, indicating that early-arriving birds remain in the bay. In 2023, departure probability was above 20% by 12 May, relatively high for early in the season and indicating high turnover in the population. Departures continued at a steady pace until 24 May when mass depatures began and continued to the end of May (Fig. 1b).

Table 4. Red Knot (*C. c. rufa*) stopover (passage) population estimate using mark-resight methods compared to a peak-count index using aerial- or ground-survey methods at Delaware Bay. The mark-resight estimate of stopover (passage) population, *N, accounts for population turnover during migration. The peak-count index, a single count on a single day, does not account for turnover in the population. "AG" indicates a combination of aerial and ground counts used to formulate the peak-count index. "CI" stands for credible interval.**

Year	Stopover population[a] (mark-resight *N**)	95% CI stopover population *N**	Peak-count index (aerial [A]; ground [G])
2011	43,570	(40,880 – 46,570)	12,804 (A)[b]
2012	44,100	(41,860 – 46,790)	25,458 (G)[c]
2013	48,955	(39,119 – 63,130)	25,596 (A)[d]
2014	44,010	(41,900 – 46,310)	24,980 (A)[c]
2015	60,727	(55,568 – 68,732)	24,890 (A)[c]
2016	47,254	(44,873 – 50,574)	21,128 (A)[b]
2017	49,405[e]	(46,368 – 53,109)	17,969 (A)[f]
2018	45,221	(42,568 – 49,508)	32,930 (A)[b]
2019	45,133	(42,269 – 48,393)	30,880 (A)[g]
2020	40,444	(33,627 – 49,966)	19,397 (G)[c]
2021	42,271	(35,948 – 55,210)	6,880 (AG)[h]
2022	39,800	(35,013 – 51,355)	12,114 (AG)[g]
2023	39,361	(33,724 – 47,556)	22,266 (G)[g]

[a] passage population estimate for entire season, including population turnover

[b] 23 May

[c] 24 May

[d] 28 May

[e] Data management procedures to reduce bias from recording errors in the field; data from observers with greater than average misread rate were not included in the analysis.

[f] 26 May

[g] 22 May

[h] 27 May

Following Lyons et al. (2016), we used the Jolly-Seber model to estimate stopover duration. Stopover duration in 2023 was similar to 2022, but slightly lower than during 2019 – 2021. In 2023, estimated average stopover duration was 9.2 days (95% credible interval (CI), 8.2 – 10.4 days). The stopover duration estimate (and 95% CI) was 12.1 days in 2019 (11.6 – 12.5), 10.7 days in 2020 (9.9 – 11.7), 10.3 days in 2021 (9.0 – 12.1),and 9.4 days in 2022 (8.6 – 10.9 days). This method of estimating stopover duration provides a coarse measure in our Delaware Bay study, however, because it is derived from the estimated number of sampling periods (i.e., the time step in the mark-recapture model) that birds remained in the study area. Each sampling period in this analysis is 3 consecutive days in which the data are aggregated (Table 1). To estimate stopover duration in number of days at Delaware Bay with this method, we first estimate the number of sampling periods that each bird remained in the study area and then multiply this by 3 (the number of days in each period). The resolution of the stopover duration estimate is thus limited by the resolution of the sampling periods.

Probability of resighting in 2023 was relatively low for much of the season, remainging below 30% from 10 May until 24 May (Fig. 1c). Probability of resighting higher during 27 May to 2 June (~40–50%) at the end of the season.

In 2023, 6.8% of the stopover population carried engraved leg flags (95% CI: 5.9–7.9%; Appendix 5 Fig. A5). This is slightly lower than 2022 (8.4% , 95% CI: 7.4%–9.7%) and suggests a declining trend in the proportion with flags. The proportion of the population with leg flags has historically been closer to 10% and was as high as 9.6 percent (95% CI: 8.8%–10.3%) in 2020.

5. Stopover Population Estimation

The passage population size estimate for 2023 was 39,361 (95% credible interval: 33,724 – 47,556; Table 4). Unlike the aerial survey, this superpopulation estimate accounts for turnover in the population and probability of detection. The 2023 stopover population estimate is similar to the 2022 population estimate, lower than the 2021 estimate, and below 40,000 for the first time since 2011, the first year of our mark-resight estimation procedures were used at Delaware Bay (Table 4). However, there was wide overlap of the confidence intervals for the stopover population estimates in recent years (Table 4).

Like 2020–2022 population estimates, the 2023 estimate is slightly lower than the 2018 and 2019 estimates (Table 4) and the confidence interval is wider. The wide confidence intervals are due in part to the low probability of resighting for many of the sampling periods during 2020–2023 compared to earlier years (early 2021 notwithstanding).

The time-specific stopover population estimates in 2023 increased steadily from the beginning of the season and peaked around 18–21 May (~18,300), similar to 2022 (Fig. 1d). After the peak, time-specific estimates declined steadily until 2 June (Fig. 1d).

Acknowledgments

We thank the many volunteers in Delaware and New Jersey who collected mark-resight data in 2023. We are grateful to Samantha Robinson and Katherine Christie (Delaware Division of Fish and Wildlife), Kathy Clark and Bill Pitts (New Jersey Department of Environmental Protection, Division of Fish and Wildlife, Endangered & Nongame Species Program), Jeannine Parvin, Lena Usyk (bandedbirds.org), and numerous volunteers in Delaware and New Jersey for data entry and data management. We are grateful to <x> and <y> for helpful peer reviews as part of U.S. Geological Survey Fundamental Science Practices. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

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Appendix 1. Locations around Delaware Bay, USA, where mark-resight surveys were conducted to estimate Red Knot (*C. c. rufa*) stopover population size in 2023.

State	Beach	Longitude	Latitude
DE	Port Mahon	-75.4021	39.1831
DE	Pickering Beach	-75.4087	39.1377
DE	Kitts Hummock	-75.4048	39.1130
DE	Ted Harvey Wildlife Area	-75.4019	39.0864
DE	North Bowers	-75.3973	39.0630
DE	South Bowers	-75.3860	39.0498
DE	Brockenbridge	-75.3638	39.0359
DE	Mispillion	-75.3131	38.9519
DE	Slaughter Beach	-75.3146	38.9282
DE	Fowlers Beach	-75.2633	38.8766
DE	Prime Hook Beach	-75.2467	38.8604
NJ	Gandys/Money Island	-75.2417	39.2767
NJ	Fortescue	-75.1675	39.2233
NJ	North Reeds	-74.8908	39.1228
NJ	South Reeds	-74.8922	39.1138
NJ	Cooks	-74.8941	39.1082
NJ	Kimbles	-74.8948	39.1049
NJ	Bay Cove	-74.8965	39.1008
NJ	Pierces Point	-74.9013	39.0897
NJ	Villas and Norburys	-74.9298	39.0449

Appendix 2. Summary ("m-array") of Red Knot (*C. c. rufa*) mark-resight data from Delaware Bay, USA, 2023. NR = never resighted.

			Next resighted at sample								
Sample	Dates	Resighted	2	3	4	5	6	7	8	9	NR
1	≤10 May	62	9	1	1	9	3	3	0	0	36
2	11-13 May	83		7	4	7	1	1	0	0	63
3	14-16 May	99			17	9	2	4	0	0	67
4	17-19 May	166				32	17	6	2	0	109
5	20-22 May	277					49	17	4	0	207
6	23-25 May	269						42	6	0	221
7	26-28 May	261							35	2	224
8	29-31 May	142								13	129
9	1-3 June	35									

Appendix 3. Statistical Methods to Estimate Stopover Population Size of Red Knots (*C. c. rufa*) Using Mark-Resight Data and Counts of Marked Birds

We converted the observations of marked Red Knots into encounter histories, one for each bird, and analyzed the encounter histories with a Jolly-Seber (JS) model (Jolly 1965, Seber 1965, Crosbie and Manly 1985, Schwarz and Arnason 1996). The JS model includes parameters for recruitment (β), survival (ϕ), and capture (*p*) probabilities; in the context of a mark-resight study at a migration stopover site, these parameters are interpreted as probability of arrival to the study area, stopover persistence, and resighting, respectively. Stopover persistence is defined as the probability that a bird present at time *t* remains at the study area until time *t* + 1. The Crosbie and Manley (1985) and Schwarz and Arnason (1996) formulation of the JS model also includes a parameter for superpopulation size, which in our approach to mark-resight inferences for stopover populations is an estimate of the marked (leg-flagged) population size.

We chose to use 3-day periods rather than days as the sampling interval for the JS model given logistical constraints on complete sampling of the study area; multiple observations of the same individual in a given 3-day period were combined for analysis. A summary (m-array) of the mark-resight data is presented in Appendix 1.

We made inference from a fully-time dependent model; arrival, persistence, and resight probabilities were allowed to vary with sampling period [β_t ϕ_t p_t]. In this model, we set $p_1 = p_2$ and $p_{K-1} = p_K$ (where *K* is the number of samples) because not all parameters are estimable in the fully-time dependent model (Jolly 1965, Seber 1965, Crosbie and Manly 1985, Schwarz and Arnason 1996).

We followed the methods of Royle and Dorazio (2008) and Kéry and Schaub (2012, Chapter 10) to fit the JS model using the restricted occupancy formulation. Royle and Dorazio (2008) use a state-space formulation of the JS model with parameter-expanded data augmentation. For parameter-expanded data augmentation, we augmented the observed encounter histories with all-zero encounter histories (n = 2000) representing potential recruits that were not detected (Royle and Dorazio 2012). We followed Lyons et al. (2016) to combine the JS model with a binomial model for the counts of marked and unmarked birds in an integrated Bayesian analysis. Briefly, the counts of marked birds (m_s) in the scan samples are modeled as a binomial random variable:

$$m_s \sim Bin(C_s, \pi), \tag{1}$$

where m_s is the number of marked birds in scan sample *s*, C_s is the number of birds checked for marks in scan sample *s*, and π is the proportion of the population that is marked. Total stopover population size $\widehat{N^*}$ is estimated by

$$\widehat{N^*} = \widehat{M^*}/\hat{\pi} \tag{2}$$

where $\widehat{M^*}$ is the estimate of marked birds from the J-S model and $\hat{\pi}$ is the proportion of the population that is marked (from Eq. 1). Estimates of marked subpopulation sizes at each resighting occasion t $\left(\widehat{M_t^*}\right)$ are available as derived parameters in the analysis. We calculated an estimate of population size at each mark-resight sampling occasion $\widehat{N_t^*}$ using $\widehat{M_t^*}$ and $\hat{\pi}$ as in equation 2.

To better account for the random nature of the arrival of marked birds and addition of new marks during the season, we used a time-specific model for proportion with marks in place of equation 1 above:

$$m_{s,t} \sim Binomial(C_{s,t}, \pi_t) \tag{3}$$

$$for\ s\ in\ 1, \ldots, n_{samples}\ and\ t\ in\ 1, \ldots, n_{occasions}$$

$$logit(\pi_t) = \alpha + \delta_t$$

$$\delta_t \sim Normal\left(0, \sigma^2_{occasions}\right)$$

where m_s is the number of marked birds in scan sample *s*, C_s is the number of birds checked for marks in scan sample *s*, δ_t is a random effect time of sample *s*, and π_t is the time-specific proportion of the population that is marked. Total stopover population size $\widehat{N^*}$ was estimated by summing time-specific arrivals of marked birds to the stopover (B_t) and expanding to include unmarked birds using estimates of proportion marked:

$$\widehat{N^*} = \sum \widehat{B_t} / \pi_t$$

Time-specific arrivals of marked birds are estimated from the Jolly-Seber model using $\widehat{B_t} = \widehat{\beta}_t \widehat{M^*}$ where $\widehat{M^*}$ is the estimate of the number of marked birds and $\widehat{\beta_t}$ is the fraction of the population arriving at time *t*.

Appendix 4. Marked-ratio scan samples of Red Knots (*C. c. rufa*).

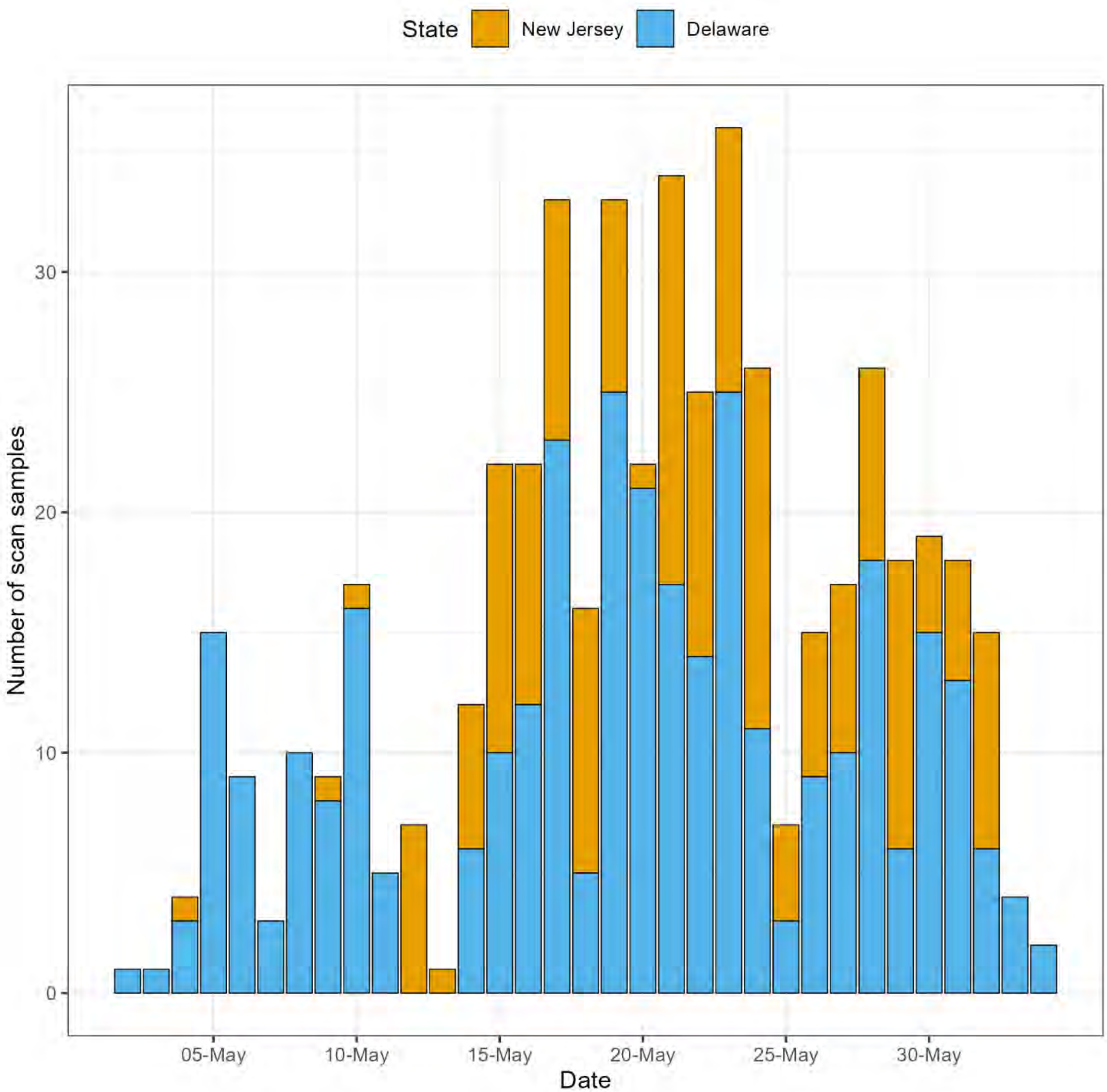

Figure A4. Number of Red Knot (*C. c. rufa*) marked-ratio scan samples (n =) collected in Delaware Bay in 2023 by field crews in Delaware (blue, n = scan samples) and New Jersey (orange, n = scan samples) and date.

Appendix 5. Marked proportion.

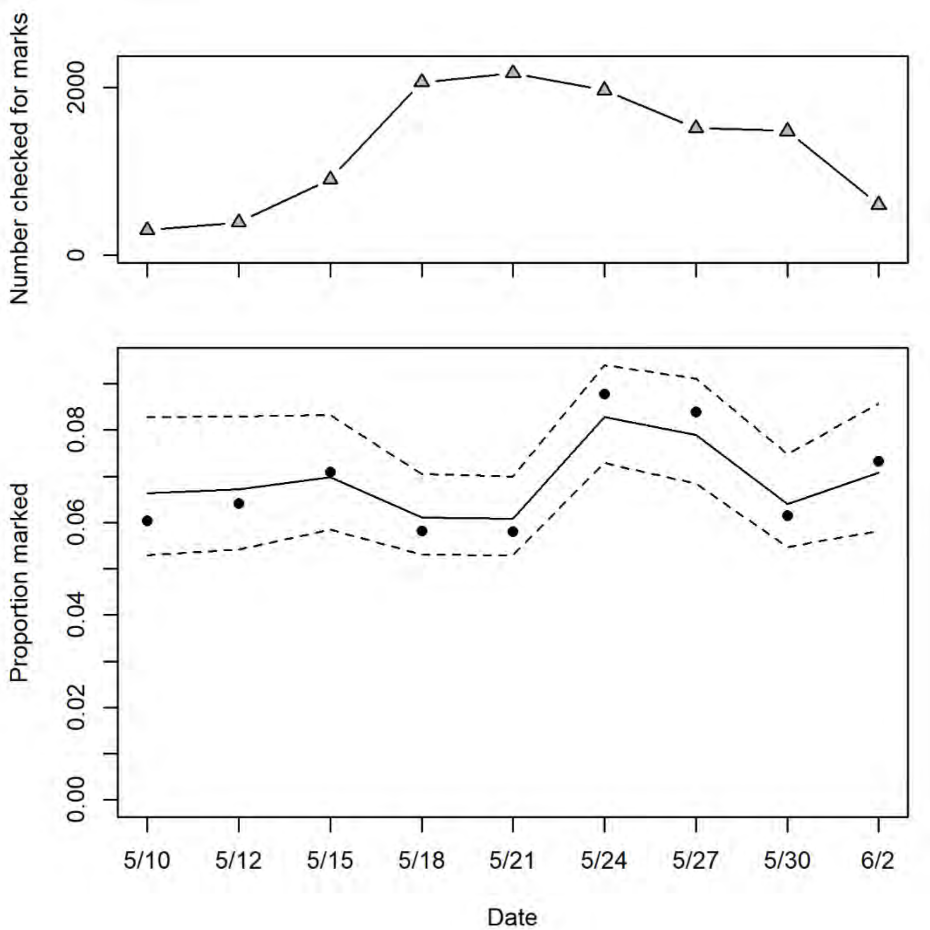

Figure A5. Estimated proportion of the Delaware Bay stopover population of Red Knots (*C. c. rufa*) carrying leg flags in 2023 (overall average and 95% credible interval: 0.068 [0.059, 0.079]). The marked proportion was estimated from marked-ratio scan samples for each 3-day sampling period. The dates for the sampling periods are shown in Table 1. The upper panel shows the sample size (number scanned, i.e., checked for marks) for each sample period. The bottom panel shows the estimated proportion marked for each sample occasion, which was estimated with the generalized linear mixed model described in Appendix 2. Solid and dashed lines are estimated median proportion marked and 95% credible interval, respectively; filled circles show (number with marks/number scanned).

ATLANTIC STATES MARINE FISHERIES COMMISSION

REVIEW OF THE INTERSTATE FISHERY MANAGEMENT PLAN

HORSESHOE CRAB
(*Limulus polyphemus*)

2022 Fishing Year

Prepared by the Plan Review Team

October 2023

Sustainable and Cooperative Management of Atlantic Coastal Fisheries

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I. Status of the Fishery Management Plan

Date of FMP Approval:	December 1998
Amendments	None
Addenda	Addendum I (April 2000) Addendum II (May 2001) Addendum III (May 2004) Addendum IV (June 2006) Addendum V (September 2008) Addendum VI (August 2010) Addendum VII (February 2012)
Management Unit:	Entire coastwide distribution of the resource from the estuaries eastward to the inshore boundary of the EEZ
States with Declared Interest:	Massachusetts – Florida, Potomac River Fisheries Commission
Active Boards/Committees:	Horseshoe Crab Management Board, Advisory Panel, Technical Committee, and Plan Review Team; Delaware Bay Ecosystem Technical Committee; Adaptive Resource Management Subcommittee

Goals and Objectives

The Interstate Fishery Management Plan for Horseshoe Crabs (FMP) established the following goals and objectives.

2.0. Goals and Objectives

The goal of this Plan is to conserve and protect the horseshoe crab resource to maintain sustainable levels of spawning stock biomass to ensure its continued role in the ecology of the coastal ecosystem, while providing for continued use over time. Specifically, the goal includes management of horseshoe crab populations for continued use by:

1) *current and future generations of the fishing and non-fishing public (including the biomedical industry, scientific and educational research);*
2) *migrating shorebirds; and,*
3) *other dependent fish and wildlife, including federally listed (threatened) sea turtles.*

To achieve this goal, the following objectives must be met:

(a) prevent overfishing and establish a sustainable population;

(b) achieve compatible and equitable management measures among jurisdictions throughout the fishery management unit;

(c) establish the appropriate target mortality rates that prevent overfishing and maintain adequate spawning stocks to supply the needs of migratory shorebirds;
(d) coordinate and promote cooperative interstate research, monitoring, and law enforcement;
(e) identify and protect, to the extent practicable, critical habitats and environmental factors that limit long-term productivity of horseshoe crabs;
(f) adopt and promote standards of environmental quality necessary for the long-term maintenance and productivity of horseshoe crabs throughout their range; and,
(g) establish standards and procedures for implementing the Plan and criteria for determining compliance with Plan provisions.

Fishery Management Plan Summary
The framework for managing horseshoe crabs along the Atlantic coast was approved in October 1998 with the adoption of the Interstate Fishery Management Plan (FMP) for Horseshoe Crabs. The goal of this plan is to conserve and protect the horseshoe crab resource to maintain sustainable levels of spawning stock biomass to ensure its continued role in the ecology of coastal ecosystems while providing for continued use over time.

In 2000, the Horseshoe Crab Management Board approved Addendum I to the FMP. Addendum I established a state-by-state cap on horseshoe crab bait landings at 25 percent below the reference period landings (RPL's), and *de minimis* criteria for those states with a limited horseshoe crab fishery. Those states with more restrictive harvest levels (Maryland and New Jersey) were encouraged to maintain those restrictions to provide further protection to the Delaware Bay horseshoe crab population, recognizing its importance to migratory shorebirds. Addendum I also recommended that the National Marine Fisheries Service (NMFS) prohibit the harvest of horseshoe crabs in federal waters (3-200 miles offshore) within a 30 nautical mile radius of the mouth of Delaware Bay, as well as prohibit the transfer of horseshoe crabs in federal waters. A horseshoe crab reserve was established on March 7, 2001, by NMFS in the area recommended by ASMFC. This area is now known as the Carl N. Shuster Jr. Horseshoe Crab Reserve (Figure 1).

In 2001, the Horseshoe Crab Management Board approved Addendum II to the FMP. The purpose of Addendum II was to allow the voluntary transfer of harvest quotas between states to alleviate concerns over potential bait shortages on a biologically responsible basis. Voluntary quota transfers require Technical Committee review and Management Board approval.

In 2004, the Board approved Addendum III to the FMP. The addendum sought to further the conservation of horseshoe crab and migratory shorebird populations in and around the Delaware Bay. It reduced harvest quotas and implemented seasonal bait harvest closures in New Jersey, Delaware, and Maryland, and revised monitoring components for all jurisdictions.

Addendum IV was approved in 2006. It further limited bait harvest in New Jersey and Delaware to 100,000 crabs (male only) and required a delayed harvest in Maryland and Virginia.

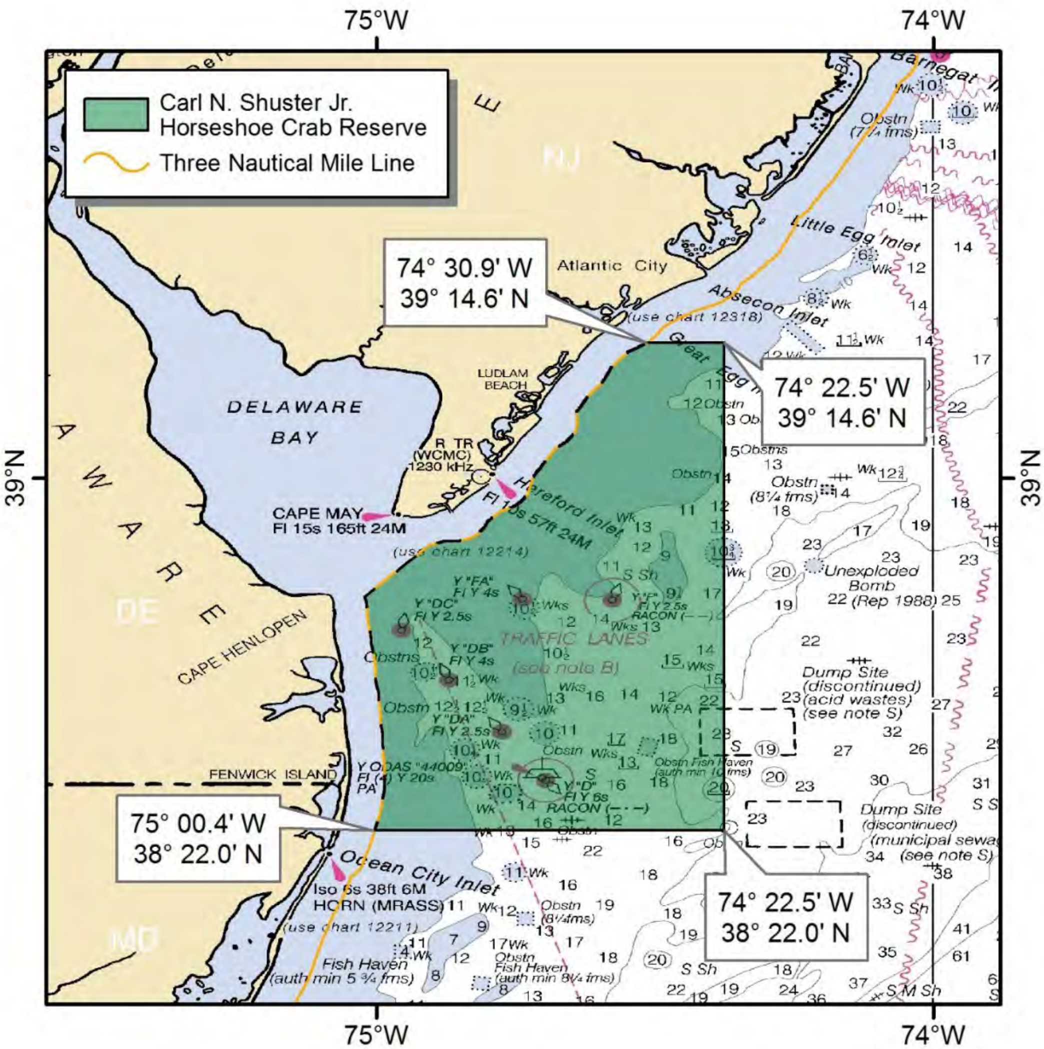

Figure 1. Carl N. Shuster Jr Horseshoe Crab Reserve.

Addendum V, adopted in 2008, extended the provisions of Addendum IV through October 31, 2010.

In early 2010, the Board initiated Draft Addendum VI to consider management options that would follow expiration of Addendum V. The Board voted in August 2010 to extend the Addendum V provisions, via Addendum VI, through April 30, 2013. The Board also chose to include language allowing them to replace Addendum VI with another Addendum during that time, in anticipation of implementing an Adaptive Resource Management (ARM) Framework.

The Board approved Addendum VII in February 2012. This addendum implemented an ARM framework for use during the 2013 fishing season and beyond. The framework considers the abundance levels of horseshoe crabs and shorebirds in determining the optimized bait harvest level for the Delaware Bay states of New Jersey, Delaware, Maryland, and Virginia (east of the COLREGS).

The ARM Framework underwent a revision process in 2021 to incorporate more available data and update the software platform. Several improvements were made to the ARM Framework during this revision. The ARM Revision improves the population models for horseshoe crabs and red knots by incorporating Delaware Bay region-specific data collected over the past few decades. Horseshoe crab population estimates from the Catch Multiple Survey Analysis (CMSA) model used in the 2019 Benchmark Stock Assessment were incorporated into the ARM Revision. Additionally, the ARM Revision includes more sources of horseshoe crab removals than the previous version, adding mortality in the biomedical industry and commercial discards from other fisheries. The maximum number of male and female horseshoe crabs the ARM Revision can recommend remains the same at 210,000 females and 500,000 males. However, harvest recommendations under the ARM Revision are now based on a continuous scale rather than the fixed harvest packages in the previous Framework. Also, the harvest of females is decoupled from the harvest of males so that each are determined separately. While additional data and model improvements are used in the ARM Revision, the conceptual model of horseshoe crab abundance influencing red knot survival and reproduction remains intact with the intent of ensuring the abundance of horseshoe crabs does not become a limiting factor in the population growth of red knots. The Board accepted the ARM Revision and Peer Review for management use in January 2022.

Addendum VIII was approved in November 2022. Addendum VIII adopts the changes to the ARM Framework as recommended in the peer-reviewed 2021 ARM Framework for use in setting annual specifications for horseshoe crabs of Delaware Bay-origin.

II. Status of the Stock and Assessment Advice

A benchmark stock assessment was completed and approved for management use in 2019. The assessment report is available at:
http://www.asmfc.org/uploads/file/5cd5d6f1HSCAssessment_PeerReviewReport_May2019.pdf

This assessment was the first to successfully apply a stock assessment model to a component of the horseshoe crab stock. A Catch Multiple Survey Analysis (CMSA) model, a stage-based model that tracks progression of crab abundances from pre-recruits to full recruits to the fishery, was applied to female crabs in the Delaware (DE) Bay region (New Jersey-Virginia). This model estimated regional female crab abundance using relative abundance information from the Virginia Tech Benthic Trawl Survey, New Jersey Ocean Trawl Survey, and Delaware Adult Trawl Survey, and estimates of mortality including natural mortality, commercial bait harvest, commercial discard mortality, and mortality associated with biomedical use. While reference points were not approved to determine stock status, the CMSA population estimates were recommended as the best estimates for female horseshoe crab abundance in the DE Bay region.

The base CMSA model population estimates show an increase in the number of female crabs in the DE Bay region since 2012, when the ARM Framework was established via Addendum VII.

This increasing trend is supported by positive trends in regional fishery-independent surveys during this time period. Population estimates from the base model are not publicly available due to the inclusion of confidential biomedical data. However, a sensitivity run assuming no biomedical mortality is publicly viewable, and these estimates are not significantly different from the base model results. Estimates of discard mortality from the Northeast Fisheries Observer Program (NEFOP) were also included in the base CMSA model and indicate that discard mortality could be significant, of similar or greater magnitude than mortality due to bait harvest. Population estimates from the CMSA are currently being considered for incorporation into the ARM Framework, which is applied annually to specify bait harvest quotas for the DE Bay region.

Autoregressive Integrated Moving Average (ARIMA) models, similar to those used in previous assessments, were applied to all regions. ARIMA models were fit to fishery-independent survey indices trends of abundance in each of the regional horseshoe crab populations: Northeast (Massachusetts-Rhode Island), New York (Connecticut-New York), DE Bay, and Southeast (North Carolina-Florida). No definitions for overfishing or overfished status have been adopted by the Management Board. However, the assessment characterized the status of each regional and the coastwide population based on the percentage of surveys within a region (or coastwide) having a >50% probability of the terminal year being below the ARIMA reference point. The ARIMA reference point was the 1998 index for each survey. "Poor" status was defined as >66% of surveys meeting this criterion, "Good" status was defined as <33% of surveys, and "Neutral" status was defined as 34–65% of surveys. Based on these criteria, stock status was neutral for the Northeast region, poor for the New York region, neutral for the Delaware Bay region, and good for the Southeast region. Coastwide, abundance has fluctuated through time with many surveys decreasing after 1998 but increasing in recent years. The coastwide status includes surveys from all regions and indicates a neutral trend, likely due to a combination of positive and negative trends.

An assessment update is expected for completion in 2024.

III. Status of the Fishery

Bait Fishery

For most states, the bait fishery is open year-round. However, because of seasonal horseshoe crab movements (to the beaches in the spring; deeper waters and offshore in the winter), the fishery operates at different times along the coast. New Jersey has prohibited commercial harvest of horseshoe crabs in state waters since 2006. State waters of Delaware are closed to horseshoe crab harvest and landing from January 1st through June 7th each year, and other state horseshoe crab fisheries are regulated with various season/area closures.

The total reported bait landings in 2022 totaled 570,988 crabs. This is well below the ASMFC coastwide quota of 1,587,274 crabs (Table 1, Figure 2) and represents a 23% decrease from 2021 landings of 741,684 crabs. Landings increased in New York but decreased in most states.

Reported coastwide landings since 1998 show more male than female horseshoe crabs were harvested annually. Several states presently have sex-specific restrictions in place which limit or ban the harvest of females. The American eel pot fishery prefers egg-laden female horseshoe crabs as bait, while the whelk (conch) pot fishery is less dependent on females. States with greater than 5% of coastal landings are required to report sex for at least a portion of their bait harvest; for 2022 these states include Massachusetts, New York, Delaware, Maryland, and Virginia. Within these states, 61% of reported bait landings were male, 17% were female, and 22% were unclassified in 2022.

The hand, trawl, and dredge fisheries accounted for the majority of reported commercial horseshoe crab bait landings in 2022. Other gears that account for the remainder of the harvest include rakes, hoes, and tongs, fixed nets, and gill nets.

Table 1. Reported commercial horseshoe crab bait landings by jurisdiction. "C" indicates confidential landings.

	MA	RI	CT	NY	NJ*	DE*	MD*	PRFC	VA**	NC	SC	GA	FL	TOTAL
ASMFC Quota 2022	330,377	26,053	48,689	366,272	162,136	162,136	255,980	0	172,828	24,036	0	29,312	9,455	1,587,274
State Quota 2022	165,000	8,398	48,689	150,000	0	151,345	255,980	-	172,828	24,036	0	29,312	9,455	1,020,820
Landings by Year														
2015	117,611	7,867	19,632	145,324	0	151,262	27,494	0	102,235	24,839	0	0	264	596,528
2016	110,399	20,676	21,945	176,632	0	109,836	157,013	0	128,848	25,197	0	0	689	751,235
2019	172,664	C	17,588	167,181	0	164,225	145,907	0	151,727	13,463	0	0	0	832,755
2020	163,695	C	15,942	63,367	0	124,803	61,165	0	24,031	3,672	0	0	0	456,675
2021	156,013	1,706	17,492	97,860	0	172,927	181,044	0	112,497	2,145	0	0	C	741,684
2022	135,731	C	1,343	111,481	0	147,558	84,627	0	89,748	500	0	0	C	570,988

*Male-only harvest

**Virginia harvest east of the COLREGS line is limited to 81,331 male-only crabs under the ARM harvest package #3. Virginia harvest east of the COLREGS in 2022 was 8,334 crabs.

Biomedical Use

The horseshoe crab is an important resource for research and manufacture of materials used for human health. There are five companies along the Atlantic Coast that process horseshoe crab blood for use in manufacturing Limulus Amebocyte Lysate (LAL): Associates of Cape Cod, Massachusetts; Lonza (formerly Cambrex Bioscience), Limuli Laboratories, New Jersey; Wako Chemicals, Virginia; and Charles River Endosafe, South Carolina. Addendum III requires states where horseshoe crabs are collected for biomedical purposes to collect and report total collection numbers, crabs rejected, crabs bled (by sex) and to characterize mortality.

The Plan Review Team (PRT) annually calculates total coastwide collections and estimates mortality associated with biomedical use. In 2022, 911,826 crabs were collected coastwide solely for biomedical purposes[1] (Table 2). This represents a 27% increase from 2021. Of the total biomedical collections in 2022, males accounted for 43.3%, females comprised 34.3%, and 22.4% were of unknown sex. Some crabs were rejected prior to bleeding due to mortality, injuries, slow movement, and size (mortality observed while crabs were going through the biomedical process is included under 'Observed Mortality' in Table 2). Approximately 2.4% of crabs collected solely for biomedical purposes were observed and reported as dead from the time of collection up to the point of bleeding.

During the 2019 benchmark stock assessment, a meta-analysis of literature estimates was performed to estimate post-bleeding mortality of horseshoe crabs. Although many of these studies did not implement biomedical best practices, these values are the only available estimates of mortality experienced after bleeding. Based on the literature review, post-bleeding mortality is estimated at 15%. Tagging data was used in the assessment to compare survivorship between crabs that were and were not bled. These results indicated some decrease in short-term survivorship, but greater long-term survivorship for bled crabs. These results are likely attributable to the culling process used by biomedical facilities to select healthy crabs for bleeding.

Post-bleeding mortality, calculated as 15% of the number of bled biomedical-only crabs (not from the bait market), for 2022 was estimated to be 124,227 crabs. Total mortality (observed mortality plus post-bleeding mortality) of biomedical crabs for 2022 was estimated at 145,920 crabs. The total estimated mortality from biomedical collections represents approximately 20% of the 2022 total directed use mortality (716,908 crabs), which includes both total biomedical mortality and removals for bait.

In 2023, a work group appointed by the Board reviewed and updated the *Best Management Practices for Handling Horseshoe Crabs for Biomedical Purposes*[2]. The work group included technical committee and advisory panel members with expertise in horseshoe crab biology, ecology, and biomedical processing. The purpose of the BMPs is to recommend broadly applicable industry standards that are expected to minimize mortality and injury of horseshoe crabs associated with the biomedical process.

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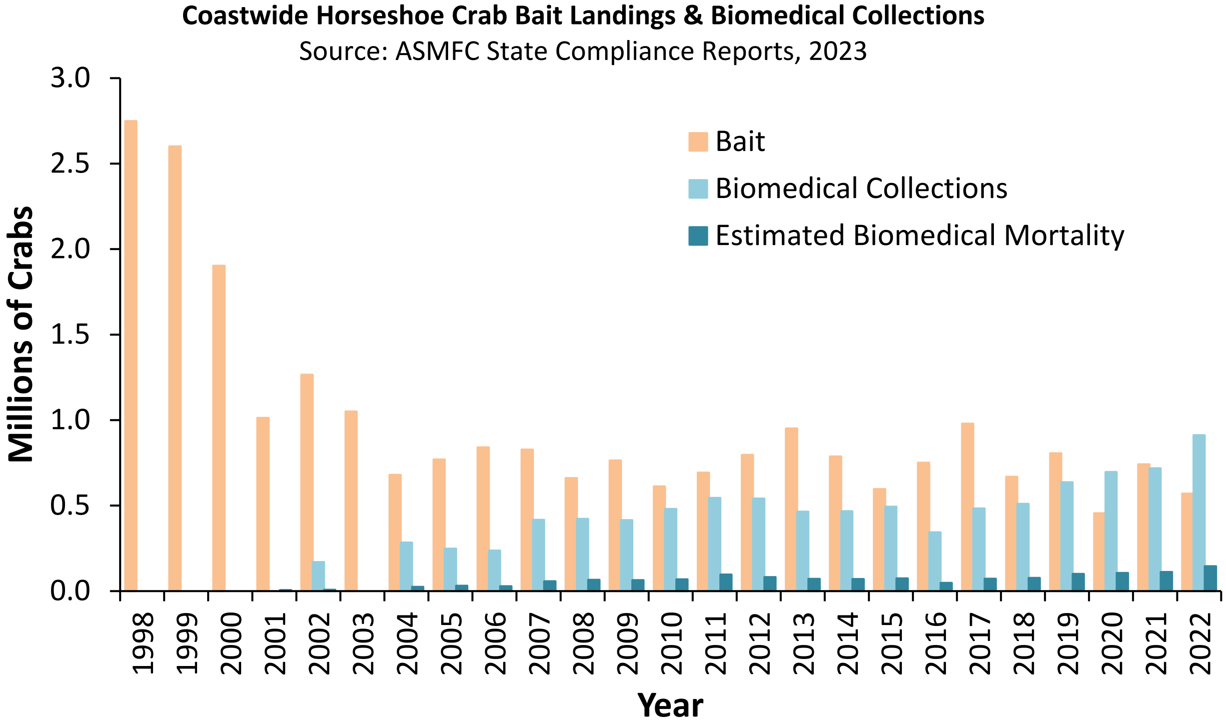
[1] This does not include bait crabs borrowed for bleeding and then returned to the bait market; these are counted against state bait quotas. The dual use of horseshoe crabs harvested for bait is encouraged as a conservation tool. Facilities that bleed horseshoe crabs to manufacture LAL can utilize crabs from the bait market in what is often referred to as the "rent a crab" program. Permitted bait harvesters and/or dealers can "rent" crabs caught for the bait industry to the bleeding facility; these crabs are returned to the bait vendor after bleeding. These crabs are caught under bait permits, are counted against the bait quota of the state of origin, and must comply with that state's regulations for bait harvest. The dual use of crabs in this program can reduce overall harvest, may decrease overall mortality, can provide the LAL manufacturers with an additional source of raw material, and may offer harvesters and dealers opportunity within this secondary market.

[2] Best Management Practices for Handling Horseshoe Crabs for Biomedical Purposes can be found here: https://asmfc.org/uploads/file/645bf065HSC_Biomedical_BMPs_2023.pdf

Figure 2. Number of horseshoe crabs harvested for bait and collected for biomedical purposes, 1998-2022.



*Biomedical collections are annually reported to the Commission and include all horseshoe crabs brought to bleeding facilities except those that were harvested as bait, "rented" by biomedical facilities and counted against state bait quotas.
*Crabs collected solely for biomedical crabs are returned to the water after bleeding; a 15% mortality rate is assumed for all bled crabs that are released. This number plus observed mortality reported annually by bleeding facilities via state compliance reports equals the 'Estimated Biomedical Mortality.'

Figure 3. Total Horseshoe Crab Mortality from Bait and Estimated Biomedical Mortality, 1998-2022.

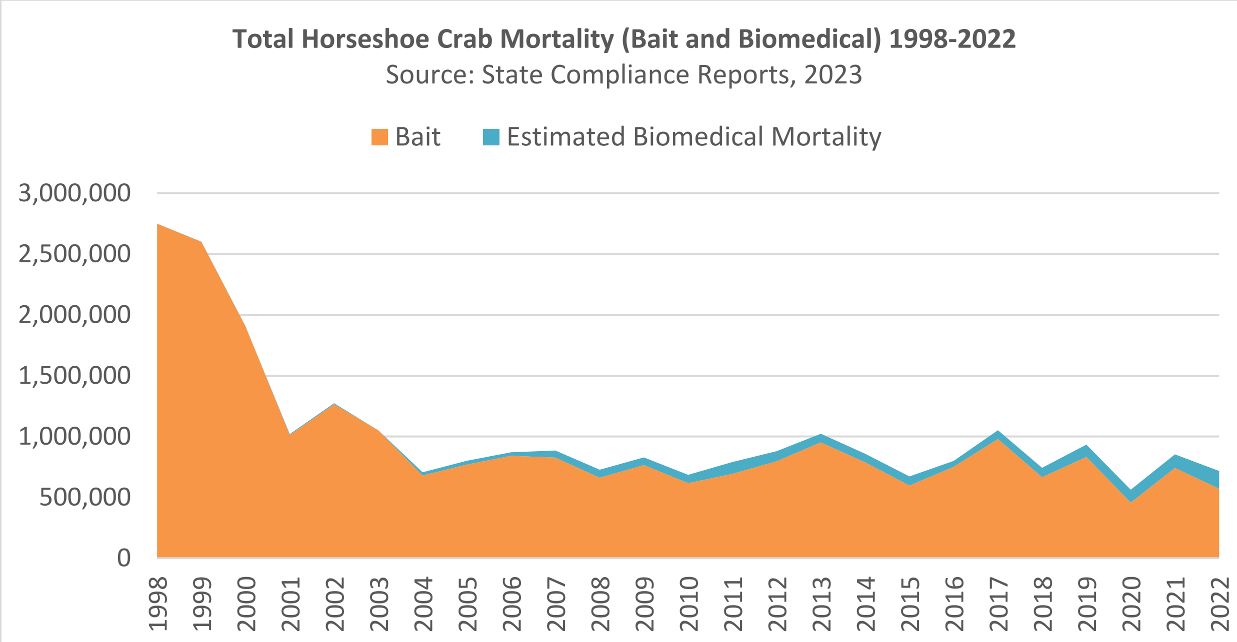


Table 2. Numbers of horseshoe crabs collected, bled, and estimated mortality for the biomedical industry. Numbers shown are for crabs collected solely for biomedical use. Mortality of bled crabs that later enter the bait industry is included in bait harvest.

Year	Crabs Collected	Crabs Bled	Post-Bleeding Mortality	Observed Mortality	Total Mortality
2010	480,914	412,781	61,917	6,829	68,746
2011	545,164	486,850	73,028	24,139	97,166
2012	541,956	497,956	74,693	7,370	82,063
2013	464,657	440,402	66,060	5,447	71,507
2014	467,897	432,340	64,851	5,658	70,509
2015	494,123	464,506	69,676	5,362	75,038
2016*	344,495	318,523	47,778	1,004	48,782
2017	483,245	444,115	66,617	6,056	72,674
2018	510,407	479,142	71,871	5,588	77,459
2019	637,029	589,361	88,404	12,789	101,193
2020	697,025	649,546	97,432	8,907	106,339
2021	718,809	667,951	100,193	11,911	112,104
2022	911,826	828,181	124,227	21,693	145,920

***Some biomedical collections were reduced in 2016 due to temporary changes in production.**

IV. Status of Research and Monitoring

The Horseshoe Crab FMP set forth an ambitious research and monitoring strategy in 1999 and again in 2004 to inform future management decisions. Despite limited time and funding there are many accomplishments since 1999. These accomplishments were largely made possible by forming partnerships between state, federal and private organizations, and the support of hundreds of public volunteers.

Addendum III Monitoring Program
Addendum III requires affected states to carry out three monitoring components:

1. All states who do not qualify for *de minimis* status report monthly harvest numbers and subsample a portion of the catch for sex and harvest method. In addition, those states with annual landings above 5% of the coastwide harvest report all landings by sex and harvest method. Although states with annual landings less than 5% of annual coastwide harvest are not required to report landings by sex, the PRT recommends all states require sex-specific reporting for horseshoe crab harvest.
2. States with biomedical collections are required to monitor and report collection numbers and mortality associated with the transportation and bleeding of the crabs.
3. States must identify spawning and nursery habitat along their coasts. All states have completed this requirement, and a few continue active monitoring programs.

Virginia Tech Research Projects
The Virginia Tech Horseshoe Crab Trawl Survey (VT Survey) was not conducted in 2013-2015, due to a lack of funding, but was conducted in 2016-2022, and is in progress for 2023. Funding sources beyond 2023 continue to be explored. The 2022 surveys were conducted between August 2 and October 12. The lower Delaware Bay area of the survey was not sampled in 2022 as increased operational costs resulted in limitations to time on the water.

For the Delaware Bay Area (DBA), the 2022 survey resulted in an increase in the stratified catch-per-tow values for newly mature females and immature individuals, and decreases in the stratified catch-per-tow values for newly mature males and mature individuals. No estimates were significantly different from the previous year with the exception of newly mature females, as none were caught in 2021. Mean stratified catch-per-tow for all demographic groups in the DBA continues to be highly variable, although mature individuals have shown a positive trend over the time series. Prosomal widths of mature and newly mature males and females show decreasing trends over the time series in the DBA.

The indices from this survey, along with the New Jersey Ocean Trawl and Delaware Fish and Wildlife Adult Trawl Survey indices, were used to estimate horseshoe crab abundance in the 2021 ARM Framework Revision to produce optimal harvest limits for the upcoming year.

Spawning Surveys
The redesigned Delaware Bay spawning survey was completed for the twenty-fourth consecutive year in 2022. Twelve beaches in Delaware and ten beaches in New Jersey were sampled. Delaware is currently in the process of analyzing survey data.

Tagging Studies
The USFWS continues to maintain a toll-free telephone number and a website for reporting horseshoe crab tag returns and assists interested parties in obtaining tags. Tagging work continues to be conducted by biomedical companies, research organizations, and other parties involved in outreach and spawning surveys. Beginning with the 2013 tagging season, additional

efforts were implemented to ensure that current tagging programs are providing data that benefits the management of the coastwide horseshoe crab population. All existing and new tagging efforts are required to submit an annual application to be considered for the USFWS tagging program and all participants must submit an annual report along with their tagging and resighting data to indicate how their tagging program addresses at least one of the following objectives: determine horseshoe crab sub-population structure, estimate horseshoe crab movement and migration rates, and/or estimate survival and mortality of horseshoe crabs. The PRT recommends all tagging programs approved by the states coordinate with the USFWS tagging program, in order to ensure a consistent coastwide program to support management.

Since 1999, over 409,859 crabs have been tagged and released through the USFWS tagging program along the Atlantic coast, and 49,993 unique crabs have been recaptured. Crabs have been tagged and released from every state on the Atlantic Coast from Florida to New Hampshire. In the early years of the program, tagging was centered around Delaware Bay; however, tagging has expanded and increased in Long Island Sound and the Southeast. Tagging information from this database has been used in the 2019 Benchmark Stock Assessment to define stock structure, estimate total mortality, and characterize impacts of biomedical use on crab mortality.

New York Region Monitoring

Following the 2019 Benchmark Stock Assessment, which characterized the status of the horseshoe crab population in the New York region as “Poor”, the Board directed the PRT to monitor fishery-independent surveys in this area to track progress of state management actions toward improving this regional population. During the assessment, five surveys were included in the ARIMA model to characterize this population. One of these, the Northeast Area Monitoring and Assessment Program (NEAMAP), includes sample areas outside of the New York region, making it too data-intensive to specify the regional index on an annual basis. The most recent information from the state-conducted surveys used in the assessment is summarized below, but can be viewed in greater detail in the Connecticut and New York state compliance reports. The Western Long Island (WLI) Little Neck Bay and Manhasset Bay seine surveys were combined in the assessment to form a single index, but are shown below separately. None of these beach seine surveys were completed in 2020 due to the COVID-19 pandemic but resumed in 2021. Figures 5-8 show the annual index for each survey over the time series until 2021.

Connecticut

- Long Island Sound Trawl (LISTS) (Fall) – 2022 index – The 2022 survey was limited in April due to staff limitations and in June because of mechanical issues with the research vessel. The LISTS indices for 2022 were above average in both the spring and fall (0.78 and 1.85 kg/tow, respectively). The fall index was one of the highest in the time series.

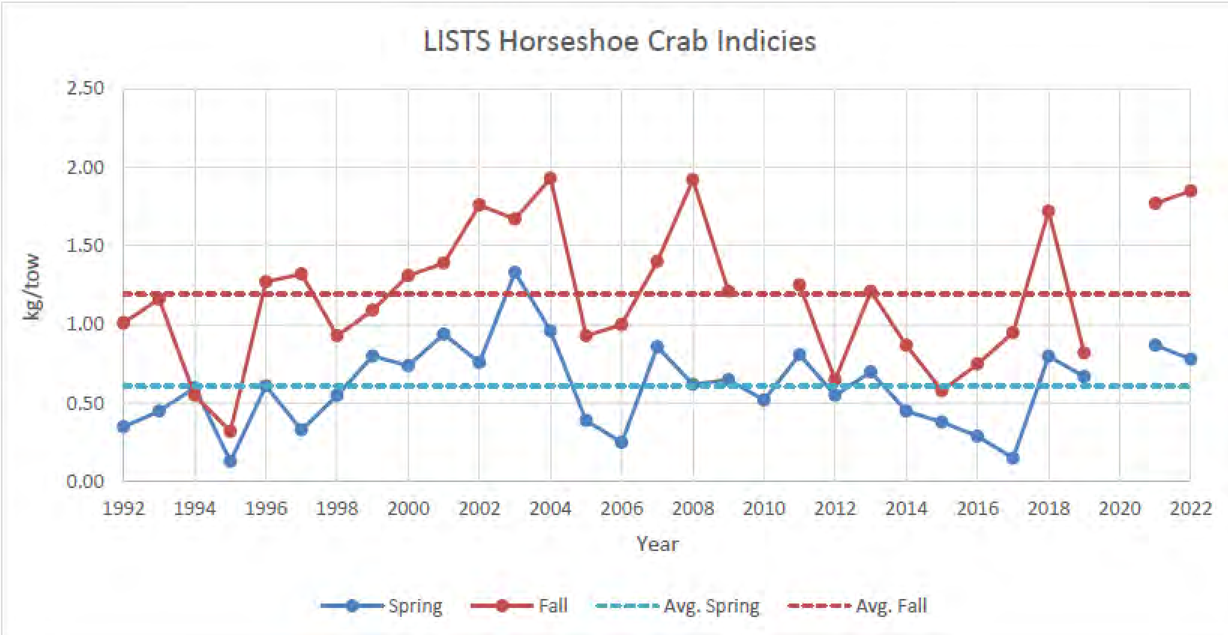


Figure 4. LISTS Horseshoe Crab Indices, 1992-2022.

New York

- Peconic Trawl – 2022 index = 0.14 (delta distribution average catch per unit effort [CPUE]), increase from 2021, below 2010-22 average.
- WLI Jamaica Bay Seine (all horseshoe crabs) – 2022 index = 0.06 (geometric mean), decrease from 2021, lowest value in time series.
- WLI Little Neck Bay Seine (all) – 2022 index = 1.23 (geometric mean), increase from 2021, below 2010-22 average.
- WLI Manhasset Bay Seine (all) – 2022 index = 0.89 (geometric mean), increase from 2019, below 2010-22 average.

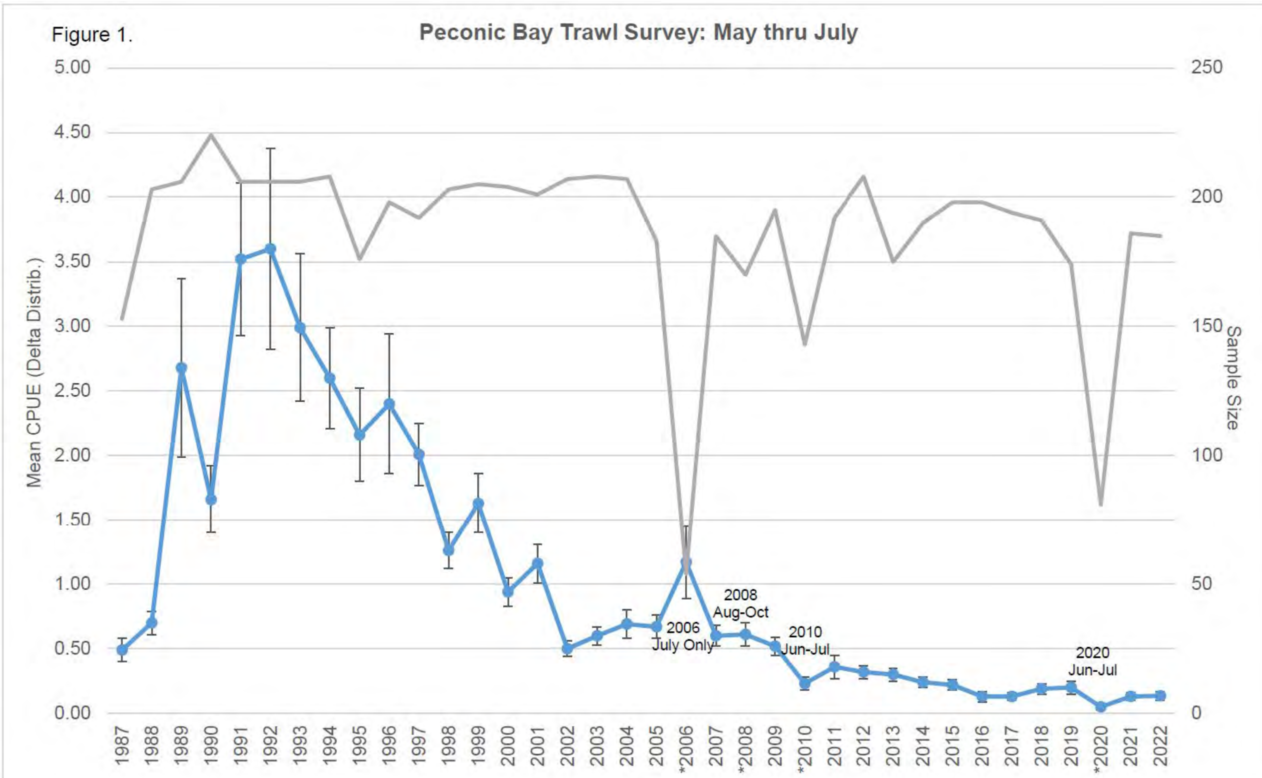


Figure 5. Peconic Bay Trawl Survey: May through July, 1987-2022. (Gray line=sample size, blue line=mean CPUE).

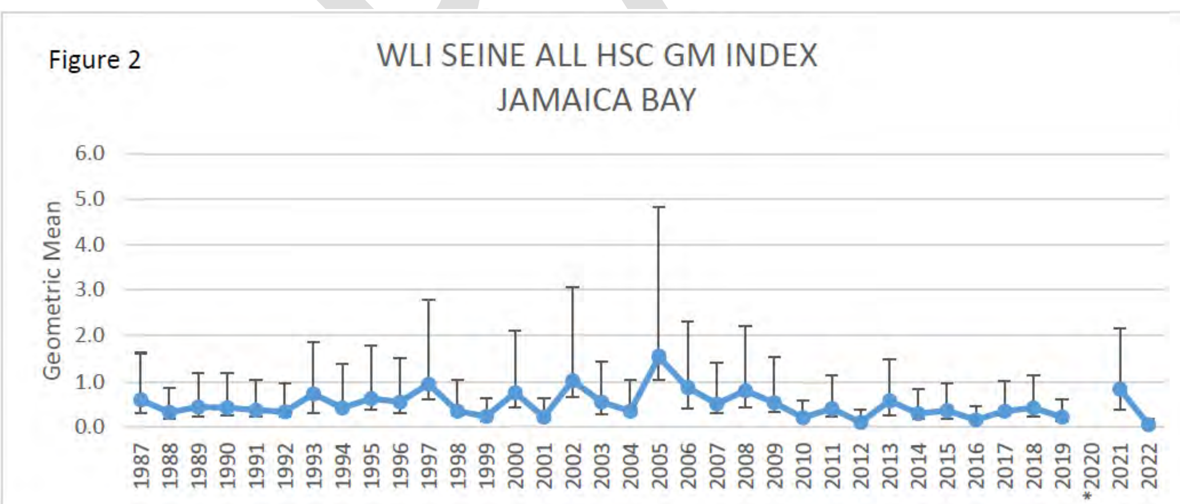


**Figure 6. NYSDEC WLI Jamaica Bay Beach Seine Survey All Horseshoe Crab GM Index, 1987-2022. ***Due to the COVID-19 pandemic, in 2020 sampling did not begin until July.

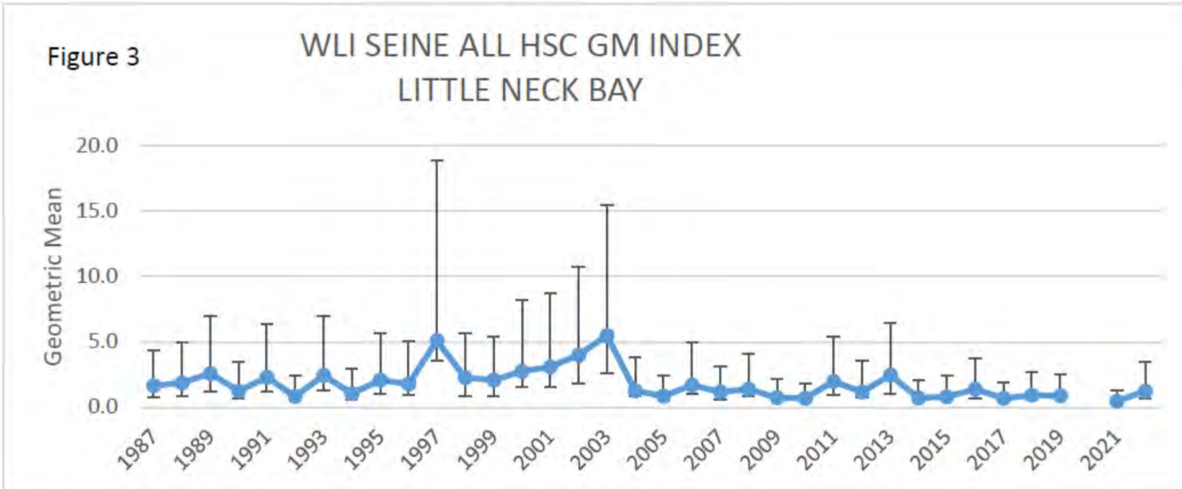


Figure 7. Little Neck Bay Seine Survey All Horseshoe Crab GM Index, 1987-2022. *Due to the COVID-19 pandemic, in 2020 sampling did not begin until July.

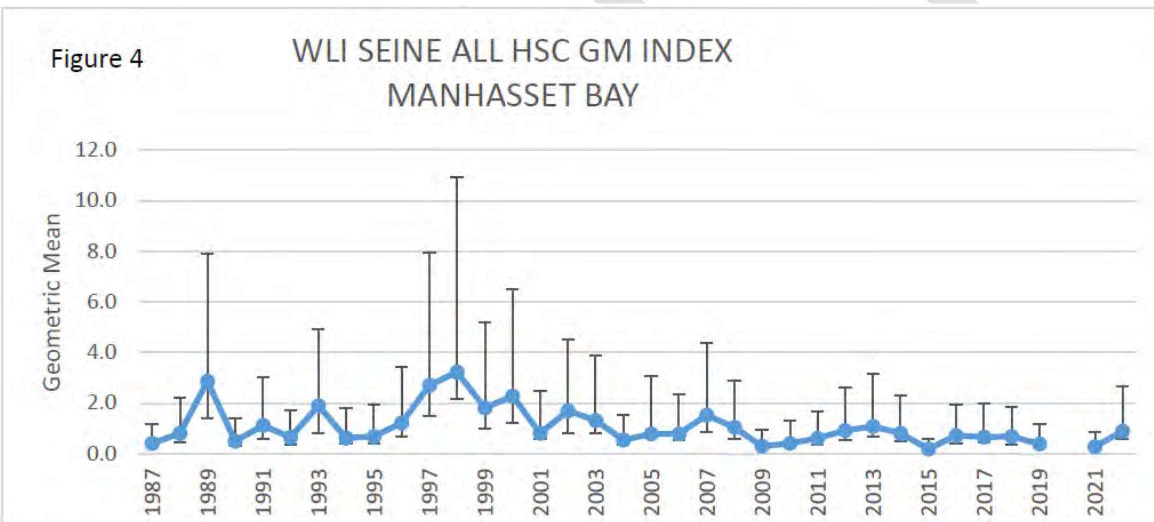


Figure 8. Manhasset Bay Seine Survey All Horseshoe Crab GM Index, 1987-2022. *Due to the COVID-19 pandemic, in 2020 sampling did not begin until July.

V. Status of Management Measures and Issues

ASMFC

Initial state harvest quotas were established through Addendum I. Addendum III outlined the monitoring requirements and recommendations for the states. Addendum IV set harvest closures and quotas, and other restrictions for New Jersey, Delaware, Maryland, and Virginia, which were continued in Addenda V and VI.

In February 2012 the Board approved Addendum VII to implement the ARM Framework; it was implemented in 2013. Addendum VII includes an allocation mechanism to divide the Delaware Bay optimized harvest output from the ARM Framework among the four Delaware Bay states

(New Jersey, Delaware, Maryland, and Virginia east of the COLREGS line). Season closures and restrictions present within Addendum VI remain in effect as part of Addendum VII.

State-specific charts outlining compliance and monitoring measures are included in Section VII. Issues noted by the PRT include:

- Massachusetts and Connecticut did not report to ASMFC by the required deadline.

The PRT finds that all other jurisdictions appear to be in compliance with the FMP and subsequent Addenda in 2022.

Changes to State Regulations

No changes were made to state regulations for fishing year 2022.

Alternative Baits

Trials testing effectiveness of alternative baits to horseshoe crab for the American eel and whelk fisheries have previously been conducted. Additionally, a survey of bait usage in the eel and whelk fisheries was conducted in 2017. This survey is available at: http://www.asmfc.org/uploads/file/5a04b785HSC_BaitSurveyTCReport_Oct2017.pdf.

Shorebirds

The USFWS received petitions in 2004 and 2005 to emergency list the red knot under the Endangered Species Act. In fall 2005, it determined that emergency listing was not warranted at the time. As part of a court settlement, the USFWS agreed to initiate proposed listings of over 200 species, including the red knot. In fall 2013, the USFWS released a proposal for listing the red knot as threatened. In January 2015 the USFWS designated the red knot as threatened under the Endangered Species Act.

In 2022 the USFWS conducted an analysis of the changes to horseshoe crab management that would occur under the 2021 ARM Revision to determine the likelihood of impacts to the red knot. The finding from analysis is that there is a < 1% chance of a red knot population decline due to the implementation of potential female harvest under the revised ARM. Therefore, the Service concluded that take, defined under the Endangered Species Act as killing or injuring, of red knots is not likely.

The red knot has been listed as an endangered species in the state of New Jersey since 2012.

VI. PRT Recommendations and Research Needs

De Minimis

States may apply for *de minimis* status if, for the last two years, their combined average horseshoe crab bait landings (by numbers) constitute less than one percent of coastwide horseshoe crab bait landings for the same two-year period. States may petition the Board at any time for *de minimis* status, if their fishery falls below the threshold level. Once *de minimis* status is granted, designated States must submit annual reports to the Board justifying the continuance of *de minimis* status.

States that qualify for *de minimis* status are not required to implement any horseshoe crab harvest restriction measures, but are required to implement components A, B, E and F of the monitoring program (Section 3.5 of the FMP; further modified by Addendum III). Since *de minimis* states are exempt from a harvest cap, there is potential for horseshoe crab landings to shift to *de minimis* states and become substantial, before adequate action can be taken. To control shifts in horseshoe crab landings, *de minimis* states are encouraged to implement one of the following management measures:

1. Close their respective horseshoe crab bait fishery when landings exceed the *de minimis* threshold;
2. Establish a state horseshoe crab landing permit, making it only available to individuals with a history of landing horseshoe crabs in that state; or
3. Establish a maximum daily harvest limit of up to 25 horseshoe crabs per person per day. States which implement this measure can be relieved of mandatory monthly reporting, but must report all horseshoe crabs harvests on an annual basis.

The following states have been removed from the Management Board since its formation: Pennsylvania (2007), Maine (2011), and New Hampshire (2014). South Carolina, Georgia, and Florida are requesting *de minimis* status for the 2023 fishing season based on the 2021-22 season landings and meet the FMP requirements for being granted this status (Table 1). The PRT recommends granting these jurisdictions *de minimis* status.

Biomedical Threshold
The 1998 FMP established a biomedical mortality threshold of 57,500 crabs that, if exceeded, requires the Board to consider management action. This threshold has been exceeded in all but one year since 2008. Results of the 2019 Benchmark Stock Assessment indicate that levels of biomedical mortality prior to 2017 (the terminal year of data used in the assessment) did not have a significant effect on horseshoe crab population estimates or fishing mortality in the Delaware Bay region.

In 2020 the Board tasked the PDT to review the threshold for biomedical use to develop biologically-based options for the threshold and to develop options for action when the threshold is exceeded. It also tasked the PDT to review the best management practices (BMPs) for handling biomedical catch and suggest options for updating and implementing BMPs. The PDT concluded that given the lack of coastwide population estimates for horseshoe crabs, it is not possible to develop a biologically-based threshold for biomedical mortality. Thus, the PDT did not recommend a change to the threshold. Based on this information the Board determined no action is warranted, but agreed to form a work group to review and update the best management practices for biomedical handling to further reduce stress, injury, and mortality to horseshoe crabs collected for biomedical purposes if possible.

Funding for Research and Monitoring Activities

The PRT strongly recommends the funding and continuation of the VT benthic trawl survey. 2022 sampling had to be reduced due to increased costs. This effort provides a statistically reliable estimate of horseshoe crab relative abundance that is essential to continued ARM implementation and use of the CMSA stock assessment model.

Discard Mortality Estimation

Results of the 2019 Benchmark Stock Assessment indicate that discard mortality may be significant, of similar or greater magnitude than bait harvest. The Review Panel's report indicated that these estimates could be further refined to reduce their uncertainty and more precisely characterize this mortality source. The PRT recommends the Board take steps to increase access to and use of data from the NEFOP, allowing for improved monitoring and estimation of discard mortality.

Improvement of the New York Regional Population

Results of the 2019 Benchmark Stock Assessment indicate a "Poor" status for the New York regional population, due to negative trends in regional abundance indices. New York and Connecticut have indicated that they will take actions within their states to improve this population. The PRT and Board have recommended such actions so that this population's status may improve.

In 2022, Connecticut implemented measures to reduce harvest in response to the Board's request. These changes include the commercial fishing season moving from May 22 to the calendar date three days after the last full or new moon (whichever is later) in May, and a new 5-day closure centered on the first moon phase in June. The daily possession limit for commercial hand-harvest was decreased from 500 to 150 crabs. These changes were implemented prior to the 2022 Spring season.

The PRT will continue to annually report regional indices of abundance so that progress of management actions may be tracked through the annual FMP Reviews.

VII. State Compliance and Monitoring Measures

MASSACHUSETTS		
	2022 Compliance	**2023 Management Proposal**
***De minimis* status**	Did not request *de minimis*	Did not request *de minimis*
Bait Harvest Restrictions and Landings		
- ASMFC Quota (Voluntary State Quota)	330,377 (165,000)	330,377 (165,000)
- Other Restrictions	Bait: 300 crab daily limit year round; limited entry; Biomedical: 1,000 crab daily limit; Conch pot and eel fishermen: no possession limit Mobile gear: 75 crab trip limit, exempted from "no-fishing days" starting 10/9/2020; All: May and June 5-day lunar closures; 7" PW minimum size; Pleasant Bay Closed Area	Bait: 300 crab daily limit year round; Biomedical: 200,000 crab quota; 1,000 crab daily limit; Conch pot and eel fishermen: no possession limit All: May and June 5-day lunar closures; No mobile gear harvest Fri-Sat during summer flounder season; 7" PW minimum size; Pleasant Bay Closed Area
- Landings	135,731	--
Monitoring Component A_1		
- Mandatory monthly reporting	Yes, plus weekly dealer reporting through SAFIS	Yes, plus weekly dealer reporting through SAFIS
- Characterize commercial bait fishery	Yes	Yes
Monitoring Component A_2		
- Biomedical reporting	Yes	Yes
- Required information for biomedical use of crabs	Yes	Yes
Monitoring Component A_3 Identify spawning and nursery habitat	Yes	Not Applicable
Monitoring Component B_1 Coastwide benthic trawl survey	Yes, VT Trawl Survey was conducted in 2022	Yes, VT Trawl Survey will be conducted in 2023; future years and spatial scope unknown at this time
Monitoring Component B_2 Continue existing benthic sampling programs	Yes	Yes
Monitoring Component B_3 Implement spawning survey	Yes	Yes
Monitoring Component B_4 Tagging program	Yes – w/NPS and USFWS; Pleasant Bay, Monomy NWR, Waquoit Bay	Yes – w/NPS and USFWS; Pleasant Bay, Monomy NWR, Waquoit Bay

RHODE ISLAND		
	2022 Compliance	**2023 Management Proposal**
***De minimis* status**	Did not request *de minimis*	Did not request *de minimis*
Bait Harvest Restrictions and Landings		
- ASMFC Quota (Voluntary State Quota)	26,053 (8,398)	26,053 (8,398)
- Other Restrictions	State Restrictions: - Daily possession limit: 60 crabs per permit - Bait Fishery Closure: May 1-May 31 - Biomedical Fishery Closure: 48 hours prior to and 48 hours following new and full moons during May. - Biomedical quota and best management practices	State Restrictions: - Daily possession limit: 60 crabs per permit - Bait Fishery Closure: May 1-May 31 - Biomedical Fishery Closure: 48 hours prior to and 48 hours following new and full moons during May - Biomedical quota and best management practices
- Landings	Confidential	--
Monitoring Component A_1		
- Mandatory monthly reporting	Yes, weekly call in and monthly on paper	Yes, weekly call in and monthly on paper
- Characterize commercial bait fishery	Yes	Yes
Monitoring Component A_2		
- Biomedical reporting	Yes	Yes
- Required information for biomedical use of crabs	Yes, included in Massachusetts' biomedical reports	Captured in Massachusetts' biomedical reports
Monitoring Component A_3 Identify spawning and nursery habitat	Yes	Not Applicable
Monitoring Component B_1 Coastwide benthic trawl survey	Yes, VT Trawl Survey was conducted in 2022	Yes, VT Trawl Survey will be conducted in 2023; future years and spatial scope unknown at this time
Monitoring Component B_2 Continue existing benthic sampling programs	Yes	Yes
Monitoring Component B_3 Implement spawning survey	Yes, since 2000	Yes
Monitoring Component B_4 Tagging program	No	No

CONNECTICUT		
	2022 Compliance	**2023 Management Proposal**
***De minimis* status**	Did not request *de minimis*	Did not request *de minimis*
Bait Harvest Restrictions and Landings		
- ASMFC Quota	48,689	48,689
- Other Restrictions	- Limited entry program - Hand-harvest possession limit of 150 crabs - seasonal and lunar closures	Prohibit hand harvest of horseshoe crabs or eggs in state waters, effective Oct. 1, 2023
- Landings	1,343	--
Monitoring Component A_1		
- Mandatory monthly reporting	Yes	Yes
- Characterize commercial bait fishery	No – exempt under Addendum III because landings are < 5% of coastwide total	No – exempt under Addendum III because landings are < 5% of coastwide total
Monitoring Component A_2		
- Biomedical reporting	Not Applicable	Not Applicable
- Required information for biomedical use of crabs	Not Applicable	Not Applicable
Monitoring Component A_3 Identify spawning and nursery habitat	Not provided	Not Applicable
Monitoring Component B_1 Coastwide benthic trawl survey	Yes, VT Trawl Survey was conducted in 2022	Yes, VT Trawl Survey will be conducted in 2023; future years and spatial scope unknown at this time
Monitoring Component B_2 Continue existing benthic sampling programs	Yes	Yes
Monitoring Component B_3 Implement spawning survey	Yes, since 1999 (methods differ from DE Bay survey)	Yes
Monitoring Component B_4 Tagging program	Yes, in collaboration with local universities (Sacred Heart University since 2015)	Yes

NEW YORK		
	2022 Compliance	**2023 Management Proposal**
***De minimis* status**	Did not request *de minimis*	Did not request *de minimis*
Bait Harvest Restrictions and Landings		
- ASMFC Quota (Voluntary State Quota)	366,272 (150,000)	366,272 (150,000)
- Other Restrictions	Ability to close areas to harvest; seasonal quotas and daily harvest limits Five-day lunar closures around the full moon in May and the new moon in June. Initial trip limit dropped to 150 crabs in period 2.	Ability to close areas to harvest; seasonal quotas and daily harvest limits - Five-day lunar closures around the full moon in May and the new moon in June. -Initial trip limit dropped to 150 crabs in period 2.
- Landings	111,481	--
Monitoring Component A_1		
- Mandatory monthly reporting	Yes	Yes
- Characterize commercial bait fishery	Yes	Yes
Monitoring Component A_2		
- Biomedical reporting	Yes	Yes
- Required information for biomedical use of crabs	Not Applicable	Not Applicable
Monitoring Component A_3 Identify spawning and nursery habitat	Yes	Not Applicable
Monitoring Component B_1 Coastwide benthic trawl survey	Yes, VT Trawl Survey was conducted in 2022	Yes, VT Trawl Survey will be conducted in 2023; future years and spatial scope unknown at this time
Monitoring Component B_2 Continue existing benthic sampling programs	Yes	Yes
Monitoring Component B_3 Implement spawning survey	Yes	Yes
Monitoring Component B_4 Tagging program	Yes	Yes

NEW JERSEY		
	2022 Compliance	**2023 Management Proposal**
***De minimis* status**	Did not request *de miminis*	Does not request *de miminis*
Bait Harvest Restrictions and Landings		
- ASMFC Quota (Voluntary state quota)	162,136 [male only] (0)	162,136 [male only] (0)
- Other Restrictions	Bait harvest moratorium	Bait harvest moratorium
- Landings	0	--
Monitoring Component A_1		
- Mandatory monthly reporting	Not Applicable	Not Applicable
- Characterize commercial bait fishery	Not Applicable	Not Applicable
Monitoring Component A_2		
- Biomedical reporting	Yes	Yes
- Required information for biomedical use of crabs	Yes	Yes
Monitoring Component A_3 Identify spawning and nursery habitat	Yes	Not Applicable
Monitoring Component B_1 Coastwide benthic trawl survey	Yes, VT Trawl Survey was conducted in 2022	Yes, VT Trawl Survey will be conducted in 2023; future years and spatial scope unknown at this time
Monitoring Component B_2 Continue existing benthic sampling programs	Yes	Yes
Monitoring Component B_3 Implement spawning survey	Yes	Yes
Monitoring Component B_4 Tagging program	No	No
Monitoring Component B_5 Egg abundance survey	Yes, no longer mandatory	Yes
Monitoring Component B_6 Shorebird monitoring program	Yes	Yes

DELAWARE		
	2022 Compliance	**2023 Management Proposal**
***De minimis* status**	Did not request *de minimis*	Did not request *de minimis*
Bait Harvest Restrictions and Landings		
- ASMFC Quota (State Quota)	162,136 [male only] 151,345 [male only]	164,364 [male only] 164,364 [male only]
- Other Restrictions	Closed season (January 1 – June 7)	Closed season (January 1 – June 7)
- Landings	147,558 (male only)	--
Monitoring Component A_1		
- Mandatory monthly reporting	Yes (daily call-in reports & monthly logbooks)	Yes
- Characterize commercial bait fishery	Yes	Yes
Monitoring Component A_2		
- Biomedical reporting	Not Applicable	Not Applicable
- Required information for biomedical use of crabs	Not Applicable	Not Applicable
Monitoring Component A_3 Identify spawning and nursery habitat	Yes –updates once every 5 years or as needed	Yes – updates once every 5 years or as needed
Monitoring Component B_1 Coastwide benthic trawl survey	Yes, VT Trawl Survey was conducted in 2022	Yes, VT Trawl Survey will be conducted in 2023; future years and spatial scope unknown at this time
Monitoring Component B_2 Continue existing benthic sampling programs	Yes	Yes
Monitoring Component B_3 Implement spawning survey	Yes	Yes
Monitoring Component B_4 Tagging program	No state program but has assisted in the past with various Delaware Bay horseshoe crab tagging initiatives	No
Monitoring Component B_5 Egg abundance survey	Removed as component	Removed as component
Monitoring Component B_6 Shorebird monitoring program	Yes	Yes

Note: The egg abundance survey has been discontinued as a mandatory monitoring element. Delaware will include information on the survey if it continues, but is no longer required to perform the survey.

MARYLAND		
	2022 Compliance	**2023 Management Proposal**
***De minimis* status**	Did not request *de minimis*	Did not request *de minimis*
Bait Harvest Restrictions and Landings		
- ASMFC Quota	255,980 (male only)	255,980 (male only)
- Other Restrictions	Delayed harvest and closed season/area combinations, catch limits	Delayed harvest and closed season/area combinations, catch limits
- Landings	84,627 (male only)	--
Monitoring Component A_1		
- Mandatory monthly reporting	Yes (weekly reports for permit holders; monthly for non-permit holders)	Yes (weekly reports for permit holders; monthly for non-permit holders)
- Characterize commercial bait fishery	Yes	Yes
Monitoring Component A_2		
- Biomedical reporting	Yes	Yes
- Required information for biomedical use of crabs	Yes	Yes
Monitoring Component A_3 Identify spawning and nursery habitat	Yes	Not Applicable
Monitoring Component B_1 Coastwide benthic trawl survey	Yes, VT Trawl Survey was conducted in 2022	Yes, VT Trawl Survey will be conducted in 2023; future years and spatial scope unknown at this time
Monitoring Component B_2 Continue existing benthic sampling programs	Yes	Yes
Monitoring Component B_3 Implement spawning survey	Yes	Yes
Monitoring Component B_4 Tagging program	Yes – through biomedical use	Yes – through biomedical use

POTOMAC RIVER FISHERIES COMMISSION		
	2022 Compliance	**2023 Management Proposal**
***De minimis* status**	Did not request *de minimis*	Did not request *de minimis*
- Ability to close fishery if *de minimis* threshold is reached	No horseshoe crab fishery	No horseshoe crab fishery
- Daily possession limit <25 for *de minimis* state		
- HSC landing permit		
Bait Harvest Restrictions and Landings		
- ASMFC Quota	0	0
- Other Restrictions	None	None
- Landings	0	0
Monitoring Component A_1		
- Mandatory monthly reporting	Yes - weekly	Yes - weekly
- Characterize commercial bait fishery	Not Applicable	Not Applicable
Monitoring Component A_2		
- Biomedical reporting	Not Applicable	Not Applicable
- Required information for biomedical use of crabs	Not Applicable	Not Applicable
Monitoring Component A_3 Identify spawning and nursery habitat	Not Applicable	Not Applicable
Monitoring Component B_1 Coastwide benthic trawl survey	Yes, VT Trawl Survey was conducted in 2022	Yes, VT Trawl Survey will be conducted in 2023; future years and spatial scope unknown at this time
Monitoring Component B_2 Continue existing benthic sampling programs	Not Applicable	Not Applicable
Monitoring Component B_3 Implement spawning survey	Not Applicable	Not Applicable
Monitoring Component B_4 Tagging program	Not Applicable	Not Applicable

VIRGINIA		
	2022 Compliance	**2023 Management Proposal**
***De minimis* status**	Did not request *de minimis*	Did not request *de minimis*
Bait Harvest Restrictions and Landings		
- ASMFC Quota	172,828 (81,331 male-only east of COLREGS line)	172,828 (81,331 male-only east of COLREGS line)
- Other Restrictions	Closed season (January 1 – June 7) for federal waters. Effective January 1, 2013 harvest of horseshoe crabs, from east of the COLREGS line, is limited to trawl gear and dredge gear only.	Closed season (January 1 – June 7) for federal waters. Effective January 1, 2013 harvest of horseshoe crabs, from east of the COLREGS line, is limited to trawl gear and dredge gear only.
- Landings	89,748 (60,693 males)	--
Monitoring Component A_1		
- Mandatory monthly reporting	Yes	Yes
- Characterize commercial bait fishery	Yes	Yes
Monitoring Component A_2		
- Biomedical reporting	Yes	Yes
- Required information for biomedical use of crabs	Yes	Yes
Monitoring Component A_3 Identify spawning and nursery habitat	Yes	Not Applicable
Monitoring Component B_1 Coastwide benthic trawl survey	Yes, VT Trawl Survey was conducted in 2022	Yes, VT Trawl Survey will be conducted in 2023; future years and spatial scope unknown at this time
Monitoring Component B_2 Continue existing benthic sampling programs	Not Applicable	Not Applicable
Monitoring Component B_3 Implement spawning survey	No	No
Monitoring Component B_4 Tagging program	No	No

NORTH CAROLINA		
	2022 Compliance	**2023 Management Proposal**
***De minimis* status**	Did not request *de minimis*	Did not request *de minimis*
Bait Harvest Restrictions and Landings		
- ASMFC Quota	24,036	24,036
- Other Restrictions	Trip limit of 50 crabs; Proclamation authority to adjust trip limits, seasons, etc.	Trip limit of 50 crabs; Proclamation authority to adjust trip limits, seasons, etc.
- Landings	500	--
Monitoring Component A_1		
- Mandatory monthly reporting	Yes	Yes
- Characterize commercial bait fishery	Yes	Yes
Monitoring Component A_2		
- Biomedical reporting	Not Applicable	Not Applicable
- Required information for biomedical use of crabs	Not Applicable	Not Applicable
Monitoring Component A_3 Identify spawning and nursery habitat	Little information available; Survey discontinued after 2002 and 2003 due to low levels of crabs recorded	Not Applicable
Monitoring Component B_1 Coastwide benthic trawl survey	Yes, VT Trawl Survey was conducted in 2022	Yes, VT Trawl Survey will be conducted in 2023; future years and spatial scope unknown at this time
Monitoring Component B_2 Continue existing benthic sampling programs	Yes	Yes
Monitoring Component B_3 Implement spawning survey	No	No
Monitoring Component B_4 Tagging program	No	No

SOUTH CAROLINA		
	2022 Compliance	**2023 Management Proposal**
***De minimis* status**	*De minimis* status granted for 2022.	*De minimis* requested for 2023 and meets criteria.
- Ability to close fishery if *de minimis* threshold is reached	No horseshoe crab bait fishery	No horseshoe crab bait fishery
- Daily possession limit <25 for *de minimis* state		
- HSC landing permit		
Bait Harvest Restrictions and Landings		
- ASMFC Quota	0	0
- Other Restrictions	None	None
- Landings	0	--
Monitoring Component A_1		
- Mandatory monthly reporting	Yes (Biomedical)	Yes (Biomedical)
- Characterize commercial bait fishery	Not Applicable	Not Applicable
Monitoring Component A_2		
- Biomedical reporting	Yes	Yes
- Required information for biomedical use of crabs	Yes	Yes
Monitoring Component A_3 Identify spawning and nursery habitat	Completed	No
Monitoring Component B_1 Coastwide benthic trawl survey	Yes, VT Trawl Survey was conducted in 2022	Yes, VT Trawl Survey will be conducted in 2023; future years and spatial scope unknown at this time
Monitoring Component B_2 Continue existing benthic sampling programs	Yes	Yes
Monitoring Component B_3 Implement spawning survey	Yes	Yes
Monitoring Component B_4 Tagging program	Yes	Yes

GEORGIA		
	2022 Compliance	**2023 Management Proposal**
***De minimis* status**	*De minimis* status granted in 2022.	*De minimis* requested for 2023 and meets criteria.
- Ability to close fishery if *de minimis* threshold is reached	Yes	Yes
- Daily possession limit <25 for *de minimis* state	25/person; 75/vessel with 3 licensees	25/person; 75/vessel with 3 licensees
- HSC landing permit	Must have commercial shrimp, crab, or whelk license; LOA permit required	Must have commercial shrimp, crab, or whelk license; LOA permit required
Bait Harvest Restrictions and Landings		
- ASMFC Quota	29,312	29,312
(State Quota)	29,312	29,312
- Other Restrictions	None	None
- Landings	0	--
Monitoring Component A_1		
- Mandatory monthly reporting	Yes	Yes
- Characterize commercial bait fishery	Not Applicable	Yes
Monitoring Component A_2		
- Biomedical reporting	Not Applicable	Not Applicable
- Required information for biomedical use of crabs	Not Applicable	Not Applicable
Monitoring Component A_3 Identify spawning and nursery habitat	Completed	Not Applicable
Monitoring Component B_1 Coastwide benthic trawl survey	Yes, VT Trawl Survey was conducted in 2022	Yes, VT Trawl Survey will be conducted in 2023; future years and spatial scope unknown at this time
Monitoring Component B_2 Continue existing benthic sampling programs	Yes	Yes
Monitoring Component B_3 Implement spawning survey	No	No
Monitoring Component B_4 Tagging program	No	No

FLORIDA		
	2022 Compliance	**2023 Management Proposal**
***De minimis* status**	*De minimis* status granted in 2022.	*De minimis* requested for 2023 and meets criteria.
- Ability to close fishery if *de minimis* threshold is reached	Yes	Yes
- Daily possession limit <25 for *de minimis* state	25/person w/ valid saltwater products license; 100/person with marine life endorsement	25/person w/ valid saltwater products license; 100/person with marine life endorsement
- HSC landing permit	See above	See above
Bait Harvest Restrictions and Landings		
- ASMFC Quota	9,455	9,455
- Other Restrictions	Daily possession limit	Daily possession limit
- Landings	Confidential	--
Monitoring Component A_1		
- Mandatory monthly reporting	Yes	Yes
- Characterize commercial bait fishery	Yes	Yes
Monitoring Component A_2		
- Biomedical reporting	Not Applicable	Not Applicable
- Required information for biomedical use of crabs	Not Applicable	Not Applicable
Monitoring Component A_3 Identify spawning and nursery habitat	Yes	Yes
Monitoring Component B_1 Coastwide benthic trawl survey	Yes, VT Trawl Survey was conducted in 2022	Yes, VT Trawl Survey will be conducted in 2023; future years and spatial scope unknown at this time
Monitoring Component B_2 Continue existing benthic sampling programs	Yes	Yes
Monitoring Component B_3 Implement spawning survey	Yes	Yes
Monitoring Component B_4 Tagging program	No	No

Chapter <86>: Frequently Asked Questions

1

What is the animal-free alternative to Limulus amebocyte lysate (LAL)?

Alternatives to naturally sourced LAL are commercially available or currently in development. These recombinant reagents utilize one (rFC) or more (rCR) recombinant zymogen proteases cloned from the natural clotting cascade of horseshoe crabs to detect and quantify endotoxins activity.

2

What is the purpose of Chapter <86>?

Chapter <86> provides additional tests to the Bacterial Endotoxins Test <85> using recombinant Factor C or recombinant cascade reagents to detect or quantify endotoxins.

3

What kind of data was gathered and reviewed to inform Chapter <86>?

The USP Microbiology Expert Committee, which includes eight FDA representatives, gathered and reviewed scientific data obtained from literature review and submissions from stakeholders, as well as from USP-generated experimental data gathered during reference standard qualification.

4

Does this proposal replace LAL for endotoxin testing?

No, manufacturers that currently use LAL for endotoxin testing can continue to do so and Chapter <86> has no impact on them. The Bacterial Endotoxins Tests (BET) described in the new chapter are additional techniques to the current *Bacterial Endotoxins Test* described in Chapter <85>. The new chapter is intended to allow manufacturers to use non-animal derived reagents, in line with USP's commitment to reduce the use of animal-derived materials.

5

From a compendial perspective, how does Chapter <86> allow for the use of rFC and other cascade reagents?

This chapter provides methods for the use of rFC or rCR and steps for how to verify their use for a specific product. Under the provisions of the chapter, manufacturers of new biopharmaceuticals can choose to use rFC or rCR without the need to demonstrate comparability to the current method using LAL. Manufacturers of existing products that want to switch to animal-free reagents need to show this comparability. This is a normal approach and information on how to do this is readily and freely available. Please note that regulatory authorities may require supplemental data prior to acceptance, and users are encouraged to consult each regulatory authority. An example of supplemental data may include a comparative study of the material tested by techniques described in this chapter and those in <85>.

6

Will FDA require additional validation to use rFC or rCR?

The new Chapter <86> outlines steps to use endotoxin testing with rFC or rCR. It is a normal requirement for any method that it needs to be validated and shown that it is fit for use. Regulatory authorities may require supplemental data and users are encouraged to discuss with each regulatory authority.

Chapter <86>: FAQ, continued...

7

How does this proposal differ from other global pharmacopeias?

This proposal is similar to the European Pharmacopeia's and the Japanese Pharmacopeia's approach. USP is additionally proposing to add rCR and the associated method, which is not in the current EP chapter, as we considered it a suitable addition based their recent commercial availability by multiple manufacturers.

USP	***European Pharmacopeia***	***Japanese Pharmacopeia***
Unless specified in an individual monograph or General Notices, the tests in this chapter are considered alternative tests and users must meet the requirements in *General Notices* 6.30.	The replacement of an LAL-based method prescribed in a monograph by an rFC-based method is considered as the use of an alternative method as described in the Ph. Eur. General Notices.	<G4-4-180> describes procedures and consideration in measurement when using recombinant protein-reagents for endotoxin assay as alternative methods, in addition to lysate reagents and test methods in Bacterial Endotoxins Test.
A test for bacterial endotoxins using rFC or rCR can be used in the same way as LAL-based methods, after demonstration of its fitness for use for the specific substance or product. Regulatory authorities may require supplemental data and users are encouraged to discuss with each regulatory authority.	A test for bacterial endotoxins using rFC can be used in the same way as LAL-based methods, after demonstration of its fitness for use for the specific substance or product.	If these reagents for endotoxin assay are used as an alternative method, confirm that accuracy, precision, sensitivity, specificity, etc. are equal or better compared to Bacterial Endotoxins Test <4.01> using lysate reagents.
To use recombinant reagents, supplier's primary validation data can be used.	The rFC can be used in the same way as LAL-based methods, after demonstration of fitness for use for the specific substance or product.	The recombinant protein-reagents for endotoxin assay are not identical to "an amoebocyte lysate prepared from blood corpuscle extracts of horseshoe crab" specified in Bacterial Endotoxins Test <4.01>.
Includes methods for rFC and rCR.	Includes methods for rFC.	Includes methods for rFC and rCR.
Reference	Reference	Reference

Chapter <86>: FAQ, continued...

8

Will Chapter <86> be harmonized?

This is a topic for discussion between several pharmacopeias. The proposed Chapter contains many similarities with the European and Japanese pharmacopeia. If Chapter <86> becomes an official standard, it will be further discussed among pharmacopeias with the intent to obtain harmonization as much as possible.

9

Will there be an opportunity for stakeholders to comment on the proposed chapter?

The Chapter comment period will be open from Nov. 1, 2023, through Jan. 31, 2024. We welcome questions or comments through our pre-publication on USP's website in advance of the official comment process.

10

When will Chapter <86> be included in the *USP–NF*?

At the end of the comment period, all comments on the proposed monograph are collected and sent to the relevant Expert Bodies for review. The Expert Committee may revise the document based on feedback and send it to the Expert Committee for review. Our USP scientific liaisons review all the public comments, organize the information received and provide science-based recommendations to the Expert Committee. Depending on the comments received, the draft Chapter may be republished for another round of comments, or the chapter may be balloted by the Expert Committee for incorporation into the *United States Pharmacopeia–National Formulary* (*USP–NF*).

11

Does USP's reference standard apply to bacterial endotoxin testing using rFC and rCR?

There is no impact on USP's Reference Standard for Endotoxins. Tests described in the new Chapter <86> utilize the standard in the same manner as <85>.

Atlantic States Marine Fisheries Commission

1050 N. Highland Street • Suite 200A-N • Arlington, VA 22201
703.842.0740 • www.asmfc.org

MEMORANDUM

September 28, 2023

To: **Horseshoe Crab Management Board**

From: **Tina Berger, Director of Communications**

RE: **Advisory Panel Nomination**

Please find attached a nomination to the Horseshoe Crab Advisory Panel – Sam Martin, a commercial mobile tending gear fisherman for Maryland. While Sam's nomination says that he has been found in violation of a criminal or civil federal fishery law or regulation. He incorrectly said yes to the answer and this has also been confirmed by the appointing state. Please review this nomination for action at the next Board meeting.

If you have any questions, please feel free to contact me at (703) 842-0749 or tberger@asmfc.org.

Enc.

cc: Caitlin Starks

M23-79

HORSESHOE CRAB ADVISORY PANEL

Bolded names await approval by the Horseshoe Crab Management Board

September 28, 2023

Massachusetts

David Meservey (comm/inshore otter trawl)
P.O. Box 128
South Chatham, MA 02659
Phone: 508.237.4366
dmese@yahoo.com
Appt Confirmed 8/2/22

Jay A. Harrington (comm/handpicker/raker)
#6 Sherman Road
P.O. Box 321
South Orleans, MA 02662
Phone: 508.255.0582
indeepH2O@gmail.com
Appt. Confirmed 4/7/98
Appt. Reconfirmed 10/02; 10/06; 5/10; 8/18

Chair, Brett Hoffmeister (biomedical)
Associates of Cape Cod
331 Barlows Landing Row
Pocasset, MA 02559
Phone (day): 508.444.1426
BHoffmeister@acciusa.com
Appt Confirmed 2/3/16
Appt. Reconfirmed 8/18

Rhode Island

Vacancy (comm/otter trawl)

New York

John L. Turner (conservation)
10 Clark Boulevard
Massapequa, NY 11762
Phone (day): 631.451.6455
Phone (eve): 516.797.9786
jturner@seatuck.org
Appt. Confirmed 2/10/05
Appt Reconfirmed 5/10

Vacancy – commercial pot

New Jersey

Benjie Swan (biomedical)
Limuli Laboratories
Dias Creek, 5 Bay Avenue
Cape May Courthouse, NJ 08210-2556
Phone: 609.465.6552
Swan24@verizon.net
Appt. Confirmed 8/5/10

Delaware

Lawrence Voss (comm./pot)
3215 Big Oak Road
Smyrna, DE 19977
Phone: (302)359-0951
shrlyvss@aol.com
Appt. Confirmed 10/24/18

2 vacancies - dealer/processor & conservation/environmental

Maryland

George Topping (comm/trawl)
32182 Bowhill Road
Salisbury, MD 21804
Phone: 443.497.2141
george@zztopping.com
Appt. Confirmed 5/16

Jeffrey Eutsler (comm/trawl)
11933 Gray's Corner Road
Berlin, MD 21811
Phone: 443.497.3078
jeffeutsler@me.com
Appt. Confirmed 2/4/98
Appt. Reconfirmed 10/02; 10/06; 5/10

Allen L. Burgenson (biomedical)
8875 Hawbottom Road
Middletown, MD 21769
Phone: 301.378.1263
allen.burgenson@lonza.com
Appt. Confirmed 8/21/08
past chair

Sam Martin (comm mobile tending/biomedical harvest)
985 Ocean Drive
Cape May, NJ 08204
Phone: 609.381.8892
smartin@atlanticcapes.com

HORSESHOE CRAB ADVISORY PANEL

Bolded names await approval by the Horseshoe Crab Management Board

September 28, 2023

Virginia
Richard B. Robins, Jr. (processor/dealer)
3969 Shady Oaks Drive
Virginia Beach, VA 23455
Phone (day): 757.244.8400
Phone (eve): 757.363.9506
richardbrobins@gmail.com
Appt. Confirmed: 2/9/00
Appt. Reconfirmed 1/2/06; 5/10

Christina M. Lecker
FUJIFILM Wako Chemicals U.S.A. Corporation,
LAL Division
Plant Manager - Cape Charles Facility
301 Patrick Henry Avenue
Cape Charles, VA 23310
Phone: 757-331-4240, 757-331-2026
FAX: 757-331-2046
christina.lecker@fujifilm.com
Appt. Confirmed 10/21/2020

1 vacancy - comm/pot/conch

South Carolina
Nora Blair (biomedical)
Charles River Laboratories Microbial Solutions
1852 Cheshire Drive
Charleston, SC 29412
843.276.7819
Nora.Blair@crl.com
Appt. Confirmed 5/1/19

Vacancy - comm/pot/trawl

Nontraditional Stakeholders
Jeff Shenot
7900 McClure Road
Upper Marlboro, MD 20772
Phone: 301.580.4524
JUGBAY@msn.com
Appt. Confirmed 8/2018

Walker Golder
Executive Director, Coastal Land Trust
3 Pine Valley Dr.
Wilmington, NC 28412
Office: 910.790.4524 x2060
Cell: 910.619.6244
walker@coastallandtrust.org
Appt. Confirmed 8/2018

ATLANTIC STATES MARINE FISHERIES COMMISSION

Advisory Panel Nomination Form

This form is designed to help nominate Advisors to the Commission's Species Advisory Panels. The information on the returned form will be provided to the Commission's relevant species management board or section. Please answer the questions in the categories (All Nominees, Commercial Fisherman, Charter/Headboat Captain, Recreational Fisherman, Dealer/Processor, or Other Interested Parties) that pertain to the nominee's experience. If the nominee fits into more than one category, answer the questions for all categories that fit the situation. **Also, please fill in the sections which pertain to All Nominees (pages 1 and 2). In addition, nominee signatures are required to verify the provided information (page 4), and Commissioner signatures are requested to verify Commissioner consensus (page 4). Please print and use a black pen.**

Form submitted by: Michael Luisi State: MD
(your name)

Name of Nominee: Sam Martin

Address: 985 Ocean Drive

City, State, Zip: Cape May, NJ 08204

Please provide the appropriate numbers where the nominee can be reached:

Phone (day): 609-381-8892 Phone (evening): same

FAX: 609-884-3261 Email: smartin@atlanticcapes.com

FOR ALL NOMINEES:

1. Please list, in order of preference, the Advisory Panel for which you are nominating the above person.
   1. Horseshore Crab
   2. ________
   3. ________
   4. ________

2. Has the nominee been found in violation of criminal or civil federal fishery law or regulation or convicted of any felony or crime over the last three years?

   yes YES no ______

3. Is the nominee a member of any fishermen's organizations or clubs?

   yes YES no ______

   If "yes," please list them below by name.

Garden State Seafood Association | Science Center for Marine Fisheries

Fishery Survival Fund

Responsible Offshore Development Association

4. What kinds (species) of fish and/or shellfish has the nominee fished for during the past year?

Horseshoe Crab | Squid

Black Sea Bass | Summer Flounder

Scallops | Surf Clams

5. What kinds (species) of fish and/or shellfish has the nominee fished for in the past?

same

FOR COMMERCIAL FISHERMEN:

1. How many years has the nominee been the commercial fishing business? 25 years

2. Is the nominee employed only in commercial fishing? yes YES no ________

3. What is the predominant gear type used by the nominee? Mobile Tending

4. What is the predominant geographic area fished by the nominee (i.e., inshore, offshore)? Inshore and Offshore - Mid-Atlantic and New England

FOR CHARTER/HEADBOAT CAPTAINS:

1. How long has the nominee been employed in the charter/headboat business? 25 years

2. Is the nominee employed only in the charter/headboat industry? yes YES no ________

   If "no," please list other type(s)of business(es) and/occupation(s): ________

3. How many years has the nominee lived in the home port community? 25 years

   If less than five years, please indicate the nominee's previous home port community.

   ____

FOR RECREATIONAL FISHERMEN:

1. How long has the nominee engaged in recreational fishing? 25 years

2. Is the nominee working, or has the nominee ever worked in any area related to the fishing industry? yes YES no ____

   If "yes," please explain.

FOR SEAFOOD PROCESSORS & DEALERS:

1. How long has the nominee been employed in the business of seafood processing/dealing? 25 years

2. Is the nominee employed only in the business of seafood processing/dealing?

   yes YES no ____ If "no," please list other type(s) of business(es) and/or occupation(s):

3. How many years has the nominee lived in the home port community? 25 years

   If less than five years, please indicate the nominee's previous home port community.

FOR OTHER INTERESTED PARTIES:

1. How long has the nominee been interested in fishing and/or fisheries management? 25 years

2. Is the nominee employed in the fishing business or the field of fisheries management? yes YES no ____

   If "no," please list other type(s) of business(es) and/or occupation(s):

FOR ALL NOMINEES:

In the space provided below, please provide the Commission with any additional information which you feel would assist us in making choosing new Advisors. You may use as many pages as needed.

I ALSO AM ON THE ADVISORY PANELS OF THE MAFMC FOR SURFCLAM/OCEAN QUAHOG, SPINY DOGFISH AND SQUID, MAC, BUTTERFISH
I SIT ON THE MONKFISH AP FOR NEFMC.

I THINK IT IS IMPORTANT TO HAVE ADVISORS THAT ARE FULLY ENGAGED IN A BROAD RANGE OF REGULATORY BODIES. WITH A FOCUS ON ECOSYSTEM MANAGEMENT THE GIVES ENHANCED PERSPECTIVE IN SUSTAINING FISHERIES AND FISHING COMMUNITIES.

I WOULD LIKE TO SIT ON THE AP FOR HORSESHOE CRAB AS WE ARE FULLY ENGAGED IN THE FISHERY COMMERCIALLY AS WELL AS IN BIO-MEDICAL.

Nominee Signature: [signature] Date: 5/4/2023

Name: Sam Martin
(please print)

COMMISSIONERS SIGN-OFF (not required for non-traditional stakeholders)

Michael Luisi for Lynn Fegley
State Director

State Legislator

Governor's Appointee

*Confirmed support from Dave and Russell via email/txt.

Atlantic States Marine Fisheries Commission

Shad and River Herring Management Board

October 16, 2023
4:15 – 5:00 p.m.
Hybrid Meeting

Draft Agenda

The times listed are approximate; the order in which these items will be taken is subject to change; other items may be added as necessary.

1.	Welcome/Call to Order *(L. Fegley)*	4:15 p.m.
2.	Board Consent • Approval of Agenda • Approval of Proceedings from August 2023	4:15 p.m.
3.	Public Comment	4:20 p.m.
4.	Progress Update on the 2024 River Herring Benchmark Stock Assessment *(K. Drew)*	4:30 p.m.
5.	Consider Approval of Fishery Management Plan Review and State Compliance for the 2022 Fishing Year *(J. Boyle)* **Action**	4:45 p.m.
6.	Other Business/Adjourn	5:00 p.m.

The meeting will be held at Beaufort Hotel (2440 Lennoxville Road, Beaufort, North Carolina; 252.728.3000) and via webinar; click here for details

Atlantic States Marine Fisheries Commission

MEETING OVERVIEW

Shad and River Herring Management Board
October 16, 2023
4:15 – 5:00 p.m.
Hybrid Meeting

Chair: Lynn Fegley (MD) Assumed Chairmanship: 2/23	Technical Committee Chair: Wes Eakin (NY)	Law Enforcement Committee Representative: Thomas Burrell (PA)
Vice Chair: Phil Edwards (RI)	Advisory Panel Chair: Pam Lyons Gromen	Previous Board Meeting: August 1, 2023
Voting Members: ME, NH, MA, RI, CT, NY, NJ, PA, DE, MD, DC, PRFC, VA, NC, SC, GA, FL, NMFS, USFWS (19 votes)		

2. Board Consent

- Approval of Agenda
- Approval of Proceedings from August 1, 2023

3. Public Comment – At the beginning of the meeting public comment will be taken on items not on the agenda. Individuals that wish to speak at this time must sign-in at the beginning of the meeting. For agenda items that have already gone out for public hearing and/or have had a public comment period that has closed, the Board Chair may determine that additional public comment will not provide additional information. In this circumstance the Chair will not allow additional public comment on an issue. For agenda items that the public has not had a chance to provide input, the Board Chair may allow limited opportunity for comment. The Board Chair has the discretion to limit the number of speakers and/or the length of each comment.

4. Progress Update on the 2024 River Herring Benchmark Stock Assessment (4:30-4:45 p.m.)
Background • The river herring benchmark stock assessment was initiated in April 2022. The assessment workshop was conducted in August 2023.
Presentations • Update on River Herring Stock Assessment Progress by K. Drew

5. Consider Fishery Management Plan Review and State Compliance for the 2022 Fishing Year (4:45-5:00 p.m.) Action
Background • State Compliance Reports were due on July 1, 2022. • The Plan Review Team reviewed each state report and compiled the annual FMP Review (**Supplemental Materials**).

Presentations
• Overview of the FMP Review Report by J. Boyle
Board Actions for Consideration
• Approve FMP Review for 2022 fishing year, state compliance reports, and *de minimis* requests

6. Other Business/Adjourn

Shad and River Herring 2023 TC Tasks

Activity level: Medium

Committee Overlap Score: Medium (Multi-species committees for this Board)

Committee Task List
• 2024 River Herring Benchmark Stock Assessment • Updates to state Shad SFMPs • Annual state compliance reports due July 1
TC Members: Mike Brown (ME), Conor O'Donnell (NH), Brad Chase (MA), Patrick McGee (RI), Kevin Job (CT), Wes Eakin (Chair, NY), Brian Neilan (NJ), Brian Niewinski (PA), Johnny Moore (DE), Matthew Jargowsky (Vice-Chair, MD), Ingrid Braun (PRFC), Joseph Swann (DC), Patrick McGrath (VA), Holly White (NC), Jeremy McCargo (NC), Bill Post (SC), Jim Page (GA), Reid Hyle (FL), Ken Sprankle (MA), Ruth Hass-Castro (NOAA), John Ellis (USFWS). Ted Castro-Santos (USGS), C. Michael Bailey (USFWS)

DRAFT PROCEEDINGS OF THE

ATLANTIC STATES MARINE FISHERIES COMMISSION

SHAD AND RIVER HERRING MANAGEMENT BOARD

The Westin Crystal City
Arlington, Virginia
Hybrid Meeting

August 1, 2023

These minutes are draft and subject to approval by the Shad and River Herring Management Board.
The Board will review the minutes during its next meeting.

TABLE OF CONTENTS

INDEX OF MOTIONS

1. **Approval of Agenda** by consent (Page 1).

2. **Approval of Proceedings of February 2, 2023** by consent (Page 1).

3. **Move to move to approve the Shad Sustainable Fishery Management Plan for Potomac River Fisheries Commission, as presented today** (Page 3). Motion by Justin Davis; second by Malcolm Rhodes. Motion approved by consent (Page 3).

4. **Move to adjourn** by consent (Page 7).

ATTENDANCE

Board Members

Pat Keliher, ME (AA)
Rep. Allison Hepler, ME (LA)
Cheri Patterson, NH (AA)
Doug Grout, NH (GA)
Dennis Abbott, NH, proxy for Sen. Watters (LA)
Mike Armstrong, MA, proxy for D. McKiernan (AA)
Raymond Kane, MA (GA)
Sarah Ferrara, MA, proxy for Rep. Peake (LA)
Phil Edwards, RI, proxy for J. McNamee (AA)
Eric Reid, RI, proxy for Sen. Sosnowski (LA)
Justin Davis, CT (AA)
Bill Hyatt, CT (GA)
Craig Miner, CT, proxy for Rep. Gresko (LA)
John Maniscalco, NY, proxy for B. Seggos (AA)
Emerson Hasbrouck, NY (GA)
Heather Corbett, NJ, proxy for J. Cimino (AA)
Jeff Kaelin, NJ (GA)
Adam Nowalsky, NJ, proxy for Sen. Gopal (LA)
Tim Schaeffer, PA (AA)
Loren Lustig, PA (GA)
John Clark, DE (AA)
Roy Miller, DE (GA)
Lynn Fegley, MD (AA, Acting)
Allison Colden, MD, proxy for Del. Stein (LA)
Pat Geer, VA, proxy for J. Green (AA)
Chris Batsavage, NC, proxy for K. Rawls (AA)
Chad Thomas, NC, proxy for Rep. Wray (LA)
Ross Self, SC, proxy for M. Bell (AA)
Malcolm Rhodes, SC (GA)
Ben Dyar, SC, proxy for Sen. Cromer (LA)
Doug Haymans, GA (AA)
Spud Woodward, GA (GA)
Erika Burgess FL, proxy for J. McCawley (AA)
Gary Jennings, FL (GA)
Marty Gary, PRFC
Dan Ryan, DC, proxy for R. Cloyd
Rick Jacobson, USFWS
Max Appelman, NOAA

(AA = Administrative Appointee; GA = Governor Appointee; LA = Legislative Appointee)

Ex-Officio Members

Wes Eakin, Technical Committee Chair

Staff

Bob Beal
Toni Kerns
Madeline Musante
Tina Berger
Katie Drew
Alex DiJohnson
James Boyle
Chris Jacobs
Jeff Kipp
Jainita Patel
Tracey Bauer
Kurt Blanchard
Pat Campfield

Guests

Aaron Kornblult
Robert LaFrance
Debra Abercrombie, USFWS
Katie Almeida
Ashley Asci, NOAA GARFO
Pat Augustine
Meredith Bartron
Jessica Best, NYSDEC
Alan Bianchi, NC DMF
Emily Bodell
Rob Bourdon, NOAA
Jeffrey Brust, NJ DFW
Danielle Carty, SC DNR
Nicole Caudell, SC DNR
Mell Bell, SC (AA)
Benson Chiles, Chiles Consulting
Joe Cimino, NJ (AA)
Haley Clinton
Margaret Conroy, DNREC
Caitlin Craig, NYSDEC
Wes Eakin
Sheila Eyler, USFWS
Emily Farr
Ryan Franckowiak, Cornell
Alexa Galvan, VMRC
Stephen Gephard
Lewis Gillingham, VMRC

These minutes are draft and subject to approval by the Shad and River Herring Management Board.
The Board will review the minutes during its next meeting.

Melanie Griffin
Brendan Harrison
Kyle Hoffman, SCDNR
Yan Jiao, Virginia Tech
Blaik Keppler, SC DNR
Kris Kuhn, PA PFBC
William Lucey, Save the Sound
Pam Lyons Gromen
Jerry Mannen Jr.
Todd Mathes, NC DMF
Genine McClair
Steve Meyers
Steve Minkkinen, USFWS
Chris Moore, CBF
Brian Neilan, NJ DEP
Thomas Newman
Miluska Olivera-Hyde, USGS
Ian Park, DE DFW
Nicole Pitts
Bill Post, SC DNR
Will Poston, ASGA
Jill Ramsey, VMRC
Kathy Rawls, NC (AA)
Kirby Rootes-Murdy, USGS
David Seigerman
McLean Seward, NCDMF
Somers Smott, VMRC
Renee St. Amand
Doug Nemety, USFWS
Michael Stangl, DE F&W
Elizabeth Streifeneder, NYSDEC
Kevin Sullivan
John Sweka, USFWS
Erik Zlokovitz, MD DNR
Renee Zobel
Steve Doctor, MD DNR

The Shad and River Herring Management Board of the Atlantic States Marine Fisheries Commission convened in the Jefferson Ballroom of the Westin Crystal City Hotel, Arlington, Virginia, a hybrid meeting, in-person and webinar; Tuesday, August 1, 2023, and was called to order at 9:00 a.m. by Chair Lynn Fegley.

CALL TO ORDER

CHAIR LYNN FEGLEY: Welcome to the meeting of Shad and River Herring. We have a fairly quick agenda today, with just one action item. Before we go to the agenda though, I did want to make an announcement that we do have a new Legislative Appointee from Connecticut. I wanted to offer Justin Davis the chance to introduce him, since everybody is here for this meeting.

DR. JUSTIN DAVIS: Thank you, Madam Chair. Yes, we have a new member of the Connecticut delegation, Representative Joe Gresko; he is sitting over there. Joe is the representative in our Connecticut House from the 121st District, which is a coastal district down in southwestern Connecticut. Joe has also served as the Chair of the Environment Committee in the Connecticut General Assembly.

That's the Committee that has cognizance of all those matters relating to our Connecticut Department of Energy and Environmental Protection. I had a chance to work with Joe in the past, mostly it's me sitting on Zoom meetings, telling Joe why we can't do something his constituents want, because of this group called the Atlantic States Marine Fisheries Commission gets to make the rules.

Happy to have Joe here around the table with us. I also want to acknowledge that there is a familiar face sitting here at the table with Connecticut. It is my understanding Joe has appointed Craig Miner as his ongoing proxy, so Craig will also still be with us here on the Connecticut delegation.

CHAIR FEGLEY: Great, thank you, Justin and welcome, Joe. Buckle up. Let's get started, the first thing, well I just want to introduce as always, James Boyle is here, Dr. Drew and Kirby Rootes-Murdy here to my left who just couldn't stay away, is now from USGS.

APPROVAL OF AGENDA

CHAIR FEGLEY: First order of business is Approval of the Agenda. Is there anyone who would like to change or modify the agenda in any way? Okay, seeing none; we're going to consider that approved by consent.

APPROVAL OF PROCEEDINGS

CHAIR FEGLEY: Does anybody have any edits, changes or modifications to the minutes from the last meeting? Okay, seeing none; we're going to consider that approved by consent.

PUBLIC COMMENT

CHAIR FEGLEY: Next stop on the agenda is public comment. Does anybody have public comment for the Shad and River Herring Management Board? Anybody on line, Toni? Okay, we're going to consider no public comment.

CONSIDER UPDATE TO POTOMAC RIVER FISHERIES COMMISSION AMERICAN SHAD SUSTAINABLE FISHERY MANAGEMENT PLAN

CHAIR FEGLEY: Coming up is this is our only action item for the meeting, and we are going to Consider an Update to the Potomac River Fisheries Commission American Shad Sustainable Fishery Management Plan. I believe Wes Eakin is on virtually from New York. Wes Eakin, take it away.

MR. WES EAKIN: Good morning, everyone. For those of you that are unfamiliar, I'm Wes Eakin. I'm the TC representative from New York, and recently became Chair of the Shad and River Herring TC. I would just like to take a second to thank Brian Newman from New Jersey, the previous Chair, for his leadership over the past two plus years.

I'm looking forward to continuing working with Brian and the rest of the TC members. Yes, jumping in for your consideration today, the Potomac River Fisheries Commission American Shad SFMP Update. Just a little background as a refresher on what is required of the SFMPs and FMP definition of sustainability.

Amendments 2 and 3 of the Shad and River Herring FMP requires states wishing to have a fishery submit a sustainable fisheries management plan that will demonstrate their stock could support a commercial and/or recreational fishery that will not diminish the future stock reproduction and recruitment.

The plans are updated and reviewed by the TC every five years, to reassess stock status and sustainability. Back in May the TC met, and reevaluated the PRFC SFMP update. The TC recommended approval of the plan as it was presented, with the recommendation of exploring additional sustainability metrics in future plans.

The PRFC is requesting continuation of their limited commercial bycatch allowance in the portion of the Potomac under the PRFC jurisdiction. As I mentioned, shad are encountered as bycatch in both the pound and gillnet fisheries that are cooperatively managed by the states of Maryland and Virginia.

This plan remains unchanged from the previous Board approved plan back in 2017. The management measures, the seasons for the pound net fishery is February 15 to December 15, and the gillnet is from November 7 to March 25. There is a two-bushel limit per day per licensee, and there is mandatory daily reporting that includes discards, as well as live releases.

This year is essentially the mechanics of the plan. The SFMP has a river-specific management unit, the Potomac River from Washington D.C to the Chesapeake Bay. The sustainability measure this is timeseries geometric mean CPUE of pound net landings. The catch plus discards. The sustainability target is a fishery dependent target, and there was a restoration target that was set in the 2007 stock assessment, which is 31.1 pounds per net-day.

The management action threshold would be three consecutive years with a geometric mean CPUE below the restoration target, and some potential management actions would be the reduction or elimination of the two-bushel bycatch allowance and/or limiting or restricting the take of broodstock egg collections by other agencies. The PRFC currently allows some take of broodstock for hatchery propagation. To wrap things up, this graph here just shows the American shad pound net indices. The blue line there indicates the restoration target, and the more recent time series here in green shows the CPUE of bycatch and the discards in the pound net fishery. They have been above their restoration target since 2011. That is about it for this update. I will gladly take any questions from the Board.

CHAIR FEGLEY: Thank you, Wes, any questions for Wes on this report? Dr. Rhodes.

DR. MALCOLM RHODES: I believe this was the correction, but they're talking about the stocking program and the amount of viable eggs, you know as around 30 percent that they would get. Is that about normal for a stocking program, or a little higher or lower? I just didn't know the answer, but I was kind of surprised by that.

MR. EAKIN: Yes, I am not sure. I am not that familiar with stocking hatchery operations. We don't operate any in New York. I defer to maybe any other Board members that have better understanding of hatchery production.

CHAIR FEGLEY: Marty Gary, do you want to address that?

MR. MARTIN GARY: Thanks, Madam Chair, I'll try. Malcolm, I'm not 100 percent sure. What we've been doing is working cooperatively with groups that have been coming down over the years to collect broodstock. U.S. Fish and Wildlife Service, Virginia Wildlife Resources, D.C Fisheries, some NGOs, and asking for some of those fish to be stretch spawned and put back.

In terms of quantifying, I'm not 100 percent sure on the contribution, and it varies from year to year quite a bit as to how many of those groups participate. They are all collecting those broodstock around Mount Vernon, that part of the river. But we have had consistency, I think with Fish and Wildlife Service in Virginia, a lot of those fish going to the Van Dyke Hatchery up in Pennsylvania. Probably not as detailed an answer as you were seeking.

CHAIR FEGLEY: Thank you, Marty, any other questions on the sustainable management plan from Potomac River? Marty.

MR. GARY: Just for a little more context for the Board. The Potomac River Fisheries Commission implemented a moratorium in 1982. Simultaneously, we initiated this bycatch program, so it's been in place for over four decades. This is working with, specifically our pound net and gillnet fisheries in the spring.

About 95 percent of the bycatch is captured in the pound net fishery, which starts a little bit later, like April into May. That catch in recent years, to give you an idea, was about a little less than 8,000 pounds for both roe and buck shad. The number of participants varies, but it's a low level of participants.

Over the last five years the average was 22. That gives you a little bit more detail on how that bycatch fishery is operating. The tools that we're working with, with the TC, to develop and integrate. We're looking at both the Maryland JAI on the Potomac River, and also the Maryland DNR Gillnet Striped Bass Spawning Survey, which captures shad when they are out in April and May, working that survey. The idea would be to integrate that into the plan and use those as potential trigger mechanisms for management responses. Hopefully, that adds a little bit of context to our SFMP.

MS. FEGLEY: Yes, thank you for that, Marty. Any other questions on this report? If not, I'm going to be looking for a motion to approve. Justin Davis.

DR. DAVIS: I'll wait and see if staff has a motion prepared.

MS. FEGLEY: Does staff have a motion prepared? Okay, we have a motion on the board, **move to approve the Shad Sustainable Fishery Management Plan for Potomac River Fisheries Commission, as presented today.** By Dr. Davis, do I have a second? Malcolm Rhodes. **Is there any discussion on this motion?**

All right, is there any opposition to the motion? Okay, great, motion carries by consent. I guess I'll read it into the record one more time. Move to approve the Shad Sustainable Fishery Management Plan from Potomac River Fisheries Commission, as presented today. Great.

UPDATE ON US GEOLOGICAL SURVEY ALOSINE GENETIC REPOSITORY AND EXPANDING COLLECTION EFFORTS

CHAIR FEGLEY: The next agenda item, we're going to talk about the U.S. Geological Survey alosine genetic repository. We've had some conversations about this, over past meetings. Kirby, looking forward to the update.

MR. KIRBY ROOTES-MURDY: It's nice to look around this morning and see a lot of familiar faces. As mentioned, I work for the U.S. Geological Surveys Eastern Ecological Science Center, and today I'm here to provide a short overview of the alosine genetic tissue repository that has been shepherd by the Eastern Ecological Science Center over the last few years.

To start, as many of you are aware, the efforts to restore American shad and river herring populations are presented with multiple challenges across the coast, from habitat fragmentation to water quality challenges, to climate change. In particular, the bycatch of alosines and marine and estuarine commercial fisheries presents challenges to recovering spawning populations.

Extinguishing stock composition can support efforts to better assess the status in the trends of specific populations. Today I'll provide an overview of work that the USGS has led to support stock assessment efforts for all three of the alosine species managed by ASMFC. To start, just a little bit more about EESC.

We provide a unique role in housing and processing alosine tissue samples from across the Atlantic coast, for across political boundaries and species. We provide an important service, not only in storing these samples, but cataloguing them, conducting analyses to better understand the population dynamics of these species.

Specific to alosines, then objectives guiding our work is to really create a genomic marker, single nucleotide polymorphisms, or SNPs, to build and expand our information on American shad, blueback herring, and alewife. For river herring species in particular, we're working to characterize populations using SNP baselines augmented with additional samples. For American shad, we are centering our work on developing new SNP panels, which should provide greater resolution of the stock structure, greater repeatability, and also cost savings when compared against other techniques, such as microsatellite markers. What we've done so far is sent out collection samples across the coast from Canada down through Georgia. In these kits we've requested data, such as species, sampling location, GPS coordinates, as well as size class, so total length, fork-length information.

To highlight some of the work to date, I'm going to start off with American shad. Really, this is what we've received the most of our samples. We've collected approximately 2,280 fin samples. As you can see, we have a good distribution across the coast, all the way up through the Gulf of St. Lawrence, down through the Atlantic coast of Florida.

We've been provided these samples from a variety of state agencies, universities, as well as NGOs. To hopefully give you a little bit more resolution of understanding which river species in particular, you can see here for American shad we just have, I think, a very good collection across a lot of these important systems that you all are familiar with.

Now moving into more the river herring species, we have inherently less samples. But starting with alewife we've received about 981 fin clips. As you can see, the distribution of these fin clips we've collected really are centered a lot more in the northeast so far, in terms of what we've received, again, a mix of the variety of state, university and NGOs.

Last, on blueback herring. This is where we've received probably the least amount of samples, so about 218. You know, a greater distance across the coast of samples collected, but a smaller number of river systems. In doing some analysis on the American shad samples that we've collected, there has been an effort to do genotype paneling.

What you can see on the screen right now, really are, in going through and sequencing, you know individuals from 12 baseline populations and two mixed stock fisheries, one in the Bay of Fundy and one in the Delaware Bay. We've been able to identify 107 microhaplotypes. For American shad in particular, you can see we've got a good collection of samples that are registering a unique or distinct population marker for the Miramichi, which is up in Canada.

That is in orange in the top kind of right corner. Next the Annapolis West, which is in Nova Scotia, and then followed by the Santee-Cooper and the St. Johns River, so that is yellow for the Santee-Cooper and brown for the St. Johns River. Again, so these are showing us more of a distinct marker, in doing the analysis across where these samples have been collected.

I would say one of the really interesting findings so far, and keep in mind these are preliminary results, in terms of our analysis, is that in looking at these two in particular water bodies, where there has been mixed stock sampling. In the Bay of Fundy, what you can see is that fish that originate from the Miramichi River, which empties into the Gulf of St. Lawrence, are being picked up and found a distinct marker in the Bay of Fundy.

If you're familiar with some of the geography around there, that means they are going up and around. You would maybe expect to see more samples popping up from the Annapolis West River, which is emptying directly into the Bay of Fundy there. Moving over to the Delaware Bay, kind of a more traditional understanding of, you know you're seeing fish that are coming out of the Delaware Bay, but also those that are originating from the Hudson, as well as the Potomac. Again, these are preliminary analysis we've been able to do on American shad, in large part because of the volume of samples we've received, and you know the emphasis we've been directed to focus on for that species, given I believe, a former TOGS guidance.

In summary, a lot of this work with American shad samples have been done, in terms of the analysis, in coordination with Cornell University colleagues. On the river herring side of things, we are really looking for more fin clips that we could get from across the coast, to further pursue more analysis, and hopefully get a better ability to evaluate some of these mixed stock fisheries, and the origin of some of those fish that are being found in them. If you have samples, please send them to my colleague Miluska.

She was not able to be here today, but I wanted to highlight her as well as Dave Kazyak. Those are our two principal investigators at USGS EESC, who are spearheading this alosine genetic tissue repository work. Last slide, just if you are interested in learning more about this research, please, you can look at this QR code, take a picture of it. It will direct you directly to our website, and you can get some more detailed information. With that I will try to answer any questions you have to the best of my ability, so thanks.

CHAIR FEGLEY: That is fascinating. I opened that stuff and the telemetry array of work, I just find that completely fascinating, so thank you. John Clark.

MR. JOHN CLARK: I'm just curious on the shad, being that there have been stocking programs going on for a bunch of years, and some of them have been between watersheds. Is that affecting the genetic samples in any way?

MR. ROOTES-MURDY: I don't know. But I can ask my colleagues and we can see if we can get some more information on that.

CHAIR FEGLEY: John Maniscalco.

MR. JOHN MANISCALCO: If I could just answer that a little bit. A lot of the shad work was done by academics at Cornell University. Not that I can understand the real specifics, but the genetic techniques they are using are aimed at identifying recent changes. The reason why they went with this was specifically because, trying to disentangle stocking, and being able to identify stock from different river systems. Without having a definite, I would say yes. It can deal with the stocking issues.

CHAIR FEGLEY: Any other questions. Sir.

MR. RICK JACOBSON: Kirby that was a wonderful presentation, thank you. Is there a target number of samples per water body you are shooting for? I mean that might help inform how the members of the Commission can work with their staffs to assist you?

MR. ROOTES-MURDY: Thanks for the question, Rick. I don't know, it's a great question. Hopefully, I can get some more information on it. I will say that again, from what I'm aware of, we need to get more samples from across the coast. I think trying to time up when these kits are sent out.

Hopefully used for spring surveys, it might allow us to kind of get through a plethora hopefully of samples to pull from. This year timing wise we just didn't quite match up as well as I would hope. But I will ask my colleagues about a specific target number per river systems, unless ASMFC staff have any suggestions, no, all right.

CHAIR FEGLEY: Okay, any other questions? Mr. Lustig, sorry.

MR. LOREN W. LUSTIG: Thank you, Kirby, for that interesting report. A number of years ago I personally did a lot of fishing down below the Conowingo Dam on the Susquehanna River, and I've always wondered about the status of the hickory shad, which precedes in migration the American shad. You mentioned the congenital work on river herring. Is there any work anticipated on the status of the hickory shad?

MR. ROOTES-MURDY: Thanks for the question, Loren. I am not aware of any specific work on hickory shad. Again, my understanding is former TOG kind of help direct where some of the efforts have been between these three species. I'm not sure if they have discussed hickory shad as one to further evaluate.

CHAIR FEGLEY: Okay, Justin Davis, I see you. I'm going to go to Wes quickly online, because I think he's got some commentary to add.

MR. EAKIN: Yes, thank you. I was just going to provide some information on the sample size and what was being requested. At our last TC meeting we discussed this topic, and I think the request was 50, ideally, a minimum of 30 USGS staff had offered to provide those kits, and it was well received by TC members, as far as collecting those samples.

There was also a request to get either multiple year's, to try to get that stability of the genetic signals, and then effort to collect more mixed stock samples, where those might be available. One such place was a fishery in Virginia, I believe had encountered a lot of American shad bycatch last year. There is going to be an effort this coming spring to work with the fishers from that fishery that collect some samples there.

CHAIR FEGLEY: Thanks, Wes, and Kirby has a follow up to that.

MR. ROOTES-MURDY: Yes, thank you, Wes, for that insight. I will note if you go back to Slide 4. In terms of these kits, we've sent out, they have 50 vials, so sending up to 50 samples with each of these kits would be great, if you can get up to that.

CHAIR FEGLEY: I think I'm going to go to the AP Chair also online, Pam, and then I'll go back to you.

MS. PAM LYONS GROMEN: Thank you, Kirby, for this presentation. It's a very interesting project, and one I've been trying to stay up to speed on. I was looking at where you've requested samples, and I'm wondering, have you requested samples from the Northeast Fisheries Observer Program for the bycatch that occurs at sea in the federal fisheries? I didn't see it listed.

MR. ROOTES-MURDY: Yes, thanks for the question. I believe we have received some samples, and they have gone into some of the analysis. I shouldn't have omitted that from the presentation, but yes, we've been getting some samples from them as well.

CHAIR FEGLEY: Dr. Davis.

DR. DAVIS: Thank you, Madam Chair, and Pam kind of got to what I was going to ask, is to what degree is USGS planning on participating in any efforts to sort of better characterize the genetic composition of bycatch occurring in the offshore commercial fisheries.

MR. ROOTES-MURDY: I would say it's an area of interest of ours. We, like so many projects that we're somewhat limited, just frankly based on funding. If we can find the ability to allocate and pursue more funding around that, we will absolutely be able to, and be interested in doing that kind of work, but that is the prohibiting factor right now.

CHAIR FEGLEY: Any other, oh and I'm going to turn back to you, Wes Eakin.

MR. EAKIN: I was just going to add to that, to the bycatch question. That is the impetus of the work with Cornell University, specifically with American shad. That is the goal there is to quantify the species or the stock composition of that bycatch. One of the challenges that we've been encountering, getting the mixed stock samples from the federal fisheries.

It is that there is such low observer coverage in some of the high-volume fisheries, the herring and the mackerel fisheries. There has been a little bit of a hurdle for us. We do have samples in hand, I don't know the total amount to date. We just got some samples last week, I do believe. That is an effort, but there is a little bit of a hurdle there, with low observer coverage.

CHAIR FEGLEY: I guess I have one question about that. Do the samples need to be taken by observers, or would industry cooperate to provide samples on their own?

MR. EAKIN: That is a good question. We haven't explored that option, but that is something that we would definitely pursue, if we feel that that is a viable option.

CHAIR FEGLEY: Yes, it seems like that might be worth an ask. Pat Keliher.

MR. PATRICK C. KELIHER: Kirby, the sampling kits are $65.00. The state of Maine could certainly provide samples for at least 18 distinct runs for river herring, blueback herring, as well as expand some of your shad work in a few of the smaller rivers. We should talk about that. Just for the record, so our Canadian friends are not upset, it's Miramichi. Just to put you on the spot.

CHAIR EAKIN: Thank you, Commissioner Keliher.

CHAIR FEGLEY: I'm glad we got that straight. Any other questions on this topic? Is there anybody online?

PROGRESS UPDATE ON THE 2024 RIVER HERRING BENCHMARK STOCK ASSESSMENT

CHAIR FEGLEY: Okay, last up, we're going to Dr. Katie Drew to get a progress update on the 2024 River Herring Benchmark Assessment. Take it away, Katie.

DR. KATIE DREW: I'll keep this brief. This was brought to the Policy Board at our last meeting, because the Shad and River Herring Board did not meet, but I am informing you all again, in case there was not enough overlap, that the assessment has been delayed by one meeting cycle.

Our original goal was to have this peer reviewed essentially now, and presented at our annual meeting. We will be aiming now to have this peer reviewed in late November, early December, to present at the winter meeting of next year. We just needed some additional time to continue work on this assessment.

We'll be having our assessment workshop in person, actually in this very hotel, the week of August 21, to kind of hopefully step back and reevaluate our progress on the assessment work itself, and hopefully be able to start transitioning into finalizing those analyses, and writing this up, in order to meet our current peer review goal. That is just an update on the schedule, and what is happening next. I'm happy to take any questions about the assessment.

CHAIR FEGLEY: Great, thank you, any questions for Dr. Drew? Okay, seeing none; thank you, Katie.

ADJOURNMENT

CHAIR FEGLEY: Our final agenda item is Other Business. Does anybody have anything else to bring before the Board? With that I will submit a Chair motion to adjourn, and if anybody objects, please say so now. Otherwise, we're adjourned.

(Whereupon the meeting adjourned at 9:30 a.m. on Tuesday, August 1, 2023)