Atlantic States Marine Fisheries Commission

Sciaenids Management Board

May 2, 2022
2:15 – 4:15 p.m.
Hybrid Meeting

Draft Agenda

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

1. Welcome/Call to Order *(C. Batsavage)* 2:15 p.m.

2. Board Consent 2:15 p.m.
   - Approval of Agenda
   - Approval of Proceedings from August 2021

3. Public Comment 2:20 p.m.

4. Consider Red Drum Simulation Assessment and Peer Review Report 2:30 p.m.
   Action
   - Presentation of Red Drum Simulation Assessment Report *(J. Ballenger)*
   - Presentation of Peer Review Panel Report *(A. Schueller)*

5. Progress Update on Black Drum Benchmark Stock Assessment (*J. Kipp*) 3:45 p.m.

6. Other Business/Adjourn 4:15 p.m.

The meeting will be held at The Westin Crystal City (1800 Richmond Highway, Arlington, VA; 703.486.1111) and via webinar; click here for details

MEETING OVERVIEW

Sciaenids Management Board Meeting
May 2, 2022
2:15 – 4:15 p.m.
Hybrid Meeting

Chair: Chris Batsavage (NC) Assumed Chairmanship: 02/22	Technical Committee Chairs: Black Drum: Harry Rickabaugh (MD) Atlantic Croaker: Dawn Franco (GA) Red Drum: Lee Paramore (NC) Spot: Harry Rickabaugh (MD)	Law Enforcement Committee Representative: Capt. Chris Hodge (GA)
Vice Chair: Vacant	Advisory Panel Chair: Craig Freeman (VA)	Previous Board Meeting: August 3, 2021
Voting Members: NJ, DE, MD, PRFC, VA, NC, SC, GA, FL, NMFS (10 votes)		

2. Board Consent

- Approval of Agenda
- Approval of Proceedings from August 2021

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 Red Drum Simulation Assessment and Peer Review Report (2:30-3:45 p.m.) Action
Background • In 2020, the Board initiated a simulation modeling process so the Red Drum Stock Assessment Subcommittee (SAS) could determine the most appropriate assessment strategy for red drum. • The SAS simulated red drum populations to test a variety of assessment modeling techniques and identify the techniques(s) best suited for tracking red drum population dynamics in the next benchmark stock assessment. The Red Drum Technical Committee provided a report of the simulation assessment for peer review. (**Briefing Materials**) • A peer review workshop for the Red Drum Simulation Assessment was conducted from March 28-30, 2022. The Peer Review Panel summarized their findings with respect to the TORs for review and made recommendations on the model(s) best suited for the next benchmark stock assessment. (**Briefing Materials**)
Presentations • Overview of the 2022 Red Drum Simulation Assessment by J. Ballenger.

- Peer Review Panel Findings by A. Schueller.

Board actions for consideration at this meeting

- Consider the Red Drum Simulation Assessment and Peer Review Report

5. Progress Update on Black Drum Benchmark Stock Assessment (3:45-4:15 p.m.)

Background

- At the 2021 Summer Meeting, the Board approved the initiation of a Stock Assessment Subcommittee (SAS) to begin the Benchmark Stock Assessment Process for black drum.
- A black drum SAS was formed and has met several times to develop the benchmark stock assessment. A Data Workshop was held in December 2021 and a Methods Workshop was held in February 2022. An Assessment Workshop is expected to be held in July 2022.
- A peer review workshop for the black drum benchmark stock assessment is tentatively scheduled for December 2022.

Presentations

- Stock assessment update by J. Kipp.

6. Other Business/Adjourn

Sciaenids Management Board

Activity level: High

Committee Overlap Score: Moderate (American Eel TC, Bluefish TC, Menhaden TC, Weakfish TC)

Committee Task List
• Red Drum SAS – Conduct Red Drum Simulation Assessment • Black Drum SAS – Conduct Black Drum Benchmark Stock Assessment • Spot TC – Review State Proposals for Regulation Changes • Atlantic Croaker TC – Review State Proposals for Regulation Changes • Atlantic Croaker TC – July 1: Compliance Reports Due • Red Drum TC – July 1: Compliance Reports Due • Atlantic Croaker TC – Conduct 2022 Traffic Light Approach analysis for Annual Meeting • Spot TC – Conduct 2022 Traffic Light Approach analysis for Annual Meeting • Black Drum TC – August 1: Compliance Reports Due • Spotted Seatrout PRT – September 1: Compliance Reports Due • Spot PRT – November 1: Compliance Reports Due

TC Members:
Atlantic Croaker: Dawn Franco (GA, Chair), Kristen Anstead (ASMFC), Tracey Bauer (ASMFC), Stacy VanMorter (NJ), Michael Greco (DE), Harry Rickabaugh (MD), Somers Smott (VA, Vice Chair), Morgan Paris (NC), Chris McDonough (SC), Joseph Munyandorero (FL)
Black Drum: Harry Rickabaugh (MD, Chair), Jeff Kipp (ASMFC), Tracey Bauer (ASMFC), Craig Tomlin (NJ), Jordan Zimmerman (DE), Ethan Simpson (VA), Chris Stewart (NC), Chris McDonough (SC), Ryan Harrell (GA), Shanae Allen (FL)
Red Drum: Lee Paramore (NC, Chair), Jeff Kipp (ASMFC), Tracey Bauer (ASMFC), Alissa Wilson (NJ), Michael Greco (DE), Robert Bourdon (MD), Ethan Simpson (VA, Vice Chair), Joey Ballenger (SC), Chris Kalinowsky (GA), Roger Pugliese (SAFMC)
Spot: Harry Rickabaugh (MD, Chair), Jeff Kipp (ASMFC), Tracey Bauer (ASMFC), Stacy VanMorter (NJ), Michael Greco (DE), Somers Smott (VA), Morgan Paris (NC), Chris McDonough (SC), BJ Hilton (GA), Joseph Munyandorero (FL)
Spotted Seatrout (PRT): Tracey Bauer (ASMFC), Douglas Lipton (MD), Joey Ballenger (SC), Chris Kalinowsky (GA)

SAS Members:
Red Drum: Joey Ballenger (SC, Chair), Jeff Kipp (ASMFC), Tracey Bauer (ASMFC), Angela Giuliano (MD), Lee Paramore (NC), Jared Flowers (GA), Chris Swanson (FL)
Black Drum: Harry Rickabaugh (MD, Chair), Jeff Kipp (ASMFC), Tracey Bauer (ASMFC), Margaret Conroy (DE), Chris McDonough (SC), Dr. Hank Liao (VA), Trey Mace (MD), Linda Berry (NJ)

DRAFT PROCEEDINGS OF THE

ATLANTIC STATES MARINE FISHERIES COMMISSION

SCIAENIDS MANAGEMENT BOARD

Webinar
August 3, 2021

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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2. **Approval of Proceedings** of March 2021 by consent (Page 1).

3. **Move to approve the Atlantic Croaker FMP Review for the 2020 fishing year, state compliance reports, and *de minimis* status requests for New Jersey, Delaware, South Carolina and Georgia** (Page 14). Motion by Joe Cimino; second by Mel Bell. Motion approved by unanimous consent (Page 14).

4. **Move to approve the Red Drum FMP Review for the 2020 fishing year, state compliance reports, and *de minimis* status for New Jersey and Delaware** (Page 14). Motion by Joe Cimino; second by Mel Bell. Motion approved by consent (Page 14).

5. **Move to approve the Atlantic Croaker State Implementation Plan from Florida (**Page 15). Motion by Pat Geer; second by Spud Woodward. Motion approved by consent (Page 15).

6. **Move to nominate Chris Batsavage as Vice-chair of the Sciaenids Management Board** (Page 17). Motion by John Clark; second by Pat Geer. Motion carried (Page 17).

7. **Motion to adjourn** by consent (Page 17).

ATTENDANCE

Board Members

Joe Cimino, NJ (AA)
Tom Fote, NJ (GA)
Adam Nowalsky, NJ, proxy for Asm. Houghtaling (LA)
John Clark, DE, proxy for D. Saveikis (AA)
Roy Miller, DE (GA)
Lynn Fegley, MD, proxy for B. Anderson (AA) Chair
Russell Dize, MD (GA)
David Sikorski, MD, proxy for Del. Stein (LA)
Pat Geer, VA, proxy for S. Bowman (AA)
Chris Batsavage, NC, proxy for K. Rawls (AA)
Jerry Mannen, NC (GA)
Mel Bell, SC, proxy for Phil Maier (AA)
Malcolm Rhodes, SC (GA)
Doug Haymans, GA (AA)
Spud Woodward, GA (GA)
Erika Burgess, FL, proxy for J. McCawley (AA)
Marty Gary, PRFC
Jack McGovern, NMFS

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

Ex-Officio Members

Dawn Franco, Atl. Croaker Technical Committee Chair
Harry Rickabaugh, Black Drum & Spot Technical Committee Chair

Staff

Robert Beal
Toni Kerns
Tina Berger
Lisa Carty
Pat Campfield
Kristen Anstead
Emilie Franke
Lisa Havel
Chris Jacobs
Jeff Kipp
Savannah Lewis
Kirby Rootes-Murdy
Sarah Murray
Mike Rinaldi
Caitlin Starks
Deke Tompkins

Guests

Mike Armstrong, MA DMF
Pat Augustine, Coram, NY
Rob Bourdon, MD DNR
Dick Brame
Mike Celestino, NJ DEP
Derek Cox, FL SWC
Jessica Daher, NJ DEP
Jennifer Farmer, VMRC
Anthony Friedrich, SGA
Alexa Galvan, VMRC
Matt Gates, CT DEEP
Lewis Gillingham, VMRC
Helen Heumacher, USFWS
Harry Hornick, MD DNR
Raymond Kane, MA (GA)
Adam Kenyon, VMRC
Kathy Knowlton, GA DNR
Wilson Laney
Mike Luisi, MD DNR
Loren Lustig, PA (GA)
Chip Lynch, NOAA
Shanna Madsen, VMRC
Chris McDonough, SC DNR
Allison Murphy, NOAA
Kennedy Neill
George O'Donnell, MD DNR
Gerry O'Neill, Cape Seafoods
Morgan Paris, SC DENR
Will Poston, SGA
Olivia Siegal, VMRC
Ethan Simpson, VMRC
David Stormer, DE DFW
Mike Waine, ASA
Craig Weedon, MD DNR
Angel Willey, MD DNR
Chris Wright, NOAA
Renee Zobel, NJ FGD

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

The Sciaenid Management Board of the Atlantic States Marine Fisheries Commission convened via webinar; Tuesday, August 3, 2021, and was called to order at 3:15 p.m. by Chair Lynn Fegley.

CALL TO ORDER

CHAIR LYNN FEGLEY: Good afternoon everyone. Welcome to the Sciaenid Board. My name is Lynn Fegley; I represent the state of Maryland, and am honored to serve as your Chair today.

APPROVAL OF AGENDA

CHAIR FEGLEY: I think we have a pretty straightforward agenda. By the first order of business, I'll ask if anybody has any requests for changes to the agenda, or is there any opposition to the agenda? If anybody wants a change, or has a problem with it, please raise your hand.

MS. TONI KERNS: I Have no hands, Lynn.

CHAIR FEGLEY: Fantastic. I will say that we're going to make a really minor adjustment. I guess I should have said this first. There is an action item listed for Item 5, which is a black drum TLA and stock assessment. We actually do not need action there. That is really just going to be an update for the Board.

We do have the single action item having to do with the croaker and red drum FMP Review, so that is going to be the extent of our action items today.

APPROVAL OF PROCEEDINGS

CHAIR FEGLEY: The next order of business would be approval of the proceedings that are in the meeting materials. These are the proceedings from the spring meeting, March of 2021. Does anybody have any changes to be made, or issues with the proceedings? If you do, please raise your hand.

MS. KERNS: I have no hands.

CHAIR FEGLEY: Great, fantastic.

PUBLIC COMMENT

CHAIR FEGLEY: All right, we'll move right along to Number 3, which is Public Comment. Is there anybody from the public who would like to address the Board about something that is not currently on the agenda, please raise your hand?

MS. KERNS: I don't see any hands.

CHAIR FEGLEY: Okay.

REVIEW TRAFFIC LIGHT ANALYSIS FOR SPOT AND ATLANTIC CROAKER

CHAIR FEGLEY: So the first meaty item we have here is to Review the Traffic Light Analysis for Spot and Atlantic Croaker. This is going to be the update TLA for the 2020 fishing year. We're going to get some recommendations along with this, because of some missing data issues due to COVID, and due to some survey calibrations. Looking forward to a good presentation, and I will hand it off to Dawn Franco and Harry Rickabaugh.

MR. HARRY RICKABAUGH: Thank you, Madam Chair, this is Harry Rickabaugh. I'm going to go ahead and get started. I believe, Maya, you're going to switch the slides for me. I'm going to go over the first two parts of this for the impacts of the data from the COVID-19 pandemic. We have quite a few, and then I will go over the 2021 Traffic Light Analysis for spot. Then I'll turn it over to Dawn, and she will go over the 2021 TLA for Atlantic croaker.

Okay, so the first one here actually is not so much COVID related, as the ChesMMAP Survey had a gear and vessel change in 2019. They did do some side-by-side comparison tows with the new and old vessel and gear, but the calibrations have not been completed as of yet, to be able to basically convert the old data into the new unit, so that we can compare the old and new vessels.

We do not currently have a 2019 or 2020 ChesMMAP Index. The survey did conduct sampling in 2020, so we will have that data eventually. But for this year we are missing both of those, which that survey is used in the adult index for both spot and croaker, and the juvenile index for spot as well, so we're going to be missing those.

Again, they should have the calibrations done by the spring of 2022, so hopefully we'll have the 2019, 2020, and 2021 for you next year. Several other surveys did have issues directly related to the pandemic. The Northeast Fisheries Science Center Survey multispecies bottom trawl and the SEAMAP bottom trawl, neither of those were conducted at all in 2020.

We're completely missing those values. The SEAMAP survey is used both in the croaker and spot adult index, as well as in informing the shrimp trawl discard information. We have to mention that we also produce a supplementary information. We'll get to that later on, but we don't have those values, and also the Northeast Fisheries Science Center trawl is also used in adult index for both croaker and spot in the Mid-Atlantic region.

A couple of their state surveys were also affected. The North Carolina Program 195, which is a trawl survey, is used in the spot adult and juvenile indices, and the croaker juvenile indices. It did survey in 2020, but it was limited. They did not do any overnight trips, and only from stations that were relatively close to a port. They sampled 28 of their 54 usual samples.

The VIM survey also did some sampling in 2020 that is used as a croaker juvenile index. Only sampled in June however, and not all areas were sampled. That whole time series has been recalibrated by VIMS, to only include that time and those sites that were sampled the entire time series, to give us something to look at for this year, as something maybe we'll look at doing differently, or ask them to do differently in the future.

But that's all we have available to us for now that came available last minute, so that is what we had to work with. We appreciate them getting us something. I also via MRIP data, it is affected through the lack of some APAIS sampling within states. The effect was different state to state, as many of you probably know.

MRIP still estimated values for all states, but they used some computed data from the previous two years. That varies from state to state by species, but that is just to let you know that even though estimates are available, they aren't completely relying on 2020 data. Similarly, commercial data is available, but there could be some impacts to the pandemic through reduced demand for certain species. That is something we can't really quantify, as it varies by species by species and area by area. But likely there could have been some reduced effort due to reduced market demand.

Next year the TC will evaluate a lot of the missing data points, when hopefully we have 2021 and 2019 data on either side of the missing, the gaps basically to try to determine how we're going to fill those. For both of these traffic light analyses, both TCs decided the best course of action was not to report on any of the triggering indices, like the composite indices, where we combine two together.

If one was missing, we didn't present that, because of composite index. We're listing that as unknown for now, and hopefully we can fill that in and better update you next year. Just as a reminder, management action was tripped in 2020, and put in place in 2021 for both species. For spot, I'm going to move into the spot TLA now.

For spot the measures cannot be relaxed until 2023. Essentially, these TLAs we're looking at an update for the Board, and the only real thing that could happen would be a trigger at the next higher level, the 60 percent level, since both species did trigger at the lower 30 percent level. For spot, this is the harvest composite, so this includes both recreational and commercial harvest, split out by the Mid-Atlantic and South-Atlantic Region.

The top figure being the Mid-Atlantic, as you can see in 2020, it was below the 30 percent threshold. For spot the triggering mechanism is two of the previous three years, so since both 2018 and 2019 were above the 30 percent threshold, spot still would have been triggered in the Mid-Atlantic Region in 2020.

In the South Atlantic you can see that the proportion of red has been somewhat higher and consistently high through about the last five years was 54 percent red in 2020. Again, that would have equaled a tripped index, as it is all three of the final three years. Just as a reminder, since we did trigger management action in 2020, and we put it in place in 2021.

The harvest composite will not be able to trigger management action, or indicate that management action is no longer required moving forward. The regulations we put in place should reduce harvest, meaning it will increase the amount of red, so it's kind of a negative feedback loop, if you will.

The more we ratchet down landings through regulation, we're going to artificially, in theory at least, increase the amount of red. Of course, the regulations we put in place weren't large reductions, so it is possible that we could see steady or even declining red if we have improvement and recruitment, and/or survivability of either species.

For the adult abundance composite, the Mid-Atlantic uses the Northeast Fisheries Science Survey and the ChesMMAP survey, and as I mentioned in the beginning, we do not have the ChesMMAP survey for both 2019 and 2020, so we're considering that status unknown for this year, because we only have one of the terminal three years. As you can see, the last eight years we do have available were above the 30 percent threshold, which is why we're currently triggered, but until we get that ChesMMAP data, and can backfill the 2020 value that we're missing from the Northeast Fisheries Science survey, we're not going to know whether that has improved or moved, find out whether it's increased.

In the South Atlantic however, the past more than 10 years have been below the 30 percent threshold from the adult composite index, which is the SEAMAP survey and the North Carolina Program 195 trawl survey. You actually see some increasing green towards the end of the time series. Again, we're missing 2020, but in this case, it was two of the terminal three years were below the 30 percent threshold. This one would not have tripped.

This is supplementary information, as I alluded to earlier in the presentation, and it's the shrimp trawl discard estimates. The graph on the left is the upper, which declined pretty steadily into the early 2000s, and has been somewhat variable at a lower level since. The right figure is the actual estimates in millions of fish discarded.

As I mentioned, SEAMAP was not available, but the estimate is informed by both SEAMAP and the observer coverage. Both of those are used for the actual catch portion of the estimate. We did have observer coverage data. However, there was no coverage from April through July, due to the pandemic.

Even though the coverage is available, it's not full year coverage as in previous years. Looking at, the TC did look at the comparison of just SEAMAP, I'm sorry, the abundance estimates with and without SEAMAP, so just the observer coverage, or the observer coverage and SEAMAP. They tracked fairly well.

There are one or two years where they don't trend together, but there are several years where if they are trending in the same direction, one would be significantly higher or lower than the other, such as the 2019 you'll see on the graph is a pretty high estimate, and that was driven more by SEAMAP than the observer coverage.

We use the SEAMAP, it was originally used in the estimate to look at hindcast back beyond when observer coverage was available, so that's how we're getting estimates back to 1990. This is the juvenile indices for spot. These are not composites, they are individual indexes for each region. The Mid-Atlantic uses the MD Seine Survey, which was not affected by the pandemic.

It was conducted as it usually would be. As you can see, the values have been very low, we have high proportions of red for approximately 10 years, and then in 2020 we did have a value that was above the reference period mean. In the South Atlantic, there you see more variability. Again, the North Carolina index was available, even though it was limited sampling, it was just over 50 percent of samples were conducted.

It did show a higher level of red, but there have been some more above the mean indices for the South Atlantic Region in the juvenile index in recent years. This is a summary table, so it just summarizes the metrics that do trigger management action by region. The lightly blue shaded area is the actual metric. Then on the right we have the three years that would be used to trigger management action, and what the outlook was for each of those years. But again, for the Mid-Atlantic harvest, we had two of the three years in red, above the 30 percent threshold in red, excuse me, with the 2020 value being just below that. The South Atlantic we're looking at 52 to 59 percent red for all three years.

Now we'll move down to the adult abundance index. Again, we're considering the Mid-Atlantic unknown, because two of the previous three years we do not have a value for. The South Atlantic adult index we do not have the 2020 year, but we do have two of the previous three. Those years were below 30 percent red, and actually had more green than red in each of those years.

For the overall status, we're considering it could be triggered at the 30 percent level, even though we are missing some of that data. We can't definitively say that we are triggered, but since we're already in the trigger, we triggered previously in the previous year, we can't change major action anyway.

In reality, we have to remain status quo, and fortunately we don't have any of these values for the 60 percent red that are available. We are looking at the increased level of action anytime soon. With that I will take any questions on either the spot TLA or the missing 2020 datapoints.

CHAIR FEGLEY: Great, thank you, Harry, that was an excellent presentation, very much appreciate the thought that you guys put into this issue of missing data. Are there any questions for Harry?

MS. KERNS: Looks like he's stumped the Board, Lynn. I don't see any hands.

CHAIR FEGLEY: Wow, good job, Harry. Okay, well seeing no questions, let's go ahead and move on to Dawn, I think you're up.

TECHNICAL COMMITTEE RECOMMENDATIONS

MS. DAWN FRANCO: All right, thank you so much. As previous years, it's going to be very similar for what I talk about for croaker as what Harry talked about for spot. Harry, thanks for setting me up so nicely. For Atlantic croaker, just like Harry said, management action was tripped in 2020, and then management actions were put into place early 2021, and those will be continued until 2023.

Then these are the harvest composites for the Mid-Atlantic and South Atlantic Regions, and again these are recreational and commercial landings combined for these two. In the Mid-Atlantic we have exceeded 30 percent for the seventh year in a row, with the past three years triggering at above 60 percent, so 2017 is a little tricky, because it looks like it is 60 percent, but it's actually 59.2 percent.

Officially, only 2018 and 2020 are above 60 percent. Then the South Atlantic, we have exceeded 30 percent for the eighth year in a row, indicating continued concern for these graphics. Then we have our adult abundance composite indices, and as stated earlier, we do have several data gaps, so for the Mid-Atlantic we do not have data points for 2019 and 2020 because of ChesMMAP calibration. Then also, no data points for any NEFSC trawl for 2020. It just made more sense to leave it at 2018, rather than have a bunch of unknowns in there. The 2018 datapoint for the Mid-Atlantic is actually 58.5, so we did not officially meet or exceed 60 percent in the past three out of the four years, because remember this is different than spot that we have three out of the four previous years, rather than two out of the three.

Also, you might notice the South Atlantic abundance graphic is a little bit different than what was in the report. We had included 2020, but we decided to cap it at 2019, because we were missing the SEAMAP data that was only data from the South Carolina trammel net survey. In this graphic, we only went through 2019.

But we haven't exceeded even 30 percent, it's been mostly green for the South Atlantic adult abundance since 2010. I believe that covers everything for that one. The adult abundance and harvest are about the same as what we saw last year, triggering at about 30 percent for the last three out of the four years.

Then again, this should look very similar, especially on the left for net hours fished. For the shrimp trawl fishery that is exactly the same as you saw for spot, slightly different for the discards in millions of fish. It's a little bit different, but follows the same trend just like Harry was saying. We looked at it split out for CPUE for observer data versus SEAMAP data, and it trends well, but there was a higher estimate of CPUE for SEAMAP in 2019, which we think is influencing that 2019 data point.

Then 2020 is only the observer data, we do not have SEAMAP data to fill in that gap just yet. This is also another supplemental piece of information. The juvenile indices fell again in the Mid-Atlantic, only through 2018, because we do not have the ChesMMAP data, but hopefully next year we can update everyone with those gaps filled in, but as you can see, we have a fair amount of red still in the Mid-Atlantic region for the juvenile abundance composite.

The lines are not filled in for us, so we are still below 0.6, except for 2018, or below 60 percent. Then similar to spot we have more green than red in the South Atlantic juvenile composite, which really technically isn't a composite for the South Atlantic, because it's only the North Carolina 195 survey.

Then we come to our final slide that breaks all of the info that I just shared down into a neat little package, to demonstrate if we have exceeded, trips our trigger. The Mid-Atlantic composite harvest triggered at 60 percent, with the South Atlantic remaining at a 30 percent level. That was for the harvest composite, where we have all data available.

Then we have several unknown values for the adult abundance index, and even if we assume the worst-case scenario of unknowns being above the 50 percent, that would not be enough to trigger further management action, because we would not have three out of the four years above 60 percent.

Therefore, final status is Atlantic croaker remains triggered at the 30 percent level. Then by the next TLA, we should have ChesMMAP calibrations to refill in the data holes from 2019 and 2020, and hopefully mechanisms to fill in the other 2020 data gap. The TC recommended maintaining the course, and no further management action is suggested at this time. I will take any questions that you might have.

CHAIR FEGLEY: Thank you, Dawn, excellent presentation. I just want to say for the record that the number of those shrimp trawl discards still boggles my mind. But I think we're good. I think we dodged a little bit of a bullet here, because everything is remaining in line with where we've been. Since we've all implemented management actions for 2021, we'll be able to hold until next year and see what we get when we analyze the 2021 update. With that, are there any questions for Dawn, or any throwback to Harry. Please raise your hand if you have a question.

MS. KERNS: Pat Geer.

CHAIR FEGLEY: Go ahead, Pat.

MR. PAT GEER: I guess this question is for Dawn. I'm just kind of wondering. I'm looking at Figure 7 that is showing the discards of croaker in the Southeast Atlantic in the shrimp fishery, but the decline that we're seeing there, part of that has to do with the implementation of the requirement of bycatch reduction devices, which occurred in the late '90s.

I'm wondering if that dataset should be truncated to that point, because the introduction of the bycatch reduction devices obviously has had an impact on bycatch, so those large numbers that you see in the early '90s, are probably not representative of the fishery at all today.

CHAIR FEGLEY: Savannah, could you go back to that slide so we could see what Pat is referring to, or Dawn, whoever is controlling the screen.

MS. SAVANNAH LEWIS: I think it's Maya. I think Maya is controlling the slide.

CHAIR FEGLEY: Sorry, hi Maya.

MS. FRANCO: He needs Slide 14.

MR. GEER: Figure 7 is what it was in the document. There you are, right there.

MS. FRANCO: Yes, I think that's a great point for us to bring back to the TC and discuss, because that is absolutely what is causing the major decline, very high discards in the early '90s. Yes, I think it's a great point, Pat. I think we should definitely discuss, and I don't know if the shorter timeline would be an issue for some people. I'm not entirely sure, but definitely a good point.

MR. GEER: The behavior and how the fishery is propagated after that, you know requiring a total excluder device, and requiring the bycatch reduction devices, all flow with bycatch, you know substantially. I would think that any data that we use should be doing post bycatch reduction device.

MS. FRANCO: I will definitely make a note of that, thank you.

CHAIR FEGLEY: Okay, thanks Pat, and thanks Dawn. Any other questions?

MS. KERNS: I don't have any other hands, Lynn.

TECHNICAL COMMITTEE RECOMMENDATIONS FOR A TRAFFIC LIGHT ANALYSIS AND BENCHMARK STOCK ASSESSMENT FOR BLACK DRUM

CHAIR FEGLEY: All right, well thank you very much for the presentation, and the next item on our agenda, we're going to move over to black drum, and talk about the TC recommendations for a traffic light analysis and a benchmark stock assessment. We talked a little bit about this the last Board meeting, and I believe that Harry has got some updates for us, so Harry, take it away when you're ready.

MR. RICKABAUGH: Just before I move on to this, I just would like to thank Chris McDonough from South Carolina for the traffic light analysis. He did pretty much all the analysis for both spot and croaker. This year was particularly challenging with all the data gaps, and having to bounce back and forth for TC recommendations.

I forgot to mention that before I started that presentation. I didn't want to leave him out, he did most of the work. On the black drum, I'm going to give a little bit of background on the previous assessment. The TCs previous conversations about assessment timing, and then I will go on to just a brief overview of the TCs discussions, deciding between a benchmark assessment and a traffic light analysis, and then the recommendations the TC came out of from that discussion.

The first, well it was the first stock assessment for black drum, was conducted in 2014, but data through 2012. We looked at a few different data poor modeling structures, and the preferred model by both the Stock Assessment Subcommittee and the Peer Review Team was the depletion-based stock reduction analysis.

It did provide reference points, which were accepted by the Board for management use, was early 2015. Now those reference points obviously were derived using the previous telephone-based estimate surveys from MRIP, so we cannot currently compare our reference points to evaluate stock status to the current plan.

That was one of the major, I guess drawbacks, shortly after we finished that assessment, was that change, and then we weren't able to evaluate the stock again to those reference points. The TC met in 2019, to review data and decide on the timing of the next assessment, which was originally scheduled for 2020 for the year prior to the previous scheduled assessment.

At that point the TC recommended delaying the assessment to 2022, to allow for a longer time series in a couple of the surveys, and to also allow for some aging of archived age structures. The TC also recommended that the next assessment be a benchmark and not an update. That was one of the other things we debated quite a while back then, and decided that it would be best to try to improve on the model structure.

The peer review of the previous assessment did recommend trying to incorporate an index into either the DB-SRA or one of the other model options we tried, to see if we could get something a little better, a little more informative of the stock status. Then of course, the PRT met, as you well know, before the last Board meeting, and recommended to the Board that we look at the traffic light analysis to monitor the stock status in between, until we do another assessment. Partially probably based on the fact that we did not decide to do the previous assessment on time, and that we delayed it, and also because it's been quite a while since we've had some method to actually look at where the stock is.

The TC did meet earlier this year, April of this year, to evaluate the available data again, and discuss the use of a TLA or an assessment. Both the Stock Assessment Team from ASMFC and the TC were in agreement that trying to do both at the same time was not going to be probably a successful endeavor.

They are both very time involved, and trying to develop a TLA from scratch is probably a little more involved than most people would realize, and doesn't necessarily use some of the same techniques, or you wouldn't want to use the indices in the same way. It's not really just adding on, it's a whole different project.

We decided we needed to do one or the other, and so we looked at which we thought would be better for evaluating the stock in the near term. The TC met, and we discussed the pros and cons in pretty much a good bit of detail, actually. I'm just going to summarize up for you really quick, I'm not going to go into a whole lot of detail.

This particular Board, of course, is familiar with TLA, since we've been using it for spot and croaker, so I'm not going to give a lot of background on that either. For a stock assessment, our current schedule is a five-year cycle, which means basically it will only be updated every five years, unless we have a reason to run an update early, due to stock status, or to get delayed again it wouldn't be done on a five-year schedule, where a TLA is generally updated annually.

A stock assessment does provide a very technical report with tables and figures that are peer reviewed, and a peer review report as well, giving recommendations for how the stock assessment could be improved in the future in its strengths and weaknesses. Where a TLA is usually developed outside of a peer review, there is a little less technical document, which could be a plus or a minus.

It is easier for a less technical audience to interpret the final product than a stock assessment may be. A stock assessment does produce reference points that are calculated within the assessment, and then those reference points can be used to calculate a response, if needed, for management. In other words, if we would cross the threshold and decide we need to reduce by a certain amount.

We could at least use our reference points to have a good gauge on how much we would need to reduce to get that. Where with a traffic light, threshold is generally assigned through, it's a lot more subjective. There is not like really a mathematical way to determine exactly at what percentage red you would need and then for how many years.

There is a little more professional judgment in there, and to determine at what level you're going to trigger how many years you need to be there, and because of that, that makes the management response not be able to be calculated from the traffic light itself. It would have to be done outside, which means there is a little bit of a disconnect there from the level triggered to then, you would have to use some other data, or if you did have a stock assessment reference point to use, you would use that. With the stock assessment, we could also update that if we had, say a management put into place, and we wanted to see whether we were moving in the right direction. You could run the update and see where you're at.

Where with a traffic light, generally it's almost the opposite, particularly if you're relying heavily on fishery dependent data, such as landings. Once you trigger management action, as I had mentioned in the croaker and spot, that you really can't then use those data to see if you are making progress, because of the negative feedback.

The more you cut back landings, the higher those fishery dependent indices and/or values will be in the red, as opposed to showing you an improvement. Also again, if you trigger management action, it could reduce which metric you could use, and as I'll touch on later, the TC thought that we probably would be heavily reliant with this particular species, on fishery dependent data.

For the stock assessment, the peer review of the last assessment, and the TC, both agreed that probably having some sort of guardrail metric, which I think in the assessment they call it roster of metrics, but the same sort of idea, where aside from just a reference point that we can identify some, either indices or other metrics that look like they may not be something we can incorporate into the assessment itself, but may be giving us beneficial information such as juvenile indices, or even some adult indices.

We can track those as well. In other words, if we were between, say the target and the threshold, we could look at these metrics, and see if they were trending up or down as well, and see how concerned we should be. This would be kind of a way to have something to evaluate annually, similar to a traffic light, as opposed to just waiting five years to run the assessment again.

Some of the discussion the TC had on the data and on the comparison of a traffic light to a stock assessment were, first the data issue with the MRIP. As mentioned before, the previous assessment did not use the current MRIP estimates, because they weren't available, obviously. Comparing the two, the newer estimates do tend to be higher, particularly in the most recent years, which likely is just going to move the values of the stock assessment up.

Everything will probably just higher abundances and reference points is probably what the bottom line would be there. The proportion of released alive fish has increased, which isn't surprising. It's likely attributed to the minimum size limit that was required by the FMP when it went into place.

There has been a recent increase in recreational trips targeting black drum, according to the MRIP estimates, which is likely due to effort shifting from other species, such as weakfish remain depleted, increased size limits and truncation of the season for summer flounder and a few other species. Then the TC all agree, one of the big points though, is we felt we did need to update these reference points, since we cannot currently evaluate the reference points from a previous assessment. We felt that was highly needed. We still are probably going to be in a data poor structure, the data we looked at, we probably don't have enough to advance the model beyond that. We probably can make improvements within that data poor modeling framework, to make a more solid stock status to provide to the Board. Setting reference periods for the TLA would be somewhat difficult.

A lot of the independent indices we have aren't very long time series, which is a very long-lived species. Ideally you would have one generation time or at least close to it. That would be tough to do, we basically are using an entire time series as our reference period. Evaluation of the data didn't really reveal a really good coastwide, long term, independent index, which is another thing that is going to hinder us moving from a data poor assessment.

I would also, as I mentioned earlier, necessitate us relying heavily on removals for TLA, which isn't ideal, considering once you trigger then that kind of limits your ability to use the TLA to see where you're at. The take home message from the TC, our recommendation would be to go ahead and conduct the next benchmark stock assessment as scheduled in 2022.

As already touched upon earlier, we will provide updated reference points. It is going to probably remain a data poor approach, but we may be able to improve on our current DB-SRA model, and we will attempt to identify or if possible, guardrail metrics, which could help monitor the stock along with the reference points on an annual basis, rather than wait five years for the next assessment. With that I'll take any questions.

CHAIR FEGLEY: All right, thank you, Harry. Just a quick question for you. You said that you would begin working on this assessment in 2022, and is it scheduled for completion in 2022 as well, or would we see the results in 2023?

MR. RICKABAUGH: I believe it's scheduled for completion in 2022. I would have to defer to ASMFC staff to be certain what they would think would be possible with that.

MR. JEFF KIPP: Hi, this is Jeff, I could jump in.

CHAIR FEGLEY: Thanks, Jeff.

MR. KIPP: Yes, so it would be scheduled for 2022, so we would anticipate the assessment at least by the Technical Committee being completed in 2022. There have been some occurrences where a peer review might happen, like the following January. Not completely clear on timing yet when that peer review would occur. But the assessment would be completed by the TC and out to peer review by 2022.

CHIAR FEGLEY: Excellent, thank you for that. I just want to say, I think this approach makes sense. I think getting that updated MRIP data into a benchmark is critical, and if we're in a place where we can get reference points for this fishery, I just think that's such a more powerful and effective management tool than the traffic light. I appreciate your deliberations on this. Are there any questions from the Board?

MS. KERNS: Just giving a second to see if any hands went up, but I currently do not have any hands raised, Lynn. Harry is really good at stumping today.

CHAIR FEGLEY: It's been a long day, and I think good job on behalf of our presenters making it all so clear.

CONSIDER ATLANTIC CROAKER AND RED DRUM FMP REVIEW AND STATE COMPLIANCE FOR THE 2020 FISHING YEAR

CHAIR FEGLEY: Okay, well, seeing no questions we will then move right along to Agenda Item Number 6, where we Consider Atlantic Croaker and Red Drum FMP Review and State Compliance for the 2020 Fishing Year. Just a reminder to everyone. I will be looking for some motions at the end of these presentations and discussion. Savannah, I think it's off to you.

MS. LEWIS: Hi everybody, good afternoon. Thank you, Madam Chair for the opportunity to present this today. I'll keep this pretty brief, but I'm going to be presenting the Red Drum and Atlantic Croaker Fishery Management Plan Review. I'm going to start with red drum. For red drum the PRT did meet, and we did overhaul some of the sections of this review this year to include, regional breakdowns of the different metrics.

In 2020, 56 percent of the total landings came from the southern region, where the fishery is exclusively recreational. Here on this graph the southern region is represented in the blue bars, and the northern region in the green bars. These shifts are a significant change from the 2019 regional split, where 20 percent of total landings of recreational landings were from the northern region, and 80 percent from the southern.

Recreational landings were estimated to be 2.5 million pounds in the northern region, a 173 percent increase from the 2019 estimates. North Carolina is estimated to have the most recreational landings, followed by Virginia. Recreational landings were estimated to be 3.3 million pounds in the southern region, which is a slight decrease from 2019 estimates.

Florida is estimated to have the most pounds of recreational landings, followed by South Carolina. These two figures show recreational removals by region, with northern removals on top, and southern removals on the bottom. You can see the different colored bars represent the number of fish landed, as well as estimated dead discards.

The number of fish caught in the recreational fishery was just over 670,000 fish, which is up 120 percent from 2019 for the northern region. It is estimated that 8 percent of released fish die as a result of being caught, which gives us an estimated value for dead discarded fish of about 290,000 in 2020.

Recreational removals from the northern region fishery are estimated to be about 962,000 fish in 2020. The number of fish caught in the southern region recreational fishery was about 1 million fish, again a decrease from 2019. It is estimated that 8 percent of released fish die, and as a result there is an estimated 420,000 dead discarded fish in 2020.
Recreational removals from the southern region of the fishery are estimated to be about 1.4 million fish in 2020. This graph shows the removals compared to their releases. What you can see here is northern and southern regions, and I apologize for the color, I couldn't get them to match, but the bar graph on the bottom is representative of what we just saw, with total removals as the bars from the northern region in blue bars and the southern region in green bars. The releases for each region are the line graphs. Releases for the northern region are green, and southern region are blue. You can see that the number of releases far exceeds the total removals from each region. The number of fish released in the northern region was 3.6 million fish, which compared to the removals was 962,000 fish.

The number of fish released declined to those in 2019 for the southern region, with 5.3 million fish released, and compared to total removals of 1.5 million fish. There is a correction in the report. On Figure 4, the proportion of regional sector-specific landings to total coastwide landings, the green for the northern region represents recreational, not commercial fisheries, and that has been updated since.

The PRT met and reviewed all state compliance reports, and compiled the FMP Review. The PRT found no inconsistencies from the FMP for any of the states. The TC recommends the approval of state compliance reports and *de minimis* status for New Jersey and Delaware. New Jersey and Delaware requested *de minimis* status through the annual reporting process.

While Amendment 2 does not include a specific method to determine whether a state qualifies for *de minimis*, the PRT chose to evaluate an individual state's contribution to the fishery by comparing the two-year average of total landings of that state to that of the management unit. New Jersey and Delaware each fit this *de minimis* criteria.

De minimis doesn't exempt either state from any requirement, but may exempt them in the future for management issues, implemented through addenda to Amendment 2. The PRT also met and revised the research recommendation section for red drum. They picked four key goals that they thought the Board should be informed of in research needs.

One such is the continued collection of length composition and age data, if possible, to better inform recreational discards for red drum. Collecting critical adult red drum data, including continued sampling and expansion of adult red drum surveys, as well as additional data on abundance, size, age, sex composition, and maturity of adults, as well as senescence in female red drum, and the impacts of the catch and release fishery on adult red drum stocks.

They also want to highlight the effects of the environmental factors on stock density and year class strength, and encourage the support and continued research to evaluate the social and economic value of this very important, and primarily recreational fishery. With that I'm going to move into the Atlantic Croaker Fishery Management Plan Review.

This graph here shows total commercial and recreational landings. Total Atlantic croaker harvest from New Jersey through the east coast of Florida in 2020 is estimated at 5 million pounds, which is a 30 percent increase from 2019. The commercial and recreational fisheries harvested 16 percent and 83 percent respectively.

This total represents a large shift from the previous ten-year average split, where traditionally commercial has previously been 52 percent and recreational 47 percent. In 2020, landings are estimated to be about 10.6 million fish or 4.1 million pounds, which is a 91 percent increase in the number of fish, and 121 percent increase in fish weight. Virginia was responsible for the majority of 2020 recreational landings in numbers of fish, followed by Florida. It is important to note that due to the COVID-19 pandemic, some MRIP data was imputed to fill in missing data, and the percent of imputed data ranged from 0 percent up to 70 percent, depending on the state. In 2020, anglers released 31.7 million fish, which you can see here on the black line.

Landings and live releases are indicated in the blue and red bars. Anglers released an estimated 75 percent of their recreational Atlantic croaker catch, which is slightly down from the highest ever recorded in the time series in 2019. The PRT met and found no inconsistencies among states, with regard to the FMP requirements.

The TC recommends approval of state compliance reports and *de minimis* status. New Jersey, Delaware, South Carolina, and Georgia applied for *de minimis* status for their commercial fishery. New Jersey and Delaware applied for *de minimis* status for their recreational fisheries. Just a reminder that *de minimis* for Atlantic croaker is by fishery and not combined.

There are additional research and monitoring recommendations found in the FMP review document. The PRT really wanted to highlight to the Board that continued and new research into the impacts of climate change on the range of the species is a high priority. For Atlantic croaker, Florida realized in their *de minimis* review process that they no longer qualified for *de minimis* as they historically have been for commercial Atlantic croaker.

Seeing this, they went ahead and submitted a state implementation plan to be in compliance with Addendum III. A copy of the implementation plan was included in supplementary materials. The TC did meet to review it, and found it to be technically sound, and recommended it for approval. Their proposal was for a commercial vessel limit of 1,200 pounds in state waters, which is projected to reduce 10-year average by 1.6 percent. With that I'm happy to take any questions.

CHAIR FEGLEY: Great, thank you, Savannah. It's good to give your voice a little rest. Are there any questions for Savannah on these items, before we move to action? Does anybody have a question?

MS. KERNS: I have Pat Geer followed by Marty Gary, and then Roy Miller.

MR. GEER: Savannah, I just was curious. I don't know if I missed it or not. Are there any studies that have recreational discard mortality rates for croaker?

MS. LEWIS: I'll have to double check the report. I believe they're in there. I don't know if I included it in the presentation, but I will double check for you, if you give me just a second.

CHAIR FEGLEY: Okay, and so I'll move on to Marty for questions, while Savannah is checking that out. Marty, go ahead.

MR MARTIN GARY: Savannah, hopefully these are softball questions for you. On red drum, I might have totally missed it, but the geographic demarcation for the northern and southern region. Is that the North Carolina/Virginia border? I was wondering where that is. That was my first question, and then a quick follow if I could. I don't know if it's a reach, based on what you're presenting today, but just curious about. It looks like the numbers on the landings for the northern region, if you fit a line to it, they've gone up quite a bit, and I was just wondering if that might be speculated to be a function of range expansion from climate change. You know, if the FMP Review doesn't really shed light on it that's fine. We can wait until the appropriate time with an assessment for that kind of question.

MS. KERNS: Lynn and Savannah, Adam Kenyon does have his hand up if you need to phone a friend for some help with these, Savannah.

MS. LEWIS: Thank you, Toni, I really appreciate that. Hopefully my voice will hold out. Again, I apologize, I've got a summer cold going on. Pat, I'll get to your question. We don't calculate discard rates within the report, but we do have discard rates from the Observer Program that you've seen in the shrimp trawl estimates. It is in the report, and they range from 7 to 8 percent annually, according to the 2010 assessment.

MR. GEER: Okay, thanks, Savannah. Hope you feel better.

MS. LEWIS: Thanks, if you have more questions, we can always chat later after, when I hopefully have a voice.

CHAIR FEGLEY: I was just going to say, if you wanted to go to Adam and give your voice a rest, but if you've got Marty's question covered, go for it.

MS. LEWIS: I do, and I believe I covered. You might have to remind me, if I remember. But the demarcation for the northern region versus the southern region is actually the Carolinas, North Carolina and South Carolina. Then what was your second question, Marty? I apologize.

MR. GARY: Yes, it was just, and maybe it's not the right time for this question, but has there been any discussion. Looking at those landings in the northern region, it looks like they have a pretty significant increase over time. I was just wondering; this is a species that there may be some range expansion going on with it related to climate change. Again, maybe that's a question for a different scenario.

MS. LEWIS: Yes, that's an excellent question, Marty. Currently we're working through the stock assessment, so that might provide some more information. We'll hear from Jeff next. But I definitely think it's an important thing to keep in mind as a consideration for more than just the red drum.

MR. GARY: Okay thank you, and thank you for a great presentation. I'm sorry to test your voice.

MS. LEWIS: That's all right, thanks, Marty.

CHAIR FEGLEY: Thanks for that, Savannah, moving on to Roy Miller.

MR. ROY W. MILLER: A quick question, Savannah, if I may, and perhaps Lynn would know it, if you don't off the top of your head. Under the *de minimis* definition for Atlantic croaker, New Jersey and Delaware, if approved, would be exempt from the 30 fish creel limit. Am I right in that? I guess the same question applies to spot while we're on the topic of *de minimis*.

MS. LEWIS: Hey Roy, I can answer that one. That is correct. Currently under Addendum III, when the TLA is triggered at 30 percent, states that have been granted *de minimis* are not required to implement the management measures. However, if the TLA does trip at 60 percent, then all states are required to implement measures, including *de minimis* states.

CHAIR FEGLEY: Yes, that is the difference, is that as long as we're at that moderate concern, the *de minimis* states don't move. But if we get into that 60 percent area, then yes, everybody is on the hook, no pun intended. Any more questions?

MS. KERNS: Chris Batsavage.

CHAIR FEGLEY: Go ahead, Chris.

MR. CHRIS BATSAVAGE: Thank you, Savannah for the presentation. I have a question on research recommendations for croaker. First to Marty's point, with the increased landings in the northern region in 2020. I think part of that might have been the result of the strong 2018-year class that worked its way into the slot limit in 2020.

However, with the trend over the last few years, with some stronger year classes, climate change might be playing a role in that. I guess you had the simulation model for the assessment, and the assessment after that may shed some light on that. Regarding research recommendations for croaker, has the Technical Committee talked about the possibility of natural mortality changing for croaker over time?

Thinking about, you know we've seen some good juvenile abundance indices for croaker over the last several years, but the adult indices are staying really low, and landings are at their lowest level. I didn't know if that was something that the TC has talked about in any meetings, or is that something that might be explored for the next stock assessment?

MS. LEWIS: Hey Chris that is a great question. It is something up to this point at least, since I have been with the Commission, that we have not discussed looking into. I think it's an important area of something that the TC should probably start thinking about as well. That's kind of one of the recommendations from the PRT, and why they wanted to look into climate impacts, perhaps on the range of the species, for why we're seeing some significant shift. It's something that I think we will be looking into in the future.

CHAIR FEGLEY: Yes, that was a good question, Chris, and just to follow up on that a little bit. When is the next crack at an assessment for spot and croaker, if you could remind the Board that would be great?

MS. LEWIS: Let me pull that up, because the date did change last year. Jeff and Kristen, if you know off the top of your heads, feel free to chime in.

MR. KIPP: Yes, Savannah, this is Jeff, I could chime in. It's 2024 for both spot and croaker.

CHAIR FEGLEY: Okay, that's excellent, thank you. Okay, any other questions?

MS. KERNS: I don't see any hands, Lynn.

CHAIR FEGLEY: Okay, all right, well thank you, Savannah for that. I think we need action on this, and I think what I would like to do is split this in two. Savannah, do you have a presentation on the implementation plan for Florida? Do you want to tackle the FMP Review compliance first, and then move on to Florida?

MS. LEWIS: Yes, let's do that first, and then we'll hop to Florida.

CHAIR FEGLEY: Okay, so I'll be looking for a motion if somebody has it, to approve the fishery management plan reviews for croaker and drum, and the state compliance, as well as the request for *de minimis*. If I've got a commissioner out there who would be willing to make that motion, it would be greatly appreciated.

MS. KERNS: I've got Joe Cimino.

CHAIR FEGLEY: All right, Joe Cimino, go ahead.

MR. JOE CIMINO: There is a double dipper in the *de minimis* world here. Let's see if I can do this. Well, we'll do it one species at a time, looks like. **Move to approve the Atlantic Croaker FMP review for the 2020 fishing year and state compliance reports, and *de minimis* status requests for New Jersey, Delaware, South Carolina and Georgia.**

CHAIR FEGLEY: All right, is there a second?

MS. KERNS: I have Mel Bell.

CHAIR FEGLEY: Excellent, thank you, Mel, for that. Okay, and I'll just ask really quick, does anybody want to discuss this motion? If you want to discuss this motion, raise your hand.

MS. KERNS: I have no hands.

CHAIR FEGLEY: All right, seeing none, I'm going to read it into the record. We're going to move to approve the Atlantic croaker FMP review for the 2020 fishing year, state compliance reports, and *de minimis* status request from New Jersey, Delaware, South Carolina and Georgia. Motion by Mr. Cimino, second by Mr. Bell. Is there any opposition to this motion? If you oppose, please raise your hand.

MS. KERNS: There are no hands, Lynn.

CHAIR FEGLEY: Excellent, so there we can cross croaker off the list. Let's move on to red drum. Joe, do you have a motion for that one as well?

MS. TINA L. BERGER: Hey Lynn, just a formality, you need to say that motion was approved.

CHAIR FEGLEY: Ah yes, thank you, Tina**. The motion on croaker to approve the compliance reports, FMP review, state compliance and *de minimis* request for croaker was approved by unanimous consent. Moving on, we have a motion that is the same for red drum, and who is our motion maker on this one?**

MS. KERNS: I've got Joe again.

CHAIR FEGLEY: Excellent, and do we have a second?

MS. KERNS: Mel Bell again.

CHAIR FEGLEY: Okay, and I'll just ask for the record if there is anybody who cares to discuss this. If you do, raise your hand.

MS. KERNS: I see no opposition.

CHAIR FEGLEY: Okay, so we are going to move to approve the Red Drum FMP Review for the 2020 fishing year, state compliance reports, and *de minimis* status for New Jersey and Delaware. Motion by Mr. Cimino, second by Mr. Bell. If there is any opposition, please raise your hand.

MS. KERNS: No opposition.

CHAIR FEGLEY: **Thanks, the motion is approved by consent.** With that, I think that leads us to move along to Florida has submitted an Implementation Plan for its commercial Atlantic croaker fishery, so we're going to hear a little bit about that, and then take action on that. Savannah, back to you.

CONSIDER STATE IMPLEMENTATION PLAN FROM FLORIDA FOR ITS COMMERCIAL ATLANTIC CROAKER FISHERY

MS. LEWIS: I'll just review. Florida has qualified for de minims historically for their commercial Atlantic croaker fishery. However, they no longer qualify for *de minimis*, and so trying to get ahead of it, they did submit a state implementation plan, so that they are in compliance with Addendum III, once that *de minimis* status falls off after 2021.

The Technical Committee did meet to review it, and found it to be technically sound, and recommended approval. It follows the same methodology as was done for their spot commercial fishery. They would like to do a commercial vessel limit of 1,200 pounds in state waters, and this is projected to reduce the 10-year average by 1.06 percent, so it meets the criteria. Today we just need to vote on whether to approve or disapprove the State Implementation Plan for Florida.

CHAIR FEGLEY: Thank you, Savannah, does anybody have any questions for Savannah, or for the Florida delegation about this plan?

MS. KERNS: Two questions, Pat Geer and Chris Batsavage.

MR. GEER: No, I was just going to make a motion. I can wait until Chris asks his question.

CHAIR FEGLEY: Excellent, Chris, do you have a question, or were you also going to make a motion?

MR. BATSAVAGE: I have a question, Madam Chair. I can't remember from the memo in the briefing material, but if this is approved, when does Florida expect to implement these management measures?

MS. LEWIS: I can answer that for you, or Erika has her hand up, I will let her speak for Florida.

CHAIR FEGLEY: Go ahead, Erika.

MS. ERIKA BURGESS: Savannah, thank you for presenting this today. Chris, our plan is to bring it forward to our Commission in October, and so it will go into effect, likely around December of 2021, so we'll have these rules take effect within the 2021 calendar year, and I'm happy to answer other questions that you may have.

CHAIR FEGLEY: Okay, thank you, Erika. Are there any other questions for Erika or for staff?

MS. KERNS: I have no other hands, Madam Chair.

CHAIR FEGLEY: Great, so Pat Geer, I believe that you are up.

MR. GEER: Move to approve the Atlantic croaker state implementation plan for Florida.

MS. KERNS: Second by Spud Woodward.

CHAIR FEGLEY: Thank you, Spud. Okay, so I'm going to read this into the record, and then just immediately call the question. This is a motion to approve the Atlantic croaker state implementation plan from Florida, motion by Mr. Geer, second by Mr. Woodward. Is there any opposition? If so, please raise your hand.

MS. KERNS: I have no hands raised in opposition.

CHAIR FEGLEY: **Excellent, so this is approved by unanimous consent, and I thank everyone for that.** I really thank you too, staff, for your excellent presentations and work, and getting us through these agenda items so efficiently.

UPDATE ON THE RED DRUM MODELING PROCESS AND THE 2022 SIMULATION STOCK ASSESSMENT

CHAIR FEGLEY: With that we'll move on to the next one, which is to get an Update on the Red Drum Modeling Process and the 2022 Simulation Stock Assessment from Jeff Kipp. I'm personally really looking forward to seeing the results of this project.

I think it's pretty creative and pretty exciting. Go ahead, Jeff.

MR. KIPP: Thank you, Madam Chair. Just as a reminder, the objective of this simulation assessment we're working on now, is to evaluate the performance of candidate assessment approaches, to guide future benchmark assessments of red drum, including the next benchmark assessment that is scheduled to start, following Board review of the simulation assessment and peer review. This subsequent benchmark assessment is scheduled to be finalized and peer reviewed through the SEDAR process in 2024.

Just to address Marty Gary's earlier question on potential range expansion of red drum. Those types of questions are more likely to be tackled during this subsequent benchmark assessment, when we'll be shifting focus from these simulated datasets that we're working with now, to the observed datasets that are collected through the monitoring programs, and grappling with standard terms of references, like stock structure, that come on in traditional stock assessments. I just thought I would throw that in there to address that question.

But since my last update to the Board at the meeting in March of this year, the Stock Assessment Subcommittee has continued meeting biweekly to review progress, and provide feedback, mostly on generating estimates from our three candidate assessment approaches we're evaluating here. Those are the statistical catch at age model that's been used in previous red drum assessments.

A stock synthesis integrated model that uses both length-structured in and age-structured data, and then also a traffic light analysis, which we've been discussing quite a bit here today. This work has been progressing well, and we're planning some initial review of performance of these three assessment methods during our next progress call, which is Wednesday, next week. We have also scheduled our last workshop of this process.

That was scheduled for October 4 through 7, and to be determined yet whether it will be in-person or virtual, like most of our other meetings, or all of our other meetings have been for this assessment process. But during that assessment workshop, we'll be working to wrap up most of the review of the performance results for each of these three assessment approaches, and to make some recommendations on assessment methods for red drum moving forward, to again guide some of these future benchmark assessments for red drum.

We anticipate having the simulation assessment peer reviewed in March of 2022, and presented to the Board at the spring meeting in May of 2022. I also just wanted to take this opportunity to thank Thom Teears, who was previously with North Carolina DMF. Tom was a Stock Assessment Subcommittee member that accepted a new position in New Caledonia.

But he was instrumental in getting the TLA or evaluating, developed before he moved on, which was a big endeavor, basically developing a TLA from scratch for red drum, which we hadn't done previously. That concludes my update, and I can take any questions on the simulation assessment.

CHAIR FEGLEY: Great, thank you, Jeff. Are there any questions from the Board?

MS. KERNS: I don't see any hands, Lynn.

MS. KERNS: I guess I should say that everybody's presentations have been so thorough that the Board has no questions, not that they've necessarily stumped them.

CHAIR FEGLEY: Well, yes, and thank you again, Jeff, and to everyone for the C for crystal clear presentations.

ELECT VICE-CHAIR

CHAIR FEGLEY: I think though, before we adjourn, we have one other order of business, which is to nominate and elect a Vice-chair, and I'm looking for somebody who may have a motion on this.

MS. KERNS: I have John Clark.

CHAIR FEGLEY: Thank you, John Clark, go ahead.

MR. JOHN CLARK: I'm honored to nominate for Vice-chair, our esteemed colleague from the tar heel state, Mr. Chris Batsavage.

CHAIR FEGLEY: Excellent, and I guess, is that the motion? Do we need a second for that, or do I ask, yes, do I have a second for this motion?

MS. KERNS: Pat Geer.

CHAIR FEGLEY: Very good, and I'm sure there is no need to discuss this, so I'll call the question. It is a motion to nominate Chris Batsavage as Vice-chair of the Sciaenids Management Board, motion by Mr. Clark, second by Pat Geer. Is there any opposition to this motion?

MS. KERNS: I have no hands.

CHAIR FEGLEY: **All right, seeing none, congratulations,** Chris, that's excellent.

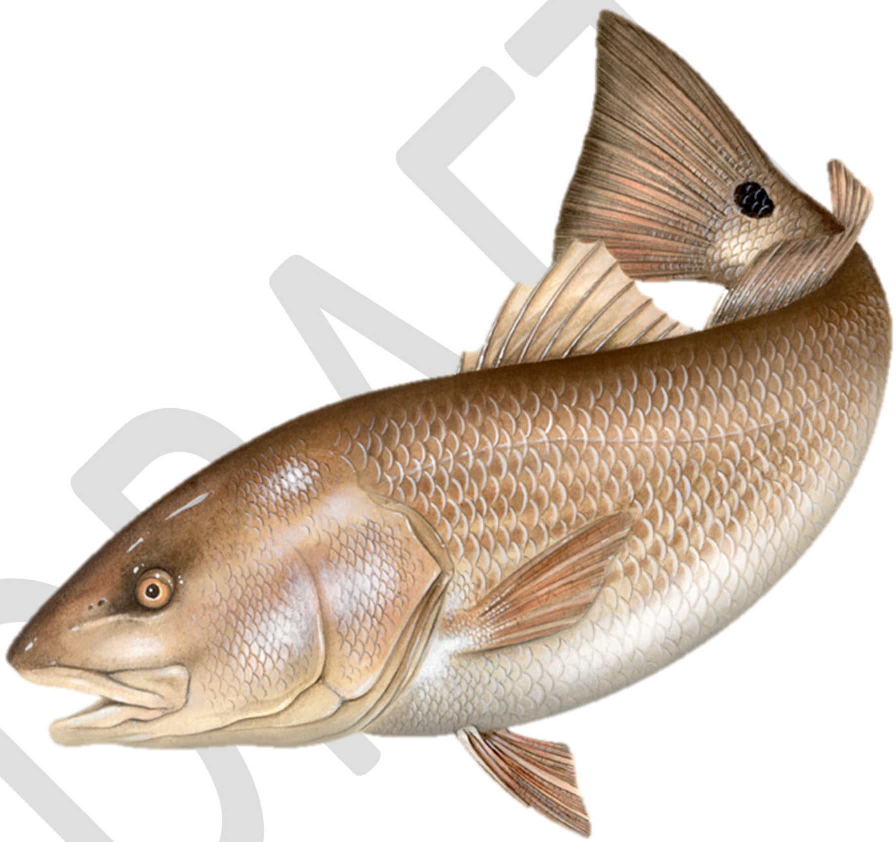
ADJOURNMENT

CHAIR FEGLEY: All right, well with that it looks like we're going to get about 45 minutes of our afternoon back, and I want to thank everybody for your attention. I really want to thank staff and our TC representatives for all of their work, and I'm going to take my prerogative as Chair to call this meeting adjourned, and wish you all an excellent evening.

(Whereupon the meeting adjourned at 4:30 p.m. on Tuesday, August 3, 2021)

Atlantic States Marine Fisheries Commission

2022 Red Drum Simulation Stock Assessment Report



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Draft for Peer Review

Vision: Sustainably Managing Atlantic Coastal Fisheries

Atlantic States Marine Fisheries Commission

2022 Red Drum Simulation Stock Assessment

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

ACKNOWLEDGEMENTS

The Atlantic States Marine Fisheries Commission (ASMFC) thanks all of the individuals who contributed to the development of the 2022 Red Drum Simulation Stock Assessment. The ASMFC specifically thanks members of the Red Drum Technical Committee (TC) and Red Drum Stock Assessment Subcommittee (SAS) who developed the consensus stock assessment report and ASMFC staff, Jeff Kipp and Savannah Lewis, 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: Katie Drew (ASMFC) for providing technical support and analytical contributions, Mike Rinaldi (ACCSP) for validating and providing commercial landings data from partner agencies, Kelli Johnson (NOAA Fisheries) for providing guidance and technical support for the ss3sim simulation software used extensively during this assessment, Kathryn Doering (NOAA Fisheries) and Rick Methot (NOAA Fisheries) for guidance on Stock Synthesis modeling, and the ASMFC's Assessment Science Committee, particularly the subcommittee of Amy Schueller (NOAA Fisheries), Matt Cieri (ME DMR), and Alexei Sharov (MD DNR), for support developing a road map to future stock assessments of red drum.

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EXECUTIVE SUMMARY

Red drum (*Sciaenops ocellatus*) are one of the most targeted recreational fish throughout the South Atlantic, with the majority of southern states reserving their harvest strictly for recreational anglers. Red drum have a unique life history that includes high vulnerability of young, immature fish to fishing mortality in heavily fished, inshore habitats and reduced vulnerability of older, mature fish that emigrate from these heavily fished habitats to offshore habitats. Current management practices (size slot limits) further reduce the habitat-induced reduction of mature fish vulnerability to harvest. This shift in vulnerability severely complicates stock assessment by causing considerable uncertainty disentangling mortality from emigration rates during the transition from inshore habitats to the spawning stock in offshore habitats. The reduced vulnerability impacts fishery-dependent and fishery-independent data collection, creating data limitations that have been addressed with influential assumptions in past stock assessment models. These limitations may have become more impactful as a poorly characterized component of stock removals, age composition of recreational discards, has become an increasingly larger portion of total stock removals. Estimates of the management quantity currently used to manage red drum fisheries, spawning potential ratio (SPR), are sensitive to these data limitations and assumptions. These limitations have also precluded estimates in past assessments of the reproductive capacity of the stocks (i.e., spawning stock biomass or total fecundity) considered reliable for management, leading to what has been termed a cryptic biomass.

There have been varying stock assessment models applied to red drum stocks through time with varying results and management advice. These stock assessment challenges led to the Atlantic States Marine Fisheries Commission's (ASMFC) Sciaenids Management Board (Board) tasking of the ASMFC's Assessment Science Committee (ASC) with providing a road map for future red drum stock assessments following the most recently completed stock assessment. The ASC formed a subcommittee that, with the Red Drum Stock Assessment Subcommittee (SAS), produced a road map recommending evaluating three potential assessment frameworks through the use of simulation analyses.

Simulation models would be used to simulate red drum stocks, with known population dynamics, subjected to various fishing mortality scenarios, with the simulated stocks subsequently being sampled for data mimicking available data streams for stock assessment of *in situ* (actual, true) red drum stocks. Data streams would then be applied to the three potential frameworks to test their reliability in characterizing the known stock status of the simulated stocks. The results would be used to infer reliability of the candidate frameworks when applied to the *in situ* red drum stocks and to recommend the preferred framework(s) for providing management advice during subsequent stock assessments of the *in situ* stocks.

The recommended timeline for the current red drum assessment cycle is for a two-stage assessment process over a four year period, with a first stage devoted to the simulation analyses recommended in the road map (which this report covers) and a second stage devoted to a traditional benchmark stock assessment of *in situ* stocks.

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Simulation models, or operating models (OMs), were constructed from available information on red drum stocks to simulate dynamics of red drum-like stocks through time and provide sampling data replicating data available from *in situ* stocks for stock assessment. Sampling data were then used by candidate assessment approaches, or estimation models (EMs), to predict the population dynamics of the simulated stocks.

Three assessment approaches were selected as candidate EMs based on their past use or consideration for red drum assessment and their suitability to the three assessment frameworks recommended in the road map for future red drum stock assessments. A red drum Traffic Light Analysis (TLA) was developed during this assessment and selected as a model-free stock indicator assessment framework. The statistical catch-at-age (SCA) models used for management advice in the most recent assessment were selected as an assessment framework intended to provide estimates primarily of the juvenile, sub-adult portion of the stocks. The models lump all ages older than age-6 into a plus group and do not estimate spawning stock biomass or a link between adults and productivity (i.e., no stock-recruit relationship). Integrated models developed in Stock Synthesis (SS) were selected as an assessment framework intended to estimate population dynamics of all life stages of the stocks. These models track all age classes in the stocks, estimate spawning stock biomass, and link adults to productivity through an estimated stock-recruit relationship.

Performance of these assessment approaches for estimating the population dynamics of the simulated stocks was evaluated using a suite of performance metrics calculated from eight population parameters identified as the highest priority parameters based on their importance to fishery managers (recruitment condition, SSB status, three-year average SPR ratios, three-year average SPR status, three-year average fishing mortality ratios, three-year average fishing mortality status, age-4 escapement, and age-6 escapement).

Performance was evaluated within and across several simulation scenarios with alternative population dynamics likely to be encountered in future red drum assessments. This scenario testing allows for a unique understanding of an EM's performance under potential structural differences between a true population being assessed and the EM that might be experienced in a benchmark stock assessment (i.e., misspecification) given the quantity and quality of data available. This type of scenario testing also allows for an evaluation of a respective EM's performance relative to other candidate EMs with their own structural differences that are being considered for stock assessment models.

For the simulated northern stock of red drum, the simulation analyses identified concerns with specific EMs, leading to recommendations on appropriate models for consideration during the upcoming benchmark stock assessment. In general, pursuing both the SS and TLA assessment approaches in the upcoming assessment is recommended for the northern stock of red drum; further pursuing the SCA model for the northern stock is not recommended. The SCA had two identified and concerning deficiencies detracting from its use as an assessment model for the northern stock, namely its sensitivity to data weighting choices and reliance on external fishing mortality information. Although the model estimated parameters with reasonable and even superior precision, this precision was driven by external fishing mortality inputs and often centered around the most biased performance of northern EMs. The SS model generally performed as well or better than the other northern EMs in terms of accuracy. The TLA performed comparably to the SS EM in making spawning stock biomass status determinations, and generally outperforms SS when characterizing recruitment condition. However, use of the TLA is not recommended for fishing mortality status determinations in the northern stock due to its poor performance in terms of error rates when estimating this status.

For the simulated southern stock of red drum, the overall similar performance (in terms of bias and precision) of all three EM approaches leads to a recommendation that all should be pursued in the upcoming benchmark stock assessment. The SCA was more robust to data weighting choice and does require external fishing mortality information, as for the northern model. Relative to the southern SCA EM, the southern SS EM generally estimated with slightly greater precision, though the SCA EM estimated with greater accuracy. Similar to the northern stock, the investigation of the TLA suggests there is utility in continuing to develop it as a potential assessment methodology for red drum. The southern stock results indicate the TLA is useful for all metrics, including fishing mortality status which was deemed unreliable using the TLA for the northern stock.

These recommendations should guide workloads and preparation for the upcoming benchmark, though, ultimately, the preferred approach will depend upon fits to the observed data from *in situ* stocks available in the benchmark.

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TERMS OF REFERENCE

For the 2022 ASMFC Red Drum Simulation Stock Assessment

Board Approved August 2020

Terms of Reference for the Red Drum Simulation Assessment

1. Describe fishery-dependent and fishery-independent monitoring programs for red drum and the data sets produced from these monitoring programs for stock assessment. Characterize precision and accuracy of data sets.
    a. Provide descriptions of each monitoring program and data collected (e.g., geographic location, sampling methodology and changes through time).
    b. Describe calculation of data sets produced from these monitoring programs for stock assessment.
    c. Discuss trends in data sets and associated estimates of uncertainty (e.g., standard errors). Discuss potential explanation for outlying or anomalous data.
2. Describe available information for parameterizing simulation models (e.g., historical stock assessment estimates, life history and fishery characteristic studies, regulation changes). Characterize uncertainty of parameters.
3. Develop methods to project a simulated population through time. Implement sampling procedures in simulation models to generate data sets mirroring data sets available from existing monitoring programs.
4. Develop simulated populations that incorporates uncertainty in information used to parameterize the simulation models. Characterize uncertainty and limitations in simulation models and potential impacts on perceived understanding of in situ population dynamics and stock status.
5. Develop candidate assessment methods and apply assessment methods to data sets sampled from simulated populations.
6. Define reference points for characterizing stock status of simulated populations.
7. Identify performance metrics and evaluate performance of each candidate assessment method for estimating the population dynamics and stock status of simulated populations. Describe strengths and weaknesses of each assessment method.
8. Recommend the preferred assessment method(s) for characterizing stock status.
9. Provide prioritized recommendations on future monitoring to improve assessment.

1 INTRODUCTION

Red drum (*Sciaenops ocellatus*) are one of the most targeted recreational fish throughout the South Atlantic, with the majority of southern states reserving their harvest strictly for recreational anglers. Red drum are commonly found along the Atlantic coast from Florida through the Chesapeake Bay, though with very rare occurrences have been reported as far north as Maine. In their common range along the Atlantic Coast, red drum are divided into two regional management areas, or stocks, a northern stock from North Carolina through New Jersey, and a southern stock from South Carolina to Florida.

Red drum have a unique life history that includes high vulnerability of young, immature fish to fishing mortality in heavily fished, inshore habitats and reduced vulnerability of older, mature fish that emigrate from these heavily fished habitats to offshore habitats. Current management practices (size slot limits) further reduce the habitat-induced reduction of mature fish vulnerability to harvest. This shift in vulnerability severely complicates stock assessment by causing considerable uncertainty disentangling mortality from emigration rates during the transition from inshore habitats to the spawning stock in offshore habitats. The reduced vulnerability impacts fishery-dependent and fishery-independent data collection, creating data limitations that have been addressed with influential assumptions in past stock assessment models. These limitations may have become more impactful as a poorly characterized component of stock removals, age composition of recreational discards, has become an increasingly larger portion of total stock removals. Estimates of the management quantity currently used to manage red drum fisheries, spawning potential ratio (SPR), are sensitive to these data limitations and assumptions. These limitations have also precluded estimates in past assessments of the reproductive capacity of the stocks (i.e., spawning stock biomass or total fecundity) considered reliable for management, leading to what has been termed a cryptic biomass.

There have been varying stock assessment models applied to red drum stocks through time with varying results and management advice. There have also been uncertainties of these stock assessment models noted by past peer review panels. These stock assessment challenges led to the Atlantic States Marine Fisheries Commission's (ASMFC) Sciaenids Management Board (Board) tasking of the ASMFC's Assessment Science Committee (ASC) with providing a road map for future red drum stock assessments following the most recently completed stock assessment (ASMFC 2017b). The ASC formed a subcommittee to develop the road map and the subcommittee recommended the Red Drum Stock Assessment Subcommittee (SAS) be repopulated to assist with the road map.

The road map produced by the ASC and SAS recommended evaluating three potential frameworks to develop management advice from the next benchmark stock assessment (in no particular order):

1) model-free stock indicators, similar to traffic light analyses used for Atlantic croaker and spot
2) a population dynamics model tracking the juvenile components of the stocks, and
3) a population dynamics model tracking all life stages of the stocks.

The anticipated advantage of the first framework is being able to provide advice on all life stages with data currently available, with the most notable disadvantage being no quantitative stock status estimates. Rather, this framework would provide stock status as changes in individual data sets or indicators relative to some predefined time period in the available data. The anticipated advantage of the second framework is being able to provide estimates of stock status relative to potential productivity from integrated juvenile data (currently available), with the most notable disadvantage being stock status estimates that are not directly influenced by changes in the mature, adult components of the stocks (data currently limited or not available). The anticipated advantage of the third framework is being able to provide estimates of stock status relative to potential productivity from integrated data across life stages, but estimates from this framework are likely to have relatively high levels of uncertainty given current data limitations on adult components of the stocks (i.e., lack of age composition data characterizing dead discards). Further, the Board has expressed interest in being able to determine whether or not the stocks can be declared rebuilt or not, necessitating the estimation of the adult component of the stocks and encouraging the exploration of this third framework.

The road map recommended the use of simulation analyses as the basis for evaluating these potential frameworks. Simulation analysis has been used as a diagnostic of stock assessment model performance and reliability, providing a means of model validation and comparison across multiple candidate stock assessment models not possible with analyses of *in situ* (actual, true) stocks (Chen et al. 2005; Deroba et al. 2015). Simulation models would be used to simulate red drum stocks, with known population dynamics, subjected to various fishing mortality scenarios, with the simulated stocks subsequently being sampled for data mimicking available data streams for stock assessment of *in situ* stocks. Data streams would then be applied to the three potential frameworks to test their reliability in characterizing the known stock status of the simulated stocks. The results would be used to infer reliability of the candidate frameworks when applied to the *in situ* red drum stocks and to recommend the preferred framework(s) for providing management advice during subsequent stock assessments of the *in situ* stocks. Simulation testing was also recommended to identify the data deficiencies causing uncertainty in assessment advice to focus improvements in data collection efforts into the future. Results and findings of the simulation analyses could then be immediately and directly incorporated into a subsequent benchmark stock assessment of the two red drum stocks along the Atlantic coast for the development of management advice.

The recommended timeline is for a two-stage assessment process over a four year period, with a first stage devoted to a simulation analysis (which this report covers) and a second stage devoted to a traditional benchmark stock assessment of *in situ* stocks. The Board agreed with the recommendations in the roadmap at the ASMFC 2020 Winter Meeting and initiated the development of this assessment.

1.1 Management Unit Definition

The management unit is defined as the red drum resource throughout the range of the species within U.S. Atlantic coast waters of the estuaries eastward to the offshore boundaries of the Exclusive Economic Zone (EEZ) from Florida through New Jersey. The ASMFC manages red drum under the authority of the Atlantic Coastal Fisheries Cooperative Management Act (ACFCMA). The selection of this management unit is based on the biological distribution of the species along the Atlantic coast and historical harvest patterns which have identified fisheries for red drum. The management unit is divided into a southern region and a northern region. The southern region includes the waters of the Atlantic coast of Florida north to the North Carolina/South Carolina border. The northern region extends from the North Carolina/South Carolina border north through New Jersey.

1.2 Regulatory and Management History

The ASMFC adopted a Fishery Management Plan (FMP) for red drum in 1984 (ASMFC 1984) with an original management unit of the states from Florida to Maryland. The plan was designed to address recreational-commercial conflicts and lack of data needed to define optimum yield (OY). At this time, the ASMFC managed red drum in tandem with the South Atlantic Fishery Management Council (Council). The Council managed red drum in federal waters whereas the ASMFC managed state waters. The plan adopted the following objectives:

1) Attain, over time, optimum yield.
2) Maintain a spawning stock sufficient to minimize the possibility of recruitment failure.
3) Promote the cooperative interstate collection of economic, social, and biological data required to effectively monitor and assess management efforts relative to the overall goal.
4) Promote cooperative interstate research that improves understanding of the biology and fisheries of red drum.
5) Promote harmonious use of the resource among various components of the fishery through the coordination of management efforts among the various political entities having jurisdiction over the red drum resource.
6) Promote determination and adoption of the highest possible standards of environmental quality and habitat protection necessary for the natural production of red drum.

In 1990, the Council adopted a similar FMP for red drum that defined overfishing and OY consistent with the Magnuson-Stevens Fishery Conservation and Management Act of 1976. Adoption of this plan prohibited harvest of red drum in the EEZ, a moratorium which still remains in effect today. Recognizing all harvest would take place in state waters, the Council FMP recommended states implement measures to constrain harvest.

Following this request, ASMFC initiated Amendment 1 in 1991 in incorporate the goal to attain OY from the fishery over time. OY was defined as the amount of harvest that could be taken while maintaining the level of spawning stock biomass per recruit (SSBR) at or above 30% of the level which would result if fishing mortality was zero (i.e., spawning potential ratio, or SPR, of 30%). However, a lack of information on adult stock status resulted in the use of a 30% escapement rate of sub-adult red drum to the offshore adult spawning stock.

Substantial reductions in fishing mortality were necessary to achieve the escapement rate; however, the lack of data on the status of adult red drum along the Atlantic coast led to the adoption of a phase-in approach with a 10% SPR goal. In 1991, states implemented or maintained harvest controls necessary to attain the goal.

Amendment 1 to the Council's FMP updated MSY to 30% SPR, OY to 40% SPR, overfishing at less than 30% SPR, and an overfishing threshold as 10% SPR (ASMFC 2002). Amendment 2 to the Council FMP identified, described and recommended measures to protect Essential Fish Habitat (EFH) and EFH Habitat Areas of Particular Concern for red drum as part of the Council's comprehensive habitat amendment (SAFMC 1998b).

In 1999, the Council recommended that management authority for red drum be transferred to the states under the ACFCMA. This was recommended, in part, due to the inability to accurately determine an overfished status, and therefore stock rebuilding targets and schedules, as required under the revised Sustainable Fisheries Act of 1996. The transfer necessitated the development of an amendment to the ASMFC FMP in order to include the provisions of the ACFCMA.

The subsequent amendment, Amendment 2 to the ASMFC FMP, moved management authority of red drum from the Council to the states in June 2002 (ASMFC 2002) and serves as the current management plan. The final rule that ultimately repealed the Council's FMP and transferred management authority of Atlantic red drum in the EEZ from the Council to the ASMFC became effective November 5, 2008. The Amendment required states to implement recreational creel and size limits to achieve the fishing mortality target, including a maximum size limit of 27 inches total length (TL), and maintain existing commercial regulations. A harvest moratorium and Presidential Executive Order, enacted in 2007, prevents any harvest or sale of red drum from federal waters. The goal of Amendment 2 is to achieve and maintain the OY for the Atlantic coast red drum fishery as the amount of harvest that can be taken by U.S. fishermen while maintaining the SPR at or above 40%. There are four plan objectives:

1) Achieve and maintain an escapement rate sufficient to prevent recruitment failure and achieve an SPR at or above 40%.
2) Provide a flexible management system to address incompatibility and inconsistency among state and federal regulations which minimizes regulatory delay while retaining substantial ASMFC, Council, and public input into management decisions; and which can adapt to changes in resource abundance, new scientific information, and changes in fishing patterns among user groups or by area.
3) Promote cooperative collection of biological, economic, and sociological data required to effectively monitor and assess the status of the red drum resource and evaluate management efforts.
4) Restore the age and size structure of the Atlantic coast red drum population.

The SPR of 40% is considered a target; an SPR below 30% (threshold level) results in an overfishing determination for red drum. All states were in compliance by January 1, 2003.

The Board approved Addendum I to Amendment 2 in August 2013. The Addendum sought to increase the knowledge base and aid in the protection of important red drum habitat. It updated Amendment 2's habitat section to include more up to date information on red drum spawning habitat and habitat by life stage (egg, larval, juvenile, sub-adult, and adult). The addendum also identified and described the distribution of key habitats of concern, including threats, habitat bottlenecks, and ecosystem considerations.

Red drum regulations through time are provided in Table 1 (northern stock) and Table 2 (southern stock).

1.3 Assessment History

There have been eight previous regional assessments for red drum inhabiting Atlantic coast waters of the U.S. (Vaughan and Helser 1990; Vaughan 1992; Vaughan 1993; Vaughan 1996; Vaughan and Carmichael 2000; SEDAR 2009a; SEDAR 2015a; ASMFC 2017b). There have also been several state-specific assessments conducted in Florida, South Carolina, and North Carolina.

1.3.1 Regional Stock Assessments

Early regional stock assessments (through Vaughan 1993) analyzed red drum as one coastwide stock and were primarily based on analysis of catch age composition data with catch curves and virtual population analyses (VPAs) of only young red drum (ages 0-5 – see note on age convention in next paragraph). These early assessments were designed to remove the effect of emigration on the apparent decline (mortality) in catches of red drum as they moved from heavily fished inshore sub-adult habitats to more lightly fished offshore adult habitats. For the most part, the condition of the stock was inferred from the calculated level of escapement through age-5, though SPR (reported in these assessments as maximum spawning potential or MSP) was also calculated as a management benchmark despite little information on adult catches. These assessments generally estimated high mortality and low escapement and MSP throughout the 1980s and into the early 1990s.

Beginning with Vaughan (1996), the assessment separated the coastwide population into the two stock definitions currently used in assessments. Major concerns beginning in this assessment were increasing numbers of live releases (and resultant dead discards) in the highly regulated recreational fisheries and the effects of minimum/maximum size restrictions complicating estimation of selectivity. The assessment introduced the use of VPA with indices of abundance included as inputs (calibrated VPA). It should be noted there was a change in the definition of the age designation after Vaughan (1996). The first calendar-year age in these early assessments was designated age-0 (January-December for biologically 4-16 month old fish). This was redefined as age-1 (given the convention of incrementing age on January 1) in more recent assessments. Also, given the difficulties estimating the decline in vulnerability associated with the sub-adult transition to offshore waters, a series of predefined linkages between age-specific selectivities were used to constrain the analyses. This assessment estimated high mortality and low MSP (<15%) continuing into the mid-1990s.

An assessment in 2000 by Vaughan and Carmichael used two VPAs (SVPA and FADAPT) and a spreadsheet-implemented, forward projecting statistical catch-at-age analysis. Uncertainty in the age structure of live-released mortalities was investigated by manipulating the lengths of red drum measured from angler creels. A range of release mortalities and selectivity linkage constraints were utilized in all analyses. The FADAPT VPA was selected as the preferred analysis for estimates of fishing mortality and SPR. In the northern stock, estimates of SPR increased from about 1.3% for the period 1987-1991 to approximately 18% for the period 1992-1998. For the southern stock, estimates of SPR increased from about 0.5% for the period 1988-1991 to approximately 15% for the period 1992-1998. These estimates indicated overfishing was occurring in both stocks.

The first SouthEast Data, Assessment, and Review (SEDAR) process for red drum, SEDAR 18, concluded in 2009 with data through 2007 (SEDAR 2009a). This assessment transitioned to new forward projecting statistical catch-at-age (SCA) models developed in AD Model Builder (ADMB). These SCA models relax assumptions required by the precursor VPA analyses that assume catch age composition data are observed without error, and were seen as advancements in models due to some data limitations in constructing the age composition data. The models included several unique aspects due to data availability and red drum life history including the constraint of estimating selectivity of ages-4 and 5+ as proportions of age-3 selectivity, grouping all ages older than age-6 into a plus group, and using fishing mortality and selectivity information from an external tagging analysis in the modeling procedures (northern stock only). The models used fishery catch and age compositions, indices of abundance, and life history information (growth, maturity, and natural mortality). Like the VPAs, these models produced fishing mortality estimates that could be used to calculate SPR for comparison to reference points and status determination.

In the northern stock, SPR estimates increased from lows less than 10% in the beginning of the time series to values above the target (40%) by the mid-1990s. SPR was estimated to have varied at these higher levels above the threshold and often above the target for the remainder of the time series. In the southern stock, SPR was estimated to have been at the highest levels in the early 1990s then declined slowly, but remained above the threshold and target throughout the rest of the time series. The assessment provided a three-year average SPR over the last three years of the assessment time period (2005-2007) for stock status determinations to address uncertainty with annual estimates. Both stocks were determined not to be experiencing overfishing. Due to data limitations and poor estimates of the adult components of the stocks, the assessment could not make a determination of spawning population status (i.e., overfished vs. not overfished).

This assessment was accepted by a peer review panel, but peer reviewers noted several limitations and concerns with the SCA models that should be addressed in future assessments. The northern model was sensitive to inclusion of the external tagging analysis estimates used as inputs in the base model configuration and results were ultimately conditional on these inputs. Without these inputs, results were very different and indicated conflict between these inputs and the other more traditional data inputs (catch age composition, indices of abundance). Further, the reviewers noted unusually high fishing mortality estimates from the external tagging analysis early in the time series. The peer review panel recommended direct inclusion of the tag-recapture data as model inputs in future assessments as opposed to externally-derived population parameter estimates.

Peer reviewers also expressed concern with uncertainty of model estimates, particularly for the southern stock. Confidence intervals were large and results were highly sensitive to selectivity estimates, allowing for only general, qualitative statements about the stock conditions. Reviewers noted highly uncertain and unrealistically large initial abundance estimate for older fish in the southern and northern models, respectively. These issues were explored during the review workshop, but remained after not arriving at solutions. Poor fits to catch age composition data resulted in age-specific patterning in residuals and the model time series was ultimately shortened during the review to exclude sparse composition data prior to 1989. The assessment team and review panel ultimately agreed that model structure was a major source of uncertainty in the assessment.

During a second SEDAR process in 2015 (SEDAR 44; SEDAR 2015a), an attempt was made to transition to integrated assessment models developed with the Stock Synthesis (SS) integrated analysis framework (Methot and Wetzel 2013). This transition was in response to some of the limitations of the SCA models and recommendations by the SEDAR 18 peer review panel. SS is an age- and size-structured assessment model in the integrated analysis class of models. It has 1) a population sub-model that simulates growth, maturity, fecundity, recruitment, movement, and mortality processes, 2) an observation sub-model which predicts values for the input data, 3) a statistical sub-model which characterizes goodness of fit and obtains best-fitting parameters and their associated variance, and 4) a forecast sub-model which projects various user-determined management quantities (Methot et al. 2020). SS allows for observed tag-recapture data and both length and age length key data as inputs, reducing data processing external to the model and better propagating uncertainty in model results. SS is also more flexible for modeling time series with varying data availability and the framework was anticipated to better utilize sparse data during the period of high exploitation prior to the 1989 start year in SEDAR 18.

Several challenges were experienced during model development resulting in poor model stability and no preferred model in time for the peer review workshop, so the objective of the workshop was changed from evaluating final model results for management advice to evaluating current model configurations and making recommendations to improve these configurations. Recommendations were addressed by the assessment team following the workshop and final model results were reviewed during a subsequent peer review. The SPR estimates were quite different from SEDAR 18, indicating the stocks had been experiencing overfishing throughout the time series. The 2011-2013 three-year average SPR was estimated to be 9.2% in the northern stock and 17% in the southern stock, both below the SPR threshold.

The assessment was accepted by the peer reviewers, but notable concerns were identified including sensitivity of the northern model stock status determination to treatment of the tag-recapture data. Ultimately, the models were not accepted by the South Atlantic State/Federal Fisheries Management Board (predecessor of the Sciaenids Management Board) due to concerns with the reliability of population parameter estimates. Instead, the Board tasked the

TC and SAS with several tasks including to evaluate the utility of the SCA models used in SEDAR 18 for updated management advice.

The SAS updated the SCA models in an additional assessment (ASMFC 2017b) with recent data and explored several potential changes to these models, including data changes, but ultimately recommended models with minimal structural changes for management advice. The 2011-2013 three-year average SPR was estimated to be 43.8% in the northern stock and 53.5% in the southern stock, both above the SPR threshold and target, indicating that overfishing is not occurring. However, most of the issues that arose with the models during SEDAR 18 remained and were noted by the peer reviews of this assessment.

Peer reviewers noted that examination of the assessment results, as well as corroborating information from the fishery-independent indices, suggest that both the northern and southern stocks appear to be above their management thresholds. However, reviewers concluded that there is a high degree of uncertainty associated with these assessments due to the lack of good fishery-dependent and -independent data on the oldest and most fecund age classes, coupled with sensitivity to data weightings and initial conditions suggesting an overall scaling problem with both regions' assessments. The wide confidence intervals in the south and the unrealistic decline in abundance over the time series in the north suggest fundamental assessment and data issues. Given the life-history and pattern of exploitation, it is unclear how these issues can be easily resolved. Further work is needed given the critical dependency of overfishing status determination on the fishing mortality estimates for older fish, and the difficulties of estimating fishing mortality when population size is indeterminate; the assessment only gives a rough measure of stock status.

While there are no major signals to suggest the stocks are in trouble, it should be recognized that even small changes in the fishing mortality on age-5 and older fish could lead to rapid overfishing. Theoretically, the SPR analysis measures exploitation in an equilibrium context. By that measure, a small increase in fishing mortality on older fish would lead to an immediate determination of overfishing. In practice, the stock dynamics would depend on the true population size of older fish. Since population size is highly uncertain, and in the north equilibrium is highly improbable, any management changes should be carefully considered. More specifically, measures that might increase fishing mortality rates on older fish should be avoided until the estimates can be verified. Moreover, the assessment cannot provide information on the potential population limits for recruitment failure as scale of the most fecund portion of the population is uncertain.

It is also important to recognize that the same concerns that were identified with the SS model formulation underlie the application of SCA models to the stocks. Despite its nominally less complex analytical structure, the data conflicts and instability of estimates remain in SCA, as in SS formulations. These issues would likewise confound any age structured modeling approach. It suggests that the overall problem is one of data and the pattern of exploitation which informs model approaches, rather than the approach itself.

1.3.2 State Stock Assessments

Florida

The Florida Fish and Wildlife Conservation Commission (FL FWC) has conducted several assessments of red drum, with the most recent assessment utilizing data through 2019 (Addis 2020). This assessment was conducted to assess the status of red drum populations found in four different regions along the Atlantic and Gulf Coast of Florida. The two regions of the Atlantic coast were defined as the southeast region (SE), from Miami-Dade through Volusia counties, and the northeast region (NE), from Flagler through Nassau counties.

SS models were developed, run from 1989 to 2019, accounted for 41 ages (0-40+), and were fit to catch, CPUE indices, length composition, and size-at-age data. Fits to the datasets from a parametric bootstrap analysis were adequate for all regions as most base run estimated parameters and derived quantities were inside the central range of the estimates produced by the bootstrap analysis.

Overall fishing mortality rate estimates for red drum ages 1-5 have remained at fairly low levels since the late 1980s in all four regions. However, recent increases have been apparent in the NE from 2010-2019 and the SE from 2015- 2018. Current spawning stock biomass ($SSB_{current}$, mt) calculated as the geometric mean of the past three years, is estimated to be 17,163 in the NE, and 27,940 in the SE region. The fishing mortality resulting in an SPR of 35% ($F_{SPR35\%}$) was estimated to be 0.26 and 0.23 in the NE and SE regions, respectively. The spawning stock biomass (mt) when the population is at SPR of 35% ($SSB_{SPR35\%}$) was estimated to be 7,801 in the NE and 10,336 in the SE.

Ratios of $SSB_{current}/SSB_{SPR35\%}$ and $F_{current}/F_{SPR35\%}$ from the two assessment regions indicate that red drum are currently neither overfished nor undergoing overfishing in Florida. The $SSB_{current}/SSB_{SPR35\%}$ ratios for the past three years were 2.2 and 2.7 in the NE and SE regions, respectively. The $F_{current}/F_{SPR35\%}$ ratios were 0.5 and 0.8 in the NE and SE regions, respectively.

Estimates of current escapement rates (geometric mean of the last 3 years, 2017-2019) in the NE regions exceeded 40%. Although the SE region of Florida is exceeding the escapement rate management target in the terminal year (2019) of the assessment (55%), it does not meet the current escapement rate management target. Current escapement rates for 2017-2019 were 61% in the NE and 35% in the SE region.

South Carolina

Using data from September 1982 thru August 2016, the South Carolina Department of Natural Resources (SC DNR) conducted a stock assessment to assess the status of the red drum population found along coastal South Carolina (Murphy 2017). Data used included catch, effort, relative abundance, size/age composition, and tag-recapture data sets. The assessment investigated three different assessment frameworks, a SS model excluding tag-recapture data, a SS model including tag-recapture data, and a SCA model as employed during ASMFC 2017b, with each giving broadly similar results.

The assessment suggested the abundance of juvenile and sub-adult red drum along coastal South Carolina increased from low levels in the early- to mid-1980s in response to increasing levels of recruitment in the early 1980s despite high levels of fishing. Abundance of adult red drum continued to remain low or decline until the mid-late 1980s when these abundant groups of sub-adults recruited to the adult population and the abundance of adults began to rise. Fishing mortality declined dramatically after hitting peak values during 1985-1988 and continued declining at a slow rate through the late 1990s. During this time, the red drum population responded with variable but slowly declining recruitment, and an increased abundance of sub-adults and adults. Fishing mortality then began to increase steadily after 2000 as the number of discarded red drum (and inevitable discard deaths) increased dramatically. Finally, recruitment declined rapidly after 2008 and abundance of sub-adults and adults followed suit after 2010. SPR increased from low levels in the 1980s to levels exceeding typical biological target levels during the 1990s and early to mid-2000s. Since 2008, SPR levels have fluctuated between about 20-40% before declining in the 2014 and 2015 fishing years to likely be below 20%, indicating the population was experiencing overfishing.

This assessment result prompted new state management regulations, which went into effect on July 1, 2018, reducing the recreational bag limit to 2 fish per person and establishing a 6 fish per day boat limit.

North Carolina (description modified from Vaughan 2009)

An assessment was conducted by the North Carolina Division of Marine Fisheries (NCDMF; Takade and Paramore 2007) and included data provided by the Virginia Marine Resources Commission (VMRC) to update the earlier assessment by Vaughan and Carmichael (2000) for the northern red drum stock.

The northern red drum stock was assessed using commercial, recreational, and fishery-independent data from 1986 to 2005. Results were broken into three regulatory periods with relatively uniform regulations (early: 1986-1991, mid: 1992-1998, and late: 1999-2005). A major assumption in this assessment was assigning an accurate length distribution to released fish from the recreational fishery. While several assumptions on the length distribution of recreational releases were calculated, the preferred matrix (Tagging) used length frequencies estimated from modeling of NCDMF tag returns. Late period age-3 selectivity was estimated to be 0.48 of fully selected fish (age-2), and was estimated from modeling of NCDMF tag returns. Two models from the Vaughan and Carmichael (2000) assessment were updated: the backward calculating FADAPT VPA and the forward calculating spreadsheet catch-at-age model.

Fishing mortality estimated from FADAPT ranged from 0.50 to 0.49, with escapement ranging from 40.6% to 41.0% and SPR ranging from 40.4% to 40.8%. The spreadsheet catch-at-age model fishing mortality estimates ranged from 0.66 to 0.63, with escapement estimated at 32.8% and SPR estimated at 32.3%. All estimated runs using the TAGGING matrix from both models were above the threshold of 30% SPR and the FADAPT estimates were above the target of 40% SPR. All runs showed improvements in escapement and SPR from the previous regulation period (1992-1998).

This assessment indicated that fishing mortality has decreased and escapement and SPR had increased for the red drum northern stock during the latest management period (1999-2005). The results from Vaughan and Carmichael (2000) indicated that overfishing was occurring, with

SPR values well below the threshold SPR. The updated model estimates in this assessment were all above 30% SPR and, therefore, indicated that overfishing was no longer occurring. It appears that the condition of the northern red drum stock had improved and that the more restrictive management measures implemented during the latest management period had aided in that improvement.

2 LIFE HISTORY

2.1 Stock Definitions

Red drum inhabit nearshore and estuarine waters of the U.S. Atlantic coast from Massachusetts to Florida and the Gulf of Mexico (GoM) from Florida to northern Mexico (Lux and Mahoney 1969; Mercer 1984). The current distribution of red drum in the Atlantic Ocean, as indicated by commercial and recreational landings, primarily extends from southern Florida to Chesapeake Bay, with infrequent, low recreational landings from Maryland through New Jersey. Previous stock assessments (Section 1.3.1) divided this distribution into a northern stock (North Carolina through New Jersey) and a southern stock (South Carolina, Georgia, and the eastern coast of Florida) based on differences identified in life history characteristics (maximum age, growth, and maturity) as well as movement information from tagging data. Seyoum et al.'s (2000) initial mitochondrial genetic work on red drum indicated a weak subdivision of red drum into GoM and Atlantic components with a genetic transition occurring around the southern Florida peninsula between Sarasota Bay and Mosquito Lagoon, supporting the separate management of these populations. Large-scale genetic analyses have been conducted on red drum in the GoM by Gold et al. (2001) and Gold and Turner (2002).

Based on mitochondrial and microsatellite data, estuaries within the GoM showed temporal, but not spatial stability in allele frequencies. Further analyses of spatial patterns indicated the variability was not able to be partitioned into discrete geographic subpopulations, instead showing a pattern of isolation by distance. The proposed model of population structure fits well with gene flow predicted by life history and due to their estuarine-dependent recruitment; a steppingstone model where gene flow primarily occurred among adjacent estuaries was described with geographic neighborhoods limited to 700-900 km.

Additionally, the degree of genetic divergence detected was similar between the two markers, indicating the occurrence of sex-biased gene flow, due to female mediated dispersal and/or male philopatry.

Only two published papers have addressed red drum population structure within the Atlantic (mitochondrial sequence data, Seyoum et al. 2000; microsatellite data, Chapman et al. 2002), both indicating little to no level of spatial structuring among estuaries. However, the Atlantic spatial scale of both projects were limited and likely confounded by low sample sizes.

Additionally, an estuarine-collapsed analysis indicated temporal heterogeneity in the SC evaluation and was interpreted as a potential temporal instability of the reproductive pool (Chapman et al. 2002). Chapman et al. (2002) estimated a variance effective population size (N_e) of Atlantic red drum using the temporal method of Waples (1989) which was an order of magnitude lower than estimates of female N_e in the GoM (Turner et al. 1999). However, due to red drum overlapping generations, an estimate of N_e requires a modification based on age-specific life history information (Jorde and Ryman 1995). At that time, the only correction factor available for red drum was based on GoM fish (Turner et al. 1999); however the appropriateness of those data for Atlantic red drum is unlikely based on suspected age-structure differences resulting from differential commercial fishery impacts during the 1980s. Therefore, determination of age-specific survival and birth rates are needed to determine accurate estimates of N_e for Atlantic red drum.

More recently, the SCDNR has utilized genetic samples from adult red drum collected from the multi-state longline surveys and other sampling efforts to evaluate genetic structure from NC to FL (Cushman et al. 2014). Temporal genetic differentiation was tested for within each of six sampling sites from NC to FL and found to be insignificant. Spatial genetic differentiation was then tested between the six sampling sites during the spawning season and non-spawning season. Significant differentiation was detected between NC and all southern sample sites (SC-FL) during the spawning season, but not during the non-spawning season. This work suggests a genetic break does exist between NC and locations south of NC during spawning, but some mixing of adults does occur during the non-spawning season. This mixing is less of a concern based on current management of the defined stocks which largely protects these adult fish from harvest (i.e., no mixed stock harvest). Estimates of N_e also supported the greater abundance of the southern stock estimated in previous stock assessments.

Based on the previous red drum assessments, the genetics work conducted by the SCDNR, and no new data, the Atlantic red drum population will continue to be defined as two stocks, a Northern stock defined as North Carolina and north and a Southern stock defined as South Carolina and south, in this assessment.

2.2 Migration Patterns

Adult red drum make seasonal migrations along at least some parts of the Atlantic coast. In the spring, adults move north and inshore but offshore and south in the fall. Overall, adults tend to spend more time in coastal waters after reaching sexual maturity. However, they do continue to frequent inshore waters on a seasonal basis. In the Indian River Lagoon (IRL), Florida, limited seasonal migrations (Reyier et al. 2011) including some movement to coastal inlets in fall during the spawning season have been detected (Reyier et al. 2011). In Mosquito Lagoon (northern IRL), a portion of the adult population remain within the estuary where documented spawning occurs (Johnson and Funicelli 1991; Reyier et al. 2011).

Tagging information provided the best insight into the movement and migration of red drum along the Atlantic coast. Each state, from Florida to Virginia, has participated in some form of tagging program (Section 4.3). Volunteer angler programs are or have been active in each state in which trained volunteers participate by tagging fish and reporting tagged fish when recaptured. Other programs include agency staff tagging and cooperative projects with local commercial harvesters. Almost every program relies heavily on angler returns for recapture information.

Despite differences in state-to-state programs, there is evidence of adult red drum movement between Virginia and North Carolina. Data suggest red drum movement into Virginia waters from North Carolina in late May. The fish appear to stay in the area until August through September before they ultimately move during fall months to North Carolina waters where the fish appear to overwinter. Movement of red drum tagged in North Carolina over 25 years is summarized in Bacheler et al 2009. The study, based on 6,173 tag returns for red drum of all sizes, found limited movement of red drum from North Carolina to adjacent states, although some adult red drum migrated seasonally to Virginia in the spring, returning the following fall. The study noted that the current stock split between North Carolina and South Carolina appeared to be an appropriate ecological division for the stock.

Programs in the southern states (Georgia, and South Carolina) provided evidence of limited movement as well. For example, of 1,780 fish tagged in Georgia, 85.3% were recaptured within state waters (11.0% were recaptured in South Carolina, and 3.7% were recaptured in Florida). In South Carolina, fish tagged in the SC DNR sub-adult tagging program were primarily recaptured within 30 miles (96.4%; SEDAR 2009b). An additional working document on movement distances by South Carolina red drum tags that were recaptured by recreational anglers (Arnott 2015b) indicated more than 95% of red drum were recaptured within 125 miles of their release location, even after 5 or more (up to 18) years at large. Of 12,754 tags with known recapture locations, 79 were recaptured from North Carolina, 12,657 from South Carolina, 13 from Georgia and 5 from Florida.

An interesting pattern of movement, or lack of movement, was observed from fish overwintering in the area of power plants. The most productive of these areas was the Elizabeth River Hot Ditch area, in Virginia. Rather than migrating out of the Chesapeake Bay during fall to North Carolina waters (considered the usual pattern for sub-adult red drum), fish in this area were observed over-wintering in bay tributaries in the area of power plants. The cycling of river water through the plants resulted in discharges of warmed water sufficient to maintain adjacent areas at temperatures generally suitable for the fish (as well as forage the fish could use - crabs, finger mullet, mummichogs, etc.). Similar patterns were also observed, to a lesser degree, at another nearby power plant (SEDAR 2009b).

The genetic work by SCDNR also suggests some movement of adult red drum between SC and NC during non-spawning seasons. However, these adult fish do appear to return to their respective stock during the spawning season.

Tagging studies indicate that late age-0 and 1 year-old red drum are common throughout the shallow portions of the estuaries and are particularly abundant along the shorelines of rivers and bays, in creeks, and over grass flats and shoals of the sounds. During the fall, those sub-adult fish inhabiting the rivers move to higher salinity areas such as the grass flats and shoals of the barrier islands and the front beaches. With the onset of winter temperatures, juveniles leave the shallow creeks for deeper water in the main channels of rivers (9–15 m) and return again to the shallows in the spring. Fish that reside near inlets and along the barrier islands during the summer are more likely to enter the surfzone in the fall.

By their second and third full year of growth, red drum are less common in rivers but are common along barrier islands, inhabiting the shallow water areas around the outer bars and shoals of the surf and in coastal inlets over inshore grass flats, creeks or bays. In the northern portion of the South Carolina coast, sub-adults use habitats of broad, gently sloping flats (up to

200 m or more in width). Along the southern part of the South Carolina coast, sub-adult red drum inhabit narrow (50 m or less), fairly level flats traversed by numerous small channels, typically 5–10 m wide by less than 2 m deep at low tide (ASMFC 2002).

2.3 Age and Growth

Otoliths are the primary ageing structure collected from red drum along the Atlantic coast. Otoliths produce clearly interpretable annual growth bands, and age estimates are precise (ASMFC 2008) and considered highly accurate. Age estimates from scales are only considered accurate through age-4 (ASMFC 2008). Age structures have been processed and read for age data by state agencies and academic institutions from Virginia through Florida. Additional detail on age processing and reading is available in SEDAR 2015a. The maximum ages observed to date are 62 in the northern stock and 41 in the southern stock.

Red drum growth has long been understood to not be described well with some of the traditional growth models like the von Bertalanffy growth function (Porch et al. 2002; Cadigan 2009). There are strong seasonal influences on growth as well as indications of changing growth rates over the age range of the stocks that result in poor fits with traditional growth functions. Alternative growth estimates are available (Porch et al. 2002; Cadigan 2009) as well as empirical estimates of length-at-age, but these options are not compatible with growth options in simulation model software used in this assessment.

In anticipation of needing to approximate red drum growth in simulation models, an alternative growth function that allows for changing the von Bertalanffy Brody growth coefficient parameters (*K*) across ages (Methot et al. 2020, age-specific K growth) was used to generate stock-specific growth patterns. The growth function includes the traditional von Bertalanffy growth parameters for asymptotic length (L_{inf}) and the Brody growth coefficient (*base K*), but also allows for multipliers of the *K* parameter at user-specified older ages giving flexibility to the growth curve. The *base K* parameter is used in growth calculations for the youngest age (age-1 here) and any subsequent ages until an age break point where a *K* multiplier is specified. At this age break point, the multiplier is applied to the *base K* and the product serves as the new *K* parameter for any subsequent ages unless another age break point is specified. If another age break point is specified, the associated *K* multiplier is applied to the *K* parameter and the product becomes the new *K* parameter. This repeats for any age break points across the age range. The number of *K* multipliers can range from one to one less than the number of ages in the age range. The parameterization of the von Bertalanffy growth function used here also includes a parameter for the length (L_{min}) at a user-specified minimum age (A_{min}) when fish begin to grow according to the growth function. In addition to the von Bertalanffy growth curve describing expected mean length-at-age, the simulation models use coefficients of variation (CVs) for size at the smallest sizes and the largest sizes in the growth function with interpolation of CVs between these sizes to describe variation in growth around the expected growth curve.

Available growth data were compiled within each stock (Table 3) and age-specific K growth curves were estimated. There is no readily available optimization routine for this growth function, including for the best fit age(s) for break point(s), so parameters were estimated by inspecting residuals of fits with the traditional von Bertalanffy growth function (Figure 1 and

Figure 2) and specifying age break points with associated *K* multipliers to improve residual patterns. Growth CV parameters were specified so that 95% confidence intervals captured most of the observed variation in growth.

Age-specific K growth parameters are in Table 4. Growth patterns include age break points with *K* multipliers for ages 2, 4, 6, 12, and 18 in the northern stock and 2, 7, 12, and 18 in the southern stock. These break points align well between stocks except the addition of a third break point for the northern stock before age-12. Final growth patterns are shown in Figure 3 and Figure 4. Some patterning in residuals remains (Figure 5 and Figure 6) mostly due to the seasonal patterning of growth in younger ages, but residuals are improved across the age range, particularly for the older ages.

2.4 Reproduction

Much of the reproductive data for red drum is based on histological data as well as observations using telemetry. Most of the hydroacoustic data seems to be supported by the histological data (Lowerre-Barbieri et al. 2008). Due to a limited amount of data from the Atlantic coastal region it was necessary to use both Gulf of Mexico and Atlantic coast data.

2.4.1 Spawning Seasonality

Spawning season on the Gulf and Atlantic coasts of Florida peaks between September and October (Murphy and Taylor 1990). The northern Gulf of Mexico appears to have a spawning season between mid-August to September. Along the coast of North Carolina spawning peaked between August and September based on GSI and hydroacoustic data (Ross et. al. 1995; Luczkovich et al. 1999). Along the Georgia coast, based on hydroacoustic data, red drum appear to congregate and spawn between August and mid-October (Lowerre-Barbieri et al. 2008).

2.4.2 Sexual Maturity

Previously published information on red drum maturity were available from North Carolina, South Carolina, the Florida Atlantic coast (Indian Lagoon) and Florida Gulf of Mexico coast. Interpolated lengths of 50% maturity for male red drum were 529 mm for Florida's Gulf coast and 511 mm for the Atlantic coast of Florida and were mature between ages 1 and 3 (Murphy and Taylor 1990). Fifty percent of females were mature between 825 mm and 900 mm and all females were mature at age-6 in Florida (Murphy and Taylor 1990). In North Carolina, females were mature at 4 years while males were mature at 3 years (Ross et. al. 1995). Fifty percent of males were mature between 1 and 2 years of age while females did not mature until 3 years old (Ross et. al. 1995). The size of 50% maturity for females in SC was 792 mm TL and 713 mm TL for males. The age of 50% maturity for females was 4.3 years (52 months), while for males it was determined to be 3.5 years (43 months; Wenner 2000). In South Carolina, all males were mature at 4 years and all females were mature at 5 years (Wenner 2000).

During the SEDAR 44 data workshop, additional analyses were performed using more recent data available from South Carolina (n = 5,540 fish; Arnott 2015a). Raw data from the North Carolina study of Ross et al. (1995) were also obtained (n = 728 fish) so that maturity could be statistically compared between North Carolina and South Carolina. In the analysis of Ross et al

(1995), developing fish were classified as immature, whereas a recent study by Brown-Peterson et al. (2011) which has been widely accepted as a standardized reproductive methodology, classifies developing fish as mature. All North Carolina and South Carolina fish were therefore reclassified according to Brown-Peterson et al. (2011).

The analyses found significant differences between North Carolina and South Carolina in relationships between both maturity-at-size and maturity-at-age, as well as significant differences between males and females. Results from the analyses are presented in Table 5 and Figure 7 through Figure 12. While SEDAR 18 assumed one maturity schedule for both stocks, based on results of this updated analysis, maturity-at-age was calculated separately for the northern and southern stocks in the most recent assessment (ASMFC 2017b).

Among the South Carolina fish, significant differences were also detected between time periods spanning 1984 through 2013. This apparent temporal effect may have been driven by data deficiency in some of the size, age or temporal categories. Also, most of the maturity assessments were made by gross (macroscopic) examination, so it was not possible to cross-check for consistent methodology across time. Therefore, temporal changes in maturity schedules were not considered any further.

2.4.3 Sex ratio

The sex ratio in North Carolina was 1:1 (349 males:373 females; Ross et al. 1995). In the northern Gulf of Mexico, the sex ratio for spawning adults was also 1:1 (Wilson and Nieland 1994).

2.4.4 Spawning Frequencies

Wilson and Nieland (1994) estimated spawning frequencies for Northern Gulf of Mexico red drum from between 2 and 4 days.

2.4.5 Spawning Location

Spawning most likely occurs in the nearshore areas adjacent to channels and passes and may also occur over nearshore continental shelves (Murphy and Taylor 1990; Lowerre-Barbieri et al. 2008). Spawning locations in South Carolina were also associated with passes and channels (Wenner 2000). More recent evidence suggests that, in addition to nearshore vicinity habitats, red drum also utilize high-salinity estuarine areas along the coast (Murphy and Taylor 1990; Johnson and Funicelli 1991; Nicholson and Jordan 1994; Woodward 1994; Luczkovich et al. 1999; Beckwith et al. 2006).

2.4.6 Batch Fecundity

Batch fecundity estimates vs. fork length (FL), gonad-free body weight, age in year, and eviscerated body weight were generated by Wilson and Nieland (1994) for red drum from the northern Gulf of Mexico from 1986 to 1992. The mean batch fecundity was 1.54 million ova. Fish ranged from 3-33 years of age, had a FL range of 697-1005 mm, and a batch fecundity range of 0.16-3.27 (ova x 10^6).

2.5 Natural Mortality

Age-structured models attempt to reconstruct the fish population and fishing mortality rates by age and year, where total instantaneous mortality rate (Z) is the sum of instantaneous rates of fishing (F) and natural (M) mortality. Unfortunately, M is typically one of the most difficult parameters to determine, despite an abundance of effort to develop empirical methods to estimate M. These empirical methods have led to the development of a host of both age-constant and age-varying approaches to estimate natural mortality external to assessments based on other life history parameters (e.g., maximum age, growth rate parameters, size-at-age, age-at-maturity, etc.).

2.5.1 Age-Constant M Approaches

Historically, most assessments assumed natural mortality was constant over age and years. Invariably, these age and time constant estimates of M were derived from a suite of life history analogies, with perhaps the most commonly assumed approaches being proposed by Alverson and Carney (1975), Pauly (1980), Hoenig (1983), Jensen (1996), and Hewitt and Hoenig (2005). Such an age-constant approach was investigated during the SEDAR 44 assessment of red drum (Table 6). Note that the Hoenig (1983) method provides an estimate of total mortality, Z. It is only when fishing mortality can be assumed small ($F \sim 0$) that this becomes an estimate of M; otherwise it is an upper bound on M. The version of the Hoenig (1983) equation shown in Table 6 was derived from fish species only. The "rule of thumb" method has a long history in fisheries science, but it is difficult to pin down its source. Hewitt and Hoenig (2005) are referenced, who compare this approach to that of Hoenig (1983). Finally, we investigated the newest approach (Then et al. 2015) herein as a method for the development of age-constant natural mortality. This approach represents the development of a more robust data set and a more thorough vetting of potential studies for inclusion than originally proposed by Hoenig (1983), including data from over 200 species representing a broader range of life histories and inhabiting a wider range of habitats.

It was assumed that red drum close to their true maximum age were caught by the long-term adult red drum sampling programs in the north and south regions, allowing *M* to be estimated by the Then et al. (2015) method. The maximum observed age was 62 years in the northern stock and 41 years in the southern stock.

Though the Hoenig method was favored in previous red drum assessments (SEDAR 44; ASMFC 2017b), the revised maximum age based estimator presented by Then et al. (2015) is now recommended as the best estimator of age-constant natural mortality (Then et al. 2015; Hoenig et al. 2016; Hoenig 2017), and as such was the primary age-constant natural mortality estimator considered in the current assessment. A notable property of the Then et al. (2015) estimator relative to the Hoenig (1983) estimator is that for a given maximum age it will always provide a higher estimate of age-constant M. The Then et al. (2015) estimates of age-constant *M* are 0.11 and 0.16 for the northern and southern stocks, respectively. In comparison, the Hoenig (1983) estimates of age-constant *M* are 0.07 and 0.10 for the given maximum ages in the north and south regions, respectively. This implies the Then et al. (2015) estimators are 67.7% and 61.6% greater than the age-constant M estimates assumed for the northern and southern stocks during SEDAR 44, respectively.

2.5.2 Age-Varying M Approaches

In many stock assessments, constant values for M have been obtained from life history analogies (e.g., maximum age, growth rate parameters) based on the aforementioned empirical studies. However natural mortality is known to scale with body mass and size, resulting in higher M at earlier life stages and lower M as adults (Lorenzen 1996). This is driven by the generality that smaller fish, of a given species, are more vulnerable to death from predation and resource limitations. Several approaches have been considered to provide such size-varying estimates of natural mortality (Lorenzen 1996; Lorenzen 2000; Gislason et al. 2010; Charnov et al. 2013).

For purposes of stock assessments, sizes are related to age to provide age-varying estimates of natural mortality. Herein, consistent with SEDAR 44, we employed the Lorenzen (1996) ocean fit equation for estimating age-varying *M*, scaling the raw age-specific estimates of *M* from age-0 through the maximum age based on the Then et al. (2015) age-constant *M* (where % survival = $100 * e^{-M*t_{max}}$), as described in Hewitt and Hoenig (2005). Length-at-age was estimated using the red drum age-specific K growth models (see Section 2.3) with age-specific M estimates using mid-year lengths from said growth model. Length was then converted to weight-at-age using region-specific weight-length relationships, as reported in SEDAR 44 (Table 39). The Then et al. (2015) based estimate of M for the northern stock was 0.11, which produces a scaling to 0.10% survival from age 0 through age 62. The Then et al. (2015) based estimate of M for the southern stock was 0.16, which produces a scaling to 0.12% survival from age 0 through age 41.

The resulting un-scaled and scaled age-varying M estimates used in the simulation models are provided in Table 7 and Figure 13.

3 HABITAT DESCRIPTION

Habitat information for red drum is summarized from a comprehensive report on sciaenid species habitat information completed by the ASMFC (Odell et al. 2017). See this report for additional detail on red drum habitat.

3.1 Spawning, Egg, and Larval Habitat

<u>*Spawning Habitat*</u>

Red drum spawn from late summer to late fall in a range of habitats, including estuaries, near inlets, passes, and near bay mouths (Peters and McMichael 1987). Earlier studies illustrated spawning often occurred in nearshore areas relative to inlets and passes (Pearson 1929; Miles 1950; Simmons and Breuer 1962; Yokel 1966; Jannke 1971; Setzler 1977; Music and Pafford 1984; Holt et al. 1985). More recent evidence suggests that in addition to nearshore vicinity habitats, red drum also use high-salinity estuarine areas along the coast (Murphy and Taylor 1990; Johnson and Funicelli 1991; Nicholson and Jordan 1994; Woodward 1994; Luczkovich et al. 1999; Beckwith et al. 2006). Direct evidence of red drum spawning has been documented deep within estuarine waters of the IRL, Florida (Murphy and Taylor 1990; Johnson and Funicelli 1991). More recently, an intensive two-year ichthyoplankton survey consistently collected preflexion (2–3 mm) red drum larvae up to 90 km away from the nearest ocean inlet from June to October with average nightly larval densities as high as 15 per 100 m^3 of water in the IRL (Reyier and Shenker 2007). Acoustic telemetry results for large adult red drum in the IRL further support estuarine spawning of this species within the IRL system (Reyier et al. 2011).

Spawning in laboratory studies have also appeared to be temperature-dependent, occurring in a range from 22° to 30°C but with optimal conditions between temperatures of 22° to 25°C (Holt et al.1981). Renkas (2010) was able to duplicate environmental conditions of naturally spawning red drum from Charleston Harbor, SC in a mariculture setting, and corroborated that active egg release occurred as water temperature dropped from a peak of ~30° C during August. Cessation of successful egg release was found at 25°C, with no spawning effort found at lower temperatures (Renkas 2010). Pelagic eggs, embryos, and larvae are transported by currents into nursery habitats for egg and larval stages, expectedly due to higher productivity levels in those environments (Peters and McMichael 1987; Beck et al. 2001).

Eggs and Larvae Habitat

Red drum eggs have been commonly encountered in several southeastern estuaries in high salinity, above 25 ppt (Nelson et al. 1991). Salinities above 25 ppt allow red drum eggs to float while lower salinities cause eggs to sink (Holt et al. 1981). In Texas, laboratory experiments conducted by Neill (1987) and Holt et al. (1981) concluded that an optimum temperature and salinity for the hatching and survival of red drum eggs and larvae was 25°C and 30 ppt. Spatial distribution and relative abundance of eggs in estuaries, as expected, mirrors that of spawning adults (Nelson et al. 1991); eggs and early larvae utilize high salinity waters inside inlets, passes, and in the estuary proper. Currents transport eggs and pelagic larvae into bays, estuaries and seagrass meadows (when present), where they settle and remain throughout early and late juvenile stages (Holt et al. 1983; Pattillo et al. 1997; Rooker and Holt 1997; Rooker et al. 1998; Stunz et al. 2002).

Larval size generally increases as distance from the mouth of the bay increases (Peters and McMichael 1987), possibly due to increased nutrient availability. Research conducted in Mosquito Lagoon, Florida, by Johnson and Funicelli (1991) found viable red drum eggs being collected in average daily water temperatures from 20°C to 25°C and average salinities from 30 to 32 ppt. During the experiment, the highest numbers of eggs were gathered in depths ranging from 1.5 to 2.1 m and the highest concentration of eggs was collected at the edge of the channel.

Upon hatching, red drum larvae are pelagic (Johnson 1978) and laboratory evidence indicates development is temperature-dependent (Holt et al. 1981). Newly hatched red drum spend approximately twenty days in the water column before becoming demersal (Rooker et al. 1999; FWCC 2008). However, Daniel (1988) found much younger larvae already settled in the Charleston Harbor estuary. Transitions are made between pelagic and demersal habitats once settling in the nursery grounds (Pearson 1929; Peters and McMichael 1987; Comyns et al. 1991; Rooker and Holt 1997). Tidal currents (Setzler 1977; Holt et al. 1989) or density-driven currents (Mansueti 1960) may be used in order to reach a lower salinity nursery in upper areas of estuaries (Mansueti 1960; Bass and Avault 1975; Setzler 1977; Weinstein 1979; Holt et al. 1983; McGovern 1986; Peters and McMichael 1987; Daniel 1988; Holt et al. 1989). Once inhabiting lower salinity nurseries in upper areas of estuaries, red drum larvae grow rapidly, dependent on present environmental conditions (Baltz et al. 1998).

Red drum larvae along the Atlantic coast are common in southeastern estuaries, with the exception of Albemarle Sound, and are abundant in the St. Johns and IRL estuaries in Florida (Nelson et al. 1991). Daniel (1988) and Wenner et al. (1990) found newly recruited larvae and juveniles through the Charleston harbor estuary over a wide salinity range. Mercer (1984) has also summarized spatial distribution of red drum larvae in the Gulf of Mexico. More recent studies conducted by Lyczkowski-Shutlz and Steen (1991) reported evidence of diel vertical stratification among red drum larvae found at lower depths less than 25 m at both offshore and nearshore locations. Larvae (ranging between 1.7 to 5.0 mm mean length) were found at lower depths at night and higher in the water column during the day. At the time of the study, water was well mixed and temperature ranged between 26° and 28°C. There was no consistent relationship between distribution of larvae and tidal stage. Survival during larval (and juvenile) stages in marine fish, such as the red drum, has been identified as a critical bottleneck determining their contribution to adult populations (Cushing 1975; Houde 1987; Rooker et al. 1999).

3.2 Juvenile and Adult Habitats

Juvenile Habitat

Juvenile red drum use a variety of inshore habitats within the estuary, including seagrass meadows, tidal freshwater, low-salinity reaches of estuaries, estuarine emergent wetlands, estuarine scrub/shrub, submerged aquatic vegetation, oyster reefs, shell banks, and unconsolidated bottom (SAFMC 1998b; Odell et al. 2017). Smaller red drum seek out and inhabit rivers, bays, canals, boat basins, and passes within estuaries (Peters and McMichael 1987; FWCC 2008). Wenner (1992) indicated red drum juvenile habitats vary slightly seasonally; most often between August and early October, red drum inhabit small creeks that cut into emergent marsh systems and have some water in them at lower tides, while in winter, red drum reside in main channels of rivers ranging in depths from 10 to 50 feet with salinities from one-half to two-thirds that of seawater. In the winter of their first year, 3 to 5 month old juveniles migrate to deeper, more temperature-stable parts of the estuary during colder weather (Pearson 1929). In the spring, they move back into the estuary and shallow water environments. Studies show red drum inhabiting non-vegetated sand bottoms exhibit the greatest vulnerability to natural predators (Minello and Stunz 2001). Juvenile red drum in their first year generally avoid wave action by living in more protected waters (Simmons and Breuer 1962; Buckley 1984).

In the Chesapeake Bay, juveniles (20-90 mm TL) were collected in shallow waters from September to November, but there is no indication as to the characteristics of the habitat (Mansueti 1960). Some southeastern estuaries where juvenile (and sub-adult) red drum are abundant are Bogue Sound, NC; Winyah Bay, SC; Ossabaw Sound, and St. Catherine/Sapelo Sound, GA; and the St. Johns River, FL (Nelson et al. 1991) and throughout SC (Wenner et al. 1990; Wenner 1992). They were highly abundant in the Altamaha River and St. Andrews/St. Simon Sound, GA, and the Indian River, FL (Nelson et al. 1991).

Peters and McMichael (1987) found in Tampa Bay that juvenile red drum were most abundant in protected backwater areas, such as rivers, tidal creeks, canals, and spillways with freshwater discharge, as well as in areas with sand or mud bottom and vegetated or non-vegetated cover. Juveniles found at stations with seagrass cover were generally smaller in size and fewer in number (Peters and McMichael 1987). Near the mouth of the Neuse River, as well as smaller bays and rivers between Pamlico Sound and the Neuse River, surveys from the NCDMF indicate juvenile red drum were consistently abundant in shallow waters of less than 5 feet. Generally, habitats identified as supporting juvenile red drum in North Carolina can be characterized as detritus laden or mudbottom tidal creeks (in Pamlico Sound) and mud or sand bottom habitat in other areas (Ross and Stevens 1992). In a Texas estuary, young red drum (6-27 mm Standard Length, SL) were never present over non-vegetated muddy-sandy bottom; areas most abundant with red drum occurred in the ecotone between seagrass and non-vegetated sand bottom (Rooker and Holt 1997). In SC, Wenner (1992) indicated very small red drum occupy small tidal creeks with mud/shell hash and live oyster as common substrates (since sub-aquatic vegetation is absent in SC estuaries).

Sub-Adult Habitat

The distribution of red drum within estuaries varies seasonally as individuals grow and begin to disperse. Along the South Atlantic coast, they use a variety of inshore habitats. Late juveniles leave shallow nursery habitats at approximately 200 mm TL (10 months of age). They are considered sub-adults until they reach sexual maturity at 3–5 years (C. Wenner, personal communication). It is at this life stage that red drum use a variety of habitats within the estuary and when they are most vulnerable to exploitation (Pafford et al. 1990; Wenner 1992). Tagging studies conducted throughout the species' range indicate most sub-adult red drum tend to remain in the vicinity of a given area (Beaumarriage 1969; Osburn et al. 1982; Music and Pafford 1984; Pafford et al. 1990; Wenner et al. 1990; Ross and Stevens 1992; Woodward 1994; Marks and DiDomenico 1996; Adams and Tremain 2000). Movement within the estuary is most likely related to changes in temperature and food availability (Pafford et al. 1990; Woodward 1994).

Tagging studies indicate late age-0 and 1 year-old red drum are common throughout the shallow portions of the estuaries and are particularly abundant along the shorelines of rivers and bays, in creeks, and over grass flats and shoals of the sounds. During the fall, those sub-adult fish inhabiting the rivers move to higher salinity areas such as the grass flats and shoals of the barrier islands and the front beaches. With the onset of winter temperatures, juveniles leave the shallow creeks for deeper water in the main channels of rivers (9–15 m) and return again to the shallows in the spring. Fish that reside near inlets and along the barrier islands during the summer are more likely to enter the surfzone in the fall.

By their second and third year of growth, red drum are less common in rivers but are common along barrier islands, inhabiting the shallow water areas around the outer bars and shoals of the surf and in coastal inlets over inshore grass flats, creeks or bays. In the northern portion of the South Carolina coast, sub-adults use habitats of broad, gently sloping flats (up to 200 m or more in width). Along the southern part of the South Carolina coast, sub-adult red drum inhabit narrow (50 m or less), fairly level flats traversed by numerous small channels, typically 5–10 m wide by less than 2 m deep at low tide (ASMFC 2002).

In general, habitats supporting juvenile red drum can be characterized as detritus or mud-bottom tidal creeks as well as sand and shell hash bottoms (Daniel 1988; Ross and Stevens 1992). Within seagrass beds, investigations have shown juveniles prefer areas with patchy grass coverage or sites with homogeneous vegetation (Mercer 1984; Ross and Stevens 1992; Rooker and Holt 1997). Wenner et al. (1990) collected post-larval and juvenile red drum in South Carolina from June 1986 through July 1988 in shallow tidal creeks with salinities of 0.8–33.7 ppt, although the preferred salinity range in the IRL, Florida is between 19–29 ppt (Tremain and Adams 1995).

Adult Habitat

Overall, adults tend to spend more time in coastal waters after reaching sexual maturity. However, they do continue to frequent inshore waters on a seasonal basis. Less is known about the biology of red drum once they reach the adult stage and accordingly, there is a lack of information on habitat utilization by adult fish. The SAFMC's Habitat Plan (SAFMC 1998b) cited high salinity surf zones and artificial reefs as EFH for red drum in oceanic waters, which comprise the area from the beachfront seaward. In addition, nearshore and offshore hard/live bottom areas have been known to attract concentrations of red drum.

In addition to natural hard/live bottom habitats, adult red drum also use artificial reefs and other natural benthic structures. Red drum were found from late November until the following May at both natural and artificial reefs along tide rips or associated with the plume of major rivers in Georgia (Nicholson and Jordan 1994). Data from this study suggests adult red drum exhibit high seasonal site fidelity to these features. Fish tagged in fall along shoals and beaches were relocated 9–22 km offshore during winter and then found back at the original capture site in the spring. In summer, fish moved up the Altamaha River nearly 20 km to what the authors refer to as “pre-spawn staging areas” and then returned to the same shoal or beach again in the fall. Adult red drum inhabit high salinity surf zones along the coast and adjacent offshore waters, at full marine salinity. Adults in some areas of their range (e.g., IRL, FL) can reside in estuarine waters year-round, where salinities are variable.

4 FISHERY-DEPENDENT DATA SOURCES

Red drum fisheries are primarily recreational and, since the 1990s, exclusively so in the southern states (South Carolina, Georgia, Florida). Some commercial catch continues in northern states, but typically as bycatch in fisheries directed at other species. Fishery-dependent data are presented by fleet and stock designations determined in previous stock assessments. In the northern stock, most commercial and recreational catch comes from North Carolina waters, followed by Virginia, with low and variable catches north of Virginia. There have been similar regulation histories in North Carolina and Virginia, so northern stock fleets cover catches from all states. There are two commercial fleets based on gear differences: a gill net and beach seine fleet (referred to as the North_Commercial_GNBS fleet in Sections 6-8) and a fleet including catch from other commercial gears (primarily pound nets; referred to as the North_Commercial_Other fleet in Sections 6-8). There is also a recreational fleet accounting for catch by recreational anglers using hook and line gear (referred to as the North_Recreational fleet in Sections 6-8). The three states in the southern stock have had different regulations through time and all regularly contribute to annual red drum catches. Past assessment have had time series starting after most of the commercial catch of red drum was phased out, so there are three recreational fleets accounting for catch by recreational anglers using hook and line gear in each of the three southern stock states (referred to as the SC_Recreational, GA_Recreational, and FL_Recreational fleets in Sections 6-8). Southern stock commercial catch is presented here, but has not been included in unique fleets in past stock assessments.

4.1 Commercial Data

4.1.1 Data Collection and Treatment

4.1.1.1 Commercial Landings

Historical 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. The Data Warehouse was queried in August 2020 for all red drum landings (monthly summaries by state and gear category) from 1950 to 2019 for the east coast of Florida (Miami-Dade/Monroe County border), and all other Atlantic states. Gear categories were based on those used in SEDARs 18 and 44, and are based on knowledge of Atlantic coast red drum fisheries and reporting tendencies. The specific ACCSP gears included in each category can be found in Table 8. Landings from gear categories for the northern stock are aggregated into two groupings for presentation and use in this assessment based on expected similarities in selectivity among gears within each grouping and differences in selectivity between the two groupings. The first grouping includes the Beach Seine and Gill Nets SEDAR gear categories (GNBS fleet) and the second grouping includes the Hook and Line, OTHER, Pound Net, Seine, and Trawls SEDAR gear categories (Other fleet). Landings for the southern stock are aggregated by state, the structure of recreational fleets in this stock, for presentation and use in this assessment.

Landings data from ACCSP were reviewed and approved by state representative partners. In cases where discrepancies occurred, data directly from state databases was preferred to ACCSP Data Warehouse values. This included North Carolina data from 1994-2019 due to better gear allocation in NC trip ticket databases. Virginia harvester reports were used for 1993-2019 due to concerns on gear and area designations. New Jersey provided a custom data set for 2014-2019 containing catch used in direct sale from fishers. New York and Delaware both provided additional landing reports. Florida’s commercial fishery ended in 1988, and between 1978 and 1988, reported gears are unreliable. Consistent with SEDAR 44, ACCSP staff extrapolated average gear proportions for Florida gears from 1962-1977 and applied those proportions to 1978-1988.

Landings data collection through time by states accounting for at least 1% of coastwide landings since 1950 are discussed below and are summarized for all Atlantic states in Table 9.

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 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 put in monthly folders and submitted to VMRC. The monthly folders are provided by the VMRC and due by the 5th of the following month.

North Carolina

The NMFS, prior to 1978, collected commercial landings data for North Carolina. Port agents would conduct 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) in a given fishery that was not available prior to 1994 and provides a much more detailed record of North Carolina's seafood harvest. Annual landings of red drum were calculated for North Carolina and reported in pounds (whole weight) broken down by month and gear categories developed by the SEDAR 18 Commercial Workgroup. The annual landings are reported on an annual basis of January through December. Data used to calculate the annual landings for North Carolina from 1950 to 2019 included landings from the NCTTP (1994 to 2019), landings from NMFS (1978 to 1993), and landings from historical data (prior to 1978). Prior to 1972, monthly landings were not recorded for North Carolina.

North Carolina also has landings from the recreational use of commercial gear allowed through the possession of a recreational commercial gear license (RCGL). This license allows for limited use of commercial gear to obtain fish for personal consumption. No sale is allowed with this license. Additionally, users must adhere to recreational bag limits. In order to estimate landings with this gear, North Carolina conducted a random survey of license holders from 2002 to 2007. Questionnaires were mailed to 30% of license holders each month. Information was obtained on locations fished, gears used, species kept and species discarded. A ratio to commercial gillnet landings was used to estimate landings in years before and after the survey.

South Carolina

Prior to 1972, commercial landings data were collected by various federal fisheries agents based in South Carolina, either U.S. Fish and Wildlife Service or NMFS personnel. In 1972, South Carolina began collecting landings data from coastal dealers in cooperation with federal agents. Mandatory monthly landings reports on forms supplied by the DNR are 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. At a minimum, effort data includes gear types and quantity, location, and hours fished. Catch data includes species, disposition of catch, and quantity (lbs) landed. Finally economic data includes the wholesale price paid to fishermen.

Given commercial harvest of red drum has been prohibited in South Carolina since June 1987, the history of red drum landings in South Carolina are not very large (Table 10), particularly relative to other states, with the largest documented landings occurring the year the commercial fishery was shut down (1987). Note, South Carolina has had some very small amount of reported illegal harvest of red drum since their designation as a gamefish.

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.

A small-scale gillnet fishery for red drum existed in the 1950s; however, the use of gillnets in Georgia's territorial waters was prohibited by statute in 1957. Since that time the commercial fishery for red drum was comprised predominately of hook and line recreational anglers and for-hire fishers that sell their catch. This catch was often sold directly to restaurants and not documented in commercial landings reporting. These landings are considered recreational (i.e., captured in the recreational catch survey – see Section 4.2.1) and all sale was restricted to the recreational bag limit. Red drum were granted game-fish status in 2013 thereby making commercial sale illegal.

Florida

Commercial landings information was obtained from the FL FWC's Marine Fisheries Information System data and from the Fisheries Statistics Division of the NMFS for the years 1950 to 1988. No commercial landings have been reported for Florida since 1988 when the sale of native-caught red drum was prohibited.

Prior to 1986, landings of red drum 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 who 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. In addition, red drum became a "restricted species" in late 1987 so only fishers who had Restricted Species Endorsements on their Saltwater Products License qualified to sell red drum (though commercial fishing effectively ended shortly after this in 1989). 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.

The commercial fishery for red drum in Florida ended in 1989 when a 'no sale' provision was enacted into law.

4.1.1.2 Commercial Discards

Currently, the only available data to describe commercial discards are from an observer program for the North Carolina estuarine gill net fishery for the period of 2004 to 2006 and 2008 to 2019. The North Carolina estuarine gill net fishery is presumed to be the primary culprit of commercial red drum discards in North Carolina. Gill nets typically account for >90% of red drum commercial harvest in North Carolina. In SEDAR 18 and the ASFMC 2017 assessments, discard estimates were calculated by area and season for both large and small mesh gill nets. Large mesh gill nets were defined as having a stretched mesh webbing of five inches or greater. CPUE was defined as the number (or weight) of dead red drum observed per trip. In addition, a release mortality (5%; consistent with SEDAR 18) was added for red drum released alive. Total gill net trips taken using estuarine gill nets in North Carolina were available through the NCTTP. Extrapolation by area and season was accomplished by multiplying the observed CPUE by the number trips made for either large or small mesh gill nets. Direct estimates from gill net observer data were available for the years of 2004 to 2006 and for 2008 to 2013. From these years, a ratio of harvest to discards was calculated and used to estimate discards in the remaining years.

For the current assessment, discard estimates were estimated using a generalized linear model (GLM) framework to predict red drum discards in North Carolina's estuarine gill-net fishery based on data collected during 2004 through 2019. This model used effort data from the NCTTP and discard data from the observer program (Table 11). Only those variables available to both data sources could be considered as potential covariates in the model. Available variables included mesh size, year, season and area; these were all treated as categorical variables in the model. Mesh sizes were categorized as large (≥5 inches) or small (<5 inches). Effort was measured as soak time (days) multiplied by net length (yards). Live and dead discards were modeled separately.

All available covariates were included in the initial model and assessed for significance using the appropriate statistical test. Non-significant covariates were removed using backwards selection to find the best-fitting predictive model. In this case, all covariates were significant. The offset term was included in the model to account for differences in fishing effort among observations (Crawley 2007; Zuur et al. 2009; Zuur et al. 2012). Using effort as an offset term in the model assumes that the number of red drum discards is proportional to fishing effort (A. Zuur, Highland Statistics Ltd., pers. comm.).

The best-fitting model was a negative binomial GLM that included mesh size, year, season and area as significant covariates for modeling both the live (dispersion = 3.2) and dead discards (dispersion = 1.7) in numbers. Results of the GLM provided discard estimates that were similar to those direct estimates derived from the extrapolation method used in prior assessments (Figure 14). Data for the GLM were unavailable prior to 2004, the year the NC gill net observer program began. For this reason, a ratio of harvest to discards was calculated and used to estimate discards in the remaining years consistent with the prior assessment.

Red drum released alive were assumed to have a 5% mortality consistent with assumptions of prior assessments.

4.1.1.3 Biological Sampling

Maryland

The Maryland Department of Natural Resources (MD DNR) has monitored commercial pound nets primarily in the Chesapeake Bay and mouth of the Potomac River since 1993. No cooperating fishermen could be located on the Potomac River in 2009 and sampling was not conducted in this area that year, but resumed in 2010. The lower portions of other rivers such as the Nanticoke and Honga Rivers have been sampled sporadically depending on year. Each site was generally sampled once every two weeks from May - September, weather and fisherman's schedule permitting. The commercial fishermen set their nets as part of their regular fishing activity. Net soak time and manner in which they were fished were consistent with the fisherman's day-to-day operations. All red drum captured were measured to the nearest mm TL (maximum or pinched). Other data collected includes water temperature (°C), salinity (ppt), and soak time (duration in minutes).

Red drum have been encountered sporadically throughout the 27 years of the commercial pound net survey, with none measured in nine years of the time series. Sixty-one percent of all red drum recorded by this survey were measured in 2012 (458 fish), a year of unusually high presence of red drum in the Chesapeake Bay. TL of red drum has ranged from 187 - 1332 mm, though almost all individuals encountered by this survey were outside of the commercial slot limit (18”-25”). None of the 458 red drum sampled in 2012 were of legal size.

Virginia

Commercial length frequency data were obtained by the VMRC Biological Sampling Program (BSP). Red drum lengths and weights were collected at local fish houses by gear, area fished, and individual watermen.

Fish were measured for both TL and FL (mm) and individual weight (nearest 0.01 lb). Typically in this program, otoliths, as well as sex and maturity data, are collected from a subsample of fish encountered. However, due to the infrequency of red drum encounters, sampling is more opportunistic and all fish encountered by technicians are sampled. Similarly, a subsample of collected age samples would be selected for full ageing, but with red drum our ageing lab processes every otolith collected due to their typically small sample size.

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 red drum were landed. Fishery-dependent length frequency data collection for red drum in Virginia began in 1989. Red drum sampling events have remained relatively infrequent throughout the lifetime of the program, but sampling does occur in a representative manner annually. Virginia has collected 2,548 length and 794 age samples since 1989, averaging 79 lengths and 25 ages on a yearly basis.

North Carolina

Commercial length frequency data were obtained by the NCDMF commercial fisheries-dependent sampling program. Red drum lengths were collected at local fish houses by gear, market grade (not typical for red drum), and area fished.

Individual fish were measured (mm, FL) 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 red drum were landed. Fishery-dependent length frequency data collection for red drum in North Carolina began in the early 1980s. Data adequate to describe the major fisheries is available beginning in 1989.

Since the late 1980s North Carolina has been the major commercial harvester of red drum, typically accounting for >90% of the coastwide annual commercial landings. Since 1989, greater than 100 lengths have been obtained annually with the majority coming from the primary gear used to harvest red drum, gill nets, followed by pound nets and haul seines (Table 12).

Lengths of discarded fish have also been recorded by observers during the observer program (Table 11). Number of lengths collected annually have ranged from 98 (2011) to 1,929 (2013).

South Carolina

Given the nature of the SCDNR commercial sampling program, the ban on commercial harvest of red drum in South Carolina since June 1987, and the lack of length sampling of the commercial harvest, there is limited to no length information available on the lengths of commercially harvested fish from South Carolina.

4.1.1.4 Catch Composition

Length distributions for North Carolina commercial landings were derived from length data provided from commercial fish house sampling. All length distributions were described annually in two-centimeter length bins with the length bin provided representing the floor (i.e., 46 cm = 46.0 to 47.99 cm). A minimum of 20 lengths by year and gear were required to represent the length distribution of a gear. Collapsing, when necessary, occurred across gears within a year. For hook and line gears, length frequency distributions from the recreational fishery (see Section 4.2.1) were used as a proxy. Prior to 1989, sample sizes were sparse and were not considered adequate to describe the fishery. For this reason, the previous red drum assessment began with 1989 as the beginning year for all catch-at-age data. Since 1989, sampling was adequate for the vast majority of the landings (i.e., gill net landings in North Carolina) and pooling was limited to minor gears/landings (Table 12).

Conversion of North Carolina commercial landings in weight to numbers was based on mean weights obtained from the commercial fish house sampling. In the rare instance when sample sizes were inadequate (n<20) by gear and year, a weighted average was obtained by pooling across gears within a year. For hook and line gears, mean weights from the recreational fishery (see Section 4.2.1) were used as a proxy. Landings in numbers are reported in Table 13.

An annual age length key representing the North Carolina catch was developed using all available age data from North Carolina. Any "holes" in the age-length key were filled using a pooled (across all years) key.

4.1.1.5 Catch Rates

Trip level commercial data were available from North Carolina (1994 to 2019) and Virginia (1993 to 2019), however, catch effort data from the red drum commercial fishery were confounded by trip limits put into place in 1992 for Virginia and in 1998 for North Carolina. Trip level information was also available in Florida but only for the years 1986 to 1988. After 1988, the sale of native caught red drum in Florida became prohibited.

4.1.2 Trends

4.1.2.1 Commercial Landings

Northern Stock

Northern stock red drum landings by the commercial gillnet and beach seine (GNBS) fleet were primarily landed with beach seines in the 1950s and early 1960s (Figure 15). Total landings were highest in the early 1950s, averaging 206,220 lbs. from 1950-1954, then declined to the lowest levels of the time series in the late 1960s (minimum of 1,400 lbs. in 1969). Landings then increase and transition to coming from mostly gill nets in the 1980s. Landings have varied without much discernible trend since the 1980s, averaging 137,186 lbs from 1980-2019.

Northern stock red drum landings by the commercial fleet fishing other gears decline from the earliest years to low levels in the late 1960s (Figure 16). Landings then increase to higher levels in the 1970s and 1980s, averaging 80,870 lbs. Landings decline through the 1990s and remain at lower levels during recent years, averaging 15,136 lbs. since 2000. Pound nets have accounted for a large proportion of the total landings throughout the time series, while trawls accounted for large proportions in the early 1950s and 1980s. Seines also accounted for a large proportion of landings from the 1960s through 1990s.

Estimated landings from RCGL gill nets in North Carolina ranged from a high of 23,136 pounds in 1999 to a low of 2,408 pounds in 1997 (Table 14). 2013 was the second highest estimate in the time series.

Overall, northern stock red drum landings were consistently high in the early 1950s, averaging 307,040 lbs. from 1950-1954, then decreased through the 1960s to time series lows (minimum of 5,000 lbs. in 1969, Figure 17). Landings increased through the 1970s and 1980s and have shown high interannual variability since, ranging from 58,951 lbs. in 1997 to 429,654 lbs. in 2013. The GNBS fleet accounted for most of the commercial red drum landings in the northern stock in the beginning of the time series through the mid-1960s. The other gear commercial fleet became a primary contributor to landings in the mid-1960s through the 1970s when seines accounted for a large proportion of this fleets landings. Landings by the other gear fleet then decline and commercial landings have come primarily from the GNBS fleet since the 1990s. The RCGL landings have accounted for ≈5% of landings (9,278 lbs.), on average, since these data have been available (1989).

Southern Stock

Overall, southern stock red drum commercial landings were highest during the 1950s when all southern states made significant contributions to the landings, averaging 204,986 lbs. from 1950-1956 (Figure 18). Landings then declined to low, stable levels and came mostly from Florida as South Carolina and Georgia made only minor contributions. Landings averaged 136,333 lbs. from 1957-1984. During the mid-1980s the commercial fisheries faced tightening restrictions resulting in declining landings prior to being prohibited in Florida after 1987. Commercial landings from the southern stock were, for the most part, phased out by 1989.

4.1.2.2 Commercial Discards

Northern Stock

Total commercial discards from North Carolina gill net fisheries have generally varied without any discernable trend throughout the time series (Figure 14). Total dead discards averaged 18,759 fish from 2004-2019 and ranged from 2,452 fish in 2011 to 68,862 fish in 2013 (Table 11).

4.1.2.3 Catch Composition

Northern Stock

Length distributions for North Carolina are presented by major gears in Table 15. For the length distributions, all gears showed a notable shift towards larger fish, particularly after 1991 when North Carolina implemented a minimum size limit change from 14 to 18 inches TL (Figure 19). Likewise, the harvest of larger red drum has declined as harvest and sale of federally harvested adult red drum became illegal after 1992 in North Carolina.

The majority of discarded lengths observed in the estuarine gill net fishery were from fish below the minimum size limit of 18 inches TL (approximately 44 cm FL) with some discards occurring within the slot likely due to exceeding the daily trip limit and fewer over the slot limit (Figure 20).

The North Carolina catch-at-age for all removals is provided in Table 16. Similar to shifts in the length distributions, a notable shift in the age distribution from age-1 to age-2 fish was noted in 1992. Current commercial harvest of red drum within the existing slot limits is primarily on age-2 and to a lesser extent age-1 and age-3 fish.

4.1.3 Potential Biases, Uncertainty, and Measures of Precision

Collection of commercial landings data has been designed as a census to capture total landings, but methods to collect these data have changed through time likely leading to changes in uncertainty. There are no quantitative measures of uncertainty accompanying commercial landings data, but Table 9 shows changes to landings data collection methodology by state through time. Each methodology is anticipated to be an improvement to the data collection methodology that preceded it. Commercial landings data uncertainty was an issue addressed during a Best Practices Workshop convened by SEDAR (SEDAR 2015b). The recommendation produced from this workshop was to assume uncertainty decreases as the data collection methodology changes through time, resulting in time blocks of decreasing uncertainty levels from historic to current data collection methods.

4.2 Recreational

4.2.1 Marine Recreational Information Program

4.2.1.1 Introduction and Methodology

The primary source of red drum 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 strata 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.

Biological data collected during the APIAS sampling include FL 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.

Two significant changes have occurred to the MRIP survey methodologies based on external reviews and recommendations through 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. Since the last red drum stock assessment occurred before the effort survey change, historical estimates prior to 2013 used in that assessment were calibrated to correct for the APAIS redesign in 2013, but all estimates used in the previous assessment were based on CHTS effort data. 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 and this is the first assessment to report these calibrated red drum catch estimates. The FES generally results in significant increases in effort estimates and, therefore, total catch estimates relative to the CHTS.

4.2.1.2 Trends

4.2.1.2.1 Catch Rates

In addition to being used for total catch estimation, catch rate data collected during APAIS sampling have been used to generate relative indices of abundance for past red drum stock assessments and as such were updated for this simulation assessment. Both nominal indices and indices standardized to account for factors affecting nominal catch rates are calculated, with the latter used in past stock assessment models. Methods to generate these indices are described in Appendix 1.

Northern Stock

In the northern stock, catch rates decreased from 1991 – 1996, then increased and became variable around a higher mean from 1997 – 2019 (Figure 21). Catch rates were highest in 2012 and lowest in 1996. Nominal catch rates largely trended with the standardized catch rates and were just outside the standardized confidence intervals.

Southern Stock

In the southern stock, standardized catch rates were variable with an increasing trend across the time series (Figure 22). Nominal catch rates largely agreed in trend with the standardized catch rates and were mostly within the standardized confidence intervals. However, the standardized index predicted a slightly lower rate of increase over time compared to the nominal index.

4.2.1.2.2 Total Catch

Investigated herein were harvest, numbers released, dead discards, and total removals (harvest + dead discards) annually. Dead discards, and subsequently total removals, were calculated based on an 8% discard mortality rate for recreationally captured and released red drum, consistent with SEDAR 18 and SEDAR 44.

Total Harvest

Northern Stock

The change to effort estimation methodology resulted in a significant increase in calibrated harvest estimates (Figure 23), but had less impact on trend of estimates. With calibrations applied for both the APAIS changes and effort survey methodology changes, estimates increased an average of 182% (≈150,000 fish) during the time series of the replaced, telephone-based CHTS (1981-2017).

Harvest from the northern stock was relatively high in the 1980s, decreased significantly in 1990, and remained at these lower levels through the mid-2000s (Figure 24). Harvest then increased through the remainder of the time series, including the three highest annual harvests during the time series (2013, 2014, and 2017). Interannual harvest is highly variable reflecting year class strength in this recruitment-based fishery.

Proportional standard error (PSE) for harvest estimates is higher in the 1980s, exceeding 40% in three years and 60% in one year (Figure 25). PSEs then decline and remain below 40%. Estimates with PSEs below 40% are considered valid inputs for stock assessment models, while estimates with values between 40% and 60% should be used with caution, and any estimates with PSEs >60% should be used with extreme caution (ACCSP 2016). Harvest estimates with confidence intervals are provided in Figure 26.

Southern Stock

The change to effort estimation methodology resulted in a significant increase in calibrated harvest estimates for all three southern stock states (Figure 27). The change had less impact on trend of estimates, with some exception during recent years in South Carolina and Georgia. With calibrations applied for both the APAIS changes and effort survey methodology changes, estimates increased an average of 164% (≈175,000 fish), 151% (≈115,000 fish), and 253% (≈420,000 fish) in South Carolina, Georgia, and Florida, respectively, during the time series of the replaced, telephone-based CHTS (1981-2017).

Patterns of harvest from states in the southern stock have been similar to the northern stock, with higher harvest early in the time series, lower harvest in the middle of the time series, and higher harvest in recent years (Figure 28). Florida has accounted for the most harvest, followed by South Carolina and then Georgia.

Patterns in PSEs have been similar in Georgia and Florida, with higher PSEs, a few exceeding 40% and 60% (in Florida), into the early 1990s and then lower PSEs (all <40%) since (Figure 29). PSEs for South Carolina harvest also start high, with some exceeding 40% and 60% in the 1980s, and, although all except in 1995 are <40%, are more variable in recent years than in the other states. Harvest estimates with confidence intervals are provided in Figure 30.

Total Discards

Northern Stock

The change to effort estimation methodology resulted in a significant increase in calibrated released alive estimates (Figure 31). The change had less impact on trend of estimates, but did show some divergence in the most recent years. With calibrations applied for both the APAIS changes and effort survey methodology changes, estimates increased an average of 168% (≈900,000 fish) during the time series of the replaced, telephone-based CHTS (1981-2017).

Red drum released alive in the northern stock accounted for a smaller proportion of total catch in the 1980s, but then increased through the remainder of the time series and account for an increasing majority of total catch (Figure 24). Assuming an 8% discard mortality due to catch, consistent with past stock assessments, dead discards account for a similar proportion of catch as the harvest since the late 1990s.

PSEs for discarded catch are high in the 1980s and regularly exceed 60% (Figure 25). PSEs then decline to levels lower than 40% in the mid-1990s and become similar to PSEs for harvested catch through the remainder of the time series. Discard estimates with confidence intervals are provided in Figure 26.

Southern Stock

The change to effort estimation methodology resulted in a significant increase in calibrated released alive estimates for all three southern stock states (Figure 32). The change had less impact on trend of estimates in Florida, but did impact the trend at various time periods in South Carolina (late 2000s, and 2010s) and Georgia (late 1980-early 1990s, 2010s). With calibrations applied for both the APAIS changes and effort survey methodology changes, estimates increased an average of 166% (≈430,000 fish), 116% (≈168,000 fish), and 249% (≈1,620,000 fish) in South Carolina, Georgia, and Florida, respectively, during the time series of the replaced, telephone-based CHTS (1981-2017).

Red drum released alive in the southern stock have also increased through the time series and become bigger components of the catch, though these changes have occurred differently in each of the states (Figure 28). Releases have exceeded harvest since the late 1980s in Florida, since the mid-1990s in South Carolina, and since the early 2000s in Georgia. As with harvested fish, Florida has accounted for the most followed by South Carolina and then Georgia. With the assumed 8% discard mortality, dead discards have yet to exceed harvested catch in any of the southern states as seen in the northern stock. However, annual dead discards still account for a significant proportion of annual total removals, averaging 32%, 19%, and 27% in South Carolina, Georgia, and Florida, respectively, during the last five years of the time series (2015-2019).

PSEs were high in South Carolina and Georgia through the 1990s, exceeding 40% and 60% in some years (Figure 29). PSEs then decrease markedly around 2000 and become similar to harvest (Georgia) or lower than harvest PSEs (South Carolina). PSEs for Florida discards are at or above 40% and <60% in a few years in the early 1980s then decline to low levels similar to harvest PSEs. Discard estimates with confidence intervals are provided in Figure 30.

Total Removals

Northern Stock

When harvest and dead discards are combined, total removals from the northern stock initially decreased from highs in the early- to mid-1980s and remained low and stable through the mid- to late-1990s (Figure 33). From these lows, total removals have steadily increased to all time high levels in recent years.

Assuming PSEs for dead discard estimates are equal to PSEs for released alive estimates, PSEs for total removals were higher in the 1980s, exceeding 40% in several years, decreased to levels around 20% in the early to mid-1990s, and decreased further in the late 1990s (Figure 34). There was an increase in the 2010s, but PSE have been below 20% every year since 1996 except 2017.

Southern Stock

When harvest and dead discards are combined, total removals from the southern stock initially decreased in each state from highs in the early- to mid-1980s (Figure 35). Trends then differ by state. In South Carolina, total removals continue to decline through the 1990s, then increase through the remainder of the time series. Total removals generally increased since the 1980s in both Georgia and Florida, but at a greater rate in Florida. Removals have increased in recent years to levels similar to the 1980s in all states.

PSEs in all states have decreased through time and have remained below 40% since the 1980s (Figure 36).

4.2.1.2.3 Catch Composition

Harvest

Length composition data for harvested fish are readily available from MRIP and were the primary composition data set used in the simulation tuning process (Section 6.2.3), and were therefore prioritized for this assessment. Age composition data are available from the last stock assessment through 2013 and were not updated here. These data indicate fairly consistent age compositions dominated by age-2 fish in more recent years for most fleets and can be seen in Appendix 4 (northern stock, appendix Figures 28-29) and Appendix 5 (southern stock, appendix Figures 24-29). Age composition data sets will be updated in the following benchmark stock assessment.

Northern Stock

Annual length compositions for fish harvested from the northern stock are in Figure 37. When aggregated within regulation periods (Figure 38), length compositions show a shift to larger sizes in later years (>1991) as well as decreasing catches of larger fish protected by the slot limit.

The number of MRIP primary sampling units (PSUs), which is a unique interviewer assignment for sampling catch, with red drum encountered for length measurements are presented here as a proxy for length composition sampling replicates (i.e., precision), assuming a clustered sampling design (i.e., lack of independence). Clustered sampling results in sample sizes less than the absolute number of individuals measured for size due to aggregations of like-sized individuals available to catch of anglers fishing at the same sampling unit (Nelson 2014). The number of PSUs encountering red drum in the northern stock increased through the mid-1990s and have since varied without trend (Figure 39).

Southern Stock

Annual length compositions for fish harvested from the southern stock states are in Figure 40, Figure 41, and Figure 42 for South Carolina, Georgia, and Florida, respectively. When aggregated within regulation periods (Figure 43-Figure 45), length compositions show regulatory-induced shifts such as narrowing slot limits.

PSUs in South Carolina and Georgia varied without much trend since increasing after the first few years of the time series (Figure 46). PSUs in Florida increased to the highest levels in the 2000s and declined to lower levels in recent years.

Discards

A primary data limitation in past red drum stock assessments has been the lack of data to describe the length and age composition of fish released alive in recreational fisheries. Because a portion of these fish are assumed to die due to interaction with the fishery (i.e., fishing mortality) and this component of the catch has become an increasingly large proportion of the total recreational catch, the lack of these data introduce a growing uncertainty in stock assessment. Several sources of auxiliary data were explored during the data workshop. These included state tagging programs (Section 4.3) and phone applications designed to collect voluntary data from anglers (iAngler- http://angleractionfoundation.com/iangler and MyFishCount - https://www.myfishcount.com/).

The tagging programs covering the southern stock (Georgia and South Carolina) and northern stock (North Carolina and Virginia) may provide useful data. The data sets include large sample sizes collected throughout the states dating back the full time series of assessment periods in past stock assessments (see Table 17 and Figure 47-Figure 48 for South Carolina tagging program and Appendix 2 for North Carolina and Virginia tagging data). However, as was noted in past assessments (Arnott and Paramore 2015), there are some potential biases, particularly for the South Carolina and North Carolina angler tagging programs, that may preclude the use of these data in the benchmark assessment. One potential bias stems from instructions to anglers on what sizes should be tagged and changes to these instructions through time.

The iAngler data are limited in sample size and almost exclusively from Florida catches (Table 18 and Figure 49), but these data have been used in Florida state stock assessments. MyFishCount data were far more limited as it is a new application with data only available since 2018 (61 release lengths measured). Therefore, these data are of no utility for characterizing historical size compositions but may be of more utility going forward in stock assessment.

Additional work is needed to determine utility and reliability of the various data sets for describing composition of the discarded recreational catch including sample size requirements/thresholds, how to address tagging size instruction biases, and whether data is representative of surrounding states in the cases where data borrowing/gap-filling is necessary to support regional stock assessments. Given the use of these data in previous stock assessments for southern states and the potential for these data to be used in the future to describe the age and length composition of released red drum, the SAS decided to provide composition data as inputs for the assessment models during this simulation assessment in base scenarios for the southern stock but not the northern stock despite data not being readily available for the tuning process in this simulation assessment. The SAS also explored the inclusion of size and age composition data for released red drum through the data prioritization scenarios.

4.2.2 Supplemental Recreational Sampling

There are several recreational fishery monitoring efforts by state agencies conducted aside from the general MRIP survey. The primary purpose of these efforts in past stock assessments has been to provide supplemental age-length key data for generating age composition data.

Virginia

Since 2007, the VMRC has operated a recreational carcass recovery program known as the Marine Sportfish Collection Project. The goal of this project is to both supplement the Biological Sampling Program with species that are traditionally scarce in the commercial sector and serve to characterize VA's recreational fishing activity. Chest freezers are established near the fish cleaning stations at a rotating series of marinas and boat ramps in the Chesapeake Bay region, depending on seasonality and freezer availability. Each freezer is marked with an identifying sign and a list of target fish species. Cooperating anglers place the filleted carcasses, with head and tail intact, in a bag, drop in a completed donation form, and then place the bag in the freezer. Each fish is identified to species, the fish length is measured, sex is determined when possible, and the otoliths are removed. These otoliths are incorporated into the subsampling scheme of VMRC's ageing lab, with their original recreational status recorded for later reference.

The number of red drum collected by the Marine Sportfish Collection Project has traditionally been low, with notable peaks in 2009 (n=73) and 2013 (n=79) with 416 total samples recovered since 2007. These fish ranged in size from 405-1146 mm TL with an average of 558 mm TL.

North Carolina

In 2014, the NCDMF initiated a formal Carcass Collection Program. The objective of the project is to develop a statewide freezer collection program in order to obtain fishery-dependent length, sex and age samples of recreationally important fish. Since the beginning of the program, the NCDMF has maintained eight operational freezer sites where carcass collection occurs. Sites include tackle stores, fishing piers, shore access points and local NCDMF offices. NCDMF staff make scheduled checks to freezers to collect carcasses and resupply freezers with collection bags and information cards. Fish samples collected from the freezers are processed and entered into the NCDMF biological database. Information collected includes species of fish, length of fish, sex, otoliths for aging and catch information (fishing mode, date, location etc.). Samples of red drum collected annually have ranged from 3 (2014) to 90 (2017) with a total of 229 collected from 2014 to 2019. The majority of red drum collected in the carcass collection program are age-2 with some age-1 to age-3 fish. This range of ages is consistent with the size of fish that can be legally harvested in the 18 to 27 inch slot limit.

South Carolina

Inshore Fisheries-Dependent Biological Sampling Programs

Given the limited information on the size and age of recreationally harvested fish from South Carolina waters, the SCDNR Inshore Fisheries Research Section conducts two fishery-dependent biological sampling programs, namely a fishery-dependent freezer fish program and a fishery-dependent tournament sampling program. Both are designed to collect biological information on the size, age, and sex composition of recreationally harvested priority species. Red drum are included as a priority species of interest for both programs.

Freezer Fish Program

Since 1995, Inshore Fisheries has operated a freezer drop off program for recreationally important inshore finfish, enabling us to obtain fish from areas and habitats not always represented in SCDNR monthly field sampling. Chest freezers are located near collaborating marinas, landings, or bait shops along the South Carolina coast. Participating anglers place the filleted rack with head and tail intact in one of the provided bags, drop in the completed catch information card, and deposit the bag in the freezer. Freezers are checked periodically by SCDNR staff and provided fish racks are brought back to SCDNR facilities for processing. Once in the lab, fish are identified to species, lengths are recorded, sex and maturity status are determined when possible, genetic samples are collected, and otoliths are removed. Otoliths are aged annually with each recreational capture day considered an independent collection event.

The number of red drum collected by the Inshore Freezer Fish Program is relatively low (Table 19) with the bulk of collections occurring from 1995 to 2003 (n=1,412). Collections have declined further in recent years with ranges from 100 in 2007 to 0 in 2021, with an average of 50 collected annually from 2004 to 2021. Historically, 2,264 have been processed by staff since the program began ranging in size from 343-810 mm TL with an average of 484 mm TL.

Tournament Program

Inshore Fisheries began participating in Recreational Angler tournaments in 1986. Inshore staff act as weigh master at tournaments and collect biological samples from fish of participating anglers. Similar to the freezer fish program, fish are identified to species, lengths are recorded, sex and maturity status are determined through gross and histological sampling, genetic samples are collected, and otoliths are removed.

Since 1986, 999 red drum have been sampled at tournaments (Table 19) with a minimum size of 277 mm TL and a maximum size of 1,150 mm TL. Average size is 552 mm TL.

State Finfish Survey

Implemented in 1988, the State Finfish Survey (SFS) was designed to address specific data gaps, within the MRFSS (precursor to MRIP), as identified by SCDNR staff. These data gaps included the lack of length data from species of concern to the SCDNR and the lack of seasonal and area-specific catch frequencies. Another concern was the lack of catch and effort data from private boat anglers, which make up a majority of the angling trips in South Carolina coastal waters. These data gaps were initially addressed by interviewing inshore anglers targeting red drum and spotted seatrout at specific sample locations. Since 2002, more emphasis has been placed on acquiring length data from all finfish retained by anglers, canvassing at additional sampling locations, and interviewing all private fishing boats within all South Carolina coastal areas. Broadening the scope of the survey may decrease some of the bias associated with the previous SFS protocol.

Sampling is conducted at public and selected private (with owner's permission) boat landings from January through December using a questionnaire and interview protocols similar to those of the MRFSS. However, the SFS questionnaire focuses on vessel surveys rather than individual angler surveys and primarily targets private boats. Interviews are obtained from cooperative anglers at each sampling site. If an angler is unwilling to participate; they can decline to be interviewed. Assigned Creel Clerks interview as many anglers as time allows at any given site.

The sampling schedule is determined by "needs assessments" of the SCDNR Marine Resources Division and creel clerks. Individual Creel Clerks are assigned to a sampling region and will determine their daily sampling schedules based on local conditions (i.e., weather, landing closures, or events), additional job duties, and research and management initiatives. Attempts are made to assess all sampling sites equally, and individual creel clerks randomly rotate between all sampling locations within their region. Creel clerks will remain at landings with fishing activity. If landings have little or no fishing activity creel clerks will move on to alternative sampling locations in close proximity.

The SFS uses a questionnaire and interview protocol similar to MRFSS/MRIP, with the same staff conducting both surveys since 2013. Data collected for the SFS questionnaire include:

1. Mode fished (i.e., private, charter, shore)

2. Specific body of water fished
3. Area fished (inshore, 0-3 miles, > 3 miles)
4. Utilization of artificial reef/reef name
5. Resident county of boat owner
6. Species targeted
7. Number of anglers participating on the vessel
8. Amount of time spent fishing for the trip
9. Expense of the trip (all anglers)
10. Angling trips the previous year, average of all anglers participating
11. Catch and disposition by species (includes both landed and released fish)
12. Length measurements obtained, with anglers permission, for retained species; 1988 – March 2009: length measurements mid-line length (ML); April 2009 – present: length measurements (TL)

Intercept data are coded and key entered into an existing Access database. Queries are used to look for and correct anomalous data and a component of the database records are checked against the raw intercept forms.

For the period January 1988 through February 2013, data are available from each month of the year. Beginning in 2013, SFS staff took on the duty of conducting the MRIP survey in SC and as a result the traditional SFS survey only operates during the months of January and February (no MRIP sampling during this period). Given this, traditional SFS data from March-December is generally included in MRIP landings reported for South Carolina since 2013.

The SFS collects information on both the nature of individual fishing trips and biological information on the species captured during the trip from cooperating anglers. Trip level information includes the date, location (intercept site, fishing location, and locale (estuarine, nearshore, offshore), fishing mode (private, shore, charter, etc.), purpose of the trip, target (primary and secondary) species, and angler information such as the number of anglers, hours fished, and average number of trips during the previous year across anglers in the party. Recorded biological information includes the species caught and the number and dispositions of caught fish. For those fish harvested, length information is verified for creel clerks and provide an analogous data set to that obtained from the harvested fish encountered by the MRFSS/MRIP APAIS. For released fish, the creel clerks obtain information on the number of legal sized fish released and the number of illegal (i.e., outside the slot limit for red drum) fish releases as well as obtain self-reported size information from the anglers on these released fish.

From 1988 through 2019 the SFS conducted 73,317 interviews, with red drum being caught in 8,575 interviews, or approximately 12% of all trips. These red drum positive trips reported the capture of 39,655 fish (landed and released), with 11,742 harvested and 27,913 released. The survey obtained length information from 11,426 fish (11,284 harvested fish; 178 released fish).

The nature of this survey suggests several potential uses in future red drum stock assessments, including as a fishery-dependent index of relative abundance or as a corroborative index for the MRIP index. Specifically, it provides the only source of information related to the harvest and relative abundance of red drum in South Carolina waters during wave 1. Three versions of a potential index presented during the simulation assessment process can be found in Figure 50. Further, due to the acquisition of length information, the survey could potentially be used as a data set to investigate recreational length compositions of anglers fishing in South Carolina, with potential uses being used to look at differences in the length composition of harvested and released fish (Figure 51) or temporal changes in the length composition of captured fish through time (Figure 52). A final use of this dataset could be to understand temporal changes in fisherman behavior relative to fishing practices, locations, within year timing of fishing, etc. which could become important to defining selectivity blocks. As illustrations of these potential uses, herein we include figures showing the number of red drum caught during different periods of the year (Figure 53), the number of positive trips during different periods of the year (Figure 54), and the number of red drum released during different periods (Figure 55).

Charterboat Logbook Program

The SCDNR issues licenses to charter vessels on a fiscal year (July 1 – June 30). In 1993, SCDNR's Marine Resources Division (MRD) initiated a mandatory trip-level logbook reporting system for all charter vessels to collect basic catch and effort data. Under state law, vessel owners/operators purchasing South Carolina Charter Vessel Licenses and carrying fishermen on a for-hire basis, are required to submit trip level reports of their fishing activity. Logbook reports are submitted to the SCDNR Fisheries Statistics section monthly either in person, by mail, fax, or scan and beginning in 2016, electronically through a web-based application. Reporting compliance is tracked by staff, and charter vessel owners/operators failing to submit reports can be charged with a misdemeanor. The charterboat logbook program is a complete census and should theoretically represent the total catch and effort of the charterboat trips in waters off of SC.

The charterboat logbook reports include: date, number of fishermen, fishing locale (inshore, 0-3 miles, >3 miles), fishing location (based on a 10x10 mile grid map), fishing method, hours fished, target species, depth range (minimum/maximum), catch (number of landed vs. released fish by species), and estimated landed pounds per vessel per trip. The logbook forms have remained similar throughout the program's existence with a few exceptions: in 1999 the logbook forms were altered to begin collecting the number of fish released alive and the number of fish released dead (prior to 1999 only the total numbers of fish released were recorded) and in 2008 additional fishing methods were added to the logbook forms, including cast, cast and bottom, and gig. Furthermore, the fishing method dive was added in 2012.

After being tracked for compliance, each charterboat logbook report is coded and entered, or uploaded into an existing database. Since the inception of the logbook program, a variety of staff have coded the charterboat logbook data. From ~1999 to 2006, only information that was explicitly filled out by the charterboat owners/operators on the logbook forms were coded and entered into the database. No efforts were made to fill in incomplete reports. From 2007 to present, staff have tried to fill in these data gaps through outreach with charterboat owners/operators by making assumptions based on the submitted data (i.e., if a location description was given instead of a grid location – a grid location was determined; if fishing method was left blank – it was determined based on catch, etc.). From 1999 to 2006, each individual trip recorded was reviewed to look for anomalies in the data. Starting in 2007, queries were used to look for and correct anomalous data and staff began checking a component of the database records against the raw logbook reports. Coding and QA/QC measures prior to 1999 were likely similar to those used from 1999 to present, however, details on these procedures are not available since staff members working on this project prior to 1998 are no longer with SCDNR. Data are not validated in the field and currently no correction factors are used to account for reporting errors via paper submission; however, the online system is built with error messages and constraints to prevent common reporting mistakes and overlaps in the data. Recall periods for logbook records are typically one month or less. However, in the case of delinquent reports, recall periods could be up to several months. The electronic reporting application has already shown a decrease in recall bias.

Through 2019, the charterboat logbook program had logged 192,695 charterboat trips across South Carolina, with red drum being caught in 101,877 individual trips (~53% of all trips). The positive trips reported the capture of 762,553 fish, with 52,669 harvested and 709,884 released (Figure 56). Note, South Carolina charterboat owners/operators have developed a strong catch-and-release ethic for red drum (and other species) over time, with most captains either requiring or strongly suggesting catch and release for even legal-sized fish since the early 2000s. This has led to a reported release rate increasing from ~70% in the mid-1990s to >95% since the early 2000s across the South Carolina charterboat fleet (Figure 56).

As a census of the catch and effort of the South Carolina charterboat owners/operators, the SCDNR charterboat logbook program has several potential uses in future stock assessments of red drum, most importantly as a fishery-dependent index of red drum relative abundance (Figure 57) and as mechanism to understand temporal changes in fishermen behavior with regards to fishing practices, fishing locations, and within year timing of fishing activities. Cursory investigations of the charterboat logbook data suggests shifts in charterboat owner/operators behavior through time, with an increase in the rate of catch-and-release fishing practices (Figure 56) as well as a shift to more effort to nearshore waters (Figure 57, Figure 58, Figure 59, and Figure 60), which given red drum life history suggests increasing fishing pressure on the adult component of the red drum stock found along coastal South Carolina.

Georgia

In the fall of 1997, the Georgia Department of Natural Resources (DNR) initiated the Marine Sportfish Carcass Recovery Project. This project takes advantage of the fishing efforts of hundreds of anglers by turning filleted fish carcasses that anglers would normally discard into a source of much needed data on Georgia's marine sportfish. Chest freezers are placed near the fish cleaning stations at 20 locations along coastal Georgia. Each freezer is marked with an identifying sign and a list of target fish species. Cooperating anglers place the filleted carcasses, with head and tail intact, in a bag, drop in a completed angler information card, and then place the bag in the freezer. Each fish is identified to species, the fish length is measured, sex is determined when possible, and the otoliths are removed. A subsample of otoliths is aged annually. Each day is considered an independent sampling event. Red drum recovered through this program are typically within the slot limit of 18”-26” and while samples mostly consist of 2 year old fish, both 1 year olds and 3 year olds are not uncommon.

The number of red drum collected by the Carcass Recovery Project ranged from 229 in 2006 to 1,336 in 2010 with an average of 608 fish collected each year. A total of 13,984 red drum have been processed by staff since the project began. These fish ranged in size from 225-950 mm FL with an average of 404 mm FL.

4.3 Tagging Programs

Virginia Game Fish Tagging Program

Since 1995, the Virginia Game Fish Tagging Program (VGFTP) has tagged recreationally important finfish with the help of volunteer anglers. A cooperative effort between the Marine Advisory Program at the Virginia Institute of Marine Science (VIMS) and Saltwater Tournament at the VMRC, the program’s funding is from state saltwater license funds and VIMS. Anglers utilize conventional and spinning rod and reel tackle, and artificial, live, and dead baits.

The number of cooperating anglers has changed from year to year and does not correlate with the number of fish that will be tagged each year. From 1995 through 2021, approximately 250 rotating anglers have tagged and released 64,871 red drum, peaking in 2012 with 18,461 tags. In recent years the number of red drum tags deployed by the VGFTP has decreased from a period of high volumes of tags between 2005 and 2013. Tag returns have remained mostly stable throughout the lifetime of the survey, with an average return of 9% in the first year, but spikes have occurred periodically, most recently in 2014, with 11% recaptured in the first year (341 fish recaptured out of 3,028 tagged fish).

Anglers in the program have tagged primarily sub-legal fish, with the average TL being 16.9”, below the 18”-26” slot limit in VA. Early in the program, larger fish were targeted to some degree, with the max recorded TL at 58”.

North Carolina

The NCDMF has conducted a tagging study on red drum since 1983. Tagging has been conducted using a variety of means and methods. The NCDMF has conducted directed and opportunistic tagging with trained NCDMF staff since 1983, in addition to trained anglers. During this period, anglers have tagged red drum primarily with large stainless-steel dart tags inserted in the muscle of the fish near the middle of the dorsal fin. Due to the large tag size, volunteer taggers were instructed to tag only large red drum (primarily greater than 685 mm TL) while NCDMF tagging efforts have focused on tagging sub-adult red drum (<685 mm TL) using primarily internal anchor belly tags.

The number of cooperating anglers has changed from year to year and does not correlate with the number of fish tagged each year. Over the entire time period, 71 taggers have participated in the red drum tagging program. Typically, most of the fish are tagged by a small subset of taggers who are commonly fishing guides. Prior to 2004, less than 15 anglers participated annually tagging approximately 600 fish per year. From 2004 to 2019, an average of 22 anglers tagged 1,064 red drum per year with a high of 1,742 tagged in 2006. Participation in the volunteer tagging program has declined in recent years with only 12 taggers tagging 245 red drum in 2019. This decline in numbers tagged has been driven by some attrition of traditional high-volume taggers.

The angler tagging program combined with tagging from NCDMF staff has resulted in more than 80,000 red drum being tagged from 1983 to 2019. Since 1991, greater than 1000 red drum have been tagged annually. Volunteer anglers accounted for approximately 35,000 of these tagged fish. Volunteer angler tagged red drum averaged 910 mm FL at the time of tagging, with most ranging from 680-1180 mm FL. Division tagged red drum averaged 451 mm FL with most ranging from 240-620 mm FL. Over the time series, the return rate across tag types and taggers has been approximately 11%. Recapture rates vary based on size of fish at tagging and the tag type used. Larger fish tagged with stainless steel dart tags have an overall return rate of around 4% (recapture rates are similar for this tag type for both angler and NCDMF tagged fish) while sub-adults tagged with internal anchor tags see overall return rates of approximately 17%.

South Carolina

The SCDNR has a long history of supporting conventional tagging programs with the primary goal of providing a forum for angler outreach which provides a mechanism for developing a conscientious angling public who know and utilize best fishing practices. In addition, the conventional tagging program is a platform that can be used for the collection of valuable information on fish populations, including information on movement and migration, gear selectivities, and exploitation rates. To this end, SCDNR employs two complimentary tagging programs, the South Carolina Marine Game Fish Tagging Program (MGFT) and the Inshore Fisheries Fishery-Independent tagging program.

Marine Game Fish Tagging Program

The MGFTP began in 1974 and was the first state-sponsored public tagging program on the East Coast. The program was initiated with a small contribution from the Charleston-based South Carolina Saltwater Sportfishing Association. Today, the program receives funding from the U.S. Fish and Wildlife Service's Sport Fish Restoration Act and South Carolina Saltwater Recreational Fishing License Funds. The tagging program has proven to be a useful tool for promoting the conservation of marine game fish and increasing public resource awareness. In addition, the program has provided biologists with valuable data on movement and migration rates between stocks, growth rates, habitat utilization, and mortality associated with both fishing and natural events. The first red drum tagged via this program was released in 1978.

The MGFTP covers the entire coast of South Carolina. Most of the tag and recapture events occur inshore, but the program does collect data from nearshore and offshore sites. Data collected by the program includes tag number, date, species, length, length type, location, condition of fish upon release, and disposition of catch (in the case of a recapture).

The survey has directed its cooperative recreational anglers who are tagging red drum to target different size classes of red drum through time. From 1978-1992, anglers were encouraged to tag any size red drum encountered. Then, from 1993-2010, cooperative anglers were instructed to only tag red drum 18 inches TL or larger. In 2011, another guidance change occurred, with this guidance remaining in place until 2020. During this period, anglers were instructed to tag any fish less than 27 inches TL with a T-bar tag and any fish 27 inches TL and greater with a nylon dart tag. A final guidance change occurred in 2020, when we began requesting anglers only tag red drum greater than 10 inches TL and that they only tag one red drum per "school" per day when fishing inshore waters. Similar to the 2011-2019 period, anglers tagged different sized red drum with different tags, using a t-bar tag when fish were less than 18 inches TL and a nylon dart tag when fish were 18 inches TL or greater.

Since its inception, the MGFTP has deployed 96,674 red drum tags and 14,807 recaptures have been reported. Of these recaptures, 73% were reported as being re-released. Peak red drum tag deployment occurred in 2017, 2018, and 2019 (4,596, 6,863 and 6,446 respectively). In more recent years, limitations were put on how many red drum a single volunteer could tag per day. This effort was put in place to allow for a greater number of program participants. A total of 4,985 tags were deployed during 2020 and 2021 combined.

Inshore Tagging Program

Since 1986, the Inshore Fisheries Research section of the SCDNR Marine Resources Research Institute (MRRI) have tagged red drum captured during research and survey sampling. As such, we have tagged most released red drum captured by our sub-adult (stop net, trammel net, and electrofishing surveys; 1986-present) and adult (historic and contemporary longline surveys; 1994-present) fishery-independent surveys. In addition, red drum have been tagged through a number of specific research projects (tag reporting rate studies; tagging of red drum outside of SC, etc.). For this program, fish are measured and tagged with either an internal anchor "belly" or stainless steel anchor "shoulder" dart tag, based on size, before being released at their site of capture (Figure 61). Released fish larger than 550 mm TL are tagged using the shoulder tag, with all released red drum between 350 and 550 mm TL tagged using the belly tag. Data collected at tagging include collection level information retained as part of the survey (e.g., water quality, location (site, stratum, latitude/longitude), date, etc.), fish length (nearest mm SL and TL), and disposition (released with tag). As all released red drum not previously recaptured greater than 350 mm TL are tagged, this program exhibits a spatial footprint as large as the widest footprint of our fishery-independent surveys, resulting in the tagging of red drum across all five South Carolina estuaries and in both estuarine and coastal waters.

Regardless of source, the desired information on angler recaptures of tagged fish remains the same. Anglers are asked to report their contact information (full name, mailing address, and telephone number), the species of fish caught, the tag number, the date and location of the recapture, and the length and disposition of the fish (was the fish retained or released, and if released, was the tag removed or left on the fish). Each angler is offered a reward of either a t-shirt, printed to commemorate their catch, or a cap, with an embroidered logo. For each recapture, a report is mailed to the angler with information on the fish that they caught, including when and where it was originally tagged and its length at that time, how long the fish was at large, a minimum distance it traveled, and any other recaptures that have been reported for the fish, including project recaptures that may have occurred during Inshore fishery-independent sampling. A cover letter is sent to each angler, with recent statistics on the numbers of fish tagged by the program and contact information for questions or reporting future recaptures.

Since its inception, the Inshore Tagging Program has tagged 75,413 red drum and obtained 31,699 red drum recaptures.

<u>Combined SCDNR Tagging Program Data</u>

Since 1978, across programs the SCDNR conventional tagging programs had tagged 172,087 red drum through 2019 (Figure 62), with 46,506 recaptures (Figure 63). Based on disposition, the conventional tagging data suggests catch-and-release rates of red drum in South Carolina has increased through time, with series lows in the late-1980s when the release rate was less than 25% to release rates in excess of 75% every year since 2000 (Figure 64).

Days at large of recaptures has varied greatly, from as short as the same day to as long as 8,403 days-at-liberty (Figure 65), with 11,576 recaptures of red drum at large at least 1 year since tagging (Table 20). The longest-at-liberty was a fish originally tagged via the SCDNR trammel net survey on 11/9/1992 when it was 580 mm TL. This individual was recaptured by an angler on 11/12/2015 in the Cooper River with a length of 1067 mm TL.

Based on location information, we can also infer information about minimum straight-line distance moved based on time-at-large for red drum based on this conventional tagging program (Figure 66). While the maximum minimum straight line distance moved was 467 km observed for a fish at-large for 739 days, only 28 fish moved >250 km with these 28 fish having days-at-large of 33-739 days. Only 0.6% of all recaptures (n = 272) occurred out of the state of South Carolina.

As part of the SCDNR tagging program, data is collected on the lengths of red drum encountered by recreational anglers across the state of South Carolina. This includes both the length at initial tagging (MGFTP only) and length at recapture by recreational anglers (MGFTP and FI tagging program). Coupled with disposition information (harvest vs. released), this provides a robust data set for investigation of harvest and release length compositions across coastal South Carolina. However, there are several caveats regarding the use of these data, including the self-reported nature of recreational length data and the non-equal distribution of lengths of tagged fish in the population.

Georgia

Georgia's Cooperative Angler Tagging (CAT) program began in 1987 and was created to involve anglers in tagging adult red drum as part of in-house research on the species. Tagging has proven to be a useful tool for promoting fish conservation as well as collecting valuable data on movement and migration, growth rates, habitat preference, and post-release survival. Partnering with recreational anglers is an efficient and cost-effective way for researchers to collect fisheries data and often creates a sense of ownership towards fisheries management decisions.

The number of cooperating anglers has changed from year to year and does not correlate with the number of fish that will be tagged each year. The number and species of fish tagged has varied over time as research objectives and staff have changed. From 1987 through 2020, approximately 200 cooperating anglers tagged and released over 9,000 red drum. In recent years the number of red drum tags deployed by the CAT has increased. Since 2017 4,635 tags have been released, between 950-1,591 annually. Tag returns have also increased, with 507 total during the period.

Historically, cooperative tagging anglers have tended to tag larger red drum, with a bimodal distribution of fish at the upper end and above the slot. The addition of staff tagging in 2020 has improved our tag coverage of red drum below and at the lower end of the slot. The mean FL of red drum tagged by cooperative anglers was 493 mm, while the mean FL was 423 mm for staff tagging.

4.4 Total Fishery Removals

Northern stock fishery removals aggregated among all sources show a slight decline from the late 1980s through the 1990s followed by an increasing trend through the remainder of the time series (Figure 67). Total removals averaged 719,475 fish over the last 10 years, compared to an average of 230,964 fish during the 1990s. The recreational fishery has accounted for an increasing proportion of the removals through time, followed by the commercial GNBS fleet. The recreational fishery accounted for 92% of the total annual removals on average over the last ten years, while the commercial GNBS fleet accounted for 7%. Recreational dead discards have accounted for an increasing proportion of the total removals through time, averaging 37% of the total annual removals over the last ten years.

Southern stock fishery removals aggregated among all sources show a decline from high levels during the late 1980s, a slow and steady increase through the 2000s, and an increase at an accelerated rate in the 2010s (Figure 68). Total removals in recent years are similar to levels in the early to mid-1980s, averaging 2,149,442 fish from 2010-2019. Florida had generally accounted for the largest proportion of removals through time, followed by South Carolina, and Georgia. These contributions have been relatively consistent since 2000, averaging 21%, 18%, and 60% contributions, on average, by South Carolina, Georgia, and Florida, respectively. Recreational dead discards accounted for very small proportions of the total removals in the early 1980s (<3%), but accounted for an increasing proportion of total removals through the mid-2000s. Dead discards accounted for a relatively consistent proportion since 2005, averaging 28% of annual total removals.

5 FISHERY-INDEPENDENT DATA SOURCES

Eleven fishery-independent surveys have been used in past red drum stock assessments to provide indices of relative abundance. Three surveys monitoring the northern stock have been used including one indexing recruitment, one indexing primarily sub-adult abundance, and one indexing mature abundance. Eight surveys monitoring the southern stock have been used including three indexing recruitment, two indexing primarily sub-adult abundance, and three indexing mature abundance. One additional survey monitoring the southern stock, the South Carolina Rotenone Survey, was included in this assessment because it provides slightly different information than another survey already included, the South Carolina Stop Net Survey. The Rotenone Survey provides a measure of recruitment to the stock, whereas the Stop Net Survey provides a measure of later age-1 abundance throughout their first full calendar year of life (in addition to some older ages). These twelve surveys and indices generated from them were selected to define index sampling specifications in simulations and are described below. The nomenclature included in parentheses next to each full survey name in the following section is used when referring to sampling specifications designed to mimic these surveys in the simulation process (Sections 6-8).

5.1 North Carolina Bag Seine Survey (NC_BagSeine)

5.1.1 Data Collection and Treatment

A red drum bag-seine survey offers complete survey coverage of 120 seine sets per year. Only in 1994 and 1999 did the number of seine sets fall below 100.

5.1.1.1 Survey Methods

The survey was conducted at 21 fixed sampling sites throughout coastal North Carolina (Figure 69) during September through November for each year from 1991 through 2019. Each of these sites was sampled in approximately two week intervals for a total of six samples with an 18.3 m (60 ft) x 1.8 m (6 ft) beach seine with 3.2 mm (1/8 in) mesh in the 1.8 m x 1.8 m bag. One "quarter sweep" pull was made at each location. This was done by stationing one end of the net onshore and stretching it perpendicularly as far out as water depth allowed. The deep end was brought ashore in the direction of the tide or current, resulting in the sweep of a quarter circle quadrant. Salinity (ppt), water temperature (^{o}C), tidal state or water level, and presence of aquatic vegetation were recorded. Locations of fixed stations were determined in 1990 based on previous catch rates and practicality for beach seining (Ross and Stevens 1992).

5.1.1.2 Biological Sampling

All red drum were identified, counted and measured to the nearest mm FL.

5.1.1.3 Catch Estimation Methods

The size distribution of red drum caught during this survey indicated most fish were age-0. Size cutoff for age-0 was 100mm and only age-0 fish were used in the index. The 100 mm cutoff was sufficiently bigger than the largest age-0 and smaller than any observed age-1 fish collected during the sample period.

The juvenile index is the arithmetic mean catch/seine haul of young-of-year (YOY) individuals.

5.1.2 Trends

Catch rates were variable early in the survey with apparent strong year classes in 1991, 1993, and 1997 (Table 21, Figure 70). During 1999-2001 there was a consistent series of low annual catch rates followed by an increase through 2005, before another decrease from 2006-2009. 2011 marked the 4th largest catch rate of the time series, indicating a strong year class. Since a recent low in 2013, values have been increasing and variable through 2019 with an apparent strong recent year class in 2018.

5.1.3 Potential Biases, Uncertainty, and Measures of Precision

The estimated standard errors for the arithmetic mean catch rates were largest for the peak catch rates during the 1990s and lower since then especially for the years of lower catch rates. Hurricanes during 1996 caused extreme high and low water conditions and may have altered survey results. For this reason, it was recommended that the 1996 data point be deleted from the index. The PSE (same as CV of the mean) indicate that the estimated arithmetic mean catch rates were at least as precise as other indices for YOY red drum in the southern stock, ranging from 14 to 31.

5.2 North Carolina Independent Gill Net Surveys (NC_GillNet)

5.2.1 Data Collection and Treatment

The North Carolina Sub-Adult Index occurs in Pamlico Sound and its tributaries. This is a stratified-random gill net survey designed to provide fishery-independent relative abundance indices for key estuarine species including red drum. Surveys in all regions use a stratified random design. Strata includes area and depth (greater or less than six feet).

5.2.1.1 Survey Methods

Sampling in Pamlico Sound (The Pamlico Sound Independent Gill Net Survey (PSIGNS)) was initiated in May of 2001. Sampling in the Rivers Independent Gill Net Survey (RIGNS) began in 2003 under the same sampling methodology. Since this time, both surveys have sampled continuously. Sampling locations are selected using a stratified random sampling design based on area and water depth (Figure 71). The PSIGNS was divided into eight areas: Hyde County 1 – 4 and Dare County 1 – 4. The RIGNS included dividing the Neuse River into four areas (Upper, Upper-Middle, Middle-Lower, Lower) and the Pamlico River into four areas (Upper, Middle, Lower and Pungo River). A one minute by one minute grid (i.e., one square nautical mile) was overlaid over all areas and each grid was classified into either shallow strata (< 6 ft), deep strata (≥ 6ft) or both based on bathymetric maps.

Each area was sampled twice a month. For each random grid selected, both a shallow and deep sample were collected. Sets in the Pamlico Sound were made over a part of the year in 2001 (237 sets), and thereafter was sampled between 300 and 320 sets per year. Sets in the Rivers (Pamlico, Pungo and Neuse) were made over a part of the year in 2003 (156 sets) and thereafter was sampled between 304 and 320 samples per year. Sample areas and coverage included in the PSIGNS and RIGNS surveys from 2001-2019 are provided in Figure 71.

For each grid selected, both the shallow and deep strata are sampled with a separate array (or gang) of nets. An array of nets consists of 30-yard segments of 3, 3½, 4, 4½, 5, 5½, 6, and 6½ in stretched mesh webbing (240 yards of gill net). Catches from this array of gill nets comprise a single sample, with two samples (one for the shallow strata, one for the deep strata) collected for each sampling trip. Gear was typically deployed within an hour of sunset and fished the following morning with effort made to keep all soak times within 12 hours. The 12-hour soak time allowed for uniform effort across all samples.

Physical and environmental conditions, including surface and bottom water temperature (°C), salinity (ppt), dissolved oxygen (mg/L), bottom composition, as well as, a qualitative assessment of sediment size, were recorded upon retrieval of the nets on each sampling trip. All attached submerged aquatic vegetation (SAV) in the immediate sample area was identified to species and density of coverage was estimated visually when possible. Additional habitat data recorded included distance from shore, presence or absence of sea grass or shell, and substrate type.

5.2.1.2 Biological Sampling Methods

Red drum for each mesh size (30-yard net) in a sample are enumerated with an aggregate weight (nearest 0.01 kg) obtained. Individuals were measured to the nearest millimeter for FL and TL.

Age data are available for each year and region from the survey. However, these data were not randomly collected but were taken as needed to provide representative samples by length bin during each monthly period sampled. Data should be valuable for growth curves and to inform model on the age of fish captured in the survey.

5.2.1.3 Catch Estimation Methods

The time series in the rivers differs from that in the Pamlico Sound, therefore the results have typically been analyzed separately for the two areas: 1) Hyde and Dare counties (PSIGNS) only, beginning 2001, and 2) Rivers (Pamlico, Pungo and Neuse; RIGNS), beginning 2003. The two regions can be combined as a single index beginning in 2003. The CPUE represents the number of red drum captured per sample and can be expressed overall or for fish assigned by the seasonal ALKs as an age-1 or age-2 index. A sample was one array of nets (shallow and deep combined) fished for 12 hours. Due to disproportionate sizes of each stratum and region, the final CPUE estimate is weighted. The total area of each region by stratum was quantified using the one-minute by one-minute grid system and then used to weight the observed catches for calculating the abundance indices.

In order to parse red drum into an aged-index, ages were assigned based on length cutoffs derived using seasonal ALKs (6-month: Jan-Jun, Jul-Dec). A large range of sizes were caught (range 220-1260 mm TL), but most sizes were associated with age-1 or age-2 fish (mean of ~400 mm TL). An overall age-aggregated index, as well as, an age specific index for age-1 and age-2 fish were generated.

5.2.2 Trends

The Pamlico Sound overall (age-aggregated) weighted CPUE showed a variable trend over the time series with the highest value occurring in 2013 (Table 22). This index was used in the simulation model tuning process (see Section 6.2.3) to incorporate the longer time series and all length and age data in the analyses. Age-1 fish varied throughout the time series with a time series high captured in 2012. Age-2 fish exhibited no clear overall trend with annual estimates being variable. Age-2 abundance peaked in 2013, corresponding with the peak in age-1 fish in 2012 and similarly peaked in 2017 following a peak in age-1 abundance from 2016.

Comparisons of the overall length composition and for the catch rates for age-1 and 2 were made between the Pamlico Sound and the shorter time-series Rivers portions of the survey (Figure 72 and Figure 73). Length compositions were similar between the two regions. Length compositions were most indicative of age-1 and age-2 fish with older fish less common in the survey. A second mode indicative of age-2 red drum was most commonly seen in the Pamlico Sound IGNS. Trends in age-1 fish were similar between those calculated from the Pamlico Sound and Rivers. Trends in age-2 abundance were similar, although age-2 fish were captured less frequently in the Rivers.

5.2.3 Potential Biases, Uncertainty, and Measures of Precision

The standard errors and PSEs are presented for the Pamlico Sound portion of the survey by age (age-1 and age-2) and for all ages aggregated (Table 22). Precision of calculated indices is good. The aggregated PSEs indicate the precision of this index is slightly less than the southern stock's Florida 183 Meter Haul Seine Survey (Section 5.12) and similar to the South Carolina Trammel Net Survey (Section 5.6). Precision decreased for age-specific indices and is higher for age-1 relative to age-2 fish.

5.3 North Carolina Adult Longline Survey (NC_Longline)

5.3.1 Data Collection and Treatment

The North Carolina Adult Longline Survey occurs in Pamlico Sound. This is a stratified-random survey designed to provide a fishery-independent relative abundance index for adult red drum in North Carolina. The survey has used continuous standardized sampling since 2007. Sampling intensity includes 72 stratified random sets per year taken over a 12 week period from mid-July to mid-October. All samples are taken with protocol for stratified random sample design.

5.3.1.1 Survey Methods

In order to begin a long-term index of abundance for adult red drum, this study employs a stratified-random sampling design based on area and time. Areas chosen for sampling were based on prior NCDMF mark and recapture studies, which indicate the occurrence of adult red drum within Pamlico Sound during the months of July through mid-October (Burdick et al. 2007; Bacheler et al. 2009). The sample area was overlaid with a one-minute by one-minute grid system (equivalent to one square nautical mile). Grids across the area were selected for inclusion in the sampling universe if they intercepted with the 1.8 m (6 ft) depth contour based on the use of bathymetric data from National Oceanic and Atmospheric Association (NOAA) navigational charts and field observations. Other factors, such as obstructions, accessibility, and logistics, were considered when grids were selected. Finally, the sample area was divided into twelve similarly sized regions (Figure 74). In order to stratify samples through space and time, two samples were collected from each of the twelve regions during each of three periods from mid-July to mid-October.

A standardized sampling protocol that is replicated each year has been consistently utilized in the survey since 2007. All sampling was conducted using bottom longline gear. Lines were set and retrieved using a hydraulic reel. Ground lines consisted of 227 kg (500 lb) test monofilament. Samples were conducted with a 1,500-meter mainline with gangions placed at 15 meter intervals (100 hooks/set). Stop sleeves were placed at 30 m intervals in order to aid in accurate hook spacing and to prevent gangions from sliding down the ground line and becoming entangled when large species were encountered. Terminal gear was clip-on, monofilament gangions consisting of a 2.5 mm diameter stainless steel longline clip with a 4/0 swivel. Leaders on gangions were 0.7 m in length and consisted of 91 kg (200 lb) monofilament rigged with a 15/0 Mustad tuna circle hook. Hooks were baited with readily available baitfish (striped mullet is the primary bait and longline squid is the first alternative). Sets were anchored and buoyed at each end. Anchors consisted of a 3.3 kg window sash weight. Multiple sash weights were used in high current areas. All soak times were standardized and kept as close to 30 minutes as logistically possible. Soak times were measured from the last hook set to the first hook retrieved. Short soak times were designed to minimize bait loss, ensure that the red drum were tagged in good condition, and to minimize negative impacts to any endangered species interactions.

Within each randomly selected grid two samples are taken. In order to maintain consistency, all samples were made in the vicinity of the 1.8 m depth contour with sample depths typically ranging from 1.2 to 4.6 m in depth. All random sampling occurred during nighttime hours starting at sunset. On average, a total of four sets were made per night.

Physical and environmental conditions, including surface and bottom water temperature (^{o}C), salinity (ppt) and dissolved oxygen (mg/L), were recorded for each longline sample. Bottom composition and sediment size were recorded in the instances where they could be ascertained. Location of each sample was noted by recording the beginning and ending latitude and longitude.

5.3.1.2 Biological Sampling Methods

All individuals captured were processed at the species level and were measured to the nearest millimeter for either FL or TL according to the morphology of the species. Most red drum were tagged and released, but a random sample including approximately every fifth fish collected is sacrificed for biological data collection, including the removal of otoliths for ageing.

5.3.1.3 Catch Estimation Methods

Catch rates were calculated annually and expressed as an overall relative abundance index, along with corresponding length class distributions. The overall index is calculated as an arithmetic mean of the number of red drum captured per sample. Longline sets were standardized to 100 hooks set at 15 m intervals for 30 minutes (measured as time elapsed from last hook set to first hook fished).

5.3.2 Trends

The index of abundance from 2007 to 2018 varied annually with little trend (Table 23 and Figure 75). The index value for 2019 was the lowest in the time series. It should be noted that the survey in 2019 was disrupted significantly by hurricane activity that occurred during the peak of the sample period.

The lengths of red drum captured ranged from 64 to 126 cm FL with most being between 86 and 114 cm FL. Length composition was similar across years (Figure 76).

Red drum ages collected from the survey ranged from age 3 to age 43 (Figure 77). Aggregated ages across all years of the survey plotted by year class (cohort) show the persistence of strong year classes and weak year classes in the population over time (Figure 78). This trend appears consistent with variability in recruitment of YOY.

5.3.3 Potential Biases, Uncertainty, and Measures of Precision

Standard errors and variances are presented for the annual estimates of CPUE (Table 23). Apparent PSEs were relatively low, <20%, for most years. The survey time series is relatively short (13 years) given the longevity of red drum in the northern stock. The geographic range of the survey is limited to Pamlico Sound.

5.4 South Carolina Rotenone Survey (SC_Rotenone)

5.4.1 Data Collection and Treatment

In the mid-1980s the SCDNR began the development of a number of long-term fishery-independent monitoring programs designed to monitor estuarine and coastal finfish populations along coastal South Carolina. One of these surveys, the Inshore Fisheries Rotenone Survey was designed to provide a survey of the estuarine finfish inhabiting estuarine, sub-tidal saltmarsh creek habitats. These creeks are less than 5 m wide and less than 1 m deep an hour before low tide; these habitats dominate the coastal South Carolina marsh environment. The survey was designed to provide relative abundance indices for key estuarine species, including red drum, as the habitat sampled serves as a primary nursery habitat for a host of recreationally important estuarine species.

5.4.1.1 Survey Methods

Collections were made by blocking a 50 m long section of tidal creek with two 0.8 mm square mesh block nets, one at the upstream end of the section and one at the downstream end, about 1 hour before locally predicted time of low tide. The nets, with heavily weighted foot ropes, were suspended through the water column on lines stretched between poles sunk in the creek on opposite banks of the creek. Rotenone (100-200 ml of 5% Fish Tox, Wolfolk Chemical Works, Fort Valley, GA) was added at the upstream net and carried through the site with the ebbing current. At the down-stream net, potassium permanganate was added to the water leaving the site to oxidize the rotenone, thereby minimizing extra-site mortality. Immediately prior to the addition of rotenone, water temperature was measured with a stem thermometer and salinity was estimated with a refractometer. Dissolved oxygen was estimated with titration kit. Fishes were collected within the site with dip nets and 3 pulls of a 3.2 mm bar mesh seine. The down-stream net was then carefully collected and those fish caught in it were removed. All specimens were returned to the lab for identification, enumeration, and measurement.

The SCDNR rotenone survey employed a fixed station sampling design. From 1986 through 1988, 9 sites were sampled for a total of 97 samples (Table 24). Beginning in 1989 through the end of the survey in 1994, sampling was conducted at 4 index stations in the Wando River

Drainage, in Charleston County, SC: Deep Creek, Foster Creek, Lachicotte Creek, and PITA Creek (Table 24).

5.4.1.2 Biological Sampling

Given the nature of the sampling procedure (rotenone) all collected fish were sacrificed and many were returned to the lab for final enumeration and the collection of biological information. Biological information for red drum included TL, SL, and weights with age determined based on length of capture. Owing to the small size of red drum encountered in the survey, there is limited information on sex with all encountered fish being considered immature.

A summary of the length and weight information provided to the simulation assessment from the SCDNR rotenone survey is found in Table 32.

Most individuals were exclusively aged based on size alone, as the survey encounters red drum prior to significant overlap in length distribution of individual cohorts, with near 100% certainty in the age determination of calendar age-0, age-1, and 2 fish, as verified by otolith thin section methodology (Figure 87). During the history of the survey, only 1 fish >1 year old was encountered, indicating that this survey represents a survey of red drum recruitment.

A summary of the age information available from the rotenone survey and provided to the simulation assessment is found in Table 33.

5.4.1.3 Catch Estimation Methods

During SEDAR 44 the SCDNR rotenone survey was presented as an age-0 index using data from Sept-Dec and an age-1 index using data from Mar-Jul, with the latter being primarily considered. However, the survey in actuality represents recruitment of red drum and can be readily converted to a survey of red drum year class, noting that young of the year red drum first recruit to the survey shortly after being born during the fall and then persist in the survey through the winter, spring and summer of the following year as calendar age-1 fish (Figure 79). Under this treatment there is no need for the development of age or length compositions, as it is assumed to be a survey of recruitment with a sampling year of August-July.

5.4.2 Trends

The SCDNR rotenone survey indicates above survey average recruitment of red drum in 1986, 1990, and 1991 (Figure 80). In other years, the abundance of red drum in the survey was generally reduced.

5.4.3 Potential Biases, Uncertainty, and Measures of Precision

The SCDNR rotenone survey was a fixed station survey of one river drainage along coastal South Carolina. While not restricted to a single site, treatment of the data requires restricting data to the four core fixed stations sampled in the Wando River. Further, it is likely the index would benefit from index standardization to account for potential covariate effects on catchability due to environmental conditions such as month/day of year, water temperature, and salinity. Finally, the survey was of a relative short temporal duration, representing the catch of only eight red drum year classes from 1985-1993. That said, the survey represents a true recruitment index and generally correlates well with other contemporary surveys operating at the same time with reasonable measures of precision while covering a temporal period not covered by most other surveys.

5.5 South Carolina Stop Net Survey (SC_StopNet)

5.5.1 Data Collection and Treatment

In the mid-1980s the SCDNR began the development of a number of long-term fishery-independent monitoring programs designed to monitor estuarine and coastal finfish populations along coastal South Carolina. One of these surveys, the Inshore Fisheries Stop Net Survey was designed to provide relative abundance indices for key estuarine species, including red drum, using salt marsh edge habitats. The survey indexed the relative abundance of numerous species and has been used in previous assessments of the southern population of red drum.

5.5.1.1 Survey Methods

The stop net was 366 m long by 3 m deep with a 51 mm stretch mesh block net made of multifilament nylon mesh. The net was set at high tide in an intertidal area. One end was attached to a stake driven into the marsh surface, and then the net was laid out from a boat over the non-vegetated bottom roughly parallel to the shore before securing the other end in the marsh with another stake. Upon deployment, the net enclosed a roughly semicircular area of approximately 12,000 square meters. Fishes trapped in the enclosed area were collected with large dip nets as the tide dropped and selected species, including red drum, were placed in oxygenated holding tanks and held until the water returned to the site and they could be measured, tagged, and released, or retained for life-history workup. Immediately after net deployment, water temperature was measured with a stem thermometer and salinity was estimated with a refractometer. Dissolved oxygen was estimated with a titration kit.

Stop net sampling took place from 1985 through 1998, but monthly survey sampling occurred at a single site in Charleston Harbor (site 0001) from the summer of 1986 through 1993, with most months sampled in 1994 (Table 25). A secondary site in northern Bulls Bay (site 0270) was sampled primarily during summers from 1990 through 1994, with a smattering of additional sites sampled throughout the survey history (Table 25).

5.5.1.2 Biological Sampling

Life history sampling of priority species, including red drum, was performed through the application of length distribution subsampling, with the number sacrificed for life history studies varying depending on species. Sacrificed red drum have several additional biological variables ascertained (e.g., weight (g) and macroscopic reproductive stage) and biological samples retained (e.g., otoliths for age and growth studies, scales for age and growth studies and ageing methodology comparisons, gonad tissues for histological determination of reproductive status, and muscle tissues for contaminant analysis).

A summary of the length and weight information provided to the simulation assessment from the SCDNR stop net survey is found in Table 32.

A combination of age methodologies was used to age red drum encountered by the SCDNR stop net survey, largely dependent on the size of the individual fish. Smaller individuals (<3 years old and approximately 500 mm TL), prior to significant overlap in length distribution of individual cohorts, can be reliably aged exclusively using TL, with near 100% certainty in the age determination of calendar age-1 and 2 fish, as verified by otolith thin-section methodology (Figure 87). The ages of larger, and hence generally older, individuals have been determined via a combination of scale readings and otolith thin-section techniques.

A summary of the age information available from the stop net survey and provided to the simulation assessment is found in Table 33.

5.5.1.3 Catch Estimation Methods

Annual length compositions for the survey were developed from the observed TL measurements made on all individuals encountered by the survey. There was no need for expansion of the length compositions given the survey sampling design.

Annual age compositions for the survey were not directly available, owing to the stratified random sampling design used to select fish to sacrifice for age determination via scales and otoliths. Thus, to develop annual age compositions we developed an all years pooled age-length key to convert the observed length composition to an age-composition. For a true assessment, additional work developing year and/or seasonal age-length keys would be conducted.

All years pooled length- and age-compositions can be found in Figure 81 and Figure 82, respectively. Modes in the pooled length composition reflect cohorts of red drum encountered by the survey, with the mode at <30 cm, 35-40 cm, and >55 cm corresponding to age-1, age-2, and age-3+ red drum encountered by the survey. When the length compositions are converted to age compositions based on a pooled age-length key, we see that the survey primarily encounters age-1 to age-4 individuals, which is to be expected based on the life history of red drum.

5.5.2 Trends

Overall, the SCDNR stop net survey shows a relatively stable abundance of sub-adult red drum along coastal South Carolina throughout the survey time series (Figure 83).

Annual length and age compositions available from the SCDNR stop net survey shows individual cohorts of red drum (identified by modes) being encountered by the survey (Figure 84 and Figure 85), with the peaks of the modes of the length compositions elucidating information on the formation of strong and weak year classes based on length alone (Figure 84). Similar signals of year class strength are seen in the annual age compositions (Figure 85).

5.5.3 Potential Biases, Uncertainty, and Measures of Precision

The SCDNR stop net survey represents a single fixed station along coastal South Carolina over a relatively short time period (9 years) limiting its utility as a coastwide index of relative abundance for the southern stock. In addition, there is relatively low sampling intensity within a year at that fixed station, owing to the time required for a single collection. Combined, these attributes lead to higher than desired measures of precision on annual estimates of relative abundance. However, this survey is one of a select few that provides any information on the relative abundance of sub-adult red drum in the late-1980s and early 1990s.

5.6 South Carolina Trammel Net Survey (SC_Trammel)

5.6.1 Data Collection and Treatment

The SCDNR established the SCDNR trammel net survey in the fall of 1990 as a survey of lower estuary, generally moderate- to high-salinity, salt-marsh edge and oyster reef habitats; these habitats dominate the coastal South Carolina estuarine shoreline environment. The survey was designed to provide relative abundance indices for key estuarine species including red drum, as the habitat sampled serves as a primary habitat for a host of recreationally important estuarine species. The survey indexes the relative abundance of numerous species throughout the five major estuaries found along the South Carolina coast (Figure 86) and has been used in numerous stock assessments as an index of relative abundance, including previous assessments of the southern stock of red drum.

5.6.1.1 Survey Methods

The SCDNR trammel net survey employs a stratified random sampling design. On each sampling day (one stratum is sampled per day), trammel nets are typically set at 10-12 sites, although weather, tide, or other constraints sometimes hinders this target. Sites are selected at random (without replacement) from a pool of 27-55 possible sites per stratum, with the exception that adjacent sites (unless separated by a creek or other barrier) cannot be sampled on the same day to avoid sampling interference.

Fish are collected using a 183 x 2.1 m trammel net fitted with a polyfoam float line (12.7 mm diameter) and a lead core bottom line (22.7 kg). The netting comprises an inner panel (0.47 mm #177 monofilament; 63.5 mm stretch-mesh; height = 60 diagonal meshes) sandwiched between a pair of outer panels (0.9 mm #9 monofilament; 355.6 mm stretch-mesh; height = 8 diagonal meshes). The trammel net is set along the shoreline (10-20 m from an intertidal marsh flat, <2 m depth) during an ebbing tide using a fast-moving Florida net boat. Each end is anchored on the shore, or in shallow marsh. Once the net has been set, the boat makes two passes along the length of the enclosed water body at idle speed (taking <10 minutes), during which time the water surface is disturbed with wooden poles to promote fish entrapment. The net is then immediately retrieved and netted fish are removed from the webbing as they are brought on board and placed in a live-well. Once the net has been fully retrieved, all fish are identified to species and counted. Measurements (TL and SL) are taken from all individuals of target species (including red drum), and from up to 25 individuals of non-target species. Most fish (>95%) are released alive at the site of capture once length measurements are obtained. Any red drum greater than 350 mm TL released at the site of capture and not previously tagged are tagged, with tag type dependent on the size of the individual. Individuals between 350- and 549-mm TL are tagged with disc belly tags, and any greater than 549 mm TL are tagged with a steel shoulder tag.

Additional data collected during each collection includes location (site nested in stratum nested in area; latitude and longitude) and a suite of physical and environmental variables. Physical and environmental variables recorded include depth (m), air temperature (°C), water temperature (°C), salinity (PSU), dissolved oxygen (mg L^{-1}), and tidal stage.

At present, (2021), seven strata, from south to north, are surveyed: Port Royal Sound (PR), ACE Basin (AB), Ashley River (AR), Charleston Harbor (CH), Wando River (LW), Cape Romain (CR), and Winyah Bay (WB). These seven strata are found in the five primary South Carolina estuaries, Port Royal Sound (PR), St. Helena Sound (AB), Charleston Harbor (AR, CH, LW), Cape Romain and Bulls Bay (CR), and Winyah Bay (WB). Note however, the time series of sampling in each estuary has varied through time (Table 27). Limited historical data is also available from additional strata and areas within current strata but are generally excluded from the development of relative abundance indices due to temporal length of surveys in these areas.

From November 1990 to December 2019 (data considered during data workshop for index development), the SCDNR trammel net survey had made 24,754 collections along the South Carolina coastline, of which 23,696 were used in the construction of the red drum index of relative abundance (Table 30).

5.6.1.2 Biological Sampling Methods

Life history sampling of priority species, including red drum, is performed through the application of length distribution subsampling, with the number sacrificed for life histories studies varying depending on the species. Sacrificed red drum (~300-500 per year) have several additional biological variables ascertained (e.g., weight (g) and macroscopic reproductive stage) and biological samples retained (e.g., otoliths for age and growth studies, scales for age and growth studies and ageing methodology comparisons, gonad tissues for histological determination of reproductive status, and muscle tissues for contaminant analysis).

A summary of the length and weight information provided to the simulation assessment from the SCDNR trammel net survey is found in Table 32.

A combination of age methodologies is used to age red drum encountered by the SCDNR trammel net survey, largely dependent on the size of the individual fish. Smaller individuals (<3 years old and approximately 500 mm TL), prior to significant overlap in length distribution of individual cohorts, can be reliably aged exclusively using TL, with near 100% certainty in the age determination of calendar age-1 and 2 fish, as verified by otolith thin-section methodology. The ages of larger, and hence generally older, individuals have been determined via a combination of scale readings and otolith thin-section techniques.

A summary of the age information available from the trammel net survey and provided to the simulation assessment is found in Table 33.

5.6.1.3 Catch Estimation Methods

Arnott et al (2010) found that SCDNR trammel net CPUE of red drum is reasonably synchronous along the South Carolina coastline, justifying the pooling of individual stratum data for the development of a statewide relative abundance index. As length and age information is available from the survey for the development of length and age compositions, we treated the trammel net survey as a length- (or age-) aggregated index of relative abundance. Herein only an arithmetic mean annual relative abundance was developed, as our primary interest in the simulation assessment was to capture the trends in relative abundance of red drum along the South Carolina coastline.

Annual length compositions for the survey were developed from the observed TL measurements made on all individuals encountered by the survey. There was no need for expansion of the length compositions given the survey sampling design.

Annual age compositions for the survey were not directly available, owing to the stratified random sampling design used to select fish to sacrifice fish for age determination via scales and otoliths. Thus, to develop annual age compositions we developed an all years pooled age-length key to convert the observed length composition to an age-composition. For a traditional benchmark assessment, additional work developing year and/or seasonal age-length keys would be conducted.

All years pooled length- and age-compositions can be found in Figure 88 and Figure 89, respectively. Modes in the pooled length composition reflect cohorts of red drum encountered by the survey, with the mode at <39 cm, 35-40 cm, and >55 cm corresponding to age-1, age-2, and age-3+ red drum encountered by the survey. When the length compositions are converted to age compositions based on a pooled age-length key, we see that the survey primarily encounters age-1 to age-4 individuals, which is to be expected based on the life history of red drum.

5.6.2 Trends

Overall, the SCDNR trammel net survey shows a decrease in abundance of sub-adult red drum along coastal South Carolina since the surveys inception, only briefly offset by a period of good recruitment in the early 2000s (Table 28 and Figure 90). Record low abundances have been observed in recent years.

Annual length compositions available from the SCDNR trammel net survey shows individual cohorts of red drum (identified by modes) being encountered by the survey, with the peaks of the modes elucidating information on the formation of strong and weak year classes (Figure 91). Evidence of the strong 2000-year class shows up in the 2001 length compositions, which seems to support a temporary increase in relative abundance across the state, as observed in the index (Figure 90). Unfortunately, length compositions have not been indicative of strong year classes occurring across coastal South Carolina over the past few years, as the apparent strong year classes based on proportion of fish encountered (e.g., 2016-2019) has not been maintained across years; length-compositions were dominated by small size classes, with those size classes not progressing to large sizes across years (Figure 91).

Not unsurprisingly, the age composition information supports the conclusions of the length compositions, with even stronger evidence for a shifting age structure and lack of strong recruitment in recent years (Figure 92). This is exemplified by the dominate age-classes in the survey being ages-2 and -3 through most of the 1990s and early 2000s, with the one exception being the strong 2000 year-class that first shows up in 2001. However, since the mid-2000s, the age composition has been dominated most years by age-1 red drum, with once again little indication of a strong year class.

5.6.3 Potential Biases, Uncertainty, and Measures of Precision

Overall the SCDNR trammel net survey exhibits relatively low CVs, with an average CV of 0.12 (range: 0.08-0.22, Table 28). However, confidence in the index generally increases through time due to the expansion of the survey spatially leading to an overall increase in sampling intensity across the state. Further, the long time-series (29+ years) provides the most comprehensive insight into the long-term trends in sub-adult red drum populations along coastal South Carolina

5.7 South Carolina Historic Longline Survey (SC_Longline_historic)

5.7.1 Data Collection and Treatment

In an effort to monitor populations of adult red drum in South Carolina's estuarine and coastal ocean waters, a longline survey off of Charleston (Figure 94) was established in 1994. A primary focus of the survey was to develop an index of relative abundance of adult red drum to develop a better understanding of adult red drum populations along the southeastern Atlantic coast, thereby allowing for more effective and responsible management of the stock. As such, the survey collected data on the CPUE for indices of abundance and collected length measurements of all red drum encountered. Further, released red drum were tagged to collect migration and stock identification data.

5.7.1.1 Survey Methods

In the first year of the study, a cable mainline (1,829 meter long) with 120 hooks was deployed. Following discussion that sharks may be deterred by the cable (as sharks were also a target species), a 600-lb test, 1,829-meter monofilament mainline was also used with 120 hooks starting in 1995, and both gear types were used until 1997. In 1998, the survey switched to monofilament mainline for all sets, since it was concluded that while the cable gear decreased the catch of sharks, red drum catches were unaffected by the gear. Terminal tackle, regardless of mainline type, was composed of 0.5 m of 200 lb test monofilament, with a 2.5 mm stainless steel longline clip affixing it to the mainline and a 15/0 Mustad circle hook. The hooks were primarily baited with Atlantic mackerel and spot, with a 30 minute soak time (1st hook down to 1st hook up) employed, though the overall retrieval time for the gear varied depending on the catch.

The majority of effort took place at index stations in Charleston Harbor (across 7 main fixed stations at the Charleston jetties or nearshore habitats off Charleston Harbor with live bottom; Figure 94), with additional exploratory sets in Port Royal Sound in 2005 and in Winyah Bay and Port Royal Sound in 2006. Two vessels were used since the survey began, the *R/V Anita* (1994-2004) and the *R/V Silver Crescent* (2005-2006). The mile-long monofilament mainline was used until the survey design was modified in 2007 (with limited mile-long sets in 2007) from fixed sites to a stratified random design with 600-meter monofilament mainlines. Existing index stations were broken into three 600 m sets, and new stations were added based on suitable habitat and previous exploratory sets (see Section 5.8 for full contemporary description).

Within a year, some sampling was conducted in each month of the year, though red drum catches were generally greater during the August-December period leading to a gradual increase in overall survey effort during this time frame. From 1994 to 2006, the SCDNR historic coastal longline survey made 1,168 collections that were used in the construction of the historic longline red drum index of relative abundance.

5.7.1.2 Biological Sampling

Each fish captured on the longline is brought on board, the hook is removed, and their length is measured to the nearest FL (i.e., mid-line length) and TL. At the conclusion of initial workup, each individual was generally tagged and released using three different tag types: nylon dart tag (1994-2006), PIT tag (2001-2006), and stainless steel dart tag (2001-2006). In addition, fin clips were taken from all encountered red drum from 2003-2006 and a limited number of fish were sacrificed for age and reproductive status determination.

5.7.1.3 Catch Estimation Methods

As length information is available from the survey for the development of length compositions and this survey is expected to capture adult red drum across a wide length range, we treated the historic SCDNR coastal longline survey as a length-aggregated index of relative abundance. Herein only an arithmetic mean annual relative abundance was developed, as our primary interest in the simulation assessment was to capture the trends in relative abundance of red drum along the South Carolina coastline. For a traditional benchmark stock assessment, the index could be standardized for the effect of collection level covariates measured at the time of each collection to account for effects of such covariates on catchability of adult red drum.

5.7.2 Trends

The SCDNR historic longline survey indicates a generally decreasing trend of adult red drum abundance from 1994-2000, followed by a short period of recovery from 2000-2003. This brief recovery period was followed by a steep decline in abundance from 2003-2006, with terminal year abundance approaching series lows seen in the mid- to late-1990s (Table 29 and Figure 95).

5.7.3 Potential Biases, Uncertainty, and Measures of Precision

Overall, the SCDNR historic coastal longline survey exhibits relatively low relative standard errors (RSE), with RSEs ranging from 0.10-0.24. Further, it represents the only source of historical information on the abundance of mature, adult fish. However the design of this survey (fixed station survey) and limited geographic scope (Charleston Harbor, SC, only) confounds the interpretation of relative abundance trends obtained from this survey. Further, there are potential sampling complications since the survey was modified from a survey designed to capture sharks initially. Though length information is available, the lack of age composition information from the survey may limit its ability to inform historic recruitment.

5.8 South Carolina Contemporary Longline Survey (SC_Longline_contemporary)

5.8.1 Data Collection and Treatment

In an effort to monitor populations of adult red drum in South Carolina's estuarine and coastal ocean waters, the SCDNR began sampling using longlines in Charleston Harbor in 1994. Though the contemporary SCDNR adult red drum and shark coastal longline survey (a.k.a. SCDNR longline survey) traces its roots to this original historic survey, the survey was less standardized in the early years and underwent a significant modification prior to the 2007 field season. In its contemporary form, the survey samples the mouths of four South Carolina estuaries, Port Royal Sound, St. Helena Sound, Charleston Harbor, and Winyah Bay, and nearshore live bottom habitat, with fixed stations found along the edge of deep channels and at known red drum aggregation sites (Figure 93). A primary focus of the survey is to develop an index of relative abundance of adult red drum to develop a better understanding of adult red drum populations along the southeastern Atlantic coast, thereby allowing for more effective and responsible management of the stock. Information from this survey has also been used for coastal shark assessments across the region.

The primary objectives of the survey are to conduct fishery-independent longline sampling on adult red drum and coastal sharks to generate information on CPUE for indices of abundance. The survey also collects biological information (size, sex, etc.) and samples (otoliths, gonads, muscle, fin clips, etc.) from random sub-samples of the red drum catch to determine size-at-age, recruitment to the spawning population, and genetic composition of the stock. Further, released adult red drum (and some sharks) are tagged to collect migration and stock identification data.

5.8.1.1 Survey Methods

With the 2007 field season, the SCDNR longline survey was redesigned to employ a stratified random sampling design. The survey samples four strata (Port Royal Sound, St. Helena Sound, Charleston Harbor, and Winyah Bay; Figure 93) during each of three six-week sampling periods (1 = Aug 1-Sept 15, 2 = Sept. 16-Oct 31, and 3 = Nov 1-Dec 15). The number of available stations for random selection per strata varies from 43-81: Port Royal Sound (78), St. Helena Sound (81), Charleston Harbor (43), and Winyah Bay (51). From this pool of stations, 30 are randomly selected for sampling from each stratum during each 6-week period, for an expected 120 collections per six-week sampling period and 360 collections per field season.

All sampling for the SCDNR longline survey has been conducted aboard the *R/V Silver Crescent* using standardized gear. Longline gear consists of a 272 kg monofilament mainline that was 610 m with weights (≥15 kg) and a 30.5 m buoy lines attached at each end. The mainline is equipped with stop sleeves every 30 m (21 line^{-1}) to prevent gangions from sliding together when a large fish is captured. The terminal tackle (gangions) is constructed of 0.5 m, 91 kg test monofilament leader, size 120 stainless steel longline snap, 4/0 swivel, and a 15/0 non-stainless-steel Mustad circle hook. Longlines were baited with Atlantic mackerel (*Scomber scombrus*), half Atlantic mackerel and half striped mullet (*Mugil cephalus*) for a bait study in Charleston Harbor (2011/2012), or all striped mullet, with 40 gangions placed on each mainline.

For each set, the station location (site nested in strata, latitude/longitude, and location (inshore vs. offshore) and gear code is recorded. When setting the gear, a start time (gear fully deployed) and end time (gear retrieval begins) of the set is noted for calculation of a set time (duration), in minutes. Gear was only set during daylight hours, and soak times for longline sets were limited to 45 minutes unless conditions or events dictated otherwise. A beginning and end depth is recorded at each station. Water quality (salinity (PSU), dissolved oxygen (mg L^{-1}), water temperature (^{o}C), tidal stage) and environmental conditions (air temperature (^{o}C), percent cloud cover, wind direction, and wind velocity) are recorded at the end of each set.

From 2007 to 2019 (data considered during data workshop for index development), the SCDNR coastal longline survey made 4,946 collections along the South Carolina coastline, of which 4,160 were used in the construction of the red drum index of relative abundance (Table 32).

5.8.1.2 Biological Sampling

Each fish captured on the longline is brought on board, the hook is removed, and their length is measured to the nearest mm. Red drum have both their FL and TL measured, are weighed to the nearest gram, and a fin tissue sample is retained for genetic analysis. At the conclusion of initial workup, each individual is either tagged and released or sacrificed for age estimation and reproductive assessment. Each red drum that is not sacrificed receive 2 tags unless previously tagged: a nylon dart tag (Hallprint©) inserted in the dorsal musculature near the mid-point of the second dorsal fin at an angle toward the head and embedded in between the pterigiophores, and a PIT tag, which is inserted in the dorsal musculature near the origin of the soft rayed dorsal fin (second dorsal).

Red drum sacrificed for additional life history studies were randomly selected, with every third fish encountered, up to a maximum of 10 fish daily, sacrificed. Sacrificed adult red drum (~100 per year) have several additional biological variables ascertained (macroscopic reproductive stage) and biological samples retained (e.g., otoliths for age and growth studies, gonad tissues for histological determination of reproductive status, and muscle tissues for contaminant analysis).

A summary of the biological information provided to the simulation assessment from the SCDNR longline survey is found in Table 32 and Table 33.

Red drum sacrificed for age from the SCDNR coastal longline survey have exclusively been aged via otolith thin-section techniques. A summary of the age information available from the trammel net survey and provided to the simulation assessment is found in Table 33.

5.8.1.3 Catch Estimation Methods

As length and age information is available from the survey for the development of length and age compositions and this survey is expected to capture adult red drum across a wide age range, we treated the coastal longline survey as a length- (or age-) aggregated index of relative abundance. Herein only an arithmetic mean annual relative abundance was developed, as our primary interest in the simulation assessment was to capture the trends in relative abundance of red drum along the South Carolina coastline. For a traditional benchmark stock assessment, the index would be standardized for a suite of covariates (e.g., stratum, water temperature, salinity, DOY, etc.) collected at the time of sampling to account for effects of such covariates on catchability of adult red drum.

Three different measures of relative abundance, based on catch per 40 hooks, were developed and presented for consideration during the data workshop. These measures varied depending on the methodology used for correcting the effect different bait (Atlantic Mackerel versus Striped Mullet) had on apparent annual CPUE, with 1) no correction, 2) a correction used in SEDAR 44 (SEDAR 2015a), and 3) a correction used in South Carolina state-specific assessment (Murphy 2017) employed.

Annual length and age compositions for the survey were developed from the observed TL measurements made on all individuals encountered by the survey and the random sub-sample of sacrificed fish aged. There was no need for expansion of the length and age compositions to the total catch of the survey given the survey sampling design.

All years pooled length- and age-compositions can be found in Figure 96 and Figure 97, respectively.

5.8.2 Trends

Depending on the correction used, the overall trend suggests stable to slightly increasing adult red drum abundance along coastal South Carolina since 2007 (Table 31 and Figure 98).

Annual length- and age-compositions available from the SCDNR coastal longline survey have more difficulty tracking individual cohorts of red drum encountered by the survey, which is not surprising given the size range and age-classes of adult red drum this survey intercepts (Figure 99 and Figure 100). Concerning is the decrease in the relative proportion of older fish in the longline survey since the mid-2010s (Figure 100), particularly given the declining numbers of sub-adult red drum encountered by the SCDNR trammel net survey (Figure 90).

5.8.3 Potential Biases, Uncertainty, and Measures of Precision

Overall the SCDNR coastal longline survey exhibits relatively low CVs, with an average CV of 0.12 (range: 0.09-0.23, Table 31). However, less effort in the 2007-2009 sampling seasons translates to generally increased uncertainty during this time block. Further, the effect of bait type on the catchability of red drum introduces an additional source of uncertainty to annual estimates of relative abundance. As Atlantic mackerel was used exclusively in 2007-2009 and striped mullet from 2010-2019, this leads to some caution when interpreting the CPUE across these years. However, a bait study conducted in Charleston Harbor in 2011 and 2012 allows analysts to develop correction factors (SEDAR 2015a; Murphy 2017) to minimize the impact bait type has on annual CPUE. Further, this time series is growing in length, with the anticipation that the increased survey length will improve our understanding of abundance changes in the adult population that may manifest slowly as the survey integrates data over many age classes.

5.9 Georgia Gill Net Survey (GA_GillNet)

5.9.1 Data Collection and Treatment

To determine red drum relative abundance, the gill net survey was conducted in Altamaha and Wassaw Sounds (Figure 101) from June through August 2003-2019.

5.9.1.1 Survey Methods

In the Altamaha River Region (Figure 102), 36 stations were sampled each month from a pool of 60 total stations using a stratified random station design. In a given survey month, each selected station is sampled one time. In Wassaw Sound (Figure 103), 36 stations were selected and sampled from a pool of 70 total stations using a stratified random station design.

A minimum of 36 stations are sampled in each sound system during each month of the sampling season (June – August). The time series covers 2003-present. The number of sites visited each year are outlined in Table 34.

In a given survey month, each selected station is sampled one time.

All sampling occurred during the last three hours of ebb tide and only during daylight hours. Station pools in both survey areas were determined by initial surveys, which identified locations that could be effectively sampled with survey gear.

Survey gear is a single panel gillnet. The net is 91.4 m (300 ft.) long by 2.7 m (9 ft.) deep. The panel has 6.4 cm (2.5 in.) stretch mesh. The net has a 1.3 cm (0.5 in.) diameter float rope and a 34 kg (75 lb.) lead line. A 11.3 kg (25 lb.) anchor chain is attached to each end of the lead line, and a large orange bullet float is attached to each end of the float line.

A sampling event consists of a single net set. The net is deployed by boat starting at the bank following a semicircular path and ending back on the same bank. Net deployment is performed against the tidal current. Immediately after deployment, the net is actively fished by making two to three passes with the boat in the area enclosed by the net. After the last pass is made, the net is retrieved starting with the end that was first set out. As the net is retrieved, catch is removed and put inside a holding pen tied to the side of the boat. After the net is fully retrieved, all catch is processed for information and released. The catch is identified to species and counted. In addition to catch information, temporal, spatial, weather, hydrographic and physio-chemical data are collected during each sampling event.

5.9.1.2 Biological Sampling

All finfish specimens are measured, centerline in millimeters.

5.9.1.3 Catch Estimation Methods

Catches of target species were first separated into age cohorts by applying a standard monthly cutoff value to the length frequency information collected with each catch. Cutoff values vary among months for each species and were based on modal analyses of historical composite monthly length frequency data and reviews of ageing studies for each species. For the earlier months of the year, cutoff values were arbitrary values that fell in between discrete modal size ranges. In the later part of the year, when early spawned, rapidly growing individuals of the most recent year class may overtake late spawned and slowly growing individuals of the previous year class, cutoff values were selected to preserve the correct numeric proportionality between year classes despite the misclassification of individuals.

The extent of the zone of overlapping lengths and the proportion within that range attributable to each year class is estimated based on the shape of each modal curve during the months prior to overlap occurring. A length value is then selected from within that range which will result in the appropriate proportional separation. In the case of red drum, specimens collected during the survey most often represented age-1 fish, with 97% of all fish captured falling in the 220 to 350 mm range. Although this process involved considerable subjectivity and ignored possible interannual variability in average growth rates, there was little likelihood that any significant error was introduced as only a very small fraction of the specific aged cohort individuals fell within the zone of overlap. Most of the data used to construct juvenile indices were drawn from months when no overlap at all is present.

Given the short sampling period of the gillnet sampling (June-August), and trammel sampling (September-November) all three months in each survey were used in these estimates. After partitioning out age-specific cohort individuals, numbers of individuals caught were logarithmically transformed (ln(n+1)) prior to abundance calculations, as this transformation has repeatedly been shown to best normalize collection data for aggregative organisms such as fishes. Annual juvenile CPUE indices were calculated as the weighted geometric mean catch per net set. Strata-specific means and variances were calculated and then combined, weighted by stratum areas according to the formulae supplied by Cochran (1977). Since stratum areas are quite variable, use of a weighted mean provided an index that more closely mirrors actual population sizes than a simple mean. Resulting average catch rates (and the 95% confidence intervals as estimated by + 2 standard errors) are then back-transformed to the weighted geometric means. CV is expressed as the log transformed mean catch divided by the standard deviation, E(Yst) / STD (Cochran 1977).

5.9.2 Trends

CPUE by year for 2003 through 2019 are provided in Table 34and Figure 104. Since 2009, CPUE has varied widely for red drum in the gill net survey ranging from a survey low of 0.41 in 2012 to a survey high of 1.55 in 2010. The Altamaha River system and Wassaw Sound have traditionally shown similar trends through the years. However, survey data differed greatly in 2018 and 2019. One thing to keep in mind is that the gill net survey is designed to target juvenile red drum, the average size of fish caught in the survey is 282 mm FL. Essentially this survey is a measure of annual recruitment and is largely driven by spawning success and environmental effects on larval/juvenile fish survivability through the winter/spring. The index generally tracks well with annual MRIP estimates.

5.9.3 Potential Biases, Uncertainty, and Measures of Precision

Overall, the GA gillnet survey is a robust long-term standardized survey, designed specifically to target YOY red drum before they enter the fishery. The survey has been in continuous operation since 2003 and the survey design has remained relatively unchanged since its inception. Geographically the survey has historically included two primary regions (Wassaw and

Altamaha). Recognizing that this could lead to an underrepresentation of statewide red drum trends, a third system (St. Andrew) was added in 2019. Data from the St. Andrew expansion is still preliminary and has not yet been included in the survey index. However, the addition of St. Andrew and any other future expansions should help improve statewide status estimates.

5.10 Georgia Longline Survey (GA_Longline)

5.10.1 Data Collection and Treatment

The GADNR utilizes a near shore red drum bottom longline survey which encompasses state and federal waters off the coast of Georgia. This is a stratified-random study to develop fishery-independent indices of abundance for multiple shark species and adult red drum occurring in state waters. Data gathered from this study will be used to support long-term fishery-independent indices for the Southeast (North Carolina – Florida) that can be used in future stock assessment work. Tagging of red drum and sharks captured during the study will allow for additional information on migratory behavior and stock identification.

5.10.1.1 Survey Methods

Current sampling occurs in waters of Doboy Sound to St. Mary's in Georgia from June to December. Stations are randomly chosen from a subset of sites identified as areas with high encounter probabilities. Three strata are delineated off Georgia (inshore; near shore; offshore) and sampling efforts are proportionally allocated to match the emigration pattern of adult red drum. All stations are sampled during daylight hours and are generally located in water depths between 13 and 65 feet. The longline is deployed from the R/V Marguerite, a 47' offshore vessel. The mainline is made of 600 lb. monofilament and is approx. ½ nautical mile in length. A total of 60 droplines are attached to the mainline, where each dropline consists of a longline snap, 1.5 ft of 200 lb. monofilament, and a 12/0 circle hook on the terminal end. Hooks are not offset and have barbs depressed. The total soak time is 30 minutes with hooks baited with mullet.

Beginning in 2018, sampling was broken up into 4, 6-week quarters. A minimum of 35 bottom-set longline stations are selected to be sampled in Georgia coastal waters each 6-week quarter (June 16-July 31, Aug 1-Sep 15, Sep 16 – Oct 31, Nov 1 – Dec 15).

Since its inception in 2006, the longline survey has captured nearly 900 large, adult red drum.

5.10.1.2 Biological Sampling

All catch is processed at the species level. All red drum are landed and processed for standard morphometrics and genetic material (fin clip) when requested. Viable red drum are tagged with conventional dart and PIT tags and released. Mortalities are processed further for sex and gonadal development information, and otoliths are extracted for age determination. Periodically, a subsample of red drum may be sacrificed to estimate the adult stock age composition.

5.10.1.3 Catch Estimation Methods

CPUE is based on the arithmetic mean of catch per 60 hooks. This measure is intended to capture annual trends of relative abundance of red drum along the Georgia coast.

5.10.2 Trends

The index has been variable with some higher values in recent years (Table 35 and Figure 105). The longline survey is still adapting due to low numbers of captured red drum per year.

The length frequency of red drum caught during the survey is in Figure 106.

5.10.3 Potential Biases, Uncertainty, and Measures of Precision

In the early years of the survey different hook sizes and bait types were tested. In 2006 and 2007 mackerel and squid were the primary bait types. From 2008-2015 mullet and squid were tested. Beginning in 2021 the survey was tuned to replicate the South Carolina longline survey which included standardized hook size and bait selection to include mullet only.

5.11 Florida 21.3 Meter Haul Seine Survey (FL_21.3_HaulSeine)

5.11.1 Data Collection and Treatment

Indices of relative abundance for red drum were derived from surveys conducted by the Florida Fish and Wildlife Research Institute's Fishery Independent Monitoring (FIM) program in northeast Florida (lower St. Johns, Nassau, and St. Mary's River basins) as well as the northern portion of the Indian River Lagoon.

The 21.3-m center bag seine was used to develop an index of relative abundance for age-0 YOY red drum.

5.11.1.1 Survey Methods

The FIM program uses a stratified random sampling design to monitor abundances of fish and invertebrates. Survey areas were divided into sampling zones based upon geographic and logistical criteria where each zone was further subdivided into 1-nm^2 grids and randomly selected for sampling. Sampling grids were stratified for each gear type by depth and habitat (defined by shore type [overhanging or not] and bottom vegetation [vegetated or not]) where a single sample was collected at each randomly selected site in shallow water ≤1.8 m. Environmental data consisting of water chemistry, habitat characteristics, and current and tidal conditions were recorded for each sample. In northeast Florida, sampling has been conducted year round since May 2001 and since late 1997 in the northern Indian River Lagoon.

5.11.1.2 Biological Sampling

All captured red drum were counted and a random sample of at least 20 individuals were measured (SL). If more than 20 red drum were encountered, then length frequencies of the 20 fish were expanded to the total number caught to estimate the sample catch length frequency.

5.11.1.3 Catch Estimation Methods

YOY were defined as red drum captured during the peak recruitment season of September through March and whose lengths were smaller than or equal to 40 mm SL. Cohorts were kept together such that fish caught in September through December were grouped with those caught January through March the following year. Prior to standardization, the data were subset to remove any months, zones, or strata that rarely encountered red drum.

Catch rates for this index were standardized using the delta lognormal model which split the process into two generalized linear submodels (Lo et al. 1992). The first submodel estimated the proportion of stations where red drum were observed. This submodel used a binomial distribution with a logit link. A separate submodel with a gamma distribution and a log link was used to estimate the mean number of red drum caught at positive stations. The estimated coefficients were then back-calculated from their linearized form used in the modeling steps. The annual index is the product of the proportion of samples where red drum were observed and the mean number of red drum by year estimated from the positive model.

Potential explanatory variables included year, month, bottom vegetation, bottom type, shore type, bay zone, water temperature (°C), dissolved oxygen (mg/L), and salinity (ppt). All potential explanatory variables were treated as categorical variables partially to account for non-linearity. Beginning with the null model, forward stepwise selection was used to identify which variables should be included in the final versions of the submodels. To be included in the final submodel, variables had to meet two criteria: the variable must be statistically significant at an alpha level of 0.05 and its inclusion must reduce deviance (a measure of the variability) by at least 0.5%.

5.11.2 Trends

The YOY index of relative abundance for red drum increased in trend between 1998 – 2005, then decreased and became variable but stable through 2019 (Table 36 and Figure 107). Stronger year-classes occurred from 2003 – 2005, with the strongest occurring in 2005 while weaker year-classes have occurred recently in 2018 – 2019.

5.11.3 Potential Biases, Uncertainty, and Measures of Precision

To estimate variability in the annual index values (Table 36), a Monte Carlo simulation approach was used with 10,000 iterations using the least-squares mean estimates and their standard errors from the two generalized linear submodels. Each iteration used the annual least-squares mean estimate on the log scale and uncertainty was added by multiplying the annual least-squares mean estimate's standard error by a random normal deviate (μ=0, s=1). These values were transformed back from their linear scales prior to being multiplied together and the index derived was the product of the probability of observing a red drum during sampling and the annual average number of red drum counted at sites where this species was encountered.

5.12 Florida 183 Meter Haul Seine Survey (FL_183_HaulSeine)

5.12.1 Data Collection and Treatment

Indices of relative abundance for red drum were derived from surveys conducted by the Florida Fish and Wildlife Research Institute's Fishery Independent Monitoring (FIM) program in northeast Florida (lower St. Johns, Nassau, and St. Mary's River basins) as well as the northern and southern portions of the Indian River Lagoon.

The 183-m haul seine was used to develop an index of relative abundance for sub-adult red drum.

5.12.1.1 Survey Methods

The FIM program uses a stratified random sampling design to monitor abundances of fish and invertebrates. Survey areas were divided into sampling zones based upon geographic and logistical criteria where each zone was further subdivided into 1-nm^2 grids and randomly selected for sampling. Sampling grids were stratified for each gear type by depth and habitat (defined by shore type [overhanging or not] and bottom vegetation [vegetated or not]) where a single sample was collected at each randomly selected site in shallow water ≤1.8 m.

Environmental data consisting of water chemistry, habitat characteristics, and current and tidal conditions were recorded for each sample. In northeast Florida, sampling has been conducted year round since May 2001 and since 1997 in the northern and southern portions of the Indian River Lagoon.

5.12.1.2 Biological Sampling

All captured red drum were counted and measured (SL). If five or fewer were captured within a single set, they were culled for further biological sampling including weight, sex, maturity, age, mercury content, and diet.

Red drum culled for further biological sampling had their otoliths removed and aged by FWRI's Age and Growth lab.

5.12.1.3 Catch Estimation Methods

Sub-adults were defined as red drum captured year round whose lengths were larger than 300 mm SL. Prior to standardization, the data were subset to remove any months, zones, or strata that rarely encountered red drum.

Catch rates for this index were similarly standardized as the 21.3-m seine index using the delta lognormal model which split the process into two generalized linear submodels (Lo et al. 1992). The first submodel estimated the proportion of stations where red drum were observed. This submodel used a binomial distribution with a logit link. A separate submodel with a gamma distribution and a log link was used to estimate the mean number of red drum caught at positive stations. The estimated coefficients were then back-calculated from their linearized form used in the modeling steps. The annual index is the product of the proportion of samples where red drum were observed and the mean number of red drum by year estimated from the positive model.

Potential explanatory variables included year, month, bottom vegetation, bottom type, shore type, bay zone, water temperature (°C), dissolved oxygen (mg/L), and salinity (ppt). All potential explanatory variables were treated as categorical variables partially to account for non-linearity. Beginning with the null model, forward stepwise selection was used to identify which variables should be included in the final versions of the submodels. To be included in the final submodel, variables had to meet two criteria: the variable must be statistically significant at an alpha level of 0.05 and its inclusion must reduce deviance (a measure of the variability) by at least 0.5%.

5.12.2 Trends

The sub-adult index of relative abundance for red drum has been variable without trend from 1997 – 2015, then declined through 2019 with low abundances in the terminal 3 years of the time series (Table 37 and Figure 108).

The survey mostly encountered red drum less than 65 cm (Figure 109) and ages 1-3 (Figure 110).

5.12.3 Potential Biases, Uncertainty, and Measures of Precision

To estimate variability in the annual index values (Table 37), a Monte Carlo simulation approach was used with 10,000 iterations using the least-squares mean estimates and their standard errors from the two generalized linear submodels. Each iteration used the annual least-squares mean estimate on the log scale and uncertainty was added by multiplying the annual least-squares mean estimate's standard error by a random normal deviate (μ=0, s=1). These values were transformed back from their linear scales prior to being multiplied together and the index derived was the product of the probability of observing a red drum during sampling and the annual average number of red drum counted at sites where this species was encountered.

6 METHODS

6.1 Description of Simulation Process

The simulation process used in this assessment consisted of several steps. The first step was the data simulation process, where observed data from *in situ* monitoring programs covered in Sections 4 and 5, acquired through the data workshop, were used to construct simulated populations of the northern and southern red drum stocks. The operating models (OMs) used to create these simulations were based in Stock Synthesis (Section 6.2). Simulated sampling datasets were then sampled from simulated stocks with the OM and passed to each of the estimation models (EMs) being considered as candidates for future red drum stock assessment models.

The performance of three candidate assessment models was evaluated in this study. These three models were: a traffic light analysis (TLA) of model-free stock indicators, used previously for Atlantic croaker and spot management advice; the Statistical Catch-at-Age assessment models (SCA) used for the most recent red drum benchmark stock assessment in 2017; and a Stock Synthesis model (SS), widely used in stock assessments. The frameworks varied in their degree of complexity and ability to assess and predict population trends. While technically SS is a statistical-catch-at-age model, it is a more flexible environment that can incorporate a wider assortment of data inputs and parameter estimates than the SCA. Further details about each model are provided in Section 6.3.

The assessment evaluation followed a structured path to evaluate the performance of each EM (Figure 111) for a range of scenarios (Section 6.1.1). The first step was to ensure that each of the methods could successfully converge and produce valid results. Next, the individual results for each of the assessment frameworks were compared, when possible. These comparisons focused on two broad fishery characteristics, fishing mortality and abundance/biomass, selected based on their importance to management and their ability to be estimated by the models. For each of the broad fishery characteristics, there were numerous fishing mortality (Table 40) and abundance/biomass (Table 41) population parameters used in performance metrics (relative error, Type I and Type II error rates) to evaluate performance of candidate red drum stock assessment approaches. While it was preferred that these population parameters could apply to all assessment approaches, due to differences in model configurations, especially the TLA, estimates could not be produced for each parameter for all approaches.

Biological reference points were selected to evaluate model performance when determining stock status. The ASMFC (2002) defines the overfishing threshold for red drum to be 30% SPR and a management goal (fishing target) of 40% SPR. SPR is calculated as the spawning stock biomass per recruit expected under the current year's fishing regime divided by the theoretical spawning stock biomass under no fishing. This was calculated as:

$$sSPR_y = \frac{\sum_a Mat_a B_a \prod_1^a e^{-M_a - F_{y,a}}}{\sum_a Mat_a B_a \prod_1^a e^{-M_a}},$$

where $\boldsymbol{Mat_a}$ and $\boldsymbol{B_a}$ are the maturity- and weight-at-age vectors through the maximum ages (62 years in north and 41 years in south), respectively.

The $SPR_{30\%}$ benchmark is the basis of several other benchmarks used in performance evaluations: ($R_{30\%}$, $F_{30\%}$, $SSB_{30\%}$). The $F_{30\%}$ benchmark is the level of fishing mortality that achieves $SPR_{30\%}$. The $R_{30\%}$ and $SSB_{30\%}$ benchmarks are the levels of these respective parameters when the stock is fished at $F_{30\%}$ according to the specified stock-recruit relationship for the simulated stocks. Due to the noisiness of the data and the general imprecision of red drum fishing mortality estimates, the reviewers in SEDAR 18 recommended using a three year average SPR for management of red drum (Section 1.3.1) and so these parameters were included with the annual estimates in performance evaluations.

The performance evaluation also included escapement (Esc), a more readily "observable" metric for red drum that is very similar to SPR when there are low levels of fishing mortality on mature adults. Past assessments (Vaughan and Carmichael 2000) presented estimates of escapement to age-4. During SEDAR 18, it was determined that it may be useful to encompass more of the immature portion of the stock in the escapement estimate, so escapement estimates to age-6 are also presented in this assessment. If there was no fishing mortality on mature adults then escapement would equal SPR levels. Static, or year specific, escapement was defined as:

$$Esc_y = e^{\sum_{a=1}^{T} -F_{y,a}},$$

where $\boldsymbol{T}$ is either age-3 (escapement through age-3 or to age-4) or age-5 (escapement through age-5 or to age-6).

The assessment approaches were evaluated based on their performance estimating population parameters through multiple iterations of each simulation scenario. Assessment model estimates were compared to the known population parameters of the OM to calculate performance metrics, and these performance metrics were then compared to those of the other assessment models to evaluate relative performance across assessment models. Evaluation of performance was both qualitative and quantitative.

The first evaluation criterion was the ability of a given model to successfully run an iteration of a scenario and converge on a solution (only applies to SCA and SS EMs). Models may have varying amounts of difficulty running scenarios depending on specification and convergence rates across all iterations (n converged iterations/n iterations) provides information on the stability of the estimation model.

If a model successfully ran an iteration, performance was then evaluated on how each approach estimated the status/condition and the precision and accuracy of parameters (Figure 111). For status/condition, Type I and Type II error rates were the metrics of interest. Type I error (false positive) was defined here as incorrect rejection of a null hypothesis of favorable condition/status (e.g., stock was estimated to be in poor condition when it was really in good condition), while Type II error (false negative) was the incorrect rejection of a null hypothesis of unfavorable condition/status (e.g., stock was estimated to be in good condition when it was really in poor condition). Error rates were quantified by their frequency of occurrence across iterations for a given model and scenario.

Relative error was used to assess precision and bias of quantitative population parameter estimates for each model. Relative error was used quantitatively to examine the magnitude and direction of error for individual parameter estimates. The main parameters of interest were recruitment (R), fishing mortality (F), sub-adult abundance (SN; sum of age2 and age-3 abundance), and mature stock abundance or biomass (MN or SSB). Two $SPR/SPR_{30\%}$ and $F/F_{30\%}$ were assessed, one using annual values (i.e., SPR_y, F_y) and one using running three-year average values (i.e., $\boldsymbol{SPR_{y-2,y-1,y}}$, $\boldsymbol{F_{y-2,y-1,y}}$). Relative error was calculated using the formula:

$$\frac{Estmated\ value - True\ value}{True\ value}$$

Estimation model performance was initially evaluated by plotting performance metrics across iterations for the simulation scenarios. Type I and Type II error rates and the distribution of relative error were plotted to examine performance over the complete time series of model estimates for individual parameter estimates and results for different candidate models were plotted against each other. This initial visualization of error patterns for model outputs provided more detail about the characteristics of uncertainty for model estimates than were provided by more summarized performance metric results.

No prescriptive scoring system was used to select the best performing assessment model overall for a given scenario, but performance metrics were further summarized and compared in decision tables to guide future modeling recommendations (see Section 7.2.1).

6.1.1 Scenarios

Simulation scenarios to be addressed in the assessment were identified at the beginning of the assessment and prioritized by the SAS. Simulation scenarios were grouped into two types: core population dynamics scenarios and data prioritization scenarios. The goal of the core population dynamics scenarios was to evaluate candidate assessment approaches for assessing red drum stocks with status quo monitoring under various scenarios that may play out in future red drum stock assessments. The data prioritization scenarios were designed to evaluate improvements in modeling performance with changes to status quo monitoring. The goal of these data prioritization scenarios was to inform research recommendations for future monitoring of red drum stocks. Scenarios were run by each candidate model, for each red drum stock, and the results evaluated. General descriptions and purpose for selected scenarios are described below and in Table 42, and additional details about the parameterizations of these scenarios in the OMs are provided in Section 6.2.5. A full table of all scenario runs performed in the assessment, including supplemental scenarios identified during development of EMs (see Section 7.1) and following review of the core population dynamics scenarios (see Section 7.3), are described in Table 43.

6.1.1.1 Core Population Dynamics Scenarios

Decreasing Fishing Mortality (***Base***) – This scenario was selected as a proxy for a recovering stock. This scenario was selected as the ***Base*** scenario because it included the most likely fishing mortality trajectory, as it is unlikely that fishing mortality would remain high (as in the ***High F*** scenario below) without being addressed by management changes. Fishing mortality was simulated to increase gradually for a period of time (fifteen years) to high levels corresponding with SPR values around ≈15%, on average, followed by a decreasing trend for a period of time (five years) to levels corresponding with SPR values ≈45%, on average, before stabilizing at these values. The shorter period for decreasing fishing mortality was selected to simulate implementation of regulations in response to the increased fishing mortality levels.

High Fishing Mortality (***High F***) – This scenario was selected because of the potential for high fishing pressure. It was noted increased participation would likely be the reason for high fishing pressure in the future and that increases would be gradual given the highly restrictive regulations currently in place. Fishing mortality was simulated to increase as in the ***Base*** scenario, but then stabilize at these high levels. Commercial fisheries in the northern stock are constrained by catch caps and unlikely to experience increasing fishing mortality in the future, so fishing mortality for commercial fleets was held constant and all increases are attributed to recreational fleets.

Increasing Adult Selectivity (***Inc Sel***) – This scenario was selected because of anecdotal information that catch and release targeting of trophy-sized red drum may have increased in recent years. The selectivity of the largest sized fish by all recreational fleets was increased to simulate this change in targeting. This scenario included the projected fishing mortality in the ***Base*** scenario.

Misspecified Natural Mortality (***Miss M***) – This scenario was selected as natural mortality is considered an uncertain life history attribute of red drum that is likely misspecified often in stock assessments. This scenario focused on misspecification, particularly scale of natural mortality, by using the Hoenig (1983) scaler for natural mortality-at-age in the OM and the Then et al. (2015) scaler for fixed natural mortality-at-age in the EMs. This scenario included the projected fishing mortality in the ***Base*** scenario.

Depressed Productivity (***Depr R***) – This scenario was selected to represent the potential for deteriorating productivity due to factors such as reduced nursery habitat (e.g., climate change, increased development of coastal areas). Indices of abundance indicate this may already be occurring in South Carolina waters in recent years. Maximum productivity (i.e., unfished recruitment) was set to decline then stabilize at a lower level. This scenario included the projected fishing mortality in the ***Base*** scenario.

Terminal Year of 2023 (***2023 Term Yr***) – This scenario was selected to evaluate the response of the EMs' performance when truncating the assessment data time series to a period similar to that of the upcoming benchmark stock assessment. The ***Base*** scenario settings were used but specified with an earlier terminal year (2023) for sampled data.

6.1.1.2 Data Prioritization Scenarios

Longline Survey Time Series Necessary to Estimate Spawning Stock Biomass (***NoLL, 15yrsLL, 30yrs, LL45yrs, LL60yrs***) – This scenario was identified based on questions in the last stock assessment about how long the adult longline surveys time series need to be to address the cryptic biomass issue and reliably estimate spawning stock biomass. This scenario was structured with a set of sub-scenarios. The first sub-scenario (***NoLL***) used the ***Base*** scenario settings, but without longline survey data (total index and composition data). The second sub-scenario (***15yrsLL***) included longline survey data, but for only the last 15 years of the assessment time series. Each subsequent sub-scenario added 15 years of longline survey data working backwards until the full time series of data back to the true survey start years was included (i.e., the ***Base*** scenario).

Implement Recreational Discard Length Composition Sampling (***B2 Dat, Prec B2 Dat***) – This scenario was identified as recreational discard length composition sampling remains the primary data gap for assessing red drum. This scenario was structured with two sub-scenarios based on different data settings for the two stocks. The first sub-scenario (***B2 Dat***) included low precision composition sampling data for the recreational discards in the northern stock, but does not apply to the southern stock because these data are already included in the core population dynamics scenarios for this stock. The second sub-scenario included high precision composition sampling data for the recreational discards and applies to both stocks. This scenario is intended to address the question of whether recreational discard composition data improves red drum stock assessments.

6.2 Operating Model Descriptions

6.2.1 Background

The ss3sim R package (Anderson et al. 2014; Johnson et al. 2021), a simulation platform to complement the SS modeling framework (Methot and Wetzel 2013), was used in this simulation assessment. The package implements an SS model configuration with all parameters fixed to user-specified values as an OM to simulate a population with true, known population dynamics according to a user-specified fishing mortality trajectory for each fishing fleet. Using the SS modeling framework allows for many of the tested complexities built into the framework that are appealing for realistic simulation of red drum-like stocks to be applied and readily modified in OMs. The package includes sampling algorithms to sample data with error from the simulated population that are subsequently used to make predictions of the population dynamics with an EM. Scenario testing can be conducted by changing the OM configuration, data sampling algorithms, or EM configuration and evaluating the EM's ability to recover the simulated population dynamics generated by the OM. Scenarios with changes to the OM configuration or EM configuration allow for a unique understanding of an EM's performance under potential structural differences between a true population being assessed and the EM that might be experienced in a benchmark stock assessment (i.e., misspecification) given the quantity and quality of data available. This type of scenario testing also allows for an evaluation of a respective EM's performance relative to other candidate EMs with their own structural differences that are being considered for stock assessment models. Scenarios with changes to the data sampling algorithms allow an understanding of changes to EM performance under changes to quantity and/or quality of data that can be used to prioritize future data collection efforts.

The package typically passes data files produced from the sampling algorithms to an SS EM in an end-to-end process (Anderson et al. 2014). However, since EMs developed outside of the SS framework were considered in this simulation, only the OM and sampling algorithm components of the package were used. Data files produced within the package were modified as necessary to the format accepted by each EM and fit externally to estimate the population dynamics. Performance statistics are then calculated and compared among candidate EMs and scenarios.

Each scenario generates a specified number of iterations of the population dynamics with unique process and observation error. For this study, 100 iterations were generated for each scenario. The package uses random seeds to generate recruitment deviations and sampled data sets specific to the iteration number across scenarios. That is, iteration 1 recruitment deviations are identical for scenario X, scenario Y, etc. Iteration-specific sampled data only changes between scenarios when there are changes to the OM specifications (e.g., fishing mortality or life history characteristics) or data sampling algorithms. The recruitment deviations represent process error and the sample data introduce observation error according to the level of user-specified precision for each sampled data set. Using random seeds specific to the iteration number allows for reproducibility and removes confounding effects of different process and observation error across scenarios. Each iteration is considered a plausible state of nature under the population characteristics and data sampling precision specified in the OM.

Data types that can be sampled include total retained catch, total discarded catch, total dead discarded catch, indices of abundance, length compositions (fishery catches and indices of abundance), and age compositions (fishery catches and indices of abundance). Additional details on the ss3sim package are available in Johnson et al. (2021).

6.2.2 Red Drum Simulation Operating Models

OMs were constructed from available information on red drum stocks to simulate dynamics of red drum-like stocks through time and provide sampling data replicating data available from *in situ* stocks for stock assessment. The goal of using available information for red drum was to arrive at reasonable approximations of *in situ* red drum stocks to allow inference about EM performance for *in situ* stocks, not to make predictions of true exploitation histories of the *in situ* stocks. An iterative tuning process (Section 6.2.3) was used to update preliminary parameterizations of the OMs described in the following section. OMs are length-and age-structured models that project the stock forward through time and track stock dynamics at an annual time step across length bins and age bins according to conversions from an internal growth model. Separate OMs were developed for each regional stock based on differences in life history as well as past and anticipated future assessment structures. Length bins were set at 2 cm intervals starting at 12 cm out to the largest bin observed in each stock. Similarly, ages were tracked starting at age-1 through the maximum age observed in each stock (62 for the northern stock, 41 for the southern stock). Spawning occurs in the middle of August and YOY settle and are tracked in the model the following January (i.e., age-1 recruitment). The model does not differentiate between sexes, except in calculation of spawning stock biomass which is females only according to a 1:1 sex ratio.

Simulation time periods were structured to include a pre-fishery burn in period, a historical fishery period, and a projection period (Table 38). Pre-fishery burn in periods were set equal to the respective stock's age structure to achieve unfished equilibrium conditions at the start of the fishery. Therefore, the pre-fishery burn in period starts the number of years before the historical fishery period equal to the number of age classes in the stock. The historical fishery period was set to start in 1901, assuming non-negligible fishing mortality began in this year, and continue through 2019, the terminal year of observed data available for this simulation. The historical fishery period was structured to simulate a historical exploitation pattern similar to that of red drum stocks based on available information. The projection period started in 2020 and was also set equal to the respective stock's age structure.

6.2.2.1 Life History

Life history information specified in the OMs includes age-specific K growth model parameters, Lorenzen (2005) length-based natural mortality-at-age (calculated internally from a fixed value for age-2 fish), length-weight relationship parameters, logistic female maturity-at-age, and stock-recruit relationship parameters (Table 39). All of these parameters were calculated from available red drum data, except stock-recruit relationship parameters, and additional details on these parameters are in Section 2. A Beverton-Holt stock-recruit relationship is used in the OMs and includes parameters for unfished recruitment (*R0*), steepness (*h*), and variation around the expected stock-recruit relationship (*sigma R*). No estimates of the relationship parameters are available for red drum, so meta-analyses were used to specify *h* (Shertzer and Conn 2012) and *sigma R* (Beddington and Cooke 1983). With these constraints, *R0* was then adjusted during the tuning process. Female spawning stock biomass (SSB) calculated from the specified maturity and length-weight relationship parameters is the measure of reproductive potential used in the stock-recruit relationship. All parameters are time-invariant with the exception of *R0* in the ***Depr R*** scenario.

6.2.2.2 Fishing Fleets and Surveys

Fishing fleets and monitoring surveys were structured to replicate those operating on the *in situ* red drum stocks. The fishing fleets are defined based on sectors and fishing gears with different regulations and selectivity patterns. Fishing fleets sample catch with lognormal error and composition data with multinomial error. Monitoring surveys sample indices of abundance with lognormal error and composition data with multinomial error.

The northern stock has three fishing fleets (Table 43) and three monitoring surveys (Table 45). Fishing fleets include a commercial fleet fishing gillnets and beach seines, a commercial fleet fishing other gears (mostly pound nets), and a recreational fleet fishing hook and line gears. The monitoring surveys include a survey indexing age-1 recruitment, a survey indexing primarily sub-adult abundance inshore, and a survey indexing mature abundance. Additionally, the model samples CPUE from the recreational fishery as a fishery-dependent index of abundance.

The southern stock has three fishing fleets (Table 46) and nine monitoring surveys (Table 47). Fishing fleets include recreational fleets fishing hook and line gears for each of the three states in the southern stock. Historically, commercial red drum fishing did occur in these states, but most of this fishing was eliminated by the late 1980s (Section 4.1). It's assumed that commercial selectivity would have been similar in these states and years to recreational selectivity and, therefore, any commercial catch was interpreted as part of the recreational fleet (i.e., combined with the recreational catch) during the tuning process. The monitoring surveys include three surveys indexing age-1 recruitment, three surveys indexing primarily sub-adult abundance inshore, and three surveys indexing mature abundance. Some of these surveys have been discontinued and were also discontinued during the same year within the historical period of the OM. Additionally, the model samples CPUE from the recreational fisheries as a fishery-dependent index of abundance (see Appendix 2 for recreational fishery CPUE specifications).

Observation error was specified in the OMs based on measures of observation error provided with the monitoring data sets available for assessment. Observation error data included standard errors for lognormal catch and index of abundance data and sampling replicates as a measure of sample size for multinomial composition data, assuming a clustered sampling design (i.e., lack of independence) that results in sample sizes less than the absolute number of individuals measured for size or age (Nelson 2014). A change point analysis was conducted on each time series of observation error data. Blocks of constant observation error levels set to the mean of the calculated observation error across the block were specified for any periods that did not have support for changes from the change point analysis up to constant levels across the full time series (Table 43 - Table 47). There are no observation error data available for commercial catch (e.g., levels of misreporting), so standard errors were assumed based on time periods identified during the SEDAR Best Practices workshop (SEDAR 2015b) and biologists' knowledge of catch monitoring programs and changes to these programs through time. All initial observation error levels were then tuned, as necessary, during the tuning process.

Fishery catch occurs throughout the year, while monitoring surveys sample at specified points within the year. These points were generally set to match the midpoint of the *in situ* surveys (Table 43 - Table 47).

6.2.2.3 Selectivity

Double normal, length-based selectivity functions were used for all fishing fleets and all monitoring surveys except age-1 recruitment surveys. The double normal selectivity patterns represent selectivity for total catch. Fishing fleet catch is further partitioned into harvest and discards according to a length-based retention curve. Subsequently, discards are partitioned into live discards and dead discards according to a specified discard mortality rate. Age-based selectivity patterns are derived from length-based selectivity and the internal growth model or set to select age-1 fish only for recruitment surveys. Fishing fleet selectivity varied through time in yearly block patterns according to changes in red drum regulations.

Initial selectivity and retention specifications were set based on available information from a combination of published studies, regulations, length composition data, life history, supporting selectivity analyses, and expert opinion (see Appendix 2 for more detail). All initial length-based selectivity specifications were then tuned during the tuning process.

6.2.2.4 Fishing Mortality

Fishing mortality estimates from past state-specific stock assessments and published studies were used for initial specifications of fleet-specific fishing mortality in the OMs, where available. As the scale of these estimates is not necessarily directly relatable to the OM configurations (e.g., age-based fishing mortality vs. length-based fishing mortality) and come from several sources, only the trend information was used by applying a constant scaler to these estimates. Assumptions were made to fill in missing fishing mortality specifications.

For the northern stock, fishing mortality at the start of the historical fishery period (1901) through the end of World War II was assumed to be low and stable. There are no fishing mortality estimates until published estimates from a tag study start in 1983 (Bacheler et al. 2008). These fishing mortality estimates start high and it's suspected this high level of fishing mortality was occurring before this year back to at least the mid-1970s when the state of North Carolina implemented its first management measures to regulate the harvest of red drum. Therefore, fishing mortality for each fleet was specified to follow a linear ramp from the low stable value at the end of World War II to an average of the Bacheler et al. 2008 estimates during a high exploitation period preceding strict regulations (1983-1991) in 1975. Random draws were then made from the 1983-1991 period for specifications from 1976-1982. The Bacheler et al. 2008 estimates were used from 1983 until they end in 2004. Random draws from the Bacheler et al. 2008 estimates during the years 1999-2004, when fishing mortality was estimated to decrease due to implementation of strict regulations, were made for specifications from 2005-2019.

The assumption of low stable fishing mortality prior to the end of World War II was made for the southern stock as well. Florida conducted an assessment in 2015 on red drum in Atlantic state waters with a start year shortly after this period in 1950 (Chagaris et al. 2015), and so the low stable values were carried forward through 1949 and the assessment estimates were used for the FL_Recreational fleet through 1988. Florida updated the 2015 stock assessment in 2020 (Addis 2020), but with a start year of 1989. These estimates were used for the remaining years of the historical fishery period. There was no information on fishing mortality of the SC_Recreational fleet until estimates for 1982 and later from a state stock assessment (Murphy 2017). Therefore, a linear ramp was assumed to occur in fishing mortality between the low, stable fishing mortality in 1946 and the average of the assessment estimates from 1982-1985 for 1981. The assessment estimates were then used for all years until they end in 2015. Random draws of the assessment estimates during 2007-2015 were used for the remaining years 2016-2019. There are no estimates of fishing mortality for the GA_Recreational fishing fleet and so the trend was assumed the same as South Carolina due to more similar regulation histories between these states.

6.2.2.5 Catchability

Each survey includes a catchability coefficient scaling its relative catch rate to the absolute abundance its tracking. Initial catchability coefficients were tuned during the tuning process.

6.2.2.6 Benchmark Calculations

The OM threshold benchmarks ($R_{30\%}$, $F_{30\%}$, $SPR_{30\%}$, $SSB_{30\%}$) are calculated with terminal three-year averages of life history characteristics, selectivity, and fleet-specific relative fishing mortality. The $F_{30\%}$ benchmark is in terms of age-2 fish and is the level of fishing mortality that achieves $SPR_{30\%}$. The $R_{30\%}$ and $SSB_{30\%}$ benchmarks are the levels of these respective parameters when the stock is fished at $F_{30\%}$ according to the specified stock-recruit relationship. The only exception is for the ***Depr R*** scenario which calculates $R_{30\%}$ and $SSB_{30\%}$ based on the historical stock-recruit relationship before productivity decreases in the projection period, as the objective of this scenario was to evaluate the EM’s ability to recognize the decreased productivity relative to the historical baseline.

6.2.3 Tuning Process

An iterative tuning process was used to adjust the OM parameterizations so they produced sampled data sets with trend, magnitude, and variability similar to observed data sets provided from *in situ* monitoring programs. Annual dynamics were not considered during tuning as simulated recruitment deviations are likely different from *in situ* recruitment deviations leading to within year differences between simulated and observed data sets.

Figures showing comparisons of observed and simulated data sets are provided in Appendix 4 and Appendix 5. Catch magnitudes and trends were used to tune *R0*, survey catchability coefficient, fishing mortality, retention, and discard mortality rate parameters. The scale of fishing mortality and *R0* were tuned until the catch magnitudes were similar, the stock status matched perception of stock status through time (overfishing in the 1970s and 1980s, reduced fishing pressure in the later 1990s and 2000s), and the trends in indices of abundance were similar. Initial fishing mortality trends were only modified if there were clear mismatches during multi-year stretches of the time series. Maximum retention parameters were tuned by comparing proportion of the catch discarded and discard mortality rates were tuned by simultaneously matching the scale of the total discarded fish and dead discards. Catchability coefficients were tuned by matching the magnitude of indices on their original scale.

Selectivity patterns, including retention, were tuned by matching the proportion of catch discarded and length and age composition data aggregated over selectivity block (fishery fleets) or the data time series (indices of abundance).

Observation error levels were tuned by comparison of variation through time (catch and indices of abundance) or within a year across the size or age structure (composition data). Simulated data sets from a single iteration were used for these comparisons so variability was not smoothed by averaging across iterations.

Tuning was only done when there were distinct differences between observed and simulated data sets and, in some cases, these differences could not be resolved with the tuning process due to the structure of the OM. When conflicts occurred resulting in mismatches, priority was placed on later more data rich periods.

6.2.4 Limitations

There are a few aspects of the OMs that limit their ability to simulate sampling data that matches observed data, indicating some differences in the population dynamics of the simulated stocks and *in situ* stocks. The first primary limitation is the lack of spatially-explicit sampling algorithms. The *in situ* southern red drum stock has multiple fishery-independent surveys indexing the same age component of the stock (e.g., age-1 recruitment), but at localized, sub-stock scales (i.e., within state waters). The non-spatially-explicit OM is providing what are essentially replicate observations of the same underlying abundance trend for the multiple indices. There has been evidence of divergent trends among the observed indices that the OM cannot replicate (Figure 10 in Appendix 5). Therefore, the OM provides a simplified simulation of data sampling that does not have the ability to provide indices with divergent trends that the EM must then reconcile in the fitting process. The inclusion of multiple surveys in the OM does, however, integrate random noise from observation error coming from multiple indices as would be experienced in assessment of the *in situ* stock. In the northern stock, this limitation is less of a concern given there is only one index available for each component of the stock abundance, all coming from the state that accounts for the vast majority of stock removals in any given year (North Carolina). Multiple indices with divergent trends can cause conflict and poor stability in non-spatially-explicit EMs (Conn 2010), so it would be worthwhile to consider index synthesis analyses that can provide a single index representing the underlying overall stock abundance trend as an input to the southern EMs. This approach would better align the OM sampling design in this simulation assessment and EM inputs in subsequent stock assessments of the *in situ* stock.

The second primary limitation of the OM is the coarse annual tracking of the stocks. Red drum grow rapidly in their first few years of life and experience differing seasonal fishing pressures throughout the year. The OM simulates fishery catches under constant fishing mortality throughout the year. This limitation precludes the OMs from simulating composition data sets that match the observed data sets. This is most noticeable in OM undersampling age-1 fish which become disproportionately more vulnerable to fishing late in the year due to fast growth from less vulnerable sizes earlier in the year in the *in situ* stocks (Figure 28 in Appendix 5). This also impacts simulated composition sampling data for fishery-independent surveys that operate over broad seasons. These surveys sample snapshots of the length compositions at a specified point in the year in the OM and tend to sample more bimodal length compositions than *in situ* surveys sampling over broader periods that capture a broader range of the annual growth (Figure 19 - NC_GillNet in Appendix 4; Figure 17 - SC_Trammel and SC_StopNet in Appendix 5).

6.2.5 Simulated Population Dynamics

The population dynamics during the historical period are shared across scenarios, while the dynamics during the projection period change through changes to the ***Base*** scenario OMs according to the core population dynamics scenarios discussed in Section 6.1. In addition to changes to the OMs across the core population dynamics scenarios, the data sampling algorithms of the ***Base*** scenario OMs were also changed for the data prioritization scenarios dealing with changes to recreational discard composition sampling (***B2 Dat*** and ***Prec B2 Dat***). The data prioritization scenarios dealing with changes to the longline survey time series (***No LL***, ***15 yrs LL***, ***30 yrs LL***, ***45 yrs LL***, ***60 yrs LL***) and the ***2023 Term Yr*** core population dynamics scenario were accomplished with changes (reductions) to the existing data sets from the ***Base*** scenario OMs and did not require any changes to these OMs. Population dynamics from the ***Base*** scenario are discussed below, followed by select population dynamics/sampling data highlighting changes to OMs in other scenarios.

6.2.5.1 Base

Both stocks experienced low, stable fishing mortality through the 1940s (Figure 112 and Figure 113). Fishing mortality ramped up and peaked in the 1970s and 1980s at levels associated with overfishing (i.e., SPR<30%; Figure 114 and Figure 115). Fishing mortality then decreased sharply following increased regulations in response to the high fishing mortality. Fishing mortality varied around these lower levels in the 1990s and started to increase again around the 2010s.

Fishing mortality was set to ramp up through the beginning of the projection period to levels associated with ≈15% SPR in the mid-2030s. Fishing mortality then decreases sharply to levels associated with ≈45% SPR, simulating a management response similar to that seen in the historical period, and remains at these levels for the remainder of the projection period.

In the northern stock, the North_Recreational fleet accounted for the greatest proportion of fishing mortality throughout most of the historical period based on the relative magnitude of observed catch by this fleet followed by the North_Commercial_GNBS and North_Commercial_Other fleets (Figure 116). Only the North_Recreational fleet fishing mortality was simulated to change in the projection period based on anticipation that the commercial fleets will remain primarily red drum bycatch fleets as they were at the end of the historical period.

In the southern stock, the FL_Recreational fleet accounted for the highest proportion of fishing mortality throughout the historical period based on the relative magnitude of observed catch by this fleet followed by the SC_Recreational and GA_Recreational fleets (Figure 117). All fleets experienced the same proportional changes to fishing mortality throughout the projection period.

The stock-recruit relationships reflect high variability in realized age-1 recruitment (Figure 118-Figure 119) which is expected for red drum due to extraneous environmental factors driving recruitment not explicit in the OMs (Goldberg et al. 2021). Age-1 recruitment shows high variability among iterations (Figure 120-Figure 121) as well as between years (Figure 122-Figure 123). Despite the high variability, there are noticeable longer-term impacts to recruitment levels from the high fishing mortality levels experienced by the future spawning stock in the 1980s and the beginning of the projection period (Figure 124-Figure 125), as well as positive impacts in response to deceasing fishing mortality following these periods.

Sub-adult abundance shows declines as fishing mortality ramps up after World War II, hitting a low point in the later 1900s at the time of the heaviest exploitation (Figure 126-Figure 127). Sub-adult abundance rebounds as regulations become increasingly conservative in the 1990s and 2000s. Sub-adult abundance then declines again as fishing mortality ramps up in the 2010s and the beginning of the projection period. There is a slight increase as the fishing mortality decreases in the late 2030s before the sub-adult abundance stabilizes under the stable fishing mortality levels just above the current management target for the *in situ* stocks ($SPR_{40\%}$).

Mature abundance (Figure 128-Figure 129) and SSB (Figure 130-Figure 131) follow similar trends as the sub-adult abundance. The stocks rebuild at slower rates under the more subtle fishing mortality reductions in the projection period than under the fishing mortality reductions during the historical period.

6.2.5.2 High F

Instead of reductions in fishing mortality following the increases at the beginning of the projection period, the fishing mortality remains at high levels equivalent to ≈15% SPR for the remainder of the projection period in the ***High F*** scenario (Figure 132-Figure 133). This high fishing mortality prevents any stock rebuilding like that seen in the ***Base*** scenario and the stock remains overfished in the later part of the projection period (Figure 134-Figure 135).

6.2.5.3 Inc Sel

Selectivity of the largest, oldest fish that have matured and moved to offshore habitats was increased to 0.4 in all recreational fishing fleets during the projection period in the ***Inc Sel*** scenario. This scenario simulates an increased targeting of these fish in a catch and release trophy fishery. The change doubles selectivity from the end of the historical period in all recreational fleets except the FL_Recreational fleet which increased from <0.01. The increased vulnerability of these larger, older fish to discard mortality decreases the SPR from the ***Base*** scenario in the latter part of the projection period to just below the current management target (Figure 136-Figure 137). The stock does rebuild by the end of the projection period in a majority of iterations, but from a greater initial depletion and to a smaller stock size than in the ***Base*** scenario (Figure 138-Figure 139).

6.2.5.4 Miss M

The natural mortality estimator used to scale the natural mortality across ages was changed to a historical estimate from Hoenig 1983 (Figure 140-Figure 141) in the ***Miss M*** scenario. This estimator is lower than the Then et al. (2015) estimator used in the ***Base*** scenario resulting in a lower natural mortality across the age range. The lower natural mortality allows more fish to escape to and build up in the spawning stock biomass, changing the scale of the stock (including during the historical period) to more than twice the size under the natural mortality in the ***Base*** scenario (Figure 142-Figure 143).

6.2.5.5 Depr R

The *R0* parameter followed a declining trend over the first twenty years of the projection period in the ***Depr R*** scenario to a value 50% lower than the historical value for the remainder of the projection period. The declines in realized recruitment result in much less frequent year classes at the levels from the historical stock-recruit relationship associated with threshold fishing levels (Figure 144-Figure 145). The stocks' decline below the historical baseline spawning stock biomass threshold is exacerbated by the diminishing productivity during the ramping fishing mortality in the beginning of the projection period before stabilizing at the smaller, less productive regime under the stable fishing mortality just above the current management target (Figure 146-Figure 147).

6.2.5.6 B2 Dat and Prec B2 Dat

Precision for recreational discard length and age composition data and recreational CPUE length composition data, which are used in the core population dynamics scenarios for the southern EMs, was set to be lower than the retained catch composition data precision from the corresponding fleet (Table 46). These specifications were also applied when introducing these data to EMs in the ***B2 Dat*** scenario for the northern stock. Precision was then increased in the OMs for both stocks to the same precision levels specified for the retained catch composition data in each respective fleet (Table 43 and Table 46, average precision across fleets for South_Rec_CPUE) for the ***Prec B2 Dat*** scenario. The impact of increased precision for these simulated sampling data can be seen in Figure 148- Figure 167.

6.3 Estimation Model Descriptions

Three assessment approaches were selected as candidate EMs based on their past use or consideration for red drum assessment and their suitability to the three assessment frameworks recommended in the road map for future red drum stock assessments (see Section 1). A red drum TLA framework was developed during this assessment and selected as a model-free stock indicator assessment framework. A TLA had never formally been applied to red drum stocks for management advice, but it was explored as a potential assessment approach following the most recent stock assessment and before the road map for future red drum stock assessments was finalized. The SCA models used for management advice in the most recent assessment were selected as an assessment framework intended to provide estimates primarily of the juvenile, sub-adult portion of the stocks. Although the models are configured to include adult information and provide estimates of the adult portion of the stocks, these estimates have not been considered reliable for management advice in previous stock assessments (Section 1.3). The models lump all ages older than age-6 into a plus group and do not estimate spawning stock biomass or a link between adults and productivity (i.e., no stock-recruit relationship). Integrated models developed in SS were selected as an assessment framework intended to estimate population dynamics of all life stages of the stocks. Although, models developed in this platform were attempted in SEDAR 44, they have not been accepted for management advice in the past. The configurations evaluated here include modifications with new features not available in SEDAR 44, notably dome-shaped retention functions for fishing fleets to better align with slot limit management approaches, that were hoped to offer improvements over the configurations in SEDAR 44. These models track all age classes in the stocks, estimate spawning stock biomass, and link adults to productivity through an estimated stock-recruit relationship.

6.3.1 Traffic Light Analysis

6.3.1.1 Introduction

The TLA was first developed (Caddy and Mahon 1995; Caddy 1998; Caddy 1999; Caddy et al. 2005) for application in data-limited fisheries and can provide an information basis for fish stock management decisions that is not constrained by a model-based framework.

The TLA uses colors like that of a traffic light to represent the state of a fishery based on appropriate indicators (i.e., an index or time-series of relevant data). Indicators are used to compare recent years of data with previous years to detect trends. The type of indicators may vary and can be based on population and/or fishery dynamics such as abundance, growth, reproduction, removals, or other metrics that are appropriate to the available data. These indicators may be derived from various fishery-independent or fishery-dependent sources (e.g., survey derived indices, harvest/landings time series) and can be representative of various phases in the life cycle (e.g., juvenile, sub-adult, adult). The temporal extent of appropriate indicators should span multiple generations to be representative of population trends.

One common method called the strict traffic light method uses hard boundaries based on reference points to assign a color and uses a binary logic model. Another method called the fuzzy traffic light method uses a fuzzy logic model where the transitional color (yellow) is based on the proportion of adjacent color the indicator is trending towards (e.g., yellow/red or yellow/green).

Reference points are identified as either limit reference points or target reference points. A limit reference point (the focus of this simulation assessment, referred to hereafter as "threshold") might be thought of as unacceptable outcomes such as an indicator value moving from yellow to red whereas target reference points are desirable outcomes where a stock status objective has been achieved such as a target SPR or SSB. Setting reference points requires identifying appropriate metrics to indicate when stock status moves from fully acceptable to unacceptable with a buffer zone between the two to provide warning of proximity to unacceptable conditions.

The objective here was to apply the simulation framework to evaluate the application of TLA methodology to the northern and southern stocks of red drum for use in resource management. The TLA structure was optimized for performance using outputs from the OM and then TLA performance was compared against other stock assessment approaches for use in predicting population dynamics under a variety of selected scenarios.

6.3.1.2 Framework and Optimization

A TLA framework was developed for this simulation analysis using R (code available upon request). The fuzzy method was applied to each indicator by calculating the relative proportions of each color for each year based on the trends from a selected reference period (RP) in the time-series that was considered representative of previous trends. This was accomplished by setting the expected value of an indicator to a relative proportion of 1 for yellow and 0 for red and green (Figure 168). The intersection of the color lines at 0.5 relative proportion corresponds to the 95% confidence intervals derived from the RP values. The relative proportion of 1 for red and green and 0 for yellow were set to 2 times the confidence intervals. Corresponding linear regression equations were calculated to determine the slope and intercept coefficients which, were used to determine a proportion of red, yellow, and green for each value of an index.

The resulting color proportions were then compared to a selected threshold and any value with a proportion red above the threshold would potentially trigger a management action (Figure 169) which, can be based on a conditional rule such as a selected number of consecutive years above the threshold. It was important to select an appropriate number of consecutive years above the threshold for the initiation of management action as a short time frame may be too sensitive to annual variability (stochasticity) in indicator values and can be mistaken for changes in fishing pressure. Conversely, a time frame requirement of too many consecutive years above the threshold may result in slow responsiveness to significant changes in fishing pressure.

Multiple indicators of the same characteristic were combined into composite “characteristics” designed to collectively represent a characteristic of interest for management (e.g., abundance, production, recruitment, fishery performance). These indicators are additive and the resulting combined index was rescaled from 0 to 1 (ASMFC 2020; Halliday et al. 2001).

The TLA is a versatile tool for application to a variety of data types and as such, this method can provide a framework for resource management when other fisheries management methods may not be appropriate due to limitations in data. However, for this reason, there were challenges to evaluating the TLA method in comparison with age-structured assessment models and decisions were made by the red drum SAS to facilitate the optimization of the TLA approach for red drum stocks and for effective comparison to other stock assessment approaches.

It may be inappropriate to select a long time series for the RP since long-term averages can be affected by regime shifts in stock productivity and/or fishing pressure. Therefore, the RP was selected for the northern red drum stock as 1996–2013 and for the southern stock as 1991–

2013 when these stocks were not overfished based on the previous stock assessment results. The expected value was calculated as the geometric mean of the indicator values during the RP and the confidence intervals were based on the expected value and standard deviation from the indicator values during the RP.

The characteristics selected for the TLA (Table 48) were chosen based on available data from the stocks and simulated in the OMs (Table 49) and these characteristics included recruitment, sub-adult abundance, adult abundance, sub-adult production, adult production, and fishery performance. Abundance indicators were developed from fishery-independent survey relative indices of abundance indexing various components of the stock abundance. Production characteristic indicators were developed using median length (sub-adult indicators) or median age (adult indicators) from available fishery-independent data that was considered representative of the population characteristic. Median length was used for sub-adult indicators because this life stage only includes a few ages and length is considered a better indication of truncation or expansion of this component of the stock. Median age was used for adult indicators because growth slows and length-at-age overlaps considerably for adults, making age a better indication of truncation or expansion of this component of the stock. Fishery performance was defined as the relative harvest fishing mortality which was calculated by dividing the harvest of slot-sized fish by an appropriate survey (same state or stock where the fleet is operating) derived index of slot-sized fish for each year. The northern stock had one fishery performance indicator with all harvest summed across the three fishing fleets, while the southern stock had two fishery performance indicators, one for SC and one for FL (no index of slot-sized fish in GA). For some characteristics such as indicators specific to the sub-adult population that were evaluated as proxies for the adult population, the changes affecting the sub-adult population may take several years to be transmitted to the adult population and, therefore, it may be appropriate to lag the sub-adult data during optimization.

A grid search was performed to optimize the threshold (in reference to proportion red), number of consecutive years to trigger management action, and appropriate lag. The grid search was performed for each year in the projection period data time series and each characteristic over 100 simulated datasets for each of the core population dynamics scenarios and for both the northern and southern red drum stocks. The grid matrix consisted of potential threshold values ranging from 0.05 to 0.95 by 0.05 increments, number of consecutive years to trigger management action from 1 to 10 years, and potential lag (for sub-adult characteristics) by year from 1 to 10 years.

For each year of the projection period, the TLA was applied to the data subset up to the year being evaluated and whether a management action was triggered or not was compared to an appropriate stock status (i.e., recruitment condition favorable or poor, SSB status of overfished or not overfished, or fishing status of overfishing or not overfishing - Table 32) generated from the OM for that year to indicate a type I error, type II error, or correct response. The minimization of combined error rate (the cumulative proportion of both type I and II error rates over the projection period years) was the basis for optimization. Optimal values were tabulated over a range that would achieve the optimal combined error rate (Table 50 and Table 51). The minimum and maximum optimal values for each characteristic over all scenarios were averaged and the average of the resulting minimum and maximum averages were used in the final simulation analysis (Table 52 and Table 53).

The final optimized values for threshold, number of consecutive years to trigger management action, and appropriate lag were then applied to the simulated data for each stock, scenario, corresponding characteristic, iteration, and for each projection period year to calculate the proportion red and whether a management action was triggered. Error rates were calculated as described above and these results were then used in comparison to other stock assessment methods to evaluate the effectiveness of TLA as a management tool.

6.3.2 Statistical Catch-at-Age Model

6.3.2.1 Historical Use of the Statistical Catch-at-Age Model

The SCA models have been used to assess the northern and southern red drum stocks since 2009. The models were first used in the SEDAR 18, replacing the three models used previously by Vaughan and Carmichael (2000): a separable virtual population analysis, a spreadsheet statistical catch-at-age analysis, and virtual population analysis conducted using FADAPT. The SCA models were coded in AD Model Builder (code available upon request) and included special features unique to red drum. This included the incorporation of tagging estimates from an external study into the model for the northern stock and restricting the selectivity for older ages in the SCA. Additionally, some discard selectivities were fixed using external estimates when discard composition data were too poor for estimation. While this assessment was accepted for management use by the ASMFC, concerns were raised about the reliability of adult red drum abundance estimates. This was especially true in the northern red drum stock assessment which showed an exponential decline is adult red drum abundance that was believed to be a model artifact. The northern red drum model was also sensitive to the inclusion of the tag-based estimates used in the model fitting. For the southern model, estimates of the SPR and other benchmark values were very uncertain. While it seemed likely that neither stock was below its $SPR_{30\%}$ threshold, the Board desired that an overfished reference point could be developed in future assessments.

During SEDAR 44, the SAS developed models using the SS integrated analysis framework. This assessment was the first done that incorporated data on the adult portion of the red drum stocks through the inclusion of longline survey data. It was hoped that the inclusion of these data would aid in the ability of the models to estimate reliable estimates of adult spawning stock biomass. Data were included to estimate discard size compositions from various state tagging programs as well as volunteer angler surveys. While the SS models were recommended for use by the peer review panel, they were not accepted for management use by the Board due to concerns with the reliability of population parameter estimates. The SAS was tasked with evaluating the use of the SCA from the previous assessment, updating it as necessary in a subsequent stock assessment (ASMFC 2017b). An updated version of the SCA had been developed earlier in SEDAR 44 which estimated the discard selectivities from discard proportion-at-age data in both stocks. While this model version was explored in the assessment, there were concerns about model stability and the SAS ultimately recommended using the SCA model from SEDAR 18 for the most recent assessment with minimal changes in model structure. The main changes in the model were in the data included, again specifically including data from the longline surveys and updating the data streams through 2013. Again, the stocks were determined to be above their $SPR_{30\%}$ thresholds but the same issues from SEDAR 18 remained. The SAS did not have confidence in the adult biomass estimates and therefore did not recommend an overfished reference point.

6.3.2.2 General Description

The SCA model used for red drum includes age-specific data for red drum ages 1 through 7^+ and the model starts in 1989. It is a standard SCA model programmed in AD Model Builder that includes some features unique to red drum.

The first unique feature involves the estimation of the selectivity-at-age for each selectivity block. Given the regulatory history of red drum (i.e., a slot size) and red drum migrations offshore as they age, selectivity of red drum drops off sharply around age 4. To model that in the SCA, selectivity is estimated non-parametrically for ages 1-3 within each block and for each fleet. The selectivity for age 4 and ages 5^+ is then calculated using an estimated proportion for each age's selectivity relative to the selectivity estimated for age 3. These two parameters, one for the proportion of age 4 selectivity and one for the proportion of ages 5^+ selectivity relative to age 3, are estimated across all selectivity blocks within the model but differed between harvest and discard fleets (if the discard fleet selectivity was estimated).

The second unique feature involves the inclusion of external tag based estimates of fishing mortality in the northern model. These estimates were based on a tagging study conducted by Bacheler et al. (2008). Two tagging datasets were used: the estimated F-at-age from 1989-2004 (the last year of the study) for ages 1, 2, 3, and 4^+ and the full F estimated for released fish between 1989-2004. The full F of released fish was used in the model fitting rather than the F-at-age as estimates of the selectivities-at-age based on tagging data were also fixed in the northern model for the discard fleet. These estimates were included in the model fitting for the base northern model runs for all of the scenarios explored in this assessment though some alternative model scenarios were explored where these data were either removed from the model fitting or were adjusted (see Section 7.1.2).

The observed data for these models included: total annual kill by fleet, CVs for total annual kill by fleet, proportion-at-age for the harvest (both stocks) and releases (southern stock only) each year, effective number of ages sampled each year for each fleet, F-at-age for the combined "harvest" fleets during 1989-2004 (northern stock only), CVs for F-at-age for the combined "harvest" fleets during 1989-2004, fully-recruited F for recreational live release fishery during 1989-2004 (northern stock only), CVs for fully-recruited F for the recreational live release fishery during 1989-2004, annual survey catch per unit effort, and CVs for annual survey catch per unit effort.

Weight-at-age and natural mortality were calculated for each iteration of each scenario the way these values would be estimated in a traditional benchmark assessment. This was intended to capture some of the uncertainty that could be introduced by misspecifying growth (i.e., using a von Bertalanffy growth curve in the assessment model as opposed to the age-specific k growth curve in the OM) and by having fewer samples of older fish to fit to.

For each iteration of each scenario, the mean and standard deviation of the OM's observed length distribution for each age class was sampled to develop a dataset of length-at-age. The number of samples generated for each age was based on the number of samples that have been historically collected for each stock. As a result, sample sizes for ages 0-5 were high and declined for older fish (Figure 170). A von Bertalanffy growth curve was fit to the sampled data to characterize length-at-age for each iteration of each scenario. Differences between the growth curves calculated for each iteration were small, which is not surprising given the overall large sample sizes being drawn from the OM distributions; however, the SCA length-at-age inputs did diverge from the OM due to the differences in growth curve structure, with the SCA inputs overestimating length-at-age for ages 9-20 and underestimating it for ages 20+ (Figure 171).

Because length-weight parameters tend to be estimated very precisely, the true length-weight relationship parameters from the OM were used to convert length-at-age to weight-at-age for each iteration.

The weight-at-age for each iteration of each scenario was used to calculate M-at-age using the Lorenzen (1996) formulation, scaled to the Then et al. (2015) longevity-based estimate of M. The estimates of M-at-age used in the SCA were very similar to the values of M-at-age used in the OM (Figure 172). M-at-age was averaged over age-7 to the maximum age for each stock to calculate the M for the plus group (age-7+).

Natural mortality in the model was assumed constant over time though age-varying for each stock (Lorenzen 1996). Natural mortality for ages 1 through 7^+ was used in the population dynamics model while natural mortality through the maximum observed age (62 in the northern stock and 41 in the southern stock) was used in calculations of SPR. Maturity-at-age differed between stocks and the values used were those calculated in SEDAR 44 and used in the OM. Recruitment in the SCA was modeled as deviations from the mean recruitment and the deviations were not constrained to sum to zero.

There were a number of input parameters (part of model structure) that were assumed to be known and without error. These input parameters included: M-at-age, maturity-at-age, defined periods of constant selectivity, selectivity for all ages for the northern recreational live release fishery, release mortality, ages selected for each survey, and survey time of year.

For each stock, a single executable file was used for most scenarios analyzed in this assessment. This executable was run from an R code which would bring in the data files created from the OM, format them to be used in the executable file, and save the outputs for each iteration. Different executables had to be compiled, however, for some of the scenarios explored. Specifically, a different executable file was used for the northern stock when the recreational discard selectivity was estimated rather than fixed; an estimated discard selectivity was one of the data prioritization scenarios explored (***B2 Dat*** and ***Prec B2 Dat***). Because of how some of the stock assessment code is hard coded for particular variables, new executable files also had to be compiled for scenarios when the terminal year of the assessment was changed (***2023 Term Yr***).

6.3.2.3 Model Configuration and Equations

The population dynamics models were based on annual fleet- and age-specific separable F:

$$F_{f,y,a} = F^*_{f,y} s_{f,y,a},$$

where $\boldsymbol{F_{f,y,a}}$ is the instantaneous ***F*** caused by fleet ***f*** in year ***y*** on age ***a*** fish, ***F**** is the apical ***F*** for fleet ***f*** in year ***y***, and ***s*** is the selectivity, a bounded number ranging from zero to one, for fleet ***f*** in year ***y*** at age ***a***. Given red drum's inherent reduced vulnerability after age-3 due to their movement from estuarine waters to nearshore waters and to enacted maximum size limits, the selectivity for ages-4 and 5^+ fish were restricted to be between 0-100% of the selectivity at age-3. Selectivity was therefore estimated for each fleet (other than the northern discard fleet) for ages 1-3 in each of the time periods for which the selectivity was assumed not to have changed for each fishery. Selectivity for ages-4 and 5^+ was derived from the estimated age-3 selectivity for a given time period and the proportional selectivity parameters for ages-4 and 5^+. In the northern model used in this assessment, these proportional selectivity parameters were assumed to be constant across selectivity blocks and harvest fleets (discard fleet selectivity was assumed fixed based on Bacheler et al. 2008). In the southern model used in this assessment, these proportional selectivity parameters were assumed to be constant across selectivity blocks and constant across fleets of the same type (i.e., constant across harvest fleets and constant across the discard fleets).

The abundances of the different age groups in the population are modeled forward in time beginning with estimates for a series of recruits ($\boldsymbol{N_{y,1}}$ in 1989 through the end of the time series for each stock's projection period) and an initial year's abundance-at-age ($\boldsymbol{N_{1989,a}}$ for ages $2\text{-}7^+$). These initial conditions were both modeled as lognormally distributed variables. From these starting abundances, older ages are sequentially modeled as:

$$N_{y+1,a+1} = N_{y,a} e^{-\sum_f F_{f,y,a} - M_a},$$

where $\boldsymbol{M_a}$ is the age-specific instantaneous natural mortality rate. A "plus" group abundance included survivors from both the previous year's plus group and that year's next-to-oldest age group

$$N_{y+1,A} = N_{y,A-1} e^{-\sum_f F_{f,y,A-1} - M_{A-1}} + N_{y,A} e^{-\sum_f F_{f,y,A} - M_A},$$

where ***A*** is age 7^+.

The observation model for these analyses involves total catch, the proportion of the fleet- and year-specific catch in each age group, and indices of abundance. The fleet- and year-specific predicted catch-at-age, $\boldsymbol{C_{f,y,a}}$, was calculated using the

Baranov catch equation:

$$\hat{C}_{f,y,a} = N_{y,a} \frac{F_{f,y,a}}{\sum_f F_{f,y,a} + M_a} \left(1 - e^{-\sum_f F_{f,y,a} - M_a}\right),$$

with the annual total catch for each fleet determined by summing across ages and the proportion- at-age in the catch determined from the age-specific catch relative to this annual total. The observed catch has an assumed lognormal error, $\boldsymbol{\varepsilon_{fya}}$, from the true catch and the model estimates the true catch.

Indices of abundance were assumed linearly related to the stock abundance of chosen age group(s):

$$\hat{I}_{s,y} = q_s N_y,$$

where $\boldsymbol{I_{s,y}}$ is the predicted index of relative abundance for the age(s) caught by survey ***s*** in year ***y***, $\boldsymbol{q_s}$ is the proportionality constant for survey ***s***, and $\boldsymbol{N_y}$ is the abundance for the age(s) included in the index.

The objective function used to confront the observation model predictions with the observed data contained abbreviated lognormal negative log likelihoods for fleet- and year-specific total catch and annual indices of abundance were:

$$negLL(T_f) = \sum_y \left(0.5 \frac{\left(ln(T_{f,y}+1.e^{-6}) - ln(\sum_a \hat{C}_{f,y,a}+1.e^{-6})\right)^2}{\sigma_{f,y}^2} + ln(\sigma_{f,y}) \right),$$

where $\boldsymbol{T_{f,y}}$ is the observed total number killed each year ***y*** by fleet ***f*** and $\boldsymbol{\sigma_{f,y}}$ is the standard error of the total catch within each fleet each year. The variance was estimated from the reported CVs using $\boldsymbol{\sigma^2=ln(CV^2+1)}$. The CVs were available for the recreational fisheries as the PSEs and were assumed low (0.01) for the commercial fisheries. Likewise, the negative log likelihoods for the indices of abundance were:

$$negLL(I_s) = \sum_y \left(0.5 \frac{\left(ln(I_{s,y}+1.e^{-6}) - ln(q_s \sum_a \hat{N}_{y,a}+1.e^{-6})\right)^2}{\sigma_{s,y}^2} + ln(\sigma_{s,y}) \right),$$

where $\boldsymbol{I_{s,y}}$ is the observed index for the age(s) in the survey in year ***y***, and $\boldsymbol{\sigma_{s,y}}$ is the standard error of the survey index in year ***y***, estimated from the original data. In the case of multi-age indices, estimated abundances across these ages would be compared to the overall index value.

For the catch proportion-at-age, a multinomial negative log likelihood was used:

$$negLL(P_{f,y}) = -\sum_a \left(n_{f,y}(P_{f,y,a} + 1.e^{-6}) ln\left(\frac{\hat{C}_{f,y,a}}{\sum_a \hat{C}_{f,y,a}} + 1.e^{-6} \right) \right),$$

where $\boldsymbol{P_{f,y,a}}$ is the observed proportion-at-age ***a*** in the total catch for fleet ***f*** in year ***y*** and $\boldsymbol{n_{f,y}}$ is the sample size for aged fish. These components were not included for the fleets where the selectivity estimates based on tagging were used (northern live release recreational fishery).

There were additional observed data derived from a long-term tag-recapture study conducted in North Carolina that was utilized in the northern stock model. The estimated ***F***-at-age and their standard errors for the pooled harvest (kept) fisheries in the north during 1989-2004 were included in the northern stock's objective function as:

$$negLL(F_{tag(y)}) = \sum_y \left(0.5 \frac{\left(ln(F_{tag(y,a)}) - ln(\sum_f \hat{F}_{f,y,a})\right)^2}{\sigma_{tag(y,a)}^2} + ln(\sigma_{tag(y,a)}) \right),$$

where $\boldsymbol{F_{tag(y,a)}}$ and $\boldsymbol{\sigma_{tag(y,a)}}$ are the observed ***F*** and its estimated standard deviation for year ***y*** and age ***a***. The estimated ***F***-at-age were only tallied for the recreational kept and commercial fisheries. Likewise, ***F***-at-age estimates for the recreational live release fishery were available for the period 1989-2004 from the tagging study. However, since the selectivity vectors from this program were used as input parameters because of the lack of observations for the catch-at-age for this fishery, only the information from its fully-recruited ***F*s** were used in the northern stock's model:

$$negLL\left(F_{full(y)}\right) = \sum_y \left(0.5 \frac{\left(ln\left(F_{full(y)}\right) - ln\left(\sum_f \hat{F}_{full(y)}\right)\right)^2}{\sigma^2_{full(y)}} + ln\left(\sigma_{full(y)}\right) \right),$$

where $F_{full(y)}$ and $\sigma_{full(y)}$ represent the fully recruited ***F*s** for the recreational live release fishery and its standard deviation.

The final component of the objective function included the sum of squares for the log of the unstandardized (to unity) selectivities for each fleet-specific selectivity period for ages-1 through 3. These values were configured as a deviation vector whose sum equaled zero. This added stability to the solution search routine.

The resulting objective function included input weights (lambdas, **λs**) for the different likelihoods that reflected the relative perceived levels of accuracy associated with the estimation equations for the predicted values. The final objective function was:

$$ObjFunction = \sum_f \left(\lambda_{TC(f)} negLL\left(T_f\right)\right) + \sum_{f,y} \left(\lambda_{P(f,y)} negLL\left(P_{f,y}\right)\right) + \sum_s \left(\lambda_s negLL\left(I_s\right)\right) + \sum_{1989}^{2004} \left(\lambda_{Ftag} negLL\left(F_{tag(y)}\right)\right) + \sum_{1989}^{2004} \left(\lambda_{Ffull} negLL\left(F_{full(y)}\right)\right).$$

Note that the F_{tag} and F_{full} negative log-likelihoods were not part of the southern stock model.

<u>*Lambda Weighting*</u>

In SEDAR 18 and ASMFC 2017b, a variety of hypotheses were developed in relation to the data inputs used in the model and the perceived quality of the data. These external lambda weights were applied to the objective function and the best assessment model was determined by using a number of criteria. These included the total standardized residual sum of squares (RSS), visual inspection of data fits, the value of the index standardized residual sum of squares, and qualitative evaluation of age-4 and 5^+ proportional selectivity parameter estimates (i.e., estimates away from the upper bound of 1).

Given the infeasibility of testing all combinations of the lambda weighting hypotheses for all scenarios and iterations, the SAS originally decided to carry forward the lambda weights of the best fitting models from the last assessment. This meant that for the northern stock model, unity weights (1) were used in the negative log likelihood for the total catch, indices, and tagging data, and commercial harvest proportion-at-age; the recreational harvest proportion-at-age data was downweighted by 0.01 (recreational discard selectivity was fixed in this model). In the southern stock model, unity weights (1) were used in the negative log likelihood for the total catch, indices, and harvest proportion-at-age data; the recreational discard proportion-at-age data was downweighted by 0.1. However, after further exploration of the effect of different lambda weighting on model convergence (see Section 7.1.1) and consideration of the setup of the SS EM used in this assessment, the SAS decided to use unity weights for all model runs (i.e., all lambda weights set to 1).

Parameters Estimated

Parameters were estimated for: age 1-3 selectivity during each block of years within a fishery where selectivity was assumed constant, age-4 and age 5^{+} selectivity as a proportion of age-3 selectivity, the fully recruited instantaneous ***F*** (also referred to as apical ***F***) for each fishery each year, the initial abundance for ages 2-7^{+}, annual recruitment, and catchability coefficients for each survey. All parameters were estimated in log space.

Uncertainty and Estimates of Precision

Estimated CVs (or PSEs) were used as measures of the precision for observed kill, index, and tagging F data. For the proportion-at-age data, the effective sample sizes indicated the precision of the observed data.

Model sensitivity to certain assumed values, such as growth and the inclusion of the tagging data, were explored in this assessment. More detail on these analyses is in Section 7.

Benchmark and Reference Points

The benchmarks estimated for this assessment include the $SPR_{30\%}$, $F_{30\%}$, and mature abundance associated with $SPR_{30\%}$ ($N_{30\%}$) as a proxy for SSB status.

For each iteration, $F_{30\%}$ was calculated using the estimated weight-at-age and M-at-age as well as the average selectivity across all fleets from the last three years of the model, weighted by the fleet-specific *F.* A single maturity curve was used for all iterations within a stock. The full age range of weight and M values were used; M was not averaged at age-7 as it was for the population model. The *sbpr()* function from the *fishmethods* package in R was used to do the calculations.

Mature abundance was used as an SSB proxy because of the sensitivity of the model estimates of SSB to the age structure and weight-at-age assumptions of the plus group in the SCA model. To calculate the corresponding mature female abundance reference point, $N_{30\%}$, the population was projected forward for 200 years under a fishing mortality rate equal to the $F_{30\%}$ using the time-series median recruitment for each iteration. The sex ratio was assumed to be 1:1. The level of mature female abundance where the population stabilized under those conditions was used as the SSB proxy reference point.

6.3.2.4 Northern Stock

Parametrization

Life history parameters used in the northern stock model are shown in Table 54.

Natural mortality was constant through time but assumed to be age varying (Lorenzen 1996). Two series of natural mortality estimates were used in different parts of the model. The population dynamics model used the natural mortality for ages-1 through 7^{+} as that was the maximum age used in developing the catch-at-age information. The SPR calculations, however, used the natural mortality-at-age estimated through age-62, the maximum age of the stock. As fishing mortality was only estimated through age-7^{+} in the population dynamics model, the SPR calculations assumed the same fishing mortality applied to each age over age-6.

Maturity-at-age information was based on the analyses conducted from North Carolina data in SEDAR 44 and used in the OM. As this information was used in developing estimates of SPR and mature abundance for this assessment, these estimates of maturity-at-age were calculated though age-62. However, all red drum in the northern stock were assumed to be fully mature by age-6.

Weights-at-age differed between iterations within a scenario and were fixed based on external estimates. These estimates were calculated using the von Bertalanffy equation and used the true length-weight relationship parameters from the OM (see Section 6.3.2.3).

Four fishing fleets were used in the northern red drum SCA model. These included: the northern commercial gill net/beach seine (North_Commercial_GNBS) fleet; the northern commercial other (North_Commercial_Other) fleet which included data on red drum commercially harvested by other gears such as pound nets; the northern recreational (North_Recreational) harvest fleet; and the North_Recreational discard fleet. Selectivity blocks for these four fleets in the model were based on changes in regulations through time (Table 55). Each of the four fleets in the northern model had three selectivity blocks: 1989-1991, 1992-1998, and 1999-2082.

Selectivity in the model was estimated for each harvest fleet and selectivity period. Selectivity was estimated non-parametrically for ages 1-3. For ages-4 and 5^+, the model estimates the proportion, bounded between 0 and 1, of the selectivity relative to the estimated age-3 selectivity. These estimates are constant across the three harvest fleets (North_Commercial_GNBS, North_Commercial_Other, and North_Recreational harvest). The resulting age-4 and 5^+ selectivity is then calculated by multiplying these estimated, constant proportions by the selectivity estimated for age-3 for each fleet and selectivity block. In the northern model, the recreational discard selectivity for each selectivity period is fixed based on estimates from the external tagging study (Bacheler et al 2008). This was done initially in SEDAR 18 as there wasn't much reliable data on the length frequencies of discards. While SEDAR 44 explored using tagging data to estimate the discarded recreational length frequencies and models were developed which could utilize those data, in the form of discard catch-at-age, the final configuration used in that assessment maintained the use of the fixed discard fleet selectivity as it improved model stability. This same configuration was maintained for this assessment in most of the scenarios analyzed except for the data prioritization scenarios that included using sampled discard proportion-at-age data to inform the recreational discard selectivity (***B2 Dat*** and ***Prec B2 Dat***).

Parameters estimated in the population dynamics model are shown in Table 56. All estimates were calculated in log space and include: annual F estimates for each fleet, selectivity estimates for ages 1-3 for each fleet and selectivity block (with the exclusion of the recreational discard fleet for most scenarios), the selectivity proportions for ages-4 and 5^+, recruitment for each year, the initial abundances for ages 2-7^+, and scalars for each of the five indices used in the model.

Input Data

Four fleets were developed to describe catch in the northern stock: a North_Commercial_GNBS fleet, a North_Commercial_Other fleet, a North_Recreational harvest fleet, and a North_Recreational discard fleet (Table 55). Input catch data to the model included total annual harvest from each of the three harvest fleets and recreational releases, both in numbers of fish. An assumed recreational discard mortality rate of 0.08 was applied to the number of fish released alive to estimate the number of recreational dead releases. Input data also included the estimated age-proportions in these annual harvests and for the data prioritization scenario about recreational discard data, also included the estimated age-proportions in the annual dead discards. CVs to the catch data as well as effective sample sizes of ageing data were based on the levels set in the OM when the data were sampled.

Indices of abundance are used in the assessment model to "tune" agreement between the model-predicted and observed trends in abundance (Table 57). Five indices were used in the northern model from four different surveys: the North Carolina bag seine survey (NC_BagSeine), the North Carolina Independent Gill Net Survey (NC_GillNet), a recreational catch per unit effort survey (North_Rec_CPUE), and the North Carolina longline survey (NC_Longline). The NC_BagSeine survey measures the relative abundance of age-1 fish. While fish are sampled in the fall, the index is advanced to the start of the year when YOY will first be age-1. The NC_GillNet survey samples both age-1 and age-2 fish in the middle of the year. These data are split into two age specific surveys as no age composition data is used in fitting this index in the SCA model. The North_Rec_CPUE index is assumed to capture information on fish ages 1-3 though as with the gill net survey above, this index does not include any age composition data and is fit as an aggregate index which is sampled mid-year. The last index, the NC_Longline survey, is assumed to occur in the late summer/fall (month=8 in the model) and it is used as a relative index of abundance of red drum ages-7^+. As with the other age-based surveys used in the SCA model, the model only fits to the age aggregate index and does not incorporate age composition data so the selectivity for the index is assumed constant for all ages. CVs for all indices were sampled to match what is observed in the *in situ* surveys.

Less conventional "tuning" in the northern SCA model was provided by estimates of age-specific instantaneous F available from the long-term tag-recapture program conducted in North Carolina (Bacheler et al. 2008). In the northern stock, estimates for F-at-age were available for the combined harvest fisheries (commercial and recreational harvest). These estimates and associated CVs were used to "tune" the model-estimated F-at-age for ages 1-4^+ during 1989-2004. The 1989-2004, annual fully recruited *F*s estimated for the live releases were also used to compare against that fishery's fully recruited *F*s estimated within the model. Only the fully recruited *F*s were fit, as the selectivity-at-age information was also used to estimate the age composition of the live release fishery mortality in the northern model.

6.3.2.5 Southern Stock

Parametrization

Life history parameters used in the southern stock model are shown in Table 58.

Natural mortality was constant through time but assumed to be age varying (Lorenzen 1996). Two series of natural mortality estimates were used in different parts of the model. The population dynamics model used the natural mortality for ages-1 through 7^+ as that was the maximum age used in developing the catch-at-age information. The SPR calculations, however, used the natural mortality-at-age estimated through age-41, the maximum age of the stock. As fishing mortality was only estimated through age-7^+ in the population dynamics model, the SPR calculations assumed the same fishing mortality applied to each age over age-6.

Maturity-at-age information was based on the analyses conducted from South Carolina data in SEDAR 44 and in the OM. As this information was used in developing estimates of SPR and mature abundance for this assessment, these estimates of maturity-at-age were calculated though age-42. However, all red drum in the southern stock were assumed to be fully mature by age-10.

Weights-at-age differed between iterations within a scenario and were fixed based on external estimates. These estimates were calculated using the von Bertalanffy equation and used the true length-weight relationship parameters from the OM.

Five fishing fleets were used in the southern red drum SCA model. These included: the Florida recreational (FL_Recreational) harvest fleet; the Georgia recreational (GA_Recreational) harvest fleet; the South Carolina recreational (SC_Recreational) harvest fleet; the FL_Recreational release fleet; and the GA_Recreational / SC_Recreational release fleet. Selectivity blocks for these four fleets in the model were based on changes in regulations through time (Table 59). Both the harvest and release fleets for Florida had a single selectivity block estimated for 1989-2061. The GA_Recreational harvest fleet had three selectivity blocks: 1989-1990, 1991-2001, and 2002-2061. The SC_Recreational harvest fleet had five selectivity blocks in the model: 1989-1992, 1993-2000, 2001-2006, 2007-2017 and 2018-2061. The combined GA_Recreational / SC_Recreational release fleet, which has been combined historically due to limited recreational discard data from Georgia as well as similar regulations between the two states, had three selectivity periods defined: 1989-1992, 1993-2001, and 2002-2061.

Selectivity in the model was estimated for each fleet and selectivity period in the southern model (i.e., no recreational release fleets were assumed to have fixed selectivity based on external estimates). This differs from the southern base model used in the SEDAR 44 assessment which had the FL_Recreational discard fleet selectivity fixed based on values from Bacheler et al 2008. While these estimates had come from North Carolina data, regulations were similar enough between the two regions for the period selected that it was deemed acceptable. Selectivity in the SCA was estimated non-parametrically for ages 1-3. For ages-4 and 5^+, the model estimates the proportion, bounded between 0 and 1, of the selectivity relative to the estimated age-3 selectivity. Separate estimates of these age-4 and age-5+ parameters were estimated for the three harvest fleets (the FL_Recreational harvest fleet, the GA_Recreational harvest fleet, and the SC_Recreational harvest fleet) combined and the two recreational release fleets (the FL_Recreational release fleet and the GA_Recreational / SC_Recreational release fleet) combined. The parameters were constant across all selectivity blocks. The resulting age-4 and 5^+ selectivity for each fleet is then calculated by multiplying these estimated, constant proportions by the selectivity estimated for age-3 for each fleet and selectivity block.

Parameters estimated in the population dynamics model are shown in Table 60. All estimates were calculated in log space and include: annual F estimates for each fleet, selectivity estimates for ages 1-3 for each fleet and selectivity block, the selectivity proportions for ages-4 and 5^+, recruitment for each year, the initial abundances for ages 2-7^+, and scalars for each of the thirteen indices used in the model.

Input Data

Five fleets were developed to describe catch in the southern stock: a FL_Recreational harvest fleet, a GA_Recreational harvest fleet, a SC_Recreational harvest fleet, a FL_Recreational release fleet, and a combined GA_Recreational / SC_Recreational release fleet (Table 59). Input catch data to the model included total annual harvest from each of the three harvest fleets and recreational releases, both in numbers of fish. An assumed recreational discard mortality rate of 0.08 was applied to the number of fish released alive to estimate the number of recreational dead releases. Input data also included the estimated age-proportions in these annual harvests and annual dead discards. CVs to the catch data as well as effective sample sizes of ageing data were based on the levels set in the OM when the data were sampled.

Indices of abundance are used in the assessment model to "tune" agreement between the model-predicted and observed trends in abundance (Table 61). Thirteen indices were used in the southern model developed from ten different surveys: the Florida 21.3 haul seine survey (FL_21.3_HaulSeine), the Georgia gill net survey (GA_GillNet), the South Carolina stop net survey (SC_StopNet), the South Carolina rotenone survey (SC_Rotenone), the South Carolina trammel net survey (SC_Trammel), the Florida 183 haul seine survey (FL_183_HaulSeine), a recreational CPUE survey (South_Rec_CPUE), the South Carolina historic longline survey (SC_Longline_historic), the South Carolina contemporary longline survey (SC_Longline_contemporary), and the Georgia longline survey (GA_Longline). Five of these surveys measure the relative abundance of age 1 fish. The FL_183_HaulSeine survey (1998-2061) and the SC_Rotenone survey (1989-1994) were both used to measure age-1 red drum relative abundance at the beginning of the year. The GA_GillNet survey (2003-2061), SC_StopNet survey (1989-1994) and SC_Trammel survey (1991-2061) were all used to measure age-1 relative abundance in the middle of the year. The SC_Trammel survey (1991-2061) was also used to estimate the ages-2 and 3 relative abundance of red drum in the middle of the year. Separate indices were developed for each age separately as no age composition data were included in the model fitting. Age-2 and 3 relative abundances were also fit to age specific indices from the FL_183_HaulSeine survey (1997-2061). This survey was also assumed to represent mid-year abundances of red drum. The South_Rec_CPUE index is assumed to capture information on red drum ages 1-3. Similar to the surveys described above, this index does not include any age composition data and is fit as an aggregate index which is sampled mid-year. This means that the index selectivity is assumed to be constant over those three ages. The last three indices are all longline surveys that are designed to sample the adult (age-7^+) red drum populations. South Carolina conducted a historic longline survey from 1994-2004 and has a contemporary longline survey that was used from 2007-2061 in the model. Georgia also has a longline survey that is used from 2006-2061 in the model. All of these adult longline survey indices are assumed to represent adult red drum abundance in the fall (month=9.5). As with the other age-based surveys used in the SCA model, the model only fits to the age aggregate index for each of these surveys and does not incorporate age composition data into the model fitting. Therefore, the selectivity for each of these adult longline indices are assumed constant for ages-7^{+}. CVs for all indices were sampled to match what is observed in the *in situ* surveys.

6.3.3 Stock Synthesis Model

General Description

SS EMs for this red drum simulation assessment were developed in Stock Synthesis version 3.30.15. Further descriptions of SS options, equations, and algorithms can be found in the SS user's manual (Methot et al. 2020), the NOAA Fisheries Toolbox website (http://nft.nefsc.noaa.gov/), and Methot and Wetzel (2013). Model code is available at https://vlab.noaa.gov/web/stock-synthesis. The r4ss software (www.cran.r-project.org/web/packages/r4ss/index.html) was also utilized extensively to develop various graphics and summarize estimation model outputs.

EMs for both stocks were developed in SS for the core population dynamic scenarios (i.e., ***Base***, ***High F***, ***Inc Sel***, ***Miss M***, ***Depr R, 2023 Term Yr***) and the data prioritization scenarios (i.e., ***No LL, 15/30/45/60 yrs LL, B2 Dat, Prec B2 Dat***) described in Section 6.1. From these we also report here alternative structural scenarios (Section 7.3), which were prompted by the results of the core population dynamics scenarios. These models were of moderate complexity and are described in greater detail for each stock below.

In SS, four input files are required: a starter file containing filenames and details about output reporting, a data file containing model dimensions and the data, a control file specifying model parameterization and set-up, and a forecast file containing specifications for reference points and forecasts (Methot et al. 2020). A single control file was developed for each of the various scenarios and used across all iterations therein. The use of a single file was a more efficient and systematic way to model each of the varying data files (i.e., an iteration) within a particular scenario, as opposed to developing separate and different control files specific to each iteration of a scenario. For example, a single control file was developed for the ***Base*** core population dynamic scenario and was used for all data file iterations therein. Next, a separate control file was developed for the ***High F*** core population dynamic scenario and used on all data file iterations, etc.

Maximum Likelihood and Uncertainty

A maximum likelihood approach was used to evaluate the overall goodness of fit to each kind of data source. Datasets contained an assumed error distribution (e.g., lognormal) and an associated likelihood determined by the difference between observed and predicted values and the variance of the error distribution. The total likelihood is the sum of the individual component's likelihoods. The global best fit to all the data was determined using a nonlinear iterative search algorithm to minimize the total negative loglikelihood across the multidimensional parameter space.

Several approaches were used to assess model convergence on all iterations of each scenario and largely follow those described in Carvalho et al. (2021). First, all estimated parameters were checked such that none were estimated on a bound, which may indicate potential issues with assumed model structure or data. Next, the maximum gradient component (a measure of the degree to which the model converged to a solution) was also compared to the final convergence criteria of 0.0001. Ideally, the maximum gradient component will be less than the criterion, but this is not an absolute requirement. Lastly, the Hessian matrix (i.e., the matrix of second derivatives of the log-likelihood concerning the parameters, from which the asymptotic standard error of the parameter estimates is derived) must be positive definite.

Uncertainty estimates for estimated and derived quantities were calculated after the model fitting based on the asymptotic standard errors from the covariance matrix determined by inverting the Hessian matrix (Methot and Wetzel 2013). Asymptotic standard errors provided a minimum estimate of uncertainty in parameter values.

The error structure for landings, discards, and indices was assumed to be log-normal. Multinomial distributions were assumed for the length and age composition data of the landings, discards, and indices, which have the variances estimated by the input effective sample sizes. The variance of the multinomial distribution is a function of true probability and sample size; thus, an increase in sample size represents lower variance and vice versa. No additional re-weighting methods on the length and age composition data (e.g., Francis 2011 or Punt 2017) were performed for both feasibility purposes (i.e., constrained time and resources to iteratively re-weight every iteration for each scenario) and congruency between the SS and SCA estimation model structures.

Weight-at-age and Natural Mortality

Estimates of asymptotic length (*Linf*), the von Bertalanffy growth coefficient (*k*), and their associated standard errors (SE) were calculated externally for each region by sampling the distributions of length-at-age from the OM and fitting a von Bertalanffy growth curve in R. The number of samples generated for each age was based on the number of samples that have been historically collected for each region. As a result, sample sizes for ages 0-5 were high and declined for older fish (Figure 170). Because the parameter estimates for each iteration were so similar, a single set of parameters was provided for each stock, rather than iteration-specific parameters. The parameters and their SEs were used as normal priors for estimating growth within the SS EM. The growth curve estimated externally did diverge from the OM size-at-age due to the differences in growth curve structure, with the fitted growth curve inputs overestimating length-at-age for ages 9-20 and underestimating it for ages 20+ (Figure 171).

Natural mortality of red drum was estimated assuming that M-at-age was inversely related to fish weight (Lorenzen 1996) and held constant over time. This relation was scaled so that the cumulative instantaneous rate predicted over the lifetime of the fish was consistent with the constant mortality-at-age estimate derived from maximum age (Then et al. 2015). The weight-at-age for each region was calculated from the predicted length-at-age from the von Bertalanffy growth curves for each region using a region-specific length-weight relationship. Again, because the M-at-age estimates across iterations were so similar, a single M-at-age vector was provided for each stock, rather than iteration-specific vectors. Estimates of M-at-age used as input to the estimation model were very similar to the M-at-age used in the OM (Figure 172).

Reference Point Calculations

Reference points for the EMs developed in SS were the same as used in the OM: $R_{30\%}$, $F_{30\%}$, $SPR_{30\%}$, and $SSB_{30\%}$ (see Section 6.2.2 and Table 40-Table 41). The $F_{30\%}$ benchmark is in terms of age-2 fish and is the level of fishing mortality that achieves $SPR_{30\%}$. The $R_{30\%}$ and $SSB_{30\%}$ benchmarks are the levels of these respective parameters when the stock is fished at $F_{30\%}$ according to the estimated stock-recruit relationship. For the ***Depr R*** scenario, $R_{30\%}$ and $SSB_{30\%}$ are estimated for the full assessment time series and represent a mix of historic productivity and reduced productivity during the projection period as the stock-recruit relationship was intentionally misspecified and not allowed to vary through time. However, for the ***Time-Var R*** scenario, $R_{30\%}$ and $SSB_{30\%}$ are calculated as in the OM and based on the historical stock-recruit relationship estimated through 2029 before productivity decreased from 2030 through the terminal year. Escapement (Esc_y) is not provided as output by SS and was therefore estimated first by calculating the *Z*-at-age from the output numbers-at-age, and then subtracting M-at-age to produce F-at-age matrices. Next, annual escapement was calculated as the exponent of the negative sum of age-specific fishing mortality rates in each year, $Esc_t=\exp(-\Sigma F_t)$, for ages 1 – 3 (Age-4 Esc_y) and ages 1 – 5 (Age-6 Esc_y).

6.3.3.1 Northern Stock

Overview

EMs developed for the core population dynamic and data prioritization scenarios in the northern stock were comprised of three fishing fleets (including landings, discards, landings-at-length and -age compositions, and discards-at-length and -age compositions where available), three fishery-independent indices of relative abundance (including length compositions where available), and one fishery-dependent index of relative abundance. The model estimated 192 out of the 223 parameters including, but not limited to, growth parameters (asymptotic length [*Linf*], von Bertalanffy growth coefficient [*k*], and the reference length for the start of von Bertalanffy growth [*Lmin*]) , virgin recruitment (*ln(R0)*), *steepness* (*h*), variability in recruitment (*sigmaR*), time-varying stock-recruit deviations, fishing mortality for each fleet and year that it was operational, length-based selectivity parameters for fleets, landings, discards, retention and indices with length composition data. The model derived estimates included a full time series of recruitment, population abundance, and biomass (total, spawning stock, and exploitable).

Data Sources

The following list summarizes the main data inputs used in the core population dynamic, data prioritization, and alternative structural scenarios (where available) for the northern stock EM:

- Stock Structure
- Life History
    - Age and growth
    - Natural mortality
    - Release mortality

- Maturity
- Fecundity

- Landings
    - North_Commercial_GNBS (thousands of fish): 1950 – 2082
    - North_Commercial_Other (thousands of fish): 1950 – 2082
    - North_Recreational (thousands of fish): 1981 – 2082
- Discards
    - North_Commercial_GNBS (thousands of fish): 1989 – 2082
    - North_Recreational (thousands of fish): 1981 – 2082
- Abundance indices
    - Fishery-independent
        - NC_BagSeine: 1992 – 2082
        - NC_GillNet: 2001 – 2082
        - NC_Longline: 2007 – 2082
    - Fishery-dependent
        - North_Rec_CPUE: 1991 – 2082
- Length and age compositions (2-cm TL bins; 1-year age bins)
    - Landings
        - North_Commercial_GNBS: 1989 – 2082
        - North_Commercial_Other: 1989 – 2082
        - North_Recreational: 1981 – 2082
    - Discards
        - North_Commercial_GNBS: 1989 – 2082
        - *North_Recreational: 1989 – 2082 (**B2 Dat, Prec B2 Dat** scenarios only*)
    - Indices
        - NC_GillNet: 2001 – 2082
        - NC_Longline: 2007 – 2082
        - *North_Rec_CPUE: 1991 – 2082 (**B2 Dat, Prec B2 Dat** scenarios only; length composition data only)*

<u>*Model Configuration*</u>

Previous stock assessments (since Vaughn 1996) have identified the northern stock of red drum on the U.S. Atlantic coast to be north of the North Carolina/South Carolina border based on differences in life history characteristics. The EM developed in SS for the northern stock continued to follow this precedent and was spatially configured as a one area model.

Growth in the northern stock EM was configured according to the von Bertalanffy growth function (Table 62). Parameter values for asymptotic length (*Linf* = 114.9 cm TL), the von Bertalanffy growth coefficient (k = 0.264 yr^{-1}), and their associated standard errors (SE_{Lmax} = 0.158; SE_k = 0.001) were calculated externally and used as normal priors for estimating growth within the SS EM. The CV parameters in SS describe the variability in length-at-age for the minimum (*CVyoung*) and the maximum (*CVold*) observed ages. Growth in SS was configured such that fish grew according to the von Bertalanffy growth model immediately upon 'settlement' at age-1 beginning at *Lmin*. The timing of spawning was configured to mid-August and since the SS EM is a one season model, settlement was configured to occur on January 1 the following year where fish 'settle' as age-1 individuals. A fixed length-weight relationship ($w = a*L^b$) was used to convert body length (cm) to body weight (kg) with parameters: a = 1.1312e−5, b = 2.9827. For the alternative structural scenario ***Tru Grow&M***, growth was configured as in the OM (see Section 6.2.2) and parameters were fixed within the EM.

Natural mortality-at-age was derived externally as described above (Section 6.1.2.2). Based on a maximum age of 62 years, constant mortality-at-age for red drum in the northern stock was found to be 0.112 yr^{-1}. Therefore, natural mortality-at-age for red drum in the northern stock was found to range from 1.298 – 0.083 and values were fixed within the SS EM as an age-specific vector (Table 62). For the alternative structural scenario ***Tru Grow&M*** scenario, natural mortality-at-age was configured as in the OM (see Section 6.2.2) and parameters were fixed within the EM.

The SS EM was configured as a single sex model where the spawning biomass would be multiplied by a user-defined fraction female, here defined as *frac_female* = 0.50. Maturity was configured to be age-based using a logistic function where the A_{50} and *slope* parameters were those calculated by Arnott (2015a) for North Carolina in SEDAR 44 and used as fixed inputs. Fecundity was configured as non-linear eggs/kg on body weight ($eggs = a + wt^b$) and parameterized such that the number of eggs was equivalent to spawning biomass by fixing a=0.5 and b=1.

A Beverton-Holt stock-recruitment model was used and three parameters were simultaneously estimated: 1) *steepness* (*BH_steep*; the recruitment obtained at 20% of the virgin biomass), 2) the virgin recruitment estimated in log-space (*ln(R0)*), and 3) the standard deviation of natural log of recruitment (*sigmaR*). *SigmaR* penalizes deviations from the spawner-recruitment curve (calculated from *ln(R0)* and *steepness*) and it defines the difference between the arithmetic mean spawner-recruitment curve and the expected geometric mean (Methot et al. 2020). Simple annual deviations from the stock-recruitment function, which were constrained to sum to zero, were estimated assuming a lognormal error structure. In the alternative structural scenario ***Base h***, steepness was fixed at 0.99 and annual deviations were configured to no longer sum to zero. For the ***Time-Var R*** scenario, the *ln(R0)* parameter of the EM was configured as in the OM to vary through time beginning in year 2030. This scenario was explored only in the northern stock EMs.

The main recruitment deviations were estimated for the time period of greatest data-richness (1989 – 2082) and corresponds to the time series when length and age composition data of the commercial fleets become available. However, early recruitment deviations were estimated for 1975 – 1988 with the assumption that length and age composition data of the North_Recreational fleet along with information on removals from natural mortality and fishing could provide some indication of recruitment level trends. In SS, expected recruitment needs to be bias adjusted because of its assumed lognormal error structure. The adjustment is accomplished by applying a full-bias correction to the recruitment deviations which have enough data to inform the model about the range of recruitment variability (Methot et al. 2020). Following the recommendation from Methot and Taylor (2011) to use the full bias adjustment on data-rich years, the SS base model used full bias adjustment between 1987 – 2080 after which it phased out to no bias adjustment from 2081 – 2082.

The northern red drum stock was not assumed to be in equilibrium in the EM's start year of 1989 given the reported fishing history. This was configured by providing a positive value for the initial equilibrium catch and adding initial fishing mortality parameters for each fleet (Methot et al. 2020). Due to the associated high uncertainty, initial equilibrium catch values for each fleet were set to 50% of the landings reported in the model start year of 1989 and the associated lambdas were set to 0, thereby removing matching the equilibrium catches from the objective function. Fishing mortality was modeled using the hybrid method that uses a Pope's approximation to provide initial values for continuous F in each year in order to match observed catch. Therefore, year-specific F values were not specified as full parameters to be estimated in the model. Initial fishing mortality rates (F_{init}, the rate occurring prior to model start) by fleet were estimated by the model in the first phase and act more as an estimate of initial total mortality (Methot et al. 2020). Constant catchability was assumed for all surveys and estimated by the model.

Selectivity patterns describe the probability of fish's capture-at-length or -age by a given fishery or gear. Selectivity can be used to model different gear types, targeting, and fish availability according to the spatial utilization of fish and/or fishery. The northern stock EM was configured using length-based selectivity for all fleets and indices except for the NC_BagSeine index, which was configured as an age-1 index of relative abundance. The double normal selectivity pattern was used to model selectivity-at-length for all three fishing fleets as well as the NC_GillNet index. The North_Rec_CPUE index was mirrored to the North_Recreational fleet given the absence of length or age composition data in the EM and the NC_Longline index was configured using the single logistic function (as opposed to the double normal function used in the OM) for flat-topped selectivity to reduce over-parameterization and increase model parsimony. For data prioritization scenarios ***B2 Dat*** and ***Prec B2 Dat***, which included additional length composition data for the North_Rec_CPUE index, selectivity for the North_Rec_CPUE index was modeled using the double normal function.

In SS, retention is defined as a logistic function of size or age (Methot et al. 2020). Since regulations for red drum during the modeled time series are in the form of a size slot limit, retention was modeled as a dome-shaped function with size for the North_Commercial_GNBS and North_Recreational fleets. Live and dead discards for these two fleets were calculated and fit within the EM. Live discards were estimated by applying the converse of the retention function to the total catch while dead discards were the result of assumed discard mortality rates (30% for the North_Commercial_GNBS and 8% for the North_Recreational fleets) and treated as fixed inputs assumed constant through time (Methot and Wetzel 2013).

Initial values for selectivity parameters were specified based on visual inspection of length compositions or on regulatory changes in size limits and parameter bounds were set large enough to avoid truncating the searching procedure during maximum likelihood estimation. The soft bounds option was applied which creates a weak penalty in order to move parameters away from the bounds (Methot et al. 2020). Furthermore, selectivity parameters which were less informed by the data (e.g., those controlling the shape of the descending portion of a selectivity function) or contained excessively high variance were constrained using a symmetric beta prior to keep the parameter out of an unrealistic solution space (e.g., peak of ascending slope below 15 cm) or local minima.

Selectivity time blocks consistent with the configuration of the OM were used to reflect changes through time in red drum vulnerability to gear and state-specific changes in minimum and maximum size limit regulations. Specified selectivity parameters were therefore newly estimated for each selectivity time block which replaced those from the previous time block.

6.3.3.2 Southern Stock

Overview

EMs developed for the core population dynamic and data prioritization scenarios in the southern stock were comprised of three fishing fleets (including landings, discards, landings-at-length and -age compositions, and discards-at-length compositions where available), nine fishery-independent indices of relative abundance (including length and age compositions where available), and one fishery-dependent index of relative abundance (including length composition data). The model estimated 192 out of the 237 parameters including, but not limited to, growth parameters (asymptotic length [*Linf*], von Bertalanffy growth coefficient [*k*], and the reference length for the start of von Bertalanffy growth [*Lmin*]) , virgin recruitment (*ln(R0)*), *steepness* (*h*), variability in recruitment (*sigmaR*), time-varying stock-recruit deviations, fishing mortality for each fleet and year that it was operational, length-based selectivity parameters for fleets, landings, discards, retention and indices with length composition data. The model derived estimates included a full time series of recruitment, population abundance, and biomass (total, spawning stock, and exploitable).

Data Sources

The following list summarizes the main data inputs used in the core population dynamic, data prioritization, and alternative structural scenarios (where available) for the southern stock EM:

- Stock Structure
- Life History
    - Age and growth
    - Natural mortality
    - Release mortality

    - Maturity
    - Fecundity
- Landings
    - SC_Recreational (thousands of fish): 1981 – 2061
    - GA_Recreational (thousands of fish): 1981 – 2061
    - FL_Recreational (thousands of fish): 1981 – 2061
- Discards
    - SC_Recreational (thousands of fish): 1981 – 2061
    - GA_Recreational (thousands of fish): 1981 – 2061
    - FL_Recreational (thousands of fish): 1981 – 2061
- Abundance indices
    - Fishery-independent
        - FL_21.3_HaulSeine: 1998 – 2061
        - SC_Rotenone: 1986 – 1994
        - GA_GillNet: 2003 – 2061
        - SC_StopNet: 1986 – 1994
        - SC_Trammel: 1991 – 2061
        - FL_183_HaulSeine: 1997 – 2061
        - SC_Longline_historic: 1994 – 2006
        - SC_Longline_contemporary: 2007 – 2061
        - GA_Longline: 2006 – 2061
    - Fishery-dependent
        - South_Rec_CPUE: 1991 – 2061
- Length and age compositions (2-cm TL bins; 1-year age bins)
    - Landings
        - SC_Recreational (thousands of fish): 1981 – 2061
        - GA_Recreational (thousands of fish): 1981 – 2061
        - FL_Recreational (thousands of fish): 1981 – 2061
    - Discards
        - SC_Recreational (thousands of fish): 1989 – 2061
        - GA_Recreational (thousands of fish): 1989 – 2061

- FL_Recreational (thousands of fish): 1989 – 2061
- Indices
  - SC_StopNet: 1986 – 1994
  - SC_Trammel: 1991 – 2061
  - FL_183_HaulSeine: 1997 – 2061
  - SC_Longline_historic: 1994 – 2006 (*length composition only*)
  - SC_Longline_contemporary: 2007 – 2061
  - GA_Longline: 2006 – 2061 (*length composition only*)
  - South_Rec_CPUE: 1991 – 2061 (*length composition only*)

Model Configuration

The EM for the southern stock was configured similar to the northern stock model; therefore, only differences will be described here.

The southern stock of red drum on the U.S. Atlantic coast (as described since Vaughn 1996) ranges between South Carolina and Florida and is based on differences in life history characteristics. The EM developed in SS for the southern stock continued to be spatially configured as a one area model representing this portion of the U.S. Atlantic coast.

Growth in the southern stock EM was configured according to the von Bertalanffy growth function (Table 63). Parameter values for asymptotic length (*Linf* = 97.6 cm TL), the von Bertalanffy growth coefficient (k = 0.366 yr^{-1}), and their associated standard errors (SE_{Lmax} = 0.150; SE_k = 0.001) were calculated externally and used as normal priors for estimating growth within the SS EM. A fixed length-weight relationship ($w = a*L^b$) was used to convert body length (cm) to body weight (kg) with parameters: a = 1.1312e−5, b = 2.9827. For the alternative structural scenario ***Tru Grow&M***, growth was configured as in the OM (see Section 6.2.2) and parameters were fixed within the EM.

Natural mortality-at-age was estimated externally as described above (Section 6.1.2.2). Based on a maximum age of 41 years, constant mortality-at-age for red drum in the southern stock was found to be 0.163 yr^{-1}. Therefore, natural mortality-at-age for red drum in the southern stock was found to range from 1.453 – 0.115 and values were fixed within the SS EM as an age-specific vector (Table 63). For the alternative structural scenario ***Tru Grow&M***, natural mortality-at-age was configured as in the OM (see Section 6.2.2) and parameters were fixed within the EM.

The SS EM was configured as a single sex model where the spawning biomass would be multiplied by a user-defined fraction female, here defined as *frac_female* = 0.50. Maturity was configured to be age-based using a logistic function where the A_{50} and *slope* parameters were those calculated by Arnott (2015a) for South Carolina in SEDAR 44 and used as fixed inputs. Fecundity was configured as non-linear eggs/kg on body weight ($eggs = a + wt^b$) and parameterized such that the number of eggs was equivalent to spawning biomass by fixing a=0.5 and b=1.

A Beverton-Holt stock-recruitment model was used and all three parameters (i.e., *steepness*, *ln(R0)*, and *sigmaR*) were estimated. Simple annual deviations from the stock-recruitment function, which were constrained to sum to zero, were estimated assuming a lognormal error structure. In the alternative structural scenario ***Base h***, steepness was fixed at 0.99 and annual deviations were configured to no longer sum to zero.

The main recruitment deviations were estimated for the time period of greatest data-richness (1989 – 2061). Early recruitment deviations were estimated for 1981 – 1988 where information on the length and age composition data of the three recreational fleets and removals from natural mortality and fishing could provide some indication of recruitment level trends. A full-bias correction to the recruitment deviations (Methot and Taylor 2011) was applied to years 1986 – 2060 after which it phased out to no bias adjustment in 2061.

The southern red drum stock was also not assumed to be in equilibrium in the EM's start year of 1989 given the reported fishing history. Model configuration follows the method reported above for the northern stock. Constant catchability was assumed for all surveys and estimated by the model.

The southern stock EM was configured using length-based selectivity for all fleets and indices except for the three age-1 indices of relative abundance: FL_21.3_HaulSeine, SC_Rotenone, and the GA_GillNet. The double normal selectivity pattern was used to model selectivity-at-length for all three recreational fishing fleets as well as the SC_StopNet, SC_Trammel, FL_183_HaulSeine, and South_Rec_CPUE indices. All three longline indices were configured using the single logistic function (as opposed to the double normal function used in the OM) to reduce over-parameterization and increase model parsimony.

Retention was modeled as a dome-shaped function with size for all three recreational fishing fleets. Live and dead discards for these fleets were calculated and fit within the EM. Live discards were estimated by applying the converse of the retention function to the total catch while dead discards were the result of assumed discard mortality rates (8% applied to all three recreational fishing fleets) and treated as fixed inputs assumed constant through time (Methot and Wetzel 2013).

Initial values for selectivity parameters were specified based on visual inspection of length compositions or on regulatory changes in size limits and parameter bounds were set large enough to avoid truncating the searching procedure during maximum likelihood estimation. The soft bounds option (Methot et al. 2020) as well as the use of symmetric beta priors were used here similar to their application in the northern stock model.

Selectivity time blocks largely consistent with the configuration of the OM were used to reflect changes through time in red drum vulnerability to gear and state-specific changes in minimum and maximum size limit regulations. Specified selectivity parameters were therefore newly estimated for each selectivity time block which replaced those from the previous time block. During the Assessment Workshop, the panel decided to make changes to the time block configuration in the southern EM for the GA_Recreational fleet where the 2002 – 2006 and 2007 – 2061 time blocks were combined to 2002 – 2061.

6.4 Model Configuration Comparisons

Configuration details are compared between the OM and the two population dynamics EMs (SCA and SS) for the ***Base*** scenario in Table 64-Table 66 (northern stock) and Table 67-Table 69 (southern stock).

7 RESULTS

Scenario results are presented in four groups: developmental, core populations dynamics, alternative structural, and data prioritization scenarios. Developmental scenarios included preliminary EM configurations used to inform the final configurations used in the core population dynamics scenarios. The core population dynamics scenarios, where EM performance was evaluated, simulated varying population dynamics likely to be encountered in future red drum assessments and are the primary scenarios informing recommendations on future red drum stock assessment models. For each of the core population dynamic scenarios, the OM was modified to generate the full range of varying population dynamics. Alternative structural scenarios were those conducted following the core population dynamics scenarios to address specific questions about stock-recruit relationship parameterizations and growth assumptions and include changes only to the EM configurations. Data prioritization scenarios were prioritized for this simulation assessment to inform monitoring and data recommendations that would improve future red drum stock assessments.

7.1 Developmental Scenarios

7.1.1 Convergence Exploration

Scenarios using alternate likelihood weighting schemes (***Base***, ***High F***, ***Inc Sel***) were conducted for the SCA EM to evaluate stability issues (i.e., low convergence rates) when using the preferred weighting schemes of the last stock assessment (***Base Alt Wgt***, ***High F Alt Wgt***, ***Inc Sel Alt Wgt***). Specifically, these scenarios were intended to address the questions: (1) Does the SCA convergence rate, particularly for the southern model, change with an alternate weighting scheme? and (2) Is the SCA stability issue likely to be a minimal concern in application of the model during a stock assessment or an issue that presents a considerable risk of applying the model during a stock assessment? In addition to the scenarios where the likelihood weighting scheme was changed within the EM, two additional summaries of performance metric data were evaluated to understand the performance effects of weighting choice that may be driven by convergence issues. The ***Max Conv*** scenario combined performance metrics from any iterations of the southern SCA model that converged using either the preferred weighting approach from the last assessment (***Base Alt Wgt***) or the weighting approach with equal unity weights on all likelihood components (***Base***). The objective of this alternative data summarization was to further evaluate if weighting scheme choice changes perception of summarized performance. This combination increased the convergence rate from 61% for the ***Base Alt Wgt*** scenario and 77% for the ***Base*** scenario to 84%. The ***Iter Filter*** scenario included performance metrics from only iterations that converged for both the SCA and SS EMs in each of the core population dynamics scenarios. The objective of this alternative data summarization was to evaluate if summarized performance is skewed by different convergence rates and potentially different tolerances to find solutions between EMs. This alternate summary of performance metrics mostly involved excluding converged iterations for the SS EM which had higher converge rates near 100% for most scenarios.

Convergence rates of the SCA EM using unity weights on all likelihood components increased relative to the EM using the preferred weighting scheme from the last stock assessment except for the southern model under the ***Inc Sel*** core population dynamics scenario, which decreased by 5% (Table 70). There was a net gain of 42 converged iterations across models and scenarios using the unity weights and scenario-specific convergence rates increased to at least 77%. The weighting scheme choice impacted estimation of the stock scale for the northern stock, but had less effect on scale estimation for the southern stock and trend estimation for both stocks (Figure 173-Figure 176). The impacts to performance of the northern model depended on parameter and scenario, with improvements to accuracy across scenarios for parameters including sub-adult abundance and age-4 escapement and more mixed impacts for parameters including mature abundance and three year SPR ratios. The additional data summarization scenarios ***Max Conv*** (Figure 173-Figure 176) and ***Iter Filter*** (Figure 177) had negligible impact on performance indicating the results from each weighting scheme for the southern ***Base*** scenario and all iterations regardless of convergence in the other EM for all core population dynamics scenarios, respectively, are representative of SCA performance.

The unity weighting scheme is consistent with the weighting scheme in the SS EMs and also consistent between stocks within the SCA EMs which had likelihood components weighted differently using the preferred weighting scheme from the last assessment. This consistency makes performance more comparable among models and so the unity weighting scheme was used in final configurations for the core population dynamics scenarios.

7.1.2 Bacheler et al. 2008 SCA Inputs

The northern SCA EM has unique aspects including using external fishing mortality time series estimates from Bacheler et al. 2008 as data in the fitting process and using selectivity estimates for recreational discards from the same publication as fixed inputs in the model. These aspects introduce misspecification in the model as applied to the simulated stock including biased low discard mortality (Figure 178), biased high harvest mortality for ages 1-3 and biased low harvest mortality for ages 4+ (Figure 179), as well as biased low recreational discard selectivity for ages 3+ (Figure 180-Figure 182). As the simulated population dynamics likely differ from *in situ* population dynamics these published estimates were made from, it is unknown how misspecification for the simulated stock compares to misspecification, if any, for the *in situ* stock. However, several sources indicate similar misspecification for the *in situ* stock. Bacheler at al. 2010 estimated length-based selectivity for recreational discards, which were used to specify selectivity in the OM, and noted that the Bacheler et al. 2008 estimates may be underestimated for older ages. Peer reviewers of the SEDAR 18 stock assessment noted concerns with the very high fishing mortality estimates from Bacheler et al. 2008, particularly the first few years used in the stock assessment. Preliminary results of the core population dynamics scenarios using the Bacheler et al. 2008 data inputs were similar to results in past stock assessments which estimated very large mature abundances at the beginning of the assessment time series that decline exponentially. Past peer reviewers have identified this as an artifact of the model. In addition to these indications of misspecification, exploration of the northern SCA in past assessments has indicated model stability relies on these estimates and, currently, there are no alternative fishing mortality estimates to use in place of the Bacheler et al. 2008 estimates.

Scenarios conducted to evaluate how treatment of the Bacheler et al. 2008 inputs impact performance included: a scenario with the recreational discard selectivity fixed to the true values from the OM (***B2 Sel***) but still using the misspecified fishing mortality estimates in model fitting, a scenario with the fishing mortality values sampled from the OM values with error levels according to the Bacheler et al. 2008 estimates (***Tru Fs***) but the discard selectivity still misspecified, a scenario with both the true OM recreational discard selectivity values and the fishing mortality values from the ***Tru Fs*** scenario (***B2 Sel&Tru Fs***), and a scenario with the external fishing mortality estimates excluded from the fitting process (***No Fs***). These scenarios were intended to evaluate performance under status quo monitoring and data availability. The unique northern SCA EM aspects are further evaluated for their impacts on performance when they interact with potentially new data sets (recreational discard composition data, Section 7.4).

Performance varied across the scenarios evaluating treatment of Bacheler et al. 2008 data in the northern SCA EM. Bias driven by the misspecified fishing mortality inputs early in the time series is reduced when the values sampled from the OM are used in place of the Bacheler et al. 2008 data and flips direction when no fishing mortality data are used in the fitting process (Figure 183). Despite the reduced bias, scenarios with fishing mortality sampled from the OM led to low convergence rates (Table 71).Treatment of the recreational discard selectivity has less affect, with the scenario using true selectivity from the OM performing similarly to the corresponding scenario with the same fishing mortality treatment (i.e., ***B2 Sel*** is more similar to ***Base*** and ***B2 Sel& Tru Fs*** is more similar to ***Tru Fs***). Once the time series of fishing mortality estimates ends (2004), selectivity misspecification affects become more apparent. Scenarios with true recreational discard selectivity (***B2 Sel*** and ***B2 Sel&Tru Fs***) have less trending in performance and the bias in the beginning of the projection period when fishing mortality ramps up is less than in the scenarios with misspecified selectivity. The configurations with no misspecified inputs (***B2 Sel&Tru Fs***) and, surprisingly, with both misspecified inputs (***Base***) perform about the same during the beginning of the projection period (Figure 184). Later in the projection period performance is more consistent through time across scenarios, but treatment of these inputs still impacts estimation of stock scale and bias. The ***Base*** scenario continues to estimate with the greatest accuracy in the long term followed closely by the ***B2 Sel&Tru Fs*** configuration. Models with one misspecification used in isolation (***B2 Sel***, ***Tru Fs***, ***No Fs***) are the least accurate performers. Notably, performance deteriorates when the fishing mortality information is removed from the fitting process (***No Fs***) and provides the most biased estimates of all scenarios across the projection period.

Due to the mixed performance across these scenarios, sources suggesting similar misspecification using the Bacheler et al. 2008 estimates in the northern SCA EM for the *in situ* stock, and lack of alternative external fishing mortality estimates to use in place of the Bacheler et al. 2008 estimates, the Bacheler et al. 2008 inputs were included in the EM configuration used in the core population dynamics scenarios and are assumed to be representative of misspecification that would occur in the next benchmark assessment of the *in situ* stock.

7.2 Core Population Dynamics Scenarios

7.2.1 Structure of Results

Initially, performance metrics summarized across the projection period were the focus for evaluating performance among the candidate EMs. However, there were trends in performance within the projection period that were important to consider when evaluating the summarized results (e.g., differing projection periods based on each stock's longevity which complicated the time-varying performance). Therefore, the projection period was summarized in two periods, the initial years when fishing mortality was set to ramp up across scenarios (Ramp period, 2020-2034) and the years after this Ramp period (Post-Ramp period, 2035-2082 for the northern stock and 2035-2061 for the southern stock). This summarization standardizes the number of years for the Ramp period between stocks, making performance evaluations between stocks more comparable. Performance metrics across the EM time series are presented, but performance during the Ramp period was considered the priority for performance evaluations as it is an indication of EM performance during considerable changes to stock conditions. In addition, the ramp period is closest temporally to the historic period and these years will be the focus in the upcoming benchmark stock assessment.

Results are presented for all parameters originally identified in Section 6.1, but there was also a clear need to refine results from all original parameters in decision tables to guide recommendations. Eight parameters were identified as the highest priority parameters for performance evaluation including recruitment condition, SSB status, three year average SPR ratios, three year average SPR status, three year average fishing mortality ratios, three year average fishing mortality status, age-4 escapement, and age-6 escapement. These variables place a heavy emphasis on fishing mortality estimation, but also prioritize performance for categorization of production and reproductive capacity. Absolute scale of stock abundance (age-1 recruitment, sub-adult abundance, mature abundance) was considered a lower priority given the fisheries are predominately recreational and managed without catch caps or quotas. Three year average ratios were prioritized because they were estimated with better accuracy, precision, and error rates than their annual counterparts (Figure 185-Figure 192).

Relative error was converted to absolute values before calculating medians across the Ramp period in each scenario to avoid canceling runs of relative error of opposite directionality within this period. These scenario-specific medians were then averaged across scenarios to summarize performance for numeric variables in decision tables. Type II error rates, where the stock was in poor condition and the model incorrectly identified it as good condition, were considered higher priority given they present more risk to the biological condition of the stock and were tallied across scenarios during the ramp period to summarize performance for categorical variables in decision tables. Performance was often worse for scenarios with misspecification of natural mortality (***Miss M***) and recruitment dynamics (***Depr R***) and there is some anticipation that this misspecification could be identified during a benchmark stock assessment. Therefore, two summary tables are included for the results, one summarizing all core population dynamics scenarios and one summarizing core population dynamics scenarios excluding the ***Miss M*** and ***Depr R*** scenarios. Results are presented by stock as well as across stocks, although differences in performance between stocks suggested focusing on results by stock for recommendations.

During review of preliminary results, it became apparent that EMs in some cases were performing better at estimating trends of population parameters given relative error distributions that were biased, but consistently biased through time. Trend-based estimates using ad hoc time period-based reference points have been used for management of other species (ASMFC 2003, ASMFC 2017a) and so performance for trend estimation is also presented as information that could support a potential alternative to current management of red drum stocks under SPR reference points. Trend-based values were calculated by selecting a reference period and dividing the annual parameters by the average of the parameter over the fixed reference period. Relative error of these scaled parameters was then calculated and summarized the same way as for absolute parameters by comparing the OM values to the EM estimates. Trend estimation performance is dependent on reference period choice, so results for two reference periods are included. The first reference period is one year selected at random from the time series (2007). The second reference period was selected as a five year period with an average SPR in the northern OM equal to the current management target ($SPR_{40\%}$, 2008-2012). There was variability in annual SPR in the northern OM during this reference period and a trend in the southern OM, so this was considered an ideal period of mixed conditions used for the reference period as a test of robustness in trend estimation.

7.2.2 Northern Stock Results

Convergence rates for the SS and SCA northern stock EMs were generally high across core population dynamic scenarios. The SS EM converged on a solution for all iterations in most scenarios with the exception of the ***Depr R*** scenario (64% convergence) and the ***Miss M*** scenario (90% convergence; Table 72). The SCA EM experienced slightly lower convergence rates which ranged between 86 – 95% (Table 72).

The SCA EM estimated parameters with significant bias in the historical period due to the inclusion of misspecified fishing mortality data identified in the previously discussed developmental scenarios (Figure 193-Figure 201). This EM then compensates and estimates with improved accuracy after the time series of these fishing mortality data end in 2004. Precision follows an opposite pattern, with very precise estimates during the period when fitting to fishing mortality data followed by lower precision when these data end. Despite the decrease in precision, the SCA EM tends to estimate with greater precision than the SS EM throughout the assessment time series including during the Ramp period (Table 73 and Table 74). This is particularly noticeable for age-1 recruitment estimates which are estimated very imprecisely by the SS EM (Figure 193). The SS EM generally estimates fishing mortality-based parameters that are influenced by the full age range (SPR and F ratios) with more accuracy during the ramp period than the SCA EM, while the SCA EM estimates fishing mortality-based parameters that only include information on the younger ages (escapement) more accurately (Table 75 and Table 76).

Another notable performance feature for both EMs is trends in bias of the fishing mortality-based parameters, particularly during periods when stock conditions change the most. Bias tends to increase as fishing mortality increases and decrease as fishing mortality decreases (Figure 202). This patterning is more pronounced and consistent for the SCA EM than the SS EM. Bias is more stable during periods of stable fishing mortality. There is less trending in abundance-based estimates, but some trends do occur for the SCA EM mature abundance estimates (Figure 203).

The SCA EM tends to underestimate abundance parameters characterizing the immature component of the stock (Figure 193 and Figure 194) and overestimate mature abundance (Figure 195). Following a similar pattern, the SCA EM tends to overestimate fishing mortality-based parameters with information on the youngest ages only (i.e., underestimate age-4 escapement-Figure 197) and underestimate fishing mortality-based parameters influenced by the full age range during the period following the fishing mortality data time series (F ratio-Figure 200, i.e., overestimate exploitation- Figure 199 and SPR-Figure 201). Age-6 escapement (Figure 198), which includes information on some intermediate ages, appears to be a relatively well-estimated transitional parameter as the model moves from a tendency to overestimation to a tendency to underestimation. The SS EM estimates with more random bias across scenarios than the SCA EM.

The TLA EM consistently estimates lower error rates than the SS EM for recruitment conditions (Figure 204). The TLA EM produces higher type II error rates than type I error rates indicating a tendency to overestimate recruitment. Error rates are evenly split between type for the SS EM in the scenarios except ***Miss M*** and ***Depr R*** indicating overall accuracy, but low precision. Notably, the SS EM produces higher type II error rates in the ***Depr R*** scenario indicating a bias as would be expected with misspecified recruitment dynamics, but the TLA EM, with its time period-based reference point, performs just as well or better than in other scenarios.

Error rates in SSB status estimates show patterns dependent on the EM's bias tendencies. For example, the SCA EM, which tends to overestimate mature abundance, estimates SSB status with increasing type II error as the stock becomes overfished in a higher frequency of iterations at the end of the Ramp period (Figure 206). Error rates then decrease as the stock starts trending back towards a not overfished status (e.g., ***Base*** scenario) or continues trending to a more depleted abundance (e.g., ***High F*** scenario). The SS EM, which tends to underestimate mature abundance in scenarios like the ***Inc Sel*** scenario, estimates with increasing type I error rates as the stock trends towards, but just before entering into, an overfished status early in the Ramp period and as the stock moves from an overfished status to a not overfished status after the Ramp period. The SCA EM collectively produces the lowest type I error rates for SSB status estimates, but the highest type II error rates across scenarios during the Ramp period (Table 75 and Table 76). The SS EM produces the lowest type II error rates during the Ramp period and these rates further decline when excluding the ***Miss M*** and ***Depr R*** scenarios. The TLA EM included four characteristics as potential indicators of SSB status, but the adult abundance characteristic consistently outperformed the other candidate characteristics for type II error rates (Figure 205). This characteristic was chosen as the final characteristic for comparison to other EM SSB status error rates and is the intermediate performer, producing error rates between the other EMs (Table 75 and Table 76).

Similar to patterns in SSB status error rates, the SCA EM, which tends to underestimate F and SPR ratios, produces high type II error rates for these status determinations. These error rates peak as the stock moves between statuses and decline as the model "catches up" with the correct status when fishing mortality trends in the same direction for additional years (Figure 207 and Figure 208). Error rates become more stable as the stock moves into more stable fishing mortality regimes in the Post-Ramp period. The other EMs follow similar patterns in error rates and the TLA EM produces the highest type II error rates during the Ramp period, while the SS EM produces the lowest type II error rates from its more accurate ratio estimates (Table 75 and Table 76).

Despite often more accurate trend-based abundance estimates (Figure 209 and Figure 210), the varying magnitudes of bias in fishing mortality-based estimates through time caused mixed results for performance of trend-based estimates (Table 77-Table 84,Figure 211 and Figure 212). The biggest improvements in average median relative error occurred for the fishing mortality-based estimates influenced by the full age range (SPR and F ratios) when using a multi-year reference period (Table 81). Reductions in relative error ranged from 3%-8%. However, relative error of trend-based escapement estimates tended to increase with increases as much as 14%. Precision also tended to decrease for the trend-based estimates.

7.2.3 Southern Stock Results

The SS EM converged on a solution for most iterations (Table 72). The SCA EM experienced lower convergence rates than the SS EM with rates as low as 67%. Notably, the SCA EM experienced its highest convergence rate for the ***2023 Term Yr*** scenario (92%).

The SS EM generally estimates with slightly greater precision than the SCA EM during the Ramp period, while the SCA EM estimates with greater accuracy (Table 73-Table 76). The SS EM estimates age-1 recruitment very imprecisely relative to other parameters (Figure 193). The SCA EM and SS EM tend to overestimate abundance for all components of the stock and underestimate fishing mortality-based parameters.

There is some trending in performance as stock conditions change. The trending for SPR ratios is less pronounced and consistent across scenarios for the southern SCA EM than was seen in the northern SCA EM, and similar between southern EMs (Figure 213). There is also no noticeable trending for mature abundance estimates (Figure 214) as was seen in some scenarios for the northern SCA EM.

The TLA EM consistently estimates lower error rates than the SS EM for recruitment condition (Table 75 and Table 76, Figure 215). The TLA EM produces higher type II error rates indicating a tendency to overestimate recruitment. Error rates are evenly split between type for the SS EM in all scenarios except ***Depr R*** indicating overall accuracy, but low precision. The SS EM appears to rely more on the final recruitment dynamics in the ***Depr R*** scenario than it does in the northern stock, as it overestimates recruitment to a greater degree in earlier years (i.e., higher type II error rates than other scenarios) and improves later in the time series once the stock has entered the lower recruitment regime. The TLA EM, again with its time period-based reference point, performs just as well or better for the ***Depr R*** scenario than in other scenarios.

As for the northern stock, the adult abundance characteristic consistently outperformed the other TLA EM SSB status characteristics for type II error rates and was chosen as the final characteristic for comparison to other EM SSB status error rates (Figure 216). All EMs perform similarly for SSB status estimates during the Ramp period (Table 75 and Table 76). The SCA and SS EMs' tendencies to overestimate abundance result in higher type II error rates than type I error rates. Error rates increase as the stock moves from one SSB status to another as the EMs "catch up" with additional years of trending abundance (Figure 217).

Trends in fishing mortality status error rates show similar patterns as for SSB, peaking as the stock moves from one mortality status to another and declining as mortality continues trending in the same direction or stabilizes (Figure 218 and Figure 219). The tendencies of the SCA EM and SS EM to underestimate fishing mortality result in higher peaks of type II error rates than type I error rates across the time series. Error rates for TLA EM fishing mortality status estimates follow similar patterns, but this EM produces the lowest type II error rates across scenarios during the Ramp period (Table 75). When excluding the ***Miss M*** and ***Depr R*** scenarios, the SCA EM and SS EM type II error rates for mortality status estimates decrease and the SCA EM produces the lowest error rates (Table 76).

The tendency for southern EMs to estimate parameters with bias, but more consistent bias through time than seen in the northern stock results in improved performance at trend-based estimation. There is generally lower relative error for trend-based abundance (Figure 209 and Figure 210) and fishing mortality (Figure 211 and Figure 212) estimates across scenarios and EMs in the southern stock. Relative error decreases by as much as 13% and standard deviation of relative error decreases by as much as 6% (Table 77-Table 84). There were slightly greater accuracy improvements when combined over all core population dynamics scenarios and when using a multi-year reference period, but improvements occurred in all cases. The only case of worse performance was for precision of the SS EM estimates of three year fishing mortality ratios.

7.2.4 Summary Across Stocks

The SS EM convergence rates were generally higher and more consistent between stocks than the SCA EM (Table 72). The SCA EM generally had lower convergence rates for the southern stock than the northern stock.

Performance metrics for the SCA EM and SS EM in both stocks generally improved when the ***Miss M*** and ***Depr R*** scenarios were excluded. There was little change for the TLA EM. However, qualitative pairwise comparisons of EMs within stocks were similar between the two groupings of scenarios. The only changes occurred in the southern stock with the best performer for fishing mortality status and age-4 escapement changing from the TLA EM to the SCA EM and the SCA EM to the SS EM, respectively.

The EMs estimating numeric parameters performed differently relative to each other between stocks. The SS EM tended to estimate with less precision and greater accuracy than the SCA EM in the northern stock, while the SS EM tended to estimate with greater precision and less accuracy than the SCA EM in the southern stock. The more accurate EMs for each stock estimated parameters with similar accuracy (absolute relative error ≈0.1-0.2), except age-6 escapement which the southern SCA EM estimated with lower accuracy than the northern SS EM. Age-4 escapement was estimated with very similar accuracy among stocks, EMs, and grouping of scenarios. Precision for this parameter, however, varied with greater precision in the southern stock. The southern EMs tend to estimate most parameters more similarly than the northern EMs.

The EMs estimating recruitment condition performed similarly between stocks, with the TLA EM performing considerably better (type II error rates <14%) than the SS EM (type II error rates >25%). Performance estimating other categorical variables varied between stocks. There was clear separation in performance for SSB status in the northern stock with the SS EM performing best, the TLA EM being an intermediate performer, and the SCA EM performing worst. There was less separation between EMs in the southern stock, all producing type II error rates within a percentage point of each other. Southern EMs performed better than northern EMs, all producing error rates lower than the best performer in the northern stock (6%). The EMs tended to estimate mortality status with similar error rates across stock, with the exception of the northern TLA EM which estimated with considerably higher error rates (>40%). The EMs estimating with more accuracy also performed best for mortality status determinations.

The other key differences between stocks was the greater tendency of northern EMs to estimate parameters with varying accuracy through time, including decreasing accuracy during periods of rapidly changing population dynamics. This trending resulted in little to no gains when using the models for trend-based estimates, while southern EMs could provide improved performance with trend-based estimates.

7.3 Alternative Structural Scenarios

Three additional scenarios were conducted following the core population dynamics scenarios to address specific questions about stock-recruit relationship parameterizations in the SS EMs and growth assumptions in the SCA and SS EMs.

7.3.1 Time-Varying Stock-Recruit Relationship

One of the results of the ***Depr R*** core population dynamic scenario was that the SS EMs for both regions were found to estimate the SSB ratios with considerably high imprecision and bias (Figure 196), indicating some form of model misspecification was occurring. However, impacts to other parameters were mostly to scale, causing shifting bias with little impacts to trend or precision. The bias and imprecision of the SSB ratio estimates was found to be caused by abnormally low values estimated for the steepness parameters as the models tried to compensate for the underlying change in productivity. In the northern stock, the median estimated value of steepness across converged iterations (64%) was 0.47, while in the south, the median estimated value across converged iterations (98%) was 0.66. The median estimated value of the ln(R0) parameter for the northern region was 7.31 while the median estimated value of the ln(R0) parameter in the south was 8.99. For both regions, the derived estimates of $SSB_{30\%}$ (i.e., the denominator of the SSB ratio) across converged iterations were found to sharply decrease with declining estimates of steepness and thereby created the wide-ranging imprecision and bias to the SSB ratios.

To explore this further, a scenario with the northern SS EM was configured to allow for time-varying R0 (***Time-Var R***) to evaluate if building in this added complexity would improve performance for estimating the SSB ratios. As expected, the precision and bias were greatly improved when this complexity was added (Figure 220) as it more resembled the configuration of the OM. Convergence rates increased to 100% and the median estimated value for steepness increased to 0.82. The median estimated value of the ln(R0) parameter in the first time block (years 1989 – 2029) was 6.97 and declined to a median estimated value of 6.30 in the final time block (years 2030 – 2082). Given these results and the constraints of time and resources, the TC and SAS did not find it necessary to explore this configuration with the southern stock as the effect was assumed to be similar.

7.3.2 Steepness

The SS EMs estimated stock-recruit relationships, including the steepness parameters, which represents a key structural difference from the other EMs which do not have explicit stock-recruit relationships. A scenario was therefore conducted to evaluate changes to performance of the SS EMs when the recruitment dynamics were configured to be more similar to the SCA EMs. Using the ***Base*** scenario SS EMs for both regions, the steepness parameters were fixed at 0.99 and recruitment deviations were no longer constrained to sum to zero (***Base h***). This change to the EM configurations had impacts to the scale and precision of the SSB ratios (Figure 221), but little impact to trend of these estimates and negligible impacts to other parameters (Figure 222). Impacts to SSB ratios depended on bias of the ***Base*** scenarios, resulting in more biased estimates for the northern stock and less biased estimates for the southern stock.

7.3.3 Growth

Characterizing red drum growth (see Section 2.3) presents unique challenges which contributed to the decision to knowingly misspecify growth (i.e., using the von Bertalanffy growth model) and subsequently, natural mortality in the EMs. A scenario was conducted where the true growth and natural mortality from the OM was passed to the EMs (***Tru Grow&M***). The objective was to help determine the level of priority given to growth modeling and specification in the upcoming benchmark stock assessment. The TC and SAS were interested to see whether the performance results would suggest parameters from a more objectively developed non-traditional growth model (e.g., von Bertalanffy growth model with age-specific k using a model selection process) for use in the SS and SCA EMs would be worth the dedicated time and resources to pursue in the upcoming benchmark stock assessment. True natural mortality was included in this scenario due to an underlying assumption that natural mortality was inversely related to fish length; thus, changes to fish length-at-age merited changes to the natural mortality-at-age dependent on those growth assumptions.

In the northern stock, the misspecified growth in the ***Base*** scenario resulted in fish estimated to weigh more for ages between about 8 to the mid-20s and then estimated to weigh less for ages greater than about 25 years when compared to the ***Tru Grow&M*** scenario (Figure 223). Differences in natural mortality-at-age were primarily observed as lower natural mortality at age-1 and slightly higher natural mortality for ages greater than about 30 years. (Figure 224). In the southern stock, the results of misspecified growth were slightly heavier fish around age 10 which were then estimated to weigh less at ages greater than 15 years (Figure 225). The natural mortality-at-age for fish in the southern stock ***Base*** scenario was estimated to be similar to the natural mortality-at-age in the ***Tru Grow&M*** scenario with slightly lower mortality observed at age-1 and slightly higher mortality observed at ages greater than 25 years (Figure 226).

The use of true growth and natural mortality had relatively little impact on performance of the SCA EMs. The bias improved slightly for the southern SCA EM while there were relatively indistinguishable impacts on the northern SCA EM (Figure 227). However, larger impacts were observed in the SS EMs, especially in the southern stock where scale estimation became more positively biased (Figure 227) compared to the ***Base*** scenario. This was perhaps due in part to the estimation of a larger virgin stock size (i.e., larger SSB_0 and R0 parameters) which allowed for the perpetuation of increased biomass throughout the time series. In the northern stock, the ***Tru Grow&M*** configuration improved precision of the SS EM performance but did not impact scale estimation as observed in the southern stock, resulting in smaller and mixed impacts throughout the time series.

7.4 Data Prioritization Scenarios

7.4.1 Longline Data Time Series

The sub-scenarios conducted to evaluate effects of changing longline survey data time series (***No LL***, ***15 yrs LL***, ***30 yrs LL***, ***45 yrs LL***, ***60 yrs LL***) only impacted the northern SCA EM performance when the earliest years of the survey were excluded from the data set (2007-2022, Figure 228 and Figure 229). The incorrectly estimated exponential decline of mature abundance does not occur when these early data are removed from the time series. Similar effects were seen in the developmental scenarios when removing misspecified fishing mortality data from the model. This suggests the effects seen here are likely an interaction between the earliest longline data and the Bacheler et al. 2008 inputs to the model. This conflict with the Bacheler et al. 2008 data could come from either the fishing mortality estimates input as data, which would contain information on the cohorts that would have recruited to the longline survey in the first few years of its operation, the fixed recreational discard selectivity, or both. Despite the more accurate estimates of the historical population dynamics, sub-scenarios without the earliest longline data resulted in increased bias throughout the projection period which is of highest priority in future stock assessments. Further reductions of the time series had negligible impact on performance. Impacts to the northern SS EM mostly occurred for estimation of the historical population dynamics (Figure 228 and Figure 229). As the data time series is shortened, the historical estimates become increasingly biased. Bias in later years changes slightly across sub-scenarios indicating changes in scale estimates, but in no systematic pattern.

In the southern stock, there are similar trends in bias between EMs as the data time series is shortened (Figure 230 and Figure 231). Relative error decreases as the time series is shortened, but at a greater magnitude for the SCA EM. This pattern indicates a decrease in estimates of scale as the longline times series is shortened. The SCA EM estimates with more imprecision as the time series is shortened. The longline data also improve the SCA EM's performance at estimating the trend in abundance during the ramp period. Without the longline data during this period (***No LL***, ***15 yrs LL***), the EM estimates a more biased depletion and a more positively biased rate of recovery (Figure 230). There were similar impacts to the SS EMs between stocks in that the historical estimates show more trend in bias as the time series is shortened. However, due to the southern SS EM's tendency to overestimate mature abundance, the bias of the historical estimates is actually trending towards less bias.

7.4.2 Recreational Discard Composition Data

Sub-scenarios dealing with changes to recreational discard composition data impacted the scale, and, therefore, bias of estimates from the northern EMs (Figure 232 and Figure 233). These impacts generally reflected a negative relationship between composition data and estimated bias. The addition of imprecise sampling data resulted in more biased estimates and the addition of precise sampling data resulted in a further increase to bias. Trends in bias were similar with the exception of the SCA EMs that retained the fishing mortality data inputs with the composition sampling data (***B2 Dat*** and ***Prec B2 Dat***). These configurations reduced trending in bias of SPR ratios during the ramp period that was seen in configurations without composition sampling data (***Base***) or without fishing mortality data (***B2 Dat&No Fs*** and ***Prec B2 Dat&No Fs***). Increases in data precision did result in increases to precision of estimates. Aside from the impact to population parameters, the composition data does impact accuracy of recreational discard selectivity estimates (Figure 234-Figure 236). Estimates improve as composition data are added (particularly for older ages in the SS EM -Figure 235) and then become more precise (particularly for the SCA EM –Figure 236).

In the southern stock, changes to data precision also impacted scale estimation, but the impact was far greater for the SCA EM than the SS EM (Figure 233 and Figure 234). Both EMs estimated a smaller stock and the SCA EM shifted to a negative bias for abundance parameters and a positive bias for fishing mortality-based parameters (i.e., negative bias for SPR-Figure 233). As with the northern EMs, precision of estimates increased as data precision increased. There were also some improvements to selectivity estimates as composition data precision increased (Figure 237 and Figure 238), most notably from the SS EM for the SC_Recreational fleet (Figure 238).

8 CONCLUSIONS AND RECOMMENDATIONS

8.1 Assessment Methodology

8.1.1 Recommended Approach to Characterizing Stock Status in Future Benchmark Assessment

For the development of recommended approaches to characterize red drum stock status in future benchmark assessments, we used the performance of our EMs (TLA, SCA, and SS EMs) for each stock as measured using a suite of performance metrics (see Section 7.2), focusing on eight parameters identified as the highest priority parameters for performance evaluation (recruitment condition, SSB status, three-year average SPR ratios, three-year average SPR status, three-year average fishing mortality ratios, three-year average fishing mortality status, age-4 escapement, and age-6 escapement). The evaluation was conducted primarily using our core population dynamics scenarios (***Base***, ***High F***, ***Inc Sel***, ***Miss M***, ***Depr R***, and ***2023 Term Yr***) developed from the OM, however we used the totality of the scenarios explored (e.g., developmental scenarios (see Section 7.1), core population dynamics scenarios (see Section 7.2), alternative structural scenarios (see Section 7.3), and data prioritization scenarios (see Section 7.4) to inform our overall conclusions. Full descriptions of the results from these scenarios can be found in Section 7 – herein we summarize major conclusions based on the totality of the results from the EMs. Due to differences in performance of the considered EMs between stocks, we developed stock specific recommendations for characterizing stock status in future benchmark assessments. These recommendations should guide workloads and preparation for the upcoming benchmark, though, ultimately, the preferred approach will depend upon fits to the observed data from *in situ* stocks available in the benchmark.

8.1.1.1 Northern Stock

For the simulated northern stock of red drum, our analyses identified concerns with specific EMs, leading to recommendations on appropriate models for consideration during the upcoming benchmark stock assessment. In general, we recommend pursuing both the SS and TLA assessment approaches in the upcoming assessment for the northern stock of red drum; we do not recommend further pursuing the SCA model for the northern stock.

Statistical Catch-at-Age

The SCA had two identified and concerning deficiencies detracting from its use as an assessment model for the northern stock, namely its sensitivity to weighting scheme and reliance on Bacheler et al. (2008) tag-based data inputs. The model was impacted substantially by both factors, as evidenced by substantial changes in model results obtained via different developmental scenarios (Section 7.1). Although the model estimated parameters in the core population dynamics scenarios with reasonable and even superior precision, this precision was driven by external fishing mortality inputs and often centered around the most biased performance of northern EMs.

Despite these concerns, the northern SCA, as parameterized during ASMFC 2017b, will be updated in the upcoming stock assessment as a continuity run. Beyond its use as a continuity run, we do not recommend further model development or a continuation of development for this model after the upcoming benchmark assessment for the northern stock.

Stock Synthesis

We recommend focusing on and developing a length- and age-structured SS model for the benchmark stock assessment of the northern stock to characterize stock status. The SS model generally performed as well or better than the other northern EMs in terms of accuracy. Additionally, the SS model performs relatively well under the ***2023 Term Yr*** scenario. This is indicated by a general lack of a decrease in precision of the SS model under the ***2023 Term Yr*** scenario relative to the ***Base*** scenario. This provides more confidence in obtaining stock status information from such a model developed during the upcoming benchmark stock assessment.

The SS model is more flexible, providing a benefit to the assessment of red drum which has unique fishery and life history characteristics that pose challenges to traditional statistical catch-at-age models, particularly in cases like that seen here where the SCA depends on external fishing mortality inputs. The increased flexibility of the SS modeling approach also means it can incorporate additional red drum data sets not considered here, like tag-recapture data available from North Carolina and Virginia. The potential improvement in stock status determination and precision of stock status estimates via the incorporation of such data could not be evaluated herein due to limitations of the OM used to simulate the stocks.

Traffic Light Analysis

Our investigation of the TLA suggests there is utility in continuing to develop it as a potential assessment methodology for red drum. For the northern stock, it is comparable to the SS EM in making spawning stock biomass status determinations, and generally outperforms SS when characterizing recruitment condition. Hence the TLA shows utility as a supplementary, alternative assessment approach for development of SSB status and recruitment condition determinations. Such development should occur simultaneously with the SS model in the upcoming benchmark assessment. An additional benefit of further TLA model development is its relative ease to update; this suggests a TLA approach could be used during interim periods between formal assessments to update stock status for management advice. However, we do caution the use of the TLA for fishing mortality status determinations in the northern stock, due to its poor performance in terms of error rates.

8.1.1.2 Southern Stock

For the simulated southern stock of red drum, our analyses continued to identify concerns with individual EMs, though the overall similar performance (in terms of bias and precision) of all three EM approaches leads to our recommendation that all should be pursued in the upcoming benchmark stock assessment.

Statistical Catch-at-Age

The SCA continues to show sensitivity to changes in weighting schemes, with weighting affecting mostly convergence rates. However, compared to the effect changing weight had on the SCA for the northern stock, the change in weighting had less of an effect on scale estimation and generally did not affect the trend of estimates for either stock. Also, it is unclear at this point if the weighting in a future assessment would focus on the previously used weighting hypotheses or instead change to another method (e.g., Francis 2011).

Given this difference in the southern stock SCA model relative to the northern stock SCA model and its similar to slightly better performance overall relative to the other southern EMs, our recommendation is to continue pursuit of this model in the upcoming benchmark assessment. It's important to note that the results here indicate performance of this model for estimating the spawning stock biomass status is comparable to the other assessment approaches for the southern stock, despite this model being viewed as only applicable for sub-adult parameters coming into this assessment. Our recommendation of pursuing this model includes for adult-based estimates.

One caution was indicated by the results for this model that should be considered in the upcoming benchmark assessment. Though precision of the SCA estimates was reasonable and comparable to the other considered EM approaches when evaluated for the full simulated time series, precision drastically decreased under the ***2023 Term Yr*** scenario. This is similar to the situation noted during the ASMFC 2017 benchmark stock assessment and would likely be the experience during the upcoming benchmark stock assessment. However, the results also indicate this deterioration of precision is far worse for estimates on their absolute scale, while not as severe for scaled, trend-based estimates of fishing mortality-based parameters (Figure 239) or not an issue for trend-based estimates of abundance parameters (Figure 240). The model is more robust for trend estimation and use of trend-based estimates could offer a potential mitigation to this issue if experienced in the upcoming benchmark assessment. Converse to the deteriorating precision, the convergence rates of the southern SCA for the ***2023 Term Yr*** scenario actually improved relative to the ***Base*** scenario and offer indication of a stable model.

During the benchmark assessment, the southern SCA, as parameterized during ASMFC 2017b, should be updated as a continuity run. Note however the SCA configuration herein employed for the southern stock differs from this configuration, in that the Florida recreational discard selectivity is fixed and not estimated, and we recommend pursuing the configuration presented in this simulation assessment for consideration as the preferred approach in the benchmark.

Stock Synthesis

We continue to recommend development of the southern SS model during the benchmark stock assessment to characterize stock status. Relative to the southern SCA EM, the southern SS EM generally estimated with slightly greater precision during the Ramp period, though the SCA EM estimated with greater accuracy. Further, the SS model remains a more flexible assessment platform, which should be a benefit to the assessment of the southern stock of red drum with its unique fishery and life history characteristics that pose challenges to traditional statistical catch-at-age models. Similar to the northern stock, the increased flexibility of the SS modeling approach also means it can incorporate additional red drum data sets not considered here, like tag-recapture data available from South Carolina and Georgia. As noted above, the potential improvement in stock status determination and precision of stock status estimates via the incorporation of such data could not be evaluated herein due to limitations of the OM used to simulate the stocks.

Traffic Light Analysis

Similar to the northern stock, our investigation of the TLA suggests there is utility in continuing to develop it as a potential assessment methodology for red drum. The southern stock results indicate the TLA is useful for all metrics, including fishing mortality status which was deemed unreliable using the TLA for the northern stock. Further, error rates in stock status in terms of fishing mortality status and SSB status are comparable to both the SCA and SS EMs for the southern stock and the TLA continues to outperform the age-structured models in characterizing recruitment condition. Hence the TLA shows utility as a supplementary, alternative assessment approach for development of fishing mortality status, SSB status and recruitment condition determinations. Such development should occur simultaneously with the other models in the upcoming benchmark assessment. An additional benefit of further TLA model development is its relative ease to update; this suggests a TLA approach could be used during interim periods between formal assessments to update stock status for management advice.

8.2 General Recommendations

Our investigation suggests the SS estimation of steepness may prove useful as a diagnostic tool (see Section 7.3.2) in the benchmark stock assessment. We recommend trying to estimate steepness initially and upon initial investigation, if unexpected values of steepness are estimated, it may be indicative of changes in stock productivity through time or other model conflicts. If unexpected steepness is estimated, additional work should be done to diagnose what may be driving the unexpected evidence of steepness and the model can be modified to address the issue or steepness can be fixed if the cause cannot be diagnosed.

Despite the recommendation to pursue the SS EM in the upcoming benchmark stock assessment, the model was unsuccessful at characterizing recruitment condition due to high levels of variability around the estimates. We advocate not using the SS model to develop management advice based on recruitment condition. However, the results of the simulation assessment suggest output parameters available via SS can be used for stock status determination, including metrics related to spawning stock biomass and spawning stock biomass status which have been unavailable during previous assessments of red drum.

Finally, it became apparent during the review of the results that models, specifically for the southern stock, generally provided accurate trends in F, SSB, and recruitment. As such, this suggests a potential alternative management approach for red drum could be developed based on trends and levels relative to a reference time period. This is similar to the approach used for the development of stock status recommendations for the ASMFC-managed Atlantic menhaden (ASMFC 2017a). Work would be needed to define an appropriate time period to develop such a set of reference points, including input from the Board.

8.2.1 Recommendations for Future Simulation Analyses

We provide a recommendation to explore the cause for trends in bias of models during periods of big changes in stock dynamics. Such trends were associated with large changes in fishing mortality in our core population dynamics scenarios, leading to changes in performance for estimating stock status. During these periods, we generally see changes in accuracy of parameters. Such changes are troubling from a management perspective, as it is generally during these real world shifts in stock dynamics that it is most crucial to obtain accurate and precise estimates of stock status. One possible means to investigate this would be to develop an OM that outputs very precise data for incorporation into the EM models. The hope is this would allow analysts to investigate whether the causes of bias are due to structural issues with the EMs or a data issue.

8.3 Prioritized Recommendations on Future Monitoring to Improve Assessment

A final objective of the simulation assessment was to conduct a number of scenarios to evaluate potential data prioritizations that could improve the accuracy and precision of stock status estimates under various assessment approaches. These scenarios included evaluating the length of the adult longline survey time series, changes in recreational discard composition data availability and quality, and impacts of growth misspecification.

Adult Longline Survey

Based on these sub-scenarios, at this time we do not recommend any changes to longline survey operations across the coast. Though the SCA and SS models generally seemed to be insensitive to the longline index overall, the longline index is essential to the application of the TLA analysis for SSB status determination. In addition, further simulation analyses should be conducted before making any recommended changes to longline surveys. Examples of additional simulation analyses include a peel of the longline survey in the other direction, ending the survey prior to the terminal year of the assessment. This could help answer the question of how a future loss of the longline survey data could impact assessment results.

Recreational Discard Composition Data

A data deficiency thought to impact the uncertainty of status determinations in previous assessments has been the lack of robust recreational discard length- and age-composition information. This is particularly pertinent to a species such as red drum, whose fisheries are primarily recreational in nature with a large component of annual fishery related mortalities being due to catch-and-release. The improvements to recreational discard composition data indicated general improvements to precision of parameter estimates and improvements for selectivity estimation for this increasingly important component of the catch (see Section 7.4.2) and strongly supports the collection of these data. However, further analyses need to be completed to determine compensation effects resulting in changes to scale estimation, and therefore bias, and impacts elsewhere when the models are constrained by more precise data.

Growth Misspecification

A lot of time and effort has been expended in past assessments to try and accurately describe the growth pattern of red drum throughout their life, leading to the development of age-specific K growth models in this assessment. This is because pursuing statistical growth models to provide fixed or starting values for assessment models is generally seen as a useful endeavor in stock assessments. However, results of the scenario evaluating growth misspecification (***Tru Grow&M***) had little impact on EM performance in most cases and negative impacts on the southern SS EM (i.e., increased bias). These results imply development of non-traditional, custom growth models external to the assessment models is a lower priority in the upcoming benchmark stock assessment. While likely efforts would improve the assessment product, because of the anticipated workload and competing priorities and general insensitivity of the EMs under different growth model assumptions, it is anticipated greater improvements can be gained by focusing efforts on other data streams, such as index development, recreational discard compositions, and tag-recapture data (see below).

Tag-Recapture Data

As noted above, a limitation of the OM models was their inability to generate tag-recapture data sets mimicking those readily available for assessment approaches. SS has the ability to directly incorporate such tagging information into assessment models to improve estimates of stock status, with such exploration of the incorporation of tagging data in red drum assessments being explored during both SEDAR 44 (SEDAR 2015a) and the South Carolina state-specific assessment (Murphy 2017). Because of the limitations of the ss3sim package, the impacts of tagging data incorporation, which *a priori* would be expected to improve accuracy and precision of status determinations, could not be evaluated. However, there is an expansive tag-recapture data set available for both the northern (North Carolina and Virginia data sets) and southern (South Carolina and Georgia data sets) stocks of red drum. As such, incorporation of these data sets into the next benchmark stock assessment should be considered a high priority.

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10 TABLES

Table 1. Red drum regulation timeline by jurisdiction for the northern stock.

<table>
<tr><th>Year</th><th>New Jersey</th><th>Delaware</th><th>Maryland</th><th>Potomac River</th><th>Virginia</th><th>North Carolina</th></tr>
<tr><td>Pre-1960</td><td rowspan="15">No Regulations</td><td rowspan="15">No Regulations</td><td rowspan="12">No Regulations</td><td rowspan="11">No Regulations</td><td>No Regulations</td><td rowspan="4">No Regulations</td></tr>
<tr><td>1960</td><td rowspan="6">2 fish allowed >32" TL person^{-1} day^{-1}</td></tr>
<tr><td>1971</td></tr>
<tr><td>1973</td></tr>
<tr><td>1976</td><td rowspan="7">14" TL MLL; 2 fish >32" TL person^{-1} day^{-1}</td></tr>
<tr><td>1978</td></tr>
<tr><td>1985</td></tr>
<tr><td>1986</td><td rowspan="6">14" TL MLL; 2 fish >32"TL person^{-1} day^{-1}</td></tr>
<tr><td>1987</td></tr>
<tr><td>1988</td></tr>
<tr><td>1989</td></tr>
<tr><td>1990</td><td rowspan="4">14" TL MLL</td><td>14-32" TL slot limit; 1 fish >32" TL; 5 fish person^{-1} day^{-1} recreational; 250,000 lb commecial cap</td></tr>
<tr><td>1991</td><td rowspan="3">14" TL MLL; 2 fish >32"TL person^{-1} day^{-1}</td><td>18-32" TL slot limit; 1 fish >32" TL; 5 fish person^{-1} day^{-1} recreational; 250,000 lb commecial cap</td></tr>
<tr><td>1992</td><td rowspan="11">18-27" TL slot limit;
5 fish person^{-1} day^{-1} with 1 fish allowed >27" TL person^{-1} day^{-1}</td><td rowspan="6">18-27" TL slot limit; 1 fish >27" TL (no sale); 5 fish person^{-1} day^{-1} recreational; 250,000 lb commecial cap</td></tr>
<tr><td>1993</td></tr>
<tr><td>1994</td><td rowspan="8">18" TL MLL;
1 fish >27" TL person^{-1} day^{-1}</td><td rowspan="9">18-27" TL slot limit;
5 fish person^{-1} day^{-1} with 1 fish allowed >27" TL person^{-1} day^{-1}</td><td rowspan="9">18" TL MLL;
5 fish person^{-1} day^{-1} with 1 fish allowed >27" TL person^{-1} day^{-1}</td><td rowspan="2">18" TL MLL; 1 fish >27" TL person^{-1} day^{-1}</td></tr>
<tr><td>1995</td></tr>
<tr><td>1996</td><td rowspan="7">18-27" TL slot limit;
5 fish person^{-1} day^{-1} with 1 fish allowed >27" TL person^{-1} day^{-1}</td></tr>
<tr><td>1997</td></tr>
<tr><td>1998</td><td rowspan="2">18-27" TL slot limit; 1 fish person^{-1} day^{-1} recreational; 250,000 lb commecial cap & 100 lb day^{-1} trip limit</td></tr>
<tr><td>1999</td></tr>
<tr><td>2000</td><td>18-27" TL slot limit; 1 fish person^{-1} day^{-1} recreational; 250,000 lb commecial cap & 5 fish commercial trip limit</td></tr>
<tr><td>2001</td><td rowspan="19">18-27" TL slot limit; 1 fish person^{-1} day^{-1} recreational; 250,000 lb commecial cap & 0-10 fish commercial trip limit (set by commission proclomation) with red drum not exceeding 50% total marketable catch (excluding menhaden)</td></tr>
<tr><td>2002</td><td rowspan="18">18-27" TL slot limit; 1 fish >27" TL person^{-1} day^{-1}</td></tr>
<tr><td>2003</td><td rowspan="17">20-27" TL slot limit;
5 fish person^{-1} day^{-1}</td><td rowspan="17">18-27" TL recreational slot limit & 1 fish person^{-1} day^{-1} recreational limit;
18-25" TL commercial slot limit & 5 fish person^{-1} day^{-1} commercial limit</td><td rowspan="17">18-25" TL slot limit;
5 fish person^{-1} day^{-1}</td><td rowspan="11">18-26" TL slot limit;
3 fish person^{-1} day^{-1}</td></tr>
<tr><td>2004</td></tr>
<tr><td>2005</td></tr>
<tr><td>2006</td></tr>
<tr><td>2007</td></tr>
<tr><td>2008</td></tr>
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<tr><td>2011</td></tr>
<tr><td>2012</td></tr>
<tr><td>2013</td></tr>
<tr><td>2014</td><td rowspan="6">18-26" TL recreational slot limit & 3 fish person^{-1} day^{-1} recreational limit;
18-25" TL commercial slot limit & 5 fish person^{-1} day^{-1} commercial limit</td></tr>
<tr><td>2015</td></tr>
<tr><td>2016</td></tr>
<tr><td>2017</td></tr>
<tr><td>2018</td></tr>
<tr><td>2019</td></tr>
</table>

Table 2. Red drum regulation timeline by jurisdiction for the southern stock.

<table>
<tr><th>Year</th><th>South Carolina</th><th>Georgia</th><th>Florida</th></tr>
<tr><td>Pre-1925</td><td rowspan="10">No Regulations</td><td rowspan="10">No Regulations</td><td>No commercial use by out of state citizens</td></tr>
<tr><td>1925</td><td>12" FL MLL</td></tr>
<tr><td>1953</td><td>15" FL MLL</td></tr>
<tr><td>1955</td><td rowspan="2">12" FL MLL</td></tr>
<tr><td>1960</td></tr>
<tr><td>1971</td><td>12" TL MLL</td></tr>
<tr><td>1973</td><td rowspan="3">12" FL MLL</td></tr>
<tr><td>1976</td></tr>
<tr><td>1978</td></tr>
<tr><td>1985</td><td rowspan="2">18" TL MLL; 1 fish >32" TL; protected species[a]</td></tr>
<tr><td>1986</td><td>14" TL MLL from June 1-Sept. 1; 1 fish >32" person^{-1} day^{-1}</td><td rowspan="3">14" TL MLL; 2 fish >32" TL person^{-1} day^{-1}</td></tr>
<tr><td>1987</td><td>14" TL MLL from June 1-Sept. 1; 1 fish >32" person-^{1} day^{-1}; commercial harvest prohibited</td><td>18" TL MLL; 1 fish >32" TL; March-April closure[b]</td></tr>
<tr><td>1988</td><td rowspan="2">14" TL MLL from June 1-Oct. 1; 20 fish person^{-1} day^{-1} & 1 fish >32" person^{-1} day^{-1}; commercial harvest prohibited</td><td>Moratorium</td></tr>
<tr><td>1989</td><td rowspan="2">14" TL MLL; 2 fish >32" TL person^{-1} day^{-1}; 10 fish person^{-1} day^{-1}</td><td rowspan="7">18-27" TL slot limit; March-May closed season; 1 fish person^{-1} day^{-1}; prohibition on sale[c]</td></tr>
<tr><td>1990</td><td>14" TL MLL; 20 fish person^{-1} day^{-1} & 1 fish >32" person^{-1} day^{-1}; commercial harvest prohibited</td></tr>
<tr><td>1991</td><td rowspan="2">14" TL MLL; 5 fish person^{-1} day^{-1} & 1 fish >32" person^{-1} day^{-1}; commercial harvest prohibited</td><td rowspan="2">14" TL MLL; 5 fish person^{-1} day^{-1}</td></tr>
<tr><td>1992</td></tr>
<tr><td>1993</td><td rowspan="8">14-27" TL slot limit; 5 fish person^{-1} day^{-1}; commercial harvest prohibited</td><td rowspan="9">14-27" TL slot limit; 5 fish person^{-1} day^{-1}</td></tr>
<tr><td>1994</td></tr>
<tr><td>1995</td></tr>
<tr><td>1996</td><td rowspan="16">18-27" TL slot limit; 1 fish person^{-1} day^{-1}; prohibition on sale</td></tr>
<tr><td>1997</td></tr>
<tr><td>1998</td></tr>
<tr><td>1999</td></tr>
<tr><td>2000</td></tr>
<tr><td>2001</td><td rowspan="6">15-24" TL slot limit; 2 fish person^{-1} day^{-1}; commercial harvest prohibited</td></tr>
<tr><td>2002</td><td rowspan="11">14-23" TL slot limit; 5 fish person^{-1} day^{-1}</td></tr>
<tr><td>2003</td></tr>
<tr><td>2004</td></tr>
<tr><td>2005</td></tr>
<tr><td>2006</td></tr>
<tr><td>2007</td><td rowspan="11">15-23" TL slot limit; 3 fish person^{-1} day^{-1}; commercial harvest prohibited</td></tr>
<tr><td>2008</td></tr>
<tr><td>2009</td></tr>
<tr><td>2010</td></tr>
<tr><td>2011</td></tr>
<tr><td>2012</td><td rowspan="8">18-27" TL slot limit; 2 fish person^{-1} day^{-1} in NE (Atlantic) and NW (Gulf) regions; 1 fish person^{-1} day^{-1} for south region; prohibition on sale</td></tr>
<tr><td>2013</td><td rowspan="7">14-23" TL slot limit; 5 fish person^{-1} day^{-1}; commercial sale prohibited</td></tr>
<tr><td>2014</td></tr>
<tr><td>2015</td></tr>
<tr><td>2016</td></tr>
<tr><td>2017</td></tr>
<tr><td>2018</td><td rowspan="2">15-23" TL slot limit; 2 fish person^{-1} day^{-1} & 6 fish boat^{-1} day^{-1}; commercial harvest prohibited</td></tr>
<tr><td>2019</td></tr>
</table>

a - harvest moratorium from 11/7/86-2/17/1987

b - harvest moratorium from 5/1-10/1/1987; reopened 10/1/1987 with 18-27" TL slot limit, 5 fish commercial possession limit & 1 fish recreational possession limit

c - prohibited gigging and spearing on 6/3/1991 (still in effect)

Table 3. Summary of red drum growth data by stock. Total length (TL) measurements are in centimeters.

Age	Northern					Southern				
	Mean TL	Min TL	Max TL	n	CV	Mean TL	Min TL	Max TL	n	CV
0	3.8	0.9	12.5	18,690	0.38	2.5	0.5	19.2	1,243	0.96
1	37.6	3.8	59.3	5,595	0.17	32.9	2.5	70.0	35,054	0.21
2	51.3	23.2	75.8	7,166	0.17	45.9	25.8	83.0	34,190	0.16
3	65.9	46.0	88.6	1,720	0.10	61.4	29.9	87.4	16,566	0.13
4	79.3	58.5	94.3	276	0.09	70.8	36.5	110.2	9,429	0.10
5	90.5	78.0	100.3	111	0.05	76.0	37.9	101.1	3,170	0.09
6	94.8	83.7	105.9	62	0.05	80.8	61.2	105.5	380	0.09
7	96.3	88.0	106.7	56	0.04	87.0	75.2	105.5	82	0.07
8	100.1	87.1	116.2	61	0.05	91.2	71.8	103.0	54	0.06
9	100.9	89.0	113.0	52	0.05	91.2	80.1	110.0	53	0.06
10	103.8	95.0	115.3	76	0.04	92.7	82.0	104.9	60	0.05
11	105.1	96.0	116.4	55	0.04	94.8	86.1	102.0	50	0.04
12	105.0	93.4	119.3	79	0.05	95.0	86.2	107.2	60	0.05
13	104.6	92.0	112.2	40	0.04	97.4	89.6	114.6	54	0.04
14	106.6	98.5	118.0	57	0.04	97.0	89.7	107.9	53	0.04
15	107.6	98.1	127.5	90	0.05	96.7	88.0	108.0	78	0.04
16	108.9	97.0	124.7	72	0.05	98.8	89.6	107.0	66	0.04
17	108.4	98.0	118.4	111	0.04	98.6	90.4	108.0	64	0.04
18	110.5	101.3	119.3	84	0.04	98.9	91.3	108.3	59	0.04
19	109.8	99.0	123.3	76	0.04	100.3	93.7	112.5	55	0.04
20	111.3	100.0	130.2	83	0.05	100.1	93.6	110.3	52	0.04
21	112.8	99.6	127.5	61	0.05	100.3	93.2	107.5	53	0.03
22	112.9	103.2	125.0	62	0.04	101.3	94.7	111.8	52	0.03
23	113.9	104.5	124.8	40	0.04	100.8	90.4	113.3	44	0.04
24	114.6	105.0	125.0	43	0.04	103.0	95.5	113.0	42	0.04
25	114.1	101.7	127.5	29	0.06	102.8	97.1	113.4	39	0.04
26	116.0	104.7	125.8	34	0.05	102.6	89.4	117.6	37	0.05
27	116.2	104.3	132.7	35	0.04	103.2	89.1	116.1	26	0.06
28	113.0	99.5	125.0	16	0.06	104.7	95.1	118.3	38	0.05
29	115.3	105.4	124.7	35	0.04	105.4	96.6	117.3	27	0.04
30	116.6	108.0	123.9	20	0.04	105.8	95.0	115.1	26	0.04
31	118.5	106.0	131.6	24	0.05	105.5	97.2	116.4	16	0.05
32	117.8	108.1	128.0	23	0.05	107.8	100.1	112.5	8	0.04
33	116.2	109.7	125.7	12	0.04	105.4	99.2	110.6	7	0.04
34	116.6	105.0	129.0	30	0.04	106.9	102.8	113.4	13	0.03
35	118.1	108.8	130.3	24	0.05	108.8	103.7	114.5	5	0.04
36	116.3	107.2	127.4	19	0.05	108.6	104.7	112.4	2	0.05
37	116.8	105.4	125.6	16	0.05	106.8	105.5	108.0	2	0.02
38	119.7	112.1	133.1	18	0.06	106.6	102.8	109.1	5	0.03
39	116.8	109.0	126.1	19	0.04	105.3	103.0	107.6	3	0.02
40	119.5	112.5	132.2	16	0.04	107.0	107.0	107.0	1	NA
41	118.7	104.5	144.1	12	0.08	107.8	107.5	108.0	2	0.00
42	119.3	111.2	128.3	8	0.05					
43	120.4	115.0	127.5	6	0.04					
44	107.0	107.0	107.0	1	NA					
45	119.2	114.5	121.6	4	0.03					
46	130.4	119.4	141.3	2	0.12					
47	118.5	112.0	126.1	5	0.05					
48	119.3	118.4	120.0	3	0.01					
49	127.9	122.2	133.6	2	0.06					
50	118.6	114.0	126.0	4	0.04					
51	121.3	121.3	121.3	1	NA					
52	126.8	123.3	130.4	2	0.04					
53	123.4	116.2	127.5	3	0.05					
54	130.0	130.0	130.0	1	NA					
55	124.4	124.4	124.4	1	NA					
56	126.0	122.2	129.8	2	0.04					
57	122.2	122.2	122.2	1	NA					
62	122.0	122.0	122.0	1	NA					

Table 4. Parameters for red drum age-specific K growth curves.

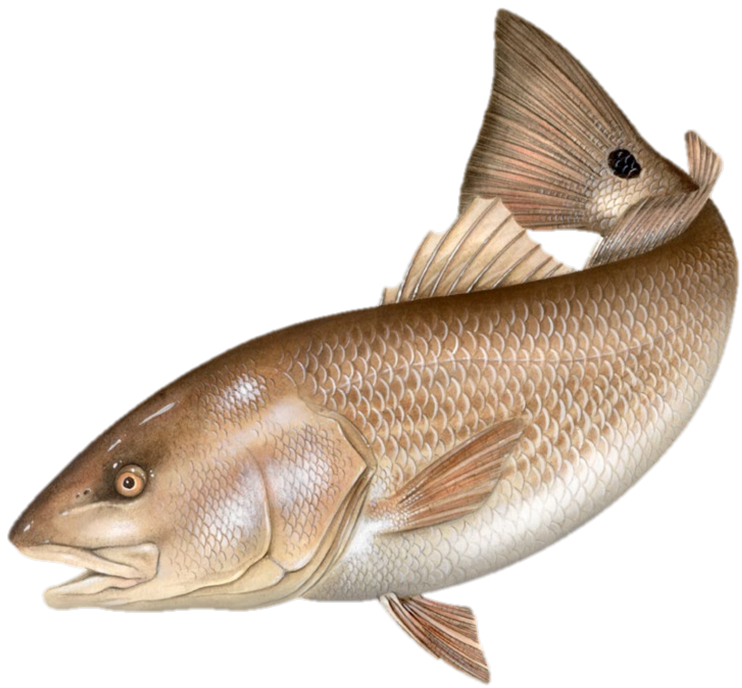
Parameter	Stock	
	Northern	Southern
Amin (age for first size-at-age, Lmin)	1.083	1.167
Lmin (cm)	10	6
Linf (cm)	125	107
von Bertalanffy Base K (youngest ages)	0.35	0.52
K age break points	2, 4, 6, 12, 18	2, 7, 12, 18
Age break point K multipliers	0.75, 0.91, 0.3, 0.6, 1.3	0.47, 0.38, 0.75, 1.6
Length-at-age CV for smallest sizes	0.23	0.18
Length-at-age CV for largest sizes	0.04	0.06

Table 5. Relationships between length at maturity and age at maturity in red drum from North Carolina and South Carolina. Parameters a and b (± SE) are for the logistic function Proportion Mature=e^Z/(1+e^Z) where Z=a+b*Predictor.

Region	Sex	n	Predictor (independent variable)	*a* (const)	±se	*b* (slope)	±se	50% maturity	Data used
NC	Female	305	Length (TL, mm)	-38.8400	7.37006	0.0445117	0.0085605	872.6	Jul-Dec
NC	Female	334	Age (decimal years, Jan 1 birth date)	-29.8740	6.05016	7.2755200	1.5720700	4.1	Feb-Dec
NC	Male	340	Length (TL, mm)	-19.8010	3.76561	0.0294404	0.0054736	672.6	Jul-Dec
NC	Male	318	Age (decimal years, Jan 1 birth date)	-10.8147	1.88893	3.6662400	0.6152680	2.9	Feb-Dec
SC	Female	1,805	Length (TL, mm)	-17.8929	1.13022	0.0228056	0.0014545	784.6	Jul-Dec
SC	Female	2,613	Age (decimal years, Jan 1 birth date)	-9.0749	0.45404	1.7918600	0.1073900	5.1	Jan-Dec
SC	Male	2,927	Length (TL, mm)	-18.3791	1.14192	0.0264934	0.0016986	693.7	Jul-Dec
SC	Male	2,930	Age (decimal years, Jan 1 birth date)	-10.1218	0.45237	2.4274500	0.1250110	4.2	Jan-Dec

Atlantic States Marine Fisheries Commission

2022 Red Drum Simulation Assessment
Peer Review Report



Conducted on
March 28-30, 2022

Prepared by the
ASMFC Red Drum Simulation Assessment Review Panel

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INTRODUCTION

Red Drum *Sciaenops ocellatus* is a popular recreational fish along the Atlantic and Gulf coasts of the United States. Red drum exhibit ontogenous movement dynamics whereby young of year and sub-adults spend their time in estuarine environments and adults migrate further offshore. Recreationally caught fish can be harvested if fish are within a slot length limit. Data collected from the adult population is sparse and mainly consists of information from various long line surveys. The lack of available adult abundance information results in stock assessments that have been unable to accurately estimate stock status. The purpose of this review is to evaluate and identify stock assessment methods most robust to the types of data available for red drum. This was accomplished by simulating data using an operating model and then fitting simulated data using various stock assessment models. The three models considered and compared in the simulation assessment include the Traffic Light Approach (TLA), SCA (a statistical catch-at-age model developed in ADMB and used historically for red drum), and Stock Synthesis (SS; a statistical catch-at-age model developed in the SS program).

The Review Panel (RP) recommends the use of the SS program to assess both the northern and southern stocks of red drum, with the use of the TLA as an accessory tool between assessments. The SCA model was not able to reproduce the outcomes from the operating model when fitting to near-perfect data. The SS model is ready to use for the northern stock, while the model for the southern stock requires more exploration before use in stock assessment. In particular, some results were unexpected and unexplained. The unexpected results are detailed below and require further attention.

The Review Panel (RP) appreciates all of the hard work by the Red Drum Stock Assessment Subcommittee (SAS) and Technical Committee to create a comprehensive simulation assessment. The Panel also thanks the Director of Fisheries Science for organizing the meeting, providing materials to the Review Panel in a timely fashion, and additional support throughout the review. A Review Workshop was conducted in Raleigh, North Carolina, during the week of March 28, 2022. Workshop discussions were professional and constructive, and overall the simulation assessment passes review.

The following report provides an evaluation of the simulation work and recommendations from the Panel, with detailed comments for each Term of Reference.

TERMS OF REFERENCE

1. Evaluate the thoroughness of data collection, data treatment, data presentation, and characterization of data uncertainty.

The Review Panel believes the Stock Assessment Subcommitee did an excellent job of summarizing and analyzing a large number of complex data sets that went into the assessment models. The simulation assessment is thorough in its description of the data sources and how they are used in the three different models. Uncertainty is well characterized overall, although we note a few cases where the models are biased via not making accurate predictions when given perfect data (e.g., SS model for southern stock). We suggest attempting a few adjustments to remove bias and improve the utility of the models.

We believe the authors should consider alternate growth curve formulations. Schueller et al. (2014) offers a potential for bias correction to consider. Alternately, Lester et al. (2004) offers a growth model that specifically models the pre-maturation phase of growth separately from the mature phase that could produce a better fit to the data. The RP believes the two approaches should be considered to better model size at age. However, the RP notes several aspects of the size at age data that could result in biased growth parameters, regardless of the model chosen.

a. Variability in size at age declines with age, an unlikely relationship that may be a result of gear bias; in most fishes, variability in size at age is constant or increases with age
b. Drum in the 70-90 cm size range are not well sampled, likely a result of gear bias; and
c. The RP also believes future explorations of size at age for red drum stocks should evaluate existing growth increment data from the tagging studies, to further elucidate growth patterns.

Thus, the data available to analyze growth for red drum are likely problematic and need further consideration and analysis. Traditionally, the expectation is that as age increases, the variability in size is likely to remain constant or increase. The lack of such a trend in the data suggests there is a bias in data collection and the full variability of size at age is not being sampled. One potential bias could be a gear bias where a certain survey or fishery gear doesn't sample specific sizes well. Another example could be a bias due to spatial dynamics of the population and no sampling occurring within a given area or time frame. This potential bias in sampling leads to a potential bias in the estimation of the growth curve parameters. When estimating growth, one assumption is the data at age are representative of the range of sizes at that age.

The Assessment Committee made the assumption that the data reflect the true size distribution at age and corrected the growth curve estimation by allowing for an age-varying K parameter for the von Bertalanffy growth curve. An alternative explanation is the data are not representative of the full distribution of sizes at a given age. If this is the case, the estimation of the von Bertalanffy growth curve should be bias corrected such that all of the parameters would be estimated in an unbiased manner. A tested method to bias correct growth curve estimations can be found in Schueller et al. (2014). The RP recommends bias correcting the growth data given the lack of samples in the 70-90 cm range, which indicates the full size range at age is unlikely to be sampled across all age classes. In addition to the bias correction, the data should be explored over time to assess the possibility of time-varying growth. However, the RP recognizes that considering and correcting for bias in the growth data could be beyond the scope of the simulation assessment. The RP suggests further exploration of how bias in growth parameters could influence the simulation assessment model results.

The RP also notes that potential growth information from tagging data has not been investigated in past stock assessments due to availability of traditional age-length data. Various tagging programs for red drum have been conducted in multiple states. There is a substantial amount of tagging data available, including information on large and old individuals. The RP recommends analyzing the size increment data from tagging programs. For example, analysts can fit the growth increment form of the von Bertalanffy function (Fabens 1965) to the size increment data. The estimated von Bertalanffy parameters (K and Linf) can then be compared with those obtained from the age-length data. The comparison may shed light on the representativeness of the age-length data. Furthermore, it may be worthwhile to fit the von Bertalanffy growth curve using both size increment and age-length data (Kirkwood 1983). Again, this is a recommendation for future assessments.

The survey index data for the northern model were appropriate and were limited to one index for recruitment, one index for sub-adults, and one index for mature adult abundance. The approach used in the northern region uses the available data to the extent scientifically possible.

The survey index data for the southern model were more plentiful and complex. The base configuration of the southern model included eight index data sets. The model included three indices of recruitment, two indices for sub-adults, and three indices representing mature abundance. When multiple indices are included that represent the same segment of the population, the estimation model will find similar trends, but will also have a difficult time fitting the data if the same underlying trends are not informing the data. Moving forward with the estimation model, analysts should consider providing the best information available on trends in abundance over time for the given size and age ranges. With multiple possible data sources, analysts should consider prioritizing the data and using the longest time series and largest, most representative spatial scales. If that is not an option and all data are equally valuable, analysts could consider combining indices using a variety of different options such as the Conn method (Conn 2010), VAST (Thorson 2019), hierarchical modeling, or dynamic factor analysis. In addition, exploring the relationship of the indices to each other through correlation analyses, with appropriate lags to account for size or age class differences, is critical to determining if the estimation model inputs provide a cohesive picture of the stock dynamics.

Natural mortality is one of the most critical parameters influencing the identification of sustainable harvest levels. The RP feels the simulation assessment handled natural mortality appropriately using surrogate measures for M and size dependency in M. Overall, the natural mortality approach used in the models was appropriate.

During discussions, the RP learned that much more tagging data exists that could provide better informed estimates of fishing mortality, particularly in North Carolina and South Carolina. There are evidently data that correct for non-reporting of tags and thus could be very useful. The RP encourages new analyses of the tagging data to obtain estimates of harvest rate information (F) that could improve future assessments.

Finally, the discard mortality rate was a key uncertainty in this assessment, as well as the number and size composition of released fish that ultimately would be exposed to discard mortality (currently set at 0.08). There is a key need to better quantify the number and sizes of discarded catch, particularly given the apparent recent increase in anglers targeting large, spawning fish offshore. The RP recommends better data collection of discard numbers and sizes as a high priority for future assessments, including the use of angler phone apps and other tools to measure the size and number of discarded fish. Further, the assessment could benefit from more sensitivity analyses to evaluate how the size and number of discarded fish could influence the assessment trends and reference points. Finally, the RP believes the discard mortality rate of 0.08 could be a bit high, and should consider the effects of lower values (e.g., 0.04). That said, the number and size of discarded fish is a major uncertainty that if quantified, would improve future assessments.

2. Evaluate the thoroughness and appropriateness of information used to parameterize simulation models.

The RP feels the SAS did a very thorough job of parameterizing the models, including critical parameters of natural mortality and recruitment compensation. There is some uncertainty in how selectivity from the different regions is influencing model outputs, as regulations changed through time and were different across the states. This creates uncertainty in the models because the north and south stocks have different selectivities, likely operating within different states for each region (north and south). Selectivity is particularly concerning for the southern stock where size and bag limits varied through time and across the states of South Carolina, Georgia, and Florida. An amalgamation of selectivities could contribute to uncertainty and possibly bias in the southern stock SS model. The RP recommends further sensitivity analyses to explore how changes in the selectivity curves influence model predictions when given perfect data.

3. Evaluate the appropriateness of models for simulating red drum populations and generating data sets sampled from the simulated populations.

The Stock Synthesis simulation package (SSsim) is used to simulate red drum populations and create data sets from the operating models. The RP agrees this is an appropropriate model or method for simulating red drum populations and generating data sets for use in the estimation models. Overall, the uncertainty in the operating model represents the observed uncertainty in the data.

4. Evaluate the incorporation and treatment of uncertainty in simulated populations.

The RP feels that uncertainty was handled appropriately overall. The SAS includes uncertainty through variable population dynamics scenarios in the operating model (OM). These include a scenario in which fishing pressure is increased in the projection period, an increase in the selectivity at age of older fish through a catch and release trophy fishery, a scenario in which natural mortality is lower than expected, and a time varying realized recruitment scenario. The incorporation of uncertainty into the simulated populations in the operating model is well described and appropriate for red drum.

5. Evaluate candidate assessment methods and application of assessment methods to data sets sampled from simulated populations.

The Stock Assessment Subcommittee (SAS) explored a few assessment methods within each of the estimation models (EM). Exploration of assessment methods is constrained by the limitations of each EM framework and by the requirement that any model configuration has to be flexible enough to fit the data provided by each of the scenarios developed in the OM.

In general, the assessment methods available for exploration in the SCA are limited compared to those available in the SS EM. For example, the SAS explored estimating time varying equilibrium recruitment (R0) in SS as an attempt to fit the data produced by the OM, which has a temporally varying stock recruitment relationship. The SCA EM does not estimate stock recruitment parameters and so no such exploration is possible.

The assessment methods available in SS are many and varied. The SAS chose to limit the tuning of SS models to configurations that would fit all of the runs from each of the OM scenarios. The approach means that some individual runs and scenarios could be fit better, and results for the SS models are possibly less precise than they could be. However, the RP recognizes it would be unreasonable to attempt to tailor each fit to the hundreds of OM runs. SS employs parameter penalties to help with estimation. The penalties can be (mis)used to direct the EM to a particular solution on the likelihood surface, inflating the perceived stability of the model. The SAS does not misuse this feature of SS. They employ appropriate penalties on parameters that are weak enough to allow a broad array of solutions and provide enough guidance to help with model convergence. Other choices made in configuring SS for each OM scenario are reasonable and would likely have been employed by other competent stock assessment scientists given similar datasets.

The RP finds the application of assessment methods to be appropriate and representative of the choices made by professional stock assessment scientists. However, a few additional items could be considered.

First, further examination of the SS estimated stock-recruit relationship, including the steepness parameter, is recommended. The estimated steepness values are unexpectedly low for both north and south stocks, causing an estimated SSB ratio with considerably high bias (e.g., scenario ***Depr R***). The RP feels the assessments do not appear to have data to inform steepness, and thus recommend fixing steepness at 0.99. However, the RP recognizes that such model configuration, in conjunction with other fixed life history parameters (e.g., natural mortality), could constrain the calculation of potential reference points. Fixing several parameters limits the flexibility for reference points to be informed by the data.

Second, the RP recommends exploration of the start year of the model. Given the time series available, the model could be started earlier than 1989 or later than 1989. The model could be started earlier, for example 1950, in order to capture the decline in the population with increased catches by both the commercial and recreational fisheries, and to leverage all of the available data. In addition, a later start year of 1991 could be considered if tagging data were to be used. Parameter estimates from the tagging data during the earliest years were quite uncertain. Censoring those earlier years may help with parameter estimation and model performance. Additional sensitivity runs should be used to diagnose the robustness of the model outcomes to the decision of the starting year of the model. In some cases, the choice of start year can lead to difficulties initializing the model at the appropriate scale of abundance given the data available and the level of depletion.

6. Evaluate the choice of reference points for characterizing stock status of simulated populations. Recommend alternatives if necessary.

In general, the RP feels the reference points selected by the SAS are appropriate. The RP agrees that an escapement reference point is vital to assessing a stock primarily driven by recruitment. The RP recommends monitoring both an annual and 3-year moving average measure of SPR status. The three year moving average introduces some inertia into the management process and reduces the probability that management actions are based on noise rather than signal. The annual measure can be important to balance that inertia with the ability to detect rapid changes in SPR status that might require immediate attention.

SSB status could turn into a trend-based reference point, but the SAS would need to select a reference time period. A general result of the simulation exercise is that trend was more stable than scale in SS models for both regions. If this result holds, once a final version of the SS model for the south is configured, there is a possibility of using an SSB reference point based on trend for management. Trend-based SSB reference points require a reference period for internal comparison. Identifying an appropriate reference period would require further study by experts in the fishery and is outside the purview of the RP.

The SS model for the south appears biased in scale, but demonstrates a stable trend. This result indicates trend based reference points could be useful for management. The RP thinks trend based reference points are a potentially useful tool to mitigate a model that shows scale instability. However, the Panel recognizes there may also be trends in bias. Once the SAS has demonstrated that the EM for the south can reproduce the dynamics of the OM when given data without observation error, it will be possible to determine if there are trends in bias and by extension whether or not trend-based reference points are appropriate.

7. Evaluate the choice of metrics used to evaluate performance of each candidate assessment method for estimating the population dynamics and stock status of simulated populations. Recommend alternatives if necessary.

The selected performance metrics are appropriate and represent standard reference points for diagnosing overfishing in stock assessments. The escapement goals for red drum are sound performance metrics for a stock with dome-shaped selectivity that focuses harvest on juvenile fish.

The SAS conducted 100 iterations for each scenario and computed relative error and error rates (Type I and Type II) as metrics for each EM and scenario. Given that process error (recruitment deviations) is also introduced to the simulation, the RP feels that 100 iterations is a low number and simulation results might reflect a substantial amount of randomness. The RP notes the actual number of iterations is lower because non-converged runs were excluded. The RP recommends the following two exercises to explore the impacts of number of iterations: (1) for a given scenario, increase the number of iterations to 200 and compare the results with 100-iteration results; (2) for a given scenario, perform several runs of 100 iterations and check variability in produced relative errors and error rates among runs. For the purpose of model comparison, however, the RP thinks 100-iteration results will likely indicate the difference in performance among EMs. For a given scenario the SAS fit all of the EMs to the same <100 datasets. The EMs used the same datasets and comparisons were based upon medians.

8. Evaluate the choice of the preferred assessment method(s) for characterizing stock status. Recommend alternatives if necessary.

The RP evaluated all three assessment methods presented by the SAS: TLA, SCA, and SS. Overall, the RP does not recommend further exploration of the SCA model. The RP recommends the use of the SS model for future analyses and assessments, and recommends use of the TLA as an accessory model.

The RP recommends that the SCA model should not be further explored for red drum stocks because the SCA seems to be intrinsically biased even when using perfect data from the operating model. The RP notes the initialization of the SCA and the bias associated with it could be remedied with alternative approaches to initialization (Figure 1). Additionally, the RP notes the SS model is essentially an SCA approach with more flexibility. While the RP agrees that, with more work, the SCA model is likely to be able to produce robust, unbiased estimates, the time and resource commitment is not worthwhile. Ultimately, the RP recommends not pursuing the SCA model further for the red drum stocks.

The RP expects the SS model to produce unbiased and robust estimates of the red drum stocks given that the Operating Model producing data was SSsim. The SS model for the northern region appeared to be unbiased when using perfect data from the operating model (Figure 2). The SS model for the southern region needs additional work to determine if the model can produce unbiased estimates while using perfect data from the operating model. The conclusions from the report for the SS south model are potentially uninformative because of the lack of a working model using the perfect data from the OM. The expectation is that the SS model will be able to reproduce the OM with further work. At that time, the sensitivity runs may need to be redone to reassess conclusions. Options to explore as the SAS determines what is leading to the inability to reproduce OM results include: 1) more years of model sensitivity runs, 2) consider impacts of growth curve biases on the results, and 3) explore the effects of different selectivity curves through time used for South Carolina, Georgia, and Florida. It would be worth exploring how the selectivity parameters influence model results, particularly given the changes in selectivity through time and across states in the southern region. In the absence of other ideas for improving the fit to data without error, it would be worth fixing all but one of the scaling parameters at their true values to make sure there are no gross specification errors present in the EM model configuration. If the one estimated scaling parameter (for example R0) is accurately reproduced in the EM, the remaining parameters could be iteratively opened to estimation in order to track down which ones are introducing bias into the model. Additional penalties (parameter priors) on troublesome parameters may be warranted.

The RP is particularly concerned with the unexpected outcomes in the “sensitivity runs” that remain unexplained for both the north and the south SS models. For the northern model, incorporation of the B2 (recreational live discards) composition data improves characterization of discards but results in more biased results, rather than less biased results. For the southern model, the use of the true growth information or model from the operating model does not improve the robustness of estimates.

Finally, the TLA may be a useful accessory tool because it shows no bias and provides recruitment information. TLA could be used as an annual, interim tool between assessments, as recommended by the SAS. TLA provides information on Recruitment Condition and SSB status and could be used as a tool to indicate the need for an assessment during periods of poor recruitment. The RP expresses concern over the methods for determining the reference points used in the evaluation of TLA performance. The grid search method uses information from the entire time series of the simulation, including the projection years. Therefore the TLA leverages information not available to the other models and would not be available to a TLA based on ‘in situ’ data. It would be informative to repeat the grid search using only the ‘burn in’ and pre-2023 periods to see if the reference points identified were similar to the ones identified in the presented assessment. The reduced time series grid search would be more directly comparable to the other assessment models and would be representative of options available in an ‘in situ’ application of the TLA.

During the Review Workshop, the RP made analytical requests to the SAS that were informative for determining the status of each of the models for use in red drum assessment and management. During Day 1, the RP requested running each of the estimation models with perfect or near perfect data from the operating model. This would allow the RP to assess how well the estimation model performs given a perfect dataset. The RP requested running data from the operating model with no error in the SS and SCA estimation models using only one iteration each for the north and south. The request included using all data from all years but with no observational error. The SAS provided the results, leading to the conclusions above regarding use of the SCA and SS models.

On Day 2 of the Review Workshop, the RP made additional analytical requests. The first was to continue to run the perfect data from the OM in the estimation model configurations for the southern region. In addition, the RP made requests intended to sleuth out why the southern region was not performing as expected or why the SCA model was not matching the operating model data well. First, the RP requested fixing the initial numbers at age at the true values for the northern SCA model in order to help with model initialization (Figure 1). Second, the RP requested fixing M at the true value whereby the value for the Age 7+ group was averaged across all of the available ages. The preferred average was the numbers-weighted M for the Age 7+ group for the south and north using the base model.

On Day 2, the RP also requested additional figures for consideration. First, the RP wanted to see the annual SPR values instead of the three year average SPR values. Second, the RP wanted to double check what SS was doing with the SPR calculations and requested the values be computed using a manual SPR calculation in a spreadsheet. Finally, the RP requested that growth and B2 be calculated annually. These requests were made in order to guide future work on the models in preparation for future red drum stock assessments.

Finally, the RP recognizes the spatial structure of the models needs further exploration and future assessments may or may not have the same structure explored here. Given the analyses explored for the simulation assessment, it was difficult to properly evaluate the most robust choices for spatial delineation and spatial assumptions within the modeling framework. Future exploration of the decisions regarding spatial assumptions should include analyses of the tagging data and the consideration of one model versus separate northern and southern models. Several capabilities within Stock Synthesis could be explored. One example could be one model with limited movement, but two separate areas for estimation of life history parameters and fishing mortality rates, plus the incorporation of tagging data. The single model could be set up to leverage all of the data available for the species while still allowing for differential management and population dynamics of red drum in the north versus the south. Another example could be two separate models, as presented here, one each for the north and the south, with tagging data incorporated.

9. **Review recommendations on future monitoring provided by the Technical Committee and comment on the appropriateness and prioritization of each recommendation. Provide any additional recommendations warranted.**

This TOR is partially addressed. The RP could not fully evaluate the simulation results for the southern area due to lack of a converged model that could accurately reproduce the OM when given data without observation error. Results from the future monitoring prioritization study are counter-intuitive and therefore could not be fairly interpreted. The RP feels the longline survey is very likely to be important to the assessment because it is the only source of information for adult fish. However, the simulation study indicates the long line data are not helpful to the assessment. Removing long line data made little or no difference to the results. Also, the RP feels additional length composition data from recreational discards should help the model inform recreational discard selectivity, and improve model performance. Counter to expectations, simulation results show increased bias relative to the OM when recreational discard composition data are added to the northern model. The RP feels it is important to understand why these results occurred before recommending a prioritization of future monitoring efforts.

One additional option to explore is the creation or collection of data to inform trends and selectivity of fish in the 70-90 cm range. The sampling gears and methods used to collect data for red drum generally do not catch large numbers of fish in the 70-90 cm range. The RP is concerned the range of ages in that size class is not well characterized. Collection of data from the 70-90 cm size range (28-35 inches) will likely provide information on age, trends in abundance, and selectivity across gears. This information will in turn lead to better, more robust analyses of growth.

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

This peer review panel report fulfills the requirements under this term of reference. The RP has provided detailed information for each review panel term of reference. The report was completed in the allocated time frame.

Following the Review Workshop, the Assessment Committee needs to work on fitting the SS southern model to the "perfect" data from the operating model, in order to show the estimation model can reproduce the truth from the operating model. Once that work is done, the Committee can move forward in considering our recommendations for the assessment of red drum in the northern and southern regions.

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FIGURES

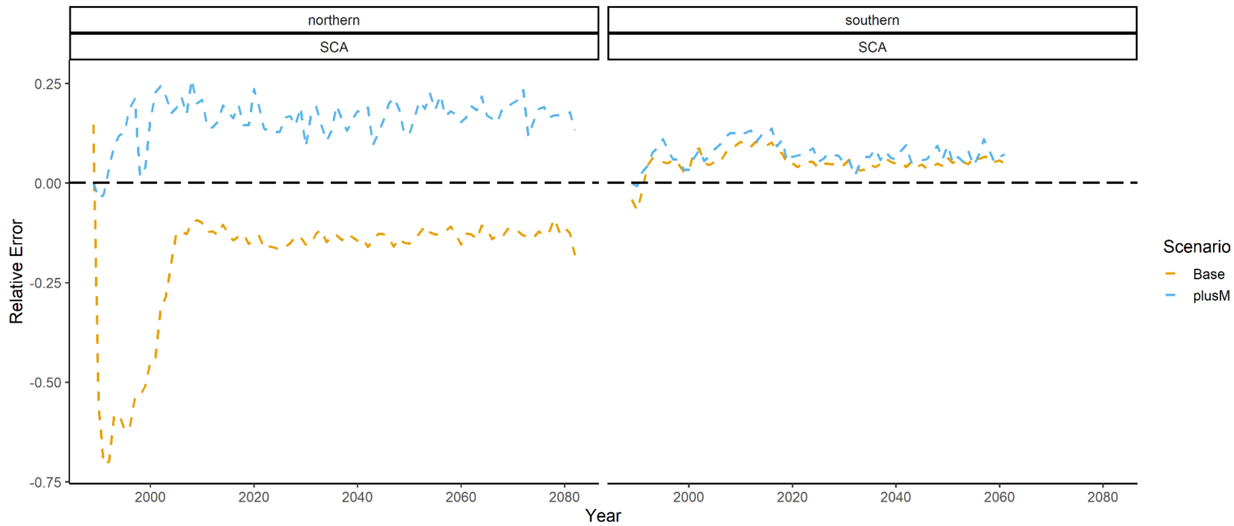

Figure 1. A plot of the relative error in sub-adult abundance for the northern and southern SCA models demonstrating that fixing parameters can lead to reduced bias in the early part of the time period for the north. This likely indicates something amiss with the initialization.

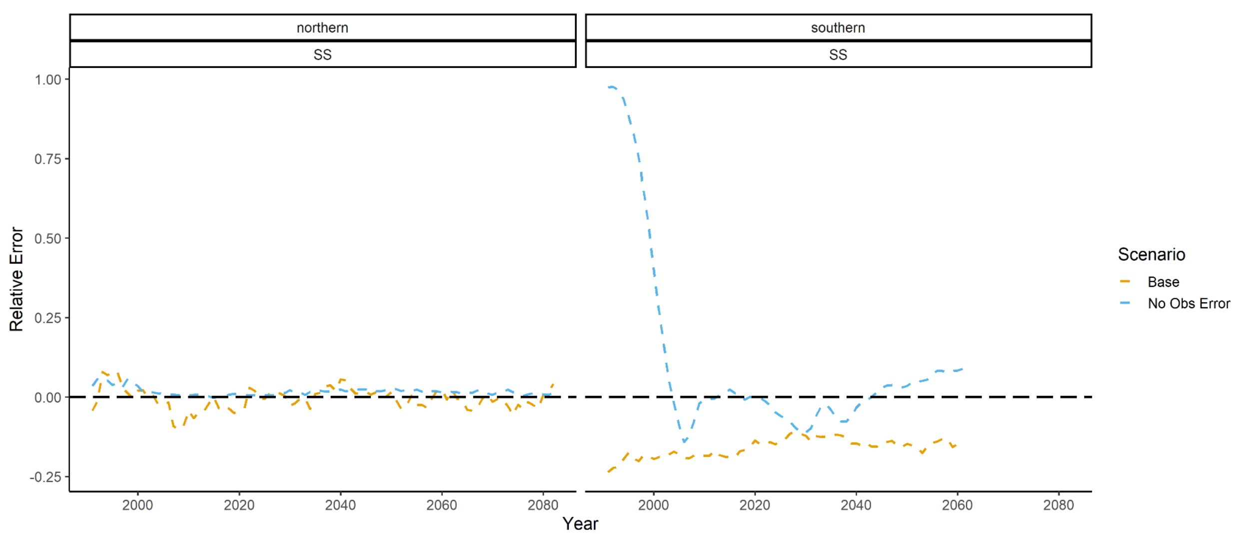

Figure 2. A plot of the relative error in the three year F ratios for the northern and southern SS models demonstrating that the northern model was able to produce unbiased results when using the perfect data from the operating model.