Atlantic States Marine Fisheries Commission

Sciaenids Management Board

November 9, 2026
3:15 – 5:15 p.m.

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 *(B. Dyar)*	3:15 p.m.
2.	Board Consent • Approval of Agenda • Approval of Proceedings from May 2026	3:15 p.m.
3.	Public Comment	3:20 p.m.
4.	Consider 2026 Atlantic Croaker Benchmark Assessment **Action** • Presentation of Stock Assessment Report (*C. Schlick*) • Presentation of Peer Review Panel Report (*D. Chagaris*) • Consider Acceptance of Benchmark Stock Assessment and Peer Review Report for Management Use	3:30 p.m.
5.	Consider Management Response to 2026 Atlantic Croaker Benchmark Assessment, if necessary **Possible Action** • Technical Committee Report on Addressing Marine Recreational Information Program Fishing Effort Survey Calibrations and Projection Guidance (*C. Schlick)*	4:15 p.m.
6.	Consider Black Drum Indicators Update (*H. Rickabaugh*) **Possible Action**	4:40 p.m.
7.	Consider Timing of Future Red Drum Traffic Light Analysis Updates (*J. Kipp*)	4:55 p.m.
8.	Progress Update on 2028 Spot Benchmark Stock Assessment (*J. Kipp)*	5:05 p.m.
9.	Elect Vice-Chair **Action**	5:10 p.m.
10.	Other Business/Adjourn	5:15 p.m.

The meeting will be held at Hotel Viking (One Bellevue Avenue, Newport, RI; 401.847.3300) and via webinar; click here for details.

Sustainable and Cooperative Management of Atlantic Coastal Fisheries

MEETING OVERVIEW

Sciaenids Management Board
November 9, 2026
3:15 – 5:15 p.m.

Chair: Ben Dyar (SC) Assumed Chairmanship: 02/26	Technical Committee Chairs: Black Drum: Harry Rickabaugh (MD) Atlantic Croaker: Margaret Finch (SC) Red Drum: Cara Kowalcyk (NC) Spot: Harry Rickabaugh (MD)	Law Enforcement Committee Representative: Col. Matthew Rogers (VA)
Vice Chair: Vacant	Advisory Panel Chair: Craig Freeman (VA)	Previous Board Meeting: May 6, 2026
Voting Members: NJ, DE, MD, PRFC, VA, NC, SC, GA, FL (9 votes)		

2. Board Consent

- Approval of Agenda
- Approval of Proceedings from May 2026

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 2026 Atlantic Croaker Benchmark Assessment (3:30-4:15 p.m.) Action

Background

- The 2026 Atlantic Croaker Benchmark Assessment evaluated the status of two Atlantic croaker stocks along the U.S. Atlantic coast, divided near Cape Lookout, North Carolina (**Briefing Materials**).
- The 2026 Atlantic Croaker benchmark assessment was peer-reviewed by a panel of independent experts in July 2026. The Peer Review Report provides the panel's evaluation of the assessments' findings (**Briefing Materials**).

Presentations

- Presentation of Stock Assessment Report by C. Schlick
- Presentation of Peer Review Panel Report by D. Chagaris

Board actions for consideration at this meeting

- Consider acceptance of benchmark stock assessment and peer review report for management use

5. Consider Management Response to 2026 Atlantic Croaker Benchmark Assessment, if necessary (4:15-4:40 p.m.) Possible Action

Background

- Following the presentation of the stock assessment, the Board may consider management responses based on the assessment results.
- The Atlantic Croaker Technical Committee (TC) met on October 1 via webinar to discuss next steps to the 2026 Atlantic Croaker Benchmark Stock Assessment results, including how to address the results of the recent Marine Recreational Information Program (MRIP) Fishing Effort Survey calibration process and specifications for projections to advise a response to the assessment. A memo was prepared with TC recommendations and requests for Board guidance for these next steps (**Briefing Materials**).

Presentations

- Technical Committee Report on Addressing MRIP Calibrations and Projection Guidance by C. Schlick

Board actions for consideration at this meeting

- Consider tasking the Atlantic Croaker TC with completing projections

6. Consider Black Drum Indicators Update (4:40-4:55 p.m.)

Background

- Empirical stock indicators were developed as part of the 2023 black drum benchmark stock assessment and were recommended to be monitored between stock assessments to detect any concerning trends in the black drum stock. The stock indicators were last updated in 2024, incorporating data through 2023.
- The Black Drum Technical Committee (TC) met on October 13, 2026 to review the results of a data update to the indicators, which incorporated data through 2025 and the newly calibrated Marine Recreation Information Program data, and make recommendations (**Briefing Materials**).
- Ultimately, the TC did not observe any concerning trends from the indicators relative to coastwide stock status, and so does not recommend any changes to the current assessment schedule of an assessment update to be completed in 2028. The TC recommends not delaying the next assessment beyond 2028 so that assessment results can be updated according to the new, lower magnitude of catch estimated for recreational fisheries.

Presentations

- Technical Committee Report by H. Rickabaugh

Board actions for consideration at this meeting

- Consider changes to the black drum stock assessment schedule

7. Provide Guidance on Timing of Red Drum Traffic Light Analysis Updates (4:55-5:05 p.m.)

Background

- A traffic light analysis (TLA) was developed for both red drum stocks during the 2024 benchmark assessment, originally intended as a tool to informally assess stock status between assessments. However, a robust, technically-sound SS model could only be developed for the southern stock, so the northern stock was assessed using the TLA. The

Red Drum Stock Assessment Subcommittee (SAS) recommended updating the TLA every two years between stock assessments.

- A motion was made by the Board at their 2025 spring meeting to adjust the timing of the next stock assessment for red drum to have a terminal year of 2031.
- The Red Drum Technical Committee (TC) and SAS met in June 2025 in part to discuss a question from the Red Drum Plan Development Team on the schedule for future TLA updates. The TC and SAS recommended continuing with TLA updates between stock assessments, but this recommendation was not presented to the Board.
- Staff are requesting direction on the timing of future updates to the red drum TLA, including whether the TLA would be updated for both stocks, or only the northern stock.

Presentations

- Stock assessment update by J. Kipp

8. Progress Update on the 2028 Spot Benchmark Stock Assessment (5:05-5:10 p.m.)

Background

- The newly formed Spot Stock Assessment Subcommittee (SAS) met via webinar on August 31 and September 3, 2026 to start work on the 2028 spot benchmark stock assessment. The Spot SAS met again on October 30, 2026 to review and make a recommendation for how to proceed in this assessment with stock structure.
- A Data and Methods Workshop is planned for January 2027.

Presentations

- Progress update by J. Kipp

9. Elect Vice-Chair (5:10-5:15 p.m.) Action

10. Other Business/Adjourn

DRAFT PROCEEDINGS OF THE

ATLANTIC STATES MARINE FISHERIES COMMISSION

SCIAENIDS MANAGEMENT BOARD

The Westin Crystal City
Arlington, Virginia
Hybrid Meeting

May 6, 2026

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

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

2. **Approval of Proceedings of October 2025** by consent (Page 1).

3. **Move to approve South Carolina and Georgia's range of options in their respective red drum management proposals to implement Addendum II** (Page 3). Motion by Spud Woodward; second by Malcolm Rhodes. Motion passes by unanimous consent (Page 3).

4. **Move to approve North Carolina's conservation equivalency proposal for its spot commercial season** (Page 5). Motion by Chris Batsavage; second by Ethan Simpson. Motion passes by unanimous consent (Page 6).

5. **Move to adjourn** by consent (Page 20).

ATTENDANCE

Board Members

Joe Cimino, NJ (AA)
Adam Nowalksy, NJ, proxy for Sen. Gopal (LA)
Richard Wong, DE, proxy for J. Clark (AA)
Roy Miller, DE (GA)
Carrie Kennedy, MD, proxy for K. Charbonneau (AA)
Russell Dize, MD (GA)
David Sikorski, MD, proxy for Del. Stein (LA)
Ethan Simpson, VA, proxy for J. Grist (Acting AA)
Chris Batsavage, NC, proxy for K. Rawls (AA)
Ben Dyar, SC, proxy for K. Keppler (AA)
Malcolm Rhodes, SC (GA)
Chris McDonough, 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)
Ron Owens, PRFC

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

Ex-Officio Members

Staff

Bob Beal
Toni Kerns
Tina Berger
Madeline Musante
Caitlin Starks
Tracey Bauer
James Boyle
Chelsea Tuohy
Katie Drew
Jeff Kipp
Samara Nehemiah
Jainita Patel

The Sciaenids 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, May 6, 2026, and was called to order at 9:15 a.m. by Chair Ben Dyar.

CALL TO ORDER

CHAIR BEN DYAR: Good morning; we'll start the Call to Order. All right, I guess we'll get started. My name is Ben Dyar; I am the Administrative Proxy for South Carolina. We have Ms. Bauer here, the fisheries Coordinator. We also have giving presentations is C.J. Schlick and Pat Campfield. I believe we have some folks online as well.

MS. TRACEY BAUER: Yes, for Commissioners online it is Adam Nowalsky and Dave Sikorski.

APPROVAL OF AGENDA

CHAIR DYAR: A lot of stuff to do today, see if we can get through it. We have the morning. Any amendments or changes to the agenda?

MR. CHRIS BATSAVAGE: If there is time, this should be short, during Other Business I just wanted to give the Board a quick update on the latest spot and sea trout cold stun event in North Carolina.

APPROVAL OF PROCEEDINGS

CHAIR DYAR: Great, thanks, Chris. Noted. Any changes to the proceedings from October of 2025? Not seeing that's consent.

PUBLIC COMMENT

CHAIR DYAR: Moving on to public comment. Does anyone in the room or online have any public comments that are not on the agenda today? Seeing none online. Erika Burgess.

MS. ERIKA BURGESS: Sorry, I was filling my coffee and missed the opportunity. Could I also be added on the agenda, just an update for sea trout regulation changes in Florida?

MR. DYAR: Yes, we'll note that. Moving along.

CONSIDER GEORGIA AND SOUTH CAROLINA RED DRUM MANAGEMENT PROPOSALS TO IMPLEMENT ADDENDUM II

MR. DYAR: First on the agenda item we have Consider Georgia and South Carolina Red Drum Management Proposals to Implement Addendum II. This is going to be a final action, and we'll have review of the proposals by Tracey Bauer.

MS. BAUER: For this agenda item I will briefly go over some background information before we lead into a high-level summary of South Carolina and Georgia's proposals, including the potential estimated stockwide minimum and maximum reductions, depending on which options are chosen. The Board action for consideration today is approval of the range of options in South Carolina and Georgia's proposals. First, I wanted to start off with a reminder of red drum Addendum IIs implementation timeline, which was set when the Board approved Addendum II this past October. Following today's consideration of approval of the proposals that Georgia and South Carolina have submitted, Georgia and South Carolina will need to choose one option to implement by September 1, 2026.

REVIEW PROPOSALS

MS. BAUER: Within Addendum II itself, the guidelines provided for these proposals, in short, the management measures in both southern stock proposals should aim to achieve the threshold and end overfishing at 30% SPR. Then the ultimate target is decreasing fishing mortality, such that it is less than the fishing mortality associated with 40% SPR under terminal year fishery selectivity patterns.

Ultimately what that equals to is a 14.4% reduction is needed to meet that, to achieve the threshold and end overfishing. Starting off here with South Carolina's proposal. I'm going to go first through

the methodology in that proposal and then move into what options are in the proposal itself.

To estimate the reduction achieved by changes to the red drum regulations, South Carolina used the approved methodology that was developed by the Technical Committee and SAS, and presented to the Board last May. In addition to that, South Carolina used a supplementary analysis to that analysis that was presented to the Board last May, where they wanted to look at estimating the impact of an increased maximum size limit on catch, because they wanted to explore adjustments to their slot.

To evaluate increasing that upper slot limit above 23 inches total length, South Carolina estimated the reduction achieved from lowering the slot limit to 22 inches or 21 inches total length, and then subtracted those amounts when modeling increases to 24 inches or 25 inches total length.

South Carolina's options are, there are six options in total that they are putting forward, with estimated percent reductions in catch ranging from 25.6 to 28.86%. All options increase the minimum size limit to between 17 and 19 inches, and all options but one increase the maximum size limit to 25 inches. Three of the options decrease the bag limit to 1 fish and a majority of the options decrease the vessel limit from 6 to 2 or 4 fish.

Moving right along to Georgia's proposal, and we can always go back to any of the options if anyone wants to look at them again. Similarly, Georgia's methodology used that analysis to estimate catch reductions that the TC developed earlier last year. Then they also developed their own supplementary methodology to also look at estimating the impact of an increased maximum size limit on catch.

Georgia was able to gauge changes in catch by comparing the proportions of red drum in each of the size bins from the most recent five-year period, with a current slot to data from a five-year period when the upper slot of the slot limit was higher. The TC when reviewing both of these proposals from South Carolina and Georgia, did you notice they do two different ways to accomplish the same thing. The TC have noted that it would be difficult for South Carolina to use historical data like Georgia has for their supplementary analysis, since South Carolina had changed both of their minimum and maximum sizes in 2007. In contrast, Georgia previously only increased their maximum size. Again, two analysis that are accomplishing the same thing, and the TC recommended both. For Georgia's options, Georgia has five main options in the proposal. But also, all consider the addition of a vessel limit in conjunctions with those five main options.

Estimated percent reductions range from 22.5% to 36.5% if we're just focusing on the five main options. Bag limits are between 2 fish and 4 fish that are under consideration, and minimum size limits between 14 and 16 inches. Total length is under consideration as well. In addition, the maximum size limits that they're looking at in the options are between 23- and 25-inches total length.

Moving on to the estimated stock-wide reduction achieved, obviously I can't calculate the estimated reductions used by all the different combinations of the options, so I went with the options that provided the smallest reduction and the options that provided the largest reduction to look at the minimum and maximum reductions that could be achieved by everything that team put forward here, to give you that range of what's the lowest possible and the highest possible.

The lowest possible reduction achieved is 19.6 %, and this is using with Florida there that is the regulations that were put into place in 2022 being accounted for, for their reduction. Here is the maximum reduction achieved that is possible. The reduction range is between 19.6% and 24.2%

reduction possible, based on the options that South Carolina and Georgia have put forward.

This means that both proposals meet the reduction in catch needed to achieve the 30%SPR threshold that 14.4% reduction. Finally, I just threw this in here. This is looking at, in South Carolina's proposal they said that they were putting forward, at least the legislature was considering Option 3.

With Option 3 and Georgia's lowest possible reduction, the option that achieves the lowest possible reduction, that is at 20.7%. That is all of the information from the proposals, other than implementation timelines in a proposal, which both said they would be able to implement by that goal of September 1st.

CONSIDER FINAL APPROVAL OF MANAGEMENT PROPOSALS

MS. BAUER: With that, the Board action for consideration today is considering approval of the range of options in both proposals, and I would be happy to take any questions.

CHAIR DYAR: Any questions? Seeing no questions, do we want to make a motion? Let's see if we can do this actually with consent. Does anybody object? We need to make a motion first. We have a draft motion. Spud.

MR. SPUD WOODWARD: I **move to approve South Carolina and Georgia's range of options in their respective red drum management proposals to implement Addendum II.**

CHAIR DYAR: I have Malcolm as a second. Spud, would you like to speak to the motion?

MR. WOODWARD: I don't think I can add a whole lot, other than a lot has gone into this, and I think we're moving the ball down the field the way we need to proportionately. I think this is a responsible response to what we've seen in the assessment, so I'm certainly satisfied that we're doing what we need to do to address the red drum situation.

CHAIR DYAR: Thank you, Malcolm.

DR. MALCOLM RHODES: Yes, I second it. When we had the public sessions we had huge widespread support for this option, which was the most stringent option it has, and the Chairman can talk about this more. But it has passed the Senate, we're legislatively mandated so it is passed the Senate.

It passed the House, but they added a deer regulation on top of the red drum, so now it has scheduled a joint session to get ironed out to be passed, to be made law. We should be done by September, but I'm just throwing out the fact that we're dealing with legislature and this has been passed by both with a plus by the House. We're working on it.

CHAIR DYAR: Thanks, Malcolm, it did go through the House Committee yesterday, so now it has to go to the floor and get two readings within the next nine days, which is doable. But as you know, I don't have full control over that process, but they are well aware of the Commission and the requirements, and the need to see this through. We're very hopeful that that will continue to happen. Our session ends 14th of May, but if they have to go to Conference Committee, they can do that, and definitely meet that deadline of September 1. Spud.

MR. WOODWARD: Just as a refresher, we can make the necessary changes to our Board of Natural Resources, and it's in queue for them to be briefed this month on it, and then there is a requirement for 30 days. We definitely should have this in place by the required deadline.

CHAIR DYAR: Any other discussion? Seeing none; **is there any opposition to the motion? I see none; passes by consent.**

CONSIDER NORTH CAROLINA SPOT CONSERVATION EQUIVALENCY PROPOSAL

CHAIR DYAR: Moving on to next agenda item, Consider North Carolina Spot Conservation Equivalency Proposal, again this is a final action. We'll hear a proposal by Chris Batsavage and then Tracey Bauer will give us the report from the PRT and the AP.

REVIEW OF NORTH CAROLINA PROPOSAL

MR. BATSAVAGE: The 2020 Traffic Light Analysis for spot triggered at the 30% threshold, requiring management as outlined in Addendum III. The management response for non-*de minimis* states was a 50-fish bag limit for the recreational fishery and states must reduce commercial harvest by 1% of the average state commercial harvest from the previous 10-years.

North Carolina implemented the 50-fish bag limit back in April of 2021, and the commercial spot fishery has closed from December 10 through April 4 every year beginning in 2021 to meet the required 1% reduction. North Carolina Division of Marine Fisheries proposes moving the current annual closure period for the commercial spot fishery to January 1 through April 28.

This option maintains a 16-week closure, and is projected to achieve an annual reduction in harvest of 6,940 pounds, exceeding both the 1% harvest reduction required by Addendum III and the projected reduction for the current closure period. The Division considered alternative season closure options that would achieve the required harvest reduction. However, these options did not minimize regulatory discards, impacts to the fishery or preferentially protect the spawning stock to the extent achieved by the options that were presented. The Division explored alternative closure options for the commercial spot fishery after receiving comments from commercial fishermen in the ocean gillnet fishery along the southern part of the coast, except the fall migration of spot now starts later and extends progressively later into the year, which disproportionately impacts their access to the spot fishery compared to fishermen in other parts of the state.

There was also concern that regulatory discards of spot following the closure date in mid-December may have increased into the ocean gillnet fisheries targeting other species such as kingfish. Feedback from fishermen suggested that a closure period beginning on January 1st, may reduce the regulatory discards of spot in that ocean gillnet fishery targeting kingfish.

Fishermen in other parts of the state however, were not as concerned about moving the closure period, because spot are no longer available to them by the pound net fishery closures. The January 1 to April 20 closed season was projected to achieve a greater landings reduction than the current closure period, provides some protection of adult fish during their spawning migration, and minimizes regulatory discards.

This option also allows access to the fishery when the fish are largest and most valuable, and the closure period is similar enough to the current closure that implementation and enforcement should be straightforward. The ten-year period from 2010 to 2019 was used to calculate the current 1% reduction in commercial harvest.

But the 2015 to 2019 time period was used to determine the closure dates, because those years are more reflective of catches and fisheries characteristics. However, landings exceeded the 10-year average from 2010 to 2019 in each year from 2020 through 2023.

Because of this, the 5-year period from 2019 to 2023 was used to create options for alternative closure periods projected to achieve that required 1% reduction in landings, based on current trends of the fishery, using the same methods required to determine the closure options. The more conservative closure options of January 1 through April 28 are appropriate, given that the commercial landings for spot have increased since 2019. That

concludes the presentation of our CE proposal. I would be happy to answer any questions.

CHAIR DYAR: Do you want to take questions before moving on? Any questions specific to Chris's proposal? Seeing none.

PLAN REVIEW TEAM AND ADVISORY PANEL REPORT

CHAIR DYAR: Tracey, do you want to go ahead and give the AP Report and PRT.

MS. BAUER: I will be going through some information on the review of North Carolina CE proposal. Just as a reminder, the Commission's CE Guidance Document outlines the process that CE proposals must go through to be approved. After a state submits a proposal, it is reviewed by the PRT to ensure the proposal contains all the necessary components, and meets the standards within the species FMP.

The PRT also recommends any other committees that the PRT believes would be appropriate to review the proposal. These comments are all compiled and presented to the Advisory Panel, which reviews everything and provides their own comments. All of this information has been presented to the Board for their consideration. First the spot PRT reviewed the proposal, and agreed that it included all the required information outlined in the Commission's CE Guidance Document, which includes the rationale description of how the conservation equivalency program meets the standards within the FMP, the review schedule and the monitoring and reporting process.

The PRT also agreed the proposal demonstrated equivalency and did not deviate from the standards within the spot FMP. Lastly, the PRT noted in particular, that North Carolina's proposed closed season exceeds both the required 1% harvest reduction and the reduction achieved by the current closure period.

The South Atlantic Advisory Panel met on April 15 to review the proposal, and did not express any major concerns regarding it. One AP member was interested in any available data in April, noting that spot had been showing up earlier in the month in recent years, and he was just a little concerned about moving the last day of the closure from April 4 to April 28.

It could potentially lead to an increase in regulatory discards in that period. Another AP member expressed strong support for the proposal, due to the benefits to the commercial fishermen in the southern part of North Carolina and how it was projected to reduce regulatory discards in December.

CONSIDER APPROVAL OF NORTH CAROLINA'S CONSERVATION EQUIVALENCY PROPOSAL

MS. BAUER: Just as a note, I wanted to mention the proposal was sent to the Spot TC through e-mail to give them a heads up in the situation and they did not express any concerns. The proposal was also reviewed via e-mail by Law Enforcement Committee representatives who also have no concerns. The Board action for consideration today is Consider Approval of North Carolina's CE proposal for its spot commercial season.

CHAIR DYAR: Any questions? Seeing none does anyone want to make a motion? Chris Batsavage.

MR. BATSAVAGE: Yes, **move to approve North Carolina's conservation equivalency proposal for its spot commercial season.**

CHAIR DYAR: Second, Ethan. Chris, do you have any comments on the motion?

MR. BATSAVAGE: Yes, just appreciate the staff and the fishermen who reached out to us about this in the first place, and then you had to kind of work through the different options. I think with changing ocean conditions, ocean is staying warmer longer. What we put in place initially made sense, but it clearly isn't working now. I think when it comes to

any seasons like this for any species, I think we definitely try to hit a moving target. Hopefully this works, we'll certainly be evaluating it after it is implemented.

CHAIR DYAR: Ethan any follow up?

MR. ETHAN SIMPSON: Yes, I just would like to say I think that the Addendum was written in a way to allow this type of flexibility. I think the amount of work that has gone into it justifies that we're well within the original intent of that addendum.

CHAIR DYAR: Thank you, see if we can do this again. **Any objection to the motion? Seeing none; it passes by consent**. All right, rock and rolling.

CONSIDER PLAN REVIEW TEAMS' REPORT ON BOARD TASKING TO REVIEW *DE MINIMIS* PROVISIONS FOR SCIAENIDS

CHAIR DYAR: The next item on the agenda is one that is going to bear a little more discussion, I believe. We have Consider the PRTs report and Board tasking to review *de minimis* provisions for sciaenids. Again, some discussion here, but this presentation will be from Tracey Bauer.

MS. BAUER: Start off with an outline of what I'm going to cover in this presentation. I'm going to go through the background behind the issues that states have been having with *de minimis* here on the Sciaenids Board and why we're discussing this today, before we move in to the PRTs discussion and recommendations, and then potential next steps.

To focus discussion, I want to start off with a reminder that established in the Commission's *de minimis* policy, *de minimis* provisions and interstates FMPs are meant to reduce the regulatory burden for states whose measures would have a negligible effect on the conservation of the species.

In recent years there has been reoccurring issues related to how *de minimis* is defined for several Sciaenids Board species. On the table here I have, and it lays out the current stock definition, *de minimis* threshold, i.e. the percentage of the coastwide landings, number of years of landings averaged, what states were most recently granted *de minimis* based on requests in the states fishing year 2024 Compliance Reports for each of the Sciaenids Board species.

All Sciaenids Board species have a 1% threshold for *de minimis*, and average three years of data. Only Atlantic croaker considers *de minimis* separately by sector and red drum now considers *de minimis* separately by stock. More specifically, in regards to the issues states have been having, states that were previously *de minimis*, particularly those on the edge of the species range such as New Jersey and Delaware, have had highly variable landings in recent years.

In particular for spot and Atlantic croaker. This has resulted in states repeatedly following just above or at the 1% threshold for *de minimis*. Recent compliance reports and in discussions with the Board, states have noted how a single year of unusually high landings averaged with two years of lower landings contributed to their state falling just above the *de minimis* threshold.

States have also noted high uncertainty in the MRIP estimates being used to calculate *de minimis* for their state. In addition, it's been noted that other states in the management area, which previously made up the majority of the fishing effort, have experienced large declines in landings, disproportionate to the states on the edge of the range.

This has caused in some cases, the states on the edge of the species range to suddenly contribute to a larger portion of harvest. There are a lot of moving pieces contributing to these issues of states hovering around the *de minimis* threshold. To sort of illustrate what I mean, on the table here I have the *de minimis* calculation percentage for Atlantic croaker. This is recreational data only using a 1%

threshold in a three-year average. White cells indicate that the value is below the current 1% threshold., meaning the state qualifies for *de minimis*, and the orange color is just to show you those values on the edge. It's just values between 1 and 2%, meaning the state did not technically meet the threshold for *de minimis*, but still had low landings relative to the rest of the coast.

You can see with New Jersey and Delaware; they are right along that 1% line. For these reasons states hovering around and above the 1% *de minimis* threshold have repeatedly requested continued *de minimis* status, noting that they wish to make sure it's a consistent trend before officially becoming non-*de minimis*.

These states have expressed concern with the appropriateness of the definition of *de minimis* and how meaningful any regulations they implement would actually be on a stock, especially considering the states relatively low contribution to the coastwide landings compared to other states, and the administrative burden to implement new regulations for non-*de minimis* states to remain compliant with the FMP.

It's also important to note that managers will likely continue to see increased variability and uncertainty in landings and changes in which states qualify for *de minimis* due to environmental factors, which contribute to the cyclical nature of recruitment in adult abundance of some of these species, and potential ongoing stock expansion.

This may not be a problem essentially that will go away soon. As a result of these ongoing issues, in August 2025 the Board tasked the PRTs for the sciaenid species to provide recommendations on whether the current 1% threshold for a state to be considered *de minimis* is appropriate, and whether there may be alternate ways to evaluate whether a state is *de minimis*.

In other words, whether there may be alternate ways to evaluate whether a state's measures have negligible effect on the conservation of a species. PRT has met 4 times between November 2025 and April 2026. To start off the PRT did agree that the current 1% threshold used for Sciaenid Board species may not always be appropriate for all the species.

However, the PRTs were not able to recommend a one-size-fits all solution, as they did not think one would be appropriate. Instead, they discussed several different ways this issue could be addressed, and stressed that the appropriateness of a definition of *de minimis* needs to be evaluated on a species-by-species basis, based on the species life history, available assessment information and other differences in the fisheries.

Lastly, before I get into the possible options the PRTs discussed in the memo, I need to go over two important points the PRTs wanted to make sure were communicated to the Board. First the PRTs stressed the importance of being cautious about the amount of leeway allowed the states who wished to remain *de minimis* despite not qualifying for it, particularly if the state has no regulations in place for a species and there are concerning trends in stock status.

Second, the PRTs recommend any changes to the definition of *de minimis* or *de minimis* process undergo review by the species respective Technical Committee prior to or as part of the development of an Addendum Amendment with the goal of ensuring that the proposed change will have a negligible effect on the conservation of a species. The options that the PRTs are recommending, either are a modification to the current definition of *de minimis*, or modified *de minimis* process itself.

I do want to note as I go through these different options, the PRTs do not necessarily recommend implementing multiple options for a single species, but it can be done. I'm going to start off reviewing the two options under modifications to the current definition of *de minimis*. First A, changing the

number of years of harvest averaged and B implementing multiple thresholds.

Changing the number of years of harvest average using something like a five-year average instead of the currently used three-average, may be appropriate for some longer-lived species, if the landings data are highly variable or in cases where the stock may be undergoing expansion, as a smoother and any single year of data would be less impactful in calculating *de minimis*.

This is a running theme for all of these approaches. The PRTs caution that this option should be evaluated on a species-by-species basis. Next, the PRTs brainstormed the idea of multiple thresholds as a possible solution or part of a possible solution to the ongoing *de minimis* issues in the Sciaenids Board species.

This option proposes multiple threshold levels and could be combined with the option I just previously went over the number of years averaged. If a state's average landings for the most recent three or five years are less than 1% of a coastwide harvest, that state would qualify for full *de minimis* with no measures or monitoring for compliance with the FMP necessary.

If the states landings for the most recent 3 or 5 years are greater than or equal to 1% but less than 3% of the coastwide harvest, a state would qualify for what we're calling provisional *de minimis*. The addition of this provisional category would recognize the state's landings are greater than that 1% threshold, but still relatively low to the coastwide landings.

Although a state that falls into provisional *de minimis* would not need to implement new measures or monitoring to remain in compliance with the FMP, a state that falls in this category would not be able to liberalize their current regulations for that species at all. Lastly, the third category. If a state's average landings for the most recent 3 to 5 years are greater than or equal to 3%, all non-*de minimis* compliance measures and monitoring would apply.

The PRTs also proposed that a hard line be drawn between provisional *de minimis* and non-de minims. If a state moves from provisional or full *de minimis* into non-*de minimis*, meaning that they are crossing that threshold of 3%, they can no longer request continuance of *de minimis* unless they are extenuating circumstances.

Because of the amount of flexibility that this multiple threshold approach allows, allowing states to not need to implement measures and monitoring to remain in compliance with the FMP until they reach that higher 3% landing threshold. The PRTs recommend the multiple threshold approach only be used when the stock is doing well. If this approach was implemented for a species, if the species PRT has concerns about the stock after reviewing the most up-to-date information on stock status, the species PRT could recommend the use of a strict 1% threshold for *de minimis* the following year, which would then need to be approved by the Board. Lastly, the PRTs discussed that the multiple threshold approach may not be appropriate for all Sciaenids Board species.

For example, spotted sea trout, which has multiple assessments up and down the coast. The species stock status could vary up and down the coast, or if a species stock status can frequently change, as we want to avoid frequent changes to how we define *de minimis*, that could get a bit messy.

Before I move into proposed options of potential changes to the process, I wanted to give you all an idea of what the two modifications to the definition of *de minimis* might look like, with spot as the example using past data. This is for recreational and commercial data combined, which is how *de minimis* is currently calculated for spot.

I'll get into separating the calculation of *de minimis* by sectors in a bit. Also, you'll note in these figures that I did not use exact percentages, which is because there is some confidential commercially involved in these calculations, so I wanted to make

sure that was all excluded. The dark blue 1% means that total harvest in that state or jurisdiction in that year was less than 1% of the coastwide total, so that state qualified for *de minimis* in that year.

When a box is just green that means that the total harvest of spot in that state or jurisdiction for that year was greater than or equal to 1% of the coastwide total. They were technically non-*de minimis*. The figure on the left shows whether or not a state qualifies for *de minimis* using the three-year average, and the figure on the right uses the five-year average.

Again, this doesn't actually reflect which states were or weren't *de minimis* in years, because of the leeway we were giving to some states. Some states would request they remain *de minimis*, despite no longer technically qualifying for it or states that qualified for *de minimis* may not request it.

This is just purely from a calculation standpoint, what states do or do not qualify for *de minimis*. In comparison, this is that same data that you just saw in the previous graph, but incorporating the multiple thresholds. Again, the dark blue 1% means the state or jurisdiction would have qualified for full *de minimis* that year.

The blank yellow box means that that state or jurisdiction would have qualified for provisional *de minimis*, meaning that the state's total harvest for that year was greater than or equal to 1% of the coastwide total, but less than 3%. If a box is green with greater than equal to 3%, this means that the state would not qualify for *de minimis* and would be non-*de minimis*.

Again, we have it for both using a three-year average and a five-year average. You can see the differences made by the three and five-year average and what states in the past would have qualified for full *de minimis*, provisional *de minimis* et cetera. PRTs also discussed a few alternate ways to address the state's issues with *de minimis*, which would be modifications to the *de minimis* process itself. This includes codifying the number of years before a state can no longer request *de minimis* status, and an option where states would remain non-*de minimis* or *de minimis* for a certain number of years after qualifying for a year. As previously mentioned, currently a state can request *de minimis* despite not technically qualifying for it.

The state will usually include reasoning as to why the requesting continues with the *de minimis* status, like if they want to see if it's a consistent trend before they officially become non-*de minimis* and need to adopt measures or monitoring to be in compliance with the FMP. The PRT will review the request and make a recommendation.

In the past the PRT has usually recommended a state remain *de minimis* if it is the first time going over the 1% threshold in a long time, and usually say that if the state continues to fall above that threshold for a specific number of years, then the PRT will no longer recommend continuance of *de minimis* for that state.

The Board then obviously makes a final decision on whether or not to grant the de minims request. This approach suggested in 2A would officially establish the number of years the state can request continuance of *de minimis* status despite no longer qualifying for it. The benefit to this would be that everyone knows the expectations ahead of time instead of it being just a PRT recommendation provided when they are reviewing the reports.

The PRTs do not recommend a specific number of years in this memo. This is something that would need to be determined on a species-by-species basis. However, they do recommend that it be non-consecutive. For example, if a state does not qualify for *de minimis* 3 out of the last 4 years, the request can no longer be granted unless there are extenuating circumstances.

This is one other possible option to address the issues that the Sciaenids Board is seeing in the species. This last option is a result of the PRTs

brainstorming, ideas of ways to provide stability to states that may frequently fall just above or below the *de minimis* threshold, in regards to the implementation of measures or monitoring to remain in compliance with the FMP.

Once a state is officially no longer *de minimis* there could be a set number of years before a state can qualify for *de minimis* again, regardless of their landings and vice-versa. If a state's *de minimis* request is approved, there could be a set number of years that they can remain *de minimis*, regardless of their landing.

Again, this is really going towards increasing stability for states that have been jumping in and out of *de minimis*. They know for a certain number of years we don't need to implement these regulations at least. Finally, the PRTs discussed a few other modifications to *de minimis*. The *de minimis* provisions didn't exactly fall under the other two umbrellas. First, considering *de minimis* separately for the commercial and recreational sectors.

This has previously been recommended by the Spot PRT for spot and similarly the PRTs thought that it should continue to be considered on a species-by-species basis in consultation with the Technical Committee. As promised, to illustrate the impacts of the split that have, I'll add a few figures comparing which states would qualify for *de minimis* using the current 1% threshold, averaging over 3 years and 5 years split by sector. First on this slide I have just recreational data who would have qualified for *de minimis* in the past 10 years. In this next slide, this is separated out. This is just commercial data, who would have qualified for *de minimis*, again using 1% average 3-year and 5-year. Next, the PRTs discussion touched on the concept of splitting *de minimis* by stock, which was recently implemented for red drum. The PRTs recommended that splitting *de minimis* by stock should continue to be considered on a species-by-species basis.

If a species has two or more stocks which are managed separately, the PRTs thought that it made a lot of sense for *de minimis* to be similarly evaluated at the stock level. Finally, the PRTs briefly discussed the possibility or the impact of considering total removals instead of total harvest when determining *de minimis*, noting total removals would allow for a more complete picture of each state's potential effect on conservation of the species.

Currently however, consideration of total removals would only be possible in combination with splitting *de minimis* by sector, as obviously state specific commercial discard estimates are not available on an annual basis. There is also some more discussion in the memo regarding how only using harvest to determine *de minimis* for these species may overestimate the impact on a population from states with lower commercial harvest and little to no discards, and underestimate the impact from states with higher commercial harvest and discards.

Moving into possible potential next steps. Overall, the takeaways from the PRT are that any of the options that they've put forward in this memo that the Board wish to explore further, should be examined on a species-by-species basis, and that the species Technical Committee would need to provide input on any definition of *de minimis* related to the conservation of the species.

The PRTs are looking for direction from the Board on how to proceed. They were sort of pulled in all different ways with all the different species and the different ways that could be done with this, all the different analyses that could be done with this. Any input on the Board, if they want to do anything else or what they want to do, will be helpful. I just have here some possible next steps that could be considered by the Board.

You know, they could task the PRT or TC to explore an option or options to provide species specific recommendations. They could wait for each Plan Review Team to meet for FMP reviews to discuss the issue, initiate an addendum for one or more species, or wait util another issue comes along and

fold this into any other future addendum, or it is up to the Board discretion on where you would like to move from here next. With that happy to take any questions.

CHAIR DYAR: Great, thank you, Tracey, I really appreciate that thorough review of kind of a lot there. I wanted to thank also the PRT members from all the different board species for a lot of work in developing this. There is a lot to look through, a lot to think about, and a lot of if this or then that. I really appreciate their time. I'm going to go ahead and open it up for now, see where we can kind of maybe hone in on some things. I have Rich Wong and then Joe Cimino. Go ahead, Rich.

MR. RICHARD A. WONG: I would like to thank Tracey and the PRT for an amazing job on that review. You could tell there was a tremendous amount of thought put into that memo. There were some really sensible options there that would help us. You know we're just trying to maintain management stability, regulatory stability without jeopardizing the coastwide stock at all. I think all of those options make a lot of sense, particularly the multiple thresholds and provisional standards in the sector splits.

This really would help the states that are hovering on around the current 1% *de minimis* threshold. It would certainly maintain stability for us. Thank you for that, and I would like to pursue this a little further. You know most of the work has been done. I feel like with the PRT review and the memo. We would want to start to initiate an addendum to implement some of those options, or provide those options for public review.

CHAIR DYAR: Thank you, Rich, I agree. Joe.

MR. JOE CIMINO: Tracey, great job. This is exactly what I was hoping for when we were talking about this at the annual meeting. I really appreciate the work that went into this. I do have one question on the calculations. When you say coastwide, you are showing those states in the plan. When you're looking at coastwide is that all landings for the coast? Because I know our neighbor to the north probably needs to start thinking about sitting on this Board as well.

MS. BAUER: Yes, Joe, that is a great question. Coastwide is a bit of a misnomer. I am only using the states in the management area. Management area-wide would be more accurate.

MR. CIMINO: Then I do have one other question that will maybe roll into the guidance. I might look to our resident *de minimis* expert, Toni Kerns, who I would say that, because Toni carried a lot of water on the *De minimis* Policy that we were trying to create an overarching policy.

What we saw during that is that it's almost impossible to get a way that some species, life species considerations, even if you do have some overarching things. I am in full agreement with the V-team on that. But I guess if we wanted to look at something like a threshold, but do that at the larger policy level, and who becomes the group to do that, I guess would be my question.

CHAIR DYAR: Toni, go ahead.

MS. TONI KERNS: We want to make a threshold a part of the actual policy that we have, then we would have the Policy Board task staff, I guess to look into that, and if we feel like we need some help then we'll ask for some help for you all that will be the Policy Board.

CHAIR DYAR: I would think we would want to be specific about which areas we want to have be a broad sense, but yes, agree. Go ahead, Joe.

MR. CIMINO: I think that that would help the situation for spot and croaker. The Delaware and New Jersey have been in in particular, is to have that provisional *de minimis* that doesn't allow them to be more active. But I would like to see that at a different policy level, so I may just wait until Policy Board, and maybe even a later policy board if we

don't have time for it today. But to maybe get that on an agenda there to have the discussion there.

CHAIR DYAR: One thought here too is it could be considered as, I think Tracey touched on it. But you know, if we're going to start looking at this on a species-by-species level and having some overarching component. You know these are going to have to go through addendums, and I think we want to be sensitive to the staff and tasking addendums and the overwork. Making sure that we want to incorporate as many things as we can and timely as we can with some of these addendums. Go ahead, Toni.

MS. KERNS: Quick follow up to that, Ben. I just note that just because we have an overarching policy doesn't actually mean that each species follows that policy, it's whatever is in the addendum. What we had said when we created the policy is, as addendum come up. If that species board wanted to do something different than what was already in the addendum, or if the addendum didn't match up with the policy, and the Board wanted to match the policy.

Then they would do an addendum to do so. But they could hold their FMP as it stood, or if they wanted to do something that was slightly different than the policy itself, we just needed to provide rationale for why we wanted to do something different, and that those changes could be made through an addendum. Even if thresholds aren't in to not end up being in the overarching policy, this Board could still utilize them with rationale.

CHAIR DYAR: Great, thanks for that clarification, and further the point of you know maybe it is time you can look at these things as they come up. It depends on, obviously the timing of stock assessments and things like that. But specifically for spot and croaker, maybe some low hanging fruit. We do have some assessments coming through. If we do want to attach some of these things and decide on them then, that might be an opportunity. But again, the will of the Board. Go ahead, Chris.

MR. BATSAVAGE: Thank you to Tracey and the PRT for exploring this pretty thoroughly. I had a question about, under additional considerations, the idea of looking at total removals when determining *de minimis* status. The paper mentions that we don't get commercial discard estimates as timely as we do recreational, which is kind of baked into MRIP.

But for states that have commercial fisheries that we know have high discards of sciaenids such as spot and croaker. Did the PRT talk about how they probably, if we used total removals that they probably wouldn't get *de minimis* status, only because we know that the discards in some of these fisheries far exceed the landings for things like spot and croaker?

MS. BAUER: Clarification question. When you say that they wouldn't get *de minimis* status, you mean the states that don't have a high, or the states that do have those high discards?

MR. BATSAVAGE: Yes, the states that do. They might have like really low landings, but they have commercial fisheries with high discards of these species. If we were looking at total removals, would that basically mean they really couldn't qualify for *de minimis*, just because we know the volume of discards to the total removals is probably going to be greater than the 1% threshold in most cases.

MS. BAUER: Yes, I think the conversation focused around the assumption that states with really large fisheries, like say spot and croaker, and really high discards of the species in the commercial fisheries would have such a high proportion of the coastwide total removals that it would dwarf anything from the smaller states with less directed effort.

Even if they have somewhat higher discards compared to what landings are bringing in. The focus is more on that part of it and not like whether or not the commercial discards might be higher in

those states that aren't bringing as many landings, and that might tip them over the other edge and have the negative effect that they were looking for.

CHAIR DYAR: Any thoughts or questions on paths moving forward? There might be some, again maybe not a directive or a motion or any task today. If there is that is fine, but you know maybe you're looking forward to, again like we said, the stock assessment is coming up. Ethan, go ahead.

MR. SIMPSON: Yes, I think to your earlier point about those stock assessments coming up. It sounds like with spot and croaker being the species of concern in this regard that those are next on the docket. That seems like a reasonable time to address a lot of these concerns.

I think that goes along as well with the consideration that these need to be looked at species by species. You do have highly variable life histories for these species, so there are implications down the road. I do think going at it, species by species as they come up, seems to be a reasonable approach.

CHAIR DYAR: Rich.

MR. WONG: What is the timeline for the new assessment for spot and croaker? New assessments.

CHAIR DYAR: I don't want to speak out of turn.

MS. C.J. Schlick: Hi, I'm CJ Schlick; I'm the SAS Chair for those assessments and I'm going to be presenting a brief timeline. But the croaker stock assessment is going to Peer Review in July, with being presented to the Board at the annual meeting this year. Spot will be proceeding next year and coming to annual meeting at 2027.

CHAIR DYAR: Yes, Rich.

MR. WONG: I'm just trying to work through the information here. I'm not sure how the stock assessments will affect this particular issue, particularly for our situation for spot and croaker. I'm just trying to figure out how there is a benefit to waiting for the stock assessment. We have regulatory requirements already built into the *de minimis* requirements, depending on the stock status. I mean those are already reflected in the definition. I'm just trying to think, since you had brought that up. What is the benefit to waiting, what is the rationale for waiting?

CHAIR DYAR: I can let Joe go, just my comment was that if there is a requirement for something after the assessments for spot and croaker, since there might be interest in separating by sector or separating by stock, and there is an addendum required at the end of that assessment process, then that can be then tacked on and added to that addendum, instead of creating a separate addendum and separate process tasking staff that are already going to be dealing with this process within the next year was the thought. But I have Joe.

MR. CIMINO: Yes, just a follow up on that, Ben. I think for a state like New Jersey, who is probably coming out of *de minimis* soon and needs to get regulations in place. A, it's just unofficial to have an updated assessment to convince the public that it needs to happen.

B, if considering the states load to carry too, it would be tough to jump to one set of regulations and get the assessment, find out that we need to have even further restrictions. Then go right back and start changing regs again. If we have the discussion of where the stock is, you know where regulations need to be, then we can do that all at once. That would be helpful.

CHAIR DYAR: Carrie.

MS. CARRIE KENNEDY: Yes, I think to Joe's point earlier. I would like the Policy Board to sort of review and process and sort of comment on the memo. I don't know if that means that the Board

has to sort of approve the memo to send it to the Policy Board, or if we just want to task the Policy Board to review it.

Then I think timing wise, you know maybe the timing of an addendum coming out of a stock assessment, and you know recommendations or a formal review by the Policy Board might also sort of coincide to have something to put into a potential addendum.

CHAIR DYAR: Regarding the Policy Board, Toni.

MS. KERNS: The Policy Board doesn't need to approve this particular memo. If we want to take components of this memo and have it included in the overarching policy that we already have on *de minimis*, then that would be the direction or someone would just bring that up and ask staff to take a look at the components of this memo to see if we can incorporate that concept into the overarching policy.

But this Board doesn't need to approve the memo that the various PRT members put together, I'll call it omnibus PRT put together. You know this Board would use that information as they wish to address here, an omnibus addendum or addendums as they come about. I guess you could, since it's not that far away, in terms of the croaker assessment.

You could look at it, and if we're nervous that we're not going to have a document or something, then after the assessment comes out, if there isn't anything then we could initiate an omnibus addendum at that time. It wouldn't adjust the timeline significantly, I don't think.

CHAIR DYAR: With that I guess, Rich, go ahead.

MR. WONG: I understand, so process wise there is an advantage to having one addendum after the assessment, in case there are regulation changes required. I just don't' want to lose the momentum from this memo. You know this memo was great. It hit all the nails on the head. In that case, if we wait for both assessments to be finished, then we're talking like two years, maybe for that addendum. That is my concern is just, I guess I would ask Tracey. Are the staffing and cost associated with waiting worth it in the waiting for two years, I guess?

MS. BAUER: I will say for Atlantic croaker, obviously finishing later this year, then we start the addendum we've initiated we would start it then. But spot is a whole other year and then you would have to start. There is like a disconnect there between Atlantic croaker and spot, of when those two would get started. I know that doesn't directly address your question. Staff workload, I mean a lot of that is really up to the will of the Board of what you guys are interested in doing.

CHAIR DYAR: Toni.

MS. KERNS: If I am allowed to make a recommendation, Rich, to just be helpful. I think it would be best, efficiency wise, it would be great if we could wait until we see what happens with the croaker assessment. If an addendum comes forward then we will figure out a way to package this in with that.

I won't promise exactly how it's done, but we will package the whole deal, everything. Whatever species you all want to address at that time, I'll say that. If we don't need an addendum at that time, then the Board could talk about starting one just for these issues. But since it's only the annual meeting, I don't think it's that far off. If you wanted to task, you know think about things that you would want to see in the policy.

Tracey just said that she could use a little direction. You could think about that over the course of the next couple weeks, or somebody can send her an e-mail and she can start to think about things ahead of time so that she's working on it, but she doesn't have as tight of a timeline, since she'll be busy with assessment reporting and probably some summer flounder, scup, black sea bass things, sector

separation, so that she can spread out her workload a little better.

CHAIR DYAR: I think of ones, we have quite a bit of flexibility here in how we do it. We can look at this just with croaker and address that right away, or as Toni mentioned, at that time if we want to lump another species or there is a priority for some reason, then we can address it then.

To Joe's point, not only is it staff timing and workload and things like that, considerations. But something that comes out of that assessment might direct us how we want to address *de minimis* as well, depending on what that assessment says for each species. But again, the will of the Board. Is there any? Yes, Rich.

MR. WONG: Just one final thought. We were ready to initiate a motion here. But I think given the information, I am fine with waiting. That makes a lot of sense logistically. I just want to ask the Board to don't let the momentum die down next year on this issue. That memo was great, so we just want to just keep it in mind.

CHAIR DYAR: Agreed, and you know I don't think these issues are going to go away any time soon, so I don't think they can be forgotten. But point noted for sure, it was a great document. There were some comments regarding bringing some things to the Policy Board. If there is interest there, I think that we can do that. But I think there was a request to be kind of specific about which components that we wanted to bring to the Policy Board. I think Joe, you mentioned it, Carrie did as well. Is there any interest there?

MR. CIMINO: I don't know about doing it as a motion from this Board. One of the things I worry about is hitting them cold without getting a similar presentation on why it was so meaningful to this group. I think we could do that quickly. I think it may be something that needs to be on their agenda as a discussion topic.

I don't know, maybe folks could throw in their ideas. I was particularly interested in the idea of that multiple thresholds with a provisional *de minimis* and then hard stops set around those. You know number of years that that could stay in place.

CHAIR DYAR: Thanks, Joe, noted. I don't know if it's best or how to do that. It seems like a presentation at the Policy Board or some high level. Is that kind of the thought there so they can have the information, or at least present to them with a packet or something prior to a meeting. Your next meeting, later today.

MS. KERNS: I'll talk to Dan and Tracey, and we'll get that on the agenda for August.

CHAIR DYAR: Great, thank you. Any other topics on this point? Any other discussion? Great.

PROGRESS UPDATE ON 2026 ATLANTIC CROAKER BENCHMARK STOCK ASSESSMENT

CHAIR DYAR: Moving on to the next we have Progress Update on the 2026 Atlantic croaker benchmark stock assessment by CJ Schlick.

MS. SCHLICK: Thank you for having me. I just want to give you a brief update on the progress of the Atlantic croaker stock assessment and the timeline for both Atlantic croaker and spot moving forward. We last came to the Board with an update on the stock assessment at the annual 2025 meeting.

There have been several developments within this stock assessment that has slowed up progress. One of which is that instead of a single population this has been modeled as two separate stocks split in central North Carolina. Also, we had several staffing issues over the years, last two years, that has changed our modeling crew. That delayed several milestones. With that we also decided to decouple the Atlantic croaker and the spot stock assessments with staffing concerns.

Spot assessment will initiate after the Atlantic croaker is completed. We have reached the final milestone for this. The Assessment Workshop was completed in March, and we did a final SAS review series in April. We have two functional models that we are in the process of writing up now. The remaining timeline for this is the Final Report will be going to the TC for review in May. They should have it finished by June, and we will be going to Peer Review in July, with the intention of bringing this in front of the Board at the annual meeting in November. Upon completion of the Peer Review, the SAS will start the spot stock assessment. We'll be data collection starting in July, model development and revisions through the fall and winter, and going to Peer Review in June, 2027 with the intention of going to the Sciaenids Board here at the annual 2027 meeting.

However, this does bring up one question for the Board, in terms of the traffic light update. The traffic light was last updated for the Board in summer, 2025. The spot TLA was not triggered and management action was no longer required. The TC still recommended to maintain the current regulations and the Board agreed. However, we are asking whether or not we should be updating the TLA for spot this year, given that the completion of the stock assessment will be the annual meeting 2027. I will be available for any questions.

CHAIR DYAR: Thank you, CJ. Any questions for CJ? All right, any thoughts on feedback for traffic light? Erika Burgess.

MS. BURGESS: CJ thank you for posing the question. I don't see, unless anyone on the Board disagrees with me, the need to produce a traffic light analysis at the same time we're completing the stock assessment. But I'm sure others may have a different idea.

CHAIR DYAR: Chris Batsavage.

MR. BATSAVAGE: Yes, I agree. It's always nice to see where we are, but knowing we have a planned stock assessment coming up and potentially management action after that. I don't know if we would be implementing any management measures after this next traffic light analysis if we know that there is a stock assessment coming up pretty quick. We could run it later if the assessment is delayed, but I tend to agree. I think it's probably best to let the TC and SAS focus on getting ready for the assessment, as opposed to updating the TLA.

CHAIR DYAR: I did have a question. Worst case scenario, assessments are done and for some reason not recommended for management use, and we want to switch to the TLA again. What is the timeline for running that to get feedback and information back? Do we know, typically? Chris McDonough.

MR. CHRIS McDONOUGH: I can address that pretty easily. The way the TLA is run, almost everything is coming out of what would be available already for the stock assessment, so updating it would be a pretty quick exercise.

CHAIR DYAR: Great, thank you. CJ.

MS. SCHLICK: I will note for Atlantic croaker we did update the TLA to compare to the stock assessment, so that you have a side-by-side comparison, and the spot was last updated in 2025.

CHAIR DYAR: Any other questions for CJ? Great, thank you, CJ, appreciate it. Final agenda item, update on the Southeast Area Monitoring and Assessment Program by Pat Campfield.

UPDATE ON THE SOUTHEAST AREA MONITORING AND ASSESSMENT PROGRAM

MR. PATRICK A. CAMPFIELD: Good morning, everyone. The Southeast Area Monitoring Assessment Program or SEAMAP has a new strategic plan or a five-year strategic plan, so we wanted to give you all a quick update on what they're up to, and plans for 2026 through 2030. As

a refresher, SEAMAP has three different regions, the South Atlantic, the Gulf and the Caribbean.

The current surveys in the South Atlantic include the Coastal Trawl Survey, the Reef fish or SERFS Survey, multiple state longline surveys and the Pamlico Sound Survey, noting that that Pamlico Sound Trawl Survey is going through some transition with the vessel and piloting new methods.

The map on the bottom shows representation on the South Atlantic Committee from each of your four states, as well as NOAA Fisheries by the South Atlantic Council and our coordinator Janita Patel. The overarching goals of the New Strategic Plan are to maintain long term survey time series, modernize surveys for efficiency and respond to adaptive management needs.

Major themes within the SEAMAP Plan include expansion of current surveys. One example again is the SERFS or Reef Fish Survey that has started to take trap video surveys north of Cape Hatteras, in anticipation of some species moving around the Cape, as well as some expansion of video surveys as far down as the Florida Keys.

We also have thoughts and ideas on new surveys, but would still need new funding for those, including nearshore live bottom habitat, as well as a need to develop a cobia fishery independent survey, and we put in a proposal for that, haven't been funded yet. But that is a glaring need for cobia stock assessments.

Then also, needs to survey ichthyoplankton to get a handle on recruitment. We also have some cross survey program enhancements, including a need to do some bottom mapping for low relief habitats, relevant to red snapper and some other species that seem to be more abundant than folks thought, have low relief habitats.

Also, look at new statistical methods for combining your state longline survey data, and also look at statistical methods for comparing catches between the trap video surveys and the area that they monitor versus the coastal trawl survey sampling. SEAMAP has always done well and continues to strive to fold in emerging technologies among all of the surveys. There is some pretty cool work that is being led by Florida Fish and Wildlife Research Institute to use machine learning to process the Trap Video Survey data.

This is just one image showing automated species identification that can be used to develop abundance metrics, but essentially teaching the computer to identify, in this case this is red snapper and I think a red porgy in those boxes. That is still in the pilot testing phases, but we hope to use that more broadly in the South Atlantic Region.

We also highlight in the strategic plan the numerous survey data uses. The table at the top summarizes all the FMPs that use SEAMAP survey data, federal FMPs, ASMFC regional plans, as well as individual state plans. Then the bottom row there shows additional data requests for research activities outside of the states and the federal agency, where we have shared the data and they resulted in numerous publications. The bottom take poll specifically shows again the numerous stock assessments that SEAMAP survey data have been used in.

I won't go through those individually, but after 40 plus years of survey data collection it is pretty impressive, and we'll keep that going. Then we also thought it would be important to provide some economic value numbers in the strategic plan for Congressional outreach and other outreach purposes, to maintain funding support for SEAMAP.

We pulled together some numbers and the coastal fisheries between North Carolina and Georgia are estimated to generate 12 billion dollars in economic impact and roughly 40,000 jobs. Florida was handled differently, because of course this coast, you have both coasts in the Gulf and South Atlantic,

but total 41-billion-dollar economic impact, 160,000 jobs.

The SEAMAP surveys were programmed budget specifically ranges between 5.1 and 6.7 million dollars annually. The budget has been pretty strong, pretty solid and consistent for the last five years or so, including some plus up funds in the last couple of years. We also have a figure in there showing what increasing cost it would require to keep the surveys going, again for outreach to Congress.

Those are numbers that we share with Bob and Alex when they make their Capitol Hill visits. But encourage you to look into the strategic plan if any of your individual state delegations are going to the Hill there are some number there you all could use. Then to wrap up, last year SEAMAP revised their websites, SEAMAP.org, so again, encourage you to check out the website.

There is a lot of great information in there if needed for individual state purposes or for outreach purposes. Then if you have any bright ideas, or if there are things that we missed in the new strategic plan, that is your South Atlantic committee representation and contacts. You're welcome to reach out to myself, or to Janita if you have any fresh ideas to address management needs. With that, Mr. Chairman, I'll stop and take any questions.

CHAIR DYAR: Thank you, Pat. Any questions? Great job, I appreciate it. Thank you for the update.

OTHER BUSINESS

CHAIR DYAR: Remember Other Business we had a couple of comments there, so Chris Batsavage.

SPOT AND SPOTTED SEATROUT COLD STUN EVENT IN NORTH CAROLINA

MR. BATSAVAGE: Appreciate the opportunity to update the Board on the cold stun event that occurred in North Carolina this past winter. North Carolina closed the recreational and commercial spotted sea trout fishery on February 6, due to the cold stun events. Staff confirmed instances of cold stun fish in multiple counties, and also confirmed that water temperatures were at or below the critical lethal temperature threshold of 3 degrees Celsius for spotted sea trout.

Cold stun events in most of North Carolina's estuarine waters. Amendment 1 to the North Carolina spotted sea trout fishery management plan specifies that if a significant cold stun event occurs, the Division of Marine Fisheries will close all spotted sea trout harvest through the end of June. The intended closure is to allow the spawning fish a chance to spawn in the spring before harvest reopens. North Carolina also closed the spotted sea trout fishery in 2025 due to cold stun events, but it's not common to have significant cold stun events in consecutive years. We often document other species, fish species dying during cold stun events, and this year included striped mullet, southern flounder and multiple reports of red drum.

However, it is not common for many red drum to die due to cold stun, which is a concern, because of the increasing trends of fishing mortality has touched the northern population in recent years. They kind of put it in context the last time there was a lot of dead red drum from a cold stun in North Carolina was in 2003, and that greatly impacted the 2001-year class of fish.

Impacts that the 2026 cold stun events had on spotted sea trout and other species are currently unknown, but fishery dependent and fishery independent sampling this year should provide some insight into at least the relative impacts. Anyways, this is a quick summary of what happened and how we responded, and I'll be happy to answer any questions.

CHAIR DYAR: Any questions for Chris? Ethan.

MR. SIMPSON: No questions, but I also wanted to essentially say the same thing occurred in Virginia, we also experienced a cold stun event. Our commercial fishery closed down in February. Our recreational fishery took a little bit longer, just to get through the regulatory process.

But we also closed our recreational fishery in April. Essentially the same concerns that Chris already outlined. We also experienced those below optimal temperatures. We did also see a number of red drum, but similarly, we don't really know the effects that will have, at least for a little while.

CHAIR DYAR: Rich.

MR. WONG: Thanks, Chris, for that update. I was in North Carolina during that '03 that winter mortality as well, and I remember thinking at the time, you could probably try to quantify the mortality there at the time. But now, with drones and all that and new technology, did you try it? To try to get a number of those mortality events?

CHAIR DYAR: Chris.

MR. BATSAVAGE: No, we don't. I guess with at least the spotted sea trout stock assessment for North Carolina, I guess how it's handled is we're able to look at the different natural mortality estimates that occur, especially during years where there are cold stun events versus when there aren't. Although we can't really come up with an estimate of how many fish died during that year, The impact of the cold stun event at least is factored into the stock assessment model.

CHAIR DYAR: I know that we got lucky in South Carolina, even though we dipped below well below the thresholds for our shrimp populations and even that for spotted sea trout. We didn't see any major impacts, major fish kills and the reports coming from some of our trawls are looking good for shrimp. I think what helped us is that we saw a slow cooling down before temperatures really dropped. But definitely impacted our states to the north, hate to hear that. Erika, you had other business as well.

MS. BURGESS: I do, but on the cold stun event. We also had a fish kill in Florida related to it. To Rich's question, at first the fish sink, so depending upon water quality you can't image the fish well and get a reliable estimate. They eventually float, but sometimes things happen before they float. Predators take them away, opportunistically the wind can blow them away into different areas.

Just like in North Carolina, we rely on a fishery independent index to track the impact of a particular cold stun event, and we've been able to see them in our indices. It tracks really well. One, it gives us confidence that indices are tracking real abundance, and then thankfully we've observed each time that it's occurred, a strong rebounding in the following year. I hope that North Carolina sees the same thing for their population.

Regarding Florida's recent regulatory changes effective April 1st of 2024. We implemented holistic regional management for spotted sea trout. You may remember me talking about this before. We've implemented it for red fish and snook, sea trout is our third species. We've divided the state into 9 management areas, based on habitat types and water sheds.

On the east coast of Florida, we have 3 regions, the northeast, the central east and the southeast. Sorry, I said central east that is the old name, we have the Indian River Lagoon, it is that body. We did modify our sea trout regulations in two of those regions, based on observed declines in our stock assessment and reports from the public about lack of abundance of larger sea trout.

Our previous regulations allowed recreational anglers in the northeast to retain one fish over the slot limit per vessel or one per person if fishing from shore. We removed that allowance, so now anglers can only keep fish between the 15-to-19-inch slot

limit, and we reduced the northeast vessel limit from 5 fish per person to 3 fish per person.

In the Indian River Lagoon, the current bag limit is 2 fish per person, we left it at that level and we removed the ability to keep one fish over the slot, so same as the northeast. We've made more conservative regulations in response to observed declines in sea trout, and if you have any questions about this management approach, please let us know. We will be evaluating impacts of this past winter's cold weather later this year, and may recommend additional rule changes.

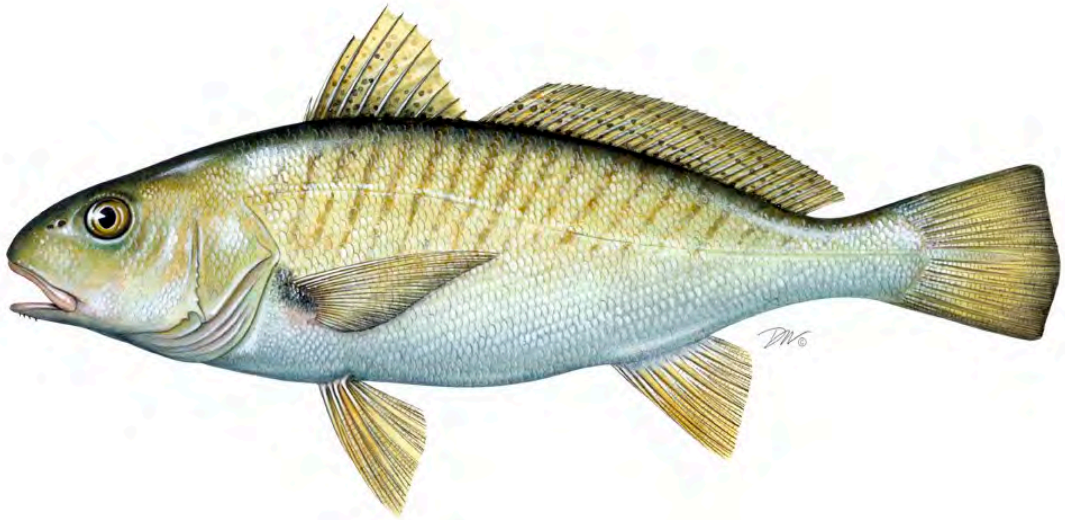
ADJOURNMENT

CHAIR DYAR: Any questions? Any other business to come before the Board? All right, seeing none; motion to adjourn. Spud, second Malcolm. All right, thank you very much.

(Whereupon the meeting adjourned at 10:45 a.m. on Wednesday, May 6, 2026)

Atlantic States Marine Fisheries Commission

Atlantic Croaker Benchmark Stock Assessment and Peer Review Report



For Consideration by the Sciaenids Management Board
November 9, 2026

Sustainable and Cooperative Management of Atlantic Coastal Fisheries

ACKNOWLEDGEMENTS

The Atlantic States Marine Fisheries Commission (ASMFC) thanks all of the individuals who contributed to the development of the 2026 Atlantic Croaker Benchmark Stock Assessment. The ASMFC specifically thanks members of the Atlantic Croaker Technical Committee (TC) and Atlantic Croaker Stock Assessment Subcommittee (SAS) who developed the consensus stock assessment report and ASMFC staff, Jeff Kipp and Tracey Bauer, for coordinating the assessment and completion of the report.

The TC and SAS would also like to acknowledge the following individuals for their support during the assessment: Anna-Mai Christmas-Svajdlenka (ACCSP) for validating and providing commercial landings data from partner agencies; Matt J. Walker, Richard Harrington, and Tanya Darden (SCDNR) for genetic data and analyses; Erik Williams (NOAA Fisheries) for sharing MRIP cumulative geographical catch data; Dennis Allen and Matt Kimball (University of South Carolina) and Ken Able and Thomas Grothues (Rutgers University) for sharing larval Atlantic croaker data; Alan Bianchi (NC DMF) for support splitting North Carolina fishery-dependent data by stock unit; Michael Lane (ODU) for providing Chesapeake Bay Benthic Monitoring Program data; Chris Stewart (NC DMF), Jeff Brunson (SC DNR), and Eddie Leonard (GA DNR) for expertise on the shrimp trawl fishery.

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PREFACE

The Atlantic Croaker Benchmark Stock Assessment and Peer Review Report is divided into two sections:

Section A – Atlantic Croaker Benchmark Stock Assessment Peer Review PDF pages 5-30

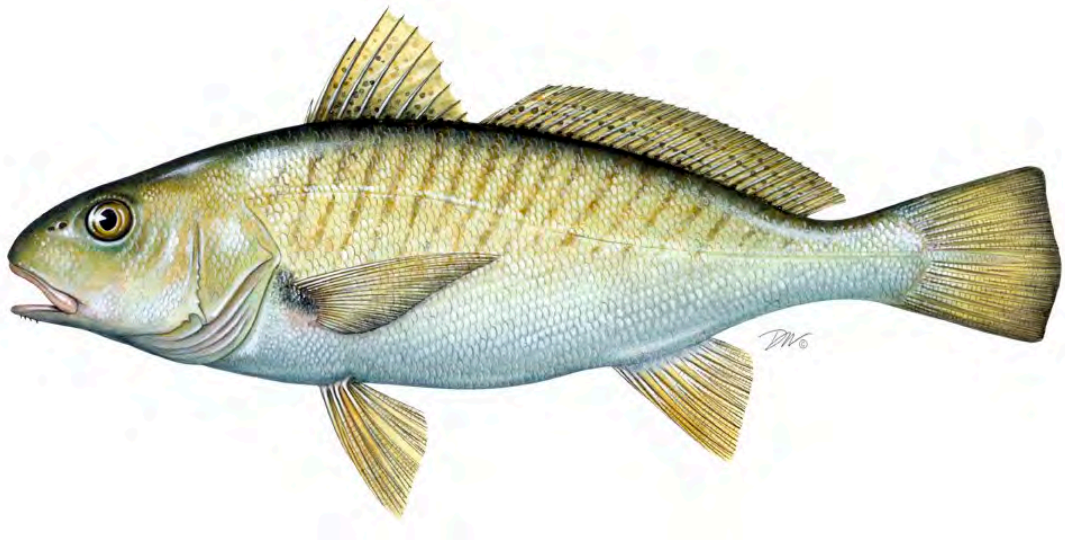
This section provides a summary of the Atlantic Croaker Benchmark Stock Assessment results from Section B supported by the Peer Review Panel. The Peer Review Terms of Reference Report provides a detailed evaluation of how each Term of Reference was addressed by the Atlantic Croaker Stock Assessment Subcommittee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

Section B – Atlantic Croaker Benchmark Stock Assessment PDF pages 31-446

This section is the Atlantic Croaker Benchmark Stock Assessment report that describes the background information, data used, and analyses for the assessment, and stock status determination submitted to the Peer Review Panel. This report begins with a Stock Assessment Terms of Reference Report which describes how the Atlantic Croaker Stock Assessment Subcommittee addressed each Term of Reference followed by the more detailed assessment report.

Atlantic States Marine Fisheries Commission

Atlantic Croaker Benchmark Stock Assessment Peer Review



Conducted on July 27-30, 2026
Arlington, VA

Prepared by the ASMFC Atlantic Croaker Stock Assessment Peer Review Panel

Dr. David Chagaris, Panel Chair, University of Florida
Dr. Shannon Calay, Southeast Fisheries Science Center, National Maine Fisheries Service, retired
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Sustainable and Cooperative Management of Atlantic Coastal Fisheries

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ACKNOWLEDGEMENTS

The Peer Review Panel appreciates the tremendous work by the Atlantic Croaker Stock Assessment Subcommittee (SAS) and Technical Committee to complete a comprehensive stock assessment. The Panel commends the team of scientists who presented at the Review Workshop meeting for the high quality of work, the clear documentation provided, as well as the open, constructive, and professional approach they took to discussions. The Panel thanks C.J. Carroll Schlick (South Carolina Department of Natural Resources & SAS Chair), Jeff Kipp (ASMFC), Trey Mace (Maryland Department of Natural Resources), Brooke Lowman (Virginia Marine Resources Commission), Samara Nehemiah (ASMFC), Tracey Bauer (ASMFC), and Harry Rickabaugh (Maryland Department of Natural Resources) for making the assessment review a valuable learning experience for all.

The Panel also thanks Patrick Campfield (ASMFC) for organizing the meeting, providing materials to the Review Panel in a timely fashion, and additional support throughout the review. The Review Workshop was conducted in Arlington, Virginia, from July 27-30, 2026. Overall, the stock assessment passes independent peer review.

EXECUTIVE SUMMARY

The review panel evaluated the 2026 Atlantic Croaker Benchmark Stock Assessment with respect to the assigned Terms of Reference. The panel concludes all Terms of Reference were satisfactorily completed using the best available scientific information and appropriate assessment methodologies. The benchmark constitutes a significant advance over previous Atlantic croaker assessments. The current benchmark addressed previous limitations by modeling Atlantic croaker as two separate stocks — northern and southern, divided near Cape Lookout, North Carolina — using independent, fully integrated Stock Synthesis (SS3) models. The panel concludes the assessment provides the best available scientific basis for management of both stocks. Remaining uncertainties are appropriately identified, and the panel's recommendations are intended to further strengthen future benchmark assessments.

Genetic evidence alone provided only weak support for separate stocks. However, the panel found the weight of evidence — parasite community composition, contrasting fishery-dependent and fishery-independent trends on either side of the boundary, regional differences in growth and maximum size, and consistent physical oceanography near Cape Hatteras/Cape Lookout — justified an operational two-stock boundary at the Carteret County, NC line. The panel agreed that the boundary is unlikely to represent a sharp biological divide and recommended continued genetic, tagging, and larval-transport research to better characterize connectivity and, eventually, support a spatially explicit two-area model.

The panel found the major fishery-dependent and fishery-independent data sources were appropriately considered and generally appropriately treated, including substantially improved estimation of shrimp trawl bycatch relative to prior assessments. Stock Synthesis was judged an appropriate modeling platform for both stocks, and model parameterization was generally consistent with current best practices in stock assessment. The panel reviewed the diagnostic outputs for each model and found the principal stock-status conclusions were robust to the alternative model configurations that converged. The southern model's diagnostics were notably cleaner (tighter jitter results, no meaningful retrospective pattern), while the northern model exhibited a genuine retrospective pattern (Mohn's rho = 1.66 for SSB) and greater sensitivity to starting parameter values. Both models also estimated unusually high initial (pre-1990) fishing mortality that reduces the initial age structure to roughly 1% of unfished biomass, followed by several years of positive recruitment deviations. Review workshop sensitivity runs testing alternative initial-condition assumptions did not materially change results. The panel recommends further investigation of this feature before the next benchmark.

Steepness in the stock-recruitment function was fixed at 0.99 in both base models. In the northern model, the data provided limited information for estimating steepness, while the southern model contained information supporting an estimated value around 0.53 that was judged implausible and therefore not used in the base model. Consequently, SPR-based reference points were used rather than MSY-based reference points, in response to a 2017 croaker assessment peer review recommendation. The panel supported a 25% SPR threshold, consistent with comparable benchmarks used for other Sciaenid species, with the specific

target left within a 35–45% SPR range for the Fishery Management Board to select based on risk tolerance and socio-economic objectives. The panel also supported the SAS's decision to define two separate fishing mortality reference points: one for all ages (including shrimp trawl bycatch of age-0 fish that falls outside ASMFC's jurisdiction) and one restricted to ages 1+ (the ASMFC-managed target fisheries). The distinction is necessary to determine whether corrective action, if needed, should focus on bycatch, targeted removals, or both.

The northern stock was found to be depleted and not currently experiencing overfishing. Spawning stock biomass fell below the SSB threshold in 2014 and has remained below it since, despite a modest increase in the most recent years. Fishing mortality on all ages (including shrimp trawl bycatch) exceeded its threshold for a longer period (2013–2019) than fishing mortality on ages 1+ alone (2016–2018), suggesting shrimp-trawl bycatch may have contributed to continued declines after the initial SSB decline. Reduced growth since approximately 2012 constrained the stock's capacity to rebuild toward historical biomass reference points. The panel accepted the assessment's terminal-year status determination as the best available basis for management, while recommending the bycatch-related history and the growth-dependence of the SSB reference point be clearly communicated to managers.

The southern stock was found to be not overfished and not experiencing overfishing. Spawning stock biomass increased steadily since 2012 and is at time-series highs, coincident with markedly improved recruitment since roughly 2010 and a sustained decline in fishing mortality, especially from a reduction in shrimp trawl bycatch mortality on age-0 fish. The panel found this determination robust across all tested sensitivity configurations.

The panel identified several priority areas for future research: the degree of mixing between the two stocks across the Cape Lookout transition zone; the assumption of constant natural mortality alongside documented time-varying growth in the northern stock; the unresolved rationale for the high initial fishing mortality estimates; and the time-varying catchability applied to the NEFSC survey. Continued investment in shrimp trawl observer coverage, recreational discard estimation and size/age sampling, and fishery-independent recruitment monitoring were also identified as high priorities.

The panel concluded that the 2026 benchmark assessment is well documented, technically sound, and responsive to prior peer-review recommendations. The assessment’s estimates of biomass, recruitment, fishing mortality, and SPR-based reference points should be adopted for management of both the northern and southern Atlantic croaker stocks.

TERMS OF REFERENCE

1. Evaluate the population structure defined and used by the assessment models.

The 2017 assessment used a single coastwide stock structure characterized by conflicting data trends that caused notable sensitivity to assumptions and degraded model performance. For these reasons, the previous assessment was not recommended for use in management. To address these limitations, the 2026 assessment team assembled multiple independent lines of evidence supporting an operational two-stock structure, separated near Cape Lookout, North Carolina. While the 2017 assessment relied primarily on limited genetic and otolith chemistry studies that supported a single coastwide stock, the current assessment incorporated additional genetic analyses, parasite assemblages, fishery-independent surveys, fishery-dependent catch trends, life history characteristics, and physical oceanography to re-evaluate stock structure.

The genetic evidence provided only weak support for stock separation. Reanalysis of microsatellite data collected from spawning-season fish identified a single genetic population as the statistically preferred solution, although comparisons of samples grouped north and south of Cape Lookout revealed weak but consistent genetic structure. Similarly, estimates of genetic differentiation (FST) were very small, suggesting substantial gene flow between regions. While genetics alone did not justify separate stocks, the weak differentiation indicates some spatial genetic structure despite substantial gene flow between regions.

Several other datasets provided stronger support for regional population structure. Parasite community composition differed systematically between northern and southern samples, suggesting a stock boundary near Cape Hatteras with a broad transition zone extending south to Cape Lookout. The team noted that seasonal patterns could shift the stock boundary within the transition zone, and concluded that parasite studies were compatible with an operational stock boundary near Cape Lookout.

The strongest support for a two-stock model came from the available fishery-dependent and fishery-independent data. During development of a single-stock assessment model, substantial conflicts were noted among regional abundance trends that prevented satisfactory model performance. Partitioning North Carolina data at the Carteret-Onslow County line resolved many data conflicts and improved interpretation of abundance and catch histories. For example, after data were partitioned, southern North Carolina abundance trends were correlated with South Atlantic states, whereas northern North Carolina trends resembled Mid-Atlantic populations. Similarly, commercial landings and recreational catches north and south of the boundary exhibited contrasting long-term trends, with northern North Carolina tracking northern states and southern North Carolina tracking southern states.

Life history characteristics also supported the two-stock operational model structure. Studies suggest that fish sampled north of Cape Lookout consistently exhibited faster growth, larger maximum sizes, and older ages than fish collected to the south. The differences were observed

across multiple monitoring programs and were particularly notable in the North Carolina Independent Gill Net Survey that sampled both regions using consistent methods, reducing the possibility that the observed differences are solely attributable to differences among sampling methods.

Finally, the assessment considered physical oceanography as a plausible mechanism for the underlying stock structure. The convergence of the Middle Atlantic Bight, the South Atlantic Bight and the Gulf Stream near Cape Hatteras/Cape Lookout creates a well-documented biogeographic boundary linked to stock structure in other marine species. Oceanographic features may influence both adult movement and larval transport, lending biological support for the demographic patterns observed in the survey and fisheries data.

Based on the evidence presented, the assessment team selected the Carteret County line (Cape Lookout) as the operational stock boundary. This location was supported by biological evidence and practical considerations. It coincided with the location at which SEAMAP trawl survey trends became uncorrelated and kept the Pamlico Sound estuarine system intact within a single stock unit. Furthermore, it also aligned with the finest spatial resolution available for the recreational and commercial catch data. **The review panel agreed that, although the Carteret/Onslow boundary is unlikely to represent a sharp biological divide and may vary over time, the weight of evidence supports its use as a practical and biologically defensible stock boundary for the current assessment.**

The review panel recommends continued research to refine understanding of Atlantic croaker stock structure and connectivity. Priority should be given to expanding genetics, tagging, otolith chemistry, and larval transport studies to better quantify movement between the northern and southern stocks and evaluate how connectivity varies across life stages. As additional data become available, future assessments should investigate spatially explicit two-area Stock Synthesis models that estimate age-dependent mixing across the stock boundary rather than assuming complete separation. Continued monitoring is also recommended to evaluate whether environmentally driven shifts in distribution alter the location of the transition zone or the degree of mixing between stocks.

2. **Evaluate the new information on life history and the influence of environmental change on life history characteristics as presented in the stock assessment.**

The review panel determined the Atlantic croaker life history data considered by the assessment team were comprehensive and adequate for the models and proper methodologies were used when analyzing the data. The review panel and assessment team also pointed out several data and knowledge gaps related to age and length sampling and environmental drivers of growth and natural mortality.

Atlantic Croaker growth dynamics exhibited notable regional and temporal variations within the stock assessment. The northern and southern stocks displayed distinct growth patterns from the beginning of the time series. Furthermore, the northern stock experienced a temporal shift in growth that was addressed by dividing the assessment into two separate time blocks (1990–

2011 and 2012–2024). Potential environmental and ecological drivers of the growth change were considered. No direct driver or mechanism could be identified from the available data. In the southern stock, growth curves relied on age-at-length data from the SEAMAP trawl survey that only sparsely sampled individuals exceeding 30 cm. Because the Florida recreational fishery regularly captures a significant component of fish larger than 30 cm that lacked age-at-length data, future assessments should prioritize collecting age and growth information from the Florida recreational sector.

Natural mortality (M) was estimated using the Hamel and Cope (2022) longevity-based equation widely accepted as a good practice for stock assessments. Natural mortality differed between the stocks, driven by differing assumptions regarding maximum longevity. M at age 2 (assumed fully selected by the fishery) was set using the Hamel and Cope longevity-based estimate, and age-specific M was calculated within Stock Synthesis using the Lorenzen relationship and model-estimated growth.

The stock assessment incorporated two separate maturity curves for the northern and southern stocks. The NEAMAP trawl survey provided data for the northern stock maturity curve, utilizing over 2,000 ovaries evaluated histologically within the spawning season to yield a length at 50% maturity of 17.1 cm centerline length. Similarly, the SEAMAP trawl survey provided data for the southern stock maturity curve, drawing upon over 2,000 ovaries evaluated histologically within the spawning season to determine a length at 50% maturity of 17.9 cm centerline length. Because both surveys encompassed extensive geographic regions of the Atlantic and relied on robust sample sizes of females collected during the spawning season, they provided appropriate, histologically validated maturity estimates for the stock assessment.

Environmental conditions were not quantitatively evaluated for effects on natural mortality, but compounding and persistent deleterious conditions should be evaluated in the future. Hypoxic conditions were noted in the stock assessment to have indirect, density dependent effects on juvenile survivorship, fecundity, and growth. Atlantic croaker from Delaware and Florida showed similar cold tolerance under the conditions examined. Lastly, juvenile growth and survivorship has been linked to salinity. There seems to be a need for an in-depth juvenile survivorship study in an estuary for the northern stock.

3. Evaluate the thoroughness of data collection and the presentation and treatment of fishery-dependent and fishery-independent data in the assessment.

The review panel agreed the available fishery-dependent and fishery-independent data were thoroughly considered, appropriately treated, and properly implemented in the assessment models. The review panel agreed with decisions made by the SAS to exclude certain datasets, or pool data from other strata (e.g. fleet, state, dispositions). Appropriate standardization techniques were used for each dataset to produce indices of abundance with measures of uncertainty. However, there remains a poor understanding of environmental linkages with Atlantic croaker.

a. Presentation of data source variance (e.g., standard errors)

Explicit measures of uncertainty were supplied with estimations of recreational landings, relative abundance standardization methods, and delta lognormal standardization of bycatch catch rates. The error estimates were appropriately converted into lognormal standard errors for inputs into Stock Synthesis. Small error estimates were chosen for the commercial landings inputs because they were obtained from census methods. Overall, the review panel approves of the error inputs to the stock assessment for each data source.

b. Justification for inclusion or elimination of available data sources

Table 32 in the assessment report lists 21 fishery independent surveys, of which 8 were included in the model. Reasons for exclusion of surveys included low percentage of positive tows, correlation with other indices, and unrepresentative sampling. All major sources of commercial data were included in the model, although some composition datasets were excluded where representativeness or sample-size limitations prevented their use. Assumptions were made in cases where data were lacking, for example by borrowing composition data or species ratios across fleets and/or states. The review panel found those assumptions to be reasonable given the data available. The panel noted that improvements were made to bycatch methodology, appropriate and contemporary standardization procedures were used, and decisions were clearly documented in the assessment report.

c. Consideration of data strengths and weaknesses (e.g., temporal and spatial scale, gear selectivity, aging accuracy, sample size)

Commercial landings were provided by the Atlantic Coastal Cooperative Statistics Program, except when discrepancies occurred between ACCSP records and data provided by state representative partners. When discrepancies occurred, state provided landings were used. Commercial landings data were collected through a combination of federal and state reporting programs that varied among states and years. Early portions of the time series relied on federal NOAA Fisheries surveys and dealer reporting programs, while all states within the management unit eventually transitioned to mandatory commercial reporting systems, including harvester reporting and trip ticket programs.

Scrap landings are landed fish that are unmarketable as food and typically sold as bait. “Scrap” is a subcategory of commercial landings unique to North Carolina and Virginia. The species composition of scrap landing subsamples was evaluated in North Carolina, and the resulting proportion of Atlantic Croaker was applied to all scrap landings in both states. Although “scrap” is only categorized in two states on the Atlantic Coast, it would be useful to explicitly state whether fish marketed as bait are included in the commercial landings of states outside of North Carolina and Virginia.

Commercial discard information was obtained from the NEFSC Observer Program for all states included in the northern stock unit. Unlike the 2017 assessment, analysts included trips from statistical areas from within the region where Atlantic Croaker were encountered, either

retained or discarded. This approach followed methods used in the ASMFC horseshoe crab stock assessment that improved discard estimates and reduced data sparsity and associated bias. The proportion of Atlantic Croaker in discards (53%) were calculated with discard species composition data collected from New York through North Carolina. Discard estimation methods and associated variance calculations followed Pollock et al. (1994) and were applied by gear type. Estimated discards were added directly to commercial landings to represent total removals, assuming a 100% discard mortality. Incorporating total removals into the assessment model reduces model complexity and has been used in other assessments when discards are relatively small and uncertain. Commercial removals were assigned a low relative standard error consistent with the census-based landings reporting. Additional uncertainty could be incorporated to account for variability in discard estimates, although estimated discards represented a relatively small component of total removals. Only two years (1992-1993) of estimated discards exceeded 150 metric tons, while landings remained above 4,000 metric tons throughout the assessment time series. Overall, the review panel agreed with the approach to include the small number of dead discards within the landings in order to stabilize the assessment model.

Shrimp bycatch was estimated using methods previously implemented in several other fisheries stock assessments. Estimates of Atlantic Croaker discards were derived by combining shrimp fishery effort, total discard estimates, and the proportion of Atlantic Croaker in the observed discards. Estimates were then incorporated into the assessment model using the Technical Committee recommended 95% discard mortality rate. Shrimp fishery effort was calculated as total net hours fished using the number of trips, average hours fished per trip, and average number of nets per vessel. The number of trips was obtained from state-specific records in the South Atlantic Shrimp System and Trip Ticket Programs. The average number of nets per vessel was obtained from the Southeast Fisheries Science Center Vessel Operating Units file, except for years in which state-generated data were available and substituted. Estimates of average hours fished per trip, total discards, and the proportion of Atlantic Croaker in the discards were provided by the NOAA Fisheries observer program during and after 2008. Before 2008, Atlantic Croaker catch rates from the SEAMAP bottom trawl survey were used to estimate discards. The assessment used a delta-lognormal method to standardize Atlantic Croaker discard rates. This approach followed methods previously applied in accepted SEDAR stock assessments, including SEDAR 17 (Spanish mackerel), and was consistent with recommendations outlined in the SEDAR Data Best Practices Final Report (SEDAR 2015). The review panel agreed the best available data were analyzed using methods previously applied in accepted stock assessments. The panel noted that future shrimp bycatch estimation would benefit from increased observer coverage and collecting more croaker length measurements.

Recreational landings and discards were primarily supplied by the Marine Recreational Information Program (MRIP). The methods of MRIP are well documented and have been routinely incorporated into fisheries stock assessments throughout the Atlantic region. For this assessment, the recreational landings were apportioned into regions using the Carteret County/Onslow County border, with the southern region further divided at the Georgia/Florida border. This separation was considered appropriate because of differences in selectivity

between Florida and the remaining southern region recreational fleets. Recreational discards were obtained from the Type B2 catch estimates generated by the MRIP survey. Dead discards were calculated using an assumed 15% discard mortality rate and were added directly to the recreational landings to calculate total removals. Future assessments would benefit from improved estimates of recreational discard mortality for Atlantic Croaker to reduce reliance on assumptions or expert opinions.

In the northern stock, both the commercial and recreational fleets had length composition data within the Stock Synthesis input files, while the commercial fleet also had age-at-length data. The ChesMMAP, NEFSC, and NEAMAP surveys all had length and age-at-length composition data. The North Carolina and VIMS YOY surveys were coded as recruitment abundance, that negated the need for any length or age information. The shrimp bycatch fleets in the northern and southern stocks had selectivity fixed at age 0 due to the inconsistent availability of length information from federal observer programs. The southern stock had length compositions from the recreational fleets from Florida to North Carolina, commercial fleets from Georgia to North Carolina, and both SEAMAP surveys. The only age information for the southern stock comes from the SEAMAP surveys. The review panel agreed that the best available length and age data were used in the assessment. However, future assessments would benefit from discard length compositions and age-at-length information from the recreational fisheries in the southern stock.

d. Calculation and/or standardization of abundance indices

The northern stock unit included adult measures of abundance from the NEAMAP, NEFSC trawl survey, and the ChesMMAP survey. There were also two measures of YOY abundance included in the stock assessment - the VIMS juvenile trawl survey and North Carolina Pamlico Sound Survey. All survey abundance models included either environmental or spatiotemporal predictor variables. The stock assessment analysts presented evidence of a shift in spatial patterns of abundance and temporal availability to the gear for the NEFSC trawl survey. The ChesMMAP and NEAMAP abundance patterns were more consistent with the other inshore indices than the NEFSC trend. However, the NEFSC trawl survey had the longest time series and a large amount of size and age information. In order to preserve the large amount of NEFSC trawl survey data, the NEFSC was included in the stock assessment with a random walk, time-varying catchability coefficient. The time-varying catchability parameter allowed the model to accommodate temporal changes in the relationship between the NEFSC survey and stock abundance and allowed a better fit to the ChesMMAP and NEAMAP surveys.

The southern stock unit included adult measures of abundance from the SEAMAP summer and fall surveys. There were also two measures of YOY abundance included in the southern stock assessment - the South Carolina and Georgia estuarine trawl surveys. All survey abundance models included either environmental or spatiotemporal predictor variables. The exclusion of the fall SEAMAP survey changed the selectivity of the summer SEAMAP survey, but not vice versa. Both SEAMAP surveys were retained in the base model to provide as much age-at-length

information as possible, as the SEAMAP surveys were the sole source of age-at-length information.

e. Consideration of the potential impacts of environmental change

While spatio-temporal information from the VAST standardization was beneficial in discovering the Atlantic Croaker offshore spatial shift in distribution, it would be beneficial to understand more about the environmental conditions that are drivers of Atlantic Croaker abundance. The standardization methods and estimations of abundance were appropriate and accepted for this assessment. However, there is a long multimodal landings history for the fishery that might be indicative of large swings in abundance. Most indices explicitly included environmental covariates in the standardization process, but not all (VAST, sdmTMB). When environmental covariates were not included, spatiotemporal random effects captured unmeasured spatial and temporal variation that may have included environmental effects. The SAS discussed potential environmental influences on availability of the species to different gears/surveys but none were directly included and remain unresolved (e.g. NEFSC). A historical tracking of environmental conditions in years of large landings values may prove useful. The panel and the SAS agreed there may be important environmental drivers influencing Atlantic croaker abundance and availability, and recommended further research in this area.

4. Evaluate the methods and models used to estimate population parameters (e.g., F, biomass, abundance) and biological reference points

The review panel found the assessment methods (models) used to estimate population parameters and reference points to be appropriate for Atlantic croaker and for providing management advice. In general, the analytical team adhered to best practices for Stock Synthesis, provided a suite of model diagnostics, and evaluated a range of candidate models prior to and during the workshop. Both models suffered from extremely high initial fishing mortality rate estimates that warrant further investigation. Concern was raised about decoupling of natural mortality from growth time blocks in the northern model.

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?

The assessment was conducted using the Stock Synthesis modeling platform (SS version 3.30). Separate age- and length-structured models were developed for the northern and southern Atlantic Croaker stocks after initial coastwide models failed to converge due to conflicting regional trends. Both models incorporated fishery-dependent and fishery-independent data, including commercial and recreational removals, shrimp trawl bycatch, survey indices, and length and age composition data. Regional growth was estimated using von Bertalanffy growth functions, while natural mortality, maturity, and the stock-recruit relationship were specified using externally derived and/or fixed parameter values, as the available data were deemed insufficient for reliable estimation. The Beverton-Holt stock recruitment steepness parameter was fixed at 0.99 for both stocks. The northern stock-recruit relationship could not provide a

robust estimate of steepness. In the southern stock, the steepness was estimable in a sensitivity run, but considered implausible and therefore fixed at 0.99. Spawning potential ratio (SPR) based reference points were adopted because the stock-recruit relationship could not be reliably estimated. Model performance was evaluated using a comprehensive set of routine model diagnostics (see TOR 5).

The review panel concluded the Stock Synthesis framework was an appropriate choice for assessing Atlantic croaker as two separate stocks given the available data and life history of the species. The decision to model separate northern and southern stocks was adequately justified and represented an improvement over previous coastwide models that failed to adequately reconcile conflicting model trends. The preferred models provided a biologically reasonable representation of the available fishery-dependent and fishery-independent data and supported estimation of key parameters and management quantities, including abundance, spawning biomass, fishing mortality and SPR-based reference points. Although the current assessment assumes complete biological separation of the two stocks, the panel noted that future assessments should consider a spatially explicit two-area model once sufficient information becomes available to estimate movement and age-dependent mixing between regions.

b. If multiple models were considered, evaluate the analysts' explanation of any differences in results.

The assessment team explored numerous Stock Synthesis model configurations before and during the review workshop, and clearly documented the rationale for selecting the preferred candidate models. **The review panel found that differences among candidate models were adequately evaluated and explained, and agreed the candidate base models were appropriate to inform management.**

The assessment team also presented an updated Traffic Light Analysis (TLA) to the review panel. The TLA produced conclusions that were generally consistent with the integrated model. Therefore, the review panel agreed the TLA could provide useful supplementary information and recommended placing greater emphasis on fishery-independent abundance trends than fishery-dependent catch trends that can be influenced by changes in fishing behavior and availability. The panel further recommended that the TLA or any future index-based management procedure be formally evaluated through Management Strategy Evaluation (MSE) to evaluate its performance under a range of plausible population and fishery conditions. Lacking a fully MSE-vetted management procedure, the review panel recommended suspending the TLA, and using the results of the 2026 stock assessment to inform management.

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).

Overall, the review panel agreed that model parameterization was appropriate and consistent with current stock assessment best practices. Nevertheless, the panel identified three areas that warrant additional investigation in future assessments.

First, the interaction between time-varying growth and the natural mortality formulation should be re-examined. Because age-specific natural mortality is calculated using the Lorenzen relationship and model-estimated growth, changes in growth alter the implied M-at-age schedule. Future assessments should evaluate whether the relationship between M and growth should also vary through time. The panel also noted the annual time-step model may not adequately characterize croaker's prolonged spawning season and associated variability in growth. The panel recommended that future assessments investigate seasonal model structures with multiple settlement/recruitment pulses (e.g. growth platoons) to better represent the prolonged spawning season and its implications for size-at-age data. These approaches may provide a more biologically realistic alternative to the current implementation of time-varying growth within an annual model framework.

Second, further investigation of initial conditions is recommended. The northern model estimated unusually high initial fishing mortality rates to drive the age structure down to 1% of virgin. Then, five straight years of high recruitment are estimated, coincident with a rapid increase in estimated biomass during the early 1990s. Spawning biomass then exceeded the unfished condition briefly during the late 1990s. The review panel and the SAS discussed the interpretation of the high initial F estimates. Typically, initial F is defined as the average fishing mortality experienced prior to the model start year. However, because the model begins in 1990 when the population size was low, the initial F necessarily absorbed any processes of mortality or recruitment to fit the data in 1990. Sensitivity runs were conducted during the workshop to test alternative initial catch inputs and F bounds, and they produced similar results to the base model run.

Finally, the justification for implementing a random-walk catchability parameter (q) for the Northeast Fisheries Science Center (NEFSC) survey should be strengthened through further investigation of potential changes in survey catchability and/or stock availability over time. Addressing these issues will improve confidence in future model configurations while building on an assessment framework the panel considered scientifically sound.

5. Evaluate the diagnostic analyses performed

Both regional stock assessments used the same suite of standard Stock Synthesis (SS) diagnostics, including convergence checks, assessment of parameter correlation, jitter analysis, likelihood profiling, retrospective analyses, and sensitivity runs. Both models performed adequately under the diagnostic tests. The southern model generally showed cleaner

diagnostics, while the northern model exhibited a significant retrospective pattern and greater sensitivity to starting values. **Overall, the review panel found the model diagnostics and sensitivity analyses were appropriately and sufficiently conducted, and the results demonstrated model stability across a range of plausible configurations.**

Northern Model

In the northern stock model, 58 parameters + 71 deviations were estimated, the max gradient was 3.07×10^{-4}, the Hessian was positive definite, no parameters were within 1% of bounds, and no parameter pairs were correlated above the |0.95| threshold. Parameter correlations were not described in the report for the northern model, but were available in the Stock Synthesis report files provided by the analytical team. The growth K and Lmax were negatively correlated as expected (-0.935), and the initial F for the shrimp bycatch fleet was moderately correlated with unfished recruitment (0.544) and other fleets' initial F (-0.729 rec, -0.472 commercial). There was a notable correlation pattern between shrimp bycatch F and recruitment deviations in the same year (ranging from 0.465-0.854). This is consistent with the difficulty in simultaneously fitting the recruitment indices and bycatch fleet.

The jitter analysis for the northern model found that 158 of 200 runs matched the base likelihood within 2 units, with 42 converging on worse (larger) likelihoods than the base run. Results suggested the base model was "somewhat sensitive" to starting values.

Likelihood profiles were conducted for unfished recruitment (R0), steepness, and deviation magnitude (σR). R0 was profiled from 12.8–15.1, and the minimum likelihood occurred at the base estimate of 13.61, with length/age data broadly consistent with total likelihood but discard and recruitment-index data uninformative of an upper bound. The steepness profile was broadly monotonic and linearly declining towards a value 1.0. However, the minimum likelihood occurred at values between 0.9 and 1.0, suggesting that steepness slightly less than 0.99 may be considered in the northern model. The profile of σR was noisy, but the minimum was estimated for a range of values from about 0.77-0.85, that contains the value used in the base run.

A retrospective pattern was evident in the northern model in the earliest peels (2018 and 2019), with Mohn's rho = 1.66 for SSB (overestimated) and −0.33 for F (underestimated) that were outside the Hurtado-Ferro et al. (2015) rule-of-thumb bounds. This was potentially associated with growth-block assumptions and data weights based on improved retrospective patterns in sensitivity runs that included a start year of 2008, a later breakpoint in growth, and reweighted data.

Nineteen sensitivity runs were conducted for the northern model to test alternative assumptions about weighting of composition data, natural mortality, growth block timing, start years, landings uncertainty, index weights and inclusions, discard uncertainty, and selectivity. Overall, the model trends were fairly robust to nearly all of the changes, with largest effects on the population scale (not trend) for M +/- 25% and dropping YOY indices. The remaining sensitivity trials mostly converged to a tight band around the base run from about 2010

onwards. An additional suite of sensitivity runs was conducted during the review workshop, as requested by the review panel, to address concerns about initial conditions estimates, explore behavior when natural mortality change with the growth block, and inclusion/exclusion of the NEFSC trawl survey. The model was robust to initial condition settings (input initial catch and initial F bounds) while the time-varying M scenario did not converge and produced a population size approximately 4x the base.

Southern Model

The base model for the southern region estimated 135 parameters and 40 deviations, had a max gradient of 8.71×10^{-5}, the Hessian was positive definite, no parameter pairs exceeded the 0.95 correlation threshold, and no parameters were estimated at their bounds. Parameters with high correlation values included strong year-to-year autocorrelation among annual Fs within a fleet, as well as expected structural correlations between some selectivity parameters.

There was a strong residual pattern in the fits to mean age for the SEAMAP summer and fall surveys. This was due to simultaneous overprediction of age-at-length in the fall survey, and underprediction of age-at-length in the summer survey CAAL data. The pattern was further evaluated during the review workshop through sensitivity runs.

The jitter analysis for the southern region model found that 186 of 200 runs matched the base likelihood. Only 14 found alternative solutions, all worse than the base model. This indicated the base model was insensitive to initial parameter values. No alternative solutions were found with a lower likelihood and the model converged to the same solution.

Unfished recruitment was profiled over a range of 10-16, and the minimum likelihood occurred at the base estimate of 12.9. The profile over the recruitment deviation parameter (σR) demonstrated the minimum likelihood occurs at the input fixed value of 0.55. Steepness was also profiled between values of 0.25-1.0 with a minimum value at around h=0.55 (where h=0.99 in the base run). This indicates there was enough data in the southern stock model to support estimating steepness and the stock-recruitment relationship. A sensitivity run with steepness estimated was presented, and it estimated a larger (higher unfished SSB), less productive stock, but did not have an effect on stock status determination. The base run used a fixed steepness of 0.99 because the estimated value of 0.53 was determined to be implausible given other estimates of steepness (Myers et al. 2003, Munyandorero 2020) and the expected resiliency of the species.

The southern stock model showed no retrospective pattern across a 6-year peel, with Mohn's rho = 0.139 (SSB) and −0.101 (F).

Fourteen sensitivity runs were presented for the southern stock model, plus an additional three sensitivities requested by the panel during the workshop. The various scenarios evaluated inclusion/exclusion of various data series, adjustments to shrimp trawl bycatch estimates, natural mortality, start year, steepness, and initial conditions. While there was some spread in the terminal year estimates across the sensitivity runs, most of the confidence intervals

overlapped considerably. The model was found to be quite sensitive to whether or not the SEAMAP fall, summer, or both surveys were included, as this was having an effect on growth estimates and fits to CAAL data. Overall, the panel found the southern model estimates of terminal-year stock status were robust across all plausible sensitivity configurations.

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

Uncertainty in estimated parameters for both models was measured with asymptotic standard errors that are obtained by inverting the Hessian at the converged solution and using the covariance matrix to propagate the uncertainty to every derived quantity. This is standard output for Stock Synthesis models.

For the northern model, the uncertainty measures were fairly tight around the estimates, with SSB_{2024} CV=0.099, F_{2024} CV=0.108, and SPR_{2024} CV=0.055. In the southern region the CVs were a bit larger, with SSB_{2024} CV=0.15, F_{2024}=0.312, and SPR_{2024}=0.134. The larger CVs indicated greater statistical uncertainty in the southern terminal-year estimates. This result was consistent with the documented conflicts among some southern data sources. In both regions, probability distributions on key derived quantities and estimated parameters were provided.

The review panel agreed the analytical team satisfied the term of reference by providing asymptotic standard errors, posterior distributions, and a range of structural uncertainty diagnostics, including sensitivity analyses, likelihood profiles, jitter analyses, and retrospective analyses. However, the true uncertainty was likely much larger in both regions as measures of uncertainty are conditional on the assumed model structure that includes M, steepness, growth time blocks, and selectivity functions that are all assumed to be known. The sensitivity runs and retrospective analyses provided evidence that structural uncertainty exists and remains unquantified.

The panel recommends continued development of uncertainty characterization such as bootstrapping and Monte Carlo procedures, as needed for management. The panel also recommends the uncertainty around stock status and benchmark measures be adequately portrayed in tables and phase plots.

7. 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.

Not applicable, no minority report was provided.

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

Northern Stock

The review panel agreed the assessment of the northern stock provided the best available estimates of stock biomass, abundance, and exploitation for use in management. The northern Stock Synthesis model demonstrated acceptable statistical performance, with acceptable fits to commercial and recreational removals, length composition data, and most survey indices. The principal data conflicts involved the age-0 recruitment surveys and shrimp bycatch estimates. It was not possible to fit both recruitment surveys closely because they provided conflicting signals regarding juvenile abundance in recent years. Similarly, the NEFSC survey exhibited trends that conflicted with other abundance indices and required annual time-varying catchability parameters to allow for possible changes in fish availability over time. Despite the conflicts, the panel concluded the model adequately represented the available data and produced robust estimates of stock status.

The assessment estimated that the northern Atlantic croaker stock abundance increased during the 1990s, peaked in 1993, and then declined steadily for more than two decades before stabilizing at approximately 10% of its peak abundance during the late 2010s. Model estimates suggested a modest increase in abundance during the final two years of the time series, coincident with above-average recruitment and reduced fishing mortality. Recruitment was highly variable during the early portion of the time series but generally declined through the 2000s, with a prolonged period of below average recruitment from 2013-2022. According to the model, recruitment increased in the most recent years, although it remained uncertain whether this represented the beginning of stock rebuilding. The panel expressed concern that recruitment in the most recent years was generally poorly estimated, and noted that in some stock assessment models, recruitment estimates are constrained to match the spawner-recruit relationship, in order to avoid creating unsupported stock biomass in projections.

Spawning stock biomass exhibited a similar trajectory. Biomass increased rapidly during the early 1990s, and reached its highest estimated level in 1996. Thereafter, spawning biomass decreased sharply throughout the 2000s, and more gradually through the 2010s, falling below the $SSB_{SPR25\%}$ threshold in 2014. Relative spawning biomass reached its lowest levels around 2018 and has remained well below the threshold despite slight increases in recent years. The delayed recovery in SSB coincided with the lower growth assumed since 2012. These estimates supported the conclusion that the northern stock remains depleted, despite recent indications of improving productivity.

Estimated fishing mortality was high at the beginning of the time series, declined to relatively low levels during the mid-1990s, and then increased steadily from the mid-2000s through the mid-2010s. Fishing mortality exceeded the $F_{SPR25\%}$ threshold for age-0 fish from 2013-2019 and for ages 1+ from 2016-2018 before declining below both thresholds in recent years. Shrimp trawl bycatch accounted for the majority of removals in numbers of fish. However, the commercial, recreational, and bycatch fleets contributed similarly to the total fishing mortality because the

shrimp trawl fishery primarily removes age-0 fish. The recent decline in fishing mortality was accompanied by increasing spawning potential ratio, and modest improvements in recruitment and stock biomass, suggesting conditions may now be more favorable for rebuilding if recruitment remains above average.

Southern Stock

The review panel agreed the assessment of the southern stock provided the best available estimates of stock biomass, abundance, and exploitation for use in management. The southern Stock Synthesis model demonstrated acceptable statistical performance, converging successfully with a positive definite Hessian matrix, no estimated parameters on bounds, and no highly correlated parameter estimates. Overall, the model provided acceptable fits to commercial and recreational removals, length composition data, and most survey indices. The principal model deficiency involved conflicting conditional age-at-length information from the SEAMAP Summer and Fall surveys. Although the model could not simultaneously fit both datasets well, sensitivity analyses demonstrated that excluding either dataset did not alter the primary assessment results or stock status determination. Consequently, the panel agreed that retaining both datasets in the base model was appropriate.

The southern assessment estimated relatively low and stable abundance throughout the 1990s and early 2000s, followed by a period of sustained population growth beginning around 2008. Total population abundance increased to 1.7 billion fish by 2020 and has remained at historically high levels through the terminal years of the assessment. Recruitment was generally low during the first half of the time series and steadily increased after 2010, reaching its highest estimated levels around 2020 and remaining relatively high thereafter. These trends are consistent with a substantial improvement in estimated recruitment and stock abundance during the past decade.

Spawning stock biomass exhibited a similar pattern. Biomass remained relatively stable at low levels through 2010 before increasing steadily, exceeding the $SSB_{SPR25\%}$ threshold in 2012 and continuing to rise throughout the remainder of the time series. Terminal SSB was estimated to be the highest in the time series, consistent with the assessment's determination that the southern stock is not overfished and has substantial spawning biomass.

Fishing mortality declined consistently throughout the assessment time series. Although the shrimp trawl bycatch accounted for the highest fishing mortality during the early 1990s, fishing mortality from all fleets has decreased over time, with the most pronounced reductions occurring in shrimp trawl bycatch of age-0 fish. Total fishing mortality on age-0 to age-3 fish has declined from approximately 0.31 yr^{-1} during the early 1990s to approximately 0.06 yr^{-1} during the most recent five years. Over the same period, SPR increased. The panel agreed the trends suggested a relationship between reduced fishing pressure and the rebuilding of the southern stock.

The panel also noted shrimp trawl bycatch remains an important component of southern stock dynamics. Fishing mortality on age-0 fish exceeded threshold levels during the early portion of

the assessment, while fishing mortality on older fish remained below the threshold, suggesting that juvenile bycatch may have contributed to the historically low spawning biomass. As shrimp trawl mortality declined, spawning biomass increased steadily above the management threshold. Although uncertainty remains in historical discard estimates, sensitivity analyses demonstrated that alternative assumptions regarding shrimp trawl bycatch did not change the assessment's conclusions regarding stock status.

9. 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.

Reference points for Atlantic croaker were based on the spawning potential ratio (SPR) because the stock-recruit relationship did not provide a sufficiently robust basis for MSY-based reference points. The move away from MSY-based reference points used in previous assessments was justified and was also a recommendation made by the 2017 stock assessment peer review. The SAS recommended an SPR of 25% as the threshold and a target in the range of 35–45% SPR, with the specific target to be selected by the Fishery Management Board. Both are valid choices that are comparable to MSY proxies for other Sciaenid species (red drum, spotted seatrout). Atlantic croaker's early maturation, batch spawning, and high fecundity were cited as evidence of high resilience and justification for a lower SPR threshold. **The review panel supported the decision by the SAS to use SPR of 25% and 35-45% for the threshold and target reference points, respectively.** The SAS and review panel also acknowledged that managers could adopt higher SPR reference points (35-45%) to be more precautionary. The fishing mortality rate leading to SPR 25% and 40%, and resulting spawning stock biomass (SSB) under those F rates were generated using the standard Stock Synthesis equilibrium per recruit analysis.

Two separate F-based thresholds were defined for Atlantic croaker depending on the inclusion of age-0 fishing mortality from the shrimp trawl bycatch fleet. The $F_{A1_SPR25\%}$ is the fishing mortality on ages 1+ that achieves an SPR of 25%, and the $F_{A0_SPR25\%}$ is the fishing mortality on all ages (including F on age-0 from shrimp trawl bycatch). The default setting for Stock Synthesis was to compute F on the basis of ages 1+ (excluding age-0 bycatch fleet F). The SAS split the F reference points to determine whether total removals, including untargeted bycatch, are keeping the population above 25% and whether the fisheries under ASMFC jurisdiction are, on their own, keeping the stock above that same 25% SPR benchmark. **The review panel supported the decision by the SAS to provide two F-based reference points because it informs whether or not to reduce shrimp trawl bycatch, targeted fishery removals, or both.**

Northern model - depleted and not experiencing overfishing

The northern stock was found to be depleted ($SSB/SSB_{SPR25\%} < 1$) but not experiencing overfishing (both $F_{A0}/F_{A0_SPR25\%}$ and $F_{A1}/F_{A1_SPR25\%} << 1$). This status determination was robust across the sensitivity runs. The term "depleted" rather than "overfished" was used because SSB declined much more rapidly from 2000-2014 than the gradual increase in F over the same time period. SSB fell below the threshold in 2014, which was a few years before F_{A1} exceeded the

threshold (2017-2019). The SAS used that evidence to claim that something other than fishing mortality (e.g., environmental driver) may have contributed to the initial decline in SSB. However, the high F_{A0} beginning in 2013 suggests that shrimp trawl bycatch led to further declines from 2015 onwards. **The review panel accepts the assessment's determination that the northern stock is depleted and is not currently experiencing overfishing, while also recognizing historical fishing mortality exceeded the F25% threshold during portions of the time series. While fishing mortality rates in the most recent years are below the threshold, spawning stock biomass has not recovered, due to slower growth, keeping the stock in a depleted state.**

Because the northern model included time-varying growth, the SSB benchmark and stock status (SSB ratio) was dependent on which growth function was assumed (early, late, or average over all years) for the equilibrium benchmark projections. The SSB benchmark was higher when the early period fast growth pattern (larger size-at-age) was assumed, and lower when the late period slow growth pattern was used. Therefore, under the current growth regime, it will be difficult, if not impossible, to achieve SSB targets that were based on larger sizes-at-age from the early period. The SAS should clearly convey this to managers by presenting the SSB ratios relative to benchmarks from each of the three periods (early, late, and all years). For projections, and general management advice, assumptions must be made about whether or not the low-growth period will persist into the future.

Southern model - not overfished, not experiencing overfishing

The southern stock was found to be not overfished ($SSB/SSB_{SPR25\%} > 1$) since 2013, with SSB on an upward trajectory since then, tracking the SEAMAP survey indices. The southern stock was also not experiencing overfishing ($F/F_{SPR25\%} < 1$) by both measures since 2010, although recreational landings have increased. The status finding was robust across all plausible sensitivity runs. **The review panel accepts the finding the southern stock is not overfished and overfishing is not occurring.**

10. Review the research, data collection, and assessment methodology recommendations provided by the SAS and 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.

The review panel agreed with all research recommendations from the stock assessment report. In addition, the panel emphasized the following research areas as high priority for the next stock assessment:

- The northern stock experienced a documented shift in growth trajectory. Because the age-specific natural mortality schedule is linked to growth through the Lorenzen formulation, future assessments should evaluate whether changes in growth warrant corresponding changes in the natural-mortality schedule. Consequently, the model convergence issues encountered when attempting to incorporate a second

time-block of natural mortality warrant further investigation prior to the next benchmark stock assessment (short-term).

- Increase discard information for the shrimp trawl fishery, particularly more robust/higher intensity observer coverage, mortality rates of discarded individuals, and size/age composition of discarded Atlantic croaker. Shrimp fishery discards are the largest source of removals for this species, particularly in the southern stock. Properly characterizing and accurately estimating it are essential for future assessment advancements (ongoing).
- Future assessments should examine potential seasonal models that allow for multiple YOY settlements during the year. Data are needed to characterize the proportion of annual recruitment that occurs at the beginning of each modeled time step (season) within the year. This could better accommodate prolonged spawning, particularly in the southern stock, that may be causing issues with estimating size at age within the model (short-term).
- Investigate drivers of observed growth changes in the northern stock. Identification of drivers would allow for inclusion of covariates in future models and help refine the reference points (short-term).
- Increase length and age data collection from recreational fisheries, with an emphasis on discarded fish, and conduct studies to estimate recreational discard mortality. This would allow for better estimation of selectivity curves, particularly for discards (ongoing).
- Initiate a sampling program in Virginia and increase sampling in North Carolina to quantify and biologically characterize commercial bait and scrap fishery catches. Composition of the catches, including proportion of Atlantic croaker, are not currently well defined, nor is the length composition of the catch (ongoing).

Other Additional Recommendations:

- Consider a tagging study to estimate natural and/or fishing mortality as a verification of assessment model estimates. Studies should consider seasonal time steps to differentiate summer mortality from mortality in overwintering areas (long-term).
- Use tagging studies to gain insight on Atlantic croaker movement in and out of estuaries as well as latitudinally in overwintering ocean habitats, to understand mixing across the stock boundary in central North Carolina (long-term due to potential interannual variation in movement dynamics).
- Conduct studies to determine the impacts of reduced estuarine habitat use on stock productivity (long-term).

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

The panel agreed with the SAS recommendation for an updated assessment every 3 years (2029) and benchmark assessment every 6 years (2032).

ADVISORY REPORT

Status of the Stocks

The panel agreed the assessment provided the best available scientific estimates of stock status for management of Atlantic croaker, indicating the northern stock was depleted but not experiencing overfishing, while the southern stock was not overfished and not experiencing overfishing.

Stock Identification

The panel concluded multiple independent lines of evidence provided sufficient support for the current two-stock assessment framework, while acknowledging uncertainty remains regarding the extent of mixing across the Cape Lookout transition zone.

Data and Assessment

The panel concluded the available fishery-dependent and fishery-independent data were sufficient to support integrated age-structured assessments for both stocks. However, important uncertainties remain regarding stock connectivity, shrimp trawl bycatch, and environmental drivers of productivity. The panel recognized that some conflicts among data sources remained, particularly involving juvenile abundance indices, shrimp trawl bycatch, and the Northeast Fisheries Science Center survey. The panel concluded the conflicts were appropriately addressed within the assessment framework and did not materially affect the principal conclusions.

The review panel concluded the Stock Synthesis framework provided an appropriate and scientifically defensible basis for assessing Atlantic croaker and represented a substantial improvement over previous coastwide assessments through the use of separate northern and southern stock models. The panel found that both Stock Synthesis models converged successfully, met the principal numerical convergence criteria, and produced robust estimates of stock status that were generally insensitive to plausible alternative model configurations examined during sensitivity analyses. Although the assessment was considered suitable for management, the panel identified several structural uncertainties, including: time-varying growth, the formulation linking natural mortality to growth, survey catchability, initial conditions, and stock mixing. Each uncertainty should be investigated in future assessments. The issues were not sufficient to alter the current management advice.

Biological Reference Points

The panel agreed SPR-based biological reference points were appropriate for the assessment because the stock-recruitment relationship could not be estimated reliably. The use of an $F_{SPR25\%}$ threshold and $SSB_{SPR25\%}$ biomass threshold provided biologically defensible management benchmarks for Atlantic croaker. Managers may wish to consider a target SPR in the 35-45% range, to appropriately recognize that target reference points should reflect management objectives, uncertainty, and risk tolerance, in addition to stock productivity.

Fishing Mortality

The panel concluded the fishing mortality estimates adequately characterized the principal sources of mortality affecting Atlantic croaker, including directed fisheries and shrimp trawl bycatch. Although uncertainty remained in historical estimates of shrimp trawl discards, sensitivity analyses indicated the uncertainty did not alter the assessment's conclusions regarding stock status.

The panel cautioned that fishing mortality may not be entirely independent of stock abundance. Strong year classes could attract increased fishing effort as they recruit to the fishery, resulting in a lagged increase in fishing mortality that follows the movement of large cohorts through the population. This dynamic may partially explain the observed timing of increases in fishing mortality relative to changes in spawning biomass and should be considered in future investigations of stock productivity and harvest dynamics.

Recruitment

The review panel concluded the assessment provides the best available scientific estimates of annual recruitment. The estimated recruitment trends were internally consistent and informed by the available fishery-independent indices, although those indices are not fully concordant. Recruitment remains one of the more uncertain model outputs because the stock-recruitment relationship could not be estimated directly (northern stock), or produced implausible estimates (southern stock). Therefore, steepness in the stock-recruitment relationship was fixed at 0.99 for both stocks. The panel agreed this approach was appropriate given the available data. The panel noted recruitment is a primary driver of future stock dynamics and projections, and therefore represents a key source of uncertainty in the assessment. Continued monitoring and maintenance of fishery-independent recruitment indices are warranted, to improve future assessments, and reduce uncertainty in estimates of stock productivity and rebuilding potential.

Spawning Stock Biomass

The review panel concluded the spawning stock biomass estimates were well supported by the integrated assessment model and associated data and provided an appropriate basis for evaluating stock status. However, the panel noted SSB estimates remain dependent on

assumptions regarding growth, natural mortality, and recruitment dynamics, emphasizing the importance of continued research to reduce uncertainty in these key biological processes.

Bycatch

The panel concluded that improved estimation of shrimp trawl bycatch is a notable strength of the current assessment because it better characterizes an important source of juvenile mortality. Continued investment in observer programs and improved bycatch estimation methods will reduce uncertainty in future assessments and strengthen management advice.

Overall Panel Conclusion

The review panel concluded the benchmark assessment represents a substantial advancement over previous Atlantic croaker assessments. The use of separate northern and southern Stock Synthesis models resolved many of the conflicting regional trends that prevented convergence in earlier coastwide assessments and provided a scientifically defensible framework for estimating stock status and supporting management. The panel agreed the assessment was well documented, technically rigorous, and responsive to previous peer review recommendations.

The panel found the available fishery-dependent and fishery-independent data were sufficient to support integrated age-structured assessments for both stocks. The assessment appropriately synthesized multiple independent sources of information to define separate northern and southern stock units, adopted biologically appropriate SPR-based reference points, and incorporated improved estimates of shrimp trawl bycatch, resulting in a more complete characterization of fishing mortality than previous assessments. Model diagnostics, sensitivity analyses, and retrospective analyses demonstrated the principal stock status conclusions were robust to alternative model configurations.

The panel concurred with the assessment's conclusions regarding stock status. The northern stock was determined to be **depleted but not experiencing overfishing**, whereas the southern stock was determined to be **not overfished and not experiencing overfishing**. The panel agreed the status conclusions represent the best available scientific advice for management and the estimated biomass, abundance, recruitment, spawning stock biomass, fishing mortality, and SPR-based biological reference points should be adopted for management purposes.

Although the panel endorsed the assessment, several important sources of uncertainty remain. They include the degree of mixing between the northern and southern stocks, the formulation of natural mortality in conjunction with time-varying growth, high initial fishing mortality rates, uncertainty in recruitment dynamics and environmental drivers of productivity, the implementation of time-varying catchability for the NEFSC survey, and historical estimates of shrimp trawl bycatch. The panel concluded the uncertainties were appropriately acknowledged and explored within the assessment and were not sufficient to alter the assessment's principal conclusions or management advice.

The panel recommended continued investment in stock identification research, fishery-independent recruitment monitoring, observer programs to improve estimation of shrimp trawl bycatch, and investigations of environmental influences on growth, recruitment, and natural mortality. Future assessments should evaluate spatially explicit models to account for stock mixing, as well as seasonal model structures to represent multiple recruitment pulses associated with the prolonged spawning season. Alternative growth formulations, including growth platoons if supported by the data, could also be evaluated to represent observed temporal changes in growth. These improvements are expected to further strengthen future assessments, while building on an assessment framework the panel considers scientifically sound and appropriate for management.

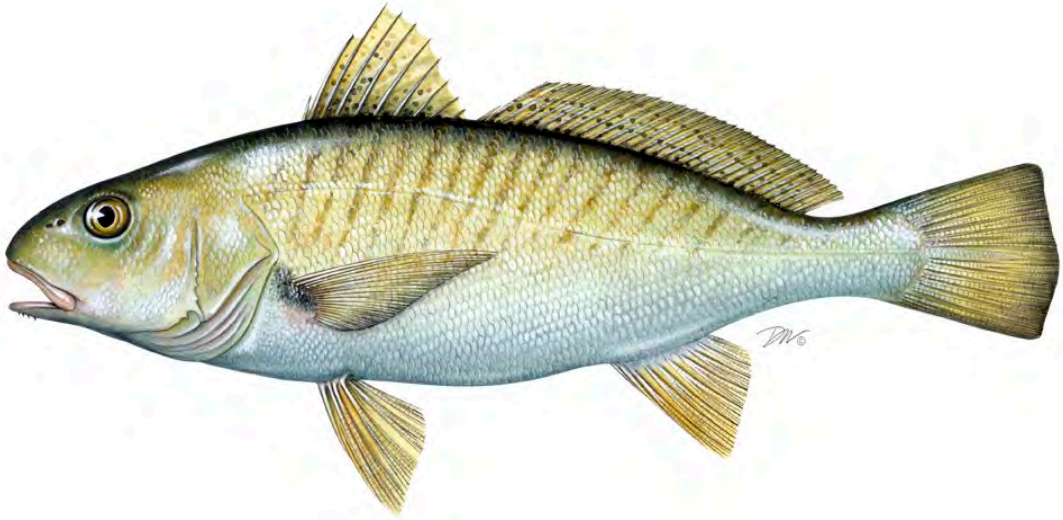
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Atlantic States Marine Fisheries Commission

2026 Atlantic Croaker Benchmark Stock Assessment



Prepared by the
Atlantic Croaker Stock Assessment Subcommittee

And

Approved by the Atlantic Croaker Technical Committee
June 5, 2026

Sustainable and Cooperative Management of Atlantic Coastal Fisheries

EXECUTIVE SUMMARY

The Atlantic croaker management unit is the Atlantic coast distribution of the species from New Jersey through Florida. Previous stock assessments were completed in 2005, 2010, and 2017. However, the 2017 assessment was not accepted for management advice and a Traffic Light Analysis (TLA) has been used in place of assessment advice in recent years. In 2020, the TLA triggered coastwide management measures at the 30% level, or moderate concern. Non-*de minimis* states were required to implement management measures that instituted a 50 fish recreational bag limit and reduced the commercial harvest by 1% of the average state commercial harvest from the previous 10 years, representing the first management measures required by ASMFC for this species.

This current assessment evaluated the Atlantic coast population as two separate stocks, a northern stock from Carteret County, North Carolina and north, and a southern stock south of Carteret County, North Carolina. The stock boundary aligns closely with Cape Lookout, North Carolina and was based on a combination of genetics data, published parasite compositions, abundance and catch data trends, growth and maximum age differences, and physical oceanography features.

Atlantic croaker have been part of mixed-stock commercial fisheries on the Atlantic Coast since the 1800s and are caught with a variety of gear throughout the year. Atlantic croaker are also discarded at sea in these fisheries, as well as other non-targeted fisheries like the shrimp trawl fishery operating throughout the South Atlantic. Recreational anglers target Atlantic croaker by bottom fishing with catch typically peaking in the warmer months (May through October) when effort tends to be greatest. The majority of recreational catch occurs in state waters.

The magnitude of commercial landings has been considerably larger in the northern stock, reaching a peak of 30.1 million pounds (13,664 metric tons) in 2001 while southern stock landings reached a peak of 660 thousand pounds (300 metric tons) in 1990. The trends are almost inverse patterns between stocks. Northern stock landings were relatively low in the early 1990s, increased steadily to the peak in 2001, then declined steadily throughout the remainder of the time series to a time series low of 312 thousand pounds in 2023. Southern stock landings were at time series highs in the early 1990s, declined sharply to a time series low of 21 thousand pounds in 2004, then increased through the remainder of the time series.

Commercial discards from fisheries in the Mid-Atlantic region are small in magnitude relative to commercial landings but discards from the shrimp trawl fishery in the South Atlantic are considerably larger and represent the largest source of fishery removals in terms of numbers. These discards are of similar magnitudes and follow similar trends in both stocks, with relatively high levels in the early 1990s. Median estimates from 1990 through 1995 are 211 million and 266 million fish in the northern and southern stocks, respectively. Discards declined to the lowest levels in the late 1990s through the mid-2000s, with medians from 1996 through 2007 of 78 million and 125 million fish in the northern and southern stocks, respectively. Discards in the

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northern stock increased from the mid-2000s through 2020 and were relatively variable in years since 2020. Discards in the southern stock increased sharply in 2008 back to levels observed in the early 1990s, then fluctuated around these levels with high interannual variability through the remainder of the time series. 95% of discards were assumed to be dead or die post-release.

Recreational harvest of northern stock fish increased in the early 1990s, was relatively stable at high levels through the early 2010s, typically surpassing 15 million fish a year, then steadily declined to its lowest value of the time series in 2024 (2.27 million fish). Releases of northern stock fish were of similar magnitude as harvest and were stable from the early 1990s through 2011. Releases increased briefly to the highest levels of the time series in 2013 (35 million fish), then declined through 2019, then increased for the remainder of the time series. Harvest of southern stock fish has been low and stable since the early 1990s, averaging 2.6 million fish from 1990-2024. Releases were low and stable in the 1990s and have increased since, peaking at just over 20 million fish in 2023. 15% of recreational releases were assumed to die post-release.

Five fishery-independent surveys operating in the northern stock, consisting of two age-0 recruitment surveys and three aggregate age surveys, were selected for use in the assessment. Survey indices have shown variable patterns in abundance believed to be reflective of changing habitat use (inshore vs offshore habitats) and changing availability to the surveys that typically operate within one of these habitats.

Three surveys, consisting of two age-0 recruitment surveys and one aggregate age survey split into two seasons, were chosen to model the southern stock. Survey indices show consistent increasing trends in abundance in the southern stock.

Fishery removals and survey indices of abundance, along with size and age data collected through biological sampling programs were analyzed with length- and age-structured, integrated stock assessment models using the Stock Synthesis platform. Models track annual recruitment, abundance, spawning stock biomass (SSB), and fishing mortality rates (F) from 1990 through 2024, though 2024 estimates are excluded from stock status determination because estimates in this final model year are more uncertain relative to previous years. Models also estimate spawning potential ratio (SPR)-based proxy reference points. SPR measures the SSB produced per recruit under a given F relative to the SSB produced per recruit under no F. The threshold SPR reference point, below which indicates poor stock conditions, is 25%. $F_{25\%}$ and $SSB_{SPR25\%}$ are the F and SSB levels associated with a 25% SPR in equilibrium conditions.

It was necessary to consider two different $F_{25\%}$ threshold reference points with different age ranges because of the various fishing fleets interacting with the Atlantic croaker stocks and their starkly different selectivity patterns. The first $F_{25\%}$ threshold includes all ages and the second includes only ages-1+. The value of the $F_{25\%}$ threshold varies depending on the inclusion of age-0 or not, but the goal for both is the same (i.e., 25% SPR). Due to the selectivity patterns for the fleets, F for ages-1+ is only from recreational and commercial fleets, which are under

the jurisdiction of ASMFC, while F for all ages including age-0 is from all fleets inclusive of the shrimp trawl fleet, which is not under the jurisdiction of ASMFC. The SAS recommended a range between 35% and 45% SPR for target reference points, but recommended consultation with the Board following the assessment for determining a specific level in order to achieve non-biological management objectives (e.g., socio-economic objectives, risk tolerance).

In the northern stock, recruitment was widely variable early in the time series with the peaks decreasing in size over time until a prolonged period of less variation around a lower average value beginning in the mid-2000s through 2020. Recruitment increased in the last few years. F was high in the first few years of the time series, declined to low levels in the mid-1990s, then increased gradually through the late 2000s. F for all ages increased sharply in the early 2010s, first exceeding the $F_{25\%}$ threshold in 2014 and increasing to higher levels through 2019. F for ages-1+ was more stable at moderate levels through the early 2010s, increased sharply in 2016 and exceeded the $F_{25\%}$ threshold in 2017 and 2018. F declined from the late 2010s through the remainder of the time series, falling below the $F_{25\%}$ threshold for all ages starting in 2022 and for ages-1+ starting in 2019. SSB increased from low levels in the early 1990s to a peak of 233,796 metric tons in 1996, remained at high levels through 2000, then declined steeply through the 2000s. The decline slowed in the late 2000s and SSB stabilized for a few years before continuing to decline in the early 2010s. SSB dropped below the $SSB_{SPR25\%}$ threshold of 32,104 metric tons in 2014 and remained below this threshold through 2024.

In the southern stock, recruitment was relatively low until about 2010, increased to a maximum in 2020, and has remained relatively stable since then. F generally decreased through the time series. F for all ages often exceeded the $F_{25\%}$ threshold through 2009 and has been below the threshold since 2010. F for ages-1+ has remained well below the $F_{25\%}$ threshold throughout the time series. SSB was stable and low through the 1990s and 2000s, remaining below the $SSB_{SPR25\%}$ threshold of 7,032 metric tons through 2011. SSB has increased rapidly since the early 2010s to a time series high of 30,817 metric tons in 2024.

The northern stock is depleted and is not experiencing overfishing, as the terminal three-year (2021-2023) average SSB was below the $SSB_{SPR25\%}$ threshold and the terminal three-year average F for both age ranges were less than their $F_{25\%}$ threshold. Action is recommended to protect the remaining spawning stock and promote resiliency and rebuilding of this stock.

The southern stock is not overfished and is not experiencing overfishing, as the terminal three-year average SSB was above the $SSB_{SPR25\%}$ threshold and the terminal three-year average F for both age ranges were less than their $F_{25\%}$ threshold. There are no troubling signs for the condition of the southern stock as this time.

The TLA used for management was updated during the assessment with some revisions to the analysis to make it more comparable with decisions made for model configurations during this assessment (e.g., boundary for splitting regions changed from the Virginia/North Carolina border to the Carteret County, North Carolina border). Comparison of the TLA to the assessment models indicated consistent conclusions about stock conditions in the terminal year. The continued poor commercial and recreational harvest in the northern region coupled

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with low fishery independent index values indicate a depleted spawning stock condition is likely. The southern region TLA metrics indicate improving stock condition with current status not requiring further management action.

To improve future stock assessment and management of Atlantic croaker, the assessment concludes with tiered research recommendations. Recommendations in the first tier include improved data collection from the shrimp trawl fishery, transition from an annual time step to a seasonal time step in assessment models to better track prolonged spawning behavior and conducting a tagging study to estimate natural and fishing mortality rates external to the stock assessment models. An assessment update is recommended in three years (2029) in place of continuing the TLA updates and the next benchmark stock assessment is recommended in six years (2032).

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TERMS OF REFERENCE

For the 2026 ASMFC Atlantic Croaker Benchmark Stock Assessment

Board Approved February 2023

1. Define population structure based on available data. If alternative population structures are used in the models (e.g., coast-wide or regional), justify use of each population structure. Explore possible impacts of environmental change on range shifts.

During the initial development of the Atlantic croaker benchmark assessment, the Atlantic Croaker Stock Assessment Subcommittee (SAS) attempted to model the entire Atlantic coast population as a single stock, similar to what was done in the 2010 and 2017 assessments. However, the SAS struggled to configure a model with conflicting data sources that suggested population dynamics were different in the northern and southern extents of the population. After reanalyzing data sources and discovering additional literature, the SAS decided to proceed with two stocks that were separated at the Carteret and Onslow counties border in central North Carolina, similar to what was done in the 2005 assessment.

While this decision was not based on any single conclusive piece of evidence of stock structure, it was based on a body of evidence that supports regional modeling (see Section 2.1 for more details). Unpublished data from South Carolina Department of Natural Resources revealed minimal genetic difference between Atlantic and Gulf of America fish but also revealed weak statistical support of difference between fish north and south of Cape Lookout, North Carolina (geographically in line with the area the SAS split the stocks). This weak statistical support indicated an effective number of migrants of approximately 173 Atlantic croaker per generation between the two Atlantic coast areas, which the SAS felt was enough for a single genetic signal but not enough individuals in a population this size to warrant a single stock.

Additionally, the SAS considered the data trends north and south of the Cape Lookout boundary. Recreational and commercial fisheries are drastically different between the two locations. This pattern held even when considering just North Carolina catch north and south of Cape Lookout, where North Carolina catches north of the Cape were similar to catches north of North Carolina and catches south of the Cape were similar to catches south of North Carolina. When exploring fishery independent data, only one survey provides a glimpse into the difference across the boundary. The SEAMAP Coastal Trawl survey has monitored Atlantic croaker since 1990 and catches were compared by strata, which are specific geographic grids from central Florida through North Carolina. The strata catch rates were highly correlated from Florida through the southern two strata of North Carolina. The northernmost two strata occur north of Cape Lookout and were not correlated with the other strata in the survey.

There were additional details from the life history of Atlantic croaker that were also considered. Major longevity and growth differences occur between the northern and southern stocks. In

the northern stock, Atlantic croaker older than age-10 have been routine in catches through the years. However, in the southern stock the oldest fish in our data set was age-7 and ages older than 5 years were rare throughout the time series. Additionally, Atlantic croaker in the northern stock grow faster and to larger sizes than Atlantic croaker in the southern stock.

Additional research was gathered from literature with similar stock boundaries occurring for species that occur throughout the Atlantic. There is evidence that confluence of currents and different water masses off the North Carolina Outer Banks region creates a biogeographical boundary. Evidence of this boundary is also seen in the parasite compositions found within Atlantic croaker captured north and south of the geographic distinction. The parasite study acknowledged that the split in parasite composition occurred in warm months around Cape Hatteras (slightly north of the stock split used in the current assessment) but likely could occur further south in colder months, likely around Cape Lookout.

2. Evaluate new information on life history such as growth rates, size-at-maturation, natural mortality rate, and migrations and review potential impacts of environmental change on these characteristics. Explore possible impacts of environmental change on life history characteristics.

The SAS conducted a detailed literature review into critical environmental factors that impact development and survivability of Atlantic croaker, including effects of dissolved oxygen, temperature, salinity, and anthropogenic interactions (i.e., climate change, noise pollution, and shoreline hardening; Section 3.2). A coastwide biological data set was compiled into a standard data set used to update all life history information for the stock assessment models. The SAS adopted centerline length as the length type used in the model, differing from past stock assessments and current management length type (total length) but determined less conversions would be required among the multitude of data sets.

Growth, body condition, natural mortality, maturity, sex ratios, and larval settlement were all updated with the complete data set and compared between stocks for proper use within the models (Section 2). Growth differed between stocks, but growth also varied through time for the northern stock and not the southern stock. Data from the 1990s and 2000s indicate that growth in the northern stock was faster and to larger sizes, but since 2012 growth has declined and become more similar to the southern stock. Relative body condition did not vary over time and no direct drivers of the growth change could be identified with available data (e.g., prey abundance changes, Section 2.8). Even though growth differed between stocks, maturity remained similar.

Additional research was centered around the estimates of abundance indices or proxies (i.e., fishery landings) used in the models. Trawl surveys conducted in each stock revealed the center of gravity of abundance estimates for the northern stock are shifting northeast (more offshore), while center of gravity estimates for the southern stock are relatively stable with slight shifts to the southwest (more inshore). Analyses of environmental covariates and recruitment indices in

the Chesapeake Bay highlighted the effect of environment on recruitment, while an updated analysis of the relationship between the North Atlantic Oscillation climate pattern and landings found the relationship had deteriorated (Section 3.3).

3. 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. Consider the consequences of environmental factors on the estimates of abundance or relative indices derived from surveys.
    c. Discuss trends and associated estimates of uncertainty (e.g., standard errors).
    d. Justify inclusion or elimination of available data sources.
    e. Discuss the effects of data strengths and weaknesses (e.g., temporal and spatial scale, gear selectivities, ageing accuracy, sample size) on model inputs and outputs.

Fishery-dependent data sources are described in Section 4 and include total fishery removals by the commercial fishery and recreational fishery, with special attention on bycatch captured in the shrimp trawl fishery. Commercial data generated included the total removals (landings and discarded dead catch), removals size compositions, and conditional age-at-length. Base estimates of discarded Atlantic croaker in the shrimp trawl fishery are described in Section 4, while additional detail and analyses considered for these fishery removals are described in Appendix 13.1. Recreational data included total removals (landings and discarded dead catch) and removals size compositions. Fishery-dependent CPUE time series were also evaluated for trends in the fisheries, but ultimately not used in assessment models in favor of indices of abundance from fishery-independent data sources.

Fishery-independent data sources provided by state and federal partners are described in Section 5. Data sources used in the models generated standardized indices of abundance (with environmental covariate exploration), size compositions, and conditional age-at-length. Standardization methods for indices were completed with model-based approaches (e.g., generalized linear models, spatiotemporal models) appropriate for each survey.

Details about additional abundance data sets considered by the SAS but not used in the assessment models are provided in Appendix 13.2 and Table 32.

4. Develop models used to estimate population parameters (e.g., *F*, biomass, abundance) and biological reference points, and analyze model performance.
    a. 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.
    b. Clearly and thoroughly explain model strengths and limitations.
    c. Justify choice of CVs, effective sample sizes, or likelihood weighting schemes.
    d. Describe stability of model (e.g., ability to find a stable solution, invert Hessian).

e. Perform sensitivity analyses for starting parameter values, priors, etc. and conduct other model diagnostics as necessary.
f. Perform likelihood profile of key parameters (e.g., stock-recruit relationship parameters) to evaluate robustness of final parameter values.
g. If multiple models were considered, justify the choice of preferred model and the explanation of any differences in results among models.

Length- and age- structure integrated Stock Synthesis (SS) models were developed for both stocks as primary analyses (Section 6). Both models underwent diagnostic testing that indicated that the models found stable solutions (e.g., inverted Hessian, relatively low maximum gradient values, likelihood profiling, jitter analysis). In the northern stock, some conflict occurred between recruitment indices and shrimp trawl discards. The available recruitment indices do not occur throughout the entire northern stock, and it is common for these indices to have localized patterns due to the impacts of environmental conditions on young-of-the-year. The shrimp trawl discards are comprised almost exclusively of age-0 recruits, but the range of the catch does not specifically align with the geographical range of the recruitment indices. The mismatch between geography and sensitive nature of these indices likely explains the disconnect. In the southern model, conflict occurred between conditional age-at-length data from the two SEAMAP Coastal Trawl surveys that monitor separate seasons. The model had good fits to individual season data sets, but struggled fitting to both seasons simultaneously. This disconnect is likely related to the protracted spawning exhibited in the southern stock, but due to modeling constraints the timing could not be fully captured. The SAS highly recommends more research into modeling protracted spawning for Atlantic croaker. However, the model did converge without major problems with both seasonal surveys included and sensitivity analyses with only one or the other survey did not change stock status.

Within the SS model, data weighting the inputs was developed based on sampling intensity and data variability. Uncertainty around data source inputs was captured for each data source treatment based on data methods. Iterative reweighting within the model was considered but the SAS chose to use as a sensitivity analysis rather than the base model. Reweighting essentially upweighted shrimp trawl discards by downweighing the other data sets (i.e., indices of abundance and compositions), which was determined as problematic given low observer coverage in the shrimp trawl fishery.

A jitter analysis with 200 runs of alterative starting values was conducted to examine input starting value assumptions and ensure the model was reaching a global minimum. A likelihood profile on R0 was completed to explore the sensitivity of the model to the estimate and ensure the best parameter was captured in the stock recruitment relationship of the base model. The northern stock was further tested with 19 sensitivity runs and the southern stock tested with 12 sensitivity runs.

Additional index-based methods (IBMs) were also explored but advice from these models was not consistent between methods and data sources used. The data-limited IBMs are designed to

consider one data source at a time rather than capable of combining sources. Also, they are typically more reactive to trends in an individual data source. Thus, the SAS does not recommend the use of IBMs for management advice. More information on the IBMs can be found in Appendix 13.3. The SS models are the preferred analyses for both stocks because they include more data and more rigorous configurations. Stable models were achieved with minimal diagnostics concerns.

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. No error in the catch-at-age or catch-at-length matrix.
    c. Calculation of *M*. Choice to use (or estimate) constant or time-varying *M* and catchability.
    d. Choice of equilibrium reference points or proxies for MSY-based reference points.
    e. Choice of a plus group for age-structured species.

The models used a Beverton-Holt stock-recruitment function with steepness fixed at 0.99 because the models could not estimate robust relationships from the available data. This effectively assumes a constant average recruitment with estimated annual deviations. Additional sensitivity analyses were conducted with the southern stock to allow the model to estimate steepness, but the analysis did not change the stock status and raised questions when compared to literature and life history dynamics. The northern model steepness went to the bound of 0.99 when freely estimated.

Due to using a fixed steepness, proxies for maximum sustainable yield (MSY)-based reference points were chosen. A threshold of 25% spawning potential ratio (SPR) was chosen based on Atlantic croaker life history characteristics and management thresholds of other sciaenid species in the Atlantic Ocean and Gulf of America. The spawning stock biomass (SSB) associated with a 25% SPR is recommended as the SSB threshold. The SAS does recommend using two fishing mortality (F) definitions with thresholds at 25% F that correspond to 25% SPR: $F_{25\%}$ for all ages 0+ and $F_{25\%}$ for ages-1+. The targeted fishery managed by ASMFC is on age-1+ Atlantic croaker, but the impact of bycatch from the shrimp trawl fishery is enough on age 0+ Atlantic croaker that monitoring of this threshold would allow for recommendations for action to protect the remaining SSB and promote resiliency and rebuilding.

Conditional age-at-length and catch-at-length matrices assumed error according to effective sample size based on the square root of the number of ages sampled or the number of trips observing Atlantic croaker, respectively. Natural mortality was fixed in the models for age-2 fish (age of full selectivity for targeted fisheries) based on external estimates using the Lorenzen (2022) method scaled to Atlantic croaker life expectancy using methods from Hamel and Cope (2022). Based on the limitations in age data from older Atlantic croaker in each stock, plus groups were specified in the models as age-10+ for the northern stock and age-4+ for the

southern stock. Spawning occurs in January and settlement as one recruitment pulse in June (northern stock) or July (southern stock). Starting values for growth parameters were estimated externally for each stock individually and growth changes did occur in the northern stock. These growth changes were captured in the model using varying growth blocks: 1990-2011 and 2012-2024.

The model also made assumptions around selectivity due to limited data based on knowledge from the fishery and biology of the species. Length data from the shrimp trawl fishery was limited but most measured individuals were smaller than 18 cm, thus assumed to be age-0 Atlantic croaker. Selectivity of the fishery was fixed at 1 for age-0 and 0 for ages-1+. No discard length data occurs for the recreational fishery, but no size restrictions occur in most of the fishery either. Sizes of discarded fish were assumed to be similar to harvested fish such that the selectivity of the discards would mirror the selectivity of the harvest. In the southern stock, the commercial and recreational stocks had to be separated between Florida and North Carolina-Georgia fisheries due to documented length being larger in Florida than in the other three states. Within the North Carolina-Georgia commercial fishery, selectivity changed to dome-shaped in 2004 due to a change in primary gears used within that fishery. The Florida commercial length data were too limited to estimate selectivity, so selectivity was set to mirror recreational selectivity as both sectors do not have size regulations and target the same geographical range of the stock. The SEAMAP trawl is a survey that occurs throughout the southern stock range but did not capture the largest sizes observed in the Florida fisheries, so selectivity was assumed to be dome-shaped rather than asymptotic selectivity used for all other trawl surveys.

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

Uncertainty was measured with 95% confidence intervals from asymptotic standard errors. Retrospective analyses were conducted to examine model stability and presence of retrospective bias and are discussed in TOR 7 as well as Sections 6.2.1.3 and 6.2.2.3. Numerous sensitivity analyses were conducted and concluded the same conclusions on the status of each stock.

7. Perform retrospective analyses, assess magnitude and direction of retrospective patterns detected, and discuss model consistency due to implications of any observed retrospective pattern for uncertainty in population parameters (e.g., *F, SSB*), reference points, and/or management measures.

A six-year retrospective analysis was completed on each stock model. The northern stock revealed signs of retrospective patterning while the southern stock did not. The retrospective patterning in the northern stock indicated that the SSB was overestimated (Mohn's rho=1.66) and F was underestimated (Mohn's rho=-0.33), with Mohn's rho values being indicative of a retrospective pattern. The 2018 and 2019 peels diverged from the remaining four peels. Preliminary analysis suggests this pattern may be driven by the maturity assumptions and

change in growth assumed in the model. The SAS considered a retrospective adjustment but ultimately did not implement it at this time due to guidelines from ASMFC's Assessment Science Committee and the knowledge that the adjustment does not change stock status for either status conclusion.

8. Recommend stock status as related to reference points (if available).

The northern stock is not experiencing overfishing but is depleted. The term depleted was used to describe the northern stock because of evidence that other drivers (i.e., environmental conditions) also influence population dynamics. The SSB time series declines below the threshold prior to when the target fishery begins overfishing (age-1+ F) and the same year total removals begins overfishing (age 0+ F). This short timeline on a fast-growing species indicates other drivers have high influence on the SSB. While management of Atlantic croaker specifically is not currently designed to control bycatch in the shrimp trawl fleet, the SAS recognized the importance of monitoring this large source of removal to protect the stock's sustainability.

The southern stock is not experiencing overfishing and not overfished. There are no concerning signs for this stock at this time.

Additional detail on stock status is provided in Section 8.

9. Compare stock status and management advice from the assessment with the results of the traffic light analysis currently used for management. If outcomes differ, discuss potential causes of observed discrepancies and preferred method.

Current management of Atlantic croaker uses a Traffic Light Analysis (TLA) to inform decisions on one coastwide management unit; however, two regions are considered (Section 7). The two regions are divided at the Virginia and North Carolina state line, which differs from the stock boundaries in the current assessment. Additionally, the TLA uses different indices of abundance than the current assessment and only consider the targeted fisheries rather than the full population structure used in the stock assessment. To give full consideration to the comparability of the TLA to the assessment models, the TLA was revised to match the decisions of the assessment with catch split into the same stock structure as the assessments and the same indices of abundance used.

When comparing the revised TLA to the current TLA, thresholds were still exceeded in the northern stock but at different levels with removals having a lower trigger and abundance indices having a higher trigger. The triggered conditions align with the stock status from the assessment model of depleted). For the southern stock, the current TLA removals were triggered at the 30% level but in the revised TLA they did not trigger. This was due to the new regional split assigning the catch differently. Indices of abundance did not trigger in either TLA. The non-triggered conditions of the revised TLA aligns with the stock status from the assessment model of not overfished. The TLA metrics do not provide inference on fishing

mortality rate and status to compare to fishing mortality determinations from the assessment models.

10. 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.

No minority report was filed.

11. 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.

The SAS recommends a tiered priority list with short-term, long term, and ongoing timelines (see Section 9). Work on all tier 1 priorities should commence immediately.

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

The SAS recommends the next benchmark stock assessment should be completed in six years (2032; Section 9). A longer timeline is not suggested due to the current stock status of the northern stock. Additionally, current management uses annual TLA updates for management decisions. The SAS recommends replacing the annual TLA updates with an assessment update in three years (2029).

1 INTRODUCTION

1.1 Management Unit Definition

Currently, the Atlantic croaker management unit is the Atlantic coast distribution of the species from New Jersey through Florida. Addendum I of Amendment 1 to the Atlantic Croaker Fishery Management Plan (FMP) states Atlantic croaker will be assessed and management measures implemented on a coastwide basis (ASMFC 2011).

1.2 Regulatory History

1.2.1 Interstate Management

The Atlantic croaker interstate management program functions under the ASMFC's Interstate Fishery Management Program (ISFMP), with immediate oversight by the Sciaenids Management Board (Board; formally the South Atlantic State-Federal Fisheries Management Board).

The FMP for Atlantic croaker was adopted in 1987 and included states from Maryland through Florida (ASMFC 1987). The major problem identified in the plan was lack of stock assessment data needed for effective management of the resource. Research and data collection programs were recommended, as were two management measures: the use of bycatch reduction devices (BRDs) in shrimp and finfish trawls and increasing fishery selectivity to Atlantic croaker age one and older.

In 1993, the Atlantic Coastal Fisheries Cooperative Management Act (ACFCMA) was established, allowing for enforcement of ASMFC management plans. Subsequently, the Board reviewed the FMP and found its recommendations to be vague and invalid, and the ISFMP Policy Board agreed that the FMP contained no requirements. The Board recommended that an amendment be prepared to define management measures necessary to achieve the goals of the FMP. A workshop was held the same year to gather and review available data from which specific and rational management measures could be drawn, and later in 1997, an Atlantic croaker Technical Committee (TC) was appointed to continue the data collection and analysis initiated at the 1993 workshop.

In 2002, the Board directed the Technical Committee (TC) to conduct the first ASMFC-sponsored coastwide stock assessment of the species in preparation of developing an amendment. The stock assessment was approved by a Southeast Data, Assessment, and Review (SEDAR) review panel for use in management in June 2004, after which the Board initiated the development of an amendment to update the FMP. In November 2005, the Board approved Amendment 1 to the Atlantic Croaker FMP, which was fully implemented by January 1, 2006 (ASMFC 2005a).

The goal of Amendment 1 was to use interstate management to sustainably maintain the Atlantic croaker resource throughout its range and generate the greatest economic and social benefits from its commercial and recreational harvest over time. Amendment 1 contains four objectives:

1. Manage the fishing mortality rate for Atlantic croaker to provide adequate spawning potential to sustain long-term abundance of the Atlantic croaker population.

2. Manage the Atlantic croaker stock to maintain the spawning stock biomass above the target biomass levels and restrict fishing mortality to rates below the threshold.

3. Develop a management program for restoring and maintaining essential Atlantic croaker habitat.

4. Develop research priorities that will further refine the Atlantic croaker management program to maximize the biological, social, and economic benefits derived from the Atlantic croaker population.

Amendment 1 expanded the management area to include the states from New Jersey through Florida. Consistent with the stock assessment completed in 2004, the amendment defined two Atlantic coast management regions: the south Atlantic region, from Florida through South Carolina; and the mid-Atlantic region, from North Carolina through New Jersey.

Amendment 1 established biological reference points (BRPs) to define an overfished and overfishing stock status for the mid-Atlantic region only. Reliable stock estimates and BRPs for the South Atlantic region could not be developed during the 2004 stock assessment due to a lack of data. The BRPs were based on maximum sustainable yield (MSY), and included threshold and target levels of fishing mortality (*F*) and spawning stock biomass (*SSB*): *F* threshold = F_{MSY} (estimated to be 0.39); *F* target = 0.75 X F_{MSY} (estimated to be 0.29); *SSB* threshold = 0.7 X SSB_{MSY} (estimated to be 44.65 million pounds); and *SSB* target = SSB_{MSY} (estimated to be 63.78 million pounds). An *SSB* estimate below the *SSB* threshold resulted in an overfished status determination, and an *F* estimate above the *F* threshold resulted in an overfishing status determination. The Amendment established that the Board would take action, including a stock rebuilding schedule, if necessary, should the BRPs indicate the stock is overfished or overfishing is occurring.

Amendment 1 did not require any specific measures restricting recreational or commercial harvest of Atlantic croaker. States that already had more conservative measures were encouraged to maintain those regulations. The Board may revise Amendment 1 through adaptive management, including any regulatory and/or monitoring requirements in subsequent addenda, along with procedures for implementing alternative management programs via conservation equivalency.

The Board initiated Addendum I to Amendment 1 at its August 2010 meeting, following a new stock assessment, in order to address the proposed reference points and management unit. The stock assessment evaluated the stock as a coastwide unit, rather than the two management units established within Amendment 1. In approving Addendum I, the Board endorsed consolidating the stock into one management unit, as proposed by the stock assessment. In addition, Addendum I established a procedure, similar to other species, by

which the Board may approve peer-reviewed BRPs without a full administrative process, such as an amendment or addendum.

In August 2014, the Board approved Addendum II to the Atlantic Croaker FMP. Addendum II established the Traffic Light Approach (TLA) as the new precautionary management framework to evaluate fishery trends and develop management actions. The TLA was originally developed as a management tool for data poor fisheries. The name comes from assigning a color (red, yellow, or green) to categorize relative levels of population indicators, or metrics. When a metric improves, the proportion of green in the given year increases and the proportion red decreases. When the metric deteriorates, the proportion red in the given year increases and the proportion green decreases. Metrics included harvest and abundance. Thresholds of 30% and 60% red were established in Addendum II, representing moderate and significant concern for the fishery, respectively. If the proportion red exceeds the thresholds for both metrics for a three-year period, then management action is enacted.

The TLA framework replaced the management triggers stipulated in Addendum I, which dictated that action should be taken if recreational and commercial landings dropped below 70% of the previous two-year average. Those triggers were limited in their ability to illustrate long-term declines or increases in stock abundance. In contrast, the TLA approach is capable of better illustrating trends in the fishery through changes in the proportion of green, yellow, and red coloring. A 2018 TC report recommended several updates to the current TLA approach (ASMFC 2018). The Board initiated Addendum III to incorporate these updates.

In February 2020 the Board approved Addendum III to Amendment 1 of the Atlantic Croaker FMP. This addendum adjusted the TLA to incorporate additional fishery-independent indices, age information, use of regional metrics, and changes to the management triggering mechanisms. Management triggers and responses include bag limits for the recreational fishery and percentage harvest reductions from a 10-year average for the commercial fishery. The response will be defined by which percent threshold (30% or 60%) is exceeded in any 3 out of 4 terminal years of the analysis.

Addendum III did not add or change any management measures or requirements, unless management-triggering mechanisms are tripped. The only pre-existing requirement is for states to submit an annual compliance report by July 1st of each year that contains commercial and recreational landings as well as results from any monitoring programs that intercept Atlantic croaker.

Additionally, in March 2017, a report on Sciaenid Fish Habitat was released including information on habitat for several species, including Atlantic croaker, during all stages of their lives, their associated Essential Fish Habitats and Habitat Areas of Particular Concern, threats and uncertainties to their habitats, and recommendations for habitat management and research (Odell et al. 2017). This report is meant to be a resource when amending future species FMPs.

1.2.2 State Management

Prior to 2020, there were no required regulations. However, several states in the management unit implemented regulations including creel/trip limits, size limits, and seasonal closures specific to Atlantic croaker. In addition, gear restrictions such as minimum mesh sizes, BRDs, and area closures have been implemented for other or multiple species to limit the harvest and bycatch of Atlantic croaker.

In 2020, the TLA triggered management measures at the 30% level, or moderate concern. Non-*de minimis* states were required to implement management measures that instituted a 50 fish recreational bag limit and reduced the commercial harvest by 1% of the average state commercial harvest from the previous 10 years. If the state already had more restrictive measures in place, they did not need to make any changes. All proposed management changes were reviewed by the TC and approved by the Board.

History of regulations specific to Atlantic croaker for the states and one additional jurisdiction (Potomac River Fisheries Commission; PRFC) in the management unit can be found below, or in Table 1. Regulations for all states and the one jurisdiction as of December 31, 2024, can be found in Table 2.

New Jersey: In 2001, New Jersey implemented a minimum mesh size of 3.75 inches stretched diamond mesh or 3.375 inches stretched square mesh in the codend of an otter or beam trawl in a directed fishery for Atlantic croaker. A directed fishery for Atlantic croaker is defined as the possession of at least 100 pounds of Atlantic croaker onboard a vessel or landed from a vessel.

Delaware: Delaware implemented an 8-inch total length (TL) minimum size limit for Atlantic croaker in 1984. In September 2024, Delaware implemented a 50 fish/day recreational bag limit.

Maryland: Maryland implemented a 10-inch TL minimum size limit for Atlantic croaker in the 1960s. In 1993, the minimum size limit was lowered to 9-inches TL and a 20 fish recreational bag limit was put into place. In 1995, Maryland also implemented a commercial fishery closure from January 1 through March 15th. In 1997, the recreational bag limit was increased to 25 fish.

Potomac River Fisheries Commission: The PRFC implemented a commercial fishery minimum size limit for Atlantic croaker of 10-inches TL in 1963. This minimum size limit was extended to the recreational fishery as well in 1982. In 1996, recreational bag limit of 20 fish was implemented. In 1999, the size limit was removed, and the recreational bag limit was increased to 25 fish. In 2022, the PRFC implemented a commercial fishery season closure from October 1-December 31.

Virginia: In 2021, Virginia implemented a 50 fish per day recreational bag limit, with an additional charter live bait allowance. In addition, a season closure for the commercial fishery from December 16 through January 14 was implemented.

North Carolina: In 2021, North Carolina implemented a 50 fish per day recreational bag limit and a commercial season closure from December 16 through December 31.

South Carolina: South Carolina implemented a commercial and recreational bag limit of 50 fish per person per day for small Sciaenidae species (including Atlantic croaker) caught with hook and line gear in 2014.

Georgia: In 1989, Georgia implemented an 8-inch TL minimum size limit, as well as a recreational and commercial bag limit of 25 fish per day, with an exception for shrimp trawlers. In 2014, Georgia removed the minimum size limit.

Florida: Florida implemented a recreational bag limit of 50 fish per day, as well as a 1,200 lbs commercial vessel limit in 2021.

1.3 Assessment History

There have been three previous peer-reviewed assessments for Atlantic croaker on the Atlantic coast.

1.3.1 2005 Benchmark Stock Assessment

The first assessment, published in 2005, split the population into two stocks: the South Atlantic region, including the states of Florida through South Carolina; and the Mid-Atlantic region, including the states of North Carolina through New Jersey. The assessment noted that regions exhibited different dynamics, specifically recent increases in recruitment in the Mid-Atlantic region that weren't observed in the South Atlantic region. The Stock Assessment Subcommittee (SAS) expressed concern that combining regions into one coastwide stock masked the different dynamics of Atlantic croaker in the southern range of the coastwide population.

The assessment used an age-structured production model which linked the population in successive years using a Beverton-Holt stock-recruitment relationship re-parameterized in terms of steepness. A published estimate for Atlantic croaker steepness (0.76; Myers et al. 2002) was first used as a prior distribution in the model, but posterior distributions with a median lower than that of the published estimate (0.5) contributed to the SAS's conclusion that data used in the model were not informative of a steepness estimate. Alternatively, the published point estimate was used as a fixed input in the final base model.

The results of the assessment were used to develop the first recommendations for reference points for Atlantic croaker. Reference points based on maximum sustainable yield (MSY) were recommended for the Mid-Atlantic region, including F_{MSY} and $0.70*SSB_{MSY}$ as threshold reference points and $0.75*F_{MSY}$ and SSB_{MSY} as target reference points. The status of the Atlantic croaker stock occurring in the South Atlantic region could not be determined. As such, reference points were not developed for the South Atlantic region. The assessment concluded that the Mid-Atlantic region was not overfished and overfishing was not occurring.

A major limitation of the assessment was insufficient data to produce annual estimates of Atlantic croaker bycatch from the shrimp trawl fishery, which is believed to be a major source of mortality. The peer reviewers recommended including at-sea observer data for estimating discards from the shrimp trawl fishery as well as other coastal fisheries and quantifying scrap landings, or those landings not marketed for human consumption.

1.3.2 2010 Benchmark Stock Assessment

The next stock assessment was completed in 2010. The assessment reversed course on stock structure and combined the Atlantic croaker population on the Atlantic coast into a single unit due to a lack of genetic evidence for separate stocks.

To address peer review comments from the 2005 assessment, scrap landings were estimated for North Carolina, bycatch in other fisheries was estimated using the Northeast Fisheries Science Center's (NEFSC) Northeast Fisheries Observer Program (NEFOP), and shrimp trawl bycatch was estimated in the South Atlantic. All three additional sources of removals for Atlantic croaker were considered highly uncertain due to large associated standard errors (or variance) of the estimates.

A statistical catch-at-age model was used during this assessment. This model was also unable to reliably estimate steepness of the stock-recruitment relationship and ultimately steepness was fixed at 0.76, although reference point sensitivity to the steepness value was noted. Due to the high degree of uncertainty of the estimates of shrimp trawl bycatch, the model estimates of absolute stock size and fishing mortality were not considered reliable. Therefore, the assessment provided trends, including relative MSY reference points, to determine stock status. The assessment concluded that Atlantic croaker were not experiencing overfishing but that *SSB* estimates were too uncertain to determine an overfished status.

1.3.3 2017 Benchmark Stock Assessment

The most recent stock assessment was completed in 2017 and maintained the coastwide stock definition. New methods for estimating discards in the shrimp trawl fisheries used observer data and total effort. Estimated shrimp trawl fishery discards constituted the majority of fishery removals of Atlantic croaker.

A new integrated modeling platform, Stock Synthesis (SS), was used to model the population. Unlike previous assessments, the steepness parameter in the final base model was estimated with a prior distribution included in the model though the estimate (0.97) was near the upper bound of one. Ultimately, the stock status of Atlantic croaker could not be determined from this assessment because the model was sensitive to certain modeling assumptions, especially those regarding fishery and survey gear selectivity. Additionally, several data sources provided conflicting information regarding population trends. This stock assessment was not recommended by the Peer Review Panel for management advice. The Peer Review Panel recommended using spawner potential ratio (SPR) reference points, as the steepness parameter did not appear to be well estimated and robust for the basis of MSY reference points used in previous assessments.

2 LIFE HISTORY

2.1 Stock Definitions

The stock definition used in previous assessments has changed from modeling two stocks in the 2004 assessment to one stock in 2010 and 2017 assessments, with reoccurring major uncertainty around which is most biologically relevant for the species. The current ASMFC management plan assumes a single stock for the Atlantic coast (ASMFC 2011); however, Amendment 1 originally identified two management areas. Given the last stock assessment did not pass peer review, the current status of Atlantic croaker is evaluated with the TLA on a regional basis (Mid-Atlantic and South Atlantic) to increase survey coverage throughout the stock (ASMFC 2020). The TLA evaluates harvest and abundance metrics for each region, but management occurs throughout the Atlantic Ocean if either region is triggered.

In the past two assessments, the justification for a single stock was based on genetics, otolith microchemistry, growth capacity, and cold tolerance of YOY Atlantic croaker, but other life history characteristics of the population suggest more than one stock. A genetic study compared 15 composite haplotypes in 93 individuals and found no evidence that a genetic boundary occurred along the Atlantic coast (Lankford et al. 1999). One otolith microchemistry study found no significant differences between juveniles from North Carolina and Virginia (Thorrold et al. 1997), while a second found significant variation in otolith chemistries between Atlantic croaker collected in Delaware versus North Carolina (Schaffler et al. 2009). During previous assessments there was not enough information to split the stocks, as was done in earlier assessments and management decisions. However, recent data and research warrant further investigation.

2.1.1 Genetics

Although not new data, the South Carolina Department of Natural Resources Marine Resources Research Institute has unpublished genetic data from Atlantic croaker that were collected in the early 2000s. Atlantic croaker collected between 1998 – 2003, from localities in Delaware (N=93), Virginia (N=27), North Carolina's Cape Hatteras region (N=105), South Carolina (N=90), Georgia (N=89), Florida's Atlantic coast (N=90), Florida's Gulf coast (N=64), and Texas (N=94) were genotyped at five microsatellite loci (7-45 alleles/locus). We reanalyzed these data limiting the dataset to include only samples collected during the putative spawning season (September – December) to ensure individuals are assigned to the appropriate spawning population. Migration that occurs for reasons other than spawning can cause assumptions about population structure due to co-mingling that do not represent the reproductive potential of a stock. The dataset included 544 individuals. All individuals from Delaware were collected outside the spawning season and therefore excluded from analysis.

We used the program STRUCTURE 2.3.4 (Pritchard et al. 2000) to identify geographic patterns of potentially distinct genetic clusters (K) in the dataset. Three replicates of each STRUCTURE analyses were run to test a range of K values (K from 1 to 8). Analyses were performed with a 250,000 iteration Markov Monte Carlo simulation, excluding the first 50,000 iterations as burn-in, and performed with an admixture model with correlated allele frequencies, with all other

parameters set at default values. We used the location prior option in STRUCTURE to examine the influence of geographic collection location on genetic clustering, with collections assigned by state (treating Florida as two groups: Atlantic coast and Gulf coast); and an iteration where all samples were assigned as collected either north or south of Cape Lookout, North Carolina. We used the program STRUCTURE SELECTOR (Li and Liu 2018) to summarize probability scores across iterations at varying levels of K and evaluate the best fit of population genetic structure for our dataset. We estimated pairwise contrasts in allele frequencies (Fixation Index, F_{ST}) using GenAlEx. Significance levels for pairwise F_{ST} comparisons were adjusted using a sequential Bonferroni correction.

The results from STRUCTURE analyses statistically support a single genetic population across the sampled range (i.e., K = 1). All iterations of STRUCTURE analyses produced similar results regardless of whether samples were grouped by state of collection or when grouped as either north or south of Cape Lookout, North Carolina. However, the group comparison of north and south of Cape Lookout suggests very weak genetic structure between the areas in both the loglikelihood and structure plots (Figure 1).

F_{ST} comparisons also indicate low genetic differentiation (F_{ST} values range between 0.00000-0.00769) between Atlantic coast sampling locations, and a single significant comparison between Georgia and Texas collections (F_{ST} =0.00743, p=0.0017; Bonferroni correction for 21 comparisons α=0.00238). The F_{ST} between north and south of Cape Lookout, NC grouped collections (0.00144) provide an estimated effective number of migrants at 173.4 per generation, also supporting weak genetic structure between these areas.

2.1.2 Parasite Compositions

Parasite compositions within a species can serve as a biological marker given the geographical range of individual parasites and the environmental conditions needed for each species of parasite (MacKenzie and Abaunza 1998; Cadrin et al. 2005; Catalano et al. 2013). These biological markers have become useful in determining stock identification for fisheries (MacKenzie and Abaunza 1998; Cadrin et al. 2005; Baker et al. 2007). Baker et al. (2007) analyzed parasite compositions for Atlantic croaker captured along the U.S. east coast, specifically Atlantic City, NJ to Cape Canaveral, FL. Thirty species of macroparasites were identified and the prevalence of 10 species of macroparasites were found to vary based on latitude of fish capture. The community composition of the parasites were suggestive of two Atlantic croaker stocks, with Cape Hatteras, NC serving as the potential break between the stocks (Baker et al. 2007). Baker et al. (2007) concluded that Cape Hatteras, NC was the boundary between the two stocks but noted there was a transition zone between Cape Fear and Cape Hatteras. Additionally, Baker et al. (2007) also explained that the study was only completed in the warm fall months and colder months with differing pattens of currents could move the boundary further south to Cape Lookout or Cape Fear.

2.1.3 Abundance and Catch Trends and Distribution Changes

During initial model development assuming only one stock along the U.S east coast, conflicts in regional trends in catch and survey data became apparent. These data were explored for

potential evidence of two stocks within the coastwide population. Review of trends by state reflected commonalities in North Carolina data sets between both areas to the south and areas to the north, so North Carolina data were split into northern and southern data sets. The boundary used for splitting data was the border between Onslow County and Carteret County. This boundary allows for aggregation of regional catch data as county is generally the finest spatial scale for these data and groups areas with large estuaries (i.e., Pamlico and Albermarle Sounds) with areas to the north and separated from areas characterized by smaller inshore estuaries to the south.

2.1.3.1 Trawl Survey Abundance Trends

The Southeast Area Monitoring and Assessment Program – South Atlantic (SEAMAP-SA) coastal trawl survey is a geographically broad survey, sampling nearshore ocean waters from central North Carolina through central Florida (Figure 2), that regularly encounters Atlantic croaker throughout the year. The survey employs a stratified random sampling design enabling summary statistics like mean relative abundance by stratum or groups of strata (see Section 5.1.6 for additional detail on the survey).

Annual design-based indices of abundance for the spring, summer, and fall SEAMAP sampling seasons were calculated by state from Florida through South Carolina and by region for North Carolina using strata 55, 57, 59, and 61 for southern North Carolina and strata 65 and 67 for northern North Carolina. This split aligns with the border between Onslow and Carteret Counties used to split catch data. Indices were tested for correlations with a Spearman's rank correlation analysis. Correlation results with a p-value < 0.05 were considered significant correlations.

All indices within seasons were positively correlated between adjacent areas from Florida through southern North Carolina (Figure 3). Additionally, the southern North Carolina index was positively correlated with the non-adjacent areas of Georgia and Florida in the fall. The northern North Carolina indices were not correlated with any indices across all three seasons, including the indices in the adjacent area of southern North Carolina. These results provide evidence of a break in population trends between areas south of approximately the White Oak River in North Carolina and those to the north measured by the same standardized survey.

2.1.3.2 Trawl Survey Distributions

The Vector Autoregressive Spatio-Temporal (VAST) modeling package (Thorson 2019) was used to account for spatio-temporal variation in estimation of indices of abundance for the NOAA NEFSC bottom trawl and SEAMAP coastal trawl surveys. Along with indices of abundance, VAST estimates location of abundance center of gravity through time as a measure of distribution change. The NEFSC bottom trawl survey is similar to the SEAMAP coastal trawl survey in that it is a geographically broad survey that regularly encounters Atlantic croaker during its fall sampling season. It provides coverage of ocean waters to the north of the SEAMAP coastal trawl survey, sampling from central North Carolina to the US/Canada border (see Section 5 for additional detail on the survey and VAST modeling).

Center of gravity estimates show different patterns of distribution through time between surveys, indicating these distributions are decoupled and may even be growing in segregation in recent years. The distribution tracked by the NEFSC bottom trawl survey has generally shifted to the north and east over time (Figure 4), while the distribution tracked by the SEAMAP coastal trawl survey has been relatively stable with some slight shifts to the south and west in more recent years during the summer survey (Figure 5 and Figure 6).

2.1.3.3 Fishery Catch Trends

Although commercial landings are not a direct measure of abundance and are influenced by other factors (i.e., effort), they can provide information on long-term patterns in availability and inference on abundance trends for a relatively unregulated species with commercial value like Atlantic croaker. Annual commercial landings of Atlantic croaker were available through the ACCSP Data Warehouse (see Section 4.1) by state back to 1950. Landings from North Carolina can be split at the county level starting in 1989. Time series were scaled to their means to remove differences in magnitude between areas and facilitate comparison of trends.

Trends were similar between southern and northern states through the 1950s but then diverged and tended to fluctuate in opposite directions during the same time periods (Figure 7). There was a pulse of high landings from northern states in the late 1970s while the landings from southern states fell to their lowest level since the start of the time series in 1978. Southern landings then consistently increased to a peak in 1987 while northern landings in 1987 decreased to less than 33% of the 1978 landings.

Once regional North Carolina data becomes available, landings from southern North Carolina more closely follow patterns in landings from southern states while landings from northern North Carolina more closely follow patterns in landings from northern states. Landings from northern North Carolina increased in the mid-1990s to their highest sustained levels of the time series through the early to mid-2000s, while landings from southern North Carolina were near their time series lows during this period. More recently, there have been consistent declines over the last twenty years in landings north of Onslow County, North Carolina, contrasted by consistent increases south of Carteret County, North Carolina (Figure 7).

In the same vein as the commercial landings comparisons, recreational catch trends from Marine Recreational Information Program (MRIP, see Section 4.2) data were compared by region and disposition (harvest and released alive). Trends are more inconsistent at the beginning of the time series in the 1980s, but since have aligned better between northern states and northern North Carolina and between southern states and southern North Carolina (Figure 8). Harvest in the northern areas generally declined since the early 2000s to near or at its lowest values at the end of the time series while it is stable with no discernible trend since the 1980s in the southern region. Releases declined below the time series means in most years since 2018 in the northern region while releases in the southern region have generally increased since the early 1990s and were consistently above time series means since 2013.

2.1.3.4 Recreational Fishery Catch Distributions

Williams (2025) analyzed empirical cumulative distribution functions of angler catches from south to north along the US Atlantic coast for temporal shifts to infer species distribution shifts. Results did not support a unidirectional shift in the core of the Atlantic croaker distribution (25th, 50th, and 75th percentiles) across years but did indicate small (≈1-2 km/year) northward shifts of distribution edges (5th and 95th percentiles). Visual inspection of distributions (Figure 6 in Williams et al. 2025) suggested shifts across percentiles in a nonlinear pattern. The data used by Williams (2025) were further analyzed during the assessment to examine these potential nonlinear shifts.

Catch data are from the Access Point Angler Intercept Survey (APAIS; see Section 4.2.1 for details) and are converted to presence/absence of each species caught during each angler intercept to limit influence of abundance and effort changes. Quadratic regression was applied to the annual cumulative density distribution percentile at the latitude closest to the boundary between Onslow and Carteret Counties (34.7492°N) and the latitude closest to the 5th, 50th, and 95th percentiles of the annual distribution. The approximations were due to data being binned in 0.334° latitudinal bins but should be precise enough to represent the pattern at exact desired latitudes/percentiles through time.

The regression model predicts a continuous decrease in the proportion of the distribution occurring south of Carteret County from ≈60% in the early 1980s to ≈29% in the early 2000s, followed by an increase back to around 60% in recent years (Figure 9). In terms of latitudinal change, the center of the distribution shifts from around central SC in the early 1980s to around the mouth of the Chesapeake Bay in the early 2000s, and then back to around central SC in 2023 (Figure 10). The distribution edges shift in similar patterns but at much smaller magnitudes, between central and northern FL at the southern extent of the distribution and the mouths of the Chesapeake Bay and Delaware Bay at the northern extent of the distribution (Figure 10).

Assuming no drastic latitudinal or temporal changes in angler behavior (e.g., species targeting, habitats fished), these shifts demonstrate an expansion then contraction of the distribution to the north of Onslow County with a greater proportion of the coastwide population south of Carteret County in recent years. Notably, the northern extent of the distribution declines at a slower rate in recent years than other percentiles indicating some potential range expansion at the northern edge of the population despite the contraction of the distribution north of Carteret County overall. These results support those observed in fishery-independent data above and suggest different patterns in regional distribution changes.

2.1.4 Life History

Several studies have investigated Atlantic croaker growth and reported regional comparisons with some debate on the meaning of these comparisons with respect to stock structure. Ross (1988) reported the largest size observed across studies (52.1 cm TL) from data collected in North Carolina and suggested different “groups” of fish. The maximum age from the study was only seven, but these scale-derived age data suggested that growth doesn’t asymptote at the

oldest observed age. The authors also note that using scales to age fish older than five is not reliable. The author proposed the groups overlap in North Carolina waters, one primarily north of Cape Lookout that grows larger and older than the other group that primarily occurs south of Cape Lookout. In contrast, sampling by Barbieri et al. (1994a) in the Chesapeake Bay and coastal waters of Virginia and North Carolina yielded a smaller maximum size (40 cm TL), and a maximum age of 8 using otoliths for aging instead of scale. This is similar to observations from other areas south of North Carolina, such as in Georgia where Music and Pafford (1984) reported a maximum size of 38.9 cm TL and maximum age of five using scales and in the northern Gulf of Mexico where Barger (1985) reported a maximum size of 41.7 cm TL and maximum age of eight using otoliths. Barbieri et al. (1994a) recommended reconsideration of stock structuring inferred from growth differences they observed, with a split they suggested at Cape Hatteras, North Carolina.

Also of interest, Hales and Rietz (1992) estimated ages from otoliths found at archaeological sites in Florida dated back to at least the 18th century. The authors back-calculated body lengths from an otolith length-body length relationship estimated from modern collections, primarily from Virginia, and reported the largest size (46 cm TL) and oldest age (15 years) among all areas south of North Carolina. It is difficult to draw comparisons of these data to northern areas without a comparative study of historical samples from areas north of North Carolina. For all these studies, there could be extraneous differences leading to differences in sizes and ages observed including differences in gear selectivities, habitats sampled, sampling intensity, etc.

The large temporal and spatial coverage of ongoing monitoring programs along the coast provides a more modern and robust investigation of regional growth differences. Table 3 and Table 4 provide summaries of growth data available for the assessment and show clear differences in size and age structure observed in northern and southern areas. Sizes larger than 35 cm centerline length (CL) and ages older than four have frequently been observed in northern areas while they have seldom been observed in southern areas. Maximum observed ages are ≥ 10 in most northern area programs, while only one southern area program near the Onslow County/Carteret County border has observed an age ≥ 10 (Age-10, North Carolina miscellaneous age sampling). These differences suggest regional differences in mortality as well (see Section 2.7 for more details).

Although differences in survey operation may lead to differences in size and age structures available to each survey much like for the published studies above, several programs collect fish from both southern and northern areas using the same methodology. The best example is the North Carolina Independent Gill Net Survey, which samples fish from systems across the state's coast. Length-at-age distributions again show a clear separation of growth between southern and northern areas within a relatively small spatial footprint (Figure 11). Fish in the northern portion of North Carolina have grown faster and attained larger sizes and older ages than fish in southern North Carolina.

2.1.5 Physical Oceanography

The oceanography around North Carolina's Outer Banks region, specifically Cape Hatteras, forms a well-known biogeographic boundary (Pappalardo et al. 2014; Seim et al. 2022; Tosetto et al. 2025). Cooler, fresher water from the Middle Atlantic Bight to the north converges with warmer, saltier water from the South Atlantic Bight and interacts with the Gulf Stream, which flows from north to south and typically turns out away from the continental shelf to the open ocean in this area. This convergence causes gradients in temperature and salinity as well as complex and dynamic ocean currents (Seim et al. 2022). There is precedent for connecting this biogeographic boundary to stock structure of marine fish species (e.g., black sea bass; Roy et al. 2012) and these processes could affect behavior of adult Atlantic croaker as well as transport of larval Atlantic croaker from ocean spawning areas to estuarine nursery areas. The Atlantic black sea bass population was divided into two stocks split at Cape Hatteras based on life history and morphometrics differences prior to conclusive genetic studies supporting this split (Roy et al. 2012). No research has investigated impacts of oceanographic processes at this biogeographic boundary specifically on Atlantic croaker and modern, focused tagging studies would be helpful to do so in the future.

2.1.6 Definitions for Current Assessment

Given the evidence described above, the SAS decided to model Atlantic croaker as two separate stocks with Carteret County, NC as the boundary (Figure 12). The specific boundary, occurring around latitude 34.6441, was decided given the evidence from the fisheries, independent surveys, and granularity of the available data. Catch data are available at the county level for recreational and commercial fisheries. Additionally, this latitudinal boundary is close to the strata in the SEAMAP survey where catch of Atlantic croaker were no longer correlated to the rest of the survey. This split allowed the connected estuary of the Pamlico Sound (a single water body in North Carolina commercial data collection) to remain as one unit, which would not have occurred with the previously recommended break at Cape Hatteras, NC. Thus, any Atlantic croaker in Carteret County, NC and north are considered in the northern stock, while any south of Carteret County are considered in the southern stock.

2.2 Migration Patterns

The distribution and migration of larval and juvenile Atlantic croaker follow the general trend of ontogenetic migration by estuarine fish described by Dando (1984) in which the post-larvae are normally found in the highly productive zone just down-estuary from the freshwater interface, and juveniles descend to the middle and lower reaches of the estuary as they grow. A three-year (1996–1999) ichthyoplankton survey conducted by Miller et al. (2003a) found little movement of larval Atlantic croaker out of the creeks where they were tagged. A 1998 tag-recapture study by Miller and Able (2002) on juvenile (age-0) Atlantic croaker in restored and reference marsh creeks of Delaware Bay found that 95% of the recaptures occurred in the subtidal and intertidal portions of the creek from which fish were tagged. A subsequent study of the restored Delaware Bay marshes by Nemerson and Able (2004) found juvenile Atlantic croaker abundance was one to three orders of magnitude higher in the lower bay, high-salinity marshes than in the upper bay, low-salinity marshes. A study conducted by Jung and Houde

(2003) in Chesapeake Bay found most young-of-year concentrated near the estuarine turbidity maximum (a zone in the upper bay of increased suspended particle concentration) in the upper bay between summer and fall and moved down-estuary afterward. Miller et al. (2003a) found that each year-class migrated out of Delaware Bay and tidal creeks between late summer and October–November. This result was consistent with that of Haven (1957) in Chesapeake Bay.

Studies investigating the vertical distribution of oceanic larval Atlantic croaker have drawn conflicting conclusions. Govoni et al. (1994) found evidence of diel (day-night) vertical migration with Atlantic croaker larvae more common in deeper water during nighttime hours, while Comyns and Lyczkowski-Shultz (2004) found evidence for the reverse situation where Atlantic croaker larvae were more common in deeper water during daylight. Atlantic croaker larvae migrate inshore from shelf waters in the lower layers of the Atlantic Ocean off of North Carolina (Hare and Govoni 2005), while larval Atlantic croaker in the Gulf of Mexico displayed no consistent vertical distribution pattern (Sogard et al. 1987). In Delaware Bay, as Atlantic croaker larvae become larger and more mobile, they became more common in bottom waters and actively use flood tides at night to move up the estuary (Hale and Targett 2018). If the change in movement patterns with length seen in Delaware Bay also occurs for larval Atlantic croaker in ocean waters, differences in length between the sampled Atlantic croaker in the oceanic studies may have influenced the conclusions.

The distribution of adult Atlantic croaker is associated with both seasonal coast-wide migrations and inshore/offshore migrations associated with spawning and maturity. Evidence based on field collections suggests that oceanic settlements of adult Atlantic croaker coincide with spawning in warm pelagic waters with area-specific recruitment peaks—in the fall north of Cape Hatteras, NC, and in the winter and early spring further south (Haven 1957, 1959; Ingle et al. 1962; Beaumariage and Wittich 1966; Music and Pafford 1984; Norcross and Austin 1988; Hare and Able 2007).

In the Middle Atlantic Bight and in the ocean between Cape Hatteras and Cape Lookout, Atlantic croaker move northward and inshore during the warmer months, and southward and into the ocean during late fall or winter (Haven 1959; Norcross and Austin 1988; see also ASMFC 1987 for a review). This migration pattern is corroborated by reports from trawlers targeting Atlantic croaker and tagging programs conducted in Chesapeake Bay and along the North Carolina coast (Haven 1957, 1959; Pacheco 1958, cited by Norcross and Austin 1988).

The Maryland Department of Natural Resources (MDDNR) conducted a tagging study on Atlantic croaker in Chesapeake Bay during 2005 and 2006 as part of a statewide MDDNR-sponsored fishing tournament. Nine hundred fifty-six Atlantic croaker were tagged in 2005 and 448 were tagged in 2006 (MDDNR Fisheries Service, unpublished data). Twenty-six Atlantic croaker tag returns were made in 2005 and 2006 combined, and all fish were recaptured in the same year they were released. Fifteen fish were recaptured in Maryland, all of which were released in June and recaptured during June through August of the same year. Three fish released in June 2005 were recaptured in Virginia, from Hampton to Virginia Beach, during October and November in 2005. Three Atlantic croaker released from the same net near the

mouth of the Potomac River on June 2, 2005, were recaptured in New Jersey during September through October in 2005. Another fish released from the net in the Potomac River in June 2005 was recaptured in North Carolina on December 28, 2005. Two Atlantic croaker released in the mouth of the Choptank River in June 2005 were recaptured in North Carolina in October 2005. One fish released in Tangier Sound in July 2006 was recaptured in October 2006 in North Carolina. The results of the MDDNR tagging study provide supporting evidence of a fall-winter migration from estuary to ocean for Atlantic croaker.

In the South Atlantic Bight, the migratory patterns of Atlantic croaker have been investigated through tagging programs in Florida and Georgia. Although there were no recaptures from Florida's program (Ingle et al. 1962; Beaumariage and Wittich 1966), enough recoveries were obtained from Georgia's program to determine seasonal movement (Music and Pafford 1984). The period of greatest movement was during spring-fall, and few Atlantic croaker remained in estuaries during winter. Although most recoveries were from the general area of release, there were three recoveries (3.5%) that occurred far from the release location. Two fish traveled southward (138 km) and were recaptured during May and August in the St. Johns River, Florida, and the third fish moved northward (179 km) and was recaptured in May near Cane Island, South Carolina.

2.3 Morphometric Relationships

2.3.1 Length-Length Conversions

Three types of length measurements are available in monitoring data, standard length, centerline length (or fork, relaxed total, or midline length), and total length. Standard length is the shortest of the three and is measured to the posterior end of the caudal peduncle. Centerline length is measured to the posterior end of the relaxed caudal fin. Although Atlantic croaker do not have a forked caudal fin, total length is measured by pinching the caudal fin which may lead to slight differences from centerline length. The assessment adopted centerline length as the length unit for assessment analyses because this is the most common length type recorded in data sets and requires the fewest conversions. Conversion factors or conversion among length types were developed separately for the northern and southern region from linear regression analyses of paired length (Table 5). Total length measurements were limited in the southern stock and conversion factors between standard length and centerline length were very similar between stocks. Therefore, total length conversion factors were borrowed from the northern stock for any southern stock total length conversions.

2.3.2 Length-Weight Relationships

Stock-specific length-weight relationship parameters were estimated with linear regression from aggregated paired length-weight measurements (Table 6).

For additional insight on apparent growth changes observed in the northern stock (Section 2.5), relative condition factors were examined. Relative condition factors can be used to determine body condition changes that may reflect resource changes such as prey abundance (Vogt et al. 2023). Relative condition factor of an individual was estimated as the ratio of observed weight

to weight predicted from time-series aggregate length-weight relationship parameters. Median and interquartile range of relative condition factors each year were examined by monitoring program, stock, sex, and month to remove variation from these factors. Monitoring programs with at least five years of 30 or more annual observations and aggregate length-weight relationship models with a coefficient of determination of ≥ 0.95 were included.

Female relative condition factors varied randomly around a value of one with no obvious trends over time (Figure 13). The most variation is within Chesapeake Bay (ChesMMAP survey) in September during a period of high spawning activity and associated movements, which may explain some of the variation. Condition factors are more stable during September in ocean waters (NEFSC survey). Similarly, male condition factors appear stable through time (Figure 14). Levels of variation, particularly in the surveys trawling in ocean waters, are similar between stocks despite the changes in growth observed in the northern stock. These data do not indicate prey limitations or a food resource issue occurring.

2.4 Age Determination

Early studies of the age of Atlantic croaker were based on the analysis of marks on scales (White and Chittenden 1976; Music and Pafford 1984; Ross 1988). These researchers found few age groups and some concluded that this species has a short life span, has an early age at maturity, and could withstand considerable exploitation (White and Chittenden 1976). Subsequent studies using otoliths for age determination (Barger 1985; Hales and Rietz 1992; Barbieri et al. 1994a) found that transverse sections of sagittal otoliths gave the most repeatable age estimates (Barger 1985) and that a single mark was deposited annually on the sagittae, specifically from April through May in Chesapeake Bay fish (Barbieri et al. 1994a). These studies generally found older ages, suggesting scales may lead to underestimated age relative to otoliths. Modern monitoring programs have used otoliths for age determination.

Since Atlantic croaker have a protracted spawning season (see Section 2.6.2) and recruit to estuarine nursery areas over an extended period, there are some problems associated with the identification of the first annulus on otoliths. Larval Atlantic croaker move into northern estuaries as early as August when they are approximately seven to ten months old. Along the southeast coast, most Atlantic croaker recruit to the estuaries during January through March when they are two to five months old. Northern young-of-year (YOY) may form an indistinct mark (“check mark”, or “smudge”) near the core of the otolith that has been designated as the first annulus by some researchers (e.g., Barbieri et al. 1994a). This mark is not seen in the transverse sections of the sagittae of all fish coastwide, posing a challenge for developing standardized ageing protocol.

In October 2008, the ASMFC sponsored an Atlantic croaker ageing workshop to compare methods for sectioning and reading otoliths and establish coastwide age interpretation methods (ASMFC 2008). For stock assessments, the decision was made to count the first distinct ring as the first annulus and not count any check marks that occurred near the core of the otolith as annuli. The first distinct ring is assumed to be deposited at the second spring of

life, keeping all fish spawned in the previous spring or fall before that together in a single cohort. The assumed birthdate for modeling purposes is accepted as January 1.

In March 2016, the ASMFC held a Quality Assurance/Quality Control Fish Ageing Workshop to revisit species that had their own ageing workshop, like Atlantic croaker. During this workshop, Atlantic croaker otoliths had an average percent error of 8% (ASMFC 2016). Differences in age readings were attributed to a persistent disagreement over the presence/absence of the check mark and whether to count it when present. Because of a research recommendation that came out of the workshop to revisit this topic, the ASMFC held a conference call in June 2016 for agers along the Atlantic and Gulf coast. During a follow up conference call held by ASMFC in June 2016, it was agreed that more age validation studies are needed and ageing labs should continue to not count the check mark. In addition, labs should provide more information regarding their methods when submitting final ages, including presence/absence of the check mark and annulus counts.

Below are details of ageing practices for each agency that provided age data for the assessment.

New Jersey
From 2006 through 2016, New Jersey Fish and Wildlife (NJFW) collected Atlantic croaker biological samples from a commercial dockside survey. In 2008, New Jersey began collecting fishery independent samples aboard the NJFW Ocean Trawl Survey. Atlantic croaker were also sampled opportunistically on other fishery independent surveys being conducted by NJFW throughout the state. The samples are weighed, measured, sexed and otoliths are removed for later ageing. Once otoliths are extracted, they are sectioned using a slow-speed saw, mounted to a slide, and aged under a microscope using transmitted light at NJFW's Nacote Creek Research lab.

Maryland
Otoliths were processed and aged by the South Carolina Department of Natural Resources prior to 2011. Since 2012, otoliths have been processed and aged by MD DNR. The left otolith from each specimen was mounted to a glass slide for sectioning. If the left otolith was damaged or missing, the right otolith was substituted. Otoliths were mounted to a glass slide using and sectioned with a low speed saw using two blades separated by a 0.4 mm spacer. Impregnated diamond metal bonded, high concentration cutting blades, measuring 102 mm in diameter and 0.33 mm thick, were used. The 0.4 mm sections were then mounted on microscope slides and viewed under a microscope at five to six power to determine the number of annuli. All age structures were read by two readers. If readers did not agree, both readers reviewed the structures together, and if agreement still could not be reached the sample was not assigned an age.

Virginia Marine Resources Commission
The otoliths collected through the VMRC's Biological Sampling Program were processed and read by the Old Dominion University's Center for Quantitative Fisheries Ecology until the VMRC Ageing Lab took over ageing samples in August 2019. Otoliths are processed following the

methods described in Barbieri et al. (1994a) with a few modifications. The left or right otolith was randomly selected and attached, distal side down, to a 1 inch x 2 inch piece of water resistant grid paper (Write in the Rain™) using hot glue. At least two serial transverse sections are cut through the core of each otolith with a Buehler Isomet low-speed saw equipped with a three-inch, fine-grit Norton diamond-wafering blade. Otolith sections are placed on labeled glass slides and covered with a thin layer of Flo-texx mounting medium.

All fish are aged in chronological order based on collection date, without knowledge of the specimen lengths. Two readers must age each otolith independently. When the readers' ages agree, that age is assigned to the fish. When the two readers disagree, both readers must re-age the fish together, again without any knowledge of previously estimated ages or specimen lengths and assign a final age to the fish. When the readers are unable to agree on a final age, the fish is excluded from further analysis.

The process for ageing Atlantic croaker otoliths in Virginia involves two steps: (1) read the otolith—count the number of annuli in the otolith transverse cross-section; and (2) determine the age of the fish in terms of sacrifice date and annulus formation period.

Virginia Institute of Marine Science

North Carolina

Atlantic croaker sagittal otolith samples are collected monthly from the winter trawl, long haul-seine, pound-net, sink-net fisheries, and NCDMF fisheries-independent programs. Sagittal otoliths have been collected since 1996. Each month, samples (n=15) are distributed across the length range in 15-mm length classes starting at 100 mm TL. Sagittal otoliths are removed, cleaned, and stored dry. Fish are weighed to the nearest 0.01 kg and measured for TL to the nearest millimeter. Date, gear, and water location are also recorded for each sample.

A transverse section through the focus on a plane perpendicular to the horizontal axis of the left otolith is prepared using a Hillquist thin-sectioning machine as described by Cowan et al. (1995). The system is calibrated with an ocular micrometer before each reading session. Sections are viewed under reflected light at 21X magnification. Ages are assigned based on the number of otolith annuli viewed. The ageing lab biologist reads the otolith section. The samples are then independently read by the species lead biologist. If any differences are not resolved, the data are omitted.

South Carolina

In general, both left and right otoliths were collected from each fish. In the laboratory, the left sagittal otoliths are processed using the embed and section method. If the left otolith was not collected or broken through the core, the right otolith was processed instead. A pencil is used to mark on the lateral otolith surface the ideal transverse cut incorporating the otolith core. Using a silicone mold, the otoliths are embedded in epoxy resin (West Systems 105 Epoxy Resin and 205 Fast Hardener) to create a flat surface for mounting and help prevent breaking during the sawing process. The embedded otoliths are glued to tabs which fit into a chuck on the arm of a Buehler Isomet low-speed saw. The saw has two or three diamond wafering blades (high

grit concentration, 0.012” thickness, 4” diameter), separated by ~0.4mm spacer(s) to create one or multiple sections with a single pass. Cytoseal XYL, a permanent resin-based mounting medium, is used to secure the sections to a microscope slide. Two readers examine each section through a dissecting microscope at 20-40X magnification using transmitted light without any knowledge of fish size. Each reader independently assigns an increment count, an edge code (a qualitative marginal increment width), and a quality code for that particular sample. The first annulus is considered the first well-defined, opaque band that can be traced around the entire section. The annuli count along with a margin code and capture date are used to supply fisheries managers with a year class for each sample.

Georgia

Atlantic croaker captured in GA DNR fishery independent surveys from March 2010 to October 2012 were aged as part of a master’s thesis (Franco 2014). Several gears were used including trawl, hook and line, gill nets, and trammel nets. Otoliths were removed from a maximum of 30 fish per site, per day, from all surveys. If more than 30 fish were collected from an individual site, otoliths were removed from only a random subsample of each size class. The left sagittal otolith was primarily used for ageing. Otoliths were sectioned and aged based on manual counts of growth bands, without knowledge of specimen lengths, in chronological order by collection date. Methods used for ageing Atlantic croaker in this study differed from methods outlined in the ASMFC ageing workshop as the check mark near the core was counted as the first annulus but were since adjusted in the data provided for this assessment to follow the ageing workshop methods.

2.5 Growth

Atlantic croaker exhibit rapid growth during their first year of life, but growth then declines sharply and sizes overlap considerably among ages. Maximum ages observed by monitoring programs are age-17 in the northern stock (Table 3) and age-10 in the southern stock (Table 4). Maximum sizes observed are 64 cm in the northern stock and 46 cm in the southern stock. Previous growth studies found no difference in length-at-age between sexes (Barbieri et al. 1994; Barger 1985).

Length-at-age data collected by monitoring programs were used to construct growth models for each stock during the assessment. Published literature has focused on von Bertalanffy models to describe Atlantic croaker growth (Barbieri et al. 1994; Barger 1985; Hales and Rietz 1992; Music and Pafford 1984; Ross 1988), so this was the focus for growth analyses during the assessment. The data indicated changes in length-at-age through time, so time-varying growth was explored as well.

Data with lengths other than centerline length were converted to centerline length using relationships developed during the assessment (Section 2.3.1). Mean length-at-age was larger in January through March then declined before increasing throughout the remainder of the year as would be expected. This pattern was consistent across areas and programs and does not appear to be explained by selectivity differences. Therefore, data from January-March were excluded from the data set. Data from the southern stock had a minor secondary mode in

length-at-age distribution that was larger than the primary mode. These data were from fishery-dependent collections in North Carolina and the commercial Trip Interview Program (TIP) in Florida, which may be affected by stock mixing and/or mobility of the commercial fleets moving back and forth across the stock boundary. These data accounted for less than 3% of all southern stock data and were excluded from the data set.

Sex-specific growth models were fit for each stock independently and von Bertalanffy growth parameters were compared between males and females using likelihood ratio tests. For the northern stock, female mean length at age was higher than males in the northern stock (Figure 15). Using likelihood ratio tests, Linf and k were not statistically different between sexes ($p=0.233$ and $p=0.101$, respectively): however, t_0 and combined parameters (overall growth curve) were statistically different ($p <0.05$ and $p < 0.001$, respectively). For the southern stock, estimated mean length at age was higher for males than for females (Figure 16). All parameters and combinations were statistically different between sexes ($p < 0.001$). There was concern among the SAS that the difference between males and females could be due to a lack of older individuals available for analysis, particularly females. Unsexed Atlantic croaker in the southern stock have been documented to reach age 10, but the sex-specific data resulted in two females at age 7, 1 male at age 7, and 1 male at age 8.

Despite the statical significant parameter differences, the differing growth curves resulted in minor discrepancies at each age that were within the 2 cm bin size used in modeling and the SAS decided these differences were not biologically meaningful enough to model in the assessment.

Data were then aggregated over sexes. Data with unidentified sex were retained for the northern stock to supplement the early portion of the data set when sex was not recorded as frequently. For the southern stock, data with individuals of unidentified sex had patterns that were not consistent with data of similar sized individuals where sex was recorded. There were considerably more individuals of unidentified sex ages 1 and 2 less than 10 cm in length. Most of these samples were from the same sampling program (Franco 2014), which may be a programmatic effect. Regardless, the entire southern data set was then filtered to remove individuals with unidentified sex.

There was a decline in mean length-at-age starting in the mid-2000s in northern areas (Figure 17-Figure 18) while length-at-age in the southern area varied without trend over time (Figure 19-Figure 20). The northern area declines were consistent across sexes and programs and did not appear to be driven by specific sampling techniques or locations. Mann-Kendall trend analysis indicated declines became more consistent for ages 2+ and before data tend to become sparse, particularly in recent years, for the oldest ages (Ages-7+, Table 7). A shift in spawning time does not appear to be a driver of the growth patterns observed due to limited evidence of time-varying length of age-0 fish and no major changes in peak larval settlement (Section 2.6.2). When growth models were fit to annual data by stock there was a declining trend in Linf in the northern stock starting around 2014 (Figure 21). No similar trends were identified in the southern stock.

Based on these results, data were aggregated into two periods (1980-2014 and 2014-2024) for the northern stock to generate period-specific growth parameters. Lengths for the youngest ages were similar between periods but there were fewer large fish at older ages in the later time period (Figure 22). Therefore, the growth model predicts a similar mean length at age for young fish between periods, but the asymptote for mean length during the later period (26.5 cm, Table 8) is lower than in the earlier period (41.0 cm). Predicted mean length at age in the northern stock in the later period was similar to the southern stock (Figure 23).

2.6 Reproduction

2.6.1 Maturity

Early maturity studies of Atlantic croaker on the Atlantic coast estimated onset of maturity at relatively older ages and larger sizes. Welsh and Breder (1924) reported that Atlantic croaker reach maturity at age-3 or 4. Wallace (1940) collected data from the Chesapeake Bay and reported that males first reach maturity at age-2 and females reach maturity at age-3. Wallace (1940) also reported a minimum length at maturity of 24 cm for males and 27.5 cm for females.

More recent studies suggest Atlantic croaker mature at smaller sizes and younger ages than reported previously. Morse (1980) used data collected on the continental shelf during the NEFSC fall trawl survey from New Jersey to Cape Hatteras, North Carolina. Annual estimates of the size at 50% maturity (*L50*) ranged from 18.7-22.4 cm for males and 18.5-23.3 cm for females from 1973-1976. Barbieri et al. (1994) estimated *L50* of 18.2 cm and 17.3 cm for males and females, respectively, collected in the Chesapeake Bay and coastal waters from Virginia to Cape Hatteras, North Carolina. Over 85% of individuals were mature by age-1 and all were mature by age-2 and 25 cm.

Differences in maturity at age between historical and more recent studies could be due to (1) biased age data derived from length frequency analysis (Welsh and Breder 1924) and scales (Welsh and Breder 1924; Wallace 1940) instead of otoliths, (2) biases due to lack of sampling smaller, younger fish (Wallace 1940; Morse 1980), and (3) sampling outside the peak spawning season (Wallace 1940). Barbieri et al. (1994) noted that *L50* estimates could be biased high due to difficulty distinguishing between resting and immature gonads and the inclusion of samples early in the spawning season before all mature individuals would have moved out of the resting stage.

Female length-based maturity was estimated from available sampling data during the assessment as inputs for maturity specifications in the assessment models (Table 9). Data were filtered to histological samples collected from July through December to capture the primary spawning season.

Logistic regression was used to estimate the maturity parameters *a* and *b*:

$$p = \frac{e^{a + bCL}}{1 + e^{a + bCL}}$$

where *p* is the proportion mature at centerline length in cm (CL).

Model fits were assessed with chi-square goodness of fit tests. A Chi-square effect size greater than 0.5 was considered indicative of a correctly specified model for the observed data. Bootstrapping was used to generate confidence intervals.

L50 estimates from northern stock data sets ranged from 17.0-19.1 cm (Table 9). Estimates from southern stock data sets were more variable, ranging from 15.9-22.4 cm. Estimates from regional trawl surveys that had the largest sample sizes and spatio-temporal coverage ranged from 17.0-19.1 cm across stocks, with only the estimate from ChesMMAP data falling outside the 17 cm size bin. These estimates are similar to the most recent published estimate from Barbieri et al. 1994 (17.3 cm). ChesMMAP sampling includes the earliest seasonal data (July), but the *L50* estimate is consistent (19.1 cm) if earlier season data (July-August) are excluded to better align with the other trawl survey fall sampling seasons. The different *L50* estimates for ChesMMAP may be due to the spatial sampling within the Chesapeake Bay where the bulk of mature individuals leave in the late summer during migrations to the primary spawning grounds in ocean waters.

Sampling programs with at least six annual data sets that supported converged models, passed chi-square model specification tests, and estimated *L50*s with 95% confidence intervals less than 10 cm (to avoid distorting figure scaling) were examined for evidence of temporal maturity changes. There was no evidence of trending maturity in the northern stock (Figure 24). ChesMMAP estimates were relatively variable but did not indicate a consistent trend throughout time.

Only the SEAMAP survey has collected enough data to investigate temporal changes in the southern stock. *L50* estimates from this program have declined through the time series (Figure 25) The pattern did not appear to be a spatial effect as estimates at the state level showed consistent patterns. However, the range of estimates was not considered significant from a biological perspective as all but three estimates fell within the 2 cm length bin resolution used in the assessment model (16-17.99 cm bin). Unfortunately, there was no recent data to assess this pattern beyond 2012.

Estimates from the NEAMAP and SEAMAP sampling program data aggregated across years were recommended for assessment models because the programs have similar sampling methodologies (i.e., nearshore trawling during the fall), robust sample sizes, broad temporal and spatial coverage, and sample the primary spawning habitats (ocean waters). Ogives are similar between stocks (Figure 26) with L50 estimates within one cm (Table 9).

2.6.2 Spawning

The timing of Atlantic croaker spawning events vary by latitude and can be prolonged in many areas, particularly in the southern stock (White and Chittenden 1976; Music and Pafford 1984; Able and Fahay 1998; Barbieri et al. 1994b; Franco 2014). In the Chesapeake Bay, spawning occurs from July through December, with peak spawning in September (Barbieri et al. 1994b). In Georgia, histological examinations showed spawning occurred from May to October, but

ingress of young-of-year (YOY) croaker later in the years provides evidence that spawning likely occurs through December (Franco 2014). Additionally, a second peak spawning event has been documented with protracted spawning seasons lasting from six to nine months (Music and Pafford 1984; Franco 2014).

Collections of gravid or running-ripe females have occurred in rivers, estuaries, and offshore habitats, indicating there are spawning locations inshore and offshore (Barbieri et al. 1994b; Franco 2014). Atlantic croaker offshore spawning in the mid-Atlantic is driven by water temperatures greater than 16 °C and spawning moves farther south in years when water temperatures are cooler (Norcross and Austin 1988). Atlantic croaker produce sounds underwater to aid in reproduction and finding mates (Ramcharitar et al. 2006; Luczkovich et al. 2012). Sound production is highest at night and is correlated with warmer water temperatures similarly to spawning (Mann and Grothues 2009).

Larval fish monitoring program data were evaluated during the assessment for timing of settlement and inference on timing of spawning along the coast. Data were analyzed to explore three characteristics, (1) seasonal timing of settlement, (2) shape of seasonal settlement distribution, and (3) timing of settlement across years. Data were not examined for relative abundance through time because of previous findings of no relationship between larval abundance and subsequent life stages modeled in the assessment, suggesting year class strength is established after the first winter of life (Hare and Able 2007).

Three larval sampling programs that occur along the U.S. east coast span the majority of the population. The southernmost program has been conducted since 1981 by the University of South Carolina's Baruch Marine Field Laboratory in Georgetown, South Carolina. Biweekly sampling occurs with an epibenthic sled with 365 micron mesh in Town Creek off the North Inlet in the North Inlet-Winyah Bay National Estuarine Research Reserve. Two replicate tows are conducted during morning mid-ebb tides each sampling session throughout the year. Up to ten individual fish are measured per replicate for standard length.

The Beaufort Bridgenet Ichthyoplankton Sampling Program has been conducted by the NOAA Southeast Fisheries Science Center's Beaufort Laboratory near the Beaufort Inlet in Beaufort, North Carolina since 1986. This location is only about twenty-five miles north of the stock boundary and just south of Cape Lookout, North Carolina. This program is the only one of the three that does not sample year-round, sampling weekly from mid-November through April. A rectangle neuston net with 1 mm mesh is fished from a bridge just below the water surface. Three (1986-spring 1987) or four (fall 1987-present) replicates occur during incoming nighttime flood tides.

The northernmost program is conducted at the northern end of the historic range by the Rutgers University Marine Field Station at the Little Sheepshead Creek near Little Egg Inlet, New Jersey. A plankton net with 1 mm mesh is fished from a bridge over the creek. Sampling began in 1989 but was not standardized until 1996, so data prior to 1996 were excluded. Weekly sampling occurs at night during incoming flood tides with three replicates during each sampling session.

Atlantic croaker length frequencies varied across programs and the New Jersey and South Carolina programs captured a similar broad size range of larvae (Figure 27). The South Carolina program caught the smallest fish with a peak at 6 mm while the New Jersey program peaked at 8 mm and caught the highest proportion of fish above 13 mm. The North Carolina program caught the narrowest size range with a peak at 10 mm and the most between 8 and 14 mm. Larval growth models for fish from the Mid-Atlantic indicate ages ranging from approximately 20 to 50 days post-hatch for peak sizes observed, depending on time of spawning (Nixon and Jones 1997).

Catch data are available as densities (number of larvae per cubic meter of filtered water). Continuous seasonal periods with no catch were excluded from the year-round sampling programs (March 8-July 31 in New Jersey and May 30-August 29 in South Carolina). Data were grouped by "run year", or cohort, from the late summer/fall sampling of year *y* through winter/early spring of year *y+1* and assigned a run year *y*. Similarly, run day of year for run year *y* was a continuous count of days since January 1 of year y. Data for any run years where the median of sampling effort timing deviated from the time series were excluded from the data set (2007 and 2017-2019 in North Carolina and 2022 in New Jersey).

The 5^{th}, 50^{th}, and 95^{th} percentiles from cumulative distribution functions (CDFs) of daily catch densities were used to represent the beginning, middle, and end of each annual settlement event, respectively. The weekly sampling causes steplike CDFs across days, so LOESS smoothers were fit to these empirical distributions to approximate a continuous function and the percentiles of interest.

The earliest settlement usually occurred in New Jersey, starting around the end of August, reaching a midpoint at about mid-October, and coming to an end around early December (Figure 28). Settlement in North Carolina ramps up the latest, around late November, reaching a midpoint around late January, and wrapping up around late March. Settlement in South Carolina is the most protracted, ramping up a little more than a month later than New Jersey in early October, reaching a midpoint around mid-January, and winding down a few weeks later than North Carolina in early April. The late start in North Carolina is the most unusual pattern but is likely influenced by the apparently narrower gear selectivity of this program and restricted seasonal sampling window. Distributions of catch densities suggest presence of settlers at the start of the sampling window (~$5/m^3$), while catch declined to zero by the end of the sampling window (Figure 29), indicating a slight positive bias in percentiles for this program.

Settlement timing does show considerably interannual variability, in some cases by multiple months, particularly in the programs with year-round monitoring. However, no significant trends were detected with Mann-Kendall analysis in any of the percentile time series. Visually, there does appear to be a consistently earlier start and midpoint of the settlement in New Jersey in the 2010s before returning to average levels of interannual variability in the late 2010s (Figure 28).

Annual catch distributions across sampling days were noisy, so data were aggregated into blocks of years depending on the program's respective time series to evaluate the shape of

catch distributions. Blocks were ten years for North Carolina (1986-1995, 1996-2005, and 2006 & 2008-2016), twelve or thirteen years for New Jersey (1996 & 1998-2008 and 2009-2021; 1997 removed due to anomalous pattern of high densities of late-year catches driving block pattern), and nine or ten years for South Carolina (1981-1990, 1991-2000, 2001-2009, and 2010-2018).

Aggregated distributions show consistent, unimodal distributions in North Carolina increasing from low densities at the beginning of the sampling season, distinct peaks in the middle of the sampling season, and declines to zero at the end of the sampling season (Figure 29). Although not used for indices of interannual abundance changes, these aggregated densities show patterns in larval production like patterns in later life history data sets for the northern stock (i.e., highest densities in the middle time period from 1996-2005).

New Jersey also has distinct peaks in density across time blocks in the first half of October, but there is evidence of smaller secondary peaks later in the calendar year after periods of relatively low densities (Figure 30). South Carolina has primary peaks across most time blocks (2-4) around early February but there are smaller secondary peaks starting as early as September (Figure 31). The broader size structures sampled/wider selectivity may be contributing to multimodal distributions in New Jersey and South Carolina.

2.6.3 Fecundity

The limited number of published estimates indicate that fecundity for Atlantic croaker is high. Hildebrand and Schroeder (1928) reported that a 39.5-cm female contained approximately 180,000 eggs. That estimate was based on a single fish caught in the mouth of the York River in October 1921. Fecundity ranged from 100,800 to 1,742,000 eggs for females ranging from 19.6 cm to 39.0 cm TL based on ovaries collected during the fall NMFS Bottom Trawl Survey in 1973 and 1974 (More 1980). Morse's (1980) estimates assumed determinate fecundity; however, Barbieri et al. (1994b) concluded that Atlantic croaker have indeterminate fecundity and suggested that estimates based on the assumption of determinate fecundity should not be used for management. A study to evaluate Atlantic croaker for its potential as a broodstock found fecundity to be approximately 81,000 eggs in a passively induced laboratory setting which increased to 267,000 eggs with the application of a hormone implant (Sink et al. 2010).

2.6.4 Sex Ratio

In both stocks, there were more females than males (northern stock = 63%; southern stock = 58%, Table 10 and Table 11). Fishery dependent data sources had slightly higher occurrences of females (northern stock = 65%; southern stock = 68%) than fishery independent data sources (northern stock = 57%; southern stock = 60%). However, it is important to note that the southern stock had a low sample size from fishery dependent data sources (n=74).

During the last benchmark stock assessment, it was also noted that sex ratios were skewed toward females in all months for all datasets, except October for the NMFS Survey, with percent females ranging from 53% to 62% in fishery independent data sources. Similarly, for Atlantic croaker collected from commercial fisheries during 1990 and 1991 in the Chesapeake Bay and nearby coastal ocean females dominated catches during the main spawning period

(June/July–September/October) and were highest during August–October in both years (Barbieri et al. 1994b). Barbieri et al. (1994b) suggested that the higher proportions of females observed during the first months of spawning could indicate that males migrate out of the bay earlier than females or that spawning-phase females are more susceptible to the commercial fishing gears from which samples were collected. While these observed ratios were skewed towards females, the magnitude varies depending on season and data type (fishery-dependent vs. fishery-independent) with many sources being only mildly skewed from an equal split. Ultimately, the SAS determined that the assumptions required and effort needed to implement a sex specific assessment model was considered a lower priority compared to other tasks that came up during the assessment, such as splitting the one stock model into two stocks and all the associated effort for splitting data sets and developing two separate models.

2.7 Natural Mortality

Atlantic croaker are important prey for many species along the Atlantic coast. Predators include striped bass (Able and Fahey 2010; Dovel 1968), southern flounder, bluefish, weakfish, and spotted seatrout (ASMFC 1987). Age-1+ bluefish prey heavily on Atlantic croaker during July-August, as they made up a majority of bluefish stomach content in the Chesapeake Bay (Hartman and Brandt 1995). Because of variation in predation rates on Atlantic croaker with life history stage the use of age or size varying natural mortality in assessment models may be appropriate for this species. Natural mortality of Atlantic croaker may also be driven by environmental or ecosystem factors, including temperature variability, hypoxia, and salinity, particularly at the juvenile life stage (see section 3.2).

Natural mortality, *M*, includes any mortality due to natural causes (starvation, disease, predation, etc.) and human-induced events not associated with fishing (Hilborn and Walters 1992; Vetter 1998; Hampton 2000; Maunder et al. 2023). This parameter is a vital component of stock assessment models, and estimating *M* is particularly difficult because it is rarely observed and can be confused with emigration (Hilborn and Walters 1992; Quinn and Deriso 1999; Haddon 2011; Hamel et al. 2023; Maunder et al. 2023). A common specification for *M* in assessment models is to allow *M* to vary with size or age, with an age or range of ages that are fully selected (Lorenzen 1996; Lorenzen 2022; Lorenzen et al. 2022). To estimate natural mortality for specifications in the assessment models used during this current assessment, the following methods were used.

A constant age-invariant natural mortality rate, *M*, was estimated based on longevity by methods developed by Hamel and Cope (2022), where $M = \frac{5.4}{t_{max}}$ and t_{max}= maximum observed age for both stocks.

To explore natural mortality at each age, the constant *M* was used to scale the generalized length-inverse mortality (GLIM) estimates developed by Lorenzen (2022). The GLIM paradigm uses length-at-age estimates from von Bertalanffy growth models to estimate mortality, using $M(L) = M_{Lr}(\frac{L}{L_r})^c$, where M_{Lr}= mortality at a reference length, Lr= reference length at a given age, and c=the rate at which mortality declines with increasing body size. The GLIM paradigm

describes the relationship between mortality and size, but not the magnitude of it within a population (Lorenzen 2022; Lorenzen et al. 2022; Hamel et al. 2023). To apply the GLIM paradigm to the Atlantic croaker stocks, the age-invariant constant was used to anchor the estimates of *M* at any given age. Scaling was completed by setting *M* at age two equal to the age-invariant constant and scaling the other ages appropriately. Age two was selected to correspond to full fishery selectivity for Atlantic croaker, ensuring that the scaled mortality schedule is consistent with the expected mortality level of the exploited population. This method has been used in other recent stock assessments (ASMFC 2024a; Brodziak 2026)

Given longevity estimates of 15 years for the northern stock during 1981-2013, 11 years for the northern stock during 2014-2024 and 8 years for the southern stock, resulting constant mortality estimates were *M*=0.360, *M*=0.491, and *M*=0.675, respectively. These estimates were higher than the previous two benchmark stock assessments. However, in the 2017 benchmark stock assessment, the Then et al. (2015) age-constant approach was used with a maximum age of 17 years for Atlantic croaker and in 2010, Hoenig's (1983) age-constant approach was used with a maximum age of 17 years. These resulted in *M*=0.306 in 2017 and *M*=0.176 to 0.271, depending on the Hoenig (1983) configuration (ASMFC 2010; ASMFC 2017).

Length specific *M* ranged estimating the GLIM paradigm decreased with increasing length as specified for each stock, with higher natural mortalities at each length for the southern stock which does not obtain the higher ages or larger lengths as the northern stock (Table 12). Similarly, natural mortality was higher at each length in the northern stock in the later time period (2014-2024), as opposed to the earlier years (1981-2013) due to smaller individuals at each age (Table 12). Scaling the *M* at length for each population using the Hamel and Cope (2022) constant age-invariant natural mortalities, produced slightly higher estimates of *M* at each length (Table 12). The assessment model used during this current assessment (Section 6) required specification of M for a reference age and then rescales M for ages other than the reference age based on model-estimated growth. The reference age for Atlantic croaker was chosen as age-2 and estimates developed here were 0.535 for the northern stock and 0.809 for the southern stock.

2.8 Diet

Atlantic croaker are opportunistic bottom-feeders with a variety of prey that change throughout their life cycle. During their early larval life stages, Atlantic croaker diet is comprised of polychaetes, zooplankton, detritus, and macroinvertebrates including crustaceans, amphipods, copepods (Laussy 1983; Overstreet and Heard 1978). Adult Atlantic croaker feed on benthic invertebrates, fishes such as anchovies, and macroinvertebrates including polychaetes, mysids, grass shrimp, clams, and crabs (Lassuy 1983; Nye et al. 2011). Diet studies in the Chesapeake Bay found polychaetes often comprised more than 50% of annual Atlantic croaker consumption, with bivalves periodically being an important prey item, and mysids varying from 18% of consumption in 2003 to 40% in 2005, demonstrating the opportunistic nature of Atlantic croaker feeding (Buchheister and Houde 2016).

Atlantic croaker diets have been found to vary seasonally and spatially within the Chesapeake Bay (Parthree 2005; Nye et al. 2011). Diets and feeding may also be influenced by environmental and climatic factors. Diet changes have been observed during hypoxic events, where croaker feed on plants and detrital material during hypoxic events in North Carolina (Powers et al. 2005). Hypoxic events may also potentially drive higher proportions of fish in Atlantic croaker diets in Chesapeake Bay (Nye et al. 2011). A positive relationship between small (<200 mm) Atlantic croaker consumption per capita and water flow and a negative relationship between medium (≥200 mm) Atlantic croaker consumption per capita and salinity was reported by Woodland et al. 2017. Juvenile Atlantic croaker diet varied by salinity gradients in Delaware Bay where in lower salinity, crustaceans figured prominently in the diet (15–34%), whereas mysids dominated at higher salinity sites (46%; Nemerson and Able 2004).

Benthic macroinvertebrate biomass is monitored within the Chesapeake Bay through the collaborative Chesapeake Bay Benthic Monitoring Program between Maryland and Virginia. Species data were categorized according to the Atlantic croaker prey categories in Parthree (2005) and evaluated for compositions and total biomass through time. Compositions varied by state, with bivalves being the dominant category in Maryland, while Virginia compositions were more diverse with major categories including bivalves, polychaetes, and other macroinvertebrates in that order (Figure 32). Compositions vary across years and there appears to be a slight shift to higher proportions of polychaetes and other macroinvertebrates replacing bivalves in the 2010s and 2020s, but otherwise no clear trends (Figure 32 and Figure 33). Total biomass in Maryland was highly variable between average and time series highs in the 2000s, more stable at average levels in the 2010s, and low in the 2020s (Figure 34). Biomass in Virginia was relatively high in the early 2000s, declined briefly in the mid-2000s and has increased since to some of the highest levels in the 2010s. Baywide, total biomass has slightly increased through time, with highs in 2001, 2005, and 2008-2009, and lows in 1998 and 2012 (Figure 35). These findings are similar to those of stable to slightly increasing biomass by Vogt et al. (2023).

3 HABITAT

3.1 Physical Habitat

3.1.1 Physical Habitat Requirements

Atlantic croaker are habitat generalists with predominate habitat types including, but not limited to, submerged aquatic vegetation, non-vegetated bottom, marsh edge, wetlands, sandy bottom and shell bottom (Petrik et al. 1999; Street et al. 2005). Their geographic range is from Massachusetts to Florida but are most commonly found from New Jersey to Florida and in the Gulf of Mexico (Diaz and Onuf 1985; Robbins and Ray 1986; Ross 1988; Able and Fahey 1998). Atlantic croaker undergo ontogenetic habitat shifts.

Localized processes like currents and tidal regimes influence the dispersal of eggs and early-stage larvae to nursery areas (Petrik et al. 1999; Joyeux 1998). Field surveys of post-settlement Atlantic croaker in estuarine nursery areas found no significant differences in abundances among submerged aquatic vegetation, marsh edge, and sandy bottom (Petrik et al. 1999).

Nursery areas differ considerably among locations, possibly in response to tidal range. Upon initial arrival in the estuary, larval Atlantic croaker are restricted to the surface water but will eventually settle into bottom waters where they complete their development into juveniles (Miller et al. 2003).

Juvenile Atlantic croaker are typically found in estuaries along the Atlantic coast (Diaz and Onuf 1985; Robbins and Ray 1986; Ross, 1988; Able and Fahey 1998). Substrate plays a larger role in distribution once Atlantic croaker reach the juvenile stage. Juveniles are positively correlated with mud bottoms that have large amounts of detritus and high amounts of benthic prey (Cowan and Birdsong 1985). Juvenile Atlantic croaker are found more commonly in deeper channel habitats as they grow (Chao and Musick 1977; Poling and Fuiman 1998). Juveniles migrate downstream as they develop and by late fall, most juveniles emigrate out of the estuaries for open ocean habitats (Miglarese et al. 1982).

Adult Atlantic croaker, over one year of age, are found over muddy and sandy substrates as well as near oyster, coral and sponge reefs (White and Chittenden 1977; TSNL 1982). Temperature and depth are strong predictors of adult Atlantic croaker distribution and the interaction between the two variables may also influence distribution (Eby and Crowder 2002).

Atlantic croaker spawn predominantly in polyhaline and eurohaline zones on the continental shelf, and in tidal inlets and estuaries, and at depths ranging from 7 to 81 m (26 to 266 ft; Diaz and Onuf 1985). Atlantic croaker are pelagic spawners (Chao and Musick 1977; Barbieri et al. 1994b) in areas dominated by soft sediment (mud and sand) (Townsend et al. 2004; Friedrichs 2009). Location of spawning may be more dependent on temperature than substrate type. Spawning along the Mid Atlantic Bight has been correlated with bottom temperatures higher than 16°C (Norcross and Austin 1988).

3.2 Critical Environmental Factors

3.2.1 Dissolved Oxygen

Atlantic croaker use of estuarine benthic habitats throughout their lifespan exposes individuals to fluctuating dissolved oxygen (DO) levels and frequent potential for hypoxic conditions (DO<2 mg/L; Table 13), particularly during the summer. Hypoxic conditions have increased and are expected to continue increasing in areas important to the species distribution (e.g., Chesapeake Bay) in the future, largely as the result of anthropogenic activities (Kemp et al. 2005; Breitburg et al. 2018; Rabalais et al. 2009). Hypoxia will become fatal at some level that may depend on other factors such as fish size, previous exposure, duration of exposure, and other environmental factors like temperature, though direct mortality due to hypoxia exposure is not expected to significantly impact interannual population dynamics given mobility and avoidance behaviors (Eby et al. 2005; Shimps et al. 2005). No known studies document the lethal threshold of DO for Atlantic croaker but a study on the closely related species, spot (*Leiostomus xanthurus)*, documented mortality increasing from 0% at 1.2 ppm DO to 100% at 0.6ppm DO (Shimps et al. 2005).

Greater impacts of hypoxia to population dynamics are expected from sublethal impacts. Further, these sublethal impacts may be due to direct exposure to the low DO concentrations or indirectly. The most established direct sublethal impact in the published literature is to reproductive potential through reduced gonadal growth of both sexes, female fecundity, hatching success, and larval survival (Thomas et al. 2006; Thomas et al. 2007; Thomas & Rahman 2009; Tuckey & Fabrizio 2016). Thomas et al. (2007) found that fecundity of female Atlantic croaker exposed to DO levels of 2.7 mg/L and 1.7 mg/L was reduced to 30% and 10%, respectively, of female fecundity in normoxic conditions (5.33 mg/L). Degradation of homeostasis has also been observed at low DO levels associated with hypoxia (Marcek et al. 2019).

Hypoxia elicits behavioral responses including avoidance, which impacts catchability and distribution. Avoidance is in a horizontal direction along the bottom as opposed to vertically throughout the water column (Craig and Crowder 2005; Craig 2012) and significant hypoxia-induced habitat shifts have been observed (Eby and Crowder 2002; Eby et al. 2005; Craig and Crowder 2005), including aggregations of Atlantic croaker at edges of hypoxic areas. Despite these habitat shifts, individuals exposed to seasonal hypoxia had similar diets of benthic organisms to those not exposed further supporting individuals remaining in benthic habitat regardless of DO concentrations (Mohan and Walther 2016). Atlantic croaker are considered relatively tolerant of hypoxia, likely due to their evolution in habitats that have experienced these conditions naturally through time (Thomas et al. 2007). This hypoxia tolerance and observations of Atlantic croaker aggregations at edges of hypoxic zones have been proposed as an adaptive behavior to forage on less mobile, impaired prey in hypoxic areas, giving the species a competitive advantage in hypoxic areas (Mohan and Walther 2016). However, this tolerance also leads to low thresholds for avoidance and greater exposure to hypoxic conditions and the sublethal effects, such as reduced fecundity (Table 13), which will increase as hypoxic conditions increase.

Generally, Atlantic croaker appear resilient to hypoxia in terms of somatic growth. There has been no evidence of reduced somatic growth in mature adults that have experienced reduced gonadal growth from hypoxia (Thomas et al. 2007; Tuckey and Fabrizio 2016). Impacts to reproductive condition and not somatic growth while maintaining homeostasis degrades suggest limited energetic resources are channeled to somatic growth to support survival at the cost of reproduction in hypoxic conditions. A laboratory study on a similar species, spot, that controlled for other conditions to isolate the direct effects of DO, showed no impacts to juvenile somatic growth until near fatal levels of DO (McNatt and Rice 2004). Field studies showed reduced juvenile growth rates in Atlantic croaker but concluded these are indirect effects of hypoxia such that these conditions reduced available prey and forced individuals into contracted habitats where increased competition led to density-dependent growth reductions (Eby et al. 2005). These indirect effects are difficult to generalize to other systems where habitat and prey abundance bottlenecks may differ. For example, Schlenger et al. (2022) found little interannual variation in optimal juvenile habitat within Chesapeake Bay attributed to the species relative tolerance of croaker to observed DO levels and other environmental factors included in their analysis.

Atlantic croaker responses to hypoxic conditions have been examined with simulation models in several analyses to examine impacts at the population level in terms of population growth rate, distribution, and abundance. The study that observed density-dependent growth reductions from hypoxia-induced habitat shifts projected a potential 4% reduction in annual growth rate at the population level in hypoxic conditions (Eby et al. 2005). This shows relatively limited impacts of indirect somatic growth effects at the population scale as well, though may become more impactful if the hypoxic conditions became the baseline and the reduced population growth rate was compounded over the long term. An analysis by Diamond et al. (2013) that positively related hypoxic conditions to projected spring precipitation estimated increases in Atlantic croaker abundance under future projected climate that are driven by other environmental and physical processes included in the model (e.g., temperature). The main effect of hypoxia was to reduce interannual variability of abundance by dampening year class strength through habitat crowding and increased density-dependent juvenile mortality. It's important to note that the analysis did not assume impacts of hypoxia to reproductive condition of mature adults.

Rose et al. (2018a, 2018b) found that hypoxic conditions representative of recent years reduced abundance by 10-25% relative to abundance under normoxic conditions regardless of whether or not hypoxia was assumed to drive Atlantic croaker prey abundance. The reduction in abundance was driven by reduced fecundity and direct mortality while impacts to growth were small. Some negative effects of hypoxia were counterbalanced by increased juvenile survival at reduced abundance levels according to the assumed density-dependent stock-recruitment relationship. Models predicting Atlantic croaker spatial distribution while considering responses to temperature and DO levels accurately predicted croaker density relative to distributions of these environmental variables but resulted in biased predictions of spatial distribution (Marcek et al. 2024). The authors postulated that one reason for the bias may be lack of information to accurately model the interaction between temperature and DO with DO potentially being more important to movement and resultant distribution. Authors of the various simulation studies collectively note the challenges of predicting population dynamics from environmental variables such as DO given the complexities of the systems (Rose et al. 2018a, 2018b; Marcek et al. 2024).

3.2.2 Temperature

The effects of water temperature have been studied in regards to many different aspects of Atlantic croaker life history and population dynamics. Thermal tolerance of juvenile (age-0) Atlantic croaker has been studied along the U.S. Atlantic Coast. One study looked at the growth and thermal tolerance of juvenile Atlantic croaker throughout the Atlantic coast from Florida to Delaware. It was found that there is no difference in cold tolerance between Atlantic croaker in the northern and southern extremes of the study region. That is, neither Atlantic croaker from Delaware nor Florida could survive water temperatures less than 3°C (Lankford and Targett 2001a). This suggests that even though there is geographic variation in water temperatures along the coast, Atlantic croaker have not developed local genetic adaptation to environmental conditions. Lankford and Targett (2001a) suggest that this means the Atlantic croaker population along the Atlantic Coast is well mixed and likely one stock.

Another study evaluated cold-winter tolerance of YOY Atlantic croaker from Delaware Bay and its impact on recruitment. Overall survival was still limited to above 3°C, but they found survival was also affected by fish size and salinity. Smaller Atlantic croaker survived colder water temperatures longer than larger fish. Atlantic croaker were also found to survive the colder water longer in more saline waters. The authors suggest that recruitment of Atlantic croaker can be negatively affected by cold overwinter water temperatures (Lankford and Targett 2001b). Similarly, it was found that recruitment is related to a higher survival of juveniles during warmer winters and in turn future adult abundance is also related to winter water temperatures (Hare and Able 2007).

Studies have found that Atlantic croaker overall abundance and distribution is related to the North Atlantic Oscillation (NAO; Hare and Able 2007) and the Atlantic multidecadal oscillation (AMO; Mathews et al. 2022), both of which have associated temperature patterns as primary characteristics. Furthermore, a decline in estuary usage in comparison to coastal habitats by Atlantic Croaker has been linked to the NAO and warming water temperatures. That is, over time, there has been a decreased usage of the Chesapeake Bay estuary compared to the Atlantic coastal waters by Atlantic croaker. There was also a slight negative trend in Delaware Bay estuary usage compared to open water for Atlantic croaker, but the relationship was not as strong as for the Chesapeake. Therefore, with the continued warming waters there is a likelihood that Atlantic croaker will prefer open water habitats more or estuaries farther to the north (Schonfeld et al. 2022).

There is a well-documented “cold pool” or mass of cold water along the ocean bottom in the Mid-Atlantic Bight during summer months. In the summer of 2004, there was a fish kill documented where over 1,000,000 Atlantic croaker washed ashore in Delmarva (Delaware, Maryland, Virginia peninsula). It was determined that the die off occurred due to cold water temperatures from a cold pool moving south from the Mid-Atlantic Bight. The thermal stress kills eventually moved southward as far as Florida. Atlantic croaker are generally considered a warm water fish and the die off occurred during summer months when Atlantic croaker are aggregated and completing their seasonal migrations (Luckett and Poukish 2016). It has been found that the Mid-Atlantic Bight cold pool is warming and decreasing in size (Friedland et al. 2022). This could mean there is less of a chance of cold water kills of Atlantic croaker in the southern part of the range and that Atlantic croaker could expand their range northward.

3.2.3 Salinity

Atlantic croaker utilize estuarine habitats during their larval and juvenile life stages, at which are exposed to various levels of salinity. Salinity in these estuarine environments is influenced by precipitation and river discharge. Atlantic croaker undergo ontogenetic migrations up-estuary as larvae to early juveniles and down-estuary as larger juveniles (Dando 1984; Lankford and Targett 2021). The Mid-Atlantic region has not seen significant changes in salinity overtime but experiences variable salinity throughout the year (Wallace et al. 2018) likely due to changes in precipitation and river discharge across seasons. In South Carolina, Atlantic croaker have been observed in bottom salinities ranging from 0.4-34.2% (Milgarese et al. 1982)

Studies have shown that smaller Atlantic croaker juveniles (26-40 mm) have a strong preference to higher salinity environments (14-18%) and larger juveniles (41-55 mm) showed a preference for lower salinities (Lankford and Targett 2021). Additionally, salinity was a significant negative explanatory variable to estimate age-0 abundance in Delaware Bay (Mathews et al. 2022). Survival of age-0 Atlantic croaker has also been linked to salinity, particularly in low temperature conditions. Lankford and Targett (2001b) found YOY croaker were more susceptible to mortality at lower salinities (2 ppt) compared to higher salinity (26 ppt) during periods of low temperature (3 °C). The authors' hypothesis that rapid mortality at 2 ppt could be a result of impaired osmoregulatory function and that overwintering Atlantic croaker are more vulnerable to mortality when they experience salinity changes (Lankford and Targett 2001b).

Multiple studies have found evidence to suggest that growth of juvenile Atlantic croaker is influenced by salinity. Total length was found to be significantly correlated to bottom salinity for most seasons in 1973 and 1974 (Milgarese et al. 1982). Peterson et al. (1999) found that juvenile Atlantic croaker had different growth rates under various salinity treatments that ranged between 5% and 20% in a laboratory setting. Notably, Atlantic croaker grew faster in lower salinity treatments (Peterson et al. 1999). Searcy et al. (2007) found a positive correlation between juvenile growth and larval growth in scenarios with high freshwater runoff (average salinity), likely a result of a reduction of successful feeding events. Further, Diamond et al. (2013) evaluated the effects of slower growth from variability in salinity through the development of a spatially-explicit simulation analysis of larval, YOY, and adult croaker dynamics. They found salinity had a negative influence on coastwide Atlantic croaker abundance. However, Lankford and Targett (2021) did not find a significant difference in growth across salinity gradients ranging between 2-18%. These dynamics could suggest that settling location and habitat selection of post-larval and juvenile croaker could potentially influence recruitment success and population dynamics. Similarly, as growth of Atlantic croaker has changed overtime, particularly in the northern stock (Figure 22), variability in salinity from changes to precipitation and river discharge could have consequences on abundance in this region.

Salinity may also affect spawning behavior and recruitment success. Krahfrost et al. (2012) found that sound production in Atlantic croaker was negatively related to salinity. Sound production has been linked to spawning behavior for many sciaenid species. Specifically, sound production could assist in forming spawning aggregations and/or mate selection (Connaughton et al. 2002).

3.2.4 Anthropogenic Interactions

3.2.4.1 Climate Change

A standardized vulnerability assessment of marine species to climate change was conducted in 2016 to prepare research and management efforts in the face of continued changes in the future (Hare et al. 2016). The assessment combines exposure and sensitivity of each species to climate change stressors to categorize the species vulnerability of abundance and productivity

to these stressors. Exposure and sensitivity are determined from a combination of quantitative data as well as qualitative expert opinion in cases where data are lacking.

Atlantic croaker were determined with high certainty to have very high exposure to climate change and low sensitivity to these changes, resulting in moderate climate vulnerability. These characteristics were estimated with low certainty to result in high potential for distribution changes and very high certainty to have positive effects on the species.

There is evidence to suggest that with climate change and increasing global water temperatures there is increased likelihood and strength of Atlantic hurricanes (Elsner 2006). It can be difficult to study direct impacts of hurricanes on fisheries, but long-term fishery independent surveys allow some conclusions to be drawn. The Chesapeake Bay has seen impacts from a few hurricanes and tropical systems over the years, and there have been several studies that have looked at their effects on fish abundance and recruitment. In particular, one study used the long-term VIMS Juvenile Trawl Survey to evaluate the impacts of hurricanes on Atlantic croaker young-of-the-year (YOY). Drastic spikes in the fall YOY Atlantic croaker were found in years coinciding with hurricanes. For example, in 2003, when Hurricane Isabel impacted the Chesapeake Bay the fall YOY index was eight times the long-term average (Montane and Austin 2005). They suggest that strong onshore winds from the Hurricanes brought large amounts of juveniles into the Bay. However, the peaks in fall YOY did not correlate with increased spring recruitment, which is likely due to cold winter water temperatures or predation (Montane and Austin 2005). Another study found very similar results, with a significant increase in YOY and larvae Atlantic croaker being found in the lower Chesapeake Bay (30 times higher) following Hurricane Isabel (Houde et al. 2005). In the southern part of the stock, Hurricane Hugo brought a similar influx of juvenile Atlantic croaker into Charleston Harbor likely from wind-induced transport of larvae (Knott and Martore 1991).

Hurricanes or extreme weather events can be very stressful on fish species due to rapid environmental changes. In the Pamlico Sound System of North Carolina, Atlantic croaker were found to have a significant increase in disease prevalence following Hurricane Floyd. Compared to sampling before the hurricane, Atlantic croaker saw an increase in both external skin lesions and systematic bacterial infections likely due to physiological condition being affected by stress (Paerl et al. 2006).

3.2.4.2 Noise Pollution

A growing concern in aquatic environments is the impact of noise pollution on species using vocal interactions within their life history strategies. Sciaenid species, including Atlantic croaker, use vocalizations to signal disturbances and distress, for courtship and spawning, and activities when vision is impaired, such as high turbidity events (Ramcharitar et al. 2006; Gannon 2007; Krahforst et al. 2012). Due to the complexities in the calls used by Atlantic croaker, the species range of hearing encompasses 100-1200 Hz (Ramcharitar and Popper 2004; Horodysky et al. 2008). This range coincides with the noise created by ships and boat motors in aquatic environments (10 Hz to 5 kHz; Hildebrand 2009; Southall et al. 2017; Helal et al. 2024). The level

of ambient noise within aquatic environments has doubled from 1950 to 2025 with an estimated increase of 3 dB per decade (Hildebrand 2009; Southall et al. 2017).

Noise pollution has been documented to alter behavioral responses and induce physical injury to several aquatic species. Badlowski (2022) documented that only 15 minutes of exposure to simulated boat noise injured sensory hairs and apoptotic cells of Atlantic croaker. After three days of exposure, hearing thresholds were increased, which limits the range of sound frequencies an individual can detect and alters a species ability to respond to the environment (Badlowski 2022). Anthropogenic noise also increases stress in fish which results in elevated levels of cortisol, which impacts an individual's health and ability to survive (Nichols et al. 2015). Additional behavioral changes have also been documented from noise, whether from disruption in communication or injury. Intermittent noise can be construed as a predator, altering swimming behaviors to avoid predation and resulting in a loss of energy from erratic behavior (Fraser and Gilliam 1992; Cox et al. 2018). Boat noise can mask predator sounds or overstimulate prey species, so the predator is not noticed. Prey species have been documented to respond slower to predator strikes when exposed to boat noise, thus are twice as likely to be consumed compared to prey not experiencing boat noise (Simpson et al. 2015). Disruptions in hearing can limit the species courtship and spawning opportunities, as many of these calls are in the same frequencies as boat motors (Ramcharitar et al. 2006; Gannon 2007; Hildebrand 2009; Southall et al. 2017). While impacts of noise pollution on Atlantic croaker have started to be examined, the long-term impacts to survival and stock biomass have not been considered. Many researchers call for more information to be gathered on how anthropogenic noise impacts Atlantic croaker on a larger scale.

3.2.4.3 Shoreline Hardening

Seitz et al. (2019) used piecewise regression analysis of species abundance and the percent of hardened shoreline within subestuaries of the Chesapeake Bay to determine that Atlantic croaker were one of the most vulnerable species to shoreline hardening along with bay anchovy, blue crab, and spot. Seventy six percent of variance in Atlantic croaker abundance was explained by percent hardened shoreline and a threshold of 10% hardening was identified as a threshold, or breakpoint, in the relationship. Abundance declined rapidly from 0-10% hardening and declined more gradually at low levels above 10% hardening.

3.3 Environmental Time Series Analyses

3.3.1 North Atlantic Oscillation Driver

The analysis that identified a mechanistic link between Atlantic croaker and the NAO included data through 2002 (Hare and Able 2007). Commercial landings from North Carolina through Rhode Island were used as a proxy for abundance and periods of high landings were positively correlated with strong positive phases of the NAO (rho=0.646, p-value<0.001), characterized by warmer, wetter winters in the eastern U.S. Hare and Able (2007) postulated that the warm conditions associated with positive phases of the NAO substantially increase suitable nursery habitat, both in regular estuarine habitats like the Chesapeake Bay and also more intermittent habitat to the north like coastal New Jersey, that promotes fishery catches a few years later. An

assumed age-structure for commercial landings was used to construct a composite NAO index such that each age class in a given year was lagged to match the NAO index at the time of the respective age class's first overwinter period as young-of-year fish. The assumed proportion of the catch accounted for by each age class was used as a weighting factor in the composite index. In the current assessment, this analysis was updated with data through 2024 to reexamine the relationship and determine the utility of the NAO index as a potential environmental indicator.

With the updated data, the relationship between the NAO index and croaker abundance is weaker than estimated by Hare and Able (2007). The Spearman's rho decreased to 0.21 and the p-value increased above 0.05 (0.07). Part of this breakdown is likely due to a change in the age structure since 2002. However, a comparison of time series shows commercial landings did not respond to a string of strong positive NAO indices for the last nine years of the time series (Figure 36). With the truncated age structure generally observed after Hare and Able (2007) was first published, fewer year classes account for the catches and catches should be more responsive to a string of positive phase NAO indices if the relationship held. The cause for this apparent breakdown is unknown but could be other interacting ecosystem drivers of mortality and/or declines in abundance due to increases in fishing mortality. This relationship should be revisited again in future assessments to determine a longer potential lag between NAO conditions and catches.

Additional analyses of the NAO and the closely related Atlantic Multidecadal Oscillation (AMO) climatic pattern since the Hare and Able (2007) analysis have found mixed results. Woodland et al. (2017) did not find a significant relationship between Atlantic croaker abundance in the Chesapeake Bay and the AMO. An analysis within the Delaware Bay found a significant relationship between smoothed NAO and AMO time series and Atlantic croaker YOY and age-1 abundance (Mathews et al. 2022). Another Delaware Bay analysis of relative habitat usage considered AMO, NAO, and NAO lagged forward by one year but excluded these covariates during model selection for explaining changes of Delaware Bay habitat use (Schonfeld et al. 2022). The same analysis found Atlantic croaker abundance in Chesapeake Bay relative to Atlantic Ocean habitats had similar trends as species with a significant, negative relationship to a NAO covariate (scup, windowplane flounder, and clearnose skate), but the relationship of Atlantic croaker to the NAO covariate was not significant (Table S1 in Schonfeld et al. 2022). Given the mixed results, the NAO index does not appear to be a reliable indicator for current population dynamics and conditions.

3.3.2 Chesapeake Bay Environmental Forecast System

The Chesapeake Bay Environmental Forecast System (CBEFS) hosted by the Virginia Institute of Marine Science (VIMS) utilizes computer models to simulate and hindcast environmental conditions throughout the Chesapeake Bay. A three-dimensional numerical model that incorporates NOAA weather information (wind) and USGS stream gauges is used to simulate salinity, water temperature, dissolved oxygen, and other factors every day within a 1.2 million grid cell of the Chesapeake Bay and its tributaries. Estimates of bottom salinity, bottom temperature, and dissolved oxygen were provided at 3-hour increments between January 1,

1985, and December 31, 2024, by VIMS (Bever et al. 2021; St-Laurent and Friedrichs 2024) and were used to evaluate relationships between environmental variables and annual recruitment trends of Atlantic croaker in the Chesapeake Bay. The number of days below 3 degrees Celsius in a year was calculated by find the average daily water temperature and summing the number of days between January and March below the specified threshold. Annual winter salinity was calculated as the average daily salinity between January and March. Fall dissolved oxygen was calculated as the sum of the daily total area that was <5 mg/L during September and November.

The CBEFS hindcast suggests that the number of winter days below 3 degrees Celsius has declined through time, with little to no days hitting that threshold in recent years (Figure 37). Average winter salinity during January and March has been variable from year to year, with 1997, 2004, and 2019 have series low salinity (Figure 38). Dissolved oxygen in the fall varied from year to year but was, on average, consistent across the time series, though 1994 and 2018 had the highest total area with DO < 5 mg/L (Figure 39).

The VIMS juvenile index of abundance for Atlantic croaker was used to represent recruitment trends in this analysis (Section 5.1.4). The average recruitment value for the time series (between 1988 and 2024) was calculated based on the average index for each year and YOY anomalies were then generated for each year by calculating the difference between the individual mean index value for each year and the average recruitment value for the entire time series. YOY anomalies were not significantly correlated with any environmental parameters (Figure 40) but had a negative correlation with the number of temperature days below 3 degrees Celsius and slight negative correlation with salinity and DO (Figure 41).

A multiple linear regression was used to evaluate the environmental drivers derived from the CBEFS hindcast and their relationship with Atlantic croaker recruitment in the Chesapeake Bay. The recruitment anomalies were used as the response variable while the explanatory variables included year, the number of days below 3° C in winter in the main stem of the Chesapeake Bay, the average winter salinity in the main stem of the Chesapeake Bay, and the total area of DO <5 mg/L in the previous fall in the main stem of the Chesapeake Bay. Fall DO was lagged forward one year to assume that fall DO would affect the index in the following year, since the YOY survey is conducted in the spring. DO, temperature, and salinity were significant variables in describing YOY anomalies (Table 14). The predicted YOY anomalies from the model tracked the observed YOY values relatively well but were not able to capture the anomalously high years of strong recruitment in 2012 and 2024 (Figure 42). Therefore, other drivers that aren't captured in this analysis are likely contributing to recruitment success in the Chesapeake Bay.

4 FISHERY DEPENDENT DATA SOURCES

Atlantic croaker are caught recreationally and commercially in estuaries and the open ocean.

Atlantic croaker have been part of mixed-stock fisheries on the Atlantic Coast since the 1800s. Atlantic croaker are caught commercially with a variety of gear throughout the year. Landings

are either sold for human consumption (referred to as “marketable landings” or just “commercial landings” throughout) or used for non-human consumption purposes (e.g., bait, industrial purposes, discarded; referred to a “scrap landings” throughout). Atlantic croaker are also discarded at sea in these fisheries as well as others monitored by NOAA Fisheries observer programs in the Mid-Atlantic region (referred to as “finfish fishery” discards throughout) and south Atlantic region (referred to as “shrimp trawl fishery” discards throughout). Some or all commercial discards, depending on fishery and gear, are assumed to be discarded dead or die post-discarding and are considered fishery removals in the assessment. A potential new source of discards that had not been explored in previous assessments was southeast (North Carolina through Florida) gillnet fisheries. An observer program began in 1992 for shark gillnets and expanded to all gillnet fisheries in 2006. Compiled observer data were not readily available, but summary data were available in reports from 2014 through 2018 (Mathers et al. 2015; Mathers et al. 2016; Mathers et al. 2017; Mathers et al. 2018; Mathers et al. 2020) and are provided in Table 15. These data indicate that observed fisheries are not a significant source of Atlantic croaker discard mortality and, therefore, were not included in the assessment.

Recreational anglers target Atlantic croaker by bottom fishing and chumming with shrimp, clams, worms, cut fish, and soft or peeler crabs. Recreational harvests typically peak in the warmer months (May through October) when effort tends to be greatest. The majority of recreational fishing occurs in state waters. Recreational anglers also discard Atlantic croaker, some of which are assumed to die post-release and are considered fishery removals in the assessment. Recreational catch data recorded separately for headboats in the southeast (North Carolina through Florida) through NOAA Fisheries Southeast Region Headboat Survey (SRHS) were considered as a source of recreational catch data in addition to Marine Recreational Information Program (MRIP) data from other recreational fisheries along the Atlantic coast. However, annual catch estimates for headboats were below 1,000 fish for most years and were not included in the assessment.

4.1 Commercial

4.1.1 Landings

4.1.1.1 Total Catch and Effort Data Collection

Commercial landings (1950 to present) for the Atlantic coast have been collected by state and federal agencies and are provided to the Atlantic Coastal Cooperative Statistics Program (ACCSP) where they are maintained in the ACCSP Data Warehouse. Landings data from ACCSP during the model time series were validated by state representative partners (prior to 2023) or verified against final data provided in compliance reports (2023-2024). Landings differed between the ACCSP data warehouse and state records for the years of 2004-2022 for New York, 2016-2022 for New Jersey, 1981-2022 for Delaware, 2008-2022 for PRFC, and various years throughout the timeseries for North Carolina. In those cases, the state data were used over those in the data warehouse.

A summary of the methodology used by individual states to obtain commercial landings data through time is available in Table 16 and additional detail for states within the management unit is provided below.

New Jersey
Commercial landings data for Atlantic croaker in New Jersey are derived from multiple reporting sources, depending on whether harvest occurs in state or federal waters. Commercial landings in state waters are primarily reported through the New Jersey Harvester Trip Report, which is submitted monthly by licensed harvesters. Atlantic croaker landings in state waters originate almost exclusively from the gill net fishery. Submission of Harvester Trip Reports is required for participants holding a Gill Net Mesh Exempt Permit, which is mandatory for the use of gill nets with a stretch mesh size of 3.25 inches or less. New Jersey does not require dealer reporting specifically for Atlantic croaker; however, a small number of dealers voluntarily provide landings information.

For federally permitted vessels, all catch is reported electronically through Vessel Trip Reports (VTRs), while federally permitted dealers report purchases through federal dealer reporting systems. Federal commercial landings are verified by matching VTR records with corresponding dealer reports. In some instances, a VTR may not have a matching dealer report because the catch was retained for home consumption or sold to a non-federally permitted dealer. These circumstances are documented and noted when landings data are compiled and submitted.

For state-water harvests, reported landings are cross-referenced with available state dealer reports when possible. If a corresponding dealer report is available, dealer-reported landings are used as the primary source. In cases where no matching dealer report exists, which is expected given the absence of a mandatory dealer reporting requirement for Atlantic croaker, the harvester-reported landings from the New Jersey Harvester Trip Report are retained and identified accordingly in data submissions.

Delaware
2026 marks the 42nd year of mandatory commercial catch reporting under the provisions enacted by the Delaware General Assembly in April 1984. Every fisherman holding a commercial foodfishing license is required to submit a monthly report specifying where they fished, the type and amount of fishing gear deployed, and the pounds landed of each commercial species taken for each day fished. Delaware does not have online reporting, however, we have instituted a fillable pdf version of our logbooks. This allows the fisherman to email forms to our fisheries email. They also have the option of taking a picture and sending it in.

Maryland
Maryland Department of Natural Resources has a mandatory harvester reporting system that began in 1980. Catch in pounds, days fished, area fished, amount of gear used, type of gear used and average daily soak time were aggregated and reported by month on paper forms mailed to the department prior to 2006. A daily trip log was phased in from 2002 to 2005 with all fishermen using the daily log for the entire year beginning in 2006. Initially these also were

paper forms, but a voluntary program for electronic daily reporting was added in 2015. However, most fishermen still are using paper forms as of 2026. Effort data is only available for 1980-1984, 1990 and 1992 – 2025. Maryland relied on the National Marine Fisheries Service (NMFS) for collecting commercial landing data prior to 1980.

PRFC

The Potomac River Fisheries Commission (PRFC) has collected commercial landings since 1964. The mandatory harvest reports are completed by individual commercial fishers daily via paper reports submitted to the Commission each week by the following Thursday. These reports collect information on daily landings including catch by species in pounds, amount of gear used, area fished, port of landing, and effort (hours fished and crew amount). All harvesters must report everything caught and released on the harvest reports. Effort data is only available beginning 1976.

Virginia

The National Marine Fisheries Service (NMFS) collected landings data for Virginia from 1950 through 1992. From 1973 to 1992, Virginia implemented a voluntary monthly inshore dealer reporting system, which was intended to supplement NMFS data. However, it was discovered that better inshore harvest data were required so the VMRC implemented a Mandatory Reporting Program (MRP) to collect Virginia commercial landings data that began January 1, 1993. The program currently is a complete census of all commercial inshore and offshore harvest in a daily format. Data collected are species type, date of harvest, species (unit and amount), gear type, gear (amount and length), area fished, dealer, vessel (name and number), hours fished (man and gear), crew amount, and county landed.

In 2001, several fields listed above (gear length, man hours, vessel information: name and number, and crew amounts) were added to come in compliance with the ACCSP-identified critical data elements. Also, data collection gaps in the NMFS offshore collection program were identified and all offshore harvest that was not on a federally permitted species or sold to a federally permitted dealer was added to the MRP. The MRP reports are collected on daily trip tickets annually distributed to all commercially licensed harvesters and aquaculture product owners. All harvesters and product owners must report everything harvested and retained on the daily tickets. The daily tickets are submitted to VMRC on a monthly basis due by the 5th of the following month. Since 2022, reports can also be submitted electronically.

North Carolina

The NMFS, prior to 1978, collected commercial landings data for North Carolina. Port agents conducted monthly surveys of the state's major commercial seafood dealers to determine the commercial landings for the state. Starting in 1978, the NC DMF entered into a cooperative program with the NMFS to maintain the monthly surveys of North Carolina's major commercial seafood dealers and to obtain data from more dealers. The NC DMF Trip Ticket Program (NCTTP) began on 1 January 1994. The NCTTP was initiated due to a decrease in cooperation in reporting under the voluntary NMFS/North Carolina Cooperative Statistics Program in place prior to 1994, as well as an increase in demand for complete and accurate trip-level commercial

harvest statistics by fisheries managers. The detailed data obtained through the NCTTP allows for the calculation of effort (i.e., trips, licenses, participants, vessels) by fishery and water body code (estuary, state ocean waters ocean, federal ocean waters) that was not available prior to 1994 and provides a much more detailed record of North Carolina's seafood harvest.

To assign landings to a stock, the following rules were applied:

1. If water body was in the ocean, then landings from Carteret County and north were in the northern stock unit (NCDMF districts 1 and 2 which is the northern and central districts, as defined by county, with the district 2 having its southern county being Carteret County).

2. If water body was in the ocean and in the southern district (from Onslow County and south) then landings were in the southern stock unit.

3. If water body was in the estuary but from Bogue Sound and north, landings were in the northern stock unit.

4. If water body was in the estuary but south of Bogue Sound, landings were in the southern stock unit.

Landings of Atlantic croaker were calculated for North Carolina and reported in pounds (whole weight) broken down by month and stock from 1989-2024. Data used to calculate the landings for North Carolina included landings from the NCTTP (1994 to 2024) and landings from NMFS (1989 to 1993). Data prior to 1989 do not include the associated stock split and come from the ACCSP Data Warehouse. Data back to 1978 were also collected by NMFS and landings from prior to 1978 are from historical data.

South Carolina

Prior to 1972, commercial landings data were collected by federal fisheries agents based in South Carolina, either U.S. Fish and Wildlife Service or NMFS personnel. In 1972, South Carolina began collecting fishery landings data from coastal dealers in cooperation with federal agents using forms supplied by the SCDNR. These mandatory monthly landings reports were required from all licensed wholesale dealers in South Carolina. Until fall of 2003, those monthly reports were summaries collecting species, pounds landed, disposition (gutted or whole) and market category, gear type and area fished; since September 2003, landings have been reported by a mandatory trip ticket system collecting landings by species, disposition and market category, pounds landed, ex-vessel prices with associated effort data to include gear type and amount, time fished, area fished, vessel, and fisherman information. Validation of landings is accomplished via dockside sampling.

At a minimum, South Carolina's trip-ticket program collects data on commercial effort, commercial catch, and economical value. Minimally, effort data includes gear types and quantity, location, and hours fished. Catch data includes species, disposition of catch, and quantity (pounds) landed. Finally economic data includes the wholesale price paid to fishermen.

Georgia
Prior to 1982, the NMFS and its predecessor agencies had been responsible for the collection of commercial fisheries landings data in Georgia. In 1982, with funding from NMFS, the Georgia Department of Natural Resources (GADNR) began collecting weekly and monthly commercial landings data from coastal Georgia. These included catch, area, effort, gear, value and associated data at various levels of detail depending on fishery and data needs. In 2001, Georgia implemented a trip ticket program in accordance with the minimum requirements set forth by the ACCSP partners. Additional data elements were added and the Georgia landings database was upgraded to meet the requirements. Trip level data are collected for all trips landing products in Georgia. Data collected include trip start and unloading dates, area fished, harvester and dealer, gear, species, market size, quantity, and value.

Florida
Prior to 1986, landings of Atlantic croaker were reported to the NMFS through monthly dealer reports made by major fish wholesalers in Florida. Since 1986, information on what is landed and by whom in Florida's commercial fisheries comes from the FWC's Marine Resources Information System, commonly known as the trip-ticket program. Wholesale dealers are required to use trip tickets to report their purchase of saltwater products from commercial fishers. Conversely, commercial fishers must have Saltwater Products Licenses to sell saltwater products to licensed wholesale dealers. Each trip ticket includes the Saltwater Products License number, the wholesale dealer license number, the date of the sale, the gear used, trip duration (time away from the dock), area fished, depth fished, number of traps or number of sets where applicable, species landed, quantity landed, and price paid per pound. During the early years of the program some data fields were deleted from the records, e.g., Saltwater Products License number for much of 1986, or were not collected, e.g., gear used was not a data field until about 1991.

4.1.1.2 Biological Data Collection

New Jersey
New Jersey initiated biological monitoring of commercially landed Atlantic croaker in 2006, partly supported with funding from the ACCSP. Annual sampling of the trawl and gillnet fisheries is conducted primarily from August through October along the New Jersey coast in Belford, Point Pleasant, Barnegat Light, and Cape May. Total length (mm), weight (kg), gear type, and location are recorded. Otoliths are collected for age determination and processed using the protocol from the ASMFC's Atlantic croaker age workshop (ASMFC 2008).

Maryland
Commercial pound nets were sampled in Maryland's portion of Chesapeake Bay, and in the mouths of its major tributaries, from the Patuxent River south to the Potomac River. Sampling locations varied each year depending on where the cooperating fishermen's nets were set. The survey has been conducted every year since 1993 from Late May to early September. Each site was generally sampled once every two weeks, weather and fisherman's schedule permitting. The commercial fishermen set all nets sampled as part of their regular fishing routine. Net soak time and manner in which they were fished were consistent with the fishermen's day-to-day

operations. All Atlantic croaker, regardless of whether they were of legal size (9 inches), were measured from commercial pound nets, when possible. In instances when it was not practical to measure all fish, a random sample was measured and the remaining individuals enumerated. Total length was measured to the nearest millimeter. Otoliths, weight in grams, and sex were taken from a non-random sub-sample of Atlantic croaker.

Dealer sampling was used to supplement the onboard sampling program in some years. A random sub-sample of Atlantic croaker by gear was taken if all Atlantic croaker were not measured. Length to the nearest millimeter total length and weight in grams was measured from all sampled fish. Random samples for otolith extraction were occasionally brought back to the lab. These fish were also measured for length and weighted and were sexed using visual examination.

Virginia
Commercial length frequency data were obtained by the VMRC Biological Sampling Program (BSP). Atlantic croaker lengths and weights were collected at local fish houses, noting gear, area fished, landing location, market category, and individual watermen.

Fish were measured for SL, CL, and TL (mm) and individual weight (nearest 0.01 lb.). Otoliths for age determination, as well as sex and maturity data, have been collected from a subsample of fish encountered since 1998. Since August of 2019, all ageing work (processing and reading) has been performed at the Age and Growth Lab at VMRC (prior ageing work was done at Old Dominion University's Center for Quantitative Fisheries Ecology).

Major commercial gears for Virginia are pound nets, anchored gill nets, and haul seines. Commercial samples were taken throughout the year and from all areas where Atlantic croaker were landed. Fishery-dependent length frequency data collection began in 1989.

North Carolina
Commercial length frequency data were obtained by the NCDMF commercial fisheries-dependent sampling program. Atlantic croaker lengths were collected at local fish houses by gear, market grade, and area fished.

Individual fish were measured (mm, CL) and total weight (0.1 kg) of all fish measured in aggregate was obtained. Subsequent to sampling a portion of the catch, the total weight of the catch by species and market grade was obtained for each trip, either by using the trip ticket weights or direct measurement. Length frequencies obtained from a sample were then expanded to the total catch using the total weights from the trip ticket. All expanded catches were then combined to describe a given commercial gear for a specified time period. Major commercial gears for North Carolina are gill net, long haul seine, and pound net. Commercial samples were taken throughout the year and from all areas where Atlantic croaker were landed. Fishery-dependent length frequency data collection for Atlantic croaker in North Carolina began in the late 1970s, though data developed with the standardized trip ticket methodology above is not available until 1994.

The NCDMF initiated sampling of scrap fish in 1986. The NCDMF defines scrap fish as those fish not marketed for human consumption and instead sold for bait, industrial use, or discarded. Staff sampled at least one-half basket (~12 kg) of the scrap fish from each catch. The sample is sorted by species and weighed (kg). All individuals in the sample are measured for CL or TL to the nearest millimeter. If the catch of a particular species is exceptionally large, a random subsample of at least 30 individuals is taken for measurement, and the remaining fish are counted. The total weight of each species in the scrap fish samples is calculated by determining the proportion of that species in the subsample and expanding to the respective species' proportional weight of the total scrap fish for the trip. The number of individuals per species in the scrap fish component is calculated by expanding the number of individuals in the sample to represent the total weight of the species for the scrap fish in the samples. Estimates of total scrap fish landings for individual species are determined by applying the tri-annual ratio of marketable fish to scrap fish in the fish house samples to the reported tri-annual marketable landings. The quantity (weight or numbers) and percentage of scrap fish (total or by species) landed by the fishery was determined by applying the seasonal (6 month periods) weight ratio of marketable fish to scrap fish in the fish house samples to the reported seasonal marketable landings from the NCTTP. The estimated scrap fish quantity is for landed fish and does not account for discards at sea. The reported commercial landings of scrap fish (unclassified for scrap or industrial purposes) from the NCTTP were not used because of inconsistencies in dealer reporting. This ratio method of estimating scrap fish assumes marketable fish are accurately collected by the NCTTP. The percent scrap fish reported was computed on a per sampled trip basis, i.e., the percent scrap fish for each sampled trip was determined and the mean was taken across all trips, thereby accounting for sampled trips with no scrap fish. Each sampled catch was viewed as an independent estimate of scrap fish.

Florida

Florida collects sample lengths from the commercial fisheries and, when opportunity allows, collects weights of Atlantic croaker intercepted through a Trip Interview Program (TIP) at fish houses. While Atlantic croaker is included on the list of species to be sampled, they are only sampled "as available" due to its low priority and the small amounts that are generally landed.

4.1.1.3 Length Composition Data Methods

4.1.1.3.1 Marketable Landings Length Compositions

North Carolina is the only state that has a standardized process for characterizing length compositions of Atlantic croaker commercial landings from biosampling data. This standardized process has been applied since 1994 when trip tickets were implemented. Data were aggregated across states for input as commercial fleets in the assessment models, so no length compositions are provided prior to 1994.

For the northern stock outside of North Carolina, the major contributing jurisdiction to Atlantic croaker landings is Virginia (Figure 43) and biosampling has been conducted since 1989. Maryland has sampled commercial fisheries annually since 1993 through an observer program in pound net fisheries and for a shorter period (2008-2014, 2017-2019) though dealer sampling of multiple gears but mostly pound nets. The observer data includes the total catch without

disposition (harvest vs discard). The dealer sampling was intermittent and limited for gears other than pound nets and was excluded in favor of the more consistent and robust observer data and VMRC data with truncations applied (see truncation description below). New Jersey has also sampled commercial fisheries, but intermittingly from 2006-2012 and 2015-2016, so the more robust and consistent sampling by VMRC was used in place of these data. No other jurisdictions have sampled their catches, so some collapsing of landings and borrowing of length data for characterizing stock wide length compositions was necessary.

Additionally, northern stock jurisdictions have had varying size limit regulations that would be expected to affect the length composition of landings. Landings from each jurisdiction and year were grouped according to consistent regulations and magnitude of landings. Virginia and New Jersey have never had a minimum size and PRFC had no minimum size from 1999-2024 so these jurisdictions and periods were grouped (group 1). Other states with negligible landings across years (Delaware, New York, Connecticut, and Rhode Island) were included in this primary group to simplify the process. PRFC had a minimum size of 10 inches from 1994-1998, so these landings were split into a second group (group 2). Maryland had a 9-inch minimum size limit from 1994-2024, so Maryland landings were separated into a third (group 3).

Length data not recorded as centerline length were converted from observed length types using conversion factors from Table 5. Differences in length distributions were apparent by season (January-June & July-December), major gear category (fixed nets, gill nets, haul seines, trawls), and area (Atlantic Ocean, Chesapeake Bay mainstem, Chesapeake Bay tributaries).

No spatial information is available with landings used in the assessment, but landings and length data could be stratified by year, season, gear, and jurisdiction. A sample size of 30 measurements was used as a threshold to accept a length data set for characterizing landings from the respective stratum. Before any borrowing of length data, 77.6% of landings from north of North Carolina had an associated length data set.

For an initial borrowing step, data were collapsed by management group. VMRC biosampling data were used to characterize the group 1, VMRC biosampling data truncated to 10 inches and greater were used for group 2, MD DNR pound net observer data truncated to 9 inches and greater (to remove regulatory discards from the observed total catch) were used for fixed gears from group 3, and VMRC data truncated to 9 inches and greater were used for the other gears from group 3. This borrowing of length data resulted in 88.6% of landings with an associated length data set.

Several years of trawl landings were still lacking length data, so as a secondary step based on comparison of length frequencies across gears indicating similarities between fixed nets and trawls, fixed net lengths were borrowed from the same year, season, and management group to characterize these trawl landings. This borrowing of length data resulted in 99.6% of landings with an associated length data set.

As a final borrowing step, length data from a preceding year for the same season, gear, and management group were borrowed to represent landings and this process was repeated until all landings had an associated length data set.

Number-based length composition proportions in 2 cm bins were converted to weight-based proportions with a length-weight relationship from the sampling data. Weight-based proportions were used to partition total landings into length bins that were then converted to numbers with the length-weight relationship for inputs to the assessment models as length frequencies.

For the southern stock outside of North Carolina, sampling is limited to the TIP program in Florida. However, only 212 lengths were collected from 2012-2024 and annual sample sizes have been below 30 in all years except 2005 (65 measurements). This limited snapshot of data suggests Florida commercial fisheries catch sizes larger than captured in North Carolina (Figure 44), but data are not useful for annual length compositions. South Carolina and Georgia have not sampled commercial catches, but these catches have been negligible (not reported here due to confidentiality).

4.1.1.4 Conditional Age-at-Length Data Methods

4.1.1.4.1 Marketable Landings

Age samples collected during commercial fishery sampling were tabulated by stock, year, and 2 cm centerline length bin. Age samples collected from January through March were excluded from the data set as described for growth analyses (Section 2.5). Effective sample sizes for these data were calculated as the square root of the observed sample size (number of ages observed for each length bin). Data with observed sample sizes of one were excluded from data sets. These data were used as conditional age-at-length (CAAL) data in the assessment models.

4.1.1.5 Trends

4.1.1.5.1 Total Marketable Landings

Coastwide, commercial landings of Atlantic croaker exhibit a somewhat cyclical pattern, with low landings in the early 1950s, the 1960s to early 1970s, the 1980s to early 1990s, and in recent years since the mid-2010s, and high landings in the late 1950s, the mid-to-late 1970s and the mid-1990s to mid-2010s (Table 17; Figure 45). Recent landings peaked in 2001 and have been on a steady decline since then. Annual coastwide landings from 2019-2024 are the lowest in the time series.

The magnitude of landings varies by stock and follow almost inverse trends through time (Table 17; Figure 46). Northern stock landings were relatively low and declined for a brief period from 1989 through 1991, then reversed trend and increase rapidly to a time series high of 30 million pounds in 2001. Landings then steadily declined throughout the remainder of the time series to a time series low of 312 thousand pounds in 2023. Southern stock landings are much lower in magnitude than the northern stock and are at time series highs from 1989 through 1991, averaging 609 thousand pounds, then declined sharply to a time series low of 21 thousand pounds in 2004. Landings then increased through the remainder of the time series. By fleet,

southern stock landings have followed similar trends, but most of the catch came primarily from North Carolina in the early 1990s and primarily from Florida since the late 1990s.

Atlantic croaker are caught commercially with a variety of gear, primarily fixed nets (e.g., pound nets), gill nets, haul seines, and trawls (Figure 47). Gear compositions have varied as landings by stock have changed, particularly earlier and late in the time series when northern stock landings were at lows and southern stock landings were at highs. Atlantic croaker have been landed throughout the year, with a relatively large winter fishery at the beginning of the year and a slightly decline in landings late in the year (Figure 48).

New York was not included in previous assessments, but the SAS was interested if landings in New York had increased in recent years indicating range expansion. The majority of landings in New York are confidential and minimal, not comprising even 1% of coastwide landings in any year. Atlantic croaker landings in New York are variable with many years indicating no landings. Landings in the state peaked in 2004 and do not exhibit increasing trends from 1981-2024. Landings from New York are included in coastwide landings in this assessment.

4.1.1.5.2 Total Bait/Scrap Landings

A scrap fishery refers to one in which the landed fish are unmarketable as food and are sold unsorted, typically as bait. Because they are unsorted, scrap fishery landings are not included in state and federal Atlantic croaker landings estimates. However, Atlantic croaker have historically been a major component of Atlantic coast scrap landings (NCDMF 2001), thus the scrap fishery is known to be an additional source of removals for at least part of the time series.

Quantifying the amount of Atlantic croaker landed as scrap fish along the Atlantic coast is difficult due to the limited availability of sampling. North Carolina is the only state along the east coast that routinely samples their commercial scrap landings (see Section 4.1.1.2). The total weight of each species in the scrap fish samples is calculated by determining the proportion of that species in the subsample and expanding to the respective species' proportional weight of the total scrap fish for the trip. The number of individuals per species in the scrap fish component is calculated by expanding the number of individuals in the sample to represent the total weight of the species for the scrap fish in the samples. Estimates of total scrap fish landings for individual species are determined by applying the tri-annual ratio of marketable fish to scrap fish in the fish house samples to the reported tri-annual marketable landings.

Virginia is the only other state within the Atlantic croaker range in which scrap landings are reported (these mixed-species landings are reported and referred to simply as "bait," rather than "scrap" in Virginia). Scrap landings are not subsampled for species composition in Virginia. Virginia scrap landings comprised of Atlantic croaker were estimated by applying the proportion of Atlantic croaker occurring in northern North Carolina's annual scrap landings by gear to Virginia's total scrap landings by gear. For years in which samples were unavailable from northern North Carolina, the proportions observed in North Carolina (statewide) were used.

Scrap fishery removals are substantially lower in southern North Carolina than in northern North Carolina and Virginia (Table 18; Figure 49). Southern North Carolina scrap Atlantic croaker landings are low for much of the time series with occasional peaks but no discernible overall trend. Northern North Carolina scrap Atlantic croaker landings were variable around a downward trend from 1994-2011, decreased sharply in 2012, remained low but variable for several years, then dropped to virtually zero for the rest of the time series. Virginia scrap Atlantic croaker landings were also on a downward trend for much of the time series and have been near zero since 2015.

North Carolina also subsamples scrap landings for lengths; however, the observed length frequencies (Figure 50) are not believed to be representative of Atlantic croaker that would be categorized as scrap in Virginia (i.e., they are larger fish which would generally be thought of as marketable in Virginia). Given this discrepancy, together with considerable difficulty fitting to the scrap fishery data during early model development (with either length-based selectivity or assuming selection at young ages), the decision was ultimately made to exclude length composition data and to aggregate scrap fishery landings with the commercial fishery landings (see Section 6.1).

4.1.1.5.3 Marketable Landings Length Compositions

Annual length compositions aggregated across gears for the northern stock show an initial expansion of the size structure to larger sizes (40-50 cm) landed in late 1990s through the late 2000s, followed by a truncation of the size structure starting around 2010 (Figure 51). The size structure has stabilized at smaller sizes for the last five years, with fish greater than 38 cm rarely landed. The number of biosampling trips conducted in the northern stock were stable through the mid-2010s but have declined in recent years as landings have declined to low levels (Table 19).

Prior to splitting the population into two stocks, TC members from the primary landings states categorized fisheries based on expected length compositions selected to support selectivity specifications in assessment models. Categorizations grouped long haul and pound nets in North Carolina as selective of small fish only, beach seines and estuarine gill nets in North Carolina as selective of medium sizes only, gill nets and trawl in Virginia and ocean gill nets and ocean trawls in North Carolina as selective of large sizes only, and fixed nets and haul seines in Virginia as selective of all sizes.

Aggregate length compositions for these categories reflect the expected selectivity differences (Figure 52). Contributions of these categories to landings show relatively stable patterns with most coming from fisheries expected to have logistic, or flat-topped selectivity (large sizes only and all sizes; Figure 53). There is a slight bump at the end of the time series as landings have declined to their lowest levels for fisheries selective of a medium size range, but not enough to support a large-scale change in overall commercial selectivity.

North Carolina length compositions for the southern stock are smaller than those observed to the north and have rarely included catch above 40 cm (Figure 54). The smaller size range lacks expansions and contractions observed in the northern stock. There is a slight shift in 2004 to a

smaller length composition without the larger fish observed in previous years. The number of biosampling trips conducted in the southern stock were low and stable through the early 2010s and increased to higher stable levels since 2014 (Table 19).

In the southern stock, the size distribution of fish observed from biosampling was slightly different than the expected sizes based on categorization by TC members. Fisheries expected to be selective of small fish only and large fish only from a coastwide perspective, select very similar sizes in a narrow range in the southern stock (Figure 55). Fisheries expected to be selective of a medium size range have caught the largest sizes in this stock with a skewed tail to larger sizes. The contribution of these fisheries to landings shows an abrupt shift in 2004 to fisheries catching smaller, more dome-shaped size distributions (Figure 56) which explains the shift observed in the annual length compositions.

4.1.1.5.4 Bait/Scrap Landings Length Compositions

We didn't use these data because they were not representative of Virginia bait landings and the total bait/scrap landings were small and were collapsed into marketable landings.

Length compositions for scrap Atlantic croaker sampled in North Carolina from 1990 through 2022 show the greatest proportions of fish falling between 20 cm and 23 cm total length (Figure 50). Most scrap croaker from which lengths were collected were harvested by ocean trawls, where the location and gear selects for larger Atlantic croaker relative to fish harvested in other fisheries. The second most prevalent fishery from which scrap Atlantic croaker were sampled was the long haul seine fishery. The range of lengths observed has truncated since 2011, coinciding with a decrease in commercial landings and the number of lengths collected annually from scrap Atlantic croaker in North Carolina.

Atlantic croaker classified as scrap or bait fish in North Carolina are generally similar in size or slightly smaller when compared to marketable fish; however, the fish are not sold as food because there are too few of them in the catch to fill a packing box or there is no market for those fish at the time or area where they are captured. Atlantic croaker may also be classified as scrap or bait if they are poor quality or very small. Although Virginia does not sample bait landings, the dominant sizes (20-23 cm) in the North Carolina scrap landings are considered marketable in Virginia.

4.1.1.5.5 Marketable Landings CPUE

North Carolina

CPUE from NCTTP commercial landings and effort data collected in the anchored gill net fisheries was calculated as landed Atlantic croaker pounds per trip. Separate time series were calculated for each stock unit and area (ocean vs. estuarine). Data were assigned to stock as described in Section 4.1.1.1.

Northern stock CPUE in ocean fisheries increased steadily from 1994 to a peak in 2004, decreased briefly to moderate levels in the late 2000s before increasing again to a second peak in 2010 (Figure 57). CPUE then generally decreased, aside from a few increases in the late 2010s, to a time series low in 2022. Estuarine CPUE in the northern stock is two orders of

magnitude smaller than in ocean fisheries and is more variable through time. There were peaks in the late 1990s, early 2010s, and 2021. CPUE was lower during the mid- to late 2010s.

Southern stock CPUE shows diverging trends between areas (Figure 57). Ocean CPUE generally increases through the time series, while estuarine CPUE generally declines for much of the time series. Estuarine CPUE reverses trend in 2018 and increases through the end of the time series while ocean CPUE is variable.

Virginia

Nominal CPUE indices were produced based on Virginia commercial harvest reports of Atlantic croaker. Several effort metrics were investigated, and number of trips (that reported Atlantic croaker catch) is the metric presented here because it is the most reliable and consistently reported. CPUE was considered in aggregate, separated by area of harvest (ocean vs. Chesapeake Bay), and separately by gear and area. The aggregate series across areas and gears indicates a peak in 1999 followed by a variable but slowly declining trend until 2018 when CPUE drops off steeply, reaching a time series low in 2020 and remaining at low levels for the remainder of the time series (Figure 58). The pattern is driven by the trend seen in the Chesapeake Bay which generally accounts for an overwhelming majority of the harvest (Figure 59). The decline is most pronounced in the Chesapeake Bay pound net fishery, falling from an average of near 1,250 pounds per trip in 2017 to less than 200 pounds per trip in 2019 (Figure 58). The ocean CPUE also shows a decline through time, but the change is more gradual from the higher and more variable period prior to 2010, decreasing steadily through the following decade.

Maryland

A commercial pound net CPUE index was generated from the Maryland commercial reporting databases. Effort was all trips that caught Atlantic croaker. Nets fished was not used due to the number of nets fished by day being recorded inconsistent in the daily catch logs used from 2006 on, and the lack of daily information on number of nets set in the monthly database used from 1992 to 2005. A separate arithmetic mean index was generated from each database to generate an annual CPUE value for 1992 to 2024 in pounds per trip. By using trips fished the effort units were consistent between databases.

The Maryland pound net CPUE indicated relatively high interannual variability and generally increased from 1992 to the early 2000s, was variable at high levels through the mid-2010s, then generally declined to a very low level in 2019, and remained at a very low level through 2024 (Figure 60). The pound nets that catch Atlantic croaker in Maryland are set for multiple species and generally in the same area from year to year. Since it is a stationary gear that is used consistently, it should not be as affected by changes in abundance as active gear that target Atlantic croaker. However, there has been a general decline in pound net effort in Maryland as fishermen drop out of this labor and cost intensive fishery.

4.1.2 Discards

4.1.2.1 Finfish Fisheries

4.1.2.1.1 Data Collection

Discard information from observed commercial fishing trips was obtained from the Northeast Fisheries Science Center's (NEFSC) Northeast Fisheries Observer Program (NEFOP). The NEFOP program collects data on harvested and discarded catch, gear, effort, and species' lengths and weights using trained fishery observers from Maine to North Carolina. The total catch and a subsample of the total catch from each observation (e.g., towed trawl net) are weighed. Each fish from the catch subsample was counted and measured to the nearest centimeter. The biological sampling program has a target of 50 lengths per sampling area for this species in its priority regions. Length sampling of discarded Atlantic croaker is summarized in Table 24**.**

The observer program started in 1989 and is mandatory for federally-permitted vessels, which are selected for observation during fishing trips based on number of sea days needed to achieve a 30% coefficient of variation (CV) in the dataset. Fisheries that require observer coverage fall under the federally managed fishery plans, such as groundfish, herring, squid, surfclam, ocean quahog, and the lobster fisheries. Atlantic croaker is a second-tier priority species for Mid-Atlantic gillnet sampling and a third-tier priority for Mid-Atlantic inshore trawl sampling (Northeast Fisheries Science Center 2016). Observed species landings and Atlantic croaker discards were used to develop discard estimates from gill nets and trawls in the waters from Delaware Bay to North Carolina.

The first commercial discard estimates for Atlantic croaker were done as part of the 2017 Atlantic croaker benchmark stock assessment (ASMFC 2017). Simply, the method developed annual ratios of observed discarded Atlantic croaker to observed landings of all species from gill net and trawl trips. It was assumed that the discarding rates during observed trips are representative of overall discarding rates in these fisheries and thus the ratios were then applied to reported gill net and trawl landings of all species in the region to estimate total Atlantic croaker discards. The Peer Review Panel recognized that bycatch estimates are unusually uncertain due to data insufficiencies, but agreed that the method used to estimate Atlantic croaker discards from the commercial fisheries were acceptable given the available data and the relatively small contribution of these discards to the total removals.

For this assessment, the NEFOP data was reanalyzed using the same methods as above but some additional data filtering was done in an effort to make the estimates more precise, if possible.

4.1.2.1.2 Data Filtering

Statistical Area

The NEFOP dataset included all landings in pounds from observed trips, including those where no Atlantic croaker were encountered, as well as trips where Atlantic croaker were discarded or kept. For the 2017 assessment, all observations from trips that landed in ports from New York to North Carolina were considered in estimating discards. Following a recommendation from

the horseshoe crab stock assessment and peer review that used the same methods as Atlantic croaker (ASMFC 2019), the SAS used statistical area instead of state to develop discard ratios (Figure 61). Only statistical areas within the region where Atlantic croaker were encountered, either discarded or kept, were included in the analysis. During preliminary analyses, of the observed trips in NEFOP that kept (landed) Atlantic croaker coastwide, 61% of the landings occurred in area 635, 11% in 631, 10% in 636, 10% in 625, and 6% in 621. All other areas combined accounted for the remaining 2% of landings. 62% of the discarded Atlantic croaker observed in NEFOP occurred in areas 635, 12% in 636, 11% in 621, 8% in 631, 4% in 701, 3% in 625. All other areas accounted for less than 1% of discards. The NEFOP data were limited to areas that land and discard Atlantic croaker at higher rates, which were 625, 631, 635, and 636. The spatial region based on these four statistical areas used in this analysis will be referred to as the Mid-Atlantic.

Gear

The gears that encountered Atlantic croaker in the NEFOP dataset were more closely examined and matched with the queried Atlantic Coastal Cooperative Statistics Program (ACCSP) data in this assessment compared to the 2017 benchmark. In 2017, the gears used in discard estimates can be found in Table 20. For this assessment, examination of the data resulted in excluding anchored and drift floating gill nets for not landing or discarding Atlantic croaker in high numbers. Both fixed or anchored sink gill nets and drift-sink gill nets were retained, along with all bottom otter trawls. Trawls that encountered Atlantic croaker but were used in the shrimp trawl fishery (e.g., twinned shrimp trawls) were excluded because shrimp trawl discards are estimated separately in this assessment.

With the collaboration of ACCSP staff, these gears from the NEFOP data were matched with ACCSP gears, which are not coded in the same format. The gears queried in ACCSP for the analysis are in Table 21.

Species

For the 2017 discard estimates, all species landed from New York to North Carolina within the specified gears were used. To further filter the data to better represent trips that would encounter Atlantic croaker, species in NEFOP and ACCSP were more closely examined. In NEFOP, data was filtered to trips that discarded Atlantic croaker. For all trips that discarded Atlantic croaker, the SAS evaluated which species were landed by weight. Of all species landings on trips that discarded Atlantic croaker in 1989-2022 in NEFOP, 53% of the landings in weight were Atlantic croaker, followed by horseshoe crab (32%), summer flounder (3%), spot (2%), weakfish (2%), and other species (Table 22). For scaling up the discard estimates to the coastwide landings, the SAS decided to focus on the landings of species that were landed when Atlantic croaker were discarded and therefore limited the landings to species that comprised at least 0.1% of those landed in NEFOP. The list of species from NEFOP (Table 22) were matched to species in ACCSP to query landings. Shrimp were eliminated from the analysis because shrimp trawl discards are estimated separately in this assessment. Hermit crabs were also excluded because they comprised a small amount of landings associated with Atlantic croaker discards (0.1%) but did not appear in the ACCSP query.

4.1.2.1.3 Methods

After examining the NEFOP and ACCSP data in finer detail than the 2017 assessment, the data used in the analysis were filtered to include four statistical areas (Mid-Atlantic), fewer gear categories of trawls and gill nets, and limited species as described in above sections. Calculating discard ratios annually by gear, rather than by month or statistical area, resulted in the best discard estimates due to missing or limited data in the other configurations. Following data filtering, NEFOP observer data were used to develop annual ratios of observed discarded Atlantic croaker to observed landings of the specified species by gill nets and bottom trawls from the statistical areas 625, 631, 635, 636 from 1989-2023.

The annual ratios by gear type were calculated as the ratio of the mean discards of Atlantic croaker per observation (i.e., tow or net set), in pounds, to the mean landings of aggregated species per observation, also in pounds:

$$R = \frac{\overline{D}}{\overline{L}} = \frac{\frac{1}{n}\sum_1^n D_i}{\frac{1}{n}\sum_1^n L_i}.$$

This ratio estimator includes all observations with observed landings of any species, including those where no Atlantic croaker were discarded. The variance of the ratio estimator (Pollock et al. 1994) was calculated as:

$$Var(R) = \frac{1}{n(n-1)\bar{L}^2}\left(\sum_1^n D_i^2 + R^2\sum_1^n L_i^2 - 2R\sum_1^n D_i L_i\right)$$

It was assumed that discard rates during observed trips were representative of overall discard rates in these fisheries. Small sample sizes of positive observations precluded developing ratios at finer resolution (e.g., season). Several years in the filtered data set had no observations and several other years had observations with no Atlantic croaker being discarded resulting in an annual ratio of zero. All of these occurrences were treated as estimates of zero Atlantic croaker discards. Additionally, 2024 data were not available in time for the assessment. However, discard estimates for the previous two years were zero for both gear groupings and were therefore assumed to be zero in 2024 during the assessment.

Ratios were then applied to reported gill net and bottom trawl landings of all species from the statistical areas and gears specified as queried from ACCSP (Figure 62). Limited species landings were used in the discard estimate analysis as described in Section 4.1.2.1.2.

In ACCSP, some landings were not available at the gear level and appear in the database as "NOT CODED." These landings were partitioned into trawl or gill net landings by calculating the annual proportion of landings by these gear categories and then these proportions were applied to the "NOT CODED" landings. The proportioning of NOT CODED landings was done after all data filtering was complete so that it did not include gears, such as dredge or rakes, that were unlikely to encounter Atlantic croaker. Landings were used to scale up the NEFOP discards by gill nets and trawls (Figure 63).

4.1.2.1.4 Discard Estimates

The ratio estimators varied by gear and year with the highest ratios of discarded Atlantic croaker to landed species occurring in the trawl fisheries compared to the gill net fisheries (Table 23). Although the ratios were generally higher for trawls than gill nets, discard estimates were comparable when scaled up to the landings since the gill net landings in the Mid-Atlantic are higher than the trawl landings for most of the time series (Figure 63 - Figure 64; Table 23). Estimated discards for both gears combined showed variable Atlantic croaker discards and high associated errors throughout the time series, although discards have been consistently low since 2016 (Figure 65). The discard estimates in the current assessment were lower than the 2017 assessment, as expected, since more data filtering was done, although the trends are generally comparable (Figure 66). Discards in the Mid-Atlantic are a small portion of the removals when compared to commercial landings (Figure 67).

4.1.2.2 Shrimp Trawl Fisheries

Commercial fisheries for shrimp species operate throughout coastal waters of the southeast Atlantic coast from North Carolina through Florida. The primary gears are otter trawls and skimmer trawls. Atlantic croaker are typically the most prevalent bycatch species in these shrimp trawl fisheries and can outweigh and/or outnumber individual species of targeted shrimp (Appendix 13.1 Tables ST1-ST3). The following sections describe the available data sets for these fisheries and how they were used to generate discard estimates of Atlantic croaker. Additional details are provided in Appendix 13.1.

4.1.2.2.1 Data Collection

Effort Data

Effort data from individual commercial shrimp fishing trips have been collected in recent years from modern trip ticket programs conducted by state agencies and described in Section 4.1.1.1. Trip ticket programs started in North Carolina in 1994, in South Carolina in 2004, in Georgia in 2001, and in Florida in 1986.

Prior to these trip ticket programs, effort data from individual commercial shrimp fishing trips were collected and processed by a cooperative effort called the South Atlantic Shrimp System (SASS). SASS data collection began in 1978 in North Carolina and Georgia, 1979 in South

Carolina, 1981 in Florida, and 1982 by the NOAA Fisheries Southeast Fisheries Science Center (SEFSC). Florida and North Carolina discontinued data collection for the SASS in 1993, leaving a one year gap in North Carolina before the trip ticket program was implemented in 1994. Data are available by year, month, state, port, and gear.

The SEFSC also maintains a database known as the Vessel Operating Units File (VOUF) which compiles data on vessel characteristics, including the number of nets that can be operated simultaneously, recorded by port agents from vessels operating in shrimp trawl fisheries.

Prior to this assessment, shrimp trawl effort data from the SASS and state trip ticket programs were provided with a standardized query by the SEFSC as has been done for SEDAR assessments of species with bycatch in shrimp trawl fisheries (Gloeckner 2014) or pulled from previous SEDAR reports. During this assessment, state partners were consulted on data to use to characterize shrimp trawl fisheries in their state. North Carolina, South Carolina, and Georgia elected to provide some or all data directly to replace data provided by the SEFSC. Specifically, North Carolina provided monthly trip counts from 1990-2024 and South Carolina and Georgia provided all annual data for the years 2004-2024 and 2001-2024, respectively. Otherwise, states reviewed and defaulted to data for other years and/or effort metrics from the SEFSC query. Data are no longer pulled from previous SEDAR reports due to inability to replicate the data (Appendix 13.1).

NOAA Fisheries Shrimp Observer Program

A shrimp trawl observer program was implemented in the South Atlantic (North Carolina-Florida) in 2001 through a cooperative agreement between NOAA Fisheries, the Gulf and South Atlantic Fishery Management Councils, and the Gulf and South Atlantic Fisheries Foundation to characterize catch and bycatch, as well as evaluate BRDs. Total catch, total shrimp catch, and a subsample (one basket per net, or approximately 32 kg) for species composition is taken from each observed net. The program began as a voluntary effort, but, beginning in 2008, the program became mandatory in the South Atlantic and NOAA Fisheries-approved observers were placed on randomly selected shrimp vessels. The voluntary component of the observer program also continued. Penaeid shrimp (primarily inshore) and rock shrimp (primarily offshore) fisheries in the South Atlantic are covered by the observer program. Observed coverage is allocated by previous effort, or shrimp landings when effort data are not available. Based on nominal industry sea days, observer coverage of shrimp trawl fishery effort is approximately 2% (Scott-Denton et al. 2020). Of note, sampling was greatly reduced in 2023 due to poor compliance (G. Decossas, NOAA Fisheries, personal communication) but returned to normal levels in 2024 (Table 25).

Biological information, such as length and weight of bycatch species, was collected from the subsample of total catch in observed nets. Very limited biological sampling has been conducted for Atlantic croaker. Only 1,343 Atlantic croaker were measured for length, caught from just 36 tows on two trips occurring from October to November in 2003. Lengths ranged from 10 to 29 cm TL (Figure 68).

See Scott-Denton (2007) for more details on the voluntary component of the Shrimp Observer Program and Scott-Denton et al. (2012) for more details on the mandatory Shrimp Observer Program.

North Carolina Commercial Shrimp Trawl Fishery Characterization Studies (P570)
These characterization studies were conducted statewide in all state waters (inshore estuarine and nearshore ocean 0-3 miles), and the primary gear was shrimp otter trawls. The sampling concept was a random design and trip ticket data from previous years was used to estimate coverage by area. Data were available from 2007-2017.

Observers contacted and obtained weekly observer trips aboard commercial vessels operating in the commercial shrimp trawl fishery through voluntary participation. Participating commercial fishermen were selected randomly from a list of active fishermen derived from license and NCDMF Trip Ticket data. Data collected included overall vessel length, net dimensions and mesh sizes, turtle excluder device (TED) type, tow time, latitude, longitude, depth, and sea surface temperature.

Because all the data was collected during observer trips aboard active commercial fishing vessels, in order to avoid interference with regular operations, data collection was sometimes limited by factors such as the pace of the tows or the size of the catches. When possible, the total catch weight was obtained for all tows, otherwise the total catch weight was estimated. All weights were recorded to the nearest kg or g, depending on the size of the sample categories being weighed. Total weight of all non-shrimp catch was recorded for every tow. Latitude and longitude were taken on each tow when the net is hauled back.

For large catches, a one-basket subsample (approximately 32 kg) was taken from each net. Finfish in each subsample were examined as follows: weighed total sample, separated to species, enumerated and weighed total of individual species, for commercially important species measured TL or FL of 30-60 individuals of each species and weighed this smaller subsample.

Aggregate length compositions show capture sizes increasing around 8 cm, a peak capture size of 15 cm, then sharp declines around 17 cm (Figure 69). Atlantic croaker larger than 18 cm were observed infrequently.

Discard Mortality Rates
Limited information is available on mortality rates of Atlantic croaker caught and discarded during shrimp trawling. A study by Johnson (2003) determined the immediate (15–30 minutes) mortality of discards onboard estuarine commercial shrimp trawlers increased as time on deck increased, from 60% mortality for Atlantic croaker that were on deck less than 20 minutes to 92% mortality for Atlantic croaker that were on deck longer than 20 minutes. This study does not take into account delayed mortality post-discarding.

Beginning in August 2012, the at-net mortality of select species (spot, Atlantic croaker, and weakfish) was obtained during the North Carolina Commercial Shrimp Trawl Fishery

Characterization Studies. Observers randomly select 30 individuals from each of the species and record the status (dead or alive) and lengths. At-net mortality of Atlantic croaker ranged from 21-41% (Appendix 13.1 Table ST3). These observations do not account for additional mortality from handling and processing or delayed mortality post-discarding.

The TC was polled for opinions on discard mortality based on their observations and encouraged communication with industry, as recommended during the 2017 Atlantic croaker assessment peer review (ASMFC 2017). The TC believes there may be some low level of survival due to Atlantic croaker being a hardy species relative to others (e.g., spot), but noted that discarding is concentrated on smaller, less hardy individuals. The TC believes total discard mortality ranges between 90 and 100%. A baseline discard mortality in the middle of this range (95%) was adopted for determining dead discards.

4.1.2.2.2 Methods

Total discard estimates for the shrimp trawl fishery were generated for the assessment by expanding model-estimated discard rates from the observer data by total shrimp trawl fishery effort. This builds upon the methodology applied during the 2017 assessment (ASMFC 2017). Several exploratory analyses were completed during this assessment in efforts to improve upon this methodology and are described in Appendix 13.1. Major changes adopted from these analyses include development of estimates with model-based discard rates using only observer data from the fishery and less direct use of supplemental SEAMAP catch rate data to hindcast estimates prior to the mandatory observer program, and use of effort data directly from state partners.

Discard rates of Atlantic croaker were standardized with the delta-lognormal method (Lo et al. 1992). The delta lognormal method combines a lognormal generalized linear model (GLM) used to predict discard rates of positive observations and a binomial GLM to predict the probability of a positive observation, with effort (net hours fished) as an offset variable. The final discard rate (number of Atlantic croaker per net hour fished) is the product of the response variables from these two GLMs. Factors considered in the GLMs were year, data set, depth zone, state, and season. Data sets included observer data from the rock shrimp (observer project types W, X, Y) and penaeid shrimp (observer project types A, C) commercial fisheries. Depth zones were less than or equal to 10 meters (=<10m), greater than 10 meters to 30 meters (10-30m), and greater than 30 meters (>30m). State borders were defined by the latitudes used by Scott-Denton et al. (2012) and North Carolina was split into stocks at the border between Carteret and Onslow Counties (NC_north is northern stock waters and NC_south is southern stock waters). Seasons were December through March (offseason) and April through November (peak season). Shrimp fishing in nearshore waters where catch rates are expected to increase has generally started as early as April and lasted through November.

Only years since the observer program became mandatory (2008) were used to model discard rates. Only discarded Atlantic croaker are recorded by shrimp trawl observers, so no adjustments were needed to account for fish landed. State observer data sets were not included. The North Carolina Commercial Shrimp Trawl Fishery Characterization Studies were

voluntary and count data are not considered reliable (ASMFC 2017). Observer data collected in Georgia were not considered representative of the shrimp trawl fishery and were not provided for the assessment (J. Flowers, GADNR, personal communication). A summary of observer data, including sample sizes and hourly catch rates, are provided in Table 25.

Model structure was evaluated with stepwise deletion of factors. AIC supported inclusion of all factors in the lognormal GLM and, to a marginal extent (AIC less than two units lower than model with all factors retained), all but data set in the binomial GLM (Table 26). Therefore, all factors were retained in each sub-model for consistency.

Three effort characteristics are used from effort data to determine total effort for discard estimates. These include total number of trips, average hours fished per trip, and average number of nets fished per vessel. The products of these, total net hours fished, are used to expand the modeled discard rates.

To estimate the missing year of trip data from North Carolina in 1993, the number of trips from the two preceding years (1992, 1994) were averaged. Hours fished were available starting in 2001, so 2001-2003 averages were used for years prior to 2001 except for SC where the trip ticket program started later and the 2004-2006 average was used for all years prior to 2004. VOUF data were only available through 2021, so 2019 through 2021 averages of number of nets per vessel were used for states that do not directly provide these data (North Carolina and Florida).

As effort was only available by state, year, and month, some assumptions were made to partition the effort among depth zones and fisheries. The proportions of observations from the observer data by depth zone were applied to overall effort, assuming that the observer data was representative of fishing effort at depth and that fishing effort at depth is static over time. A similar assumption was then made to partition the effort data into different state fisheries since data was collected at the state level. The proportions of observations in each depth zone allocated to penaeid and rock shrimp fisheries were applied to the effort data in the respective depth zone.

Discard rates were applied to effort data summarized by “strata” (i.e., combination of factors included in the model). Confidence intervals of discard rates using the delta method with the predict function in R are propagated through total discard estimates and are similar to confidence intervals estimated by bootstrapping discard rate estimates (Appendix 13.1). These delta method-derived confidence intervals are provided to characterize uncertainty of discard estimates. Effort data collection is a census design and does not have associated measures of variance for characterizing uncertainty.

To estimate discards for years prior to the mandatory observer program (1990-2007), the same analysis as above was conducted with SEAMAP Coastal Trawl survey CPUE data added to the observer discard rate data, as was done for base discard estimates in the 2017 assessment. SEAMAP data are available back to 1990 and serve as proxy discard rate data for years prior to the observer program. This survey uses a similar gear as shrimp trawl fisheries and operates in a

similar footprint. Total discards were then calculated as above using the product of model-estimated discard rates and total net hours fished. SEAMAP data were categorized as a third data set in the GLM data set factor so that the estimated effect size of this data set is not used when expanding to total discard estimates (i.e., only the rock shrimp and penaeid shrimp data set effects are used). Only the relative trend information from the SEAMAP data are used in expanded discard estimates by informing the GLM-estimated year effects. Finally, the annual ratio of total discards from both methods (i.e., using observer discard rate data only and SEAMAP CPUE combined with observer discard rate data) were calculated for overlapping years (2008-2022; Table 27 and Table 28). The median of these ratios was then applied to annual discard estimates using the SEAMAP CPUE data combined with observer discard rate data for final discard estimates in years prior to 2008.

4.1.2.3 Trends

4.1.2.3.1 Effort

Effort has declined steadily in all areas (Figure 70). Average annual effort from the last ten years of the time series (2015-2024) decreased from the average of the first ten years (1990-1999) by 61%, 87%, 84%, and 77% in North Carolina, South Carolina, Georgia, and Florida, respectively. Florida effort has generally been the highest due to relatively high average hours fished per trip in that state.

4.1.2.3.2 Total Discards

Discards are of similar magnitudes and follow similar trends in both stocks, with relatively high levels in the early 1990s, including anomalously large estimates in 1991 (Table 27 and Table 28; Figure 71). Median estimates from 1990 through 1995 are 211 million and 266 million fish in the northern and southern stocks, respectively. These estimates appear driven by both high effort levels (Figure 70) and higher catch rates than later years (Table 25). Discards declined to the lowest levels in the late 1990s through the mid-2000s, with medians from 1996 through 2007 of 78 million and 125 million fish in the northern and southern stocks, respectively. Discards in the northern stock show an increasing trend from the mid-2000s through 2020. Discards declined sharply to near time series lows in 2022 (22 million fish), then increased back to relatively high levels in 2024 (247 million fish). Discards in the southern stock increased sharply in 2008 back to levels observed in the early 1990s. This shift is partly the result of change in methods from hindcast estimates to estimates derived directly from observer discard rates. Discards then fluctuated around these levels with high interannual variability including peaks in 2013 (379 million fish) and 2019 (285 million fish) and lows in 2015 (99 million fish) and 2022 (31 million fish). Higher estimates in recent years as well as the sharp decline in 2022 appear driven by discard rates, as effort has remained relatively low.

4.2 Recreational

4.2.1 Total Catch and Effort Data Collection

The primary source of Atlantic croaker recreational catch data along the Atlantic coast is the Marine Recreational Information Program (MRIP). MRIP consists of three general surveys to estimate recreational catch, the Access Point Angler Intercept Survey (APAIS), the Fishing Effort

Survey (FES), and the For-Hire Survey (FHS). The APAIS is a dockside survey where interviewers intercept anglers returning from fishing trips to collect information on catch and fishing area. Data are used to estimate species-specific catch rates by disposition, characterize the size structure and weight of fish harvested, and determine the proportion of fishing effort occurring in three general areas of marine waters (inland, state seas from the coastline out to three miles, and the federal EEZ beyond three miles from the coastline). Dispositions reported by anglers include harvested and either available for inspection (Type A catch) or unavailable for inspection (e.g., fileted at sea, Type B1 catch) and released alive (Type B2 catch). The FES is a mail-based survey that collects data on fishing effort by anglers from U.S. households fishing from shore and private/rental boats to estimate total fishing effort. The FHS is the counterpart to the FES that collects data on fishing effort by for-hire charter boat and headboat captains through a telephone survey. Each of these components of the MRIP survey have undergone design changes since 1981, with a brief description of survey design changes below. Interested readers who would like more details on the survey design changes are encouraged to review the resources available through the NMFS Office of Fisheries Statistics (www.fisheries.noaa.gov/recreational-fishing-data/about-marine-recreational-information-program).

MRIP surveys implement a stratified sampling design, stratifying by state, year, wave (bimonthly period), and fishing mode (shore, private/rental boat, headboat, and charterboat). Catch rate data collected during the APAIS for each stratum are applied to total effort data from the FES and FHS to estimate total harvested catch (Type A+B1 catch) and total catch released alive (Type B2 catch). The area data collected during the APAIS are used for post-stratification of estimates by area.

Two significant changes have occurred to the MRIP survey methodologies based on external reviews and recommendations throughout the duration of the program. The APAIS was redesigned in 2013 to improve the sampling design and the use of APIAS data in catch estimation methods. In 2018, the telephone-based effort survey used historically to collect effort data from U.S. households (Coastal Household Telephone Survey-CHTS) was replaced with the current mail-based FES. MRIP now provides all historical estimates prior to 2018 with calibrations applied to correct for both the APIAS redesign changes and the transition to the mail-based FES. The FES results in increases in effort estimates and, therefore, total catch estimates relative to the CHTS.

MRIP studies recently indicated potential overestimation of private/rental and shore fishing effort. Adjusted catch estimates for all years are currently being developed to account for effects determined from these studies and were not available in time for this assessment. See the MRIP website for more details on this development (https://www.fisheries.noaa.gov/recreational-fishing-data/fishing-effort-survey-research-and-improvements). Potential impacts from this development were investigated through sensitivity analysis in consultation with MRIP staff.

For the current assessment, data were split by stock with data from Carteret County, North Carolina and any areas to the north assigned to the northern stock and data from Onslow County, North Carolina and any areas to the south assigned to the southern stock. The county recorded is for the location of the interview not fishing activity, so there is potential for some stock mixing in data close to the Carteret County/Onslow County border. In addition, the southern stock was further divided into two fleets including one for Florida and one for all states north of Florida. This was done as fish from Florida were slightly larger than other states in the southern region and so selectivity may be different or there may be large fish available to anglers in Florida.

4.2.2 Biological Data Collection

Biological data collected during the APAIS sampling include centerline length and weight of Type A fish. Both are collected opportunistically but field interviewers are instructed to measure and weigh up to fifteen fish of each available species from each angler interviewed. The individual fish are to be selected from the total landed catch at random to avoid any size-bias in the resultant sample. These data are used to estimate harvest in weight and the size composition of harvested fish.

4.2.3 Trends

4.2.3.1 Total Catch

Northern stock harvest increased in the 1980s and early 1990s, was relatively stable at high levels through the early 2010s, then steadily declined to its lowest value of the time series in 2024 (Table 29, Figure 72). Releases were relatively low in the 1980s, increased in the early 1990s to higher levels that were relatively stable through 2011, increased briefly to the highest levels of the time series in 2013, then declined through 2019. Releases increase for the remainder of the time series. The proportion of catch occurring north of the core catch areas in the northern stock (northern North Carolina, Virginia, and Maryland) was evaluated for any potential signs of range expansion. The proportion of catch coming from these northern areas was near or at zero in the 1980s and early 1990s then increased in the late 1990s and 2000s, averaging 11.5% of the harvest and 13% of the releases in the 2000s (Figure 73). Proportions then declined as the catch declined in the 2010s. There has been an increasing trend at the end of the time series in the 2020s, but these values observed are less than those observed in the 2000s and evidence of a consistent northern range shift is inconclusive.

Southern stock harvest was at a time series high in the 1980s in both fleets, then declined to lower levels in the 1990s (Table 29; Figure 72). Harvest from North Carolina through Georgia follows a gradual increasing trend from time series lows in the early 2000s through the remainder of the time series. Harvest in Florida remains at low, stable levels for the remainder of the time series. Aside from a few anomalously large data points for Florida in the 1980s and 1999, releases from the two southern stock fleets follow increasing trends throughout the time series but increased at a greater rate from North Carolina through Georgia.

Proportional standard errors (PSEs) of catch estimates are provided as measures of uncertainty and indicate increasing estimate uncertainty as PSE values increase (Table 30). PSEs for northern stock catch estimates generally decreased from high levels in the 1980s, but have been increasing in recent years as catch has declined. Despite the increasing trends, values remain at relatively low levels (<20%). PSEs for southern stock catch estimates from North Carolina through Georgia have generally decreased through time. PSEs for Florida catches have varied with no discernible trend through time and have generally been at the highest levels among fleets.

4.2.3.2 Length Compositions

Time-aggregated harvest length compositions show the different sizes harvested by each fleet (Figure 76). Southern stock fish harvested from North Carolina through Georgia are the smallest with a peak size at 20 cm and fish larger than 30 cm infrequently harvested. Southern stock fish harvested from Florida are a moderate size structure with a peak at 22 cm. Northern stock harvest had the largest size structure with a peak similar to Florida fish at 22 cm, but a sharper ascent in sizes smaller than 22 cm and a more gradual descent for sizes larger than 22 cm. Annual length compositions show a more variable size structure in the northern stock through time (Figure 77). There was a moderate expansion of the length composition in the late 1980s and a more prolonged and larger expansion in the late 1990s and 2000s, with fish larger than 40 cm regularly harvested. There were noticeable contractions in the early 1990s and 2010s, with the size structure remaining truncated at the end of the time series. Fish larger than 40 cm are infrequently harvested during these contractions. Southern stock length compositions are more stable though time. Fish larger than 40 cm are intermittently (Florida) or rarely (North Carolina-Georgia) harvested throughout the time series.

The number of MRIP primary sampling units (PSUs), which is a unique interviewer assignment for sampling catch, where Atlantic croaker were encountered for length measurements are presented here (Table 31) as a proxy for length composition sampling replicates (i.e., precision), assuming a clustered sampling design (i.e., lack of independence). Sample sizes for the northern stock increased through the mid-1990s, were stable at high levels through the mid-2000s, and then declined through the remainder of the time series (Table 31). Southern stock sample sizes from North Carolina through Georgia were at relatively high levels through the early 1990s, then declined to lower, stable levels through the remainder of the time series. Sample sizes from Florida have varied at lower levels without trend.

4.2.3.3 Effort and CPUE

MRIP provides effort data in terms of angler trips. Effort directed at individual species can be defined in multiple ways including using voluntary angler responses on targeted species during interviews, catch of species during trips, and catch of associated species during trips. For this assessment, directed trips is defined as any trip where an angler identified Atlantic croaker as a primary or secondary target species. Effort in the northern stock was relatively stable through the 1980s and early 1990s, then increased to a time series high in 2010 (Figure 74). Effort remained at relatively high levels through 2016, then declined through 2022 before a short uptick for the last two years. Effort in the southern stock was at its highest levels in 1980s then

declined to a time series low in 1997 (Figure 74). Effort gradually increased for the remainder of the time series, with the exception of a brief downturn in the late 2010s.

CPUE was calculated as the total number of Atlantic croaker caught per directed trip. Northern stock CPUE increased through the 1980s and 1990s, then decreased from the early 2000s through the 2010s (Figure 75). There was a brief increasing trend in the early 2020s. Southern stock CPUE generally increased throughout the time series (Figure 75).

5 FISHERY INDEPENDENT DATA SOURCES

Six fishery independent surveys were used in the 2017 Atlantic croaker stock assessment to provide indices of abundances, and these were prioritized for model development during this assessment. However, special consideration was given to potential new data sources available for indices of abundance due to the population being split into two stocks with a different boundary than previous assessments, particularly for the Southern Stock that would have only had one survey that was used in the last stock assessment (SEAMAP).

Atlantic croaker are a fast-growing species, particularly in the first few months (Ross 1988; Miller et al. 2003). Combined with a prolonged spawning season, especially in the southern stock (Music and Pafford 1984; Barbieri et al. 1994b; Franco 2014), the fast growth results in a lot of overlap in lengths among ages (Figure 78). Extreme overlaps in lengths for several ages, especially age-0 and age-1 Atlantic croaker, made splitting surveys into recruitment surveys or age-1+ surveys from age-length keys impossible. Also, this overlap and the sampling strategies (length-binned age sampling) of the SEAMAP Coastal Trawl Survey hampered compiling age composition data. Therefore, surveys that regularly encountered several ages were included as age-aggregate indices of abundance. Surveys that encounter exclusively or primarily young-of-year fish are used to generate age-0 indices of abundance with predetermined length cut-offs.

Index time series were assessed with correlation analyses (see Section 5.2) to evaluate consistency among trends and support index selection and combined with dynamic factor analysis (see Appendix 13.2) for alternate index data to consider.

Five surveys operating in the northern stock were selected for use in the assessment (Table 32). Of the five surveys, two were age-0 recruitment surveys and the other three were aggregate age surveys. Three surveys were chosen to model the Atlantic croaker southern stock (Table 32). Of the three chosen surveys, two were age zero recruitment surveys and the third is an aggregate age survey split into two seasons. Surveys used in the model are described below. Other surveys considered but ultimately not modeled are described in Appendix 13.2.

5.1.1 Northeast Fisheries Science Center (NEFSC) Bottom Trawl Survey

5.1.1.1 Survey Design and Methods

In fall 1963, the NOAA Fisheries Northeast Fisheries Science Center (NEFSC) implemented a multispecies bottom trawl survey program to monitor a large portion of the northeast Atlantic Ocean (Figure 79). The program conducts seasonal cruises in the spring (starting in 1968; generally during March through May) and fall (generally September through November). The

surveys did not complete sampling in spring 2014 due to delays, fall 2017 due to vessel mechanical issues, 2020 (spring or fall) due to covid-19 sampling restrictions, and spring 2023 due to vessel mechanical and staffing issues. Aside from the incomplete seasonal survey sampling, it is common for the survey to have a limited number of strata incomplete due to time constraints, vessel complications, or weather impacts.

The survey utilizes a stratified random sampling design with depth used for stratification. 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. Inshore strata (depths less than 27 m) south of Massachusetts were sampled beginning in fall 1972 and spring 1973 and inshore Gulf of Maine strata were added beginning in spring 1979. Stations are randomly selected within strata with the number of stations in the stratum being proportional to stratum area.

Most survey cruises prior to 2009 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. Trawls were made for 30 minutes at a vessel speed of 3.5 knots measured relative to the bottom (as opposed to measured through the water). Since 2009, the surveys have been conducted by the NOAA ship R/V Henry B. Bigelow, a 63 m long stern trawler. Standard trawl hauls are made for 20 minutes on-bottom duration at a vessel speed over ground of 3.0 kts. Due to the deeper draft of the Bigelowc compared to the Albatross, sampling of the two shallowest series of inshore strata (< 9 m, 9-18 m) was discontinued in 2009. Calibration experiments, comprising paired standardized tows of the Albatross and Bigelow, were conducted to measure the relative catchability between the two vessel-gear configurations. Model-based estimators of catch ratios between survey vessel-gear configurations are available as calibration factors to convert survey catches (Miller et al. 2010).

The catch of each tow is identified, counted, weighed, and measured. When the catch of a particular species is large, a subsample of individuals is measured. Species are subsampled for biological data on length, individual weight, stomach weight and volume, sex, maturity (macroscopic), and age determination according to standard survey protocols. Atlantic croaker are not included in survey protocols for age determination, but otoliths and gonad cross sections collected from subsamples using a length bin stratified sampling strategy have been shipped to SCDNR for full biological data workups starting in 1997 (Table 33). Otoliths were processed and aged as described for South Carolina in Section 2.4. Maturity determination was made according to methodologies of Brown-Peterson et al. 2011. Unprocessed Atlantic croaker collected from 2020-2022 are archived at the NEFSC and sampling was discontinued in 2023 due to personnel and time constraints.

Environmental and physical data collected during each tow include temperature (air, surface, and bottom), salinity (surface and bottom), cloud cover, barometric pressure, wind details (direction and speed), wave and swell details (height and direction), weather, latitude, longitude, and depth.

5.1.1.2 Evaluation of Survey Data

Data prior to 1972 were excluded from analyses due to lack of inshore strata sampling. The survey footprint was reduced to a continuous area of strata where Atlantic croaker have been observed (Figure 79). The southern boundary of this footprint aligns with the stock boundary in the current assessment so that data represent the northern stock. Additionally, any strata sampled for fewer than 38 years were excluded, which effectively dropped the two shallowest strata that were discontinued after the vessel change in 2009. Stratum 1360 in the Gulf of Maine was also excluded despite one anomalous positive observation in 1974 given its isolated location and distance from other strata where Atlantic croaker have been observed.

Atlantic croaker are not consistently encountered during the spring survey (≈3% positive tows and 16 no catch years) and lack of observations during the vessel calibration study precluded estimation of calibration factors for this season. Therefore, spring survey data were excluded from analyses. The fall survey has consistently encountered Atlantic croaker through time (≈28% positive tows and 0 no catch years; Table 33). Fall survey catch data collected prior to 2009 were adjusted to Bigelow units so that a consistent time series was available using the catch units of the current vessel. Calibration factors indicate the Bigelow is more efficient at catching Atlantic croaker, particularly considering the shorter tow durations of the Bigelow (Bigelow: Albatross catch ratio of 1.134, table 53 in Miller et al. 2010).

Given the broad temporal and spatial coverage of this survey and interest in evaluating distribution changes (TOR #1) in addition to generating an index of abundance, the Vector Autoregressive Spatio-Temporal (VAST) modeling package (Thorson 2019) was used as the primary tool to evaluate the survey catch data and generate an index of abundance for the SS assessment model.

A number of model configuration choices were tested during model development and AIC and residual diagnostics were used to select the best model configuration described here. The model used a zero-inflated negative binomial distribution. The zero-inflated model consists of two linear predictors, a first linear predictor modeling zero-inflation probability and a second linear predictor modeling distribution of the catch. Residual diagnostics show no major patterns indicative of misspecification (Figure 80).

Spatial and spatio-temporal variation were estimated for the second linear predictor, but not for the first linear predictor (i.e., zero-inflation probability assumed constant over space and time). Thorson (2019) notes count data typically do not contain information to estimate spatial and spatio-temporal variation in zero-inflation probability and testing during model development confirmed this was the case for the survey data. A random walk temporal correlation was estimated for spatio-temporal variation due to some unsampled strata in some years. One hundred knots, which control the spatial resolution of abundance estimates across the extrapolation grid, were used to estimate abundance.

Environmental data were not used in the spatio-temporal VAST model due to a large portion of tows missing observations and potential correlation of environmental variables with spatial-

temporal variation at the heart of the VAST analysis. Therefore, environmental effects were explored from a subset of data in a separate analysis with a non-spatial model. A zero-inflated negative binomial generalized linear model (GLM) with year, depth, bottom temperature, and bottom salinity as explanatory variables of positive catch rates and depth, bottom temperature, and bottom salinity as explanatory variables of zero-inflation probability was constructed. AIC supported the inclusion of all variables in a final model. The goal of this analysis was to understand potential environmental effects on catchability. Indices from this analysis should be interpreted with caution in terms of stock abundance trends because they're estimated from a reduced data set filtered to observations with paired environmental data.

A final analysis of the catch rates from this survey focused on trends by depth. The overall abundance trend from this survey has deviated from fishery catch trends and inshore fishery-independent survey indices (i.e., ChesMMAP), which may be due to lack of spatial overlap and exacerbated as observations occur further from inshore areas. Design-based trends by depth strata, including discontinued strata, were investigated to better understand spatial dynamics within the survey. Catches have only been consistent in the first four depth strata, so data from deeper strata were excluded.

Length frequencies describing the size structure of the catch for all indices evaluated for this survey were generated with stratified random design-based estimators. Age compositions for the survey were not generated, but rather frequencies by size bin were tabulated for inputs to the SS assessment model as conditional age-at-length data.

5.1.1.3 Survey Data Trends

VAST abundance estimates were at relatively low levels from the 1970s through the early 1990s (Figure 81; Table 33). Abundance then increased through the early 2000s and has remained relatively stable at high levels since. The time series high was observed in 2024. The VAST-estimated index smooths out interannual variability measured by the design-based index in the 1970s, 1980s, and 2020s, increases interannual variability in the 2000s, and estimates greater abundance peaks in 1995, 2006, and 2024, but otherwise provides a similar trend as the design-based index (Figure 81). Index CVs were relatively large and stable around an average of 0.35 through the early 1990s, a decline through the late 1990s and 2000s, and became stable at relatively low levels, around an average of 0.22 through the 2010s and 2020s (Table 33).

Lengths encountered have typically been larger than 14 cm and smaller than 40 cm with a peak at 20 cm (Figure 82). Annual median length reflected a larger size structure in the late 1970s and late 1990s through the early 2000s, often measuring 25 cm or greater (Figure 82). The size structure was smaller from the 1980s through the early 1990s, typically around 22 cm, and was the smallest of the time series from the 2010s through the end of the time series in 2024, falling to 19 cm in several of these years.

Ages range from 0-13 years old (Figure 83), although most fish are ages 0-4. Ages collected show an expansion in the age structure in the 2000s followed by a contraction since. No fish older than 7 have been collected since 2014. Data show indication of relatively strong year

classes in 1998, 2002, and 2012 and relatively weak year classes in 1996, 2000, and 2011. Number of ages collected annually ranged from 20 to 1,303 with an average of 435 (Table 33).

The zero-inflated GLM with environmental covariates estimates an exponential increase in catch rates as temperature increases (Figure 84). Conversely, the model estimates an exponential decrease in catch rates as salinity increases, though the magnitude of this effect is considerably smaller than for temperature (Figure 84). Given the stronger influence of temperature, the stratified mean bottom water temperature observed during the survey is provided in Figure 85 and has generally increased through the time series, indicating the potential for temperature-induced increases in catchability in recent years. There is high interannual variability, but conditions have consistently been warmer the last eleven years of the time series, with the mean remaining above 15.4° C since 2014 (insufficient observations in 2017 and 2020). Four years of the previous eleven-year period (2002-2013) fell below 15.2° C and two fell below 14° C (insufficient observations in 2007 and 2008). Interestingly, an annual index using the model with environmental effects to adjust catch rates predicts a dampened abundance trend in most years since 2004 relative to an index from a model without these environmental effects included (Figure 86). The index with environmental effects accounted for also predicts a much stronger 2012-year class that is more consistent with observations from other data sources (NEAMAP, ChesMMAP as YOY in 2012 fall index and as age-1 in 2013 summer index).

Trends by depth strata show some similarities as well as some differences across depths (Figure 87). Trends in the first three depth strata are similar with increases in the late 1990s and 2000s. Catch rates in the fourth depth strata show delayed increases with sharp increases in the mid-2000s that then level off at relatively high levels. Unfortunately, trends in the first two depth strata with the highest catch rates were discontinued after the vessel switch and remain an uncertainty. The NEAMAP survey index is the best source of information to infer recent trends in these depth strata and does not indicate discernible trends during the missing years. The third depth strata indicates more of a decline in the late 2010s that is not apparent in the fourth depth stratum, but then increases in the 2020s.

There are also some discrepancies in indices of specific years. For example, the 1995 peak in the overall survey index appears driven by an anomalous peak constrained to the fourth depth strata, the 2024 peak in the overall index is driven by the catches in the third depth stratum while declines are observed in the fourth depth stratum, and the indices (particularly in the fourth depth stratum) do not reflect as strong a 2012 year class as observed in other data sets.

The length structures by depth show similar signals including an expansion in the late 1990s and early 2000s followed by a contraction in the late 2000s (Figure 87).

VAST center of gravity estimates indicate two primary periods of northeast distribution shifts in the 1970s, from its most southwesterly location at the start of the time series (northern outer banks of NC), and again in the 1990s. The latitudinal position of the population is relatively stable through the 1980s, 2000s, and 2010s at the highest latitudes of the time series (off the eastern shore of VA, approximately 200 kms of northward movement across the time series).

The longitudinal position shifts are not surprisingly smaller in scale (≈15 km) than latitudinal shifts (≈100 kms) given the orientation of the Atlantic coast in this region. The longitudinal position is relatively stable in the 1980s, while there is a small scale (≈10 kms) bimodal pattern with short term eastward movement in the early 2000s and again in the early 2010s. There is indication of a strong northeast shift in the last three years of the time series driven in scale by an apparently strong 2024-year class. This shift will be interesting to monitor in coming years to determine if this is a long-term distribution shift or is more reflective of just the 2024-year class.

5.1.2 Northeast Area Monitoring and Assessment Program (NEAMAP)

5.1.2.1 Survey Design and Methods

The Northeast Area Monitoring and Assessment Program (NEAMAP) was designed to collect fisheries independent data and develop fishery-independent surveys for areas in nearshore areas of the Northeast United States where sampling has been inadequate or absent. NEAMAP began with a pilot survey in the fall of 2006 and began conducting routine surveys twice a year, one in spring and one in fall, in 2008. Samples are collected in near shore waters to a depth of 60 feet, including some areas that reach a depth of 120 feet. During each season, approximately 150 samples are taken according to a stratified random design where strata are based on region and depth (Figure 88). At each station the net is trawled along the bottom for 20 minutes at a speed of 2.9-3.3 knots. The same vessel F/V Darana, a 90-foot commercial trawler, has been used for the entire history of the survey. The net is a 4 seam, 3 bridle, 400 x 12 cm net with a cookie sweep and 2.54 cm knotless liner in the cod end.

5.1.2.2 Biological and Environmental Sampling

After each tow, the catch is sorted by species and size class. Aggregate weights, individual length measurements, and counts are recorded for each species and size class. In addition, for each species and size group, 3 individuals for common species, and 5 individuals for other species are subsampled for length, weight, sex, and maturity stage. Variables recorded at each station include tow duration, water depth, latitude and longitude for beginning and end tow location, atmospheric and weather data, and water quality data such as temperature, salinity, dissolved oxygen concentration.

5.1.2.3 Evaluation of Survey Data

Both spring and fall data were initially evaluated and we chose to only use the fall data because of the low proportion of positive tows and lower number of Atlantic croaker encountered during the spring compared to fall. Individuals of all ages and lengths were included in the index. We used year as the only covariate in the model as researchers from VIMS advised us that they had unreasonable model estimates when including environmental covariates, likely due to the correlation between environmental covariates and spatial random effects. The R package sdmTMB (Anderson et al. 2024) was used to fit a model with only a fixed effect for year and several distributions were considered. Also included in the model were spatial and spatio-temporal random effects, where the spatio-temporal random effects were independent and identically distributed. The best model was chosen based on AIC values (Akaike 1973) and residual diagnostics (DHARMa R package, Hartig 2022). The delta negative binomial model

converged but the hessian matrix was not positive definite, therefore, this model was excluded from further consideration. Both the negative binomial model and the tweedie model converged and had a positive definite hessian matrix. The AIC value for the negative binomial model was 15879.52 and for the tweedie model was 16567.3. The negative binomial model was chosen as the final selected based on the AIC value.

5.1.2.4 Abundance Index Trends

The nominal and standardized indices had similar trends over time (Figure 89). There were no obvious trends from 2007-2011 with relatively low abundance and then a large increase to the maximum of the time series in 2012, before decreasing and staying relatively low before increasing in the final year (Table 34; Figure 89). There was some evidence of a potential model misfit based on formal hypothesis tests (Figure 90).

For aggregated length data, the mean length was 180 mm with a maximum of 444 mm and a minimum of 10 mm (Figure 91). Most individuals (95%) were in the size range of 125-255 mm. There was a decreasing trend in mean length over time from 244 mm in 2007 to 155 mm in 2024 (Figure 92). The proportion of ages collected over time has been relatively stable and ages ranged from 0 to 11 (Figure 93).

5.1.3 Chesapeake Bay Multispecies Monitoring and Assessment Program (ChesMMAP)

5.1.3.1 Survey Design and Methods

The Chesapeake Multispecies Monitoring and Assessment Program (ChesMMAP) began in 2002 and was designed to provide data to support stock assessments for fish species commonly found in Chesapeake Bay (Latour et al. 2023). The survey occurs in the mainstem of Chesapeake Bay and sampling during 2002-2018 was conducted bi-monthly from March through November according to a stratified random design with the strata based on region and depth (Figure 94). The net used during this time was a 13.7 m four seam bottom trawl with 15.2 cm stretch body mesh and 7.6 cm stretch cod end mesh constructed from twisted nylon twine.

In 2018, major changes to the survey included a new vessel, net, and sampling design (Latour et al. 2023). The new vessel is the R/V Virginia, a 93-foot twin diesel vessel. The new net consisted of a 200 x 12 cm, 4 seam, 3 bridle bottom trawl with a 5 cm flat sweep. The forward mesh in the body is 12 cm tapering back to 6 cm meshes in the main body and extension. The codend is made of double 12 cm braided polyethylene with a 2.52 cm knotless nylon liner insert. The stratified sampling design includes four regions and two depth strata where a total of 80 stations are sampled each year, with cruises occurring during March, June, September, and November. At each station the net is trawled along the bottom for 20 minutes with the current at a target speed of 3 knots.

Paired tows with both vessels and gears were conducted and coefficients to adjust for the catches between both data sets are used to ensure data from the prior survey set up is comparable with the new survey (Latour et al. 2023).

5.1.3.2 Biological and Environmental Sampling

Each sample is sorted on board the vessel and an aggregate weight is measured. Also, the number of each species is counted, and individual lengths are measured for a subset of each species. A further subsample of each species is processed for individual weight, sex, maturity, aging, and diet composition. Environmental data are recorded, including temperature, salinity, dissolved oxygen, and water depth.

5.1.3.3 Evaluation of Survey Data

The survey data were evaluated based on three seasons: spring (March, April, May), summer (June, July), and fall (September, October, November). Given the limited number of Atlantic croaker encountered during spring and a smaller portion of the age range encountered in fall (primarily YOY), we chose to focus on developing indices and using length data from summer. Individuals of all ages and lengths were included in the index. We used year as the only covariate in the model as researchers from VIMS advised us that they had unreasonable model estimates when including environmental covariates, likely due to the correlation between environmental covariates and spatial random effects. The R package sdmTMB (Anderson et al. 2024) was used to fit a model with only a fixed effect for year and several distributions were considered. Also included in the model were spatial and spatio-temporal random effects, where the spatio-temporal random effects were independent and identically distributed. The best model was chosen based on AIC values (Akaike 1973) and residual diagnostics (DHARMa R package; Hartig 2022). The final model selected included a delta distribution with a negative binomial distribution used for the positive catches.

5.1.3.4 Abundance Index Trends

The nominal and standardized indices had similar trends over time (Figure 95). There were no obvious trends from 2004-2012 and then a large increase to the maximum of the time series in 2014, before decreasing and staying relatively low for the remaining part of the time series (Table 35; Figure 95). There were no major issues seen in the qq plot (Figure 96).

For aggregated length data, the mean length was 212 mm with a maximum of 499 mm and a minimum of 38 mm (Figure 97). Most individuals (95%) were in the size range of 115-326 mm. There was a decreasing trend in mean length over time from 254 mm in 2005 to 147 mm in 2024 (Figure 98). There has been a decrease in the number of ages collected over time (Figure 99). There were individuals from age-0 to age-13 collected during 2002-2005 but in the most recent years only ages 0 to 5 were collected.

5.1.4 Virginia Institute of Marine Science (VIMS) Juvenile Trawl Survey

5.1.4.1 Survey Design and Methods

The Virginia Institute of Marine Science (VIMS) Juvenile Trawl Survey was implemented in 1955 to monitor the seasonal distribution and abundance of important finfish and invertebrate species occurring in the Chesapeake Bay and its tributaries. The main objective of this survey is to develop indices of relative abundance to track year-class strength of target species.

The survey sites and sampling frequency has not been consistent throughout the history of the survey. The survey currently employs a mixed design, incorporating both stratified random sites and fixed (historical mid-channel) sites (Figure 100). The stratification system is based on depth and latitudinal regions in the bay (random stations), or depth and longitudinal regions in the tributaries (random and fixed stations). Each bay region spans 15 latitudinal minutes and consists of six strata: western and eastern shore shallow (4–12 ft), western and eastern shoal (12–30 ft), central plain (30–42 ft), and deep channel (>42 ft). Each tributary is partitioned into four regions of approximately ten longitudinal minutes, with four depth strata in each (4–12 ft, 12–30 ft, 30–42 ft, and >42 ft). Strata are collapsed in areas where certain depths are limited. In each tributary, fixed stations are spaced at approximately 5-mile intervals from the river mouths up to the freshwater interface. Fixed sites are assigned to strata based on location and depth. The stratified random sites are selected randomly from the National Ocean Service's Chesapeake Bay bathymetric grid, a database of depth records measured or calculated at 15-cartographic-second intervals.

The trawl gear configuration has been modified a number of times but was standardized in 1979. The various gear configurations have been compared through extensive sampling in order to standardize the catch rates associated with each gear combination. Currently, a 30-ft semi-balloon otter trawl is towed by the R/V Fish Hawk using a 60-ft bridle.

Two to four sites are randomly selected for each bay stratum each month, and the number of sites varies seasonally. In shallow water strata, only one station is sampled per month. One to two stations are randomly selected for most river strata each month. Fixed stations are sampled monthly.

5.1.4.2 Biological and Environmental Sampling

The catch from each tow is sorted by species, and fish are enumerated and measured for length, and all are released. Lengths are measured to the nearest millimeter using the length type appropriate for the morphology of each species. Random subsamples are taken when catches of a particular species are too large to process efficiently in the field.

Hydrographic and station data such as latitude and longitude, depth, tidal current stage, secchi depth, water temperature, salinity, and dissolved oxygen are also collected. Data characterizing the habitat or substrate type sampled by the trawl have been recorded since May 1998.

5.1.4.3 Evaluation of Survey Data

Data collected from the spring months (April-June) from 1988-2014 was evaluated in order to develop an index of relative abundance for YOY Atlantic croaker. VIMS uses a length cutoff by month to determine YOY from age-1+ Atlantic croaker. The length cutoff for YOY is 11 cm in April, 13.5 cm in May, and 16 cm in June. All Chesapeake Bay and river stations were considered. Because this survey reliably catches YOY Atlantic croaker during spring months, has a relatively long time series, and uses a random sampling design, the SAS supported its use for developing an index of relative abundance.

Data from the spring months (April–June) were used to develop an index of relative abundance for Atlantic croaker (number per tow of croaker less than 11 cm, 13.5 cm, and 16 cm TL in April, May, and June). A standardized index of juvenile abundance was developed using the R package glmmTMB. The final was zero-inflated negative binomial with effects of system, water temperature, salinity, dissolved oxygen, and depth for both model components and effort offset in the count component.

5.1.4.4 Abundance Index Trends

The index of relative YOY abundance developed from the VIMS survey shows low abundance in the mid-1990s and mid-2000s with peaks in 1993, 1997, 2008, and a very large peak in 2012 (Figure 101). The abundance of age-0 has increased since 2020, with the 2024 estimate nearly reaching the 2012 time series high.

5.1.5 North Carolina Pamlico Sound Survey (Program 195)

5.1.5.1 Survey Design and Methods

The Pamlico Sound Survey, also known as Program 195 (P195), was initiated by the NCDMF in 1987 to provide a long-term, fishery-independent database for the waters of the Pamlico Sound, eastern Albemarle Sound, and the lower Neuse and Pamlico rivers. The survey samples fifty-four randomly selected stations based on a grid system (one-minute by one-minute grid system equivalent to one square nautical mile (Figure 102). Sampling is stratified by depth and geographic area. Shallow water is considered water between 6 to 12 feet in depth and deep water is considered water greater than 12 feet in depth. The seven designated strata are: Neuse River; Pamlico River; Pungo River; Pamlico Sound east of Bluff Shoal, shallow and deep; and Pamlico Sound west of Bluff Shoal, shallow and deep. As of March 1989, the randomly selected stations have been optimally allocated among the strata based upon all the previous sampling to provide the most accurate abundance estimates (PSE < 20) for selected species. A minimum of three stations (replicates) are maintained in each stratum. In 2022, 24 stations were discontinued due to high tunicate interactions. In total 108 stations are sampled each year to ensure maximum areal coverage. Tow duration is 20 minutes at 2.5 knots using the R/V Carolina Coast, which is equipped with double-rigged demersal mongoose trawls.

All species are sorted, and a total number and aggregate weight is recorded for each species. For Atlantic croaker, thirty to sixty individuals are measured, and total aggregate weights are taken. The catches from each of the two towed nets are combined to form a single sample. Environmental data are recorded, including temperature, salinity, and dissolved oxygen.

The sampling season has undergone some changes since the survey's inception. Beginning in 1991, sampling has been performed over a two-week period, usually the second and third weeks of both June and September. Sampling since 1991 has occurred only in the Pamlico Sound and associated rivers and bays. There have been some exceptions to the sampling design due to weather and other barriers. In 1999, June sampling was conducted in July due to weather. In 2019, June sampling occurred over three weeks instead of two weeks. In 2020-2021, sampling was affected due to the COVID-19 pandemic. In 2023, sampling in September

extended into a third week due to vessel repairs. In September 2024, coastal flooding and poor weather caused sampling to extend until September 25th. The R/V Carolina Coast was decommissioned in December 2024.

5.1.5.2 Evaluation of Survey Data

An evaluation of the proportion of zero catches indicated that Atlantic croaker have been regularly encountered during both the June and September components of the survey. The length-frequency distributions indicate that age-0 and age-1 Atlantic croaker were captured during the June component of the Pamlico Sound Survey and that only age-0 Atlantic croaker were encountered during the September component of the survey. Because the P195 survey reliably catches YOY Atlantic croaker, is statistically designed, and represents a portion of the Atlantic croaker geographic range, it was used as an index of abundance for only the month of June.

An index of relative YOY abundance (number per tow) was developed using the June observations of Atlantic croaker less than or equal to 14 cm TL (Table 36; Figure 103). The best model selected was a negative binomial generalized linear model (GLM) with year, depth, bottom salinity, wind speed, and wind direction as explanatory variables.

5.1.5.3 Abundance Index Trends

The index of relative abundance for YOY Atlantic croaker developed from the P195 program indicated variable abundance. YOY Atlantic croaker had relatively low biomass in the late 1980s followed by some variability in 1990s, and then high abundance 1999 (Figure 103). The 2000s were relatively low, except for 2004 and 2008. YOY increased in the early 2010's, with high abundance in 2010, a series high in 2012, and 2017. However, YOY abundance has generally declined in the last 10 years of the time series.

The negative binomial GLM with environmental covariate estimated increase in Atlantic croaker YOY catch as depth and wind speed increased (Figure 105). Alternatively, Atlantic croaker YOY catch decreased as bottom temperature increased (Figure 105). Wind direction had varying effects on Atlantic croaker YOY catch, with highest catch rates observed for east and south winds, and the lowest catch rates observed with north and northeast winds (Figure 105). The effect of environmental variables suggests that there could be salinity and temperature induced trends in catchability overtime; however, catchability is also driven by depth at sampling and wind direction.

5.1.6 Southeast Area Monitoring and Assessment Program (SEAMAP)

5.1.6.1 Survey Design and Methods

The Southeast Area Monitoring and Assessment Program - South Atlantic (SEAMAP-SA) Coastal Trawl Survey (CTS; previously known as the Shallow Water Trawl Survey) began in 1986 and is conducted by the South Carolina Department of Natural Resources (SCDNR) Marine Resources Division (MRD). This survey has provided long-term, fisheries-independent data characterizing the seasonal abundance and biomass of all finfish, elasmobranchs, decapod and stomatopod

crustaceans, sea turtles, horseshoe crabs, and cephalopods that are accessible by high-rise trawls. The sampling area extends from the coastal zone in Atlantic waters off the southeastern United States between Cape Hatteras, North Carolina, and Cape Canaveral, Florida (Zimney and Vecchio 2025; Figure 2). The survey uses a stratified random design, where strata are delineated by the 4-m depth contour inshore and the 10-m depth contour offshore. A total of 102 stations are sampled each season within 24 shallow water strata. Through 2023, the R/V Lady Lisa, a 23-m wooden-hulled, double-rigged, St. Augustine shrimp trawler owned and operated by the SCDNR, was used to tow paired 22.9-m mongoose-type Falcon trawl nets, without turtle excluder devices (TEDs). The body of the trawl was constructed of #15 twine with 47.6-mm stretch mesh. The cod end of the net was constructed of #30 twine with 41.3-mm stretch mesh and protected by chafing gear of #84 twine with 10-cm stretch "scallop" mesh. A 91.4-m three-lead bridle was attached to each of a pair of wooden chain doors, which measure 3.0 m × 1.0 m and to a tongue centered on the headrope. The 26.3-m headrope, excluding the tongue, had one large (60 cm) Norwegian "polyball" float attached top center of the net between the end of the tongue and the tongue bridle cable and two 22.3-cm PVC foam floats located one-quarter of the distance from each end of the net webbing. A 1-ft chain drop-back was used to attach the 89-ft footrope to the trawl door. A 0.6-cm tickler chain, which was 0.9 m shorter than the combined length of the footrope and drop-back, was connected to the door alongside the footrope. Trawls are towed for twenty minutes, excluding wire-out and haul-back time, exclusively during daylight hours (1 hour after sunrise to 1 hour before sunset; Zimney and Vecchio 2025).

Historically, each net was processed separately and assigned a unique collection number. From March 2020 until June 2021, the CTS suspended field sampling efforts due to the COVID-19 pandemic. When the survey restarted after COVID, catch was processed from only one net instead of two. Net comparison analyses were completed in 2020 to ensure this change did not introduce bias into catch data. Originally, multi-legged cruises were conducted in the spring (April–May), summer (July–August), and fall (September–November). In 2023, the CTS changed from three sampling seasons to just two sampling seasons: Spring (April-June) and Fall (August-October; Zimney and Vecchio 2025).

In 2024, the SEAMAP-SA CTS replaced the R/V Lady Lisa with the R/V Lady Lillian, a 90 ft stern trawler owned and operated by SCDNR-MRD, switching the approach from a double-rigged trawl operation to a stern trawl operation, requiring a new net configuration. In anticipation of this change, the CTS began using net mensuration gear to collect data on the net spread and headrope height of the historic gear (75' Mongoose). The new net configuration is a single 60' (18.3 m) four-seam fly trawl net (manufactured by Beaufort Marine Supply, Beaufort, SC) without a Turtle Excluder Device (TED). The body of the trawl was constructed of #9 Spectra twine with 1.875 in (47.6 mm) stretch mesh and was protected by chafing gear of #96 polypropylene net twine with 4 in (10.2 cm) stretch mesh. Using the net mensuration data from the new and old gears, the average net spread and headrope height was determined for each gear. These averages were then used along with distance towed to calculate effort for each tow event as area swept (hectares) or volume filtered (cubic meters; Zimney and Vecchio 2025).

Hydrographic data, including a temperature and salinity profile, were logged with a Seabird SBE-19 plusV2 CTD profiler for each station. Additionally, sampling depth (start and end) and atmospheric data such as air temperature, barometric pressure, precipitation, wind speed and direction were recorded.

5.1.6.2 Biological and Environmental Sampling

After each tow, the contents of the net are sorted to species (limited exceptions to genus or family only), and the total biomass and number of individuals are recorded for all species of finfish, elasmobranchs, decapod and stomatopod crustaceans, cephalopods, sea turtles, xiphosurans, and cannonball jellies (*Stomolopus meleagris*). For other miscellaneous invertebrates and algae, which were treated as two separate taxonomic groups, only total biomass was recorded. When trawls contained high volume catches (generally greater than 100kg), all endangered and rare species and species that pose a risk to staff during handling (e.g., elasmobranchs, catfish, scorpionfish) were removed and given priority for processing. The remaining net contents were subsampled into shrimp baskets. Each shrimp basket was weighed, and a randomly selected basket (two baskets for catches greater than 250 kg) was sorted and processed as described above. Abundance and biomass for each species was then expanded to estimate total abundance and biomass of each species in the full catch using the ratio of the subsampled basket weight to the total catch weight. When large numbers of a species are encountered in the catch (selected basket or full net contents), all individuals of that species are weighed, but only a haphazardly selected subsample were processed for abundance. The species subsample consisted of approximately 32 to 64 individuals when the estimated total number in the processed catch was at least 70 or more than 120 individuals, respectively. The total number of individuals in the catch are then estimated based on the ratio of the processed subsample weight to the total weight for that species (Zimney and Vecchio 2025).

During catch processing (full net, selected basket, or haphazardly selected subsample), a select group of priority species (including Atlantic croaker) were measured to the nearest millimeter (length-frequency work-up). Then during the length-frequency work-up some of the priority species (including Atlantic croaker) were selected to undergo full life history work-up. Life history finfish specimens were selected using a length-based sampling design through 2023 but beginning in 2024 life history specimens were selected randomly (Atlantic croaker at 10%). Atlantic croaker processed for life history were measured to the nearest millimeter for total length, fork length, centerline length, and/or standard length, weighed to the nearest gram, and the sex of each individual was determined macroscopically (Zimney and Vecchio 2025).

Otolith samples were collected from Atlantic croaker from 2001 through 2024. Sagittal otoliths were removed and processed following accepted standard procedures (Harris et al. 2004). Biological sampling was discontinued in 2007 due to insufficiency of allocated funds but began again in 2008. Gonad samples were taken to determine sex and maturity histologically from 2001 to 2012 (with the exception of 2007). Otoliths were processed and aged following South Carolina's methodology described in Section 2.4. All gonad samples were examined by two readers independently, without knowledge of size data or capture information. Maturity codes

were assigned based on descriptions in Brown-Peterson et al. (2011). When sex and/or maturity assignments differed, the sample was reviewed simultaneously by both readers, and if consensus could not be reached, the sample was removed from analysis.

5.1.6.3 Evaluation of Survey Data

The SEAMAP-SA Coastal Trawl Survey has been conducted consistently since 1990, so data collected from 1990 onward were evaluated. SEAMAP-SA Coastal Trawl Survey has regularly encountered Atlantic croaker in the spring, summer, and fall components of the survey. Historically, percent positive was lowest in the spring sampling season and higher in both the summer and fall sampling seasons. Atlantic croaker ages 0-1 are captured during all sampling seasons and are difficult to parse out by length (Figure 78). Therefore, it was decided to treat the SEAMAP-SA Coastal Trawl Survey as an age aggregate index rather than separate out YOY and age 1 +. There are other surveys in the South Atlantic that will act as the YOY index of abundance for Atlantic croaker. Indices of abundance and age/length compositions were created for summer and fall sampling seasons separately. Summer in general has the highest catch rates, percent positive, and number of fish measured. However, with the switch to two sampling seasons beginning in 2023 we only have true summer data through 2022. The fall data and indices go through 2024 with the second sampling season for the new sampling design in the new sampling design being treated as fall. Comparing the length/age compositions and abundance trends, the second season for the new sampling design appears to be more similar to the original fall sampling season rather than summer.

When it was decided to split the stock into two units, it was determined that the break should be at Cape Lookout rather than the traditional Cape Hatteras break. Therefore, the SEAMAP-SA Coastal Trawl Survey data was subset to exclude data from the northern two strata in Raleigh Bay. Data included in the index standardization goes from Cape Canaveral, Florida to Cape Lookout, North Carolina.

Stations without complete covariate information were dropped from analyses. Vector-autoregressive spatiotemporal (VAST; R Package: VAST) models were used to standardize the Atlantic Croaker abundance index from the SEAMAP-SA Coastal Trawl Survey (Thorson et al. 2017; Thorson 2019). The VAST model correlates the abundance in a sample to covariates for that sample, as well as other factors included in the model. By decomposing the time series into two components, the probability of encounter and the expected catch rate, VAST effectively creates a delta model that generally performs well with zero-inflated datasets, such as multi-species fisheries surveys (Maunder and Punt 2004). Area swept was included as an offset, year as a fixed factor, and latitude, longitude, depth, water temperature, salinity, and day of year as continuous variables in the VAST models. The zero-inflated negative binomial error distribution was used for the presence/absence portion of the model, and the negative binomial error distribution was used for the abundance model based on Akaike's Information Criterion (AIC) during preliminary model fitting (Akaike 1973). The VAST model was conducted with up to 1000 knots, spatial and spatiotemporal autocorrelation as random effects, and anisotropy turned on. In addition, a bias correction was included in the model to account for any changes in the spatial footprint of the survey over time. The index of abundance from the VAST model

estimated the total number of fish expected when covariates (including sampling density) are taken into consideration.

The VAST model including covariates had a lower AIC than the VAST model without covariates for the fall sampling (AIC 26871 versus 26926). The VAST model for fall with covariates included converged with the maximum gradient component significantly less than 0.01 (4.02e-07). The VAST model including covariates had a lower AIC than the VAST model without covariates for the summer sampling (AIC 28802 versus 28826).

The VAST model for summer with covariates included converged with the maximum gradient component significantly less than 0.01 (7.11e-07). The standard errors of the parameter estimates all seem reasonable for both sampling seasons (not N/A or extremely large). The q-q plot and residuals vs. Predicted values look fairly good for both seasons. Slight pattern near the extremes, but otherwise fine (Figure 112; Figure 113).

5.1.6.4 Abundance Index Trends

The SEAMAP-SA Coastal Trawl Survey index of abundance for Atlantic croaker including covariates from the fall shows an overall increase in abundance through time. Abundance was relatively stable from 1990-2010 but has been increasing since then up until 2024 (Table 37; Figure 106). The center of gravity and effective area occupied from the fall sampling season have fluctuated a lot through the study period. Center of gravity shows no apparent pattern while the effective area occupied has increased slightly through time (Figure 107; Figure 108).

The SEAMAP-SA Coastal Trawl Survey index of abundance for the summer sampling only goes through 2022 and is a lot more variable than the fall index. The index shows an overall increase in Atlantic croaker total abundance through time, but the year-to-year variability is large (Table 38; Figure 109). The center of gravity and effective area occupied from the summer sampling season have fluctuated a lot through the study period. Center of gravity shows no apparent pattern and has remained relatively constant, while the effective area occupied has increased slightly through time (Figure 110; Figure 111).

5.1.7 South Carolina Estuarine Trawl

5.1.7.1 Survey Design and Methods

The Estuarine Trawl Survey, managed by SCDNR's Crustacean Research and Monitoring Section, started in 1979 to monitor crustacean species in South Carolina estuaries. Sampling currently occurs monthly at four fixed stations in the Charleston Harbor and Ashley River, as well as an additional 20 fixed stations in Saint Helena Sound, Port Royal Sound, and Calibogue Sound in March, April, August, and December (Figure 114). Otter trawls with 2.54 (1") stretch mesh are towed for 15 minutes from the 52-ft. *R/V Silver Crescent*. The use of this survey was to develop an Age-0 recruitment survey, so only data from June-August 2011-2024 in the Charleston Harbor and Ashley River were included.

All specimens captured are identified to species and counted. Up to 30 individuals of each species are measured for standard length (SL) and total length (TL), and the remaining

individuals in the catch are enumerated. While on station, environmental variables are recorded, which include location (estuary, latitude, and longitude), tide stage (categorical), temperature (℃), salinity (PSU), and max depth (m).

Specimens are measured in standard length (SL) and total length (TL) to the nearest mm. Based on examining all biological data collected by SCDNR independent surveys, any Atlantic croaker above the specified cutoffs for each month were excluded from analysis in this index (May ≤120 mm TL; June ≤ 140 mm TL; Jul ≤ 160 mm TL; Aug ≤ 180 mm).

5.1.7.2 Evaluation of Survey Data

The data passed spatial persistence (p=0.46), indicating that the fixed stations had similar variations of abundance through time (Lee and Rock 2017). While stations and area were still considered as covariates in determining the best fit model, a spatiotemporal model with stations as a fixed effect were not needed. The model was fitted with a generalized linear mixed model (GLMM) using the *glmmTMB* R package (Brooks et al. 2017). Model estimation was conducted using maximum likelihood. Several covariates were tested, with residual diagnostics (*DHARMa* R package, Hartig 2022), AIC (Akaike 1973), and BIC (Schwarz 1978) were used to select the best fit model. The best model configuration used year, area (river versus sound), and water temperature as covariates in a generalized linear model fitted with a negative binomial error distribution and a log link to accommodate overdispersion in count data.

Residuals plotted against predicted values indicated slight patterning (Figure 117) with failed test for normality (KS test; p=0.0075) and failed test for outliers (p=0.037, Figure 118). However, the magnitude was not high enough to indicate overdispersion or issues with overall fit. Given the episodic nature of recruitment indices, the slight deviations were deemed acceptable for the index.

5.1.7.3 Abundance Index Trends

The nominal and standardized indices track each other well through time with only the standardized index showing a higher scaling through time. Abundance of Atlantic croaker recruits has increased since 2011 (Table 39; Figure 115) with peaks in abundance in 2017 and 2022. The absolute lowest value in the time series is the start year, 2011. The only tested significant environmental covariate that impacted the model was temperature, where abundance was higher above 25℃ (Figure 116).

5.1.8 Georgia Estuarine Trawl

5.1.8.1 Survey Design and Methods

The GA Ecological Monitoring Trawl Survey (EMTS) monitors fish and invertebrate populations in six Georgia estuaries (Wassaw, Ossabaw, Sapelo, St. Simons, St. Andrew, and Cumberland) and offshore state waters. Each of the six estuaries is divided into three separate sectors: (1) large creeks and rivers, (2) open sounds, and (3) nearshore ocean (0 to 3 miles) waters, all within the state's territorial waters. In each system, at least two trawl stations are sampled within each sector, for a minimum of six sample stations per sound system and a statewide

total of 36 fixed sites each month. Since 1976, personnel with CRD have conducted this trawl survey using standardized gear, standardized tow times, and fixed sites. Between January 1976 and March 2003, personnel primarily focused on recording information on penaeid shrimp and blue crabs *Callinectes sapidus* observed in catches. During two periods, April 1995-March 1998 and March 2003-present, personnel also recorded information on finfish and other marine organisms. The objective of this survey is to provide a comprehensive, long-term fishery-independent monitoring program for finfish, invertebrates, and water quality.

The EMTS uses an otter trawl configured with a "naked" (i.e., no Bycatch Reduction Device [BRD] or Turtle Exclusion Device [TED]) 12.2 m flat net towed behind the Research Vessel (*R/V*) *R/V Reid W. Harris* (Figure 119). Fifteen-minute tows are performed at each station. After the net is deployed via a winch, the net is stopped, or "dogged off", and the official tow time recorded. At the end of the tow, the winch is re-engaged, and the net retrieved. The cod end of the net is brought onboard the vessel and its' contents released into a culling table for sorting. The catch is then sorted to species. Once sorted, data are collected for each species. GPS coordinates (decimal degrees), tow duration (minutes), and depth (feet) are recorded at all stations.

Individuals captured by the trawl are identified to species and counted. Total weights are recorded for each species and a representative random sample of up to 30 individuals of each species are measured for centerline length (CL). These measurements are taken to the nearest gram and millimeter, respectively. All individuals are released at the capture site.

Water quality data (i.e., water temperature (°C), salinity (ppt), and dissolved oxygen (mg L^{-1}) are collected at all EMTS stations. Wind speed (mi H^{-1}), wind direction (degrees), tidal stage, and air temperature (°C) are also recorded at each station.

Specimens are measured in centerline length (CL) to the nearest mm. A length cutoff was developed to only captured age-0 Atlantic croaker in the survey. Based on a Georgia length and growth study, any Atlantic croaker above the specified cutoffs for each month were excluded from analysis in this index (May ≤120 mm TL; Jun ≤140 mm TL; Jul ≤ 160 mm TL; Aug ≤ 170 mm TL; Franco 2014).

5.1.8.2 Evaluation of Survey Data

Only data from May through August in the recent time period, 2003-2024, were used for standardization due to consistent sampling techniques. The data failed spatial persistence (p=0.005), indicating that the fixed stations had different variations of abundance through time (Lee and Rock 2017). To account for this, we used a spatiotemporal modeling application, *sdmTMB* R package (Anderson et al. 2024), which allowed for area to be a fixed effect in the model. Several covariates and fixed effects were tested, with residual diagnostics (*DHARMa* R package; Hartig 2022), AIC (Akaike 1973), and BIC (Schwarz 1978) were used to select the best fit model. The best model configuration used year, month, waterbody (estuary), depth, and temperature as covariates in a zero-inflated model with a negative binomial error distribution, as well as spatial random effects and independent and identically distributed (iid) spatio-

temporal random effects with isotropy. Due to the fixed design of the survey, only predictions for mesh cells with station coordinates were used for index calculation.

Residuals plotted against predicted values showed a weak overprediction at low fitted values and underprediction at high fitted values (Figure 121); however, the magnitude was not high enough to indicate overdispersion or issues with overall fit (Figure 122). DHARMa residual diagnostics show an overall good fit to the standardization model, with a minor but statistically significant deviations (Figure 123). A Kolmogrov-Smirnov test (KS test) revealed small but signification deviation from uniform distribution (p=0.02), which was likely due to restricted sample sizes in a recruitment survey. Additionally, the episodic nature of recruitment in estuarine species likely accounts for the outlier test indicating significant residuals (p=0.02).

5.1.8.3 Abundance Index Trends

The recruitment index of abundance for Atlantic croaker captured in the GA EMTS shows high variability through time. Abundance peaks occurred in 2003, 2013, 2016, and 2020, as well as low abundance years in 2006, 2011, and 2012 (Table 40; Figure 120). The high variability is expected in a recruitment index with environmental variables playing a significant role, such as depth and temperature. Abundance of YOY Atlantic croaker generally decreased with increasing depth and increasing temperature (Figure 121).

5.2 Index Correlations

Indices of abundance from fishery-independent surveys used for past Atlantic croaker assessments and management analyses (NEFSC, NEAMAP, ChesMMAP, SEAMAP, SC DNR Trammel), indices of abundance from additional surveys in the southern stock, and time series of commercial CPUE were compared with Spearman's rank correlation analysis. Indices from additional surveys in the southern stock were included following the decision to split the coastwide population into two stocks and concerns that these surveys were bypassed in previous assessments due to being located in areas outside those accounting for the majority of coastwide catches (i.e., Mid-Atlantic region in the northern stock). Commercial CPUE time series were included based on recommendations from the review panel of the 2017 assessment (ASMFC 2017) and were treated the same as fishery-independent survey indices tracking broad length/age components of the population (i.e., measures of aggregate abundance). Additionally, commercial CPUE time series were compared between stocks. See Section 4.1.1.5.5 for details on commercial CPUE time series. The purpose of the correlation analyses was to determine consistencies, or lack thereof, in data sets considered for modeling purposes. Correlation results with a p-value <0.05 were considered significant for these analyses.

Among all significant results (Table 41), correlations between YOY indices were positive and correlations between aggregate abundance data sets within the northern stock were also positive. Positive correlations between aggregate abundance data sets included the ChesMMAP fishery-independent survey index and several different commercial CPUE time series from both fisheries operating in the Chesapeake Bay and Atlantic Ocean across all three states with data sets (North Carolina, Virginia, and Maryland). Notably, there were no correlations with the Atlantic Ocean fishery-independent survey indices (NEFSC and NEAMAP).

Three negative correlations were detected, and all of these were between commercial CPUE time series from opposite stocks (Table 41). No positive correlations were detected between stocks, further supporting regional differences in population dynamics.

None of the southern stock recruitment indices were significantly correlated (Table 42), indicating recruitment is heavily impacted by local processes. Within the age aggregate indices, the only statistically significant correlations occurred between SCECAP and GA gillnet, between SEAMAP fall survey and SEAMAP summer survey, and between SEAMAP summer survey and NC CPUE Ocean survey (Table 43). Lack of correlations between most surveys provides potential conflicts in the models, particularly with this many indices. The SAS decided to use the two indices that correlated, had the longest time series, and the greatest spatial coverage of the stock: SEAMAP fall survey and SEAMAP summer survey. The correlation between SCECAP and GA gillnet was a slightly more positive correlation (Rho=0.651 versus Rho=0.576; Table 43); however, the spatial coverage of the SEAMAP survey spans the entirety of the southern stock. Thus, the SAS concluded it was a better representation of the stock population.

Ultimately, the SAS decided against using fishery-dependent time series in modeling given the availability of and preference for fishery-independent time series. The northern stock analysis revealed some inconsistencies between indices of abundance from broad, regional surveys that were considered during model development for configuration choices (random walk catchability for the NEFSC bottom trawl survey). Additionally, the limited spatial coverage of fishery-dependent surveys for the southern stock, provided little value when compared to the fishery-independent surveys available.

6 STOCK SYNTHESIS MODELS

6.1 General Model Configuration

Population models were developed in SS version 3.30.24.1. SS is an integrated analysis platform that is widely used for statistical age-structured population modeling in fishery stock assessments (Methot and Wetzel 2013). For a full description of SS, the reader is referred to the GitHub repository (https://github.com/nmfs-ost/ss3-source-code) and user manual (Methot et al. 2020). SS requires four input files: a starter file with filenames and report details, a data file with model dimensions and data, a control file with model parameterization and structural details, and a forecast file with reference point and forecast specifications.

Early model explorations attempted a coastwide stock structure, but conflicting trends in the data and apparent differences in growth patterns and size structure lead to an inability to develop a model that could fit to the various data sources and converge on a solution. The coastwide stock decision was reconsidered, and ultimately, the assessment proceeded with separate models for the northern stock and southern stock, as defined in Section 2.1. The general model configuration details are provided here with stock-specific details in the subsequent sections.

Length data were organized into 2 cm length bins (centerline length), from 6 cm to 46+ cm for the northern stock and 8 cm to 34+ cm for the southern stock. The maximum bin is consistent

with the largest survey observations. When centerline length was not the recorded length metric, stock-specific length-length conversion factors were applied. Ages were tracked from age-0 through age-10 in the northern stock and age-0 through age-4 in the southern stock, with maximum age bin representing a plus-group determined by the oldest age commonly observed in each region. The annual time step follows the calendar year where spawning is assumed to occur in January (to streamline data entry due to nominal age-assignment protocols and protracted spawning season), and timing of other processes were adjusted to maintain correct timing relative to the assumed January 1 birthdate. All data are sex aggregated with an assumption of 1:1 sex ratio. The model time series is 1990-2024 for both models. The start year was chosen due to the availability of shrimp trawl discards starting in 1990.

Estimated life history parameters included: von Bertalanffy parameters L_{min}, L_{inf}, and K, CVs defining the variance of growth, and R0, or unfished recruitment (Table 44). Fixed life history parameters included: natural mortality (M) for reference age-2, length-weight relationship parameters, female age-at-50% maturity, slope of maturity ogive, sigma R (variance of recruitment around the stock-recruitment relationship), and steepness (h) of a Beverton-Holt stock-recruitment relationship (Table 44). Natural mortality-at-age for ages other than age-2 is calculated within the model based on reference M at age-2 and model-estimated growth. The maturity ogive and length-weight relationship are used to calculate female spawning stock biomass, assumed equal to fecundity. The steepness parameter was fixed at 0.99 due to inability to reliably estimate the parameter from the available data, effectively assuming a constant average recruitment with estimated annual deviations. Sigma R is generally not estimable and was fixed based on tuning guidance from the r4ss package as recommended in the SS manual (Methot et al. 2020). Similarly, settings controlling bias adjustments to ensure mean unbiased recruitment from the lognormally distributed estimates were tuned according to recommended inputs after initial runs of the models (Methot and Taylor 2011).

Models included commercial and recreational fishing fleets, dead discards from the shrimp trawl fishery, and fishery-independent surveys. Fishery catch occurs throughout the year, and survey timing is assigned to the month that it occurs (or when most sampling occurs). Commercial and recreational fishing fleet selectivity was modeled as a length-based increasing logistic function, except for one selectivity time block for one commercial fleet in the southern stock which was modeled as a double normal function. To simplify the models due to data limitations (lack of discard length composition data) and to aid convergence, retention curves were not estimated. Instead, for commercial fleets the discards were added to total removals and, for recreational fleets, a 15% discard mortality rate (ASMFC 2017) was assumed for released fish and those discards were added to the harvest. The shrimp trawl fishery was modeled as a bycatch fleet with a 95% discard mortality rate (Section 4.1.2.2.1). SS allows designation of bycatch fleets such that removals are accounted for but not considered in estimating reference point calculations because these are generally an unmanaged source of removals. A nominal value must be included in the catch data for bycatch fleets, but this value is ignored and the actual values are included in the discards section of the data file. Selectivity

for the shrimp trawl fleet was age-based with selectivity = 1 for a specified age range (Pattern 11, Methot et al. 2020). Available discard length composition data was limited to a small subset of years, all from one state (North Carolina), and was not split by stock, and was, therefore, not used in the models. Several configurations were evaluated, and ultimately, selectivity was fixed such that age-0 fish are the only age selected.

Young-of-year surveys were specified as special type = 33 (Methot et al. 2020) so that selectivity parameters are not estimated and only age-0 recruits are selected. All age aggregate surveys used a length-based selectivity function with age-based selectivity derived from the length-based estimates and model-estimated growth.

Data sets fit in the models included fishing fleet total removals (retained plus discarded) with assumed SEs of 0.01 for commercial fleets, SEs of 0.35 for hindcast bycatch fleet (1990-2007), SEs of 0.30 for estimated bycatch fleet (2008-2024), and scaled year-specific SEs derived from reported PSEs (recreational fleets; Table 30) as measures of variance, and survey indices of abundance with SEs derived from standardization CVs as the measure of variance. Length and conditional age-at-length compositions for the fishery catches and survey indices of abundance used effective sample sizes based on number of trips (for length compositions) or square root of number of ages sampled (for conditional age-at-length) as measures of variance. Conditional age-at-length data were frequencies of ages observed within length bins. The square root of the raw age sample size was used because there was no trip identifier for age samples for all data sets and these samples likely come from common trips.

The fishing mortality estimation method was specified as method 4, as recommended in the SS user manual (Methot et al. 2020). Method 4 is a fleet-specific combination of F parameter estimation and the hybrid F approach which uses Pope's approximation first followed by the Baranov catch equation in later estimation phases to tune fishing mortality to match each fleet's observed catch (see Methot and Wetzel 2013 Appendix A for more detail).

Model derived estimates included a full time series of annual fishing mortality, spawning potential ratio (SPR), recruitment, population abundance, total biomass, and spawning stock biomass.

6.1.1 Maximum Likelihood and Uncertainty

Overall goodness of fit was assessed using a maximum likelihood approach. Lognormal error structure was assumed for landings, discards, and indices, and multinomial distributions were assumed for composition data. Likelihood for each model component is determined by the difference between observed and predicted values and variance of the error distribution. The negative total log-likelihood was minimized using an iterative search algorithm to find the overall best fit to the data.

Candidate models were assessed for model convergence to a sufficiently small maximum gradient component, an invertible positive definite Hessian matrix, and parameter estimates not on bounds. When these criteria were met and visual inspection indicated acceptable lack of residual patterning, jitter analysis and likelihood profiling were conducted. Jitter analyses

indicate a model's sensitivity to starting parameter values as an indication of convergence on a global minimum in the likelihood surface. The jitter analysis consisted of 200 iterations where the parameter starting values were adjusted by a jitter factor of 0.1, and resulting total likelihoods were compared to the total likelihood of the base model. Likelihood profile is a diagnostic tool to indicate data conflicts that can lead to model instability by plotting total likelihood and likelihoods for various model components against the range of plausible fixed values for a key parameter. An ideal likelihood profile shows a single well-defined minimum at the same parameter value for all likelihood components. For this assessment, likelihood profiles were conducted on the primary population scaling parameter (R0).

Sensitivity analyses and retrospective analyses were conducted to evaluate model configuration decisions. Sensitivity analyses are alternative model runs where the model structure or data inputs are changed relative to the base model to determine the sensitivity of the model to such decisions or data. Retrospective analysis is routinely performed to check for model misspecification. The model is rerun to produce retrospective "peels" for a number of years, dropping the final year one at a time, and comparing the resulting timeseries of fishing mortality and biomass estimates. A retrospective pattern refers to the situation in which the estimates change in a consistent direction with each additional year of data. Retrospective patterning often indicates model misspecification, and if unaddressed can lead to inappropriate management advice. For this assessment, six retrospective peels were performed.

6.1.2 Reference Point Calculations

Models were unable to estimate robust stock-recruitment relationship parameters (i.e., steepness). Therefore, SPR reference points that do not consider a stock-recruitment relationship are recommended as reference points in this assessment in place of MSY reference points used in previous assessments and management. SPR represents the reproductive capacity of a fished stock relative to its reproductive capacity under unfished conditions. Threshold reference points are intended as reference points for the biological health of the stocks that should not be exceeded, while target reference points consider non-biological aspects such as socio-economic considerations and risk tolerance stakeholders and managers desire for stocks to stay above threshold levels.

Fishing mortality-based SPR reference points ($F_{XX\%}$) define the percentage of unfished spawning stock biomass-per-recruit expected under a given fishing intensity in long-term, equilibrium conditions. SPR levels used to approximate MSY for many exploited species have often ranged from 20-40% (Mace 1994) but are highly dependent on life history characteristics with ranges reported from 13-95% (Zhou et al. 2020). Atlantic croaker are considered a relatively resilient species due to life history characteristics such as early maturation, batch spawning, and high fecundity, as well as external estimates of steepness (Munyandorero 2020). Therefore, the SAS chose an SPR of 25% (i.e., $F_{25\%}$) as a threshold reference point for Atlantic croaker on the Atlantic coast. For additional context, spotted seatrout is currently managed at thresholds ranging from 20% to 35% in Louisiana, Florida, and North Carolina, while a later-maturing species, red drum, is managed on the Atlantic coast with a threshold of 30%. Both of these species are similar to Atlantic croaker and all belong to the family Sciaenidae. Although

northern stock fish historically grew to larger sizes and older ages, growth is currently similar between stocks, and the same threshold level provides additional buffer against these growth changes observed in the northern stock.

Because of the various fishing fleets interacting with the Atlantic croaker stocks and their starkly different selectivity patterns, it was necessary to consider two perspectives on overfishing status. The first status ($F_{A1}/F_{A1_25\%}$) includes just ages-1+ in the estimate of the $F_{25\%}$ reference point ($F_{A1_25\%}$) and annual numbers-weighted average F estimates (F_{A1}) compared to this reference point. The second status ($F_{A0}/F_{A0_25\%}$) includes all ages-0+ in the estimates. The $F_{25\%}$ reference point does not account for shrimp trawl fleet impacts as this is a bycatch fleet for Atlantic croaker managed with different strategies by bodies outside ASMFC, but annual F estimates do include F from all fleets including the shrimp trawl fleet. The value of the $F_{25\%}$ threshold varies depending on the inclusion of age-0 or not, but the goal for both is the same (i.e., 25% SPR). Due to the selectivity patterns for the fleets, F_{A1} is only from recreational and commercial fleets which are under the jurisdiction of ASMFC, while F_{A0} is from all fleets inclusive of the shrimp trawl fleet which is not under the jurisdiction of ASMFC.

Spawning stock biomass reference points represent the spawning stock biomass expected under recruitment observed during the assessment when the population is fished at the F reference point. This SSB reference point value is unaffected by the age range used in the F reference point. The SSB threshold reference point was set at 25% of spawning stock biomass experiencing no fishing mortality ($SSB_{SPR25\%}$).

The SAS recommended a range between 35% and 45% for target reference points, but recommended consultation with the Board following the assessment for determining a specific level in order to achieve non-biological management objectives (e.g., socio-economic objectives, risk tolerance). The lower end of this range would provide higher access to the fishery and higher risk of poor stock conditions while the higher end would provide lower access and lower risk of poor stock conditions. Some important topics that should be included in discussions on target levels are discards in the shrimp trawl fishery and uncertainty about changes in natural mortality. Discards in the shrimp trawl fishery are not accounted for in reference point calculations although they do impact realized survival, stock abundance, and ultimately reproductive capacity. A target reference point may allow for an extra buffer to protect the stocks from increases in discard mortality in the future. The assessment assumes a constant age-specific natural mortality through time due to lack of information to support a hypothesis of time-varying natural mortality. If this is an incorrect assumption, fishing mortality estimates and reference points would be biased and this potential uncertainty could be considered in selection of a target value.

With one exception, reference point calculations were based on observed stock dynamics from 1990-2023, which included biology (natural mortality, growth, and maturity), recruitment, and fishery operation (distribution of F across fleets, or relative F, and fleet selectivity). The fishery selectivity and relative F in the southern stock only included dynamics from 2004-2023 following the selectivity change in the NC through GA commercial fleet. The terminal year

model conditions (2024) were excluded because estimates in this final model year are more uncertain relative to previous years. All years of time-varying growth were included in reference point calculations for the northern stock because there were no clear drivers of these changes determined (fishing mortality, environment, or combination of both) and it is assumed that this stock can experience a return to greater growth and associated productivity observed early in the time series. To smooth out interannual variability in model estimates and maintain consistency with the TLA triggering period used in prior management, three-year averages of F and SSB relative to their reference points are used to describe stock conditions.

6.1.3 Northern Stock

The northern stock has three fishing fleets (Table 45) and five surveys (Table 46). Fishing fleets include a commercial fleet, recreational fleet, and a bycatch fleet. The commercial fleet includes directed Atlantic croaker catches as well as landings from the VA and NC scrap (i.e., bait) fisheries. The bycatch fleet, which is by far the most substantial component of removals, comprises discarded fish from the shrimp trawl fishery. The surveys include two age-0 recruitment indices (VIMS_YOY and NC_P195_YOY), and three age-aggregate surveys (ChesMMAP, NEFSC, and NEAMAP).

The commercial fleet data include catch (sum of landings, estimated discards from the directed fisheries, and landings from the scrap fisheries), length composition for the retained catch (i.e., landings), and conditional age-at-length data for the retained catch. Data from the bycatch fleet included discard estimates from an observer program from 2008-2024 and hindcast discard estimates for 1990-2007.

Survey data included indices of abundance from each of the surveys, as well as length compositions and conditional age-at-length data from the age-aggregate surveys. All aggregate surveys used an increasing logistic selectivity function.

There were conflicting signals in abundance trends, with the NEFSC trawl survey indicating an increasing and stable population, which was different from other abundance indices and removal data. Therefore, a time varying catchability was specified for the NEFSC trawl survey by implementing a random walk on the q parameter. Given the disparate nature of the NEFSC survey relative to other surveys, which are all further inshore, a change in catchability over time may be explained by a shift in availability if the northern stock is utilizing different habitat or migrating between habitats at varying times across years. Schonfeld et al. (2022) found a declining trend in estuarine habitat usage by Atlantic croaker in the Chesapeake and Delaware Bays relative to habitat in the Atlantic Ocean. Comparison of the historical NEFSC trawl survey index to landings also supports a change in catchability for this survey (Figure 124) assuming long-term landings for this relatively unregulated species is a reasonable indication of abundance. The survey measured low relative abundance in the 1970s when landings hit record highs, moderate relative abundance in the late 1990s and early 2000s when landings again peaked near record highs, increased relative abundance in the mid-2000s as landings start to decline, and sustained high relative abundance as landings continued to decline in the 2010s and 2020s (Figure 124). The length and age structures observed by this survey were truncated

in recent years, similar to other data sets which are often indicative of increased mortality and lower abundance.

Different growth patterns were assigned to two time blocks (1990-2011 and 2012-2024) in the northern stock to account for apparent changes in growth observed over time (Section 2.5). Von Bertalanffy growth parameters were freely estimated for both time blocks. Several sensitivity runs were completed to investigate different breakpoints for the time blocks and the run with the lowest total negative log-likelihood was selected as the base run. Additional runs attempted to apply different natural mortality rates to the two time blocks, but these runs did not converge.

Data availability by year is shown in Figure 125.

6.1.4 Southern Stock

The southern stock has five fishing fleets (Table 47) and four surveys (Table 48). Fishing fleets include two recreational fleets primarily using hook and line gears. There was a fleet representing recreational removals in North Carolina, South Carolina, and Georgia (Recreational NC-GA) and a separate fleet for Florida (Recreational_FL). There were also two commercial fleets that represented removals from commercial landings and scrap landings in two separate areas, like the recreational fleets, North Carolina, South Carolina, and Georgia combined into a fleet and a separate fleet for Florida. A bycatch fleet, which like the northern stock is by far the most substantial component of removals, comprises discarded fish from the shrimp trawl fishery.

Selectivity for the recreational fleets was assumed to be an increasing logistic function of length because there are no restrictions on the lengths of fish that may be retained. There was insufficient composition data to estimate selectivity of the commercial fleet in Florida, therefore, this selectivity was set to mirror the recreational fleet in Florida. The commercial fleet in NC-GA was assumed to follow an increasing logistic selectivity function based on length during 1990-2003 and then a double normal selectivity pattern during 2004-2024. This time varying selectivity pattern was used to represent a change in the gear type representing most of the harvest during these two time periods (Section 4.1.1.5.3). This is implemented in the model by having two blocks for selectivity, with a double normal length-based selectivity in both but fixing the descending limb parameter at its upper bound in the first block and freely estimating it in the second time block. Selectivity for the SEAMAP surveys was assumed to be a dome-shaped, double normal function of length while the two young-of-year surveys (SC YOY, GA YOY) were assumed to select only age-0 individuals.

Fishing fleets include retained catch, discarded catch, and length compositions for retained catch, except for the Florida commercial fleet which lacked length compositions.

The SEAMAP monitoring surveys included indices of abundance, length compositions, and conditional age-at-length data. The young-of-year surveys only included indices of abundance. Catchability for all abundance indices were assumed to be constant over time and were estimated using the closed form maximum likelihood estimator.

Data time series are shown in Figure 126. Note that the SEAMAP summer sampling and index was discontinued in 2022.

6.2 Results

6.2.1 Northern Stock

6.2.1.1 Base Model

The final model had a maximum gradient component of 3.07x10-4 and a positive definite Hessian matrix. There were 58 estimated parameters, and 71 estimated deviations (Table 49-Table 51). No parameters were within 1% of their bounds.

In the jitter analysis, there were 158 model runs that had a likelihood within two units of the base model value (Table 52). Forty-two runs converged on solutions with larger negative loglikelihoods than the base model. These results provide no evidence that the model has converged on a local minimum in the likelihood and indicate the base model is somewhat sensitive to initial values used for parameters.

Fits to the commercial and recreational removals data (all entered as kept catch in the SS data input file) were very tight (Figure 127 and Figure 128). The discard data for the bycatch fleet was not fit as closely due to considerably higher standard errors assigned to this series corresponding to higher uncertainty in the estimates (Figure 129). The model tended to underpredict the bycatch fleet's discards early in the time series, followed by a period of close fits for much of the early 2000s, then overpredicts the discards for much of the 2010s, and finally achieving close fits during the 2020s.

Fits to survey indices were variable. The model struggled to reconcile fitting to the recruitment indices together with the bycatch fleet (which selects only age-0 fish). The model tended to overpredict the NC_P195_YOY index early and underpredict later in the series, with a period in the 2000s of closer fits with more random error (Figure 130). The model tended to overpredict the NC_P195_YOY index early and underpredict later in the series, with a period in the 2000s of closer fits with more random error (Figure 131). The pattern of over and underpredictions is nearly opposite of that seen relative to the bycatch discard series, indicating the model's tendency to smooth through both series because it cannot fit closely to both.

The model fitted the observed trend in the ChesMMAP index with residuals fairly evenly distributed for most of the time series, though the model tends to overestimate the survey in the most recent years (Figure 132). Given the increasing trend in the NEFSC index is at odds with most other signals evaluated during the assessment and its focus on offshore habitat, the NEFSC index is hypothesized to track availability more closely than stock abundance. To account for this and address model instability associated with attempting to fit to the conflicting series, this survey catchability was modeled on a time-varying random walk. The change in catchability over time allows the model to fit closely to the survey index (Figure 133) and suggests a gradual increase in availability from the mid-2000s through the early 2010s, followed by a steep increase peaking in 2019 and declining in recent years (Figure 134). Fit to NEAMAP is variable

without much patterning (Figure 135). The NEAMAP index itself does not suggest much trend, and the model tends to estimate a timeseries of relative abundance more similar to ChesMMAP.

The model fits the length compositions well across the time series overall (Figure 136). Fits to the annual length compositions are generally good for the commercial catch (Figure 137) and recreational removals despite several years where the model smooths over with multimodal distributions, with a tendency to overestimate smaller sizes in those years that occur in the first half of the time series (Figure 138). The model struggled more with fitting to annual length compositions from ChesMMAP, generally estimating a broader range of sizes (Figure 139). Fits to annual NEFSC length compositions are reasonable with a few exceptions (i.e., the model overpredicts small fish in 2001 and smooths through a bimodal distribution in 2005, overestimating intermediate sized fish; Figure 140). The model fits annual length compositions of NEAMAP relatively well (Figure 141).

The model fit the mean age of fish in the commercial catch fairly well from 1995 through 2008, followed by a period of underestimates in most years from 2009 through 2018, and ending with a good fit for remainder of the time series (Figure 142). The model fit the ChesMMAP conditional age-at-length data well, with only the final year's mean age substantially underestimated (Figure 143). Model fits to the NEFSC (1997-2019) and NEAMAP (2007-2022) conditional age-at-length exhibited bias, overestimating the mean age in most years for both surveys (Figure 144 and Figure 145).

The commercial fleet, recreational fleet, and the three age-aggregate surveys all had asymptotic length-based selectivity patterns (Figure 146). NEAMAP and ChesMMAP selected for the smallest sizes, catching some fish as small as 10cm. The slope of the NEAMAP selectivity function is quite steep, with fish fully selected by approximately 21cm, similar to the NEFSC survey. Fish are fully selected in the ChesMMAP survey at approximately 30cm. Fish begin to be selected into the commercial and recreational fisheries at approximately 18cm and are fully selected at approximately 30cm. Selectivity parameters are not estimated for recruitment surveys. Selectivity for the bycatch fleet is fixed at 1 for age-0 fish and at 0 for all other ages (Figure 147). ChesMMAP and NEFSC have similar derived age-based selectivities, though ChesMMAP does not appear to fully select fish at any age. NEAMAP has the highest selectivity across all ages compared to the other aggregate surveys. The commercial and recreational fleets are estimated to have a gradually ascending, derived age-based selectivity across all ages that does not reach full selection, possibly because the fisheries fully select fish at a size larger than Linf in the late time block growth pattern.

The model estimated a period of positive recruitment deviations in the early 1990s, followed by random variation around the average until a period of negative recruitment deviations from 2013 to 2022 (Figure 148). Estimated recruitment was widely variable early in the time series with the peaks decreasing in size over time until a prolonged period of less variation around a lower average value beginning in the mid-2000s through 2020 (Figure 149). Estimated recruitment increased in the last few years.

The model estimated an increasing population at the beginning of the time series, peaking in 1993 and declining steadily until around 2015 when the population leveled out at an average of about 10% of the peak value until 2022 (Table 53, Figure 150). Abundance increased in the final two years of the model. Spawning stock biomass had a similar trend (Table 54, Figure 151). SSB was below the threshold early in the time series, then increased rapidly, exceeding the threshold in 1993 and peaking in 1996, then declined steeply through the 2000s then more gradually, dropping below the threshold in 2014 (Figure 152). Relative SSB continued to decline to near zero in 2018 and remained low with a possible slight increase in the final years of the time series.

Although the shrimp trawl bycatch fishery has accounted for the overwhelming majority of catch in both numbers and weight since the early 2010s, the fishing mortality was on a similar scale across the three fleets (Figure 153). However, bycatch is comprised primarily of age-0 fish in contrast to the commercial and recreational fleets which comprise ages 1-10+. Estimated initial condition and first model year fishing mortality was high in all fleets then dropped within the first few years to low, stable values from the mid-1990s until the mid-2000s, when all fleets' fishing mortality began to increase gradually until around 2010 then increased rapidly through the mid-2010s (Figure 153 and Figure 154). Commercial fleet fishing mortality declined sharply from 2018 to 2020 and continued to decline (Figure 153). Recreational fishing mortality followed a similar pattern of decline beginning in 2021. Bycatch fishing mortality also generally declined in later years but remained more variable. Total fishing mortality declined steadily from 2018 through the end of the time series (Figure 154). The decrease in fishing mortality early in the time series allowed SPR to increase through the mid-1990s (Figure 155). After the initial increase, SPR declined gradually until the late 2000s then sharply in 2013, falling below the 25% threshold, remaining until 2019. SPR has been generally increasing since 2019, exceeding the threshold in 2020.

6.2.1.2 Likelihood Profile

A likelihood profile on the R0 parameter for values from 12.8 to 15.1 in increments of 0.1 indicates length and age data support a similar likelihood surface to the total likelihood based on the minima occurring at a similar value (Figure 156). Index data supports a slightly larger R0 value, and neither discard data nor recruitment series are informative of the upper bound, suggesting instead a continually decreasing negative log-likelihood at increasing values of R0. Overall, the total likelihood surface shows a well-defined minimum at the base model estimate 13.61.

6.2.1.3 Retrospective Analysis

A six-year retrospective analysis was conducted to investigate model performance. The model shows some signs of retrospective patterning in the earliest peels. Estimates of SSB since around 2007 were revised downward beginning with the 2020 peel; however, there is no visibly discernible revision to estimates across the remaining four peels (Figure 157). There is a stronger pattern of downward revisions to SPR estimates (also beginning around 2007) across the 2018, 2019, and 2020 peels, with the most recent four peels generally consistent with the base model (Figure 158). Relative F estimates indicated issues in the same years, where the

2018 and 2019 peels were consistent with each other, and the remaining peels revised the estimates upward considerably but were all consistent with each other (Figure 158). Mohn's rho for SSB was 1.66 and for F was -0.3.

The Mohn's rho for both SSB and F are outside those proposed by Hurtado-Ferro et al. (2015), indicating the presence of a retrospective pattern. Preliminary analysis suggests this pattern may be driven by the maturity assumptions and potentially related to the change in growth assumed in the model. A retrospective adjustment was considered by the SAS but ultimately was not implemented for either metric. ASMFC's Assessment Science Committee (ASC) has provided guidance on what conditions require an adjustment (ASMFC 2024b) but these guidelines are currently under revision. Some of the decision points within the guidance document do not apply to Atlantic croaker (e.g., there is no comparable previous stock assessment for comparing stock status) and the ASC guidance calls for SAS judgement on when an adjustment is needed in certain scenarios. An adjustment would not change the stock status determination. Therefore, because the more recent peels are largely settled on a similar solution (i.e., each peel does not trend significantly in a single direction) and because stock status would not change, the SAS did not support a retrospective adjustment for F or SSB for this assessment. However, future assessment updates should re-evaluate the retrospective pattern as new years of data are added and reconsider the adjustment decision.

6.2.1.4 Sensitivity Analyses

Nineteen sensitivity configurations were developed to explore the impact of key model assumptions and data decisions. Run names are bold and italicized in the descriptions that follow. To improve visual discernibility, the analyses have been organized into two groups. The first set of analyses focuses primarily on growth assumptions and data pertaining directly to all ages (top panels in Figure 161-Figure 163). The second set of analyses are primarily related to data on age-0 fish (bottom panels in Figure 161-Figure 163).

A configuration with composition data reweighted by the Francis (2011) iterative reweighting method (***Reweight***) was considered to investigate model sensitivity to data weighting decisions. A configuration where natural mortality was fixed at the externally estimated value at age-2 in the early growth period (M=0.535; ***EarlyM***) to determine the sensitivity to the change in natural mortality across time periods of different growth patterns. Two configurations where the base age-2 natural mortality value was increased 25% (M=0.7425) and decreased 25% (M=0.4455) as a standard source of uncertainty (**M_+25%** and **M_-25%**). Three configurations with alternative start years for the recent growth pattern time block explored sensitivity to the assumption of the timing of the new growth pattern (***Growth2006***, ***Growth2010***, ***Growth2014***). Alternative start years were considered to align with the beginning of the North Carolina Trip Ticket Program and availability of commercial size composition data in 1994 (***SY_1994***) and with the availability of direct shrimp trawl observer estimates in 2008 (***SY_2008***). A configuration to explore sensitivity to MRIP estimates of recreational removals in light of upcoming revised estimates decreased recreational removals by 30% across all years (***MRIP_-30%***).

Several configurations explored treatment of data sources that inform recruitment: one configuration where standard errors for both young-of-year indices were decreased to 0.2 (***YOY_SE_0.2***), a configuration omitting NC_P195_YOY (***No_NC_P195***), a configuration omitting both young-of-year indices (***No_YOY***), and a configuration where standard errors for the shrimp trawl bycatch fleet were decreased to 0.2 (***Shrimp_SE_0.2***). Shrimp trawl bycatch data are a source of considerable uncertainty impacting the smallest fish in the population. Four sensitivity runs explored the scale of bycatch: increasing by 30% (***Shrimp_+30%***), decreasing by 30% (***Shrimp_-30%***), decreasing by 60% (***Shrimp_-60%***), and decreasing by 90% (***Shrimp_-90%***). Additionally, a configuration was considered where shrimp trawl bycatch fleet selectivity was fixed allow for partial selection (0.20) of age-1 fish (***ShrimpPartialSel_A1***) to investigate the impact of the assumption of only age-0 fish selected by the shrimp trawl fishery.

Results from all sensitivity runs indicated that model trends are robust to most assumptions and data decisions that were made in developing the base model. Differences are most notable in the time series of relative fishing mortality (Figure 161). With exception of ***M_+25%*** and ***Shrimp_-90%***, and ***YOY_SE_0.2***, all alternative configurations produce a similar trend in relative F to the base model. The increased natural mortality rate implies a larger population, leading to the low fishing mortality estimates across the time series. Unsurprisingly, reducing the shrimp trawl bycatch by an order of magnitude results in much lower estimates of F. ***Growth2010, Growth2014, MRIP_-30%,*** and ***SY_1994*** as well as most of the age-0 configurations track the base model F estimates closely. ***Reweight*** suggests a lower relative F over the time series. ***M_-25%, SY_2008, Growth2006,*** and ***M_Early*** result in higher estimates of relative F. ***M_Early*** applies a lower value of natural mortality in the early part of the time series, scaling the population down and implying higher F corresponding to the observed removals. Starting the model in 2008 (**SY_2008**) and shifting the new, slower, smaller growth pattern to an earlier onset (***Growth2006***) have a similar effect of reducing the number of years in the model when the stock exhibited faster growth. The impact of the partial selection at age-1 to the shrimp trawl fishery (***ShrimpPartialSel_A1***) is seen in the peak fishing mortality rates lagged one year relative to the base run.

The trends in SPR are very consistent across runs, with only ***M_+25%***, ***Shrimp_-90%***, and ***YOY_SE_0.2*** standing out at much greater values particularly for the second half of the time series (Figure 162). Conversely, ***M_-25%*** results in lower SPR estimates that get closer to the base run estimates beginning in the early 2010s, around the time the alternate growth pattern is implemented. Spawning stock biomass trends are also quite consistent across runs with some configurations having a more substantial impact on scale than others (Figure 163). **M_+25%** results in considerably higher SSB estimates than the base model estimates in all years. ***No_YOY*** and ***No_NC_P195*** produce higher SSB estimates when the population is large because the model does not have to reconcile conflicting signals and can follow the signal from the shrimp trawl bycatch more closely. In contrast, ***YOY_SE_0.2*** produces lower estimates of SSB over the same years because the model must fit more closely to the recruitment indices (which it tends to overestimate in the base model during that time period). ***M_-25%*** and ***Reweight*** also produced lower estimates of SSB in the early part of the series when the stock was large. Despite scaling differences in the first part of the time series, almost all configurations

converged upon a very tight range of values around the base run from 2010 through the end of the time series. Only ***M_+25%*** remains above the base run estimates for the full series, and ***Shrimp_-90%*** and ***YOY_SE_0.2*** break from a similar series of estimates for the early years producing considerably higher SSB estimates starting in the mid-2000s through the end of the time series. Terminal year stock status does not differ from the base model in any sensitivity runs.

6.2.2 Southern Stock

6.2.2.1 Base Model

The base model had a maximum gradient component of 8.71252e-05 with a Hessian matrix that was positive definite. There were 135 estimated parameters and 40 estimated deviations (Table 56-Table 59). No parameters were estimated at their bounds, no parameter pairs were highly correlated (>+0.95), and one parameter had low correlation (<0.01) with all other parameters. The parameter with lowest correlation was F_fleet_4_YR_2012_s_1 with a maximum correlation of 0.0014. This parameter corresponds to the bycatch fleet mortality rate in 2012, which was estimated at zero. There was also a large difference between the observed value for discards that year and the estimated value (Figure 164).

In the jitter analysis, there were 186 model runs that had a likelihood identical to the base model (Table 60). Fourteen runs converged on solutions with larger negative loglikelihoods than the base model. These results provide no evidence that the model has converged on a local minimum in the likelihood and indicate the base model is not too sensitive to initial values used for parameters.

Fits to catch data were good overall and for almost all years and fleets the observed value closely matched the predicted value, which is expected given the small values assumed for the standard error on these catch data. For a few years, the observed Florida recreational catch did not match the predicted values very well, which happened mostly in years with high observed catch (Figure 165). Fits to the discard data were not as good as the catch data but were not too bad overall (Figure 164). There were a couple of years when the predicted values were low or very close to zero but the observed values were much larger than zero.

Fits to the SEAMAP summer and fall abundance indices were better than the South Carolina and Georgia young-of-year indices (Figure 166 and Figure 167). The SEAMAP summer and fall index fits were generally good, but the model could not match some of the deviations in the index. The model underestimated the Georgia young-of-year index at the beginning of the time series and overestimated at the end. The model could not match the increase seen in the South Carolina young-of-year index at the beginning of the time series.

The aggregated length compositions fit relatively well (Figure 168). The observed and estimated peak were slightly different for the length distribution of SEAMAP summer survey. The fits to length frequencies for individual years were generally similar but there were some years where the fit was worse, e.g., SEAMAP fall in 2016 and 2019 were predicted to have slightly larger individuals than observed (Figure 169-Figure 178).

The model could not fit the conditional age-at-length data well for both the SEAMAP summer and SEAMAP fall surveys (Figure 179). The model tended to underestimate conditional age-at-length for the SEAMAP summer survey while overestimating conditional length-at-age for the SEAMAP fall survey. When only SEAMAP fall was included in the model and SEAMAP summer is excluded, or vice versa, the model could adequately fit the conditional age-at-length data (see results of sensitivity runs in Section 6.2.2.4). The reason for this misfit in the base model could not be identified; however, the SAS chose to keep both conditional age-at-length data sets in the base model. Additionally, the choice of which to keep in or out (only SEAMAP fall, only SEAMAP summer, or both) does not have a large effect on the primary conclusions of the assessment.

The length-based selectivity for SEAMAP summer and SEAMAP fall was dome shaped with most individuals between 10-25 cm having selectivity greater than 0.05 (Figure 180). Selectivity for SEAMAP summer peaked for individuals slightly above 20 cm while selectivity for SEAMAP fall peaked slightly below 20 cm. The recreational fleet for NC-GA and Florida both had increasing length-based logistic selectivity and the NC-GA fleet included selection for slightly smaller individuals compared to the Florida feet. The NC-GA commercial fleet had an increasing length-based logistic selectivity during 1990-2004 that selected individuals larger than 20 cm while after 2004 this fleet had a domed shape selectivity with a peak for individuals slightly less than 25 cm (Figure 181).

The recruitment deviations had a non-random pattern with a decreasing trend during the first half of the time series followed by an increasing trend with the largest positive deviations occurring at the end of the time series (Figure 182). This was primarily because we fixed steepness at 0.99. If steepness was estimated or fixed at a lower value (0.69) then these deviations did not have any major trends, but this fixes the underlying productivity of the stock. We chose to fix steepness at 0.99 because this essentially takes an underlying stock-recruit relationship out of the model so it has no influence on reference points. However, this decision does not change the primary results from the assessment and the stock status in the most recent years. In general, estimated recruitment was relatively low until about 2010, and increased to a maximum in 2020 and has remained relatively stable since then (Figure 183).

Total population abundance was less than 500 million individuals for most years during 1990 to 2007 and then started to increase in 2008 to a maximum of 1.72 billion individuals in 2020 and has remained above 1.2 billion individuals since then (Figure 184). Spawning stock biomass remained stable and below 10,000 metric tons until an increase starting in 2011 to a maximum in the most recent year of about 30,000 metric tons (Table 62, Figure 185). Relative to the SSB produced from fishing at 25% SPR, the SSB was below this threshold until 2012 and has been increasing and above the threshold since 2012 (Figure 186).

Among the fishing fleets, the Florida recreational fleet accounted for the most removals almost every year and had the highest fishing mortality rate followed by NC-GA recreational, commercial NC-GA, and commercial FL (Figure 187). The shrimp bycatch had the highest estimated fishing mortality among all fleets that was up to about 3 yr^{-1} in the 1990s but has

decreased to less than 0.5 in recent years (Figure 188). All fleets have had an overall decreasing trend in fishing mortality from the early 1990s to the most recent years. Fishing mortality on age 0-3 individuals has decreased from an average of 0.31 yr^{-1} in the early 1990s to 0.06 yr^{-1} during the most recent 5 years (Figure 189). In terms of SPR, high fishing mortality led to SPRs below the management threshold of 25% during half the years in the 1990s. SPR then increased above the threshold starting in 2005 and has remained above the threshold for the remainder of the time series (Table 63, Figure 190).

6.2.2.2 Likelihood Profile

A likelihood profile was conducted for the R0 parameter across a range of 10 to 16 with increments of 0.1 (Figure 191). Some conflict among data sets was apparent with index data supporting a smaller R0, while discard and age support a larger R0. Discard, age, and length data are informative of the lower bound of the R0 parameter, but less informative of the upper bound, while the index data is informative for the lower and upper bounds. The total likelihood is the balance of these information sources and shows a well-defined total likelihood surface with a minimum at the base model estimate of 12.9.

6.2.2.3 Retrospective Analysis

A retrospective analysis with a six-year peel shows minor retrospective bias in the model. The model tended to overestimate SSB (Figure 192) and underestimate fishing mortality (Figure 193). Mohn's rhos for SSB (0.139) and F (-0.101) are within the rule of thumb range proposed by Hurtado-Ferro et al. (2015) for determining no retrospective pattern in an assessment of a short-lived species. Because Mohn's rho values are within these bounds and an adjustment would not affect stock status, a retrospective adjustment of F and SSB was not recommended.

6.2.2.4 Sensitivity Analysis

Twelve sensitivity configurations are presented here (run names bolded) to demonstrate the impact of key model assumptions and data choices. A configuration with only fitting to the SEAMAP summer conditional-age-at-length data (**SEAMAPsummerCAAL**) and another model only fitting to the SEAMAP fall conditional-age-at-length data (**SEAMAPfallCAAL**). A configuration with the amount of shrimp bycatch increased by 30% (**Shrimp_+30%**) and another configuration with shrimp bycatch decreased by 30% (**Shrimp_-30%**) were used to examine sensitivity in the scale of the shrimp discards. To examine sensitivity to the assumption that the shrimp discards consisted of only age-0 individuals, we ran a model that included an age base selectivity decreasing logistic selectivity such that selectivity for age-0 was 1 and for age-1 was approximately 0.2 (**Shrimp_age1_20%sel**). Two alternative natural mortality values were evaluated as a standard source of uncertainty in stock assessment. The first configuration included the base model age-2 value decreased by 20% (**M_-20%**) and the second configuration included the base model age-2 value increased by 20% (**M_+20%**). A configuration to examine the sensitivity to the scale of recreational removals was done by reducing removals by 30% (**MRIP_-30%**). A configuration with the start year advanced to 1994 (**SY_1994**) was done to examine sensitivity to lack of commercial length composition data prior to the beginning of the North Carolina Trip Tikcet Program in 1994. Another configuration with the start year advanced to 2008 (**SY_2008**) was done to examine the sensitivity to the availability of direct shrimp trawl

observer estimates. A configuration with the standard error for the young-of-year indices reduced to 0.2 (**YOY_SE_0.2**) was done to examine the sensitivity to the weightings of these indices. To examine sensitivity of the input weightings for the shrimp discards, a model was run with the standard error for the shrimp discards set to 0.2 (**Shrimp_SE_0.2**). To examine sensitivity of model results to the assumptions about the stock recruitment steepness parameter, two runs were conducted. The first allowed the model to freely estimate steepness (**Estimate_steep**) and for the second, steepness set at a literature derived value of 0.69 (**fix_steep_0.69**).

All sensitivity configurations estimated trends like the base model but with some differences in the scale of the population. When fitting only to the SEAMAP summer conditional-age-at-length data (**SEAMAPsummerCAAL**), the conditional-age-at-length fits were improved (Figure 194) compared to the base model. SSB was lower and average F for ages 1-3 was higher than the base model (Figure 195 and Figure 196). When fitting only to the SEAMAP fall conditional-age-at-length data (**SEAMAPfallCAAL**), the conditional-age-at-length fits were improved (Figure 197) compared to the base model. SSB was slightly lower and F for ages 1-3 was slightly higher than the base model. The sensitivity runs that resulted in the highest SSB were the 25% increase in natural mortality (**M_+20%**) and decreasing the standard error for the shrimp trawl discards to 0.2 (**Shrimp_SE_0.2**). Sensitivity runs that resulted in the lowest estimated SSB were reducing the standard error for the young-of-year indices to 0.2 (**YOY_SE_0.2**) and fitting only the SEAMAP summer conditional-age-at-length data (**SEAMAPsummerCAAL**). The estimated SPR ratio was most sensitive to a 20% increase (**M_+20%**) or 20% decrease in natural mortality (**M_-20%**) (Figure 198). When allowed to freely estimate steepness the model estimate was 0.53 and the recruitment deviations did not have any obvious patterns. Terminal year stock status does not differ from the base model in any sensitivity runs.

7 TRAFFIC LIGHT ANALYSIS

7.1 Methods

The Traffic Light Analysis (TLA) was originally developed (Caddy 1998, 1999, 2002) as a precautionary management framework for data poor fisheries whereby reference points could be developed that would allow for a reasonable level of resource management. The name comes from assigning a color (red, yellow, or green) to categorize relative levels of different indicators of the state of either a fish population or a fishery. These indicators can be combined to form composite characteristics within similar categories and can include biological indicators such as growth and reproduction, population level indicators such as abundance and stock biomass estimates, or fishery indicators such as harvest/landings and fishing mortality. However, each indicator must be evaluated separately to determine its appropriateness for use in a management scheme.

The purpose of developing the TLA for Atlantic croaker was to monitor index trends and provide management advice in the absence of an assessment approved for management advice. It is important to note that while the TLA does provide a management guidance framework based on different index characteristics, it does not provide population level

parameters such as biomass (B_{MSY}) spawning potential ratios (SPR) or fishing mortality (F_{MSY}), so its utility for providing stock specific fishery parameters is limited. However, the ability to illustrate trends in different fishery or population parameters (e.g., abundance, landings, etc.) is useful in the absence of more rigorous population models.

The specific TLA model used for Atlantic croaker is the fuzzy traffic light model. In the fuzzy traffic light model, we use boundary reference points to determine the relative proportion of each color that includes the buffer (yellow) zone based on the upper and lower 95% confidence intervals from the index values for either the entire data series or a pre-determined reference period (Halliday et al. 2001). The TLA established in Addendum II of the Atlantic croaker FMP was used to monitor the stock between assessments to trigger management action. This original Atlantic croaker TLA evaluated the stock as a coastwide unit, used a 1996-2008 reference time period, and set the mean index value at 1.0 for yellow and 0.0 for both red and green as the mean of that reference period for each index used. The 0.5 proportion value for all three colors is set at the mean index value minus the lower 95% confidence interval (CI) (red and left yellow leg) and the mean index value plus the upper CI (green and the right yellow leg). Finally, the value of 1.0 is set for red at the mean index value minus 2X the lower CI or zero, if the index mean minus 2X the lower CI is a negative number. For green the 1.0 value is set at 2X the upper 95% confidence limit. Once the known index values at the proportion values for each color are determined, the relative color proportions for each year can be estimated via linear regression using the annual values of the index. Any negative values are reset to zero and the proportion of yellow is set at 1 minus the color proportion for either red or green in that year. This allows a better illustration of the annual trends within a given color and whether values are approaching levels of concern about the reference boundaries. All revised Atlantic croaker TLAs in this document use the same methodology of assigning proportion of color, but have differing reference periods as discussed below. Composite figures of combined indices can then be created using the color proportion tables from each individual index. These indexes are additive and the total index is re-scaled to 0-1. This type of composite index is what Halliday et al. (2001) referred to as a Characteristic, while the individual indices that make it up are the Indicators.

Addendum III of Amendment 1 revised the TLA structure to a regional structure using the indices developed during the 2017 assessment (ASMFC 2017). The original coastwide TLA will not be described or discussed further in this document. The Addendum III TLA will be referred to as the current TLA and a TLA developed to match the current assessment stock definition and indices will be referred to as the revised TLA for the remainder of this section. The revised TLA was developed as a comparison to the current assessment models, but the SAS does not present it as an alternate assessment model. The SAS dedicated resources to developing the SS models in hopes of providing more sound stock status advice, and the potential for providing statistically derived management measures to reach reference point values if deemed necessary.

The current TLA uses regional Characteristics to evaluate the fisheries north and south of the Virginia-North Carolina state border (labeled the Mid-Atlantic and South Atlantic regions). The Harvest Characteristic is the commercial landings and recreational harvest by region. The Adult

Abundance Characteristic utilizes age-2+ indices as indicators. The Mid-Atlantic Characteristic uses ChesMMAP and NEFSC survey data, and the South Atlantic Characteristic uses SCDNR Trammel Net and SEAMAP survey data. The reference time period for all surveys is 2002-2012 to accommodate the shortest time-series of data (the ChesMMAP survey). Management action would be triggered coastwide according to red thresholds of 30% red (moderate concern level with minimal management action taken) and 60% red (significant concern with more significant management action taken) if both the abundance and harvest thresholds are exceeded in either region in any three of the four terminal years. The TLA triggered at the 30% red threshold in 2020, and management measures were enacted in 2021.

With the stock structure changing from coastwide to a split at Carteret County and Onslow County border in North Carolina, the TLA regions in the updated TLA were changed to match this new stock definition, and renamed the northern stock and the southern stock. The Harvest Characteristic indicators for each stock are commercial harvest and total recreational removals. The change from recreational harvest to total recreational removals was done in recognition of the increase in recreational discards in recent years, and since it could be easily calculated if the TLA were to be used in any capacity in the future. The Abundance Characteristic Indices were those utilized in the SS models for each stock, which are age aggregated as opposed to the age-2+ used in the current TLA. The northern stock only uses the ChesMMAP survey index and southern stock uses both the summer and fall SEAMAP survey indices. The time series used remained 2002-2024 for the northern stock, but was changed to 1990 to 2024 for the southern stock, since it is no longer confined to the ChesMMAP time-series. The reference period for the northern stock remained 2002-2012, but the southern stock reference period was changed to 2009-2019 to encompass a timeframe of perceived stable stock condition for that stock.

7.2 Results of Current TLA

The current TLA Harvest Characteristics had high proportions of red in both regions, with the Mid-Atlantic exceeding 60% red in all four terminal years, and the South Atlantic exceeding 30% red in all four terminal years (Figure 199, Figure 200). The Mid-Atlantic Abundance Characteristic exceeded the 30% red threshold in three of the four terminal years (Figure 201). Index values were up in 2024 with no red and a 79% green proportion. However, the Mid-Atlantic abundance index still exceeded the 30% threshold for three of the four terminal years, indicating moderate concern. The South Atlantic abundance Characteristic did not exceed the 30% or 60% thresholds (Figure 202). The last four years are predominantly green or yellow, representing no concern. Management actions would need to remain in place for the entire coast, since the Mid-Atlantic region exceeded 30% red in three of the four years.

7.3 Results of Revised TLA

The revised TLA Harvest Characteristics had high proportions of red for the northern stock, exceeding 60% red in two of the four terminal years and exceeding 30% red in all four terminal years (Figure 203). The southern stock Harvest Characteristics did not exceed 30% red in any of the four terminal years, and was mostly green and yellow for that period (Figure 204). The northern stock Abundance Characteristic exceeded the 30% red threshold in all four terminal years, and was above the 60% threshold for three of the four terminal years (Figure 205). The

index value was up in 2024 but was still 30% red. Applying the framework of the current TLA to the revised version, the northern stock would trigger at the 60% threshold level, indicating elevated management measures would be necessary. However, the significant changes to the TLA indices would require a review of the management framework, if the revised TLA were to continue to be used to trigger management action, to ensure they are still appropriate. The southern stock Abundance Characteristic did not exceed the 30% or 60% thresholds (Figure 206). The last four years are predominantly green or yellow, representing no concern.

7.4 Comparing the Current TLA to the Revised TLA

Comparing the current TLA Mid-Atlantic region for harvest to the revised TLA northern stock for harvest, the trends are very similar, but the proportion of red in the most recent years is lower using the revised TLA. The only two changes to this Characteristic are the change in region split and the addition of recreational discards, and the northern part of the species range accounts for a higher proportion of total removals, so the similarity between the two is not unexpected. The two Harvest TLAs for the South Atlantic and southern stock are not nearly as similar, with the current South Atlantic indicating 30% proportion of red the past 11 years, and the revised southern stock has very low to no red in the most recent five years and only 3 of the past 11 years are above 30% red. They also disagree on stock condition at the beginning of the time series, with the current TLA structure indicating some red in the first seven years and the revised has no red and some high proportion of green in those same years. The reference period also changed for the southern revised Harvest TLA, so an exploratory southern stock Harvest TLA was created using the current TLA reference period and not including recreational discards, so only the regional split was changed, to see how much of the status change in the revised TLA was due to the change in regional split (Figure 207). The exploratory Harvest TLA was very similar to the revised TLA, indicating the regional split was responsible for the significant change in status of the revised TLA. This gives more support to the revised regional split more accurately delineating areas of differing harvest trends for the Atlantic coast Atlantic croaker population.

The fishery independent Abundance Characteristic change from adult age 2+ indices in the current TLA to an aggregate age index, so greater differences are to be expected between the two sets of TLAs. The revised southern stock TLA also utilizes only the ChesMMAP survey, which has been more negative in recent years than the NEFSC Trawl survey had been, leading to the change from triggered at the 30% red level to the 60% red level in the revised TLA for the terminal years. The general trend remained similar for most years. Comparing the southern fishery independent current TLA and revised TLA Characteristics also has a similar trend, in this case generally improving over time, but the magnitude of proportion of red increased substantially in the earlier years of the revised TLA. The change to using two SEAMAP surveys, and including age-0 and age-1 fish, likely amplifies the effect of year class strength in the revised southern stock TLA.

7.5 Comparing the Revised TLAs to the SS Models

For the northern stock, both the TLA and the SS model indicate a similar stock condition in the terminal years. The continued poor commercial and recreational harvest coupled with low

fishery independent index values indicate a depleted spawning stock condition is likely. For the southern stock, the model and revised TLA indicate improving stock condition with current status not requiring further management action. It is important to note the thresholds used for comparison in the revised TLA were developed for the current TLA and may not be appropriate for continued use, particularly considering the change to aggregated age indices. A review, and potential further revision of the revised TLAs would be needed by the TC if the TLA were to continue to be used as a management tool. However, the current status of both stocks based on the revised TLAs are not near the bounds, so the SAS is comfortable using them as a comparison to the models produced in this assessment. The SAS also feels the TLA was a useful tool to track a declining stock in the absence of an approved stock assessment, but if stock status is available through model derived reference points, the TLAs would no longer be required.

8 STOCK STATUS

8.1 Stock Status Definitions

Model estimates from the base SS models are recommended for status determination of each stock. Stock status definitions and associated recommended responses include the following:

- Fishing mortality status:
    - If $F_{A1}/F_{A1_25\%} < 1 < F_{A0}/F_{A0_25\%}$, overfishing of age-0 fish is occurring and action is recommended to reduce F on age-0.
    - If $F_{A1}/F_{A1_25\%} > 1 > F_{A0}/F_{A0_25\%}$, overfishing of adult fish is occurring and action is recommended to reduce F on ages-1+.
    - If $F_{A1}/F_{A1_25\%} > 1 < F_{A0}/F_{A0_25\%}$, overfishing of all ages is occurring and action is recommended to reduce F on all ages.
    - If $F_{A1}/F_{A1_25\%} < 1 > F_{A0}/F_{A0_25\%}$, overfishing is not occurring. If overfishing is determined to not be occurring, the fishing mortality would then be compared to the target reference point, once defined in consultation with the Board following this assessment, to determine if desired conditions with respect to all management objectives are being achieved.
- Spawning stock biomass status:
    - If $SSB/SSB_{SPR25\%} < 1$, the stock is below the threshold. Status will be described as either overfished or depleted depending on evidence considered from other metrics (e.g., fishing mortality, recruitment, environmental drivers). Depleted is defined by ASMFC as low levels of abundance though it is unclear whether fishing mortality is the primary cause for reduced stock size. Regardless of the description, action is recommended to protect the remaining spawning stock and promote stock resiliency and rebuilding.

- If $SSB/SSB_{SPR25\%} \geq 1$, the stock is not overfished. The spawning stock biomass should be compared to the target reference point, once defined in consultation with the Board following this assessment, to determine if desired conditions with respect to all management objectives are being achieved.

8.2 Stock Status Determination

8.2.1 Northern Stock

The northern stock is depleted and is not experiencing overfishing, as the terminal three-year average SSB ratio is less than one (Figure 152) and the terminal three-year average F ratios for both age ranges are less than one (Figure 208). The upper limit of the 95% confidence interval for the terminal three-year average SSB ratio is also less than one indicating the confidence interval does not overlap the not overfished SSB range. Similarly, the upper limits of the 95% confidence intervals for the terminal three-year average F ratios for both all ages and ages-1+ are less than one indicating the confidence intervals do not overlap the overfishing F ranges for either age definition. No sensitivity runs estimated stock status the differed from the base run status estimates.

Northern stock status finding is described as depleted as opposed to overfished due to a relatively short time series of population dynamics that appears to be influenced by drivers other than fishing mortality (e.g., environmental conditions). Overfishing was not occurring from the mid-1990s, when SSB was at time series highs, through 2012, the year before SSB had declined to below the threshold in 2013. This time series of dynamics does not clearly support fishing mortality as the primary driver of SSB declines in the 2000s. Specific drivers were not determined during the assessment despite some exploration of environmental time series (Section 3.3) and additional research is necessary to do so.

However, annual fishing mortality increased continuously since the mid-1990s and exceeded the threshold in the mid-2010s (2013-2019 for F_{A0} and 2016-2018 for F_{A1}) following a brief period of stable SSB which may have limited stock recovery following its decline. Recreational effort also appears to have peaked and remained high after the stock started declining (Figure 74). Some slight increases in SSB can be seen in the most recent years as the fishing mortality has decreased below the threshold in 2020 and 2022-2024. Therefore, the SAS believes fishing mortality is still a driver of long-term population dynamics and recovery potential and recommends action to protect the remaining spawning stock and promote resiliency and rebuilding. Inaction for a depleted stock presents a very risky situation that could reduce resiliency and lead to reduced yield if favorable environmental conditions for expanding biomass and size structure occur, or at worst stock collapse.

In addition to the poor SSB status, length and age structure of the northern stock remains truncated relative to those observed in the past. These truncations indicate the stock has experienced unfavorable changes in mortality reducing access to larger, older fish previously available to fisheries and the presence of the largest, most fecund individuals in the population.

Truncation appears related to observed reduction in growth which has negative fishery (reduced yield per recruit) and biological (reduced SSB per recruit) implications. Growth started declining in the late 2000s according to the empirical information and sharply in 2014 according to modeled estimates. There was no clear indication of prey abundance bottlenecks as neither prey abundance nor Atlantic croaker body condition factors have consistently trended down. The cause for slowing growth remains unknown.

The shrimp trawl fishery appears to have influenced northern stock population dynamics. Overfishing of age-0 fish, which are almost exclusively selected by the shrimp trawl fleet, began earlier in the 2010s and lasted longer than for age-1+ fish. Shrimp trawl discard data are very limited, but are the best available information to characterize historical impacts of discards in the shrimp trawl fishery on Atlantic croaker dynamics. Data collection improvements will help future characterizations and are strongly recommended by the SAS, but historical data will not change and will continue to represent the best available information on historical discards for future assessments. The limited data led to high uncertainty in these estimates, but there is high confidence that removal in this fishery are significant and likely larger than all other removal sources combined in terms of numbers of individuals. Sensitivities, including around the magnitude of discards, do not change perspective of stock status.

8.2.2 Southern Stock

The southern stock is not overfished and is not experiencing overfishing, as the terminal three-year average SSB ratio is greater than one (Figure 186) and the terminal three-year average F ratios for both age ranges are less than one (Figure 209). The lower limit of the 95% confidence interval for the terminal three-year average SSB ratio is also greater than one indicating the confidence interval does not overlap the overfished/depleted SSB range. Similarly, the upper limits of the 95% confidence intervals for the terminal three-year average F ratios for both all ages and ages-1+ are less than one indicating the confidence intervals do not overlap the overfishing F ranges for either age definition. No sensitivity runs estimated stock status the differed from the base run status estimates.

The southern stock SSB is at time series highs and F rates are at time series lows at the end of the assessment. The history of fishing in the southern stock also demonstrates $F_{25\%}$ as an appropriate threshold level, as SSB remained at low, but stable levels for about twenty years while F_{A0} fluctuated around the threshold level and expanded as fishing mortality declined. There are no troubling signs for the condition of the southern stock as this time.

As for the northern stock, the shrimp trawl fishery appears to have influenced southern tock population dynamics. SSB remained well below the threshold level while F_{A0} exceeded its threshold and F_{A1} did not. SSB has consistently increased as F_{A0} consistently remained below the threshold starting in 2010. Also as observed for the northern stock, sensitivities, including around the magnitude of discards, do not change perspective of stock status.

9 RESEARCH RECOMMENDATIONS

The SAS recommends conducting an assessment update in three years (2029) and the next benchmark stock assessment in six years (2032). An assessment update would replace the TLA previously used for updated management advice on a reduced frequency due to the greater data processing demands and modeling workload. The update would provide updated stock status estimates and evaluation of any potential management responses to the results of this assessment which would likely take multiple years to fully implement.

Following this assessment, the SAS recommends the following research priorities be considered and addressed, where possible. Priorities are categorized in tiers listed in order starting with the highest priority. Timeframes provided for each priority indicate timeframe from initiation of work including monitoring efforts that should continue indefinitely (i.e., ongoing). A benchmark stock assessment in six years would allow time to address some of these priorities to advance the information and methods used during the assessment.

Priority Tier 1

- Increase discard information for the shrimp trawl fishery, particularly more robust/higher intensity observer coverage, mortality rates of discarded individuals, and size/age composition of discarded Atlantic croaker. This is the largest source of removals for this species, particularly in the southern stock, so properly characterizing and accurately estimating it are essential for future assessment advancements (**ongoing**).

- Future assessments should examine possibilities for seasonal models that allow for multiple settlements during the year. Data are needed to characterize proportion of annual recruitment that occurs at the beginning of each modeled time step (season) within the year. Prolonged spawning, particularly in the southern stock, may cause some of the issues with estimating size at age within the model (**short-term**).

- Conduct a tagging study to estimate natural and fishing mortality as a verification of assessment model estimates. Studies should consider seasonal time steps to differentiate summer mortality from mortality in overwintering areas (**long-term**).

Priority Tier 2

- Collect fecundity data and generate fecundity estimates for Atlantic croaker from the southern and northern stocks as a potential replacement of biomass as an indicator of reproductive capacity in biological reference points. For these batch spawners with indeterminate fecundity (Barbieri et al. 1994), fecundity information should include size/age-specific eggs per batch and average frequency of batches per spawning season (**short-term**).

- Increase length and age data collection from recreational fisheries with an emphasis on discarded fish, and conduct studies to estimate recreational discard mortality. This would allow for better estimation of selectivity curves, particularly for discards (**ongoing**).

- In the absence of a seasonal model, explore using a biological year model rather than a calendar year with the year start being aligned with when juveniles start showing up in the monitoring programs (young-of-year surveys in late spring). The goal would be to keep year classes together in a model year. Data should be examined for the best year definition. Once determined, data will need to be structured according to this year definition when requested ahead of the assessment (**short-term**).

- Use tagging studies to gain insight on Atlantic croaker movement in/out of estuaries as well as latitudinally in overwintering ocean habitats to understand mixing across the stock boundary in central North Carolina (**long-term due to potential interannual variation in these dynamics**).

- Initiate new sampling of Atlantic croaker maturity-at-size/age within the southern stock and examine maturity schedules (**ongoing**).

Priority Tier 3

- Examine aging methods among agencies to determine if massive overlap in size-at-age is biological, geographical, or aging error (particularly in the southern stock). Investigate and resolve, if necessary and possible, the pattern of larger size-at-age earlier in the calendar year observed during this assessment in historical age data from both stocks (**short-term**).

- Conduct simulation studies to determine impacts of reduced estuary habitat use on stock productivity (**long-term**).

- Initiate sampling program in Virginia and increase sampling in North Carolina to quantify and biologically characterize commercial bait and scrap fishery catches. Composition of these catches, including proportion of Atlantic croaker, are not currently well defined, nor is the length composition of the catch (**ongoing**).

- Investigate drivers of observed growth changes in the northern stock. Identification of these drivers would support definition of reference points (**short-term**).

- Investigate steepness estimates for Atlantic croaker. The southern model performed well with an estimated steepness but it was lower than published literature and inconsistent for the expected resilience and productivity of this species. Research aimed at improving understanding of recruitment process and stock-recruitment relationships may help determine whether the low estimate reflects biological processes, data limitations, or model structural assumptions (long-term).

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11 TABLES

Table 1. History of state regulations by state or jurisdiction specific to Atlantic croaker.

State/ Jurisdiction	Regulation	Date Implemented
New Jersey	Minimum 3.75” stretched diamond mesh or 3.375” stretched square mesh in beam or otter trawl cod end for directed harvest (>100 pounds)	2001
Delaware	8” total length minimum size limit	1984
	50 fish/day rec limit	2024
Maryland	10” total length minimum size limit	1960s
	9” total length minimum size limit; 20 fish recreational creel limit	1993
	9” total length minimum size limit; 20 fish recreational creel limit; commercial closure January 1–March 15	1995
	9” total length minimum size limit; 25 fish recreational creel limit; commercial closure January 1–March 15	1997
Potomac River Fisheries Commission	10” total length commercial minimum size limit	1963
	10” total length commercial and recreational minimum size limit	1982
	10” total length minimum size limit; 20 fish recreational creel limit	1996
	25 fish recreational creel limit; no size limits	1999
	25 fish rec limit; com open 1/1 to 9/30	2022
Virginia	50 fish/day rec limit, with additional charter live bait allowance; com open 1/15 to 12/15	2021
North Carolina	50 fish/day rec limit, com open 1/1 to 12/15	2021
South Carolina	Aggregate bag limit of 50 fish per person per day for small Sciaenidae species for commercial and recreational hook and line gear	2014
Georgia	8” total length minimum size limit; 25 fish/day recreational and commercial, except shrimp trawlers (no limit)	1989
	25 fish/day/angler limit in the commercial and recreational sector, except shrimp trawlers	2014
Florida	50 fish/day rec limit; 1,200 lbs commercial vessel limit	2021

Table 2. Summary of state/jurisdiction regulations for Atlantic croaker in 2024.

State/ Jurisdiction	Recreational	Commercial
New Jersey	None	Otter/beam trawl mesh restriction for directed croaker harvest (>100 lbs in possession)
Delaware	8" min; 50 fish/day; recreational gill nets (up to 200 ft.) with license	8" minimum
Maryland	9" min, 25 fish/day	9" minimum; open 3/16 to 12/31
Potomac River Fisheries Commission	9” min, 25 fish/day	Open 1/1 to 9/30; Pound net season: 2/15 to 12/15
Virginia	50 fish/day, with additional charter live bait allowance	Open 1/15 to 12/31
North Carolina	50 fish/day, recreational use of commercial gears with license and gear restrictions	Open 1/1 to 12/15
South Carolina	Small Sciaenidae species aggregate bag limit of 50 fish/day	None
Georgia	25 fish/day	25 fish/day limit except for trawlers harvesting shrimp for human consumption (no limit)
Florida	50 fish/day	1,200 commercial vessel limit

Table 3. Summary of Atlantic croaker length-at-age data from monitoring programs in the northern stock. Lengths are centerline length.

Monitoring Program	n	First Year	Last Year	Minimum Length (cm)	Maximum Length (cm)	Proportion of Length Samples ≥ 36 cm	Minimum Age	Maximum Age	Proportion of Age Samples ≥ Age-5
NEFSC*	9,356	1997	2019	8	49	0.06	0	13	0.12
NEAMAP	5,851	2007	2024	4	44	0.01	-1	11	0.06
NJFW Fisheries Dependent Sampling	3,544	2006	2016	16	50	0.08	0	12	0.23
NJFW Ocean Trawl Survey	320	2008	2022	11	44	0.02	0	7	0.17
MD DNR Fish Dealer Sampling	601	2009	2017	17	41	0.00	1	11	0.26
MD DNR Gill Net Onboard Sampling	61	2012	2012	19	34	0.00	2	6	0.13
MD DNR Pound Net Survey	3,646	2000	2022	11	46	0.05	0	13	0.32
ChesMMAP	9,226	2002	2024	2	50	0.04	-1	17	0.14
VMRC Biosampling	8,333	1998	2021	8	64	0.12	0	15	0.51
NCDMF Program 930 / FD	9,291	1979	2023	8	52	0.13	0	15	0.20
NCDMF Program 930 / FI	1,748	1979	2022	8	45	0.07	0	13	0.11
NCDMF Program 930 / Misc	4,724	1979	2021	8	53	0.15	0	15	0.18
NCDMF Program 930 / P195 Pamlico Sound Trawl Survey	2,054	1992	2023	7	30	0.00	0	5	0.00
NCDMF Program 930 / P915 Independent Gill Net Survey	4,787	2002	2023	10	52	0.03	0	13	0.08
SEAMAP*	1,956	2001	2024	11	37	0.00	0	7	<0.01

**Samples processed by SCDNR*

Table 4. Summary of Atlantic croaker length-at-age data from monitoring programs in the southern stock. Lengths are centerline length.

Monitoring Program	n	First Year	Last Year	Minimum Length (cm)	Maximum Length (cm)	Proportion of Length Samples ≥ 36 cm	Minimum Age	Maximum Age	Proportion of Age Samples ≥ Age-5
NCDMF Program 930 / FD	364	1990	2023	14	42	0.01	0	9	0.16
NCDMF Program 930 / FI	539	1997	2022	11	38	0.00	0	6	0.02
NCDMF Program 930 / Misc	337	1996	2016	12	44	0.10	0	10	0.13
NCDMF Program 930 / P915	832	2008	2023	11	46	0.00	0	6	0.01
SEAMAP*	14,112	2001	2024	6	35	0.00	0	8	0.01
SCDNR - 20' OTTER TRAWL, 1" MESH, SINGLE NET	52	2014	2014	7	15	0.00	0	1	0.00
SCDNR - COMMERCIAL SHRIMP TRAWL	4	2014	2014	22	26	0.00	2	3	0.00
SCDNR - ELECTROFISHING	12	2014	2023	10	26	0.00	0	3	0.00
SCDNR - HOOK & LINE	32	2012	2022	15	43	0.03	0	4	0.00
SCDNR - TRAMMEL NET - 200 YD X 8 FT - 14 & 2.5 IN STR MESH	467	2014	2024	13	31	0.00	0	3	0.00
Franco Thesis	2,390	2010	2012	2	32	0.00	0	4	0.00
FLORIDA RECFIN	1	2005	2005	38	38	1.00	3	3	0.00
FLORIDA SOUTHEAST REGIONAL HEADBOAT	17	2005	2021	22	40	0.06	1	4	0.00
FLORIDA SRFS	1	2023	2023	32	32	0.00	2	2	0.00
FLORIDA SRHS	17	2023	2024	21	31	0.00	0	4	0.00
FLORIDA TIP	194	2012	2024	22	45	0.24	0	6	0.07

**Samples processed by SCDNR*

Table 5. Conversion factors between length measurement types available in monitoring data estimated with linear regression. Length types are standard length (SL), centerline length (CL), and total length (TL).

Stock	Units	y	x	n	Intercept	Slope	R^2	Length Conversions		
								10	20	30
Northern	cm	TL	CL	6,064	0.22	1.01	0.996	10.3	20.5	30.6
Northern	cm	CL	TL	6,064	-0.09	0.98	0.996	9.8	19.6	29.4
Northern	cm	SL	CL	5,226	-1.26	0.87	0.997	7.5	16.2	25.0
Northern	cm	CL	SL	5,226	1.53	1.14	0.997	12.9	24.3	35.7
Northern	cm	SL	TL	86,406	-0.77	0.85	0.987	7.7	16.2	24.7
Northern	cm	TL	SL	86,406	1.26	1.16	0.987	12.9	24.5	36.1
*Southern**	*cm*	*TL*	*CL*	*33*	*5.99*	*0.81*	*0.922*	*14.1*	*22.1*	*30.2*
*Southern**	*cm*	*CL*	*TL*	*33*	*-4.79*	*1.15*	*0.922*	*6.7*	*18.1*	*29.6*
Southern	cm	SL	CL	42,083	-0.50	0.83	0.997	7.8	16.1	24.4
Southern	cm	CL	SL	42,083	0.64	1.20	0.997	12.7	24.7	36.7
*Southern**	*cm*	*SL*	*TL*	*25*	*-0.27*	*0.80*	*0.758*	*7.7*	*15.7*	*23.6*
*Southern**	*cm*	*TL*	*SL*	*25*	*6.82*	*0.96*	*0.758*	*16.5*	*26.1*	*35.8*

*Northern stock conversion factors for total lengths are recommended for southern stock fish due to low sample sizes of this length type in southern stock monitoring programs.

Table 6. Length-weight relationship parameters estimated from available monitoring data with linear regression.

Stock	Units	n	alpha	beta	R^2
Northern	weight in kg; centerline length in cm	258,106	1.16E-05	3.028	0.948
Northern	weight in g; centerline length in mm	258,106	1.09E-05	3.028	0.948
Southern	weight in kg; centerline length in cm	17,853	8.22E-06	3.069	0.969
Southern	weight in g; centerline length in mm	17,853	7.01E-06	3.069	0.969

Table 7. Mann-Kendall trend analysis results for decreasing trends in annual Atlantic croaker mean length-at-age. Data sets included at least five individual observations for each annual data point and at least four annual data points. Tests results with a p-value <0.05 were considered decreasing.

Sex	*Stock*		*Age*									
			0	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***
F	Northern	n data sets	8	8	8	9	9	9	7	6	4	2
		n decreasing	2	5	8	8	7	6	4	0	0	0
		% decreasing	25%	63%	100%	89%	78%	67%	57%	0%	0%	0%
	Southern	n data sets	6	8	7	5	1					
		n decreasing	0	1	0	0	0					
		% decreasing	0%	13%	0%	0%	0%					
M	Northern	n data sets	7	8	8	8	8	7	6	5	2	
		n decreasing	1	6	7	6	6	5	4	0	0	
		% decreasing	14%	75%	88%	75%	75%	71%	67%	0%	0%	
	Southern	n data sets	6	8	5	1						
		n decreasing	1	0	0	0						
		% decreasing	17%	0%	0%	0%						
U	Northern	n data sets	8	9	9	9	4	1	1			
		n decreasing	0	2	4	2	2	0	1			
		% decreasing	0%	22%	44%	22%	50%	0%	100%			

Table 8. Atlantic croaker growth parameter estimates from von Bertalanffy models using monitoring program length-at-age data. Confidence limits are estimated with a 10,000 replicate bootstrap analysis.

Stock	First Year	Last Year	n	L Infinity			K			t0		
				Estimate	Lower 95% CL	Upper 95% CL	Estimate	Lower 95% CL	Upper 95% CL	Estimate	Lower 95% CL	Upper 95% CL
Northern	1981	2013	32,766	41.0	40.5	41.5	0.190	0.183	0.197	-2.26	-2.33	-2.18
Northern	2014	2024	13,391	26.5	26.2	26.8	0.454	0.426	0.484	-1.49	-1.61	-1.37
Southern	1997	2024	16,119	28.1	27.5	28.8	0.357	0.330	0.384	-1.66	-1.77	-1.56

Table 9. Female Atlantic croaker maturity parameter estimates from available data sets. Bolded and underlined values indicate data used for base assessment models.

Sampling Program	Stock	State(s)	Years	n	*a*	*b*	*L50*	*L50* LCB	*L50* UCB	Notes
NEFSC Trawl	Northern	NJ-NC	1997-2019	4,608	-9.05	0.53	17.0	16.7	17.2	Brown-Peterson et al. 2011 maturity staging methods; samples processed by SCDNR
ChesMMAP Trawl	Northern	MD-VA	2002-2024	3,443	-6.91	0.36	19.1	18.8	19.3	Brown-Peterson et al. 2011 maturity staging methods
NEAMAP Trawl	Northern	NJ-NC	2007-2024	2,390	***-11.45***	***0.67***	***17.1***	***16.9***	***17.3***	Brown-Peterson et al. 2011 maturity staging methods
NC Maturity Study	Northern	NC	2016-2018	58	NA	NA	NA	NA	NA	Brown-Peterson et al. 2011 maturity staging methods; glm did not converge
SEAMAP Trawl	Southern	NC-FL	2001-2012	2,156	***-10.45***	***0.58***	***17.9***	***17.7***	***18.1***	Brown-Peterson et al. 2011 maturity staging methods
NC Maturity Study	Southern	NC	2017	19	-13.85	0.62	22.4	19.0	25.7	Brown-Peterson et al. 2011 maturity staging methods
SC Trammel	Southern	SC	1996-2023	320	-2.98	0.19	15.9	-4.3	18.9	Brown-Peterson et al. 2011 maturity staging methods; failed specification test; minimum size 18 cm
Franco Thesis	Southern	GA	2010-2012	479	-10.30	0.65	15.9	15.4	16.3	Barbieri et al. 1994 maturity staging methods

Table 10. Sex ratio by data set for Atlantic croaker in the northern stock.

Sampling Agency	Data Type	Males	Females	Total	Proportion Males	Proportion Females	Sex Ratio F:M
ChesMMAP	FI	3,757	4,962	8,719	0.43	0.57	1.32
MD DNR Dependent Surveys	FD	1,549	2,972	4,521	0.34	0.66	1.92
NCDMF Dependent Surveys	FD	1,900	3,510	5,410	0.35	0.65	1.85
NCDMF Independent Surveys	FI	937	3,059	3,996	0.23	0.77	3.26
NEAMAP	FI	2,772	3,401	6,173	0.45	0.55	1.23
NEFSC	FI	5,093	5,580	10,673	0.48	0.52	1.10
NJFW Dependent Surveys	FD	90	158	248	0.36	0.64	1.76
NJFW Independent Surveys	FI	131	107	238	0.55	0.45	0.82
SEAMAP	FI	852	1,050	1,902	0.45	0.55	1.23
VA Surveys	both	13,393	26,849	40,242	0.33	0.67	2.00
Fishery Dependent (Combined)	FD	3,539	6,640	10,179	0.35	0.65	1.88
Fishery Independent (Combined)	FI	13,542	18,159	31,701	0.43	0.57	1.34
Total	-	30,474	51,648	82,122	0.37	0.63	1.69

Table 11. Sex ratio by data set for Atlantic croaker in the southern stock.

Sampling Program	Data Type	Males	Females	Total	Proportion Males	Proportion Females	Sex Ratio F:M
Southeast Regional Headboat Survey	FD	13	16	29	0.45	0.55	1.23
SEAMAP	FI	6,930	9,743	16,673	0.42	0.58	1.41
SCDNR Dependent Sampling	FD	3	5	8	0.38	0.63	1.67
SCDNR Independent Sampling	FI	93	604	697	0.13	0.87	6.49
GADNR Dependent Sampling	FD	8	29	37	0.22	0.78	3.63
Fishery Dependent (Combined)	FD	24	50	74	0.32	0.68	2.08
Fishery Independent (Combined)	FI	7,023	10,347	17,370	0.40	0.60	1.47
Total	-	7,047	10,397	17,444	0.40	0.60	1.48

Table 12. Natural mortality-at-length of Atlantic croaker in the northern and southern Atlantic stocks. Estimates of *M* were determined followed Lorenzen (2022) and then scaled based on the constant *M* estimate developed by Hamel and Cope (2022). The northern stock was separated by time blocks that corresponded to the different growth blocks.

	Northern Stock						Southern Stock		
	1981-2013			2014-2024			1990-2024		
Age (yr)	Length (cm)	*M*	Scaled *M*	Length (cm)	*M*	Scaled *M*	Length (cm)	*M*	Scaled *M*
0	14.3	0.573	0.852	13.0	0.795	0.961	12.6	1.101	1.319
1	18.9	0.433	0.644	17.9	0.576	0.697	17.2	0.803	0.962
2	22.7	0.360	0.535	21.0	0.491	0.594	20.5	0.675	0.809
3	25.9	0.316	0.470	23.0	0.449	0.543	22.8	0.607	0.728
4	28.5	0.287	0.427	24.3	0.425	0.514	24.4	0.567	0.680
5	30.7	0.267	0.397	25.1	0.412	0.498	25.5	0.543	0.650
6	32.4	0.252	0.375	25.6	0.404	0.488	26.3	0.526	0.631
7	33.9	0.241	0.359	25.9	0.399	0.482	26.8	0.516	0.618
8	35.1	0.233	0.346	26.1	0.396	0.478	27.2	0.508	0.609
9	36.2	0.226	0.336	26.2	0.394	0.476			
10	37.0	0.221	0.329	26.3	0.392	0.474			
11	37.7	0.217	0.323	26.4	0.392	0.473			
12	38.3	0.214	0.318						
13	38.7	0.211	0.314						
14	39.1	0.209	0.311						
15	39.4	0.207	0.308						

Table 13. Dissolved oxygen levels from published literature relevant to Atlantic croaker.

Threshold Level	Process	Life Stage	Source
<2 mg/L	Hypoxia	NA	Thomas and Rahman 2009; Tuckey and Fabrizio 2016; Rose et al. 2018a
≤2.7 mg/L	Reduced fecundity	Adults	Thomas et al. 2007
<1.7– 2.7 mg/L	Behavioral avoidance	Juveniles	Eby and Crowder 2002; Craig and Crowder 2005; Craig 2012
<1.5 mg/L*	Reduced somatic growth*	Juveniles*	McNatt and Rice 2004*
<≈1 mg/L*	Mortality*	All, threshold dependent on size*	Shimps et al. 2005*
<≈2 mg/L	Standard metabolic rate (i.e., the minimum metabolic rate necessary for the maintenance of homeostasis)	Adults	Marcek et al. 2019

** Study of closely related species (spot)*

Table 14. Summary of the multiple linear regression to predict Atlantic croaker recruitment in the Chesapeake Bay. Estimated coefficients for each variable are reported. Significant explanatory variables. are denoted with an asterisk (p<0.05)

	Dependent variable:	YOY Residual
Independent Variable	Intercept	Standard error
Constant	-1,894.485	1,135.992
Year	1.087*	0.562
Salinity (Jan-Mar)	-10.349**	4.085
Temperature Days <3 (Jan-Mar)	-2.424***	0.558
Total Area DO< 5 mg/L (Sept-Nov)	-0.0001**	0.0001
R^2	0.451	
Adjusted R^2	0.382	

Table 15. Summary of NOAA Fisheries Southeast Gillnet Observer program discard data for Atlantic croaker. Discard CPUE is calculated as the total number of discarded Atlantic croaker (alive and dead) per set.

Gear	Target Species	Year	Area	n Observed Sets	Total Number Caught	% Kept	% Discarded Alive	% Discarded Dead	Discard CPUE
Sink Gillnet	Spanish Mackerel	2018	central FL	55	4	100	0	0	0.00
Sink Gillnet	Spanish Mackerel	2017	central FL	63	2	100	0	0	0.00
Sink Gillnet	Spanish Mackerel	2016	northern NC and central FL	147	4	75	25	0	0.01
Sink Gillnet	Atlantic Croaker	2016	northern NC	13	13,219	99.67	0.07	0.26	3.36
Sink Gillnet	Southern Kingfish	2016	northern NC	12	15	100	0	0	0.00
Sink Gillnet	Spanish Mackerel	2015	northern NC and central FL	131	1	100	0	0	0.00
Sink Gillnet	Southern Kingfish	2015	NC	34	506	99	0	1	0.15
Sink Gillnet	Spanish Mackerel	2014	northern NC and central FL	129	22	66.7	26.7	6.7	0.06
Sink Gillnet	Mixed Teleost and Shark	2014	northern NC and central FL	57	2,938	100	0	0	0.00

Table 16. Commercial landings data collection methodology by Atlantic coast state.

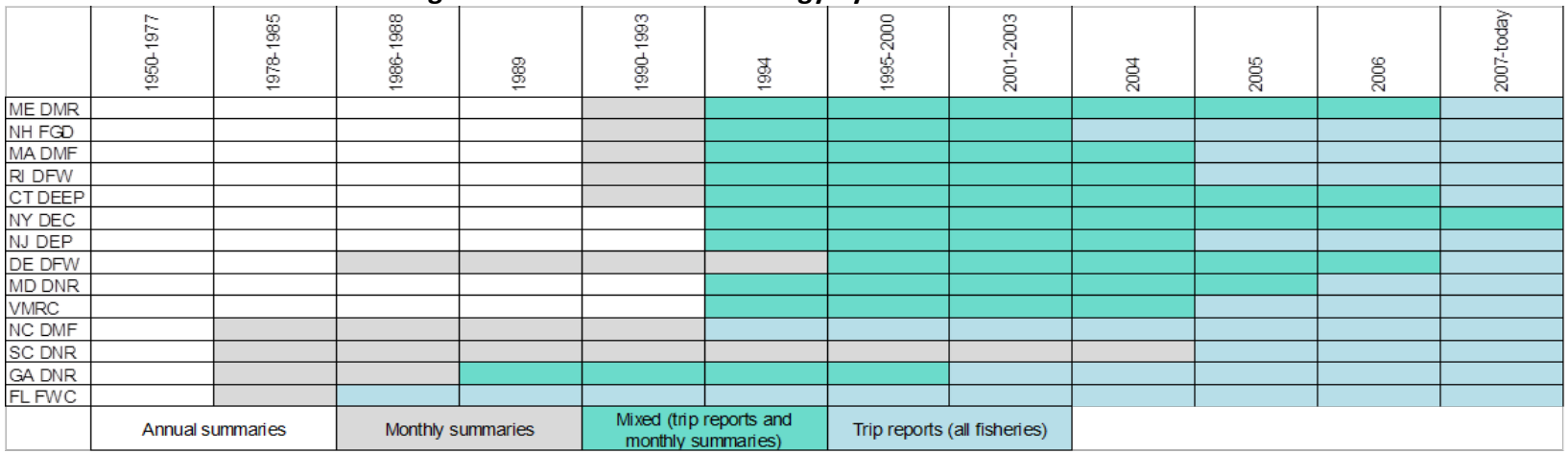


Table 17. Commercial landings (pounds) of Atlantic croaker by stock and fleet.

Year	All	Year	Northern	Southern			All
	All		All	NC_GA	FL	All	All
1950	11,422,077	1989	7,509,145	490,784	95,021	585,805	8,094,950
1951	8,374,283	1990	5,417,101	556,086	104,401	660,487	6,077,588
1952	6,102,988	1991	3,116,965	523,239	56,739	579,978	3,696,943
1953	6,257,287	1992	3,875,094	324,079	79,040	403,119	4,278,213
1954	7,611,985	1993	8,676,987	143,725	52,031	195,756	8,872,742
1955	14,091,572	1994	10,801,527	49,440	96,051	145,491	10,947,018
1956	16,561,267	1995	14,346,448	58,472	22,739	81,211	14,427,659
1957	18,916,762	1996	21,818,320	17,103	26,046	43,149	21,861,470
1958	19,606,061	1997	27,930,735	18,118	41,818	59,936	27,990,672
1959	11,655,277	1998	24,890,548	22,829	26,439	49,268	24,939,816
1960	6,781,286	1999	26,902,142	8,054	26,825	34,879	26,937,021
1961	5,097,590	2000	27,818,230	10,331	37,968	48,299	27,866,529
1962	3,167,494	2001	30,126,073	8,552	14,831	23,383	30,149,455
1963	2,549,495	2002	26,479,585	12,528	17,193	29,721	26,509,306
1964	2,375,395	2003	28,814,353	5,378	16,445	21,823	28,836,176
1965	3,397,693	2004	24,874,443	9,564	11,413	20,977	24,895,421
1966	3,065,794	2005	23,477,521	4,947	16,520	21,467	23,498,989
1967	1,756,496	2006	22,259,482	4,171	30,272	34,443	22,293,925
1968	1,276,797	2007	19,877,238	8,333	27,028	35,361	19,912,599
1969	1,484,097	2008	19,483,797	10,479	31,560	42,039	19,525,836
1970	1,010,398	2009	16,219,358	10,248	32,313	42,561	16,261,919
1971	1,305,297	2010	16,207,259	22,017	36,960	58,977	16,266,236
1972	4,697,820	2011	12,065,330	29,062	44,977	74,039	12,139,368
1973	5,876,856	2012	11,608,801	19,144	74,023	93,167	11,701,968
1974	7,862,830	2013	9,855,872	19,062	76,416	95,478	9,951,350
1975	16,564,262	2014	7,954,038	22,589	45,354	67,943	8,021,981
1976	22,793,329	2015	6,358,646	20,090	37,112	57,201	6,415,847
1977	29,831,919	2016	5,806,200	15,442	55,155	70,597	5,876,797
1978	29,344,137	2017	3,551,563	33,460	42,394	75,854	3,627,417
1979	22,960,496	2018	3,694,006	31,063	53,891	84,954	3,778,960
1980	21,939,337	2019	1,829,228	35,118	68,247	103,365	1,932,593
1981	11,736,509	2020	680,154	41,308	95,864	137,172	817,326
1982	11,049,251	2021	801,799	54,038	124,632	178,670	980,469
1983	7,486,799	2022	515,111	51,907	104,545	156,453	671,564
1984	10,211,857	2023	312,390	66,361	101,578	167,939	480,329
1985	11,061,494	2024	724,594	53,713	97,648	151,361	875,955
1986	12,210,177						
1987	10,705,586						
1988	10,455,525						

Table 18. Atlantic croaker landings (metric tons) in the scrap fishery by state/region. Northern_NC and Southern_NC are the northern and southern regions of North Carolina as defined in Section 2.1.6.

Year	Virginia	Northern_NC	Southern_NC
1994	393.7	898.4	6.0
1995	374.1	1052.6	250.0
1996	519.1	763.8	3.8
1997	183.0	786.1	2.8
1998	117.0	895.8	1.0
1999	552.3	506.9	0.1
2000	828.2	448.8	8.7
2001	313.1	783.6	0.0
2002	180.0	605.8	42.9
2003	101.7	905.4	82.3
2004	208.8	520.2	100.8
2005	22.8	293.1	77.8
2006	66.4	410.2	7.3
2007	183.8	525.6	8.8
2008	110.3	737.3	43.7
2009	34.9	356.1	0.0
2010	64.9	779.5	0.0
2011	114.9	384.9	16.6
2012	109.6	107.7	11.6
2013	12.3	41.8	0.0
2014	38.6	17.6	36.9
2015	0.8	96.2	49.7
2016	0.0	5.5	0.3
2017	1.4	91.4	1.6
2018	0.2	0.0	6.9
2019	9.3	0.4	26.9
2020	3.6	0.0	71.0
2021	0.0	0.0	0.0
2022	0.4	5.2	8.3
2023	0.0	0.0	0.0
2024	0.0	0.0	0.0

Table 19. Number of biosampling trips used for commercial length composition data.

Year	Northern Stock				Southern Stock
	MD	NC	VA	Total	NC
1994	27	142	256	425	5
1995	38	170	157	365	5
1996	22	200	195	417	25
1997	25	159	222	406	18
1998	25	183	212	420	20
1999	15	202	102	319	12
2000	12	230	81	323	23
2001	7	247	109	363	38
2002	9	218	252	479	13
2003	15	166	229	410	5
2004	14	185	217	416	11
2005	27	206	319	552	14
2006	22	240	380	642	8
2007	31	201	141	373	16
2008	22	182	124	328	31
2009	19	212	245	476	23
2010	22	207	190	419	16
2011	20	175	198	393	20
2012	26	167	264	457	15
2013	19	141	282	442	30
2014	18	186	255	459	61
2015	12	165	241	418	52
2016	11	141	243	395	46
2017	16	85	213	314	36
2018	7	54	180	241	33
2019	11	72	159	242	55
2020	4	59	41	104	29
2021	14	91	46	151	38
2022	7	74	50	131	39
2023	7	76	40	123	56
2024	3	49	40	92	38

Table 20. Gears in the NEFOP data set used to estimate Atlantic croaker discards for the 2017 benchmark stock assessment. Gears in italics were not used in this assessment for NEFOP discards due to limited Atlantic croaker landings or discards in those gears.

GILL NET, ANCHORED-FLOATING, FISH
GILL NET, DRIFT-FLOATING, FISH
GILL NET, DRIFT-SINK, FISH
GILL NET, FIXED OR ANCHORED, SINK, OTHER/NK SPECIES
TRAWL, OTTER, BOTTOM, FISH
TRAWL, OTTER, BOTTOM, SCALLOP
TRAWL, OTTER, BOTTOM, TWIN

Table 21. Total all species landings in pounds by statistical area and gear in the ACCSP query for 1989-2022. Gears in italics were provided by ACCSP not used to scale up the NEFOP discard estimates due to their limited interaction with Atlantic croaker based on the NEFOP analysis.

ACCSP Gear	621	625	631	635	636
GILL NETS, DRIFT, SMALL MESH	*6,090*				
GILL NETS, FLOATING ANCHOR	*2,123,450*	*438,692*	*2,724,158*	*13,217,330*	*5,346*
GILL NETS, FLOATING DRIFT	*14,352,652*	*88,841,278*	*1,371,812*	*5,845,625*	*123,793*
GILL NETS, OTHER	2,326,231	3,124,457	10,693,169	7,096,290	
GILL NETS, SINK ANCHOR	11,580,548	222,284,248	71,130,483	305,097,081	
GILL NETS, SINK DRIFT	873,091	1,343			
GILL NETS, STAKE	3,937,256	4,641,300	37,507		
NOT CODED	18,356,213	647,155,682	389,428	35,019	
OTTER TRAWL BOTTOM, CRAB	45,138	49,443	1,702	34,937,397	
OTTER TRAWL BOTTOM, FISH	74,636,438	11,406,290	9,128,285	97,732,339	267,781
OTTER TRAWL BOTTOM, OTHER	9,491			500	
OTTER TRAWL BOTTOM, PAIRED			3,475		
OTTER TRAWL BOTTOM, SCALLOP	872,155	7,792	251	3,491,740	
OTTER TRAWL, PEELER				*843*	
OTTER TRAWL, TWIN				*203,134*	

Table 22. Species used in the commercial bycatch analysis for Atlantic croaker. Species were selected that comprised at least 0.1% of all species landed on trips that discarded Atlantic croaker in the NEFOP database and what percentage of landings they comprised. Species were then matched with the ACCSP database. Shrimp and hermit crabs were excluded from the analysis.

NEFOP Species	% of all NEFOP landings in weight	ACCSP Species
CROAKER, ATLANTIC	53.3%	CROAKER, ATLANTIC
CRAB, HORSESHOE	31.9%	CRAB, HORSESHOE
FLOUNDER, SUMMER (FLUKE)	3.2%	FLOUNDER, SUMMER
SPOT	2.2%	SPOT
WEAKFISH (SQUETEAGUE SEA TROUT)	2.1%	WEAKFISH
DOGFISH, SPINY	0.9%	SHARK, DOGFISH, SPINY
SKATE, CLEARNOSE	0.8%	SKATE, CLEARNOSE
MENHADEN, ATLANTIC	0.6%	MENHADENS
BLUEFISH	0.6%	BLUEFISH
DOGFISH, SMOOTH	0.5%	SHARK, DOGFISH, SMOOTH
BASS, STRIPED	0.4%	BASS, STRIPED
BUTTERFISH	0.3%	BUTTERFISH
KINGFISH, SOUTHERN	0.3%	KINGFISH, SOUTHERN; KINGFISHES
WHELK, MELONGENIDAE, NK	0.3%	WHELKS
MACKEREL, SPANISH	0.3%	MACKEREL, SPANISH
SKATE, NK	0.3%	SKATES, RAJIDAE (FAMILY)
KINGFISH, NORTHERN	0.2%	KINGFISH, NORTHEN; KINGFISHES
SHARK, SANDBAR (BROWN SHARK)	0.2%	SHARK, SANDBAR
WHELK, KNOBBED	0.2%	WHELK, KNOBBED; WHELKS
KINGFISH, NK	0.2%	KINGFISHES
CUTLASSFISH, ATL	0.2%	CUTLASSFISH, ATLANTIC
WHELK, CHANNELED (SMOOTH)	0.1%	WHELK, CHANNELED; WHELK
CRAB, HERMIT, NK	0.1%	
SHEEPSHEAD	0.1%	SHEEPSHEAD
SQUID, ATL LONG-FIN	0.1%	SQUID, LONGFIN LOLIGO
SHRIMP, PENAEID (SOUTHERN)	0.1%	
SKATE, WINTER (BIG)	0.1%	SKATE, WINTER
LOBSTER, AMERICAN	0.1%	LOBSTER, AMERICAN
MONKFISH (GOOSEFISH)	0.1%	GOOSEFISH

Table 23. Estimated ratios and coefficient of variation (CV) of discarded Atlantic croaker to total landings of species from observed gill nets and trawls and Atlantic croaker discard estimates in pounds with lower (LCI) and upper (UCI) 95% confidence intervals for, 1989-2023. Blank cells indicate years with no data.

Year	Gill Nets					Trawls				
	Ratio	Ratio CV	Discards (lbs)	Discards LCI	Discards UCI	Ratio	Ratio CV	Discards (lbs)	Discards LCI	Discards UCI
1989										
1990										
1991						0.0004	0.7022	2,507	0	5,957
1992						0	0	0	0	0
1993	0.0041	0.3340	44,095	15,226	72,963	0.0305	0.5028	52,719	761	104,677
1994	0.0018	0.4044	20,792	4,314	37,270	0.0004	0.4868	96	4	188
1995	0.0008	0.1471	8,074	5,746	10,401	0.0001	0.7295	2	0	5
1996	0.0015	0.1990	37,334	22,770	51,897	0.0001	0.6513	8	0	19
1997	0.0007	0.3306	18,112	6,374	29,850	0.0028	0.5038	420	5	834
1998	0.0002	0.3670	6,071	1,703	10,438	0	0	0	0	0
1999	0.0020	0.5721	44,548	0	94,500	0.0098	0.8634	6,070	0	16,343
2000	0.0015	0.2069	36,218	21,533	50,902	0.0003	0.7146	211	0	507
2001	0.0068	0.6425	145,267	0	328,207	0	0	0	0	0
2002	0.0005	0.5734	8,264	0	17,551	0	0	0	0	0
2003	0.0019	0.3035	32,350	13,105	51,594	0	0	0	0	0
2004	0.0098	0.8569	164,685	0	441,289	0.0000	1.0329	13	0	39
2005	0	0	0	0	0	0.0007	1.0332	825	0	2,495
2006	0	0	0	0	0	0.0000	0.9720	0	0	1
2007	0.0001	0.7442	1,417	0	3,483	0.0330	0.7353	11,195	0	27,328
2008	0.0002	0.5600	2,719	0	5,704	0.0237	0.6072	20,111	0	44,046
2009	0.0004	0.5560	5,213	0	10,893	0.0179	0.4939	9,117	291	17,943
2010	0.0000	0.7385	412	0	1,009	0.0149	0.3947	5,021	1,137	8,905
2011	0	0	0	0	0	0.0108	0.8055	1,858	0	4,791
2012	0	0	0	0	0	0.0110	0.7176	3,422	0	8,235
2013	0.0000	1.0580	180	0	553	0.1225	0.5151	108,182	0	217,403
2014	0.0003	0.4389	3,792	530	7,055	0.2730	0.4991	76,064	1,659	150,469
2015	0.0012	0.1846	12,775	8,152	17,398	0.1452	0.7607	9,701	0	24,166
2016	0.0004	0.2117	2,616	1,530	3,702	0.3731	0.1680	18,572	12,456	24,689
2017	0.0004	0.1548	2,489	1,734	3,244	0.5886	0.1886	12,502	7,882	17,122
2018	0.0006	0.1882	2,785	1,758	3,813	0	0	0	0	0
2019	0.0011	0.1877	6,140	3,881	8,398	0	0	0	0	0
2020	0.0000	1.0028	2	0	7					
2021	0.0008	0.4780	2,450	155	4,745					
2022	0	0	0	0	0					
2023	0	0	0	0	0	0	0	0	0	0

Table 24. Number of length samples in NEFOP by gear and year.

Year	Gill Nets	Trawls	Total
1989	0	0	0
1990	0	0	0
1991	0	0	0
1992	0	0	0
1993	0	77	77
1994	0	0	0
1995	8	207	215
1996	0	98	98
1997	70	52	122
1998	0	110	110
1999	1	49	50
2000	128	0	128
2001	88	1518	1606
2002	5	147	152
2003	23	287	310
2004	11	167	178
2005	0	10	10
2006	12	0	12
2007	1	86	87
2008	0	89	89
2009	2	137	139
2010	0	390	390
2011	0	4	4
2012	0	0	0
2013	15	143	158
2014	2	71	73
2015	29	73	102
2016	5	134	139
2017	6	7	13
2018	39	2	41
2019	24	0	24
2020	1	0	1
2021	0	0	0
2022	0	0	0

Table 25. South Atlantic Shrimp Observer Program number of tows observed, proportion positive observations, and CPUE (numbers of fish per net hour) mean and standard deviation for Atlantic croaker by factor level considered in discard rate models.

Season	***n***	***Proportion Positive***	***Mean CPUE***	***CPUE SD***
Off	974	0.88	212	554
Peak	5,130	0.81	364	657
Depth	***n***	***Proportion Positive***	***Mean CPUE***	***CPUE SD***
=<10m	3,346	0.92	467	771
10-30m	1,829	0.96	276	454
>30m	929	0.16	3	15
Fishery	***n***	***Proportion Positive***	***Mean CPUE***	***CPUE SD***
penaeid_shrimp	5,173	0.94	400	682
rock_shrimp	931	0.16	3	15
Area	***n***	***Proportion Positive***	***Mean CPUE***	***CPUE SD***
NC_north	1,266	0.97	944	960
NC_south	81	1.00	512	796
SC	993	0.92	226	496
GA	1,017	0.87	129	290
FL	2,747	0.69	174	375
Year	***n***	***Proportion Positive***	***Mean CPUE***	***CPUE SD***
2008	350	0.68	442	708
2009	477	0.94	230	427
2010	245	0.68	511	861
2011	320	0.76	298	566
2012	372	0.94	527	886
2013	391	0.80	561	926
2014	210	0.81	354	561
2015	327	0.85	106	184
2016	483	0.77	363	657
2017	415	0.86	262	435
2018	410	0.99	468	628
2019	222	0.85	352	792
2020	363	0.98	469	693
2021	732	0.79	184	363
2022	434	0.59	76	194
2023	25	1.00	440	547
2024	328	0.76	485	901

Table 26. Model AIC for sub-models of delta model used to estimate Atlantic croaker discard rate from south Atlantic Shrimp Observer Program data. The lowest AIC is bolded for each sub-model.

Factor Excluded	Binomial	Lognormal
<none>	3,467.7	**18,283.8**
YEAR	3,646.9	18,657.8
data_set	**3,466.2**	18,287.4
depth_zone	3,499.8	18,327.5
state	3,591.8	19,480.6
season	3,528.6	18,554.2

Table 27. Shrimp trawl fishery effort and discards of Atlantic croaker in the northern stock. Bolded values are estimates used in assessment model.

Year	Hours Fished (thousands)	Discards with Observer CPUE Only (millions)	Discards with SEAMAP CPUE (millions)	Observer Only: With SEAMAP Ratio	Discards Hindcast (millions)	Discards 95% LCB (millions)	Discards 95% UCB (millions)
1990	339		399		**258**		
1991	500		1,115		**723**		
1992	203		262		**170**		
1993	347		259		**168**		
1994	354		322		**209**		
1995	375		328		**213**		
1996	262		177		**115**		
1997	248		71		**46**		
1998	163		118		**76**		
1999	221		158		**102**		
2000	215		97		**63**		
2001	160		140		**91**		
2002	205		105		**68**		
2003	165		118		**76**		
2004	142		158		**102**		
2005	28		28		**18**		
2006	88		162		**105**		
2007	148		121		**79**		
2008	126	**228**	206	1.11		180	287
2009	112	**131**	149	0.88		107	161
2010	99	**152**	155	0.98		114	201
2011	82	**98**	201	0.49		75	127
2012	118	**145**	223	0.65		118	178
2013	110	**297**	290	1.02		239	368
2014	112	**175**	361	0.49		135	228
2015	142	**117**	271	0.43		93	147
2016	167	**210**	341	0.62		169	261
2017	180	**236**	290	0.81		188	295
2018	135	**385**	513	0.75		316	470
2019	102	**218**	513	0.43		167	286
2020	119	**240**	388	0.62		194	298
2021	118	**155**	215	0.72		126	190
2022	55	**22**	78	0.28		16	28
2023	67	**151**				83	272
2024	75	**247**				194	316

Table 28. Shrimp trawl fishery effort and discards of Atlantic croaker in the southern stock. Bolded values are estimates used in assessment model.

Year	Hours Fished (thousands)	Discards with Observer CPUE Only (millions)	Discards with SEAMAP CPUE (millions)	Observer Only: With SEAMAP Ratio	Discards Hindcast (millions)	Discards LCI (millions)	Discards UCI (millions)
1990	2,944		713		**332**		
1991	3,199		1,499		**698**		
1992	2,395		503		**234**		
1993	2,879		394		**183**		
1994	3,319		586		**273**		
1995	3,267		557		**259**		
1996	2,859		359		**167**		
1997	3,034		141		**66**		
1998	2,790		369		**172**		
1999	2,823		336		**156**		
2000	2,180		176		**82**		
2001	1,884		317		**148**		
2002	1,455		134		**63**		
2003	1,592		246		**115**		
2004	1,225		290		**135**		
2005	783		132		**62**		
2006	929		356		**166**		
2007	875		162		**75**		
2008	850	**256**	301	0.85		186	354
2009	824	**178**	267	0.67		136	234
2010	919	**249**	332	0.75		171	364
2011	925	**172**	479	0.36		123	240
2012	1,146	**228**	488	0.47		170	307
2013	732	**379**	520	0.73		285	507
2014	614	**157**	453	0.35		111	223
2015	667	**99**	312	0.32		73	134
2016	626	**156**	346	0.45		112	219
2017	761	**177**	300	0.59		129	244
2018	397	**217**	397	0.55		164	289
2019	816	**285**	963	0.30		207	396
2020	733	**252**	585	0.43		189	338
2021	661	**142**	257	0.55		109	188
2022	518	**31**	155	0.20		22	44
2023	472	**192**				104	355
2024	492	**234**				170	324

Table 29. Atlantic croaker recreational catch estimates in millions of fish.

Year	Harvest					Releases				
	Northern	Southern			All	Northern	Southern			All
	All	NC-GA	FL	All	All	All	NC-GA	FL	All	All
1982	0.84	1.53	7.32	8.86	9.70	0.37	1.44	0.83	2.26	2.63
1983	4.86	0.95	3.83	4.78	9.65	5.66	0.65	1.03	1.68	7.35
1984	6.83	2.74	7.03	9.77	16.60	3.02	3.79	0.97	4.76	7.78
1985	6.08	2.00	6.14	8.14	14.21	5.17	2.42	9.56	11.98	17.15
1986	9.48	3.40	23.35	26.75	36.23	4.43	0.65	1.17	1.82	6.26
1987	7.26	0.70	20.56	21.27	28.53	4.70	0.47	14.65	15.12	19.82
1988	10.41	1.75	2.73	4.47	14.89	3.09	0.77	0.61	1.39	4.47
1989	7.56	3.38	1.66	5.04	12.60	5.31	0.79	0.27	1.06	6.37
1990	5.49	2.68	1.03	3.71	9.20	9.82	1.76	0.83	2.60	12.41
1991	9.13	1.35	2.24	3.59	12.73	21.50	0.82	1.70	2.52	24.03
1992	12.65	2.54	2.60	5.14	17.78	13.63	1.59	0.61	2.20	15.83
1993	14.83	1.06	1.20	2.27	17.10	21.80	0.71	0.50	1.21	23.01
1994	16.05	0.91	1.70	2.61	18.66	19.60	0.99	1.13	2.12	21.72
1995	13.24	1.10	1.02	2.12	15.35	12.11	0.91	0.41	1.32	13.42
1996	11.21	0.84	0.35	1.19	12.39	11.21	0.82	0.59	1.41	12.62
1997	15.91	0.61	0.64	1.25	17.15	17.55	0.81	0.25	1.07	18.62
1998	15.75	1.01	0.99	1.99	17.74	18.51	1.54	0.60	2.13	20.64
1999	16.12	0.96	2.25	3.21	19.33	22.03	1.27	9.95	11.22	33.25
2000	15.86	0.50	1.61	2.11	17.97	24.66	1.22	1.53	2.75	27.41
2001	17.49	0.51	1.85	2.36	19.85	16.66	1.04	1.07	2.10	18.77
2002	20.09	0.85	0.74	1.60	21.69	21.68	1.86	0.89	2.76	24.44
2003	18.02	1.70	0.66	2.36	20.38	18.56	4.43	0.62	5.06	23.61
2004	18.14	0.82	1.70	2.52	20.66	16.98	3.10	1.09	4.19	21.18
2005	17.34	0.94	1.07	2.01	19.35	22.99	3.20	1.35	4.55	27.54
2006	15.27	1.17	0.72	1.89	17.16	17.34	5.97	0.83	6.80	24.14
2007	15.94	0.53	2.11	2.65	18.59	21.09	2.69	2.79	5.48	26.57
2008	15.98	0.58	1.06	1.64	17.62	24.47	2.45	1.74	4.19	28.67
2009	15.80	1.49	2.25	3.75	19.55	24.36	4.51	2.02	6.53	30.89
2010	17.17	0.62	0.47	1.09	18.27	20.93	2.88	1.01	3.90	24.83
2011	11.34	1.34	2.59	3.93	15.27	20.52	3.99	2.56	6.55	27.07
2012	12.90	0.58	2.19	2.77	15.66	29.12	3.21	3.00	6.21	35.33
2013	18.71	1.28	1.33	2.61	21.33	35.03	7.73	1.27	9.00	44.03
2014	14.52	1.69	1.36	3.05	17.58	19.74	12.63	2.27	14.89	34.64
2015	11.31	1.91	2.43	4.34	15.65	13.66	9.13	2.45	11.59	25.24
2016	8.64	1.11	3.55	4.66	13.30	12.06	9.86	4.07	13.93	25.99
2017	8.58	1.36	0.97	2.33	10.91	14.63	7.50	1.77	9.27	23.89
2018	6.13	0.82	1.18	2.00	8.12	7.60	9.48	1.07	10.55	18.15
2019	3.42	1.34	0.80	2.14	5.56	9.99	7.33	2.26	9.59	19.59
2020	7.28	1.34	2.01	3.35	10.63	11.91	17.79	2.06	19.85	31.76
2021	2.60	1.67	0.95	2.63	5.23	11.25	15.02	1.36	16.38	27.63
2022	3.07	1.16	0.94	2.10	5.17	14.07	13.53	2.90	16.44	30.50
2023	2.89	1.73	0.89	2.62	5.51	14.73	18.98	1.17	20.15	34.88
2024	2.27	1.35	0.82	2.16	4.43	15.12	13.65	1.63	15.28	30.41

Table 30. Proportional standard errors for Atlantic croaker recreational catch estimates.

Year	Harvest			Releases		
	Northern	Southern		Northern	Southern	
	All	NC-GA	FL	All	NC-GA	FL
1982	26%	19%	31%	39%	40%	39%
1983	22%	22%	21%	17%	22%	32%
1984	28%	23%	42%	18%	59%	43%
1985	14%	19%	40%	16%	53%	73%
1986	11%	22%	89%	12%	21%	67%
1987	18%	18%	71%	14%	20%	90%
1988	18%	35%	57%	20%	24%	52%
1989	12%	15%	48%	11%	20%	25%
1990	13%	16%	33%	15%	30%	30%
1991	20%	23%	30%	12%	13%	34%
1992	15%	13%	20%	11%	15%	27%
1993	12%	23%	23%	13%	24%	25%
1994	10%	14%	24%	7%	19%	25%
1995	12%	32%	37%	10%	21%	27%
1996	13%	27%	34%	13%	19%	52%
1997	12%	15%	37%	10%	21%	35%
1998	15%	26%	38%	8%	12%	26%
1999	11%	19%	38%	7%	21%	72%
2000	9%	21%	23%	7%	18%	22%
2001	9%	21%	23%	7%	16%	21%
2002	9%	20%	28%	7%	17%	21%
2003	8%	20%	26%	7%	16%	21%
2004	16%	19%	22%	10%	14%	27%
2005	11%	28%	39%	10%	15%	27%
2006	18%	30%	30%	10%	16%	25%
2007	10%	20%	54%	7%	13%	62%
2008	13%	21%	29%	9%	13%	27%
2009	11%	28%	20%	10%	11%	16%
2010	13%	16%	23%	9%	11%	22%
2011	13%	19%	30%	9%	14%	21%
2012	12%	18%	24%	12%	16%	24%
2013	12%	16%	33%	7%	8%	34%
2014	11%	14%	34%	8%	13%	24%
2015	17%	18%	26%	9%	11%	34%
2016	13%	15%	43%	11%	15%	38%
2017	15%	16%	50%	12%	11%	53%
2018	19%	15%	26%	12%	11%	28%
2019	14%	17%	59%	13%	15%	41%
2020	17%	14%	28%	9%	14%	47%
2021	17%	12%	44%	10%	11%	25%
2022	19%	16%	20%	13%	13%	30%
2023	19%	16%	37%	13%	15%	24%
2024	18%	18%	28%	13%	16%	20%

Table 31. Number of MRIP primary sampling units that encountered Atlantic croaker for length measurements.

Year	Northern	Southern	Southern
	All	NC-GA	FL
1982	18	58	53
1983	62	40	48
1984	49	51	49
1985	163	149	31
1986	219	63	19
1987	121	83	21
1988	96	71	21
1989	193	112	15
1990	121	91	8
1991	141	48	18
1992	166	111	32
1993	191	38	29
1994	449	56	31
1995	278	67	22
1996	286	39	7
1997	331	45	11
1998	390	62	26
1999	337	22	36
2000	332	29	38
2001	393	37	42
2002	385	31	24
2003	408	55	16
2004	331	37	25
2005	400	28	15
2006	245	32	21
2007	305	28	27
2008	294	50	23
2009	262	56	39
2010	317	44	25
2011	228	45	25
2012	199	34	38
2013	323	58	22
2014	254	56	17
2015	249	63	25
2016	183	53	18
2017	160	51	21
2018	146	60	12
2019	123	55	11
2020	166	68	19
2021	142	74	20
2022	126	49	25
2023	62	56	13
2024	82	46	26

Table 32. Fishery-independent surveys considered for use in the Atlantic Croaker stock assessment. Surveys that were accepted for use are described in the stock assessment report. Reasons surveys were rejected from the stock assessment are provided.

State	Region	Survey	Considered	Modeled	Rejected	Reason(s) Rejected
NC-MA	Northern	NEFSC Trawl		X		
NC-MA	Northern	NEAMAP		X		
MD-VA	Northern	ChesMMAP		X		
VA	Northern	VIMS Juvenile Trawl		X		
NC	Northern	Fisheries-Independent Trawl (p195)		X		
NC	Northern	Beaufort Bridgenet Ichthyoplankton	X			Not representative of later life stage abundance (Hare and Able 2007)
NJ	Northern	NJ Ichthyoplankton	X			Not representative of later life stage abundance (Hare and Able 2007)
SC	Southern	SC Ichthyoplankton	X			Not representative of later life stage abundance (Hare and Able 2007)
FL-NC	Southern	SEAMAP		X		
NC	Southern	Estuarine Trawl (p120)	X			Fringe of stock, possible stock mixing; trend more similar to northern trends
NC	Southern	Gillnet (p915)	X			Included in DFA, but not used individually due to localized dynamics according to correlation analyses
SC	Southern	SCECAP Trawl	X			Included in DFA, but not used individually due to localized dynamics according to correlation analyses
SC	Southern	Trammel Net	X			Included in DFA, but not used individually due to localized dynamics according to correlation analyses ; used in TLA
SC	Southern	Electrofishing			X	Low positive tows (13.1%), preference for other available indices
SC	Southern	Estuarine Trawl		X		
GA	Southern	Gillnet	X			Included in DFA, but not used individually due to localized dynamics according to correlation analyses
GA	Southern	Trammel Net			X	Low positive tows (11.1%), preference for other available indices
GA	Southern	Estuarine Trawl		X		
FL	Southern	183 Haul Seine	X			Included in DFA, but not used individually due to localized dynamics according to correlation analyses
FL	Southern	YOY Seine			X	Targets extremely small YOY fish, environmental issues adjacent, small spatial scale, localized dynamics
FL	Southern	Estuarine Trawl			X	ends in 2020, adjacent to enviro issues, standardization diagnostic issues, shorter than FL YOY Seine, standardizing model underdispersed

Table 33. NOAA Fisheries Northeast Fisheries Science Center bottom trawl survey data summary.

Year	Index	CV	Observations			Catch	Year	Index	CV	Observations			Catch	Age Samples
			Total	Positive	Proportion Positive					Total	Positive	Proportion Positive		
1972	8,987,744	0.340	91	9	0.099	3,762	1997	14,743,081	0.325	74	13	0.176	2,284	20
1973	16,002,814	0.360	94	14	0.149	794	1998	37,695,779	0.298	65	18	0.277	3,764	449
1974	27,868,797	0.353	83	18	0.217	1,318	1999	95,187,156	0.247	70	22	0.314	17,573	212
1975	28,704,979	0.352	77	14	0.182	4,020	2000	76,431,472	0.272	74	23	0.311	11,219	648
1976	27,305,786	0.350	80	13	0.163	2,626	2001	12,139,678	0.319	73	13	0.178	977	400
1977	30,071,135	0.314	78	14	0.179	5,717	2002	22,508,134	0.285	73	15	0.205	3,464	380
1978	18,814,175	0.344	76	15	0.197	959	2003	190,786,100	0.261	73	32	0.438	9,884	751
1979	8,108,884	0.351	78	12	0.154	159	2004	72,646,004	0.249	68	19	0.279	13,305	544
1980	10,957,158	0.336	71	12	0.169	1,715	2005	74,065,394	0.257	72	18	0.250	12,682	604
1981	21,928,336	0.317	75	18	0.240	1,457	2006	274,697,203	0.267	76	34	0.447	15,252	1,303
1982	9,755,332	0.362	74	11	0.149	437	2007	145,194,740	0.238	74	23	0.311	29,163	710
1983	16,924,535	0.317	76	16	0.211	1,217	2008	64,850,985	0.258	73	22	0.301	8,301	742
1984	41,005,025	0.322	66	17	0.258	3,489	2009	162,032,214	0.227	97	39	0.402	33,939	262
1985	75,934,549	0.343	66	20	0.303	5,076	2010	108,194,370	0.228	106	45	0.425	12,394	296
1986	14,623,761	0.321	74	13	0.176	2,333	2011	179,522,480	0.212	97	48	0.495	24,535	301
1987	9,631,409	0.352	74	9	0.122	2,833	2012	188,617,273	0.200	101	46	0.455	38,676	320
1988	7,270,432	0.371	74	10	0.135	245	2013	103,418,587	0.212	101	41	0.406	22,265	NA
1989	23,189,980	0.303	74	17	0.230	3,364	2014	109,350,851	0.229	100	40	0.400	16,958	259
1990	18,439,855	0.324	76	15	0.197	1,405	2015	114,022,138	0.203	99	37	0.374	34,344	243
1991	3,397,199	0.434	74	6	0.081	52	2016	176,459,705	0.225	99	44	0.444	22,107	266
1992	8,001,259	0.365	75	10	0.133	438	2017	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
1993	3,433,590	0.429	73	6	0.082	123	2018	114,610,394	0.233	85	33	0.388	13,144	188
1994	38,469,331	0.271	75	9	0.120	14,570	2019	124,891,357	0.218	99	43	0.434	14,862	244
1995	333,463,074	0.327	67	30	0.448	12,824	2020	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
1996	39,573,655	0.295	71	17	0.239	3,973	2021	109,512,996	0.205	99	39	0.394	21,797	NA
							2022	134,750,508	0.233	97	34	0.351	35,857	NA
							2023	144,748,333	0.216	98	37	0.378	25,453	NA
							2024	339,257,410	0.210	98	48	0.490	59,167	NA

Table 34. NEAMAP fall trawl survey summary including annual index values (number-based), standard error (SE) of the index on the log scale, total number of Atlantic croaker caught, number of positive tows that caught Atlantic Croaker, the proportion of positive tows, and number of age samples.

Year	Index	SE $\log_e$(Index)	Total	Positive	Proportion Positive	Age Samples
2007	145444.9	0.36	58763	78	0.52	209
2008	154382.7	0.48	66823	67	0.45	307
2009	157925.6	0.35	45730	89	0.56	414
2010	146580.5	0.57	73685	61	0.41	271
2011	226822	0.46	58671	73	0.49	323
2012	1591380	0.48	319363	87	0.58	412
2013	322141.8	0.43	97463	71	0.47	289
2014	145629.3	0.44	40543	51	0.34	223
2015	51283.07	0.50	20839	37	0.25	134
2016	96269.2	0.75	37127	58	0.39	166
2017	188940.1	0.61	62739	56	0.37	188
2018	237173	0.68	83133	50	0.33	157
2019	20574.03	0.63	9780	26	0.17	44
2020	181734.5	1.09	39006	69	0.46	216
2021	503735.7	0.47	116618	75	0.50	322
2022	163712.2	0.62	36469	60	0.40	221
2023	107219.5	0.71	32371	56	0.37	-
2024	1096023	0.34	184363	96	0.64	-

Table 35. ChesMMAP summer trawl survey summary including annual index values (number-based), standard error (SE) of the index on the log scale, total Atlantic croaker caught, number of positive tows for Atlantic croaker, the proportion of positive tows, and number of age samples.

Year	Index	SE $\log_e$(Index)	Total	Positive	Proportion Positive	Age Samples
2002	88704.27	0.49	12563.82	36	0.47	245
2003	77753.22	0.36	26601.37	40	0.51	182
2004	100676.7	0.55	20001.45	30	0.51	158
2005	87001.54	0.29	26394.31	42	0.53	230
2006	219303.2	0.43	58708.63	57	0.69	287
2007	118469.2	0.32	27917.21	48	0.62	208
2008	57423.16	0.49	7606.03	20	0.25	75
2009	219205.2	0.38	40888.41	39	0.49	172
2010	64951.03	0.53	26493.89	29	0.50	92
2011	220073.9	0.44	47439.85	33	0.40	101
2012	118867.4	0.41	25200.35	33	0.35	91
2013	602275.1	0.28	399387.8	68	0.43	195
2014	16315.82	0.51	6836.94	22	0.17	55
2015	62702.21	0.52	21283.35	45	0.25	115
2016	56428.48	0.56	10652.04	29	0.23	78
2017	43605.04	0.50	8593.68	16	0.20	65
2018	1465.776	0.57	245.53	9	0.11	15
2019	8479.707	0.38	5106	36	0.49	90
2020	1817.966	0.18	279	41	0.51	139
2021	9509.394	0.28	4461	54	0.51	142
2022	11362.3	0.50	9703	51	0.51	101
2023	16520.85	0.35	4504	40	0.50	129
2024	78858.09	0.59	23752	44	0.55	245

Table 36. Index of abundance for the p195 survey (mean and the upper (UCI) and lower (LCI) confidence intervals. Size is the total number of tows per year, and Positive is the percent positive tows per year.

Year	Mean	CV	LCI	UCI	Size	Positive
1987	89.77	0.29	39.28	140.26	27	0.93
1988	54.51	0.24	28.69	80.33	42	0.93
1989	97.24	0.23	53.02	141.47	42	0.83
1990	300.73	0.22	172.91	428.56	53	1.00
1991	401.91	0.23	221.36	582.46	53	1.00
1992	111.02	0.21	65.36	156.67	52	0.77
1993	325.46	0.21	192.49	458.43	53	0.98
1994	216.13	0.21	127.85	304.41	51	0.92
1995	276.59	0.23	152.51	400.68	48	0.98
1996	55.46	0.33	19.05	91.88	20	0.95
1997	346.58	0.26	166.57	526.59	41	0.93
1998	578.91	0.33	206.07	951.75	25	0.92
1999	1161.39	0.21	674.35	1648.42	51	1.00
2000	180.40	0.24	94.10	266.69	43	1.00
2001	113.47	0.21	66.26	160.68	53	0.79
2002	161.94	0.23	88.71	235.18	47	0.79
2003	88.37	0.26	43.28	133.46	38	0.92
2004	417.33	0.20	252.18	582.47	54	0.74
2005	179.54	0.23	99.68	259.40	45	0.82
2006	164.40	0.20	99.03	229.77	54	0.89
2007	126.75	0.22	71.98	181.52	51	0.84
2008	423.70	0.21	248.37	599.02	54	0.70
2009	112.19	0.22	63.55	160.82	54	0.67
2010	845.07	0.21	499.57	1190.56	54	0.94
2011	141.60	0.20	85.52	197.68	54	0.69
2012	1717.27	0.21	994.74	2439.81	54	0.94
2013	886.15	0.23	494.27	1278.03	54	0.98
2014	506.25	0.21	299.25	713.24	54	0.96
2015	362.18	0.20	218.21	506.14	54	0.91
2016	288.91	0.21	168.75	409.08	53	0.94
2017	1164.61	0.20	702.89	1626.33	54	0.89
2018	154.78	0.21	91.87	217.68	53	0.79
2019	837.12	0.22	476.07	1198.17	54	0.83
2020	533.78	0.33	188.81	878.75	20	0.95
2021	331.11	0.28	149.50	512.73	35	1.00
2022	478.53	0.22	273.20	683.86	54	0.91
2023	353.30	0.22	198.26	508.33	53	0.85
2024	132.00	0.32	50.30	213.69	52	0.75

Table 37. Southern stock Atlantic croaker index of abundance (with standard errors (SE)) and catch demographics from the SEAMAP-SA Coastal Trawl Survey from 1990-2024 for the Fall sampling season. Number of trips reflects all sampling events that occurred within the SEAMAP-SA Coastal Trawl Survey and percent positive reflects the percent of trips that caught Atlantic croaker. Biological information gathered from the SEAMAP-SA Coastal Trawl Survey are reported in the number of lengths (number of croaker measured) and the number of ages (number of otoliths collected from croaker for aging).

Year	Index	SE	Number of Tows	Positive Trips	Percent Positive	Number of Lengths	Number of Ages
1990	73,924.9	0.32	71	52	73.2%	8,343	-
1991	206,835.5	0.33	72	52	72.2%	21,634	-
1992	22,894.3	0.27	74	49	66.2%	2,793	-
1993	34,633.0	0.27	74	52	70.3%	4,316	-
1994	77,795.3	0.33	74	51	68.9%	13,511	-
1995	27,206.5	0.26	74	54	73.0%	4,664	-
1996	53,257.9	0.26	74	64	86.5%	6,941	-
1997	17,660.0	0.26	74	41	55.4%	2,703	-
1998	42,225.0	0.32	73	48	65.8%	4,908	-
1999	71,375.9	0.24	74	49	66.2%	12,740	-
2000	10,613.1	0.36	74	40	54.1%	1,838	-
2001	19,838.7	0.23	93	60	64.5%	4,404	217
2002	28,379.9	0.25	89	49	55.1%	8,198	233
2003	68,419.0	0.21	92	63	68.5%	17,690	242
2004	46,858.6	0.21	91	56	61.5%	9,022	221
2005	87,124.8	0.20	91	65	71.4%	17,516	281
2006	71,725.1	0.25	93	48	51.6%	12,855	196
2007	52,345.5	0.22	94	56	59.6%	11,253	-
2008	94,345.9	0.26	94	67	71.3%	17,533	262
2009	67,866.0	0.19	103	70	68.0%	13,538	249
2010	125,689.6	0.21	103	65	63.1%	28,944	245
2011	55,569.7	0.25	102	45	44.1%	11,454	142
2012	237,096.6	0.22	103	82	79.6%	55,882	282
2013	190,372.1	0.21	93	71	76.3%	35,228	344
2014	132,082.7	0.22	93	69	74.2%	26,288	314
2015	430,121.9	0.19	102	94	92.2%	76,040	370
2016	320,399.3	0.20	98	78	79.6%	52,705	341
2017	116,419.8	0.23	87	63	72.4%	22,936	301
2018	650,076.1	0.33	67	61	91.0%	37,953	253
2019	410,488.5	0.27	68	61	89.7%	63,699	285
2020	-	-	-	-	-	-	-
2021	442,033.2	0.26	74	58	78.4%	27,177	226
2022	382,383.6	0.20	76	66	86.8%	28,542	267
2023	373,563.1	0.21	92	61	66.3%	28,453	-
2024	425,426.2	0.19	94	70	74.5%	28,422	263

Table 38. Southern stock Atlantic croaker index of abundance (with standard errors (SE)) and catch demographics from the SEAMAP-SA Coastal Trawl Survey from 1990-2024 for the Summer sampling season. Number of trips reflects all sampling events that occurred within the SEAMAP-SA Coastal Trawl Survey and percent positive reflects the percent of trips that caught Atlantic croaker. Biological information gathered from the SEAMAP-SA Coastal Trawl Survey are reported in the number of lengths (number of croaker measured) and the number of ages (number of otoliths collected from croaker for aging).

Year	Index	SE	Number of Tows	Positive Trips	Percent Positive	Number of Lengths	Number of Ages
1990	233,631.1	0.25	73	54	74.0%	27,469	-
1991	318,829.0	0.26	73	41	56.2%	39,794	-
1992	219,793.4	0.27	73	35	47.9%	28,411	-
1993	125,688.9	0.29	72	35	48.6%	19,695	-
1994	97,403.7	0.25	74	43	58.1%	15,342	-
1995	158,392.8	0.24	72	52	72.2%	17,204	-
1996	117,001.2	0.28	69	45	65.2%	16,888	-
1997	64,237.4	0.25	73	37	50.7%	11,298	-
1998	157,284.4	0.23	73	59	80.8%	21,341	-
1999	68,793.3	0.26	74	30	40.5%	10,781	-
2000	184,587.7	0.23	73	41	56.2%	28,882	-
2001	460,230.7	0.20	85	75	88.2%	59,161	435
2002	131,433.0	0.20	93	53	57.0%	30,952	219
2003	180,395.8	0.21	92	59	64.1%	33,771	287
2004	321,223.5	0.21	92	48	52.2%	56,528	256
2005	119,793.2	0.22	90	46	51.1%	24,509	243
2006	229,601.0	0.21	91	55	60.4%	34,827	226
2007	123,251.7	0.20	94	62	66.0%	24,042	-
2008	175,553.9	0.22	94	47	50.0%	32,192	200
2009	187,280.5	0.19	103	67	65.0%	29,741	262
2010	274,109.4	0.20	103	65	63.1%	43,292	229
2011	1,009,399.4	0.20	102	82	80.4%	118,897	356
2012	314,456.9	0.17	103	94	91.3%	45,156	371
2013	581,702.0	0.18	93	86	92.5%	79,560	381
2014	1,077,777.1	0.19	93	83	89.2%	129,890	438
2015	499,206.9	0.19	103	67	65.0%	93,393	376
2016	422,801.7	0.18	103	84	81.6%	72,173	383
2017	350,048.7	0.19	95	77	81.1%	62,052	380
2018	495,211.6	0.19	96	70	72.9%	86,875	400
2019	949,414.6	0.18	96	85	88.5%	142,286	486
2020	-	-	-	-	-	-	-
2021	615,439.5	0.49	38	28	73.7%	9,867	146
2022	344,813.0	0.19	96	63	65.6%	27,734	315

Table 39. Southern stock Atlantic croaker index of abundance (with standard errors (SE)) and catch demographics from the SC Estuarine Trawl Survey from 2011-2024. Number of trips reflects all sampling events that occurred within SC Estuarine Trawl Survey and percent positive reflects the percent of trips that caught Atlantic croaker.

Year	Index	SE	n Trips	Positive	Percent Positive
2011	81.20	28.76	10	8	80%
2012	253.09	138.79	4	4	100%
2013	514.66	180.90	11	10	92%
2014	447.03	153.33	11	10	92%
2015	679.44	222.95	12	12	100%
2016	765.14	253.28	12	12	100%
2017	1337.27	468.58	11	10	92%
2018	393.28	134.26	12	12	100%
2019	734.23	242.00	12	12	100%
2021	892.42	377.14	7	7	100%
2022	1431.06	413.31	18	18	100%
2023	647.79	185.13	18	18	100%
2024	1022.61	295.76	16	15	94%

Table 40. Southern stock Atlantic croaker index of abundance (with standard errors (SE)) and catch demographics from the GA Estuarine Trawl Survey from 2003-2024. Number of trips reflects all sampling events that occurred within GA Estuarine Trawl Survey and percent positive reflects the percent of trips that caught Atlantic croaker.

Year	Index	SE	n Trips	Positive Trips	Percent Positive
2003	283,254.4	0.12	136	113	83.1%
2004	122,047.9	0.12	133	114	85.7%
2005	101,060.5	0.12	140	118	84.3%
2006	42,910.0	0.12	140	112	80.1%
2007	101,422.9	0.11	140	121	86.4%
2008	135,940.4	0.11	140	123	87.6%
2009	155,625.9	0.12	133	119	89.6%
2010	163,304.6	0.13	131	108	82.4%
2011	63,105.2	0.12	144	116	80.6%
2012	35,887.8	0.12	140	112	80.0%
2013	240,183.4	0.11	140	125	89.3%
2014	105,132.5	0.12	139	112	80.6%
2015	134,449.3	0.12	137	113	82.5%
2016	244,952.5	0.12	141	119	84.4%
2017	138,335.8	0.14	119	94	79.0%
2018	159,453.4	0.12	136	115	84.6%
2019	176,287.8	0.11	142	122	86.0%
2020	303,279.5	0.12	139	122	87.8%
2021	104,087.3	0.12	138	120	87.0%
2022	130,720.3	0.12	143	119	83.2%
2023	131,847.1	0.12	133	110	82.7%
2024	165,787.8	0.12	143	113	79.0%

Table 41. Significant Spearman's rank correlation results (p-value <0.05) for comparisons between northern stock fishery-independent indices of abundance and commercial CPUE time series from both stocks.

Index 1	Index 2	Spearman's Rho	p-value	Assumed Relationship
NC_P195	VIMS_YOY	0.354	0.031	Within Stock YOY Abundance
ChesMMAP	MD_CPUE	0.666	0.001	Within Stock Aggregate Abundance
ChesMMAP	NC_CPUE_MA_Ocean	0.636	0.001	Within Stock Aggregate Abundance
MD_CPUE	NC_CPUE_MA_Ocean	0.738	0.000	Within Stock Aggregate Abundance
ChesMMAP	VA_CPUE_Bay_Gill	0.519	0.016	Within Stock Aggregate Abundance
MD_CPUE	VA_CPUE_Bay_Gill	0.693	0.000	Within Stock Aggregate Abundance
NC_CPUE_MA_Ocean	VA_CPUE_Bay_Gill	0.615	0.000	Within Stock Aggregate Abundance
MD_CPUE	VA_CPUE_Bay_Seine	0.419	0.027	Within Stock Aggregate Abundance
NC_CPUE_MA_Ocean	VA_CPUE_Bay_Seine	0.450	0.016	Within Stock Aggregate Abundance
VA_CPUE_Bay_Gill	VA_CPUE_Bay_Seine	0.389	0.041	Within Stock Aggregate Abundance
ChesMMAP	VA_CPUE_Ocean_Gill	0.625	0.002	Within Stock Aggregate Abundance
MD_CPUE	VA_CPUE_Ocean_Gill	0.710	0.000	Within Stock Aggregate Abundance
NC_CPUE_MA_Ocean	VA_CPUE_Ocean_Gill	0.629	0.000	Within Stock Aggregate Abundance
VA_CPUE_Bay_Gill	VA_CPUE_Ocean_Gill	0.697	0.000	Within Stock Aggregate Abundance
NC_CPUE_SA_Ocean	VA_CPUE_Ocean_Gill	-0.542	0.002	Between Stock Aggregate Abundance
NC_CPUE_SA_Ocean	VA_CPUE_Bay_Gill	-0.511	0.005	Between Stock Aggregate Abundance
MD_CPUE	NC_CPUE_SA_Ocean	-0.430	0.018	Between Stock Aggregate Abundance

Table 42. Significant Spearman's rank correlation results (p-value <0.05) for comparisons between southern stock fishery-independent recruitment indices of abundance.

Index 1	Index 2	Spearman's Rho	p-value
NCTrawl	SCTrawl	0.223	0.486
NCTrawl	GATrawl	0.301	0.185
SCTrawl	GATrawl	0.285	0.346
NCTrawl	FL21Seine	-0.222	0.321
SCTrawl	FL21Seine	0.117	0.702
GATrawl	FL21Seine	0.263	0.237

Table 43. Significant Spearman's rank correlation results (p-value <0.05) for comparisons between southern stock fishery-independent age aggregate indices of abundance, as well as comparing fishery-independent age aggregate indices with commercial CPUE time series from both stocks. Bold values indicate statistically significant tests. * Denote fishery dependent CPUE indices.

Index 1	Index 2	Spearman's Rho	p-value
NCGill	SCTrammel	0.009	0.974
NCGill	SCECAP	-0.168	0.535
SCTrammel	SCECAP	0.417	0.034
NCGill	GAGill	0.197	0.464
SCTrammel	GAGill	0.324	0.142
SCECAP	GAGill	**0.651**	**0.001**
NCGill	FL183Haul	-0.279	0.315
SCTrammel	FL183Haul	0.214	0.326
SCECAP	FL183Haul	-0.295	0.171
GAGill	FL183Haul	-0.218	0.342
NCGill	SEAMAP_Fall	0.256	0.339
SCTrammel	SEAMAP_Fall	0.244	0.171
SCECAP	SEAMAP_Fall	0.282	0.172
GAGill	SEAMAP_Fall	0.305	0.179
FL183Haul	SEAMAP_Fall	-0.285	0.198
NCGill	SEAMAP_Summer	-0.011	0.970
SCTrammel	SEAMAP_Summer	0.070	0.708
SCECAP	SEAMAP_Summer	0.264	0.224
GAGill	SEAMAP_Summer	0.030	0.904
FL183Haul	SEAMAP_Summer	-0.477	0.029
SEAMAP_Fall	SEAMAP_Summer	**0.576**	**0.001**
NCGill	NC_CPUE_Estuarine*	-0.062	0.820
SCTrammel	NC_CPUE_Estuarine *	-0.319	0.086
SCECAP	NC_CPUE_Estuarine *	0.249	0.221
GAGill	NC_CPUE_Estuarine *	0.420	0.052
FL183Haul	NC_CPUE_Estuarine *	-0.400	0.058
SEAMAP_Fall	NC_CPUE_Estuarine *	-0.399	0.032
SEAMAP_Summer	NC_CPUE_Estuarine *	-0.427	0.026
NCGill	NC_CPUE_Ocean *	-0.353	0.180
SCTrammel	NC_CPUE_Ocean *	0.152	0.421
SCECAP	NC_CPUE_Ocean *	0.221	0.279
GAGill	NC_CPUE_Ocean *	0.102	0.651
FL183Haul	NC_CPUE_Ocean *	-0.050	0.819
SEAMAP_Fall	NC_CPUE_Ocean *	**0.578**	**0.001**
SEAMAP_Summer	NC_CPUE_Ocean *	0.475	0.012
NC_CPUE_Estuarine	NC_CPUE_Ocean *	-0.244	0.195

Table 44. Life history parameters used in the SS models for Atlantic croaker. Parameter values for estimated parameters are provided in Table 49 and Table 56 for the northern and southern stocks, respectively.

Parameter	Stock	
	Northern	Southern
Age-2 Natural Mortality	0.594	0.809
Maximum age	10	4
Amin (age for first size-at-age, Lmin)	0	0
Lmin (cm)	estimated (early, late)	estimated (static)
Linf (cm)	estimated (early, late)	estimated (static)
von Bertalanffy K	estimated (early, late)	estimated (static)
break point for new growth pattern	2012	NA
Length-at-age CV for smallest sizes	estimated	estimated
Length-at-age CV for largest sizes	estimated	estimated
Length-weight relationship alpha	1.16E-05	8.22e-06
Length-weight relationship beta	3.03	3.07
Female 50% maturity (length, cm)	17.1	17.9
Female maturity slope	-0.67	-0.58
R0 (thousands of fish)	estimated	estimated
sigma R	0.83	0.55
steepness	0.99	0.99

Table 45. Configuration details for fishing fleets in the SS northern stock model.

Fishing Fleet Name	Years	Discard Mortality	Catch Error Type	Selectivity	Composition Error Type
Commercial	1990-2024	1	lognormal	length-based logistic	multinomial
Recreational	1990-2024	0.15	lognormal	length-based logistic	multinomial
Bycatch	1990-2024*	0.95	lognormal	age-specific, age-0 only	NA

*Shrimp trawl bycatch estimates prior to 2008 were hindcast based on ratios of observer program estimates to SEAMAP catch rate data and are considered more uncertain due to lack of any direct observer data.

Table 46. Configuration details for fishery-independent surveys in the SS northern stock model.

Survey Name	Years	Timing	Catch Error Type	Selectivity	Composition Error Type
VIMS_YOY	1990-2024	May	lognormal	Age-0 Recruitment (SS special survey type 33)	NA
NC_P195_YOY	1990-2024	June	lognormal	Age-0 Recruitment (SS special survey type 33)	NA
ChesMMAP	2002-2024	July	lognormal	length-based logistic	multinomial
NEFSC	1990-2024, except 2017, 2020	November	lognormal	length-based logistic	multinomial
NEAMAP	2007-2024	November	lognormal	length-based logistic	multinomial

Table 47. Configuration details for fishing fleets in the SS southern stock model.

Fleet Name	Fleet Type	Years	Discard Mortality	Catch Error Type	Selectivity	Composition Error Type
Recreational_NC_GA	Fishing	1990-2024	0.15	Lognormal	Increasing Length Logistic and Derived Age	Multinomial
Commercial_NC_GA	Fishing	1990-2024	NA	Lognormal	Double Normal Length* and Derived Age	Multinomial
Recreational_FL	Fishing	1990-2024	0.15	Lognormal	Increasing Length Logistic and Derived Age	Multinomial
Commercial_FL	Fishing	1990-2024	NA	Lognormal	Increasing Length Logistic and Derived Age	NA
Shrimp Bycatch	Bycatch	1990-2024	0.95	Lognormal	Derived Length and Age-0 only	NA

*Two time blocks were used to represent a change in the type of gear that constituted the majority of the harvest between the time periods (see text for details).

Table 48. Configuration details for monitoring surveys in the SS southern stock model.

Fleet Name	Years	Timing	Catch Error Type	Selectivity	Composition Error Type
SEAMAP_fall	1990-2024	Oct. 1	Lognormal	Double Normal Length and Derived Age	Multinomial
SEAMAP_summer	1990-2024	July 1	Lognormal	Double Normal Length and Derived Age	Multinomial
GA_YOY	2003-2024	July 1	Lognormal	Derived Length and Age-0 only	NA
SC_YOY	1987-1993	April 1	Lognormal	Derived Length and Age-0 only	NA

Table 49. Life history and recruitment parameters for the SS northern stock model.

Parameter	Type	Final Value	SE	Lower Bound	Upper Bound
NatM_Lorenzen_Fem_GP_1	Fixed	0.594	NA	NA	NA
L_at_Amin_Fem_GP_1	Estimated	12.6808	0.164776	8	20
L_at_Amax_Fem_GP_1	Estimated	28.7631	0.745481	20	50
VonBert_K_Fem_GP_1	Estimated	0.175306	0.0117454	0.05	0.5
CV_young_Fem_GP_1	Estimated	0.268286	0.00647096	0.01	0.5
CV_old_Fem_GP_1	Estimated	0.0847616	0.00511358	0.01	0.5
Wtlen_1_Fem_GP_1	Fixed	0.0000116	NA	NA	NA
Wtlen_2_Fem_GP_1	Fixed	3.02784	NA	NA	NA
Mat50%_Fem_GP_1	Fixed	17.1	NA	NA	NA
Mat_slope_Fem_GP_1	Fixed	-0.67	NA	NA	NA
Eggs/kg_inter_Fem_GP_1	Fixed	1	NA	NA	NA
Eggs/kg_slope_wt_Fem_GP_1	Fixed	0	NA	NA	NA
CohortGrowDev	Fixed	1	NA	NA	NA
FracFemale_GP_1	Fixed	0.5	NA	NA	NA
L_at_Amin_Fem_GP_1_BLK1repl_1989	Estimated	12.595	0.167331	8	20
L_at_Amax_Fem_GP_1_BLK1repl_1989	Estimated	41.7467	0.529481	20	50
VonBert_K_Fem_GP_1_BLK1repl_1989	Estimated	0.194718	0.00695933	0.05	0.5
SR_LN(R0)	Estimated	13.6082	0.0294791	8	18
SR_BH_steep	Fixed	0.99	NA	NA	NA
SR_sigmaR	Fixed	0.831604	NA	NA	NA
SR_regime	Fixed	0	NA	NA	NA
SR_autocorr	Fixed	0	NA	NA	NA
Main_InitAge_1	Deviation	0.648704	0.587782	-5	5
Main_RecrDev_1990	Deviation	-0.0996095	0.139585	-5	5
Main_RecrDev_1991	Deviation	1.06862	0.139732	-5	5
Main_RecrDev_1992	Deviation	0.862093	0.119549	-5	5
Main_RecrDev_1993	Deviation	1.94064	0.0730083	-5	5
Main_RecrDev_1994	Deviation	1.04011	0.119723	-5	5
Main_RecrDev_1995	Deviation	0.956846	0.098934	-5	5
Main_RecrDev_1996	Deviation	-1.11388	0.169278	-5	5
Main_RecrDev_1997	Deviation	0.94676	0.0672755	-5	5
Main_RecrDev_1998	Deviation	1.29254	0.0550379	-5	5
Main_RecrDev_1999	Deviation	0.535819	0.0730531	-5	5
Main_RecrDev_2000	Deviation	-0.481284	0.105862	-5	5
Main_RecrDev_2001	Deviation	-0.397028	0.114818	-5	5
Main_RecrDev_2002	Deviation	0.768936	0.0502676	-5	5
Main_RecrDev_2003	Deviation	-1.34965	0.104063	-5	5
Main_RecrDev_2004	Deviation	-0.0789167	0.0782434	-5	5
Main_RecrDev_2005	Deviation	-0.794127	0.0753038	-5	5
Main_RecrDev_2006	Deviation	0.171083	0.0676298	-5	5
Main_RecrDev_2007	Deviation	-0.758392	0.100048	-5	5
Main_RecrDev_2008	Deviation	0.441488	0.0763457	-5	5
Main_RecrDev_2009	Deviation	-0.219672	0.086444	-5	5
Main_RecrDev_2010	Deviation	0.0027171	0.080687	-5	5
Main_RecrDev_2011	Deviation	-1.19877	0.131602	-5	5
Main_RecrDev_2012	Deviation	0.470019	0.0549927	-5	5
Main_RecrDev_2013	Deviation	-0.0408201	0.105039	-5	5
Main_RecrDev_2014	Deviation	-0.705921	0.120282	-5	5
Main_RecrDev_2015	Deviation	-1.0925	0.113026	-5	5
Main_RecrDev_2016	Deviation	-0.447782	0.11097	-5	5
Main_RecrDev_2017	Deviation	-0.232362	0.102084	-5	5
Main_RecrDev_2018	Deviation	-1.49043	0.207357	-5	5
Main_RecrDev_2019	Deviation	-0.211517	0.0976815	-5	5
Main_RecrDev_2020	Deviation	-0.642002	0.168477	-5	5
Main_RecrDev_2021	Deviation	-0.590179	0.11477	-5	5
Main_RecrDev_2022	Deviation	-0.342575	0.10489	-5	5
Main_RecrDev_2023	Deviation	0.137599	0.117746	-5	5
Main_RecrDev_2024	Deviation	1.00345	0.128714	-5	5

Table 50. Fishing fleet initial fishing mortality and selectivity parameters for the SS northern stock model.

Parameter	Type	Final Value	SE	Lower Bound	Upper Bound
InitF_seas_1_flt_1Commercial	Estimated	1.84469	2.00503	0.01	4
InitF_seas_1_flt_2Recreational	Estimated	1.99046	1.91623	0.01	4
InitF_seas_1_flt_6Bycatch	Estimated	3.01217	0.502006	0.01	4
Size_inflection_Commercial(1)	Estimated	25.3016	0.0914492	20	30
Size_95%width_Commercial(1)	Estimated	3.69757	0.0617873	0.01	10
Size_inflection_Recreational(2)	Estimated	23.9283	0.140075	20	30
Size_95%width_Recreational(2)	Estimated	4.43751	0.0927319	0.01	10
minage@sel=1_Bycatch(6)	Fixed	0	NA	NA	NA
maxage@sel=1_Bycatch(6)	Fixed	0	NA	NA	NA
F_fleet_6_YR_1990_s_1	Estimated	1.44509	0.285644	0	4
F_fleet_6_YR_1991_s_1	Estimated	0.409149	0.150505	0	4
F_fleet_6_YR_1992_s_1	Estimated	0.105173	0.0449779	0	4
F_fleet_6_YR_1993_s_1	Estimated	0.0367695	0.0146726	0	4
F_fleet_6_YR_1994_s_1	Estimated	0.0691955	0.0448553	0	4
F_fleet_6_YR_1995_s_1	Estimated	0.108269	0.0491985	0	4
F_fleet_6_YR_1996_s_1	Estimated	1.04037E-08	2.08074E-05	0	4
F_fleet_6_YR_1997_s_1	Estimated	0.0300233	0.0107722	0	4
F_fleet_6_YR_1998_s_1	Estimated	0.0336736	0.0126033	0	4
F_fleet_6_YR_1999_s_1	Estimated	0.107621	0.0359325	0	4
F_fleet_6_YR_2000_s_1	Estimated	0.149032	0.0615986	0	4
F_fleet_6_YR_2001_s_1	Estimated	0.0997082	0.0816133	0	4
F_fleet_6_YR_2002_s_1	Estimated	0.0443848	0.018852	0	4
F_fleet_6_YR_2003_s_1	Estimated	4.27824E-08	8.55611E-05	0	4
F_fleet_6_YR_2004_s_1	Estimated	0.1933	0.0639022	0	4
F_fleet_6_YR_2005_s_1	Estimated	0.0725373	0.0247282	0	4
F_fleet_6_YR_2006_s_1	Estimated	0.139187	0.0518361	0	4
F_fleet_6_YR_2007_s_1	Estimated	0.37237	0.0960396	0	4
F_fleet_6_YR_2008_s_1	Estimated	0.279981	0.070356	0	4
F_fleet_6_YR_2009_s_1	Estimated	0.344213	0.0797128	0	4
F_fleet_6_YR_2010_s_1	Estimated	0.299917	0.0732458	0	4
F_fleet_6_YR_2011_s_1	Estimated	0.894859	0.172181	0	4
F_fleet_6_YR_2012_s_1	Estimated	0.26595	0.0438387	0	4
F_fleet_6_YR_2013_s_1	Estimated	1.59279	0.131201	0	4
F_fleet_6_YR_2014_s_1	Estimated	1.31125	0.150075	0	4
F_fleet_6_YR_2015_s_1	Estimated	2.01228	0.196223	0	4
F_fleet_6_YR_2016_s_1	Estimated	1.47988	0.14338	0	4
F_fleet_6_YR_2017_s_1	Estimated	1.50721	0.133105	0	4
F_fleet_6_YR_2018_s_1	Estimated	1.28536	0.288019	0	4
F_fleet_6_YR_2019_s_1	Estimated	2.00065	0.170522	0	4
F_fleet_6_YR_2020_s_1	Estimated	0.204761	0.194166	0	4
F_fleet_6_YR_2021_s_1	Estimated	0.865633	0.171362	0	4
F_fleet_6_YR_2022_s_1	Estimated	0.0600606	0.0184065	0	4
F_fleet_6_YR_2023_s_1	Estimated	0.327198	0.0918329	0	4
F_fleet_6_YR_2024_s_1	Estimated	0.137965	0.052289	0	4

Table 51. Survey catchability coefficient and selectivity parameters for the SS northern stock model.

Parameter	Type	Final Value	SE	Lower Bound	Upper Bound
Size_inflection_ChesMMAP(5)	Estimated	18.1692	0.477857	12	30
Size_95%width_ChesMMAP(5)	Estimated	7.67897	0.555764	0.01	12
Size_inflection_NEFSC(7)	Estimated	18.6922	0.190209	12	30
Size_95%width_NEFSC(7)	Estimated	2.72446	0.202809	0.01	10
Size_inflection_NEAMAP(8)	Estimated	15.7084	0.172121	12	30
Size_95%width_NEAMAP(8)	Estimated	4.75095	0.257846	0.01	10
LnQ_base_VIMS_YOY(3)	Fixed	-13.9954	NA	NA	NA
LnQ_base_NC_P195_YOY(4)	Fixed	-13.4774	NA	NA	NA
LnQ_base_ChesMMAP(5)	Fixed	-12.8046	NA	NA	NA
LnQ_base_NEFSC(7)	Estimated	-11.6664	0.577166	-25	25
LnQ_base_NEAMAP(8)	Fixed	-12.2448	NA	NA	NA
LnQ_base_NEFSC(7)_dev_se	Fixed	0.5	NA	NA	NA
LnQ_base_NEFSC(7)_dev_autocorr	Fixed	0	NA	NA	NA
LnQ_base_NEFSC(7)_DEVrwalk_1990	Deviation	-4.79206E-08	1	-10	10
LnQ_base_NEFSC(7)_DEVrwalk_1991	Deviation	-4.11951	0.653906	-10	10
LnQ_base_NEFSC(7)_DEVrwalk_1992	Deviation	-1.70578	0.641556	-10	10
LnQ_base_NEFSC(7)_DEVrwalk_1993	Deviation	-1.57738	0.634619	-10	10
LnQ_base_NEFSC(7)_DEVrwalk_1994	Deviation	2.05547	0.601894	-10	10
LnQ_base_NEFSC(7)_DEVrwalk_1995	Deviation	2.54475	0.558362	-10	10
LnQ_base_NEFSC(7)_DEVrwalk_1996	Deviation	-2.22536	0.567659	-10	10
LnQ_base_NEFSC(7)_DEVrwalk_1997	Deviation	-1.10364	0.566809	-10	10
LnQ_base_NEFSC(7)_DEVrwalk_1998	Deviation	1.15754	0.567582	-10	10
LnQ_base_NEFSC(7)_DEVrwalk_1999	Deviation	1.33283	0.531068	-10	10
LnQ_base_NEFSC(7)_DEVrwalk_2000	Deviation	-0.227252	0.516991	-10	10
LnQ_base_NEFSC(7)_DEVrwalk_2001	Deviation	-1.8279	0.55266	-10	10
LnQ_base_NEFSC(7)_DEVrwalk_2002	Deviation	1.2073	0.558177	-10	10
LnQ_base_NEFSC(7)_DEVrwalk_2003	Deviation	3.12463	0.530629	-10	10
LnQ_base_NEFSC(7)_DEVrwalk_2004	Deviation	-0.480796	0.510662	-10	10
LnQ_base_NEFSC(7)_DEVrwalk_2005	Deviation	0.609762	0.508284	-10	10
LnQ_base_NEFSC(7)_DEVrwalk_2006	Deviation	2.06257	0.518754	-10	10
LnQ_base_NEFSC(7)_DEVrwalk_2007	Deviation	-0.643714	0.509195	-10	10
LnQ_base_NEFSC(7)_DEVrwalk_2008	Deviation	-0.962885	0.502836	-10	10
LnQ_base_NEFSC(7)_DEVrwalk_2009	Deviation	1.01966	0.496497	-10	10
LnQ_base_NEFSC(7)_DEVrwalk_2010	Deviation	-0.298766	0.478077	-10	10
LnQ_base_NEFSC(7)_DEVrwalk_2011	Deviation	0.937664	0.468282	-10	10
LnQ_base_NEFSC(7)_DEVrwalk_2012	Deviation	0.498363	0.449706	-10	10
LnQ_base_NEFSC(7)_DEVrwalk_2013	Deviation	-0.346862	0.449224	-10	10
LnQ_base_NEFSC(7)_DEVrwalk_2014	Deviation	0.612066	0.468143	-10	10
LnQ_base_NEFSC(7)_DEVrwalk_2015	Deviation	0.862403	0.462566	-10	10
LnQ_base_NEFSC(7)_DEVrwalk_2016	Deviation	1.44302	0.466497	-10	10
LnQ_base_NEFSC(7)_DEVrwalk_2017	Deviation	0.36209	0.753079	-10	10
LnQ_base_NEFSC(7)_DEVrwalk_2018	Deviation	0.36209	0.753079	-10	10
LnQ_base_NEFSC(7)_DEVrwalk_2019	Deviation	0.222454	0.488337	-10	10
LnQ_base_NEFSC(7)_DEVrwalk_2020	Deviation	-0.676111	0.749286	-10	10
LnQ_base_NEFSC(7)_DEVrwalk_2021	Deviation	-0.676111	0.749286	-10	10
LnQ_base_NEFSC(7)_DEVrwalk_2022	Deviation	-0.48601	0.474844	-10	10
LnQ_base_NEFSC(7)_DEVrwalk_2023	Deviation	-0.651484	0.47944	-10	10
LnQ_base_NEFSC(7)_DEVrwalk_2024	Deviation	0.20657	0.481245	-10	10

Table 52. Jitter analysis results for the SS northern stock model. The Δ -LL column shows the change in total negative log-likelihood relative to the base model.

ln(R0)	-LL	Δ -LL	Frequency	Percent
13.6074	5635.90	-1.4	92	46%
13.6082	5637.30	0	66	33%
13.5813	5643.89	6.59	20	10%
13.5817	5645.48	8.18	20	10%
13.5634	5671.10	33.8	1	1%
13.6206	5748.49	111.19	1	1%

Table 53. Beginning of fishing year abundance-at-age estimates (in 1000s of fish) for the SS northern stock model.

Year	0	1	2	3	4	5	6	7	8	9	10+	Total
1990	651,367	31,263	7,757	1,192	75	2.4	0.1	0.0	0.0	0.0	0.0	691,657
1991	2,217,960	60,184	10,259	948	45	1.2	0.0	0.0	0.0	0.0	0.0	2,289,397
1992	1,980,590	583,207	25,492	3,327	218	8.0	0.2	0.0	0.0	0.0	0.0	2,592,843
1993	5,879,230	709,707	276,191	12,233	1,538	98	3.5	0.1	0.0	0.0	0.0	6,879,000
1994	2,398,970	2,258,120	342,035	140,379	6,243	783	50	1.8	0.0	0.0	0.0	5,146,581
1995	2,209,100	892,497	1,099,770	180,229	76,330	3,455	440	28	1.0	0.0	0.0	4,461,850
1996	278,614	790,554	436,714	589,007	100,862	43,882	2,027	262	17	0.6	0.0	2,241,940
1997	2,187,090	111,110	386,914	233,934	329,571	57,952	25,725	1,208	159	10	0.4	3,333,674
1998	3,090,150	846,278	54,229	205,315	128,750	185,293	33,138	14,932	711	94	6.5	4,558,897
1999	1,450,050	1,191,320	412,866	28,743	112,801	72,233	105,709	19,189	8,760	422	60	3,402,153
2000	524,384	519,162	580,736	218,151	15,700	62,782	40,826	60,598	11,141	5,142	286	2,038,907
2001	570,327	180,128	252,992	306,447	118,864	8,709	35,349	23,308	35,032	6,511	3,203	1,540,870
2002	1,829,250	205,793	87,593	132,510	164,764	64,782	4,805	19,744	13,173	20,009	5,613	2,548,035
2003	219,813	697,451	99,726	45,381	69,956	87,720	34,806	2,609	10,842	7,307	14,376	1,289,987
2004	782,838	87,604	336,892	51,012	23,390	36,046	45,364	18,139	1,373	5,757	11,690	1,400,105
2005	382,577	257,125	42,245	171,441	26,067	11,921	18,412	23,333	9,415	719	9,317	952,572
2006	1,003,220	141,755	123,474	21,196	85,474	12,862	5,868	9,104	11,627	4,732	5,162	1,424,474
2007	395,707	347,693	67,785	60,974	10,263	40,544	6,048	2,762	4,310	5,547	4,804	946,438
2008	1,311,990	108,585	165,251	32,772	28,435	4,632	18,007	2,678	1,228	1,929	4,694	1,680,201
2009	677,170	394,749	51,274	78,041	14,650	12,130	1,927	7,433	1,107	510	2,794	1,241,785
2010	845,697	191,084	186,860	24,456	35,549	6,412	5,201	822	3,178	476	1,450	1,301,185
2011	254,272	249,428	90,288	88,525	11,003	15,301	2,697	2,172	344	1,337	827	716,194
2012	1,347,270	41,390	119,243	44,583	42,888	5,226	7,208	1,272	1,031	164	1,050	1,611,325
2013	805,221	411,108	20,225	58,601	20,722	18,805	2,205	2,987	525	427	510	1,341,336
2014	410,891	65,029	198,451	10,531	25,295	7,446	5,834	617	787	135	241	725,256
2015	276,273	43,913	31,162	100,911	5,293	9,011	2,031	1,298	118	136	62	470,207
2016	517,631	14,630	20,907	15,538	48,484	2,334	2,495	410	207	15	22	622,673
2017	627,506	46,628	6,920	10,219	7,156	19,782	819	503	58	23.0	3.0	719,619
2018	174,159	54,856	21,797	3,281	4,442	2,666	6,082	206	71	5.9	2.0	267,569
2019	599,564	18,942	25,150	9,735	1,255	1,329	592	982	25	3.9	0.3	657,578
2020	384,993	32,020	8,870	11,949	4,233	466	404	145	195	4.0	0.4	443,279
2021	429,400	123,373	14,788	4,102	5,001	1,505	136	96	29	32.1	0.6	578,463
2022	560,005	71,670	59,197	7,554	2,075	2,398	667	55	36	9.7	10.3	703,676
2023	932,295	209,471	34,650	30,928	4,007	1,078	1,195	316	25	15.3	8.1	1,213,990
2024	2,258,450	267,464	102,172	18,551	17,227	2,254	602	657	171	13.2	12.1	2,667,573

Table 54. Female spawning stock biomass estimates for the SS northern stock model. 95% confidence intervals are based on asymptotic standard errors.

Year	Annual SSB (metric tons)			3-Year Average Relative SSB		
	LCI	Estimate	UCI	LCI	Estimate	UCI
Unfished	148,565	157,781	166,997	NA	NA	NA
Threshold	30,310	32,104	33,898	NA	1.000	NA
1990	2,010	2,201	2,203	NA	NA	NA
1991	2,254	3,445	3,447	NA	NA	NA
1992	18,567	24,224	24,226	0.246	0.310	0.375
1993	47,612	57,890	57,892	0.730	0.888	1.047
1994	126,390	146,388	146,390	2.034	2.373	2.711
1995	182,814	207,888	207,890	3.738	4.280	4.821
1996	208,340	233,796	233,798	5.391	6.106	6.821
1997	193,418	215,890	215,892	6.077	6.828	7.578
1998	182,076	201,630	201,632	6.062	6.763	7.463
1999	193,934	212,318	212,320	5.911	6.540	7.168
2000	192,990	209,584	209,586	5.897	6.474	7.051
2001	169,739	183,416	183,418	5.756	6.285	6.814
2002	137,902	148,586	148,588	5.169	5.623	6.077
2003	124,812	133,664	133,666	4.462	4.835	5.208
2004	104,457	111,669	111,671	3.788	4.090	4.392
2005	85,720	91,495	91,496	3.245	3.497	3.749
2006	67,466	72,092	72,094	2.654	2.858	3.062
2007	58,718	62,742	62,744	2.184	2.350	2.516
2008	48,863	52,376	52,378	1.806	1.944	2.082
2009	47,471	50,893	50,894	1.600	1.724	1.848
2010	46,617	49,925	49,927	1.475	1.591	1.706
2011	45,270	48,297	48,299	1.434	1.548	1.662
2012	38,806	41,421	41,423	1.343	1.450	1.557
2013	27,655	29,443	29,445	1.146	1.237	1.329
2014	17,457	18,675	18,677	0.861	0.930	0.999
2015	11,619	12,471	12,473	0.581	0.629	0.677
2016	7,473	8,060	8,062	0.375	0.407	0.439
2017	4,936	5,405	5,407	0.247	0.269	0.291
2018	3,546	4,007	4,009	0.165	0.181	0.198
2019	2,292	2,706	2,708	0.112	0.126	0.139
2020	2,040	2,465	2,467	0.082	0.095	0.108
2021	3,359	4,106	4,108	0.081	0.096	0.111
2022	4,181	5,136	5,138	0.102	0.122	0.142
2023	7,075	8,607	8,609	0.155	0.185	0.215
2024	10,671	13,249	13,251	0.235	0.280	0.325

Table 55. Fishing mortality (F, ages 1-9) and spawning potential ratio (SPR) estimates for the northern stock SS model. 95% confidence intervals are based on asymptotic standard errors.

Year	3-Year Average Relative F (Age 1-9)			Annual SPR		
	LCI	Estimate	UCI	LCI	Estimate	UCI
Threshold	0.218	0.237	0.256	NA	0.250	NA
1990	1.748	2.522	3.297	0.024	0.055	0.086
1991	0.532	0.900	1.267	0.165	0.237	0.308
1992	0.351	0.548	0.746	0.465	0.529	0.592
1993	0.288	0.426	0.563	0.618	0.660	0.702
1994	0.128	0.157	0.185	0.659	0.728	0.797
1995	0.108	0.128	0.148	0.678	0.753	0.828
1996	0.100	0.116	0.132	0.820	0.839	0.857
1997	0.155	0.179	0.203	0.754	0.780	0.805
1998	0.184	0.211	0.238	0.747	0.774	0.800
1999	0.194	0.221	0.247	0.656	0.708	0.761
2000	0.179	0.202	0.225	0.593	0.676	0.759
2001	0.222	0.250	0.277	0.577	0.688	0.799
2002	0.303	0.340	0.377	0.669	0.700	0.730
2003	0.330	0.369	0.408	0.680	0.698	0.715
2004	0.369	0.412	0.454	0.494	0.566	0.638
2005	0.389	0.433	0.477	0.578	0.612	0.645
2006	0.483	0.538	0.593	0.489	0.546	0.604
2007	0.489	0.545	0.600	0.332	0.410	0.488
2008	0.560	0.625	0.691	0.366	0.426	0.486
2009	0.509	0.568	0.628	0.344	0.409	0.474
2010	0.540	0.603	0.666	0.360	0.421	0.482
2011	0.446	0.498	0.549	0.170	0.257	0.344
2012	0.532	0.596	0.659	0.407	0.447	0.487
2013	0.489	0.546	0.604	0.073	0.099	0.124
2014	0.541	0.604	0.668	0.090	0.128	0.166
2015	0.561	0.629	0.696	0.041	0.066	0.091
2016	0.794	0.901	1.009	0.083	0.116	0.149
2017	0.949	1.089	1.229	0.084	0.114	0.145
2018	0.991	1.151	1.311	0.059	0.135	0.212
2019	0.832	0.990	1.148	0.049	0.075	0.102
2020	0.714	0.873	1.032	0.276	0.442	0.608
2021	0.485	0.606	0.727	0.185	0.282	0.380
2022	0.324	0.412	0.499	0.645	0.686	0.727
2023	0.136	0.172	0.208	0.473	0.584	0.694
2024	0.097	0.123	0.149	0.666	0.747	0.828

Table 56. Life history and recruitment parameters for the southern stock SS base model.

Parameter	Type	Final Value	SE	Lower Bound	Upper Bound
NatM_Lorenzen_Fem_GP_1	Fixed	0.809	NA	NA	NA
L_at_Amin_Fem_GP_1	Estimated	14.936	0.167021	8	40
L_at_Amax_Fem_GP_1	Estimated	39.5538	0.876045	20	70
VonBert_K_Fem_GP_1	Estimated	0.157802	0.00820658	0.05	0.8
CV_young_Fem_GP_1	Estimated	0.158132	0.00533535	0.01	0.5
CV_old_Fem_GP_1	Estimated	0.0867026	0.0118603	0.01	0.5
Wtlen_1_Fem_GP_1	Fixed	8.22E-06	NA	NA	NA
Wtlen_2_Fem_GP_1	Fixed	3.07	NA	NA	NA
Mat50%_Fem_GP_1	Fixed	17.9	NA	NA	NA
Mat_slope_Fem_GP_1	Fixed	-0.58	NA	NA	NA
Eggs/kg_inter_Fem_GP_1	Fixed	1	NA	NA	NA
Eggs/kg_slope_wt_Fem_GP_1	Fixed	0	NA	NA	NA
CohortGrowDev	Fixed	1	NA	NA	NA
FracFemale_GP_1	Fixed	0.5	NA	NA	NA
SR_LN(R0)	Estimated	12.8851	0.0936998	6	25
SR_BH_steep	Fixed	0.99	NA	NA	NA
SR_sigmaR	Fixed	0.545634	NA	NA	NA
SR_regime	Fixed	0	NA	NA	NA
SR_autocorr	Fixed	0	NA	NA	NA
Early_InitAge_5	Estimated	0.0809535	0.553698	-5	5
Early_InitAge_4	Estimated	-0.00431037	0.544621	-5	5
Early_InitAge_3	Estimated	0.137343	0.499713	-5	5
Early_InitAge_2	Estimated	-0.357504	0.462559	-5	5
Early_InitAge_1	Estimated	0.162788	0.43056	-5	5
Early_RecrDev_1990	Estimated	-0.207551	0.250428	-5	5
Early_RecrDev_1991	Estimated	0.280716	0.27991	-5	5
Early_RecrDev_1992	Estimated	-0.197359	0.178348	-5	5
Early_RecrDev_1993	Estimated	-0.67867	0.229962	-5	5
Early_RecrDev_1994	Estimated	-1.03262	0.32981	-5	5
Early_RecrDev_1995	Estimated	-0.3753	0.217924	-5	5
Early_RecrDev_1996	Estimated	-0.46449	0.173597	-5	5
Early_RecrDev_1997	Estimated	-1.55841	0.196283	-5	5
Early_RecrDev_1998	Estimated	-0.300909	0.149516	-5	5
Early_RecrDev_1999	Estimated	-0.680599	0.203248	-5	5
Early_RecrDev_2000	Estimated	-0.933854	0.149935	-5	5
Main_RecrDev_2001	Estimated	-0.16827	0.113848	-5	5
Main_RecrDev_2002	Estimated	-1.08953	0.146421	-5	5
Main_RecrDev_2003	Estimated	-0.524337	0.120769	-5	5
Main_RecrDev_2004	Estimated	-0.367394	0.122357	-5	5
Main_RecrDev_2005	Estimated	-0.633719	0.102531	-5	5
Main_RecrDev_2006	Estimated	-0.499053	0.155889	-5	5
Main_RecrDev_2007	Estimated	-1.01297	0.13888	-5	5
Main_RecrDev_2008	Estimated	-0.150086	0.146297	-5	5
Main_RecrDev_2009	Estimated	-0.36825	0.131488	-5	5
Main_RecrDev_2010	Estimated	0.12714	0.119945	-5	5
Main_RecrDev_2011	Estimated	0.06478	0.104986	-5	5
Main_RecrDev_2012	Estimated	-0.340553	0.0891854	-5	5
Main_RecrDev_2013	Estimated	0.492467	0.12511	-5	5
Main_RecrDev_2014	Estimated	0.264064	0.0916051	-5	5
Main_RecrDev_2015	Estimated	-0.0605424	0.0921002	-5	5
Main_RecrDev_2016	Estimated	0.217771	0.0865707	-5	5
Main_RecrDev_2017	Estimated	0.129434	0.100735	-5	5
Main_RecrDev_2018	Estimated	0.558329	0.100661	-5	5
Main_RecrDev_2019	Estimated	0.734754	0.101289	-5	5
Main_RecrDev_2020	Estimated	0.758167	0.116276	-5	5
Main_RecrDev_2021	Estimated	0.266745	0.105979	-5	5
Main_RecrDev_2022	Estimated	0.320005	0.0954438	-5	5
Main_RecrDev_2023	Estimated	0.727366	0.116185	-5	5
Main_RecrDev_2024	Estimated	0.553684	0.141487	-5	5

Table 57. Fishing mortality parameter estimates for the southern stock SS base model. Rec_NC_GA and shrimp bycatch are fleets 2 and 4, respectively.

Parameter	Estimate	SE	Parameter	Estimate	SE	Parameter	Estimate	SE
F_fleet_2_YR_1990_s_1	0.112	0.022	F_fleet_2_YR_2019_s_1	0.020	0.003	F_fleet_4_YR_2013_s_1	0.394	0.157
F_fleet_2_YR_1991_s_1	0.042	0.008	F_fleet_2_YR_2020_s_1	0.028	0.005	F_fleet_4_YR_2014_s_1	0.413	0.107
F_fleet_2_YR_1992_s_1	0.098	0.017	F_fleet_2_YR_2021_s_1	0.026	0.004	F_fleet_4_YR_2015_s_1	0.348	0.096
F_fleet_2_YR_1993_s_1	0.055	0.011	F_fleet_2_YR_2022_s_1	0.022	0.004	F_fleet_4_YR_2016_s_1	0.474	0.114
F_fleet_2_YR_1994_s_1	0.056	0.011	F_fleet_2_YR_2023_s_1	0.030	0.005	F_fleet_4_YR_2017_s_1	0.451	0.131
F_fleet_2_YR_1995_s_1	0.056	0.011	F_fleet_2_YR_2024_s_1	0.021	0.004	F_fleet_4_YR_2018_s_1	0.220	0.099
F_fleet_2_YR_1996_s_1	0.047	0.009	F_fleet_4_YR_1990_s_1	0.481	0.324	F_fleet_4_YR_2019_s_1	0.349	0.117
F_fleet_2_YR_1997_s_1	0.040	0.007	F_fleet_4_YR_1991_s_1	3.006	0.767	F_fleet_4_YR_2020_s_1	0.337	0.102
F_fleet_2_YR_1998_s_1	0.064	0.011	F_fleet_4_YR_1992_s_1	1.748	0.361	F_fleet_4_YR_2021_s_1	0.344	0.101
F_fleet_2_YR_1999_s_1	0.056	0.010	F_fleet_4_YR_1993_s_1	1.227	0.395	F_fleet_4_YR_2022_s_1	0.057	0.020
F_fleet_2_YR_2000_s_1	0.035	0.006	F_fleet_4_YR_1994_s_1	0.124	0.398	F_fleet_4_YR_2023_s_1	0.201	0.078
F_fleet_2_YR_2001_s_1	0.032	0.006	F_fleet_4_YR_1995_s_1	3.212	0.633	F_fleet_4_YR_2024_s_1	0.353	0.132
F_fleet_2_YR_2002_s_1	0.057	0.011	F_fleet_4_YR_1996_s_1	0.881	0.215			
F_fleet_2_YR_2003_s_1	0.100	0.018	F_fleet_4_YR_1997_s_1	2.409	0.623			
F_fleet_2_YR_2004_s_1	0.051	0.009	F_fleet_4_YR_1998_s_1	0.829	0.196			
F_fleet_2_YR_2005_s_1	0.056	0.011	F_fleet_4_YR_1999_s_1	1.357	0.300			
F_fleet_2_YR_2006_s_1	0.069	0.013	F_fleet_4_YR_2000_s_1	1.067	0.214			
F_fleet_2_YR_2007_s_1	0.033	0.006	F_fleet_4_YR_2001_s_1	1.318	0.186			
F_fleet_2_YR_2008_s_1	0.032	0.006	F_fleet_4_YR_2002_s_1	0.394	0.174			
F_fleet_2_YR_2009_s_1	0.072	0.014	F_fleet_4_YR_2003_s_1	0.874	0.182			
F_fleet_2_YR_2010_s_1	0.030	0.005	F_fleet_4_YR_2004_s_1	1.286	0.201			
F_fleet_2_YR_2011_s_1	0.043	0.008	F_fleet_4_YR_2005_s_1	0.306	0.111			
F_fleet_2_YR_2012_s_1	0.019	0.004	F_fleet_4_YR_2006_s_1	1.041	0.234			
F_fleet_2_YR_2013_s_1	0.032	0.006	F_fleet_4_YR_2007_s_1	0.615	0.191			
F_fleet_2_YR_2014_s_1	0.040	0.007	F_fleet_4_YR_2008_s_1	0.954	0.204			
F_fleet_2_YR_2015_s_1	0.035	0.006	F_fleet_4_YR_2009_s_1	1.123	0.211			
F_fleet_2_YR_2016_s_1	0.028	0.005	F_fleet_4_YR_2010_s_1	0.681	0.170			
F_fleet_2_YR_2017_s_1	0.028	0.005	F_fleet_4_YR_2011_s_1	0.428	0.127			
F_fleet_2_YR_2018_s_1	0.023	0.004	F_fleet_4_YR_2012_s_1	0.000	0.000			

Table 58. Fishing mortality parameter estimates for the southern stock SS base model Rec_FL fleet (fleet 6).

Parameter	Estimate	SE
F_fleet_6_YR_1990_s_1	0.192	0.045
F_fleet_6_YR_1991_s_1	0.281	0.061
F_fleet_6_YR_1992_s_1	0.282	0.059
F_fleet_6_YR_1993_s_1	0.155	0.034
F_fleet_6_YR_1994_s_1	0.264	0.061
F_fleet_6_YR_1995_s_1	0.150	0.036
F_fleet_6_YR_1996_s_1	0.062	0.015
F_fleet_6_YR_1997_s_1	0.098	0.022
F_fleet_6_YR_1998_s_1	0.156	0.033
F_fleet_6_YR_1999_s_1	0.506	0.104
F_fleet_6_YR_2000_s_1	0.285	0.058
F_fleet_6_YR_2001_s_1	0.293	0.059
F_fleet_6_YR_2002_s_1	0.136	0.030
F_fleet_6_YR_2003_s_1	0.101	0.022
F_fleet_6_YR_2004_s_1	0.234	0.050
F_fleet_6_YR_2005_s_1	0.155	0.036
F_fleet_6_YR_2006_s_1	0.089	0.020
F_fleet_6_YR_2007_s_1	0.258	0.066
F_fleet_6_YR_2008_s_1	0.128	0.028
F_fleet_6_YR_2009_s_1	0.253	0.053
F_fleet_6_YR_2010_s_1	0.056	0.012
F_fleet_6_YR_2011_s_1	0.227	0.050
F_fleet_6_YR_2012_s_1	0.160	0.034
F_fleet_6_YR_2013_s_1	0.068	0.015
F_fleet_6_YR_2014_s_1	0.061	0.013
F_fleet_6_YR_2015_s_1	0.085	0.017
F_fleet_6_YR_2016_s_1	0.123	0.027
F_fleet_6_YR_2017_s_1	0.036	0.008
F_fleet_6_YR_2018_s_1	0.037	0.007
F_fleet_6_YR_2019_s_1	0.028	0.007
F_fleet_6_YR_2020_s_1	0.049	0.010
F_fleet_6_YR_2021_s_1	0.022	0.005
F_fleet_6_YR_2022_s_1	0.024	0.005
F_fleet_6_YR_2023_s_1	0.018	0.004
F_fleet_6_YR_2024_s_1	0.017	0.003

Table 59. Fishing fleet initial fishing mortality, selectivity, and survey catchability coefficient for the southern stock SS base model.

Parameter	Type	Final Value	SE	Lower Bound	Upper Bound
LnQ_base_SEAMAP_Fall(1)	Fixed	-8.94	NA	NA	NA
LnQ_base_SEAMAP_Summer(5)	Fixed	-11.95	NA	NA	NA
LnQ_base_GA_YOY(8)	Fixed	-12.92	NA	NA	NA
LnQ_base_SC_YOY(9)	Fixed	-13.25	NA	NA	NA
Size_DblN_peak_SEAMAP_Fall(1)	Estimated	18.16	0.171991	11	30
Size_DblN_top_logit_SEAMAP_Fall(1)	Estimated	-5.58	4.19089	-10	3
Size_DblN_ascend_se_SEAMAP_Fall(1)	Estimated	1.91	0.106652	0	6
Size_DblN_descend_se_SEAMAP_Fall(1)	Estimated	2.29	0.15395	0	6
Size_DblN_start_logit_SEAMAP_Fall(1)	Fixed	-999.00	NA	NA	NA
Size_DblN_end_logit_SEAMAP_Fall(1)	Fixed	-999.00	NA	NA	NA
Size_inflection_Rec_NC_GA(2)	Estimated	20.90	0.187219	0	60
Size_95%width_Rec_NC_GA(2)	Estimated	3.71	0.137808	0.01	40
Size_DblN_peak_Comm_NC_GA(3)	Estimated	26.14	0.572793	11	30
Size_DblN_top_logit_Comm_NC_GA(3)	Estimated	1.25	2.05023	-10	3
Size_DblN_ascend_se_Comm_NC_GA(3)	Estimated	1.51	0.36008	0	6
Size_DblN_descend_se_Comm_NC_GA(3)	Fixed	6.00	NA	NA	NA
Size_DblN_start_logit_Comm_NC_GA(3)	Fixed	-999.00	NA	NA	NA
Size_DblN_end_logit_Comm_NC_GA(3)	Fixed	-999.00	NA	NA	NA
Size_DblN_peak_SEAMAP_Summer(5)	Estimated	20.29	0.224514	11	30
Size_DblN_top_logit_SEAMAP_Summer(5)	Estimated	-7.36	3.0213	-10	3
Size_DblN_ascend_se_SEAMAP_Summer(5)	Estimated	3.41	0.104273	0	6
Size_DblN_descend_se_SEAMAP_Summer(5)	Estimated	1.50	0.219377	0	6
Size_DblN_start_logit_SEAMAP_Summer(5)	Fixed	-999.00	NA	NA	NA
Size_DblN_end_logit_SEAMAP_Summer(5)	Fixed	-999.00	NA	NA	NA
Size_inflection_Rec_FL(6)	Estimated	25.00	0.29985	0	60
Size_95%width_Rec_FL(6)	Estimated	4.40	0.189506	0.01	40
SizeSel_P1_Comm_FL(7)	Fixed	-1.00	NA	NA	NA
SizeSel_P2_Comm_FL(7)	Fixed	-1.00	NA	NA	NA
minage@sel=1_Bycatch(4)	Fixed	0.00	NA	NA	NA
maxage@sel=1_Bycatch(4)	Fixed	0.00	NA	NA	NA
Size_DblN_peak_Comm_NC_GA(3)_BLK1repl_2004	Estimated	22.95	0.210901	11	30
Size_DblN_top_logit_Comm_NC_GA(3)_BLK1repl_2004	Estimated	-6.39	3.91583	-10	3
Size_DblN_ascend_se_Comm_NC_GA(3)_BLK1repl_2004	Estimated	0.73	0.217462	0	6
Size_DblN_descend_se_Comm_NC_GA(3)_BLK1repl_2004	Estimated	3.28	0.184134	0	6
InitF_seas_1_flt_2Rec_NC_GA	Estimated	0.46	0.511478	0	2
InitF_seas_1_flt_3Comm_NC_GA	Estimated	0.60	0.760427	0	2
InitF_seas_1_flt_4Bycatch	Estimated	1.36	0.402125	0	3
InitF_seas_1_flt_6Rec_FL	Estimated	0.64	0.794162	0	2
InitF_seas_1_flt_7Comm_FL	Estimated	0.64	0.794162	0	2

Table 60. Jitter analysis results for the southern stock SS model. The -LL column shows the change in total negative log-likelihood relative to the base model.

LL	Δ LL	Frequency
2335.23	0	186
2371.84	36.61	1
2381.62	46.39	1
2386.67	51.44	1
2468.46	133.23	1
2493.13	157.9	1
2497.22	161.99	1
2573.59	238.36	1
2624.25	289.02	1
4113.55	1778.32	1
4127.46	1792.23	1
4129.18	1793.95	1
4139.22	1803.99	1
4147.08	1811.85	1
6090.96	3755.73	1

Table 61. Beginning of fishing year abundance estimates (in 1000s of fish) for the southern stock SS base model.

Year	0	1	2	3	4	5
1990	495860	62480.7	12509.4	4971.14	635.747	70.1256
1991	794320	100569	23649	4678.31	1691.48	219.718
1992	484395	12936.1	38773.9	9349.17	1753.54	674.546
1993	298263	27685.4	4929.74	15133.3	3515.03	874.72
1994	209005	28765.2	10743.4	2042.58	6370.45	1874.24
1995	404589	60694	11102.5	4359.73	823.08	3273.66
1996	368160	5361.95	23474.2	4479.16	1718.29	1589.06
1997	123588	50194.7	2095.96	10018.6	2006.7	1599.55
1998	432788	3657.85	19616.1	890.779	4434.85	1693.72
1999	297499	62112.2	1417.65	8139.45	378.238	2672.85
2000	230360	25168.6	23733.9	552.217	3005.16	1004.82
2001	494963	26062.3	9762	9743.04	226.22	1623.29
2002	197191	43600.2	10120.4	4023.05	4020.59	762.969
2003	348092	43740.1	16929.5	4207.75	1707.68	2068.26
2004	407735	47704.3	16821.8	6889.77	1735.95	1621.97
2005	312294	37039.1	18353.2	6767.18	2775.35	1394.45
2006	358518	75657.9	14309.2	7522.96	2831.55	1822.74
2007	214555	41626.6	29369.5	5998.67	3279.21	2153.74
2008	507980	38154.9	16174.3	12153.1	2503.97	2284.03
2009	408874	64398.1	14887.8	6819.73	5310.07	2227.57
2010	670875	43723.6	24795	6037.97	2769.4	3059.7
2011	632506	111866	17164.3	10697.4	2753.6	2908.66
2012	422763	135655	43395.2	7089.14	4472.6	2418.51
2013	973953	139241	53132.5	18444.2	3115.32	3148.26
2014	776251	216249	54614.8	22860.8	8362.77	3081.34
2015	561429	169129	84656.8	23401.9	10324.3	5510.2
2016	741592	130484	66212	36197.8	10500.7	7580.25
2017	678864	152089	51120.3	28289	16131.7	8528.43
2018	1042550	142452	59821.8	22210.7	13077.5	12362.3
2019	1244550	275564	56088.7	26046.3	10295.6	12979.8
2020	1274740	289155	108590	24477.5	12127.4	12070.4
2021	780096	299784	113562	46909.1	11199.1	12146.9
2022	822723	182155	118036	49511.8	21829.7	12055.6
2023	1236530	256129	71781.6	51550	23090.4	17230
2024	1039630	333286	100756	31242.1	23949.3	20606.5

Table 62. Female spawning stock biomass estimates for the southern stock SS base model. 95% confidence intervals are based on asymptotic standard errors.

Year	Annual SSB (metric tons)			3-year average relative SSB		
	LCI	Estimate	UCI	LCI	Estimate	UCI
Unfished	23116.80	28342.10	33567.40	NA	NA	NA
Threshold	5857.81	7031.70	8205.59	NA	1.00	NA
1990	1591.70	3238.95	4886.20	NA	NA	NA
1991	3686.65	5209.09	6731.53	NA	NA	NA
1992	3376.78	4745.41	6114.04	0.50	0.63	0.75
1993	2532.79	3817.68	5102.57	0.52	0.65	0.78
1994	2004.60	3501.35	4998.10	0.45	0.57	0.69
1995	2967.47	4161.44	5355.41	0.43	0.54	0.66
1996	1990.09	3187.80	4385.51	0.40	0.51	0.63
1997	2603.10	3567.92	4532.74	0.41	0.52	0.63
1998	1788.58	2940.24	4091.90	0.37	0.46	0.55
1999	2613.53	3690.14	4766.75	0.40	0.48	0.57
2000	2189.75	3260.40	4331.05	0.39	0.47	0.55
2001	1991.90	3151.21	4310.52	0.39	0.48	0.57
2002	1997.23	3291.35	4585.47	0.37	0.46	0.55
2003	2437.42	3850.43	5263.44	0.39	0.49	0.58
2004	2685.79	4122.28	5558.77	0.43	0.53	0.63
2005	2316.64	4040.16	5763.68	0.46	0.57	0.68
2006	3252.81	5004.43	6756.05	0.50	0.62	0.74
2007	3524.45	5192.62	6860.79	0.55	0.67	0.80
2008	3043.22	4832.57	6621.92	0.58	0.71	0.85
2009	3413.11	5236.81	7060.51	0.59	0.72	0.86
2010	2803.52	5154.78	7506.04	0.58	0.72	0.86
2011	3853.74	6892.25	9930.76	0.66	0.82	0.97
2012	5495.08	9046.19	12597.30	0.81	1.00	1.18
2013	6687.82	11227.00	15766.18	1.06	1.29	1.51
2014	9570.38	14745.90	19921.42	1.39	1.66	1.93
2015	11673.11	16892.30	22111.49	1.71	2.03	2.35
2016	11590.79	16897.10	22203.41	1.94	2.30	2.65
2017	11345.63	16730.10	22114.57	2.02	2.39	2.77
2018	10845.92	17155.00	23464.08	2.02	2.41	2.78
2019	13096.87	20536.70	27976.53	2.18	2.58	2.97
2020	15811.78	24402.60	32993.42	2.50	2.94	3.38
2021	19291.30	27626.20	35961.10	2.92	3.44	3.95
2022	18778.59	27020.10	35261.61	3.16	3.75	4.32
2023	18898.90	27930.40	36961.90	3.31	3.91	4.51
2024	29504.52	30816.60	32128.68	3.48	4.07	4.64

Table 63. Fishing mortality (F, ages 1-3) and spawning potential ratio (SPR) estimates for the northern stock SS model. 95% confidence intervals are based on asymptotic standard errors.

	Age 1-3 average F			Annual SPR			3-year average SPR
Year	LCI	Estimate	UCI	LCI	Estimate	UCI	Estimate
Threshold	0.170	0.264	0.358	NA	0.25	NA	0.25
1990	0.053	0.087	0.122	0.156	0.420	0.685	NA
1991	0.037	0.055	0.074	-0.019	0.036	0.091	NA
1992	0.083	0.132	0.180	0.034	0.127	0.219	0.194
1993	0.039	0.066	0.094	0.052	0.239	0.427	0.134
1994	0.029	0.054	0.078	0.154	0.686	1.219	0.351
1995	0.030	0.048	0.066	-0.008	0.031	0.070	0.319
1996	0.026	0.043	0.059	0.210	0.367	0.523	0.361
1997	0.019	0.029	0.039	-0.018	0.078	0.174	0.159
1998	0.042	0.066	0.090	0.218	0.359	0.500	0.268
1999	0.045	0.068	0.090	0.071	0.185	0.299	0.207
2000	0.034	0.054	0.074	0.150	0.272	0.395	0.272
2001	0.041	0.065	0.089	0.128	0.214	0.299	0.224
2002	0.025	0.039	0.053	0.360	0.556	0.752	0.347
2003	0.038	0.056	0.075	0.203	0.332	0.461	0.367
2004	0.042	0.064	0.086	0.122	0.215	0.309	0.368
2005	0.036	0.058	0.079	0.452	0.599	0.745	0.382
2006	0.023	0.035	0.047	0.157	0.300	0.444	0.371
2007	0.031	0.052	0.074	0.263	0.437	0.610	0.445
2008	0.028	0.043	0.058	0.193	0.330	0.468	0.356
2009	0.035	0.054	0.073	0.141	0.254	0.367	0.340
2010	0.014	0.022	0.030	0.302	0.461	0.619	0.348
2011	0.026	0.040	0.054	0.382	0.528	0.673	0.414
2012	0.016	0.025	0.033	0.818	0.862	0.906	0.617
2013	0.016	0.023	0.030	0.416	0.608	0.799	0.666
2014	0.016	0.023	0.030	0.458	0.594	0.729	0.688
2015	0.019	0.028	0.037	0.497	0.627	0.757	0.609
2016	0.021	0.032	0.044	0.412	0.547	0.682	0.589
2017	0.011	0.017	0.023	0.435	0.593	0.751	0.589
2018	0.010	0.015	0.021	0.601	0.750	0.899	0.630
2019	0.008	0.012	0.015	0.508	0.665	0.821	0.669
2020	0.013	0.019	0.025	0.515	0.654	0.793	0.690
2021	0.010	0.014	0.019	0.529	0.667	0.805	0.662
2022	0.010	0.015	0.020	0.850	0.893	0.935	0.738
2023	0.011	0.016	0.021	0.646	0.768	0.890	0.776
2024	0.007	0.010	0.014	0.493	0.669	0.844	0.776

12 FIGURES

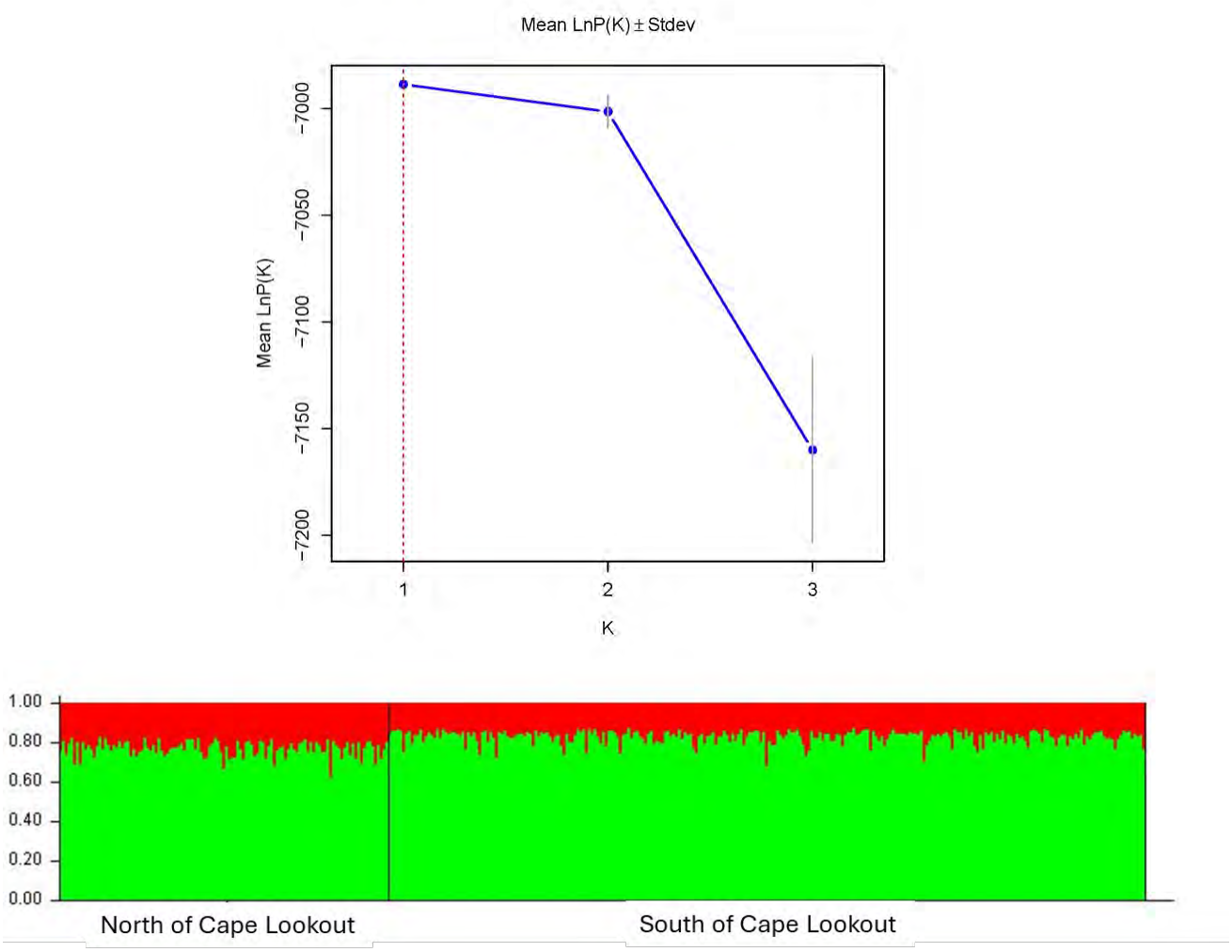


Figure 1. STRUCTURE results for comparison of groups north and south of Cape Lookout, North Carolina. Upper panel is the loglikelihood plot; lower panel is the ancestry plot by individual.

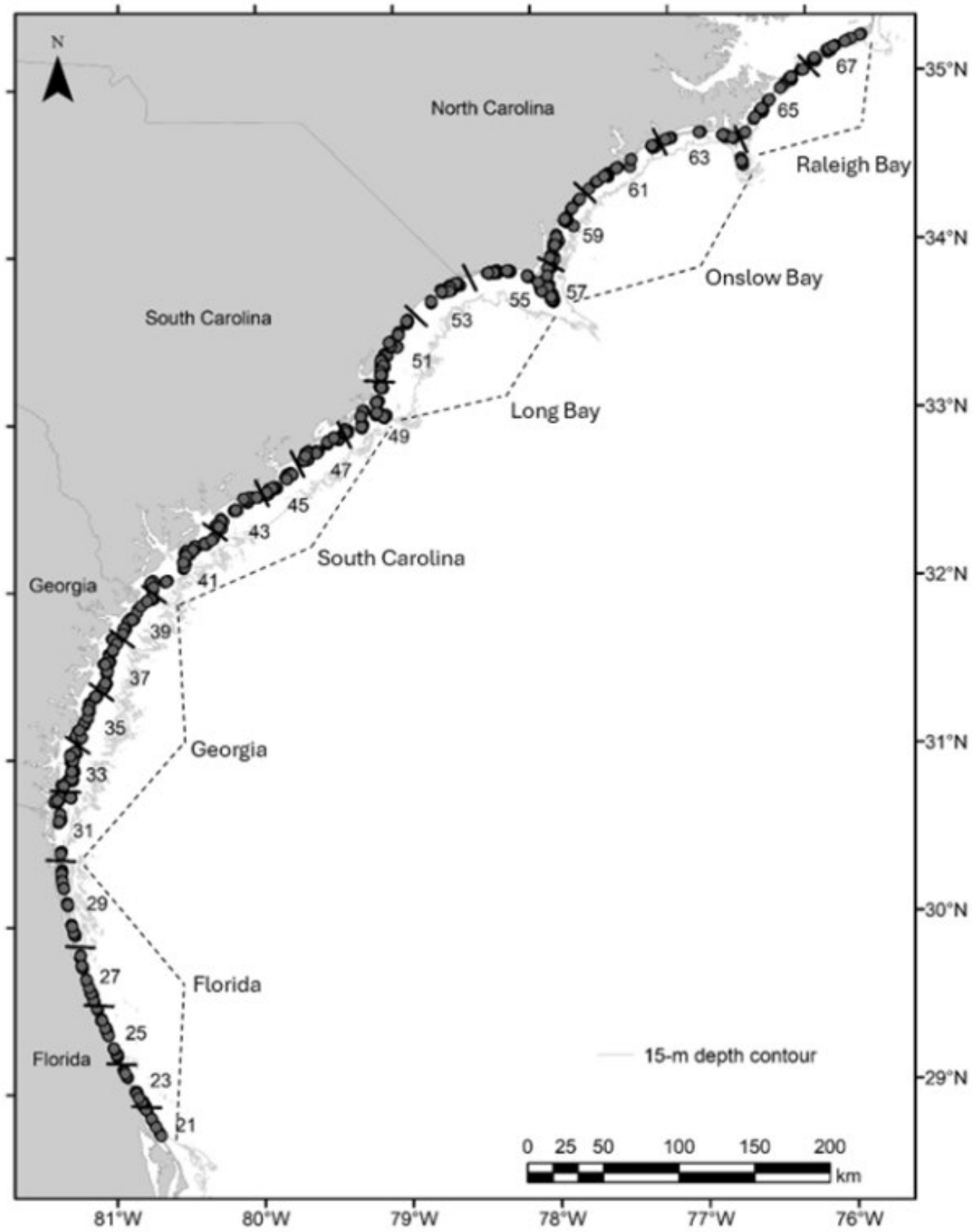


Figure 2. Strata (labelled as numbers) sampled within each region (names) by the SEAMAP-SA Coastal Trawl Survey (Strata are not drawn to scale).

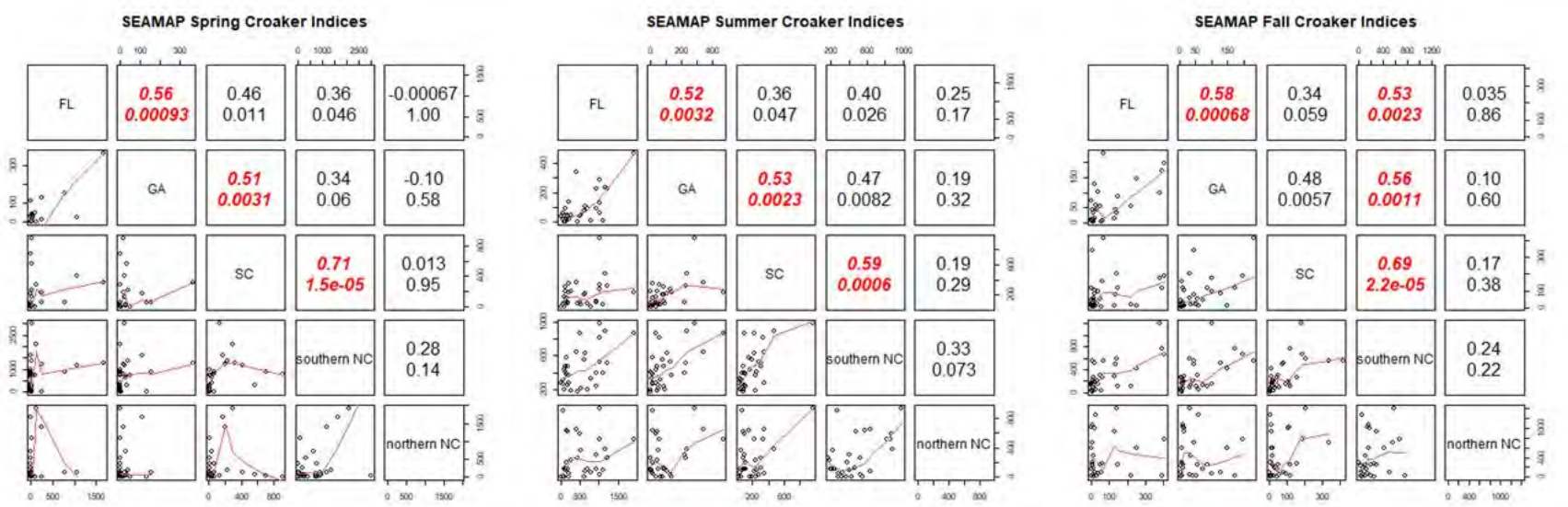


Figure 3. Spearman's correlation analysis results for SEAMAP coastal trawl survey seasonal indices of abundance by state (Florida-South Carolina) or sub-state region (North Carolina). Spearman's rhos are the top numbers and p-values are the bottom numbers to the right of the diagonal. Results bolded in red are the strongest significant positive associations (rho≥0.5 and p-value<0.05).

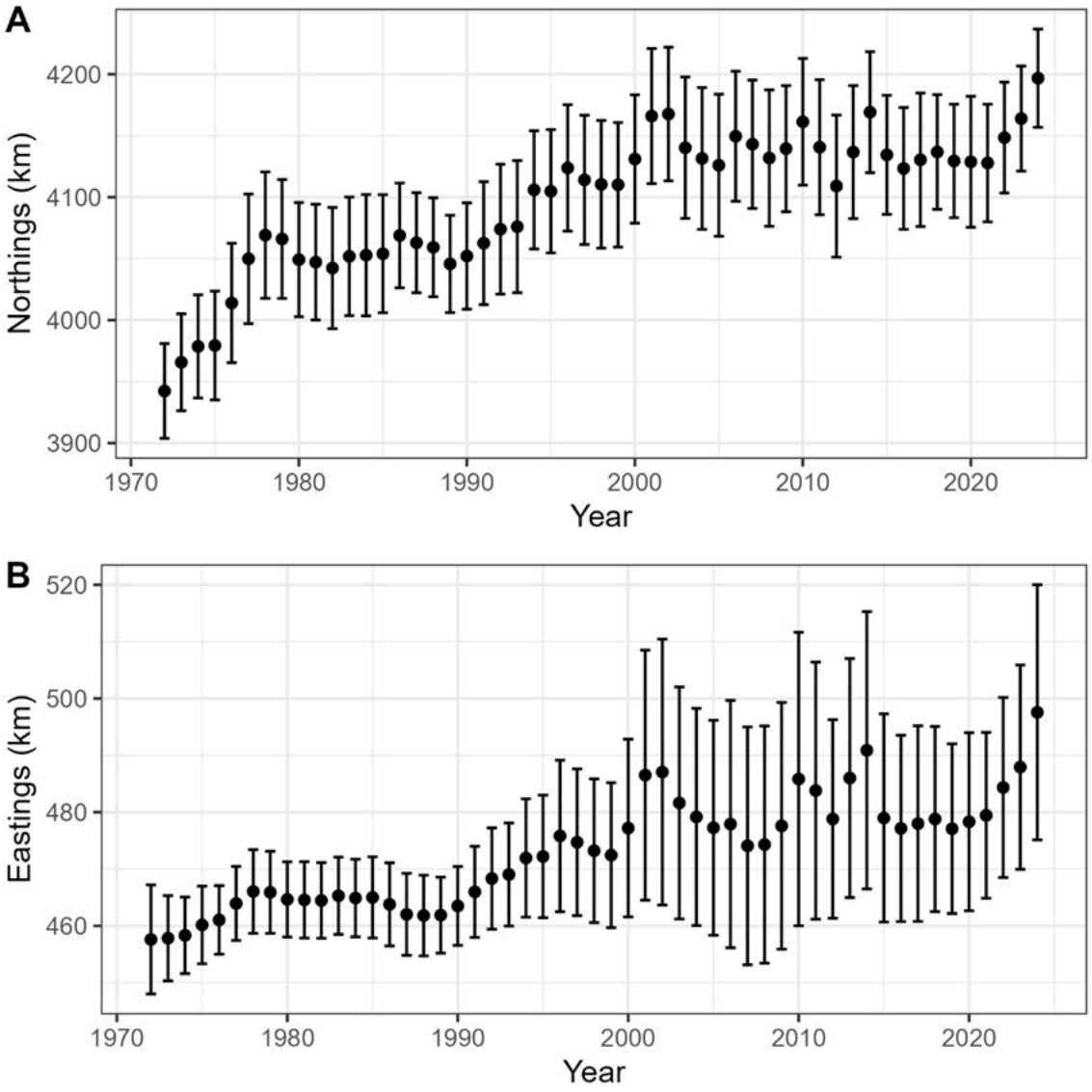


Figure 4. NOAA Fisheries Northeast Fisheries Science Center bottom trawl fall Atlantic croaker center of gravity estimates in terms of (A) northward distance from the equator and (B) eastings from the 75th meridian west. Error bars represent ±1.96 standard errors.

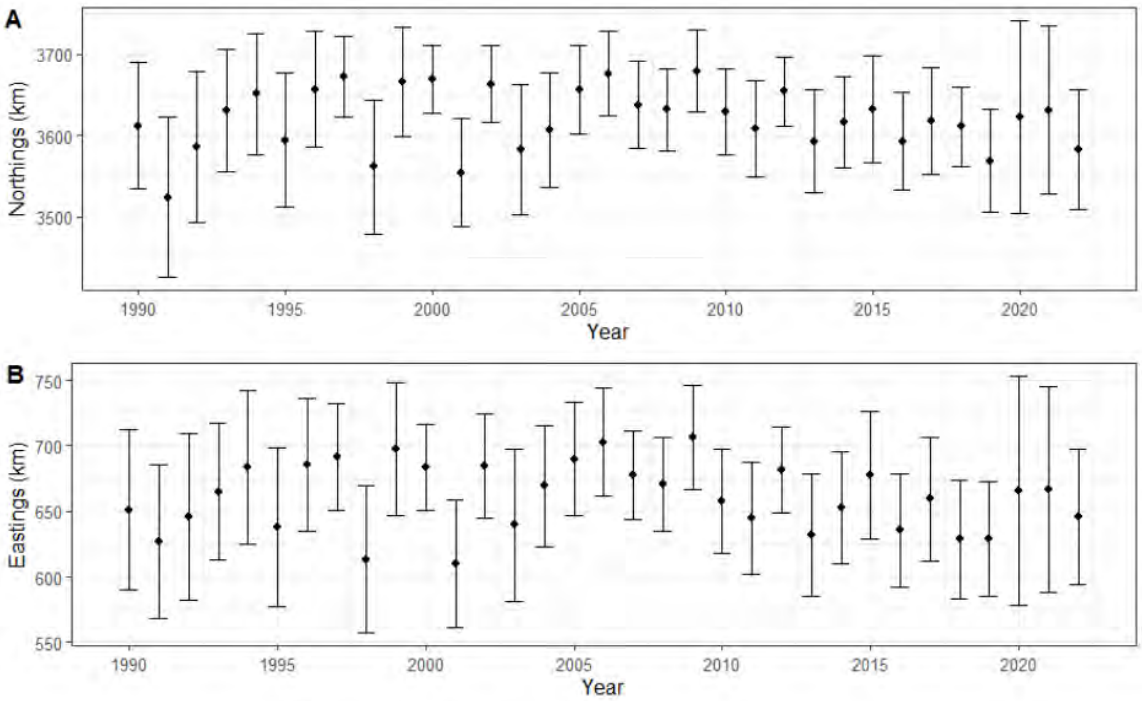


Figure 5. SEAMAP coastal trawl summer Atlantic croaker center of gravity estimates in terms of (A) northward distance from the equator and (B) eastings from the 75th meridian west. Error bars represent ±1.96 standard errors.

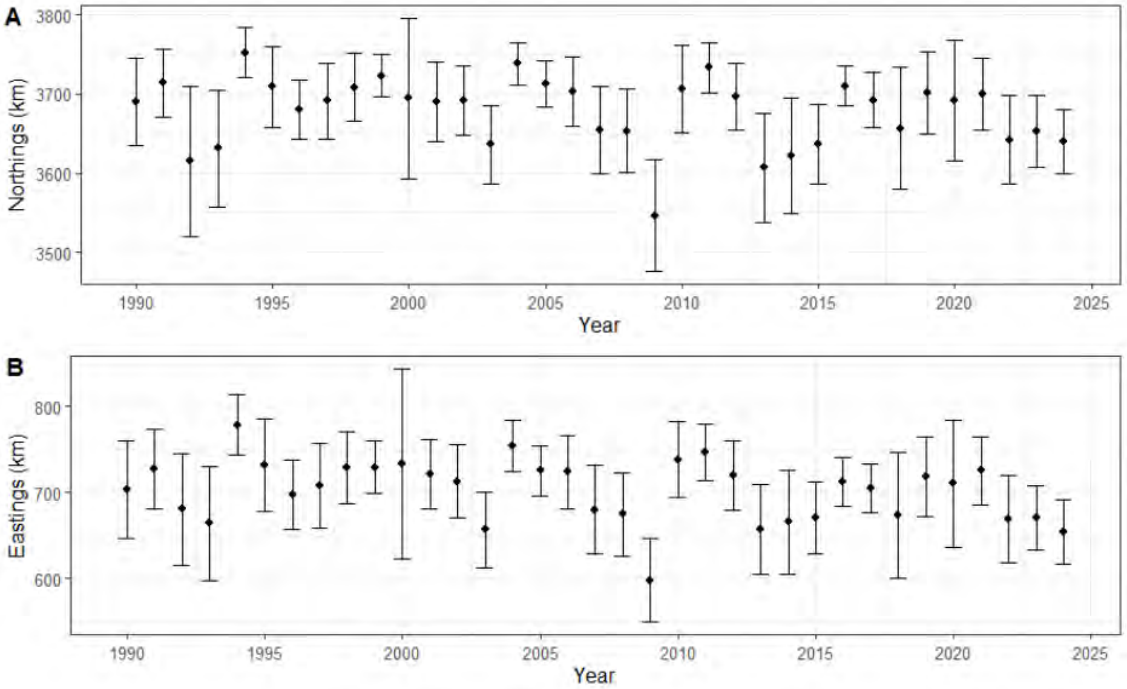


Figure 6. SEAMAP coastal trawl fall Atlantic croaker center of gravity estimates in terms of (A) northward distance from the equator and (B) eastings from the 75th meridian west. Error bars represent ±1.96 standard errors.

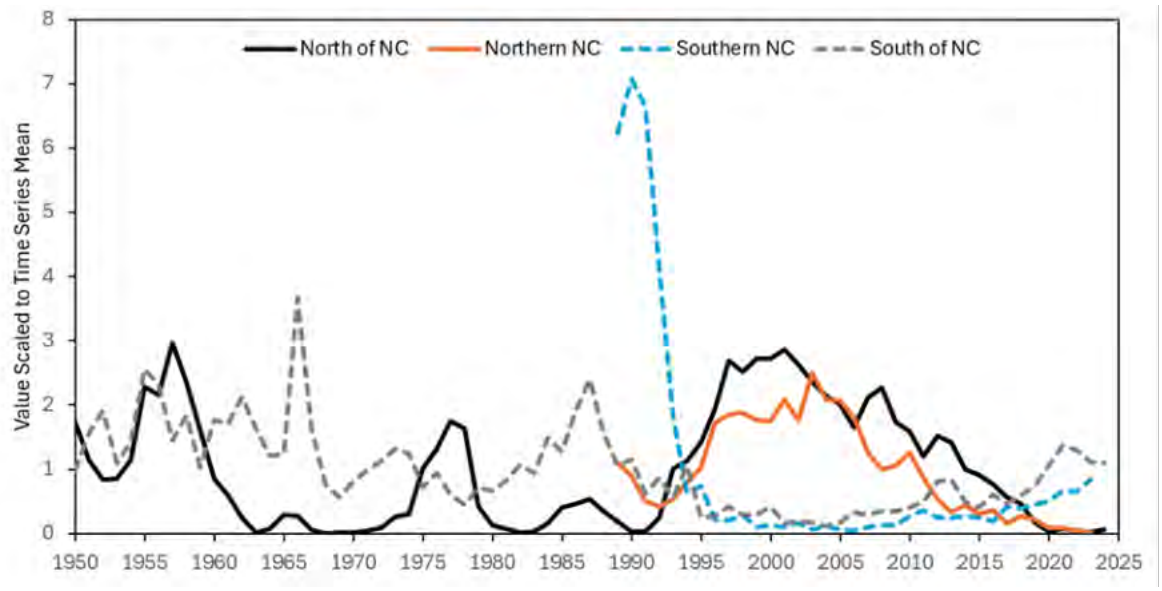


Figure 7. Regional Atlantic croaker commercial landings scaled to time series means. North Carolina landings are not available at the regional level prior to 1989.

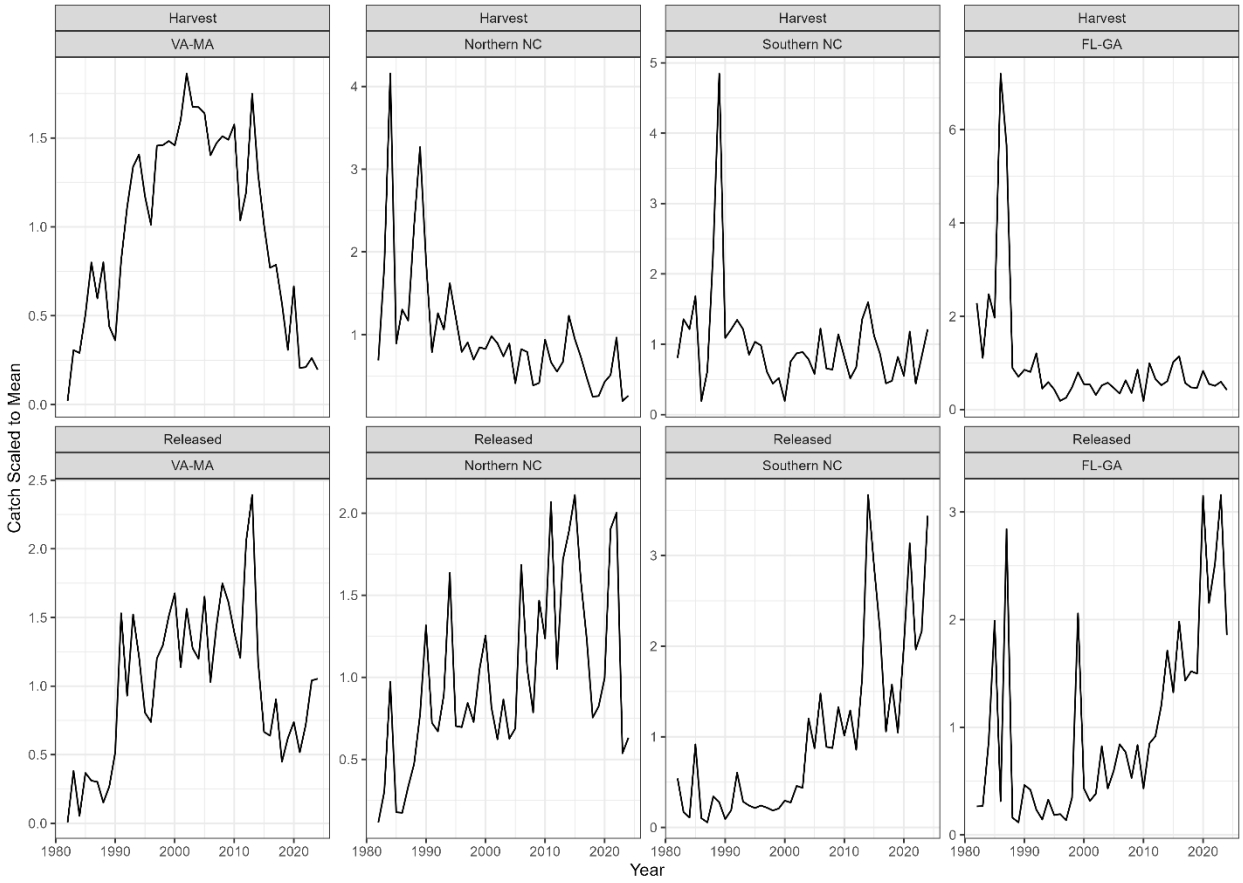


Figure 8. Regional Atlantic croaker recreational catch scaled to time series means. North Carolina catch is split at the border between Carteret and Onslow Counties.

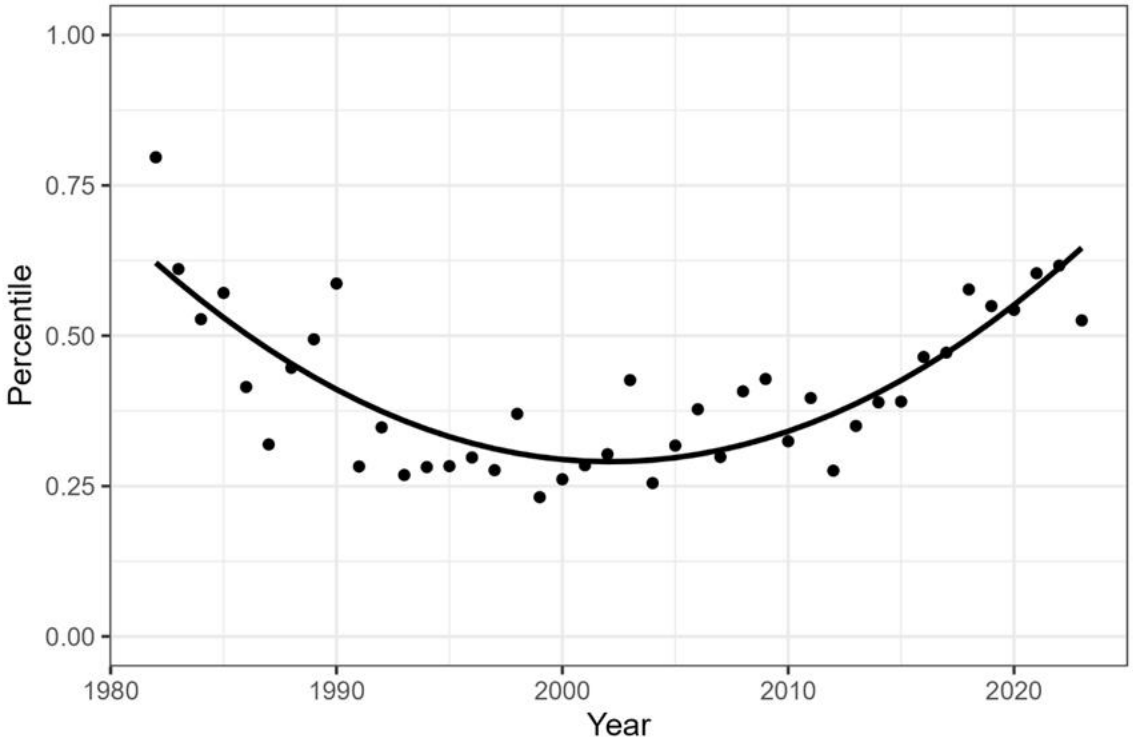


Figure 9. Percentile of annual latitudinal angler catch empirical cumulative distribution functions near the border between Onslow and Carteret Counties, North Carolina (34.7492°N). Circles are observed percentiles and solid line is predicted percentiles from a quadratic regression model.

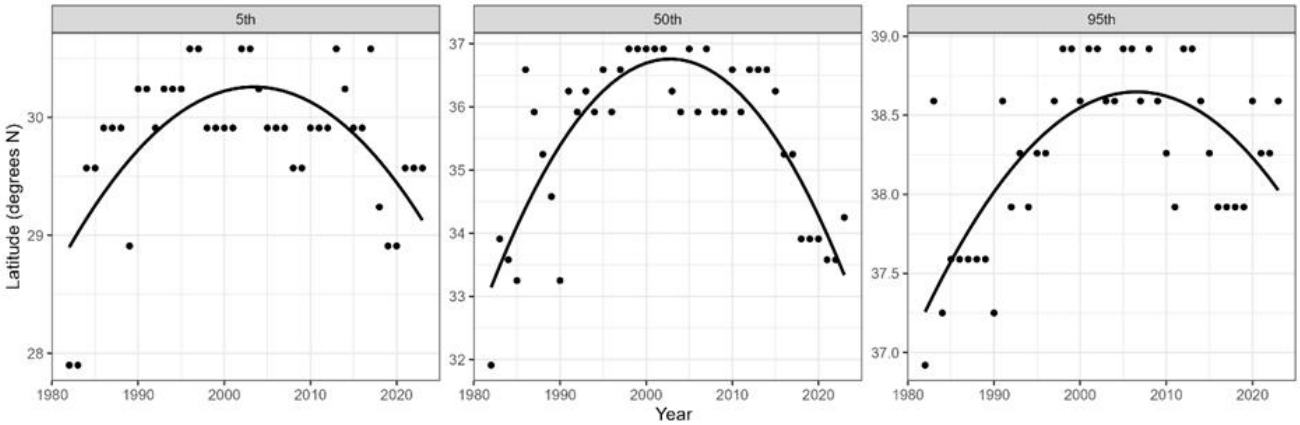


Figure 10. Latitude of select percentiles (panel ribbon) of annual latitudinal angler catch empirical cumulative distribution functions. Circles are observed percentiles and solid line is predicted percentiles from a quadratic regression model.

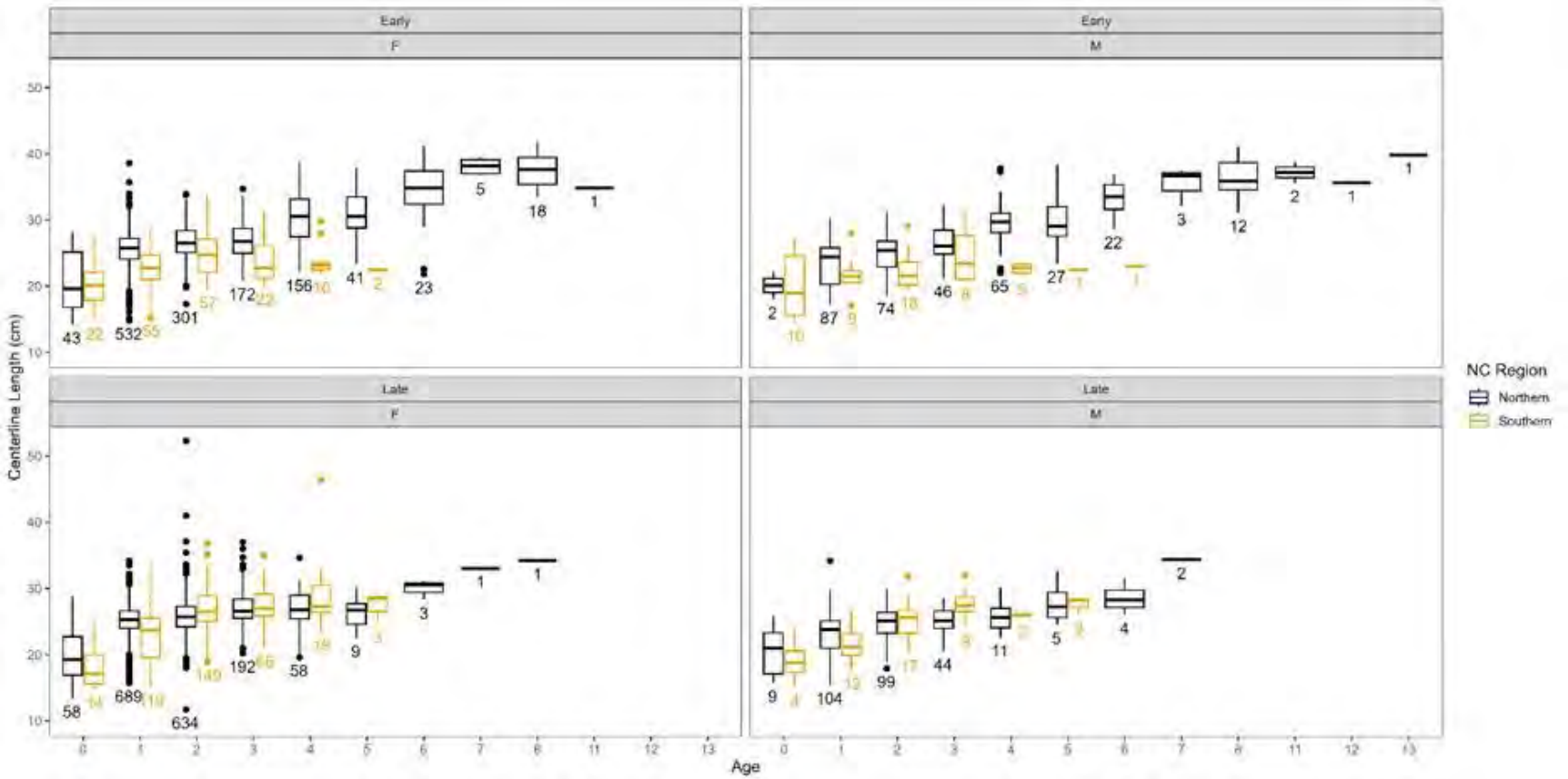


Figure 11. Distribution of length-at-age from North Carolina Independent Gill Net Survey data by region, period (top ribbon), and sex (bottom ribbon). Numbers below distributions are sample sizes.

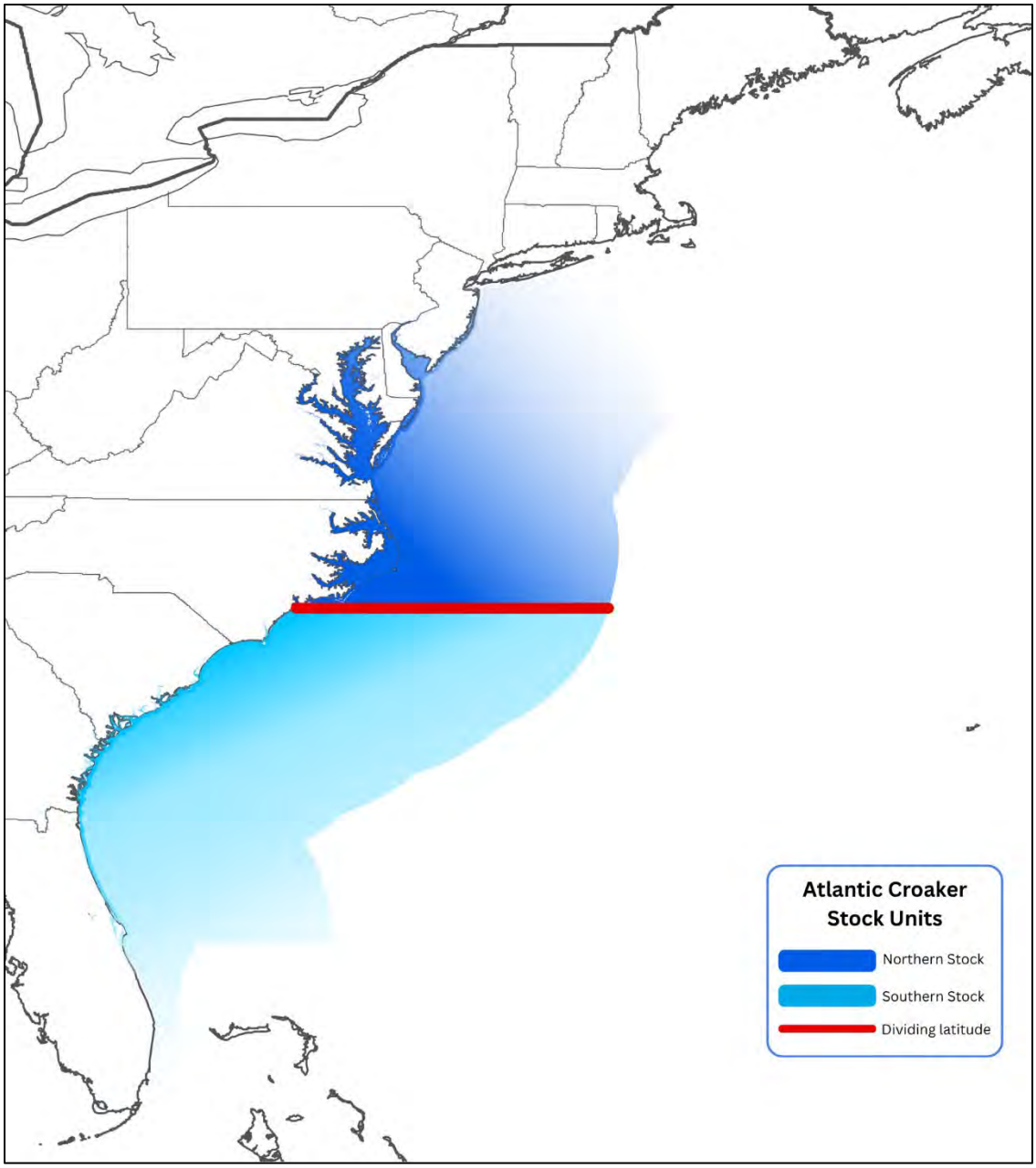


Figure 12. Stock units adopted in this assessment for the Atlantic croaker population along the U.S. Atlantic coast.

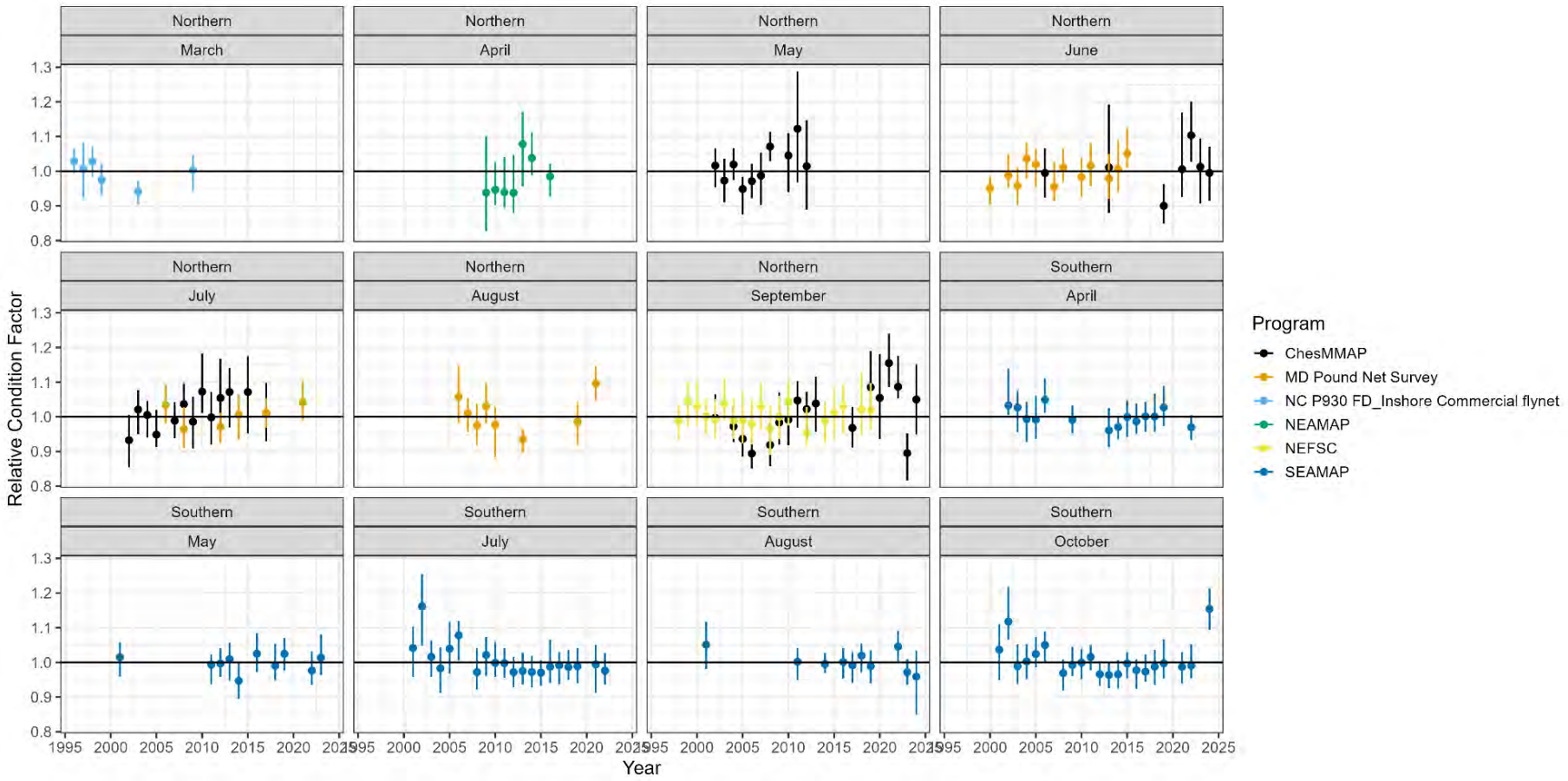


Figure 13. Relative condition factors of female Atlantic croaker by stock and month of sampling. Points are median condition factors across individuals and horizontal bars are interquartile ranges.

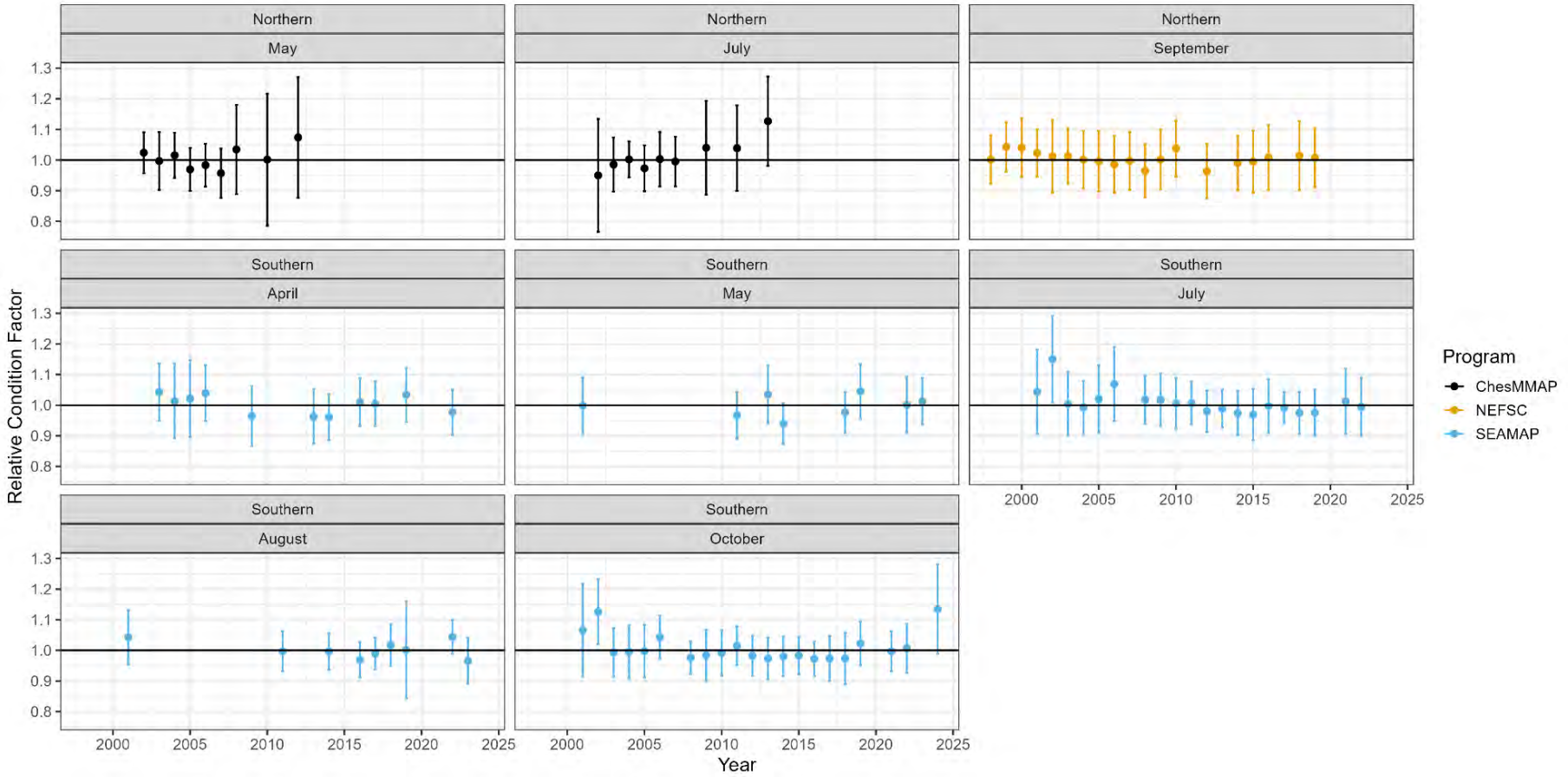


Figure 14. Relative condition factors of male Atlantic croaker by stock and month of sampling. Points are median condition factors across individuals and horizontal bars are interquartile ranges.

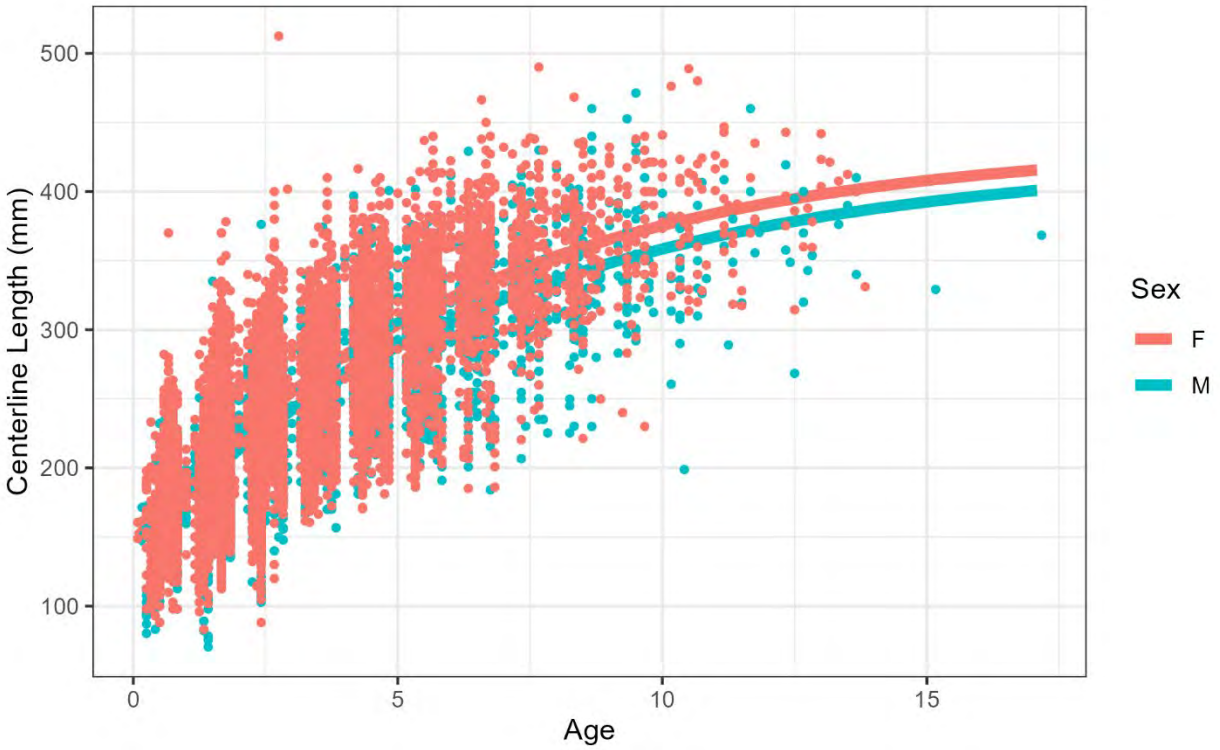


Figure 15. Von Bertalanffy growth curves for the northern stock by sex.

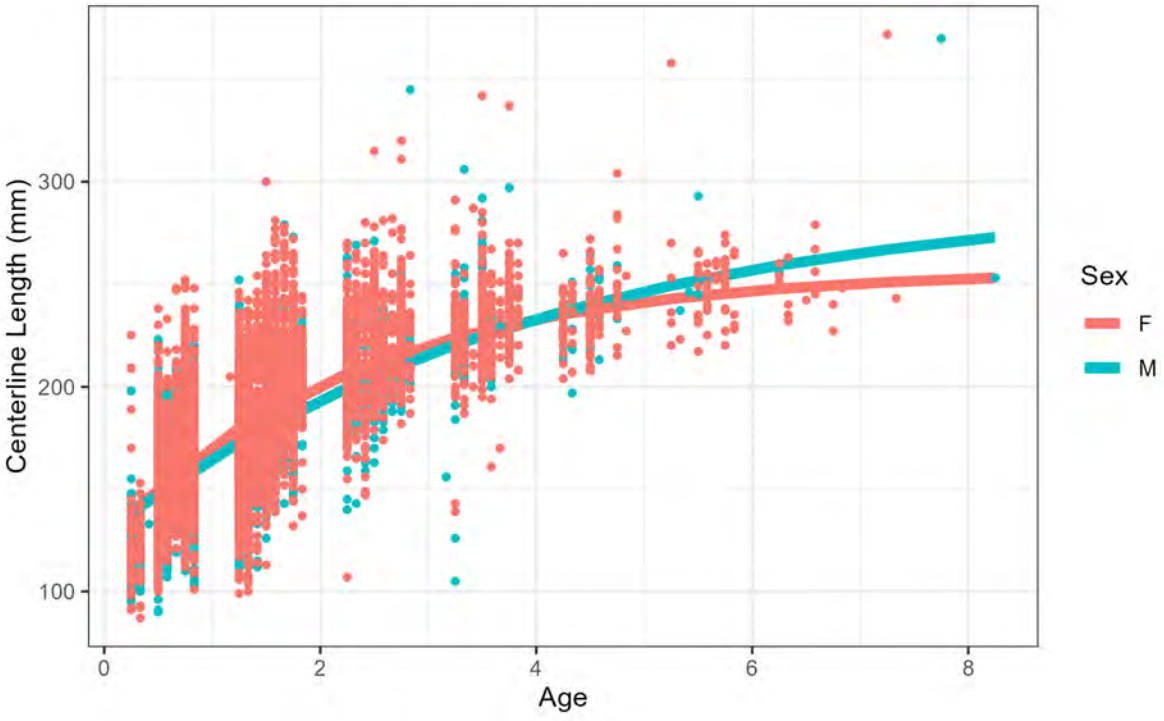


Figure 16. Von Bertalanffy growth curves for the southern stock by sex.



Figure 17. Annual female mean length-at-age for northern stock monitoring programs. Points represent at least five observations and only time series with four or more data points are presented.

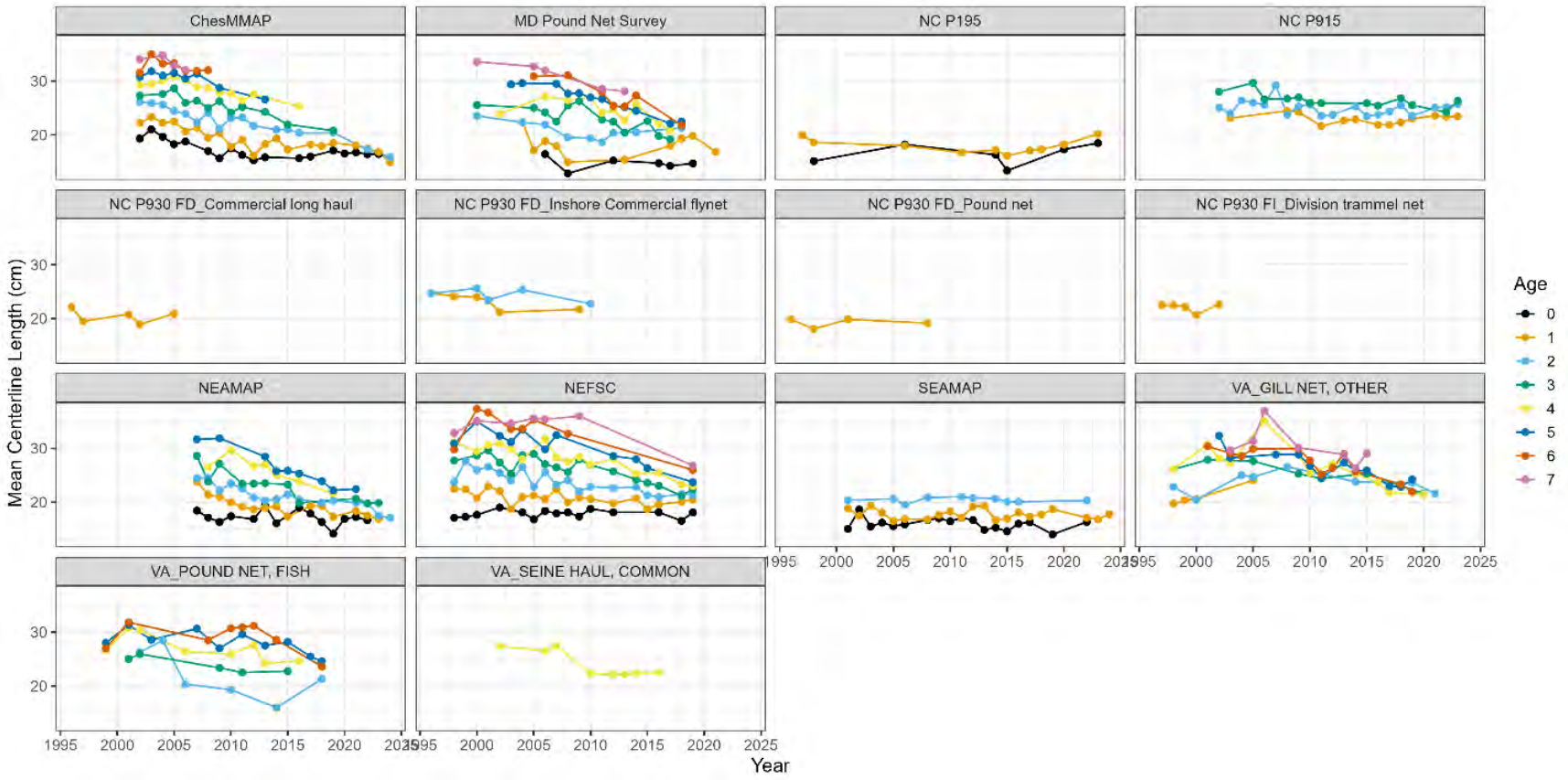


Figure 18. Annual male mean length-at-age for northern stock monitoring programs. Points represent at least five observations and only time series with four or more data points are presented.

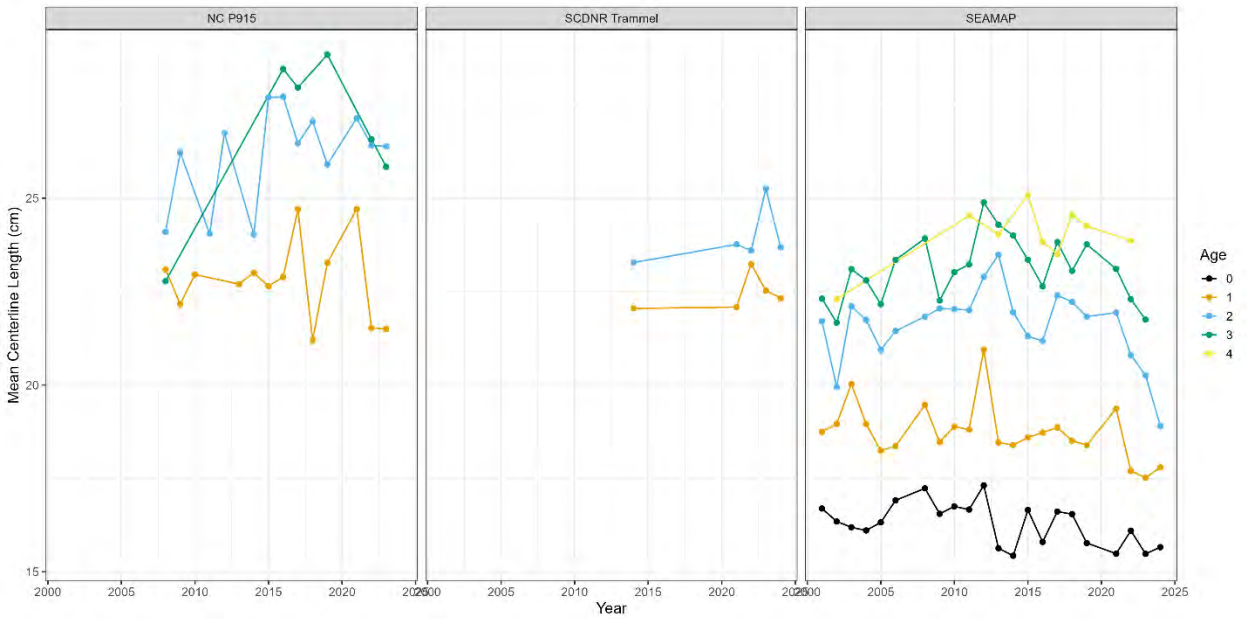


Figure 19. Annual female mean length-at-age for southern stock monitoring programs. Points represent at least five observations and only time series with four or more data points are presented.

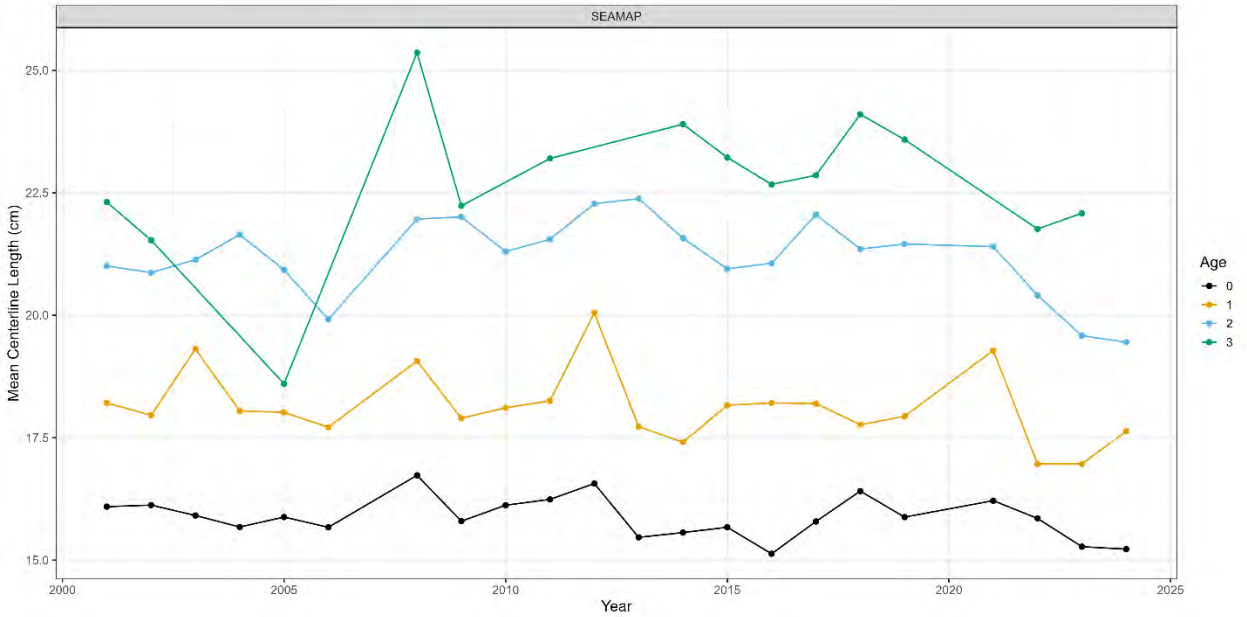


Figure 20. Annual male mean length-at-age for southern stock monitoring programs. Points represent at least five observations and only time series with four or more data points are presented.

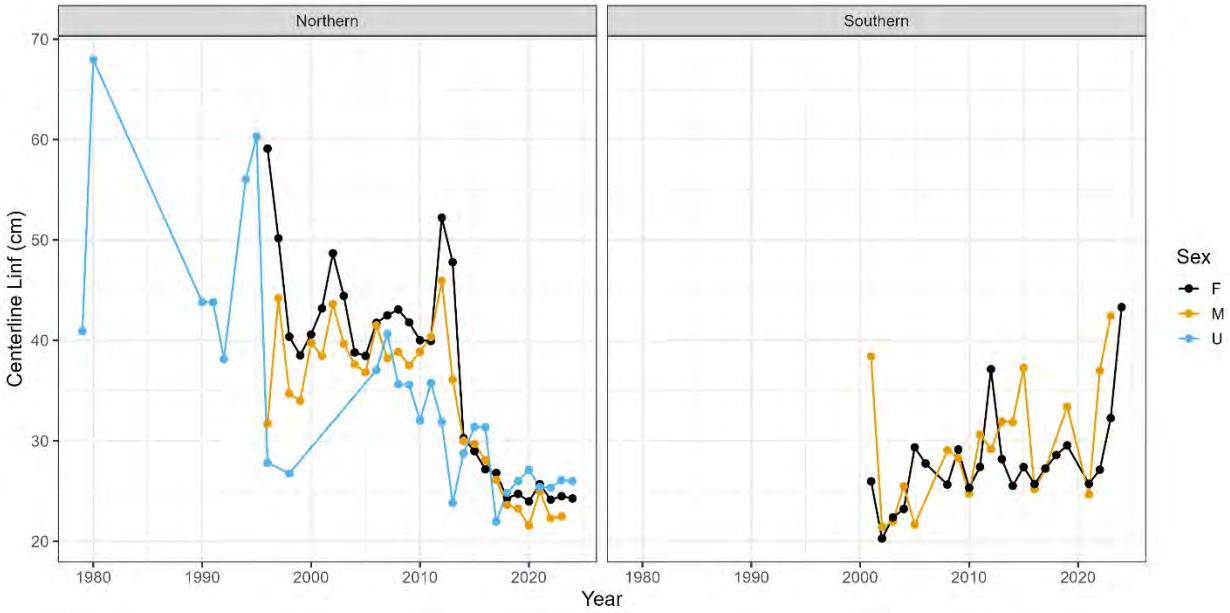


Figure 21. Annual von Bertalanffy L infinity estimates by stock.

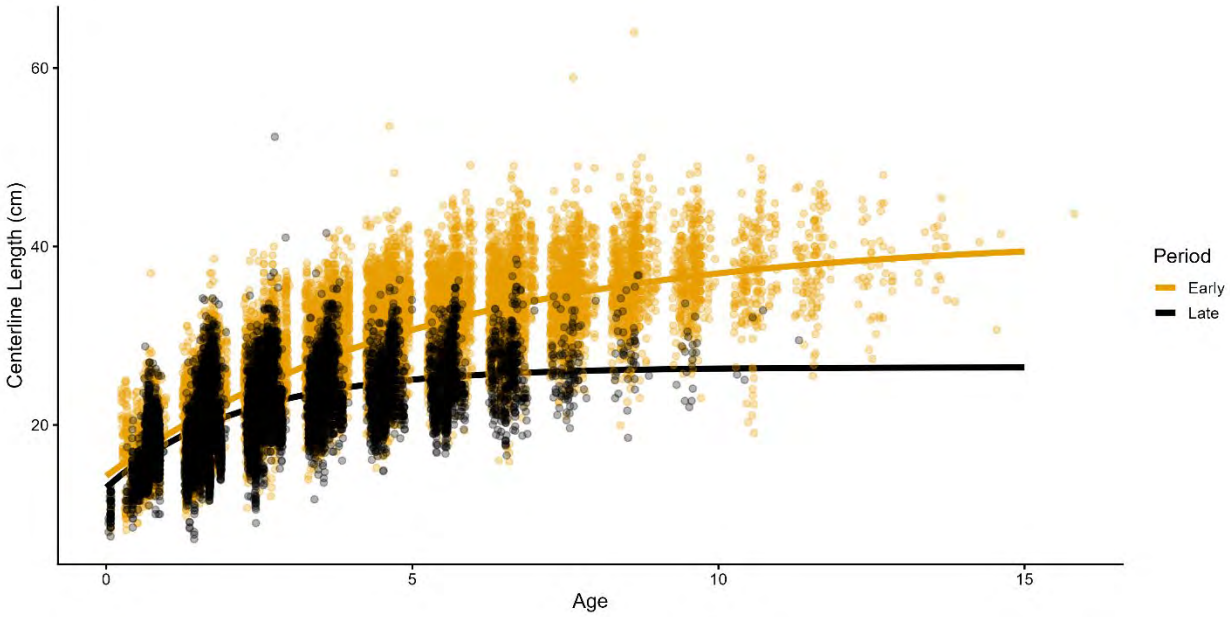


Figure 22. Period-specific northern stock Atlantic croaker length-at-age data and estimated von Bertalanffy growth curves.

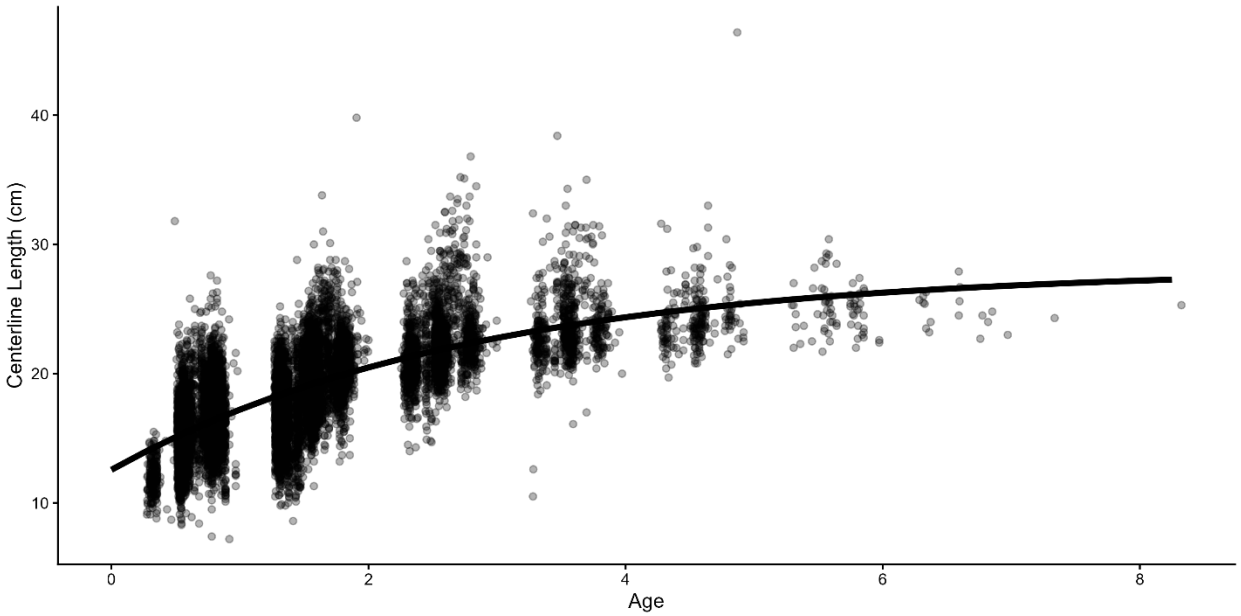


Figure 23. Southern stock Atlantic croaker length-at-age data and estimated von Bertalanffy growth curve.

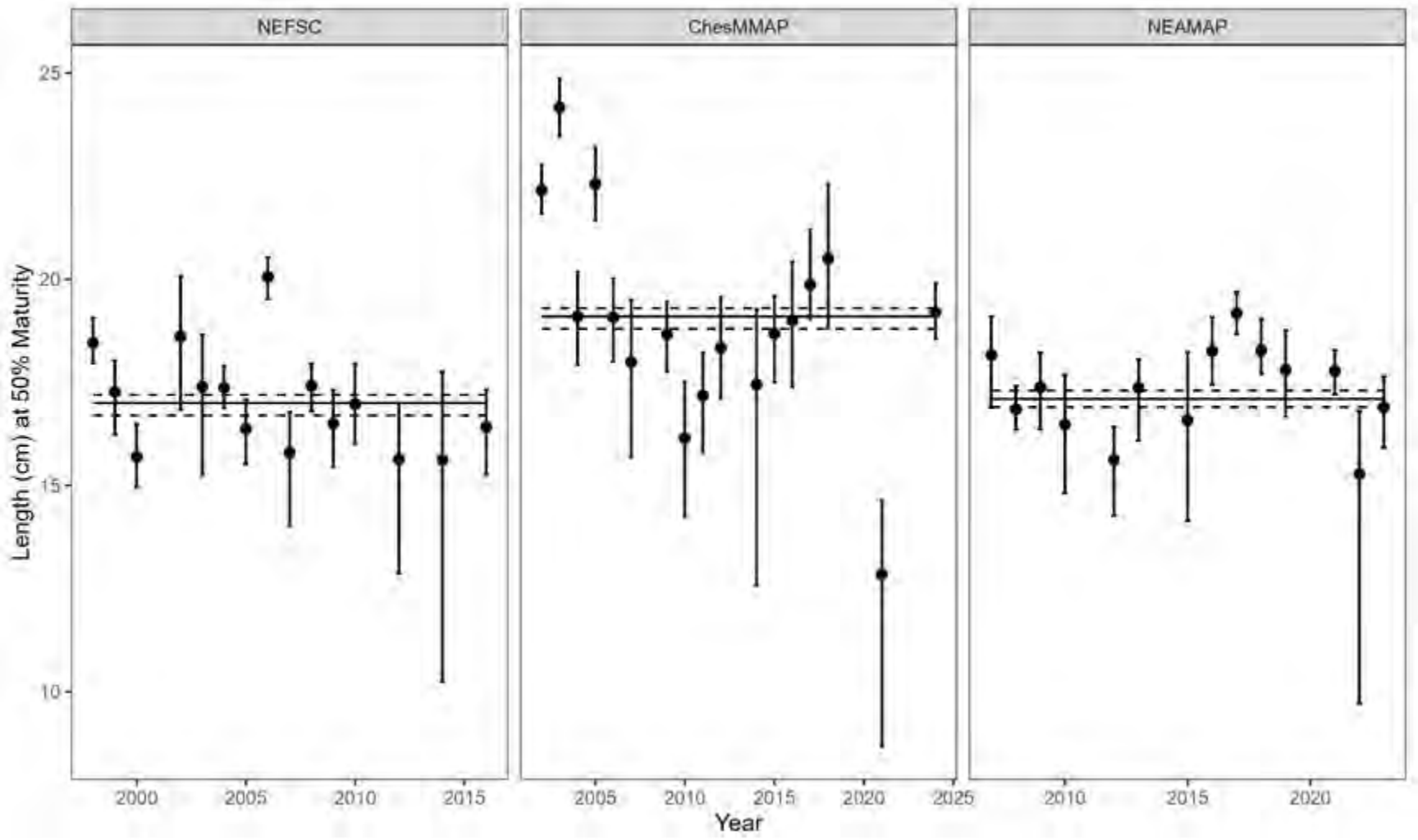


Figure 24. Annual female *L50* estimates and 95% confidence intervals for northern stock sampling programs. The horizontal lines are the *L50* estimates (solid lines) and 95% confidence intervals (dashed lines) from all years combined.

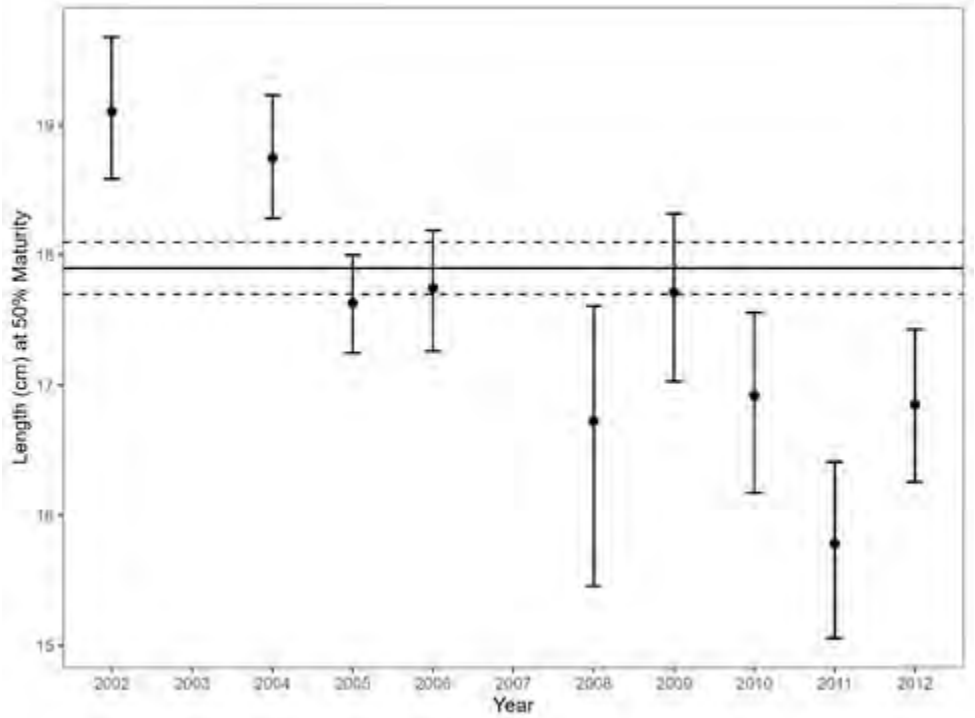


Figure 25. Annual female *L50* estimates and 95% confidence intervals for the SEAMAP sampling program in the southern stock. The horizontal lines are the *L50* estimate (solid line) and 95% confidence interval (dashed lines) from all years combined.

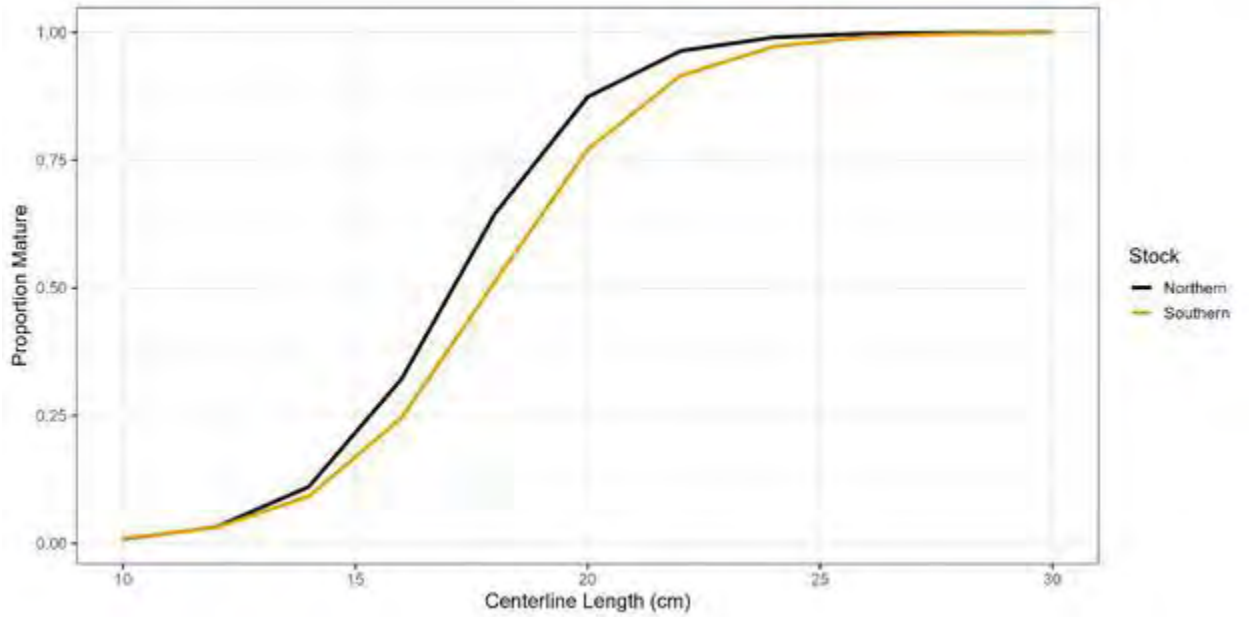


Figure 26. Female Atlantic croaker maturity ogives used in assessment models. Northern stock data are collected by the NEAMAP trawl survey and southern stock data are collected by the SEAMAP trawl survey.

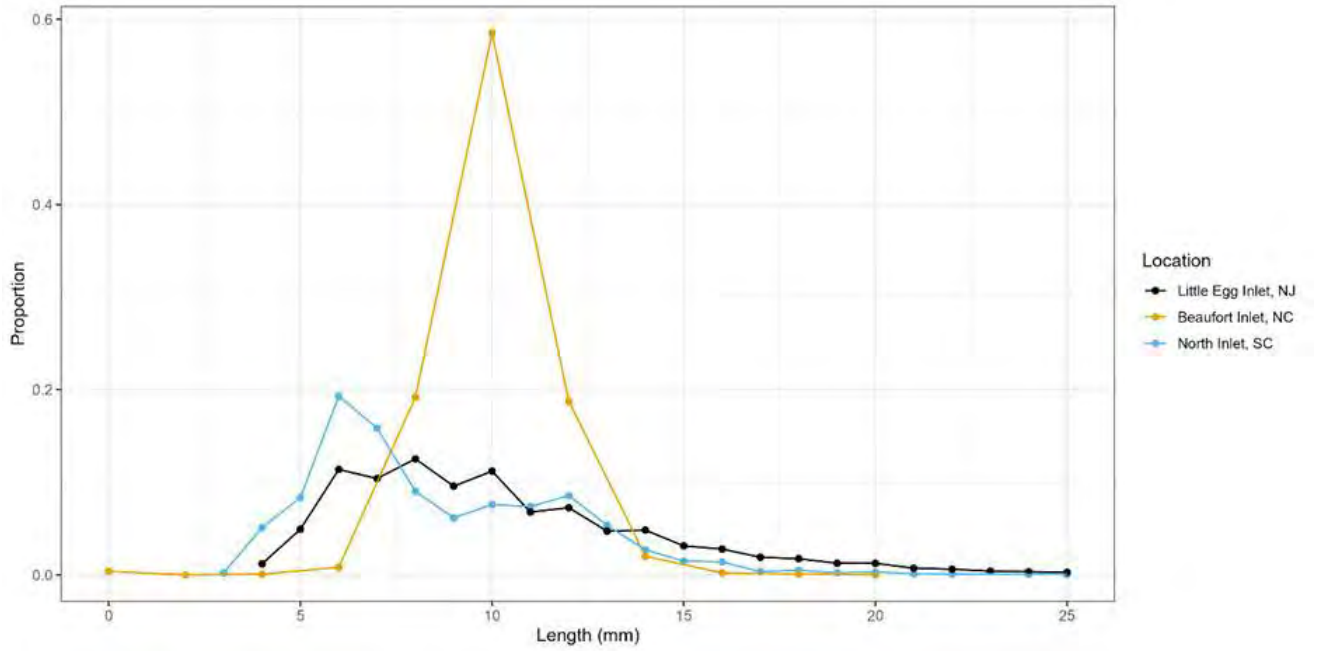


Figure 27. Length frequencies of larval Atlantic croaker sampled along the coast.

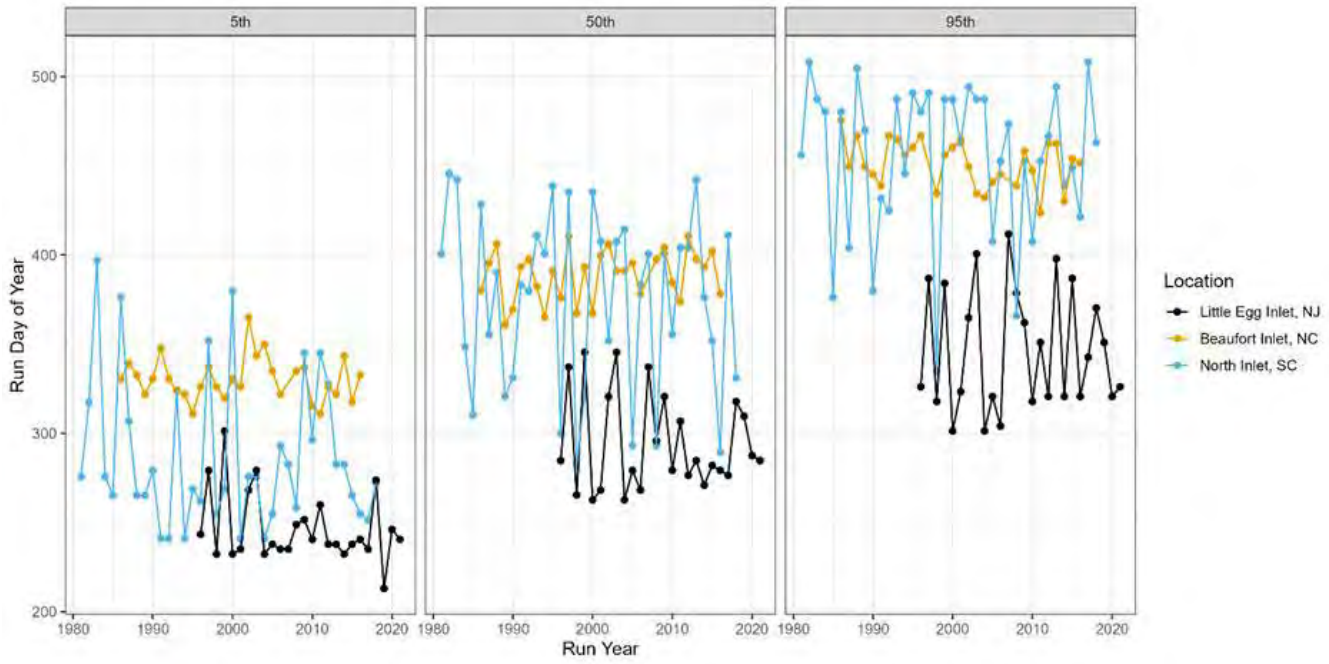


Figure 28. Percentiles from annual cumulative distribution functions of LOESS-smoothed Atlantic croaker daily catch densities from larval sampling programs along the coast.

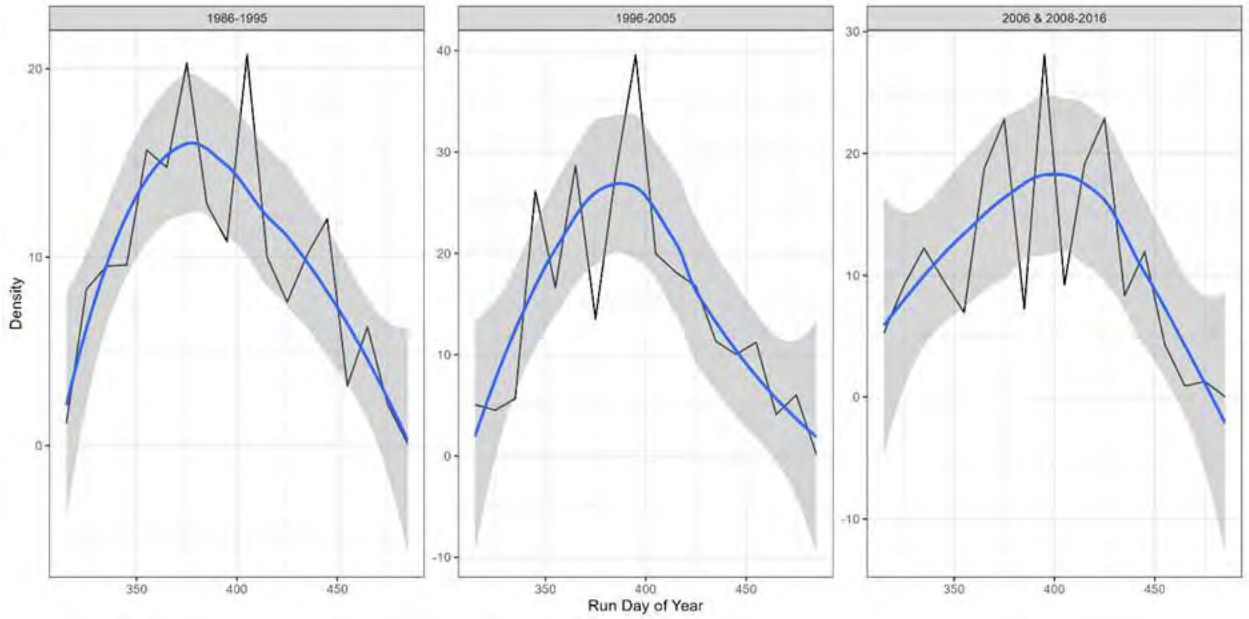


Figure 29. Time period-aggregated Atlantic croaker catch densities from Beaufort Inlet, North Carolina. Blue lines are LOESS smoothers and shaded regions are smoother 95% confidence intervals.

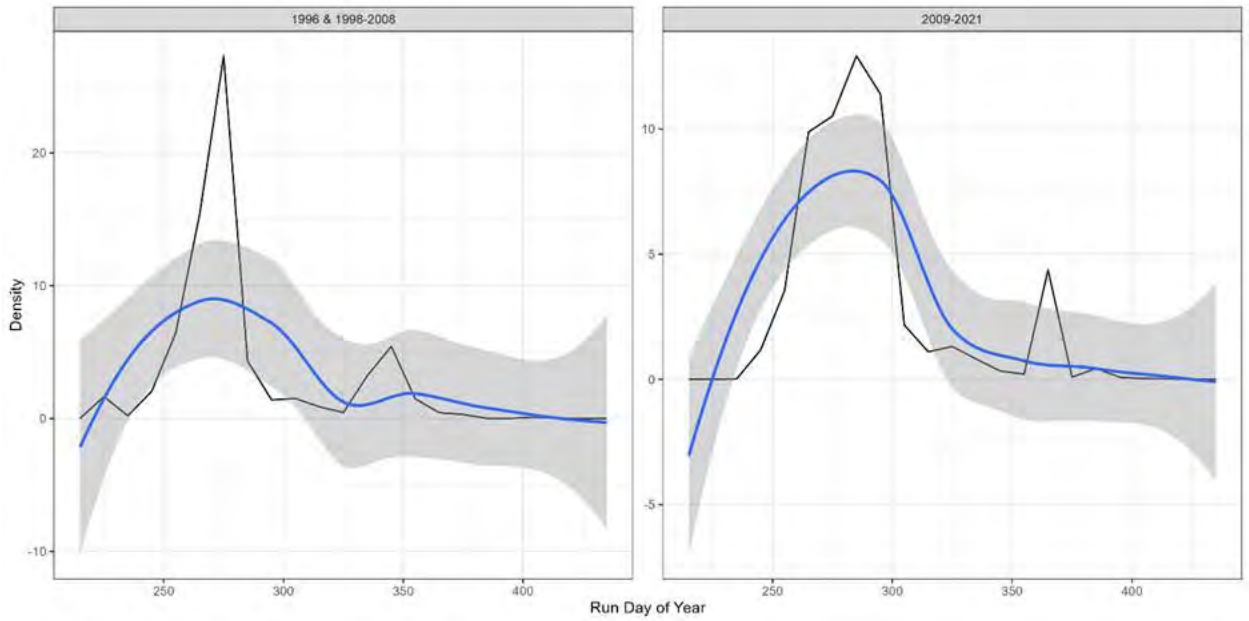


Figure 30. Time period-aggregated Atlantic croaker catch densities from Little Egg Inlet, New Jersey. Blue lines are LOESS smoothers and shaded regions are smoother 95% confidence intervals.

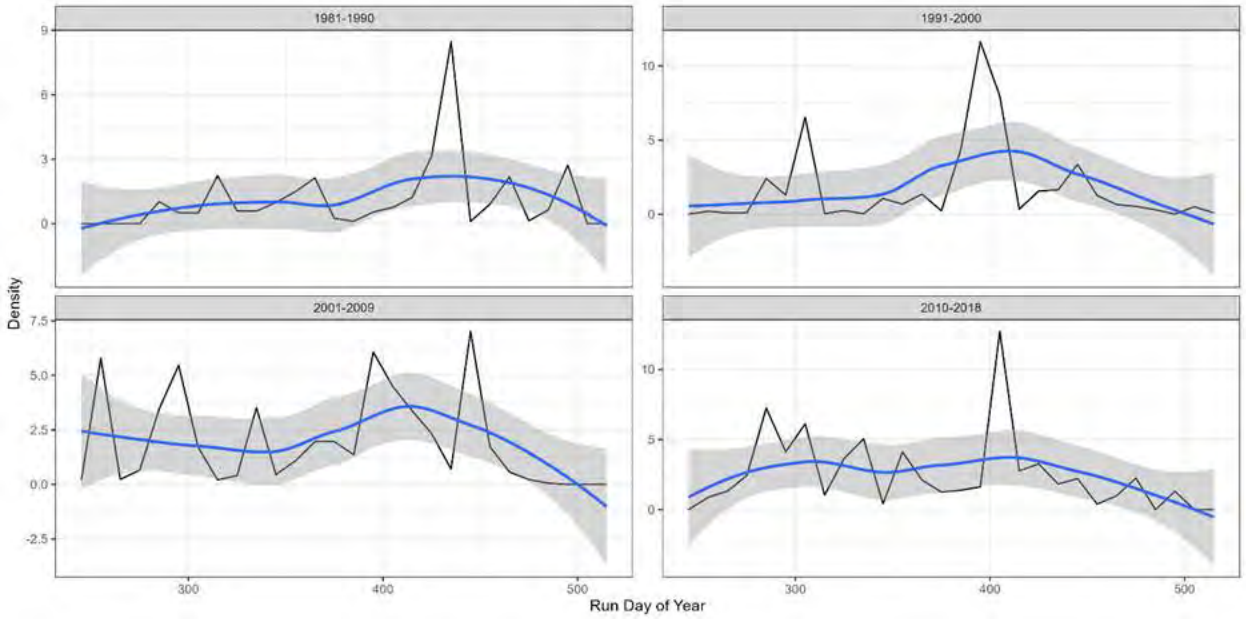


Figure 31. Time period-aggregated Atlantic croaker catch densities from North Inlet, South Carolina. Blue lines are LOESS smoothers and shaded regions are smoother 95% confidence intervals.

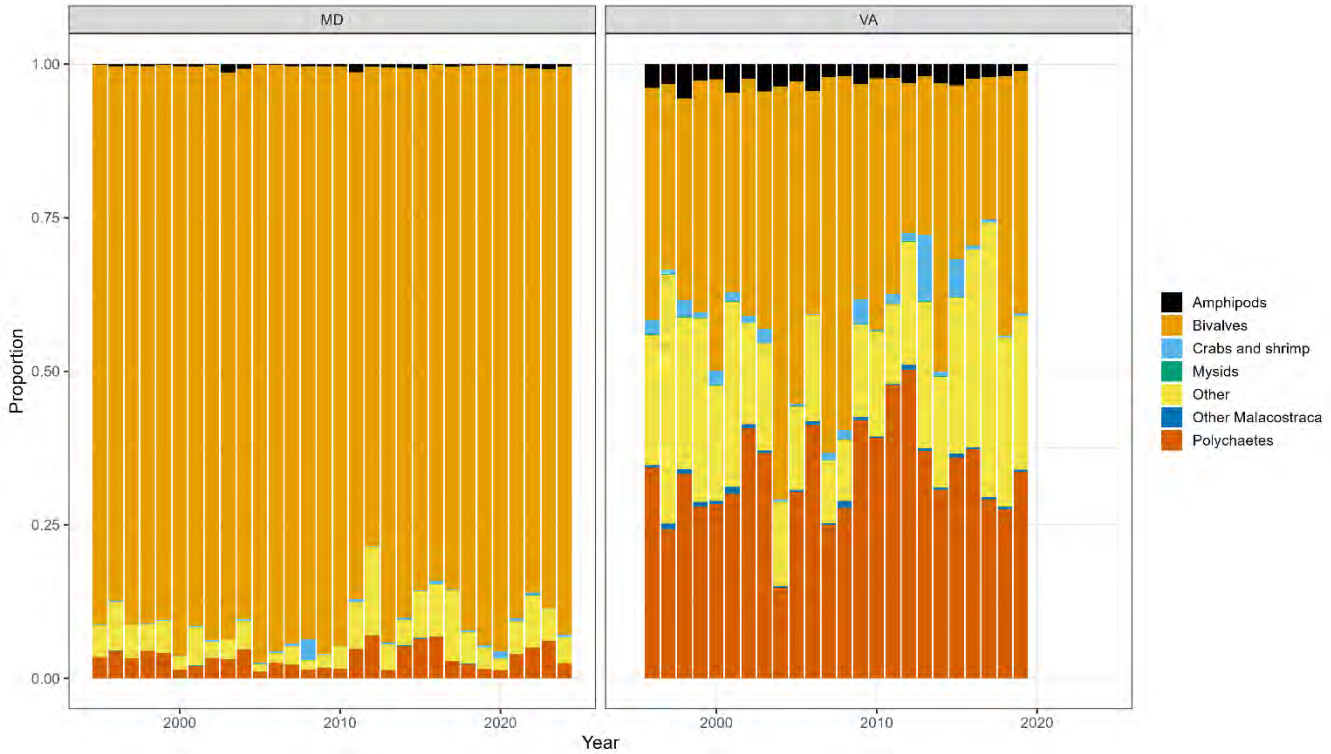


Figure 32. Macroinvertebrate compositions within state waters of the Chesapeake Bay.

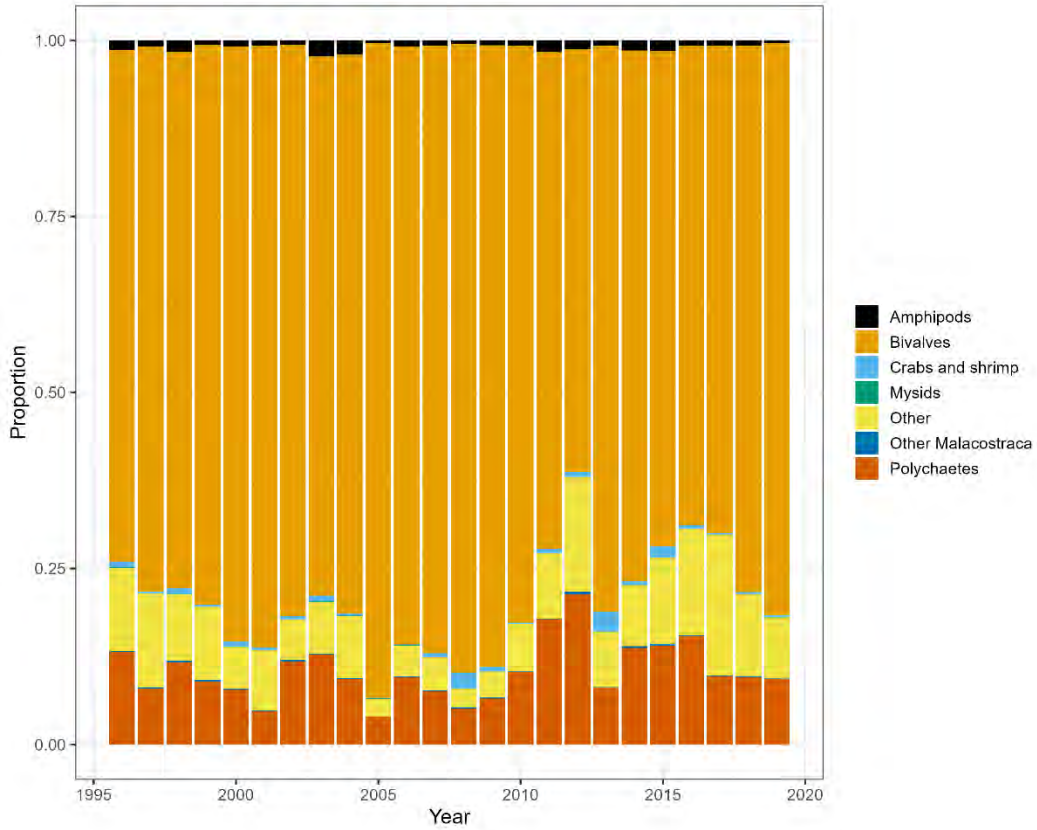


Figure 33. Macroinvertebrate compositions in the Chesapeake Bay.

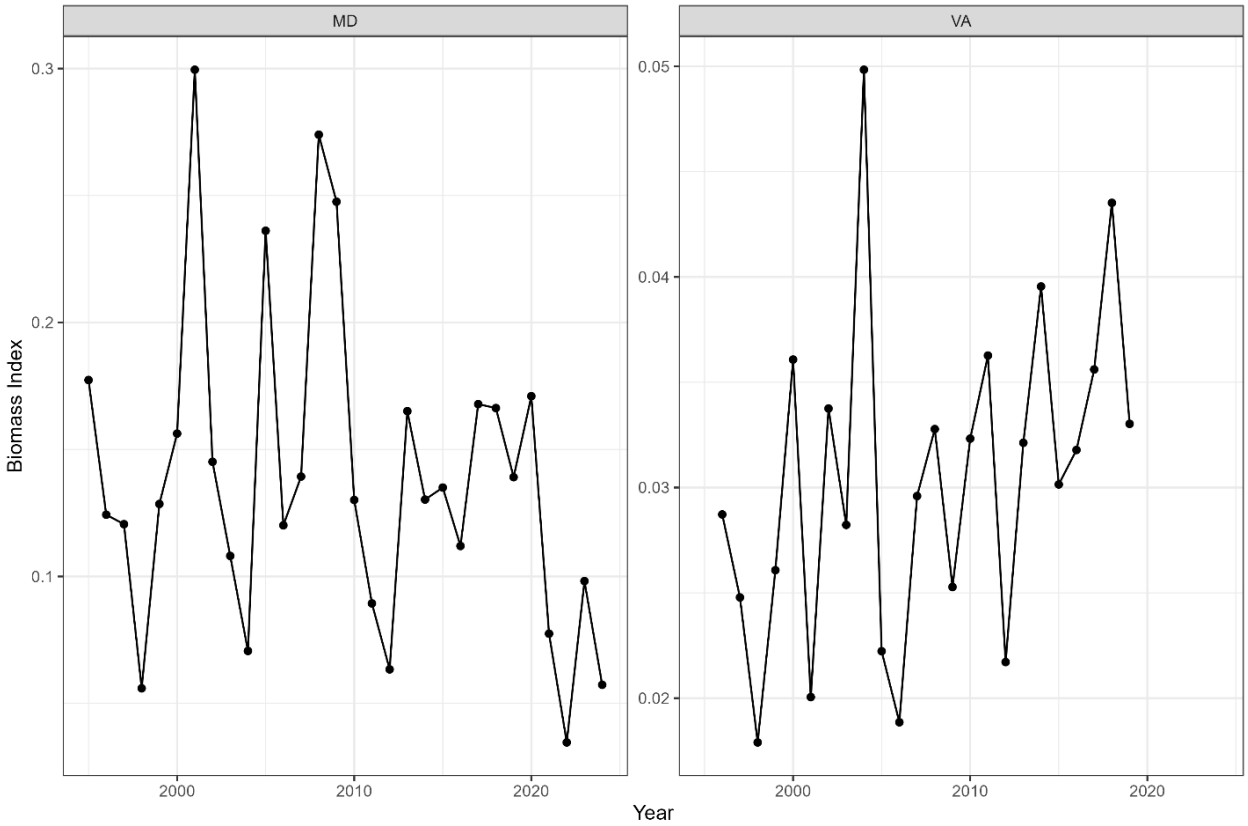


Figure 34. Macroinvertebrate biomass index within state waters of the Chesapeake Bay.

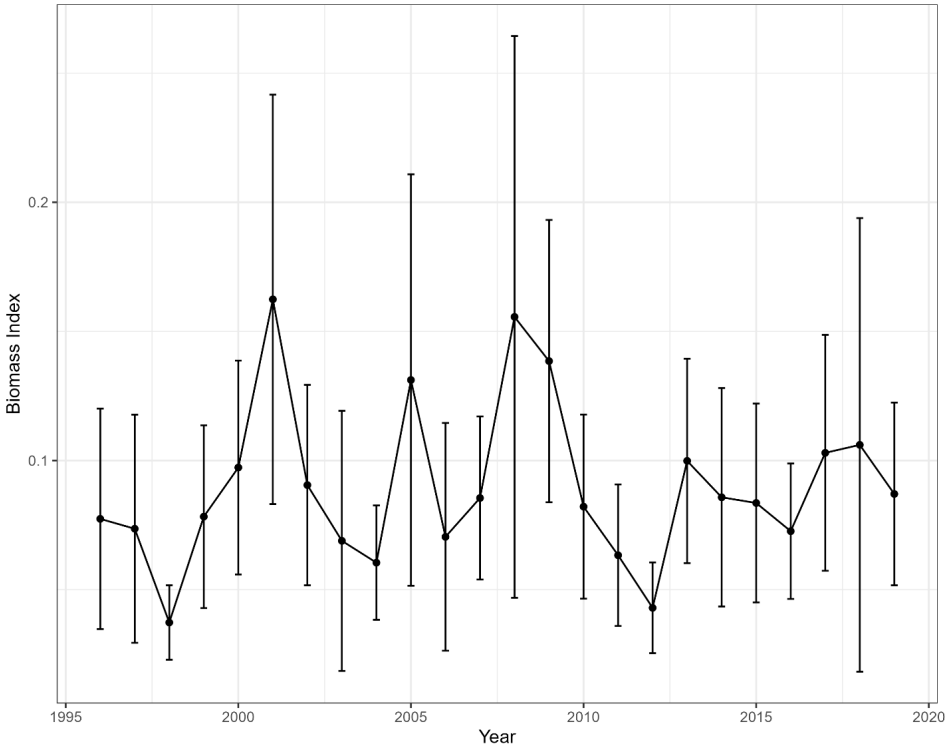


Figure 35. Macroinvertebrate biomass index in the Chesapeake Bay.

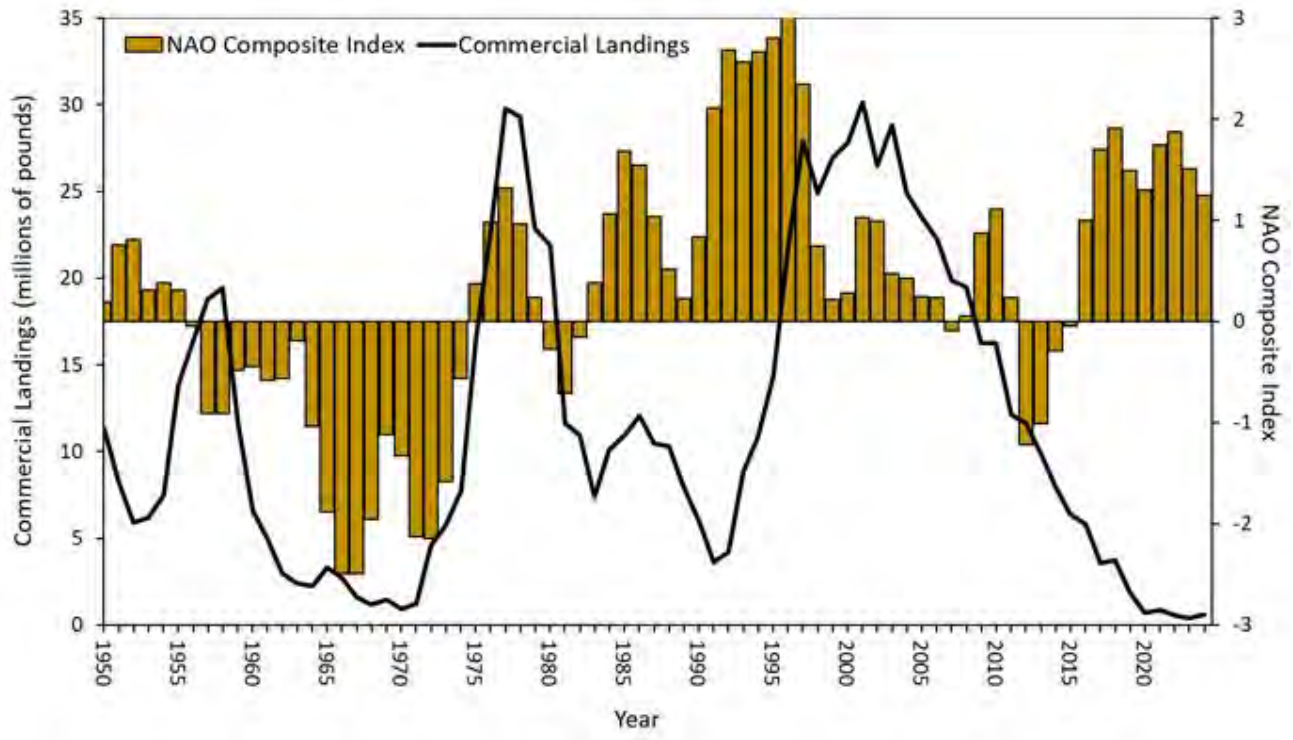


Figure 36. North Atlantic Oscillation (NAO) composite index based on Atlantic croaker age structure assumptions and Atlantic croaker commercial landings from North Carolina through Rhode Island.

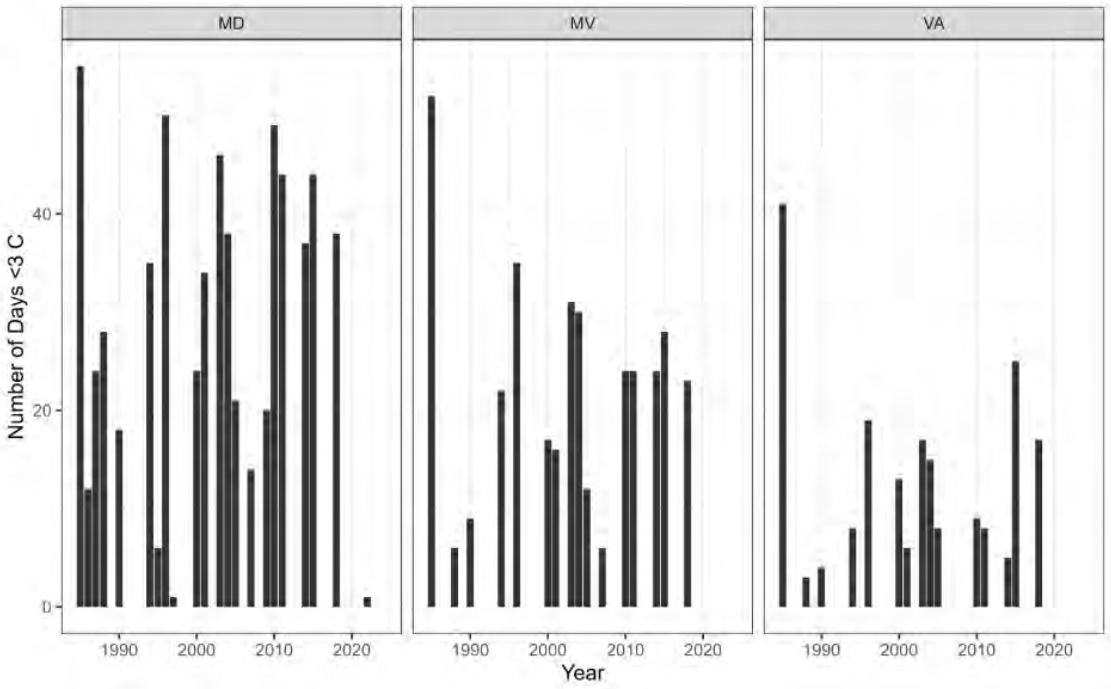


Figure 37. Total number of days during January-March with an average daily bottom temperature of less than 3° Celsius(C) in the Maryland (MD), main stem (MV), and Virginia (VA) portions of the Chesapeake Bay.

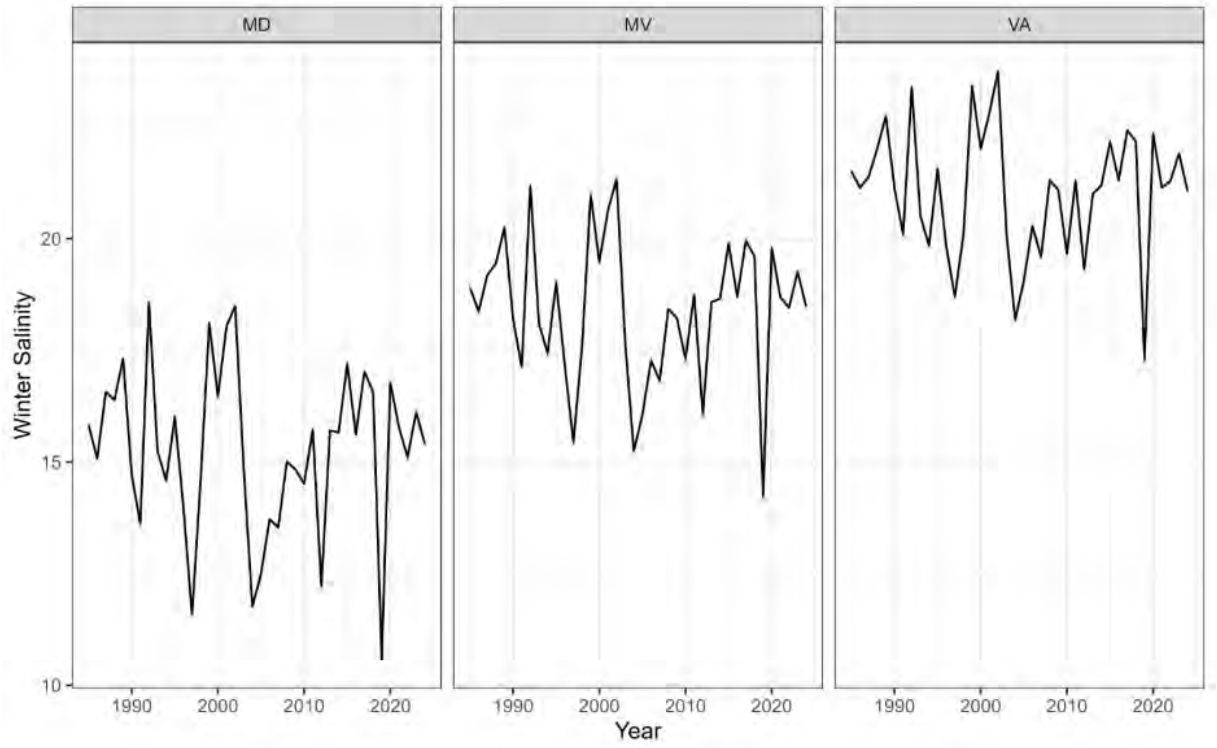


Figure 38. Average salinity (psu) during January-March in the Maryland portion of the Chesapeake Bay main stem (MD), the entire may stem of the Chesapeake Bay (MV), and the Virginia portion of the Chesapeake Bay mainstem (VA).

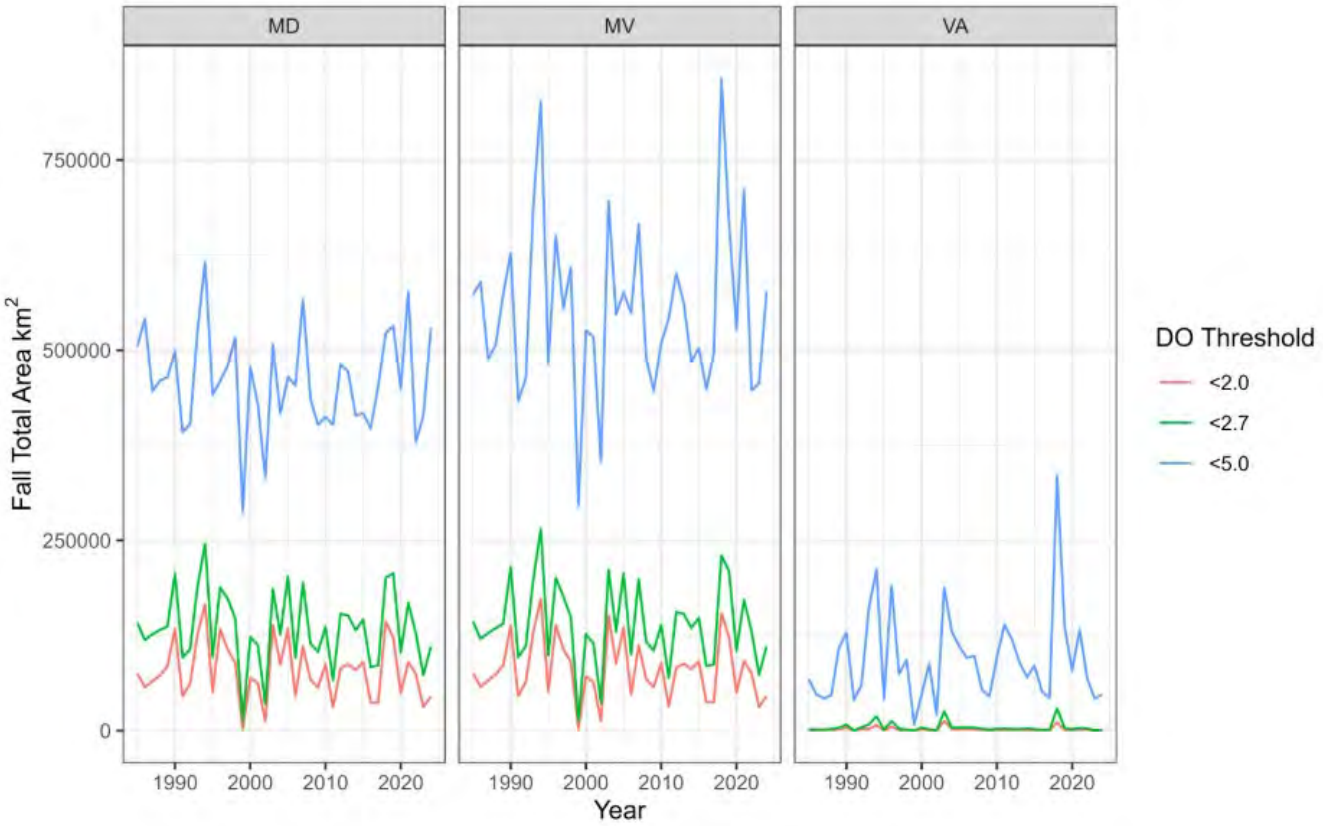


Figure 39. Total bottom area (km^2) with dissolved oxygen in September-November under 2 mg/L (pink), 2.7 mg/L (green), and 5 mg/L (blue), rescaled to their series means. Total bottom area is provided for the Maryland portion of the Chesapeake Bay main stem (MD), the entire Chesapeake Bay main stem (MV) and the Virginia portion of the Chesapeake Bay main stem (VA).

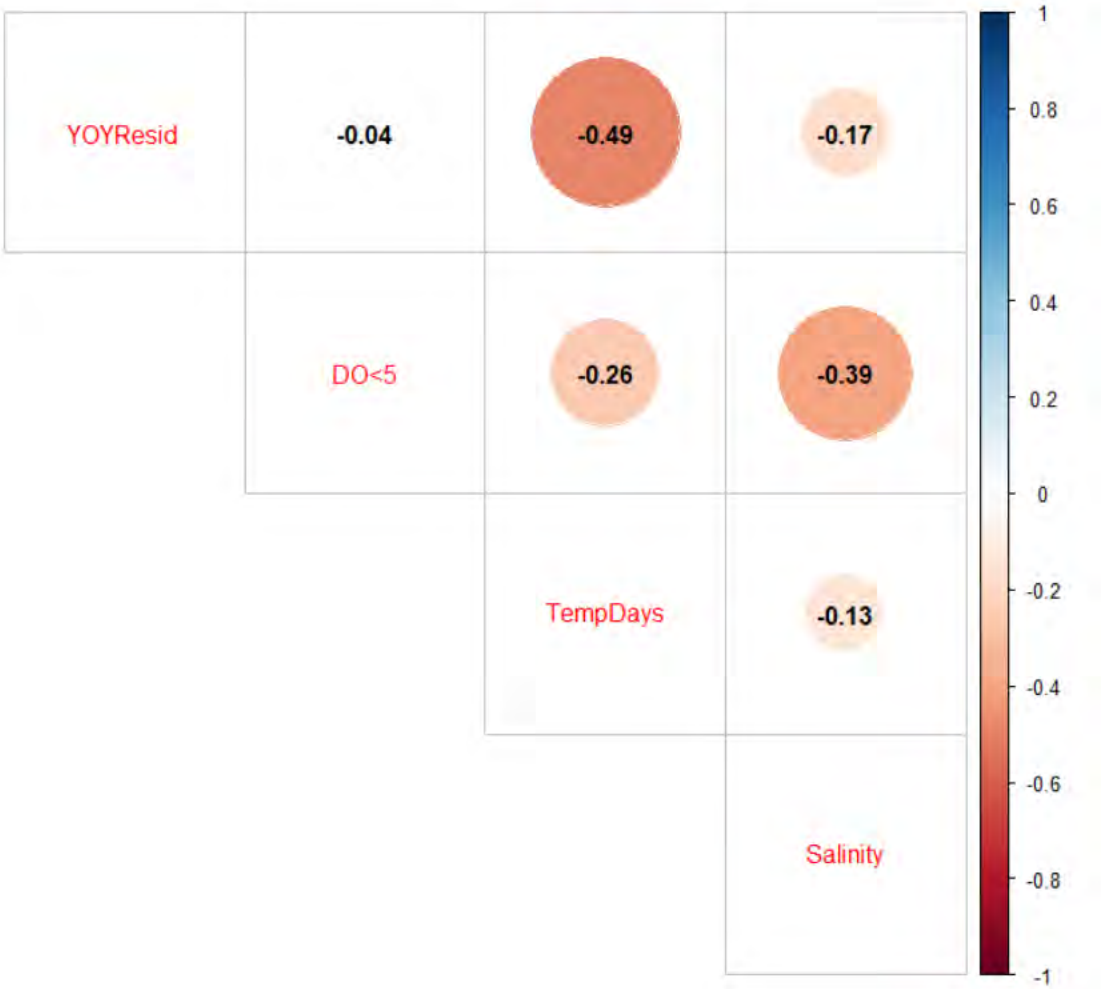


Figure 40. Significant Pearson correlation coefficients for each environmental variable and YOY residuals.

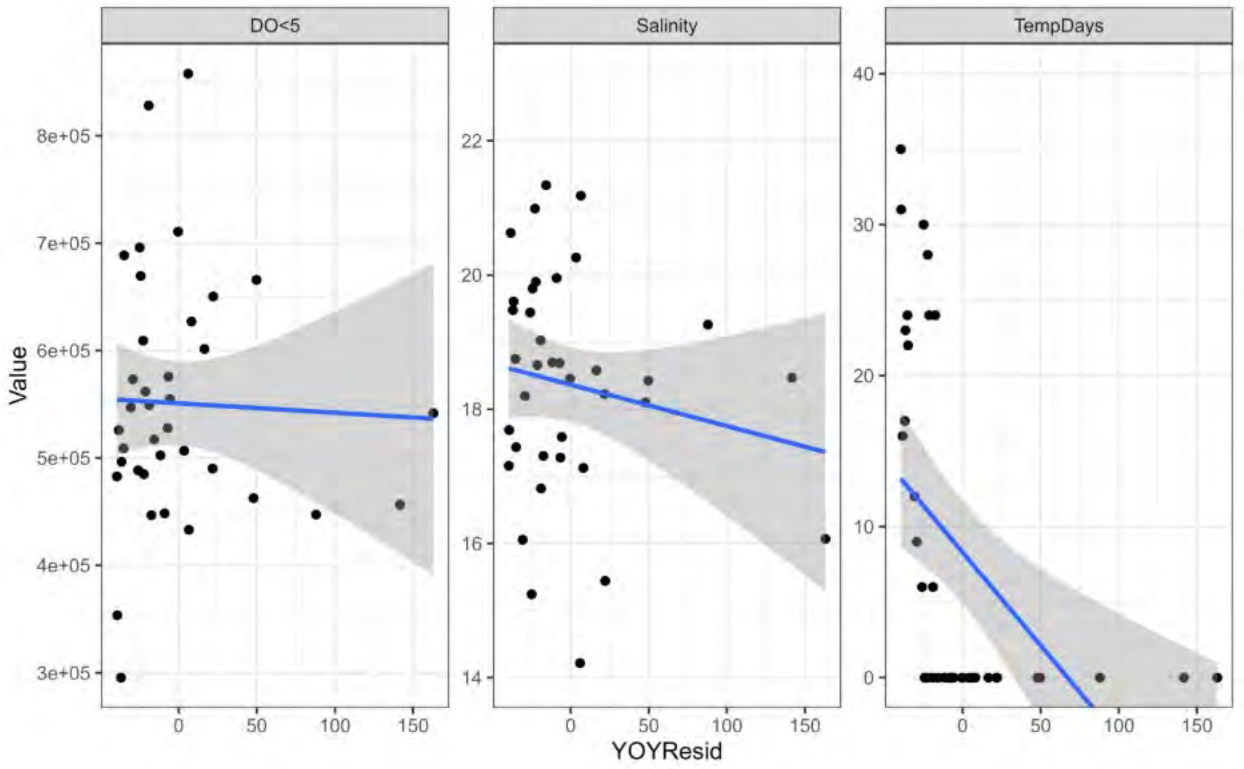


Figure 41. Linear relationships (blue solid line) between centered YOY index of recruitment anomalies and the environmental variable in the main stem of the Chesapeake Bay. Relationships are provided for Fall total area with DO less than 5 mg/L (left), winter salinity (middle), and the number of temperature days below 3° C (right).

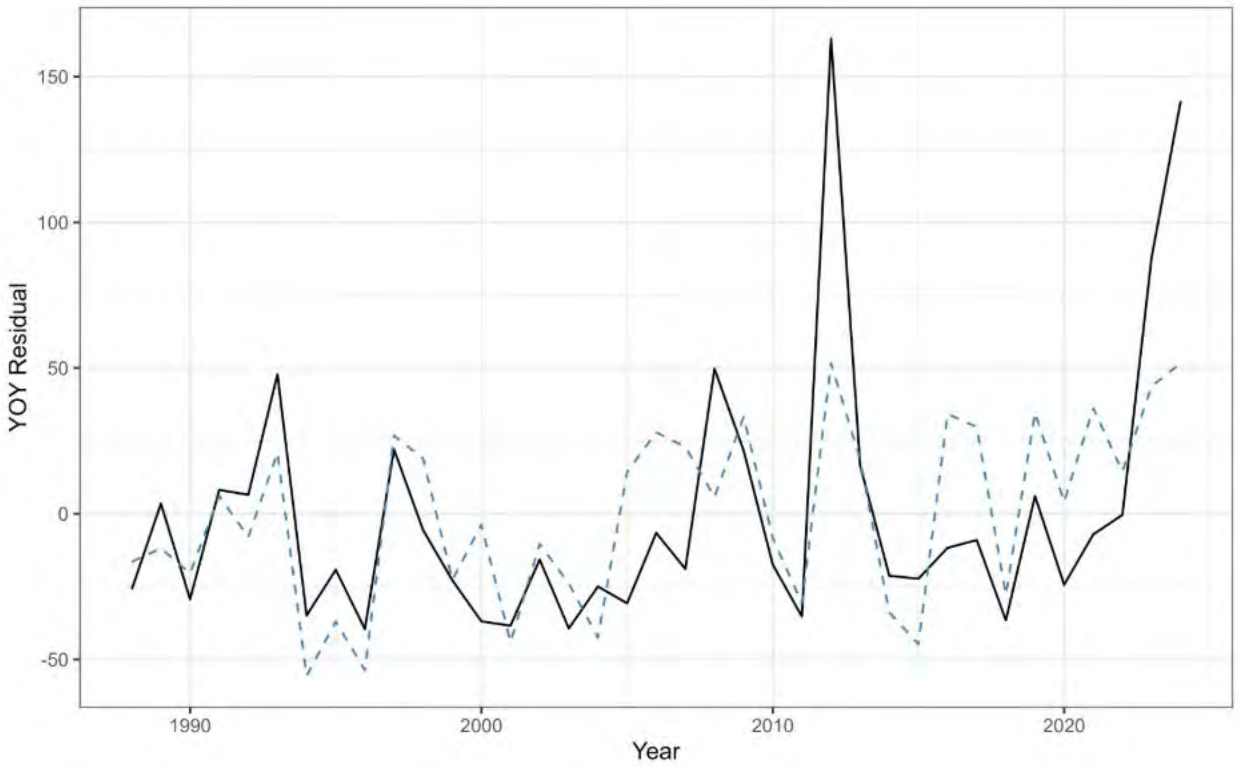


Figure 42. Observed index of abundance residuals for young-of-the-year Atlantic croaker developed from the VIMS survey plotted (black) against the predicted index of abundance residuals from the best model to predict recruitment (dashed line).

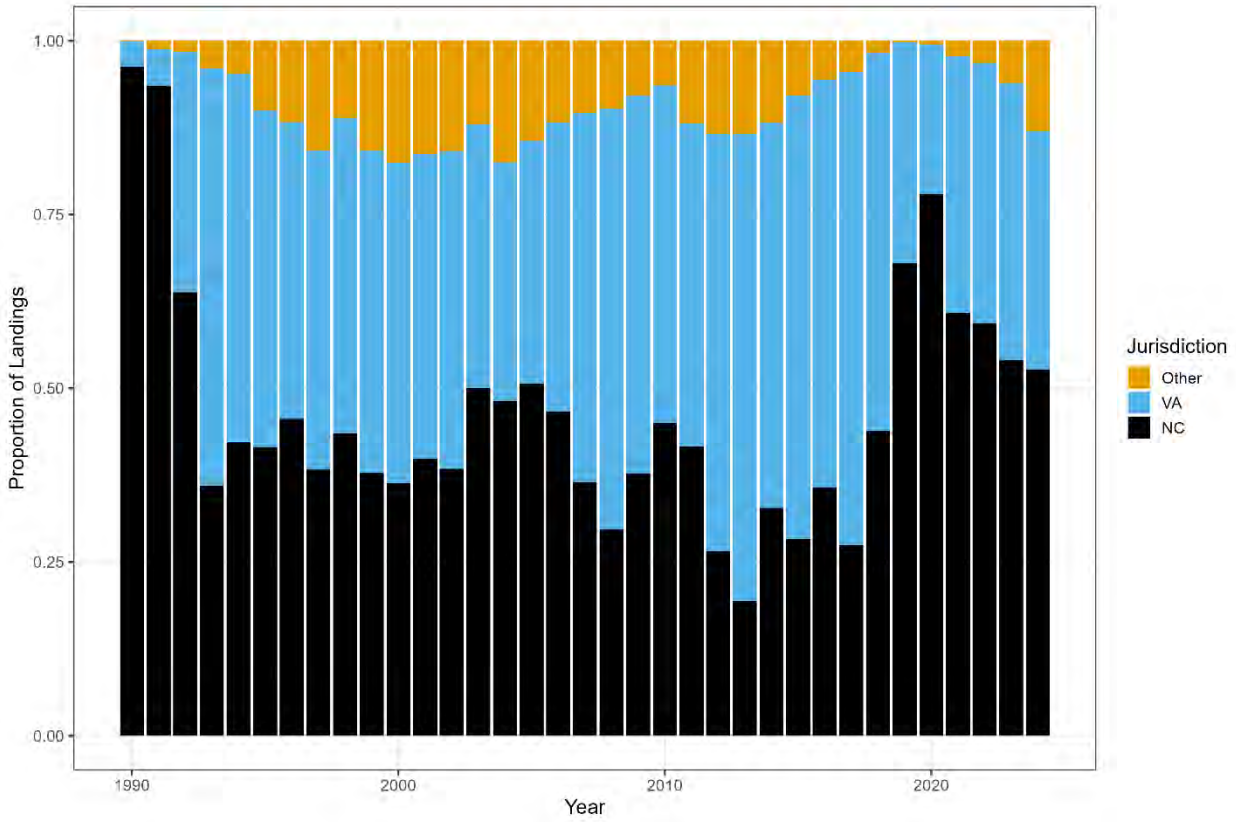


Figure 43. Jurisdiction contributions to commercial landings of northern stock Atlantic croaker. Jurisdictions other than VA and NC are collapsed to protect confidentiality.

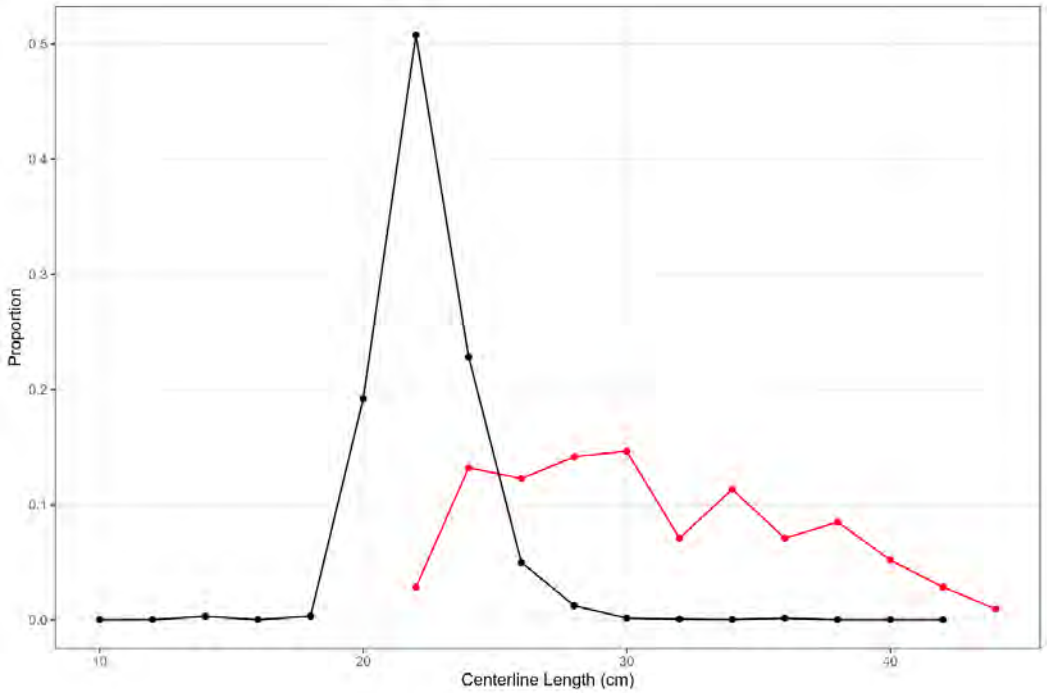


Figure 44. Southern stock Atlantic croaker length composition data from 2012-2024 collected from Florida (red) and North Carolina (black).

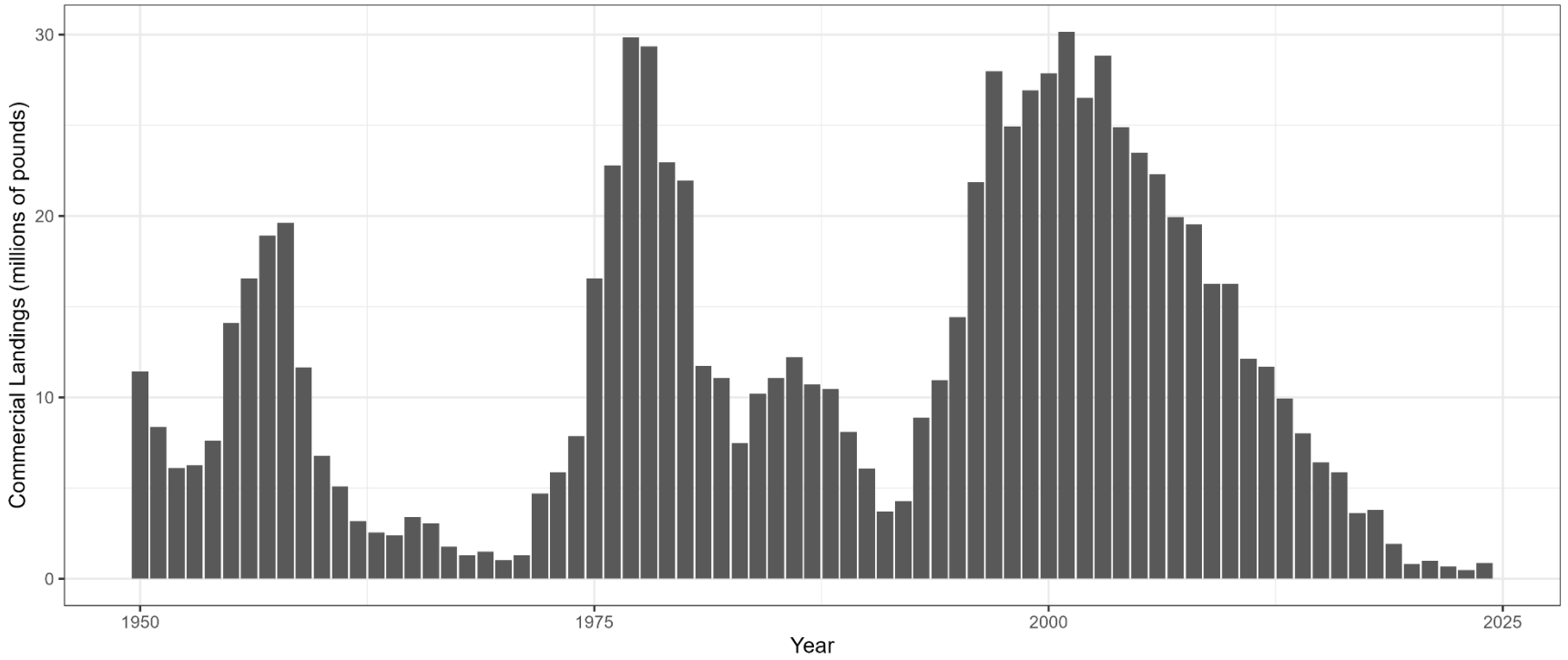


Figure 45. Atlantic croaker coastwide commercial landings.

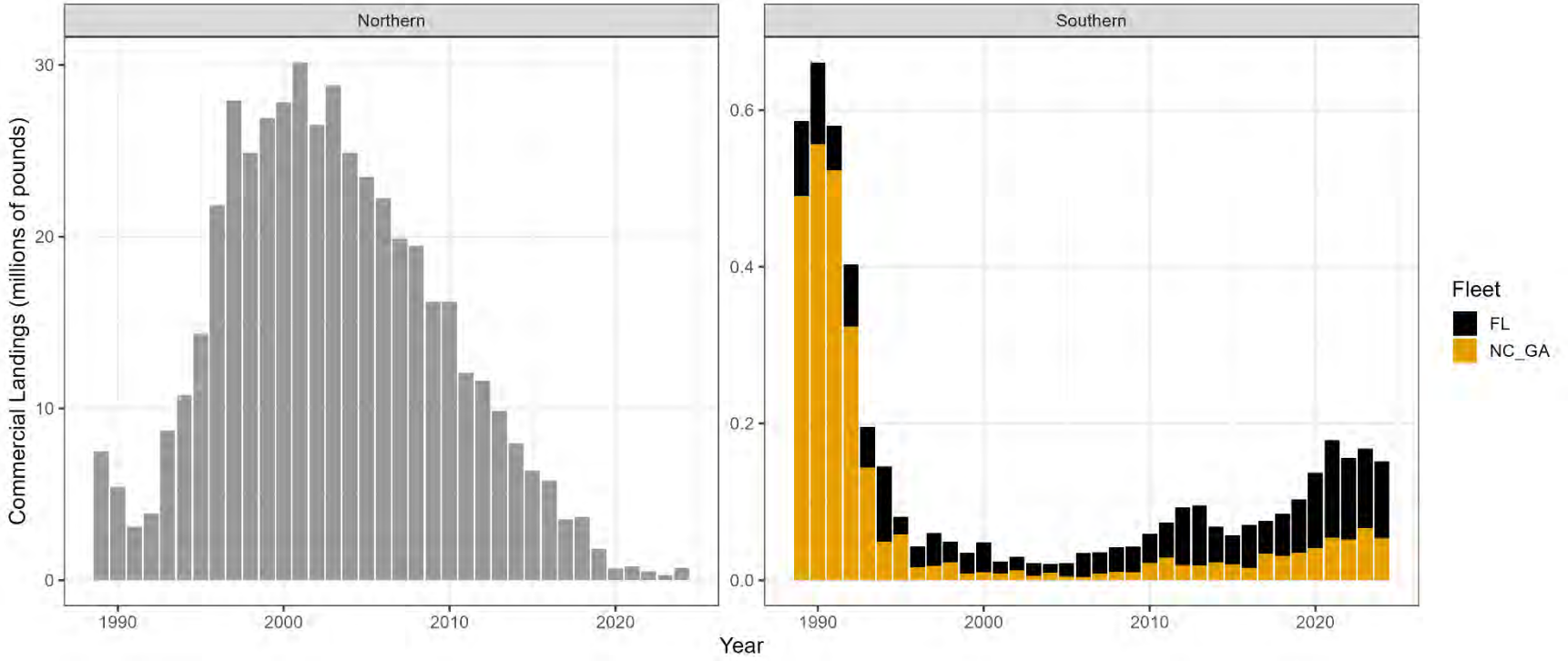


Figure 46. Atlantic croaker commercial landings by stock and fleet within the southern stock.

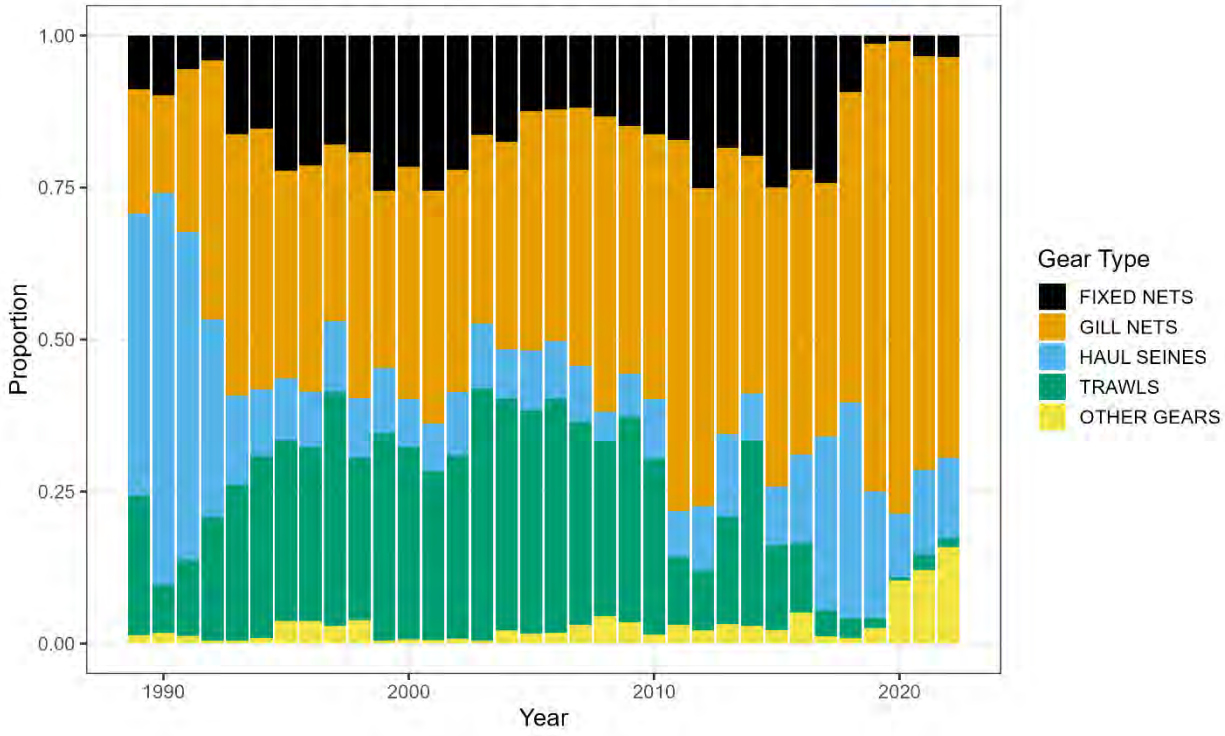


Figure 47. Atlantic croaker commercial landings by gear type.

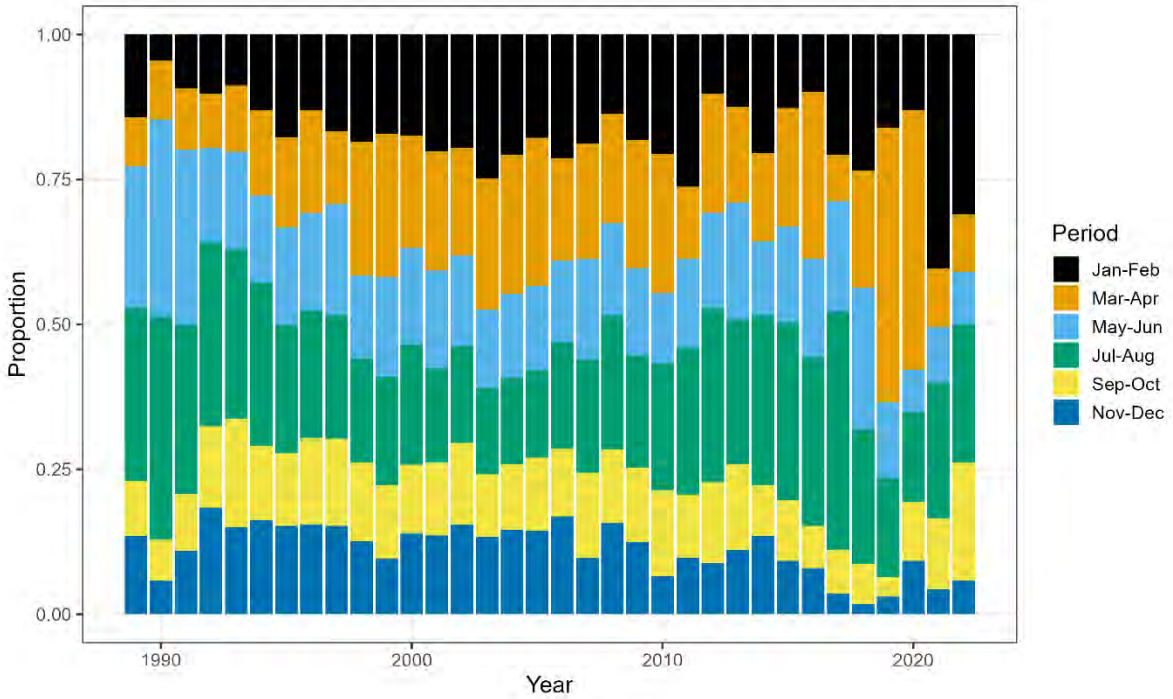


Figure 48. Atlantic croaker commercial landings by bimonthly period.

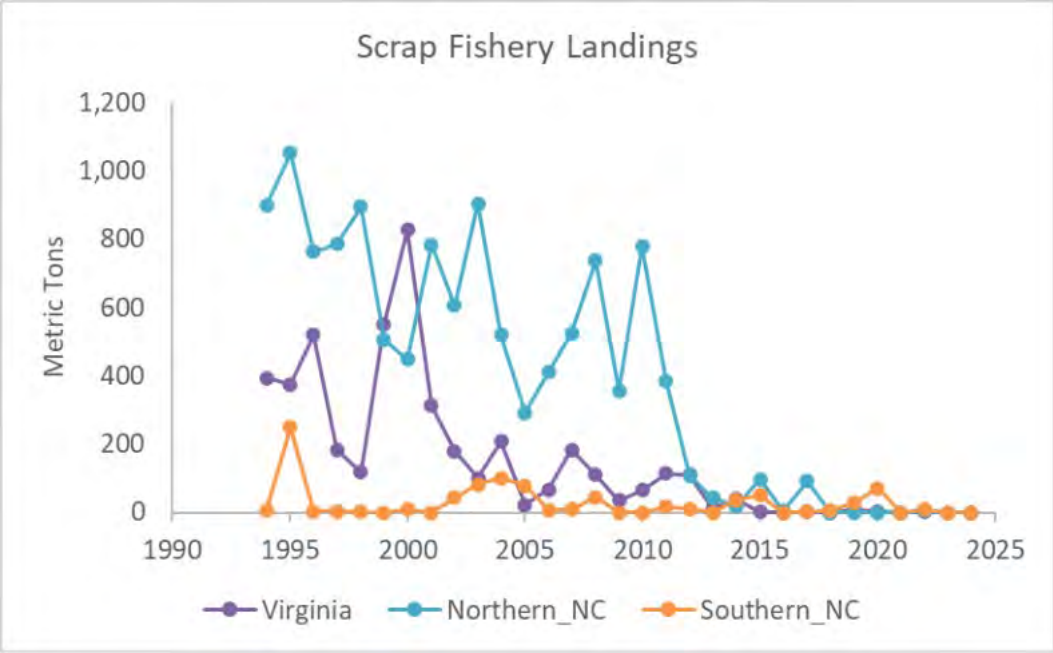


Figure 49. Atlantic croaker landings (metric tons) in the scrap fishery by state/region. Northern_NC and Southern_NC are the northern and southern regions of North Carolina as defined in Section 2.1.6.

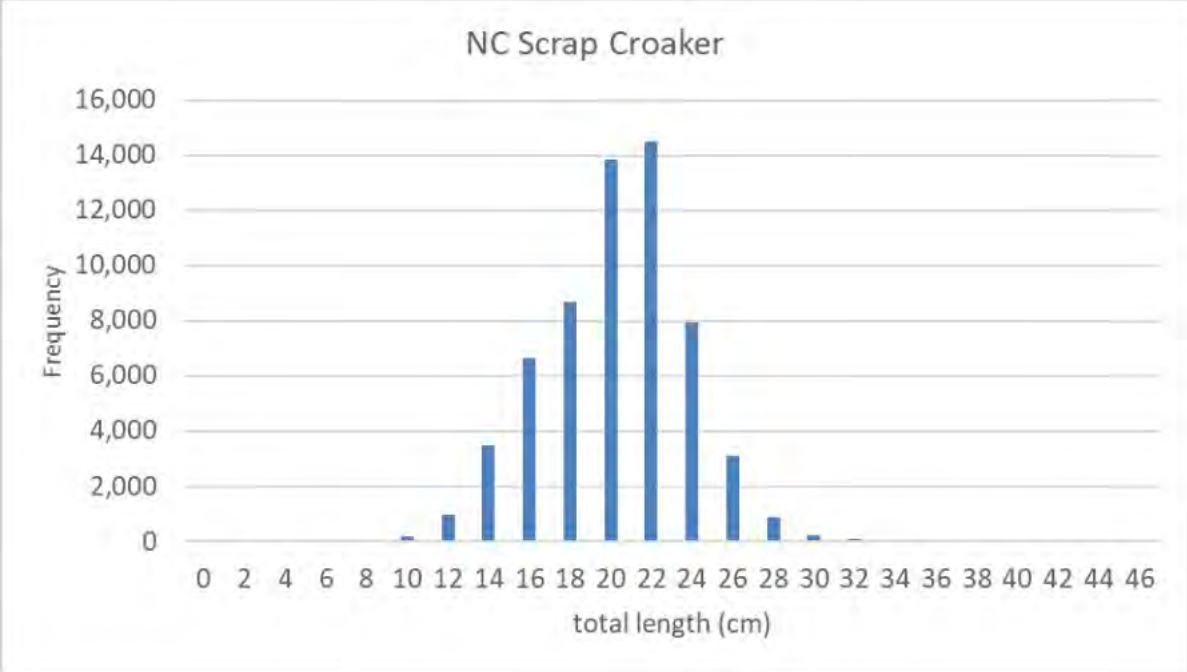


Figure 50. Length frequency of Atlantic croaker measured in North Carolina's scrap fishery subsamples from 1994-2022.

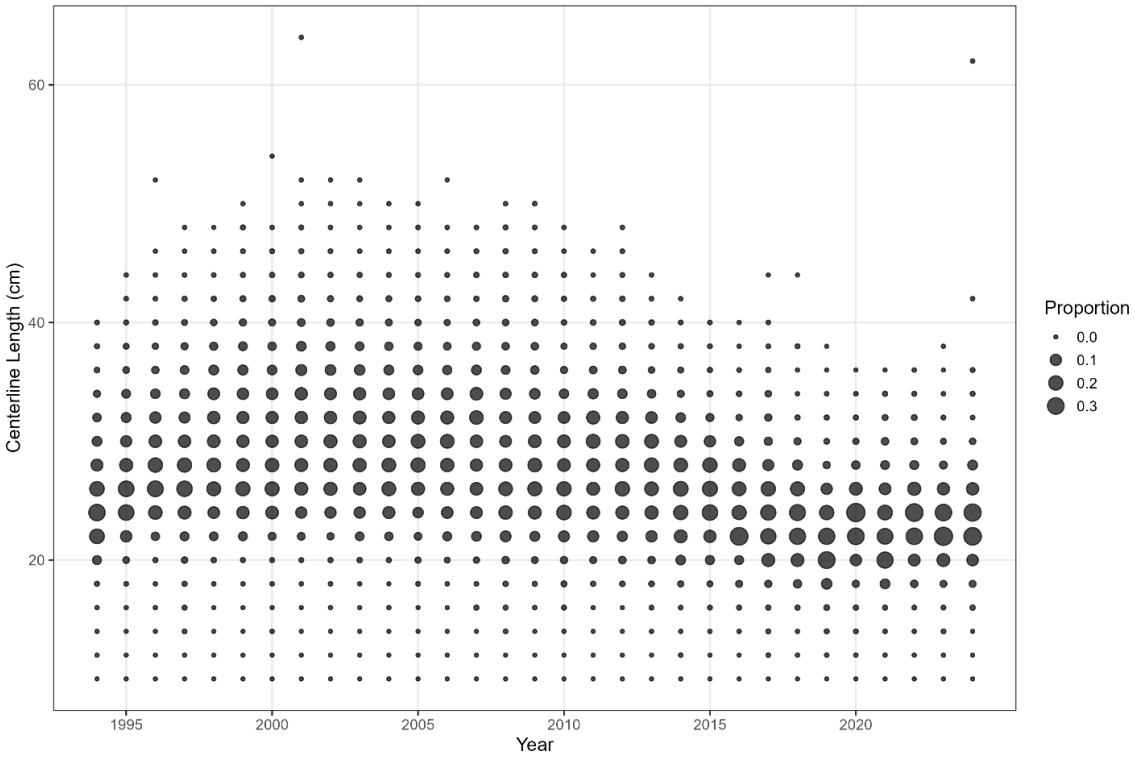


Figure 51. Annual commercial length compositions for northern stock Atlantic croaker.

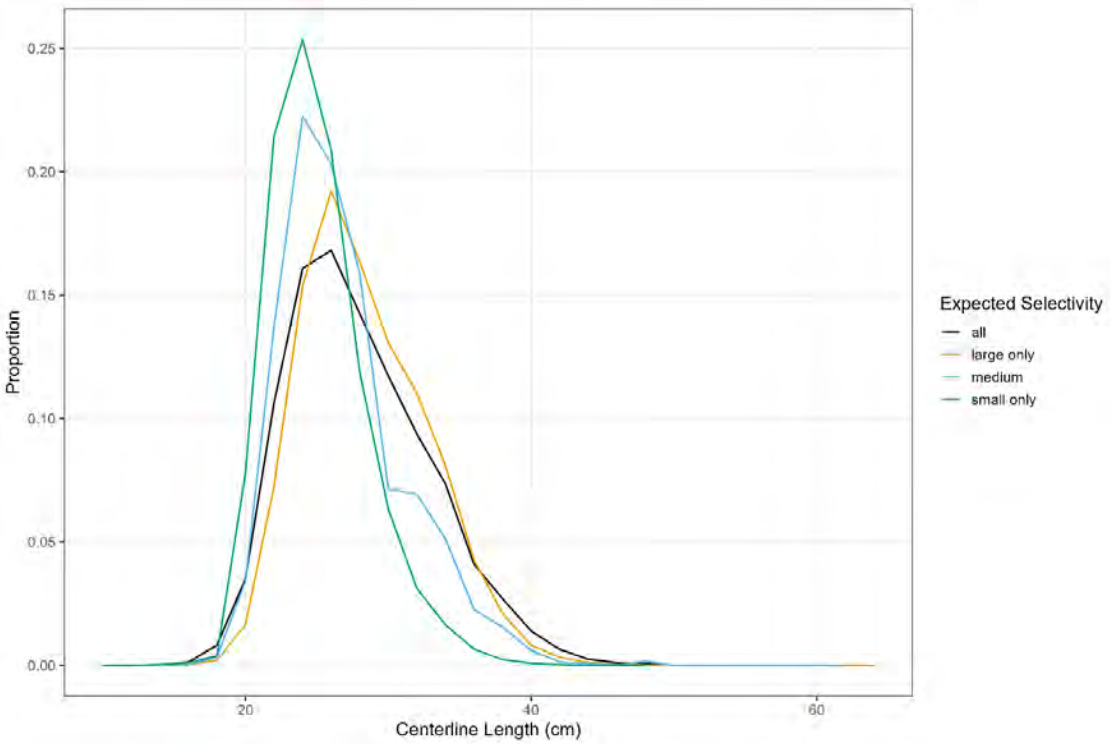


Figure 52. Aggregate length compositions by fishery selectivity category for northern stock Atlantic croaker.

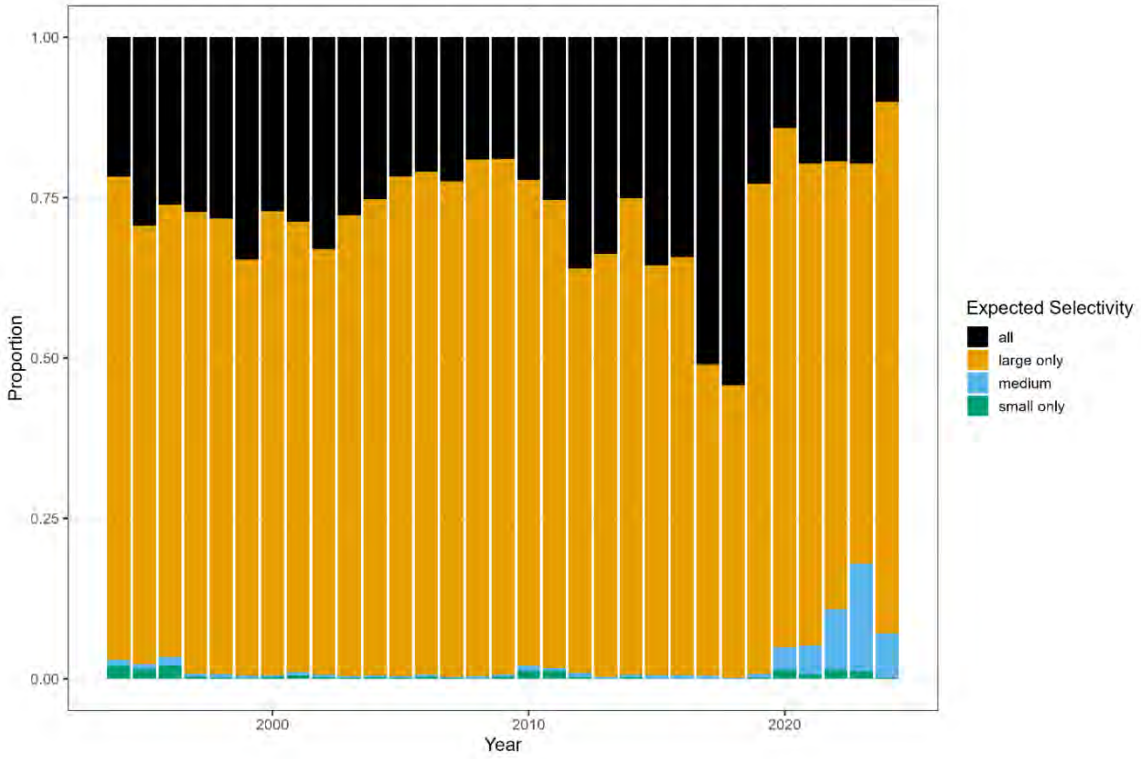


Figure 53. Fishery selectivity category contributions to annual landings of northern stock Atlantic croaker.

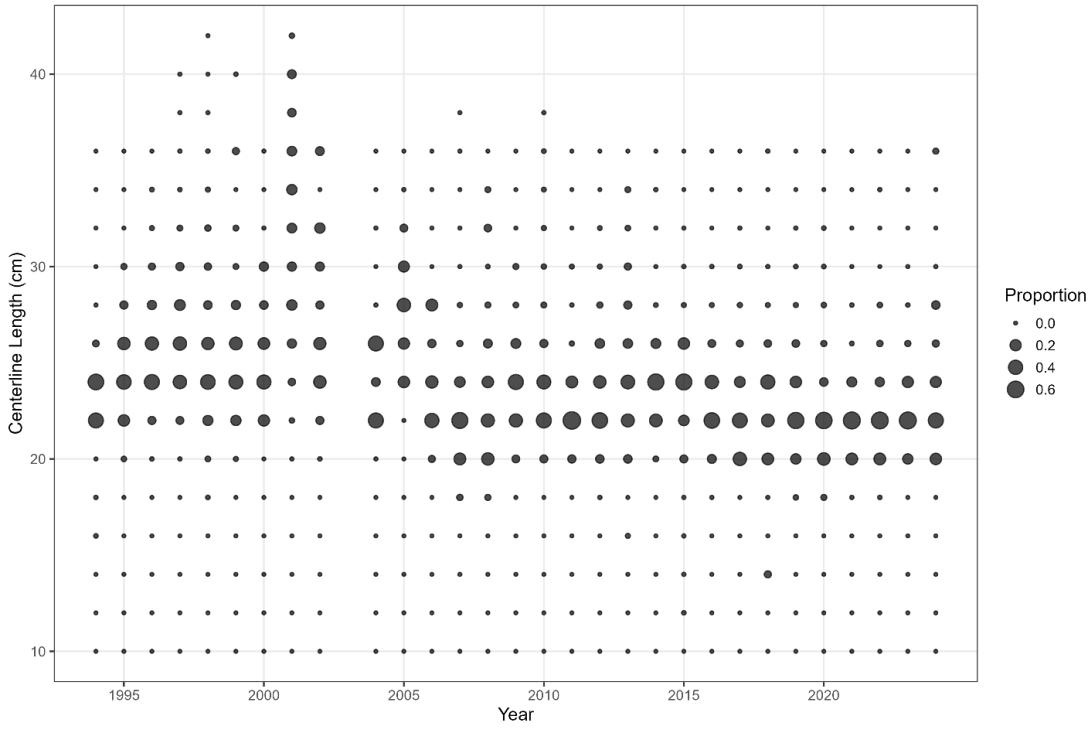


Figure 54. Annual commercial length compositions from North Carolina for southern stock Atlantic croaker.

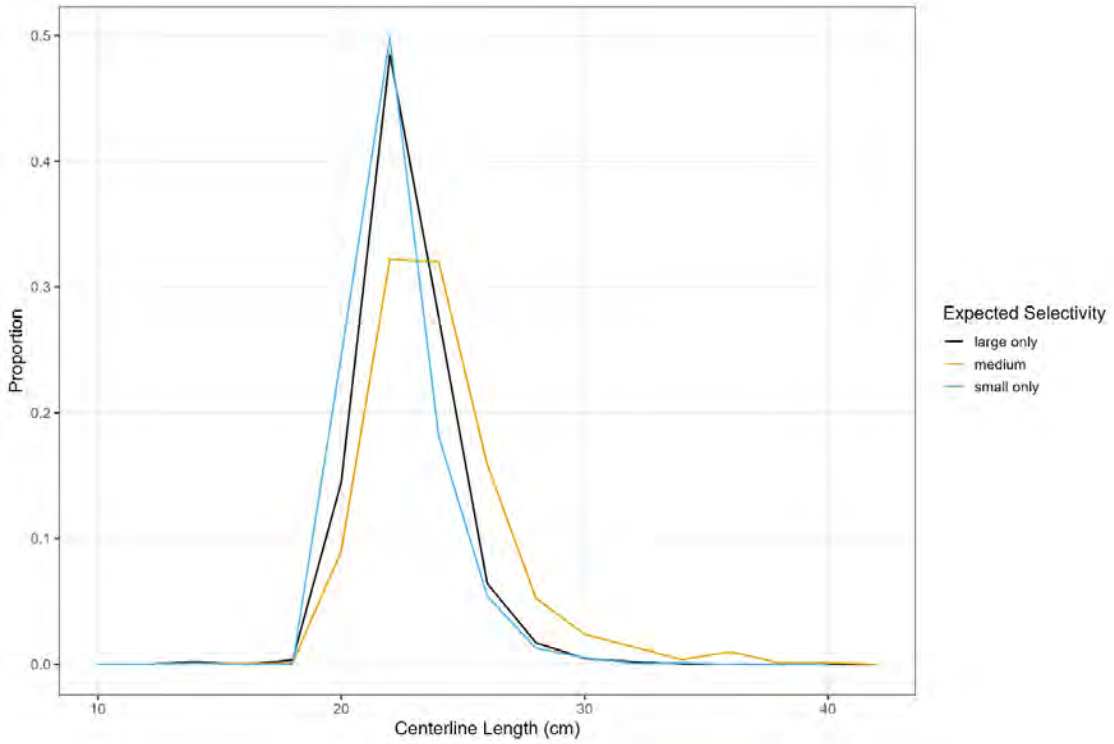


Figure 55. Aggregate length compositions by fishery selectivity category for southern stock Atlantic croaker.

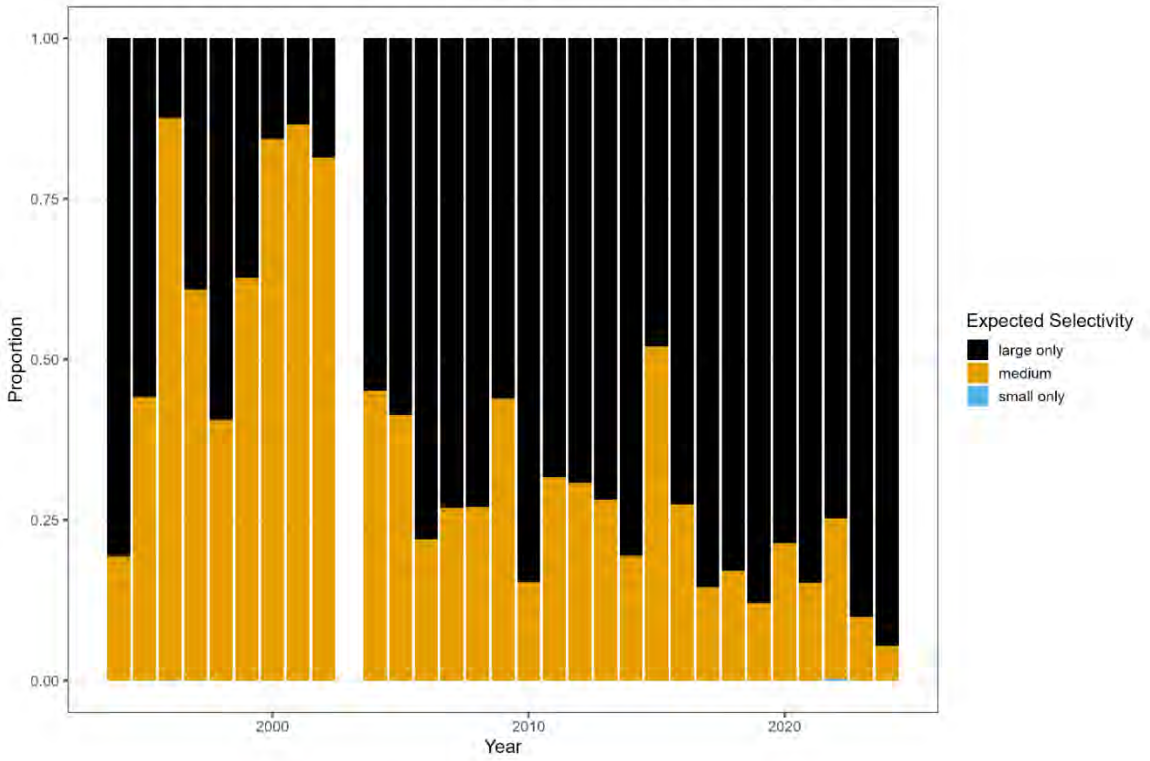


Figure 56. Fishery selectivity category contributions to annual landings of southern stock Atlantic croaker.

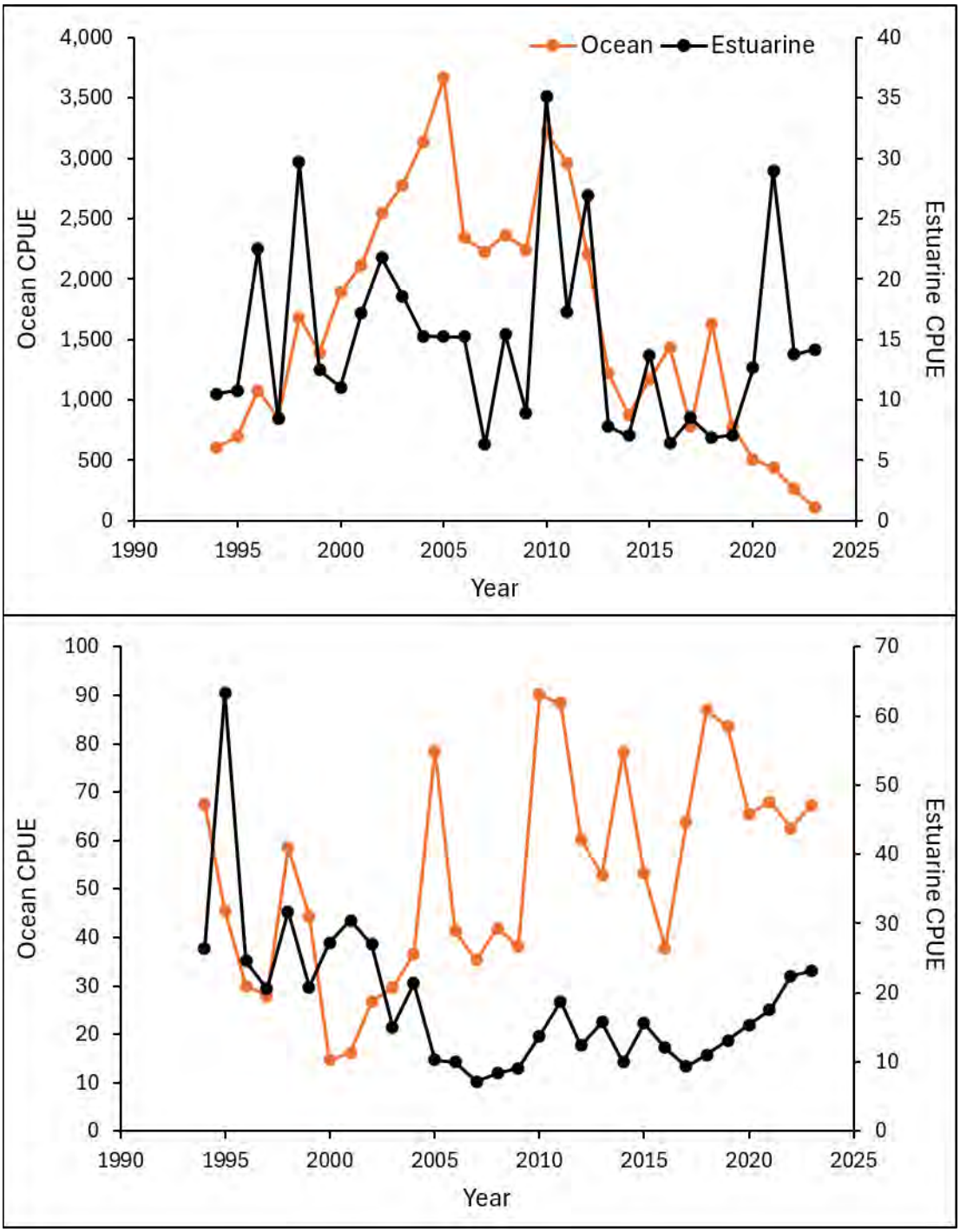


Figure 57. North Carolina commercial anchored gill net fishery CPUE (pounds of Atlantic croaker landed per trip) in the northern (top) and southern (bottom) stocks.

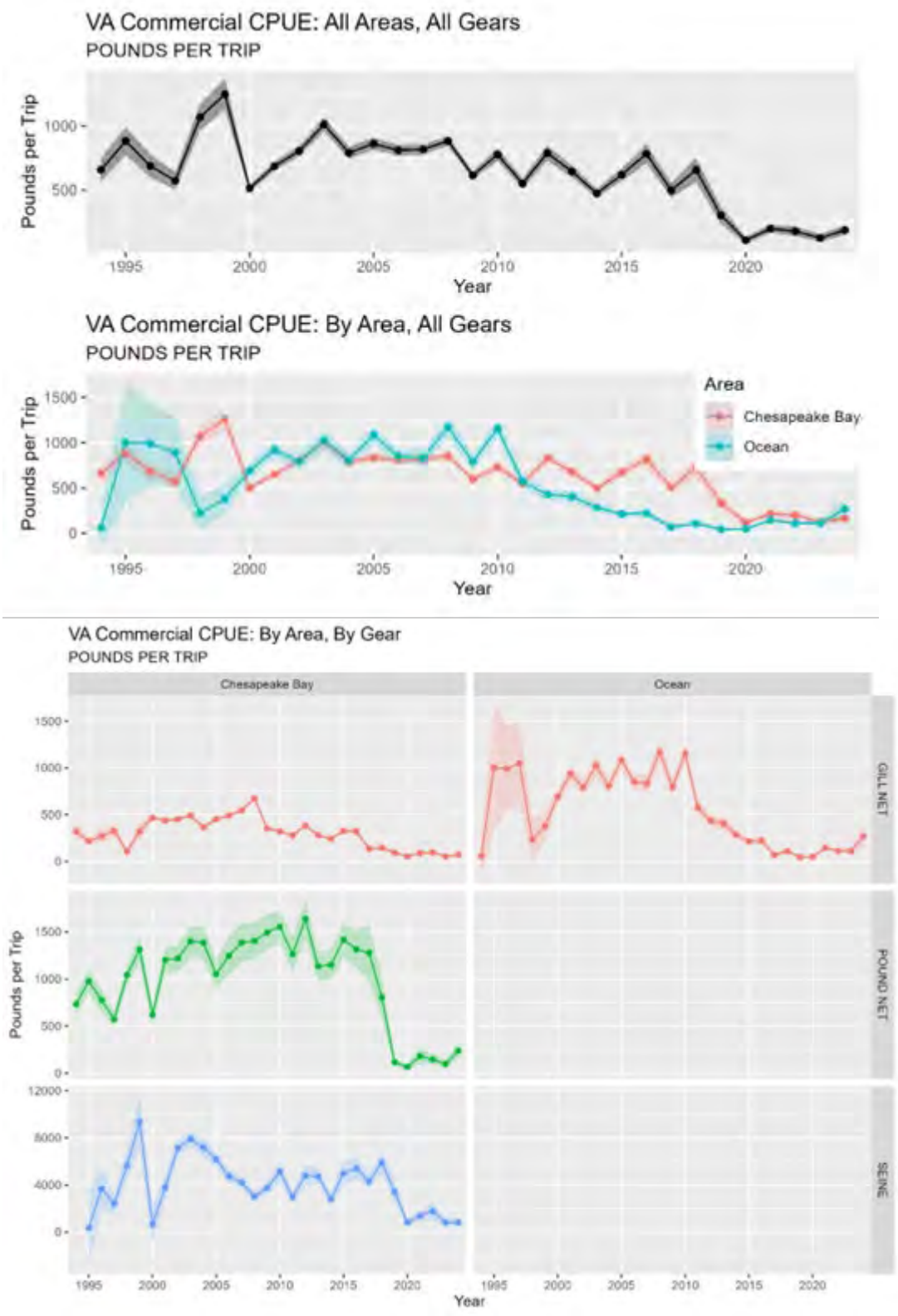


Figure 58. Nominal CPUE for commercial harvest of Atlantic croaker in VA waters, in aggregate (top), by area (middle), and by area and gear (bottom set of panels). Points are the arithmetic mean. Shaded area is the 95% confidence interval.

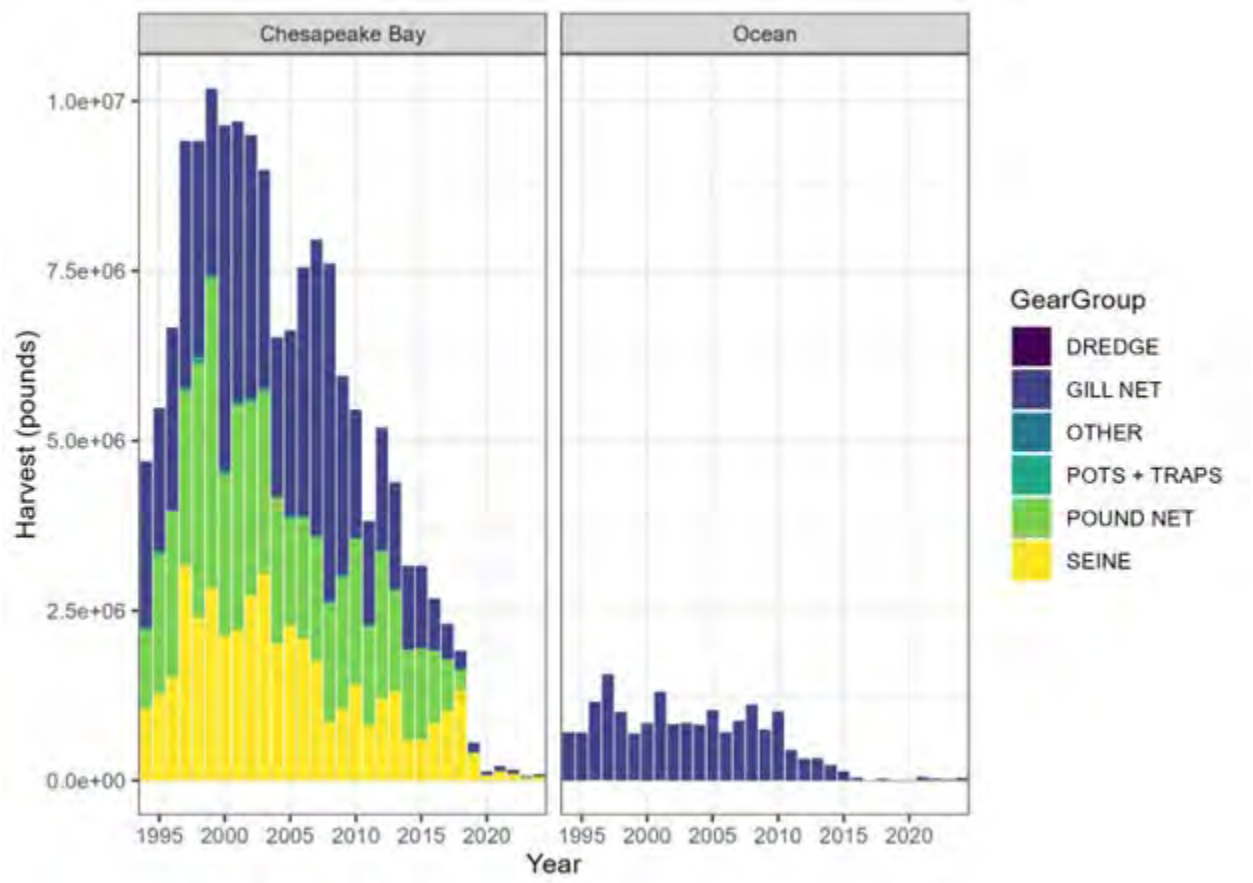


Figure 59. VA commercial Atlantic croaker harvest by gear in the Chesapeake Bay and Atlantic Ocean.

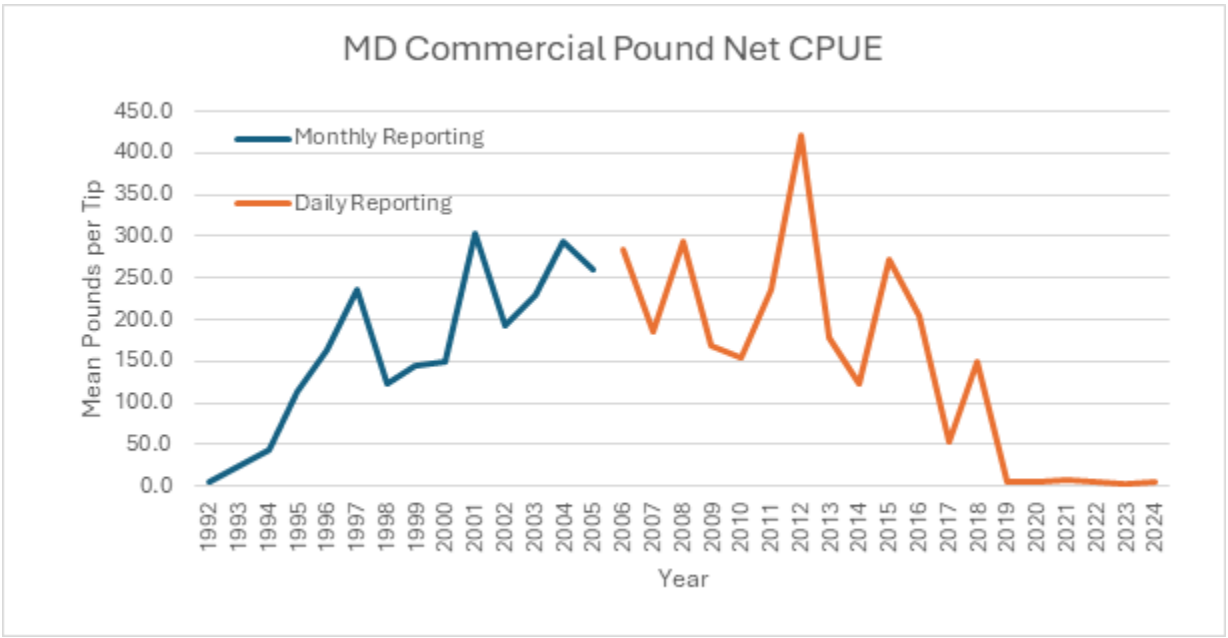


Figure 60. Arithmetic mean pounds of Atlantic croaker per trip for Maryland's pound net fishery by reporting system, 1992-2024.

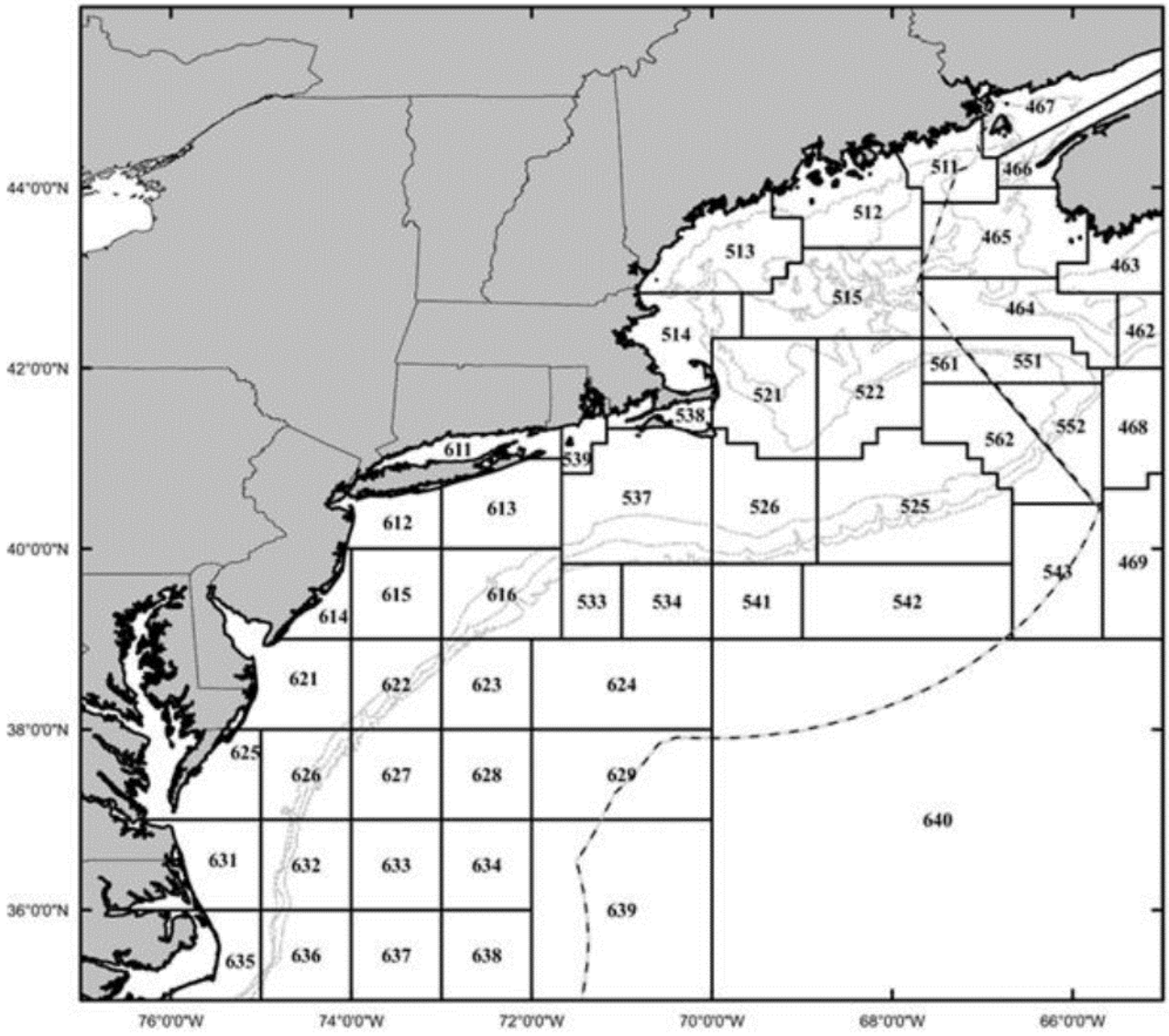


Figure 61. Statistical areas as defined in the NEFOP and ACCSP data sets.

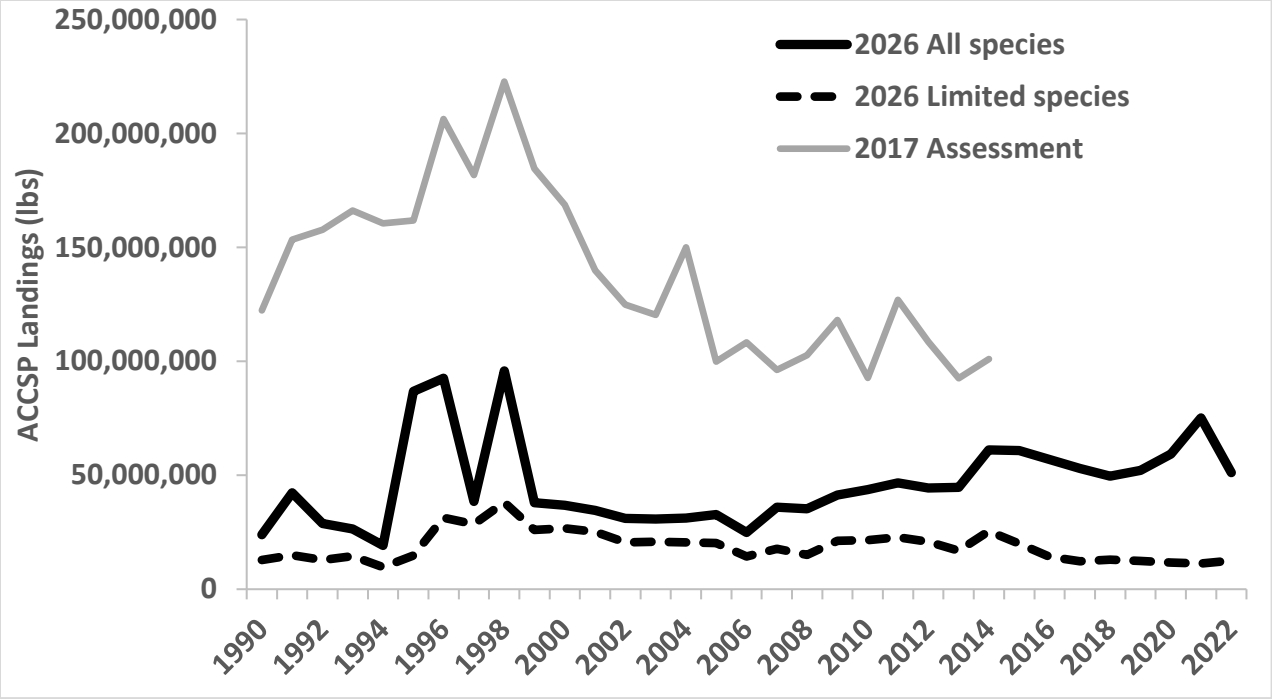


Figure 62. All species landings as queried in ACCSP for specified gears and spatial areas defined in the 2017 and 2026 assessments. The 2026 assessment evaluated all species landings and a limited number of species associated with Atlantic croaker discards in NEFOP. Source: ACCSP.

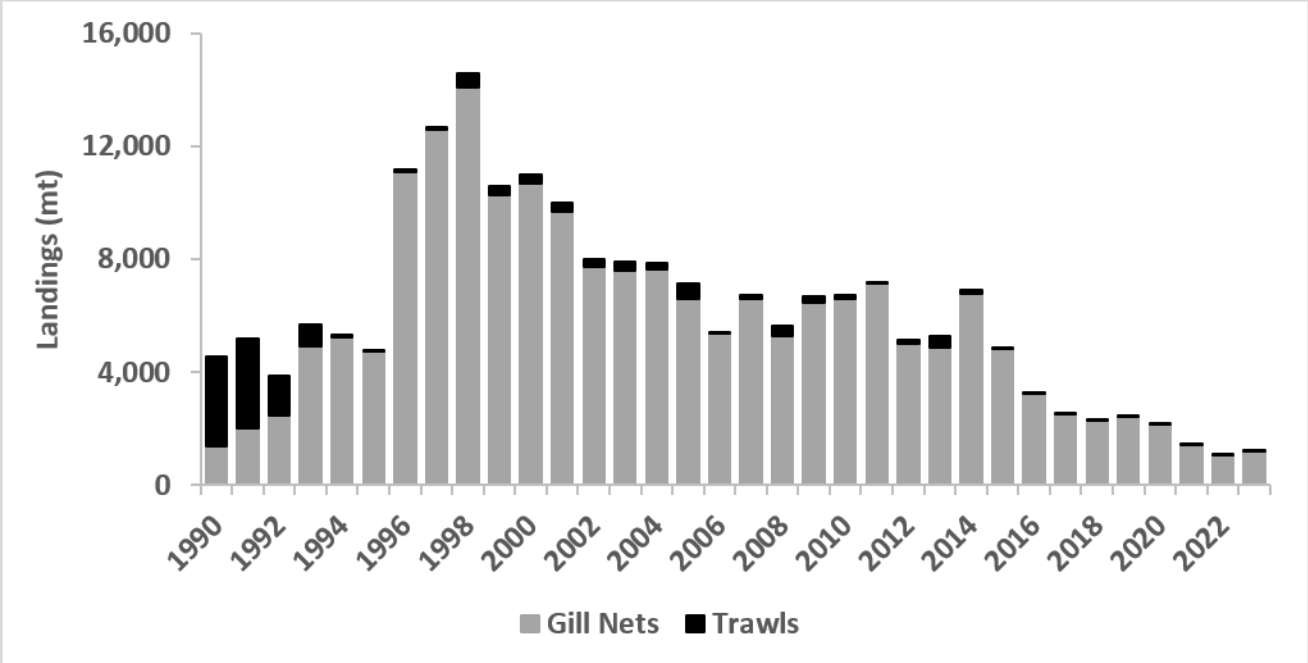


Figure 63. All species landings (in metric tons) in the Mid-Atlantic by gear with "not coded" gears portioned between gill nets and trawls. Source: ACCSP.

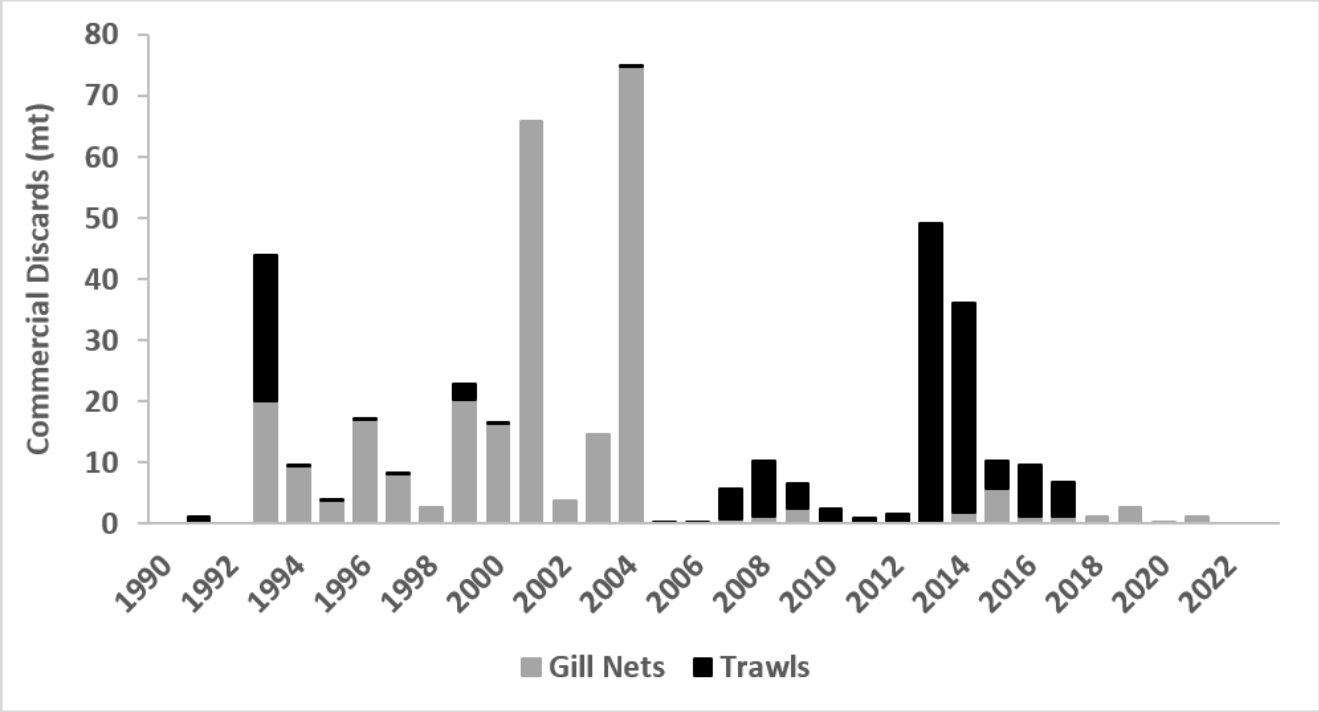


Figure 64. Atlantic croaker discards in the Mid-Atlantic by gear, 1990-2023.

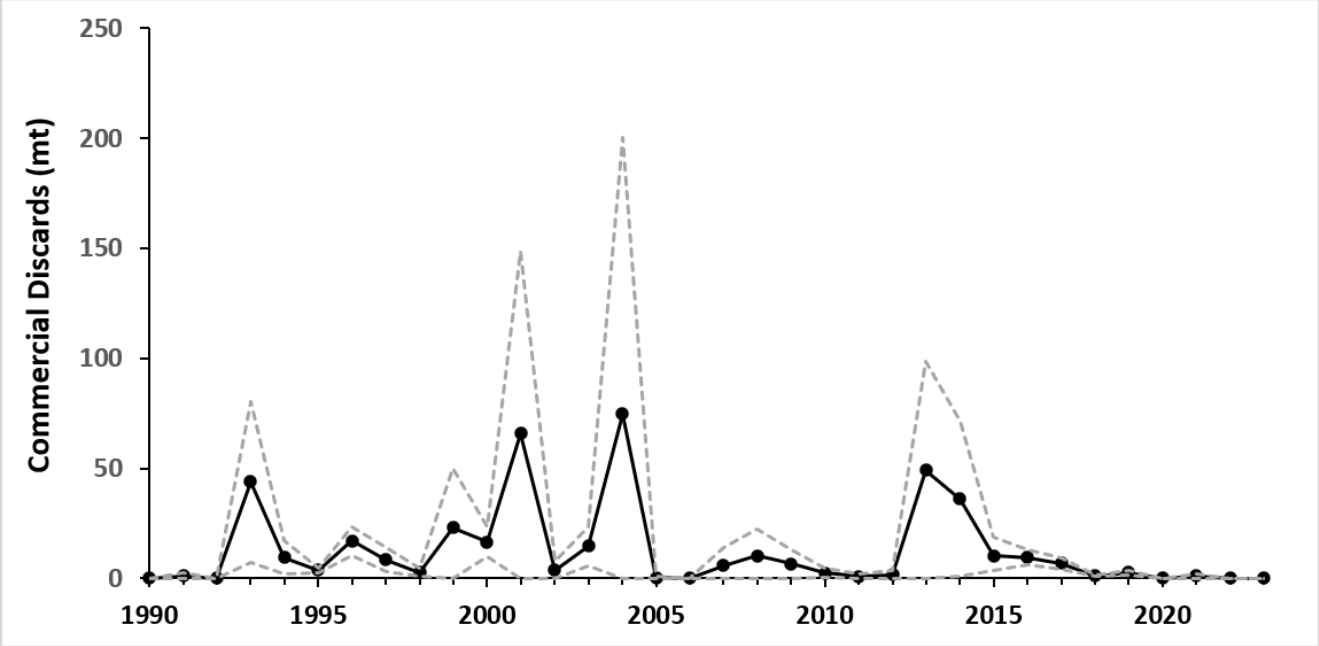


Figure 65. Atlantic croaker discards in the Mid-Atlantic with 95% confidence intervals, 1990-2023.

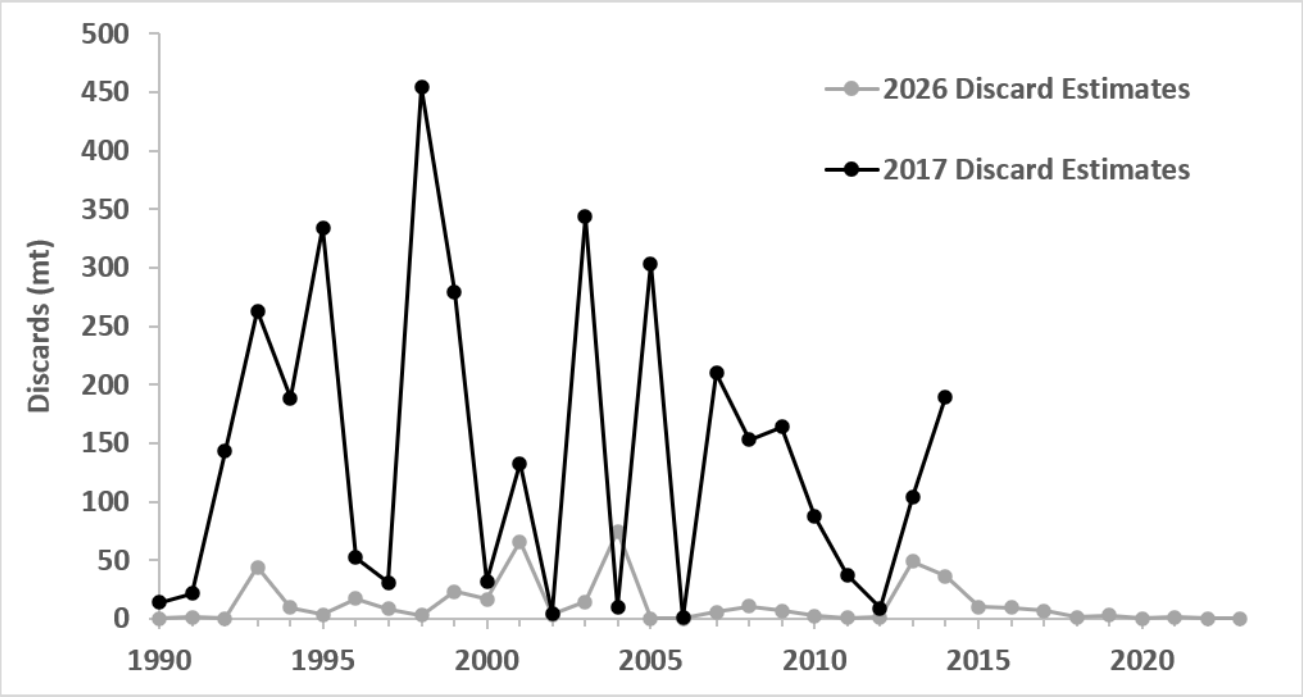


Figure 66. Comparison between discard estimates for the 2017 and 2026 stock assessments.

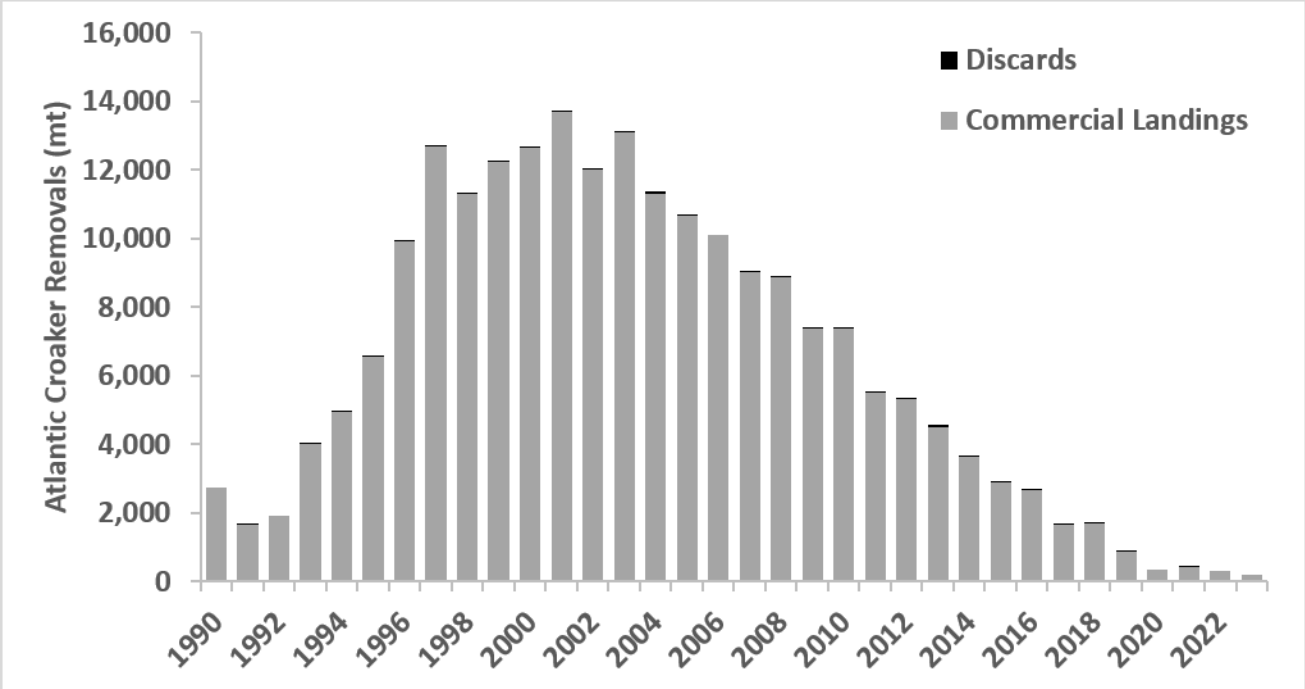


Figure 67. Comparison between discard estimates and commercial landings in mt, 1990-2023.

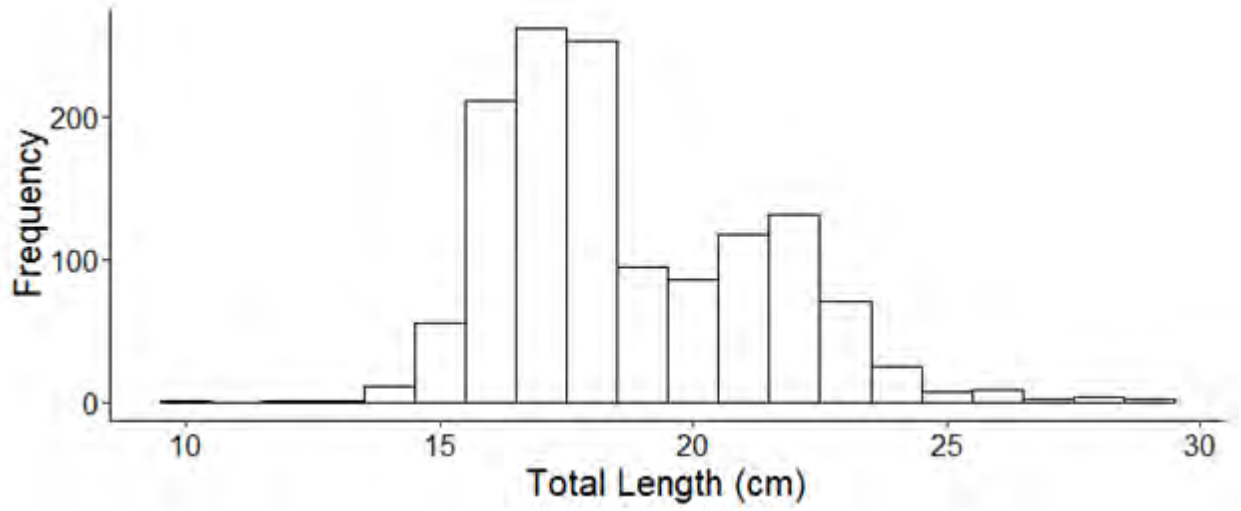


Figure 68. South Atlantic Shrimp Trawl Observer Program length composition data from 2003. All data were collected during two observed trips in 2003.

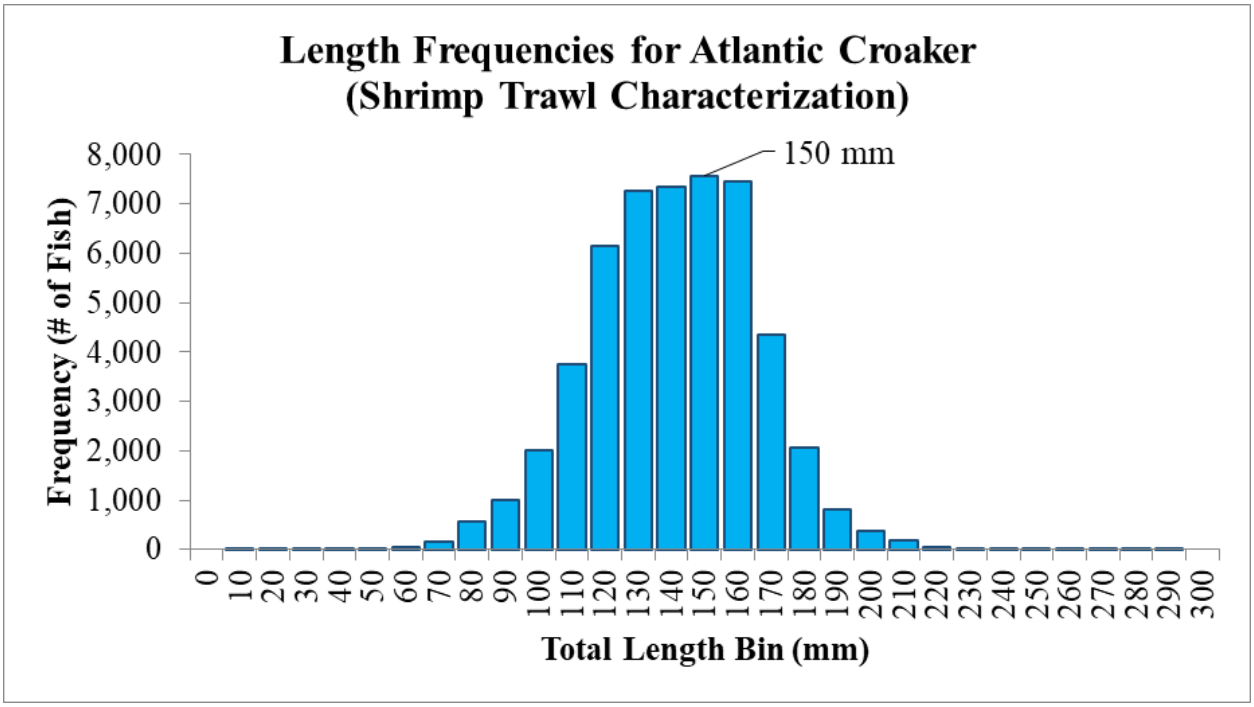


Figure 69. North Carolina Commercial Shrimp Trawl Fishery Characterization length composition data from 2007-2017.

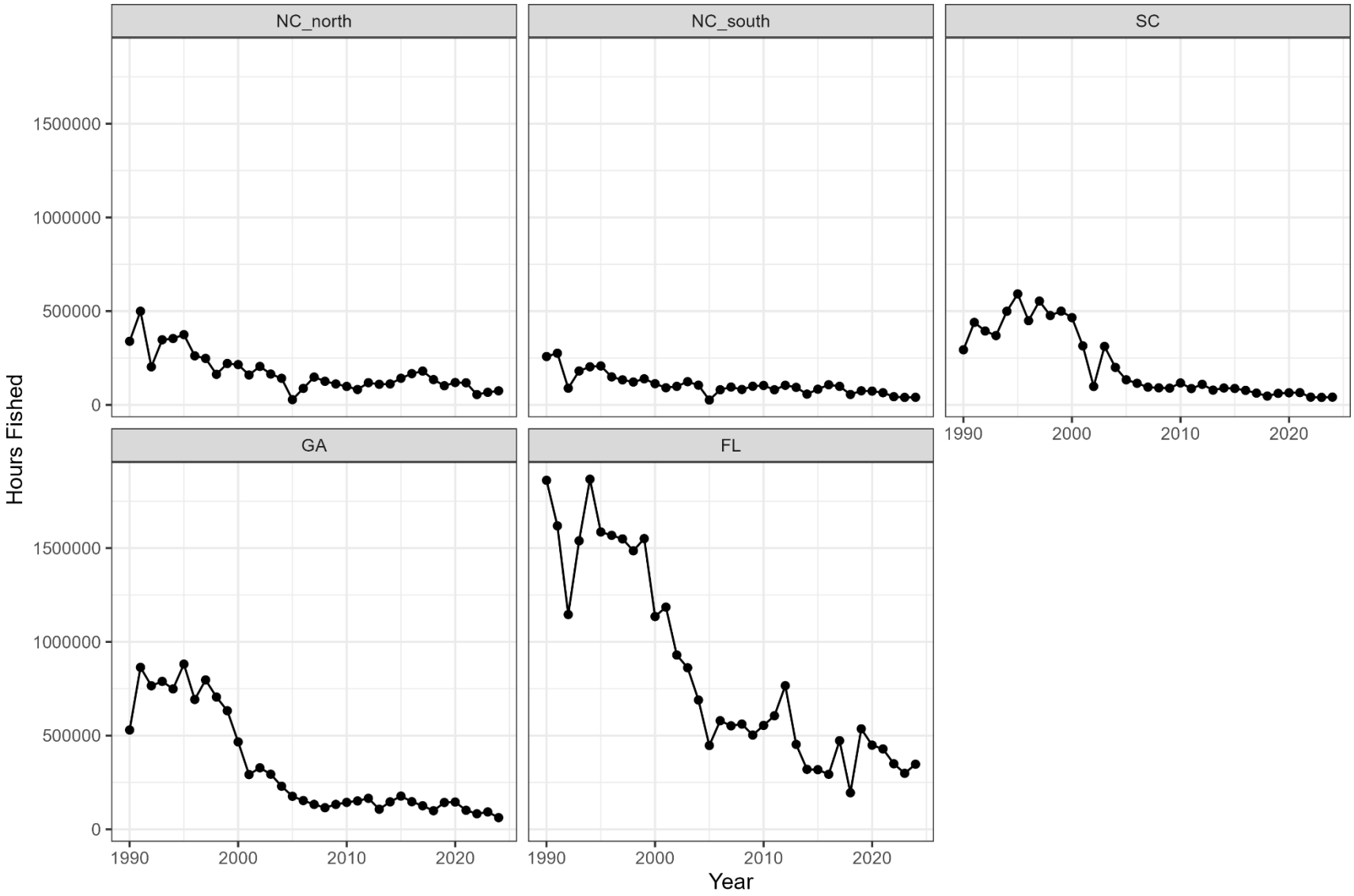


Figure 70. Shrimp trawl fishery effort by state.

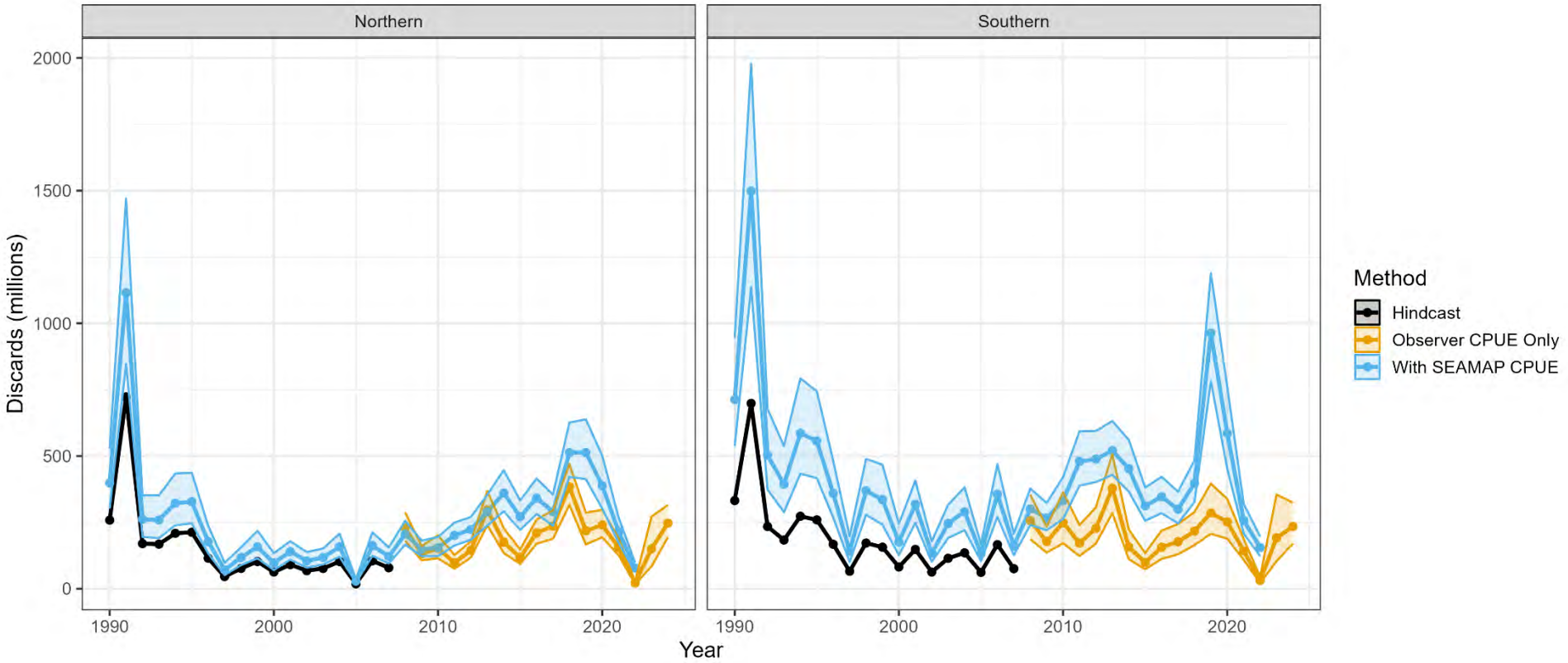


Figure 71. Shrimp trawl fishery discards of Atlantic croaker by stock and method with 95% confidence intervals. Discards estimated with the Hindcast method (1990-2007) and using observer CPUE only (2008-2024) are used in assessment models.

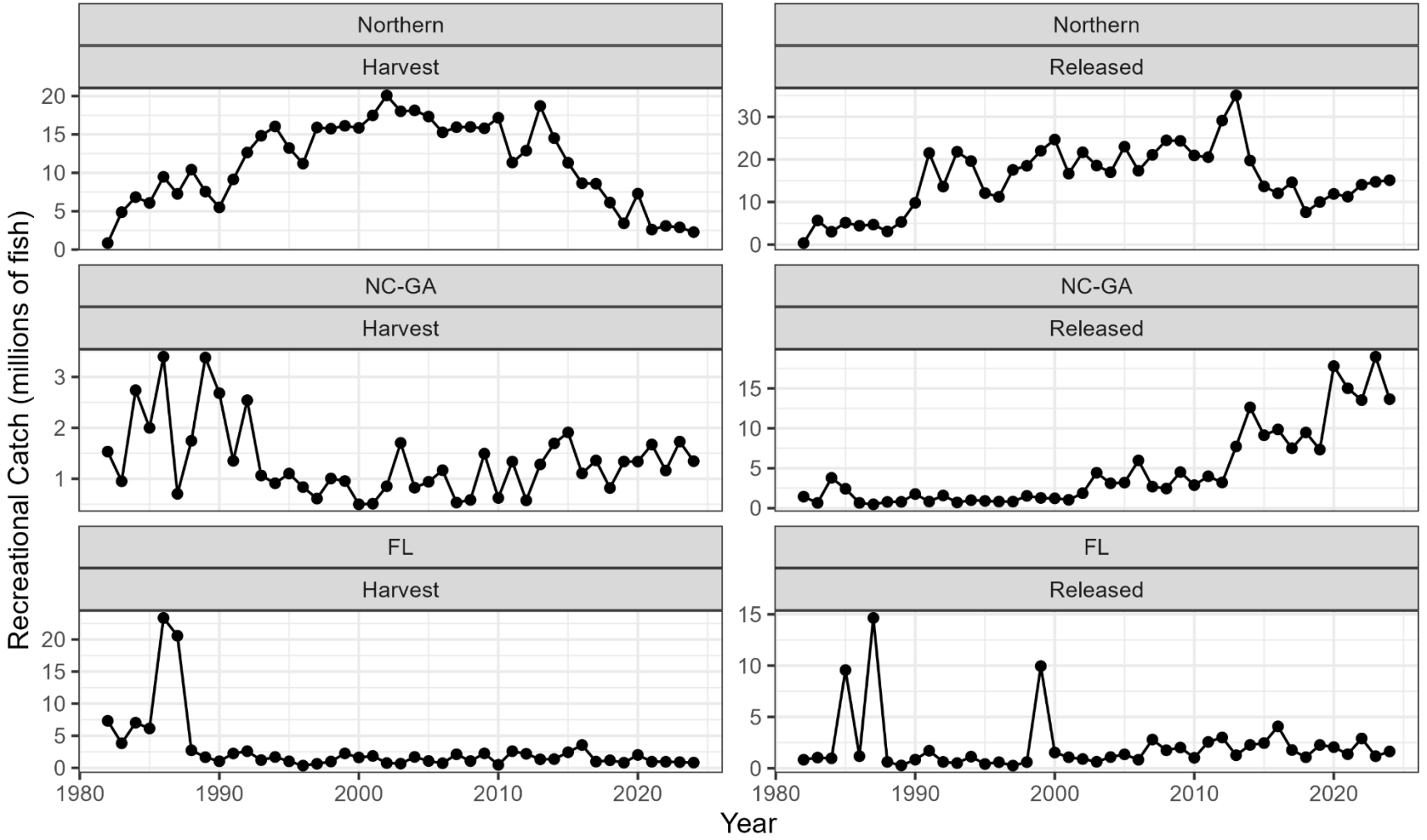


Figure 72. Atlantic croaker recreational catch by fleet and disposition.

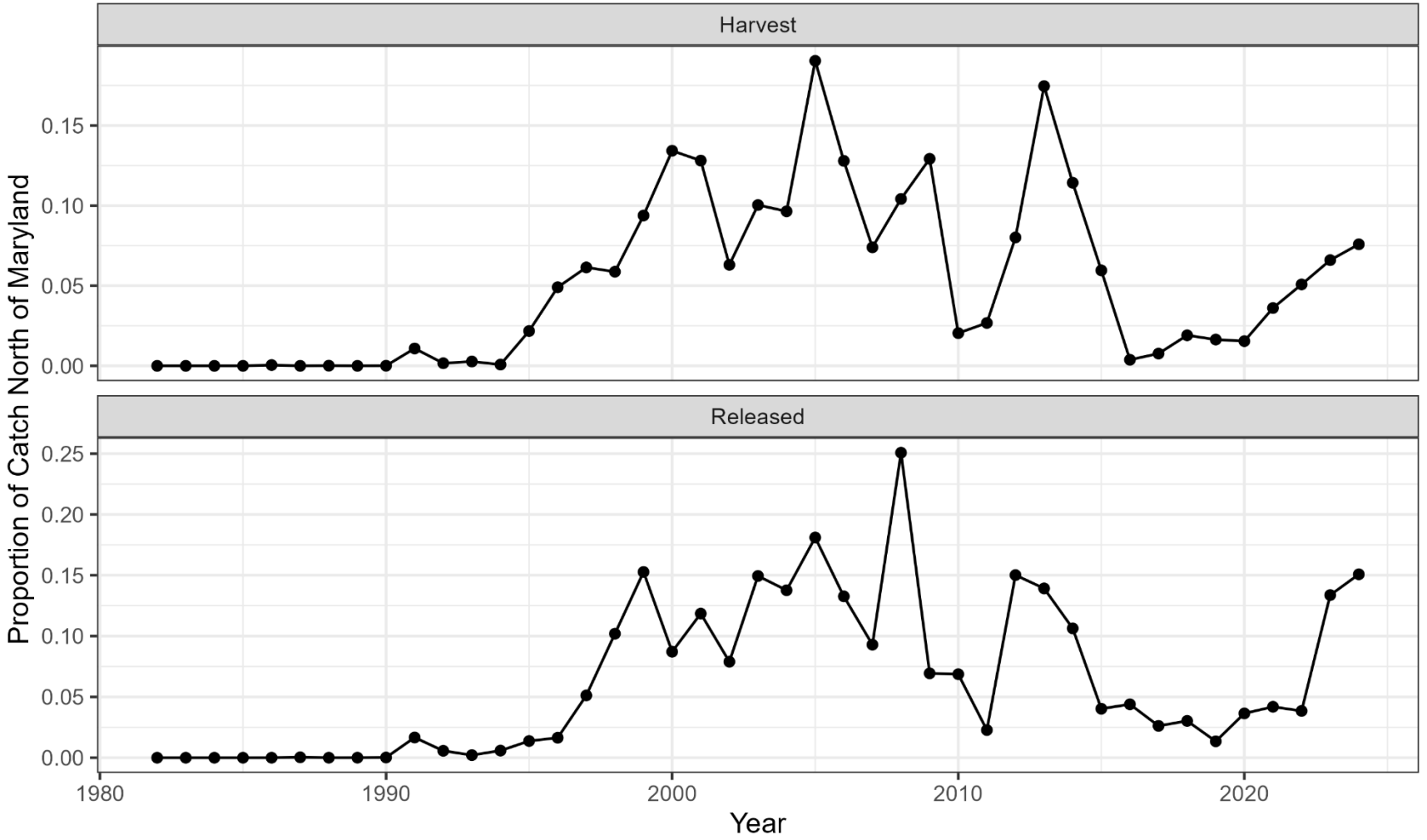


Figure 73. Proportion of northern stock Atlantic croaker recreational catch occurring north of Maryland.

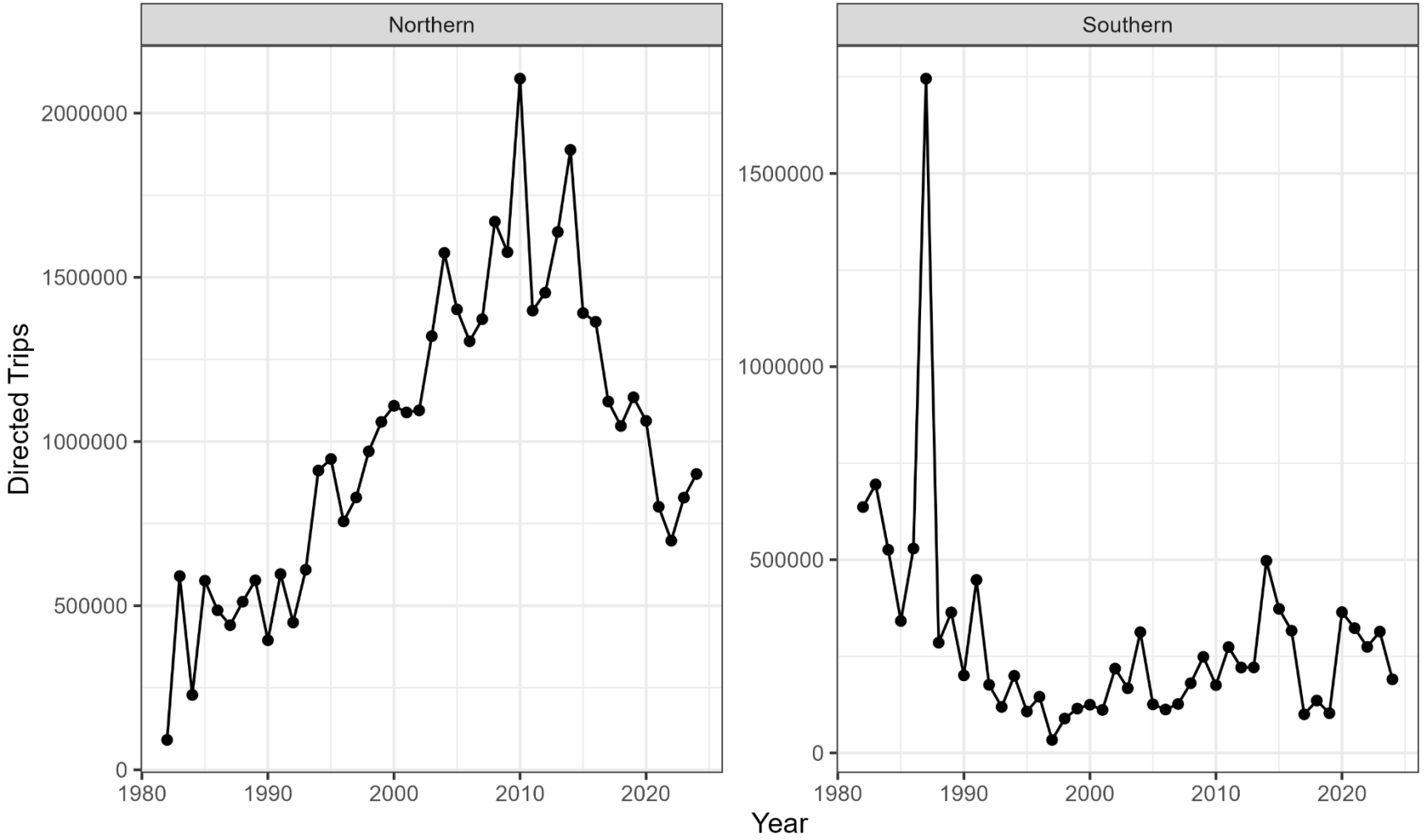


Figure 74. Atlantic croaker recreational effort. Effort is defined as trips where Atlantic croaker were identified by anglers as either the primary or secondary target species.

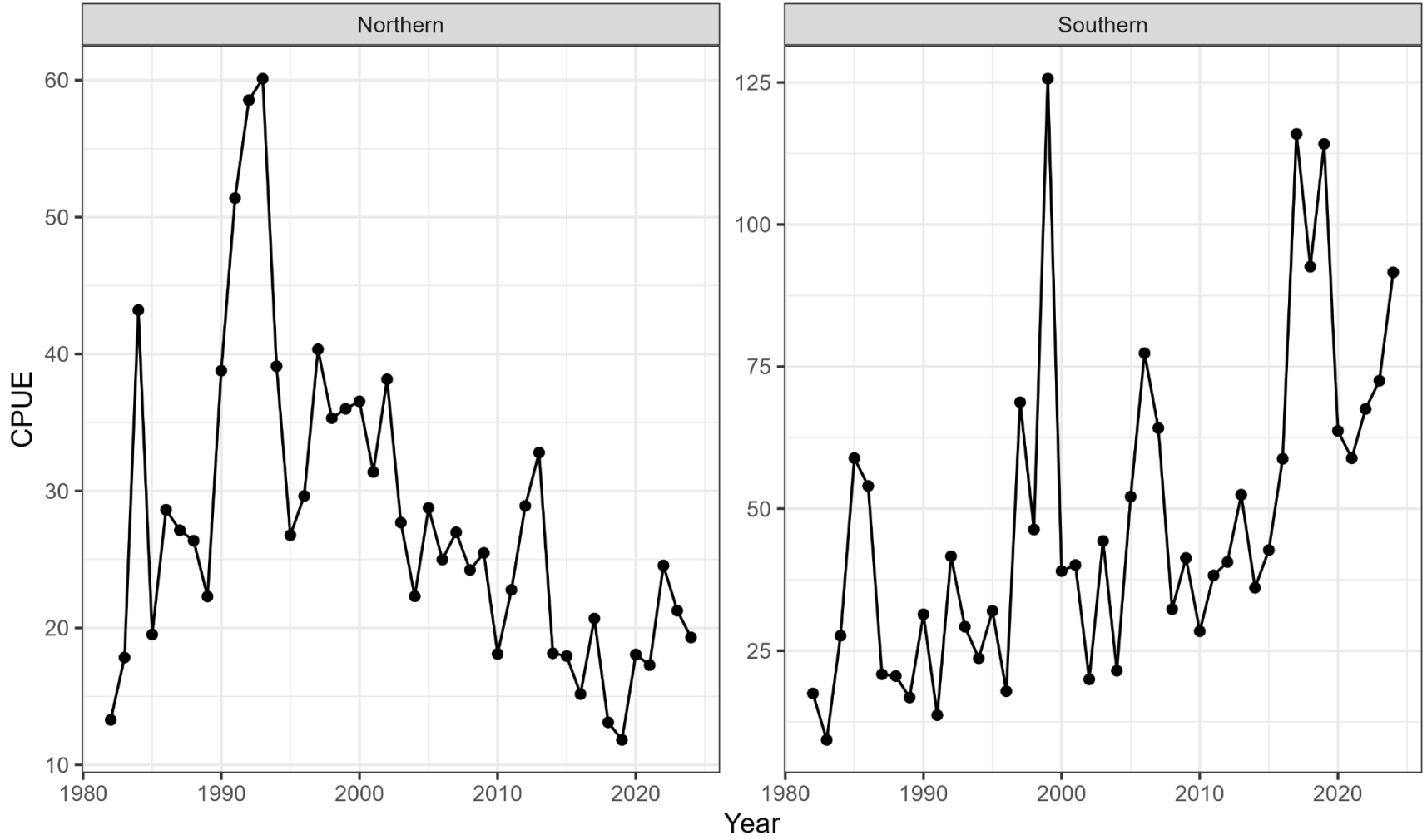


Figure 75. Atlantic croaker recreational CPUE (number of fish caught per directed trip) by stock.

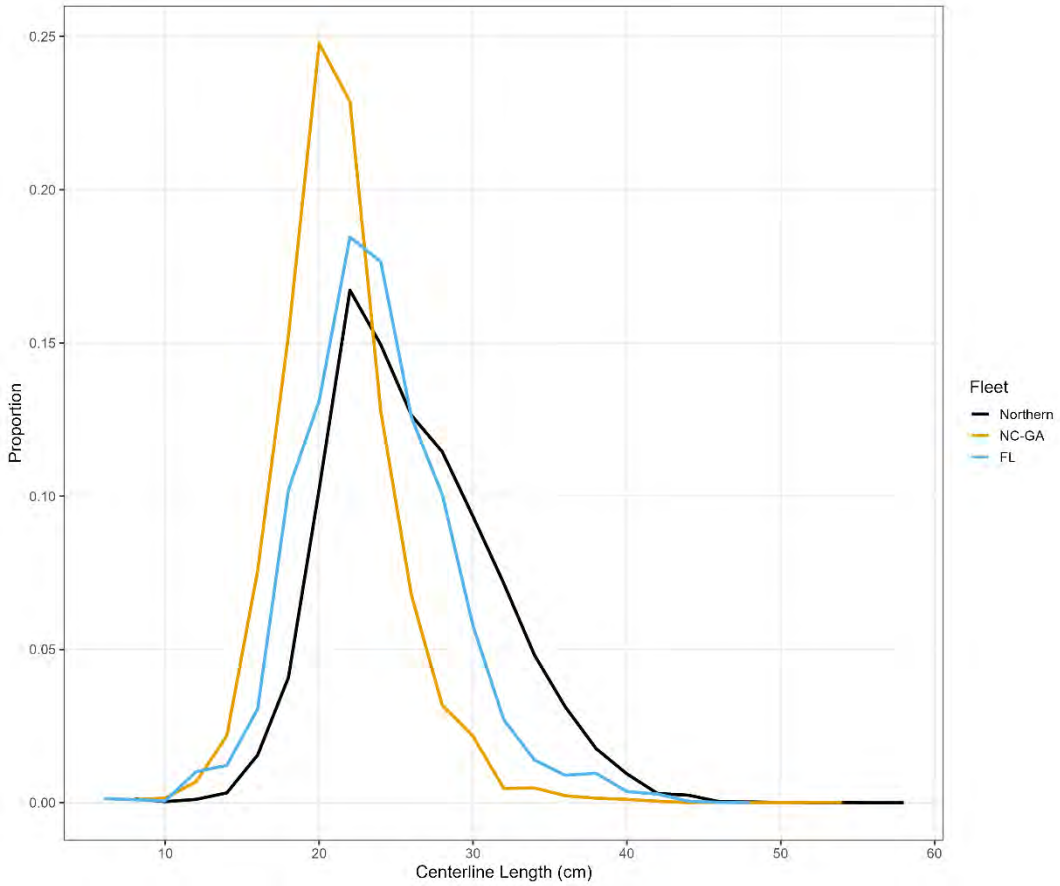


Figure 76. Atlantic croaker recreational harvest length compositions aggregated across the years 1982-1985 and 1987-2024. Data from 1986 are excluded due to anomalous secondary spike at 26 cm in the Florida length composition driven by this one year of data.

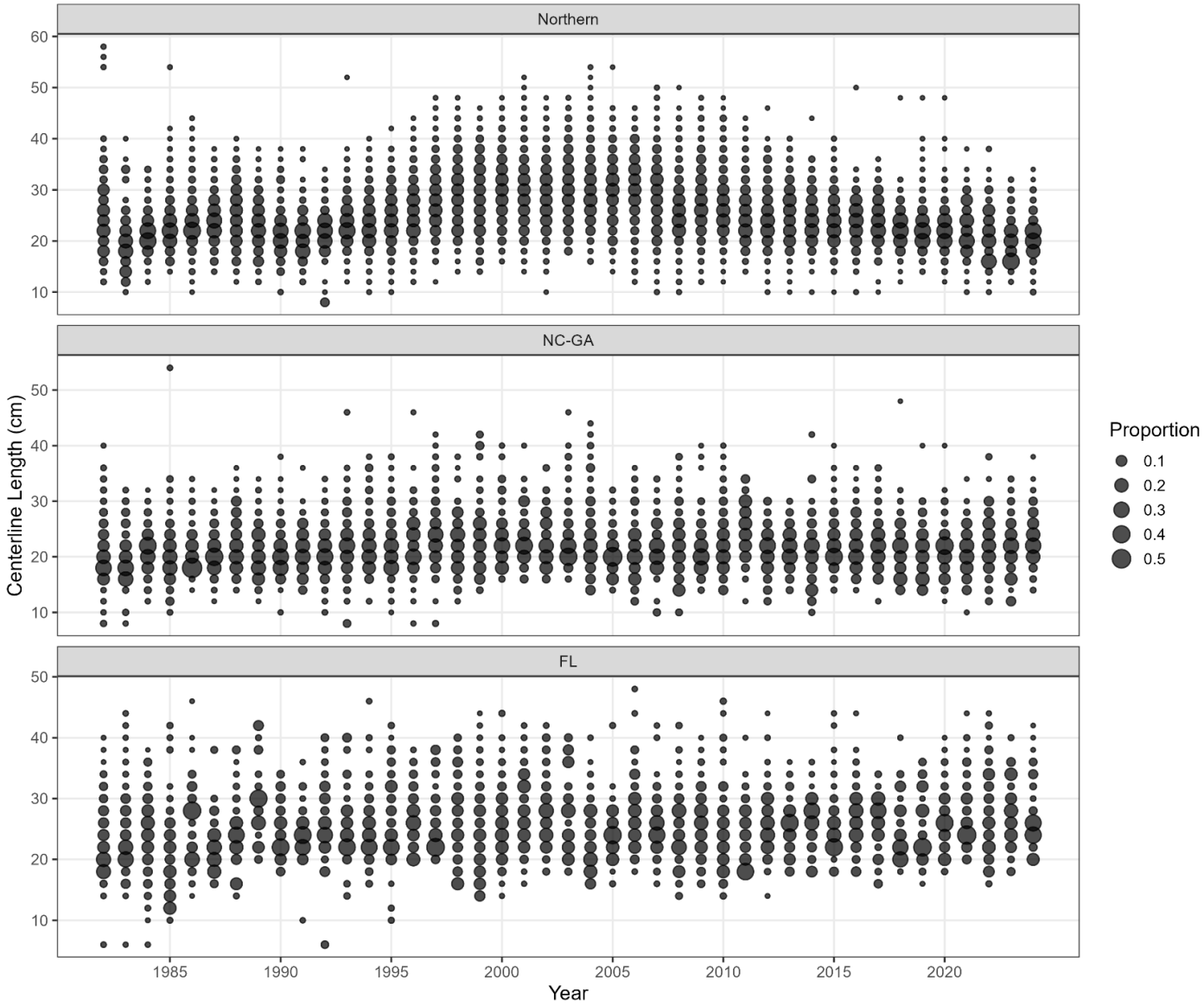


Figure 77. Atlantic croaker recreational harvest length compositions.

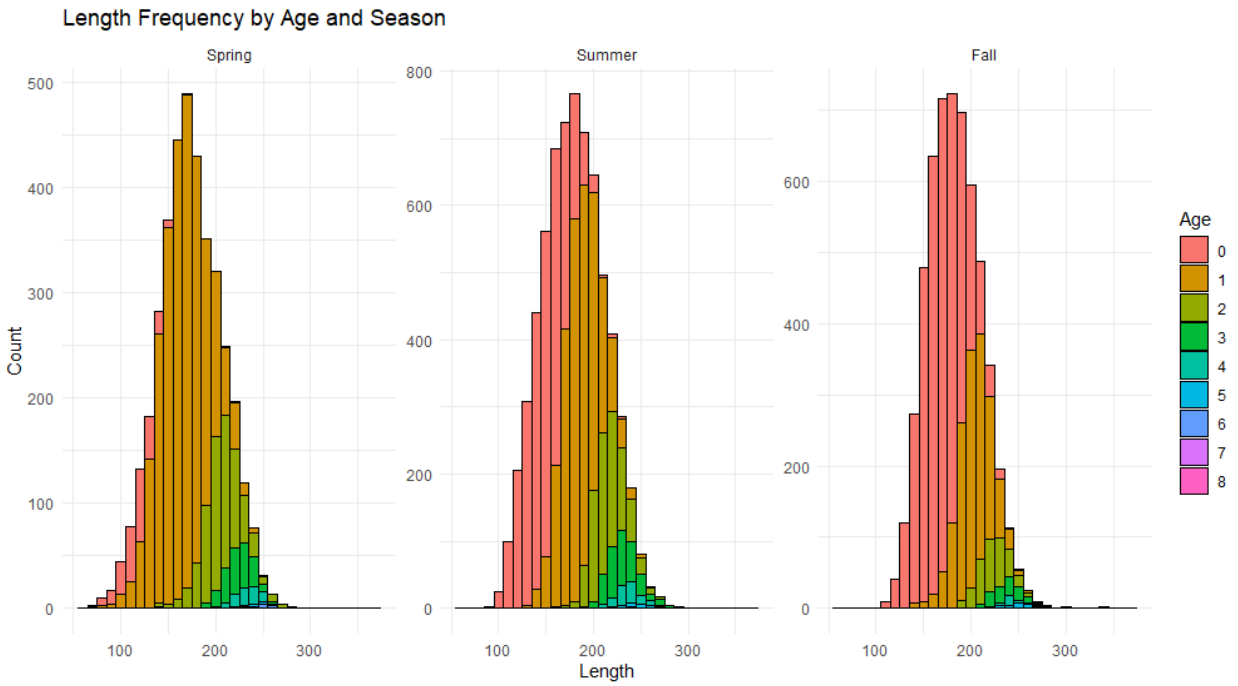


Figure 78. Paired age-length frequency of Atlantic croaker captured in the SEAMAP Coastal Trawl Survey by season.

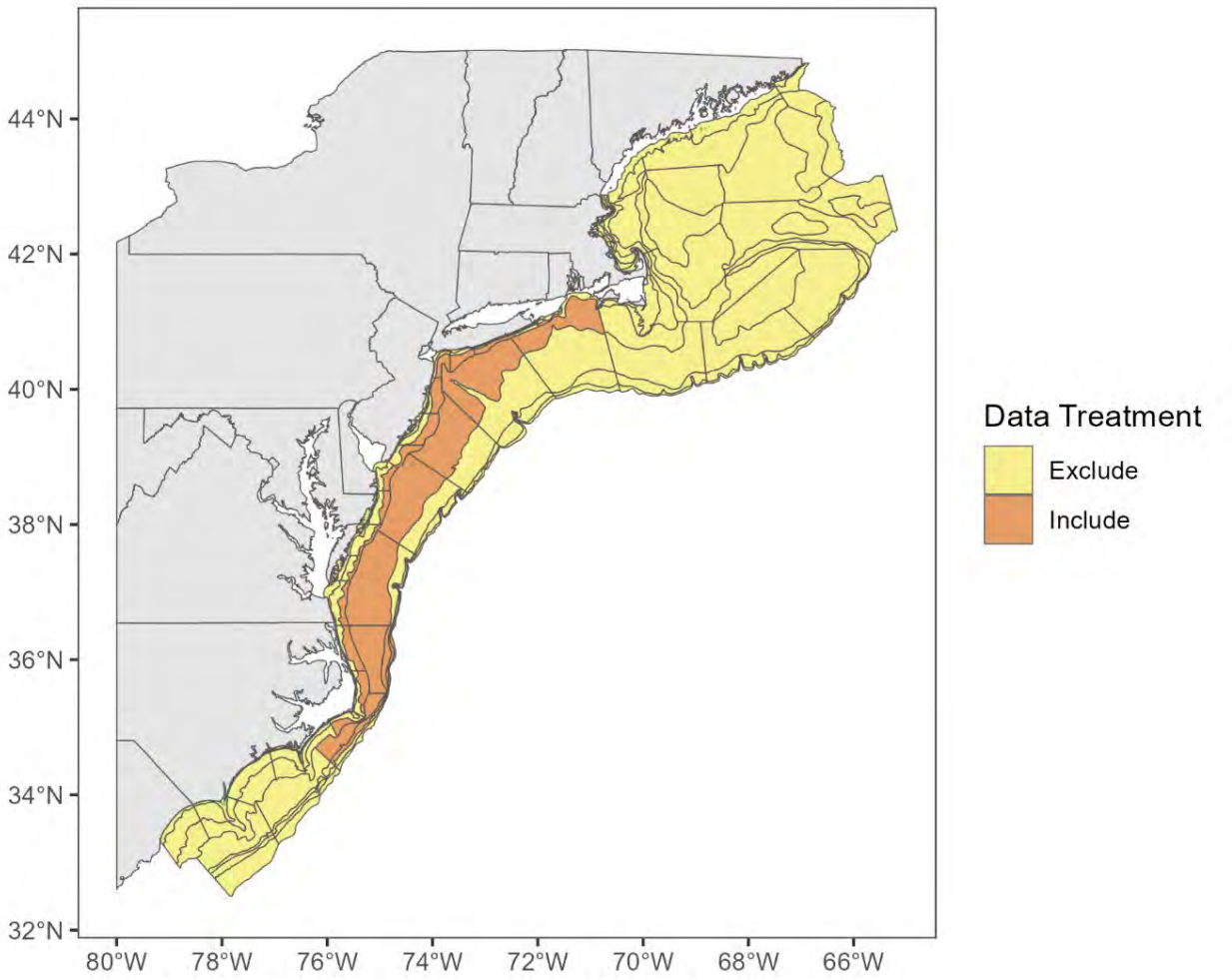


Figure 79. NOAA Fisheries Northeast Fisheries Science Center bottom trawl survey footprint (colored region) and strata used for index and length compositions for the assessment model (orange region).

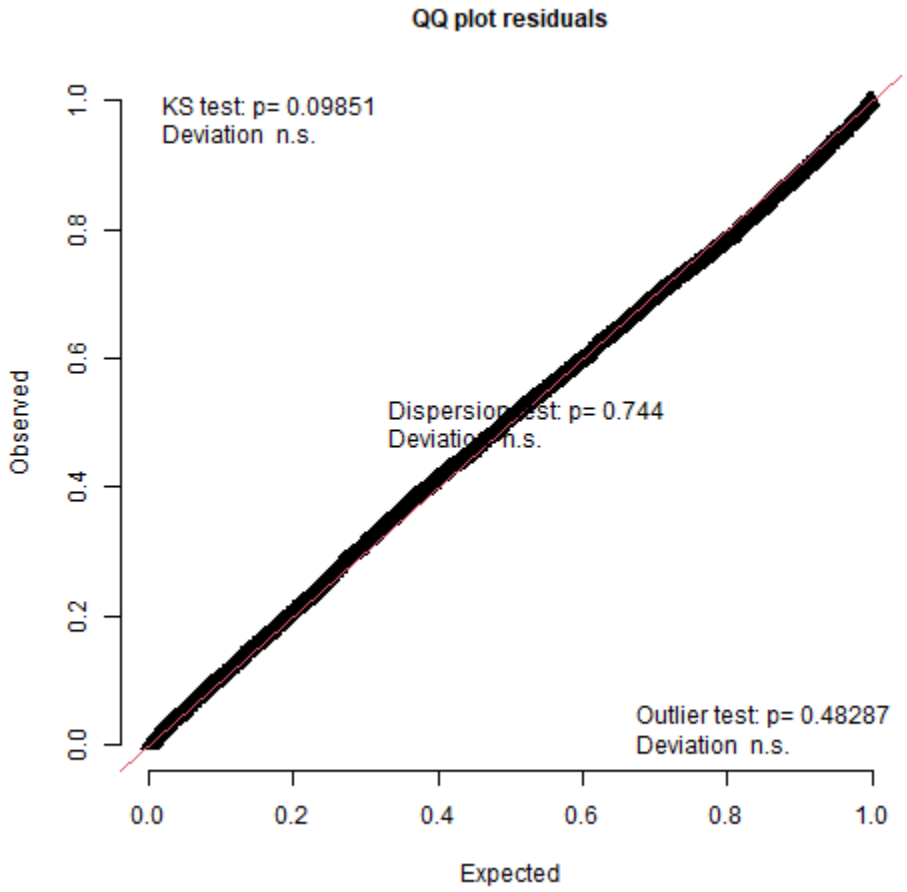


Figure 80. Residual diagnostics for NOAA Fisheries Northeast Fisheries Science Center bottom trawl fall index of Atlantic croaker abundance estimated with VAST.

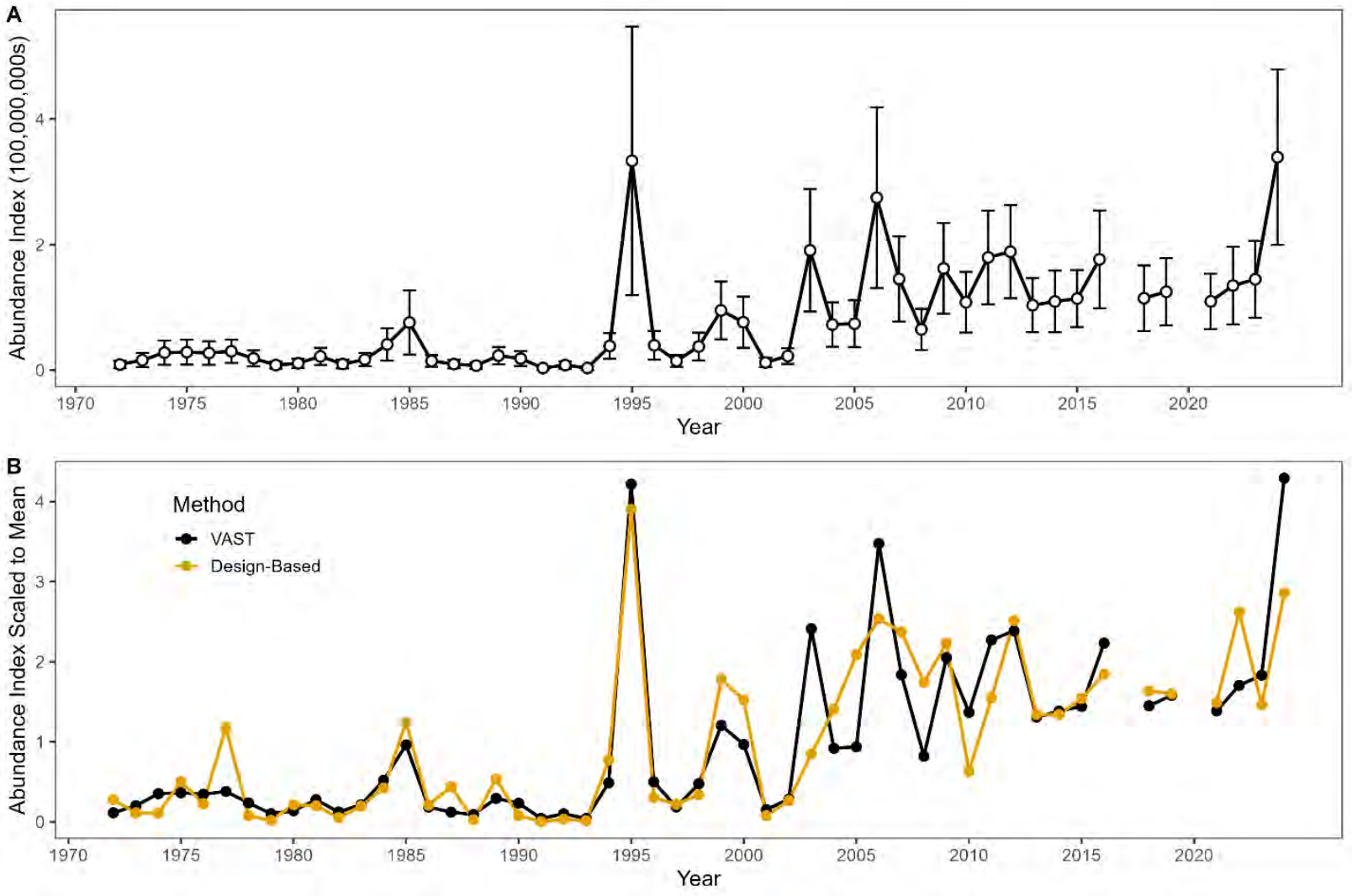


Figure 81. NOAA Fisheries Northeast Fisheries Science Center bottom trawl fall index of Atlantic croaker abundance estimated with VAST (A) with error bars representing ±1.96 standard errors and (b) compared to the stratified random design-based estimates.

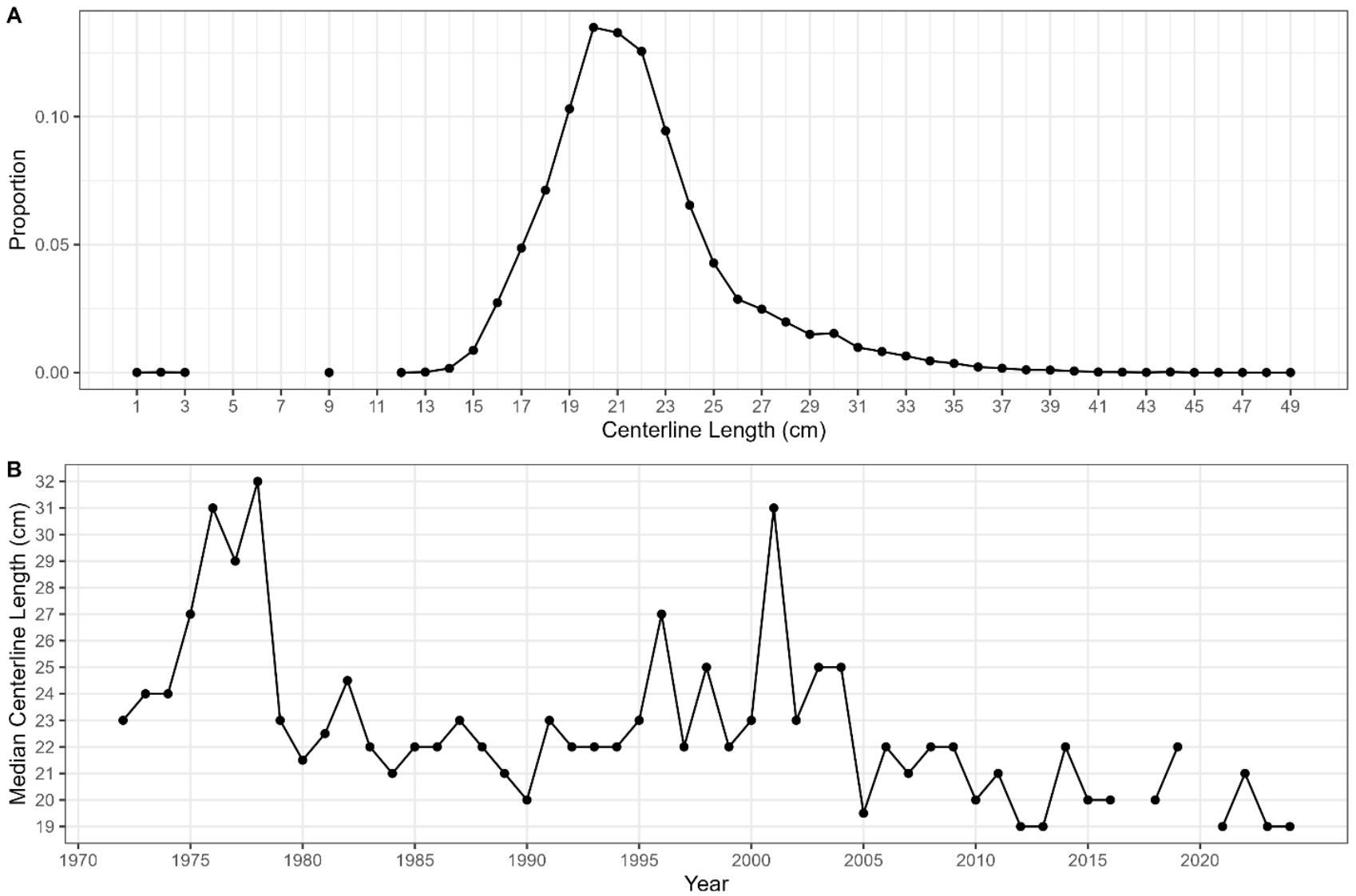


Figure 82. NOAA Fisheries Northeast Fisheries Science Center bottom trawl fall Atlantic croaker (A) length composition aggregated across years and (B) annual median length.

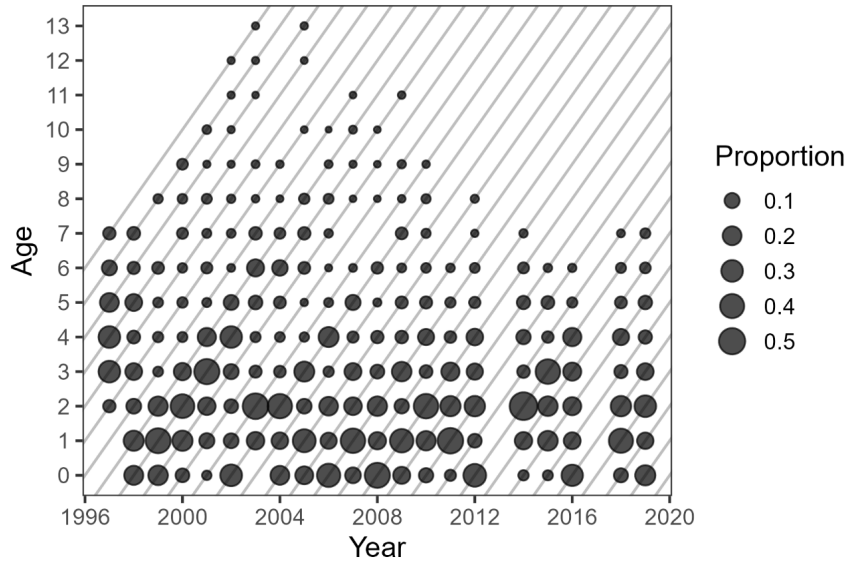


Figure 83. NOAA Fisheries Northeast Fisheries Science Center bottom trawl fall Atlantic croaker age sample proportions. Proportions sum to one each year and annual sample sizes are provided in Table 33. Diagonal grey lines track year classes.

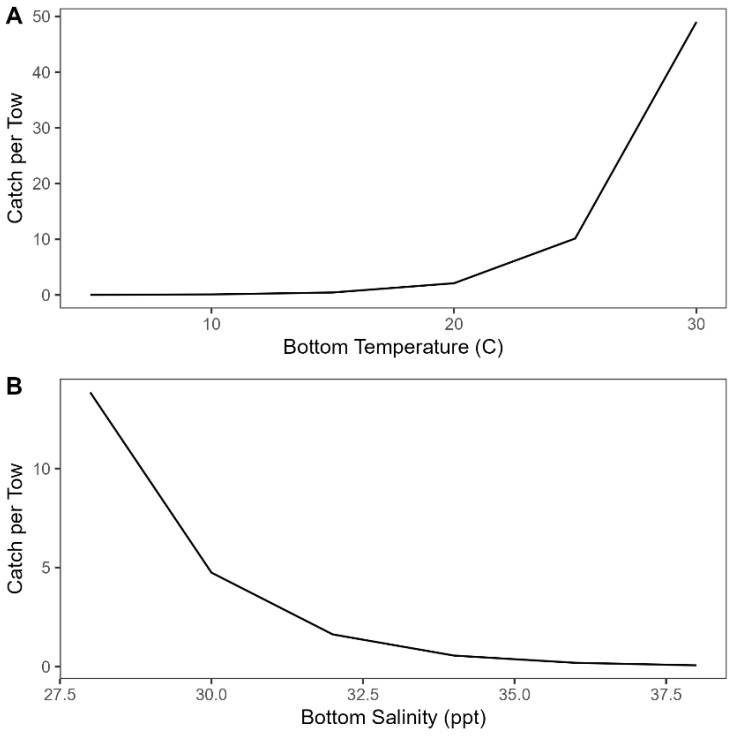


Figure 84. Environmental effects estimated for the NOAA Fisheries Northeast Fisheries Science Center bottom trawl fall catch rates of Atlantic croaker. Effects are conditional on fixed values for other effects in the model.

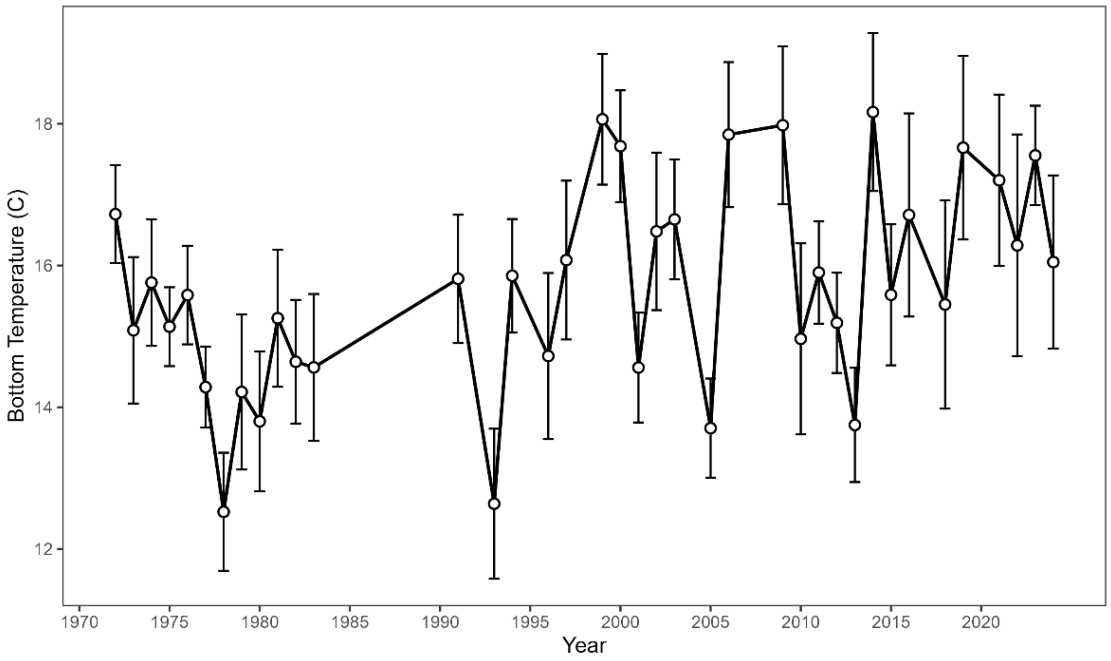


Figure 85. NOAA Fisheries Northeast Fisheries Science Center bottom trawl fall index of bottom water temperature. Error bars represent ±1.96 standard errors.

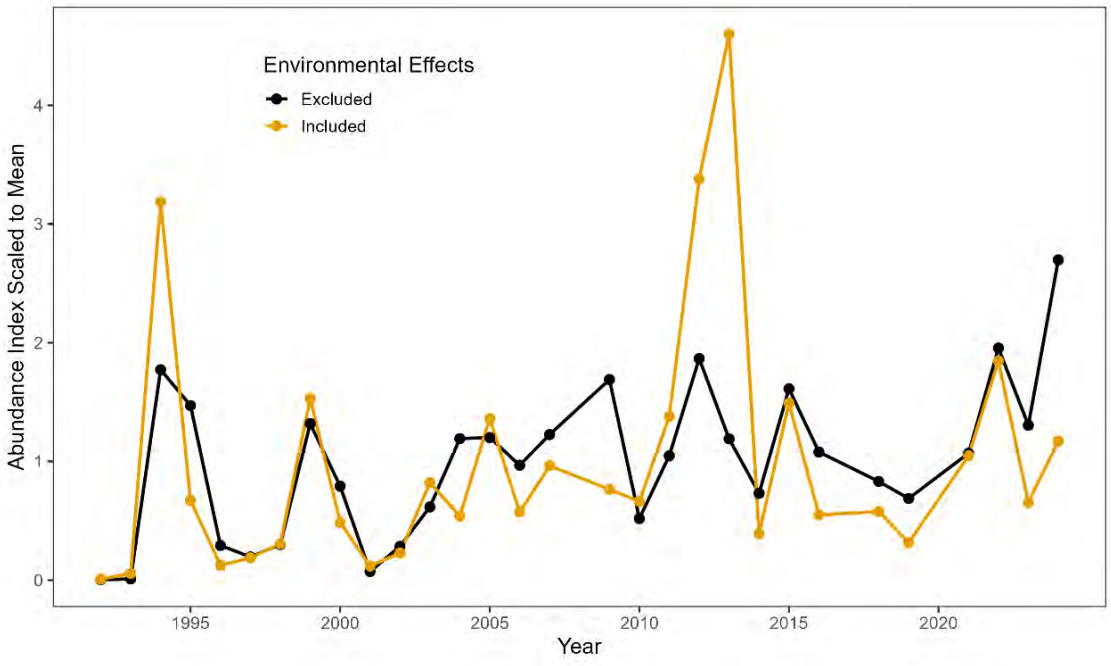


Figure 86. NOAA Fisheries Northeast Fisheries Science Center bottom trawl fall indices estimated from zero-inflated GLMs with and without environmental effects (bottom temperature and salinity).

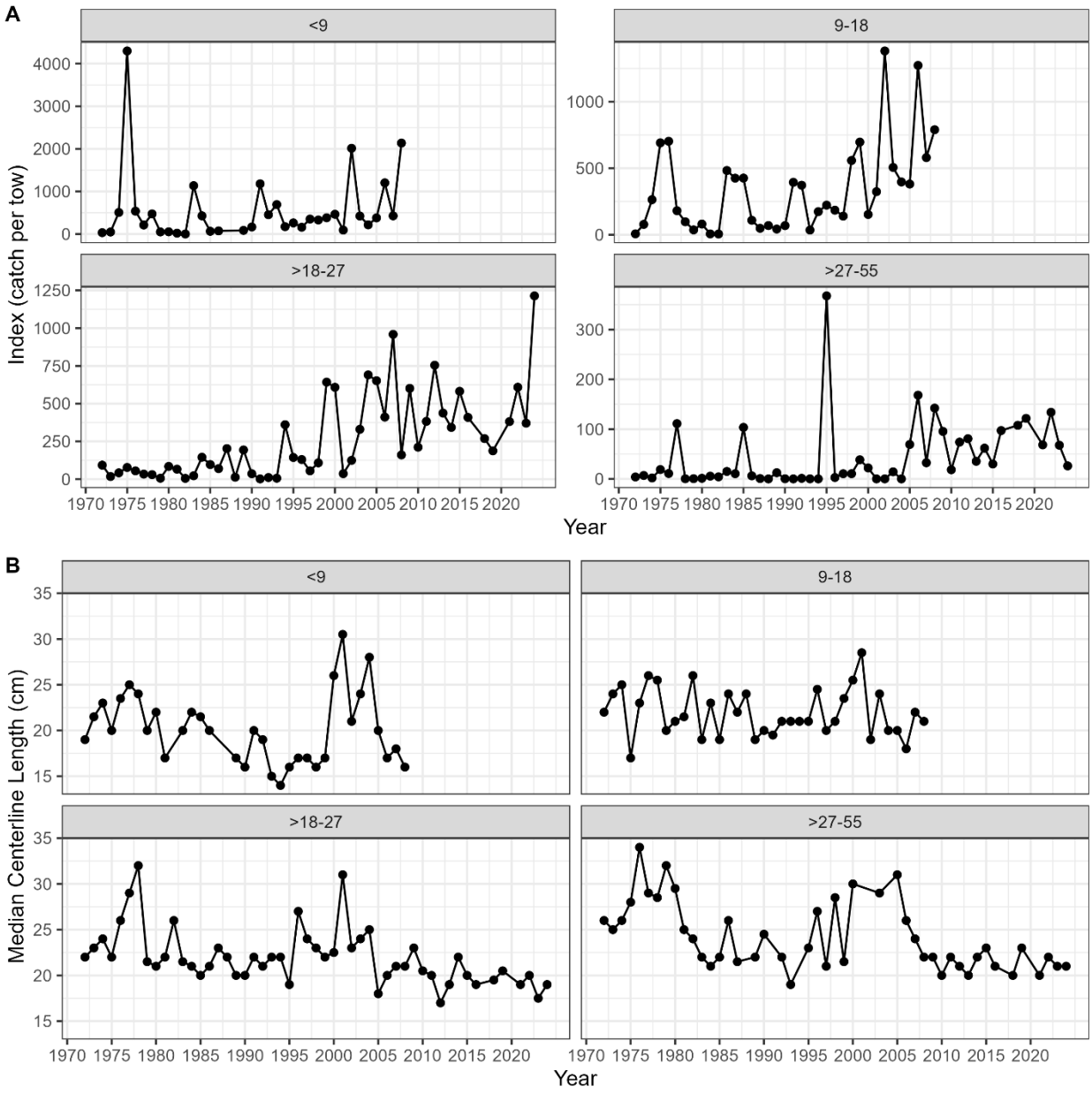


Figure 87. NOAA Fisheries Northeast Fisheries Science Center bottom trawl fall depth strata-specific (A) index of Atlantic croaker abundance estimated with stratified random design-based estimators and (B) median length of the catch. Depths are in meters.

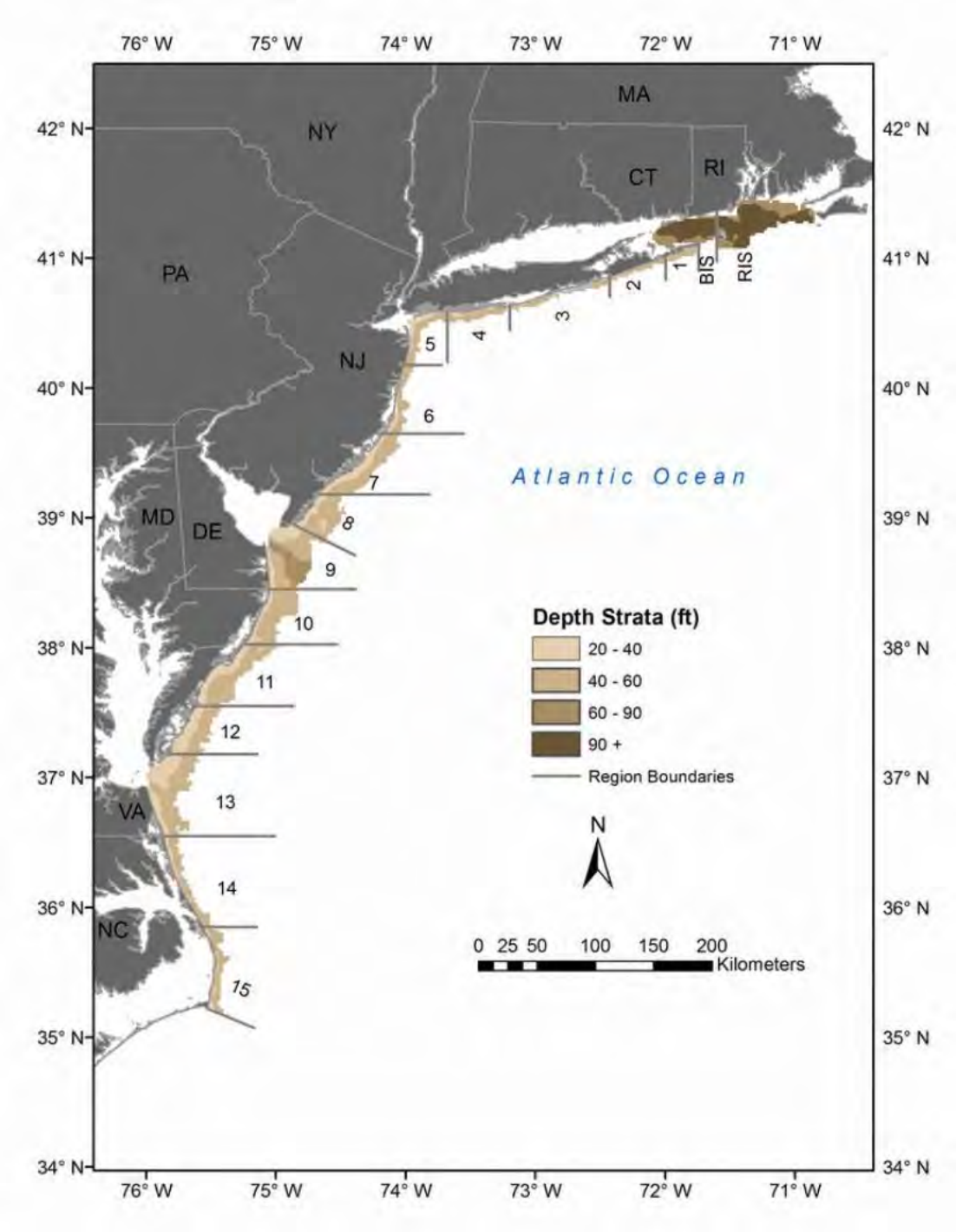


Figure 88. Spatial and depth strata for NEAMAP survey

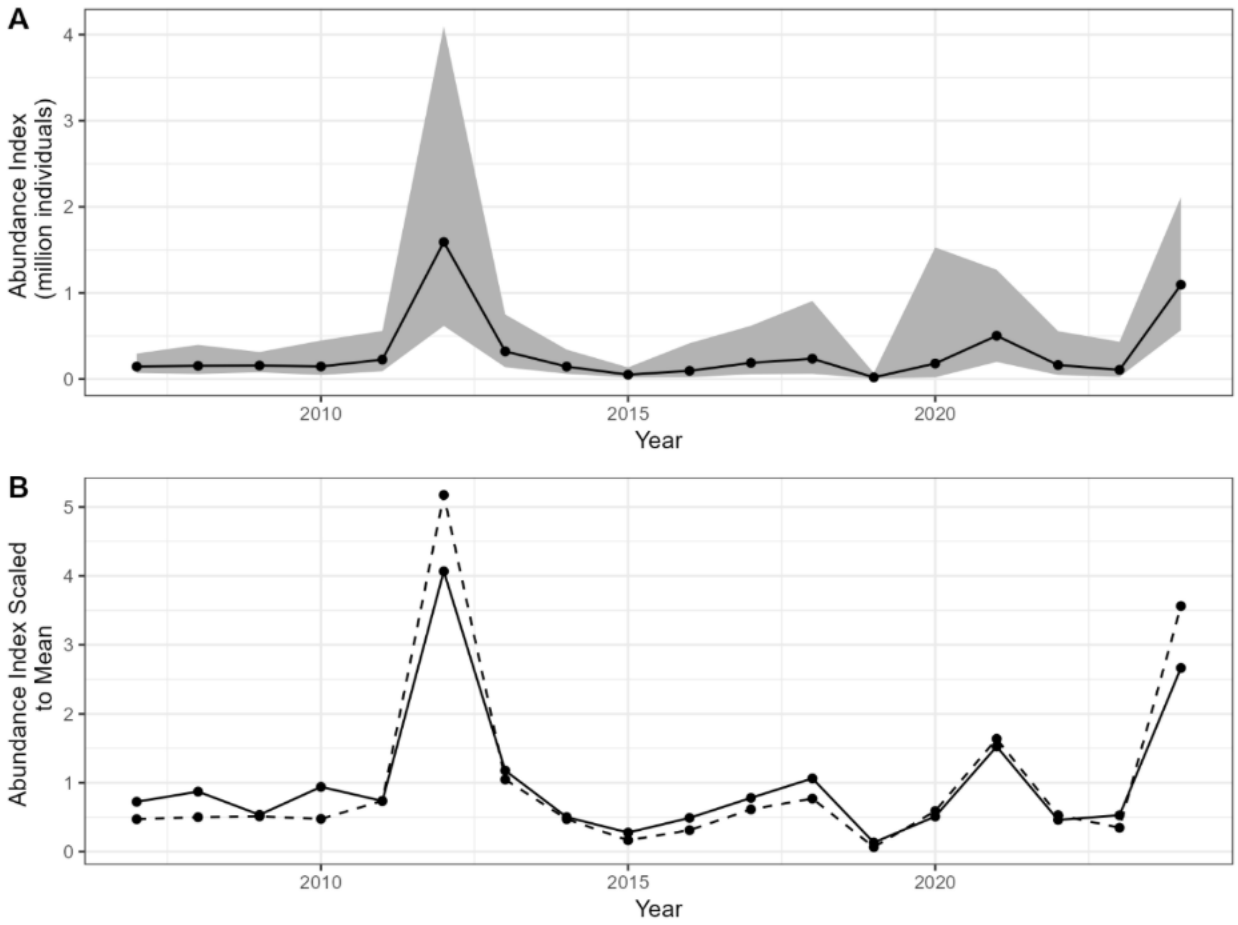


Figure 89. NEAMAP fall index of Atlantic croaker abundance estimated with sdmTMB (A) and (b) compared to the nominal index. Shaded region in (A) represents 95% confidence intervals.

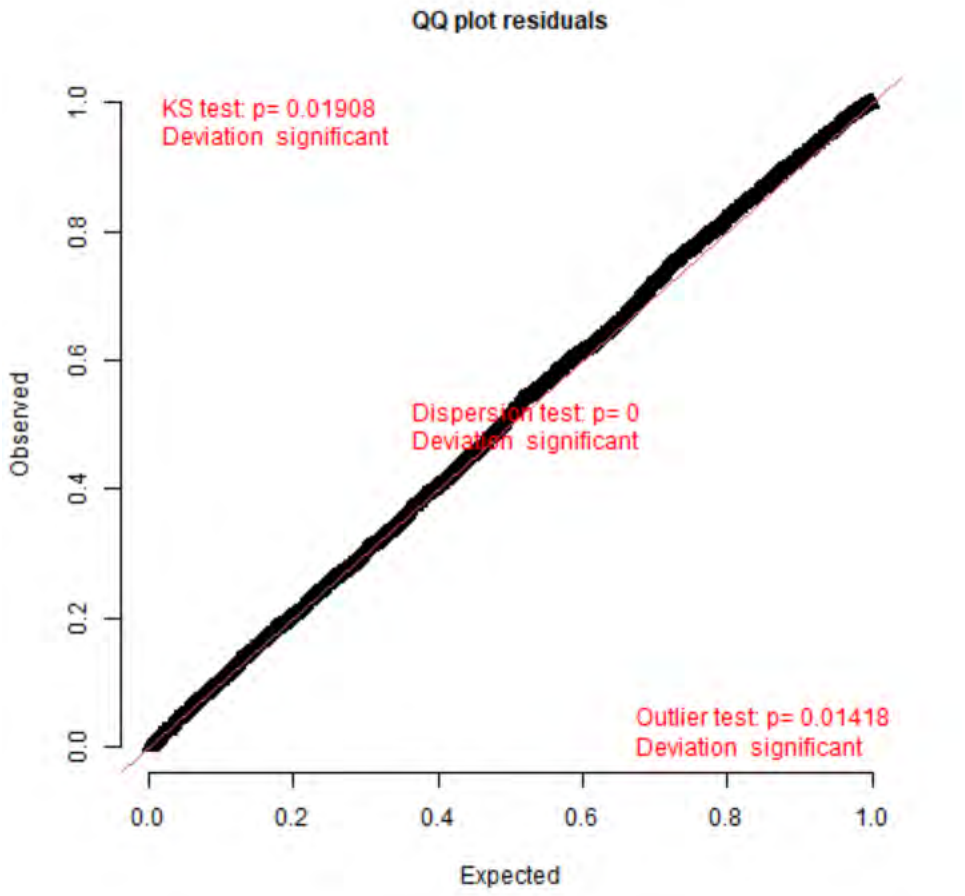


Figure 90. Residual diagnostics for NEAMAP fall index of Atlantic croaker abundance estimated with sdmTMB.

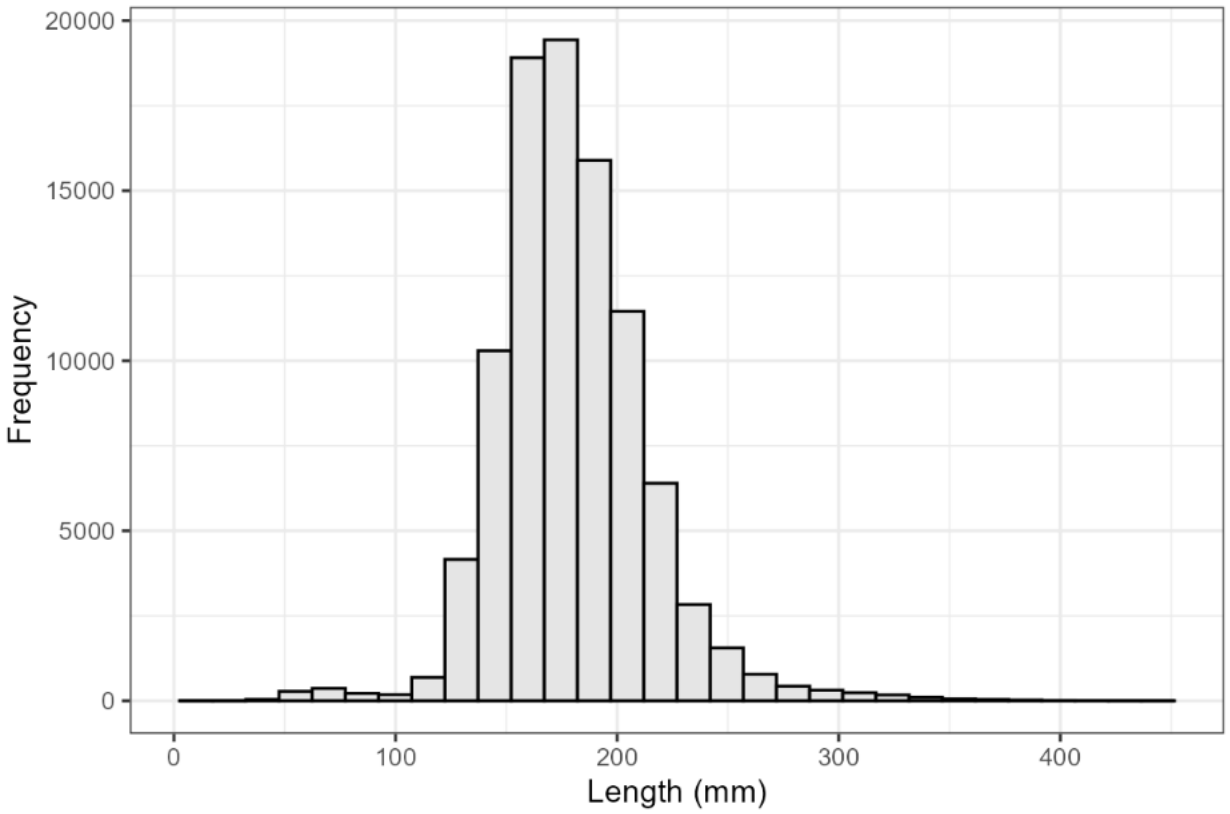


Figure 91. Aggregated length composition for fall NEAMAP survey.

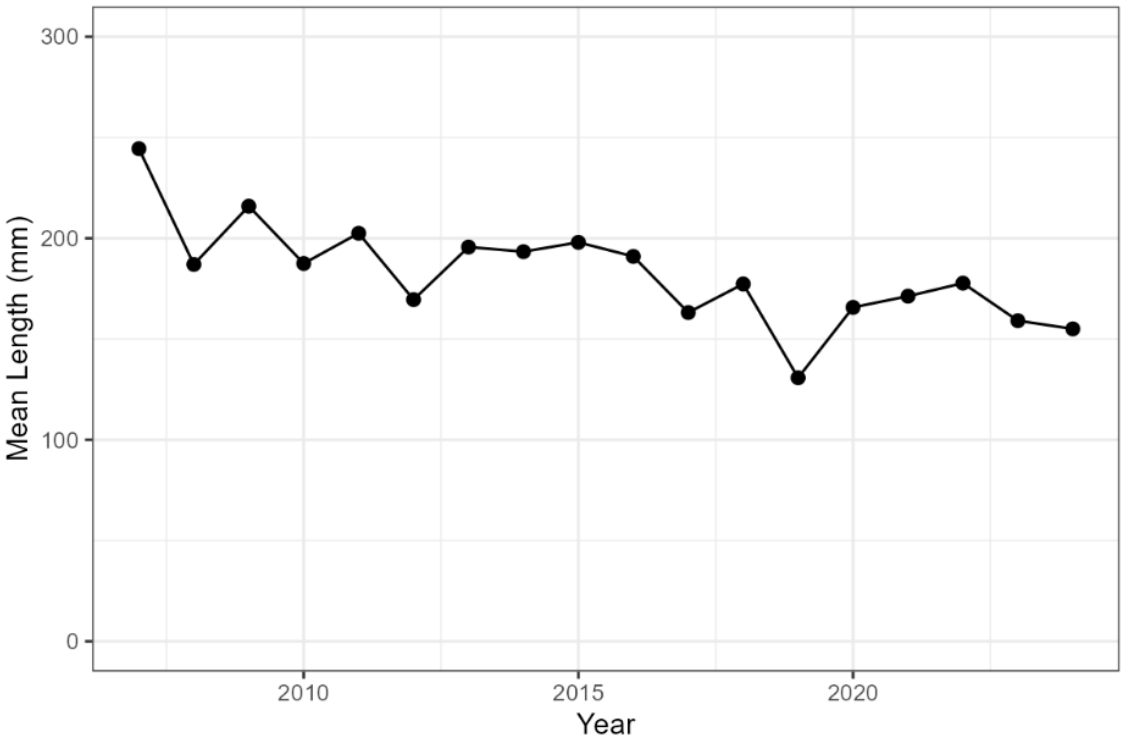


Figure 92. Mean length of Atlantic croaker for fall NEAMAP survey.

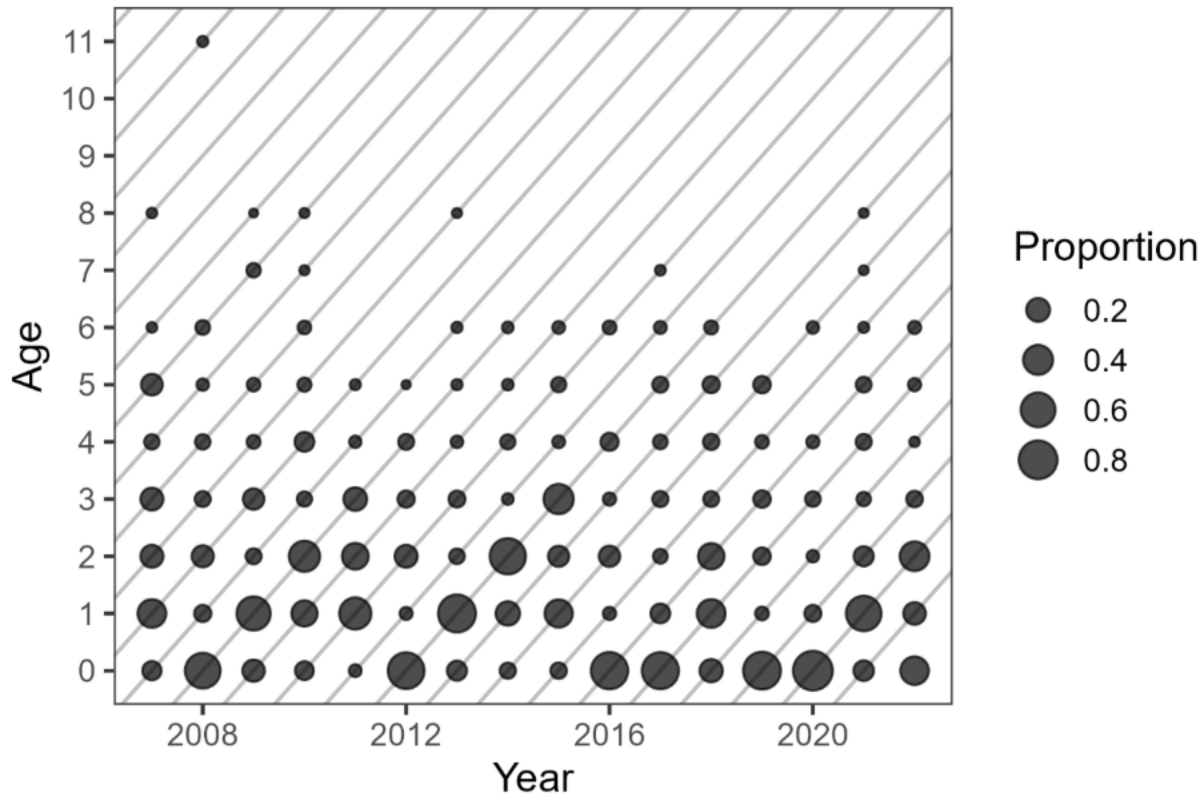


Figure 93. NEAMAP fall Atlantic croaker age sample proportions. Proportions sum to one each year and annual sample sizes are provided in Table 34. Diagonal grey lines track year classes.

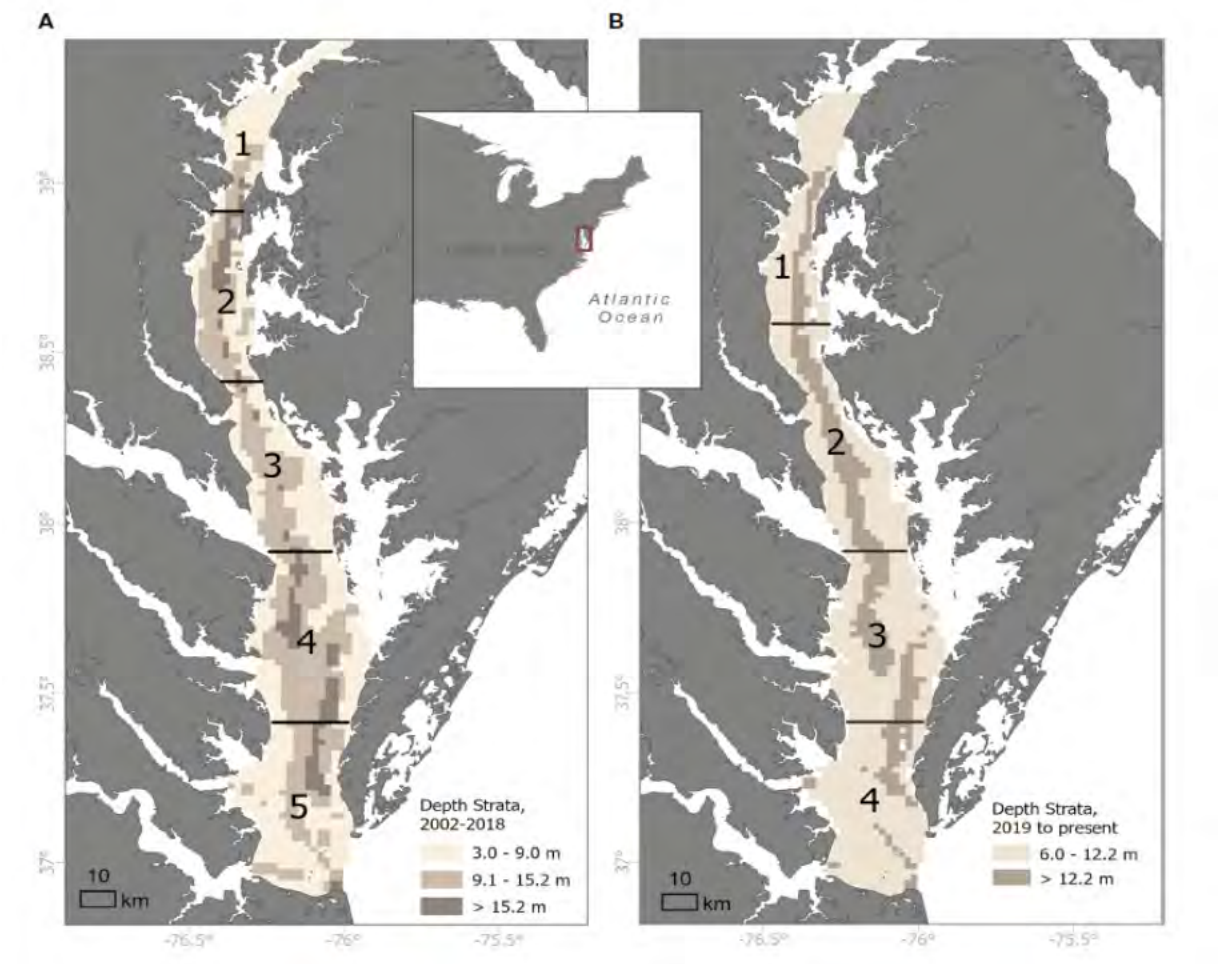


Figure 94. Spatial and depth strata for ChesMMAP survey during 2002-2018 (left) and from 2018 to present (right).

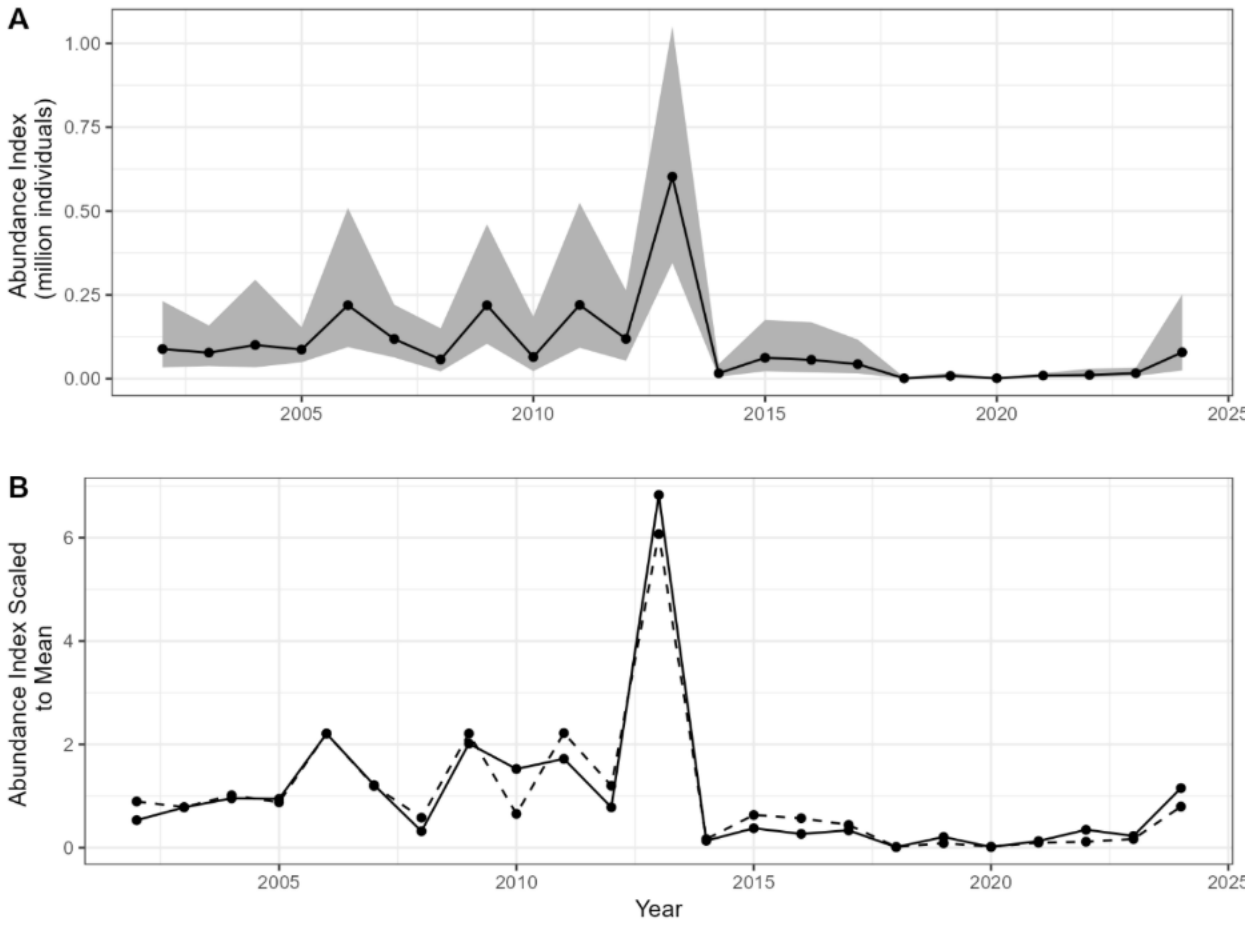


Figure 95. ChesMMAP summer index of Atlantic croaker abundance estimated with sdmTMB (A) and (B) compared to the nominal index. Shaded region in (A) represents 95% confidence intervals.

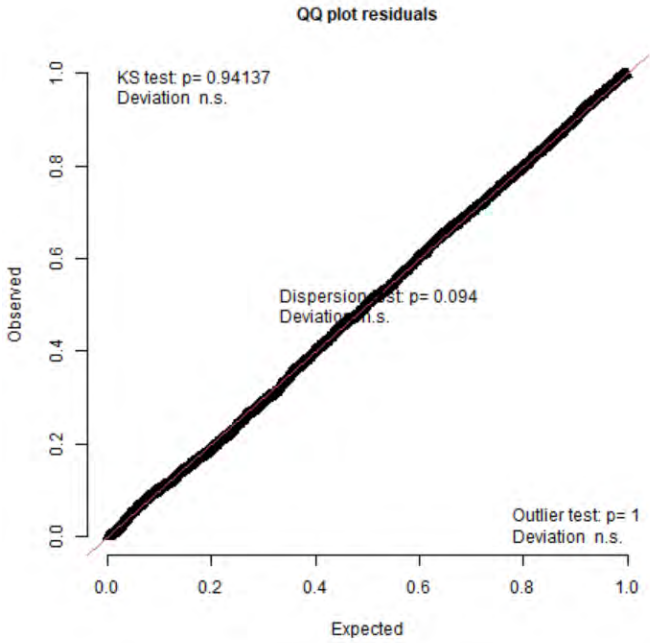


Figure 96. Residual diagnostics for ChesMMAP summer index of Atlantic croaker abundance estimated with sdmTMB.

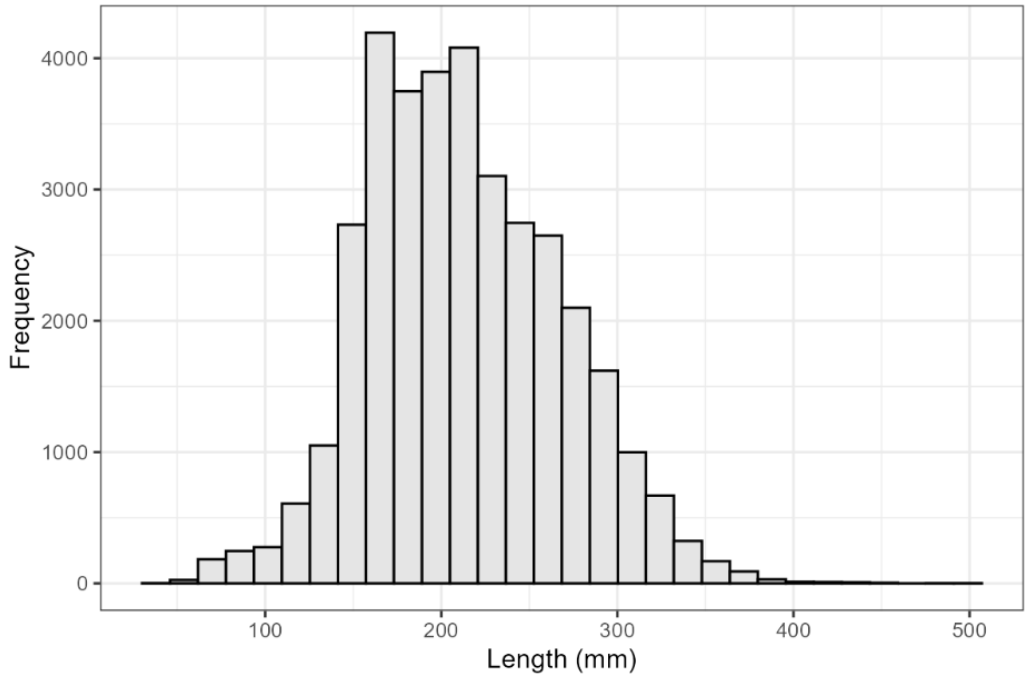


Figure 97. Aggregated length composition for summer ChesMMAP survey.

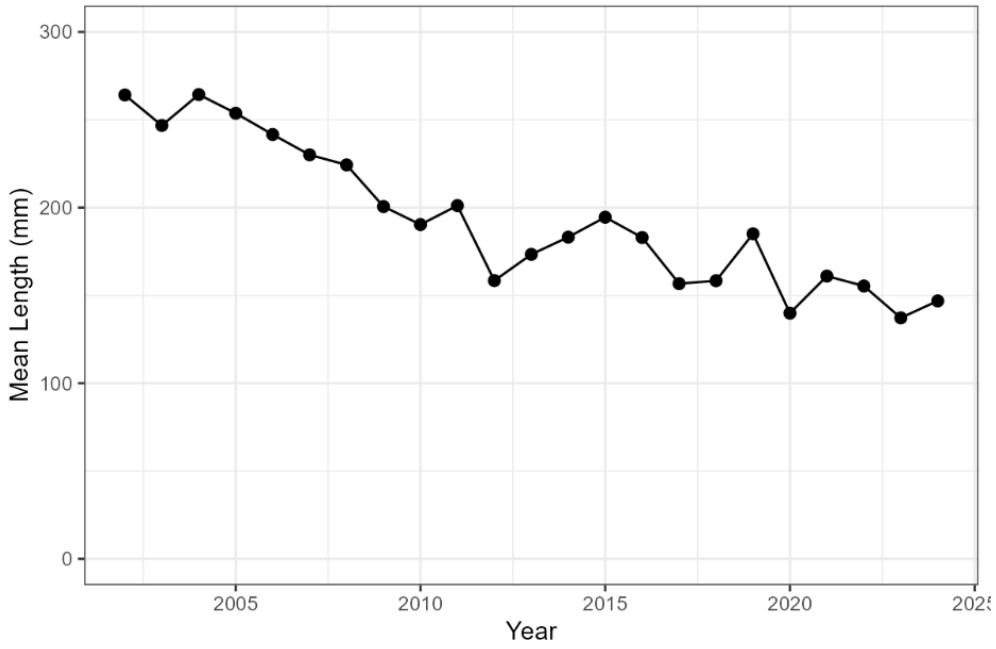


Figure 98. Mean length of Atlantic croaker for summer ChesMMAP survey.

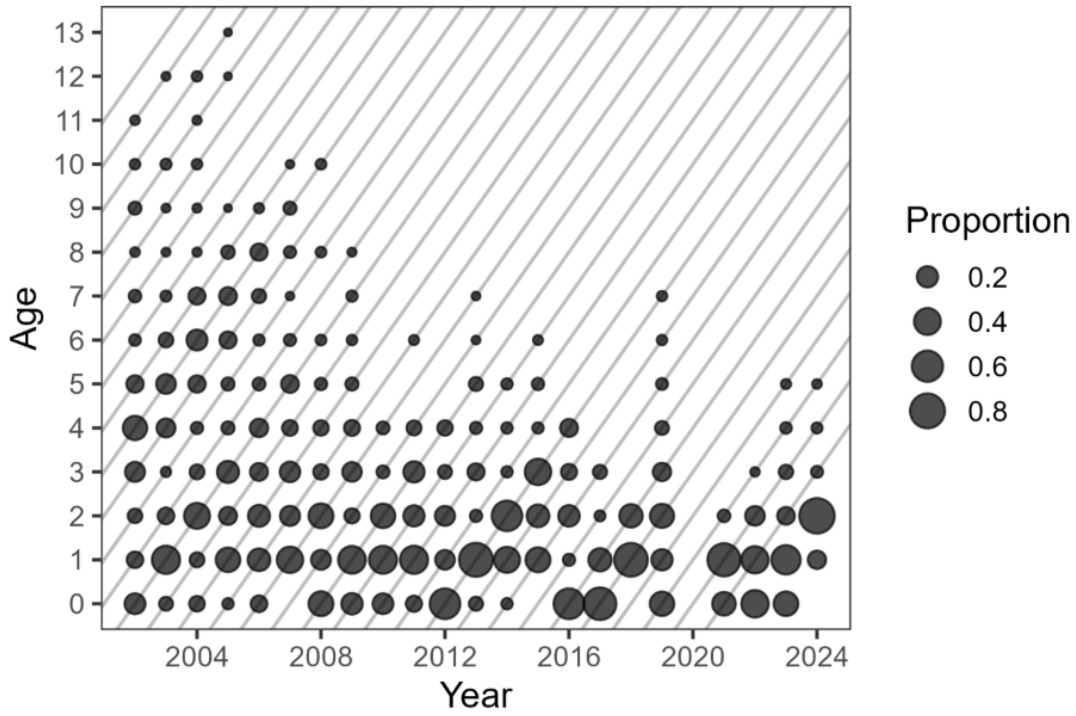


Figure 99. ChesMMAP summer Atlantic croaker age sample proportions. Proportions sum to one each year and annual sample sizes are provided in Table 35. Diagonal grey lines track year classes.

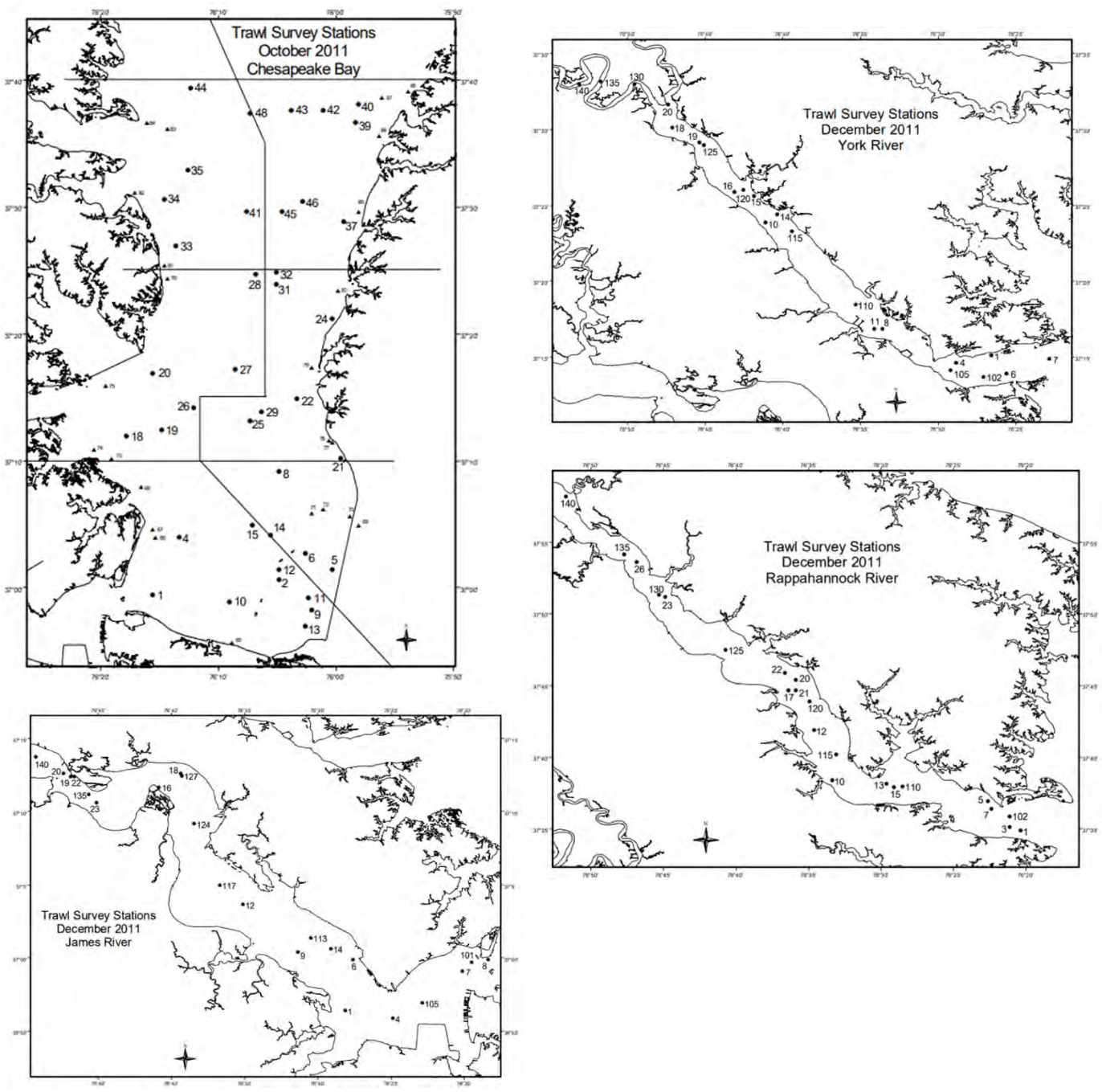


Figure 100. Maps of the Virginia Institute of Marine Science (VIMS) Juvenile Trawl Survey sampling sites.

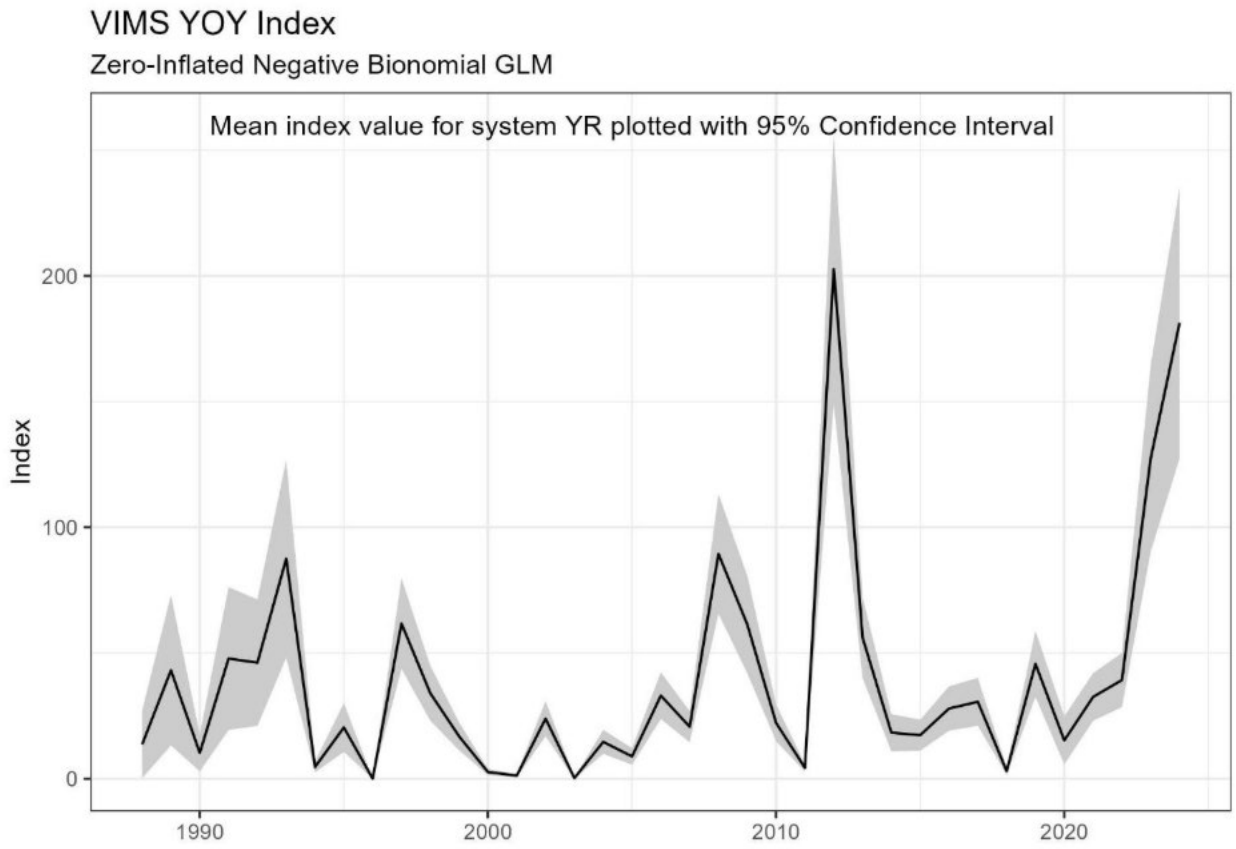


Figure 101. Standardized index of age-0 abundance from the VIMS Juvenile Trawl Survey.

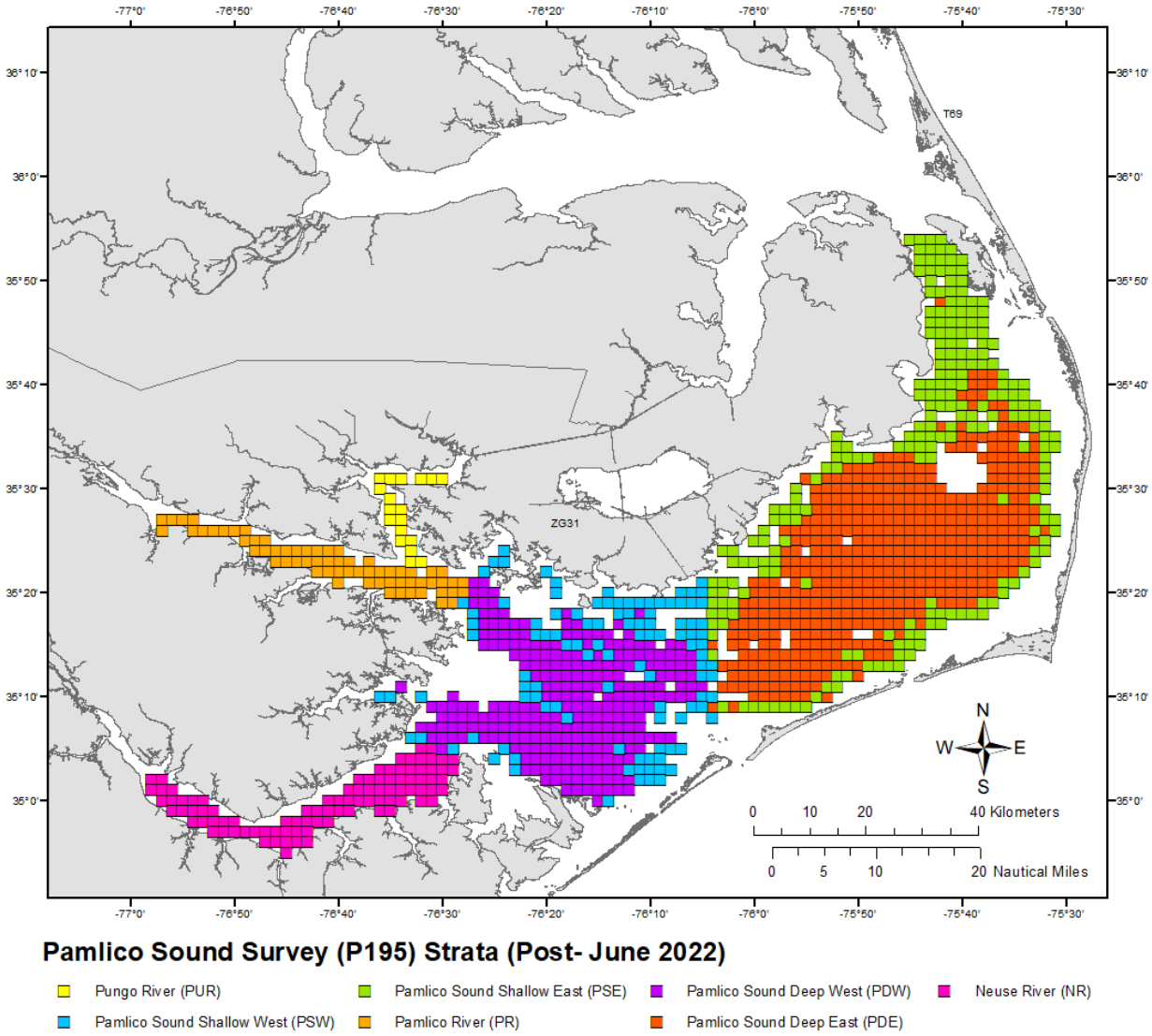


Figure 102. Locations and grids of Pamlico Sound Survey area of eastern North Carolina, September 2022 – present.

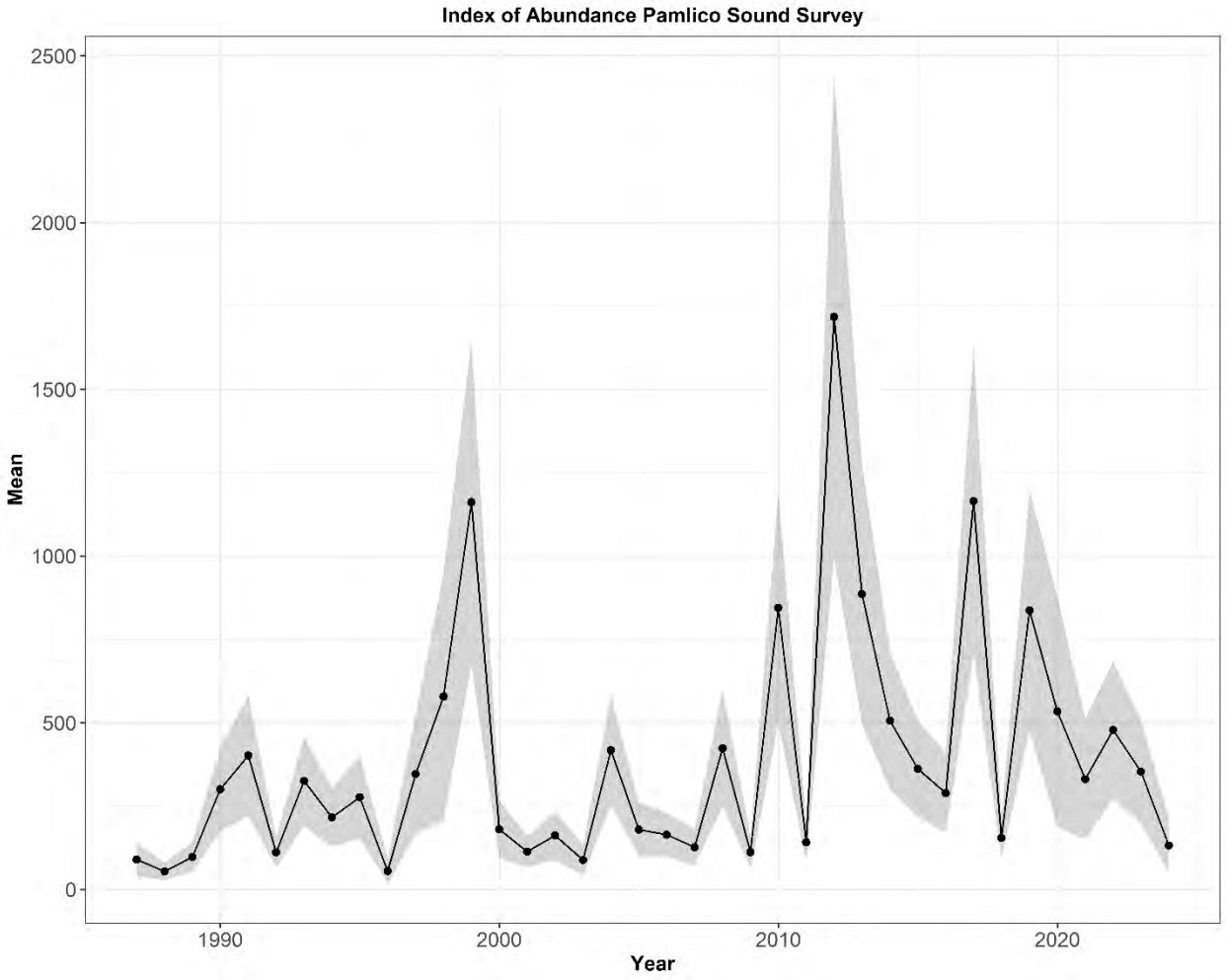


Figure 103. Negative binomial index of abundance for the P195 survey from 1987-2024.

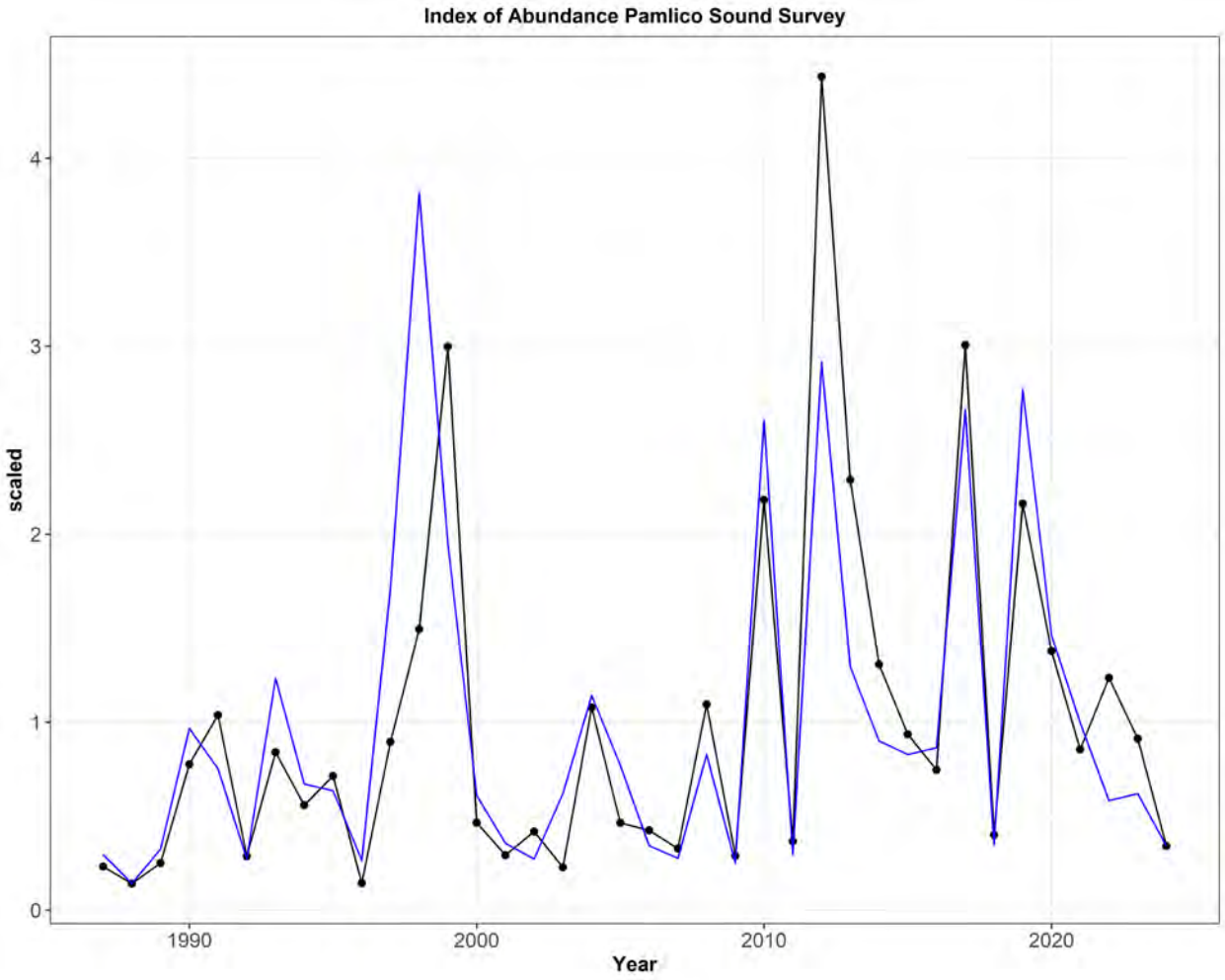


Figure 104. Comparison of the negative binomial index of abundance (black) and the nominal means (blue) from 1987-2024.

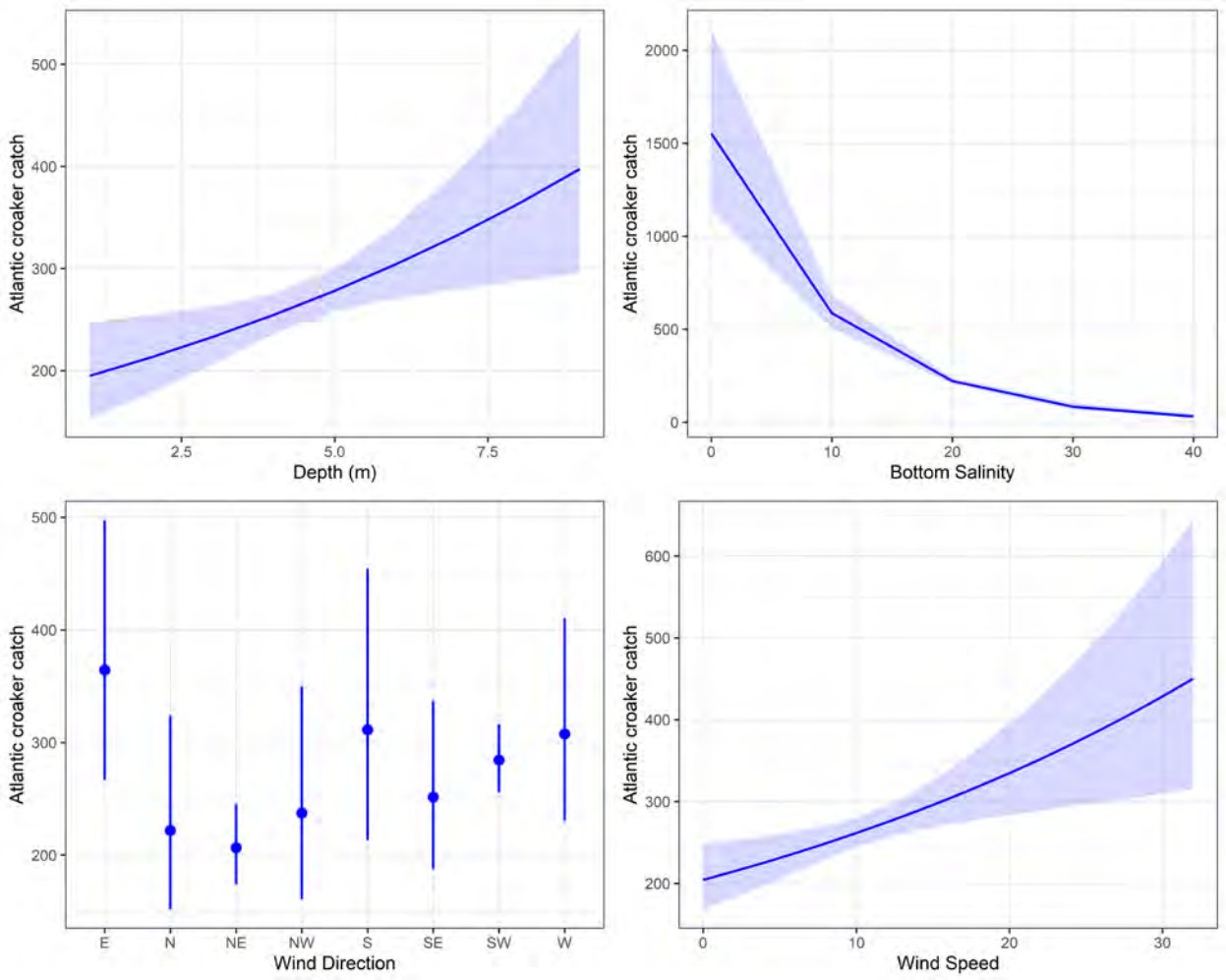


Figure 105. Environmental explanatory variables used in the negative binomial to estimate P195 YOY croaker catch.

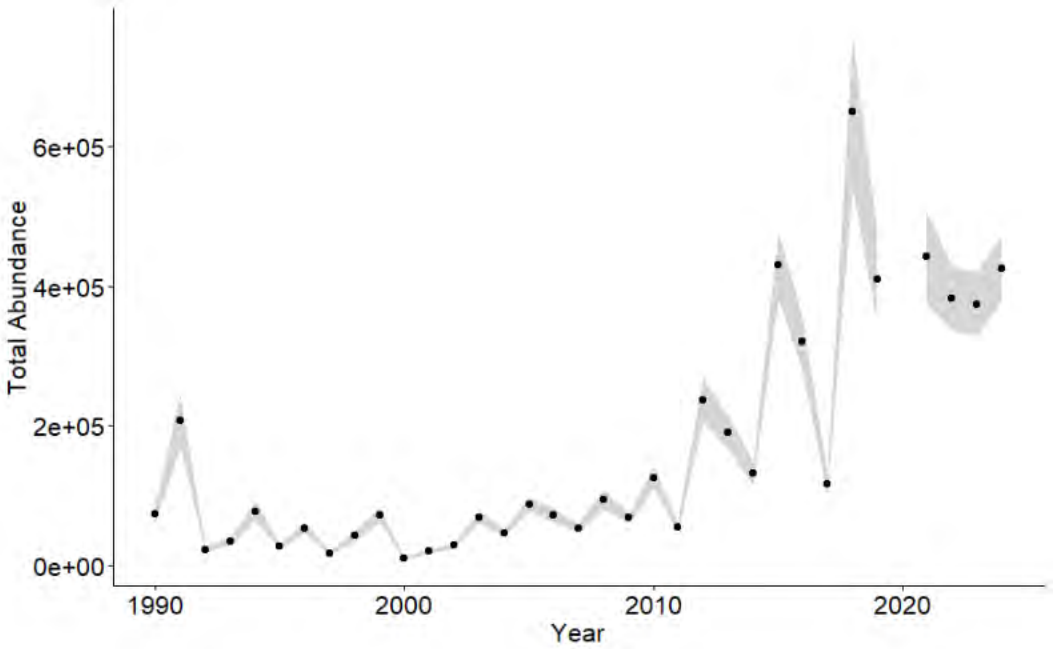


Figure 106. Estimated total abundance for Atlantic croaker from SEAMAP-SA Coastal Trawl Survey from 1990-2024 for the Fall sampling season.

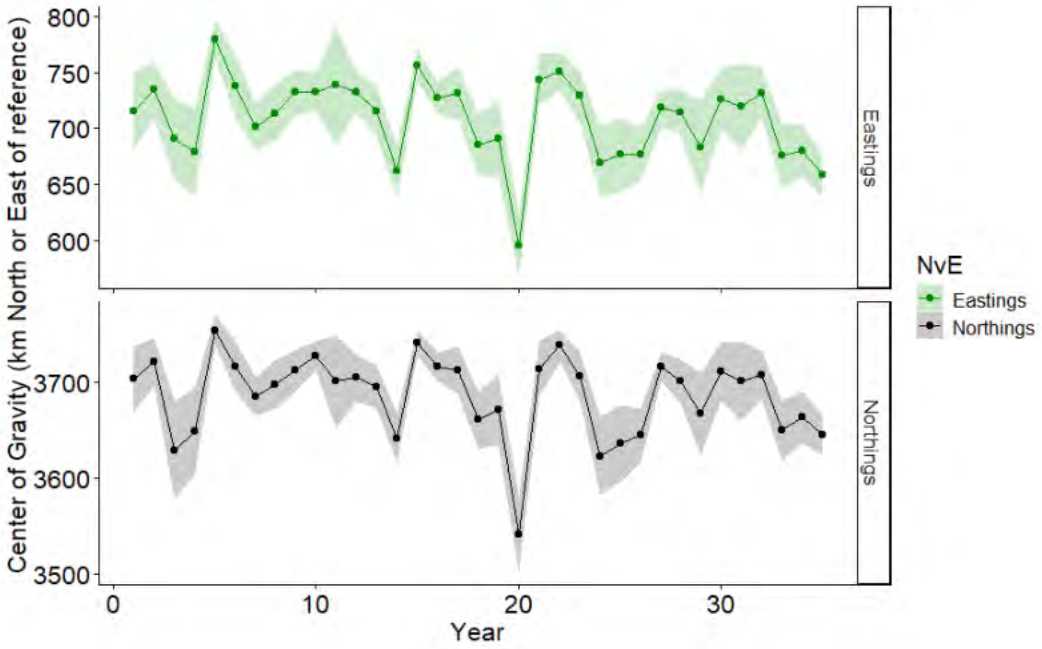


Figure 107. Center of Gravity for Atlantic croaker from the VAST index from the SEAMAP survey fall sampling from 1990-2024.

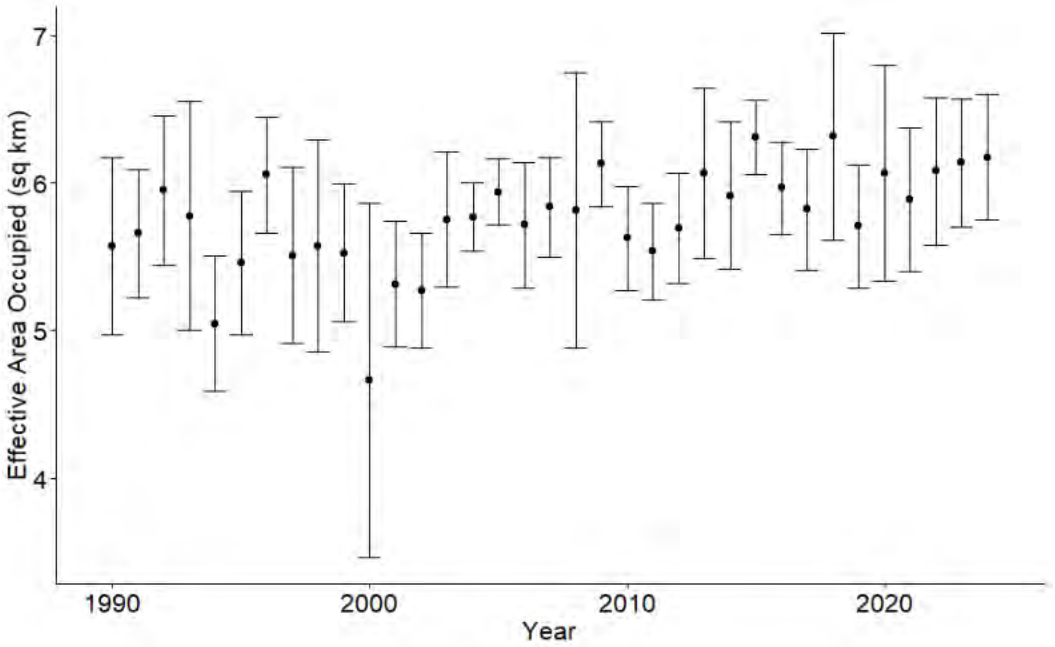


Figure 108. Effective area occupied for Atlantic croaker from the VAST index from the SEAMAP survey fall sampling from 1990-2024.

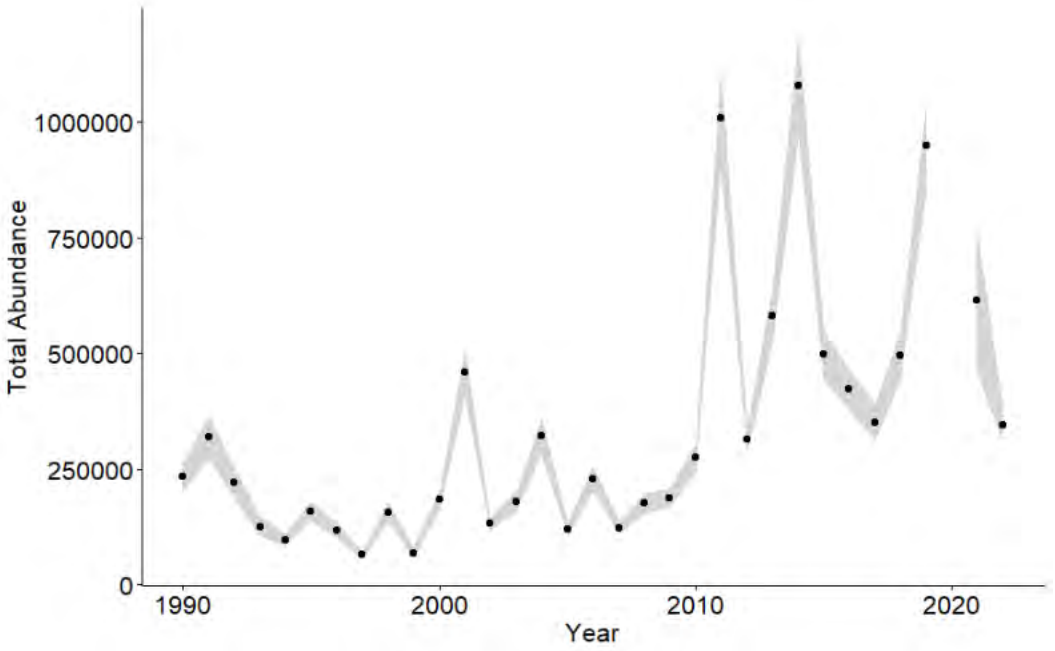


Figure 109. Estimated total abundance for Atlantic croaker from SEAMAP-SA Coastal Trawl Survey from 1990-2022 for the summer sampling season.

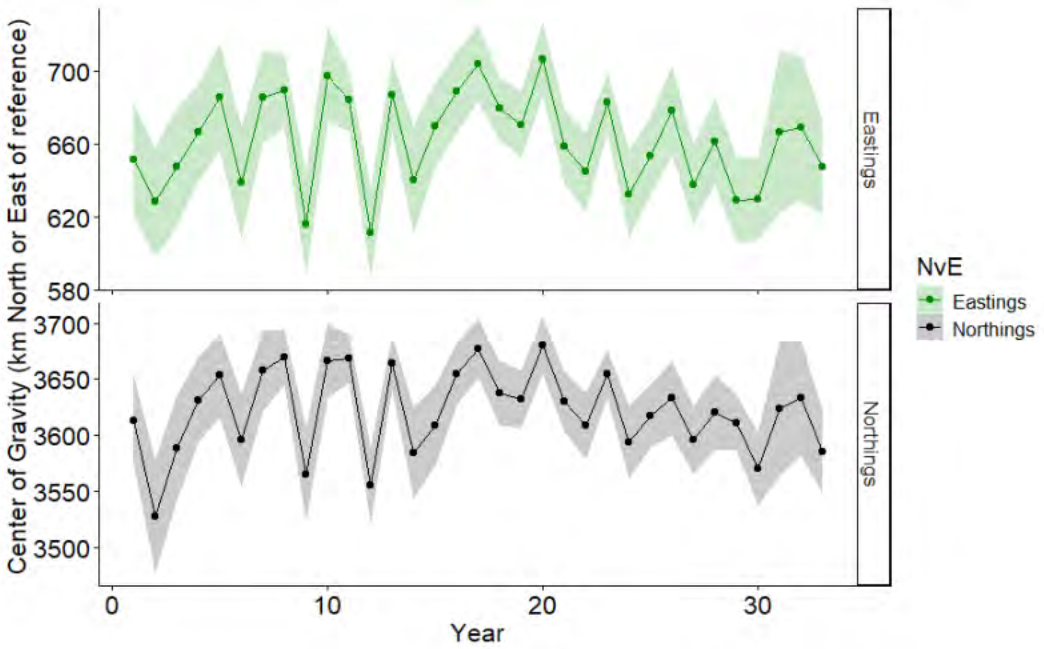


Figure 110. Center of Gravity for Atlantic croaker from the VAST index from the SEAMAP survey summer sampling from 1990-2022.

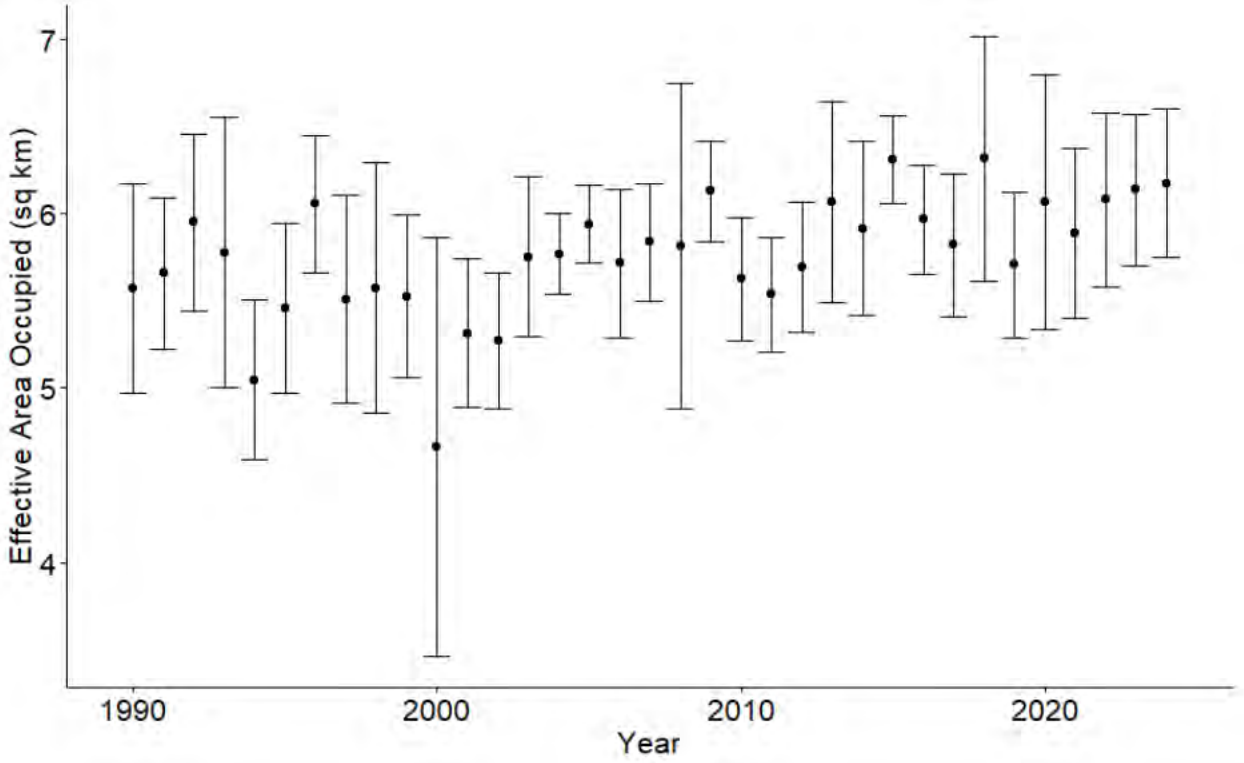


Figure 111. Effective area occupied for Atlantic croaker from the VAST index from the SEAMAP survey summer sampling from 1990-2022.

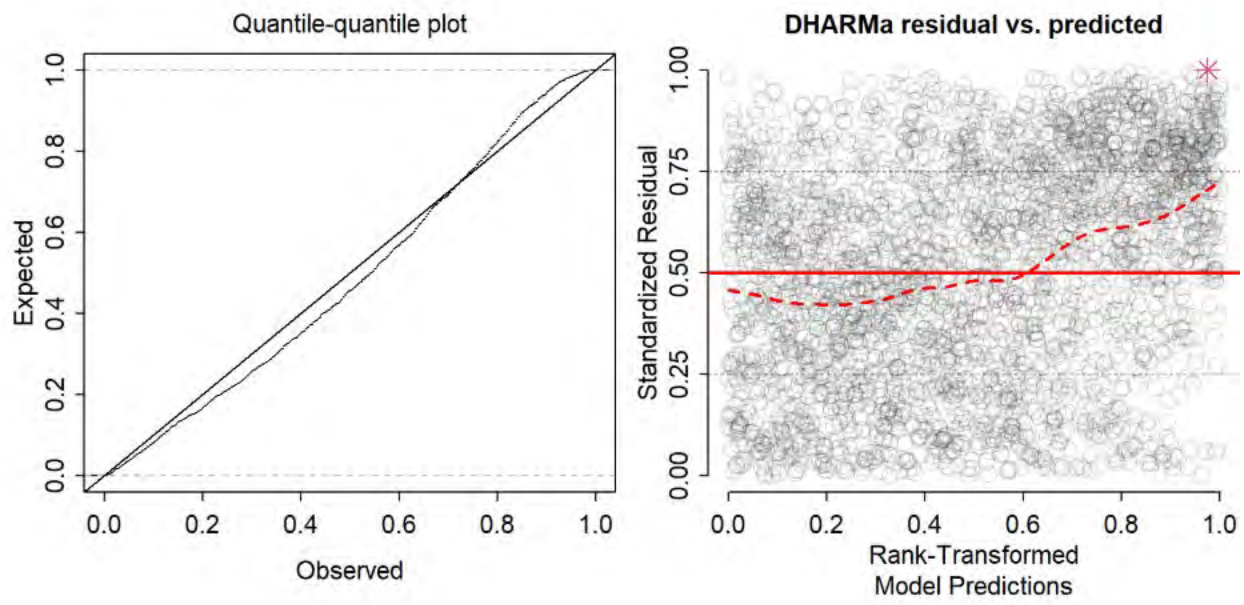


Figure 112. Q-Q plot and Residuals vs. Predicted plot from the VAST model from Fall sampling from the SEAMAP-SA Coastal Trawl Survey.

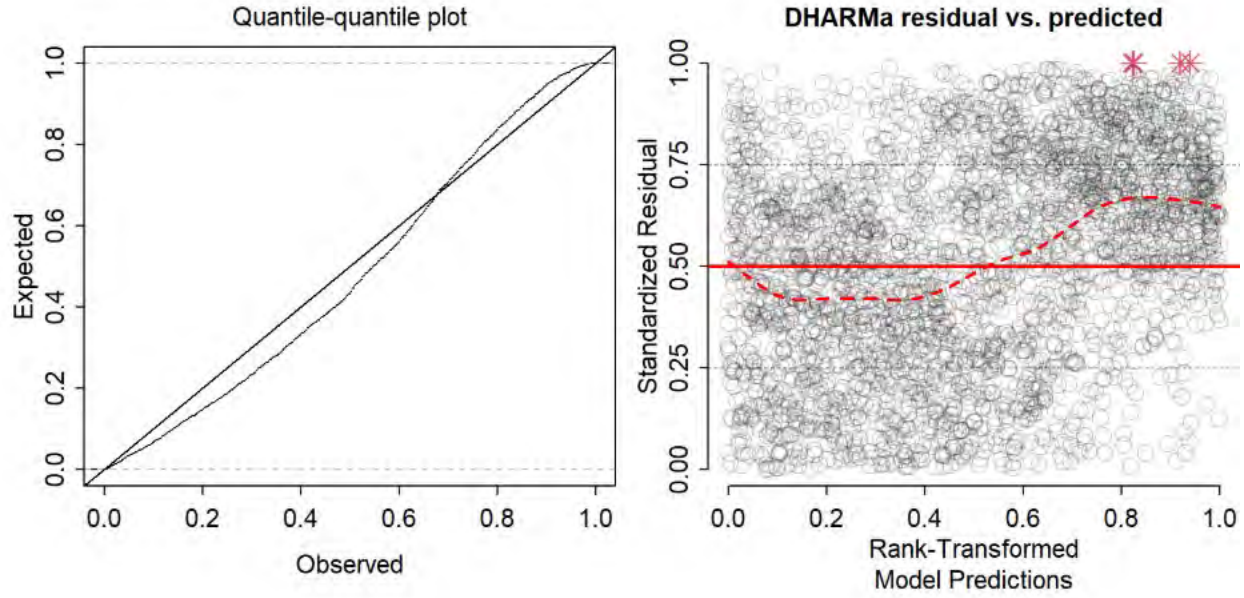


Figure 113. Q-Q plot and Residuals vs. Predicted plot from the VAST model from summer sampling from the SEAMAP-SA Coastal Trawl Survey.

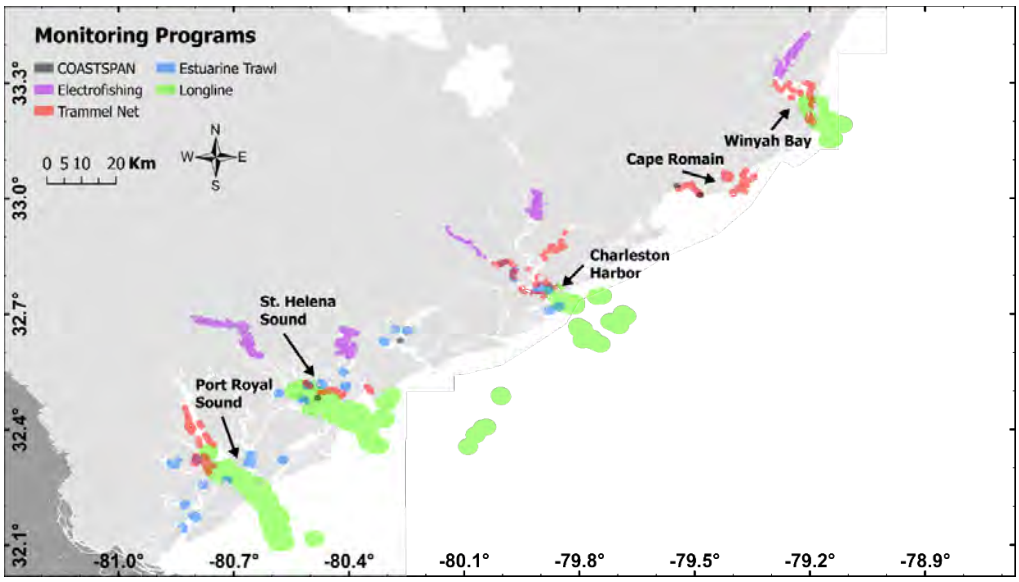


Figure 114. Sampling sites for the SCDNR surveys, including the SCDNR Estuarine Trawl Survey and SCDNR Trammel Net Survey.

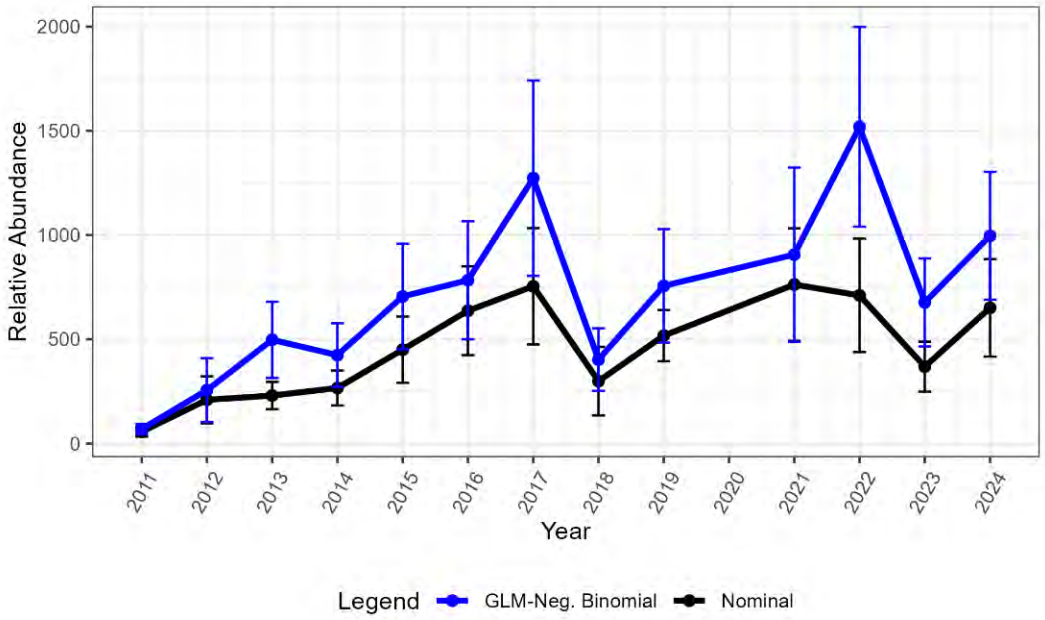


Figure 115. Estimated relative abundance for Atlantic croaker from SC Estuarine Trawl Recruitment Survey from 2011-2024 calculated by geometric mean (nominal=black line) and standardized by GLM with negative binomial error distribution (GLM-Neg. Binomial=blue line). Error bars indicated standard errors.

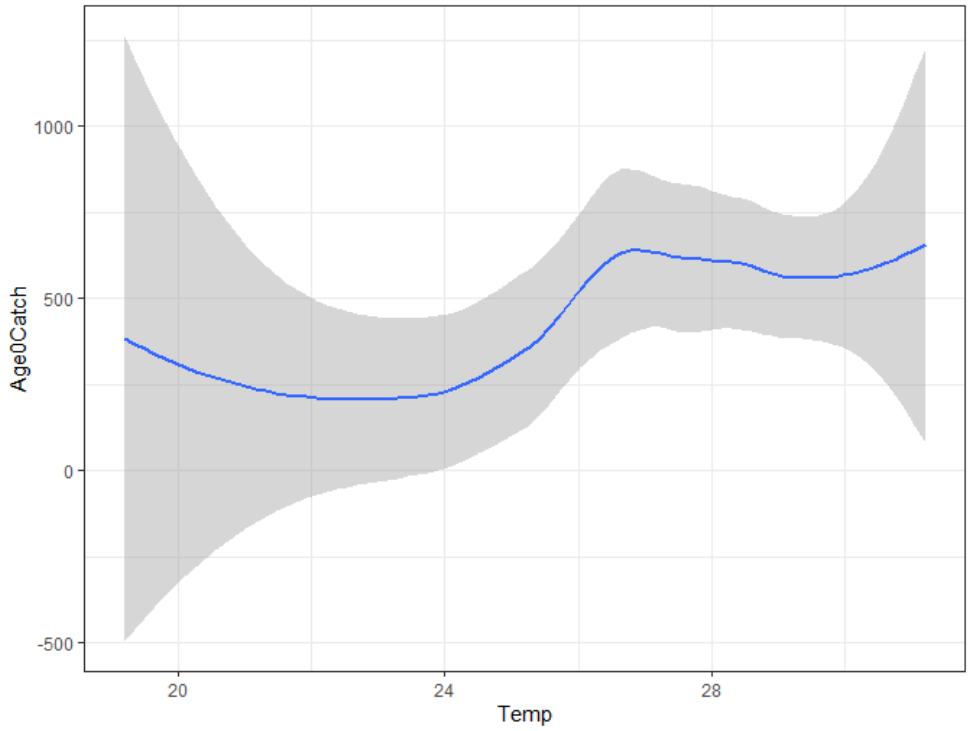


Figure 116. Significant environmental covariate, temperature, relationship to abundance of Atlantic croaker from SC Estuarine Trawl Survey from 2011-2024 standardized by GLM with negative binomial error distribution with glmmTMB R package. Gray shading indicated 95% confidence interval.

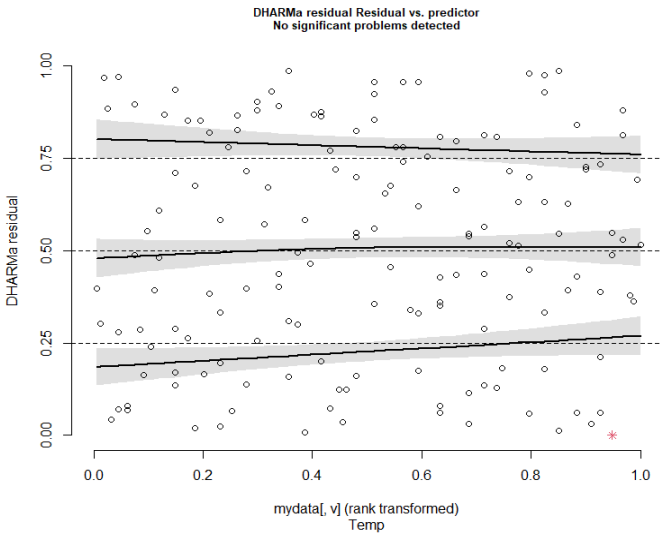


Figure 117. Scaled residuals of the model fit for the standardized SC Estuarine Trawl Survey for Age-0 Atlantic croaker demonstrating residuals against predicted values with an overlaid quantile regression (right; 0.25, 0.5, and 0.75 quantiles).

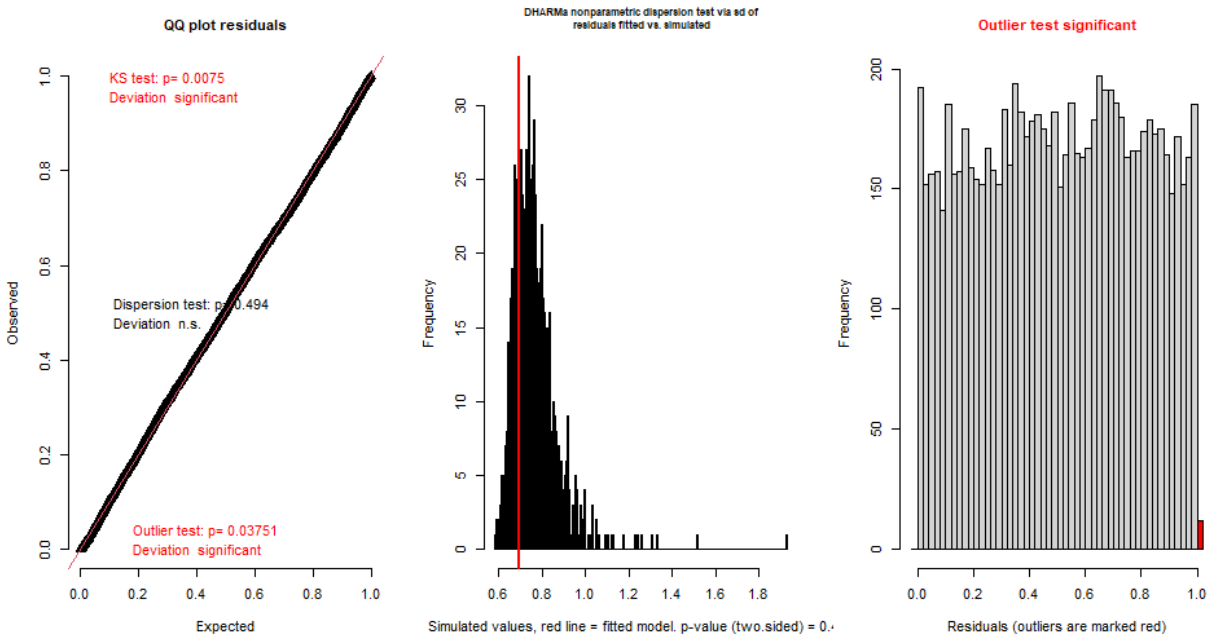


Figure 118. Scaled residuals of the model fit for the standardized SC Estuarine Trawl Survey for Age-0 Atlantic croaker displayed in a qq-plot to detect overall deviations in the distribution (left) and in a residual plot demonstrating residuals against predicted values with an overlaid quantile regression (right; 0.25, 0.5, and 0.75 quantiles in black lines).

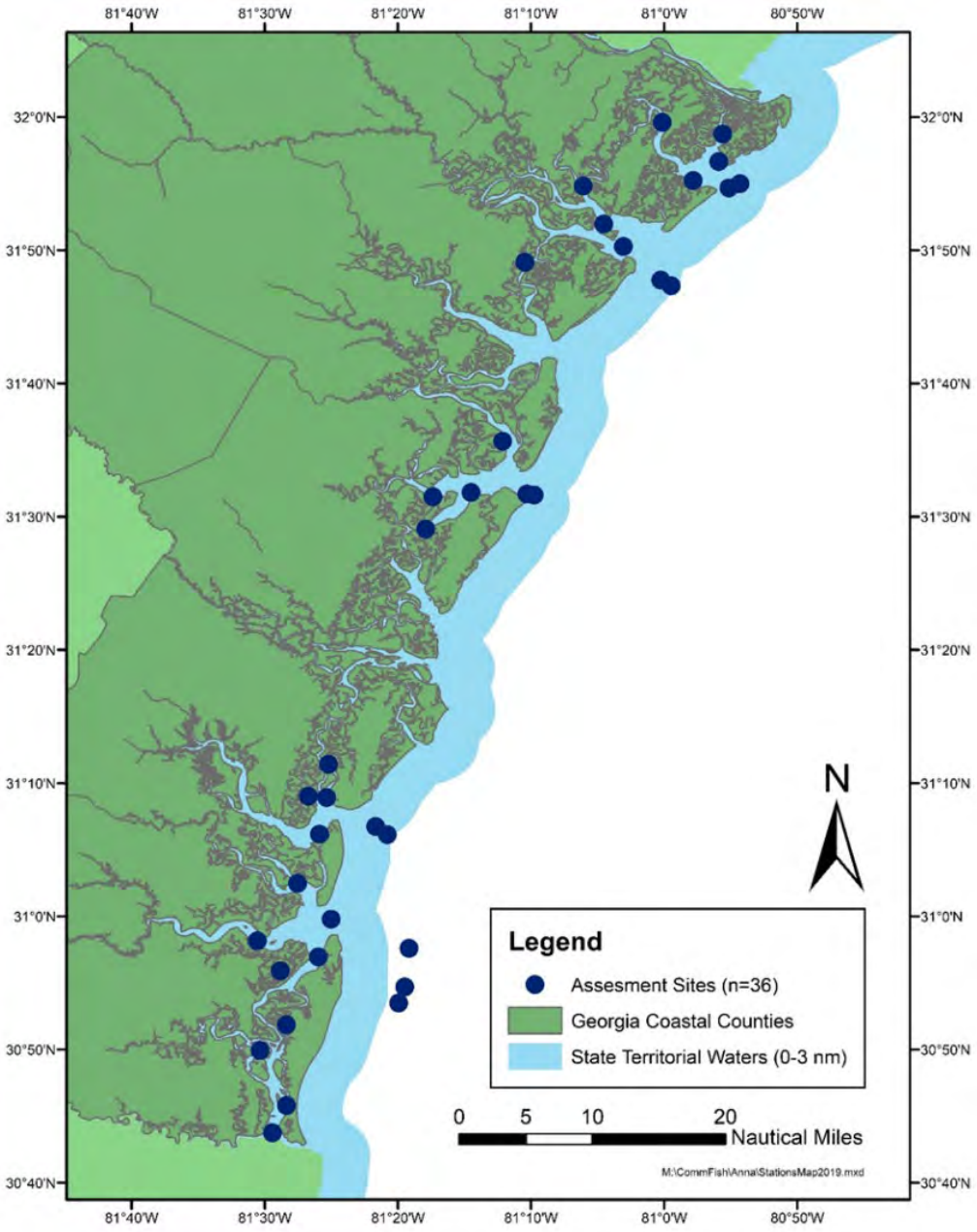


Figure 119. Sampling locations for the GA Ecological Monitoring Trawl Survey.

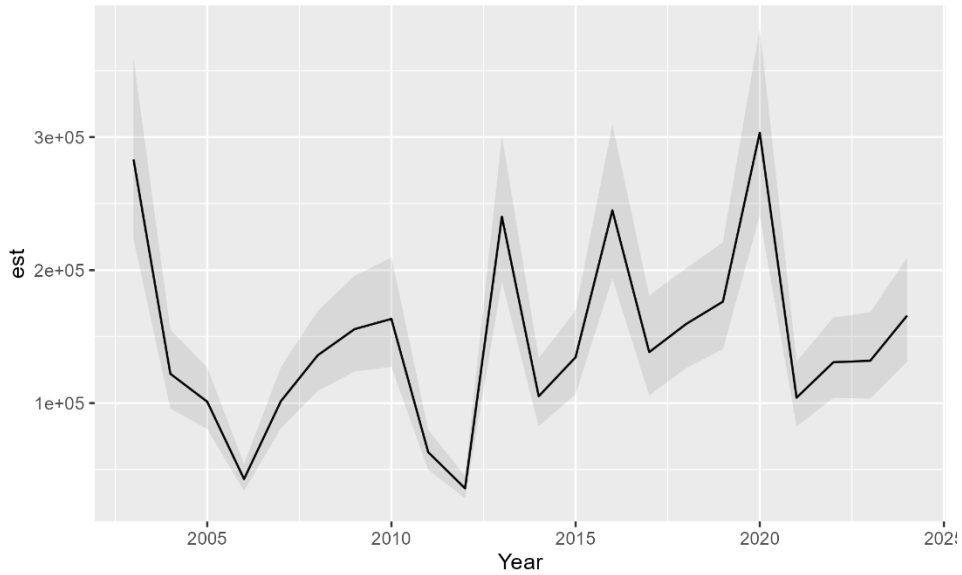


Figure 120. Estimated total abundance for Atlantic croaker from GA Ecological Monitoring Trawl Survey (EMTS) from 2003-2024 standardized by GLMM with negative binomial error distribution with sdmTMB R package. Gray shading indicates 95% confidence intervals.

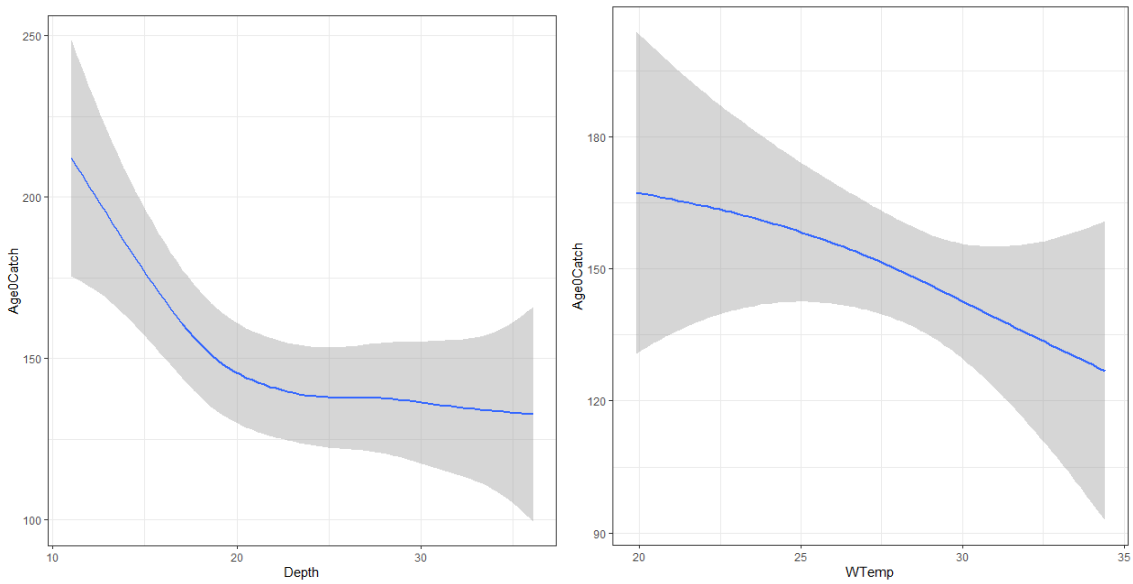


Figure 121. Significant environmental covariates (depth-left, water temperature-right) relationships to abundance of Atlantic croaker from GA Ecological Monitoring Trawl Survey (EMTS) from 2003-2024 standardized by GLMM with negative binomial error distribution with sdmTMB R package. Gray shading indicated 95% confidence intervals.

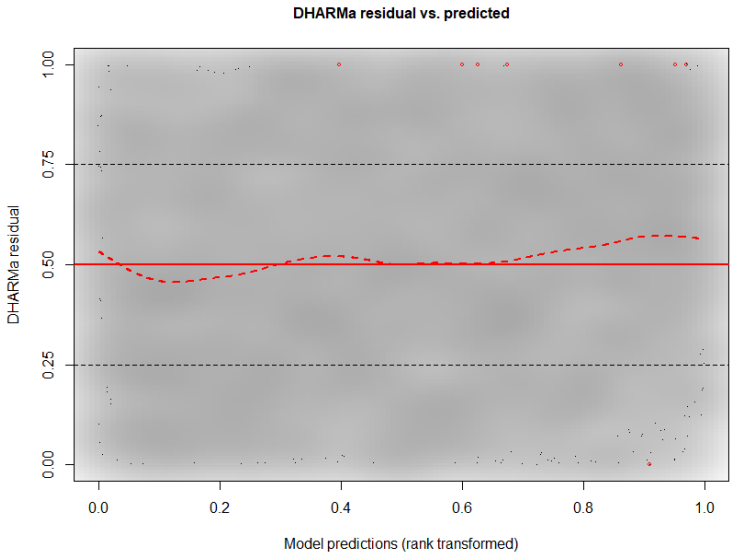


Figure 122. Scaled residual plot demonstrating residuals against predicted values with an overlaid quantile regression (right; 0.25, 0.5, and 0.75 quantiles).

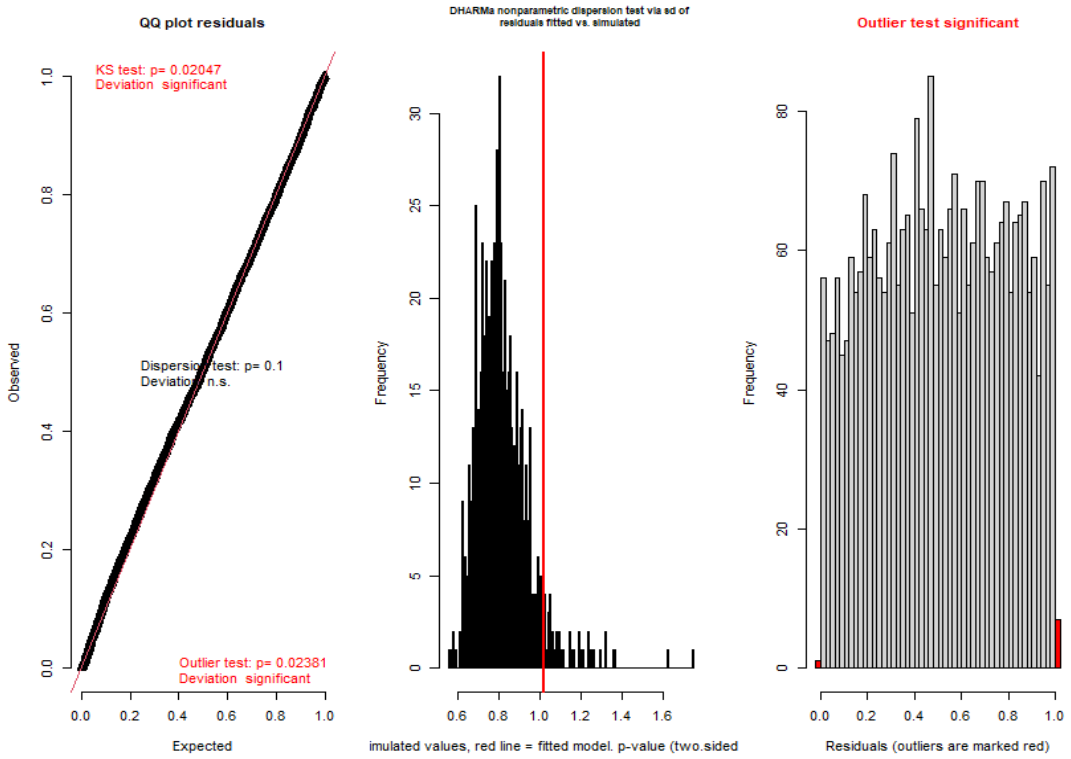


Figure 123. Scaled residuals of the model fit for the standardized SC Estuarine Trawl Survey for Age-0 Atlantic croaker displayed in a qq-plot to detect overall deviations in the distribution (left), a residual fitted versus simulated histogram plot demonstrating the nonparametric dispersion test (middle), and a frequency of residuals histogram demonstrating outliers in residuals (right).

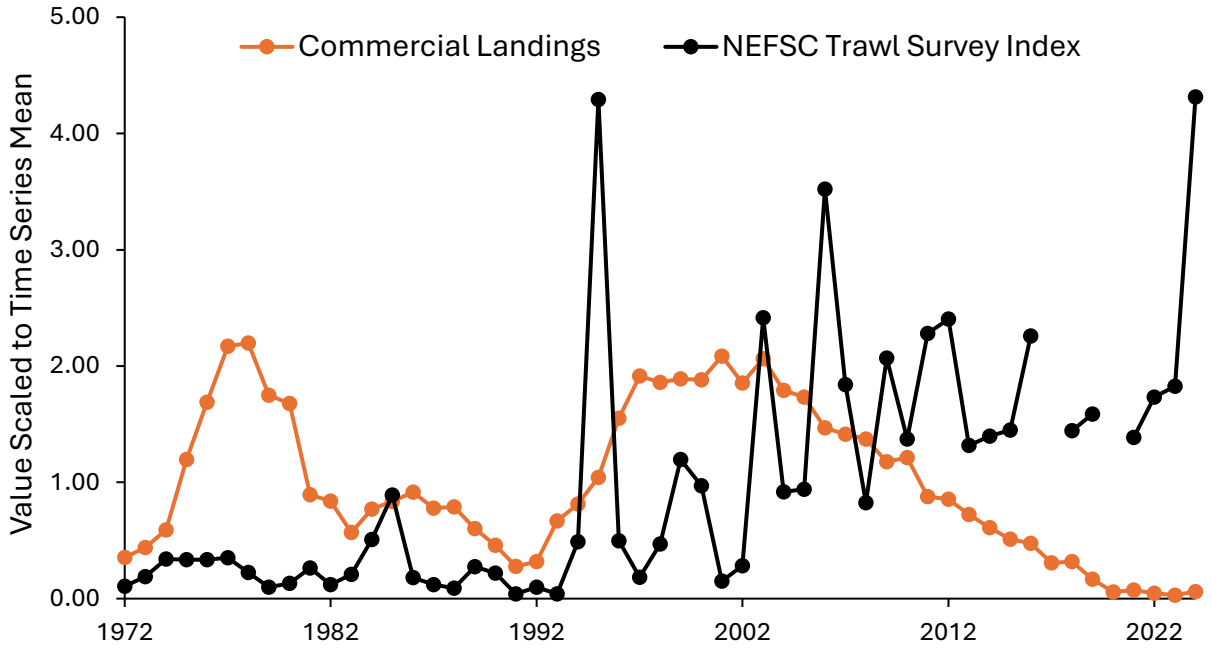


Figure 124. Atlantic croaker commercial landings north of South Carolina and NEFSC Trawl Survey index of relative abundance. Values are scaled to their time series means for comparison of trends.

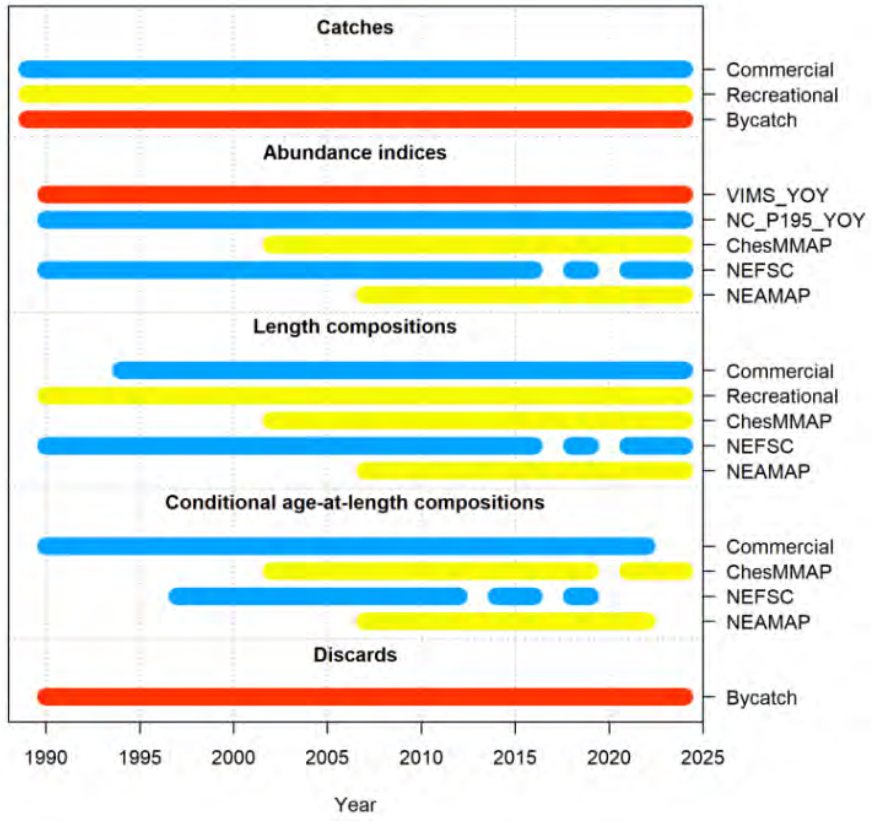


Figure 125. Data time series used in SS northern stock model.

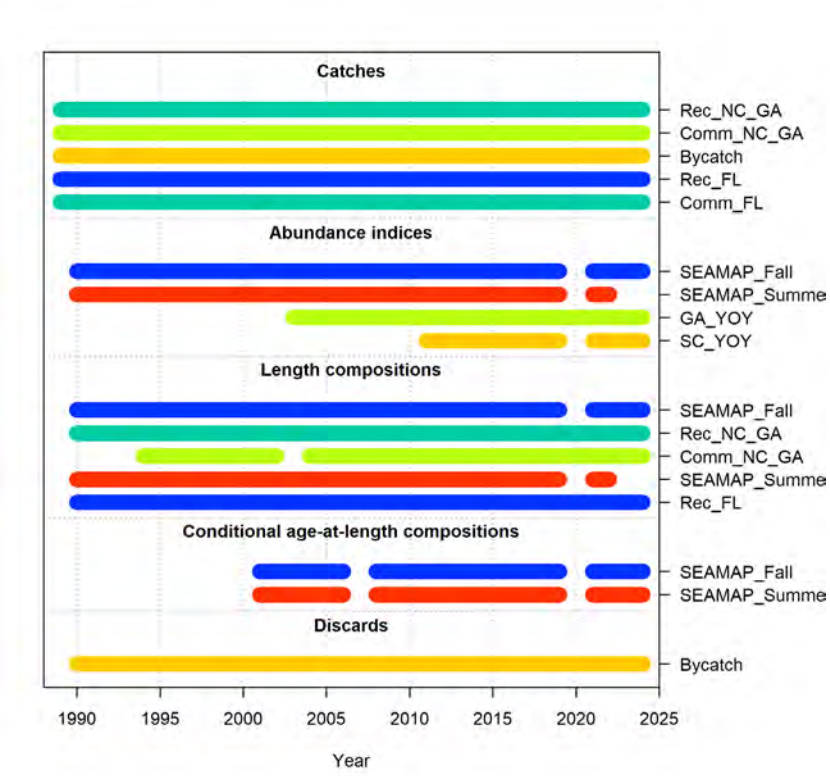


Figure 126. Data time series used in SS estimated selectivity model for the southern stock.

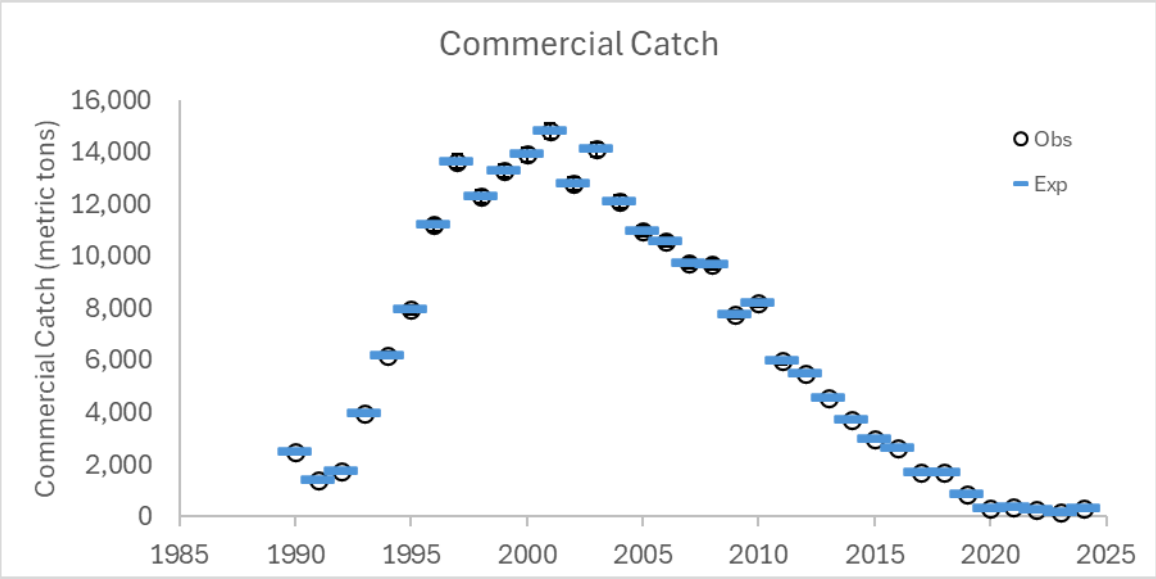


Figure 127. Observed and estimated catches for the Commercial fleet for the northern stock SS model.

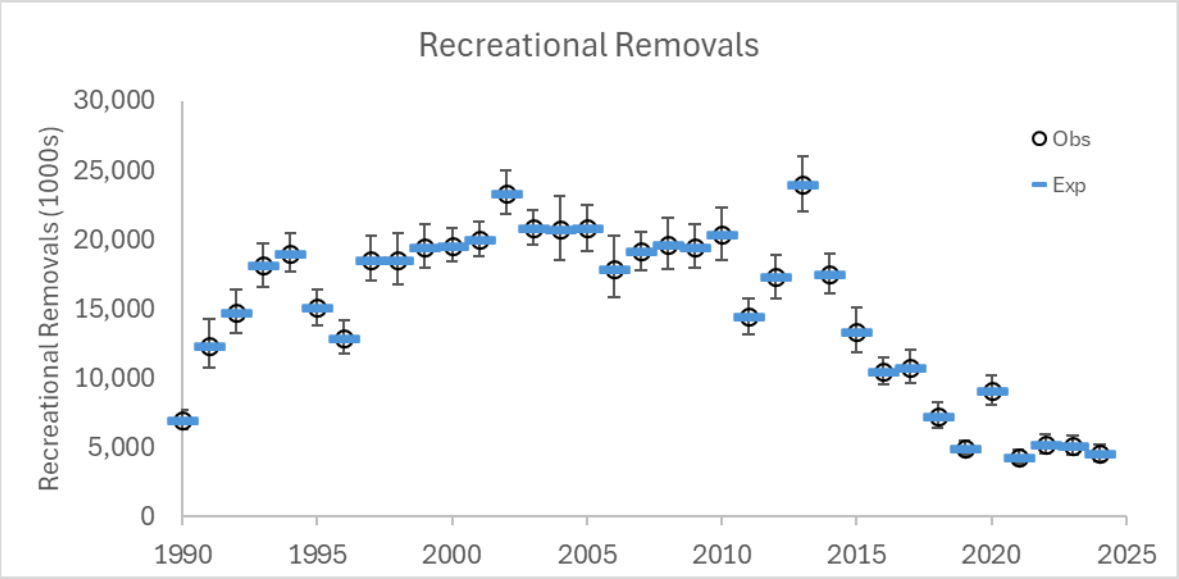


Figure 128. Observed and estimated catches for the Recreational fleet for the northern stock SS model.

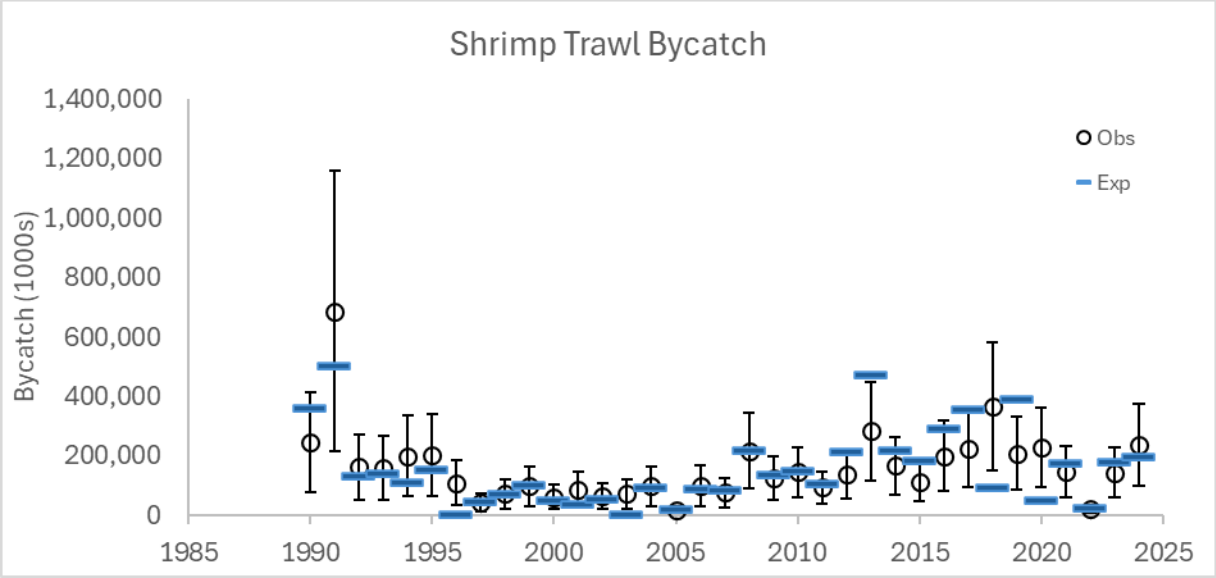


Figure 129. Observed and estimated discards for the Bycatch fleet for the northern stock SS model.

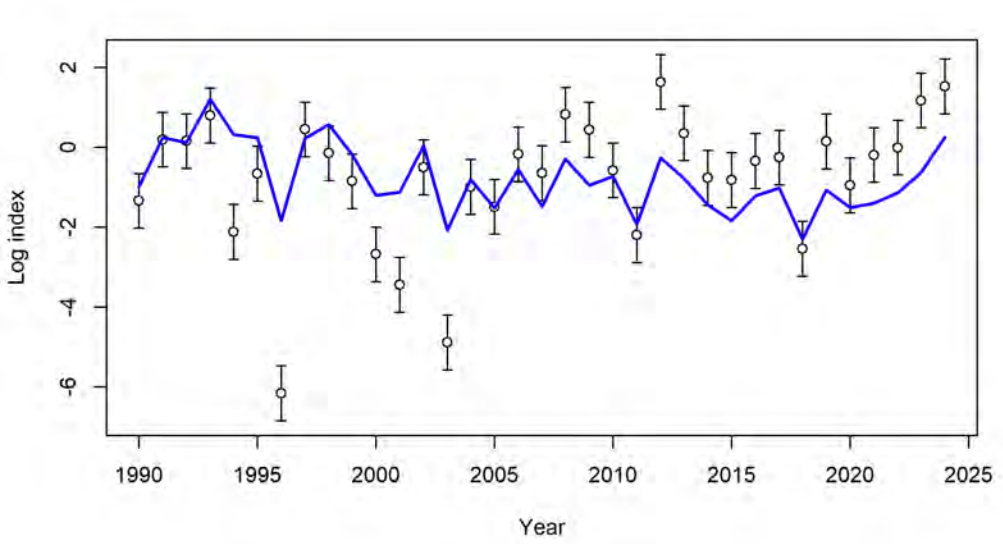


Figure 130. Observed and estimated index values on log scale for VIMS_YOY. Error bars indicate 95% uncertainty interval around index values based on model assumption of lognormal error.

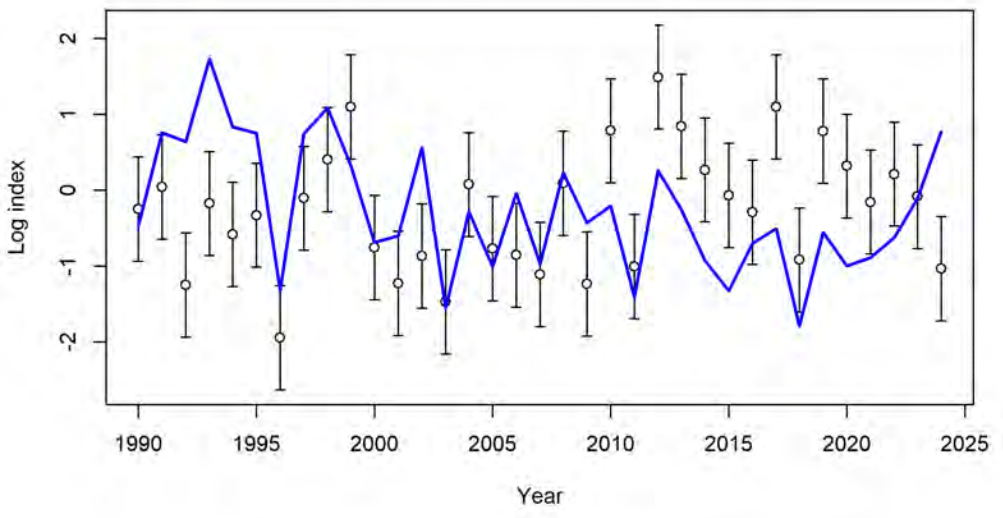


Figure 131. Observed and estimated index values on log scale for NC_P195_YOY. Error bars indicate 95% uncertainty interval around index values based on model assumption of lognormal error.

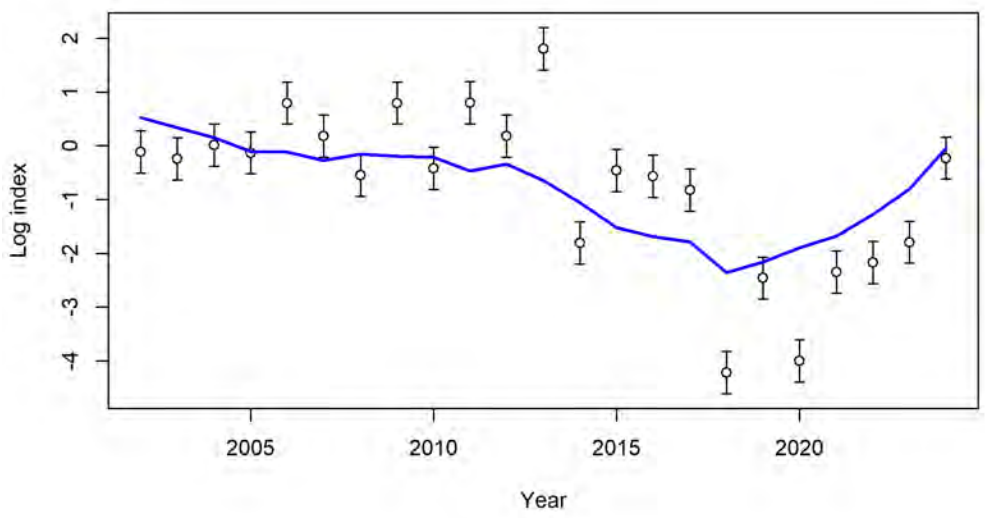


Figure 132. Observed and estimated index values on log scale for ChesMMAP. Error bars indicate 95% uncertainty interval around index values based on model assumption of lognormal error.

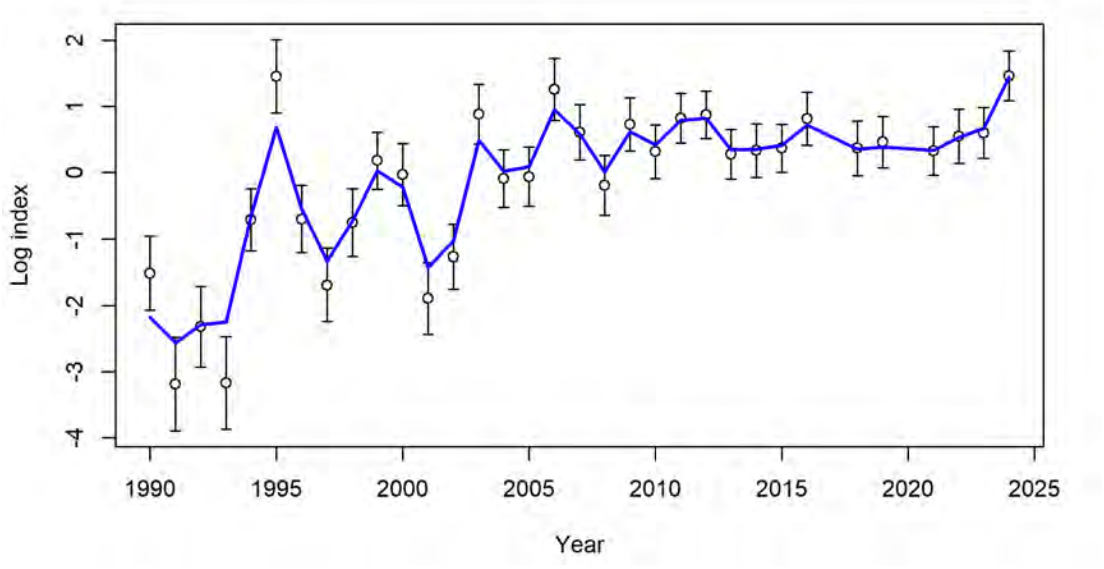


Figure 133. Observed and estimated index values on log scale for NEFSC. Error bars indicate 95% uncertainty interval around index values based on model assumption of lognormal error.

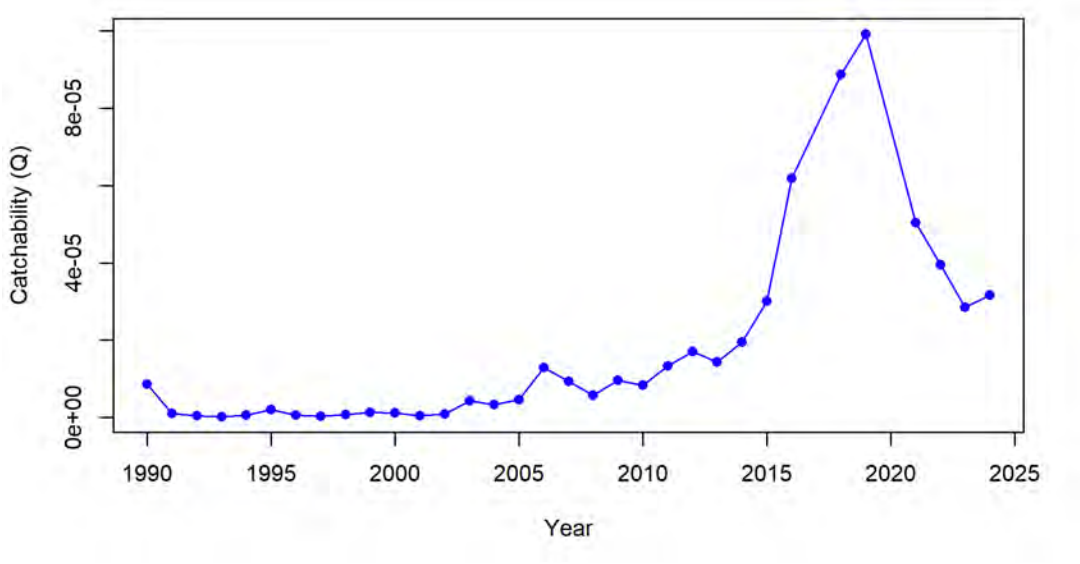


Figure 134. Time series of estimated catchability for NEFSC.

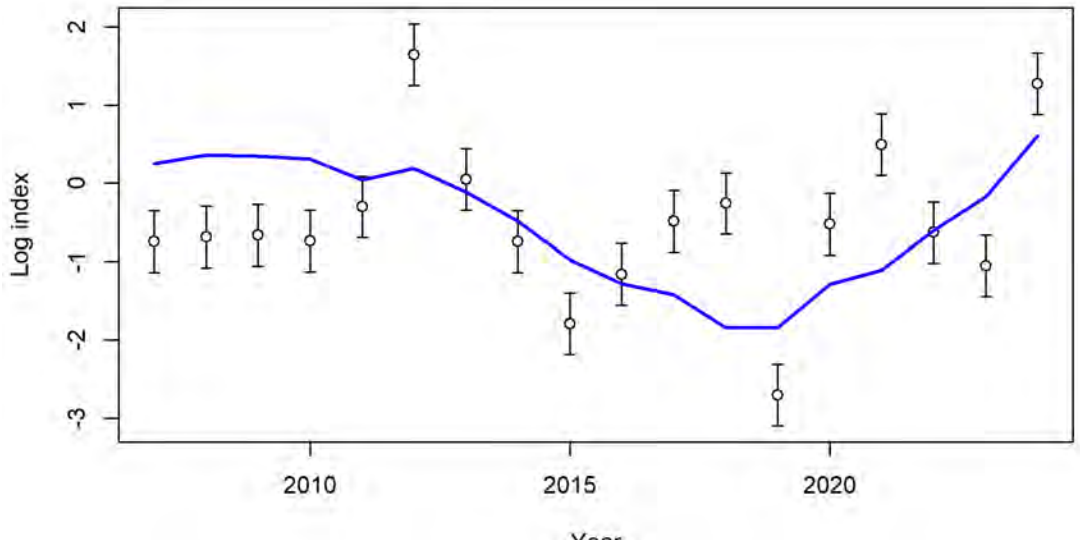


Figure 135. Observed and estimated index values on log scale for NEAMAP. Error bars indicate 95% uncertainty interval around index values based on model assumption of lognormal error.

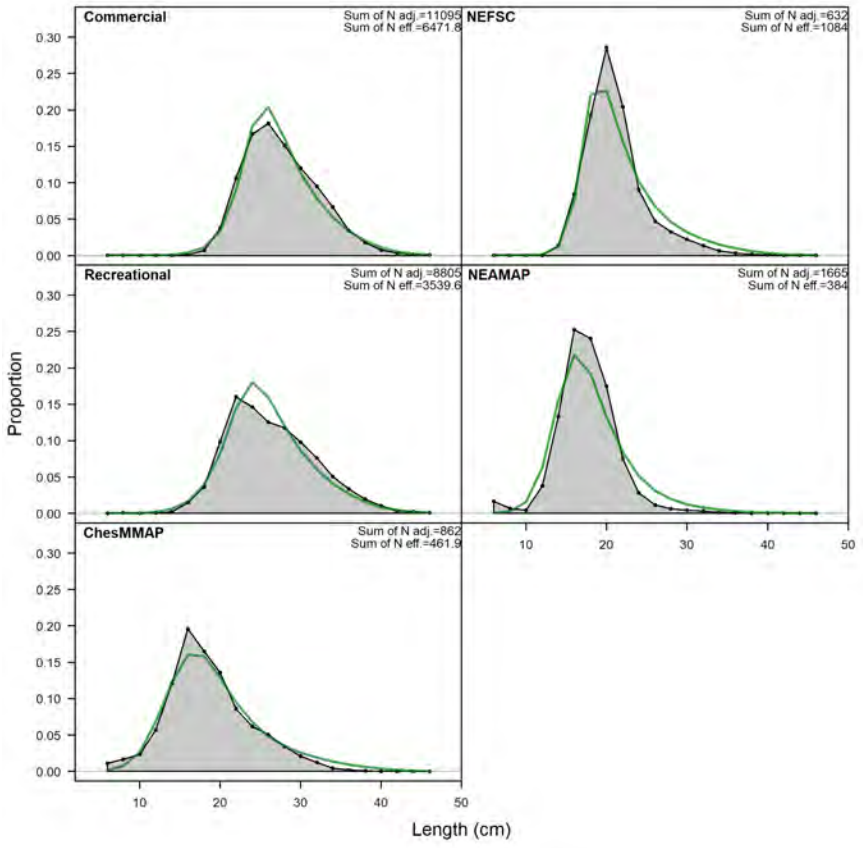


Figure 136. Length compositions, aggregated across time by fleet/survey for the northern stock SS model.

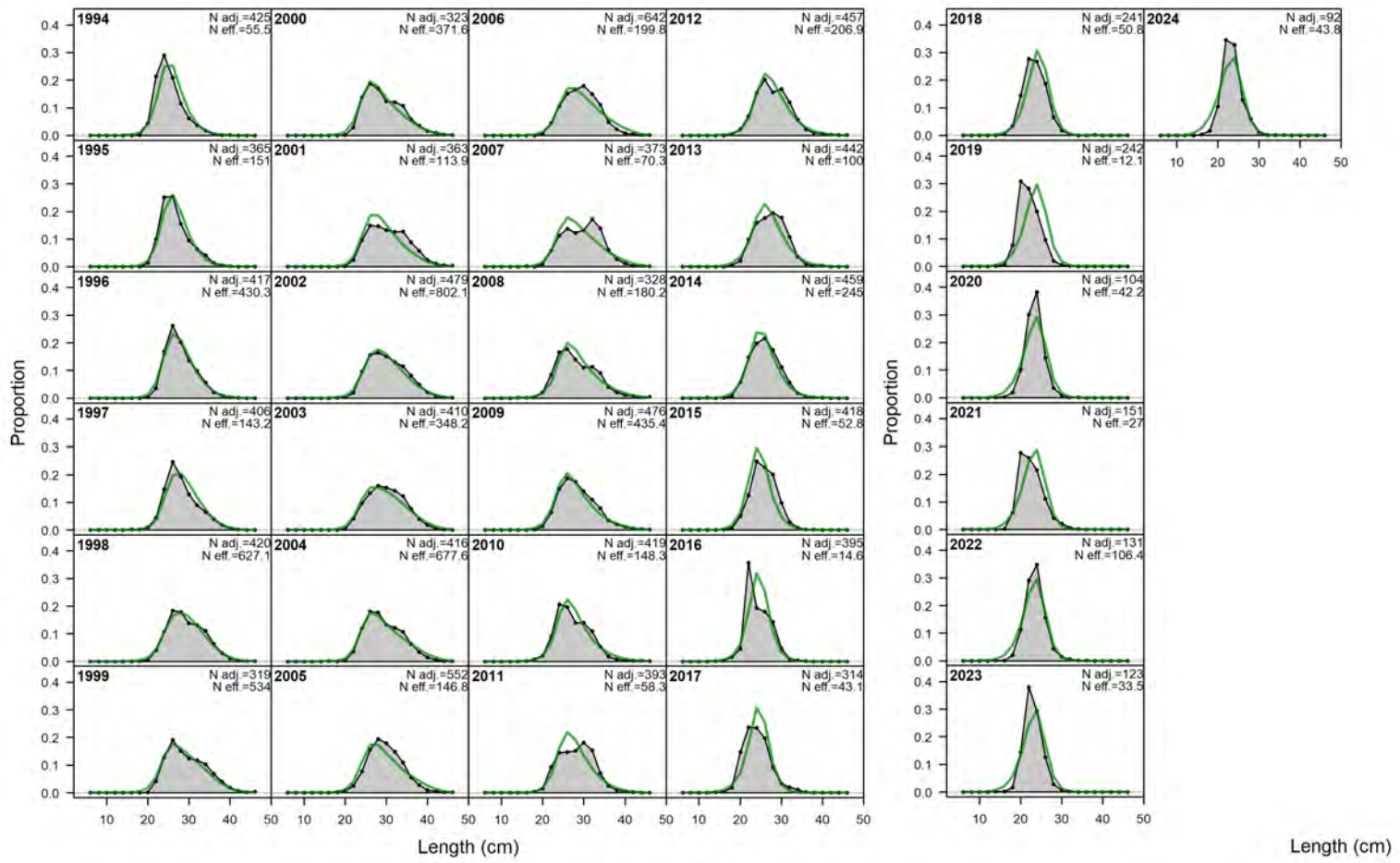


Figure 137. Annual length compositions for Commercial catch for the northern stock SS model.

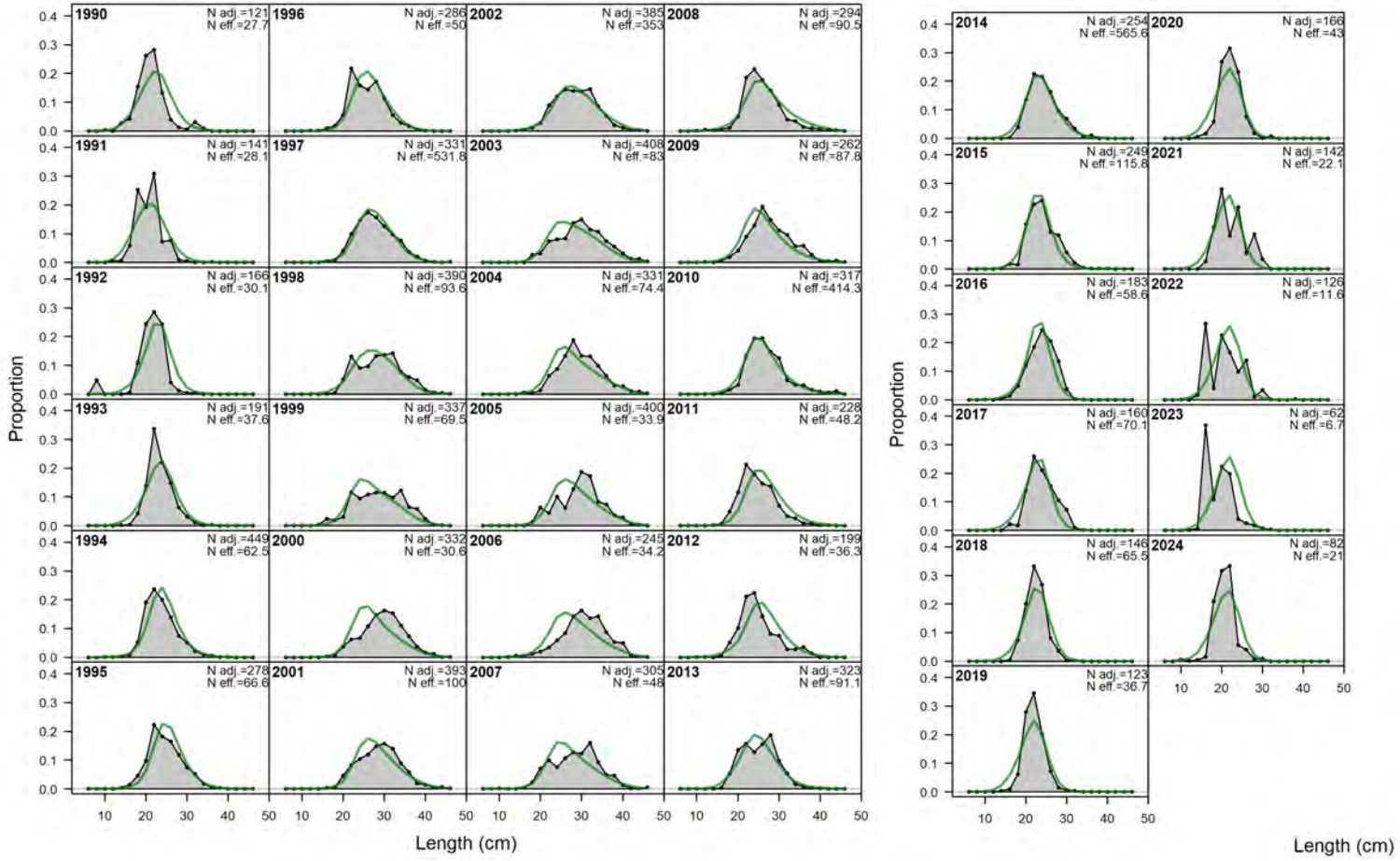


Figure 138. Annual length compositions for Recreational removals for the northern stock SS model.

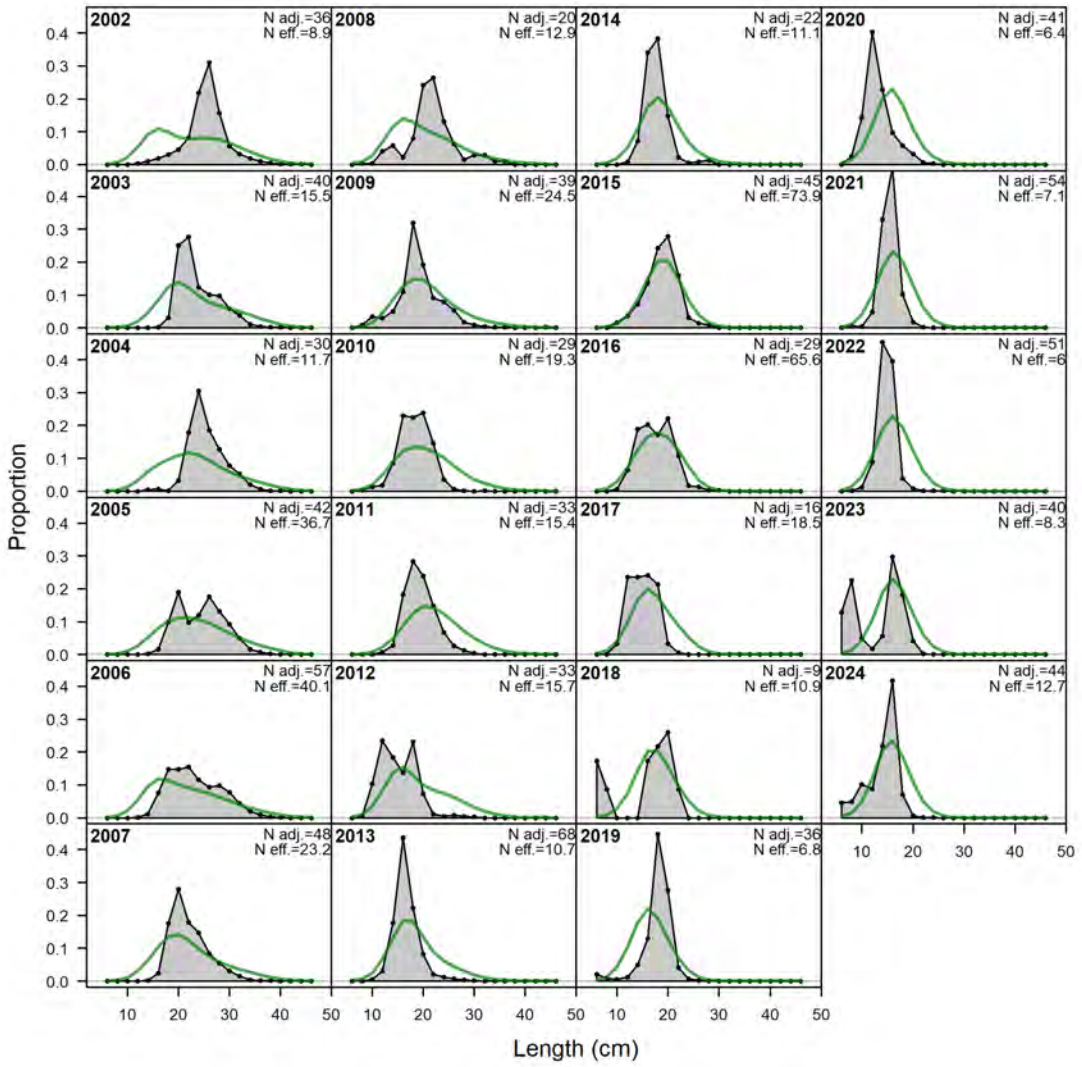


Figure 139. Annual length compositions for ChesMMAP for the northern stock SS model.

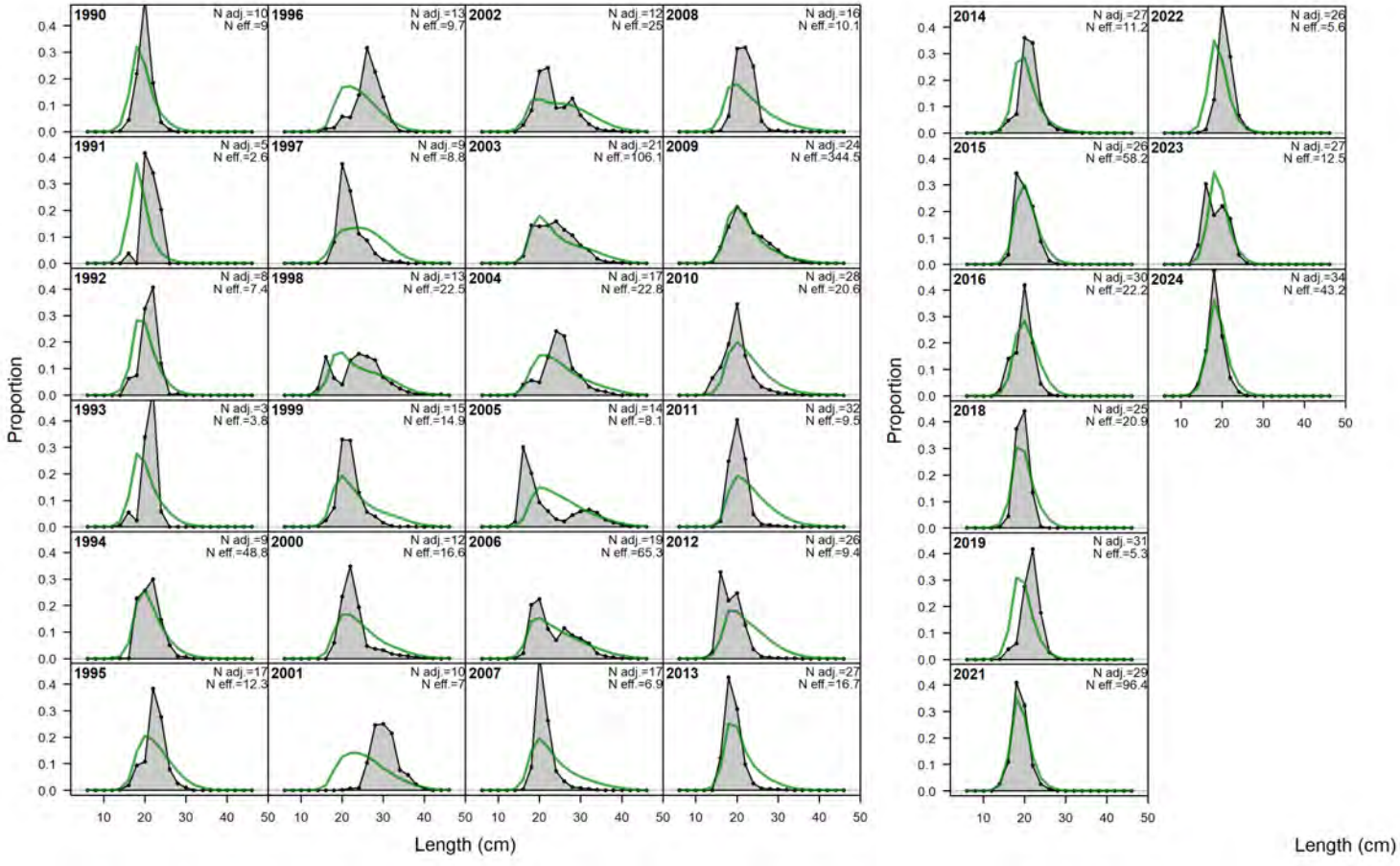


Figure 140. Annual length compositions for NEFSC for the northern stock SS model.

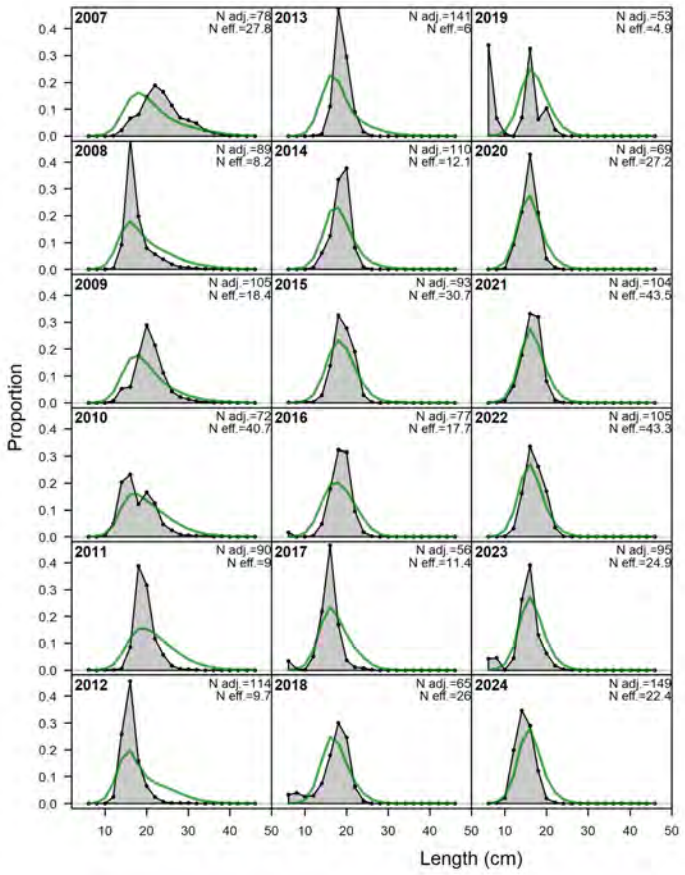


Figure 141. Annual length compositions for NEAMAP for the northern stock SS model.

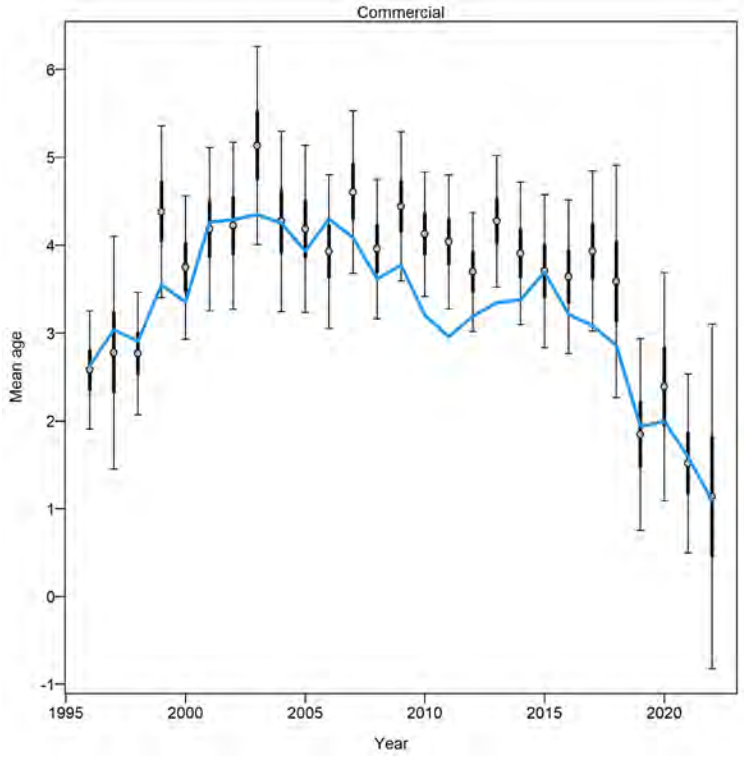


Figure 142. Mean age from conditional data (aggregated across length bins) for Commercial data with 95% confidence intervals.

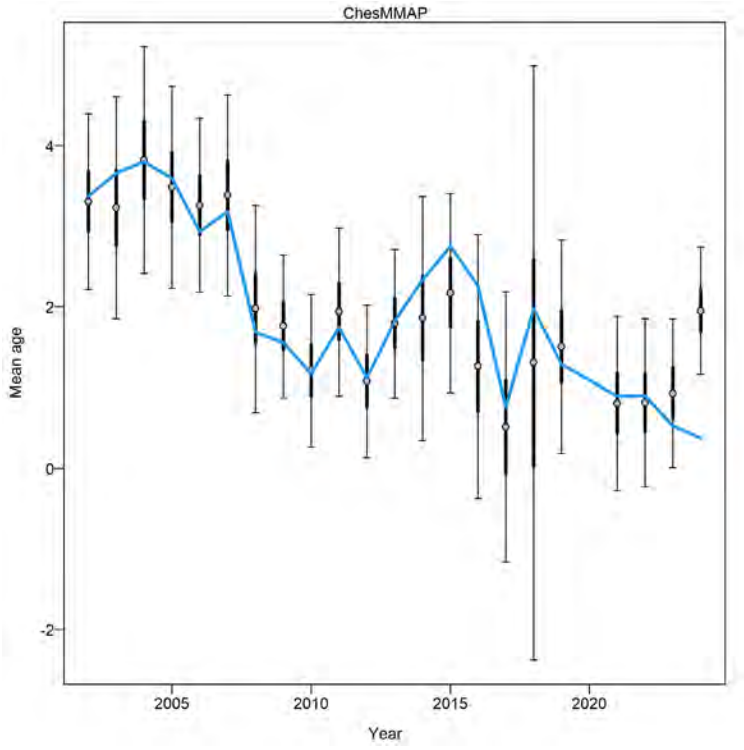


Figure 143. Mean age from conditional data (aggregated across length bins) for ChesMMAP with 95% confidence intervals.

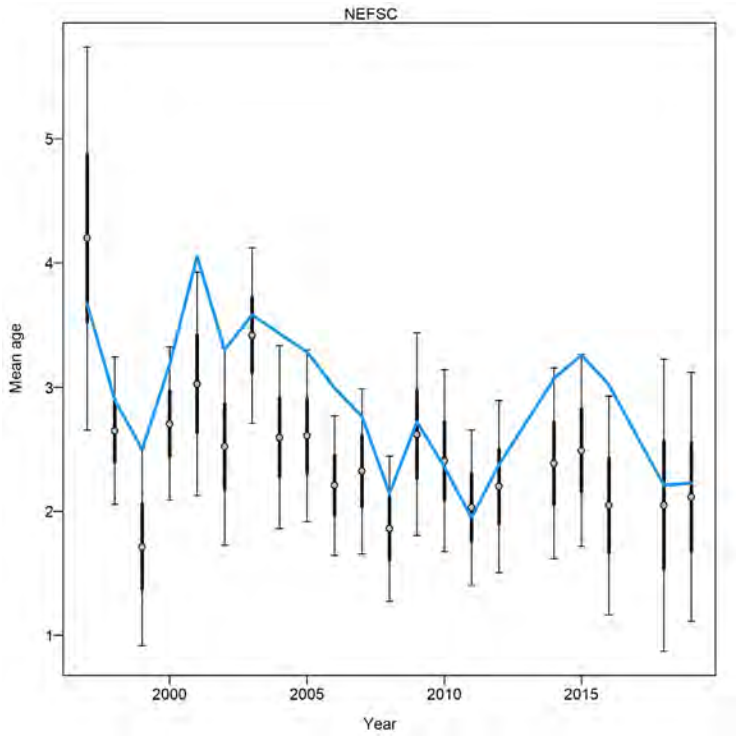


Figure 144. Mean age from conditional data (aggregated across length bins) for NEFSC with 95% confidence intervals.

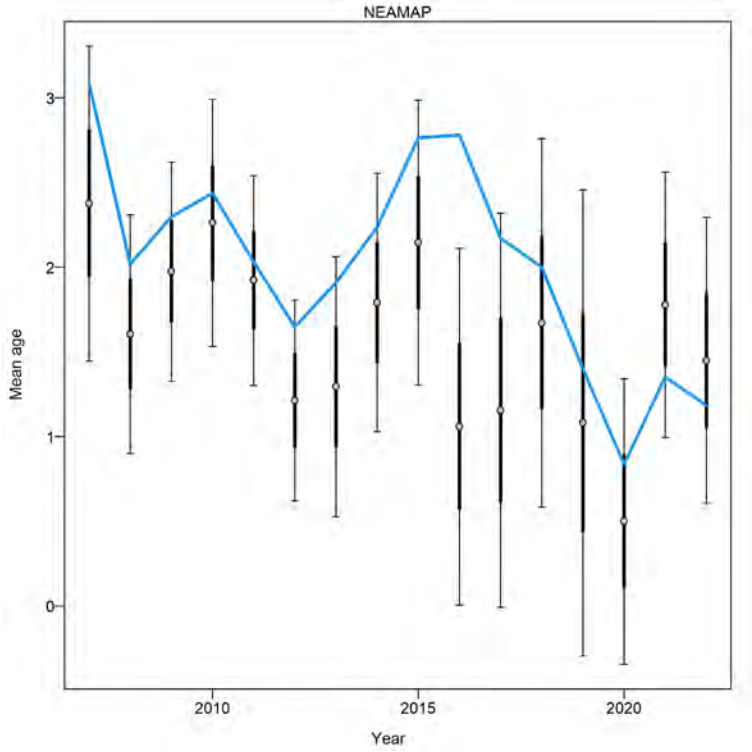


Figure 145. Mean age from conditional data (aggregated across length bins) for NEAMAP with 95% confidence intervals.

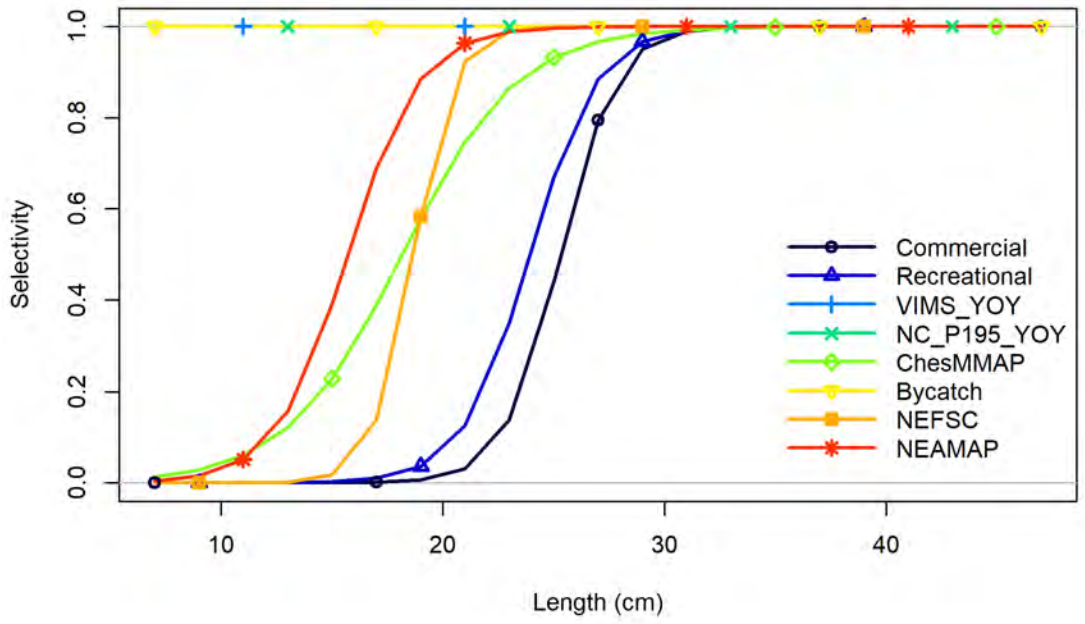


Figure 146. Estimated length-based selectivities for the northern stock SS model.

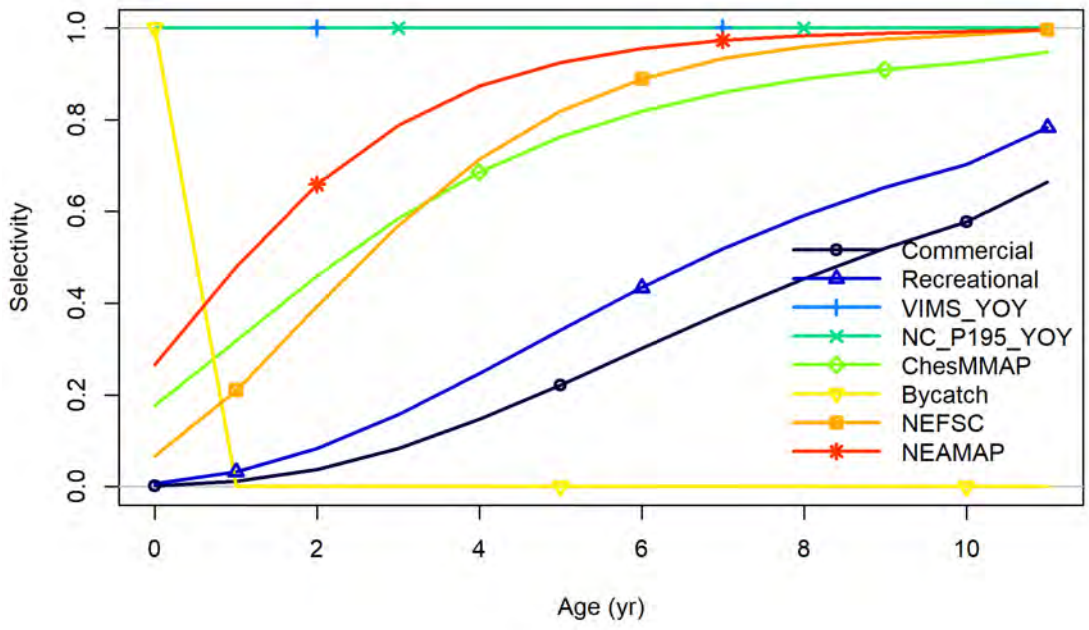


Figure 147. Age-based selectivity (fixed) for the Bycatch fleet with derived age-based selectivities for the other fleets/surveys for the northern stock SS model.

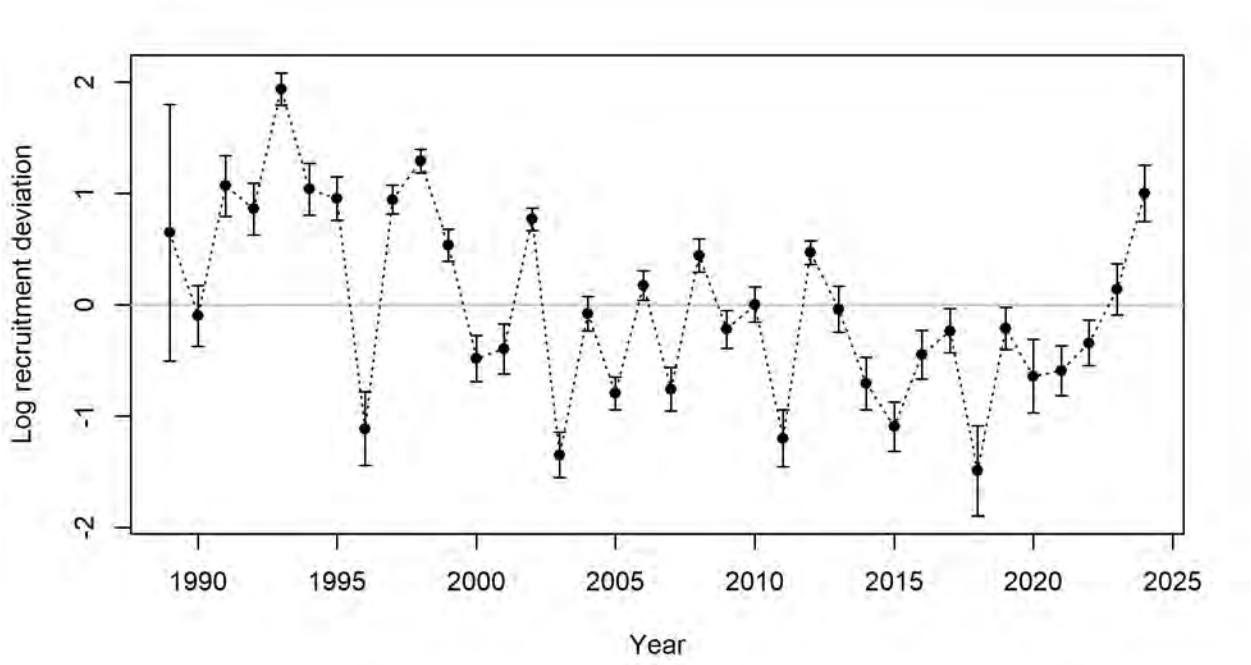


Figure 148. Recruitment deviations with 95% confidence intervals for the northern stock SS model.

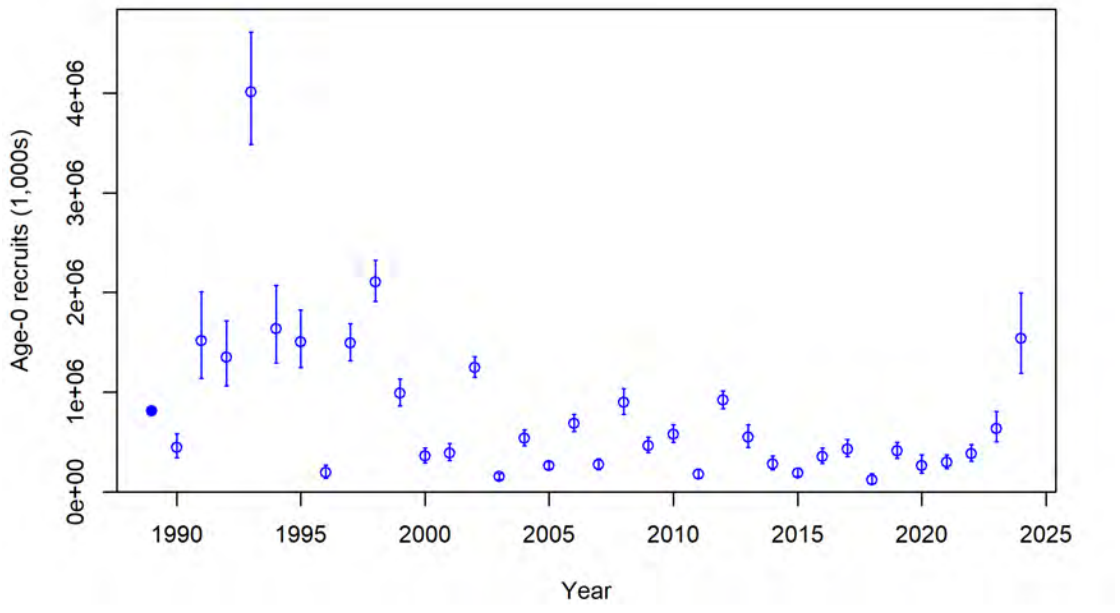


Figure 149. Estimated recruitment (in 1000s) for the northern stock SS model. Error bars are 95% confidence intervals based on asymptotic standard errors.

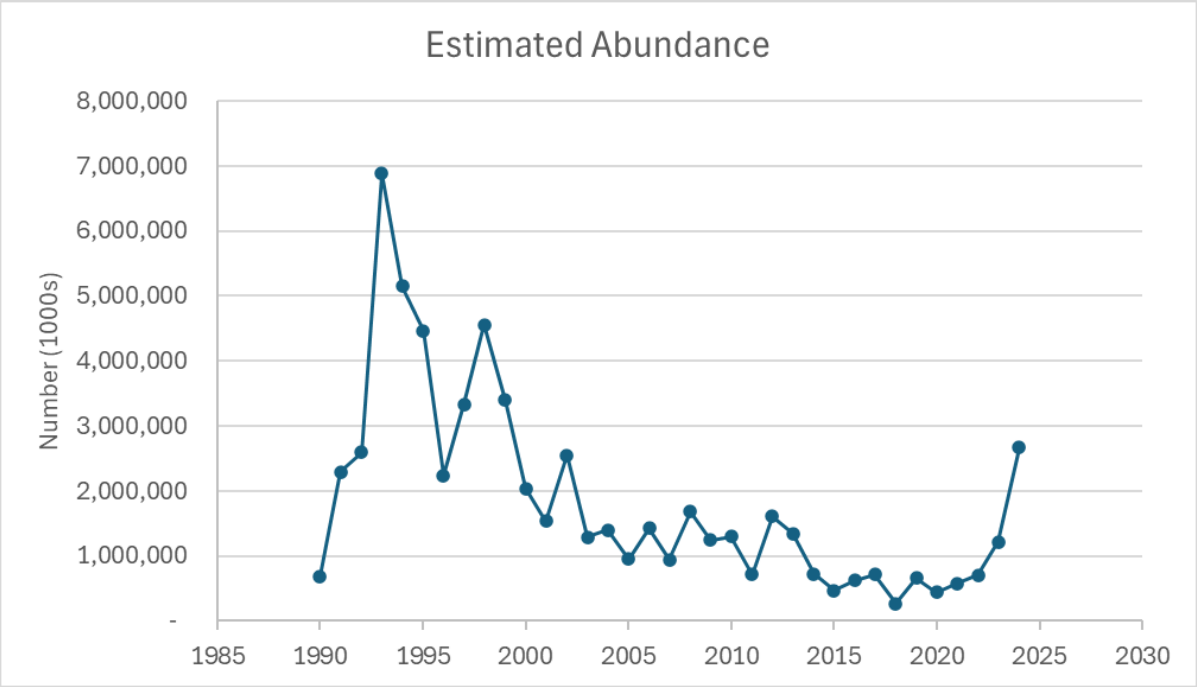


Figure 150. Estimated abundance (in 1000s of fish) for the northern stock SS model.

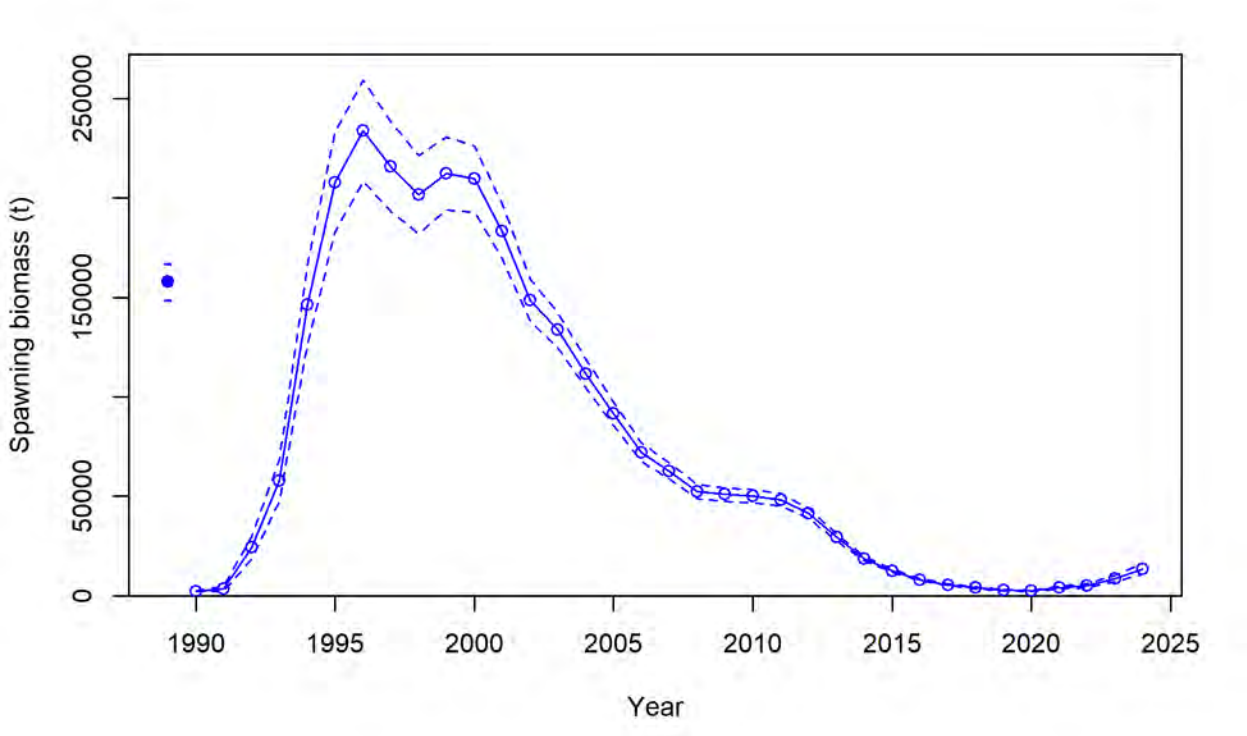


Figure 151. Estimated female SSB (metric tons) for the northern stock SS model. Error bars are 95% confidence intervals based on asymptotic standard errors.

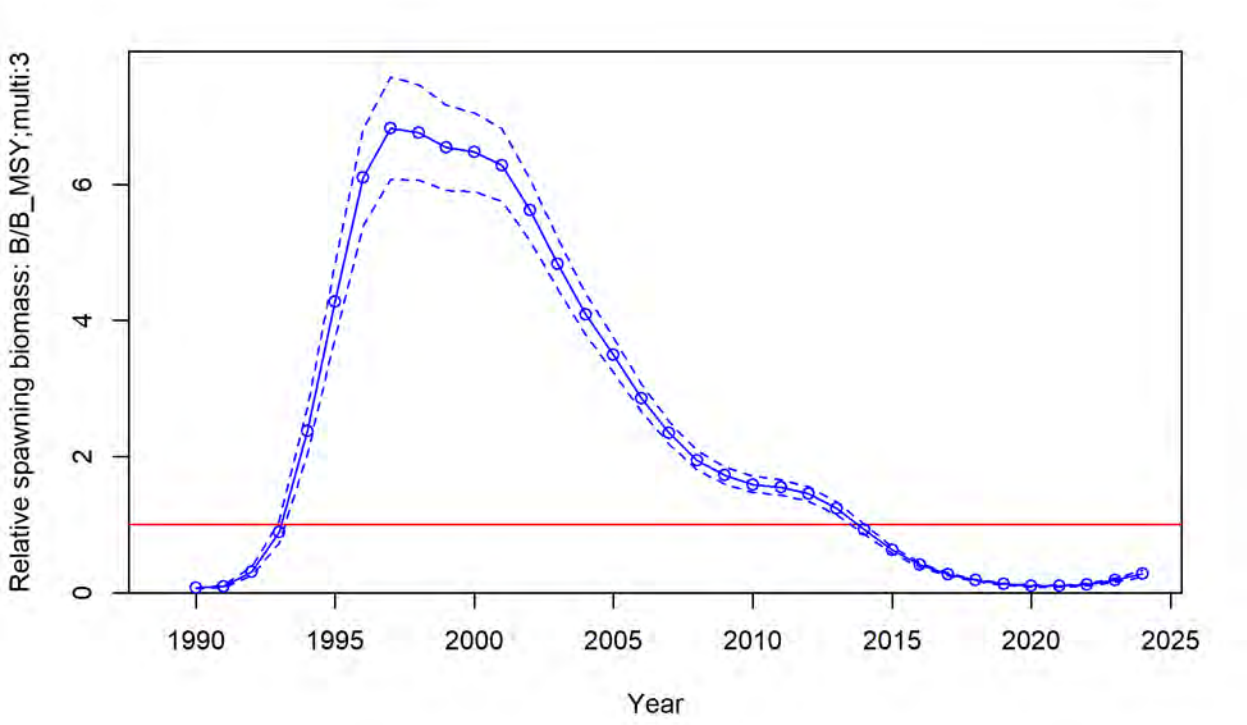


Figure 152. Estimated female SSB (three-year average) relative to the estimated $SSB_{SPR25\%}$ threshold for the northern stock SS model. Error bars are 95% confidence intervals based on asymptotic standard errors.

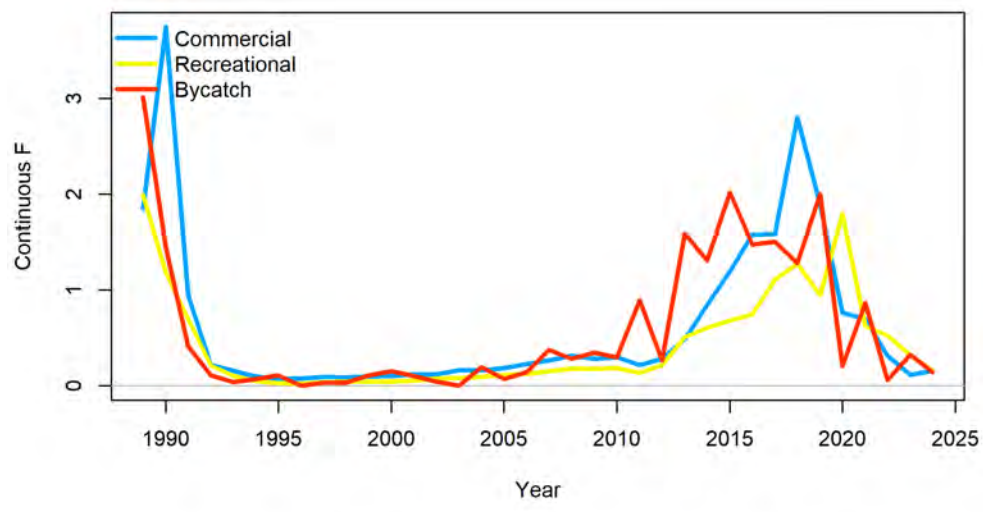


Figure 153. Estimated fleet-specific fishing mortality for the northern stock SS model.

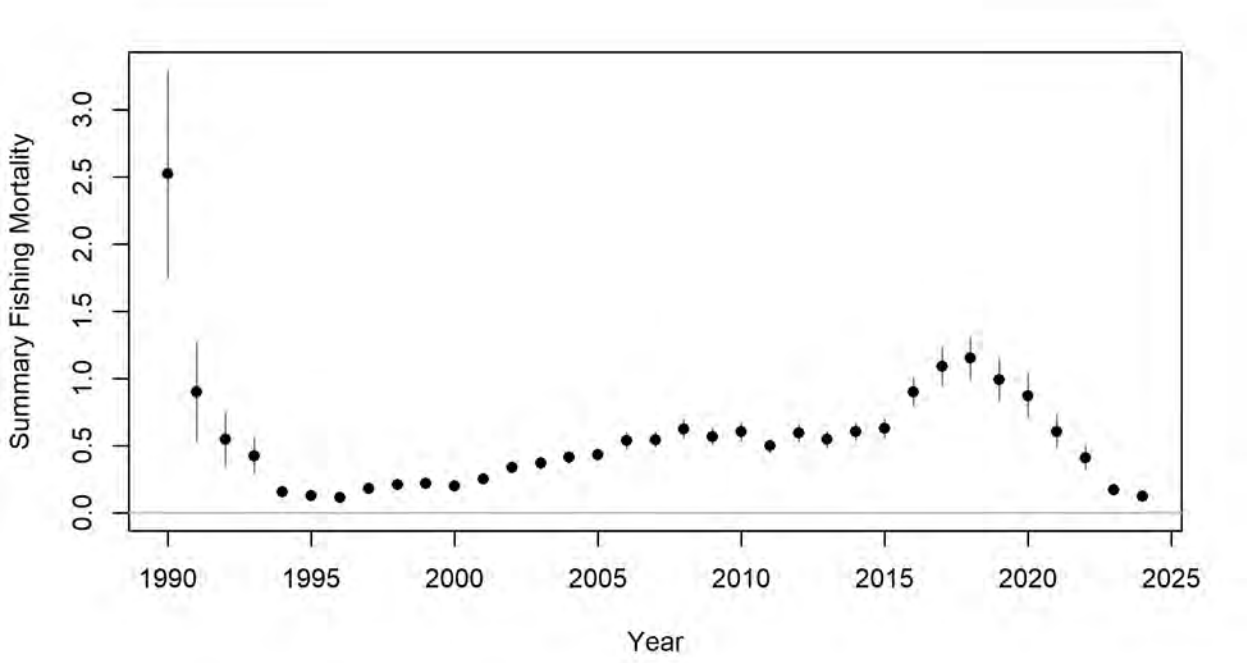


Figure 154. Total fishing mortality for the northern stock SS model.

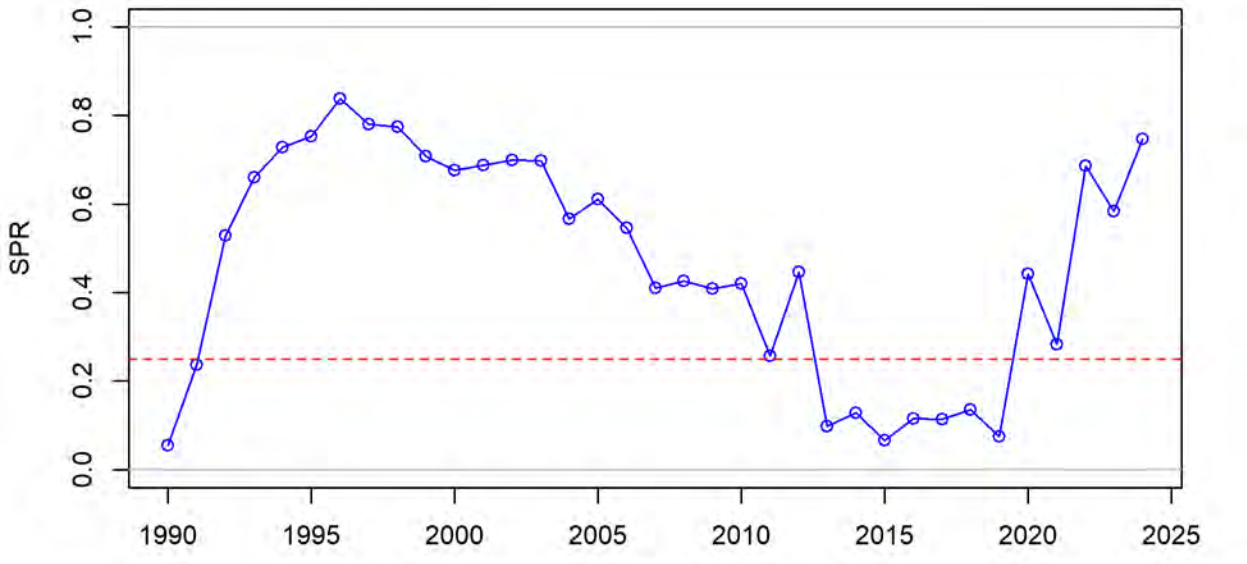


Figure 155. SPR timeseries for the northern stock SS model. Horizontal line is the SPR target (0.25).

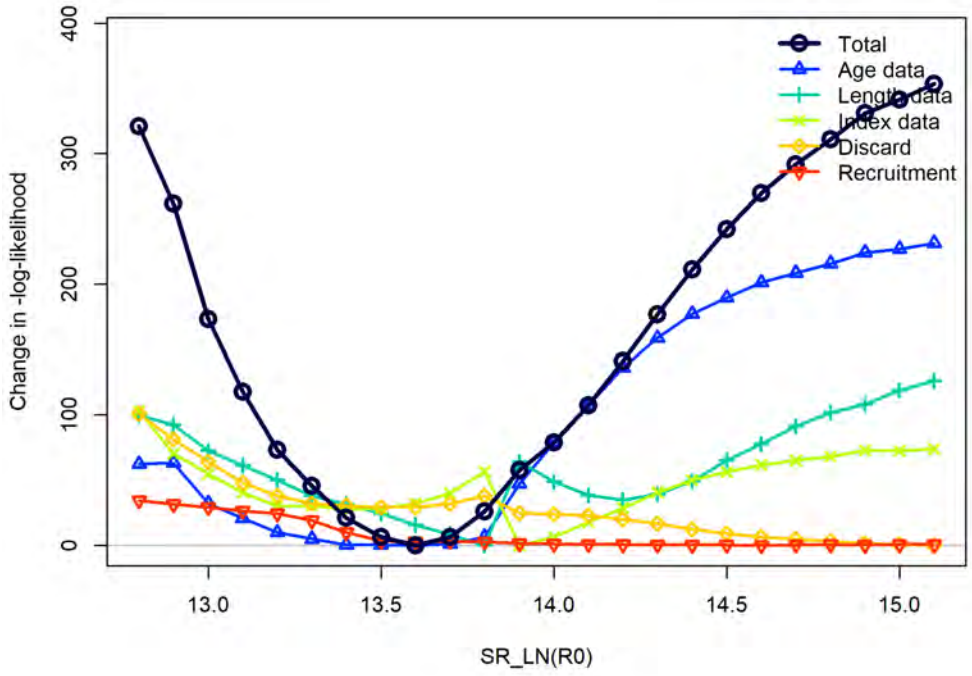


Figure 156. Likelihood profile plot for unfished recruitment (R0) parameter (on the log scale) for the northern stock SS model.

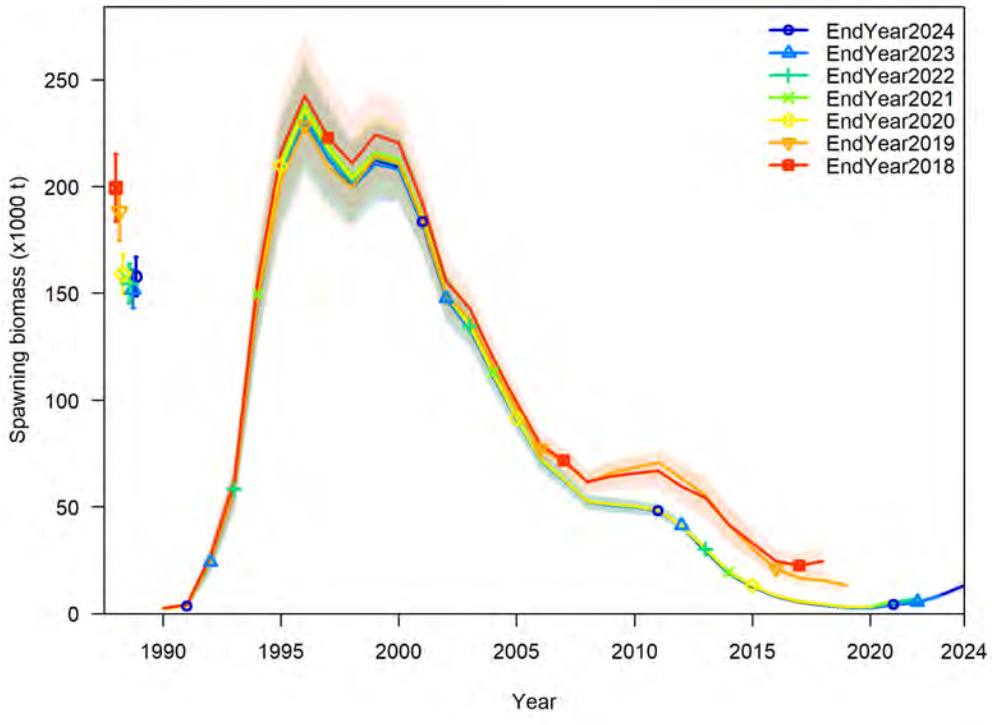


Figure 157. Spawning stock biomass estimates from retrospective analysis of northern stock SS model.

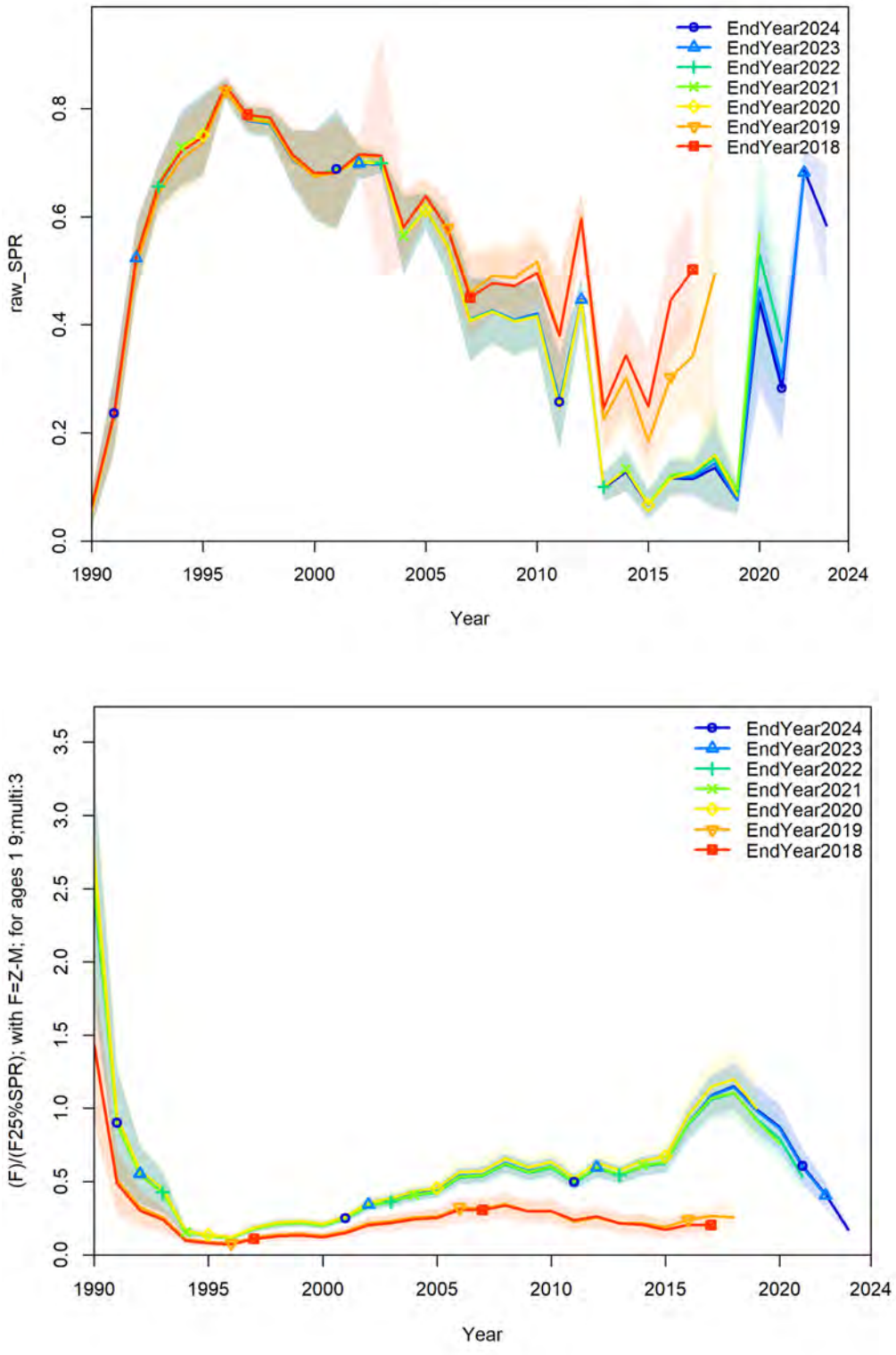


Figure 158. Spawning potential ratio and relative fishing mortality (ages 1-9, average weighted by numbers) estimates from retrospective analysis of northern stock SS model.

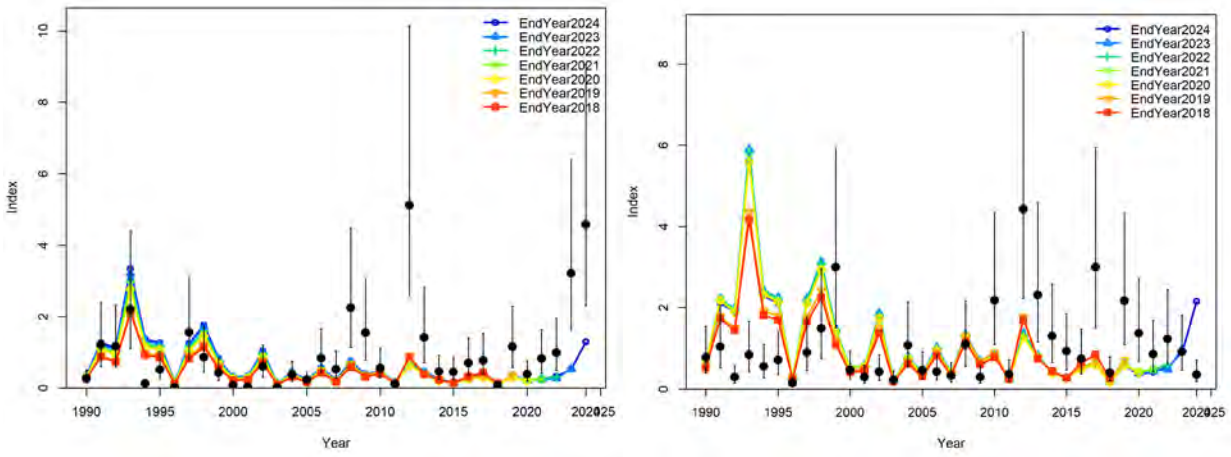


Figure 159. Observed and estimated index values for the VIMS_YOY (left) and NC_P195_YOY (right) surveys from the retrospective analysis for the northern stock SS model.

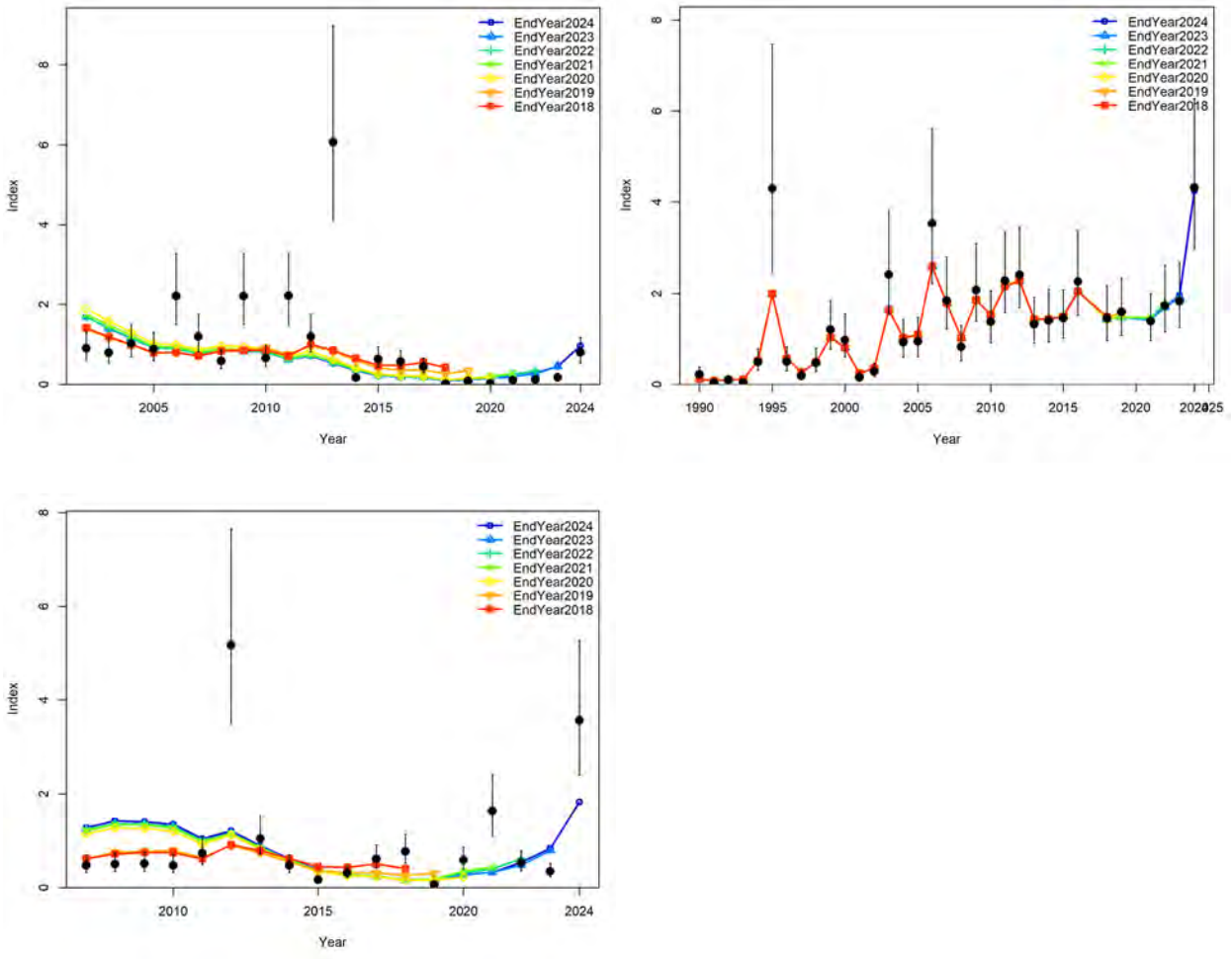


Figure 160. Observed and estimated index values for the ChesMMAP (top left), NEFSC (right), and NEAMAP (bottom left) surveys from the retrospective analysis for the northern stock SS model.

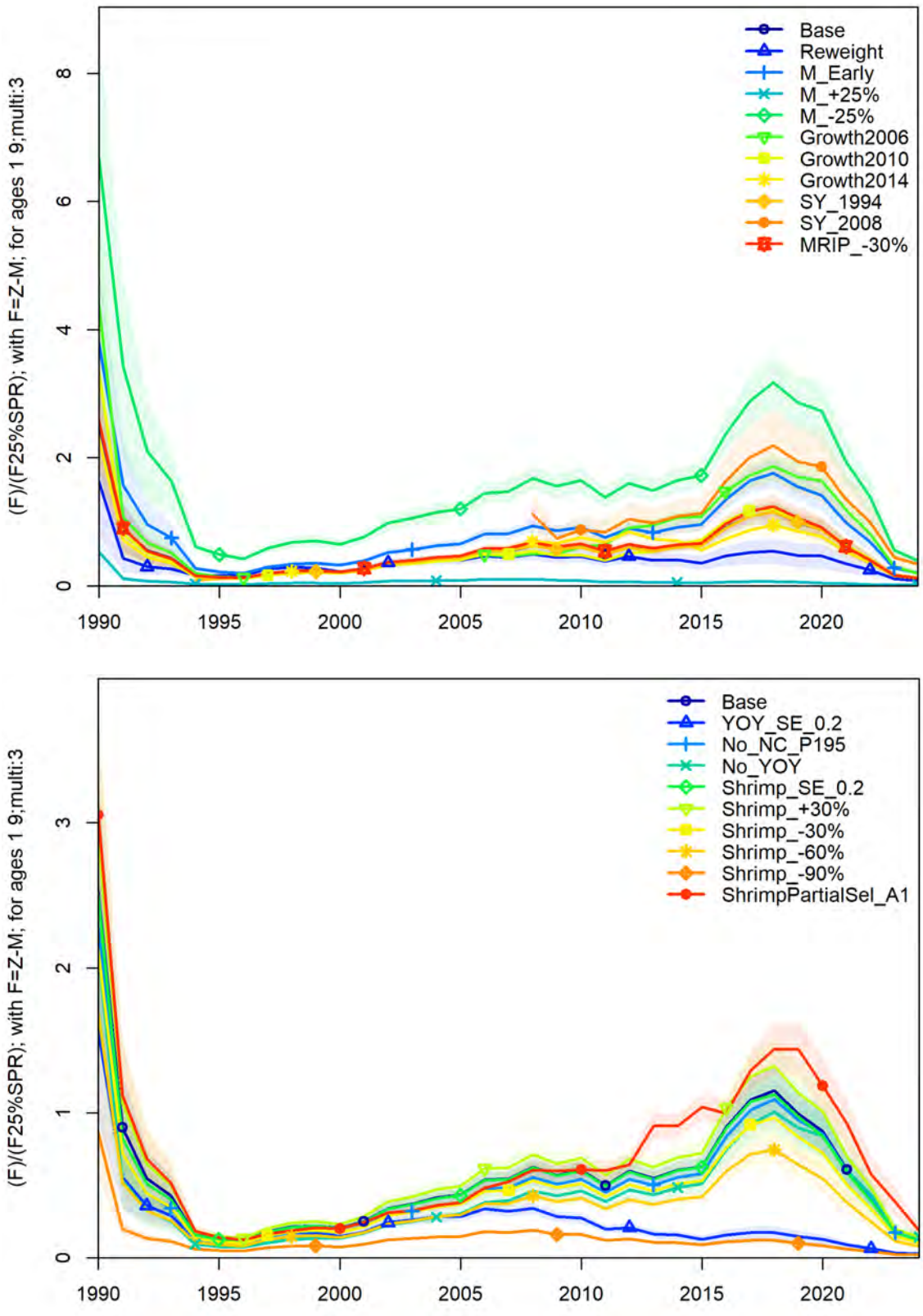


Figure 161. Relative fishing mortality from sensitivity analyses of northern stock SS model.

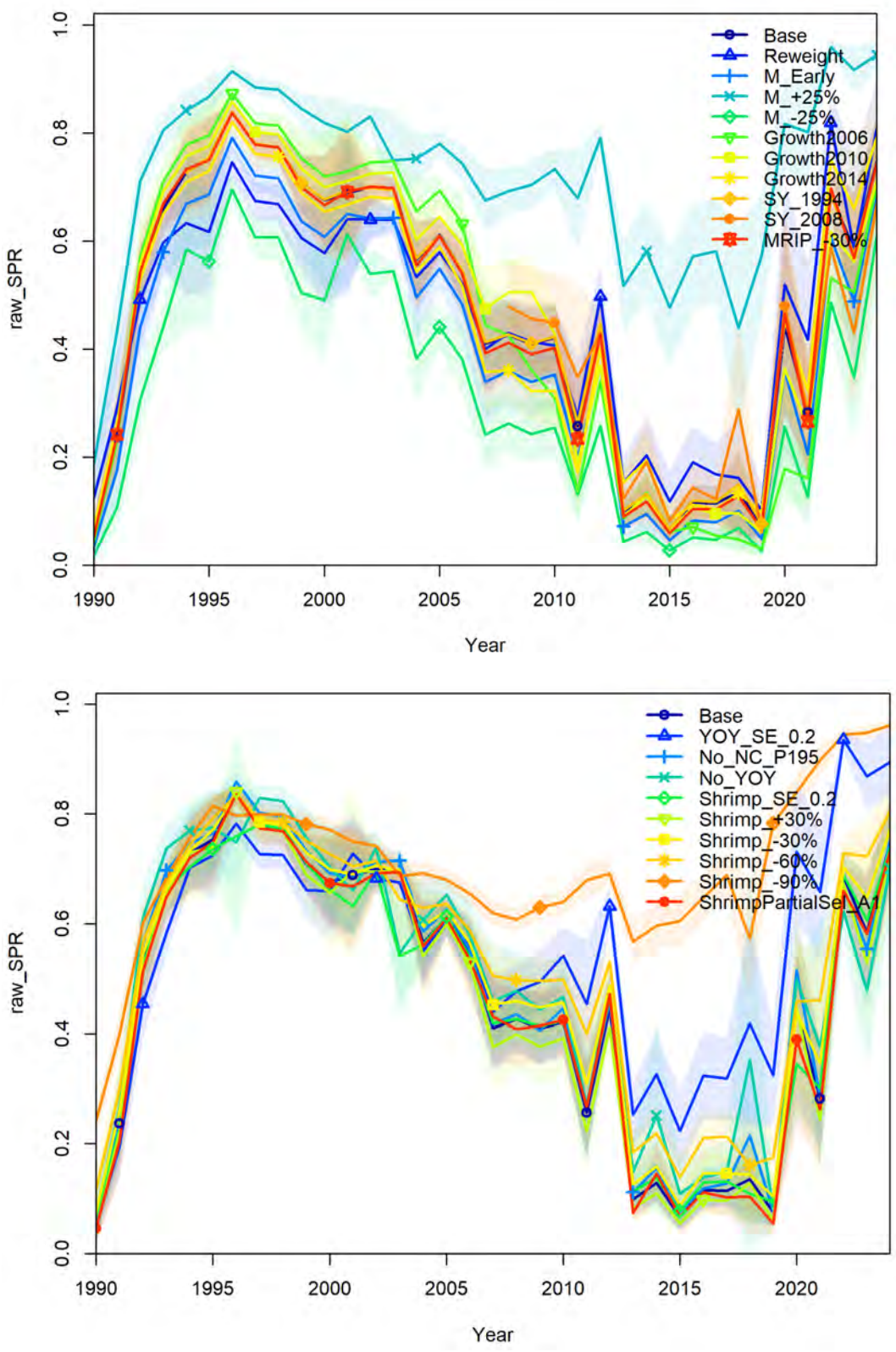


Figure 162. Spawning potential ratio estimates from sensitivity analyses of northern stock SS model.

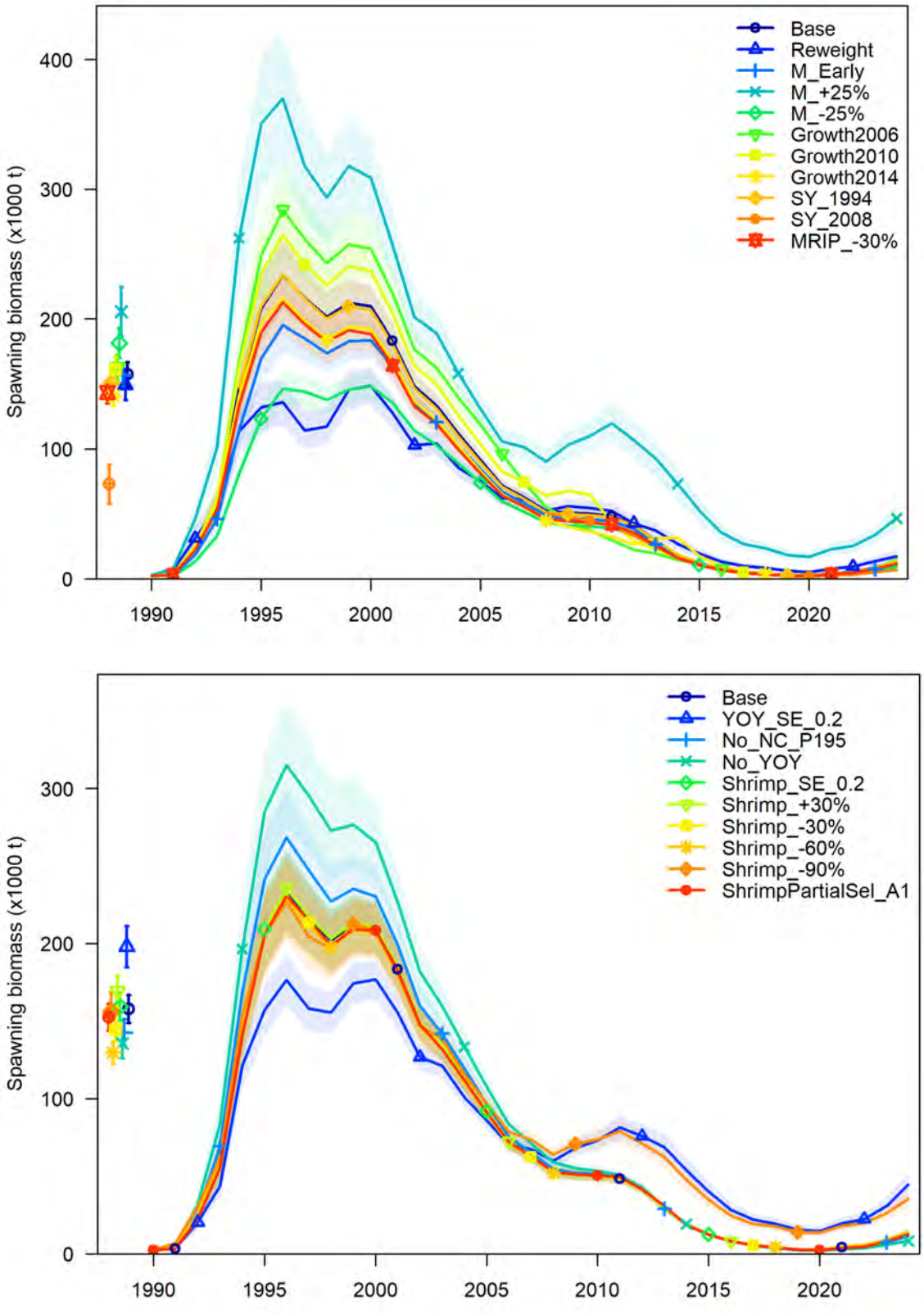


Figure 163. Spawning stock biomass estimates from sensitivity analyses of northern stock SS model.

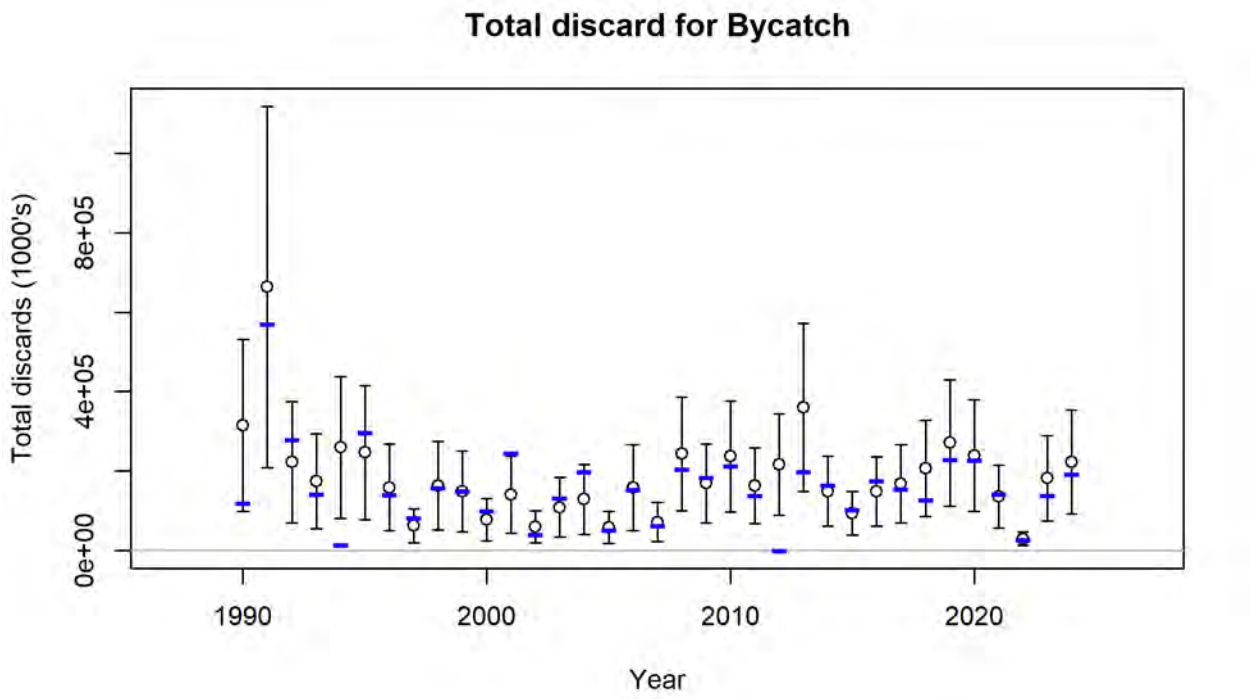


Figure 164. Observed and estimated discards (in 1000's of fish) for the southern stock SS base model.

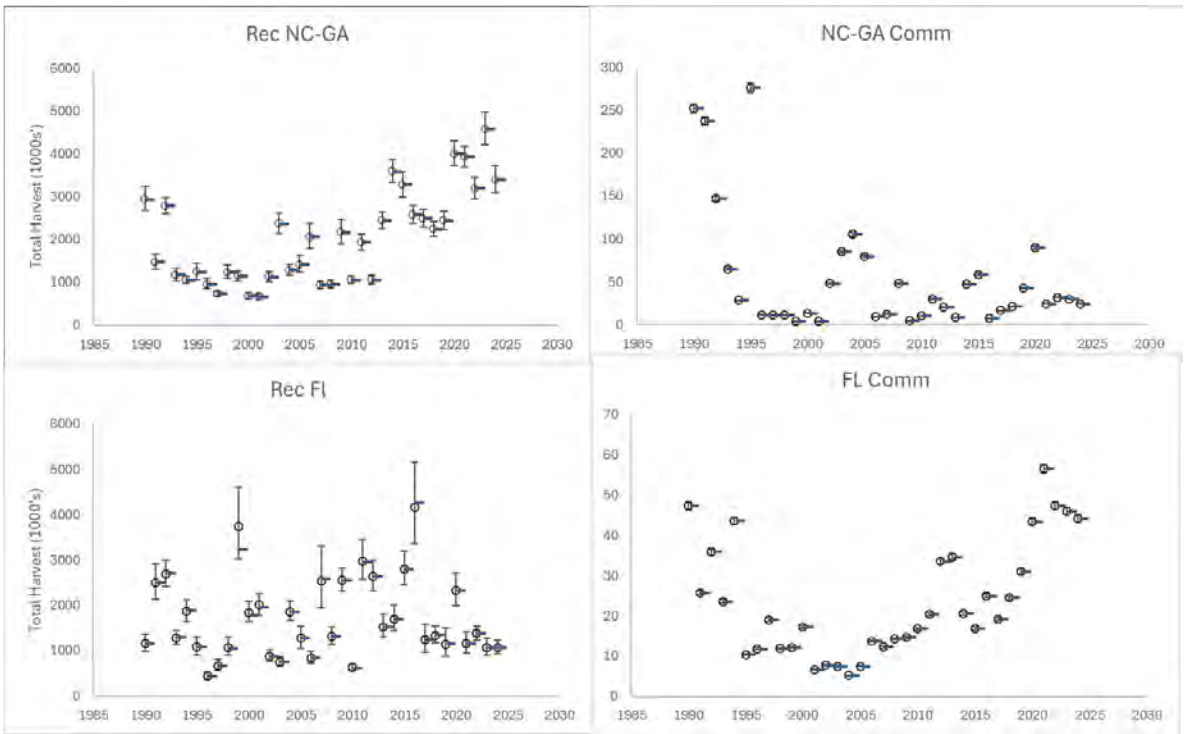


Figure 165. Observed and estimated catches for the NC-GA recreational, NC-GA commercial, FL recreational, and FL commercial fleets for the southern stock SS base model.

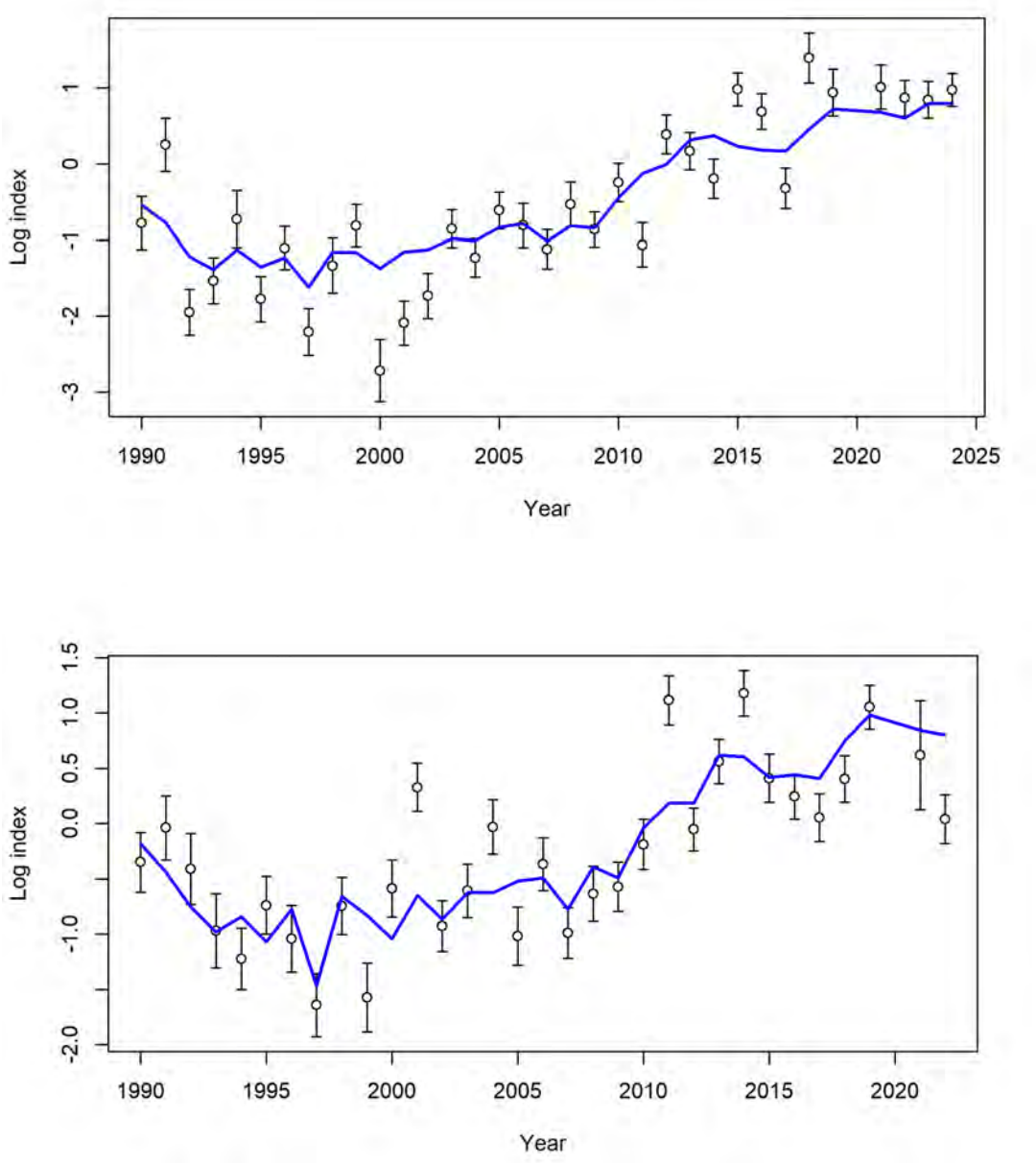


Figure 166. Observed and estimated index values for the SEAMAP fall (top) and SEAMAP summer (bottom) abundance indices for the Southern region SS base model.

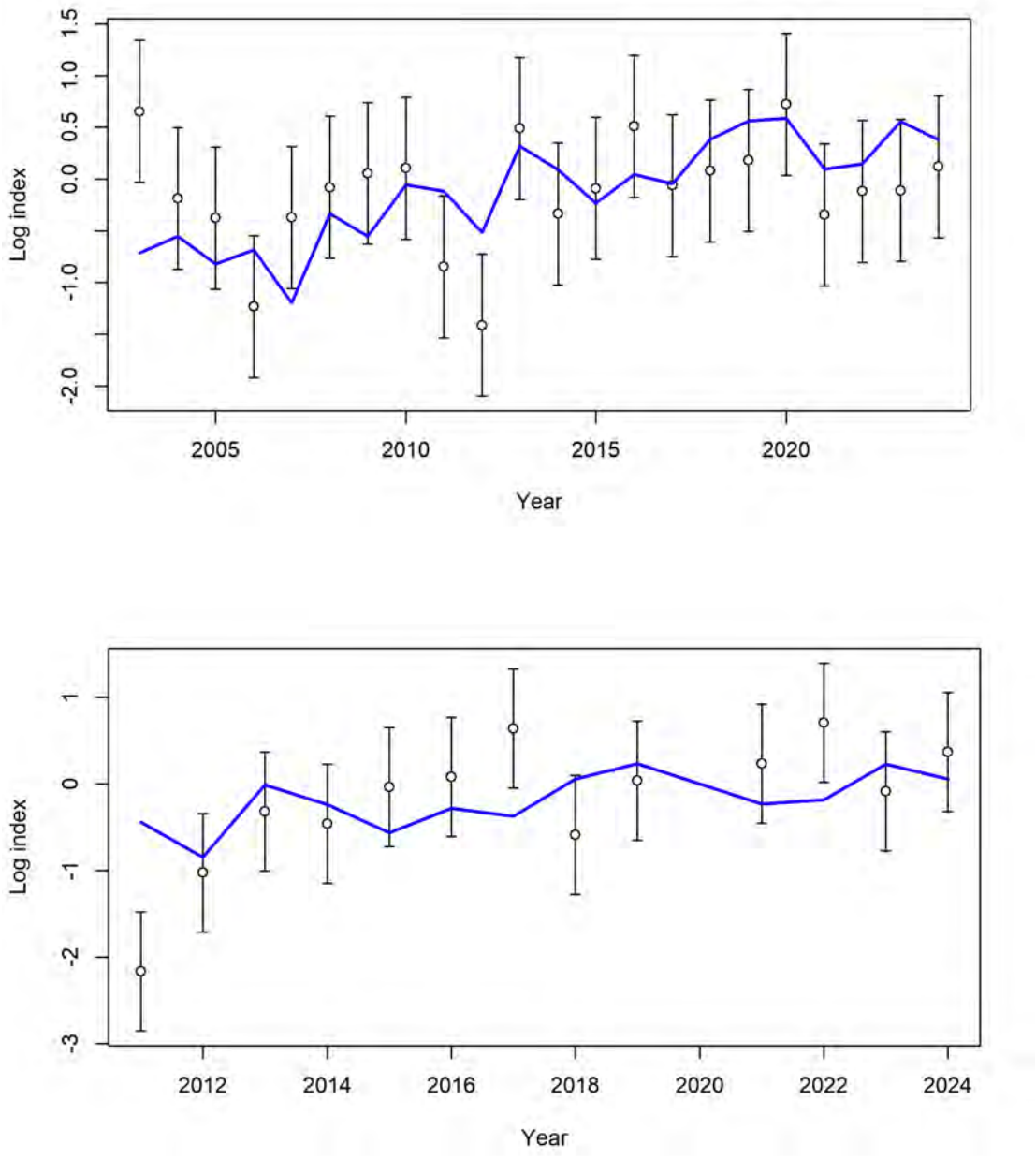


Figure 167. Observed and estimated index values for the Georgia (top) and South Carolina (bottom) young-of-year abundance indices for the Southern region SS base model.

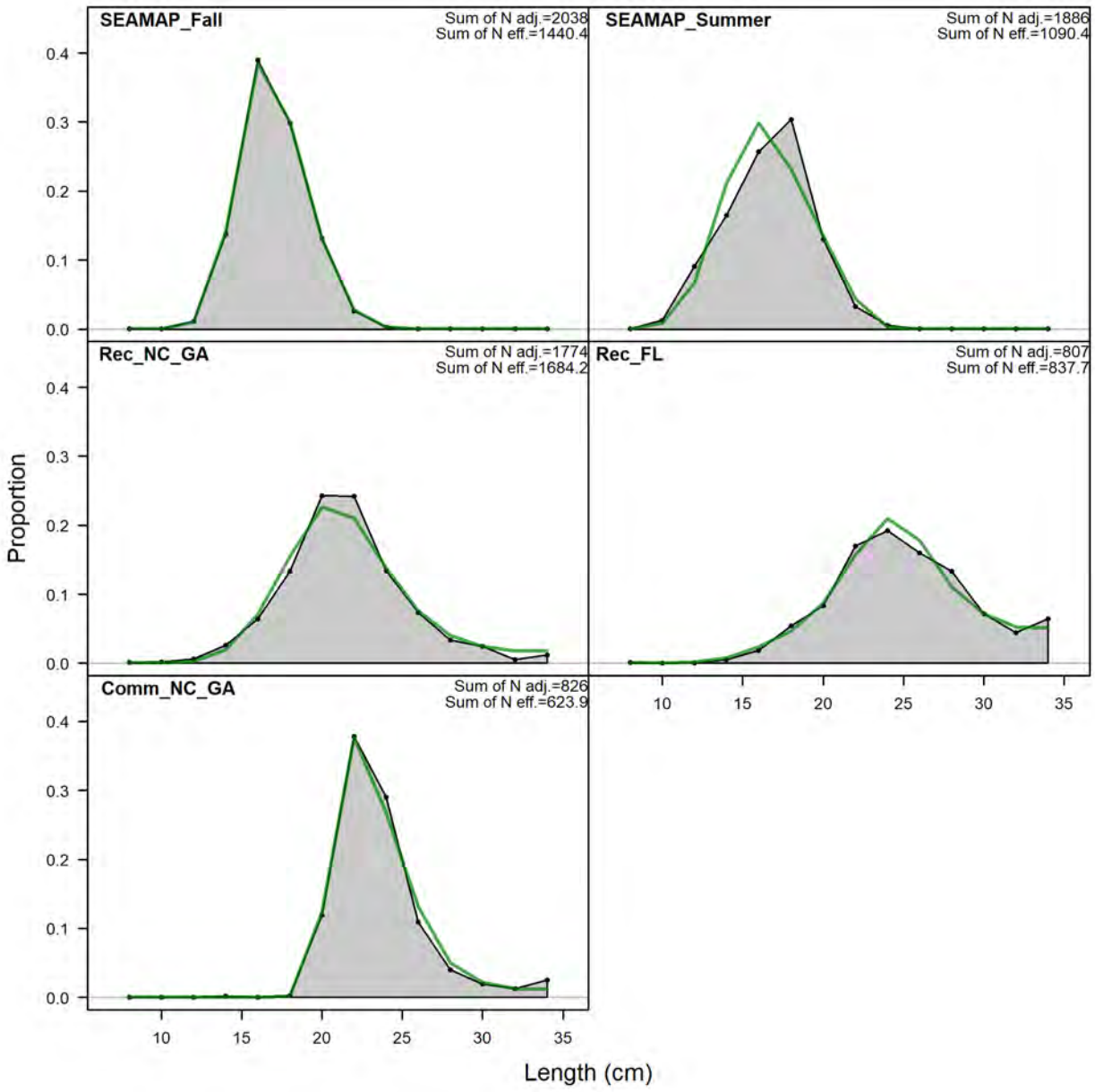


Figure 168. Length compositions, aggregated across time by fleet/survey for the southern stock SS base model.

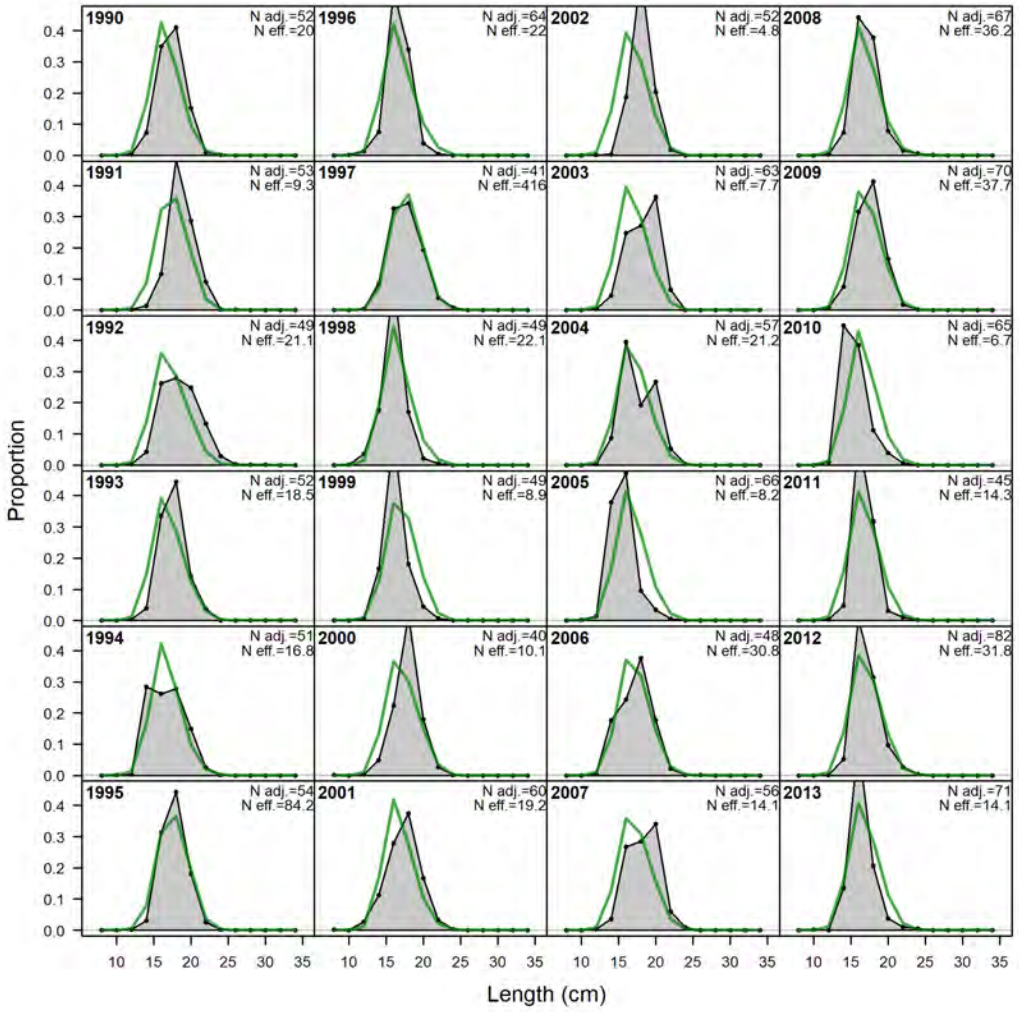


Figure 169. Annual length compositions for the SEAMAP fall fleet for the southern stock SS base model.

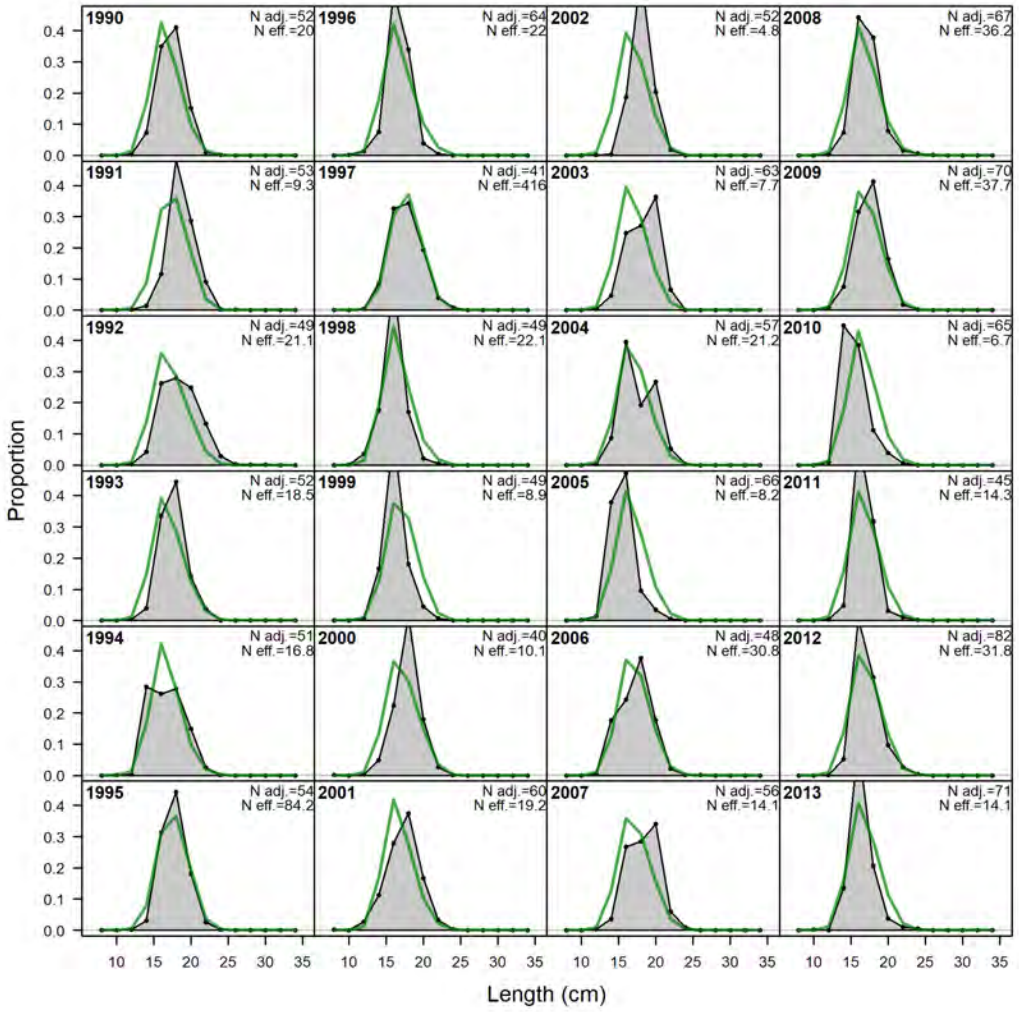


Figure 170. Annual length compositions for the SEAMAP fall fleet for the southern stock SS base model.

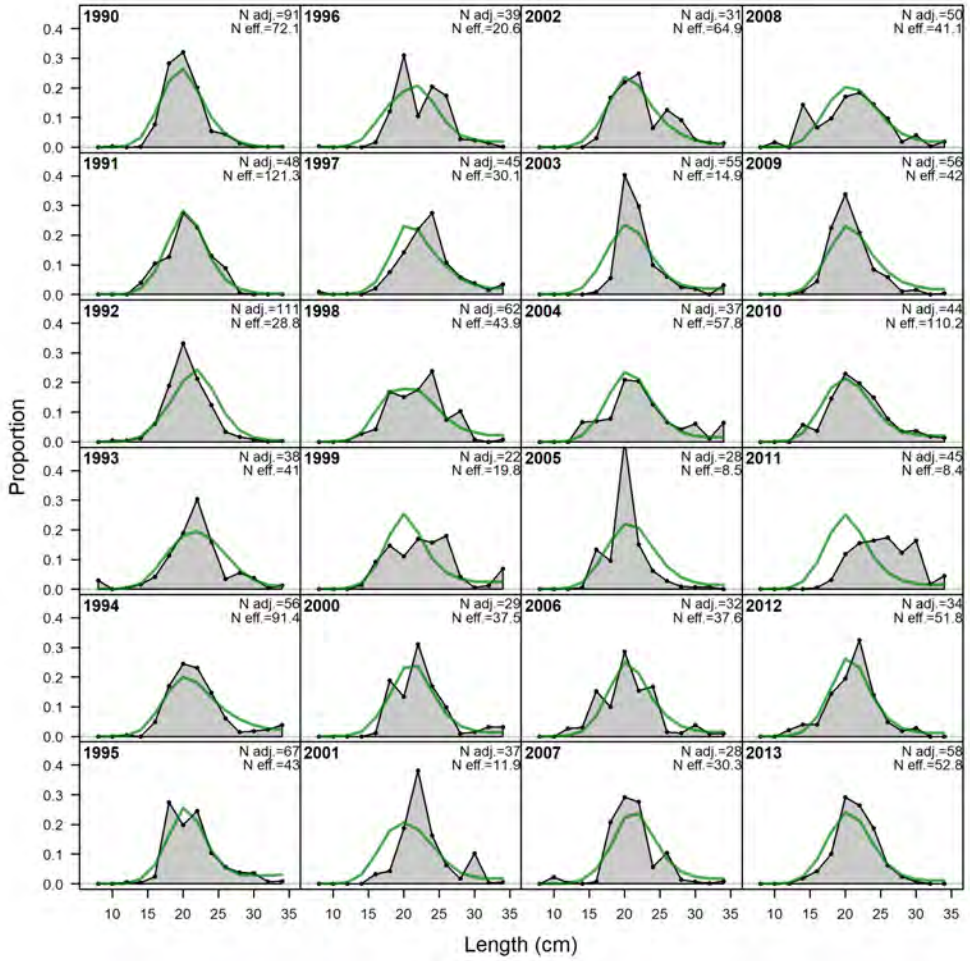


Figure 171. Annual length compositions for the NC-GA recreational fleet for the southern stock SS base model.

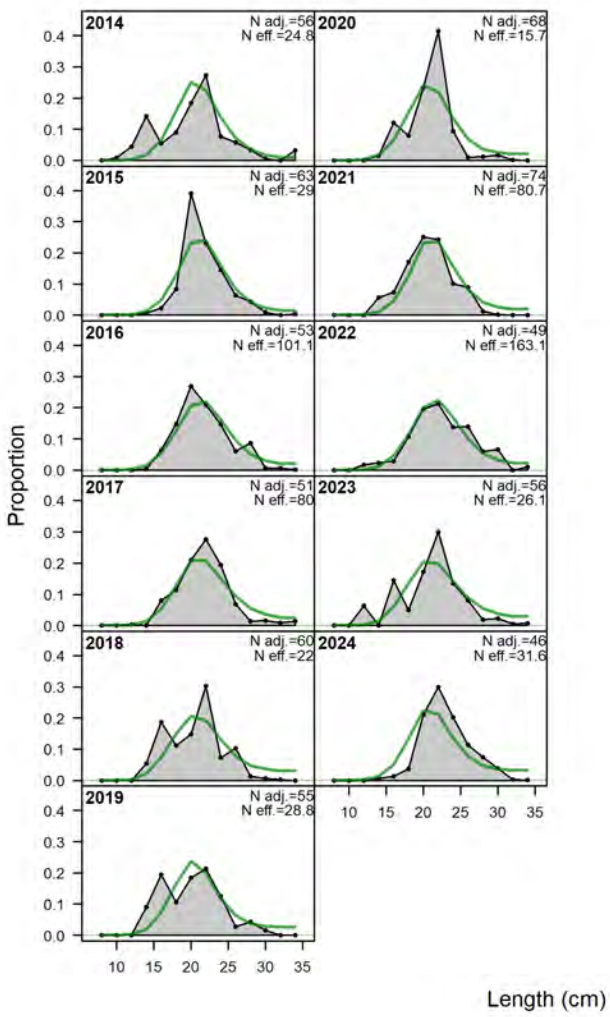


Figure 172. Annual length compositions for the NC-GA recreational fleet for the southern stock SS base model.

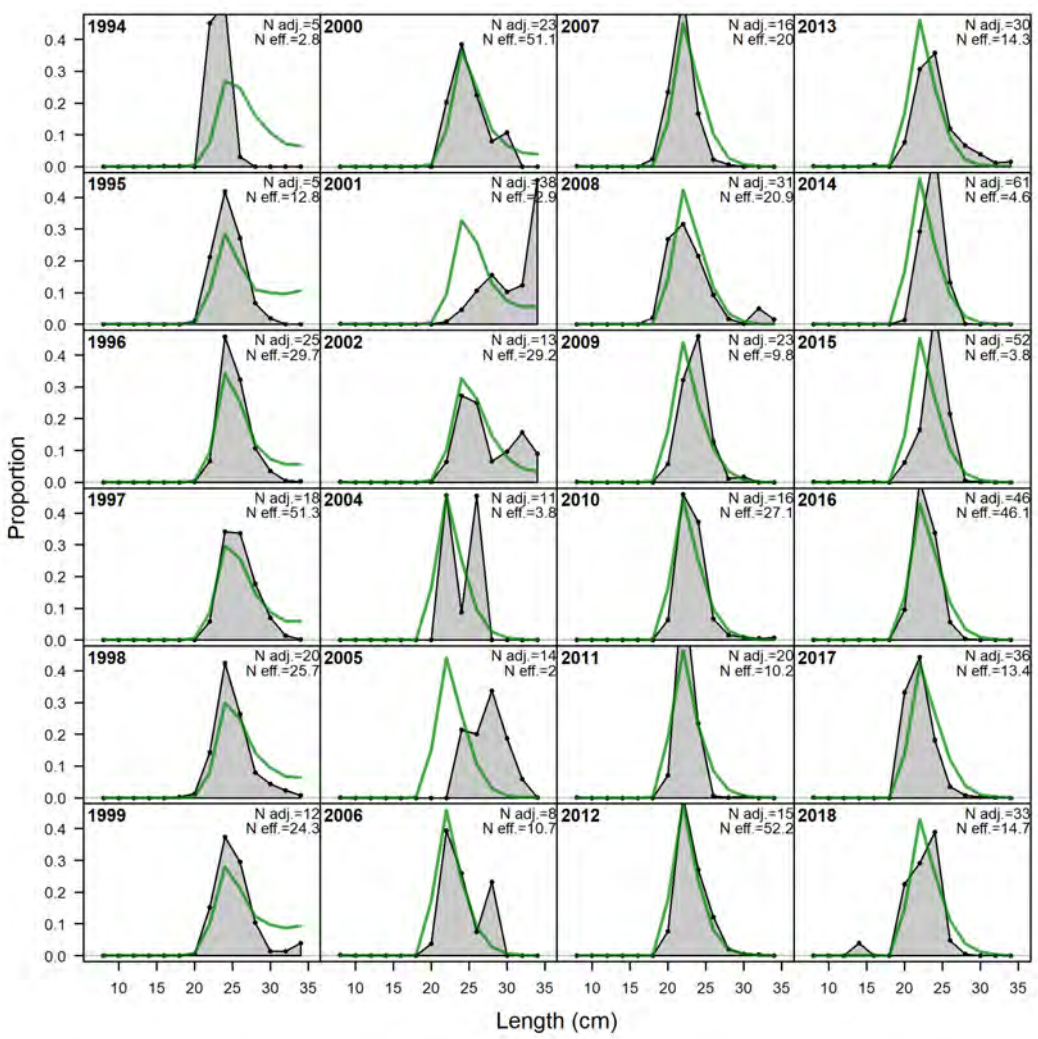


Figure 173. Annual length compositions for the NC-GA commercial fleet for the southern stock SS base model.

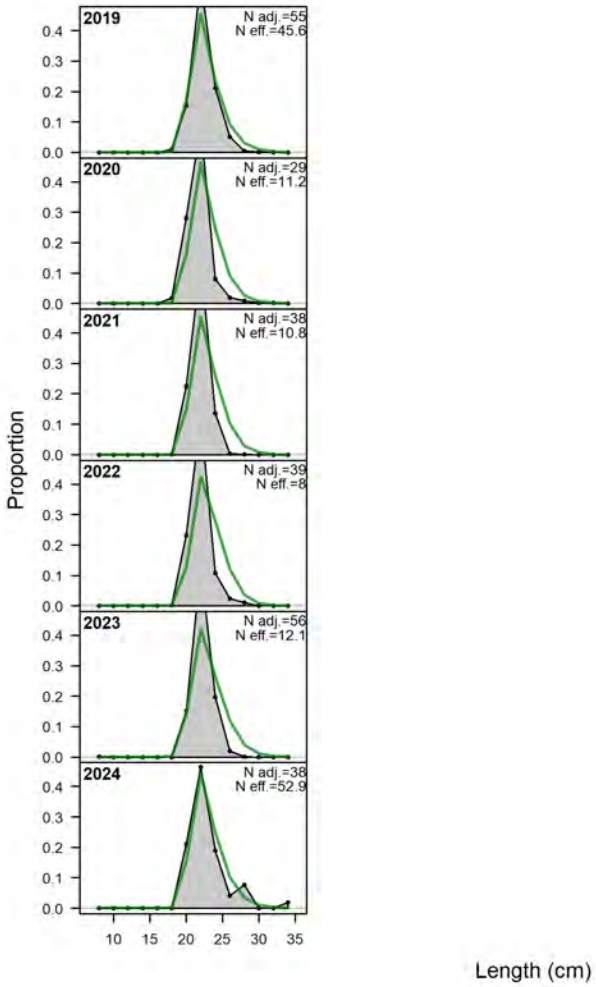


Figure 174. Annual length compositions for the NC-GA commercial fleet for the southern stock SS base model.

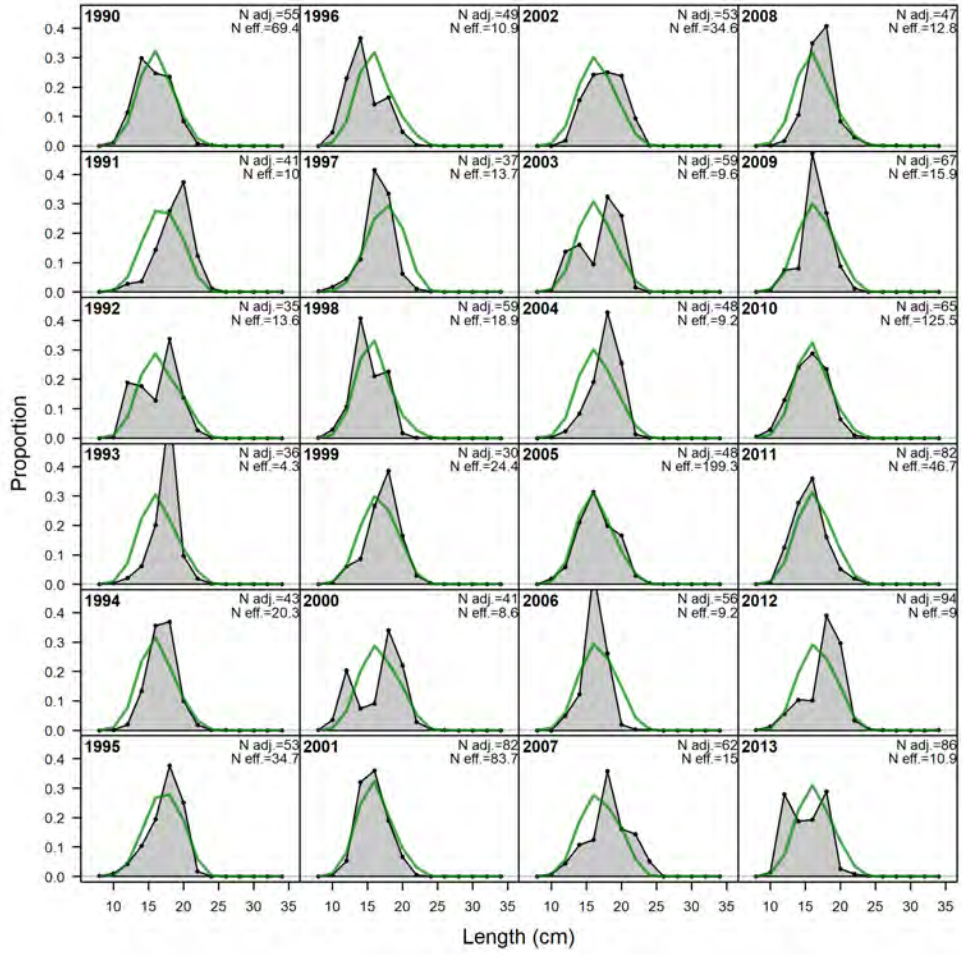


Figure 175. Annual length compositions for the SEAMAP summer fleet for the southern stock SS base model.

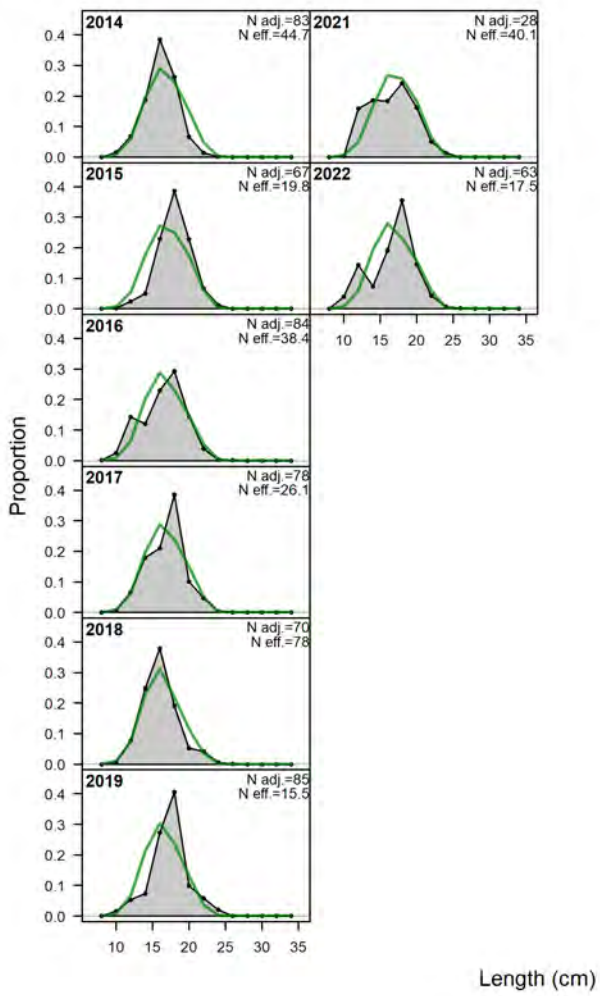


Figure 176. Annual length compositions for the SEAMAP summer fleet for the southern stock SS base model.

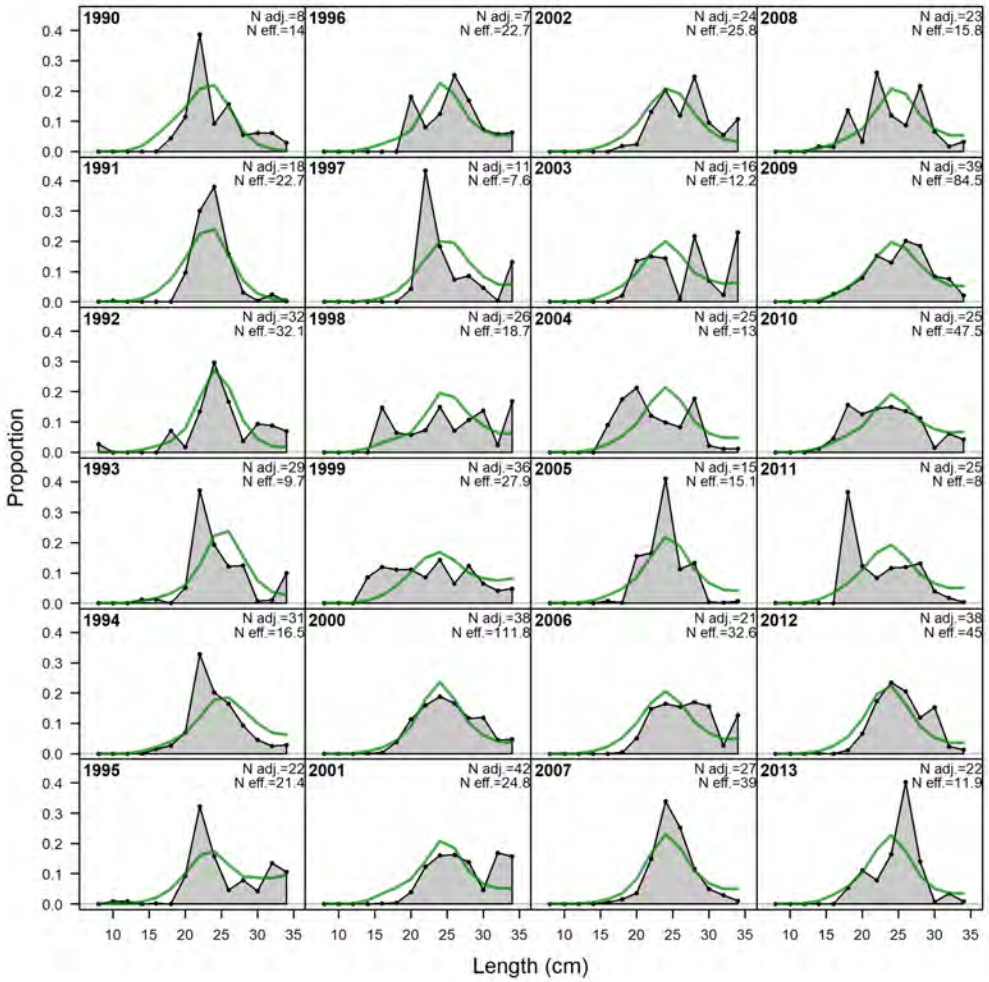


Figure 177. Annual length compositions for the Florida recreational fleet for the southern stock SS base model.

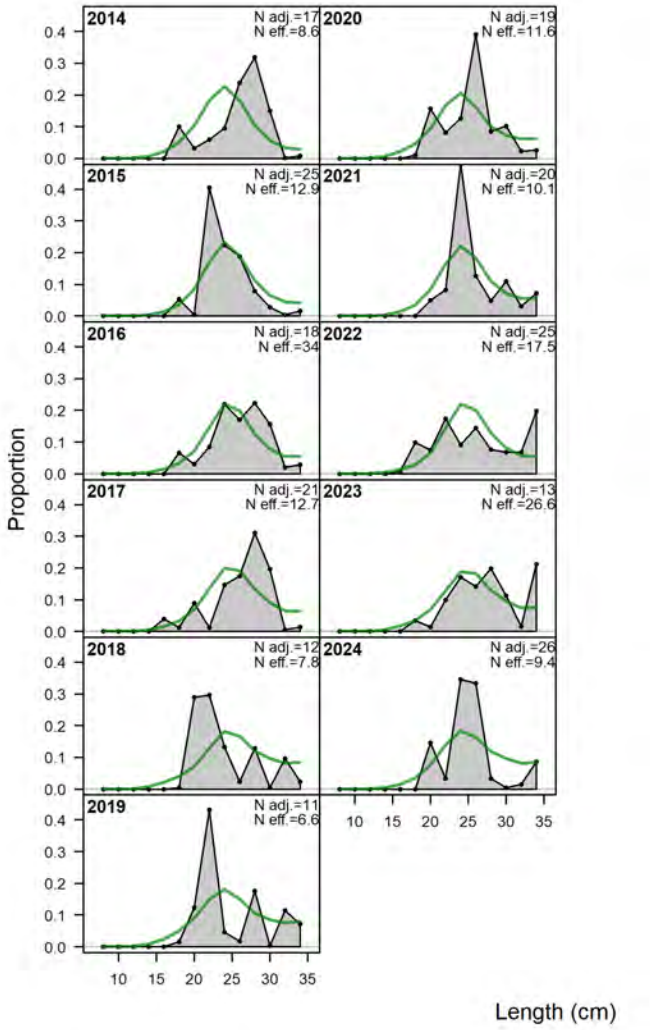


Figure 178. Annual length compositions for the Florida recreational fleet for the southern stock SS base model.

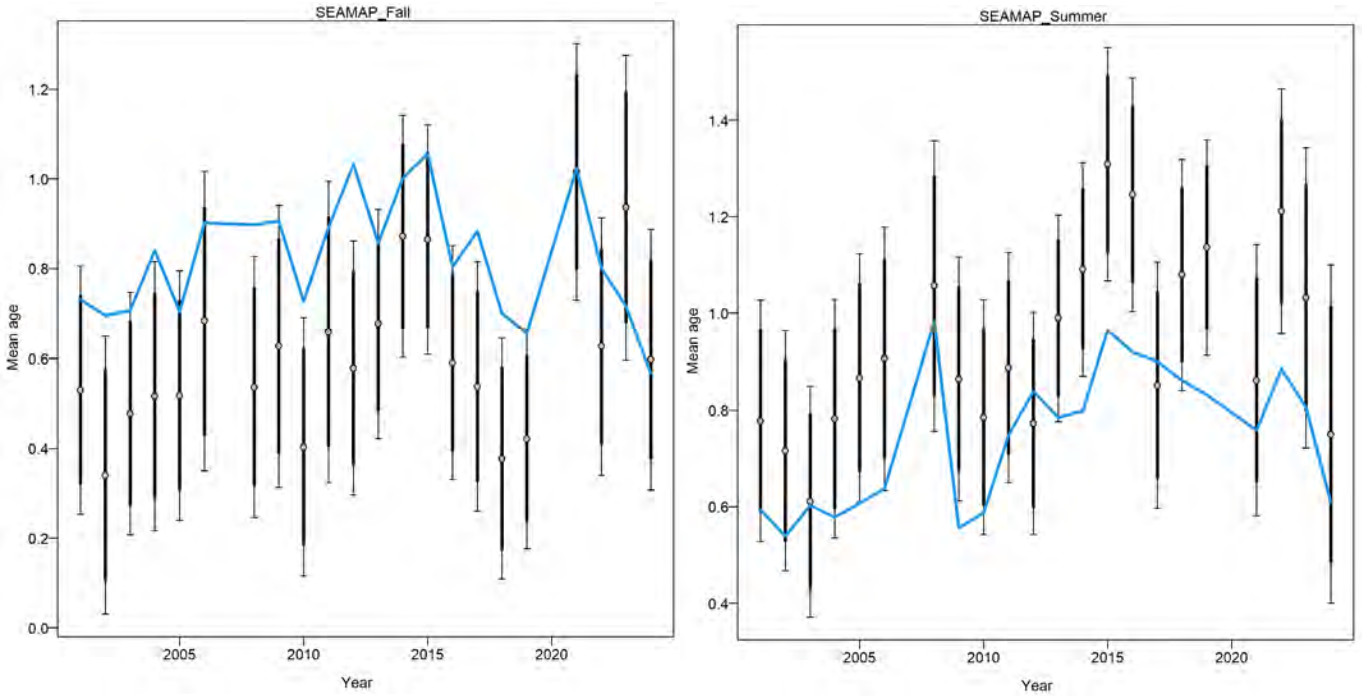


Figure 179. Mean age from the conditional age data for the SEAMAP fall (left) and SEAMAP summer (right) fleets for the southern stock SS base model.

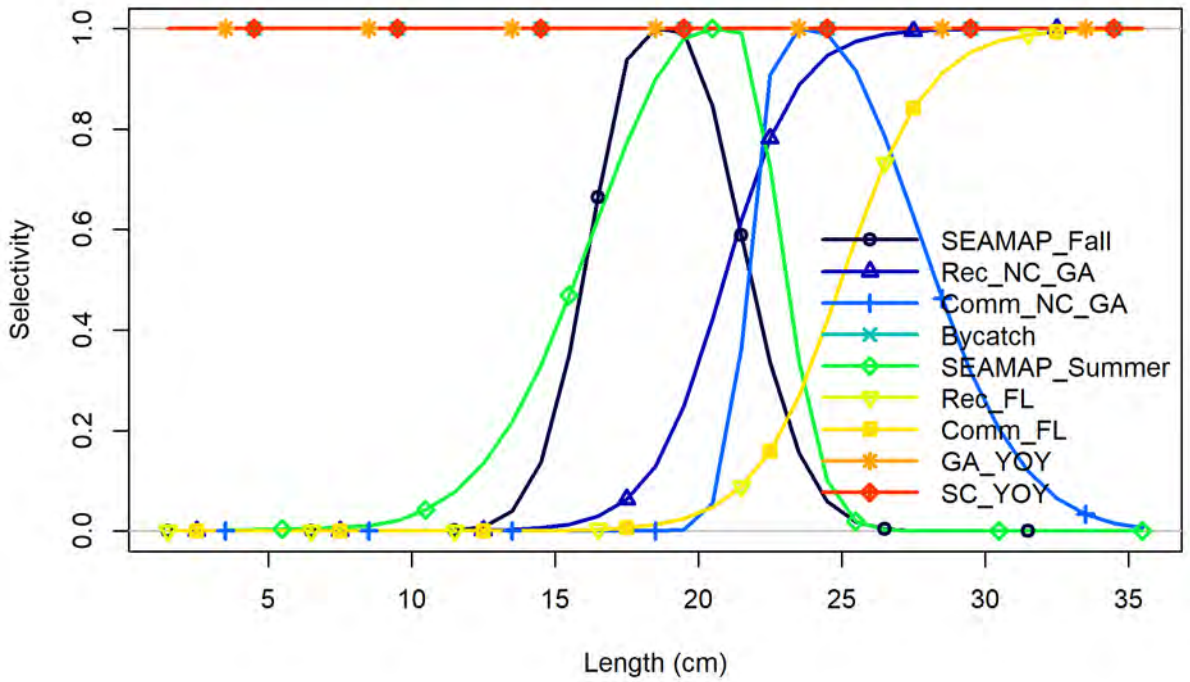


Figure 180. Length based selectivities for the southern stock SS base model.

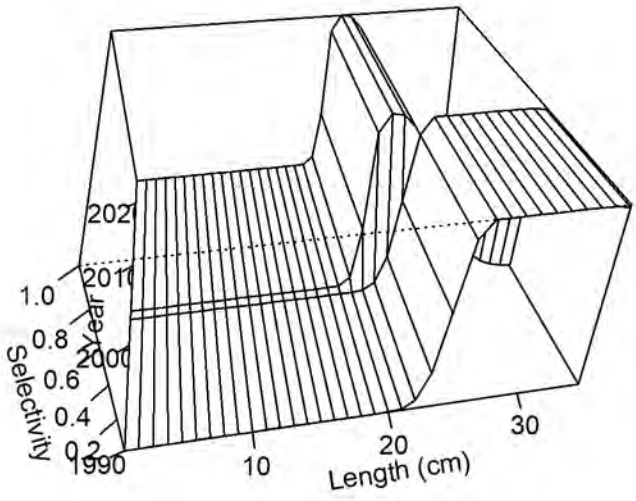


Figure 181. Length based selectivity for NC-GA commercial with two different time blocks.

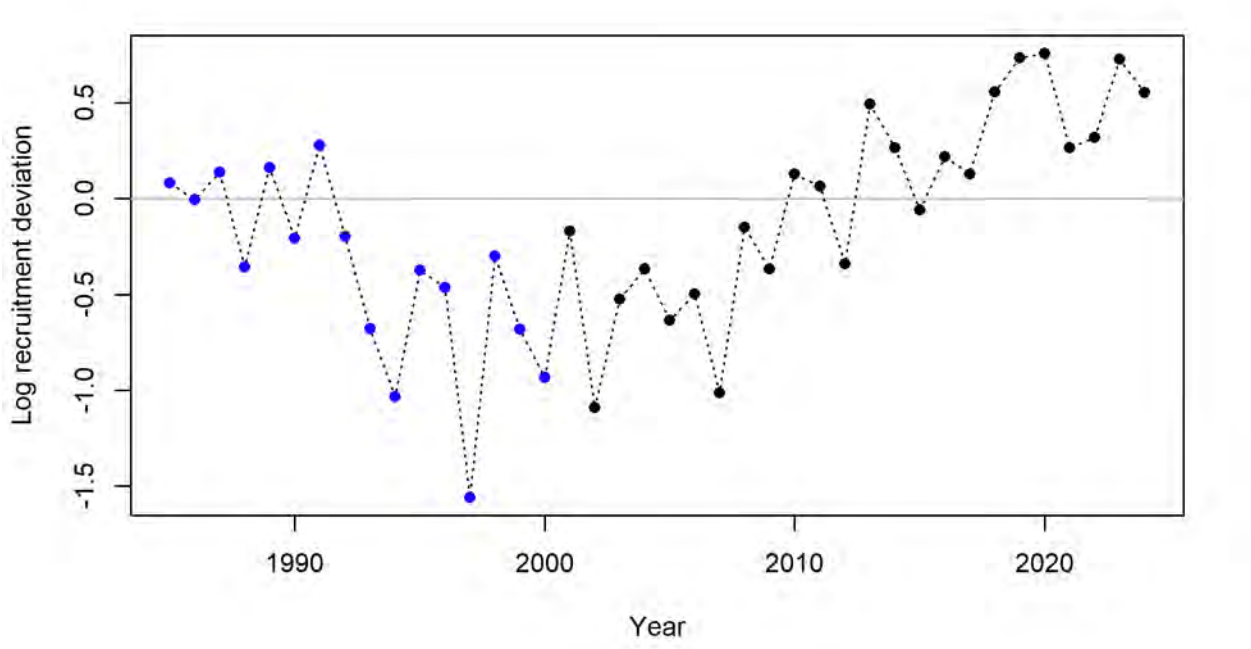


Figure 182. Recruitment deviations for the southern stock SS base model.

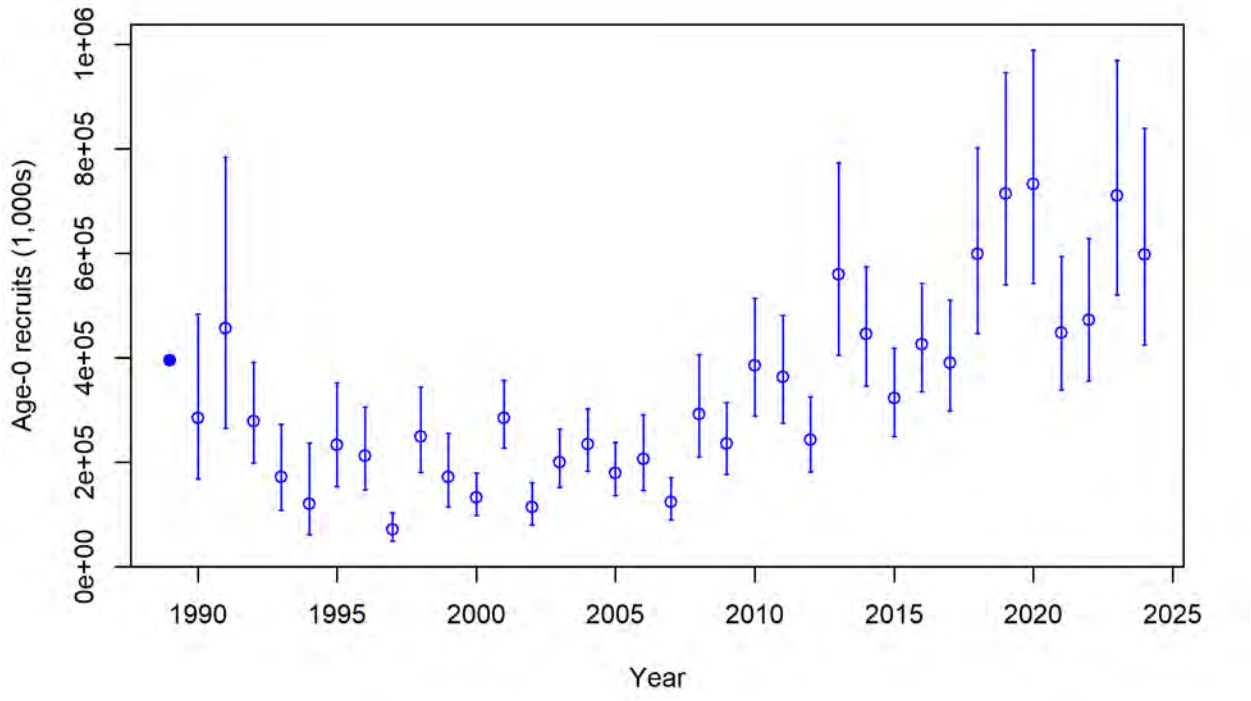


Figure 183. Estimated recruitment (in 1000s) for the southern stock SS base model. Error bars are 95% confidence intervals based on asymptotic standard errors.

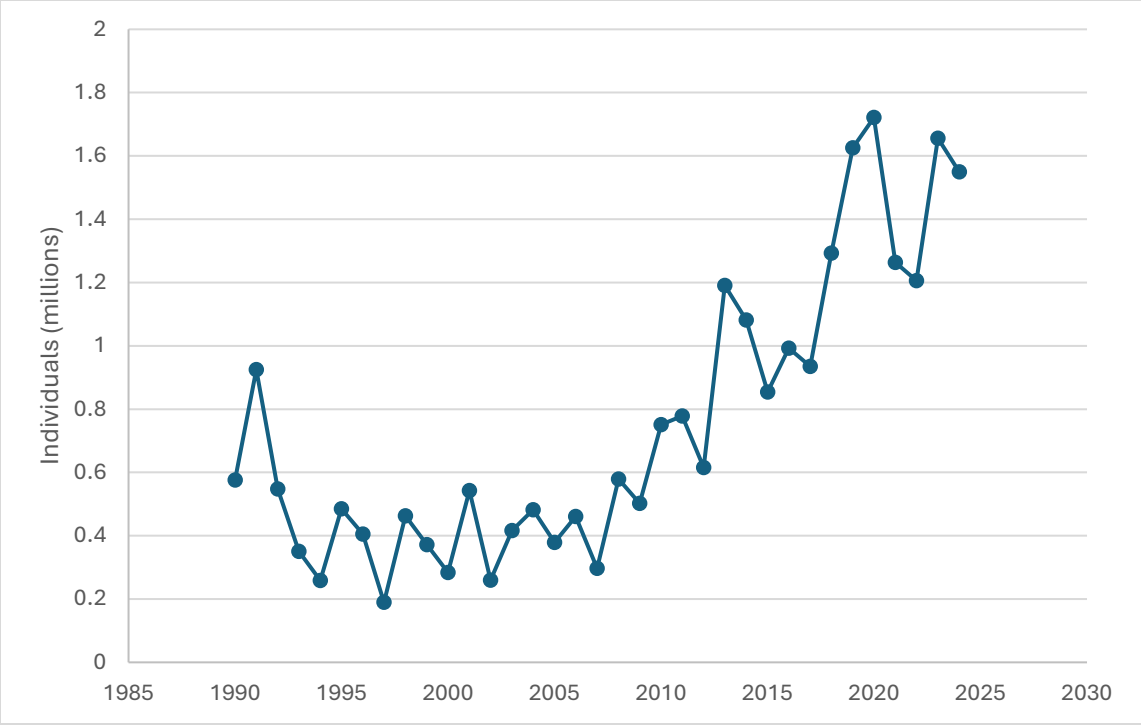


Figure 184. Estimated population abundance (in 1000s of fish) for the southern stock SS base model.

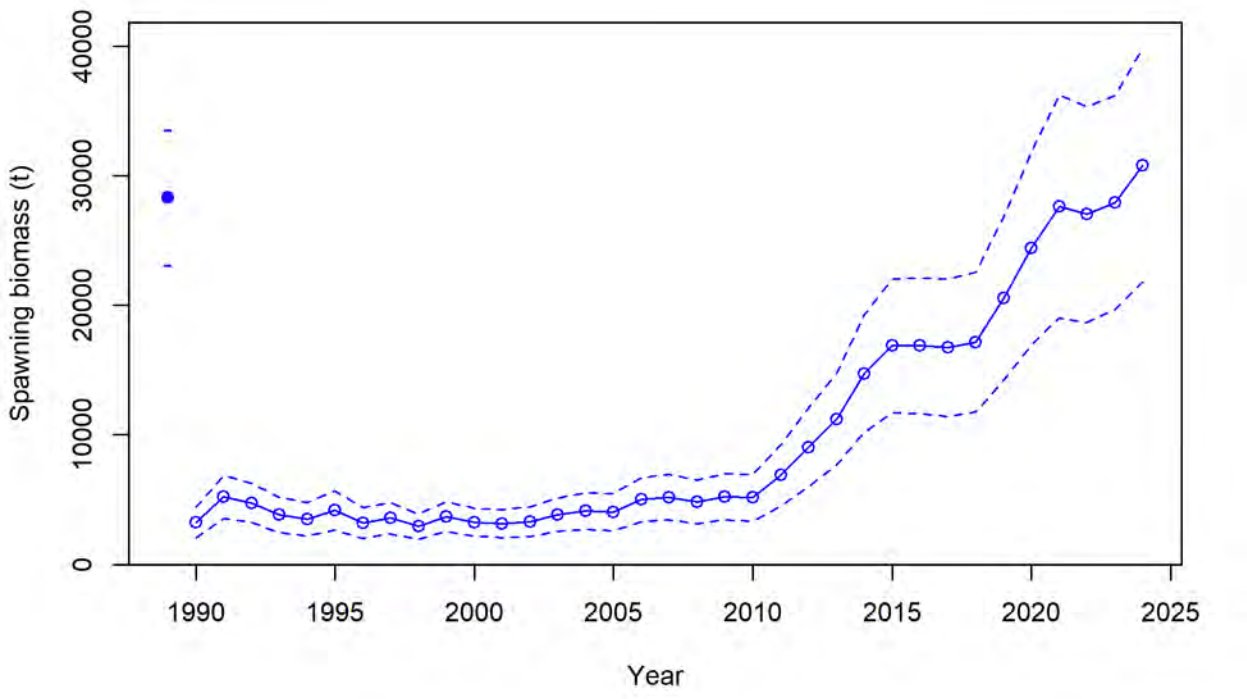


Figure 185. Estimated female SSB (metric tons) for the southern stock SS base model. Error bars are 95% confidence intervals based on asymptotic standard errors.

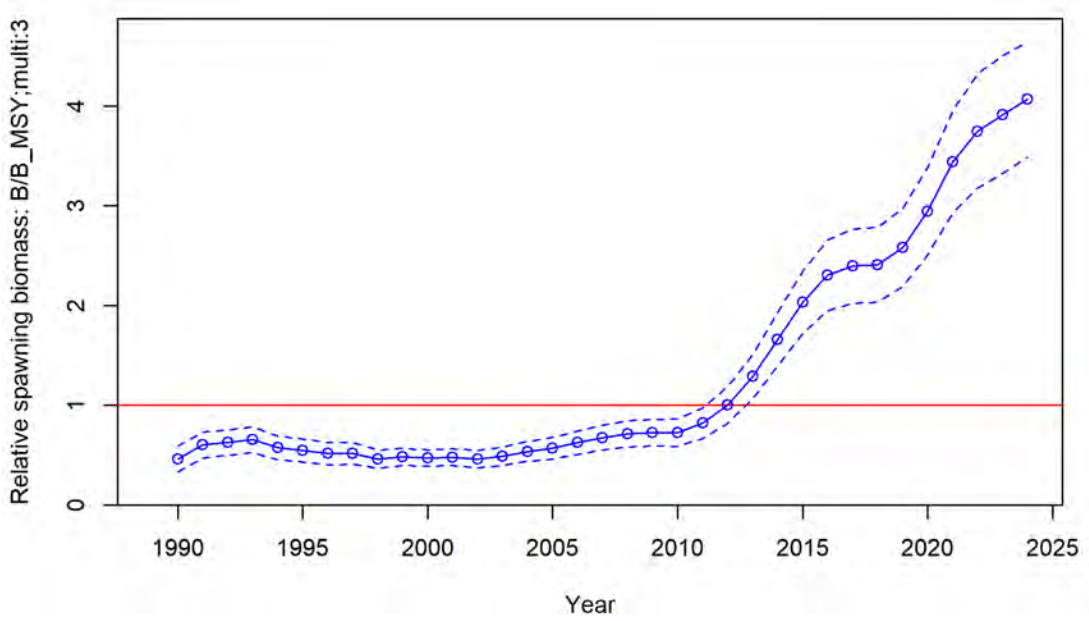


Figure 186. Estimated female SSB relative to the estimated $SSB_{SPR25\%}$ threshold for the southern stock SS base model. Error bars are 95% confidence intervals based on asymptotic standard errors.

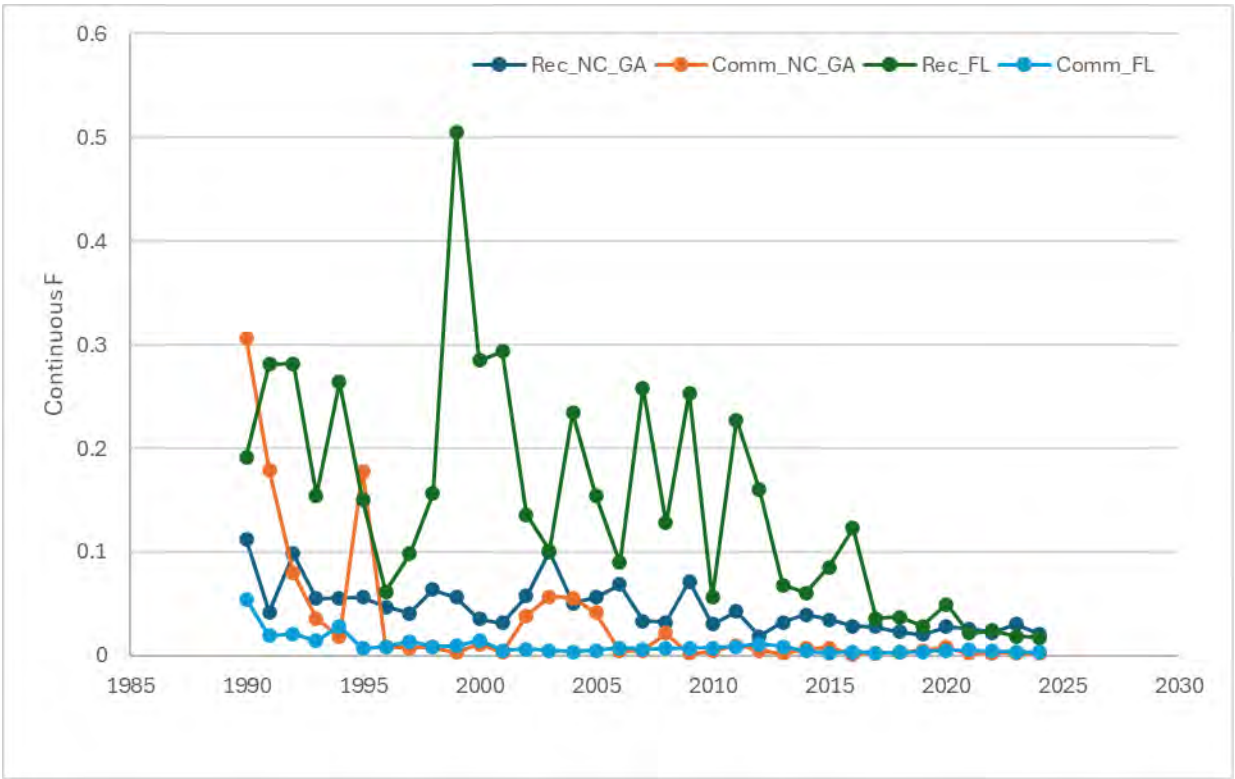


Figure 187. Estimated fleet-specific fishing mortality (F) for the southern stock SS base model.

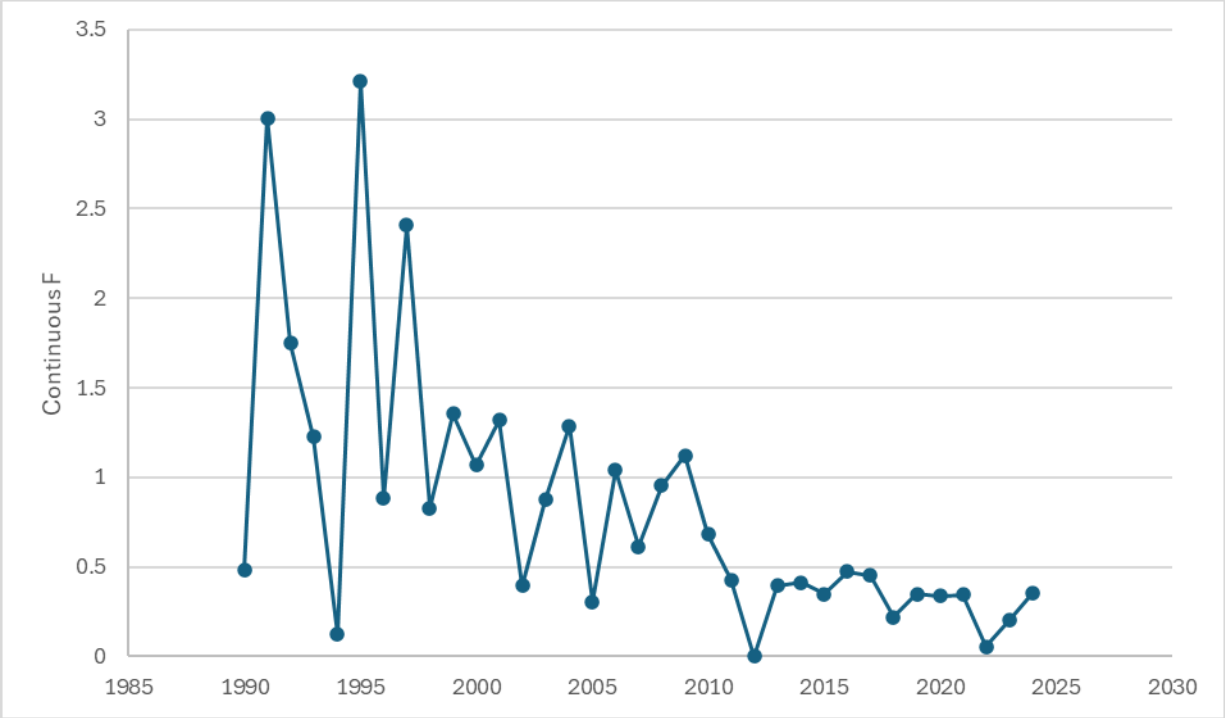


Figure 188. Estimated fishing mortality for the shrimp trawl discards, the bycatch fleet.

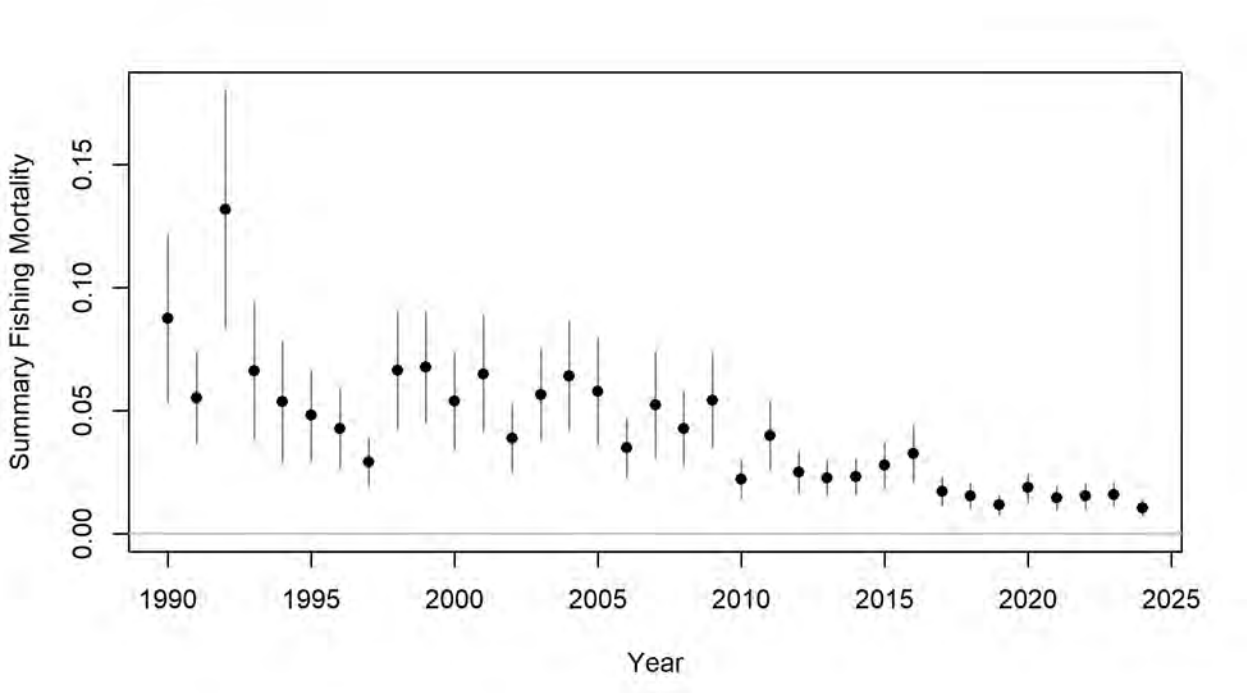


Figure 189. Average age-1-age-3 fishing mortality (F) for the southern stock SS base model. Error bars are 95% confidence intervals based on asymptotic standard errors.

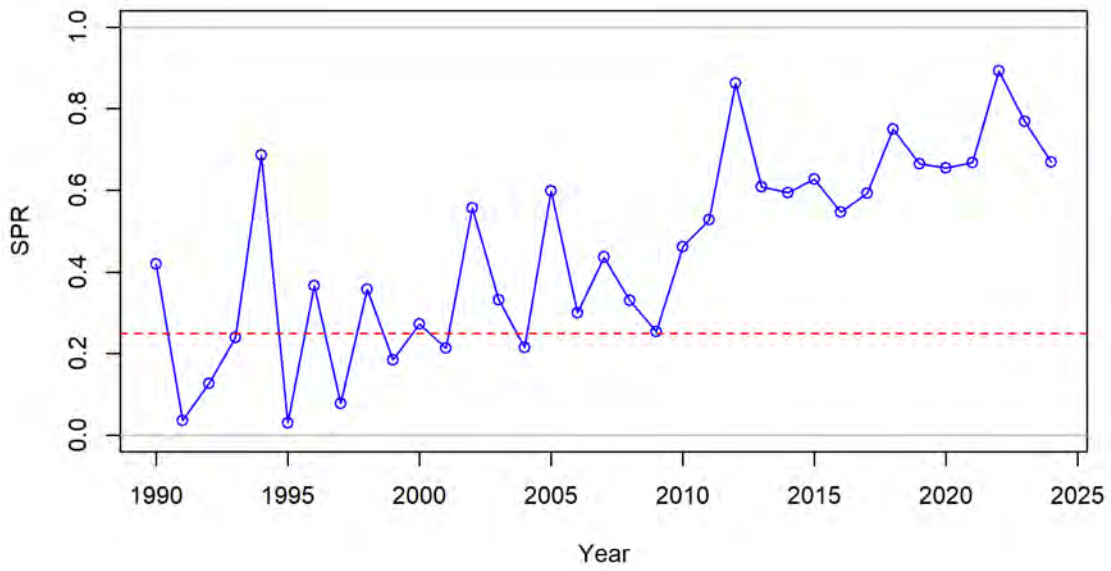


Figure 190. SPR timeseries for the southern stock SS base model. Horizontal line is the SPR target (0.25).

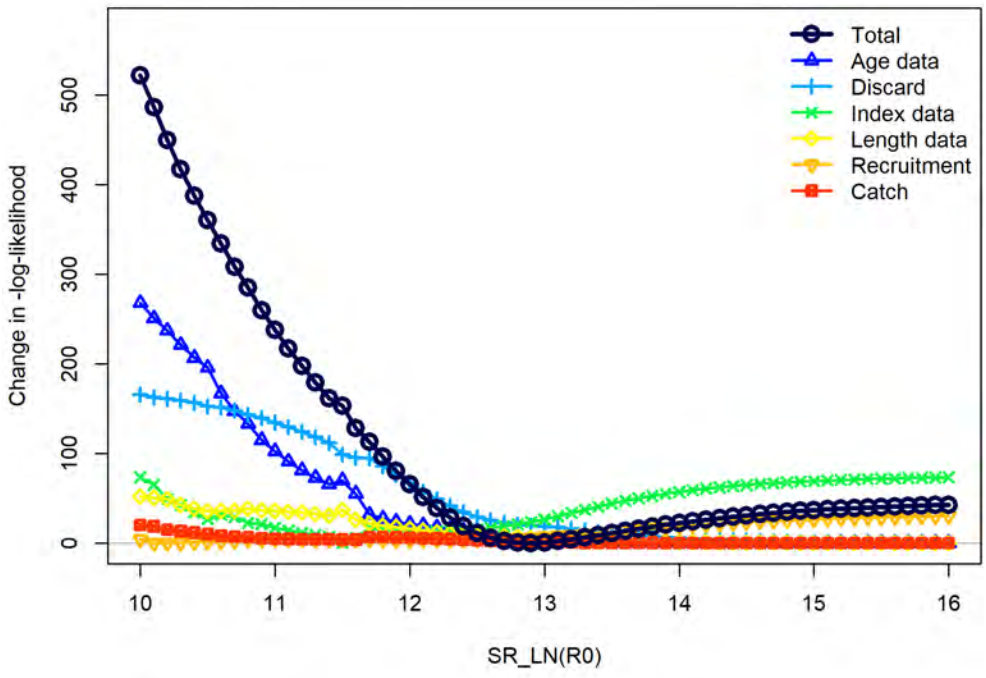


Figure 191. Likelihood profile plot for unfished recruitment (R0) parameter (on the log scale) for the southern stock SS model.

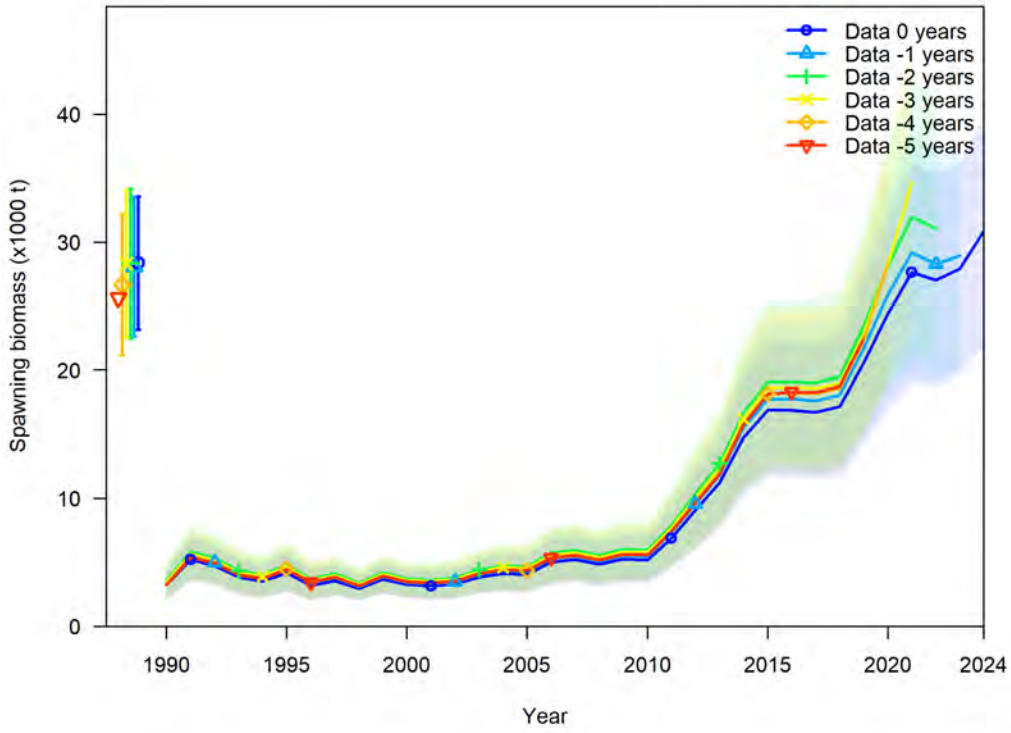


Figure 192. Spawning stock biomass estimates from retrospective analysis of southern stock SS model.

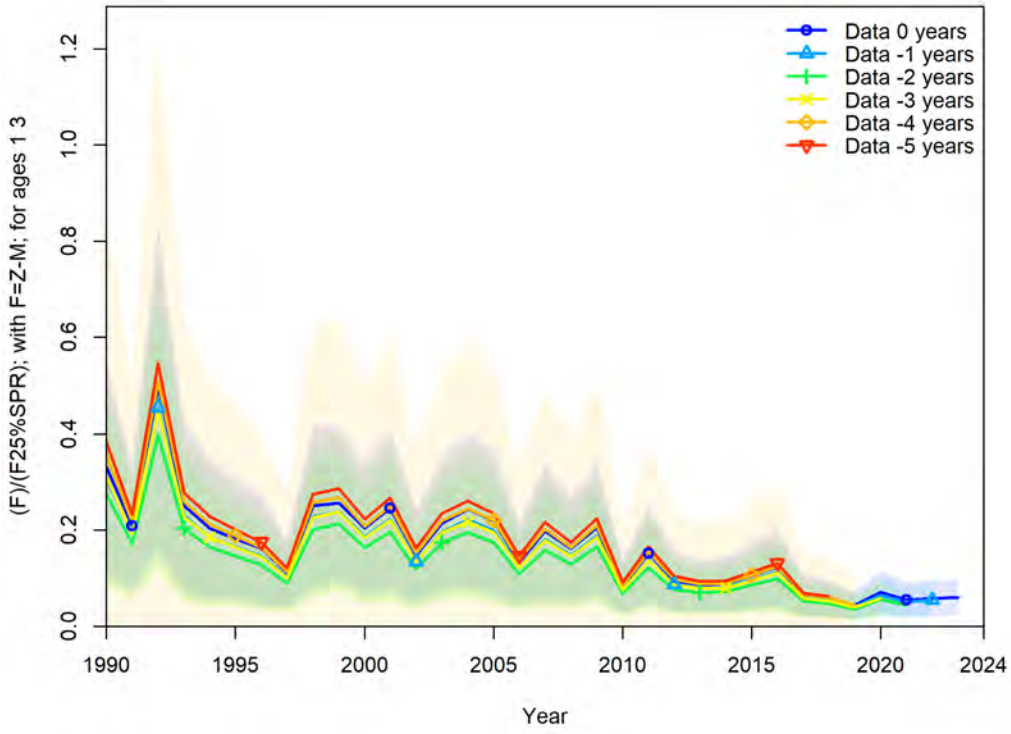


Figure 193. Fishing mortality estimates from retrospective analysis of southern stock SS model.

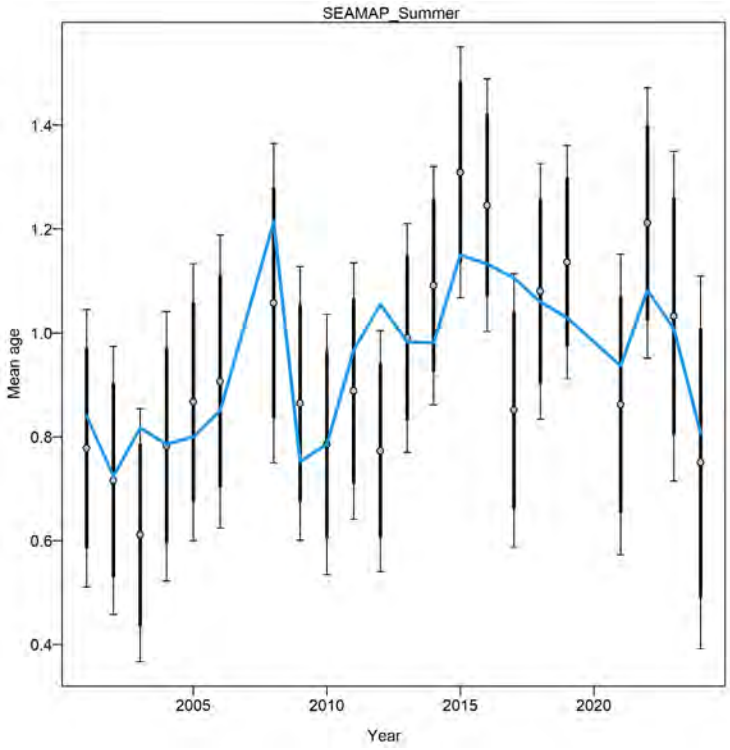


Figure 194. Fit to SEAMAP summer conditional-age-at-length data for sensitivity analysis with model only fit to SEAMAP summer data, i.e., excluding SEAMAP fall conditional-age-at-length data.

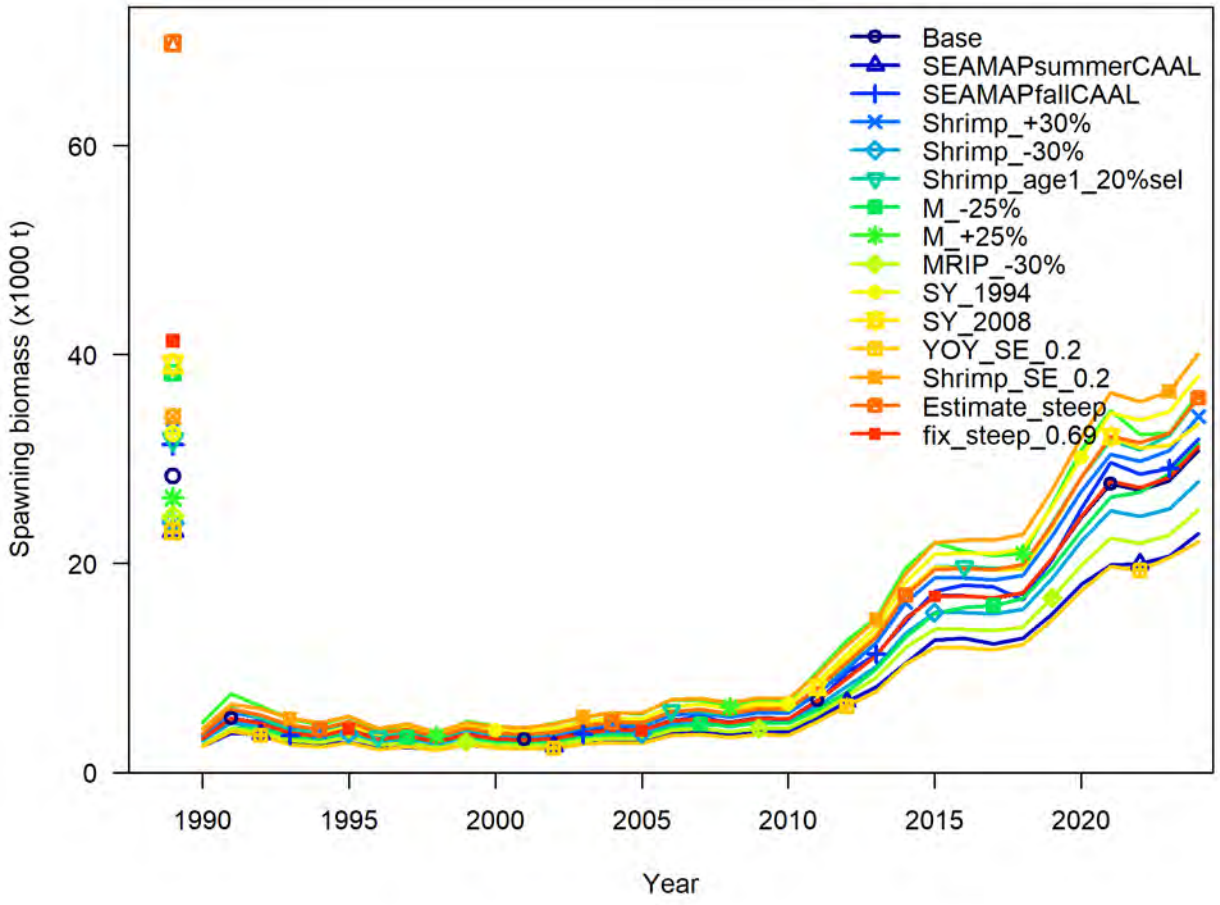


Figure 195. Spawning stock biomass estimates from sensitivity analysis of southern stock SS model.

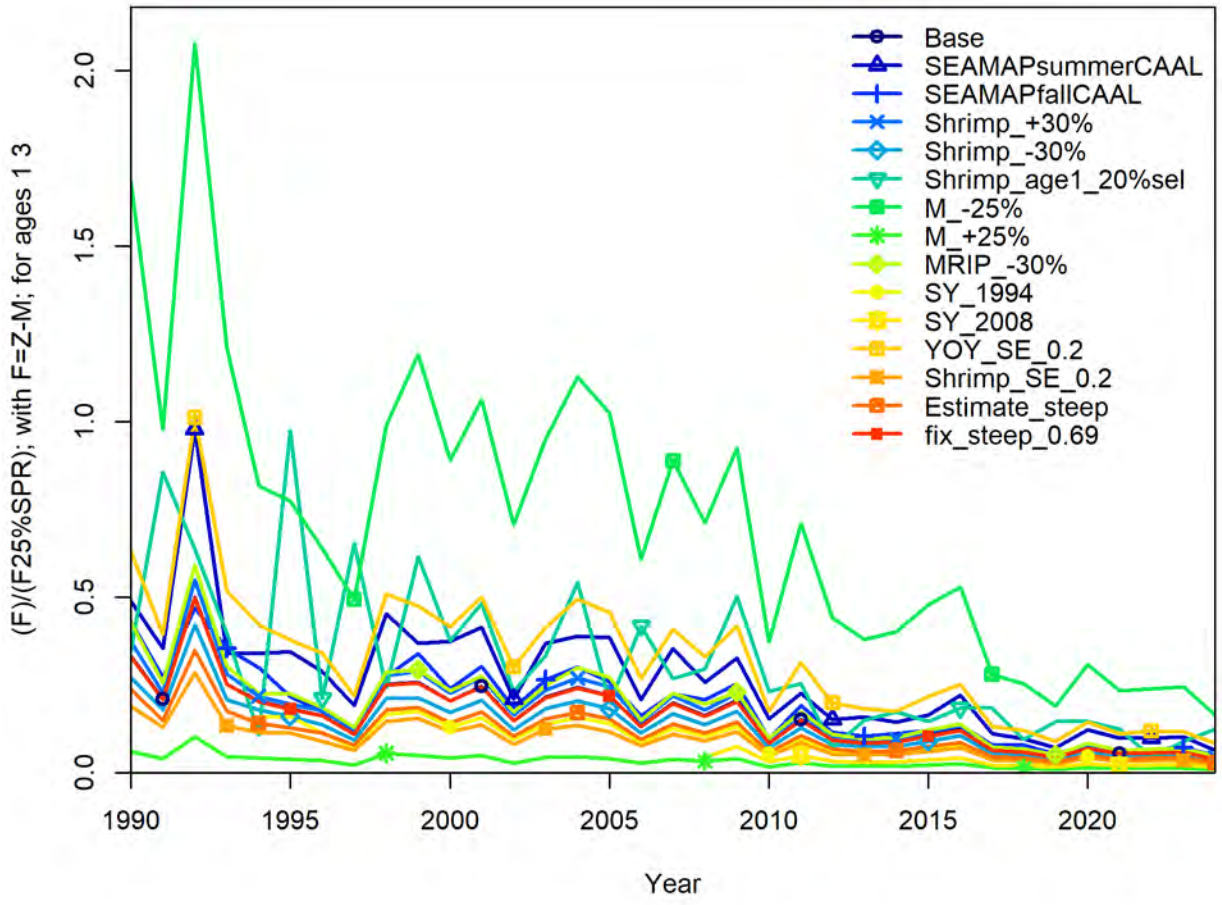


Figure 196. Fishing mortality estimates from sensitivity analysis of southern stock SS model.

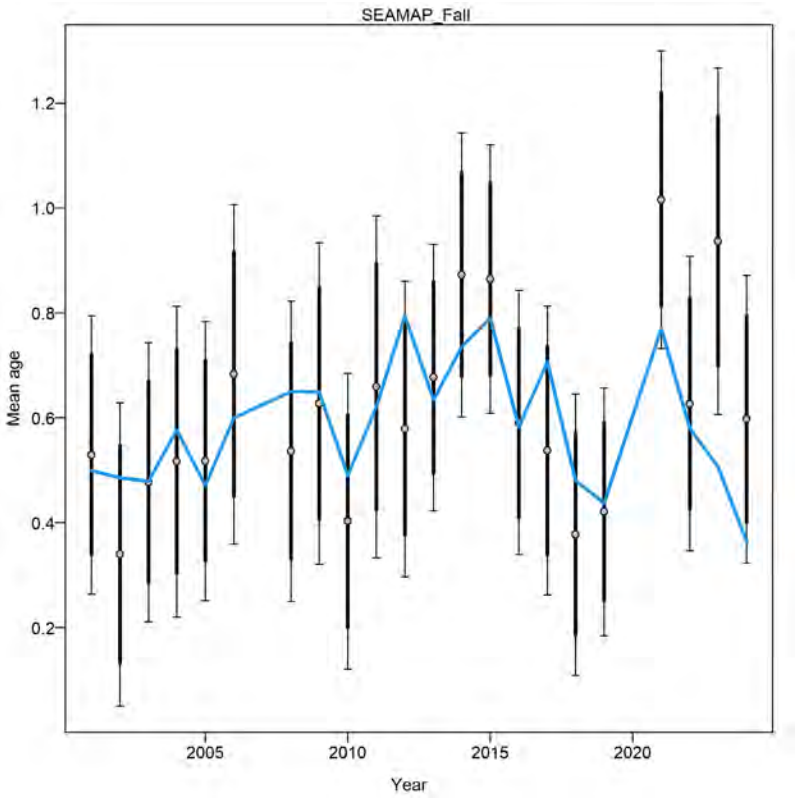


Figure 197. Fit to SEAMAP fall conditional-age-at-length data for sensitivity analysis with model only fit to SEAMAP fall data, i.e., excluding SEAMAP summer conditional-age-at-length data.

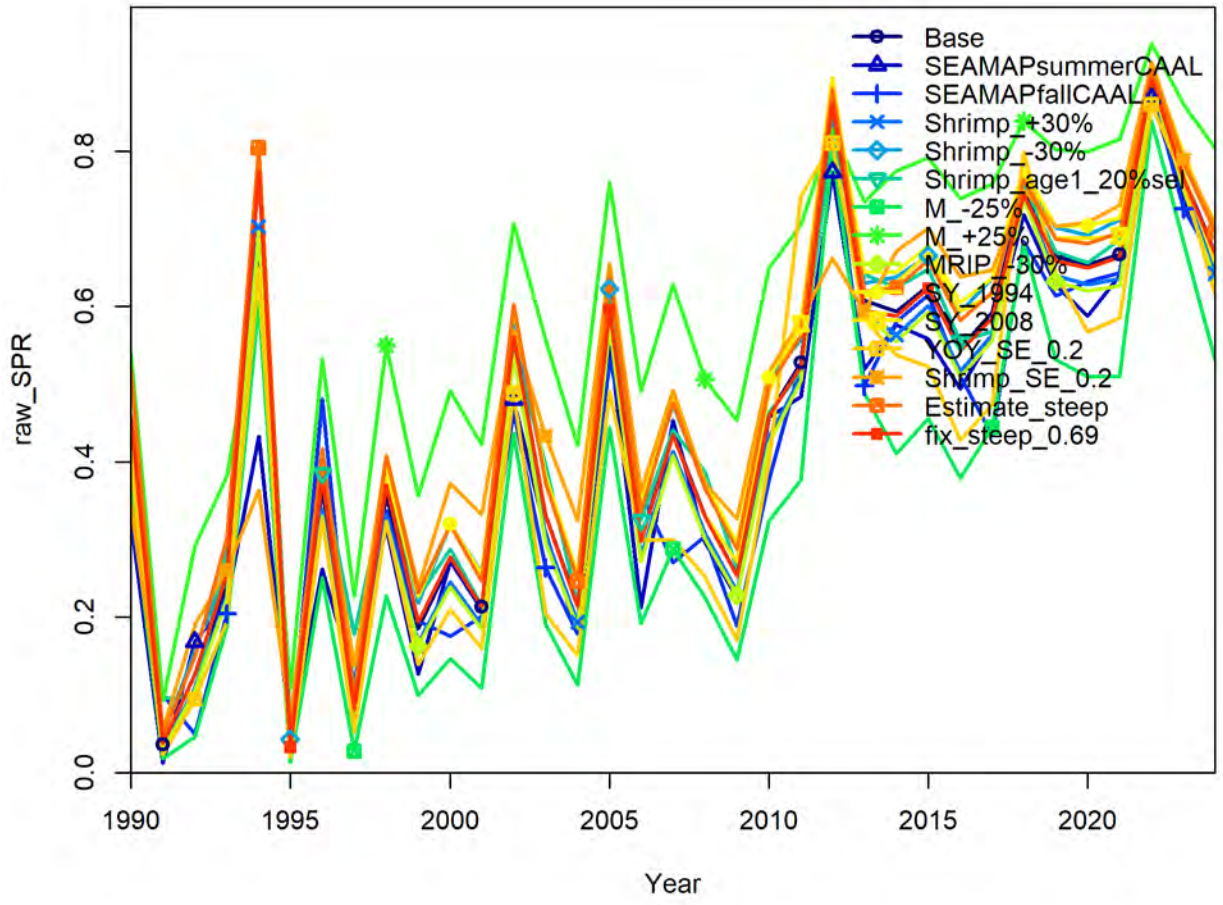


Figure 198. Spawning potential ratio estimates from sensitivity analysis of southern stock SS model.

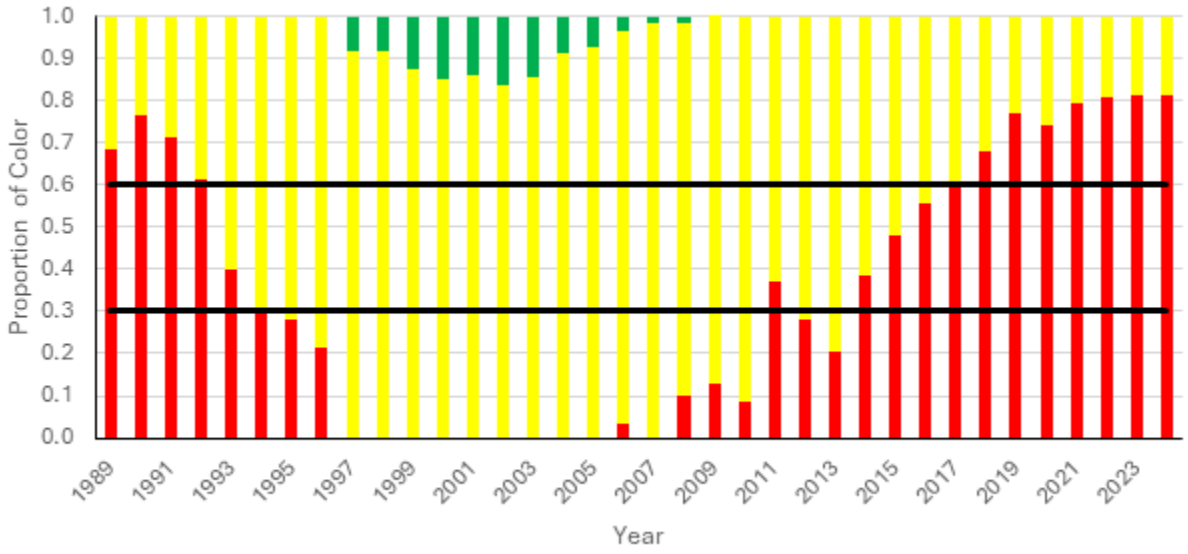


Figure 199. Fishery dependent current Atlantic croaker TLA Harvest Characteristic (commercial and recreational landings) for the Mid-Atlantic region from 1989-2024 (2002-2012 reference period), and 30% and 60% threshold lines.

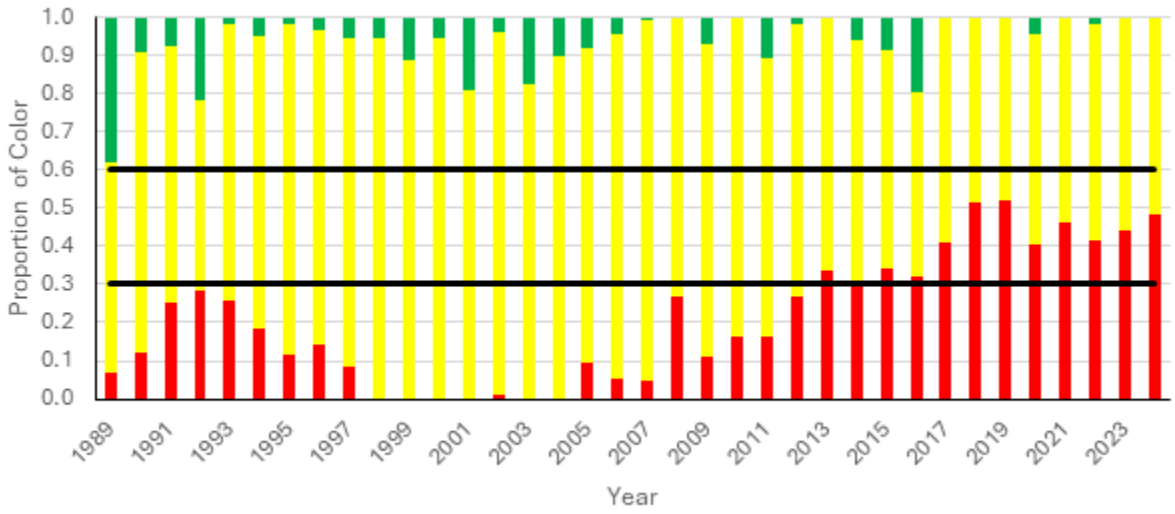


Figure 200. Fishery dependent current Atlantic croaker TLA Harvest Characteristic (commercial and recreational landings) for the South Atlantic region from 1989-2024 (2002-2012 reference period), and 30% and 60% threshold lines.

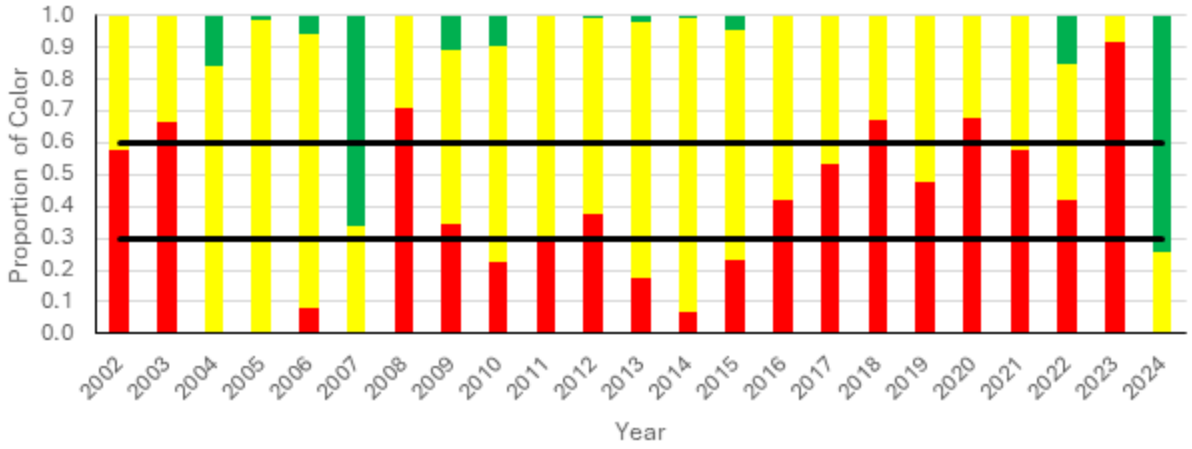


Figure 201. Fishery independent current Atlantic croaker TLA Adult Abundance Characteristic (Age 2+ indices from ChesMMAP and NEFSC trawl surveys) for the Mid-Atlantic region from 2002-2024 (2002-2012 reference period), and 30% and 60% threshold lines.

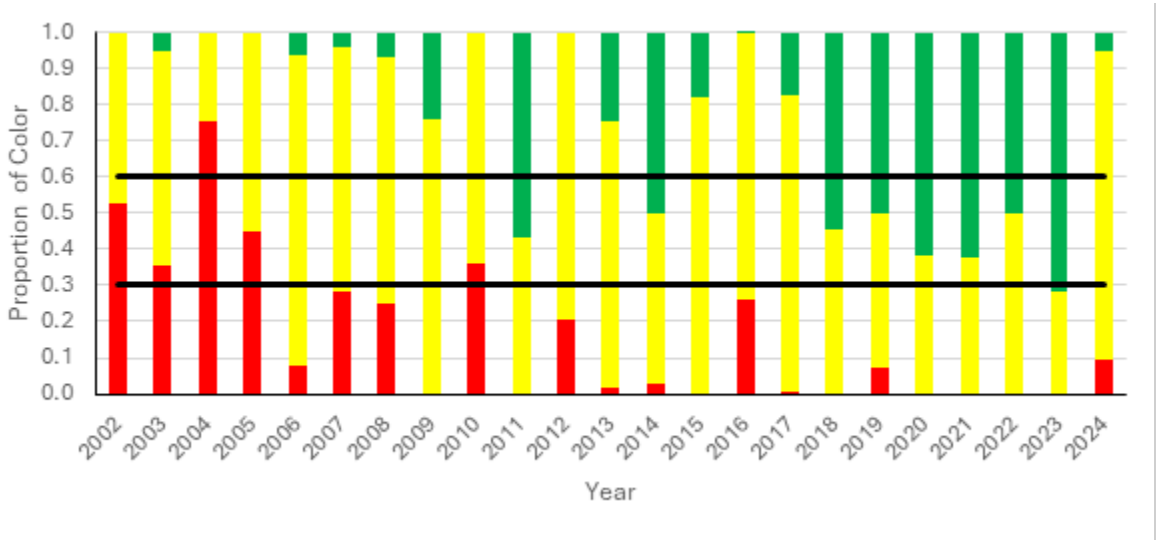


Figure 202. Fishery independent current Atlantic croaker TLA Adult Abundance Characteristic (Age 2+ indices from SC Tramel Net and SEAMAP trawl surveys) for the South Atlantic region from 2002-2024 (2002-2012 reference period), and 30% and 60% threshold lines.

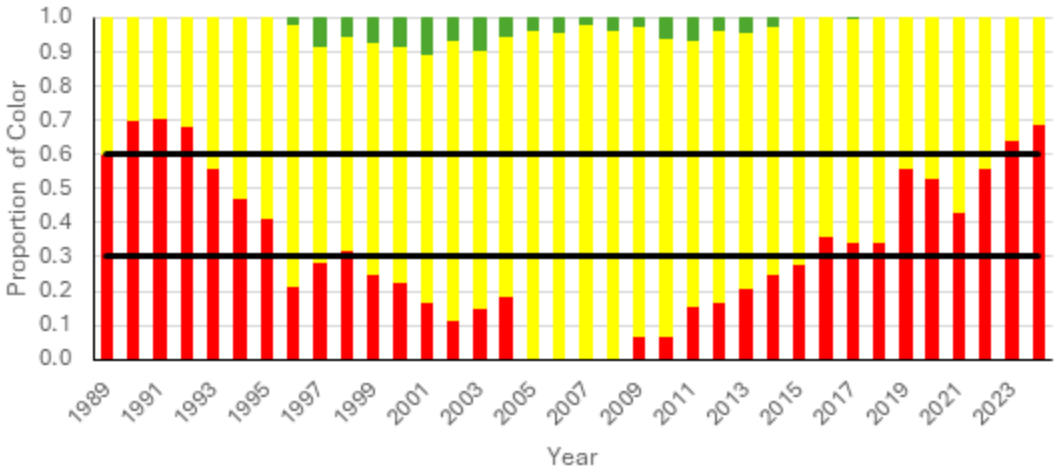


Figure 203. Fishery dependent revised Atlantic croaker TLA Harvest Characteristic (commercial landings and recreational removals) for the northern stock region from 1989-2024 (2002-2012 reference period), and 30% and 60% threshold lines.

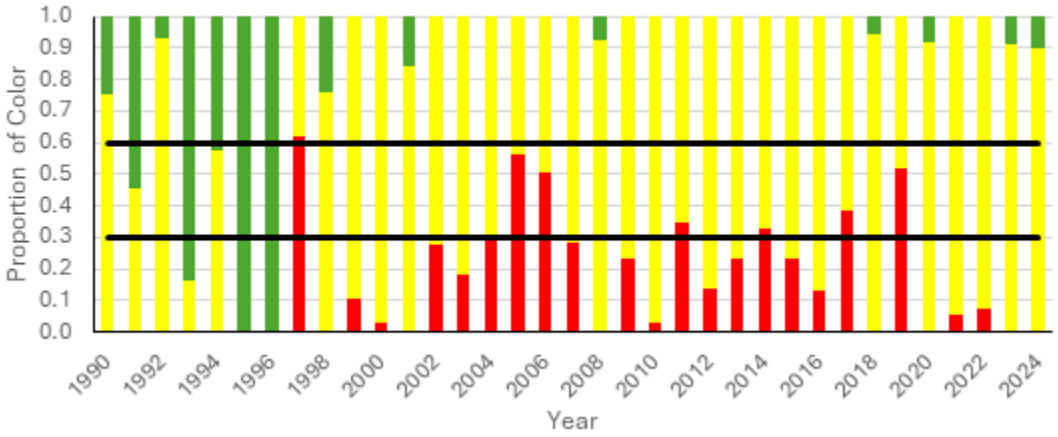


Figure 204. Fishery dependent revised Atlantic croaker TLA Harvest Characteristic (commercial landings and recreational removals) for the southern stock region from 1990-2024 (2009-2019 reference period), and 30% and 60% threshold lines.

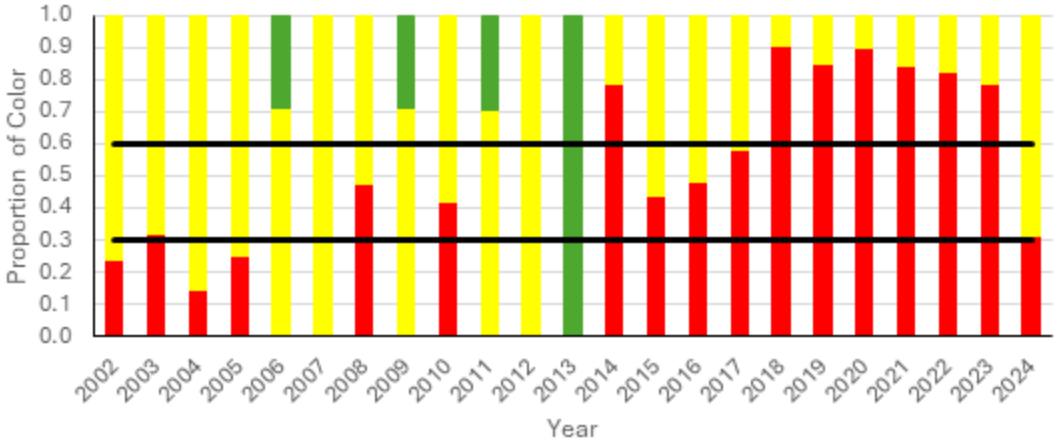


Figure 205. Fishery independent revised Atlantic croaker TLA Adult Abundance Characteristic (Age aggregate ChesMMAP index only) for the northern stock region from 2002-2024 (2002-2012 reference period), and 30% and 60% threshold lines.

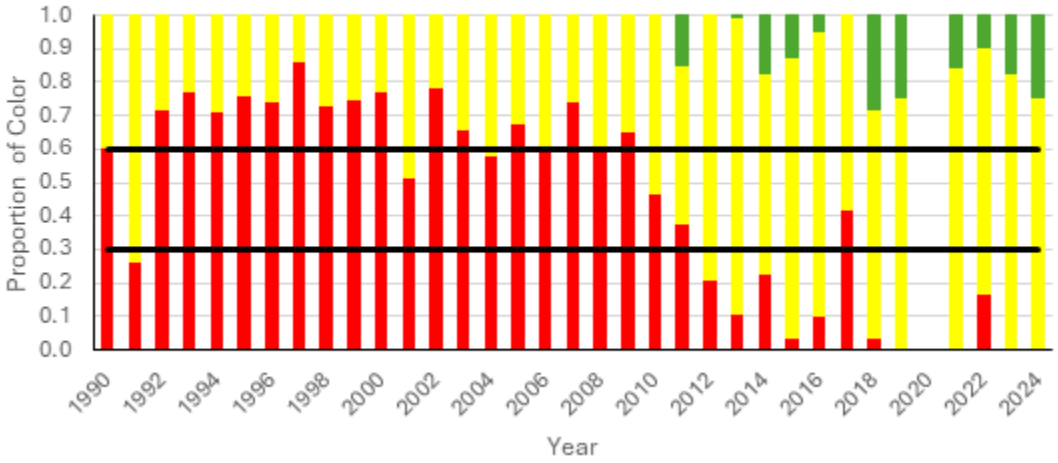


Figure 206. Fishery independent revised Atlantic croaker TLA Adult Abundance Characteristic (aggregated age indices from SEAMAP summer and fall surveys) for the southern stock region from 1990-2024 (2009-2019 reference period), and 30% and 60% threshold lines.

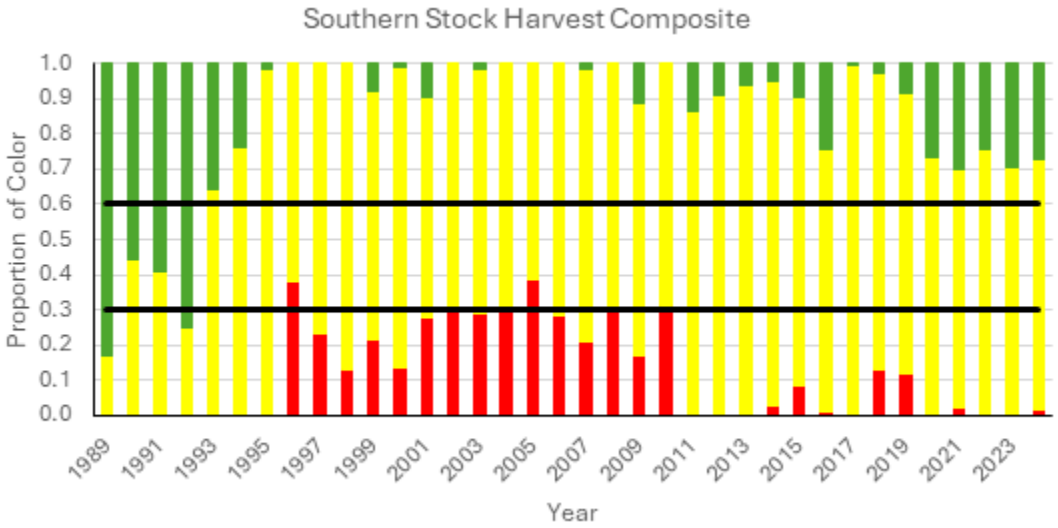


Figure 207. Fishery dependent exploratory Atlantic croaker TLA Harvest Characteristic (commercial and recreational landings) for the northern stock region from 1989-2024 (2002-2012 reference period), and 30% and 60% threshold lines.

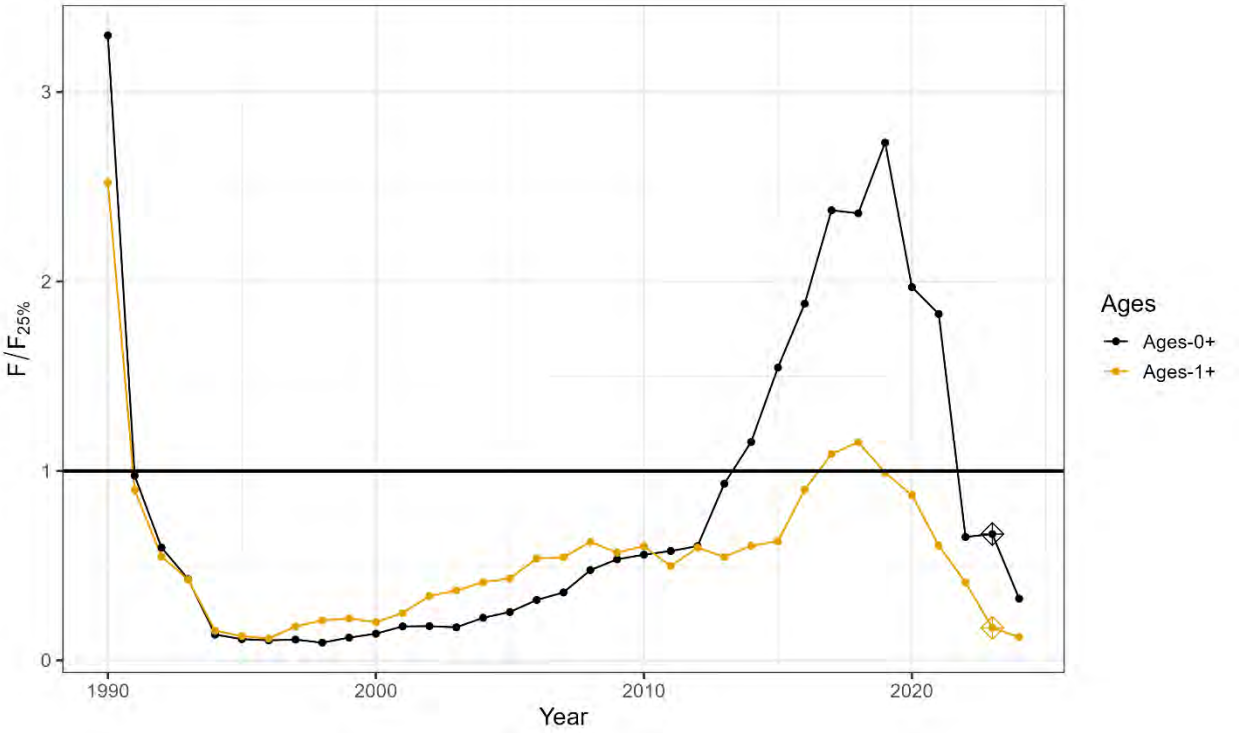


Figure 208. Three-year average fishing mortality ratios for northern stock Atlantic croaker using average F for all ages (Ages-0+) and ages older than age-0 (Ages-1+). The diamond is the 2021-2023 average used for status determination.

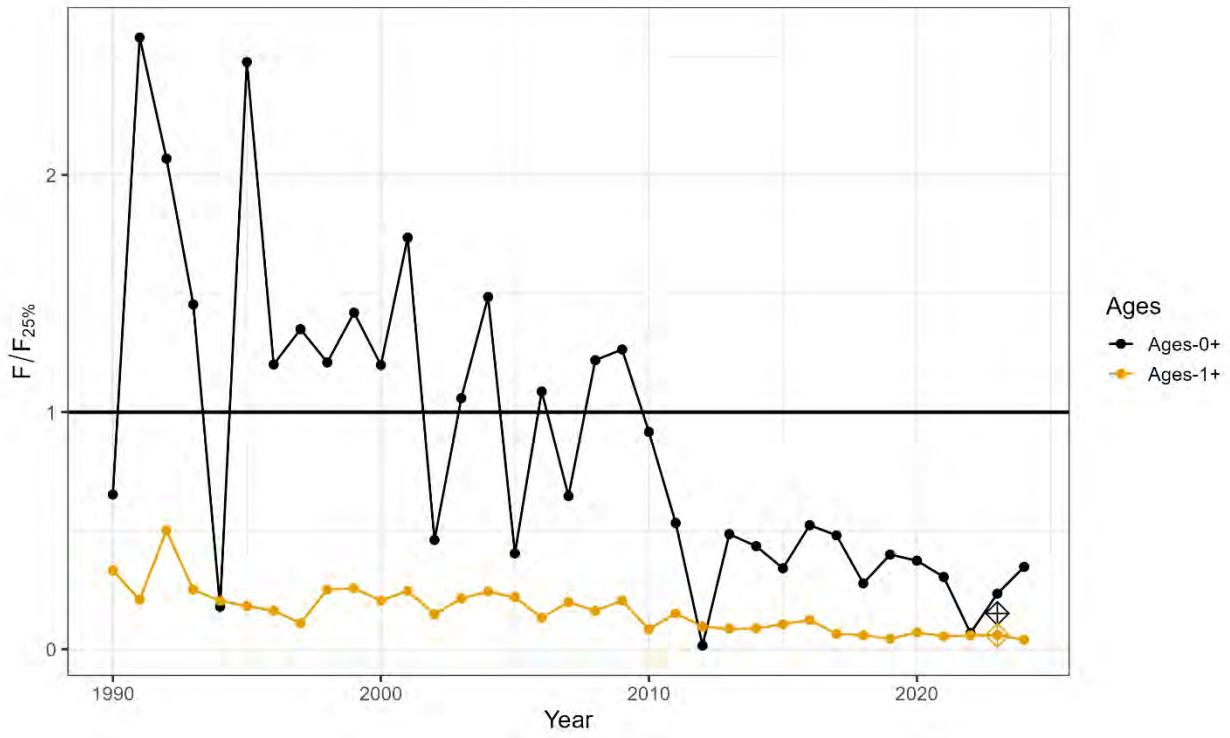


Figure 209. Three-year average fishing mortality ratios for southern stock Atlantic croaker using average F for all ages (Ages-0+) and ages older than age-0 (Ages-1+). The diamond is the 2021-2023 average used for status determination.

13 APPENDICES

13.1 Commercial Shrimp Trawl Fishery Discard Analyses

13.1.1 Background

Commercial fisheries for shrimp species operate throughout coastal waters of the southeast Atlantic coast from North Carolina through Florida. The primary gears are otter trawls and skimmer trawls. Atlantic croaker are typically the most prevalent bycatch species in these shrimp trawl fisheries and can outweigh and/or outnumber individual species of targeted shrimp (Table ST1, Table ST2, Table ST3).

Historically, these fisheries operated in estuarine (inside waters), nearshore ocean, and offshore ocean habitats, but estuarine habitats have become increasingly restricted through time including designated estuarine closed areas of North Carolina (e.g., Primary or Permanent Secondary Nursery Areas, crab spawning sanctuaries), the closure of these areas in South Carolina since 1988 except for the lower areas of some sounds and bays, the closure of Georgia inshore state waters to food shrimp trawling since at least 1979, and closure of some areas of Florida's Atlantic coast. Other areas have seasonal restrictions that may or may not allow trawling in some seasons of a given year depending on several factors.

Several species are targeted including penaeid shrimp species (white, brown, and pink shrimp) inshore and nearshore, and rock shrimp offshore. Penaeid shrimp fishery effort generally focuses on larger, spawning white shrimp in the spring, brown shrimp in the summer, and white shrimp, the predominate fishery in terms of landings, in the fall (Whitaker and Kingsley-Smith n.d.). Pink shrimp are the least common and are typically small components of the overall shrimp fishery. Rock shrimp support offshore fisheries in deeper waters, primarily off the coast of Florida.

Shrimp trawl fisheries are managed by states out to three miles from the coast and the South Atlantic Fishery Management Council (SAFMC) beyond three miles from the coast in Federal waters. North Carolina was the first state to require bycatch reduction devices (BRDs) on shrimp trawl gear in its state water shrimp trawl fishery starting in 1992 (NCDMF 2022). North Carolina adopted an FMP for the fishery in 2006. The regulatory history under this FMP has focused on additional gears modifications to reduce finfish bycatch and area restrictions (Special Secondary Nursery Habitats). The SAFMC adopted an FMP for Federal waters in 1993. BRDs were required in federal penaeid shrimp fisheries in 1996 under Amendment 2 to the Shrimp FMP for the South Atlantic Region (SAFMC 1996) and federal rock shrimp fisheries in 2005 under Amendment 6 to the Shrimp FMP (SAFMC 2004). South Carolina, Georgia, and Florida do not have formal FMPs for shrimp in state waters and manage these fisheries through rules outside a formal FMP framework. BRDs have been required in these states starting in 1996 in South Carolina, 1997 in Georgia, and from the 1990s through the early 2000s in Florida depending on gear, waterbody, and region.

13.1.2 Methods

Methods to generate Atlantic croaker discards in commercial shrimp trawl fisheries from observer discard rate data and effort were first applied in the 2017 assessment (ASMFC 2017). These methods followed those used by Walter and Isley (2014) to estimate discards of king mackerel from the same fisheries and data sets. First, Atlantic croaker discard rates were estimated with the delta-lognormal method (Lo et al. 1992). The delta-lognormal method combines a lognormal generalized linear model (GLM) used to predict discard rates of positive observations and a binomial GLM to predict the probability of a positive observation, with effort as an offset variable. The final discard rate is the product of the response variables from these two models. Second, estimated discard rates were multiplied by total shrimp trawl fishery effort to expand rates to total number of Atlantic croaker discarded.

Observer data have been collected through the NOAA Fisheries Shrimp Observer Program. The Shrimp Observer Program began in 2001 in the South Atlantic on a voluntary basis and expanded to a mandatory program in 2008. Data were limited during the voluntary period of the program (Table ST4) and were not available prior to 2001, but the assessment model time series started in 1990. Therefore, there was a need to borrow data from elsewhere to generate earlier estimates in the assessment time series. The SEAMAP Coastal Trawl survey uses a similar gear as shrimp trawl fisheries, has a sampling domain that overlaps much of the fishery, samples in most seasons (Spring, Summer, and Fall), and has sampled according to a consistent design since 1990. Realtive catch rate data from this survey were combined with observed data as a proxy for Atlantic croaker discard rates prior to and during the observer program. By assigning data set to each catch rate observation and including data set as a factor in the model (fishery-independent survey data vs fishery-dependent observer data), the predicted effects for just fishery-dependent observer data could be applied to effort to scale discard estimates to discard rate magnitudes from just observer data in all years while predicted year effects could scale annual estimates to relative changes in availability of croaker estimated from both the SEAMAP fishery-independent survey data and observer data, including during years prior to the observer program back to the start year of the assessment. Catch rate trends from the two data sets have been similar during overlapping years (Figure ST1).

Observer data were subset to exclude operation codes X, M, H, and J (Table ST5) because these observations were not considered reliable (e.g., net was dumped overboard without recording catch data). Observations with all other operation codes were included under the assumption that these observations are representative of effort in the shrimp trawl fisheries. Observed nets with disabled BRDs after the requirement of BRDs were also dropped from the analysis.

Factors considered in the discard rate models were year, data set, depth zone, state, and season. Data sets included observer data from the rock shrimp (observer project types W, X, Y) and penaeid shrimp (observer project types A, C) commercial fisheries and fishery-independent data from SEAMAP Trawl Survey tows. Depth zones were less than or equal to 10 meters (=<10m), greater than 10 meters to 30 meters (10-30m), and greater than 30 meters (>30m). All SEAMAP tows were conducted in the shallowest depth zone and the majority of observer tows were in the shallowest depth zone. State borders were defined by the latitudes used by Scott-Denton et al. (2012). Seasons were December through March (offseason) and April through

November (peak season). The seasons were defined to align with shrimp fishing relative to operation in nearshore waters throughout the time series. Shrimp fishing in nearshore waters, where catch rates are expected to increase, has generally started as early as April and lasted through November.

Discard rates were applied to effort data summarized by "strata" (i.e., combination of factors included in the model). For more detail on effort data, see Sections 4.1.2.2.1 and 4.1.2.3.1in the main report. Standard errors (SEs) of model-estimated discard rates were estimated with the predict.glm function in the R package stats (R Core Team 2025).

Because there were no observer data before BRDs were required in the penaeid shrimp fishery, discard estimates for the penaeid shrimp trawl fishery prior to 1997 were adjusted to account for higher catch rates expected before these gear modifications were required in the fishery. Adjustments were based on a weighted average of Atlantic croaker catch reductions in the Gulf of Mexico shrimp trawl fishery estimated depending on the distance of fisheye BRDs from tie-off rings (Helies et al. 2009). 99.6% of observer trips used fisheye BRDs. BRDs in the observed trips ranged from 6 to 21 feet from tie-off rings. Catch reduction estimates were available for BRDs <9 feet (69.7% reduction), 9-10 feet (0% reduction), and 10-11 feet (17.2% reduction) from the tie off rings. There was no estimated reduction for fisheye BRDs greater than 11 feet from the tie-off rings, so the estimate for the 10-11 foot category was used for the proportion of nets greater than 11 feet from the tie-off rings. The proportion of observed trips that fell into the categories of <9 feet, 9-10 feet, 10-11 feet, and >11 feet were 0.22, 0.28, 0.31, and 0.20, respectively. The weighted average adjustment was 0.23 (i.e., discards = unadjusted discards*1/(1-adjustment)). We assumed that observed trips were representative of BRDs used in the fisheries.

13.1.2.1 Updated Analyses

Since these estimates were generated during the 2017 assessment, there have been concerns that these discard estimates were overestimated given the sheer magnitude of estimates. No other data have been cited with these concerns, but one speculation was that the inclusion of fishery-independent catch rate data from the SEAMAP Coastal Trawl survey could be biasing the estimates high despite the design of the modeling approach intended to remove magnitude of SEAMAP catch rates from expanded discard estimates. During the 2017 peer review, reviewers also offered a recommendation to estimate state-specific discards and then sum these across states for total coastwide discards, thereby removing any potential interactions between state and other factors in estimates generated with coastwide models using state as a factor. It also became apparent since the 2017 assessment that effort data provided by the SEFSC query may not be verified by all state partners that collect these data.

During discussion of shrimp trawl estimation methods in this assessment, the Atlantic Croaker Stock Assessment Subcommittee prioritized several analyses of shrimp trawl discard data and estimates to better explore these data and methods for potential improvement. Prioritized analyses include: (1) effort data changes and verification with state partners, (2) generating state-specific estimates with separate models and summing for total coastwide discard

estimates, (3) excluding fishery-independent catch rate data from modeled discard rate estimates, (4) generating strictly empirical discard estimates, (5) generating discard estimates with an alternative effort definition, and (6) alternative methods for characterizing uncertainty of discard estimates. Methods and results are described below.

Effort Data

Prior to this assessment, shrimp trawl effort data were provided with a standardized query by the SEFSC as has been done for SEDAR assessments of species with bycatch in shrimp trawl fisheries (Gloeckner 2014) or pulled from previous SEDAR reports.

Average hours fished per trip used in total effort calculations during the 2017 assessment came from Table 7 in NMFS Sustainable Fisheries Branch (2012) for the SEDAR 28 king mackerel assessment. Since that assessment, discard estimates were updated for the SEDAR 38 king mackerel assessment in 2020 with updated effort (Zhang and Walter 2020). During this update, average hours fished per trip increased dramatically for Florida during update years 2011-2017 (Table 5 in Zhang and Walter 2020). Data provided directly from the data provider for SEDAR 38 back to 2001 showed higher average hours fished per trip for years prior to 2011 that were more similar to those from 2011 and later (D. Glockner, NOAA Fisheries, personal communication). In consultation with Florida commercial data providers, the data in table 7 of NMFS Sustainable Fisheries Branch (2012) could not be replicated or tracked to an original source (C. Bradshaw, FL FWC, personal communication). Therefore, these data were replaced with updated data from the updated SEFSC query for all years and states.

The data from the SEFSC query were then sent to state partners for review. North Carolina, South Carolina, and Georgia elected to provide some or all data directly to replace data provided by the SEFSC. Specifically, North Carolina provided monthly trip counts from 1990-2024, while South Carolina and Georgia provided all annual data for the years 2004-2024 and 2001-2024, respectively. Otherwise, states reviewed and defaulted to data for other years and/or effort metrics from the SEFSC.

Final effort data compared to the final effort data from the 2017 assessment show the most notable changes for Florida, with increases during this assessment due to the change in average hours fished data (Figure ST2). North Carolina data generally decreased for overlapping years while Georgia data generally increased slightly and South Carolina data changes were variable and largest before the trip ticket program started in 2004.

Discard Estimates with SEAMAP Catch Rate Data

Updated estimates with the methodology used during the 2017 assessment and updated effort described above are provided in Figure ST3. These estimates are only updated through 2022 due to the discontinuation of summer sampling by the SEAMAP Coastal Trawl Survey after this year. These are referred to as the Base estimates in this appendix.

Discard Estimates by State

In this analysis, the same methodology used in the 2017 assessment was applied except that a separate delta-lognormal analysis was used to estimate discard rates for each state from data within each state and the state factor was excluded from these analyses. These discard rates were then applied to state-specific effort to expand to total discard estimates. Finally, discards within each state were summed across states and compared to the Base estimates.

State-specific estimates were generally greater in magnitude than Base estimates and were more variable among years (Figure ST4).

Discard Estimates with Only Observed Data

In this analysis, the same methodology used in the 2017 assessment was applied except SEAMAP Coastal Trawl Survey data were excluded from the catch rate data set. Estimates start in 2008, the first year observer data from mandatory program are available. Preliminary estimates with all years of observer data, including voluntary participation back to 2001, showed extreme interannual variability for the first several years that is believed to be due to variability in coverage across factors like state (Table ST4).To remove information from earlier years in the Base analysis for comparison purposes, the Base analysis was repeated but only with data since 2008.

Estimates with only observer data were generally lower in magnitude than those from the Base analysis, particularly since 2011 (Figure ST5). The ratios of these estimates showed slight trending down from these first few years when estimates were more similar but were then relatively stable around 0.6 indicating Base estimates run about 40% higher, on average (Figure ST6).

Empirical Estimates

This analysis used just the empirical mean discard rates by state, year, and season to expand effort to total discard estimates. Estimates are generated only from observer data, so start in 2008. This analysis addresses the influence of model-based estimates, as well as some assumptions to partition effort data for applying to modeled factors affecting catch rates (i.e., depth and fishery).

These estimates are generally lower than the model-based estimates using only observer data (Figure ST7).

Alternative Effort Definition

In this analysis, the alterative effort definition of trip was used to expand discard rates to total discards. Estimates were generated only from observer data, so start in 2008. This analysis removed the average hours fished per trip and number of gear fished per vessel from the effort definition and only relies on the metric collected through a census data collection design. There were a few additional assumptions required to adjust the discard rate effort unit from net

hours fished to trip. First, the observed program attempted to observe 50% of nets when multiple nets are towed simultaneously (E. Denton-Scott, NOAA Fisheries, personal communication). Therefore, the total catch per net during observed tows was multiplied by the number of unobserved nets towed simultaneously to calculate total catch per tow. Second, there were trips during which some tows were not observed. The majority of occurrences resulted in few tows not being observed, but ranged to as many as 25 unobserved tows (Table ST6). To address this, the catch per tow from observed tows was multiplied by the number of unobserved tows to estimate catch per trip.

This analysis resulted in highly variable estimates that were often greater in magnitude than those estimated with a net hours fished effort definition using only observer data (Figure ST8).

Alternative Uncertainty Methods

Uncertainty of discard estimates was previously reported using SEs of discard rate estimates carried through expansion by effort data to calculate 95% confidence intervals (MLE method). During this assessment, bootstrapping was applied to discard rate data sets to estimate discard rates with 1,000 replicate data sets. Bootstrapped discard rate estimates across replicates were carried through expansion by effort data to calculate confidence intervals as an alternative approach.

Comparisons show similar levels of uncertainty between the methods (Figure ST9).

13.1.3 Discussion and Recommendations

The various analyses suggest the general magnitude of discarded Atlantic croaker in shrimp trawl fisheries estimated from available data is very large relative to other fishery removal sources (i.e., directed fisheries) and a primary source of fishing mortality on the population. The additional effort data verification with state partners was seen as an improvement in data during this assessment, but this did not lead to dramatic changes in the scale of discard estimates.

The SAS believes the model-based approach that accounts for effects from several sources expected to influence catch rates (e.g., depth) is superior to empirical methods and recommends continuation with the model-based approach. The SAS did not observe any differences in the state-specific analysis that suggested it was a superior approach, so recommended the coastwide analysis with state as a factor for more efficient estimation. The SAS also recommends against the alternative effort definition of trip as several additional extrapolation assumptions are required to use this definition and recommends continuing with net hours fished as the effort definition.

Comparisons of estimates from the data including SEAMAP data and estimates from only observer discard rate data suggest the use of SEAMAP data may in fact be inflating the estimates. This may be due to missed interactions between data set and other factors in the model. The SAS recommend adopting the change of excluding SEAMAP data from the discard

rate data set. To hindcast estimates prior to the mandatory observer program, the SAS recommends calculating the median ratio of estimates with and without these data during overlapping years (2008-2022) and applying this ratio to discard estimates with SEAMAP data included prior to 2008. This still relies on the SEMAP data for trend but should reduce any influence from magnitude that may have been present when using the data directly in the model-based discard rate estimates.

Given the similarities in confidence intervals between uncertainty methods, the SAS recommends continuing with the method used in the previous assessment (MLE method) but recommends revisiting this comparison in future assessments to determine if the pattern of similar confidence intervals holds. It's important to note that uncertainty from discard rate data alone is likely an underestimate of total uncertainty. Effort data collection is a census design for trips (i.e., no sampling variance) and associated measures of variance for other metrics were not available with effort data for the assessment. Future efforts could explore inclusion of uncertainty in non-trip count metrics as a more complete characterization of data uncertainty. Additionally, observer coverage of the overall fishery is low. However, if observer data are collected in an unbiased manner even at these low coverages, discard estimates should be unbiased. Increased coverage would be the best way to determine any potential biases from current sampling practices.

13.1.4 References

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13.1.5 Tables

Table ST1. Species documented from bycatch characterization samples, based on mandatory observer coverage of the U.S. southeastern shrimp fishery from January 2011 through December 2016 (excerpt from Table 9 of Scott-Denton et al. 2020).

Common name	Scientific name	Gulf mandatory penaeid (kg)	Gulf mandatory penaeid (%)	South Atlantic mandatory penaeid (kg)	South Atlantic mandatory penaeid (%)	Mandatory rock (kg)	Mandatory rock (%)	Gulf mandatory skimmer (kg)	Gulf mandatory skimmer (%)	Total	Percent total
Fish (superclass)	*Pisces*	1,281,387.2	31.8	35,558.6	12.4	14,615.4	22.0	7,635.8	32.7	1,339,197.0	30.4
Atlantic croaker	*Micropogonias undulatus*	630,639.1	15.7	70,947.1	24.7	169.9	0.3	2,473.6	10.6	704,229.7	16.0
Brown shrimp	*Farfantepenaeus aztecus*	509,084.0	12.6	24,340.2	8.5	861.2	1.3	7,575.0	32.5	541,860.4	12.3
White shrimp	*Litopenaeus setiferus*	461,067.8	11.4	37,674.2	13.1	16.2	0.0	2,249.4	9.6	501,007.5	11.4
Arthropod subphylum	Crustacea	248,130.4	6.2	4,916.1	1.7	2,594.5	3.9	985.9	4.2	256,626.9	5.8
Seatrout (genus)	*Cynoscion* spp.	218,008.4	5.4	11,666.5	4.1	43.8	0.1	343.1	1.5	230,061.8	5.2
Invertebrate	Invertebrate	210,182.3	5.2	6,347.3	2.2	5,062.4	7.6	137.7	0.6	221,729.6	5.0
Pink shrimp	*Farfantepenaeus duorarum*	135,793.5	3.4	134.0	0.0	1,139.1	1.7			137,066.6	3.1
Longspine porgy	*Stenotomus caprinus*	124,005.8	3.1							124,005.8	2.8
Debris (rocks,logs,etc.)	Debris	61,360.1	1.5	2,562.1	0.9	1,268.1	1.9	279.7	1.2	65,470.0	1.5
Rock shrimp (genus)	*Sicyonia* spp.	11,305.6	0.3			23,704.6	35.6			35,010.3	0.8
Spot (flat croaker)	*Leiostomus xanthurus*	3,941.7	0.1	29,685.9	10.3	806.7	1.2			34,434.4	0.8
Discarded penaeid shrimp (brown, pink, white)	Penaeus discard	29,471.4	0.7	1,759.2	0.6	15.1	0.0	43.9	0.2	31,289.6	0.7
Atlantic sharpnose shark	*Rhizoprionodon terraenovae*	15,354.5	0.4	1,770.8	0.6	80.7	0.1	26.2	0.1	17,232.3	0.4
Red snapper	*Lutjanus campechanus*	13,990.9	0.3	1.2	0.0	0.3	0.0	0.0	0.0	13,992.4	0.3
Cannonball jellyfish	*Stomolophus meleagris*			13,979.9	4.9					13,979.9	0.3
Jellyfish family	Carybdeidae			11,361.6	4.0					11,361.6	0.3
Star drum	*Stellifer lanceolatus*	66.3	0.0	10,750.4	3.7					10,816.6	0.2
Spanish mackerel	*Scomberomorus maculatus*	9,593.9	0.2	471.5	0.2	1.5	0.0	69.4	0.3	10,136.3	0.2
Red drum	*Sciaenops ocellatus*	9,650.8	0.2	8.2	0.0			6.1	0.0	9,665.1	0.2
Southern kingfish	*Menticirrhus americanus*	1,077.4	0.0	8,401.7	2.9					9,479.1	0.2
Inshore lizardfish	*Synodus foetens*	3,720.6	0.1			4,796.2	7.2			8,516.8	0.2
Lane snapper	*Lutjanus synagris*	6,492.6	0.2	0.1	0.0	15.9	0.0	3.8	0.0	6,512.4	0.1
Southern flounder	*Paralichthys lethostigma*	5,487.4	0.1	660.4	0.2	47.2	0.1	48.2	0.2	6,243.2	0.1
Dusky flounder	*Syacium papillosum*	2,359.5	0.1			3,813.7	5.7			6,173.2	0.1
Longspine swimming crab	*Portunus spinicarpus*					3,914.7	5.9			3,914.7	0.1
Bonnethead shark	*Sphyrna tiburo*	2,950.7	0.1	834.3	0.3			1.6	0.0	3,786.6	0.1
Black drum	*Pogonias cromis*	3,737.2	0.1	3.3	0.0			32.5	0.1	3,773.0	0.1
Gulf menhaden	*Brevoortia patronus*	2,951.9	0.1							2,951.9	0.1
Blue crab	*Callinectes sapidus*	0.6	0.0	2,912.9	1.0					2,913.5	0.1
Weakfish	*Cynoscion regalis*			2,780.8	1.0					2,780.8	0.1
Pinfish	*Lagodon rhomboides*	2,725.5	0.1							2,725.5	0.1
Penaeid shrimp genus brown, pink, white)	*Penaeus* spp.	1,800.7	0.0					780.4	3.3	2,581.2	0.1
Blacktip shark	*Carcharhinus limbatus*	2,399.3	0.1	67.9	0.0			48.1	0.2	2,515.3	0.1
Atlantic bumper	*Chloroscombrus chrysurus*	2,488.8	0.1							2,488.8	0.1
Rock seabass	*Centropristis philadelphica*	545.7	0.0	590.8	0.2	1,124.8	1.7			2,261.3	0.1
Atlantic menhaden	*Brevoortia tyrannus*			2,154.0	0.7					2,154.0	0.0
Smooth dogfish shark	*Mustelus canis*	2,108.6	0.1	21.8	0.0					2,130.4	0.0
Atlantic cutlassfish	*Trichiurus lepturus*	2,079.5	0.1							2,079.5	0.0
Silver seatrout	*Cynoscion nothus*			2,040.2	0.7	2.4	0.0			2,042.7	0.0
Rock shrimp discards	Sicyonia discards	414.0	0.0			1,108.0	1.7			1,522.0	0.0
Gulf butterfish	*Peprilus burti*	1,436.1	0.0							1,436.1	0.0
King mackerel	*Scomberomorus cavalla*	1,246.2	0.0	132.8	0.0	2.5	0.0	0.3	0.0	1,381.8	0.0
Cownose ray	*Rhinoptera bonasus*	860.7	0.0					412.2	1.8	1,272.9	0.0
Northern kingfish	*Menticirrhus saxatilis*	1.2	0.0	929.4	0.3	81.5	0.1			1,012.1	0.0
Summer flounder	*Paralichthys dentatus*			856.0	0.3	47.6	0.1			903.6	0.0
Bank seabass	*Centropristis ocyurus*			2.9	0.0	785.6	1.2	0.1	0.0	788.6	0.0
Common crevalle jack	*Caranx hippos*	619.8	0.0					0.2	0.0	620.0	0.0
Sharks grouped	General sharks	552.9	0.0	19.8	0.0					572.7	0.0
Scalloped hammerhead shark	*Sphyrna lewini*	413.1	0.0	146.4	0.1					559.5	0.0
Hake (genus)	*Urophycis* spp.	514.7	0.0							514.7	0.0
Atlantic stingray	*Dasyatis sabina*	510.1	0.0							510.1	0.0
Sand perch	*Diplectrum formosum*	498.3	0.0							498.3	0.0
Sea bob shrimp	*Xiphopenaeus kroyeri*	238.6	0.0	258.2	0.1			1.0	0.0	497.9	0.0
Spinner shark	*Carcharhinus brevipinna*	486.5	0.0							486.5	0.0
Spotted seatrout	*Cynoscion nebulosus*	369.1	0.0	19.7	0.0			65.2	0.3	454.1	0.0
Irridescent swimming crab	*Portunus gibbesii*					422.1	0.6			422.1	0.0
Vermillion snapper	*Rhomboplites aurorubens*	399.4	0.0							399.4	0.0
Bluefish	*Pomatomus saltatrix*	1.2	0.0	370.4	0.1	4.3	0.0			375.8	0.0
Blacknose shark	*Carcharhinus acronotus*	300.2	0.0	7.5	0.0					307.7	0.0
Finetooth shark	*Carcharhinus isodon*	278.8	0.0	2.9	0.0					281.7	0.0

Table ST2. Selected South Atlantic fish species recorded from all penaeid shrimp nets from bycatch characterization samples, based on mandatory observer coverage from January 2011 through December 2016 (Table 11 from Scott-Denton et al. 2020).

Scientific name	Common name	Extrapolated weight (kg)	Kg/h	CV
Carcharhinus brevipinna	Spinner shark	0.0	0.0	0.0
Carcharhinus falciformis	Silky shark	0.0	0.0	0.0
Mycteroperca microlepis	Gag	0.0	0.0	0.0
Penaeid shrimp (brown,white, pink)	Penaeid shrimp (brown,white, pink)	0.0	0.0	0.0
Litopenaeus setiferus	White shrimp	37,674.2	6.8	<0.1
Pisces	Fish (superclass)	35,601.5	6.4	<0.1
Farfantepenaeus aztecus	Brown shrimp	24,340.3	4.4	<0.1
Micropogonias undulatus	Atlantic croaker	70,947.1	12.8	<0.1
Leiostomus xanthurus	Spot (flat croaker)	29,686.0	5.4	<0.1
Invertebrate	Invertebrate	6,347.3	1.1	<0.1
Cynoscion spp.	Seatrout (genus)	11,666.5	2.1	<0.1
Stellifer lanceolatus	Star drum	10,750.4	1.9	0.1
Carybdeidae	Jellyfish (family)	11,361.6	2.1	0.1
Crustacean	Crustacean	5,235.8	0.9	0.1
Stomolophus meleagris	Cannonball jellyfish	13,979.9	2.5	0.1
Paralichthys dentatus	Summer flounder	856.0	0.2	0.1
Callinectes sapidus	Blue crab	2,912.9	0.5	0.1
Debris	Debris (rocks, logs, etc.)	2,562.1	0.5	0.1
Penaeus discard	Penaeid shrimp discard (brown,white, pink)	1,759.2	0.3	0.1
Brevoortia tyrannus	Atlantic menhaden	2,154.0	0.4	0.1
Rhizoprionodon terraenovae	Atlantic sharpnose shark	1,770.8	0.3	0.1
Centropristis philadelphica	Rock seabass	590.8	0.1	0.1
Cynoscion nothus	Silver seatrout	2,040.2	0.4	0.1
Paralichthys lethostigma	Southern flounder	660.4	0.1	0.1
Scomberomorus maculatus	Spanish mackerel	471.5	0.1	0.1
Menticirrhus saxatilis	Northern kingfish	929.4	0.2	0.1
Sphyrna tiburo	Bonnethead shark	834.3	0.2	0.1
Pomatomus saltatrix	Bluefish	370.4	0.1	0.1
Farfantepenaeus duorarum	Pink shrimp	134.0	0.0	0.1
Cynoscion regalis	Weakfish	2,780.8	0.5	0.1
Menticirrhus americanus	Southern kingfish	8,401.7	1.5	0.1
Scomberomorus cavalla	King mackerel	132.8	0.0	0.2
Sphyrna lewini	Hammerhead scalloped shark	146.4	0.0	0.2
Trachinotus carolinus	Florida pompano	35.9	0.0	0.2
Lutjanus campechanus	Red snapper	1.2	0.0	0.3
Cynoscion nebulosus	Spotted seatrout	19.7	0.0	0.3
Centropristis striata	Black seabass	3.7	0.0	0.4
Carcharhinus limbatus	Blacktip shark	67.9	0.0	0.4
Mustelus canis	Smooth dogfish shark	21.8	0.0	0.4
Centropristis ocyurus	Bank seabass	2.9	0.0	0.5
Stenotomus chrysops	Scup	0.3	0.0	0.5
Pogonias cromis	Black drum	3.3	0.0	0.5
General sharks	Sharks grouped	19.8	0.0	0.6
Carcharhinus isodon	Finetooth shark	2.9	0.0	0.7
Acipenser spp.	Sturgeon (genus)	2.3	0.0	1.0
Rachycentron canadum	Ling cobia	1.0	0.0	1.0
Alosa spp.	Herring (genus)	0.1	0.0	1.0
Sciaenops ocellatus	Red drum	8.2	0.0	1.0

Table ST3. Summary of North Carolina Commercial Shrimp Trawl Fishery Characterization studies from 2007-2017 (Table 2.4.1 from NCDMF 2022).

	Study Details		Bycatch Characteristics	Species: Atlantic croaker	spot	weakfish	blue crab	southern flounder	sheepshead	protected species	
Study 1	Study Period	7/2007 – 6/2008	Percent of Catch	25%	7%	2%	<1%	<1%	<1%	sea turtles	3
	Area Fished	Ocean	Size Range	120 – 180 mm	90 – 140 mm	50 – 305 mm	-	<355 mm	-	Atlantic sturgeon	0
Brown 2009	Fishing Days Observed	143 (trips)	At-net Mortality	n/a	n/a	n/a	n/a	n/a	n/a	marine mammals	0
	Trawl Type	Otter								birds	0
	Number of Tows Sampled	314									
Study 2	Study Period	7/2009 – 12/2009	Percent of Catch	33%	13%	6%	2%	<1%	0%	sea turtles	0
	Area Fished	Pamlico Sound	Size Range	100 – 140 mm	80 – 120 mm	70 – 150 mm	-	130 – 180 mm	n/a	Atlantic sturgeon	0
Brown 2010	Fishing Days Observed	66 (trips)	At-net Mortality	n/a	n/a	n/a	n/a	n/a	n/a	marine mammals	0
	Trawl Type	Otter								birds	0
	Number of Tows Sampled	191									
Study 3	Study Period	8/2012 – 8/2015	Percent of Catch	34 – 49%	10 – 21%	2%	<1 – 2%	<1 – 2%	<1%	sea turtles	1
	Area Fished	Estuary and Ocean	Size Range	100 – 170 mm	80 – 120 mm	70 – 180 mm	-	100 – 300 mm	-	Atlantic sturgeon	0
Brown 2015	Fishing Days Observed	388	At-net Mortality	23%	66%	87%	-	0 – 88%	-	marine mammals	0
	Trawl Type	Otter								birds	0
	Number of Tows Sampled	1,037									
Study 4	Study Period	1/2015 – 11/2015	Percent of Catch	5%	1%	1%	2%	<1%	<1%	sea turtles	4
	Area Fished	Estuary	Size Range	100 – 180 mm	60 – 110 mm	140 – 210 mm	-	80 – 130 mm	-	Atlantic sturgeon	0
Brown 2016	Fishing Days Observed	62	At-net Mortality	41%	82%	97%	-		-	marine mammals	0
	Trawl Type	Skimmer								birds	1
	Number of Tows Sampled	238									
Study 5	Study Period	1/2016 – 12/2016	Percent of Catch	8 – 27%	1 – 11%	<1 – 4%	<1%	<1%	0 - <1%	sea turtles	4
	Area Fished	Estuary and Ocean	Size Range	70 – 180 mm	60 – 190 mm	80 – 190 mm	-	-	-	Atlantic sturgeon	2
Brown 2017	Fishing Days Observed	72	At-net Mortality	21%	77%	100%	-	-	-	marine mammals	0
	Trawl Type	Otter and Skimmer								birds	0
	Number of Tows Sampled	218									
Study 6	Study Period	7/2017 – 12/2017	Percent of Catch	6 – 35%	1 – 7%	<1 – 6%	<1 – 3%	<1 – 1%	0 - <1%	sea turtles	1
	Area Fished	Estuary and Ocean	Size Range	100 – 170 mm	70 – 210 mm	-	-	-	-	Atlantic sturgeon	0
Brown 2018	Fishing Days Observed	25	At-net Mortality	24 – 33%	n/a	-	-	-	-	marine mammals	0
	Trawl Type	Otter and Skimmer								birds	0
	Number of Tows Sampled	70									

Table ST4. NOAA Fisheries Shrimp Observer Program sample sizes (number of tows observed) by state and year.

Year	FL	GA	SC	NC
2001	52	0	0	0
2002	177	0	0	0
2003	169	8	0	0
2004	0	0	0	0
2005	6	18	133	0
2006	22	0	0	0
2007	0	3	127	0
2008	130	24	55	141
2009	235	101	74	67
2010	92	57	23	73
2011	91	82	116	31
2012	122	25	56	169
2013	172	56	94	69
2014	74	39	23	74
2015	169	68	58	32
2016	255	41	44	143
2017	243	78	51	43
2018	143	69	96	102
2019	96	89	17	20
2020	156	15	65	127
2021	326	177	147	82
2022	271	92	0	71

Table ST5. Shrimp Observer Program database net performance operation codes.

A - Nets not spread; typically doors are flipped or doors hung together so net could not spread.
B - Gear bogged; the net has picked up a large quantity of sand, clay, mud, or debris in the tail bag possibly affecting trawl performance.
C - Bag obstructed; the catch in the net is prevented from getting into the bag by something (i.e. grass, sticks, turtle, tires, metal/plastic containers etc.) or constriction of net (i.e. twisting of the lazy-line around net).
D - Gear not digging; the net is fishing off the bottom due to insufficient weight or not enough cable let out (etc.).
E - Twisted warp or line; the cables composing the bridle get twisted (from passing over blocks which occasionally must be removed before continuing to fish). Use this code if catch was affected.
F - Gear fouled; the gear has become entangled in itself or with another net. Typically this involves the webbing and some object like a float or chains or lazy line (etc.).
G -Bag untied; bag of net not tied when dragging net.
H - Rough weather. Bags mixed due to rough seas (too dangerous to separate); if the weather is so bad fishing is stopped, then the previous tow should receive this code if the rough conditions affected the catch.
I - Torn, damaged, or lost net; usually results from hanging the net and tearing it loose. The net comes back with large tears etc. if at all. Do not use this code if there are only a few broken meshes. Continue using this code until net is repaired or replaced
J - Dumped catch; tow was made but catch was discarded, perhaps because of too mud. Give reason in comments. SEDAR38RW01 18
K - Catch not emptied on deck; nets brought to surface, boat changes location, nets redeployed. (explain in comments)
L - Hung up; untimely termination of a tow by a hang. Specify trawl(s) which were hung and caused lost time in Comments.
M - Bags dumped together, catches could not be kept separate.
N - Net did not fish; no apparent cause. Describe reasoning in comments.
O - Gear fouled on submerged object but tow was not terminated. Performance of tow could be affected. Give specifics in Comments.
P - No measurement taken of shrimp and/or total catch.
Q - Main cable breaks and entire rigging lost. Describe in Comments.
R - Net caught in wheel.
S - Tickler chain heavily fouled, tangled, or broken.
T - Other problems. Describe in comments.
U - Turtle excluder gear intentionally disabled.
V – Unknown operation code.
W - Damaged (i.e., bent or broken) excluder gear.
X - BRD intentionally disabled or non-functional. (Damaged) Describe in comments.
Y - Net trailing behind try net.
Z - Successful tow.

ST6. Number of unobserved tows recorded for observed trips by the Shrimp Observer Program.

n Unobserved Tows	n Trips
0	224
1	68
2	30
3	18
4	9
5	5
6	5
7	4
8	2
9	5
10	1
12	2
13	2
14	1
16	2
17	1
25	2

13.1.6 Figures

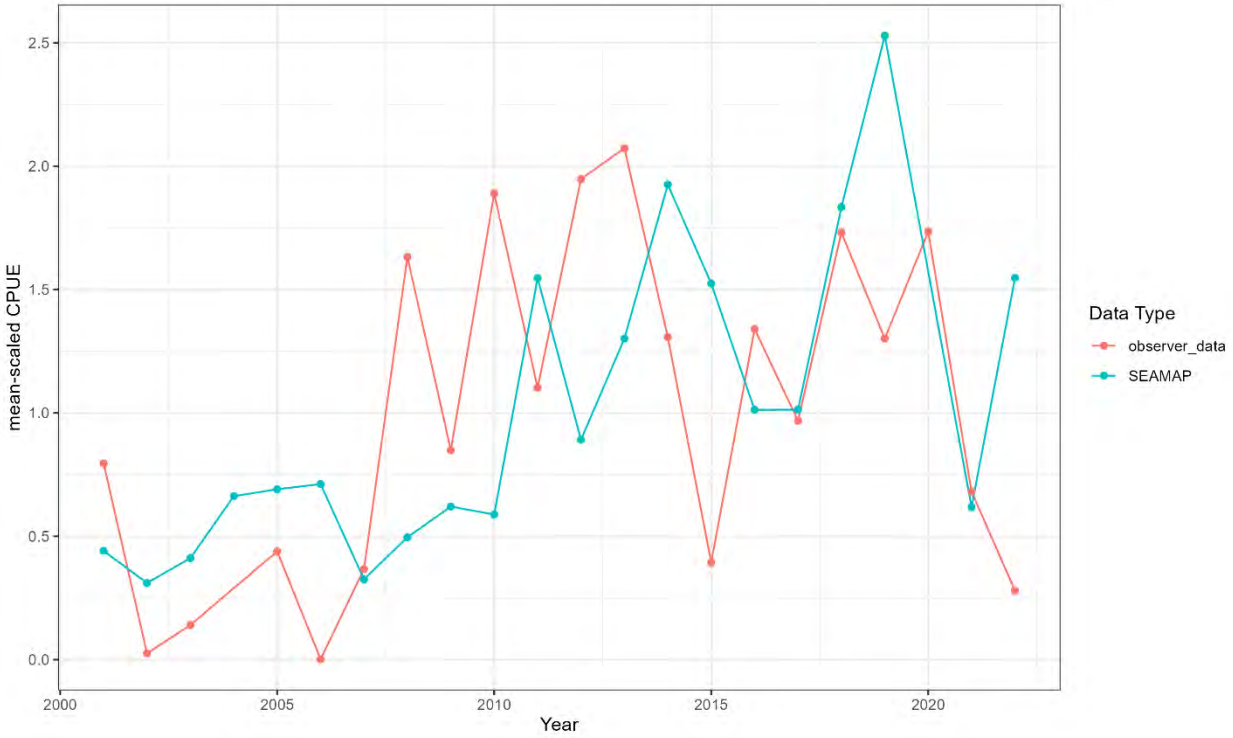


Figure ST1. Annual relative catch rates from fishery-independent SEAMAP Coastal Trawl survey data and Shrimp Observer Program data scaled to their time series means.

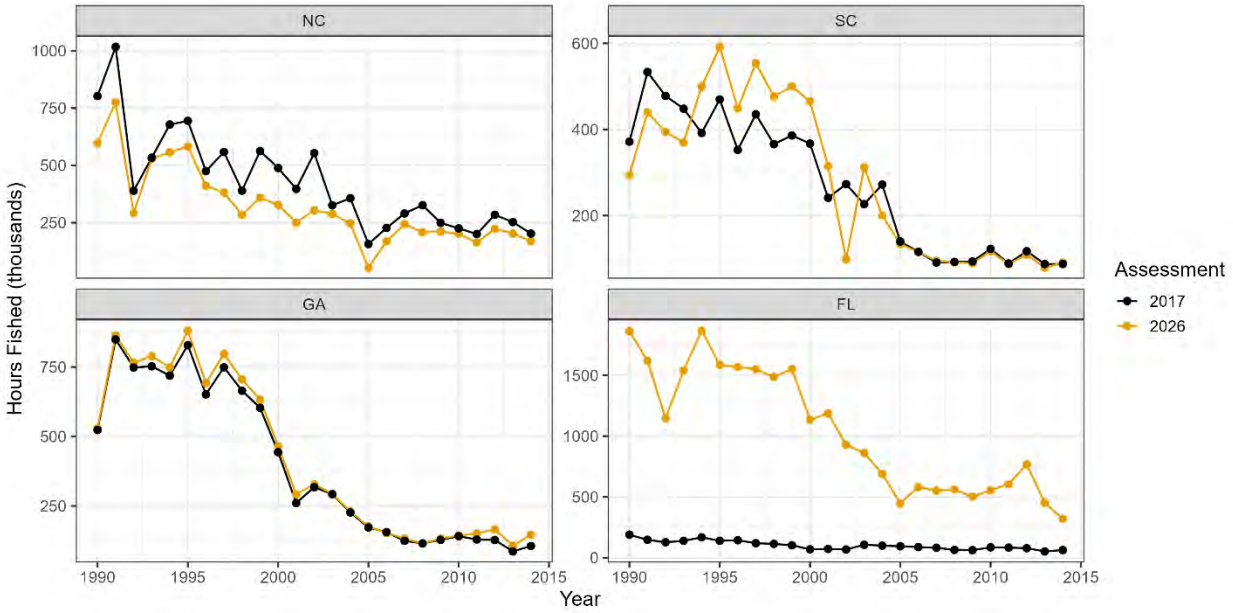


Figure ST2. Comparison of shrimp trawl fishery effort data between the 2017 and current assessments.

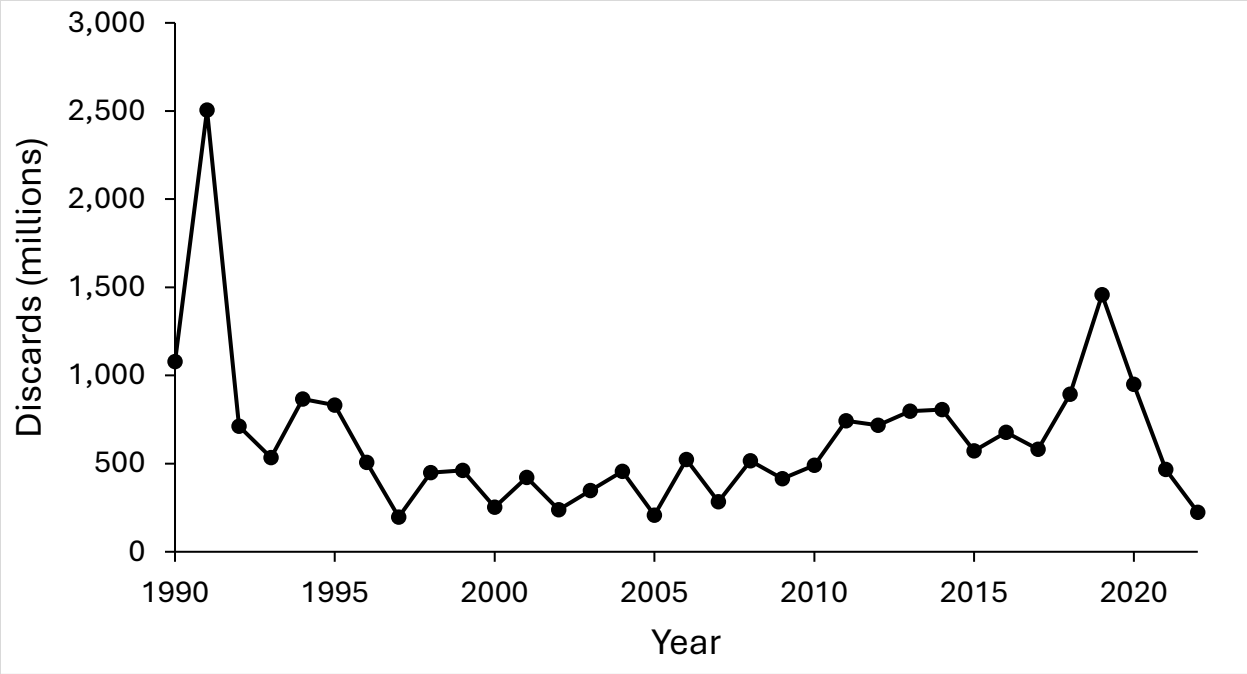


Figure ST3. Shrimp trawl fishery Atlantic croaker discard estimates using the Base method.

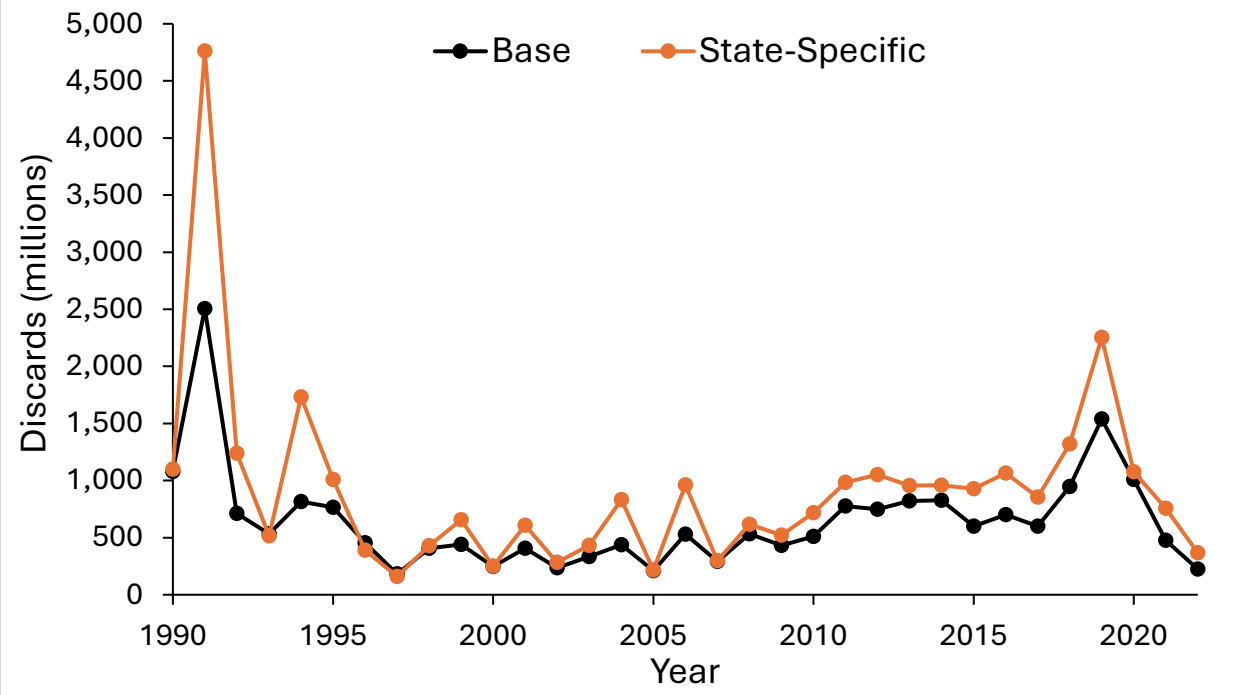


Figure ST4. Shrimp trawl fishery Atlantic croaker discard estimates from state-specific discard rate models compared to estimates using the Base method.

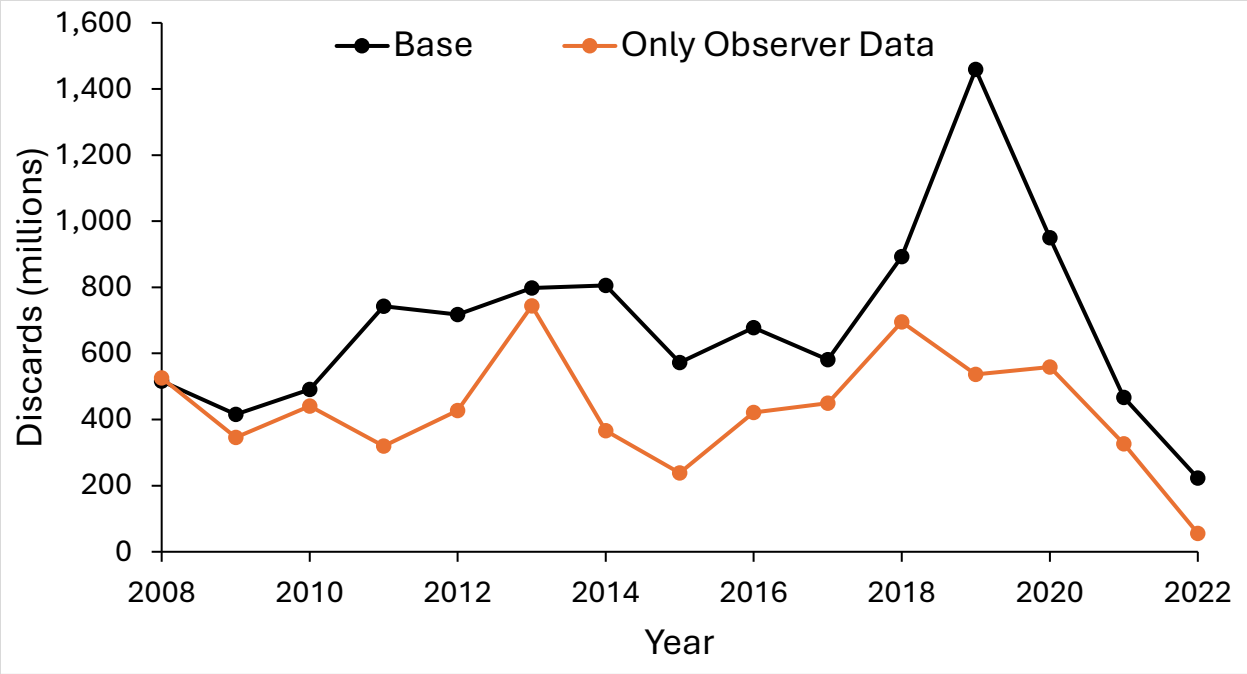


Figure ST5. Shrimp trawl fishery Atlantic croaker discard estimates using only observer data compared to estimates using the Base method.

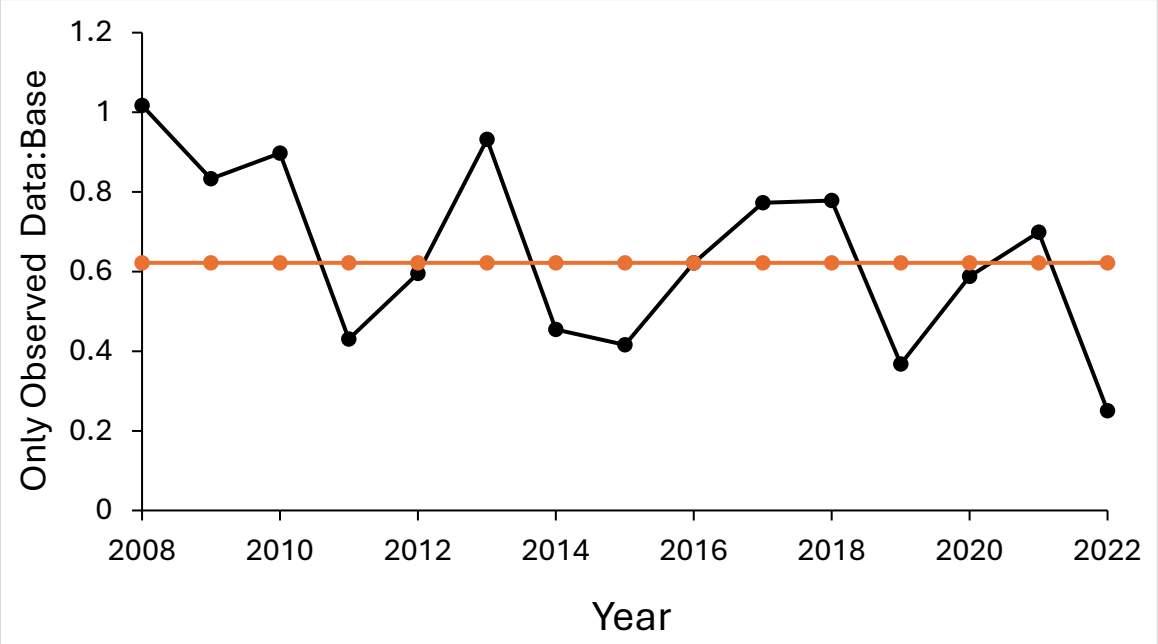


Figure ST6. Ratio of shrimp trawl fishery Atlantic croaker discard estimates using only observer data and using the Base method. The horizontal orange line is the median ratio across the time series.

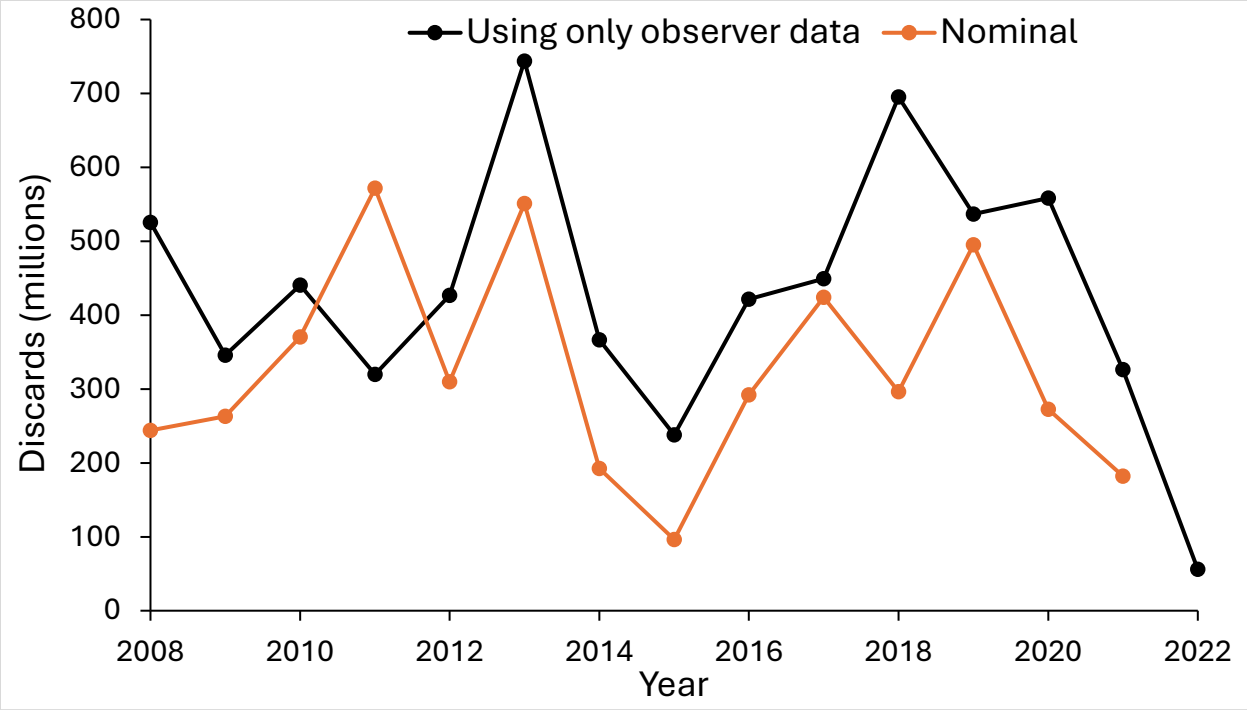


Figure ST7. Shrimp trawl fishery Atlantic croaker nominal discard estimates compared to model-based estimates using only observer data. There were no observer data from South Carolina waters in 2022 precluding a coastwide nominal discard estimate.

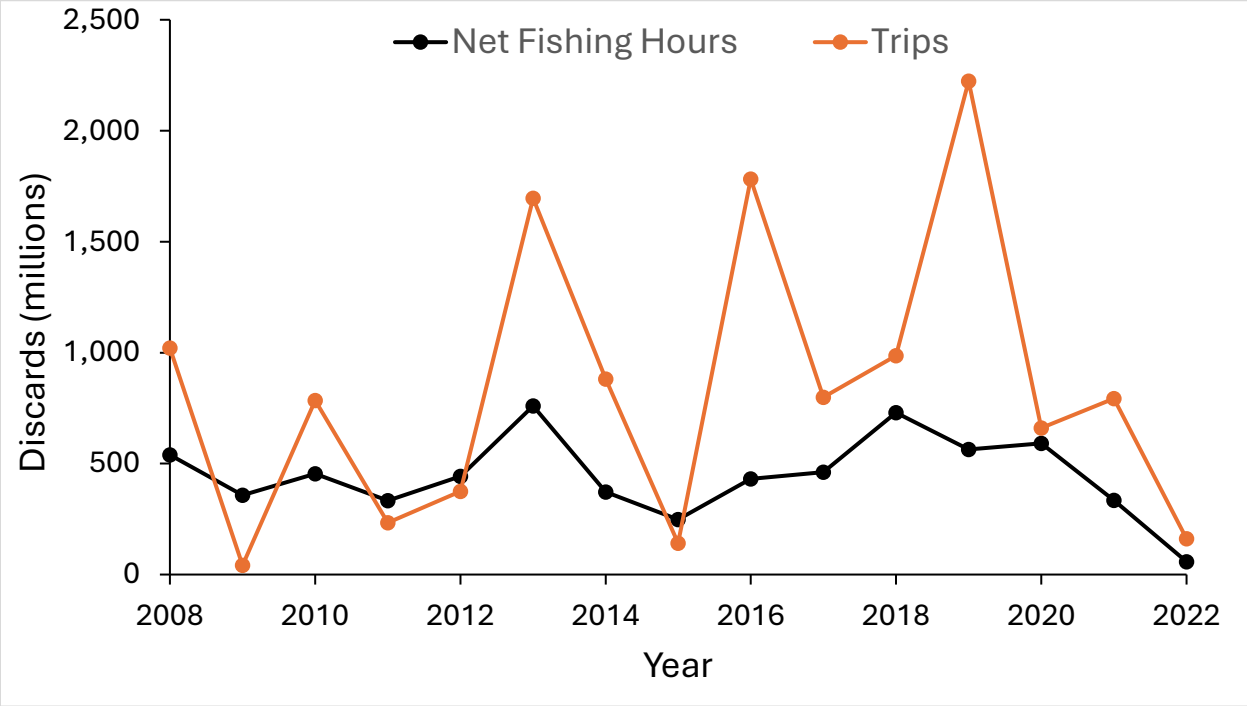


Figure ST8. Shrimp trawl fishery Atlantic croaker discard estimates using a trip effort definition compared to estimates using a net fishing hour effort definition.

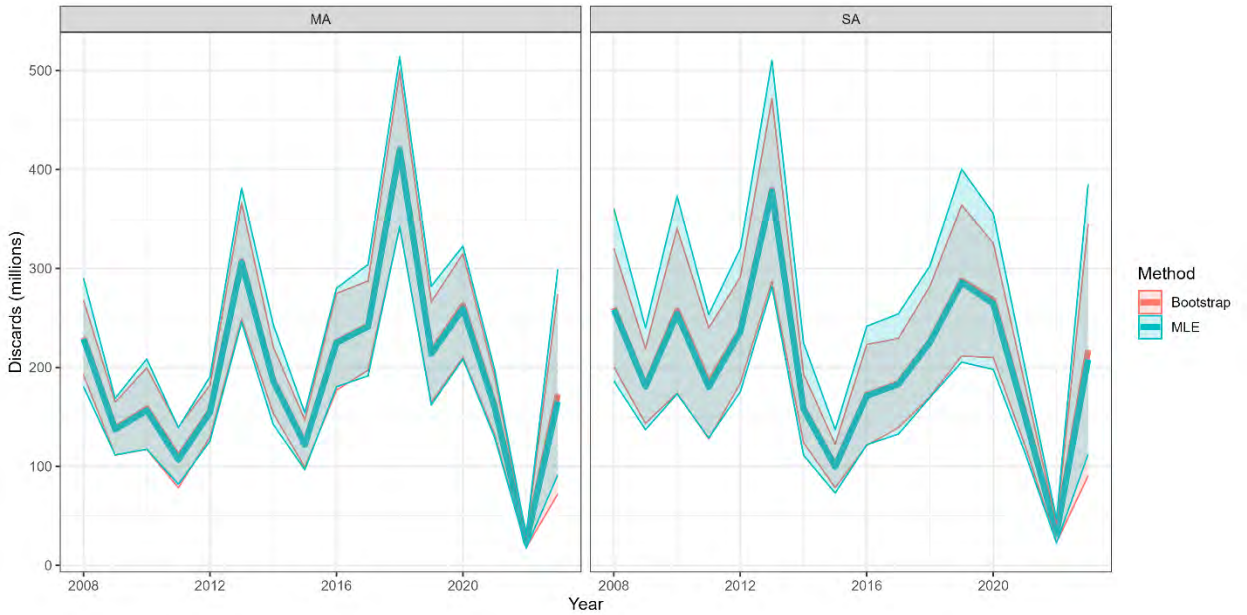


Figure ST9. Comparison of confidence intervals estimated from shrimp trawl fishery Atlantic croaker discard estimates using only observed data.

13.2 Dynamic Factor Analysis

13.2.1 Introduction/Justification

A number of additional indices of abundance were available for the Atlantic croaker stock assessment but were excluded for several reasons (see Table 32 in section 5), with a common reason being localized dynamics. To further examine the potential utility of these surveys in the stock assessment models, dynamic factor analysis (DFA) was considered as a statistical framework to compare multiple time series while accounting for observation error and temporal dependence (Zuur et al. 2003 a, b; Holmes et al. 2012). DFA allows for different surveys, that could be monitoring localized patterns, be combined using linear combinations of the observed indices that evolve through time (Harvey 1989). By reducing each survey to linear functions and modeling their covariance, DFA can be used to extract potential population signals, thus improving estimates of abundance, reducing noisy or biased observation, and quantifying uncertainty (Zuur et al. 2003a, b; Holmes et al. 2012; Peterson et al. 2021; Ward et al. 2021).

The assumption underlying DFA is that you have multiple observed time series, and these series may share hidden common trends (latent factors) that drive their behavior. DFA sees each series as a combination of common trends (latent variables), series-specific loadings (how strongly each series relates to each trend), and noise (random variation). By modeling multiple series together and allowing them to share latent factors, DFA extracts the dominant patterns that explain most of the variability across time series, filtering out individual noise. The underlying common trends often reflect large-scale processes. Here, the goal was to identify whether common temporal trends exist in each population (mid-Atlantic and south Atlantic).

13.2.2 Methods

13.2.2.1 Indices Considered

13.2.2.1.1 SEAMAP Coastal Trawl Survey

The SEAMAP Coastal Trawl Survey was developed into two season specific (Fall and Spring) age-aggregated indices and used in the southern stock SS model. While the two indices were also used in the DFA, details on the analysis can be found in Section 5.1.6.

13.2.2.1.2 NC Estuarine Trawl Survey (Program 120)- Age 0 Recruitment Survey

13.2.2.1.2.1 Survey Design and Methods

The NC Estuarine Trawl Survey (P120) has been ongoing since 1971 to determine primary nursery habitats and estimate annual recruitment of key species in terms of relative abundance indices. Major standardization processes changed the methods of the survey in 1978 and 1989. Since 1989, tows have been completed at 105 fixed stations in May and June, with July occurring in some years (Figure DFA1). A 3.2-m headrope and 0.64-cm bar mesh otter trawl were towed for 1 min covering 75 yards. Environmental data, such as temperature, salinity, dissolved oxygen, wind speed, and direction were noted, with habitat fields added in 2008.

13.2.2.1.2.2 Biological and Environmental Sampling
All species captures are identified and counted. Total Length (TL) is measured from 30-60 individuals of each targeted species (including Atlantic croaker), and several are sacrificed for age determination. Sacrificed individuals are returned to the lab, where otoliths are removed. Thin sections of otoliths are prepared and read for ages based on methods developed by Vanderkoy et al. (2020).

13.2.2.1.2.3 Evaluation of Survey Data
The survey data failed a persistence test ($p< 0.001$), indicating temporal variation in relative catch rates across surveyed stations (Lee and Rock 2017). Therefore, the sdmTMB R package (Anderson et al. 2025) was used to develop a standardized index accounting for this spatio-temporal variation. Very similar to the VAST package, sdmTMB allows fitting spatio-temporal models and is suitable for single species index development. An index for the southern stock was the focus of the analysis as the northern stock already had core YOY indices, including one from the Pamlico Sound in North Carolina (P195).

A length cut-off of 120 mm in May and 140 mm in June was applied to filter catch to assumed YOY. Data prior to the most recent survey methodology change in 1989 were excluded. Data were further filtered to core stations sampled continuously through the time series and only samples in May and June. Sampling location was assumed to capture variation from recorded habitat and environmental variables and variables other than location and year were not considered in index development. Residual diagnostics and AIC were used to select the final model configuration among those tested, which was a negative binomial model with spatial random effects and independent and identically distributed (iid) spatio-temporal random effects with isotropy. Due to the fixed design of the survey, only predictions for mesh cells with station coordinates were used for index calculation.

13.2.2.1.2.4 Abundance Index Trends
The nominal and standardized indices show some slight differences in interannual variation but follow similar patterns across the time series (Table DFA1; Figure DFA2). Indices were higher through the early 2000s, then declined sharply to lower values for the remainder of the time series. These patterns are more similar to abundance patterns observed in the northern stock and may be affected by stock mixing due to sampling being near the stock boundary.

13.2.2.1.3 NC Gillnet Survey (Program 915)
13.2.2.1.3.1 Survey Design and Methods
North Carolina's Pamlico Sound and Rivers Fisheries-Independent Gill-Net Survey (P915) is a multispecies survey utilized to estimate the abundance of target estuarine species in North Carolina waters. Beginning in 2001, the survey collected abundance data using gill nets in the Pamlico Sound with expansions to the Neuse, Pamlico, and Pungo rivers in 2003 and areas in the Southern District in 2008 (Figure DFA3). The Gill-Net Survey data was utilized for Atlantic croaker in the southern stock, so data prior to 2008 were excluded to keep spatial consistency.

The Gill-Net Survey uses a stratified random sampling design based on area and depth to fish using a one-minute by one-minute grid system and delineated into shallow (< 6 feet) or deep

water (>6 feet). Floating gill nets placed in shallow water were paired with sink gill nets placed in deep water to compose two samples in one trip. Each net consists of 30-yard segments with different mesh sizes increasing from 3.0-ISM to 6.5-ISM with 0.5-ISM increments for a total of eight gangs and 240 yards fish. Gill nets are deployed for 12-hour soak times with deployment occurring within an hour of sunset. Gill nets are configured to fish the entire water column with vertical heights of 6 to 7 feet in shallow water stations and 10 feet for deep water stations.

Sampling occurred from February 14 to December 15 each year. However, sampling could not be completed in 2020 due to COVID restrictions. Each region is sampled twice a month with 3 regions in the Southern Region for a total of 40 samples completed each year. During sampling, environmental conditions, such as bottom temperature, bottom salinity, bottom DO, Secchi depth, weather conditions, wind velocity, wind direction, and tidal stage were recorded.

13.2.2.1.3.2 Biological and Environmental Sampling

Captured fish are sorted by species, counted, and weighed for a total weight by species to the nearest 0.01 kg. A subsample of at least 30 individuals were measured for total length in mm with many of these sampled for weight, age, and reproductive samples. Thin sections of otoliths are prepared and read for ages based on methods developed by Vanderkoy et al. (2020). Age samples collected each year were selected by length bin representation rather than random selection.

13.2.2.1.3.3 Evaluation of Survey Data

The NC gillnet survey was standardized using a GLMM framework, where catch was modeled as a function of year, waterbody, depth, bottom temperature, bottom DO, and secchi depth using the *glmmTMB* package in R (Brooks et al. 2017). A negative binomial distribution was used with a log link function. Best model was determined using AIC and BIC criterion, as well as examining residual diagnostics in the *DHARMa* R package (Akaike 1973, Schwarz 1978, Hartig 2022).

13.2.2.1.3.4 Abundance Index Trends

The standardized index tracked closely to the nominal index (Figure DFA4). The lowest abundance was recorded in 2011 and the highest in 2016. The survey did have an overall high occurrence of Atlantic croaker in the catch (Table DFA2). However, the patterns of abundance were not correlated with any other southern stock index. Additionally, the survey was limited spatially due to the stock structure used for Atlantic croaker and the limited number of samples in the southern portion of NC.

13.2.2.1.4 SC Estuarine Trawl Survey- Age 0 Recruitment

The SCDNR Estuarine Trawl Survey is an age-0 recruitment index that was used in the southern stock SS model. While it was also used in the DFA, details on the analysis can be found in Section 5.1.7.

13.2.2.1.5 SC Trammel Net Survey

13.2.2.1.5.1 Survey Design and Methods

In 1990, SCDNR established the trammel net survey to provide relative abundance indices for key estuarine species that are recreationally important to the state and utilize the estuary as

primary habitat, such as Atlantic croaker and red drum. The survey is conducted in the five major estuaries found along the South Carolina coast (Figure 114 in section 5.1.7.1) and has been used in several stock assessments as an index of relative abundance, including the most recent ASMFC red drum stock assessment (ASMFC 2024a). Sampling is conducted monthly from April to October from nine strata (Colleton River (CT), Broad River (BR), ACE Basin (AB), Ashley River (AR), Charleston Harbor (CH), Wando River (LW), Muddy & Bulls Bay (MB), Romain Harbor (RH), and Winyah Bay (WB) within the five estuaries (Port Royal Sound (CT & BR), St. Helena Sound (AB), Charleston Harbor (AR, CH, LW), Cape Romain and Bulls Bay (MB & CR), and Winyah Bay (WB)).

The SCDNR trammel net survey has a stratified random fixed station sampling design, where 12-14 states are randomly selected from 27-36 stations on any given sampling day. Adjacent stations cannot be sampled on the same day to avoid sampling interference and crews typically conduct 10-14 stations on a sampling day. A 183 x 2.1 m trammel net is set along the shoreline during ebbing tide. The trammel net is fit with a polyfoam float line (12.7 mm diameter), a lead core bottom line (22.7 kg), and the netting is composed of an inner panel (0.47 mm #177 monofilament; 63.5 mm stretch-mesh; height = 60 diagonal meshes) in between two outer panels (0.9 mm # 9 monofilament; 355.6 mm stretch-mesh; height = 8 diagonal meshes). While the net soaks, the boat makes two passes parallel to the net at idle speed and technicians disturb the water surface with wooden poles to encourage fish movement into the net. Fish captured during net recovery are placed in a live well.

Fish are identified to species and counted. Target species (such as Atlantic croaker, red drum, black drum, spotted seatrout, sheepshead, southern flounder, spot, southern kingfish, etc.) are measured with total lengths (TL) and standard lengths (SL) recorded for each individual. However, when large catches of one species occur, a sub-sample of twenty-five fish of that species are measured and the remainder are only counted. Most captured fish are released at the site of capture, except for a sub-sample retained for biological sampling (see details below).

While still on station, technicians collected additional environmental data, which includes location (site nested in stratum nested in estuary, latitude, and longitude), depth (m), air temperature (℃), water temperature (℃), salinity (PSU), dissolved oxygen (mg L^{-1}), and tidal stage. More information about the SCDNR trammel net survey can be found at: https://youtu.be/d8_VNKIsFPQ?si=FcS9hCWUQPqjjGdl.

13.2.2.1.5.2 Biological and Environmental Sampling

Atlantic croaker has been listed as a priority species for SCDNR in 2018, so samples are collected for a variety of life history traits. A subsample of Atlantic croaker (~ 30 individuals) is collected from the trammel nets that are sacrificed for otoliths to estimate age and growth and gonad tissues for histological determination of reproductive status.

13.2.2.1.5.3 Evaluation of Survey Data

The SC Trammel net survey runs from April through October but was truncated to samples from June to September due to low catches of Atlantic croaker in the excluded months. The survey was standardized using a GLMM model with spatiotemporal random fields with the R package

sdmTMB (Anderson et al. 2024). The best model configuration was chosen based on AIC (Akaike 1973), BIC (Schwarz 1978), and residual diagnostics of model fit examined with the R package *DHARMa* (Hartig 2022). Given the high occurrence of zero catches in the survey, a delta truncated negative binomial distribution was used with year, day of year, stratum, depth, and salinity as covariates within the model. This model construction allows for the probability of occurrence to be considered with a logit link as well as a second component that models positive catches conditional on occurrence using a log link and truncated negative binomial distribution to account of overdispersed count data. Spatial structure was incorporated using a stochastic partial differential equation based on a spatial mesh. Spatial random fields and spatiotemporal random effects were included.

13.2.2.1.5.4 Abundance Index Trends

The standardized SC Trammel net survey has unexpectedly high annual variability for an age aggregate survey (Figure DFA5), especially when compared to the SC Estuarine Trawl Recruitment Index (see section 5.1.7). There was not an increasing or decreasing trend throughout the timeseries, nor extremely large confidence intervals around the index estimates. The percent positive occurrence of Atlantic croaker improved after removing three months with low catches but still remained less than 50% of catches containing croaker in many years (Table DFA3).

13.2.2.1.6 SCECAP

13.2.2.1.6.1 Survey Design and Methods

This estuarine trawl survey has been conducted since 1999 as part of the South Carolina Estuarine and Coastal Assessment Program (SCECAP). The primary objective of SCECAP is to evaluate overall estuarine habitat quality and biotic condition over time and throughout the state's coastal zone in a manner that is integrated with and complementary to the SC Department of Environmental Services (SC-DES) Water Quality Monitoring Program. SCECAP sampling locations range from Little River Inlet at the NC-SC border down to the Savannah River at the SC-GA border. Sampling occurs from the saltwater-freshwater line to the mouth of the estuarine drainage basin (Figure 114 in section 5.1.7.1). Sites are selected each year to represent both open water (rivers, bays and sounds) and large tidal creek habitats (important nursery areas) using sampling methods that permit quantification of the percentage of each habitat type that meets, or does not meet, a desired level of quality. Approximately 30 randomly chosen sites are sampled each year to measure water quality, sediment quality, and biological condition. While SCECAP sampled from June through September for some years in the survey, the only two months that were consistently sampled throughout the entire time period were July-August (Tweel et al. 2024). Therefore, the index for Atlantic croaker was calculated using only those two months.

Sampling for water quality, sediment quality and biological condition occur at each station within three hours surrounding low tide. Trawling occurs at each station to quantify the bottom nekton community (fish and large invertebrates). At each station, two replicate tows are dragged in the same direction as tidal flow using a 4-seam trawl (5.5 m foot rope, 4.6 m head rope and 1.9 cm bar mesh throughout). Tow length was standardized to 0.5 km for open

water stations and 0.25 for tidal creek stations. All fish and invertebrates captured are identified and counted. Up to 30 individuals of each taxon are measured to the nearest centimeter. Water quality data collected at each station via YSI (Model 6920, 6600, or EXO2) included temperature, salinity, dissolved oxygen (DO) and pH (Tweel et al. 2024).

13.2.2.1.6.2 Biological and Environmental Sampling

The SCECAP survey captured Atlantic croaker that ranged in size from 2-22 cm total length with the most abundant classes ranging from 8-12 cm (3-5 inches) total length. Given this annual size range, the SCECAP survey was catching primarily age 0-1 Atlantic croaker. Larger specimens (14+ cm) captured in other fishery independent surveys were not seen in large numbers in the SCECAP survey and represented 10.6% of the measured fish from 1999-2024. So, the primary utility of the SCECAP survey is as an annual summer index of relative abundance for juvenile Atlantic croaker.

13.2.2.1.6.3 Evaluation of Survey Data

The standardized index for Atlantic croaker from the SCECAP survey runs from 1999-2024 during the months of July and August. Since duplicate tows occur at each station the mean of Atlantic croaker abundance and all covariates was calculated prior to index standardization. Stations without complete covariate information were dropped from analyses. Vector-autoregressive spatiotemporal (VAST; R Package: VAST) models were used to standardize the Atlantic Croaker abundance index from the SCECAP Survey (Thorson et al. 2017; Thorson 2019). The VAST model correlates the abundance in a sample to covariates for that sample, as well as other factors included in the model. By decomposing the time series into two components, the probability of encounter and the expected catch rate, VAST effectively creates a delta model that generally performs well with zero-inflated datasets, such as multi-species fisheries surveys (Maunder and Punt 2004). Area swept was included as an offset, year as a fixed factor, and latitude, longitude, depth, water temperature, salinity, and dissolved oxygen as continuous variables in the VAST models. The zero-inflated negative binomial error distribution was used for the presence/absence portion of the model, and the negative binomial error distribution was used for the abundance model based on Akaike's Information Criterion (AIC) during preliminary model fitting (Akaike 1973). The VAST model was conducted with up to 200 knots, spatial and spatiotemporal autocorrelation as random effects, and anisotropy turned on. In addition, a bias correction was included in the model to account for any changes in the spatial footprint of the survey over time. The index of abundance from the VAST model estimated the total number of fish expected when covariates (including sampling density) are taken into consideration.

13.2.2.1.6.4 Abundance Index Trends

The SCECAP index of abundance for Atlantic croaker including covariates shows increase in the most recent years of the survey. Abundance was relatively stable from 1999-2017 but has been increasing since then up until 2024 (Table DFA4; Figure DFA6). The center of gravity and effective area occupied have fluctuated a lot through the study period with no apparent pattern (Figure DFA7-DFA8).

13.2.2.1.7 GA Estuarine Trawl Survey- Age 0 Recruitment

The GADNR Estuarine Trawl Survey is an age-0 recruitment index that was used in the southern stock SS model. While it was also used in the DFA, details on the analysis can be found in Section 5.1.8.

13.2.2.1.8 GA MSPHP Gill Net

13.2.2.1.8.1 Survey Design and Methods

The GA gillnet survey began in 2003 to monitor the abundance of estuarine species in the Altamaha River Estuary and Wassaw Sound. The stratified random fixed sampling design uses a pool of 60 stations in the Altamaha River estuary and 70 stations in Wassaw Sound, where 36 stations in each are randomly sampled monthly. Sampling has been consistent since the inception of the survey through the terminal year of the model in 2024.

Sampling occurs during the last three and a half hours of ebb tide in daylight. A single panel gillnet, 91.4 m (300 ft) in length and 2.7 m (9 ft) deep is set from the bank in a semicircular path until ending back at the bank. The net has a stretch mesh of 6.4 cm (2.5 in), a 1.3 cm (0.5 in) diameter float rope, and a 34 kg (75 lb) lead line. While the net is deployed, the boat makes two to three passes in the enclosed area of the net to actively fish the area. When the net is retrieved, the catch is placed inside a holding pen on the side of the boat for processing.

All finfish specimens identified to species and measured to the nearest mm CL unless there is a large quantity of a species capture. When catches are greater than 25 individuals of a specific species, a subsample of 25 individuals are measured, and remaining individuals are counted. All specimens are released at site capture. Additional environmental variables are recorded at each sampling location, which include location (latitude and longitude), depth (m), water temperature (℃), salinity (ppt), dissolved oxygen (mg L-1), tidal stage, wind direction, wind velocity, and weather condition.

13.2.2.1.8.2 Biological and Environmental Sampling

Specimens are measured in centerline length (CL) to the nearest mm.

13.2.2.1.8.3 Evaluation of Survey Data

The GA gill net survey represents an aggregation of all Atlantic croaker ages available to the gear from June through August each year. Catch rates were standardized using the *sdmTMB* R package (Anderson et al. 2024), which has a suite of options to examine spatial and/or spatiotemporal effects within generalized linear mixed effects models (GLMM). The GA gill net survey is a stratified random sampling design from an array of fixed stations (discrete location), so a spatiotemporal GLMM was fit using latitude and longitude of each stations to develop a spatial mesh and year as the temporal variable.

Additional environmental variables tested within the GLMM were sound system (larger waterbody), day of year, salinity, temperature, dissolved oxygen, wind direction, wind velocity, tidal stage, weather conditions, and depth. Models were compared using AIC and BIC to select for the best fit model. A delta-truncated negative binomial error distribution and a zero-inflated negative binomial error distribution were examined for the best model fit.

The best fit model was a delta-truncated negative binomial error distribution with year, day of year, and depth as significant covariates. A prediction grid of available combinations from significant covariates was used to estimate the year class effects using the best fit model. The catch was then predicted from this grid using the *sdmTMB* function "get_index" (Anderson et al. 2024). The model fit and predictions were further explored using residual diagnostics available from the *DHARMa* R package (Hartig 2022).

13.2.2.1.8.4 Abundance Index Trends

The relative abundance of Atlantic Croaker in the GA gill net survey have been variable, but stable through time (Figure DFA9). Estimates were high in 2004 then declined in 2005 through 2007. Since 2008, catches slowly increased until 2019, then catch greatly increased in 2020 and became more variable at elevated levels from 2021 to 2024. The number of trips with positive catch has been variable through time, ranging from 16% to 52% (Table DFA5).

13.2.2.1.9 FL 21.3 Seine- Age 0 Recruitment Survey

13.2.2.1.9.1 Survey Design and Methods

Several surveys are conducted by the Florida Fish and Wildlife Research Institute's Fishery Independent Monitoring (FIM) program that monitors fish and invertebrate abundance in estuaries of Florida. Surveys focused on northeast Florida (lower St. Johns, Nassau, and St. Mary's River basins) were of interest for calculating Atlantic croaker indices of abundance for the southern stock. Data collected in the Indian River Lagoon were considered, but ultimately excluded, based on recommendation from Florida Fish and Wildlife personnel. Indian River Lagoon is a transition zone dominated by mangrove wetlands, a stark difference from the salt marsh habitats found in the rest of northeast Florida. Additional water quality concerns within the Indian River Lagoon, prompted excluding this survey data from the indices of abundance calculations.

For a recruitment index, the 21.3-m center bag survey was used. The survey used a stratified random sampling design where sampling zones are based on geographic area and logistical criteria (Figure DFA10). Zones are further divided into sampling grids and stratified based on depth and habitat (defined by shore type and bottom vegetation). The survey selects locations based on shallow water habitat (≤1.8 m). Grids have been sampled monthly since May 2001. Only samples collected from December to April are used in the croaker index to ensure these are young-of-the-year being targeted by this recruitment survey. The 21.3 m seine with 3.2 mm stretch mesh is deployed via boat in a semicircle fashion against the shoreline. Scientists pull the seine in towards shore by hand to collect the catch.

Fish captured by the haul seine are identified to species and measured for standard length (SL) to the nearest mm. If catches of a particular species are greater than 40 individuals, a subsample of the species is measured, and all remaining individuals are counted. Additional environmental variables are recorded at each sampling location, including temperature (℃), salinity (PSU), and depth (m).

13.2.2.1.9.2 Biological and Environmental Sampling
Specimens are measured in standard length (SL) to the nearest mm. Only Atlantic croaker ≤ 50 mm SL are recorded in this young-of-the-year survey.

13.2.2.1.9.3 Evaluation of Survey Data
The FL 21.3 Seine Age-0 recruitment survey was standardized using a GLMM framework with the R package *glmmTMB* (Brooks et al. 2017). The model was developed with a negative binomial error distribution and significant covariates included Year, temperature, salinity, and bottom type. The best model configuration was determined based on AIC, BIC, and residual diagnostics developed using *DHARMa* package in R (Hertig 2022).

13.2.2.1.9.4 Abundance Index Trends
The age-0 abundance of Atlantic croaker captured in the FL 21.3 Seine survey was similar between the standardized index and the nominal index, with no discernible increase or decrease over the time series (Figure DFA11). The high annual variability is expected given this survey targeted age-0 Atlantic croaker; even more so given it targeted the smallest individuals in the first few months of life. The survey had a very high catch rate, with catches of Atlantic croaker occurring in greater than 90% of tows in many years (Table DFA6). However, the survey did not correlate with other southern stock surveys and was truncated spatially due to sampling concerns in the Indian River Lagoon.

13.2.2.1.10 FL 183 Haul Seine
13.2.2.1.10.1 Survey Design and Methods
The Florida Fish and Wildlife Research Institute's Fishing Independent Monitoring (FIM) program monitors several areas in northeast Florida (lower St. Johns, Nassau, and St. Mary's River basins; Figure DFA10) to estimate the relative abundance of key estuarine species, including Atlantic croaker. The Indian River Lagoon is also monitored, but this analysis excluded the area due to concerns mentioned above. A stratified random sampling design within sampling zones subdivided into 1-nm^2 grids. Sampling grids are designated based on geographic criteria, depth, and habitat (defined by shore type and bottom vegetation). Samples are collected in shallow water (≤1.8 m). A 183-m haul seine with 38 mm stretch mesh was deployed by boat with 45 m of net deployed perpendicular to shore, then a 90-degree turn was made with an additional 90 m of net deployed. A second 90-degree turn was made, and the final 45 m of net was deployed. This deployment creates a rectangle with the shore. The net was then pulled in by hand by two sets of scientists on each end. The net has been deployed monthly from 1997-2023. However, most northeast Florida stations were not sampled year-round until 2001, resulting in low catches from 1997-2000. So, all data prior to 2001 were excluded from analysis.

Fish captured by the haul seine are identified to species and measured for standard length (SL) to the nearest mm. If catches of a particular species are greater than 40 individuals, a subsample of the species is measured, and all remaining individuals are counted. Additional environmental variables are recorded at each sampling location, including temperature (°C), salinity (PSU), and depth (m).

13.2.2.1.10.2 Biological and Environmental Sampling
Specimens are measured in standard length (SL) to the nearest mm.

13.2.2.1.10.3 Evaluation of Survey Data
The FL 183 Haul Seine Survey was standardized using a spatiotemporal GLMM framework with the R package *sdmTMB* (Anderson et al. 2024). The best model configuration was chosen based on AIC, BIC, and residual diagnostics developed using the R package *DHARMa* (Hartig 2022). The best model had a negative binomial error distribution with Year, day of year, stratum, depth, and salinity as significant covariates. Spatial structure was incorporated using a stochastic partial differential equation based on a spatial mesh. Spatial random fields and spatiotemporal random effects were included.

13.2.2.1.10.4 Abundance Index Trends
The FL 183 Haul Seine had little change through time (Table DFA7; Figure DFA12). Overall, the survey had a high percent positive occurrence of Atlantic croaker in the catches but little annual variability in the index trend (Table DFA7). Given the survey is limited to the northeast portion of Florida, no correlation to other surveys in the region, and the low variability.

13.2.2.2 Dynamic Factor Analysis Models
The dynamic factor analysis was completed using the *MARSS* R package (Holmes et al. 2012; Holmes et al. 2025a, b). DFAs were conducted separately for the northern and southern stocks. Within each unit stock, two DFAs were performed—one for young-of-year (YOY) indices and one for adult indices. For each DFA, a suite of models was fit with a varying number of common trends (K) and different assumptions about the observation error (R), process variance (Q), and intercept (A). Data were detrended and standardized using z-score transformation so the analysis would not be biased by scale issues by ensuring all series contribute equally to detecting shared patterns. Data were also log-transformed to stabilize the variance and reduce skewness.

To determine the optimal number (K) of common trends in the DFA, the Akaike Information Criterion corrected for small sample sizes (AICc) was used. Among candidate models, the one with the lowest AICc was selected as the best-supported model. For the northern stock, after identifying the optimal number of common trends, we tested and compared different variance structures (0; see Holmes et al. 2012; Holmes et al. 2025a, b; and Zuur 2003a, b for more details) and assumed the optimal trend number. Again, AICc was used to select the best model.

13.2.3 Results
DFA was carried out for the northern and southern stocks for both YOY and adult life stages. Up to three trends were considered for the northern stock and up to five trends were considered for the southern stock. In all cases, the best-fitting model (lowest AICc) assumed one common trend (Factor 1; Table DFA9).

The common trend for the northern YOY fish shows a general increase since the early 2000s (Figure DFA13). Of the two observed time series for the northern YOY Atlantic Croaker, the VIMS_yoy had a higher loading though only slightly higher than the NCDMF_yoy loading (Table

DFA10). Both northern YOY indices had positive loadings, which indicates a similar directional trend. The similarity in loading values suggests both northern YOY indices respond in a similar way to the same common trend.

The common trend estimated for adults in the northern stock increases from the beginning of the time series through the early 2010s, decreases through 2020, and has since increased (Figure DFA14). All three adult indices available for the northern stock had positive loadings and the ChesMMAP index showed the highest loading (Table DFA10). The loadings for the NEFSC and NEAMAP indices were similar in value to each other but smaller than the ChesMMAP loading value, suggesting that the ChesMMAP time series is driving most of the signal.

In the southern stock, the common trend for YOY Atlantic Croaker shows little variation with the exception of a decrease in the late 2000s/early 2010s (Figure DFA15). The NCTrawl_yoy, SCTrawl_yoy, and GATrawl_yoy had positive loadings while the FL21Seine_yoy time series had a negative loading (Table DFA10). The negative loading attributed to the FL21Seine_yoy index indicates it moves in the opposite direction of the estimated common trend. The largest loading value was attributed to the SCTrawl_yoy index. Loading values for the NCTrawl_yoy and GATrawl_yoy series were similar to each other, suggesting similar contributions to the common trend.

The common trend for southern stock adult Atlantic Croaker has been increasing since the early 2000s (Figure DFA16). Of the nine observed adult indices for the south Atlantic, all but two (NC_Estuarine and FL183Haul) had positive loading values suggesting most of these time series are moving in the same direction as the common trend (Table DFA10). The SEAMAP_Fall had the highest loading among the south Atlantic adult time series followed closely by the SEAMAP_Summer time series.

13.2.4 Conclusions

The DFA results suggest there is one dominant underlying process for each life stage (YOY and adult) and system (northern and southern stocks) driving the variability across all series. The dominant trend for each life stage and system likely reflects overall population dynamics rather than survey-specific noise. Indices within the northern and southern Atlantic systems appear to be highly synchronized (within the system and life stage), with most survey sites responding similarly to the same environmental driver (it may be different for each system and life stage). That driver is influencing most survey indices in a similar manner. The indices that show a negative loading response in an opposite manner to the driver are responding differently to the environmental drivers or to separate environmental drivers.

While the DFA combined indices into a plausible abundance trend, the analysis provided strong evidence that local environmental factors were an influential driver in estimated abundance patterns. The recruitment indices created by the DFA did not reflect the interannual variability that would be realistic in nature and the SAS felt that disconnect added more uncertainty in the stock assessment model than using separate indices. When using the DFA-created adult indices, the stock assessment model resulted in diagnostic problems that could not easily be resolved at this time. With more research, the DFA analysis could provide more insights into the overall

abundance trends and potential localized drivers important to the stocks; however, it was not ready for this assessment.

13.2.5 References

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13.2.6 Tables

Table DFA1. Southern stock Atlantic croaker index of abundance from the NC Estuarine Trawl Survey (Program 120) from 1989-2023. Index and standard errors (SEs) are on the log scale. Number of tows reflects all sampling events included in index calculations and percent positive reflects the percent of tows that caught Atlantic croaker.

Year	Index	SE	Number of Tows	Positive Tows	Percent Positive
1989	7.206524	0.34	36	31	86%
1990	5.073472	0.27	36	21	58%
1991	6.126728	0.29	36	26	72%
1992	6.572938	0.27	36	27	75%
1993	6.960508	0.29	36	28	78%
1994	5.793424	0.27	36	27	75%
1995	7.307886	0.28	36	27	75%
1996	5.804025	0.27	36	20	56%
1997	5.381373	0.32	36	26	72%
1998	6.772944	0.28	36	27	75%
1999	4.78256	0.27	36	26	72%
2000	6.049101	0.28	36	26	72%
2001	6.91313	0.25	36	26	72%
2002	5.81435	0.27	36	28	78%
2003	6.26634	0.29	36	27	75%
2004	5.369517	0.30	36	21	58%
2005	5.415829	0.27	36	20	56%
2006	5.192921	0.32	36	19	53%
2007	5.052124	0.29	36	24	67%
2008	4.333748	0.28	36	17	47%
2009	5.164055	0.32	36	25	69%
2010	6.017556	0.28	36	23	64%
2011	4.393889	0.30	36	17	47%
2012	4.197692	0.28	36	19	53%
2013	5.250714	0.31	36	25	69%
2014	6.304698	0.37	36	31	86%
2015	5.105175	0.31	36	21	58%
2016	6.046799	0.27	36	25	69%
2017	6.087953	0.28	36	24	67%
2018	5.682209	0.31	36	23	64%
2019	5.047084	0.33	36	18	50%
2020	4.463068	0.36	36	17	47%
2021	5.516715	0.28	36	23	64%
2022	4.832421	0.27	36	18	50%
2023	4.852906	0.28	36	22	61%

Table DFA2. Southern stock Atlantic croaker index of abundance and catch demographics from the NC Gillnet Survey (P915) from 2008-2024. Index is scaled to its mean and standard errors (SE) are in terms of log(Index). Number of trips reflects all sampling events that occurred within P915 and percent positive reflects the percent of trips that caught Atlantic croaker. Biological information gathered from P915 are reported in the number of lengths (number of croaker measured) and the number of ages (number of otoliths collected from croaker for aging).

Year	Index	CV	Number of Trips	Positive Trips	Percent Positive	Number of Lengths	Number of Ages
2008	0.84	0.227	41	18	43.9%	46	92
2009	0.87	0.216	47	22	46.8%	56	47
2010	0.47	0.271	43	16	37.2%	26	41
2011	0.25	0.300	52	11	21.2%	21	24
2012	0.43	0.259	49	13	26.5%	27	18
2013	0.50	0.263	45	16	35.6%	27	32
2014	0.98	0.201	48	23	47.9%	81	73
2015	1.15	0.187	52	27	51.9%	91	67
2016	1.34	0.200	48	29	60.4%	72	50
2017	0.85	0.225	44	24	54.5%	59	47
2018	0.94	0.202	49	25	51.0%	47	36
2019	0.59	0.203	66	21	31.8%	46	43
2020	-	-	-	-	-	1	1
2021	0.56	0.222	56	24	42.9%	33	32
2022	0.74	0.199	62	26	41.9%	66	54
2023	0.90	0.173	72	33	45.8%	94	81
2024	0.82	0.191	69	29	42.0%	55	5

Table DFA3. Southern stock Atlantic croaker index of abundance (with standard errors (SE)) and catch demographics from the SC Trammel Net Survey from 1991-2024. Number of trips reflects all sampling events that occurred within the SC Trammel Net Survey and percent positive reflects the percent of trips that caught Atlantic croaker. Biological information gathered from the SC Trammel Net Survey are reported in the number of lengths (number of croaker measured) and the number of ages (number of otoliths collected from croaker for aging).

Year	Index	SE	Number of Trips	Positive Trips	Percent Positive	Number of Lengths	Number of Ages
1991	15423	0.26	31	24	77.4%	297	-
1992	9879	0.26	53	30	56.6%	342	-
1993	5872	0.21	86	40	46.5%	188	-
1994	2692	0.18	152	47	30.9%	166	-
1995	2415	0.14	235	72	30.6%	171	-
1996	2556	0.19	228	49	21.5%	155	-
1997	4292	0.12	267	109	40.8%	424	-
1998	8265	0.11	282	138	48.9%	981	-
1999	5123	0.12	296	127	42.9%	492	-
2000	4268	0.11	288	124	43.1%	437	-
2001	2105	0.13	264	81	30.7%	221	-
2002	4455	0.11	275	138	50.2%	554	-
2003	5348	0.11	296	130	43.9%	636	-
2004	1615	0.16	301	58	19.3%	140	-
2005	4285	0.11	287	112	39.0%	482	-
2006	4945	0.10	301	148	49.2%	531	-
2007	7171	0.10	305	145	47.5%	852	-
2008	9160	0.11	265	144	54.3%	781	-
2009	10581	0.09	286	190	66.3%	1246	-
2010	4030	0.11	318	125	39.3%	508	-
2011	6816	0.09	337	174	51.6%	900	-
2012	3705	0.10	338	136	40.2%	528	-
2013	6423	0.10	282	132	46.8%	674	-
2014	4322	0.09	301	150	49.8%	568	282
2015	6025	0.10	295	126	42.7%	659	2
2016	2388	0.11	323	108	33.4%	338	-
2017	5080	0.10	217	111	51.2%	547	-
2018	5363	0.11	243	120	49.4%	561	-
2019	4022	0.10	330	130	39.4%	545	-
2020	7341	0.12	193	102	52.9%	565	-
2021	8038	0.12	180	100	55.6%	605	42
2022	8078	0.11	198	110	55.6%	613	42
2023	11196	0.10	257	151	58.8%	1057	56
2024	7302	0.12	191	90	47.1%	560	44

Table DFA4. Southern stock Atlantic croaker index of abundance (with standard errors (SE)) and catch demographics from the SCECAP from 1999-2024. Number of trips reflects all sampling events that occurred within the SCECAP survey and percent positive reflects the percentage of trips that caught Atlantic croaker. Biological information gathered from the SCECAP Survey is reported in the number of lengths (number of croaker measured) and the number of ages (number of otoliths collected from croaker for aging).

Year	Index	SE	Number of Trips	Positive Trips	Percent Positive	Number of Lengths
1999	21,338.26	0.37	53	11	20.8%	54
2000	27,958.83	0.29	44	16	36.4%	123
2001	47,074.83	0.28	49	16	32.7%	190
2002	48,626.13	0.32	43	12	27.9%	150
2003	88,990.08	0.27	47	20	42.6%	327
2004	20,699.77	0.35	51	10	19.6%	135
2005	37,581.47	0.34	42	11	26.2%	172
2006	15,139.82	0.48	42	6	14.3%	85
2007	68,609.60	0.35	29	9	31.0%	164
2008	13,489.04	0.47	28	7	25.0%	20
2009	44,706.33	0.46	30	7	23.3%	41
2010	28,377.62	0.40	28	9	32.1%	98
2011	48,394.28	0.37	29	9	31.0%	100
2012	21,934.31	0.41	30	6	20.0%	77
2013	71,036.06	0.37	29	15	51.7%	86
2014	38,908.44	0.35	30	9	30.0%	118
2015	13,939.16	0.55	30	5	16.7%	57
2016	38,207.84	0.40	30	9	30.0%	69
2017	12,036.17	0.45	30	7	23.3%	24
2018	60,134.74	0.35	29	10	34.5%	112
2019	77,279.18	0.26	30	15	50.0%	266
2020	108,436.60	0.27	29	19	65.5%	144
2021	139,806.60	0.40	29	9	31.0%	188
2022	67,750.53	0.30	30	15	50.0%	143
2023	213,020.30	0.27	26	17	65.3%	247
2024	110,887.30	0.35	30	17	56.7%	134

Table DFA5. Southern stock Atlantic croaker index of abundance (with standard errors (SE)) and catch demographics from the GA Gillnet Survey from 2003-2024. Number of trips reflects all sampling events that occurred within the GA Gillnet Survey and percent positive reflects the percent of trips that caught Atlantic croaker. Biological information gathered from the GA Gillnet Survey are reported in the number of lengths (number of croaker measured).

Year	Index	SE	Trips	Positive Trips	Percent Positive	Number of Lengths
2003	1612.37	0.199	80	33	41.3%	125
2004	786.96	0.198	104	36	34.6%	90
2005	934.32	0.180	126	38	30.2%	93
2006	818.22	0.165	121	43	35.5%	101
2007	181.03	0.281	94	15	16.0%	22
2008	456.88	0.187	129	30	23.3%	59
2009	1078.88	0.133	188	63	33.5%	206
2010	402.24	0.163	186	37	19.9%	84
2011	507.47	0.141	215	54	25.1%	114
2012	508.59	0.138	216	62	28.7%	103
2013	816.73	0.133	205	71	34.6%	155
2014	585.46	0.160	175	53	30.3%	128
2015	660.57	0.147	178	51	28.7%	153
2016	773.59	0.133	204	65	31.9%	157
2017	688.74	0.140	198	64	32.3%	129
2018	885.45	0.126	200	83	41.5%	175
2019	966.34	0.128	211	80	37.9%	172
2020	1738.92	0.119	206	104	50.5%	308
2021	1451.43	0.118	216	112	51.9%	243
2022	909.53	0.134	196	74	37.8%	173
2023	1447.18	0.120	209	92	44.0%	275
2024	991.96	0.123	216	77	35.6%	205

Table DFA6. Southern stock Atlantic croaker index of abundance (with standard errors (SE)) and catch demographics from the FL 21.3 m Haul Seine Survey from 2002-2024. Number of trips reflects all sampling events that occurred within FL 21.3 m Haul Seine Survey and percent positive reflects the percent of trips that caught Atlantic croaker.

Year	Index	SE	Number of Trips	Positive Trips	Percent Positive
2002	6.80	1.09	62	59	95.2%
2003	9.20	1.62	50	49	98.0%
2004	7.25	1.28	51	47	92.2%
2005	16.76	2.42	74	69	93.2%
2006	11.89	1.82	66	63	95.5%
2007	8.92	1.49	59	55	93.2%
2008	13.55	1.75	94	90	95.7%
2009	11.67	1.96	58	55	94.8%
2010	10.87	1.61	77	72	93.5%
2011	6.76	1.44	40	35	87.5%
2012	9.47	1.57	62	57	91.9%
2013	10.82	1.76	61	58	95.1%
2014	5.69	1.04	52	46	88.5%
2015	6.13	1.15	46	37	80.4%
2016	9.62	1.52	63	62	98.4%
2017	9.74	1.35	90	81	90.0%
2018	13.37	1.90	89	85	95.5%
2019	6.60	1.01	72	67	93.1%
2020	17.59	2.35	96	93	96.9%
2021	9.29	1.20	109	104	95.4%
2022	10.12	1.53	73	66	90.4%
2023	7.86	1.64	36	35	97.2%
2024	7.23	2.18	17	17	100.0%

Table DFA7. Southern stock Atlantic croaker index of abundance (with standard errors (SE)) and catch demographics from the FL 183m Haul Seine Survey from 2001-2024. Number of trips reflects all sampling events that occurred within the FL 183 m Haul Seine Survey and percent positive reflects the percent of trips that caught Atlantic croaker. Biological information gathered from the FL 183 m Haul Seine Survey is reported in the number of lengths (number of croaker measured).

Year	Index	SE	Number of Trips	Positive Trips	Percent Positive	Number of Lengths
2001	290.73	0.56	43	35	81.4%	279
2002	352.16	0.54	45	39	86.7%	290
2003	321.25	0.55	57	49	86.0%	452
2004	291.93	0.55	65	45	69.2%	431
2005	274.39	0.54	90	72	80.0%	445
2006	410.01	0.56	63	41	65.1%	491
2007	372.84	0.48	74	58	78.4%	443
2008	398.95	0.54	65	44	67.7%	435
2009	624.39	0.56	55	42	76.4%	467
2010	363.49	0.55	57	42	73.7%	1059
2011	306.21	0.49	73	57	78.1%	785
2012	348.28	0.54	52	40	76.9%	279
2013	360.05	0.51	44	35	79.6%	152
2014	273.40	0.55	44	31	70.5%	176
2015	299.73	0.55	43	34	79.1%	394
2016	313.49	0.56	34	22	64.7%	343
2017	396.85	0.49	52	36	69.2%	236
2018	270.59	0.55	54	42	77.8%	645
2019	316.63	0.54	67	51	76.1%	500
2020	317.55	0.57	40	31	77.5%	197
2021	273.00	0.54	42	30	71.4%	282
2022	419.93	0.55	58	38	65.5%	326
2023	265.60	0.56	39	31	79.4%	187

Table DFA8. Dynamic factor model combinations tested and compared for Atlantic croaker. R represents observation error, Q represents process variance, and A represents the intercept.

R	Q	A
diagonal and equal	diagonal and equal	zero
diagonal and equal	diagonal and unequal	zero
diagonal and unequal	diagonal and equal	zero
diagonal and unequal	diagonal and unequal	zero
diagonal and equal	diagonal and equal	unconstrained
diagonal and equal	diagonal and unequal	unconstrained
diagonal and unequal	diagonal and equal	unconstrained
diagonal and unequal	diagonal and unequal	unconstrained

Table DFA9. Summary of AICc values for DFA models assuming different numbers of common trends (K). The lowest AICc value for each unit stock and life stage is formatted in bold.

Unit Stock	Life Stage	K	AICc
North	YOY	1	**203.1713**
		2	207.8890
		3	212.9164
	Adult	1	**207.1445**
		2	208.5877
		3	217.4504
South	YOY	1	**263.5679**
		2	273.2985
		3	284.0372
		4	295.9532
		5	309.2515
	Adult	1	**649.4142**
		2	664.5924
		3	671.5181
		4	690.7579
		5	719.3891

Table DFA10. Factor loadings for the strongest factor identified from the best-fit DFA models for each unit stock and life stage.

Unit Stock	Life Stage	Index	Strongest Factor	Loading
North	YOY	VIMS_yoy	Factor 1	0.4406232
		NCDMF_yoy	Factor 1	0.3939359
	Adult	ChesMMAP	Factor 1	2.770596
		NEFSC	Factor 1	1.539510
		NEAMAP	Factor 1	1.497919
South	YOY	NCTrawl_yoy	Factor 1	0.8538070
		SCTrawl_yoy	Factor 1	1.3933177
		GATrawl_yoy	Factor 1	0.8497576
		FL21Seine_yoy	Factor 1	-0.3949590
	Adult	NCGill	Factor 1	0.1950670
		NC_Estuarine	Factor 1	-0.7821105
		NC_Ocean	Factor 1	1.0928016
		SCTrammel	Factor 1	0.5765464
		SCECAP	Factor 1	0.6714750
		GAGill	Factor 1	0.4850309
		FL183Haul	Factor 1	-0.3146274
		SEAMAP_Summer	Factor 1	1.4387857
		SEAMAP_Fall	Factor 1	1.6110793

13.2.7 Figures

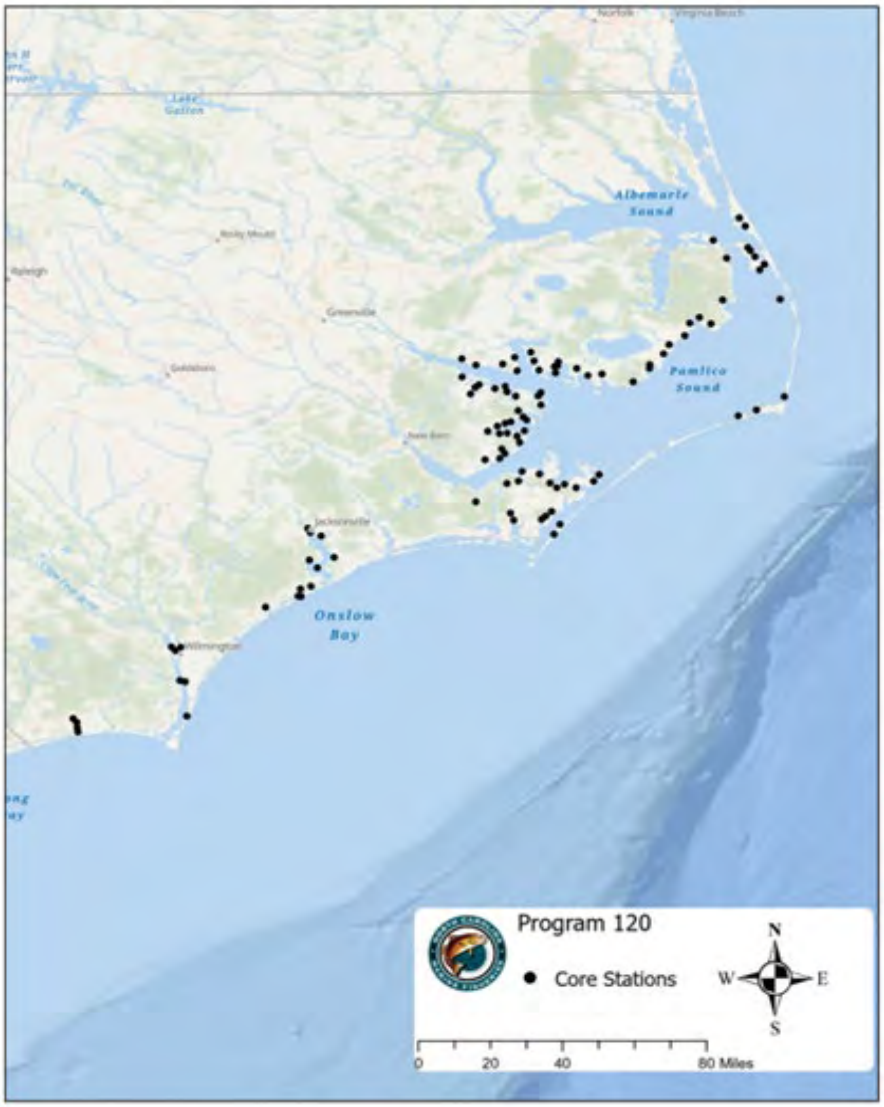


Figure DFA1. The NC Estuarine Trawl Survey (Program 120) fixed stations sampled from 1989-2024.

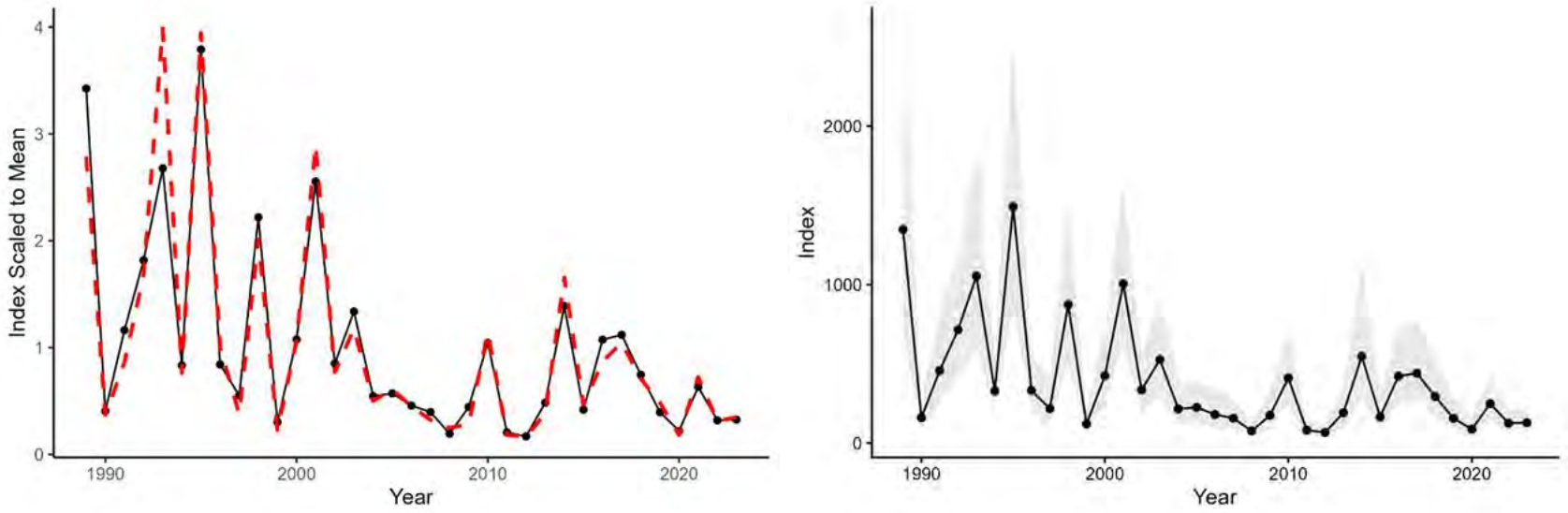


Figure DFA2. NC Estuarine Trawl Survey (Program 120) relative abundance of Age-0 Atlantic croaker. The standardized index (black line and points) is compared to the nominal index (dashed red line) on the left. The standardized index (black line and points) with 95% confidence intervals (shaded grey region) are on the right.

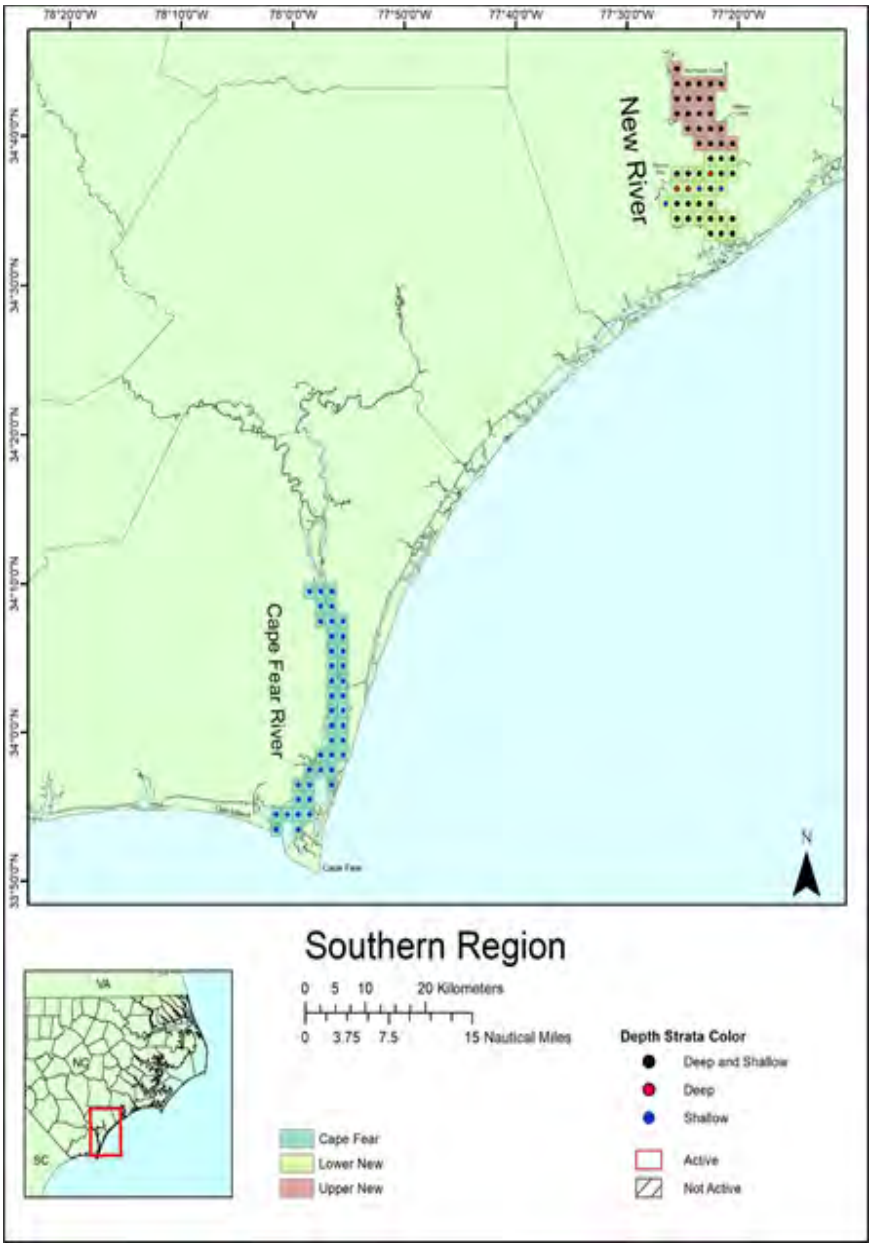


Figure DFA3. The NC Gillnet Survey (Program 915) Southern Region stations sampled from 2008-2024.

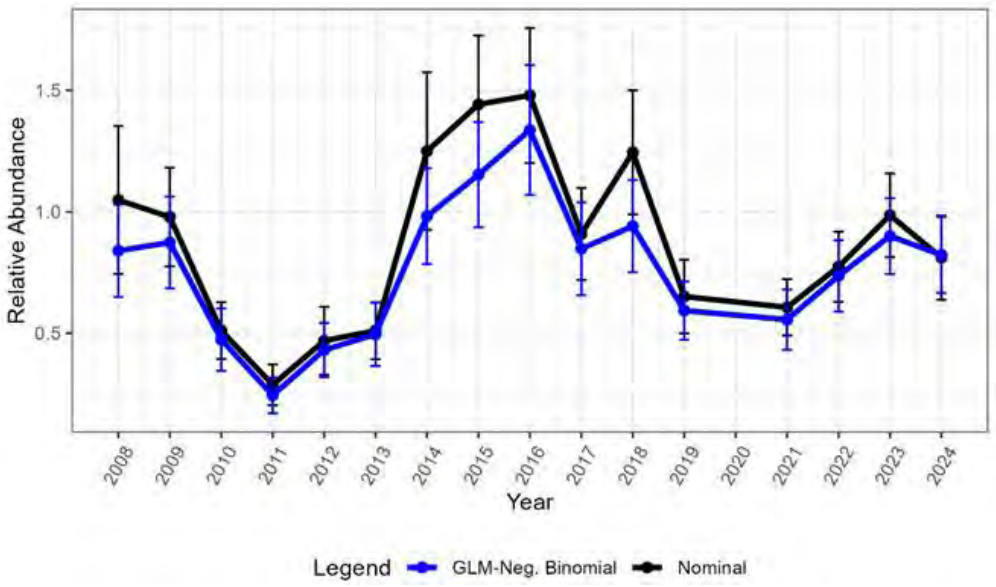


Figure DFA4. The NC Gillnet Survey (P915) relative abundance of Age 1+ Atlantic croaker, standardized to its mean (blue), from 2008-2024. Error bars are ± one standard error.

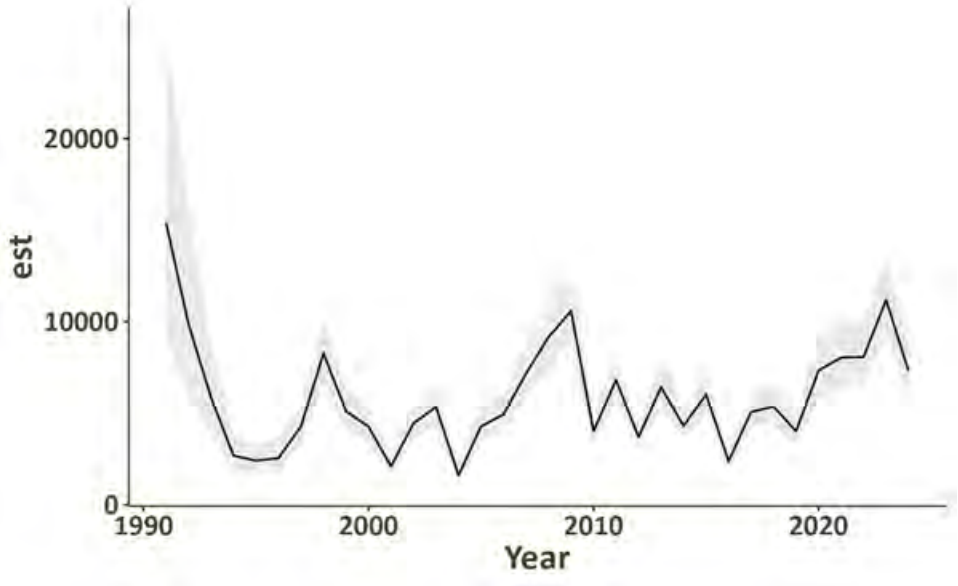


Figure DFA5. Estimated relative abundance for Atlantic croaker from SC Estuarine Trawl Recruitment Survey from 1991-2024 standardized by GLMM with negative binomial error distribution through sdm-TMB R package. Gray shading indicates confidence intervals.

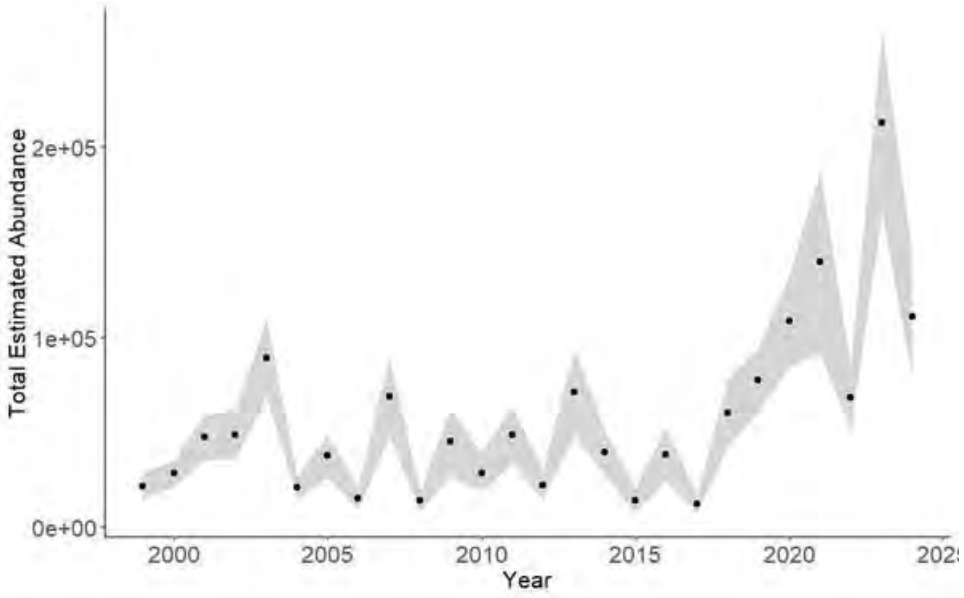


Figure DFA6. Estimated total abundance for Atlantic croaker from SCECAP Survey from 1999-2024 standardized by Vector Autoregression Spatiotemporal models (VAST). Gray shading indicates confidence intervals.

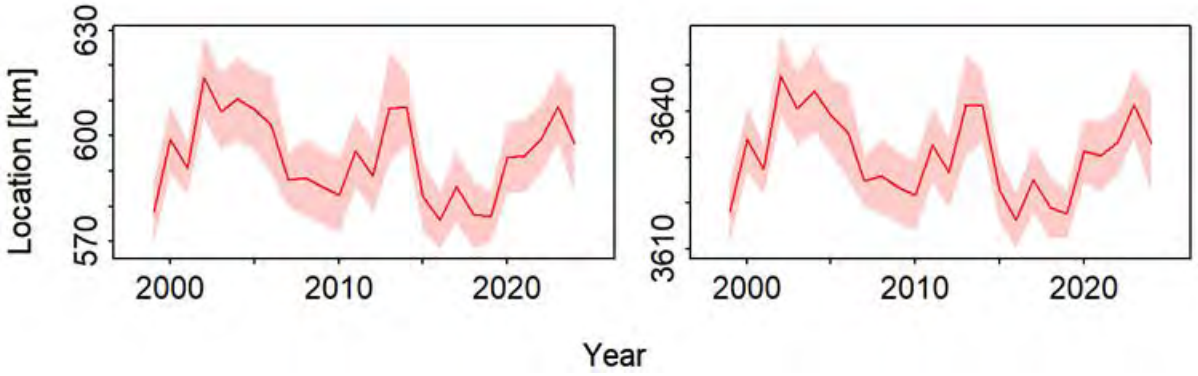


Figure DFA7. Center of Gravity for Atlantic croaker from the VAST index from the SCECAP survey from 1999-2024.

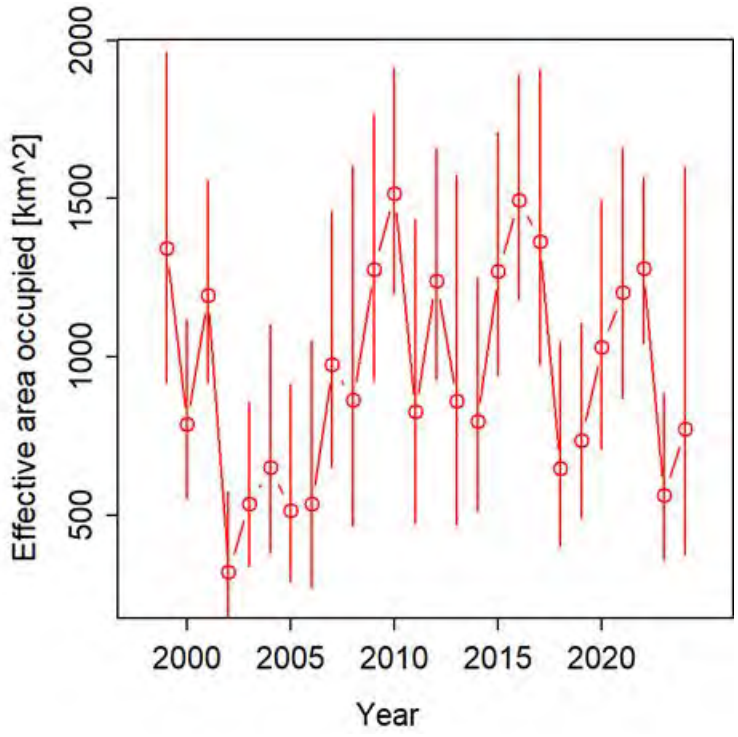


Figure DFA8. Effective area occupied for Atlantic croaker from the VAST index from the SCECAP survey from 1999-2024.

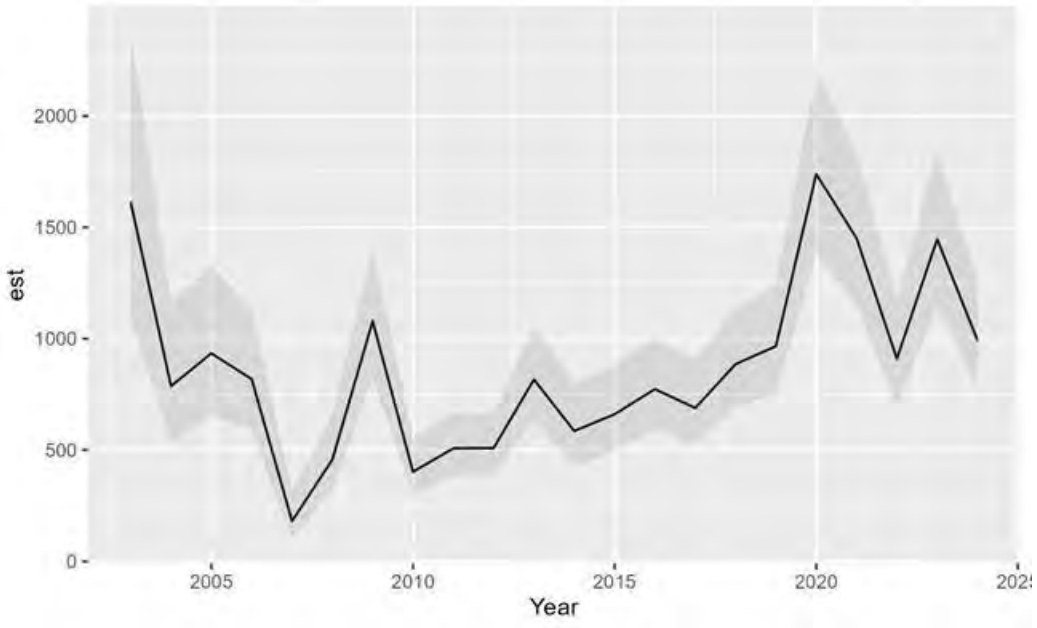


Figure DFA9. Estimated total abundance for Atlantic croaker from GA Gillnet Survey from 2003-2024 standardized by GLMM with negative binomial error distribution through sdmTMB R package. Gray shading indicates confidence intervals.

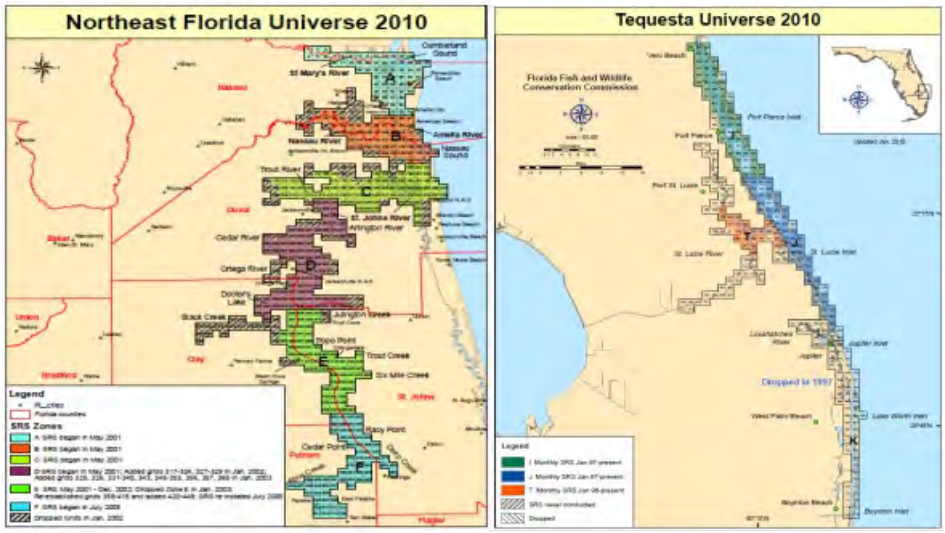


Figure DFA10. Sampling grids for the Fish and Wildlife Research Institute's Fishery Independent Monitoring (FIM) program.

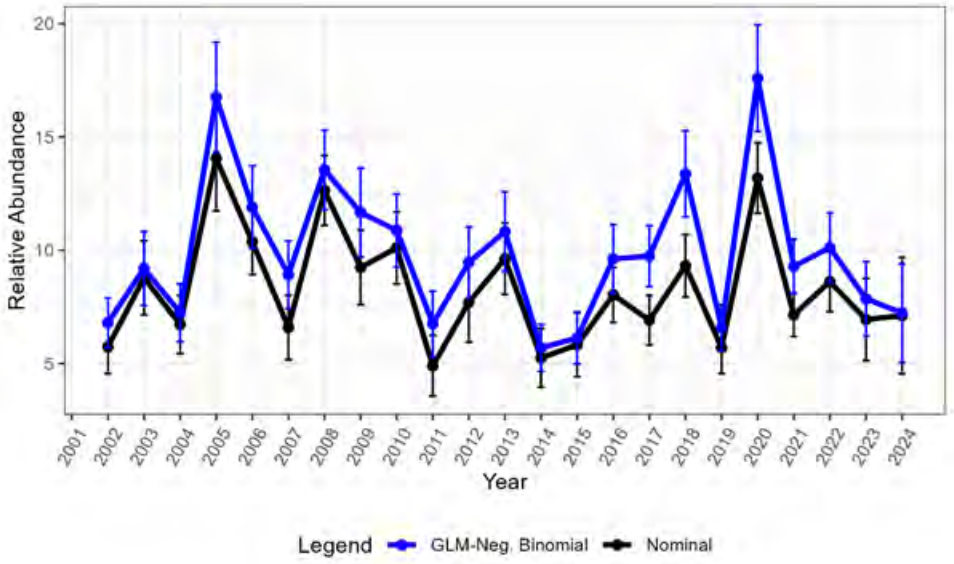


Figure DFA11. Estimated relative abundance for Atlantic croaker from FL 21.3 m Haul Seine Recruitment Survey from 2002-2024 calculated by geometric mean (nominal=black line) and standardized by GLM with negative binomial error distribution (GLM-Neg. Binomial=blue line). Error bars indicated standard errors.

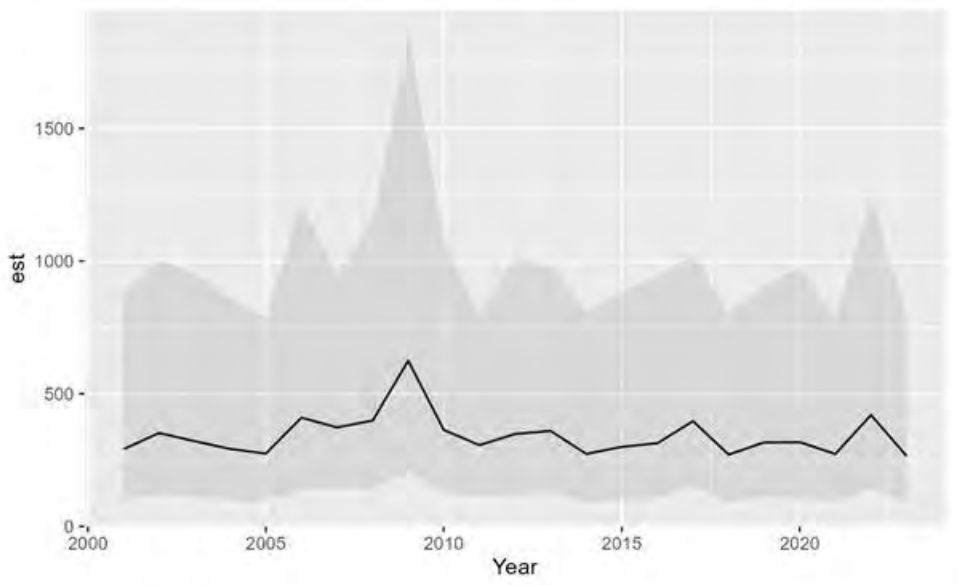


Figure DFA12. Estimated relative abundance for Atlantic croaker from FL 183 m Haul Seine Survey from 2001-2023 standardized by GLMM with negative binomial error distribution through sdm-TMB R package. Gray shading indicates confidence intervals.

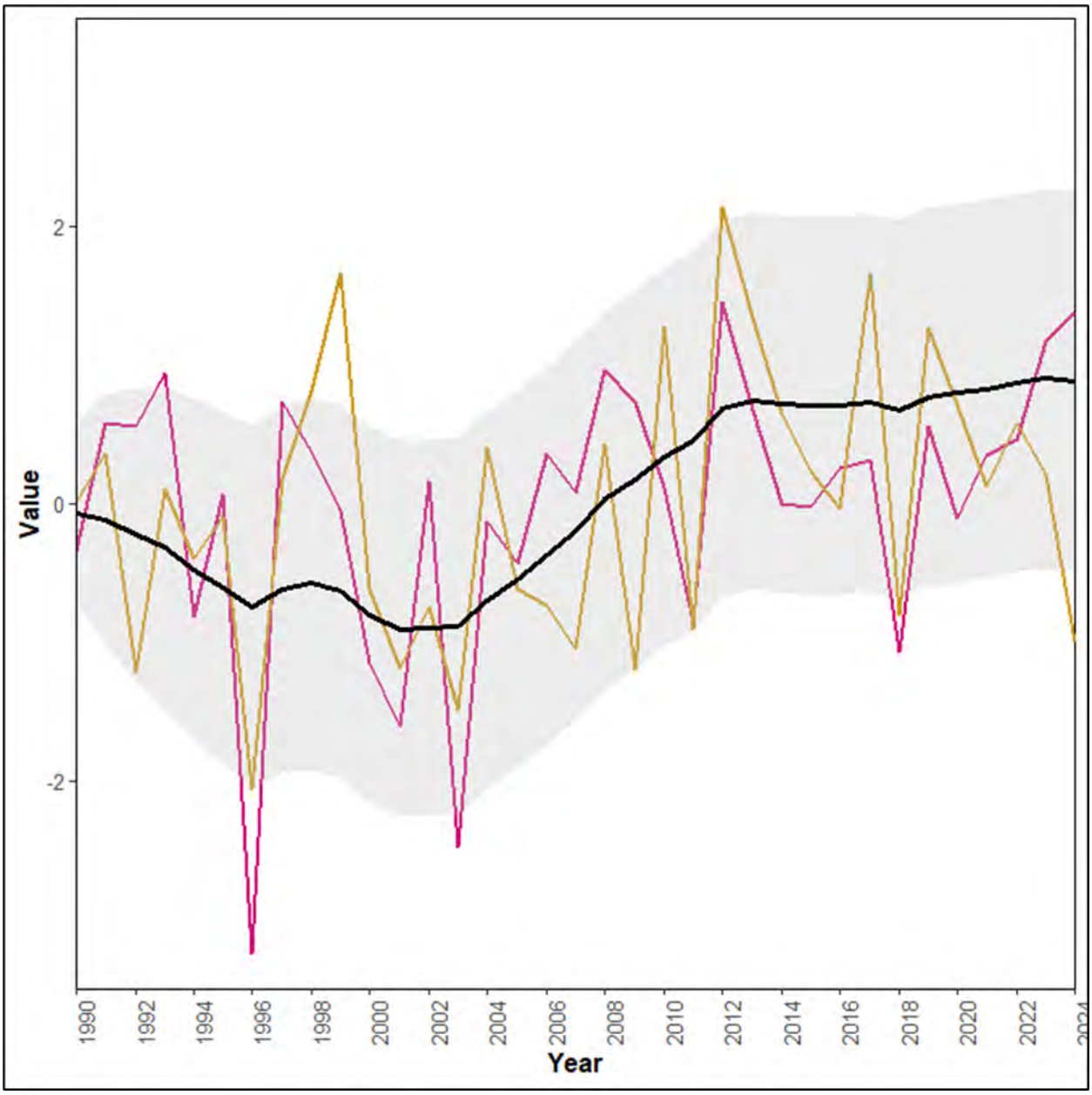


Figure DFA13. Best-fit common trend (thicker, black line) for Atlantic croaker YOY in the northern stock compared to observed time series. The shaded region represents the 95% confidence intervals for the common trend.

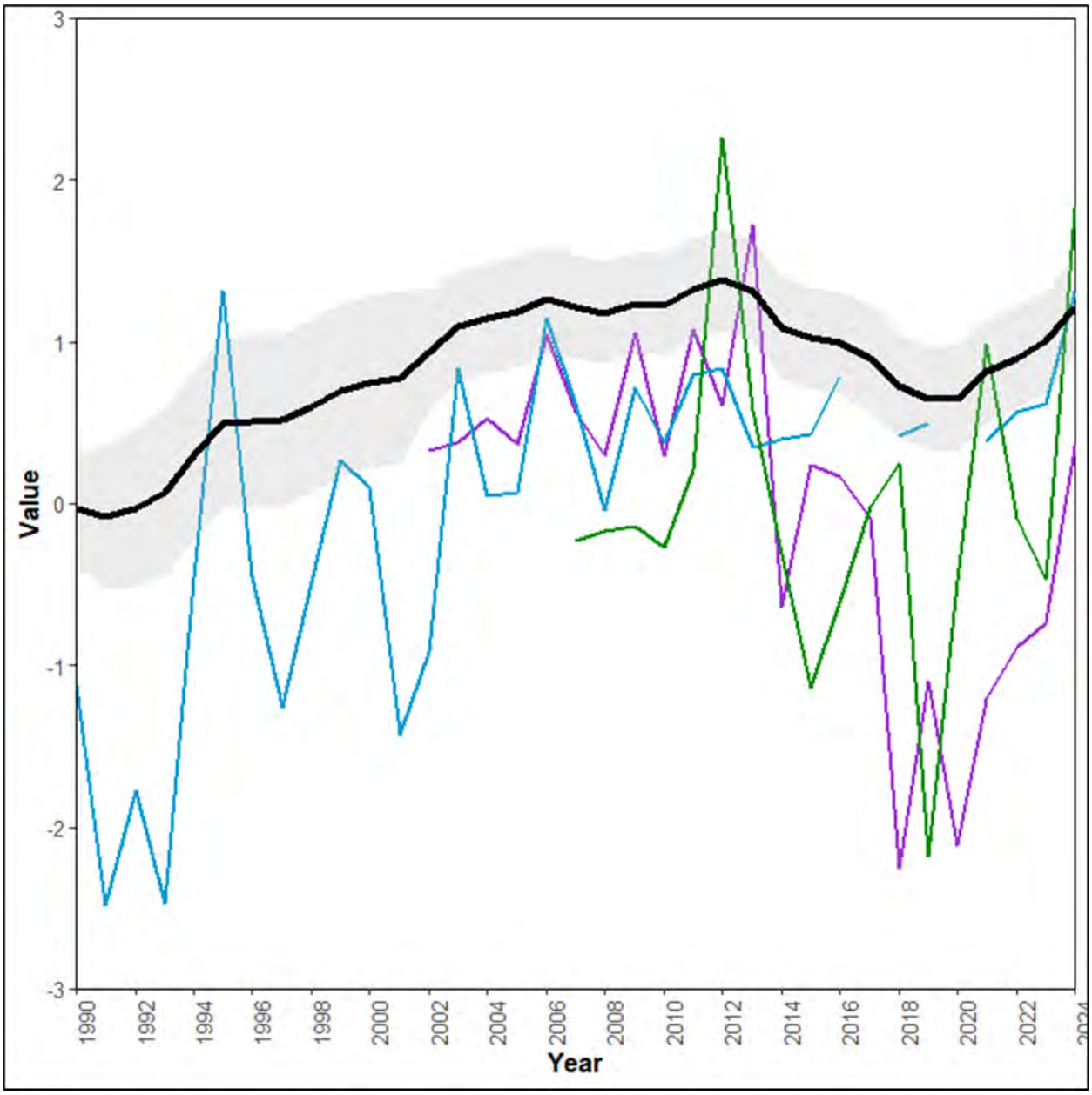


Figure DFA14. Best-fit common trend (thicker, black line) for Atlantic croaker adults in the northern stock compared to observed time series. The shaded region represents the 95% confidence intervals for the common trend.

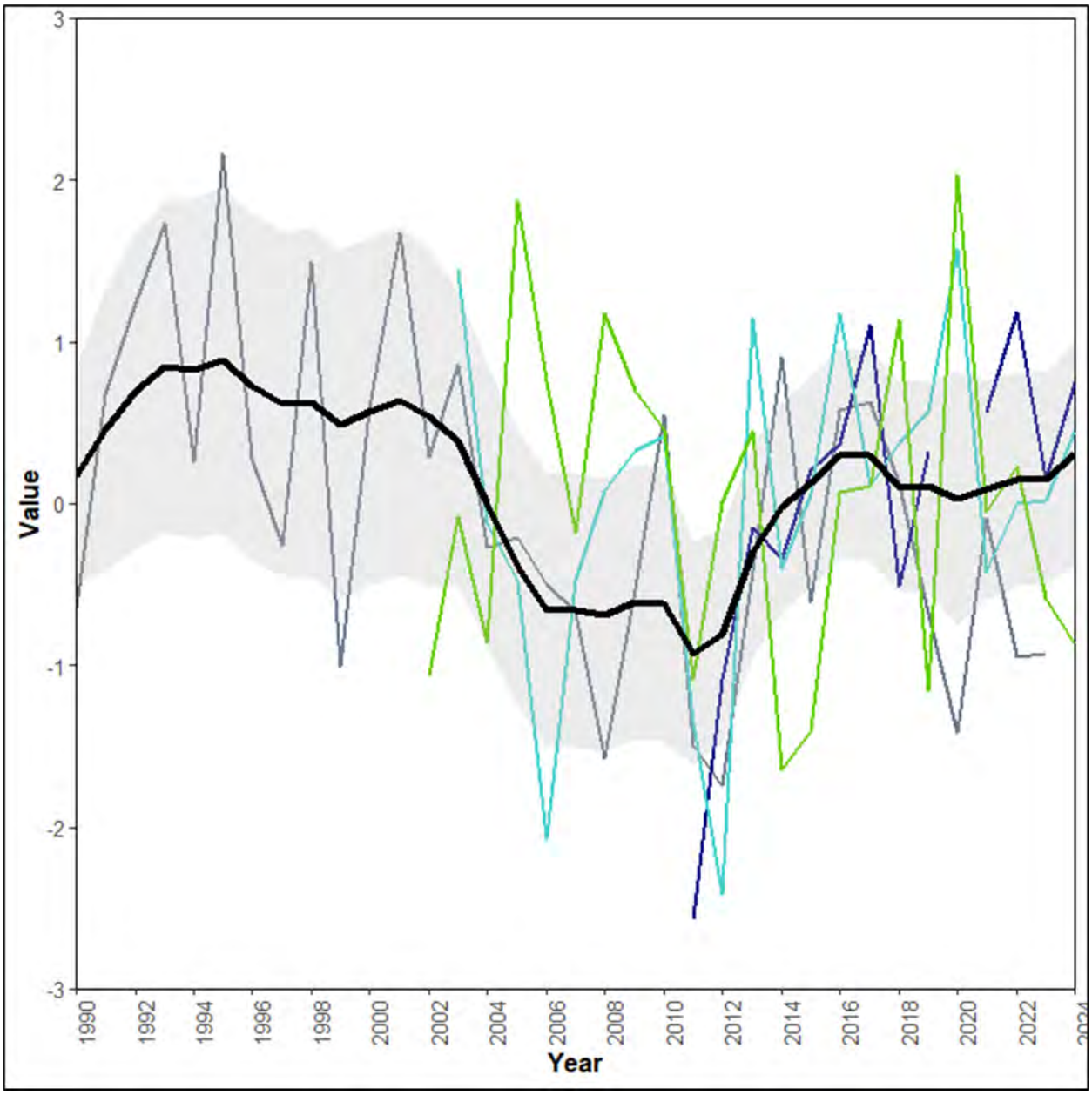


Figure DFA15. Best-fit common trend (thicker, black line) for Atlantic croaker YOY in the south Atlantic compared to observed time series. The shaded region represents the 95% confidence intervals for the common trend.

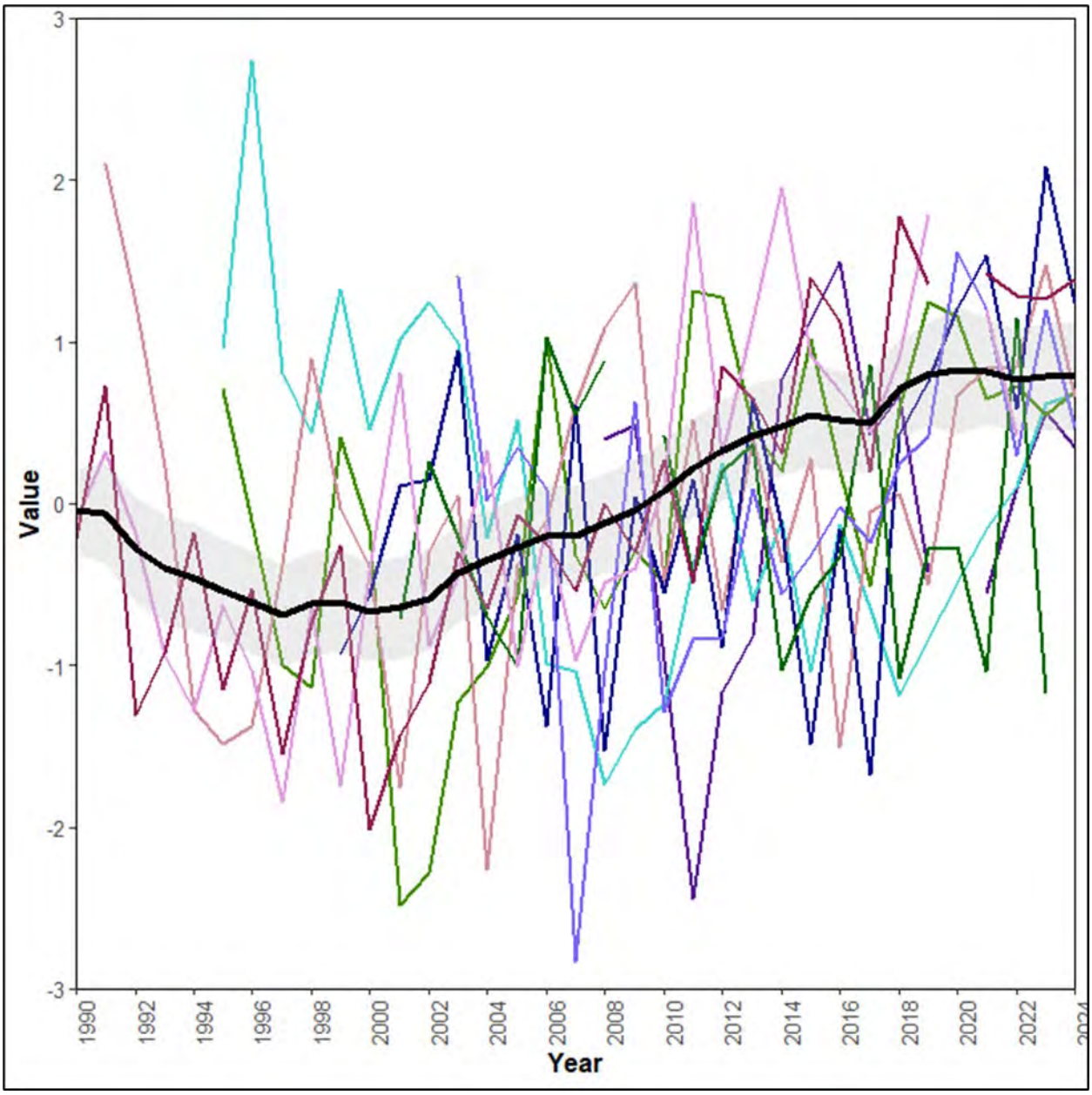


Figure DFA16. Best-fit common trend (thicker, black line) for Atlantic croaker adults in the south Atlantic compared to observed time series. The shaded region represents the 95% confidence intervals for the common trend.

13.3 Index Based Methods

13.3.1 Introduction/Justification

Index-based methods (IBM) have been used in several stock assessments when data are limited or when diagnostics performed on age-structured models indicate model instability or bias. Index-based methods are empirical approaches that use trends in relative abundance indices (e.g., fishery-dependent or fishery-independent CPUE) to inform catch advice (Geromont and Butterworth 2015; NEFSC 2023; Legault et al. 2023). However, Atlantic croaker are not currently managed on catch limits, so the use of these IBMs was to give exploitation information about the stock to management with the goal of informing whether current fishing levels could be maintained or if reductions were needed. These analyses do not examine the overall spawning stock biomass of the population; thus, they cannot be used to determine whether a stock is overfished.

Three IBMs were explored for both stocks of Atlantic croaker given the historical and current difficulties in modeling this species. These methods were applied to the landings and exploitable abundance indices to provide supplemental information on stock trends and potential removals. The SAS chose to use the ISLOPE, Plan B Smooth, and Skate methods based on the data available for Atlantic croaker. The IBMs assumed the index is proportional to the population biomass and changes in the index reflect changes in the abundance of the species rather than catchability or environmental conditions. None of these methods model recruitment, growth, or mortality processes, limiting their interpretability in population dynamics. Additionally, these methods are sensitive to the longevity and consistency of the index time series. However, they can be useful tools in data limited or model instability situations (Geromont and Butterworth 2015; Legault et al. 2023).

13.3.2 Methods

ISLOPE

The ISLOPE method calculates a log-linear regression using a recent abundance index trend to propose an adjusted catch level (Geromont and Butterworth 2015). The slope of the log-linear regression of the abundance index is used to estimate a multiplier that can be applied to recent catch levels to inform potential catch in subsequent years. A five-year terminal average was used as the baseline of the log-linear regression. The slope from this was used in the following equation:

$$ACT = Cmult * \overline{Catch} * (1 + \lambda * e^{slope})$$

where $\overline{Catch}$ is the average catch over the five-year time period (matching the log-linear regression of the abundance index) and *slope* is the slope of the log-linear regression. The parameters *Cmult* and λ are based on how conservative the catch needs to be. The four options are:

1) λ=0.4, *Cmult*=0.8
2) λ=0.4, *Cmult*=0.7
3) λ=0.4, *Cmult*=0.6

4) λ=0.2, *Cmult*=0.6

where option 1 is the least conservative and 4 is the most conservative. For the Atlantic croaker stocks, only version 2 was explored.

If the slope of the five-year terminal average is greater than 0, the stock is increasing. Conversely, if the slope of the five-year terminal average is zero, then the stock is decreasing. The slope of the trajectory can then be used to estimate

Plan B Smooth

The Plan B Smooth method works similar to the ISLOPE method but applies a LOESS smoother to the abundance index time series to allow for more gradual changes and less reactivity to the year-to-year variability. This also allows for the entire time series of the abundance index to be used, but the Loess smoother is created to cover 9.9 years of data. The slope is also used to estimate a multiplier to inform the next year's catch using:

$$Next\ Year\ Catch\ Target = \overline{Catch} * e^{slope}$$

where $\bar{Catch}$ represents the average catch over the specified reference period and *slope* represents the slope of the smooth abundance index trajectory. Multiplier values greater than 1 indicate increasing catch recommendations, while values less than 1 indicate reductions in catch. Because the method uses a smooth index trajectory, annual changes in recommended catch are generally less reactive to short-term variability in the index.

Skate

The Skate method independently smooths the abundance index and catch time series, then estimates a relative exploitation metric using the ratio of catch to index values (NEFSC 2023). Relative fishing mortality is estimated as:

$$Relative\ F = median(\frac{Catch}{Index})$$

The method allows the reference period used to estimate relative exploitation to be specified independently for each stock. For the northern stock, the SAS selected 2002–2012, corresponding to the same reference period used in the Traffic Light Analysis (TLA), during which stock conditions were considered relatively stable. For the southern stock, 2009–2019 was selected based on relative stability and reduced interannual variability in the index. Recommended annual catch can then be calculated with

$$\frac{Catch}{Index_{norm,y}} = \frac{\frac{Catch}{Index_y}}{Relative\ F}$$

where $Index_{norm,y}$is the normalized abundance index in year y. Because the Skate method derives relative exploitation directly from catch and index relationships, results are sensitive to assumptions regarding index proportionality, stability of catchability, and selection of the reference period.

13.3.3 Results

For the northern stock, catch advice between the three methods resulted in more conservative measures using ISLOPE and the least conservative measures using Plan B Smooth for each index (Table IBM1; Figure IBM1-IBM3). Catch could increase based on the ChesMMAP index but should stay at current levels using the NEFSC and NEAMAP indices. However, when the three indices were combined using DFA (see Appendix 13.2 for details), all three methods indicated catch should be reduced (Figure IBM4). The skate method provided a relative *F* estimate for the time series and revealed the stock was not currently experiencing overfishing, though the years without overfishing varied based on the index (Figure IBM5). The NEFSC index and DFA created index indicated the stock had not been experiencing overfishing since the late 2000's, while NEAMAP index indicated overfishing ended around 2017 and ChesMMAP indicated overfishing was ending in the terminal year.

Southern stock catch advice between the three methods resulted in a more conservative approach calculated with Plan B Smooth and a more lenient approach using ISLOPE (Table IBM2; Figure IBM6-IBM8). Using the SEAMAP summer index, catch could increase but not to levels seen in 2020. The catch advice using the SEAMAP fall index or the DFA created index (created with all explored southern indices, see Section 13.1) indicated catch should stay relatively the same as it was in the terminal year. Relative *F* estimated using the skate method revealed the stock was not experiencing overfishing for at least 4 years, regardless of which index was used (Figure IBM9). The other southern stock indices were also considered in this analysis, but did not provide any different results than the SEAMAP or DFA indices (Table IBM2).

Results from the ISLOPE, Plan B Smooth, and Skate methods were considered exploratory and were evaluated primarily for consistency in directional trends among indices. Due to sensitivity to index selection, smoothing assumptions, and reference period specification, these approaches were not used directly for management advice.

13.3.4 Literature Cited

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. https://doi.org/10.1093/icesjms/fst232

Legault, C.M., J. Wiedenmann, J.J. Deroba, G.Fay, T.J. Miller, E.N. Brooks, R.J. Bell, J.A. Langan, J.M. Cournane, A.W. Jones, and B. Muffley. 2023. Data-rich but model-resistant: an evaluation of data-limited methods to manage fisheries with failed age-based stock assessments. Canadian Journal of Fisheries and Aquatic Sciences 80:27-42. https://doi.org/10.1139/cjfas-2002-0045

Northeast Fishery Science Center (NEFSC). 2023. Report of the Index-Based Methods Working Group. NOAA Technical Memorandum NMFS-NE-285, NMFS, Woods Hole, MA. 582 p.

13.3.5 Tables

Table IBM1. Index-based method results for Atlantic croaker northern stocks.

Stock	Survey	Method	Slope	exp (Slope)	Catch Advice	2022-2024 Average Catch	2020-2025 Average Catch
Northern	ChesMMAP	Plan B	0.99	2.26	14905	6589	8252
Northern	ChesMMAP	ISLOPE	0.92	2.30	11089	6589	8252
Northern	ChesMMAP	Ensemble	NA	NA	12997	6589	8252
Northern	NEFSC	Plan B	1.00	1.47	9664	6589	8252
Northern	NEFSC	ISLOPE	0.69	1.27	8716	6589	8252
Northern	NEFSC	Ensemble	NA	NA	9190	6589	8252
Northern	NEAMAP	Plan B	1.00	1.76	11608	6589	8252
Northern	NEAMAP	ISLOPE	0.24	1.38	8973	6589	8252
Northern	NEAMAP	Ensemble	NA	NA	10290	6589	8252
Northern	Northern DFA	Plan B	1.00	1.10	7229	6589	8252
Northern	Northern DFA	ISLOPE	0.98	1.08	8271	6589	8252
Northern	Northern DFA	Ensemble	NA	NA	7750	6589	8252

Table IBM2. Index-based method results for Atlantic croaker southern stock.

Stock	Survey	Method	Slope	exp (Slope)	Catch Advice	2022-2024 Average Catch	2020-2025 Average Catch
Southern	NCGill	Plan B	1.00	1.16	11651	10065	11514
Southern	NCGill	ISLOPE	0.78	1.13	11689	10065	11514
Southern	NCGill	Ensemble	NA	NA	11670	10065	11514
Southern	NCGill	Plan B	1.00	1.16	11651	10065	11514
Southern	NCGill	ISLOPE	0.78	1.13	11689	10065	11514
Southern	NCGill	Ensemble	NA	NA	11670	10065	11514
Southern	SCTrammel	Plan B	0.23	0.99	9956	10065	11514
Southern	SCTrammel	ISLOPE	0.08	1.03	11389	10065	11514
Southern	SCTrammel	Ensemble	NA	NA	10673	10065	11514
Southern	SCECAP	Plan B	0.52	1.01	10204	10065	11514
Southern	SCECAP	ISLOPE	0.03	1.05	11437	10065	11514
Southern	SCECAP	Ensemble	NA	NA	10821	10065	11514
Southern	GAGill	Plan B	0.97	0.86	8680	10065	11514
Southern	GAGill	ISLOPE	0.41	0.89	10940	10065	11514
Southern	GAGill	Ensemble	NA	NA	9810	10065	11514
Southern	FL183Haul	Plan B	0.57	1.00	10366	10056	11872
Southern	FL183Haul	ISLOPE	0.00	0.99	12269	10056	11872
Southern	FL183Haul	Ensemble	NA	NA	11317	10056	11872
Southern	SEAMAP_Summer	Plan B	0.93	0.72	7907	5442	10939
Southern	SEAMAP_Summer	ISLOPE	0.21	0.89	11456	5442	10939
Southern	SEAMAP_Summer	Ensemble	NA	NA	9682	5442	10939
Southern	SEAMAP_Fall	Plan B	0.25	1.01	10116	10065	11514
Southern	SEAMAP_Fall	ISLOPE	0.13	0.98	11228	10065	11514
Southern	SEAMAP_Fall	Ensemble	NA	NA	10672	10065	11514
Southern	SA-DFA	Plan B	0.03	1.00	10064	10065	11514
Southern	SA-DFA	ISLOPE	0.33	1.00	11295	10065	11514
Southern	SA-DFA	Ensemble	NA	NA	10679	10065	11514

13.3.6 Figures

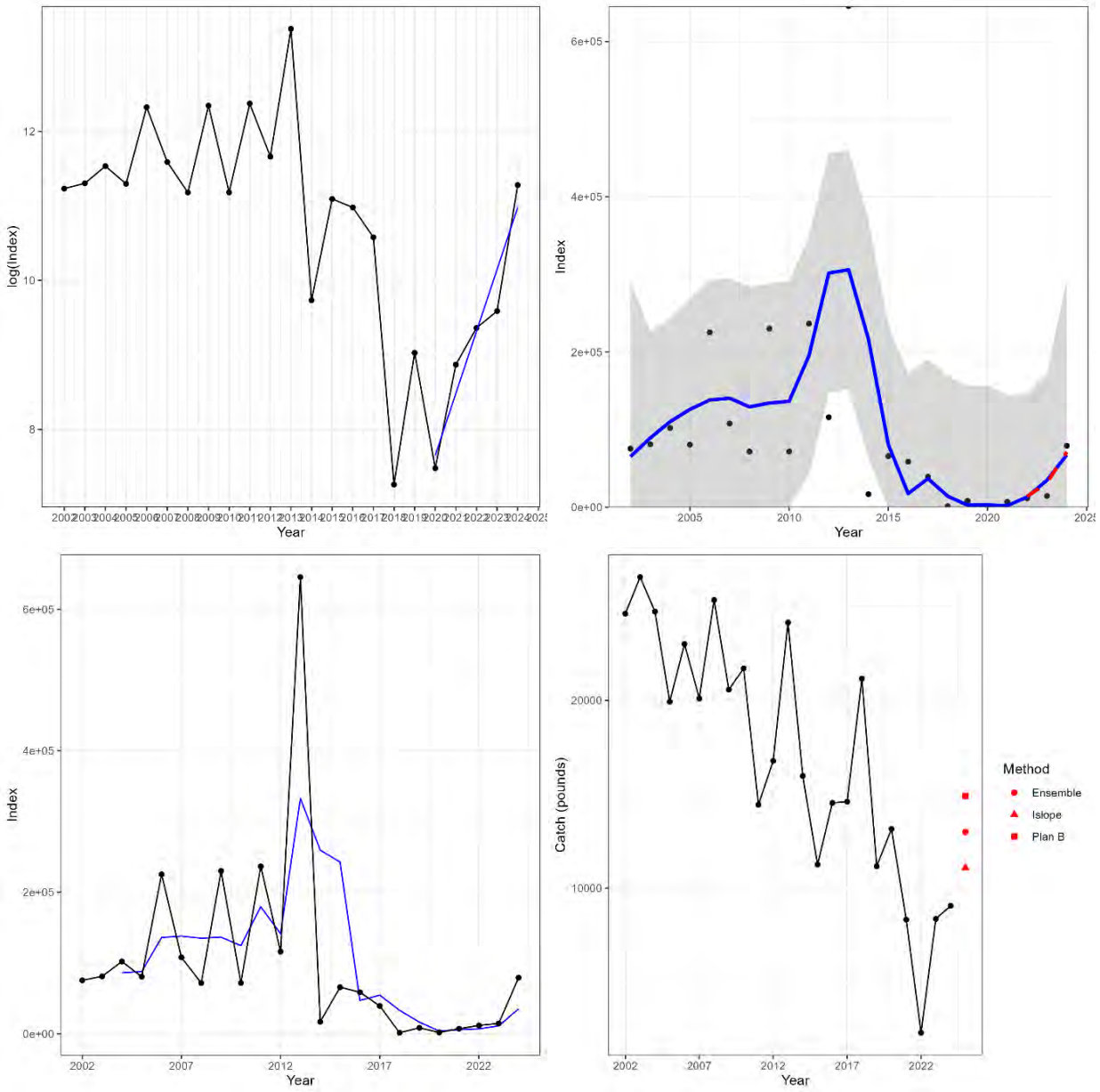


Figure IBM1. Index-based method results for the northern Atlantic croaker stock with the ChesMMAP index including the ISLOPE log-linear regression line and observed index on the log scale (upper left), Plan B log-linear regression line (transformed to original index scale) and LOESS smoother (blue line, upper right), Skate (Ensamble) relative *F* time series and median (dashed line, lower left), and comparison of catch advice from all methods to the observed landings (lower right).

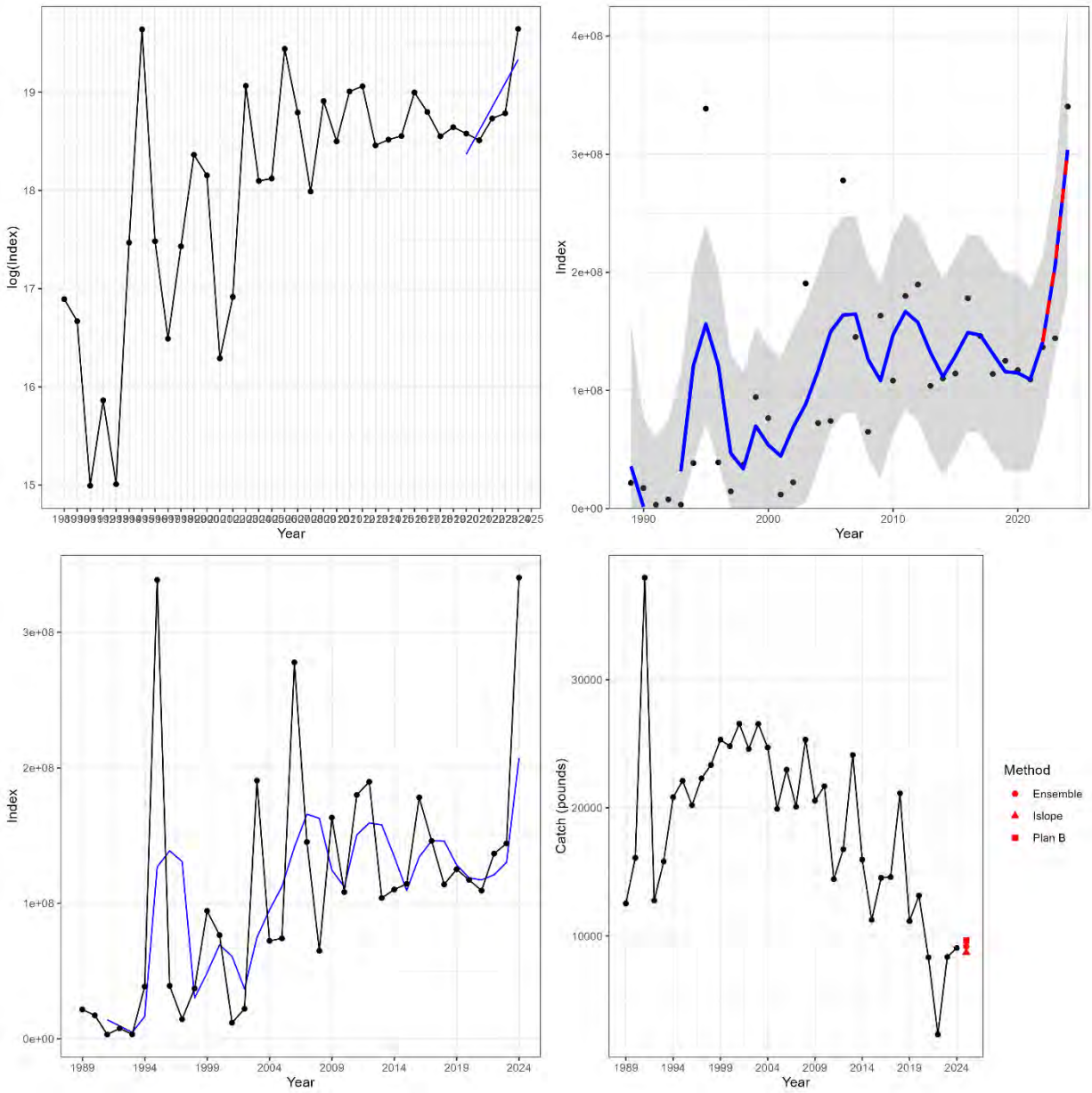


Figure IBM2. Index-based method results for the northern Atlantic croaker stock with the NEFSC index including the ISLOPE log-linear regression line and observed index on the log scale (upper left), Plan B log-linear regression line (transformed to original index scale) and LOESS smoother (blue line, 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).

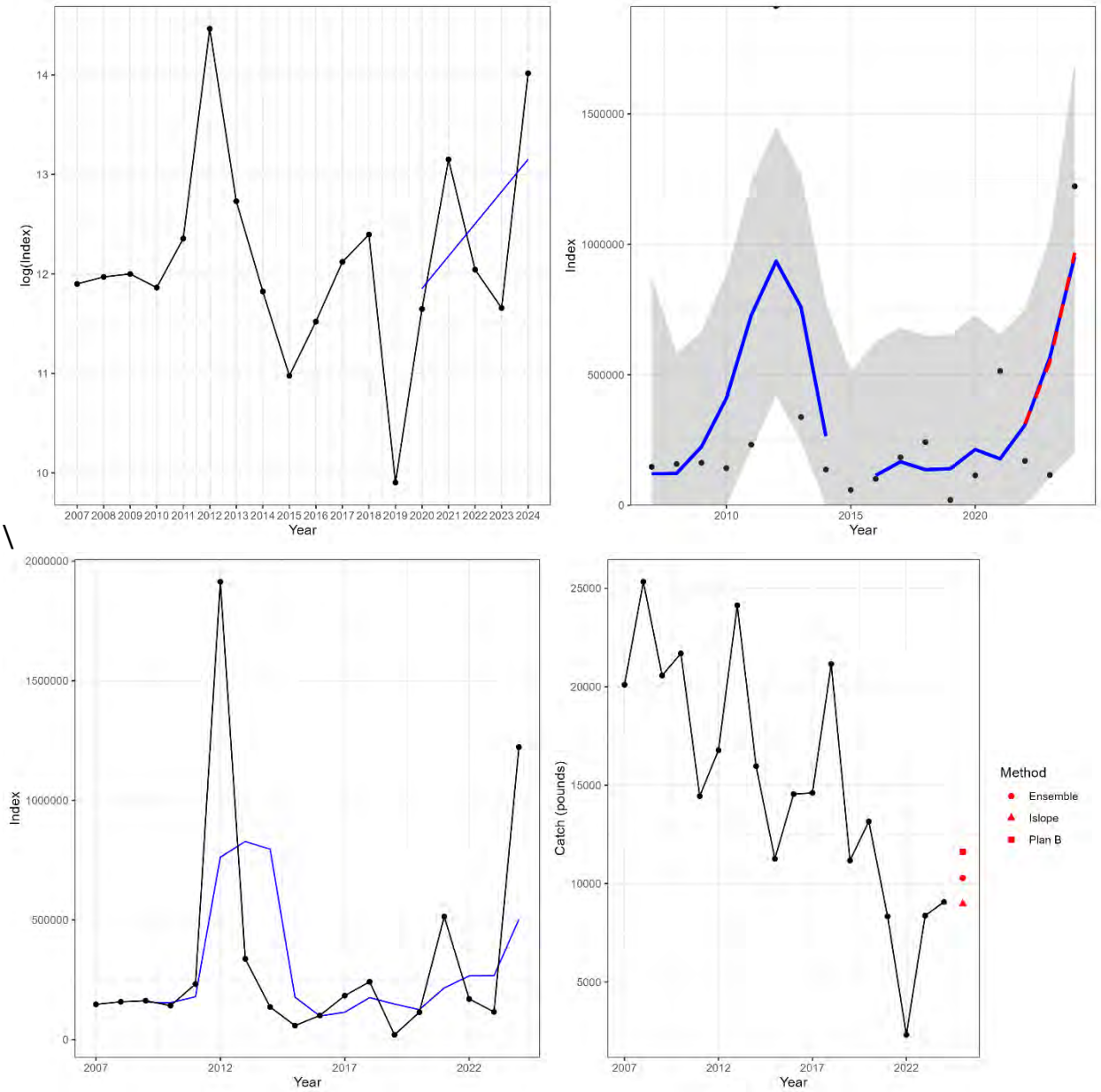


Figure IBM3. Index-based method results for the northern Atlantic croaker stock with the NEAMAP index including the ISLOPE log-linear regression line and observed index on the log scale (upper left), Plan B log-linear regression line (transformed to original index scale) and LOESS smoother (blue line, 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).

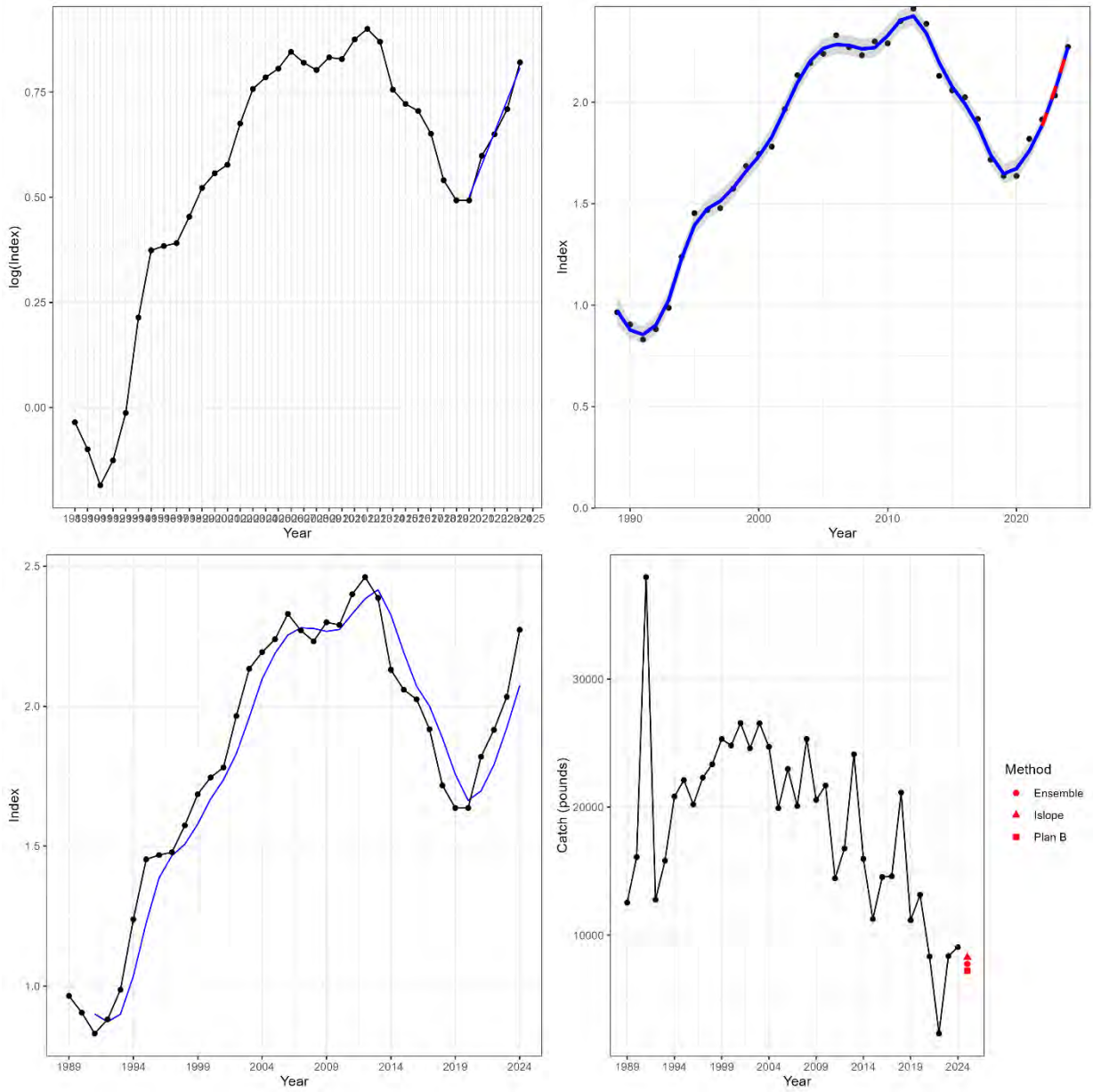


Figure IBM4. Index-based method results for the northern Atlantic croaker stock with the ChesMMAP, NEFSC, and NEAMAP indices combined through dynamic factor analysis including the ISLOPE log-linear regression line and observed index on the log scale (upper left), Plan B log-linear regression line (transformed 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).

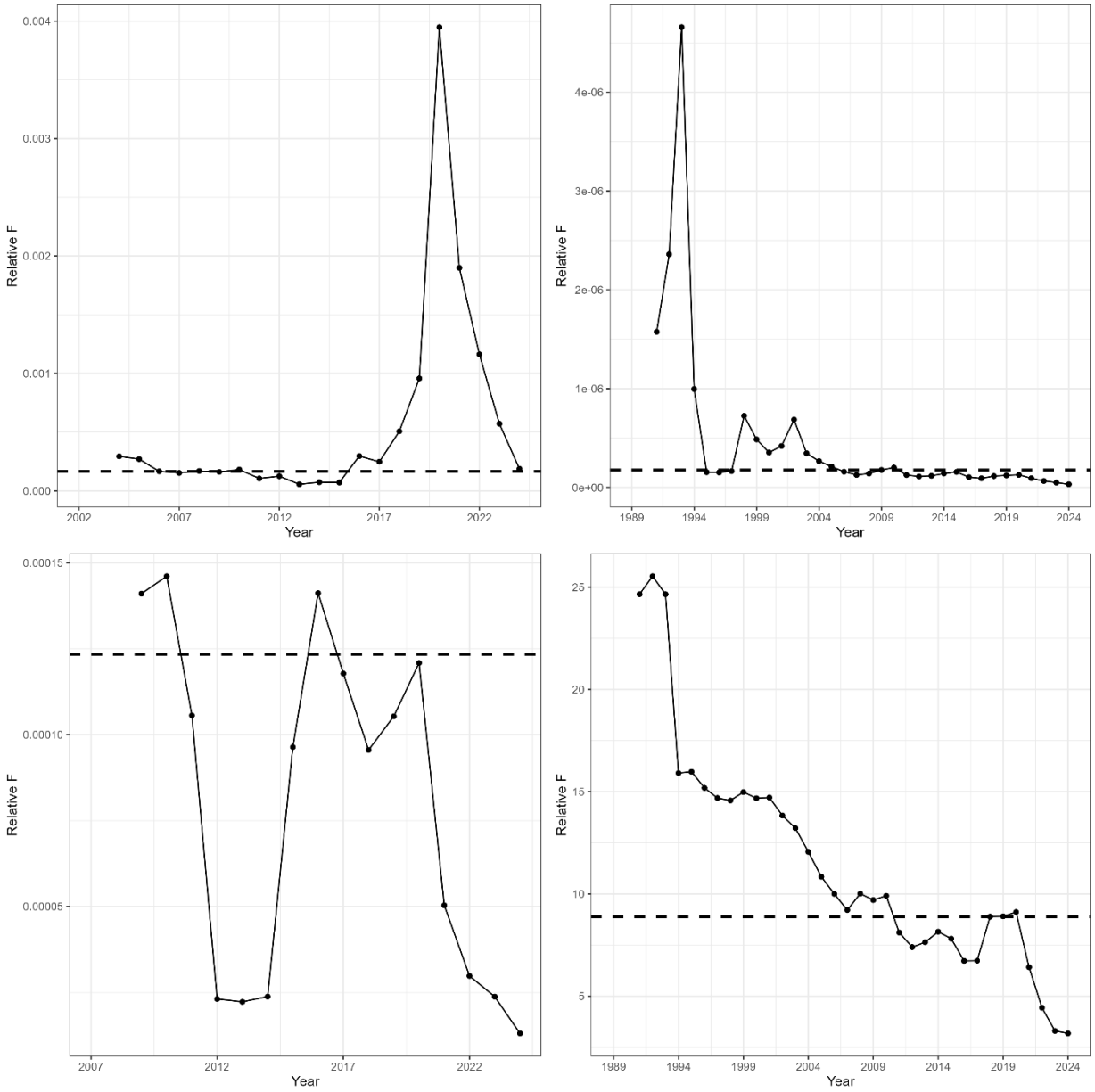


Figure IBM5. Estimates of relative *F* in comparison to total catch for each index: ChesMMAP (top left), NEFSC (top right), NEAMAP (bottom left), and combined indices using DFA (bottom right).

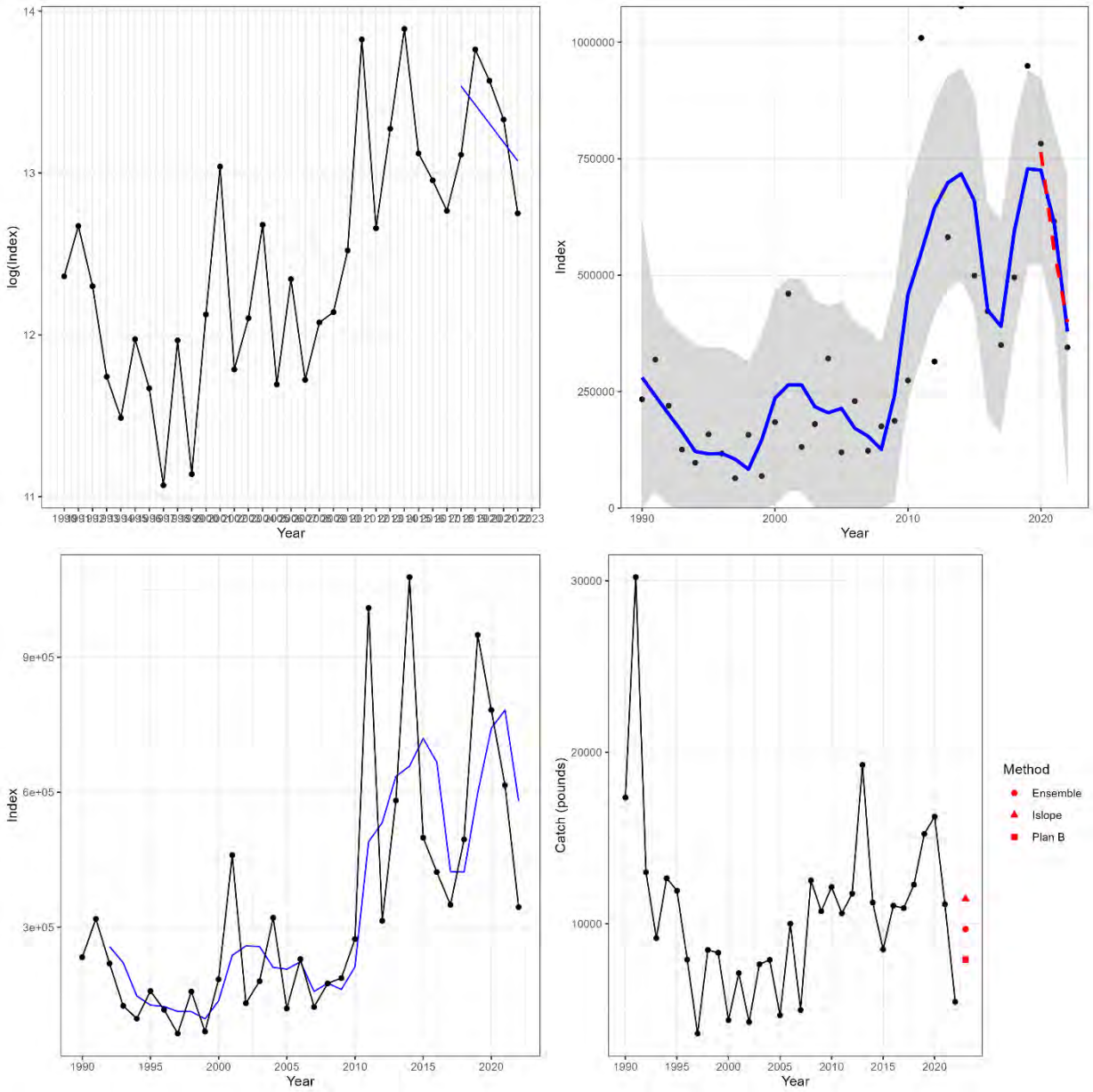


Figure IBM6. Index-based method results for the southern Atlantic croaker stock with the SEAMAP summer index including the ISLOPE log-linear regression line and observed index on the log scale (upper left), Plan B log-linear regression line (transformed to original index scale) and LOESS smoother (blue 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).

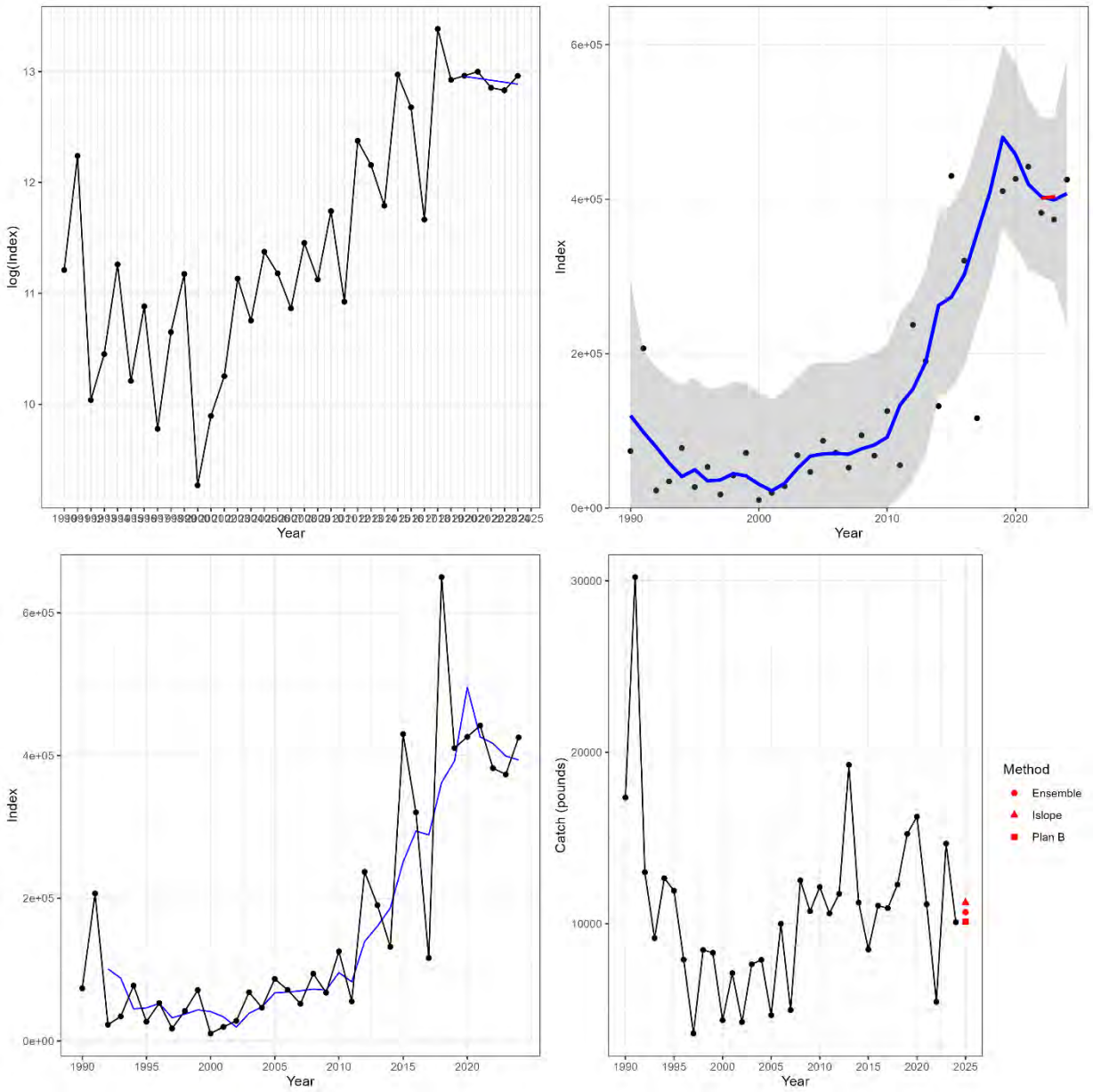


Figure IBM7. Index-based method results for the southern Atlantic croaker stock with the SEAMAP fall index including the ISLOPE log-linear regression line and observed index on the log scale (upper left), Plan B log-linear regression line (transformed to original index scale) and LOESS smoother (blue 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).

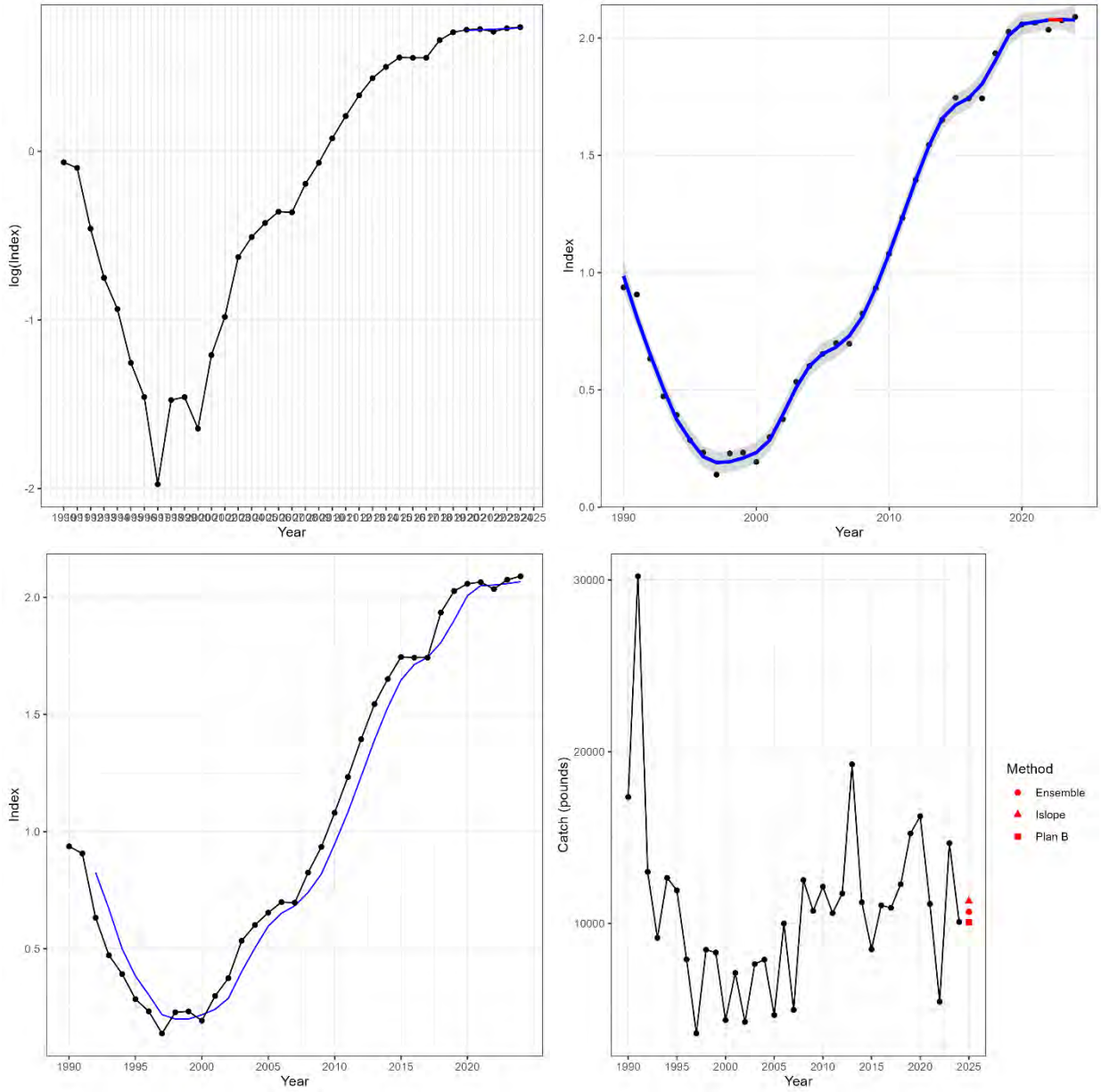


Figure IBM8. Index-based method results for the southern Atlantic croaker stock with the SEAMAP, NC Gill, GA Gill, SC Trammel, SCECAP, and FL183Haul indices combined using dynamic factor analysis including the ISLOPE log-linear regression line and observed index on the log scale (upper left), Plan B 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).

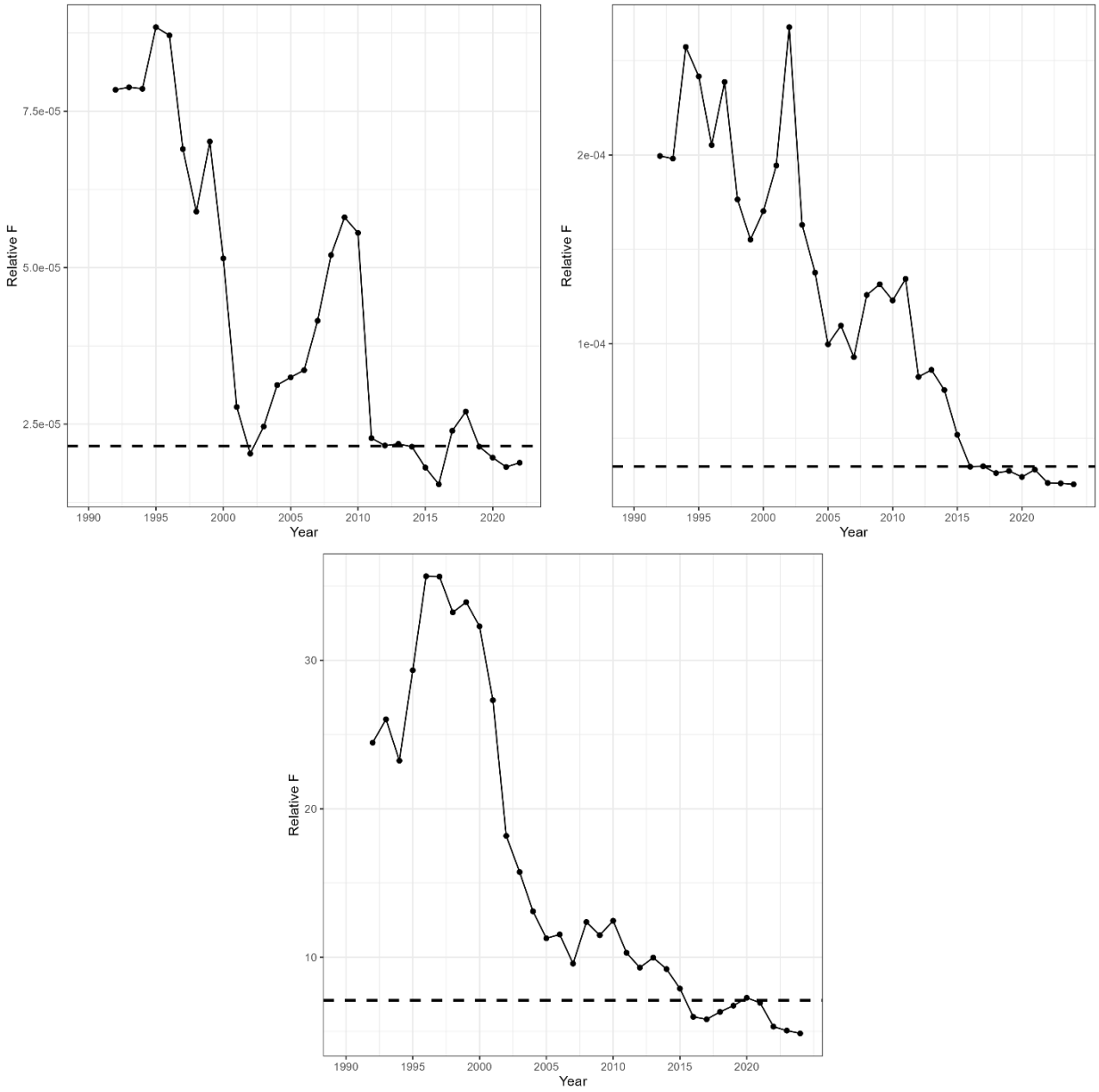


Figure IBM9. Estimates of relative *F* in comparison to total catch for the Atlantic croaker southern stock with each index: SEAMAP-summer (top left), SEAMAP-fall (top right), and combined indices using DFA (bottom).

Atlantic States Marine Fisheries Commission

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MEMORANDUM

TO: **Sciaenids Management Board**

FROM: **Atlantic Croaker Technical Committee**

DATE: **October 22, 2026**

SUBJECT: **Next Steps to 2026 Atlantic Croaker Benchmark Stock Assessment**

The Atlantic Croaker Technical Committee (TC) met on October 1 via webinar to discuss next steps to the 2026 Atlantic Croaker Benchmark Stock Assessment, including how to address the results of the recent Marine Recreational Information Program (MRIP) calibration process and specifications for projections to advise a response to the assessment.

The TC ultimately recommended proceeding directly to next steps with the current assessment results based on uncalibrated MRIP data rather than updating results with calibrated MRIP data. There are several projection items the TC is requesting guidance on from the Sciaenids Management Board (Board) which are included in the projection specifications section below.

MRIP Calibration Results

NOAA Fisheries determined the Fishing Effort Survey (FES) was overestimating effort for the private boat and shore fishing modes through studies conducted in 2023 and 2024. Recreational catch used in stock assessments is estimated by scaling catch rate data collected through the Access Point Angler Intercept Survey (APAIS) to effort estimates from the FES, leading to overestimated catch with the overestimated effort.

Following successful peer review in 2025 of an improved FES design to address the overestimation, the historical FES was fully replaced by the improved FES design in 2026. The survey design change and effort overestimation was addressed for historical estimates prior to 2026 by calibrating, or rescaling, historical effort estimates using a calibration model, also successfully peer reviewed in 2025. Additional details on the improved FES design and calibration process are available on the MRIP website.

The Atlantic Croaker Benchmark Stock Assessment was developed and finalized for peer review in July 2026 using uncalibrated MRIP catch estimates from the historical FES due to an assessment schedule that was ahead of the release of the calibrated catch estimates on August 31, 2026. This is the only ASMFC stock assessment completed on a timeline that precluded incorporation of calibrated MRIP catch estimates while results were delivered to a management board after the release of calibrated catch estimates.

NOAA Fisheries communicated the pending design changes and calibration in advance, so the TC was aware of this during the stock assessment. However, at that time, it was not known yet to what extent effort had been overestimated. To explore potential data change impacts to assessment model estimates, the Stock Assessment Subcommittee (SAS) included a sensitivity run based on consultation with MRIP staff that applied a constant 30% reduction to all years of recreational catch estimates. The sensitivity run indicated robust trend and stock status estimation with the primary impacts being the reduction in the scale of stock abundance and biomass and slightly higher fishing mortality estimates (Figure 1 and Figure 2).

Following the release of the calibrated catch estimates, the TC reviewed the results of the calibration process for years in the assessment models (1990-2024) and the additional year available since (2025). Comparisons were reviewed at the fleet level for information on impacts to the estimates as they are used within the stock assessment models, at the stock level for information on impacts stockwide, and the coastwide level for information on impacts to the overall population. Only fleet-specific comparisons are provided here due to similarities of results at the other spatial levels. Fleet definitions include all recreational fisheries north of Onslow County, North Carolina for the northern stock, and the recreational fisheries for Onslow County, North Carolina through Georgia and the recreational fishery for Florida in the southern stock. Dead discards are estimated assuming a 15% mortality rate of fish released alive, consistent with the benchmark stock assessment.

As expected, calibrated estimates are lower in magnitude than uncalibrated estimates (Figure 3). The magnitude differences vary across years and fleets (depending on their catch magnitudes), with total removal differences ranging from 33,160-14,507,795 fish for the northern stock recreational fishery, 71,557-1,246,924 fish for the southern NC-GA recreational fishery, and 174,220-1,891,630 fish for the FL southern stock recreational fishery (Figure 4). Trends of calibrated estimates follow similar patterns as uncalibrated estimates, but do generally indicate relatively lower catches through the 2000s followed by relatively higher catches since (Figure 5). This difference in trend is due to different rates of change in calibrated estimates from higher rates in earlier years trending to lower rates in recent years, particularly for the northern stock and FL recreational fisheries (Figure 6). Estimates for the northern stock recreational fishery change from approximately 50-60% reductions in early years to approximately 15% reductions in recent years. Estimates for the Florida recreational fishery change from approximately 40-50% reductions in early years to approximately 20-30% reductions in recent years. Estimate differences for the southern NC-GA recreational fishery are more consistent across years, with approximately 20-30% reductions. Length compositions are robust and do not show much change aggregated over years (Figure 7). Percent standard error of estimates is generally greater for calibrated estimates when they differ, particularly early in the time series, indicating increased imprecision of these calibrated estimates (Figure 8). However, it's important to note that bias is expected to be reduced in calibrated estimates due to the improved effort estimation.

Given the realized change in catch estimates diverged from the expectation during the stock assessment before calibration results were released (i.e., a constant 30% reduction across years), an additional assessment model sensitivity run was conducted for the northern stock following the TC call. The sensitivity run included uncalibrated MRIP catch estimates reduced by 50% for the years 1990-2015 and 15% for the years 2016-2024. All other base run settings and data inputs were unchanged. The sensitivity run indicated robust trends (Figure 1). Spawning stock biomass estimates decreased by greater magnitudes from the base run than the original sensitivity run with a constant 30% catch reduction. Fishing mortality estimates were more similar to the base run through the early 2010s, increase by greater magnitudes from the base run in the late 2010s than the original sensitivity run, and then decline to similar levels at the end of the time series. Stock status estimates are robust and do not change from the base model.

In anticipation of the Board obtaining assessment results using the uncalibrated MRIP estimates and the separate calibrated MRIP estimates at the same time during its November 2026 meeting, the TC discussed several potential approaches for considering these collective results.

A. Proceed directly to next steps with assessment results as is.

This approach would require no additional assessment model analyses of the historical time series and the TC could begin work on projections, if desired. ***The TC recommends this approach.*** The TC was aware of this MRIP design change and pending calibration at the time it recommended the next

assessment (an update) occur in three years following the benchmark assessment (2029). The Peer Review Panel, also aware of the looming MRIP changes, supported this timeline for future assessments. The results of the calibration were not different enough from the expectation during the benchmark stock assessment to warrant a change to the assessment timeline recommendations. Specifically, the TC is not concerned with incorrect stock status estimates from the benchmark stock assessment due to the similar trends in uncalibrated and calibrated catch estimates and the robustness of model estimates to the MRIP catch change sensitivity run included in the stock assessment. It's also worth noting that MRIP plans to produce catch estimates on the uncalibrated scale for the near future that could be used to support management working from information using the uncalibrated estimates.

B. Replace the uncalibrated estimates with the calibrated estimates for years included in the stock assessment (1990-2024) and rerun models to generate updated population estimates.

This approach would require MRIP data updates in the model files, moderate modeling analyses, and at least one full TC call to review and approve results. The objective of this approach would be to replace the base runs of the benchmark stock assessment with these alterative model runs using the calibrated catch estimates. The updates would be provided in a memo to the Board and could potentially be completed for a Spring 2027 Board meeting. Following the presentation of these model runs, the TC could then begin work on projections, if desired. ***The TC recommends moving forward with the assessment results as is (approach A) over approach B because the costs of any additional assessment analyses of the historical time series outweigh the benefits likely to be produced.*** Costs would include delays to competing workloads for other species, including the ongoing spot stock assessment which has already been delayed for several years, and delayed response to the unfavorable stock status estimated for the northern stock of Atlantic croaker. Projections would be needed to evaluate relative changes (spawning stock biomass relative to spawning stock biomass target) and, therefore, the magnitude changes in calibrated MRIP estimates are less important to these projections than catch trends, minimizing benefit of updated model runs with calibrated catch estimates.

C. Conduct a full stock assessment update.

An assessment update would be considerably more work, including data requests for other updated data sets from TC members, heavy modeling analyses, multiple SAS and TC meetings, and development of another stock assessment report. The timeline for this approach would be at least one year. This workload would exacerbate delays to other competing workloads and would require approval by the ISFMP Policy Board as it represents a change to the Commission's stock assessment schedule. ***The TC does not recommend consideration of approach C.***

Projection Specifications

The benchmark stock assessment estimated the northern stock is depleted. Amendment 1 to the Interstate Fishery Management Plan for Atlantic Croaker states the Board must take action to recover the stock to the target level (in terms of spawning stock biomass) should the stock be defined as depleted. As a potential next step, the TC has started discussions about what information the TC will need from the Board to complete projections using the stock assessment model in the case the Board desires to task the TC with this to respond to the depleted stock status at subsequent meetings. In addition, the TC discussed several technical considerations and made recommendations for the Board to consider for projections.

The TC requests guidance on the following items:

- **Target reference points** – *What target level should the TC use for projections?* During the stock assessment, the SAS recommended a target spawning potential ratio (SPR) between 35% and

45% but recommended consultation with the Board following the assessment for determining a specific level in order to achieve non-biological management objectives (e.g., socio-economic objectives, risk tolerance). The lower end of this range may require less restrictive measures and associated higher probability of poor stock conditions while the higher end may require more restrictive measures and associated lower probability of poor stock conditions. Some important topics that should be included in discussions on an appropriate target level are discards in the shrimp trawl fishery and uncertainty about changes in natural mortality. Discards in the shrimp trawl fishery are not accounted for in reference point calculations although they do impact realized survival, stock abundance, and ultimately reproductive capacity. A target reference point may allow for an extra buffer to protect the stocks from increases in discard mortality in the future. The assessment assumes a constant age-specific natural mortality through time due to lack of information to support a hypothesis of time-varying natural mortality. If this is an incorrect assumption, fishing mortality estimates and reference points would be biased and this potential uncertainty could be considered in selection of a target value. The spawning stock biomass reference point associated with the SPR target is $SSB_{SPRXX\%}$, where XX% represents the target SPR percentage selected.

- **Rebuilding schedule** – *What schedule should the TC use for projections?* The rebuilding schedule will specify the number of years to include in projections.
- **Probability of achieving targets** – *Does the Board desire a specific probability of achieving* $SSB_{SPRXX\%}$*?* A default probability from stochastic projections would be the central tendency, or a 50% probability.

In addition to these requests, the TC recommends the following specifications for projections and seeks additional guidance if the Board desires alternative specifications.

- ***Northern stock only*** - The TC believes projections would only be desired for the northern stock, so clarification would be needed if there is a desire for southern stock projections.
- ***Recent growth patterns*** – Time-varying growth was observed and estimated for the northern stock. Growth in the stock assessment model changes in 2012 such that fish can grow to a maximum size approximately 13 centimeters smaller than they could in earlier years. The TC recommends using the recent growth pattern for projections as there is no evidence that growth patterns are rebounding to those observed in the early part of the time series. Reference points assume an average growth pattern over the modeled time series because there were no clear drivers of these changes determined (fishing mortality, environment, or combination of both) and it is assumed that this stock can experience a return to greater growth and associated productivity observed early in the time series in the future.
- ***Full recruitment time series*** – Recruitment was estimated to be highest in the 1990s and lower since, with some indication of recruitment returning to 1990 levels in the last year of the model time series. The model was not able to estimate a reliable stock-recruitment relationship, but the TC does not see any evidence that mechanisms have changed productivity of this stock in a directional way that is likely to continue. The TC recommends projections that assume

recruitment levels observed throughout the model time series, as opposed to some reduced range of years within the assessment time series.

- ***Shrimp trawl fleet fishing mortality*** – The TC discussed large scale changes to the shrimp trawl fishery since the start of the assessment time series and that years in the 1990s may not represent current fishery operation that would be expected to occur in the near future. The TC recommends using model-estimated annual shrimp trawl fleet fishing mortality averaged over a reference period within the assessment time series that is representative of current fleet operation to project fishing mortality for this fleet. The TC has been communicating with shrimp fishery experts for guidance on appropriate years for the reference period. The reference period is likely to start no earlier than 2019 due to a change in gear configuration requirements for most North Carolina estuarine waters within the northern stock, but effort data are also being considered, and exact period recommendations are still being determined. This can be presented to the Board during a future update.

Figures

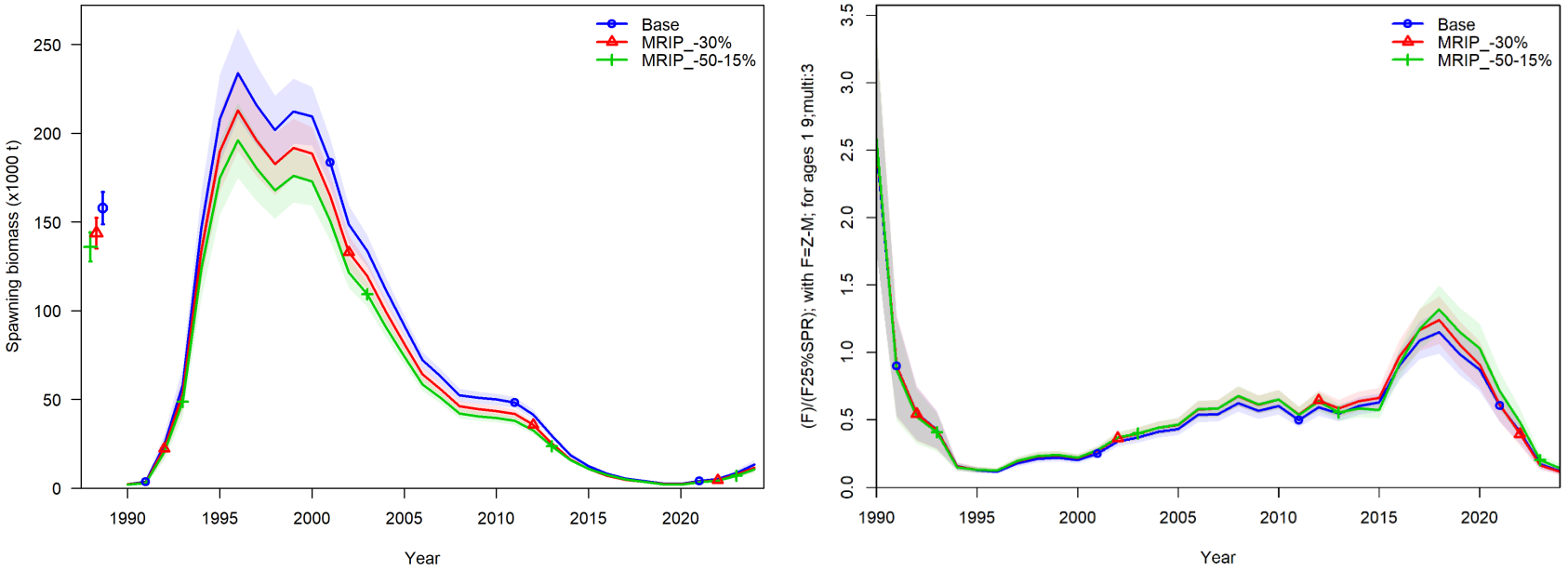


Figure 1. Spawning stock biomass (left) and relative fishing mortality (right) estimates for the northern Atlantic croaker stock from the 2026 benchmark stock assessment base model run and MRIP catch reduction sensitivity run (MRIP_-30%), as well as an additional catch reduction sensitivity run completed after the assessment (MRIP_-50-15%). Relative fishing mortality is defined as age-1+ annual fishing mortality over the fishing mortality threshold ($F_{25\%}$).

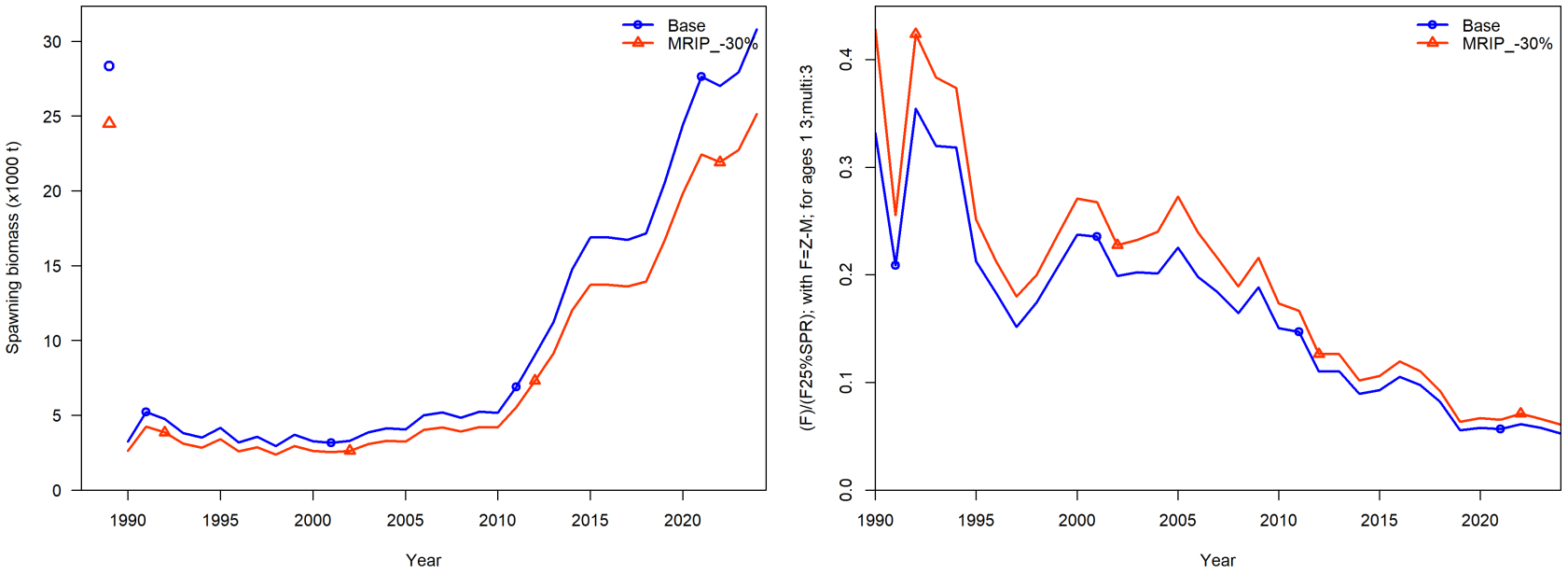


Figure 2. Spawning stock biomass (left) and relative fishing mortality (right) estimates for the southern Atlantic croaker stock from the 2026 benchmark stock assessment base model run and MRIP catch reduction sensitivity run (MRIP_-30%). Relative fishing mortality is defined as age-1+ annual fishing mortality over the fishing mortality threshold ($F_{25\%}$).

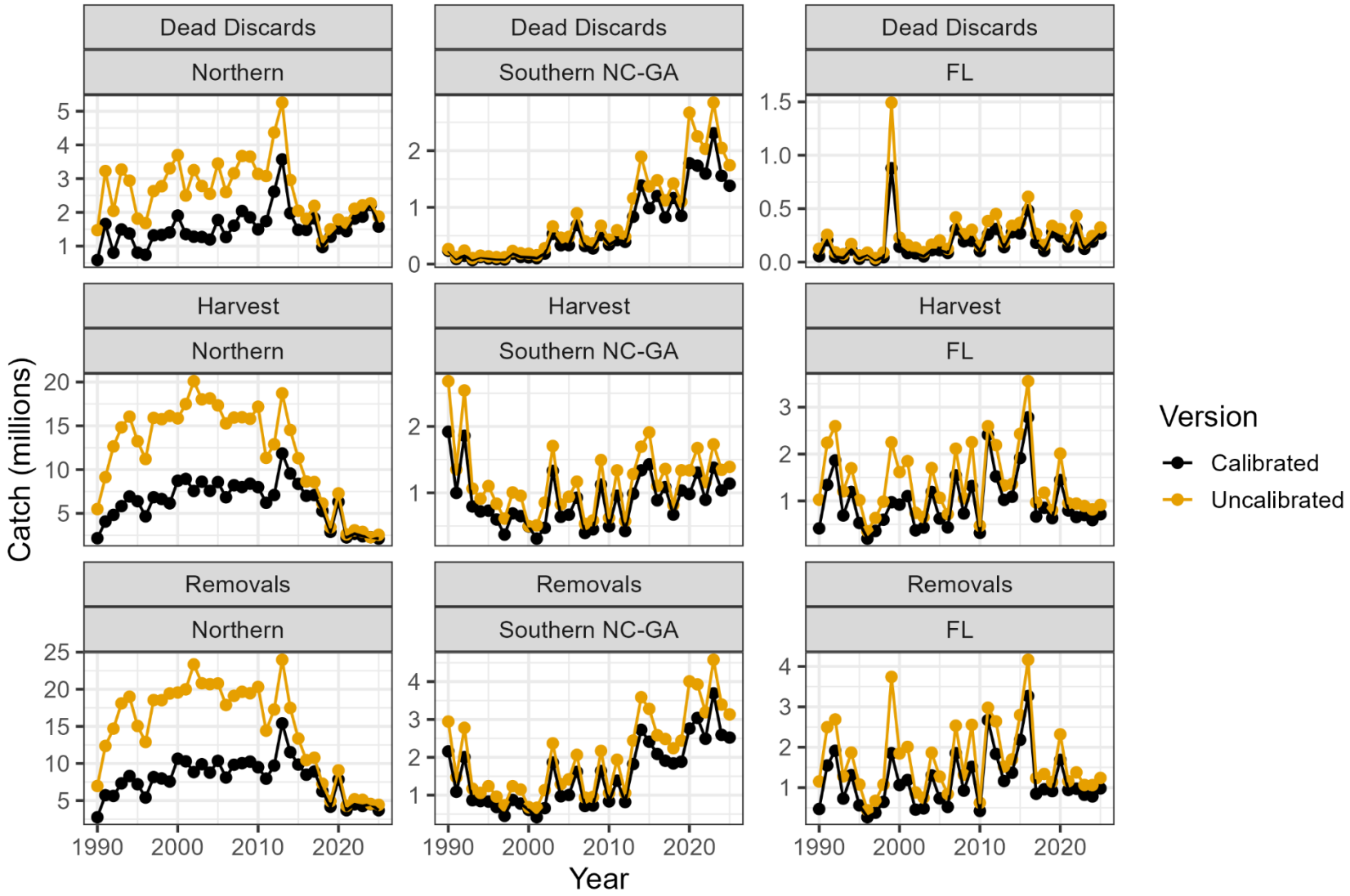


Figure 3. Fleet-specific MRIP catch estimates for Atlantic croaker before and after the 2026 calibration.

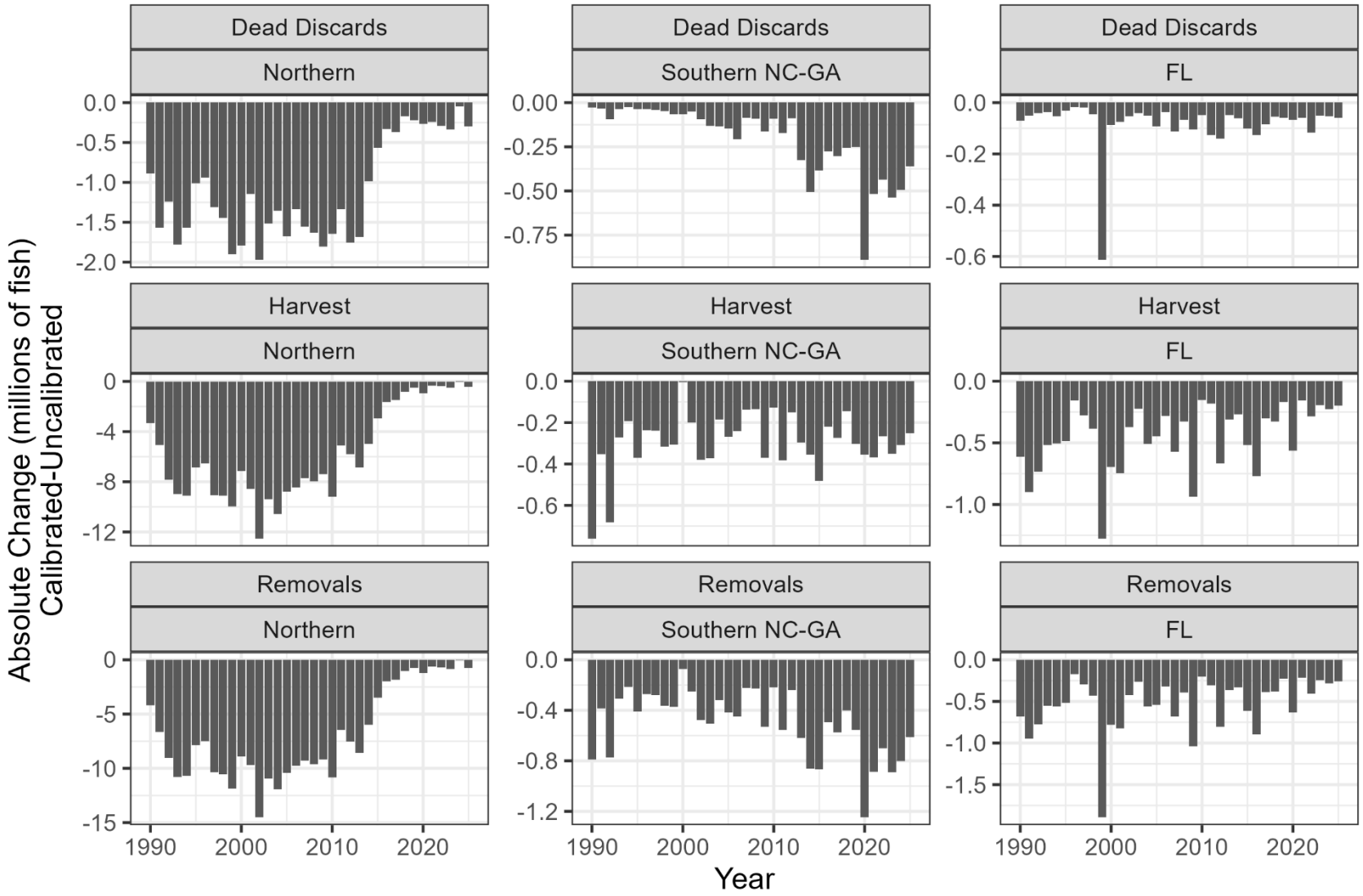


Figure 4. Change in fleet-specific MRIP catch estimates of Atlantic croaker due to the 2026 calibration.

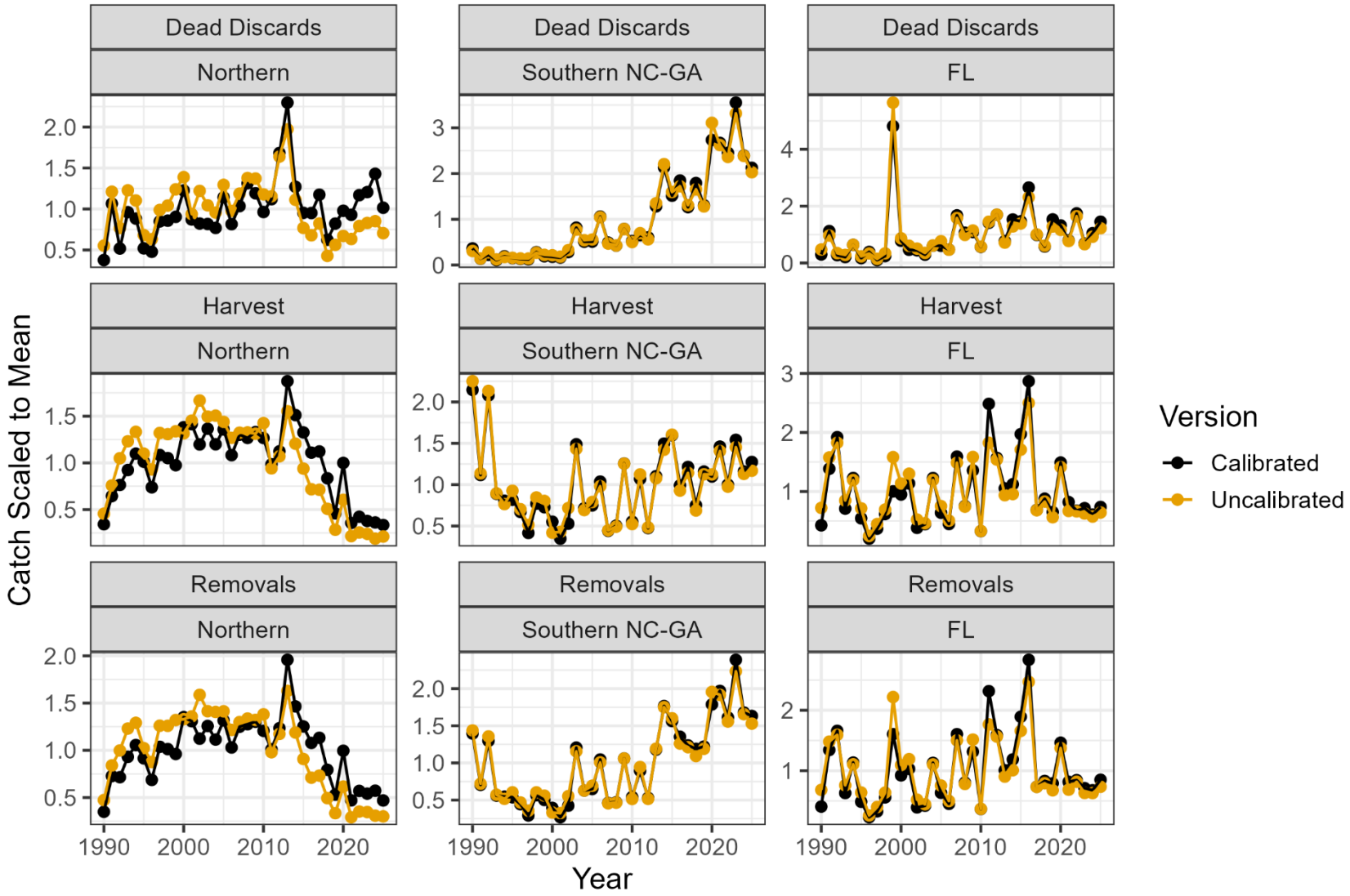


Figure 5. Fleet-specific MRIP catch estimates for Atlantic croaker before and after the 2026 calibration scaled to their time series mean.

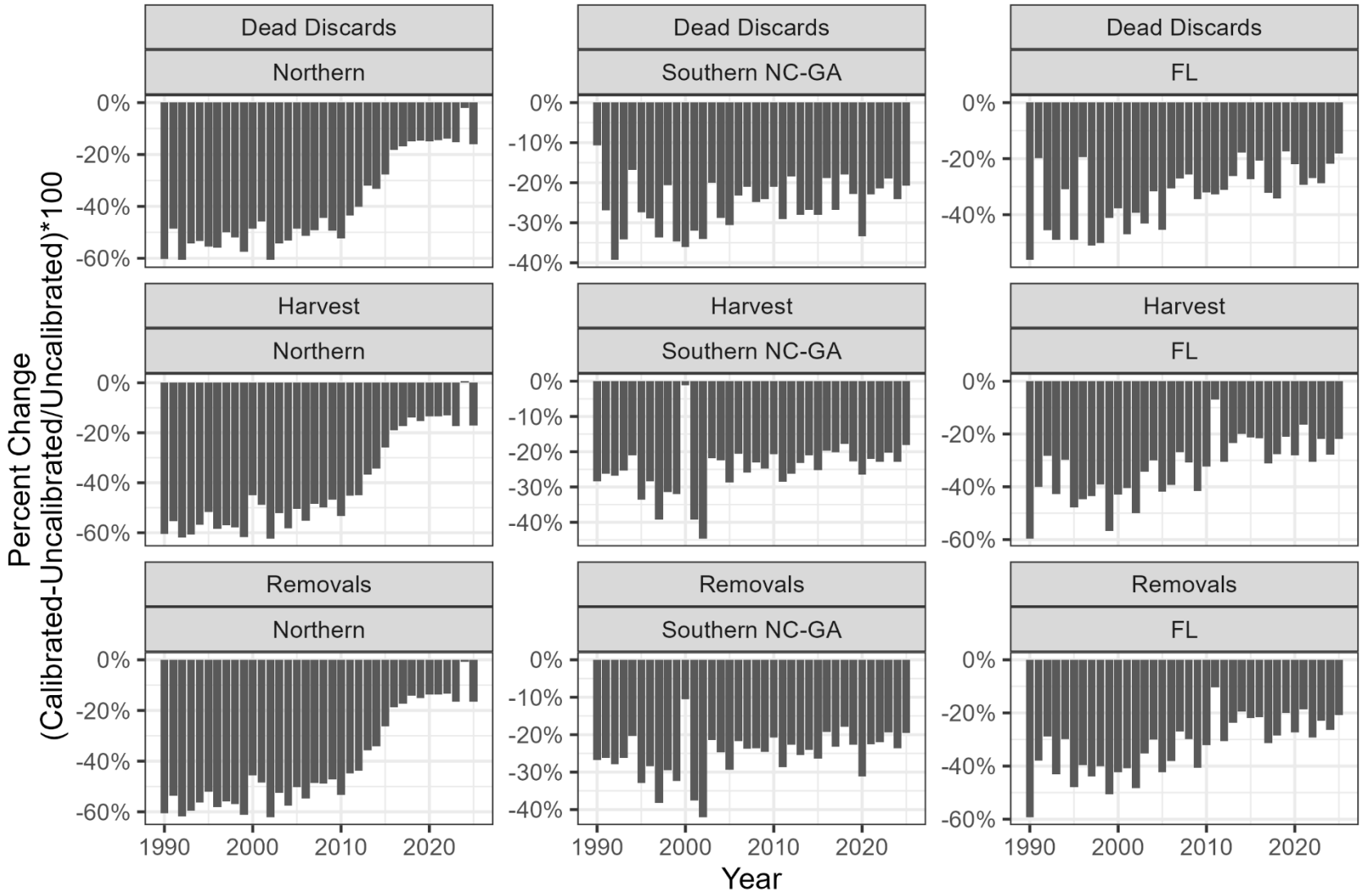


Figure 6. Percent change in fleet-specific MRIP catch estimates of Atlantic croaker due to the 2026 calibration.

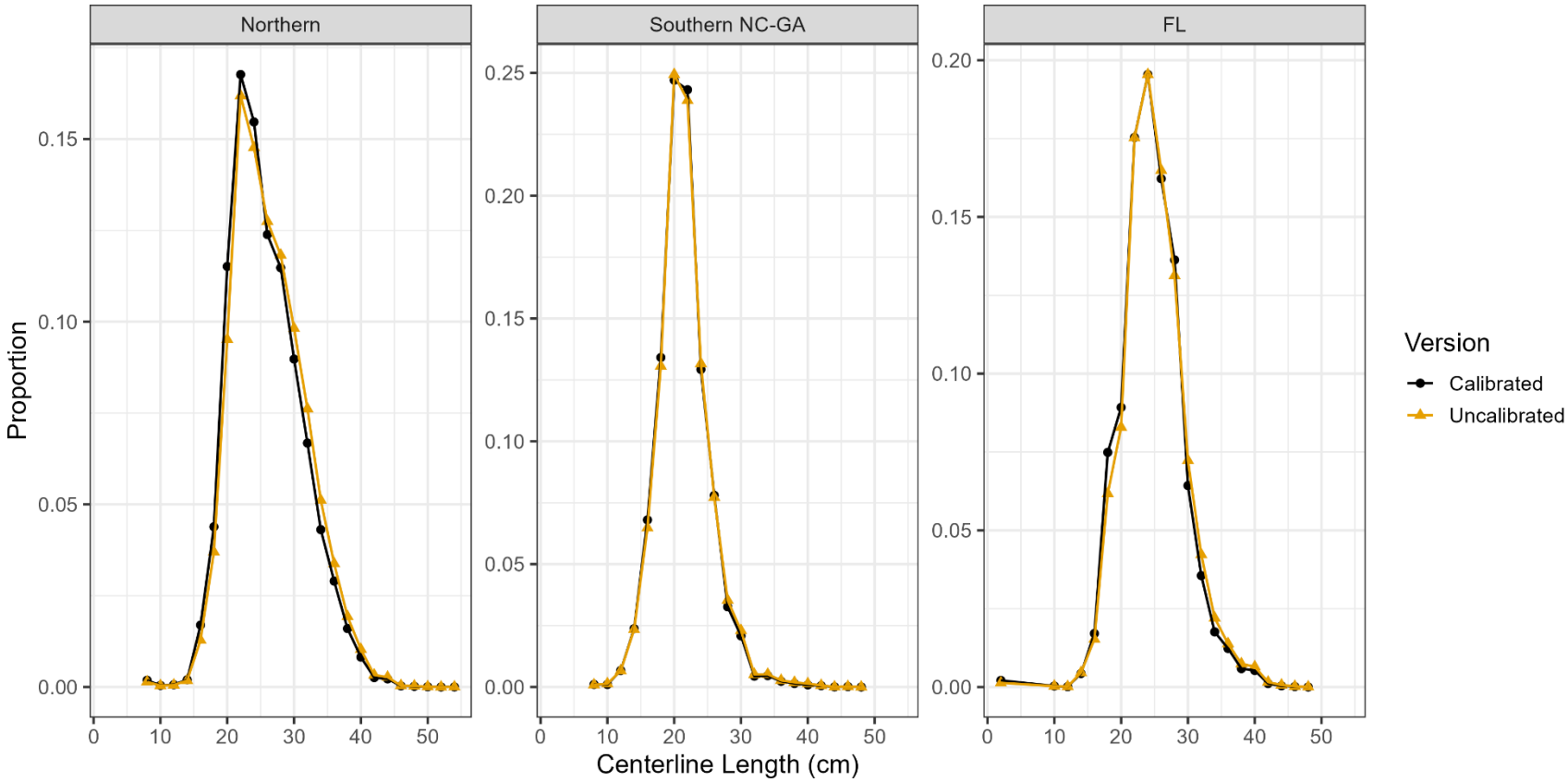


Figure 7. Fleet-specific MRIP harvest length composition estimates for Atlantic croaker aggregated across years (1990-2025) before and after the 2026 calibration.

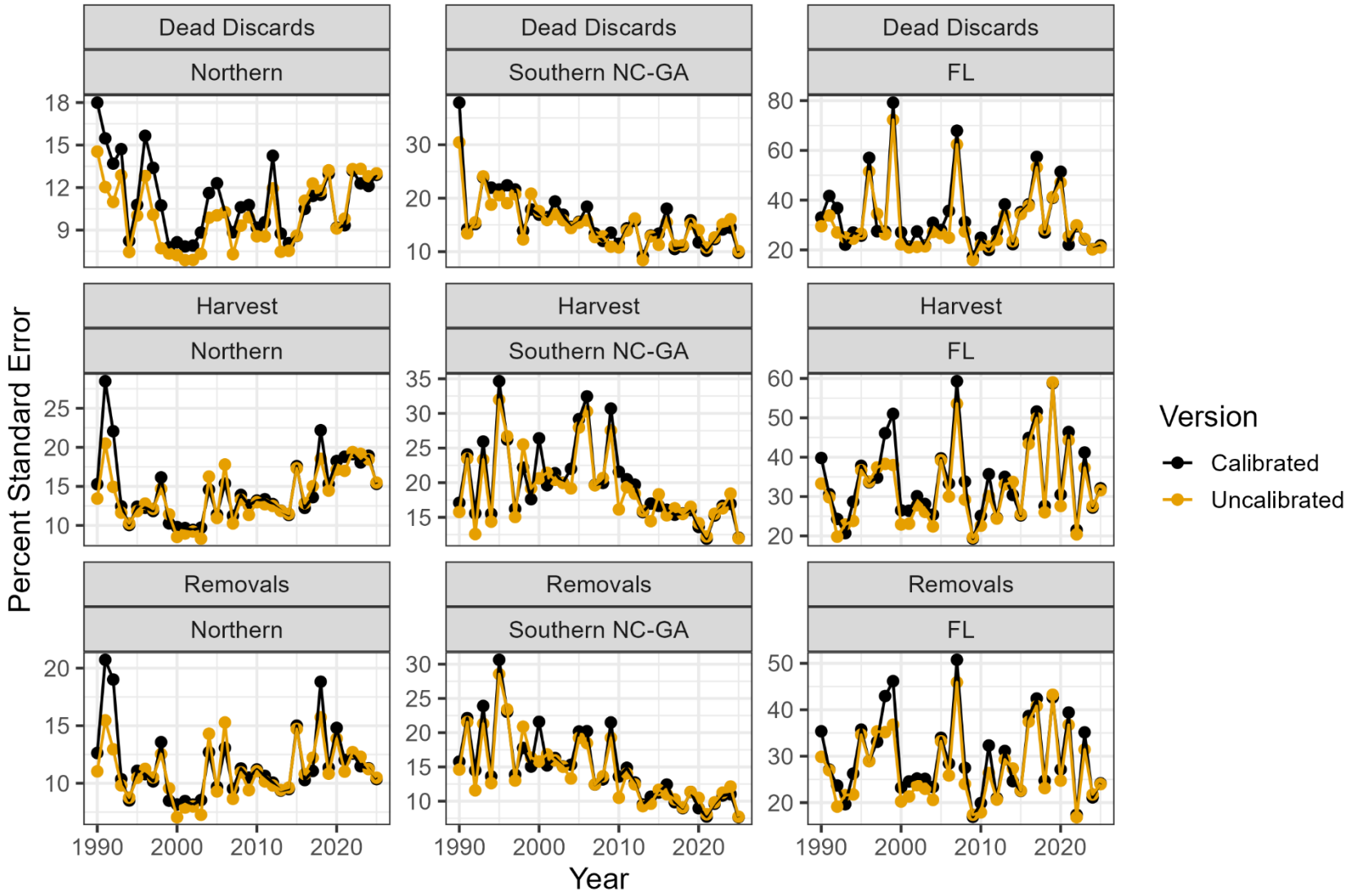


Figure 8. Percent standard error (PSE) of fleet-specific MRIP catch estimates for Atlantic croaker before and after the 2026 calibration. **PSEs of dead discards are assumed equal to those for released alive estimates.*

Atlantic States Marine Fisheries Commission

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MEMORANDUM

TO: **Sciaenids Management Board**

FROM: **Black Drum Technical Committee**

DATE: **October 22, 2026**

SUBJECT: **2026 Black Drum Data Update**

Background

The 2023 Black Drum Benchmark Stock Assessment determined the Atlantic coast stock was not overfished nor experiencing overfishing in the terminal year of the assessment (2020). However, the assessment acknowledged lack of contrast in black drum data sets coupled with high uncertainty in model-based estimates**.** To this end, the Black Drum Technical Committee (TC) recommended close monitoring of empirical stock indicators between stock assessments to identify any concerning trends in a timely manner. Should any concerning trends occur, the TC may recommend an expedited assessment.

Indicators developed during the stock assessment include abundance (young-of-year, age 0-1, subadult, and exploitable abundance), range expansion, recreational live releases and harvest, and commercial landings. Most indicators are split into Mid-Atlantic (New York-Virginia) and South Atlantic (North Carolina-Florida) regions. Time series averages are included in indicator figures as a reference to aid visual interpretation of the indicator, but do not serve as benchmarks for stock status. Additional details on these indicators are available in Section 6 of the 2023 stock assessment report. Of note for this update is completion of the 2026 MRIP calibration process which changes all years of recreational catch estimates reported in previous updates and assessments. These changes are detailed in Appendix 1.

Previous data updates were completed in October 2023 and October 2024. The TC concluded there were no concerning indicator trends relative to coastwide stock status during these previous updates, consistent with indicator results during the stock assessment. During the 2024 data update, the TC recommended scheduling the next data update to the indicators in 2026, and moving the scheduled black drum stock assessment from 2027 to an assessment update in 2028. At that time, based on the results of the stock assessment, the TC will discuss the future schedule of data updates to the indicators.

This memo provides results and recommendations from the third data update since the assessment with data through 2025.

Results

Overall, indicators showed similar conditions to the terminal year of the assessment. Indicator changes were variable with no consistent pattern, except lower recent YOY abundance in the Mid-Atlantic region.

- Mid-Atlantic abundance indicators (all YOY) have primarily been below their time series means since the assessment, including 2024 and 2025 across all four indicators (Figure 1).
- South Atlantic abundance indicators track different age structures and have shown variable patterns since the assessment. Indicators agree on above average abundance in 2024, while two decrease and one increases in 2025 (Figure 2).
- MRIP CPUE (exploitable abundance indicator) remains below highs observed at the end of the assessment time series, but has remained above average for the last three years (Figure 3).
- The range expansion indicator remained below the time series mean in 2022 and 2023 (Figure 4). The indicator is not available in 2021, 2024 and 2025 due to lack of October sampling.
- Recreational live releases varied around the time series mean in the Mid-Atlantic. Recreational live releases in the South Atlantic have been below highs observed near the end of the assessment time series but have remained above the time series average since the assessment (Figure 5).
- Recreational harvest has been relatively stable since the assessment, near the time series mean in the Mid-Atlantic and above the time series mean in the South Atlantic, with the exception of a decline below the time series mean in the South Atlantic in 2025 (Figure 6).
- Commercial landings have remained well below the time series mean in the Mid-Atlantic and well above the time series mean in the South Atlantic (Figure 7).

Conclusions and Recommendations

The TC met on October 13, 2026 to discuss the data update to the indicators and make recommendations to the Board for its November 2026 meeting. Ultimately, the TC did not observe any concerning trends from the indicators relative to stock status, including newly-calibrated MRIP catch. **The TC does not recommend any changes to the current assessment schedule of an assessment update completed in 2028.** The TC recommends not delaying the next assessment beyond 2028 so that assessment results can be updated according to the new, lower magnitude of catch estimated for recreational fisheries.

In addition to the MRIP calibration, the TC also discussed a new development since the last indicator update, a black drum information paper by the North Carolina Division of Marine Fisheries (NCDMF) with a potential explanation for the recent above average catch levels in the South Atlantic (unpublished; C. Stewart, NCDMF, personal communication). This paper was put together in response to a request by the North Carolina Marine Fisheries Commission (NCMFC) to determine if proactive management measures were needed in the state. The paper, presented to the NCMFC in August 2025, considered similar data streams as those included in

this indicator update, as well as a deep dive into effort and fishery characteristics. The paper shows response of fisheries to the southern flounder restrictions and also suggests that species misidentification between black drum and sheepshead, which had a minimum legal size (10 inches) four inches smaller than black drum, could explain observed harvest of undersized black drum. The paper recommended no management changes for black drum and the NCMFC supported the NCDMF recommendation. A similar information paper was requested for sheepshead and the NCMFC ultimately increased the minimum size for sheepshead to 14 inches in 2026, which could reduce harvest of misidentified undersized black drum.

Figures

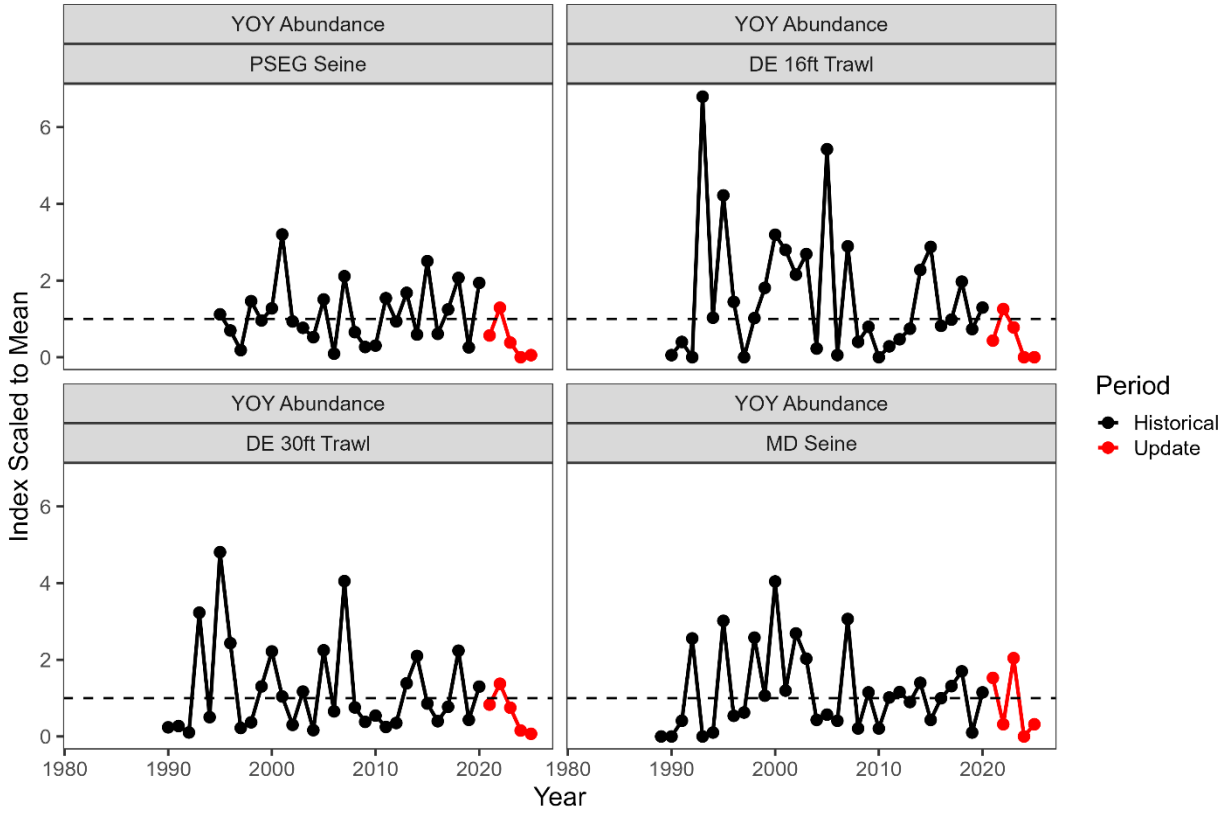


Figure 1. Mid-Atlantic abundance indicators. The dashed line is the time series mean.

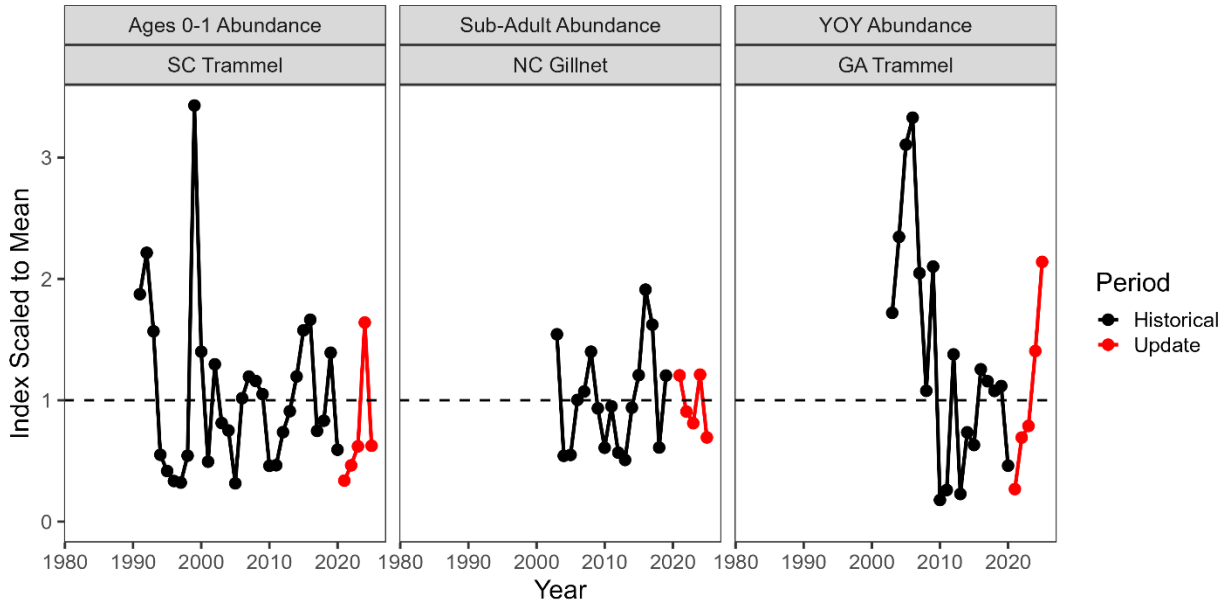


Figure 2. South Atlantic abundance indicators. The dashed line is the time series mean.

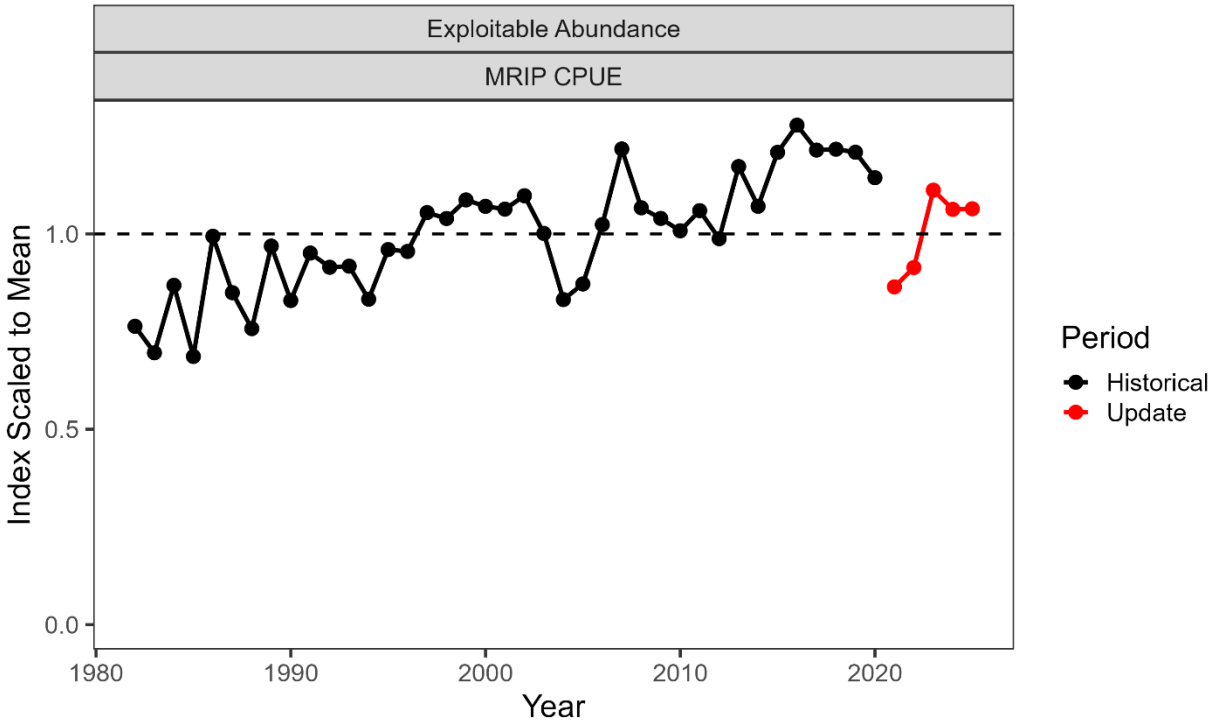


Figure 3. Coastwide abundance indicator. The dashed line is the time series mean.

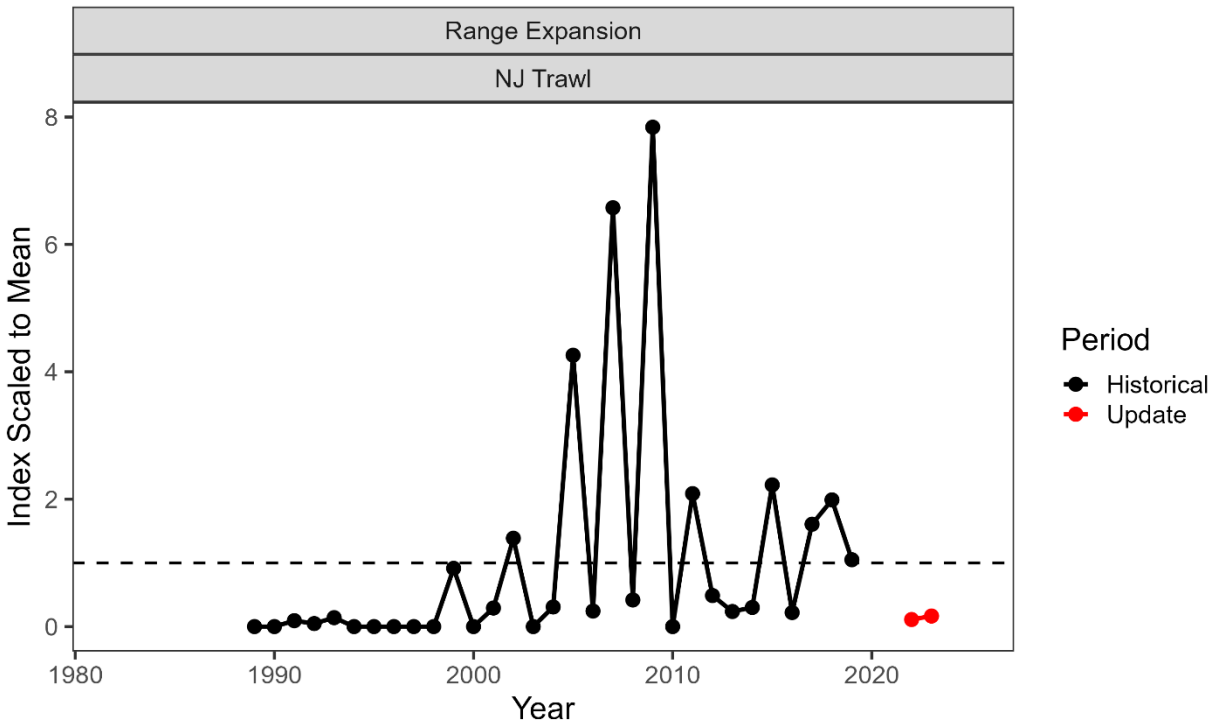


Figure 4. Range expansion indicator. The dashed line is the time series mean.

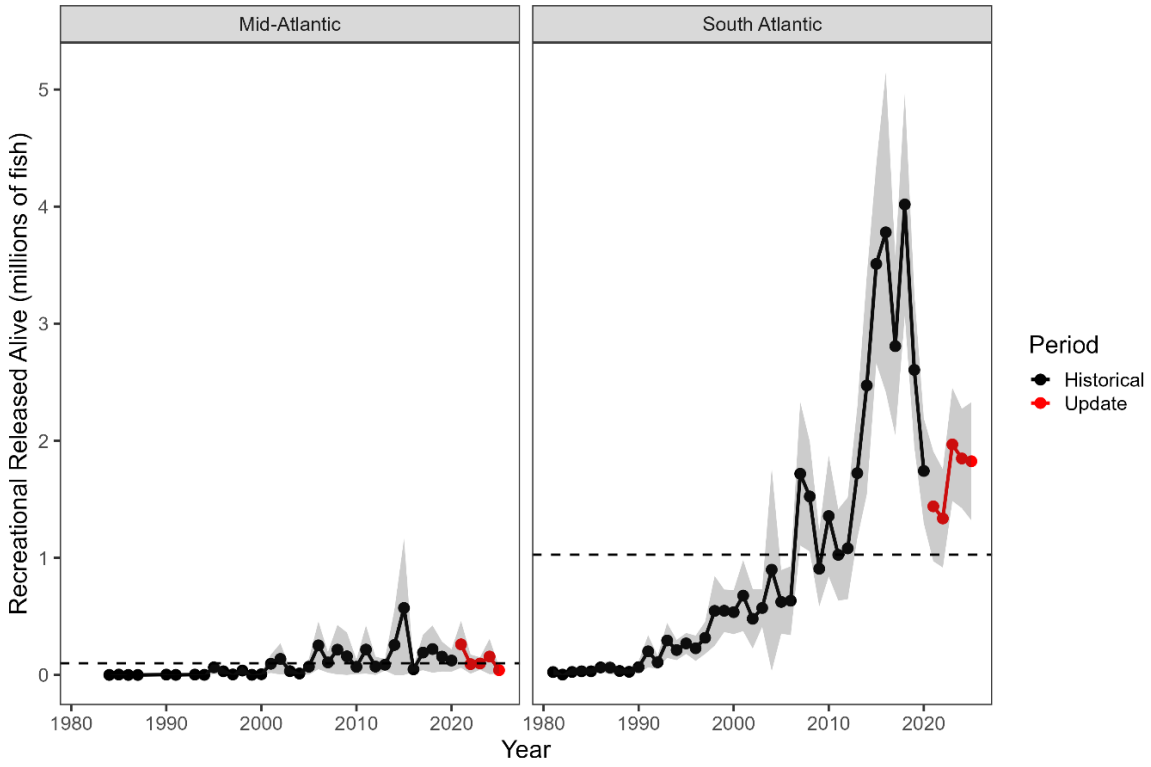


Figure 5. Recreational live release indicators. The dashed line is the time series mean. These indicators have been updated for all years with the calibrated data described in Appendix 1.

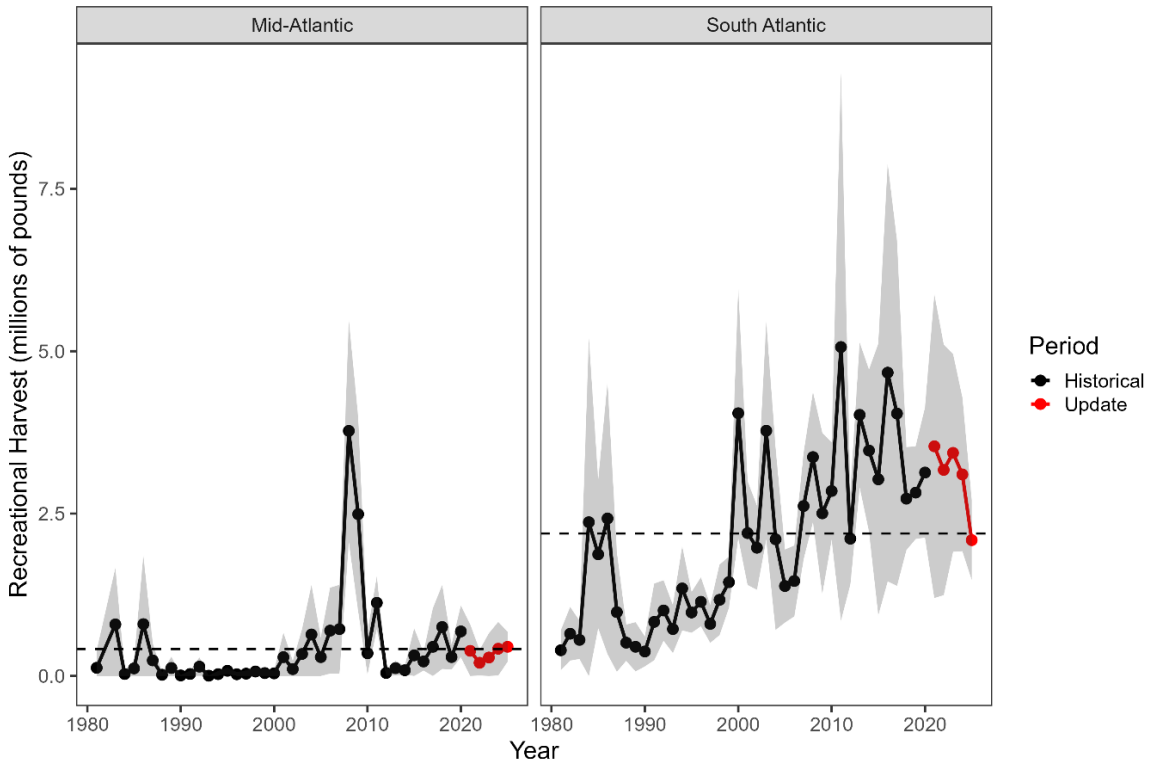


Figure 6. Recreational harvest indicators. The dashed line is the time series mean. These indicators have been updated for all years with the calibrated data described in Appendix 1.

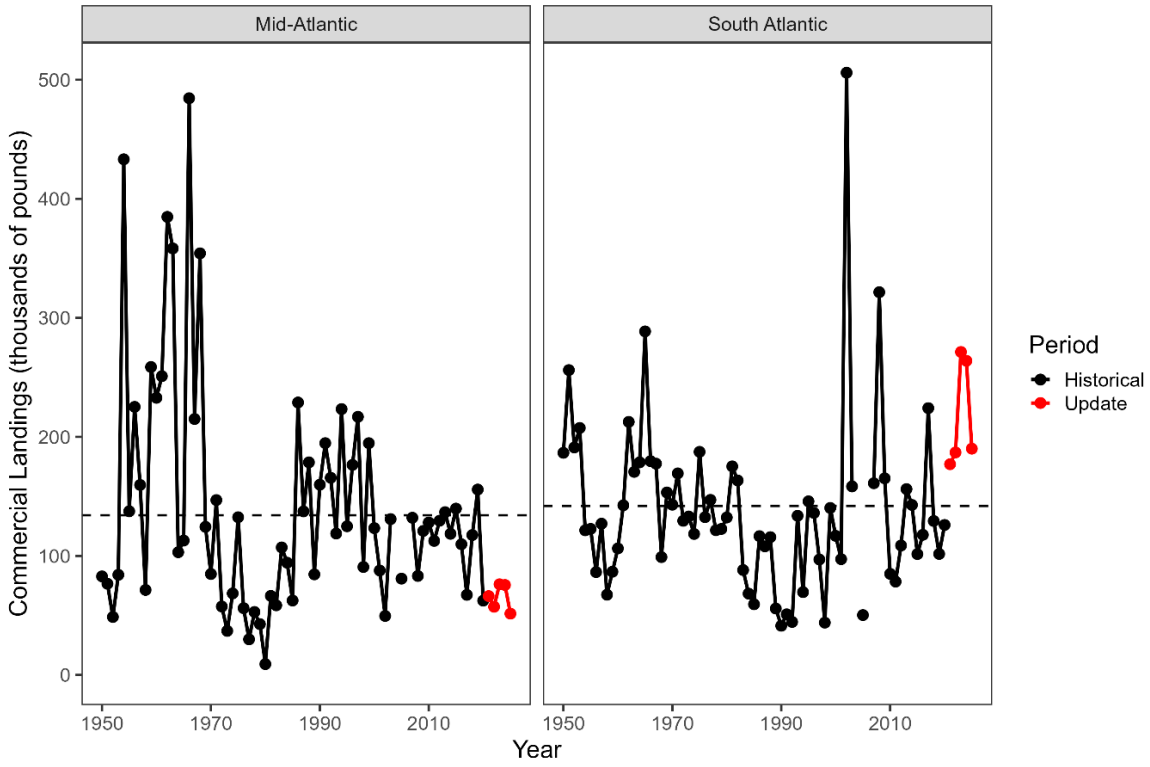


Figure 7. Commercial landings indicators. The dashed line is the time series mean.

Appendix 1: 2026 MRIP Calibration Results

Comparisons of MRIP recreational catch estimates for black drum before and after the recently completed 2026 calibration are provided in this appendix. Estimates prior to the calibration were used in the most recent stock assessment and previous data updates. Calibrations affect estimates from all years.

Comparisons are provided for coastwide estimates for information on the overall impact to the stock and fleet-specific estimates for information on impacts to the estimates as they are used within the stock assessment model. Fleet definitions include Mid-Atlantic states (New York-Virginia) for waves one through four (January- August; MA_early), Mid-Atlantic states for waves five and six (September-December; MA_late), and South Atlantic states (North Carolina through Florida) for all waves combined (SA). Dead discards are estimated assuming an 8% mortality rate of fish released alive, consistent with the 2023 benchmark stock assessment.

Calibrated coastwide estimates of harvest and discards decrease across years relative to uncalibrated estimates previously reported (Figure A1). Annual decreases range from 52-161,557 fewer fish discarded dead, 129,822-1,169,563 fewer fish harvested, and 133,882-1,202,563 fewer fish estimated to have been removed by the recreational fishery. Estimate trends are similar, but do indicate relatively lower catch in earlier years and relatively higher catch in recent years (Figure A2). These trend differences are due to a trend in percent change from higher percentages in earlier years to lower percentages in recent years. Harvest length composition estimates are robust when aggregated across years, only changing a few percentage points where changes are apparent (Figure A3).

When separated into fleets, comparisons follow similar patterns as those observed coastwide (Figure A4-Figure A8). Occasional small increases in catch estimates occur in the MA_late fleet (Figure A4, Figure A5), but these changes are swamped by the greater magnitudes of catch by the MA_early and, particularly, SA fleets.

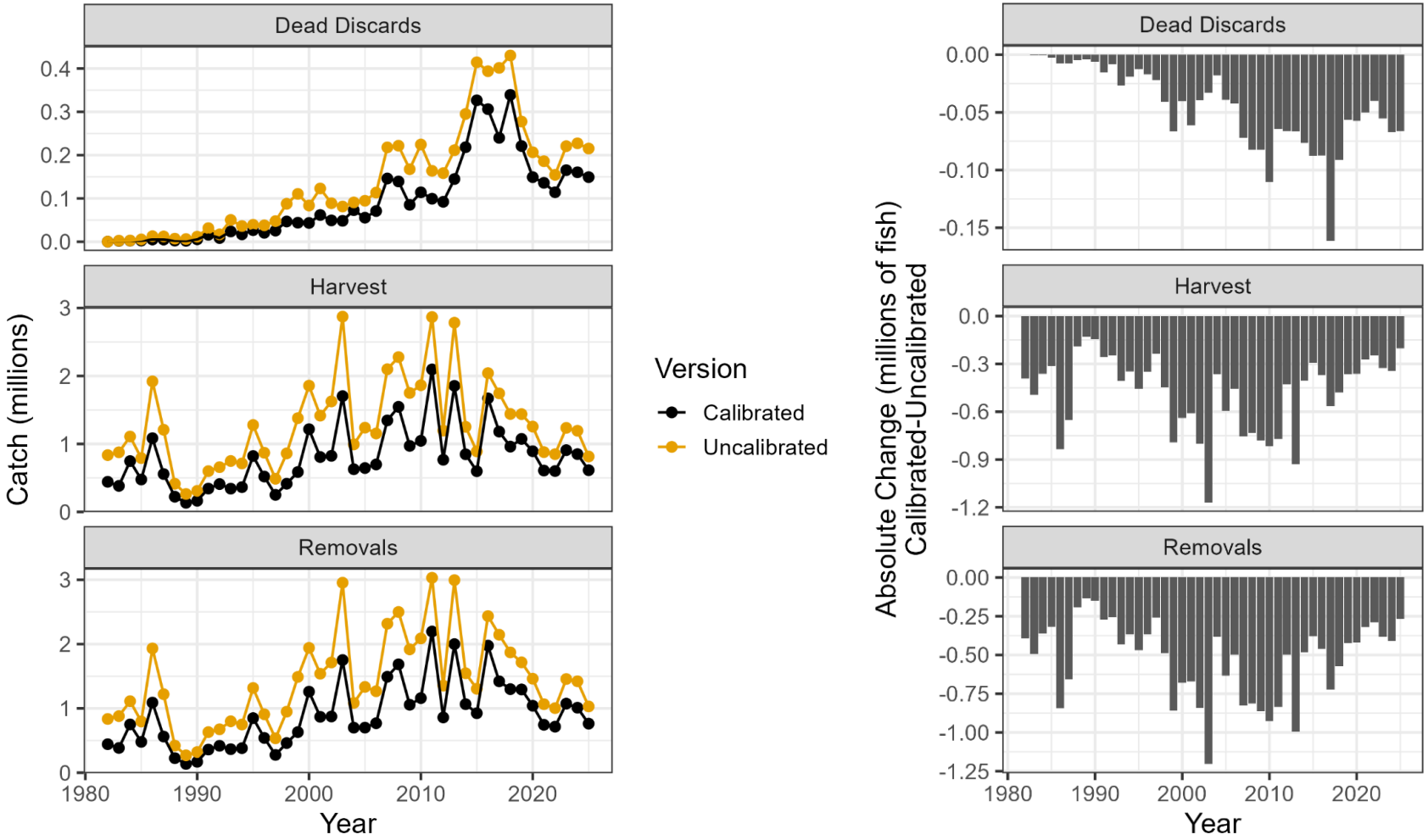


Figure A1. Coastwide MRIP catch estimates for black drum before and after the 2026 calibration (left) and changes in estimates (right).

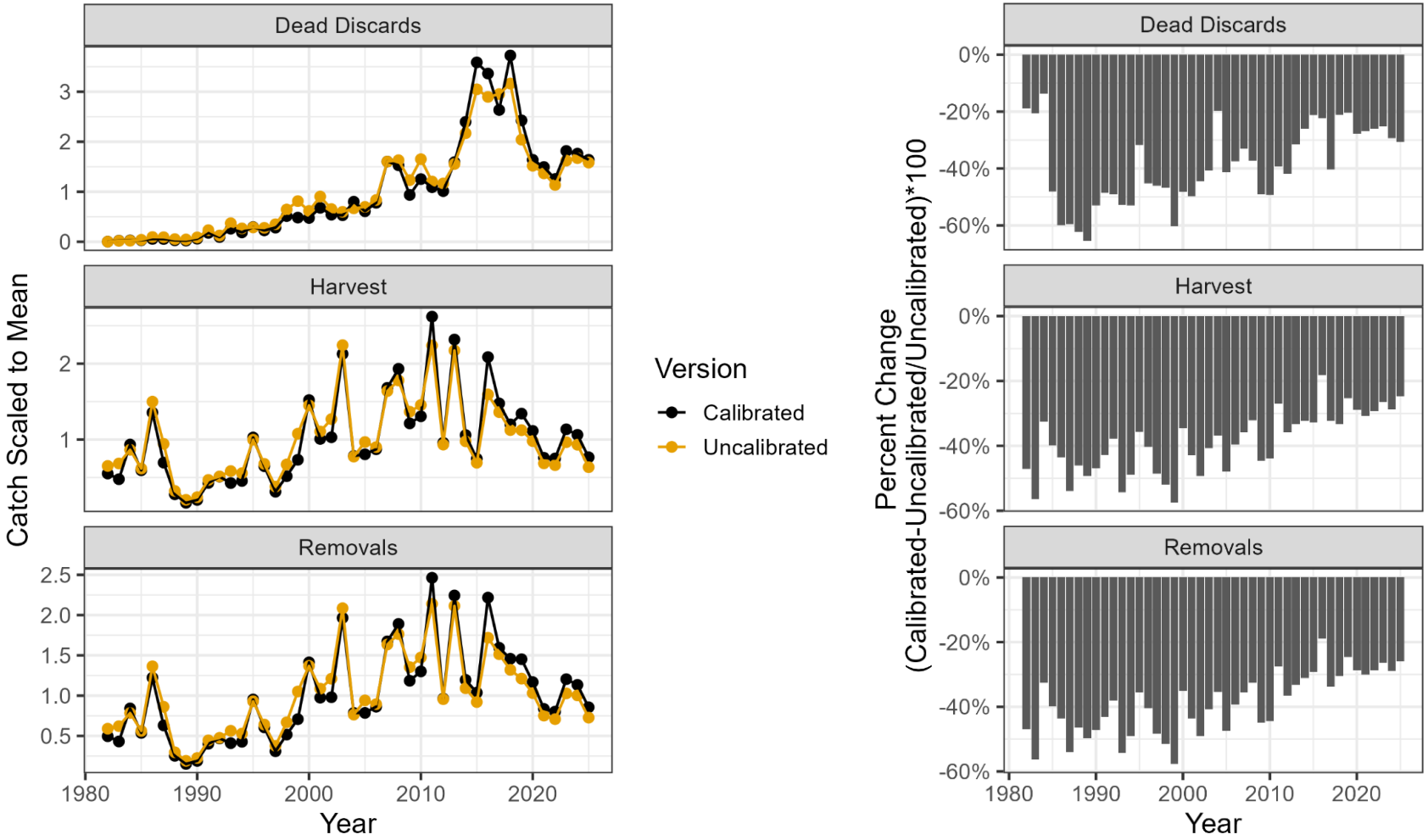


Figure A2. Coastwide MRIP catch estimates for black drum before and after the 2026 calibration scaled to their time series mean (left) and changes in percentage (right).

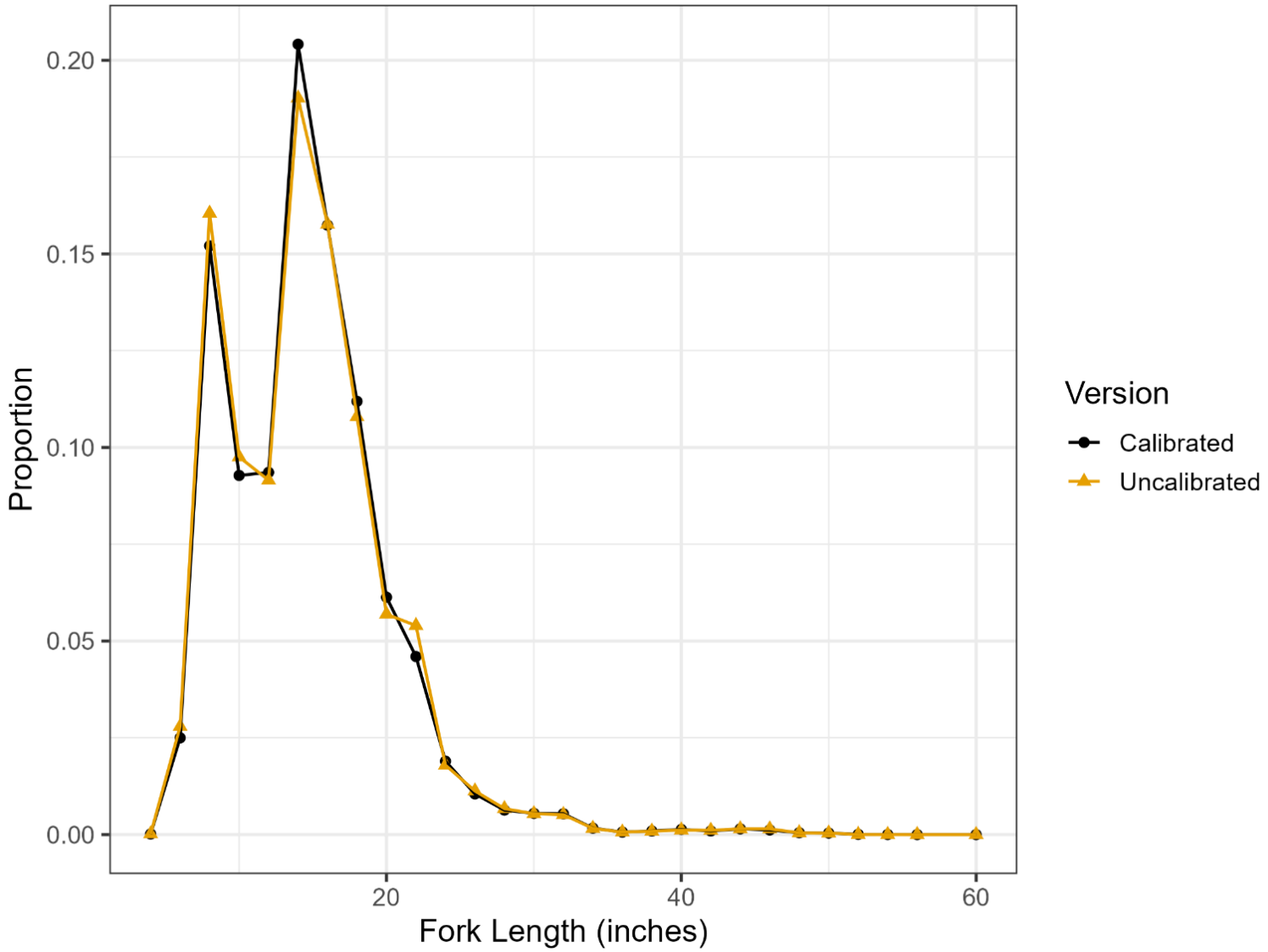


Figure A3. Coastwide MRIP expanded harvest length composition estimates for black drum aggregated across assessment years (1982-2020) before and after the 2026 calibration.

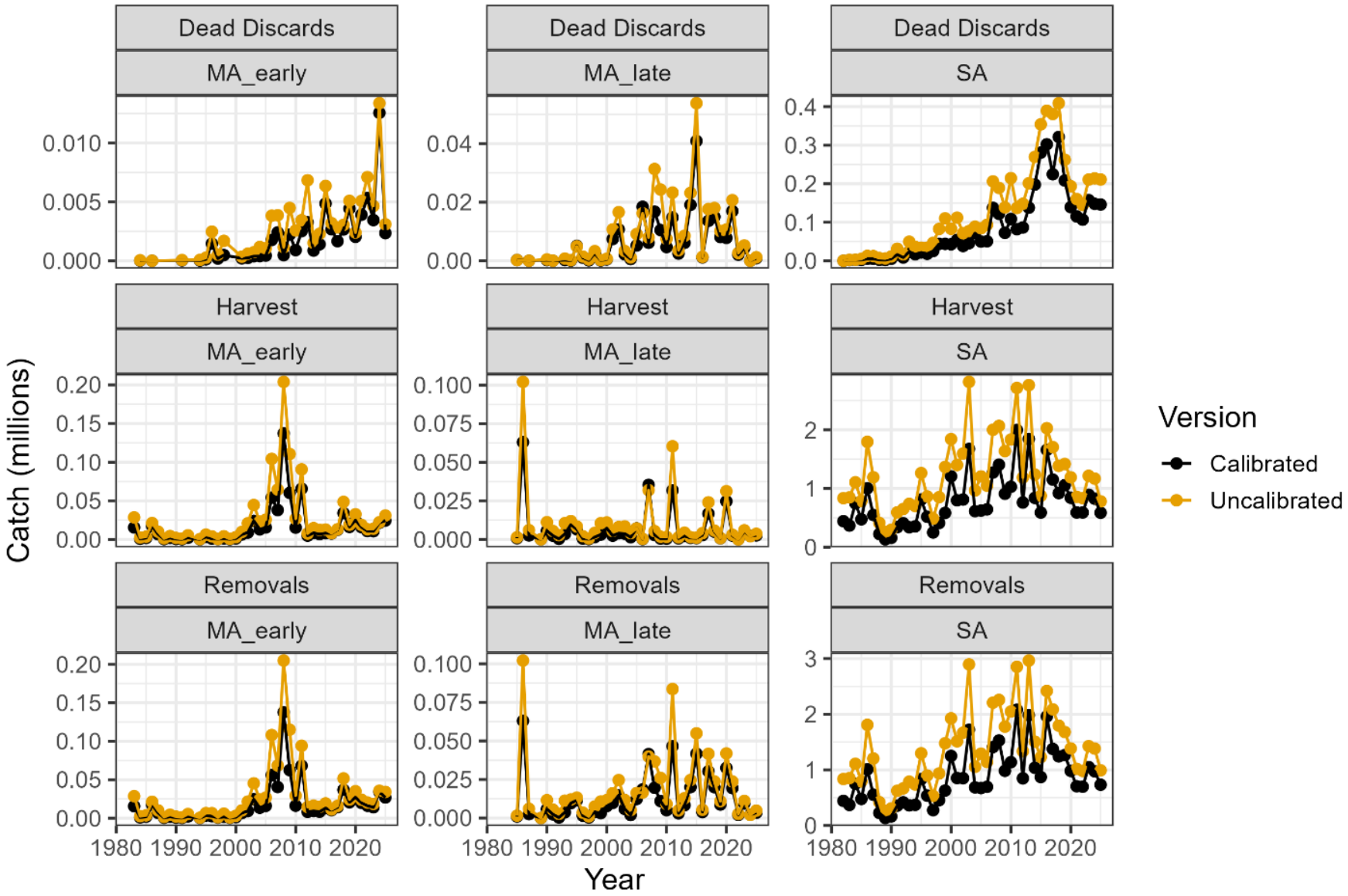


Figure A4. Fleet-specific MRIP catch estimates for black drum before and after the 2026 calibration.

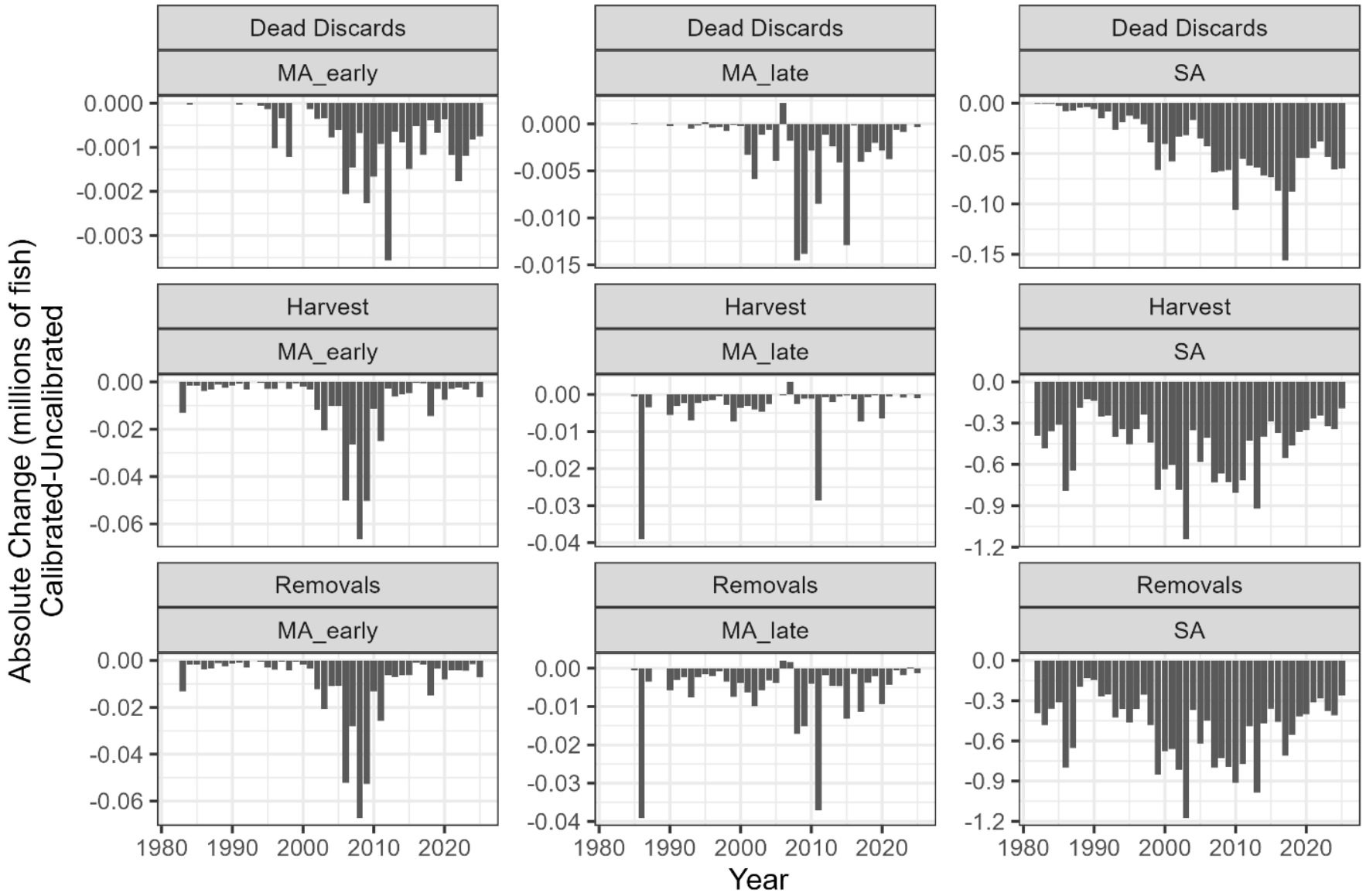


Figure A5. Change in fleet-specific MRIP catch estimates due to the 2026 calibration.

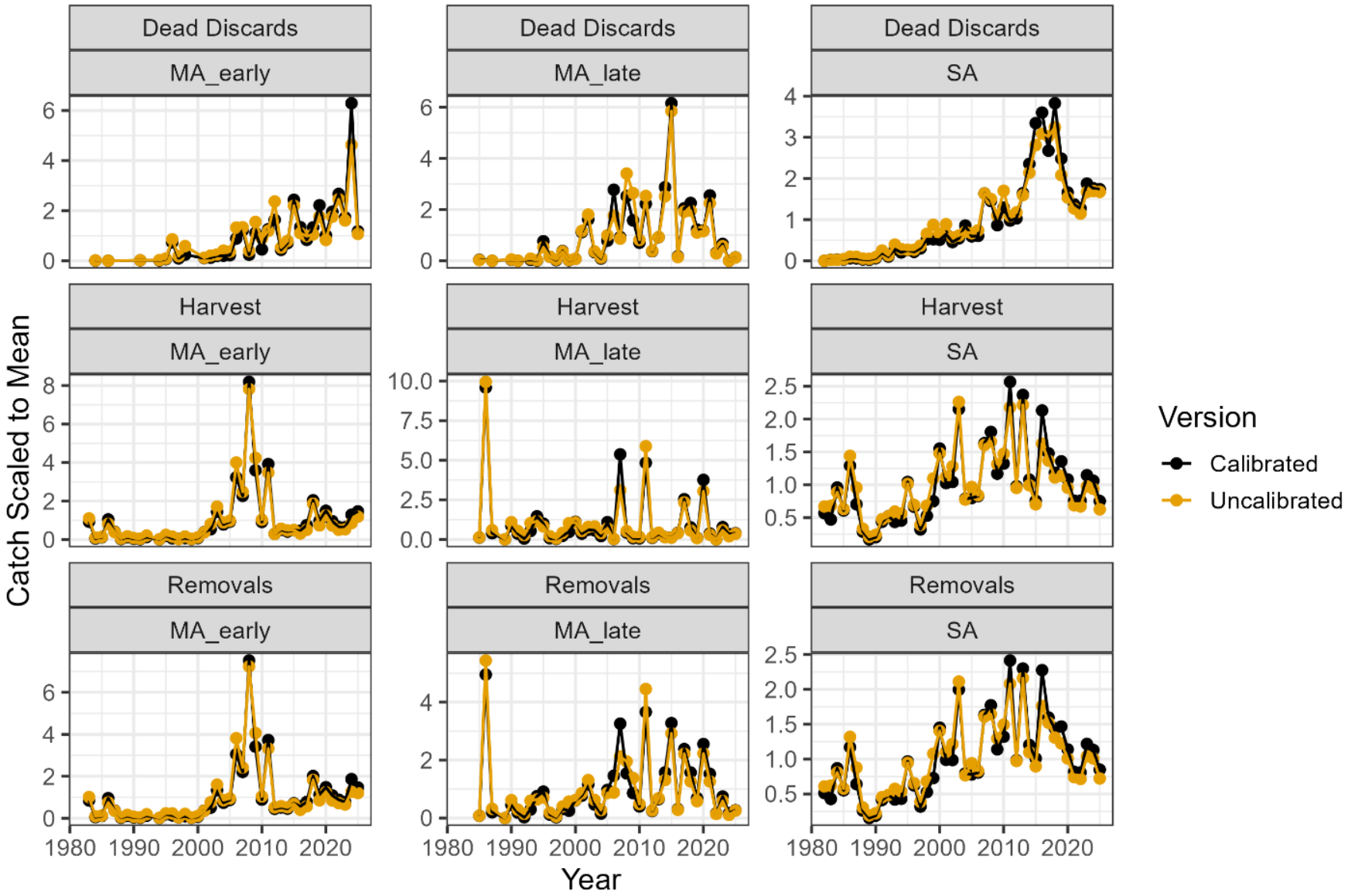


Figure A6. Fleet-specific MRIP catch estimates for black drum before and after the 2026 calibration scaled to their time series mean.

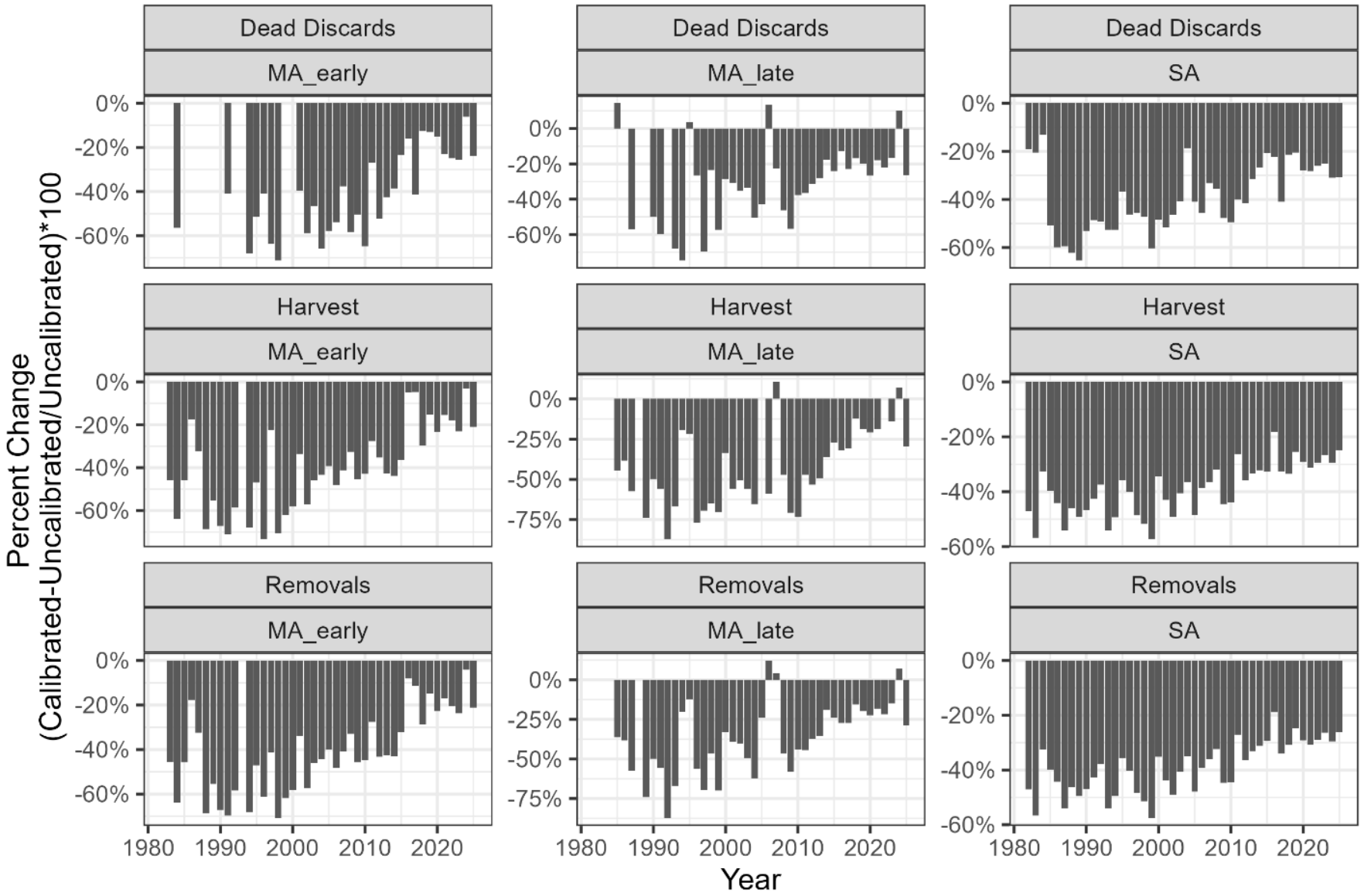


Figure A7. Percent change in fleet-specific MRIP catch estimates due to the 2026 calibration.

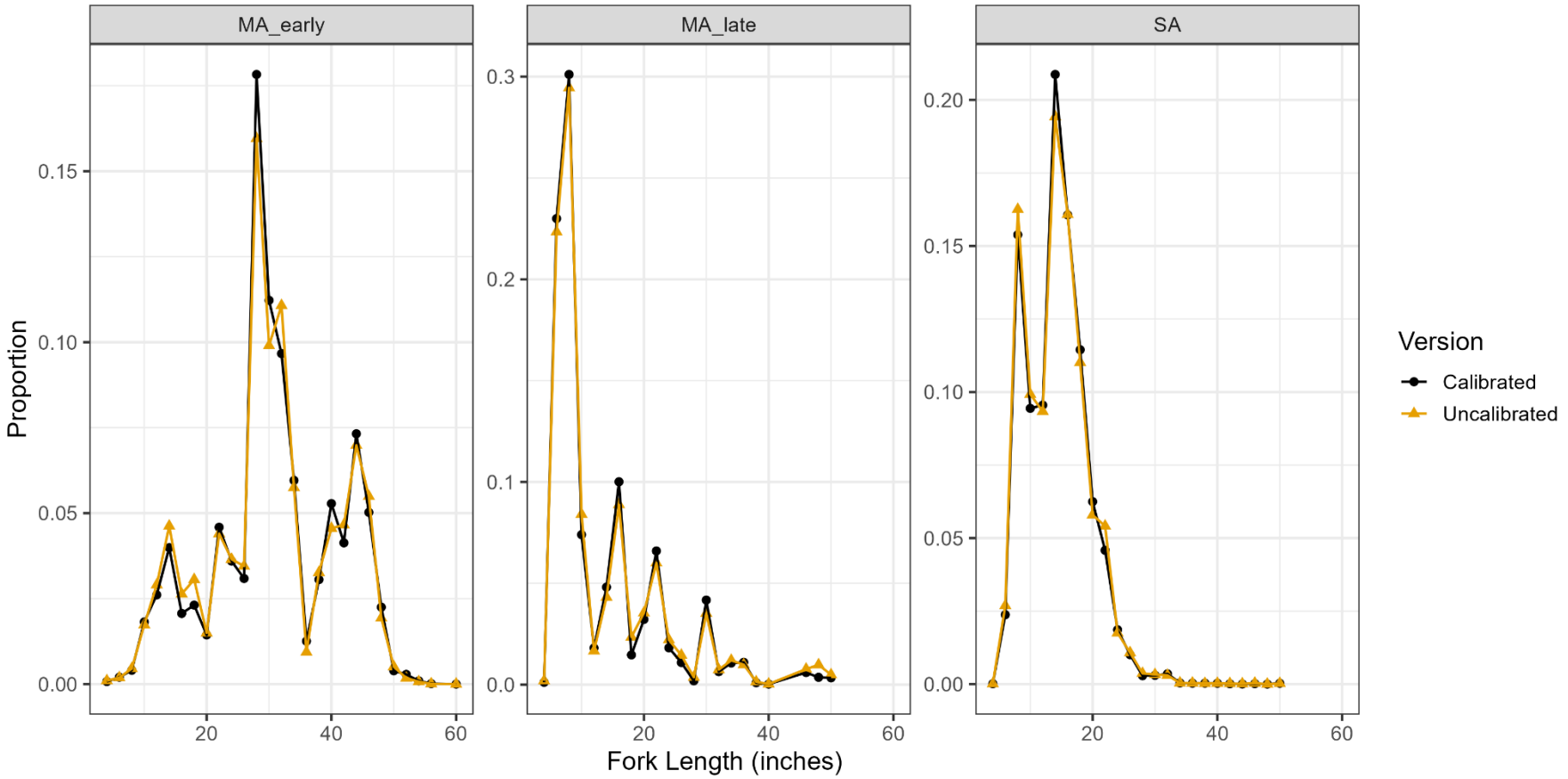


Figure A8. Fleet-specific MRIP expanded harvest length composition estimates for black drum aggregated across assessment years (1982-2020) before and after the 2026 calibration.

NATIONAL WILDLIFE FEDERATION

NWF.ORG

July 24, 2026

Atlantic States Marine Fisheries Commission (ASMFC)
1050 N. Highland Street, Suite 200 A-N
Arlington, VA 22201

Re: Comments to Inform the Atlantic Croaker Benchmark Stock Assessment Peer Review

Dear Director Beal, Sciaenid Board, and Atlantic Croaker Technical Committee,

The National Wildlife Federation is the nation's largest grassroots non-profit wildlife conservation organization, with a mission of *uniting all Americans to ensure wildlife thrive in a rapidly changing world*. Since our founding 90 years ago, we have worked to safeguard America's wildlife and habitats, and connect people of all ages with nature to foster their appreciation for and engagement with the natural world. With our 52 state and territorial affiliates, we represent more than seven million members, supporters, and conservation advocates and our supporters span the political spectrum and represent the fullest range of conservation and outdoor interests. Our work includes a focus on marine conservation policy in support of healthy and sustainable marine fisheries.

The Federation is pleased to submit the following comments for consideration as the updated Atlantic Croaker benchmark stock assessment is being prepared. As estuarine-dependent species in the region and forage fish in the food web, Atlantic croaker play a critical ecological role. As both predators and prey, they act as conduits of energy between benthic invertebrates and higher predators, with Atlantic croaker serving as are a primary food source for bottlenose dolphins residing in estuaries[1] as one example. Still, despite their ecological significance and coastwide importance to commercial and recreational fishing, Atlantic croaker are a vulnerable species in need of more aggressive management measures to support recovery.

For years, the ASMFC's stock status for the Atlantic croaker (both overfished and overfishing) has been listed as "unknown". Similarly, the current population abundance and fishing mortality is designated as "unknown". Chronic data gaps and the uncertainty of the stock status have impeded the ASMFC's assessments and have led to deficient management approaches. It was problematic that the last benchmark stock assessment released in 2017 was deemed not recommended for management use. While the subsequent 2020 Traffic Light Analysis (TLA) resulted in resulted in some management measures being taken, it remains clear that time is of the essence and that there

[1] Atlantic Sciaenid Habitats A Review of Utilization, Threats, and Recommendations for Conservation, Management, and Research, Atlantic States Marine Fisheries Commission Habitat Management Series #14 Winter 2017

are significant sources of mortality that need to be better addressed to inform more effective management solutions.

The severe decline in combined Atlantic croaker commercial and recreational landings from 47 million pounds in 2003, to the lowest number reported in 2024 for the period 1950-2024, is alarming. There is a need for enhanced understanding of all sources of commercial harvest, and to revisit quotas for more effective management. There is also a need to better understand the declines, particularly as they relate to biological factors. This includes reassessing biomass targets, which are arguably low for species of such ecological importance and where there are serious data limitations. We also recommend that the size limits for spot and Atlantic croaker must be set to correspond with the L75 data for each species as minimum standards moving forward to help ensure spawning potential and increase species' resiliency.

It is imperative that the ASMFC and fisheries managers address *all* known sources of Atlantic croaker fishery mortality, including both natural sources and sources of fishing-related mortality. In particular this should include unreported harvest from flynets and gillnets and the devastating effects of the shrimp trawl fishery. The ASMFC *Atlantic Sciaenid Habitats* plan explicitly recommends that nursery areas for sciaenid species—such as Atlantic croaker, spot, and weakfish—be fully protected from trawl activity.[2] North Carolina is the only state that allows extensive trawling in crucial nursery habitats like the Pamlico Sound, which has negative implications for valuable, interjurisdictional fisheries throughout the ASMFC region.

Continuing to ignore the ecological harms from shrimp trawl bycatch in the Pamlico Sound to Atlantic croaker and other estuarine species, such as weakfish and spot, is incongruent with the ASMFC's mission "To promote cooperative management of marine, shell and diadromous fisheries of the Atlantic coast of the United States by the protection and enhancement of such fisheries, and by the avoidance of physical waste of the fisheries from any cause."[3] The perpetuation of this wasteful situation is extremely damaging and to the detriment of the rebuilding of the coastwide Atlantic croaker population, among others.

Additionally, there are other factors influencing fishery recovery for the Atlantic croaker that must be examined, including significant sources of habitat degradation, and other broader ecosystem stressors such as climate change effects. The Federation supports a wholistic and comprehensive management approach that addresses all sources of species' decline, including habitat degradation, and the pursuance of supportive measures for the recovery of the Atlantic croaker fishery and the multitude of species that rely on it.

[2] https://asmfc.org/wp-content/uploads/2024/12/HMS14_AtlanticSciaenidHabitats_Winter2017.pdf?utm_source

[3] https://asmfc.org/about/

We thank you for the opportunity to provide these comments and urge that the ASMFC generates a strong and actionable peer-reviewed stock assessment that is based on the best available biological data and that addresses persistent harvest and damaging bycatch concerns. Please feel free to contact me at gardnerl@nwf.org or 202-797-6815 if you have any questions or concerns. We look forward to an opportunity to work collaboratively with the ASMFC and states to support healthy ASMFC-managed species and stocks, like the Atlantic croaker, for people and wildlife today and generations to come.

Sincerely,



Lindsay Gardner
Director of Marine Conservation