Atlantic States Marine Fisheries Commission

South Atlantic State/Federal Fisheries Management Board

August 1, 2017
9:45 a.m. – 1:30 p.m.
Alexandria, Virginia

Draft Agenda

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

1. Welcome/Call to Order *(J. Estes)* 9:45 a.m.
2. Board Consent 9:45 a.m.
   - Approval of Agenda
   - Approval of Proceedings from May 2017
3. Public Comment 9:50 a.m.
4. Review and Consider Cobia Draft Fishery Management Plan for Public Comment (*L. Daniel*) **Action** 10:00 a.m.
5. 2017 Spot Benchmark Stock Assessment **Final Action** 11:25 a.m.
   - Presentation of Benchmark Assessment Report (*C. McDonough*)
   - Presentation of Peer Review Panel Report (*P. Campfield*)
   - Consider Acceptance of Benchmark Stock Assessment and Peer Review Report for Management Use
   - Consider Management Response to Benchmark Stock Assessment and Peer Review Report (*J. Estes*)
6. Lunch (provided for Commissioners, proxies and Board members) 12:15 p.m.
7. Consider 2017 Traffic Light Analyses for Atlantic Croaker and Spot (C. *McDonough*) 12:45 p.m.
   - Review 2017 Traffic Light Analyses
   - Progress Update on Exploratory Analyses for Incorporation of Additional Indices and Adjustments to the Atlantic Croaker Traffic Light Analysis
8. Consider 2017 Atlantic Croaker FMP Review and State Compliance *(M. Schmidtke*) **Action** 1:20 p.m.
9. Other Business/Adjourn 1:30 p.m.

The meeting will be held at the Westin Alexandria, 400 Courthouse Square, Alexandria, Virginia 22314; 703.253.8600

MEETING OVERVIEW

South Atlantic State/Federal Fisheries Management Board Meeting
Tuesday, August 1, 2017
9:45 a.m. – 1:30 p.m.
Alexandria, Virginia

Chair: Jim Estes (FL) Assumed Chairmanship: 02/16	Technical Committee Chairs: Red Drum: Ryan Jiorle (VA) Atlantic Croaker: Chris McDonough (SC)	Law Enforcement Committee Representative: Capt. Bob Lynn (GA)
Vice Chair: Pat Geer	Advisory Panel Chair: Tom Powers (VA)	Previous Board Meeting: May 11, 2017
Voting Members: NJ, DE, MD, PRFC, VA, NC, SC, GA, FL, NMFS, USFWS, SAFMC (12 votes)		

2. Board Consent
- Approval of Agenda
- Approval of Proceedings from May 11, 2017

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. Cobia Draft Fishery Management Plan (FMP) (10:00 – 11:25 a.m.) Action
Background • In February, 2017, the Plan Development Team (PDT) was directed to construct a Draft FMP for cobia to complement the federal FMP. • The Board initiated a Working Group in February, 2017, to investigate potential options for allocation. Options were provided to the PDT and included in the Draft FMP. • The PDT completed the Draft Cobia FMP in July, 2017.
Presentations • L. Daniel will present the Draft Cobia FMP (**Supplemental Materials**).
Board actions for consideration at this meeting • Approve the Draft Cobia FMP for Public Comment

5. Spot Stock Assessment (11:25 a.m. – 12:15 p.m.) Final Action
Background • The 2017 benchmark stock assessment was completed in February, 2017. • A peer review was held April 18-21, 2017.
Presentations • C. McDonough will present the Stock Assessment Report (**Supplemental Materials**).

• P. Campfield will present the Peer Review Panel Report (**Supplemental Materials**).
Board actions for consideration at this meeting • Consider acceptance of the Stock Assessment and Peer Review Report for management use

6. Lunch

7. 2017 Traffic Light Analyses (TLA) for Atlantic Croaker and Spot (12:45 – 1:20 p.m.)
Background • Addendum II (2014) of the Atlantic Croaker FMP and Addendum II (2014) of the Spot FMP establish TLA as the new management framework for these species in non-assessment years. • In May, 2017, the Board directed the Technical Committee (TC) to conduct exploratory analyses to potentially incorporate additional indices and adjustments into the TLAs; the TC has begun working on this task and has preliminary results and recommendations for the Atlantic croaker TLA.
Presentations • C. McDonough will present the 2017 Traffic Light Analysis Reports for Atlantic croaker and spot (**Supplemental Materials**) and an update of the TC's progress on analyses exploring incorporation of additional indices and adjustments into the TLAs**.**

8. 2017 Atlantic Croaker FMP Review (1:20 – 1:30 p.m.) Action
Background • Atlantic Croaker State Compliance Reports are due on July 1. The Plan Review Team reviewed each state report and compiled the annual FMP Review. Delaware (commercial), South Carolina (commercial and recreational), Georgia (commercial and recreational), and Florida (commercial) have applied for *de minimis.*
Presentations • M. Schmidtke will present an overview of the Atlantic Croaker FMP Review Report (**Supplemental Materials**).
Board actions for consideration at this meeting • Accept 2017 FMP Review and State Compliance Reports • Approve *de minimis* requests

9. Other Business/Adjourn

DRAFT PROCEEDINGS OF THE

ATLANTIC STATES MARINE FISHERIES COMMISSION

SOUTH ATLANTIC STATE/FEDERAL FISHERIES MANAGEMENT BOARD

The Westin Alexandria
Alexandria, Virginia
May 11, 2017

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1. **Approval of Agenda** by Consent (Page 1).

2. **Approval of Proceedings of February 2017** by consent (Page 1).

3. **Motion to request that the South Atlantic Fishery Management Council and the Gulf of Mexico Fishery Management Council consider transferring management authority of the Atlantic migratory cobia stock to the Atlantic States Marine Fisheries Commission** (Page 12). Motion by David Bush; second by Joe Cimino. Motion carried (Page 15).

4. **Motion to adjourn by Consent** (Page 36).

ATTENDANCE

BOARD MEMBERS

Roy Miller, DE (GA)
Rachel Dean, MD (GA)
Craig Pugh, MD, proxy for Rep. Carson (LA)
Ed O'Brien, MD, proxy for D. Stein (LA)
Russ Allen, NJ, proxy for l. Herrighty (AA)
Adam Nowalsky, NJ, proxy for Asm. Andrzejczak (LA)
Lynn Fegley, MD, proxy for D. Blazer (AA)
David Bush, NC, proxy for Rep. Steinburg (LA)
Michelle Duval, NC, proxy for B. Davis (AA)
Robert Boyles, SC (AA)
Malcolm Rhodes, SC (GA)
Patrick Geer, GA, proxy for Rep. Nimmer (LA)
Spud Woodward, GA (AA)
Rep. Thad Altman, FL (LA)
Jim Estes, FL, proxy for J. McCawley (AA)
Martin Gary, PRFC
Wilson Laney, USFWS
John Carmichael, SAFMC

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

Ex-Officio Members

Staff

Toni Kerns
Robert Beal
Katie Drew
Kristen Anstead
Mike Schmidtke
Louis Daniel
Lisa Havel
Jeff Kipp

Guests

John Clark, DE DFW
Joe Cimino, VMRC
Roy Crabtree, NMFS
Lynn Fegley, MD DNR
Laura Lee, NC DNR
Chris McDonough, SC DNR

The South Atlantic State/Federal Fisheries Management Board of the Atlantic States Marine Fisheries Commission convened in the Edison Ballroom of the Westin Hotel, Alexandria, Virginia, May 11, 2017, and was called to order at 11:45 o'clock a.m. by Chairman Jim Estes.

CALL TO ORDER

CHAIRMAN JIM ESTES: I would like to call the South Atlantic State/Federal Fisheries Management Board to order please.

APPROVAL OF AGENDA

CHAIRMAN ESTES: You all should have received an agenda; and I'm going to suggest some fiddling with the agenda. I suggest that we move cobia to the top of the agenda. I also would like to add a short discussion about Spanish mackerel at the end of the agenda. Are there any other suggested changes for the agenda? Yes.

DR. MICHELLE DUVAL: Not a change, just for the record to let the Board know that I will be sitting at the table for our discussion on items with regard to cobia; and Chris Batsavage, my counterpart, will be at the table for the spot and croaker items.

CHAIRMAN ESTES: Are there any other suggestions to the agenda? If not, is there any objection to taking the agenda as it is? Seeing none; the agenda is approved.

APPROVAL OF PROCEEDINGS

CHAIRMAN ESTES: We all have proceedings from our February, 2017 meeting. Are there any suggested changes to those proceedings? Seeing none; we'll take those as approved.

PROGRESS REPORT ON COBIA DRAFT FMP

CHAIRMAN ESTES: Our first item is going to be about cobia and we're going to get an update about where we're at. Louis is going to give us an update.

DR. LOUIS B. DANIEL: Good morning, still. I am Louis Daniel, staff with the commission working on the cobia issue. I would like to go over a summary of the work that has been done by the working group; and get your advice and direction on next steps for the Atlantic migratory group cobia FMP. First there is some new information that John Carmichael has on the stock assessment for cobia, and I was going to get him to give us a quick briefing on that; and then I'll proceed.

MR. JOHN CARMICHAEL: I heard the emphasis on quick, so I'll do that. The Steering Committee, which oversees the SEDAR schedule and balances the workload met last Friday. One of the things they discussed was the research track process, which we have discussed, and the effects of that on the cobia assessment and the timing of cobia.

The Steering Committee has come to the conclusion that the research track has not been fully fleshed out to the extent that it's ready to be implemented here in 2018. There are still a number of logistical and procedural details that are yet to be worked out within the principal players of the Southeast Center.

They've agreed to continue to work on that but as a result the Steering Committee has put off a bit, implementing the research track approach for stock assessments. Our scamp will start probably in 2019 instead of 2018; and then cobia, the recommendation is to not do this as a research track, but to do it as a regular SEDAR benchmark. This came from the folks themselves within the Center, and the SEDAR staff working on trying to define the research track process.

There were some concerns about that being a new approach, and uncertainty into how it would proceed; particularly with resolving this critical stock identification question. That group felt that really this needed to be a benchmark with resolution of stock ID occurring, before it gets started.

The Steering Committee supported that and the recommendation now is that we would start cobia in 2018 with a stock ID resolution during the first half of the year. That will include a workshop with participants from all the different entities involved, so the South Atlantic, the Mid-Atlantic, the ASMFC folks, the state folks, and probably also some folks from the Gulf; because some initial genetics research suggests the potential for at least one overall stock.

That would include everybody, and then we'll have a recommendation from that group on stock ID, which will be reviewed by the technical groups, SSCs and technical committees; and then have an independent peer review. If there are any remaining issues, then the management leadership will have to figure out how to resolve it.

We're hoping that will take place during the first half of 2018, with the specific timing of the workshop really scheduled with an eye toward much of the research that is currently underway, and being able to bring that into the process and have it considered; because we would like to be able to get this stock ID question addressed in a way that is acceptable to everyone who is involved.

Then that would put us into a mid-late 2018 data workshop as a target, which would include 2017 data. There is a little bit of a wrinkle there, because the South Atlantic had asked that cobia have 2019 data; to allow some of the management changes which were pending to be considered. That was made at a time when we had the spike in recreational landings in 2015. It really was a thought at that time that perhaps that was just a spike. We didn't want to go into an assessment with a spike in a terminal year, potentially having a real driving effect.

Since that time we've learned that it really is more of an ongoing issue. We had higher landings in 2016 as well, which then of course raises the concerns about getting this assessment done sooner, and what may happen if it is pushed back until say a 2019 terminal year as the council asked for. The Steering Committee happened last week. The council will meet in June and get all of this, and at that time we'll have to inform them about the Steering Committee's recommendation relative to the South Atlantic's request on terminal years.

But I think they are well aware of the issues with cobia, and they've certainly been kept up-to-date on what's happened around this board with cobia; and the work on proceeding with the Atlantic State's FMP on cobia. I think that they will be in support of the recommendation to get this assessment going sooner; even using the 2017 terminal year.

CHAIRMAN ESTES: Dr. Carmichael, I have one curiosity question. I know that there is an assessment due about the same time in the Gulf. Is there coordination between the two assessments, beings that we're going to have some stock issues?

MR. CARMICHAEL: The Gulf hadn't prioritized their cobia, but they did mention it at the Steering Committee meeting that they were interested in getting cobia. What the Science Center told them was due to the analyst assignments and what they're already working on that they wouldn't be able to do cobia in the Gulf in 2018.

That would be something that would have to be pushed back a little bit farther. Of course if it comes out that the one genetic study suggesting one overall stock of the Atlantic in the Gulf were the case, then certainly the Center would have to consider what that means to their folks and that resource, and who does the actual models. They'll be involved at the stock ID phase, and depending on how that goes, they may have to have some involvement in this assessment; depending on where the lines end up being drawn.

CHAIRMAN ESTES: Any other questions; yes, Roy?

DR. ROY CRABTREE: Just a comment. We are hearing some concerns coming out of the northern Gulf of Mexico that they're not seeing fish at the numbers they feel they should be. I suspect this will come up at the Gulf Council meeting, which is the second week in June. I think there will be renewed interest in looking at cobia in the Gulf; and we're still going to have to work the timing out on that.

DR. WILSON LANEY: John, the last time, at least I thought the last time we had a genetics discussion about cobia at the South Atlantic Council, there was some discussion of the fact there might be as many as three different stocks with that coastal South Carolina/Port Royal Sound stock being one, possibly Chesapeake Bay being another, and the Atlantic pelagic stock being a third. What changed? I guess obviously there is a new study. Did they use a different technique? Are they looking at more genetic markers? What is going on there?

MR. CARMICHAEL: There is a lot going on, on the genetics front. There could be multiple stocks. It certainly seems like there are multiple spawning units within the Atlantic population that go to different river areas and spawn; and then they're all mixed up out in the ocean itself. Then there is really some uncertainty as to how far around through the Keys and into the Gulf those fish extend.

There is always some wandering fish that can throw off a genetic study, and I expect a lot of the discussion at the workshop about the connectivity between the Gulf and South Atlantic and Atlantic components, will be just how much of that is going on versus how much are they functioning; contributing to each other types of populations?

There is genetic study underway now, there are some genetic studies that were completed between the last assessment and today, and we're hoping to get as much of that as we can in a workshop; in front of enough genetics experts that we can tease out what the real answer is, or at least an answer that is acceptable to all of the management and scientist entities that have to weigh in.

CHAIRMAN ESTES: Let's listen to Dr. Daniel's work that they've done with the document. What I would like to do is, first of all he has some very specific questions for us to answer; and so we can't get out of here until we answer those questions. I promised him that we wouldn't. Also, I would like to try to be more inclusive and exclusive, and so I would like to try to work for a consensus if we're going to add things; rather than have to go through motions, and go through that lengthy process if it's possible. Go ahead.

DR. DANIEL: Thank you, John, for that update. It's good news. The working group meetings that you established at the last meeting consisted of Lynn Fegley, Joe Cimino, Michelle Duval, Robert Boyles and Kathy Knowlton, from Georgia. We had three conference calls to discuss various management options for Board review.

They had an opportunity to look over white papers that were put together by me, with help from my partner next to me; Mike Schmidtke. We were able to review those and discuss some of the options and some of the concerns that the Board had. All the data and discussion summaries were also provided to the Plan Development Team to make sure that everyone was in the loop; as best I could.

Going back, just as a refresher on the primary board objectives for the development of the plan, were to complement the South Atlantic's coastal migratory pelagics FMP for cobia; to constrain the coastwide harvest to the allowable catch limits established by the South Atlantic Council, and to provide the states with maximum flexibility to manage their specific cobia fisheries.

The issues that we discussed at the working group comprised of a series of issues; size limits, bag limits, vessel limits, state allocations, seasons. There were some other issues that I'll bring up and the commercial fishery, which we did not discuss at the working group; but I did want to add that in for clarity.

The first issue revolved around size limits. The South Atlantic Council's Framework 4 established a 36 inch fork length size limit in federal waters. The working group generally recommended a consistent coastwide 36 size limit for the FMP. Concerns raised were that different size limits can create enforcement and assessment concerns, if there are varying size limits up and down the beach.

But also recognizing one of the primary intents is to try to extend the season for as long as possible. Lower minimum size limits could result in higher catch rates and shorter seasons, and a larger minimum size limit while it could result in longer seasons, it could increase discards and potential safety concerns.

The primary issue here is making sure that there is consensus amongst the Board to limit the size limit options to the 36 inch fish consistent with the federal council plan. Assuming there are no comments or questions that would be the consensus of the Board. The next issue is bag limits. Again Framework 4 established a one fish recreational individual bag limit in federal waters.

The working group also recommended consistency with the one fish limit in the plan. Again, higher bag limits result in higher catch rates and shorter seasons; and we can't go lower than one without a season; which we'll talk about here in just a moment. Any discussion or comment on bag limits? If not, we will recommend maintaining a one fish bag limit. Vessel limits, here is where you've got some flexibility potentially as you move forward. The South Atlantic framework allows up to six fish per vessel in federal waters. The working group really had no specific recommendation regarding vessel limits, but the vessel limits could vary based on specific state objectives. What we know is based on current actions by the various states is that they have selected variable vessel limits from 1 to 3 in Virginia, I believe; and 4 in North Carolina.

That is what is going to adjust the landings to a large degree is the amount of fish allowed and the vessel limits. Whether or not you want to have specific vessel limit options in the plan, or whether you would like for that to be an option that you consider when developing your state-specific plan to move forward, is a question for the Board. Right now if you agree to leave it the way it is it would be at your discretion, to determine at the state level the vessel limits that you would want to implement in your state-specific plan.

CHAIRMAN ESTES: Yes sir, Robert.

MR. ROBERT H. BOYLES, JR.: I'll just bring it up for discussion purposes. I can imagine how this might go. Six fish per vessel to me seems very generous; given what we are trying to do, in terms of constraining the catch. I recognize that there are new fisheries that have grown and developed, and maybe that's a "bridge to far" right now. If the objective here is to find ways to constrain the catch of this popular and growing fishery, six just seems to send a message that we're not so concerned. I'll just state that Mr. Chairman.

CHAIRMAN ESTES: Yes, Michelle.

DR. DUVAL: I think in consideration of Robert's comments, my recommendation would certainly be that in regards to any state-specific seasonal measures, because as Dr. Daniel stated, you know that is one of the areas where states do have flexibility; that six would be the limit. That would be the cap. I would not recommend going above that.

There might be states that were interested in individual approaches that included perhaps a one fish, or two fish per vessel limit for this chunk of time; and maybe a four-fish vessel limit for this chunk of time. But I would certainly recommend no more than six per vessel; recognizing Robert's concerns about what we're doing here.

MR. JOE CIMINO: There is one other element to it I think. I agree with Robert, it does seem generous, and I think from the many public comments we heard in Virginia, they were fully understanding of it is an important way to constrain the catch. But one of the interesting things that we see is it is very likely that a for-hire fleet charter boat can manage that six fish vessel limit.

However, they're extremely underrepresented in Virginia's catch. We see very few charter intercepts. What we see is a large, private recreational catch that doesn't even achieve that six or even four-fish vessel limit anyway. It is a challenge. I think as we institute this mandatory reporting we'll find out more about what the for-hire fleet does. I think I am leaning towards Michelle's suggestion. Since it is one of the few places we're going to have some flexibility of a six-fish cap.

CHAIRMAN ESTES: Okay, did you get enough direction there?

DR. DANIEL: I did. My intent there was to simply mirror the federal plan of up to six fish, and I think that is what I'm hearing is that is a reasonable limit. Just let me point out too that these are not management. I will go back and develop these management options, and they will be included in the FMP for your review in August.

You are not making any final decisions here, just to make sure everybody is clear on that. But I am clear on vessel limits. If there is no further discussion on vessel limits; next are the state allocations. There are several different opinions and issues that need to be resolved here. This is probably one of the big meatier items.

I am going to go through this as briefly as I possibly can, and if there are any questions please don't hesitate to ask. Much of the data tables were very large and cumbersome to put up on the screen. You wouldn't have been able to see them. I'm hoping that you've got those tables in front of you from the white paper that was in the supplemental materials.

What we did was looked at the landings time series, and we considered a three, five, and ten year period. It was also suggested by the working group that we include an option that looks at 50 percent of the five-year average to account for more recent timeframe, and 50 percent of the ten-year average to look more at the historical timeframe.

All of the tables represent those timeframes, three, five, ten and the 50/50 option is what I'll call it from here on. One of the big questions also was in the terminal year. Working group reviewed 2014 and 2015 as terminal years, to develop allocations based on landings. There was a PDT member that proposed 2013, and that was a period prior to some state-specific cobia management changes.

I believe the specific one mentioned was the South Carolina spawning season closure in May. The working group had no final opinion on terminal year, but appeared to agree; and I'm not trying to speak for them, but appeared to agree that 2015 provided the most recent information and did not include a year with a closure.

It did not include, there was some confusion and some misstatements that were made that 2015 had a closure, and that some states elected to continue fishing. That was not the case. That occurred in 2016. At present we've got essentially three options to develop the allocations; either looking at '13, '14, '15. I think it would be very helpful if we selected one terminal year to analyze for the public comments. Unless a working group member has a different opinion, I believe '15 was the proposed year to use.

CHAIRMAN ESTES: Are there any problems with that?

DR. DANIEL: All right, great. The next issue and this one is probably the one that generated the most discussion and comment, is looking at the landings and the weights. The working group first reviewed a bunch of different tables with a bunch of different allocation options; that were looking at the MRIP landings data in weight, and the Southeast Fisheries Science Center landings data in weight, and those differ due solely to the different methods for estimating average weight. The MRIP uses the annual length weight data regardless of sample size. If you go back and look at the 2012 landings in New Jersey, those have been estimated based on one fish that was measured and weighed. But that was the average weight of the fish that was used, and that number was multiplied by the number of fish harvested; to generate the annual landings. The Southeast Fisheries Science Center requires a minimum sample size.

They may combine states or years depending on the sample size. Landings and allocations based on weights, whether it was the Southeast Fisheries Science Center method or the MRIP method, and the numbers of fish, are in the working group memo; and I'll have those up here in just a second.

Every time when we looked at there were very big differences between using the MRIP data, using the Southeast Fisheries Science Center data; and I'll give you a brief review of what we found. Based on the number of samples in the southern states, South Carolina and Georgia were actually combined; and their average weights were the same, between South Carolina and Georgia.

North Carolina arguably had more samples, and they had individual, annual average weights through the Southeast Fisheries Science Center process. Virginia had fewer lengths, and weren't able to get the SEFC required sample size, so all their samples were combined for an average weight that was used over a ten-year time series; 33.9 pounds.

There were all different variability's in how the different weights were calculated; and most of that was due to sample sizes, and the difficulty of going out and getting samples on a fishery like cobia that is considered somewhat of a rare event in a pulse fishery. In discussions with some of the PDT members, and in working with a student I've got at N.C. State, we started looking at the possibility of using numbers of fish; to remove those inconsistencies in average weight estimates throughout the management unit and amongst the different methods.

If we look at the next slide, you can get an idea of what this actually means using just one of the examples. This is the allocation using the five and ten year 50/50 average landings for the 2005 to 2014 time series; so that would be adjusted for the 2015 time series, based on our previous discussions.

You can see how the numbers change, albeit slightly they do change. If you look at Georgia as an example, using the five and ten year pounds from the Southeast Fisheries Science Center, which is what the Board directed us to use at the very beginning; is about 9.5 percent of the coastwide ACL allocation recreationally to Georgia.

If you use numbers, it jumps up to 10.2 percent. You can see we've also included the actual ACL that would be allocated to the individual state, were either one of those options chosen. You can go through and look at your individual state. We only were able to look at Georgia, South Carolina, North Carolina, and Virginia; because those were the data that we had.

But it kind of breaks it down to where it is about a 40/40 Virginia/North Carolina and about 10 percent for Georgia and South Carolina. Those numbers, if you look at those tables that were produced, those numbers really don't vary a whole lot. But depending upon which time; until you get into the three-year time series, it really doesn't make a huge impact, and it doesn't have a huge difference in those allocation schemes. We believe, and from discussions and what I heard, I don't think there was a consensus at the working group meeting. But what I've heard is primarily support; at least for cobia, not dissing on the Southeast Fisheries Science Center, because they recognize the numbers are not there to really do the complete analysis that they may otherwise do, but for cobia and for allocation analysis, looking only at the numbers of fish. The proposal would be to use numbers as opposed to weights when we develop the various scenarios for allocation.

CHAIRMAN ESTES: Yes, Robert.

MR. BOYLES: Just perspective from a working group member. One of my motivations, I think you all know this, but our General Assembly made cobia a gamefish several years ago in South Carolina; so there is no commercial take. The message we've heard consistently from our anglers is, they are interested in the experience, and experience is measured in numbers of fish not in pounds of fish. I just offer that perspective for the Board.

CHAIRMAN ESTES: Pat.

MR. PATRICK GEER: Louis, I had a real quick question about if we went with the numbers, how would that play out with the development of a stock assessment?

DR. DANIEL: Well, if I'm not mistaken the stock, I'm sorry, John. If you want to answer that question you would be more appropriate.

MR. CARMICHAEL: It actually really wouldn't at all; because the stock assessment, fish die is a number anyway, and the stock assessment includes catch in numbers for many of the data series. Certainly all the recreational discards are numbers, and the recreational harvest is numbers. The only thing that comes into the system in weight is the commercial; and the commercial has the much better weight sampling than any of the recreational fishery.

It is actually much more logical from reducing uncertainties to do this as numbers, because you would be using your commercial average weights; which are quite good, to convert that into the numbers. It won't have any impact on the assessment and will reduce uncertainties really, I think in terms of setting your allocations.

DR. DUVAL: I mean the one thing I will say though is that any weights that are collected by MRIP are certainly available to the assessment scientist, for use in any way that they would see fit. Because I would just note that the commercial minimum size limit on the federal side is still 33 inches at this point. There would certainly likely to be greater variability in the average weights of the fish, I would think a little bit, based on that. But certainly, Pat, any weights collected by MRIP would be available for use in analysis during the assessment process; if needed.

CHAIRMAN ESTES: Louis made a suggestion, is there any opposition to the use of numbers instead of weights? Do we need to discuss this further? Okay, thank you.

DR. DANIEL: The next issue, Issue 5 is Seasons. The South Atlantic Council's Framework 4 provides analysis to examine coastwide seasons based on a suite of bag size and vessel limits. You've all seen that where it is presented for you. The working group spent a lot of time looking at the various Framework 4 analyses. We also received a detailed analysis from Mr. Chris Wilson with the North Carolina Division of Marine Fisheries. He was able to do a very detailed analysis for all the states from Virginia to Georgia.

What was requested of the working group was to look at issues such as variable start dates. The South Atlantic had thought about looking at changing the fishing year, but could not do that in a framework action. They had begun to put together some information on the impacts of say a May 1 start date to the fishery, and a June 1 start date to the fishery.

Obviously that has extreme variable impacts, depending upon where you are on the coast. A June 1 start date may eliminate the Georgia fishery, whereas it may not have such an impact on the Virginia fishery. Trying to do that on a coastwide basis is unlikely to result in parity amongst the various states.

We provided that information to the working group, so that they could look at the state-specific information that was available; to look at the various reductions that could be achieved by having variable season restrictions. This is where it gets a little bit difficult. If you look at Framework 4 and you consider the options that are available in there; that is for a coastwide, seasonal option.

Those unlikely would satisfy the needs of the individual states of the Commission. Several questions that are important for moving forward with the development of the management options are whether or not we want to include state or regional-specific season options in the FMP at all. There are seasonal decisions best left to the states to develop and have approved by the Technical Committee and the Board.

If state or regional-specific seasons are desired for the FMP, should they be based on state-specific allocations? If not, are there other options to ensure equity and accountability? The issue here really is, if you've got as we've discussed so far, if you've got a one-fish bag limit, a 36 inch minimum size limit, variable vessel limits, and a state-specific allocation based on the '15 terminal year and numbers; will provide the 3, 5, 10 and 50/50 options to take out in the management options.

If you've got a specific allocation at that point, do you want to leave it to the states to make the decision based on the analyses that have been done, to tailor make your own specific season; or do you want to somehow develop specific seasons in the FMP that are specified for each individual state? I know that is a lot, and I will be happy to answer any questions related to that and direct you to any information that I can. That is probably the biggest decision we need to clarify today.

MR. BOYLES: I think Louis, to that question. I can't imagine a lot of other states around the table finding acceptable South Carolina's May closure that we've done for just a portion of our state waters. I'm not sure that there is a lot of fruit in mandating seasons as part of the interstate plan.

I would like, quite frankly, that was a management tool that we employed that got a lot of support for our anglers, a lot of support in our General Assembly. I would like to have that in my tool kit, but I don't know that it is necessary for us to include those kinds of things as a requirement for the fishery management plan.

MR. A.G. "SPUD" WOODWARD: I just want to echo what Robert said. I think we've got enough other things to work with. We don't need to put parameters around season in this plan. I know from our perspective, we certainly want to be able to extend the opportunity to harvest over as wide a period of time as we can; and I'm thinking we've got the tools to do that.

DR. DUVAL: I will add my echoing to Robert's comments about not having any mandated type of coastwide season that is clearly not going to work. I think looking at the questions that Dr. Daniel has on the board, are season decisions best left to the states to develop and have approved by the TC and the Board. I think my response to that would be yes.

CHAIRMAN ESTES: Okay, anything else with that? I think we got what we need, unless there is somebody that has something else to say. Yes, Michelle.

DR. DUVAL: I would probably be remiss if I didn't once again state for the record what we've heard from stakeholders in North Carolina at least, with regard to having hard and fast state-by-state allocations. They are not interested in that at this point. They are more interested in the flexibility that would be provided with state-by-state seasonal approaches.

I think having sat around the Commission and watch some of the struggles with trying to implement recreational state-by-state allocations on other boards. Having something hard and fast like that I think really trends us in much more supportive of seasonal decisions left to the states that come forward through a technical committee review; and then are reviewed and approved by the Board. I just wanted to add that.

CHAIRMAN ESTES: Joe.

MR. CIMINO: I'll be brief. Just to that end. In Virginia we did go with a May closure, and of course it doesn't have the meaning that it might have in South Carolina or Georgia. But we know with these MRIP estimates which is putting us in this difficult situation that as you drill down, the estimates are even more questionable.

When we're talking about a wave estimate, we may not have that much confidence in that. But we did make a biological argument as staff at VMRC to our commission that any removals that are prevented in May, are going to allow more fish to spawn. I think that really drove that closure, so to have that type of flexibility at the state level and not forced by an FMP is why I would support that.

DR. DANIEL: I think it's important. I hear some disconnects, and so I just need to make sure that I am moving forward in the appropriate direction in developing the management options. I heard concerns over a state-specific allocation; and developing a season based on a state-specific allocation.

The way it is moving right now and my understanding thus far, is that we actually would be developing options for state-specific allocations; based on the number of fish with the 2015 terminal year. The states would be assigned a specific allocation under the current options. There would be no alternative, at least at this particular minute; there would be no alternative seasonal option that was not anchored by a specific state allocation. I'm not exactly sure how to develop seasons without a specific target harvest amount. But if there is that interest by the Board, I mean I certainly heard from North Carolina that there is an interest in not having a specific state allocation.

I'm not sure how to develop those seasonal options for the plan. My understanding is the individual state would go back home with a specific quota, and develop the season that they believed would constrain their harvest to within that specific allocation. If there is more that needs to be included in the document, I need that direction; and an explanation as to how you would like to see that developed.

DR. DUVAL: Yes, you know when we had this discussion at the working group there were several of us who indicated that we were not interested in state-specific allocations. I think we've seen the difficulty in trying to manage a recreational fishery by a state-specific allocation. We spent probably eight hours on that yesterday. That is why I bring forward or in support of the more flexible approach of the states developing state-specific seasonal options. Certainly for inclusion in the draft fishery management plan that would go out to public comment.

I think looking at how each state's proportion of the overall harvest changes, based on the scenarios that you've illustrated here; and you know, the three year, the five year, the weighted options so that the public can have something to look at to see how those have varied. But I think stakeholders have been pretty loud and clear that they are not interested in state-specific allocations until after there is a new assessment. That is where I'm coming from.

CHAIRMAN ESTES: Lynn.

MS. LYNN FEGLEY: Just to echo that point. I think as one of the states to the north of the epicenter, if we were to go to state-by-state allocation, which I agree with Michelle. I think we had a slightly different direction on the work group calls. I am not clear what happens to Maryland, Delaware, and New Jersey. Does that mean we get 0 percent?

Does that mean we have no fishery? What does that actually mean? I would have a very difficult time going home and saying, well gee folks, you know we've got 0 percent because we have no history; so just toss back that cobia. I think we can work within the confines of the size limits and the vessel limits that we discussed. But if we go to state-by-state allocation I think things are going to get a little more dicey, at least in our more northern waters.

DR. DANIEL: In terms of the episodic landings north of Virginia, I think that's going to have to be worked out in the de minimis criteria and how we develop that. I don't think there is any intent of sending anybody home with a zero quota when they have a historical landing. That does occur in New Jersey. There was one year with landings in Delaware and Maryland. I think that was one of the concerns that we had discussed, especially when you go north of Virginia and there seems to be these smaller fish.

We really haven't discussed how to deal with those fish that are being caught that are in the 20, 22, 24 inch range. But the idea so far has been, if we have this one fish, 36 inch size limit there may be, as somebody brought up the point that there could be some misidentification problems up there in the northern sub unit that they may have been remoras of some kind as opposed to cobia. It is kind of hard to imagine a 24 inch cobia in New Jersey that is a two-year-old fish. That would be an interesting situation. It is hard to determine that. I guess going back; I mean I understand the working group discussions on the seasonality. But what we've got in our tool box right now as I understand it is there are options out there to begin the season later; to implement some type of a spawning season closure, which we'll talk about here in a minute. We probably don't even need to at this point.

But there is some interest at the Plan Development Team at least, of having some type of spawning season closure; if that is something that the Board would want to consider and individual states would want to consider. But essentially, when do you start your season and when do you end your season?

In order to make that determination the only way I can come up with doing it is to have some type of target, some kind of an allocation that assures at the South Atlantic that we're maintaining our harvest within that 620,000 pound ACL. If that assurance is not provided in the Commission plan, I don't know how that is going to impact the decision making at the federal level to get the EEZ open, which tends to be one of the big issues, is one of the major issues for the more southern states.

That issue tends to vary and be more important as you go from north to south; very little harvest in the EEZ off of Virginia, more off North Carolina, even more off South Carolina, and the majority off of Georgia. That is an issue that Bob and I want to discuss with the South Atlantic in June at their meeting in Florida.

But trying to get from the National Marine Fisheries Service what type of plan do they want to see, and I think the allocation issue is the only way that I've been able to come up with to meet the first requirement that the Board directed me to do, was to stay within the ACL. I don't know any other way to do it, and I don't know how to construct the seasons without there being some kind of a target to shoot for. That is my problem. If there are other issues and if there are other ways to do that I just don't know how to do it.

CHAIRMAN ESTES: Dr. Crabtree.

DR. CRABTREE: It is not entirely clear to me how you would do it and still fit it under a management construct that is built around annual catch limits. There will still have to be an overall annual catch limit in the Council plan. Now I guess it might be possible if you did some sort of more F-based, mortality-based approach to set seasons that you think are going to constrain the fishing mortality appropriately; and not focus so much on how many pounds of fish that are caught.

But that is problematic with the annual catch limit approach that is required under the Magnuson-Stevens Act. I think one thing you ought to think about, because I know your objective is maximize flexibility I've heard a number of times. The alternative way to go with this would be to remove cobia from the federal fishery management plan, the Atlantic stock; and then let the Commission manage the fisheries through your Commission plan.

At that point you wouldn't have to base your management around an annual catch limit type of strategy, and you may be able to implement some of these types of management schemes like Michelle has brought up. That is probably something that you ought to give some consideration of. I think that could potentially get us to a less cumbersome, more efficient way of managing the fishery. I think the Service's interest in this is just finding a management paradigm that can work in this fishery efficiently.

I don't think just federal management. Clearly that is not a successful way to go now. There may be a way to get to what Michelle is describing under an annual catch limit management paradigm, but it's not entirely clear to me how we could get there. But the alternative might be to rethink how we approach the whole problem.

DR. DUVAL: Roy, I'm really sorry that you weren't here for the seven and a-half hours worth of debate that we had yesterday around the summer flounder, scup, and black sea bass board, because that board is constrained by the federal annual catch limit for those species recreationally; and that was the bulk of the conversation yesterday, was how to craft state-specific measures to maintain harvest within an overall annual catch limit.

I feel like we've answered the question that is on the board, our season decisions best left to the states to develop and have approved by the TC and the Board, and we said yes. What are the tools that we have to do that with? We've agreed on a one-fish-per-person bag limit, a 36 inch size limit. Where the flexibility lies is in when you start and end your season, and the vessel limits that you apply.

It wouldn't matter if we had an annual catch limit or not. When you calculate what type of harvest you are likely to end up with, based on once again past performance of the fishery, which as we know is uncertain with the numbers that we have to deal with through MRIP. But that's what you do.

You base any projection of how much you might harvest, based on the past performance of the fishery, by applying those variable season and vessel limits. I mean that's how you would project it. It doesn't matter if you have a state-specific allocation or not. What I've heard from other folks is that they don't have a desire to try to manage a state-specific allocation, and indeed don't necessarily have the tools to manage a state-specific allocation.

We're always going to be in a situation with a pulse fishery like cobia, where we develop a suite of management measures based on past performance of the fishery. We're going to evaluate that the next year. It's clear to me that there is not really an effective way of in-season management with this fishery right now, and it is so subject to environmental variability as well that it is going to be very difficult to do that.

Now Dr. Crabtree has brought up the option of transitioning from a complementary state/federal fishery management plan to solely a Commission plan, which would certainly provide I think flexibility to manage under an F-based approach; which is what we used for striped bass. Maybe that's a separate conversation.

But I really wanted to get to the question that I thought we'd answered with regard to season decisions best left to the states and developed and approved by the TC and the Board, which I think is not much different than how we do things under some other boards; and that is how we would evaluate what projected harvest is. It's not relevant whether or not there is a specific allocation to one state.

CHAIRMAN ESTES: Dr. Carmichael.

MR. CARMICHAEL: It seems to me what Louis is getting at is there needs to be some way of anchoring how you determine this flexibility. If we know that the combination of the bag limit and the size limit won't constrain the fishery to the ACL, then there is going to have to be some type of season.

If you were to say set an overall base season coastwide, then you may have a way of giving states some flexibility to deviate how they take that length of season and apply it to their respective fisheries. That won't be easy, because you're going to have to come to grips with, you know what periods do you use to establish that base; because we've had a number of regulations changing and we've got a lot of data changes that are underway.

It will certainly be a challenge. Then you know that the catch rates are probably not consistent across time. When a state shifts its season may affect that state's respective catch rates. You will have to have some way of deciding what is equitable across the different states, if they chose times with different catch rates.

But I think you will have to anchor this in some way, if not by the state-by-state shares of some sort then by some base season that you allow states to deviate some; which I think an example there is what happens with waterfowl seasons where the Fish and Wildlife Service sets X number of days.

Then states regionally have the ability to decide when to apply those numbers of days over the particular window. You may have to do something like that. You may pick a six-month window and have a four-month season that states can deviate the start and end dates within their perhaps. But I think that one or the other is going to have to be anchored.

CHAIRMAN ESTES: David, I see your hand up.

MR. DAVID E. BUSH, JR.: The state quotas that I've heard from as well, going back to the conversation previous here, would be interested in having it removed from federal fisheries management. That would apply the flexibility needed too, especially the southern states that have no access otherwise. I'm not sure what needs to be done to bring that further into conversation or even a motion, but I would be interested in hearing some other perspectives.

CHAIRMAN ESTES: Why don't we break? Lunch is being served out there right now, I guess. Can we break for lunch, think about all this, come back; because I think we're kind of in a spot we're a little stuck.

(Whereupon a recess was taken.)

CHAIRMAN ESTES: If I could have your attention. I think we had a suggestion or a question that was asked right at the end, before we broke for lunch, about whether we want to have a complementary plan, and whether we might want to request management through the Atlantic States Marine Fisheries

Commission. I would like to go ahead and have a discussion about that if we could, please.

DR. CRABTREE: Let me say, Jim that from the Service's perspective, we're just looking towards an effective management paradigm. We're not looking to withdraw the level of support and particularly scientific support that we've provided in recent years. Our intent would be to continue to provide all of the types of support we have.

CHAIRMAN ESTES: Do we have anybody that would like to start the discussion? Spud.

MR. WOODWARD: Let me swallow my biscuit down here. I'll speak in support of that. Being on the southern end of this, our fishery is almost episodic. We know generally when the fish might move through, but when they are there and how long they are there is dictated by a lot of environmental factors.

If we are unsuccessful through whatever we do at the interstate level to show the Service that we are constraining the harvest; in order to be able to stay within the ACL. We are going to end up with the federal waters closed like they're closed this year. Since our fishery is almost exclusively federal waters, then the longer we're bound to an ACL the more risky things are from our state's perspective. I can certainly speak to I think it needs reconsideration, especially after the necessity of closing it this year.

CHAIRMAN ESTES: Anybody else not have a biscuit that can talk to this issue? Michelle.

DR. DUVAL: I think this was a conversation that we had early on when the South Atlantic came forward. The question was would the Commission consider complementary, joint, or sole management. I think if the Board is reconsidering the decision of complementary management, and would like to move forward with the request for sole management.

I think my recommendation would be to probably make a motion, and to request the South Atlantic Council that they consider turning over management of Atlantic cobia to the ASMFC. I would look to others around the Board, but I think having a motion to do so would probably be useful.

Then the Commission could send a letter to the South Atlantic Council. Clearly there would need to be some conversations there about how we would move forward doing that logistically; given that there are a few balls in the air with regard to stock delineation and what that might mean.

MR. BUSH: I don't know that I have all of that memorized, but I would like to make a motion to that; if I could get some assistance putting it together.

CHAIRMAN ESTES: While we're doing that do we have a second? I guess while we're getting that. Well, we already have it up on the board. How about some discussion about this, David, I think you first, please.

MR. BUSH: Certainly, thank you, Mr. Chairman. I probably can't give as much of the technical justification. I just understand that the way that it has been managed so far, the stakeholders are obviously not happy with it. The flexibility for the states to do what is particularly tailored to them has been discussion of the past couple of days. Without that ability all we're doing is trying to make a one-size-fits-all for everyone. It is obviously not working at this point. I think that we'll have hurdles that we'll need to address, and that is the case with any other fisheries. I am willing to put in the time that I can to help address those hurdles, but I know I'm speaking more so for the others doing the work. That is about it, thank you.

MR. CIMINO: When Dr. Crabtree brought this up today, it really was no surprise; because to some extent it was an elephant in the room, I think. We know that if this moved forward we would at least likely be managing towards an F target instead of an ACL. We know many of the folks on this Board know there are still challenges to that.

Overall I support it. I know managing to F targets means you need updated assessments, and you need assessments that are speaking to whether or not your management actions are working. I know moving forward that maybe one of our biggest challenges is where cobia falls on assessment updates, and who ends up handling that responsibility?

MR. BOYLES: My thinking on this continues to evolve. As the Board knows, we've been very aggressive in managing cobia in South Carolina. A lot of concerns I've mentioned already, and just to remind folks. We have a spawning season closure in an area where these fish are very accessible.

I've talked about cobia fishing in a canoe, which is literally obtainable in the Port Royal Sound area. It is a game fish, so there is no commercial take of cobia in South Carolina waters. I remind the Board that last count 80 some odd percent of our cobia were taken from federal waters. Our fishery has transformed the last several years as that inshore fishery has been fished down.

But having said that I think I could support this, with the understanding that what Dr. Crabtree indicated that the Agency intends to continue to provide scientific support for assessments. I would also be looking at ways to extend our management measures into federal waters, recognizing that at least off South Carolina 80 some odd percent of our fishery is located there.

CHAIRMAN ESTES: This is a pretty bold step. I want to make sure that we don't have discomfort that's not said out loud. Spud.

MR. WOODWARD: The one thing I guess I just want to make sure I get on the record. I certainly don't want to slow down what we're doing, while this potential change in direction is debated; because if we don't do something we could find ourselves in the same situation next year, where the Service is compelled to close the EEZ.

I don't know how we're going to balance that out. I think the commercial fishing management part of this is something that is going to have to be considered and contemplated. If the Board supports this motion, and we decide to engage in a renewed discussion with the Council and the Service about this, is it going to stop everything we're doing?

In terms of promulgating an interstate plan, or can we move forward with promulgating an interstate plan with its own specific measures and requirements; and you'll have the option to go complementary or sole at some point down the road, when some of the legal discussions and other matters that have to take place are concluded.

CHAIRMAN ESTES: Can somebody talk about the process here? Toni.

MS. TONI KERNS: I was focused on my biscuit just now, so sorry. Can you repeat the question for the process? I heard process.

CHAIRMAN ESTES: Spud was concerned that by us doing this that we might slow the process down, and he might be in the same shape next year that he's in this year.

CHAIRMAN ROBERT E. BEAL: I don't want Toni to choke on her biscuit, so I'll give it a shot. I think Spud's concerns are valid in that this Board should probably keep moving down some path to serve as at a minimum an interim transitional period. I don't remember the exact timeline, but when red drum management authority was transferred to solely ASMFC management that took quite a while.

Maybe that was because the federal waters were closed and there was no urgency to do that. But as you said, this is a bold step. It's a big change, and we don't know what the council's response to this would be. I think time can elapse pretty quickly here before something like this gets sorted out. Some interim step through a Commission FMP that allows more flexibility later on, should this occur, is probably a reasonable thing to do.

CHAIRMAN ESTES: Any comments on that? Roy.

DR. CRABTREE: From the Council side of things, we're going to need to do probably some type of amendment in either circumstance. It is a little different than red drum, because in red drum we were withdrawing an entire fishery management plan. In this case we would just be removing a stock from the fishery management plan, and we've done that on a number of occasions in the last few years.

I think Bob's advice is good that we continue to explore both options here, and so we have a better read on what the Council's likely view of this would be. Also I think it would be wise to sit down and spend us some time with the Council and with the Regional Office attorneys; talking about all the pieces of this, and get a better appreciation of how quickly either avenue can move.

CHAIRMAN ESTES: Okay Wilson and then Robert.

DR. LANEY: One change that would occur if cobia is transferred to ASMFC is the same thing that happened with red drum; which is you would lose essential fish habitat. I can't remember whether any HAPC has been designated for cobia or not, but you would also lose that. You could potentially, depending on what happens with the Gulf Council or Gulf Commission, I suppose.

Roy and I had a little bit of conversation about that. But you could also wind up in a situation where you have essential fish habitat and HAPC in place in the Gulf of Mexico, like is the case for red drum, but not in place on the Atlantic coast. That is just one thing to think about, and I am saying that from the perspective of a member of your Habitat Committee.

MR. BOYLES: Just a perfecting comment. I believe were we to go and approve this, I would suggest that the request should be made to both the South Atlantic and the Gulf Council's. I think they share jurisdictions for the plan itself.

CHAIRMAN ESTES: Yes, so we're not really clear. In my mind we're not really clear about what it is that we're doing. Are we removing the one existing stock? Are we going to request removal of both stocks? I'm not really clear on what we're requesting here.

MR. BOYLES: To that point, Mr. Chairman, either way if the Feds were to turn loose of this, I believe it would require action on both councils. I'll look to Dr. Crabtree to clarify that.

DR. CRABTREE: Yes, I think it would be fine to send the request to the South Atlantic Council. But Robert is right that it is a joint FMP, coastal migratory pelagics, so the Gulf would have to approve it. I'm reading that we're talking about the Atlantic cobia stock. That is what the interstate management plan has been focused on, and that is where the problems that we're talking about have been. My assumption has been that that is what the motion applied to.

CHAIRMAN ESTES: Okay. Michelle.

DR. DUVAL: Given the comments that have been made around the table, it sounds like there is a little bit of uncertainty. People want to continue moving forward on the path that we're on; which I completely agree with. I'm wondering if there might need to be some additional perfecting that you know the requests would be that the Council's consider transferring management authority. Because that might allow for that discussion and not seem like a cow grab, or whatever you want to call it. That softening might help.

CHAIRMAN ESTES: Is the maker and seconder comfortable with that? Joe.

MR. CIMINO: To that end. I think we do need to continue moving forward with something. I assume that this may be a process that takes some time, and I would actually kind of hope that the Council wouldn't make that decision until perhaps after the assessment is done and decisions on stock ID.

DR. CRABTREE: Well it will be a process, and so I think what you're really asking the South Atlantic is to consider this and advise you. But they would have to go through an amendment, so there will have to be public hearings and development of amendment and analysis; and particularly a rationale for why federal management is not necessary and state management would be more efficient.

My hope would be we could get through that process along the timeline that's similar to the one we are here. But under any circumstance the Council will have to come in and make modifications to the plan to reflect the interstate management plan, whether it is complementary or the sole plan. We're going to have to go through that process under any circumstance.

CHAIRMAN ESTES: I get the sense we kind of have our minds made up about this, so with no objections. I'm sorry.

DR. DANIEL: Just a couple of comments, and just to make sure that we're all on the same page here, is that this would not impact the SEDAR 2018 proposal. We don't want to lose that opportunity, not only to address the genetic stock boundary issues, but also the stock assessment.

CHAIRMAN ESTES: I'll read the motion. Move to request that the South Atlantic Fishery Management Council and the Gulf of Mexico Fishery Management Council consider transferring management authority of the Atlantic migratory cobia stock to the Atlantic States Marine Fisheries Commission. Motion by Mr. Bush and seconded by Mr. Cimino. Robert.

MR. BOYLES: Mr. Chairman, I presume that this is going to come in the form of a letter that would have to go to the Policy Board?

CHAIRMAN ESTES: I was going to suggest the same thing. Is that correct, Robert?

EXECUTIVE DIRECTOR BEAL: Just a quick comment. Looking back at the motions from the Policy Board, when the Policy Board granted this Board the authority to initiate a cobia FMP, it actually said for this Board to explore management options; either complementary, joint, or sole management of cobia.

Given the timing of this it is a little bit awkward, because the Policy Board has already met. We can send around an e-mail to the Policy Board, let them know that this group would like to do that and some rationale. We'll get an approval that way. But I think they've already set the course essentially to allow this to happen; should this Board decide it's appropriate. But I'll follow up with an e-mail to the Policy Board after this meeting.

CHAIRMAN ESTES: Are you good, Robert? **Okay let me try it this way. Is there any opposition to this motion? I guess seeing none; the motion is approved.** I think now, based on the discussion that we can quickly maybe go back to what Louis was trying to put together, and we can finish that up; because it sounds like we still need to be thinking about management. This may need to be adjusted in the future, but I think we can just continue.

DR. DANIEL: Let me try to summarize where I think we are. The state-specific allocations were more intended to provide a framework on how seasonal options might be constructed to maintain the harvest within the ACL. There was not a consensus of the working group that specific statewide allocations be implemented at this time.

That may be something decided on in August, but at the present because the options would be developed that would provide that summary of how the state landings occur. If you go back and look at Framework 4, and you look at the different seasonality of when the fishery occurred, it has changed dramatically. A one fish, 36 inch size limit, with a two-fish vessel limit would extend the season out to October, if you only looked at data through 2012; whereas that season is constrained to around the middle of August if you look at the more current data.

I think it is important to continue moving forward with the various options that would provide the states with the authority to select their own seasonal options, reviewed by the Technical Committee and the Board. That seems to be the direction that the group is heading. One point of clarification that I think is important, and I'm glad Roy is here so he can correct me if I say anything wrong and Michelle too. We're not overfished and overfishing is not occurring. The terminal year of the stock assessment is 2012, and the stock status was declining in terms of biomass. Down from an F over Fmsy, in the 4 to 5 range down to about a 1 and a fraction, so we're close based on the stock assessment. Depending upon the level of confidence you have in that peer reviewed stock assessment, we're probably in a concerning state.

The fact that we've doubled the quota in the last two years might lead one to believe that an updated stock assessment using current methodologies probably wouldn't show any improvements. The concern is still though trying to maintain the catch levels within the Council's ACL, which we've been mostly unsuccessful doing to this point.

But if we go over, and I think this is an important point to make. If we go over the 620,000 pound recreational allocation, or the 50,000 pound commercial allocation, there is no payback provision at this particular point in time. What the Council plan does is drop you back to the allowable catch target, which would suggest that you're trying to harvest 500,000 pounds as opposed to 620, or 670.

But there is no requirement other than to shorten seasons in order to try to accommodate that. It is my understanding that as we proceed in this plan, and develop any kind of options that would develop seasons; that if we didn't hit the mark in the first year that our reaction would be to adjust those seasons the following year, in order to try to limit the harvest back down to the allowable catch limits.

For those of you that might believe that there is a payback provision or some kind of a penalty for going over; that doesn't exist at the present time. But I think it is something we need to be cognizant of, because in some level of likelihood the stock is probably not going to fare as well in the next stock assessment; maybe it will.

Maybe the new information, maybe additional information will tend to suggest that things are better than we anticipated. But if it doesn't then we kick ourselves into an overfished, overfishing situation; which kicks in a totally different scenario, and a whole different set of rules and requirements.

The one thing that I would ask is that we consider what is in the best interest of the resource moving forward. Is it to remove the ACLs, because they're a hassle, and because they may not allow us to manage it specifically the way we want to at the state level; or is having those constraints from an ACL an important component of the fishery?

I think it would be important to have our technical folks look at those questions to see, how can we best manage this fishery to maintain its important status on the coast? I hope that helps to explain part of the confusion was mine, in terms of the state specific allocations. But if everyone seemed to be satisfied with the decisions made to date, if we go back, well I can't go back for some reason.

My computer won't let me go back. The previous slide, no keep going, so it was the one we were on. There was general understanding at this point. Go with one fish, 36 inches up to six fish vessel limit; the allocation information and the potential for states to develop their own seasons. That is where we are right now. I believe that is consistent with what I've heard around the Board table today.

CHAIRMAN ESTES: Roy.

MR. ROY W. MILLER: Jim, just to pursue something I talked to you about over the break. Following up on Lynn's suggestion, could we reach an agreement that all states north of Virginia that are within the historical range of this species consider the one fish per person daily harvest limit and 36 inch minimum size limit, the six fish per vessel limit and no further restrictions; like no seasons to worry about for those states that could otherwise qualify for de minimis.

CHAIRMAN ESTES: Any issues with having that as an option in the document? Okay, seeing none.

DR. DANIEL: The next is Issue 6. These are some other board questions, decisions. I'm not so sure that we really need to get into this now, after the discussions that we've had, unless there is interest from the Board to discuss these. I brought up the point, because this has been a very important issue for the state of South Carolina that they have implemented a spawning season closure in their southern management area; the question of should the FMP include options for similar closures in other states.

There was some strong interest, maybe strong expressed by some of the PDT members about spawning season closures. But it appears to me that based on the previous discussion that would be left up to the states if they wanted to try to set up seasons that would impact spawning season times.

Try to get the best bang out of their spawning season as possible but that there not be anything specific. I am not sure we have the best data to analyze what the actual spawning seasonality is on a coastwide basis. Unless there is interest from the Board in pursuing this option, I would ask that we potentially remove it from the document.

MR. CIMINO: Dr. Daniel, if your predictions on a new assessment are right that may be Addendum I, but I agree to leave that out for now.

DR. LANEY: Well, given the interest of the PDT and given what Louis just said about whether or now we have adequate data to really make a determination as to when these fish spawn, I would be interested in at least seeing us look into the literature; and see what information is out there.

As you said that could still be left up to the states to determine, based on whatever data are available to them. I would guess that if we do have sufficient information, it is probably going to show some sort of latitudinal variation with fish further south spawning earlier; and so forth and so on.

DR. DANIEL: Next slide. Again current vessel limits vary by state up to four fish, and again as we've discussed vessel limits could impact the NMFS decision to open the EEZ. It does seem that everyone agrees that the FMP should include options to complement federal actions sufficient to allow the EEZ to open. One option is to include a request to extend state regulations into the adjacent EEZ. I'm not sure at this point where we are in the game, if we're requesting the transfer.

This is going to require action from the Council, and so I would wonder if we want to put our Council request eggs just in the transfer basket or ask for these various modifications. I'm not sure what the Board would prefer here. Otherwise, we would be relying on NMFS that if we were to implement a plan that constrained the harvest to the ACL; that there would be some agreement that we would be able to get the EEZ open at some level during the seasonality where the states are most involved in the EEZ fisheries.

DR. DUVAL: I agree with Dr. Daniel in terms of putting all the eggs in the transfer basket. I think you want to have that conversation first, so my recommendation would be to keep some component of this in here that could go out to public comment; because if the eventual decision ends up being complementary management or it is complementary management for some period of time.

I think this example here to include a request to extend those state regulations out into the adjacent EEZ provides some of that access and equity and parity for states like South Carolina and Georgia, where the major component of their fishery is in those EEZ waters. I guess it would be my recommendation to leave that in there as we have those exploratory conversations.

CHAIRMAN ESTES: Dr. Crabtree.

DR. CRABTREE: Yes, let me assure you that my goal in all of this is to get the EEZ open again, so we can have a season. We have a stock that is not overfished, not undergoing overfishing; and I certainly am not comfortable with having the EEZ closed under those circumstances.

There are a couple of ways to think about just mechanically how this would work. Currently we have an annual catch limit, and the fishery opens when the season starts, and then we close it in order to avoid going over the ACL. If we had the complementary plan in place, we could open when the first state decides their season is going to begin; and then the states would control the landings in their states by controlling when they allow landings to occur.

At least in theory the ACL should be caught when the last state closes their season down, because that would be what the full conservation equivalency would be based on. That would be one way to do it. The EEZ just opens. The states control their harvest by regulating landings in those states; and then the EEZ closes when all the states are closed.

I guess the other way to do it would be for the states to come in advance and tell us this is going to be our season, and then we could open and close the EEZ according to what each individual state does. I guess we would have to have some lines out as to what's open and closed. That is more bureaucratically cumbersome I think. But I think we could really do it either way.

But I think it is a good topic to discuss at the Council level, because it might require changes to the accountability mechanisms. But that is sort of my thinking on how mechanically two ways I could see this working in a complementary plan. Then the commercial fishery, which we haven't talked about very much, we would have to figure out how that would go as well. But I think that's a lot more straightforward.

DR. DANIEL: Next slide. This has been an issue that has been brought up in multiple boards over many years, in terms of tracking the recreational ACL on an annual basis. Effort data are unavailable until after a wave is complete, and could result in significant overages; despite best efforts, as we've seen in the cobia fishery. The question would be should the FMP try to develop or discuss alternative ACL monitoring methods to track the ACL on a scale finer than waves?

I'm not exactly sure how to do that. That was a request from various folks, but I can tell you from the work that Mr. Wilson did in North Carolina, he was not very comfortable in looking at the data at any finer a scale than I believe it was monthly; for the majority of the data. I know there have been discussions around the building about ACCSP and other avenues, but I'm not precisely sure how we might go about making those changes specifically for cobia. But I bring it up for your thoughts.

DR. DUVAL: I think as Dr. Daniel indicated there are a number of balls in the air with regard to alternative means of at least reporting harvest recreationally. The Council has a pilot project that has been funded by the Fisheries Service that is looking at working with the Snook and Game Fish Foundation to modify their reporting Ap. It was specifically for red snapper, I believe, and discards of red snapper.

But we've had some discussions about possibly expanding that to include cobia on a pilot basis, you know to determine if anglers are amendable to that, what type of response we get; that sort of thing. Our chairman is probably familiar with multiple programs that are going on in the Gulf of Mexico, similarly looking at almost census type of reporting I think; in some of the smaller states like probably Alabama and Mississippi with regard to red snapper.

I think all those things are good, and we can probably learn from those experiences, in regards to recreational reporting for cobia. The state of Virginia has required reporting they're doing this year. North Carolina, our Commission voted to request anglers to bring fish to our citation weigh stations; which we're sort of piloting that this year.

There are some alternative methods out there. I think there is a certification process that would probably have to be undertaken to be able to use those numbers, rather than MRIP to track harvest. I think the other thing that we are interested in pursuing, and I've brought this up a couple other times at the Board, are some of these alternative estimation techniques that the MRIP staff have developed for rarely intercepted species that they have applied to several of the South Atlantic Council rarely intercepted species.

Cobia does not happen to be one of them, but some of our deepwater species and that has been a presentation made to the SSC. We've had some back and forth on again, who is the decider, in terms of when those methods can be applied and how you would apply them. But given that at least at the federal level right now, our accountability measures are not in-season accountability measures they are post-season accountability measures.

It doesn't seem to me that there is a great need to track harvest on a wave-by-wave basis in season, because we can't track it quickly enough or accurately enough to actually take any action. Some of these alternative techniques that use annual or multi-year levels of catch estimates and effort estimates that result in greater precision in harvest estimates might be more appropriate. The Council is pursuing that. Dr. Van Voorhees referenced a workshop that the South Atlantic, Mid-Atlantic, Gulf are working on to evaluate those. Personally I would like to see cobia move along a little bit faster on that; but that is just my opinion, so thank you for letting me talk on a little bit. I'll shut up.

DR. DANIEL: All right, I think that is a long way of saying no. Yes, okay. I didn't mean it disrespectfully. I think I agree with Dr. Duval, and I don't know that we would get much traction if we just tried to do it for cobia. But there is the need, and I think everybody is aware of that.

Just before I move on away from the recreational side, I will let you know that we have been working on putting together the document. We're very close to an FMP. I'm glad to at least see some light of day before any transfer of authority. All the states have submitted their information, and I'm hopeful that we can move forward.

We probably will not need another working group call, but if we do I will contact the Chairman, if we run into any problems. I will work up some language, because there was clear interest in the de minimis section, and get that out as well; so that folks can take a look at that and make sure that they're comfortable with that approach, especially for those states north of Virginia. Make sure they know they were not left out.

The final issue is commercial management options. The working group really didn't discuss commercial issues. The Framework 4 essentially maintains status quo, which is the current essentially bycatch allowance; which is a coastwide two fish at 33 inches fork length and six fish per vessel.

We've received very few public comments on the commercial fishery. In fact, I think all of the comments were maintain it as a bycatch fishery and essentially maintain it as it currently is, it's working. The quotas have not been exceeded to much degree, and just to maintain what we currently have.

The only suggestion that was put forward and it was by a commercial fisherman, I believe in Virginia, was to require that commercial landings be reported in whole weight. I don't know if that is something we want to consider or not, how that might conflict with the federal plan. But at the present time I would move forward on the commercial options; maintaining the Framework 4 options, which is status quo coastwide.

They have about a 50,000 pound ACL, and there was not the intent at least at this point, to try to look at allocations amongst the various states on that fishery. We could do that if you would like, but if we're not going to make any changes I didn't see the need to do that unless you request it. The information will be in the document so that you can look and see what the various states land; in terms of commercial landings.

MR. BOYLES: I think we need to think carefully about this. Before he left, Spud had suggested you know one of the issues with completely eliminating federal management is how do you manage the commercial fishery? At least in my experience cobia has been a bycatch fishery on the commercial side. The 33 inch fork length might be a problem and a problem in the following way. Are you fishing as a commercial fisherman, you can take a smaller fish. It is my understanding there is no permit in federal waters, and so right now we're dealing with some issues back home where folks are buying a state commercial fishing license to go out and access that commercial ACL. I think this is something that is going to require us to think about consistency, and I'm going to refute what I said last meeting. Quoting Oscar Wilde, "Consistency is the last refuge of the unimaginative." But the first refuge of the fisheries manager.

DR. DUVAL: Just a couple things, in terms of tracking landings and pounds whole weight. Right now coastal migratory pelagic species landings are tracked. They are tracked as landed, so it is a mix of whole weight and gutted weight. This was something that we had a discussion on at the previous Council meeting in March, and that we've asked.

I believe it's going to come up again on the mackerel/cobia agenda for this meeting; because we wanted to get some input from the Gulf Council with regard to, would you want it tracked all in whole weight or gutted weight. But the pitch I made was that really for the data providers, it would be good to have a consistent metric, because right now that causes some confusion when they are pulling data down from ACCSP; you know which cell you're pulling data from to compile it. I just wanted to let folks know that.

Then in terms of the commercial fishery, at the Mackerel/Cobia Advisory Panel meeting just a few weeks ago, I believe there was a motion made to implement a commercial cobia permit. Now the council had considered this previously, and I think maybe in Amendment 20A, when we were looking at splitting things into northern zone and southern zone, and at that time none of the states were interested in moving forward with any federal permit at that time; given that it was more of a bycatch fishery.

But I think the motion from the Advisory Panel was to ask for a limited access cobia federal commercial permit, with requirements to have a history of commercial sales to qualify; or any other federal permit. This is something similar to what the Council has considered in the past, where I think if you had any other federal commercial permit you could land cobia. That is just an FYI for the Board that that topic, in terms of the commercial fishery has come up in sort of this loophole that has been created by not having a federal permit.

DR. DANIEL: Just to the earlier point, Michelle, the issue of whole versus gutted weight. It would be interesting to hear some discussion from folks as to which one provides more biological information. It would seem to me for cobia, with a pulse fishery during the spawning season that perhaps whole weight versus gutted weight might be more informative.

I'm not sure. But in the discussions on that if it's based on the ease of doing it or the quality of information received, you might want to err on the side of the quality of information received; since we do know so little about the reproductive ecology that could help there. Then my final comment would be, and I'm sorry Spud's gone, but it's to thank Kathy Knowlton put together a lot of good information.

She's been very helpful on the working group and the Plan Development Team, and there is a lot of information that she's provided that will be very helpful in developing the plan. I'm sorry she's not here, but I do want to shout out to her for the work that she's done for the state of Georgia; thank you.

CHAIRMAN ESTES: Thank you, Louis. I expect we'll see a nice, nifty document in August that will have all this information in it? Okay if we can move on then to a couple of stock assessments. Atlantic croaker, Chris is going to give a report on the Atlantic croaker stock assessment. Yes, sir.

DR. MALCOLM RHODES: Before we leave cobia, and I don't know if this is the right venue for it, but I didn't know where to ask. Last year the ACL was reached and federal waters were closed. After that point essentially another ACL was prosecuted, closing this season, which closed Georgia with 100 percent and South Carolina, since we follow the federal mandates.

Both of our states have no seasons for cobia fishing at all. What measures have North Carolina and Virginia put in place this year to try and prevent a recurrence of over catching the coastwide ACL, and possibly us looking at 2018 with a closed season also? I mean I don't know if this is the appropriate time to ask; but while we have the whole venue together.

CHAIRMAN ESTES: Michelle or Joe.

DR. DUVAL: Malcolm, are you asking what state specific measures our respective commissions have put in place?

DR. RHODES: Correct, because we're under the same.

DR. DUVAL: Our Commission established measures effective May 1st through August 31st of one fish per person up to four per vessel for both charter vessels and private vessels; and then you know we have a shore-based fishery that is probably the chunkiest on the coast, and that would be one fish per person as well.

It is different than what we had last year, which was a Monday, Wednesday, Saturday two fish per vessel, private boat season that ran from like May 23rd through September 30th. Then for charter vessels it was fishing seven days of the week, one per person, four per vessel; shorter on the back end by a month this year, but far more generous on the private boat fishery.

I will just say that was not an option. Staff provided analyses to the Commission that looked at different start dates of measures, different vessel limits, one fish per person limits; and that was what the Commission chose. That was not an option, it was advocated by staff.

MR. CIMINO: It was a difficult challenge for us as well. Michelle talked about the analyses, and I think that we've all been pretty much on the same page on how to do that. We did something very similar to what the Science Center was doing to predict harvest. We were concerned with what happened in 2015.

We put measures in place in 2016 that we projected would have a harvest estimate of about 330,000 pounds. That estimate came in at over 900,000 pounds; so it was a very difficult challenge to go to the public and to go to our Commission and give them projections. They went with something that they felt would be restrictive.

There is a three-fish vessel possession limit. We've been at one fish for a long time on the possession limit. We have a 40 inch total length, which we feel is a good conversion for the max fork length that is used in the South Atlantic; and they went with a season of June 1st to September 15th. Again, we didn't spend a lot of time on what those projections are, because they haven't been all too meaningful to us lately. But hopefully it will provide some reasonable harvest level.

CHAIRMAN ESTES: You good, go ahead.

ATLANTIC CROAKER BENCHMARK STOCK ASSESSMENT 2017

BENCHMARK STOCK ASSESSMENT REPORT

MR. CHRIS McDONOUGH: All right, are we all set? Just before we start, we're going to actually split this up. I'm going to do the data portion and then Laura Lee is going to cover the modeling section; since she did that. Okay next slide. I don't have the clicker, so Megan you are going to have to click it.

Okay so what we're going to cover is a little bit of basic life history; different datasets we looked at, commercial discards, recreational as well as the fishery independent index data. Then we'll cover the assessment model, the reference points and the stock status that their model estimated; and then research recommendations.

Okay spot are, oh spot, sorry. I apologize for doing that but going back and forth between those two species gets a little confusing. Croaker are demersal sciaenid and they're generally found nearshore waters from the Gulf of Maine all the way down to Argentina, and most abundant from Florida to New Jersey.

Relatively fast growing, they reach about 80 percent of their maximum growth within two years. Maximum age is 17 years. They typically mature between ages 1 and 2, and 100 percent maturity is reached by Age 3. One thing that confounds a little bit with croaker is the fact that they have this extended spawning season; depending on the area of the coast it can range anywhere from September to April, and there are arguments that could be made to stretch a little bit outside of that.

But that could sometimes throw some issues in the aging and some other things that we've dealt with in the past. Okay for the datasets, actually you can go two slides ahead. Start off with the commercial landings. The majority of commercial landings over the years have come from Virginia and North Carolina.

You've got periods of high landings that occurred in the fifties, the seventies, and then into the two thousands. In recent years you've seen essentially a steady decline from the peak that happened in about 2004 or 5. Landings by gear, early years you see the majority of the landings coming from haul seines as well as trawls.

The assessment time period shows a shift to gillnets and trawls in recent years, and then the fixed gear that's in there is primarily pound net, is the pound net fishery in the Chesapeake. Okay the commercial scrap bait fishery, these landings come primarily from North Carolina and Virginia. North Carolina is actually the only state that samples by species that gives us estimates for the species composition within the scrap and bait fishery.

We use the angle ratios of croaker to the total landings in North Carolina to estimate scrap landings; for landings of croaker in Virginia, and actually this was the same method that was used in the 2010 assessment for these scrap and bait landings. For the discard estimates, and this is one of the big sticking points that has happened, particularly with croaker for every assessment it's had; and that is the South Atlantic shrimp trawl fishery. We used a general linear model approach, which is the same basic approach that was used in the king mackerel assessment, which did pass.

Then we also looked at the Mid-Atlantic gillnet and trawl fisheries bycatch for discard estimates as well. One note, for some of the material we're covering here in croaker, some of the detail that I'm going to go into a little bit here for the shrimp fishery, I'm not going to cover in spot; because spot we basically did the same exact thing. To save time and just what we're covering, just so you're aware of that.

Okay the shrimp trawl observer program data was only available from 2001 onward. What we did was we used the SEAMAP survey, which essentially covers the same geographic range. It was used to estimate the discard rates for years prior to 2001. The way this was done was that the GOM used that fishery survey catch rate to estimate a trend of relative abundance.

Then the shrimp trawl observer data catch rates was used to estimate the magnitude and the trend of the discarding rates in the fishery. The assumption is that as abundance changes the discard rates would change proportionately. As you can see on that graph, the discard rate and the SEAMAP survey, actually those two correlated fairly well.

Okay for the actual discards. Discards were relatively high in the beginning of the time series, but decreased through the early 1990s before bycatch reduction devices were required. There were particularly high discards in 1991; this was due to high effort and catch-per-unit effort that occurred in that year.

Discards were pretty stable through most of the 2000s, and then despite the declining or stable trends in effort during the 2010s, there actually was a slightly increasing trend in discards in the last couple years; and that is mostly driven by an increasing catch-per-unit effort over those particular years.

But the discard estimates generally followed the same trends as landings by the shrimp trawlers, your positive trend between the shrimp landings and the bycatch landings. The discard estimates from this assessment using this technique were actually greater than the discard estimates that were developed in the 2010 benchmark assessment; average is a little over 7.5 times greater. The 2010 assessment used a ratio estimator.

The gill net and trawl discards, this one we did use a ratio estimator expanded by reported landings. High discards occurred in the gillnet fishery in the late nineties, and the trawl fishery discards were variable; but there was really no consistent pattern there. We did see if there was a correlation between the gillnet and trawl net discards with the National Marine Fisheries Service Fall Groundfish Survey, which occurred in the same geographic area as the gill and trawl net fisheries.

But there really was no consistent relationship there. One thing to point out, the fishery discards for the gill net and trawl net were included in the model for removals. However, there was relatively low number of discards, particularly compared to the shrimp fishery; on the order of less than 250 metric tons annually. This was significantly less than the removals from the shrimp trawl fishery, so it plays a part but a very small one. For the recreational removals to the harvest, and this is total harvest as well as the estimated mortality from the recreationally released fish. Total recreational removals used in the model were the sum of the harvest, as well as the estimated discard mortality by number. Estimated discard mortality for the recreational fishery was fixed at 15 percent. We'll talk a little bit more about that. That was decided by the Stock Assessment Committee, and we'll address that a little bit more in a bit.

Commercial landings are included on this plot to show how well they track with the recreational harvest and mortality. For the recreational removals, total harvest and release mortality were done in number. Then recreational harvest in numbers and estimated annual discard mortalities was used as one of the annual removal factors in the stock synthesis model. Just to give you a big picture of the total removals that orange or yellow there that is the shrimp fishery discards.

You can note the difference in the scale, it's a huge, about a 24 fold difference in scale from some of the other; when you pile them all together and include them with the shrimp fishery. The shrimp fishery accounts for greater than or equal to 90 percent of total removals in all those years.

Then afterwards there is commercial and recreational essentially account for the next highest levels, but they're pretty much drowned out by those shrimp fishery removals. For the fishery independent data, the criteria we use to evaluate the surveys, the time series had to be – we were looking for something that was at least 17 years long or one generation time for croaker.

No changes in methodology or the gear. The survey had to operate in a place and a time where croaker were present and typically available, and then have a relatively high proportion of positive tows. We reviewed 43 fishery independent surveys, and then we narrowed the ones we were considering down to six. These included the National Marine Fisheries Service Trawl Survey, the SEAMAP Survey, the VIMS Trawl Survey, and then the North Carolina DMF Program 195 Survey; all of which were used in the 2010 assessment.

Two additional surveys, ChesMMAP and NEAMAP were considered for sensitivity runs in the stock synthesis model, but they represented shorter time periods of 2002 to 2014 for ChesMMAP, and 2007 to 2014 for NEAMAP. The indices, the timeframe used in the indices was 1989 to 2014, 1989 was the start year; primarily due to the availability of that was the first year we had complete-removal data.

Just to cover the trends in the various surveys. For the NMFS Trawl Survey, the first 20 years for the croaker abundance was relatively stable, and then you start to see this beginning increasing trend in the early '90s, peaked at 2009 and has declined after that point. The SEAMAP survey, it has more annual variability compared to the NMFS survey, but has also shown a general increasing trend that began at about 2001 and into recent years; although the last two years in SEAMAP have also shown a decline.

The North Carolina DMF, the Program 195 Survey showed a high degree of inter annual variability, but given that this survey catch is primarily young-of-the-year fish that is not uncommon in a young-of-the-year survey. Then the VIMS index, similar to the North Carolina Survey, the VIMS Survey catches a high number of juvenile fish; so it also showed a high degree of inter annual variability. Both the North Carolina and the VIMS surveys actually correlated fairly well with each other. The ChesMMAP Survey had peak biomass, actually wait, yes it is biomass. Making sure I got the right graph. Peak biomass occurred in 2002 and then in 2005 and 6, but otherwise it has essentially been a long term declining trend of croaker. Then NEAMAP, which was the shortest dataset we had, other than peak years at the beginning of the survey in 2007 and 2012 has been relatively stable with no clear trends.

In conclusion for those fishery independent surveys, what we used in the base run were NMFS and SEAMAP indices, as well as biomass; and then the VIMS and North Carolina Program 195 indices for young-of-the-year relative abundance. ChesMMAP was negatively correlated with the other indices.

It was basically a big conflicting signal, and so it was used in the sensitivity analysis but was not used in the base model. Then NEAMAP it was decided that the dataset or the time period was just still too short to be of much use in the model; but certainly will continue to be considered in future efforts for assessment. All right, and with that I am going to hand it off to Laura.

STOCK ASSESSMENT MODELING

MS. LAURA M. LEE: Okay so we used the stock synthesis model, program rather, to assess Atlantic croaker. This is considered a state-of-the-art model, it is forward projecting. It is very flexible in that it can use all types of data, including length and age data, multiple indices, multiple fisheries.

We implemented a two-sex model and we use it to estimate stock size, fishing mortality, and our reference points. As far as our configuration, we modeled 1989 through 2014, and our unit stock was New Jersey to the east coast of Florida. We had four fleets, which included the commercial, the recreational, commercial scrap landings and the shrimp trawl fishery, which was modeled as a bycatch only fleet.

Then we had the five surveys that Chris described. I also want to mention that we did a Bayesian prior on steepness of 0.76. This value comes from two sources. One, it was the value we assumed in the last assessment, and that value for that assessment came from a meta-analysis. Joseph Munyandarero on our committee, he also did a life history approach to estimate steepness, and it just happened to come out as that same value of 0.76. We included that in the model as a prior.

This is a summary. I apologize, this is difficult to read. Of all the data that was used in the model, including catch data, abundance indices, length compositions, age-at-length, mean-length-at-age, and discards. The width of the line gives an indication of the length of the time series for each different input from each different source.

Getting into the results, the trend in annual recruitment deviations showed the expected patterns; it was very variable over the time series, but it is decreasing in the very most recent years, and the variance is increasing over time; and that is typical of these models, where the most recent years are the most uncertain.

Spawning stock biomass started at a very low value, and just steadily increased over the time series again, just like recruitment the variability is greatly increasing with time. Those estimates in the terminal year are the most uncertain. Estimates for fishing mortality were variable with a general decreasing trend over the time series. The smallest fishing mortality was observed in 2005 at a value of 0.11. As I said before, we had that prior 0.76 of steepness for the stock recruit relationship, but despite that the estimated steepness value was 0.99 essentially, and you can see that the model is giving a very poor fit to the stock recruit relationship; so the data we have is just not informing that.

We did a number of sensitivity analyses. We looked at recreational discard mortality and the base run. We assumed a value of 15 percent mortality, and we varied that over a range in the sensitivity analyses. We removed one survey at a time in another set of sensitivity analyses. We looked at different values of steepness. We looked at different assumptions relative to the shrimp trawl bycatch, and we also did the traditional retrospective analysis.

Now for each of these sensitivities I'm going to show you the spawning stock biomass and fishing mortality estimates. This first slide you can see that we varied the level of recreational discard mortality from 8 percent to 18 percent. For SSB fishing mortality and recruitment, which isn't shown here, varying that level had little impact on the model results.

Our next set of sensitivity analyses was to remove one index at a time and not just the index but all the data associated with it, so the biological data associated with it. You can see that there is just a small impact on SSB and fishing mortality. Removing the NMFS and the SEAMAP Survey probably had the biggest impact on recent recruitment, which isn't shown.

But recruitment and SSB in recent years appeared to be most sensitive to which survey data were removed. We looked at a range of steepness values from, I think 0.61 and I just want to note that we did implement this reweighting procedure, and the models wouldn't converge without doing that reweighting procedure when we varied the steepness value.

There is definitely an impact on recruitment and female spawning stock biomass. Assuming the smaller levels of steepness resulted in higher estimates of recruitment, especially in the recent years. Similarly assuming smaller levels of steepness resulted in higher predicted estimates of female spawning stock biomass, especially in the final years of the models; as you can see here.

Predicted fishing mortality tended to be smaller at smaller assumed values of steepness. For shrimp trawl bycatch we had the base levels and then we reduced that level by 10, 20, 30, 40 and 50 percent; to see what the impacts were on the models. Thirty percent is in the ledger, but the estimates aren't shown because the model couldn't find a solution when we made that assumption.

But you can see there wasn't much impact on the model estimates of SSB and fishing mortality. When we showed the data that 1991 value from trawl bycatch was estimated to be really high, because I think effort and CPUE were really high in that year. We changed that value in two ways, one is we basically took that value out of the model, and that's the new 1991 run.

Then the dent in 1991 run is where we set the 1991 value equal to the median of the other values prior to the implementation of the BRDs. You can see there is not much impact on spawning stock biomass. There is a little bit of impact on fishing mortality in the initial years of the assessment. Finally the retrospective analysis shown here suggested there is no consistent over or under estimation of terminal year values for recruitment; which isn't showing female spawning stock biomass or fishing mortality. Reference for Atlantic croaker is defined in Addendum I to Amendment 1 of the fishery management plan, and they are shown here. The stock synthesis model was used to estimate the reference point values; which are also given here, the threshold and targets for spawning stock biomass in fishing mortality.

The overfished and overfishing definitions are based on the ratio of current F and spawning stock biomass to the respective thresholds. If F in the terminal year over F threshold is greater than 1 then overfishing is occurring. Likewise, if spawning stock biomass in the terminal year over spawning stock biomass threshold is less than 1, then the stock is considered overfished.

This graph shows the relative status over time, and you can see for relative spawning stock biomass we start out very low, below the threshold and increasing very optimistically in the terminal years. As far as the fishing mortality threshold, there were maybe three years where the stock was considered overfishing occurring; but throughout most of the time series and including the terminal year, overfishing is not occurring.

You can see that below with the actual values of terminal year SSB and F to their respective thresholds. We developed a series of short term and long term research recommendations and ranked them according to priority. Start with the short term recommendations; high priority, increase observer coverage for commercial discards, particularly the shrimp trawl fishery.

Developing a standardized protocol for biological samples from this fishery, this is needed just to characterize what those discards look like; and better inform the model. The next high priority is to describe the coastwide distribution, behavior and movement of croaker by age, length and season, with emphasis on collecting larger, older fish; which is what is currently lacking in the available data.

For short term medium priority, the way I conduct studies of discard mortality for recreational and commercial fisheries. I don't think I mentioned for commercial fisheries any discards we had there we assumed 100 percent mortality, and for recreational those estimates came from meta-analyses. I don't think they were specific to croaker; the estimates that we came up with.

We recommend conducting these studies. In recreational fishery, we really don't have samples of discarded fish, so if we can get ages and lengths from that that would be good for characterizing those recreational discards in the model. Encourage fishery dependent biological sampling with proportional landings representative of the distribution of the fishery, so more samples from states with higher landings; and of course develop associated prototypes.

For the long term high priority, we're suggesting to continue state and multistate fisheries independent surveys throughout the range, and to continue to subsample for lengths and ages. Another thing, this might be written twice, is looking at factors affecting catchability and long term fishery independent surveys, so that if there are significant factors affecting catchability then we would consider standardizing our indices, using something like a GLM approach based on those significant factors.

Next would be to quantify the effect of BRDs and TEDs implementation in the shrimp trawl fishery, by examining their relative catch reduction rates on Atlantic croaker. Continue to develop estimates of length at maturity and year round reproductive dynamics throughout the species range. Look at historical ichthyoplankton studies for the magnitude of estuarine and coastal spawning. Then we have out medium priority for the long term. One was investigating environmental covariates in stock assessment models, including climate cycles and recruitment of year class strengths, spawning stock biomass, stock distribution, maturity schedules and habitat degradation.

Utilize NMFS ecosystem indicators biannual reports to consider folding indicators into the assessment, and identifying mechanisms for how environmental indicators affect the stock. Encouraging efforts to recover historical landings data, this would be important for us to take that to a start year back in time; and maybe get a better estimate of initial equilibrium catch.

Collect data to develop gear specific fishing effort estimates. Investigate methods to develop historical estimates of effort. Investigate the relation between estuarine nursery areas and their proportional contribution to the biomass. This could eventually end up being used in weighting of the indices in the stock assessment model.

This is the last one. Continuing with the medium priority, develop gear selectivity studies. There is not a lot out there, but it will be great if we could get a better handle on the actual shapes of the selectivity curves for the different gears; and maybe get external parameter estimates to inform our models better.

Conduct studies to measure female reproductive output at size and age and impact on the assessment models and biomass reference points. Developing sampling programs for state-specific commercial scrap and bait fisheries; in order to monitor the relative importance of croaker in those fisheries.

Currently North Carolina is the only one that does biological sampling of those fisheries, and we're not sure of the importance in other states. That's why we're recommending this. As far as the timing of the next assessment, the Subcommittee and the Technical Committee recommend that the next assessment be completed five years from the completion of this assessment, so 2022.

We also recommend that we not do them at the same time, because it was kind of a burden on the Subcommittee to have to try and complete two assessments at the same time. If you could recommend staggering them next time that would be great, and with that we would be happy to take any questions.

CHAIRMAN ESTES: Thank you, Laura and Chris. I think before we'll do questions maybe, I would like to have Pat talk about the peer review; and then we can get questions all together.

PEER REVIEW PANEL REPORT

MR. PATRICK A. CAMPFIELD: I am going to provide a summary of the highlights from the peer review of both assessments; starting with croaker. Just real quick on the process, the Stock Assessment Subcommittee and TC developed a new coastwide assessment. Our review panel consists of three reviewers; the Chair and then two technical reviewers.

In combination they had expertise in general population dynamics, stock assessment modeling, statistics, and croaker biology. Their charge or their task was to provide a scientific review, focusing on data inputs, model results, and sensitivities and the overall quality of the assessment. The review workshop was held down in Raleigh, and the Review Panel consisted of Ken Able from Rutgers, Dr. Shannon Cass-Calay from NMFS Southeast Science Center, and Dr. Mike Wilberg from the University of Maryland. To start with the overall peer review findings, the Panel really reached two conclusions or looked at this at two different levels. They were in full support that the stock assessment provides the best available science; that the stock assessment team turned over every rock in looking for data that the suite of analyses and models that they attempted were very rigorous, in terms of comparisons to other assessments.

However, they found that the stock status determinations were uncertain. Although the biomass is increasing in most of the model runs, they didn't see sort of commensurate increases in the population age and length structure that you often see with a population that's increasing in biomass.

Under the modeling context, they noted that the stock status results were sensitive to some key assumptions; most notably the gear selectivity options for the commercial fishery, as well as the Northeast Science Center trawl survey. While the Panel does not recommend using the absolute estimates of population size, they were fairly comfortable saying that the trends in landings and surveys suggest that the current removals are sustainable.

Then I'll go quickly by each review term of reference and try to hit the highlights. The first term was essentially to evaluate the data that were collected and how they were treated in the assessment. The Panel concluded that all major sources of removals were accounted for and Chris described those in more detail.

The criteria and the process that was used for selecting abundance indices were adequate and correctly applied; leading to selection of a subset of five indices. Data source variances and uncertainties were well described; they were very thorough about that and that the procedures for data weighting meet typical stock assessment standards.

However, the Panel did note that model stability was highly sensitive to how the data sources were weighted; and you might get different model results depending on those weighting factors. The Panel recommendations related to the data, the assessment as Chris and Laura described started in 1989 through 2014.

But the Panel noted that there were of course significant removals of croaker prior to 1989, and they suggested trying to develop historic estimates and evaluate the sensitivities of the initial depletion in the assessment; by going back and looking to see if a longer time series might inform the trends and the overall model results in a different fashion. They are not guaranteeing that that would improve things, but they suggested at least looking at it.

Their second recommendation was to develop CPUE indices from the fishery dependent data. But of the overall concerns this was that the biomass seemed to be increasing from the model results. Landings have been coming down, and the Panel thought that using these fishery dependent CPUE indices may tease apart those contrasting trends.

Their third recommendation was to consider standardizing all of the survey indices. Again, not suggesting that is going to fix things; but it is worth looking at. The fourth recommendation was to develop criteria to better evaluate the reliability of each data source; again for model data weighting purposes. The second term of reference was to evaluate the methods used to develop discard and bycatch estimates. The Panel concluded that the bycatch estimation methods from the shrimp trawl fishery were innovative, and similar and consistent with what the most recent SEDAR assessments have used. They were completely onboard with that and noted it was a major improvement from the last croaker stock assessment.

As I think Chris described the methods, essentially taking observer data from the shrimp trawl fishery and combining that with trends in SEAMAP survey information, as well as sort of calculating for the change of when bycatch reduction devices went in, again was innovative and a smart way to go about bycatch estimation.

Similarly, the Panel agreed with the approach for estimating discards from the Mid-Atlantic gillnet and trawl fisheries. Term of Reference 3, was to evaluate the methods and models used to estimate population parameters and reference points. The Panel concluded that the stock synthesis catch-at-age model configuration and parameterization were reasonable.

However, they noted alternative configurations that were requested and provided by the assessment team at the review workshop could result in different stock status determinations. The Panel's recommendations again were to look into starting the model prior to 1989, although the time period selected by the assessment promoted model stability, again it reduced the Panel's confidence in the initial depletion starting point.

One of the other recommendations or sort of a set of recommendations within the models was to look at the different selectivity options. I mentioned that in the earlier slide, but essentially compare results between dome shaped selectivity, which was used I think for all but one of the inputs in the assessment; and also to try asymptotic selectivity.

There are other recommendations there more technical that we'll spare for today. The fourth term of reference was to evaluate sensitivity in retrospective analyses performed in the assessment; to look at model stability and consequences of model assumptions. The Panel concluded that the range of sensitivity analyses that was conducted was reasonable; that they took a strong look at sensitivities.

It showed the model was insensitive to recreational discard mortality and index selection, but they did have a recommendation, again for additional sensitivity analyses around commercial fleet selectivity as well as effective sample sizes. You guys covered the retrospective analyses, but in summary the Panel was not concerned about retrospective patterns.

Term of Reference 5 was to evaluate the methods used to characterize uncertainty in the stock assessment. The assessment team used asymptotic standard errors to characterize uncertainty. A minor recommendation from the Panel was to try likelihood profiles to better understand parameter uncertainties.

Term of Reference 6 was to recommend best estimates of stock biomass abundance and exploitation. The Panel does not recommend using the assessment estimates of absolute biomass abundance and exploitation, due to the model sensitivities that we mentioned; again on selectivity. However, they thought there were several important take homes that could be gleaned from the stock assessment; one that abundance indices are increasing across most of the stock range, and they were confident in that conclusion. That second catch appears to be stable and declining over time. That catch and indices patterns together indicate declining fishing mortality rates. It looks like the croaker stock in recent years is in better shape than the late ’80s and early 1990s. Finally that shrimp fishery effort and croaker bycatch appears to be declining. Related to this the Panel recommended reviewing the shrimp bycatch estimates on an annual basis, given their substantial contribution to overall mortality; and to consider adding this to the annual-traffic-light analyses.

Term of Reference 7 was to evaluate the choice of reference points and the methods used to estimate them, and recommend the stock status. Again the Review Panel does not recommend specific absolute values for reference points, due to uncertainty in the scale of biomass and fishing mortality; although stock status cannot be determined reliably, because models with alternative plausible selectivity assumptions resulted in different stock status determinations.

Although we’ve used MSY based reference points to date for croaker, given some of the uncertainties the Panel recommended making a switch to spawning potential ratio reference points. Finally, the last two terms were to review the research recommendations that the stock assessment team developed; and help them prioritize them.

Both the Review Panel Chair and Chris, as the Assessment Team Chair, we spent a lot of time at the review developing top priorities. I won’t repeat all those, but the take-home was that the most important research recommendations were to increase shrimp trawl fishery observer coverage and to increase collection of croaker lengths and ages from the shrimp trawl fishery.

It is fairly obvious, but definitely supported continuing the fishery independent surveys; and again to subsample to take lengths and ages from those surveys. The last term was to recommend timing for the next benchmark assessment, and the Panel agreed with the stock assessment team that the next benchmark should be in five years; continue the traffic-light-analyses, and again consider adding shrimp bycatch estimation to those analyses. Thank you, Mr. Chairman that is all from the Review Panel.

CHAIRMAN ESTES: Do we have questions about the assessment or about the review; Marty?

MR. MARTIN GARY: Well thanks, Chris and Laura and Pat for the update. It was really appreciated. From our little jurisdiction, PRFC, and then a little bit north and south of there where our constituents fish in the lower part of Maryland’s Bay and the upper part of Virginia’s Bay, croaker have been really, really important.

I have two questions, the first one, and I would like to follow it up if I could. I know it was stated up front that range of the stock is New Jersey south, and it may not have been an emphasis. But is there any indication in any of the data that this species is expanding northward like we see some? I was curious about that.

MR. McDONOUGH: Yes there was some data that showed that you see increasing, particularly in recent years in New York, Massachusetts, Rhode Island, a little bit here and there. It is not a consistent pattern. The most consistent pattern in terms of increase in about the last five years has been seen in New Jersey; but then that's pretty variable. One year they won't get a whole lot, the next year they'll triple to quadruple what they're seeing. But there does seem to be. It's not so much; I wouldn't call it a range expansion or anything like that. But it seems like the core of the distribution has broadened or at least gone north. I shouldn't say broaden, because the distribution in the south has stayed about the same.

MR. GARY: Mr. Chairman, could I have a follow up?

CHAIRMAN ESTES: Yes, sir.

MR. GARY: Then for this next question, it's a two-parter, and I'll put myself in the shoes of one of my for-hire constituents, just to throw it out to you. If anybody was around for the Striped Bass Advisory Board and you heard, like you have on several occasions, the frustration from our for-hire fleet. Part of it is driven by the lack of diversity of what they can fish for.

They're really restricted as you go from the mouth of the Potomac to Potomac and then north to almost striped bass and maybe bluefish and white perch, et cetera. But croaker, weakfish and some other species were available, spot, throughout the '90s a prodigious fishery for the for-hire fleet; really important to them, and your data showed all that as I was watching it.

By the time we got to like '03, '04, '05 that fishery was waning. They are catching some now, but it is a shadow of what it was. I think the first question, to put myself in their shoes, and I can go back and talk to them about what this revealed, is what caused that? It wasn't clear to me, was it environmentally driven? Did the shrimp bycatch lead to some of that as a combination of factors?

One question is why did we go from that abundance and down? Again, I'm putting myself sort of in my constituent's shoes. Then the other part is I see some of the information suggesting that spawning stock biomass is increasing. Is there room for optimism for these folks to get back close to maybe what we had before? That is somewhat hypothetical, but I thought I would put it out to you.

MR. McDONOUGH: Well I'll start. I think we really don't have a clear picture as to that. The model was showing that biomass increase. We've seen increases in some of the fishery independent surveys. But those commercial and recreational rates have been going down. There are some differences in terms of the age structure between the fishery independent surveys; they tend to such a smaller, younger fish versus what the commercial and recreational fishery gets.

Recruitment has been pretty poor for croaker, and there is a lot we don't know about the recruitment processes along the coast. We know they spawn along the coast, but we don't know how those recruits distribute out and whether or not you're getting high recruit mortalities in some of those northern estuaries.

The Chesapeake has had the dissolved oxygen issues, although I think for the PMRC that is more concern with the center of the bay than back in the rivers, maybe not as much of an issue. But some of the work we did with the traffic-light-analysis, there was some differential between those commercial and recreational and the independent surveys. It pointed more to the difference in the age, you know the relative age structure of what the fishery was targeting versus what some of the surveys were finding. But there really isn't a good direct answer for that.

MR. CAMPFIELD: I would just add to that that we did see corroboration of that in the ChesMMAP index. You see a completely different trend from that index. I think we do recognize that there does appear to be something different going on in the Chesapeake Bay than from what we've seen elsewhere along the coast, and even in the NMFS bottom trawl survey that covers the mouth of the bay.

We do see that and we certainly don't know the mechanisms to explain those differences in trends. But the model is a coastwide model trying to give us a picture of what the coastwide stock unit is doing. The indices that we did use within the modeling framework are different than that and are showing what we hope is more so a picture of the coastwide stock. Until we can get to a more spatially explicit model that is kind of what we're held to and limited to, as far as trying to determine, as far as stock status from the coastwide population or stock unit.

MR. CIMINO: I would just like to add to the discussion. First, thank all of you for the work that you've done. I am a little concerned as well. If you look at the removals without shrimp trawls that is a pretty considerable downward trend in recent years. I put in a plug for NEAMAP and all the other surveys that are still tracking this, because that may be our only answer.

One of the interesting things that I've heard from quite a few fishermen now over the past couple of years, is that they really feel that the overwintering migration, where we used to have croaker and weakfish sitting just offshore, have moved into considerably deeper water. Now it seems that there are some fisheries that are fishing in 400, 500 feet of water for croaker and weakfish in the winter. I find that pretty interesting.

CHAIRMAN ESTES: Chris.

MR. CHRIS BATSAVAGE: Thank you for all the work that the group did on this assessment, as you know it is no small task. From seeing the results and the peer review, it of course showed that biomass has increased quite a bit here in recent years. However, just some of the comments it doesn't really bear out as far as what people are seeing. If you consider like black sea bass being two times over the target, you know they're hard to get away from in certain areas; not really the case with croaker.

My question is, you know with I guess the uncertainty in the gear selectivities chosen for the model, specifically the commercial fishery where you kind of have a mix of dome shaped selectivity type fishery like the gillnet fishery versus more asymptotic selectivity fisheries such as the ocean trawl, long haul seines, and probably even pound nets to a certain extent. Is there I guess a future direction to maybe split the commercial fleets out by the gear selectivity, you know to maybe get a better idea of what the stock status is?

MS. LEE: Thanks, Chris, I've been thinking about that; because we talked about that a little bit. I think that that would be a good approach moving forward, because of the issues that we had with the selectivity modeling. I didn't completely agree with going to totally logistic for the commercial fishery, but he convinced me that maybe dome shape wasn't appropriate either, so I think that would be the best way to go.

MR. DAVID BUSH: The first question I had originally for Laura was answered when the Peer Review went over it, because I couldn't quite see some of the scales up there. But it looks like in general we can't use the numbers but the trends are there, and the trends are pretty substantial. They are increasing, spawning stock biomass is going up, and one of the biggest impacts could be the shrimp trawl bycatch side of it.

Looking at it for the past few years there, you know that trend has dramatically increased and it's probably the wrong place to do it, but I'm going to try anyway. My division here has worked very well with our fishermen in our state to get to the source of some of this discard issue, and over the past few years have really had huge impacts.

Hopefully that bears out in this. But I do have one question that was brought up by the comments earlier. I know that we check for where these fish traditionally were, and that is where we do our surveys, but have we ever made any efforts to try to see what the extent of their ranges are; because if they are moving out past our surveys, then we're going to get a very skewed perception of what the biomass of the stock really looks like?

MR. McDONOUGH: We have, as far as looking at those broader areas, we have on occasion looked at the NMFS survey; we look primarily from about New York Harbor down to Hatteras. That is what the index is generated from, because that is where 60 to 70 percent plus the positive tows for croaker occur. However, they sample all the way up to the Gulf of Maine in that survey. We have looked at croaker catches outside of the regular strata on occasion.

Those numbers still kind of bear out. You really don't see much. There is variability. Some years they might go up, but then you'll have a couple of down years where you might see them off of Rhode Island and Massachusetts. Then I think Joe's point about the depth distribution is a good one.

The NMFS survey does sample fairly deeply, however they don't sample the really deep strata on a regular basis, like they do, I call it the mid-shore strata, because NEAMAP took over their inshore strata from starting in 2008 and '09. Croaker weren't consistently caught at those deeper stations over the years, and that's another reason why that data hasn't been paid as much attention to. But that is probably something that warrants going back and looking at it, because certainly it is all available.

CHAIRMAN ESTES: Yes, John.

MR. CARMICHAEL: Laura, when I went through it I read the assessment report first, and I didn't get the same sense of it as I got once I read the review. I didn't get the sense of doubt that the reviewers cast upon it from the assessment report, and I was wondering if the reviewer's opinions took the Technical Committee somewhat by surprise; or were they anticipating some of that?

MS. LEE: That's a good question. I think we were taken more by surprise than not. I think we were probably going in most worried about the shrimp trawl discards, just because that was such a concern at the last assessment; and we spent so much time trying to come up with really good estimates. The issues that they came up with were a little unexpected, but they weren't wrong in what they brought up.

MR. CARMICHAEL: Follow up if I could. I noticed one thing and I think it is important to the SSB trend, because in the introduction of the overview executive summary from the reviewers, they talk about the selectivity issue that Chris raised and the problems with, I think we're all well aware when you have a lot of dome shaped selectivities, you're older age fish can kind of do whatever they wish to do.

They mentioned the chance or the possibility that the increased SSB could be cryptic, and just be driven by the dome shape selectivity so the fish can get out past those selectivities and just continue to grow. I thought that raised some concern, because then they say later, well it seems like the trends are good, and fishing mortality is low, and spawning stock biomass is increasing.

But I have to go back and say well, if you tell me spawning stock biomass is increasing in the base runs, but you told me earlier that maybe the increase in the older fish was cryptic; then that might shed a little bit of uncertainty onto whether or not spawning stock biomass is really increasing that much.

But especially because they also in there mention that the length-in-age comps didn't really support the increasing population, they supported more of a static or potentially declining population. I kind of was disappointed that they didn't delve into that more in the other terms of reference.

Because this chance that there is some cryptic population out there is really pretty critical, in terms of interpreting these results and what you might do, and how you view what is maybe increasing or is it the landings aren't there and the landings aren't increasing as much? Maybe there is something else at work here.

CHAIRMAN ESTES: What is the pleasure of the Board? It seems that we have an assessment that has quite a bit of data, folks worked really hard on it; yet the review says we really can't use it for management purposes. What is the pleasure of the Board?

MR. BOYLES: First of all before we answer the question. You know for Jeff, Kristen, Megan, Michael, Pat, all the staff, Chris, Laura, and everybody who has worked on this, thank you. I know it is disappointing when we find ourselves kind of scratching our head to try to answer Jim's question, Chairman Estes' question of where do we go from here? But I would like to say on behalf of the Board thank you. I know it was a long slog. We've got data limitations. I'm grateful, and I think I'll go out on a limb and say I think the Board is grateful for your effort.

Job well done, and we've got challenges before us and we'll make things better next time, but thank you. Mr. Chairman, at the risk of sounding really, really parochial, a number of us, I included, have a flight to catch and there is a lot to think about here; not only with this one, but with the spot assessment as well. I would like a little bit of time to think about this. If you want a motion to accept this, accept the assessment and the peer review and give us a little bit of time to chew on it. I think this probably warrants for some further discussion, maybe at our next meeting.

CHAIRMAN ESTES: Agreed, so how do we procedurally do that?

EXECUTIVE DIRECTOR BEAL: Well usually the peer reviews are accepted for management, and since the assessment wasn't upheld by the peer review, I don't think there is any necessary motion by the Board that has to accept the peer review results; or anything along those lines for management use, since that won't be the plan. I think if there is comfort around the table of waiting until the August meeting, allow folks to sleep on this for a few months and think about the next steps forward. That is the Board's prerogative for sure.

CHAIRMAN ESTES: Yes, Joe.

MR. CIMINO: Very quickly, Mr. Chair. I don't want Laura to have to leave without some sort of promise that we can decouple these two assessments. I think we'll hear a lot more about the challenges with spot. I would be happy to do this at the next meeting, but I probably think it's logical that spot could be a more delayed; and maybe give croaker another shot in the near future.

MR. CARMICHAEL: Laura, I think to that I would say, given the issues that they raised with the data and such, I don't think a year prediction for when you do this next; in five years or what have you. But when do you guys think you can actually make some progress on the real issues? You're not going to resolve the past shrimp trawl bycatch.

The numbers we have are the numbers we have, and they said that you used the accepted methods and appropriate methods, so the issue is with the data. Well you can't go back in time to fix the data, so I think it would be a better use of the Technical Committee's time to think about how you deal with that limitation within the tools we have to deal with making good predictions for croaker.

Maybe in the near term you guys could look at something like F max or some yield per recruit type approach for this, since there is not stock recruitment relationship that is at all discernible. I think dig into the selectivity issues, as was mentioned, and maybe try to do some research to really determine what the selectivity is; and not have to estimate so many selectivities in this model.

Then maybe you can come up with a croaker model that will be informative and acceptable to those guys. It is a lot of work to go down this path, and I hate to see folks go do that when you can't resolve the issues that are standing in the way of its acceptance now.

CHAIRMAN ESTES: Okay, following Robert's suggestion. Oops, hang on a minute.

MS. KERNS: I think that's helpful, John, at least for the TC to look into some information on the path forward. I think one of the things that might be helpful for the Board, and if you guys disagree with me that is perfectly acceptable, but it is to update the traffic-light-approach with the last two years of data; because the assessment only went through 2014.

Have the TC work on that between now and the August meeting, and present the updated traffic light at the August meeting. Especially I think that there may be some hesitation with spot, and I think it would be good for the Board to see the information with the new years for spot on that; because we had seen some declining trends earlier. They can at least review that. We can think long term or even medium term for some of those suggestions of which John just brought up as well. There are also suggestions from the Peer Review Panel, I think from both assessments or just for the croaker assessment that we may want to consider adding the shrimp trawl discard information into the traffic-light-approach. I don't think we necessarily need to do that for the August meeting, but that is something that the TC could think about if there is some sort of possible way to do that or not. Those are some things that could happen between now and August, and then some things could happen between now and question mark end date.

CHAIRMAN ESTES: In the meantime I think we will postpone the spot assessment until our August meeting, as I think was suggested. If that is all right with everybody, does anybody have a problem with that? Okay it doesn't look like anybody has a problem with that.

SPANISH MACKEREL ADDENDUM I

CHAIRMAN ESTES: I think we will go to what is our last agenda item, it is Spanish mackerel Addendum I, I believe that Michelle would like to talk to us about.

DR. DUVAL: I will be very brief. If you all recall, Addendum I to the Spanish mackerel fishery management plan for the Commission allowed for seasonal exemption from the 12 inch minimum size limit, specifically for pound nets and only for the months of July through September.

The past couple years, so North Carolina is the only state that has utilized this particular exemption, and the past several years we've provided the Board with a report; generally at this meeting, with regards to the previous year's performance of the fishery. I had spoken to the Chairman previously about this.

We had a little bit of trouble trying to get that report together within that timeframe. This year we do have it together now. It should be finalized tomorrow, and so Mr. Chairman, I was simply going to ask and I believe we have done this in the past, if perhaps the Board will be amendable to reviewing that via an e-mail type of review.

I will put forward that North Carolina is indeed interested in continuing that exemption for this upcoming 2017 fishing year, so if I can provide that report to staff first thing Monday, and then they can get it out to the Board; that would be my recommendation.

CHAIRMAN ESTES: Is that acceptable to the Board that we should get it sometime in the next week or so? Okay, thank you, Michelle.

ADJOURNMENT

CHAIRMAN ESTES: Is there any other business to come before the Board today? Seeing nobody rushing up front here, I think that we are adjourned.

(Whereupon the meeting was adjourned at 2:53 o'clock p.m. on May 11, 2017.)

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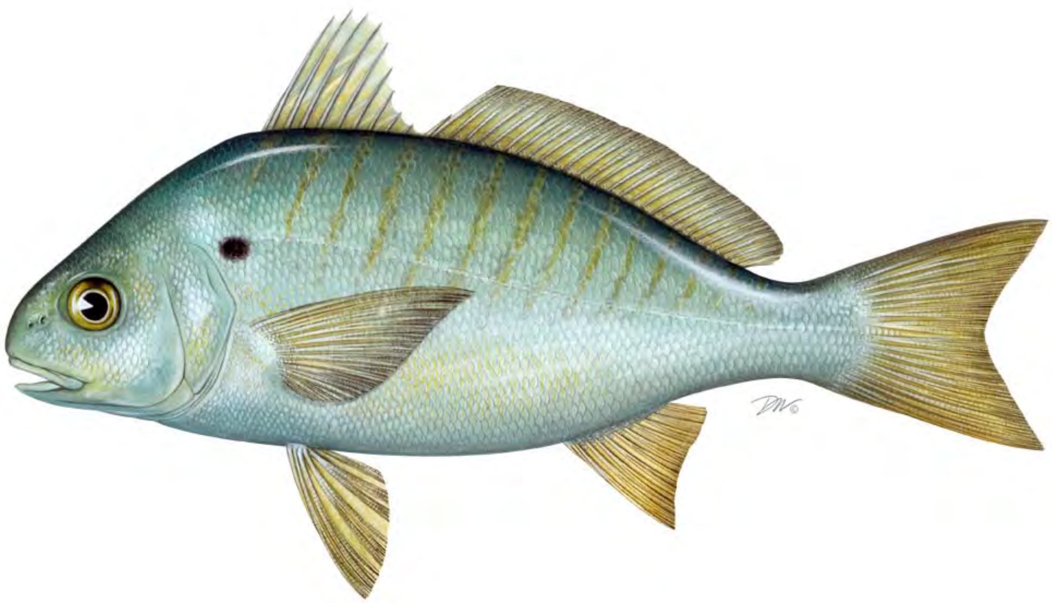
Atlantic States Marine Fisheries Commission

2017 Spot Stock Assessment Peer Review



May 2017

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Atlantic States Marine Fisheries Commission

2017 Spot Stock Assessment Peer Review

Conducted on
April 18-21, 2017
Raleigh, North Carolina

Prepared by the
ASMFC Atlantic Croaker and Spot Stock Assessment Review Panel

Dr. Ken Able, Rutgers University, Institute for Marine and Coastal Science
Dr. Shannon Cass-Calay, NMFS Southeast Fisheries Science Center
Dr. Michael Wilberg, University of Maryland Center for Environmental Science

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Executive Summary

Spot are caught in commercial and recreational fisheries, primarily in the Chesapeake Bay and Mid-Atlantic (New York-Virginia) and South Atlantic (North Carolina-Florida) coastal waters. The majority of annual fishery removals of spot were discards in South Atlantic shrimp trawl fisheries, followed by commercial landings and recreational harvest. Data to estimate discards in South Atlantic shrimp trawl fisheries were available starting in 1989 and the terminal year of data for this assessment was 2014. From 1989-2014, total annual removals of spot from all fishery sources (landings and discards) have ranged from between 4,637 and 57,287 metric tons, or 41 and 1,324 million fish. Removals were relatively large, but variable in the 1990s. Removals since 1997 have been relatively stable, coinciding with the requirement of bycatch reduction devices (BRDs) across shrimp trawl fisheries. The long term mean removals were 12,785 metric tons, or 254 million fish. However, total removals after the peak year that occurred in 1991 averaged 9,399 metric tons, or 158 million fish.

Indices of relative abundance from the NMFS Trawl Survey and the NCDMF Pamlico Sound Trawl Survey were used in the preferred stock assessment model (modified-CSA model). The indices generally suggested a period of low abundance through the 1990s and early 2000s, followed by increasing abundance in the late 2000s and 2010s. There was a decline across indices in the assessment terminal year (2014).

Although the current stock status could not be inferred with confidence, the Panel noted that the models generally suggested spawning biomass was increasing. Therefore, the Panel agreed no immediate management actions are required. However, monitoring of abundance indices, removals, and age/length composition should continue (Traffic Light Analysis). If new information suggests the stock could be declining, a new assessment should be expedited.

The Panel noted the uncertainty of the stock assessment outcome was due to inherent data uncertainties, and to conflicting information regarding population trends contained in the various data components. The Panel agreed the assessment used the best available information, all significant removals were incorporated, the data analyses conducted were based on current best practices, the structure and application of the assessment model appeared reasonable, and that important uncertainties were identified and explored.

Terms of Reference

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

The Review Panel commended the analytical team for their concise and comprehensive presentation of data inputs used in the stock assessment. The Panelists agreed the written report and summary presentations were unusually complete which greatly facilitated evaluation.

All major sources of removals of Spot were thoroughly described including: discards in the shrimp trawl fisheries, commercial landings, and recreational harvest. Discards from the shrimp trawl fisheries accounted for 31-70% of annual removals, commercial landings for 10-40% most years, while recreational harvest typically accounted for approximately 10% each year. The remaining sources of fishery removals were typically 5% or less of total annual removals over the last 20+ years (e.g., scrap fishery). The assessment period was 1989-2014. This timeframe was used because fishery dependent and independent data sets were more widely available. The Panelists noted that important removals began much earlier than 1989. Therefore, it may be useful to attempt to recover or estimate historical removals to improve initial estimates of depletion in the stock assessment.

Data strengths and weaknesses – temporal and spatial scale, sample sizes, coefficients of variation (CV) – were described in the stock assessment report, and input directly in assessment models when possible with an adjustment applied for the CVs of the indices. The justification for inclusion or elimination of available data sources was evaluated, particularly criteria for inclusion of abundance indices. A total of 35 fishery-independent surveys that encountered Spot were reviewed during the assessment. Of these, five met most of the criteria for inclusion. The criteria included the length and continuity of the time series, the spatial scale (population-wide/regional/local) and the constancy of survey methodologies. The Panelists agreed index selection criteria were adequate and suitably applied. The base model application (Catch-Survey Analysis or CSA Model) used indices of abundance for Age 0 and Age 1+ Spot from two sources, the NMFS NEFSC Groundfish Trawl Survey and the NCDMF Pamlico Sound Trawl Survey. The effect of index selection was explored through sensitivity runs.

Some potential data sources were not considered during the assessment, including fishery-dependent catch rate indices and annual effort estimates from the commercial and recreational fleets. It was not mandatory to include these inputs in the assessment, and some reviewers would not recommend including fishery-dependent indices in assessment models if high quality fishery independent indices are available. However, the availability of fishery-dependent catch-per-unit-effort (CPUE) inputs may have facilitated better interpretation of the commercial and recreational catch series in the context of increasing stock biomass predicted by the assessment model. I.e. catch in some fisheries has declined while the indices of abundance have increased. Typically, catches are expected to increase with increasing population abundance.

All but one of the indices of relative abundance were developed using a statistical standardization (e.g., delta-logormal, negative-binomial). The exception was the NMFS/Northeast Fisheries Science Center fall groundfish trawl survey which was a non-standardized, nominal index developed from design-based estimates. The Panelists noted many expert reviewers recommend a non-standardized approach, but also suggested that a standardized index be developed for future assessments, and that the sensitivity of the model results to these alternative approaches be considered.

Spot are an important component of Atlantic coast scrap (bait) landings. Quantifying the amount of spot landed as scrap fish along the coast is problematic due to the limited availability of sampling data. The Panel agreed the methods used during the assessment appear reasonable, but noted the resulting estimates from the scrap fishery are quite uncertain due to the number of required assumptions. However, as the magnitude of scrap landings is very small relative to total removals, the Panel agreed the assessment is not likely to be sensitive to these assumptions.

2. Evaluate methods used to develop discard and bycatch estimates.

Estimates of spot discard rates in South Atlantic shrimp trawl fisheries were developed using discard rate data from the Shrimp Trawl Observer Program to estimate the magnitude of discard rates and the SEAMAP Trawl Survey to estimate the trend of discards prior to (1989-2000) and during the observer program (2001-2014). Discard rate estimates were then applied to effort data from state trip ticket programs and the South Atlantic Shrimp System (SASS) to estimate total discards in these fisheries from 1989-2014 (Walter and Isley, 2014). Discard rates were applied to effort estimates summarized by "strata" (combinations of factors included in the model). Because there were no observer data before Bycatch Reduction Devices (BRDs) were required in the penaeid shrimp fishery, discard estimates prior to 1997 were adjusted for the reduction in catch due to the required use of certified BRDs on observed tows. Adjustments were based on a weighted average of Atlantic croaker catch reductions in the Gulf of Mexico shrimp trawl fishery estimated depending on the distance of fisheye BRDs from tie-off rings (Helies et al. 2009).

Discards from the Mid-Atlantic gill net and trawl fisheries were estimated using observer data from the Northeast Fisheries Science Center's Northeast Fisheries Observer Program (NEFOP) and At-Sea Monitoring Program (ASM). Annual ratios of observed discarded spot to observed landings of all species by gillnets and bottom trawls were calculated, then applied to reported gillnet and bottom trawl landings of all species to estimate total discards of spot.

The Panelists recognized discard/bycatch estimates are unusually uncertain due to data insufficiencies, but agreed the method used to develop estimates of spot bycatch from the southern shrimp trawl fishery was current, supported, and similar (or identical) to methods used in SEDAR assessments of South Atlantic king mackerel, and Gulf of Mexico red snapper, king mackerel, gray triggerfish and domestic sharks. The Panel also agreed the method used to estimate spot discards from the commercial and recreational fisheries were acceptable given the available data, and noted the relatively small contribution of these discards to total removals.

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

a. Evaluate the choice and justification of the preferred model(s). Was the most appropriate model (or model averaging approach) chosen given available data and life history of the species?

The Assessment Team chose a catch-survey analysis (CSA) model as their preferred base model. The Review Panel agreed with the choice of the CSA model over the surplus production model because the CSA model uses more of the available information. However, the Review Panel also noted that the CSA (and production model) results did not follow the same pattern as catch-curve estimates of the total mortality rates; catch curves indicated relatively stable total mortality, while the CSA model indicated declining total mortality. Additionally, the CSA model had some difficulties reconciling differences in trends between the two primary indices, which was why the models that allowed catchability to change over time improved the model fits. The NMFS trawl survey index of Age 1+ biomass indicated about a 6.4X increase between 1990-1993 and 2011-2014, while the SEAMAP index of Age 1+ biomass indicated about a 10% increase. Given the inherent conflicts in the data (among the indices) and the conflicts between the catch curve and CSA estimates of Z, a more complicated model that can make fuller use of the available data may allow future progress in spot stock assessments. In future efforts the Assessment Team may want to consider simple age-length structured models (e.g., SCALE) that can use all of the available data or a simple Stock Synthesis model.

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

The Assessment Team applied CSA and surplus production models. The base CSA model and the base surplus production model generally agreed on the trend and stock status determinations. The approach of fitting multiple models is considered best practices.

c. Evaluate model parameterization and specification (e.g., choice of CVs, effective sample sizes, likelihood weighting schemes, calculation/specification of M, stock-recruitment relationship, choice of time-varying parameters, plus group treatment).

In general, the Review Panel agreed the approaches used by the Assessment Team for specifying the assessment models were appropriate and followed best practices. The Assessment Team used the approach of adding a constant to the CV of the index for each year to represent the process error in the indices of abundance. CSA models separate the population into pre-recruits (Age 0) and fully recruited (Age 1+) age classes, which seems reasonable for a short-lived species like spot. The Assessment Team used a maximum age approach combined with a Lorenzen size-based adjustment to calculate natural mortality, M. The CSA model included a Beverton-Holt stock-recruitment relationship. The base CSA model did not include time-varying parameters, but allowing catchability to change was explored in sensitivity analyses. These choices by the Assessment Team appear to be well founded and follow standard practices used in the region. One of the assumptions that caused fairly large changes in the results was whether catchability changes were allowed in the indices. See TOR 8 below for research recommendations from the Review Panel that would support research to better understand the need for time-varying catchability.

4. Evaluate the diagnostic analyses performed, including but not limited to:

a. Sensitivity analyses to determine model stability and potential consequences of major model assumptions

Sensitivity analyses were conducted for both assessment models including evaluations of sensitivity described in the Stock Assessment Report Table 95 for the CSA and sensitivity analyses around the assumed initial level of biomass relative to carrying capacity (i.e., initial depletion) for the surplus production model. During the Review Workshop, the Panel requested additional sensitivity runs for the penalty on total instantaneous mortality (Z) that was calculated outside the CSA, and alternative initial depletion levels. The CSA was sensitive to the time trend in Z because the catch curves indicated a relatively stable Z, but the model without the time series of Z values estimated declining Z. The model that used the time series of Z values resulted in the stock being overfished in the last year, while the CSA that only used mean Z during the period resulted in no concerns about stock status. The surplus production model was sensitive to the assumed initial depletion level and values of initial depletion below about 0.16 of carrying capacity resulted in the stock being overfished in the most recent year. However, the overfishing determination was less sensitive to these alternative assumptions.

b. Retrospective analysis

The Assessment Team conducted retrospective analyses for the base CSA model. The results of the retrospective analyses indicated no concerning patterns in estimates of static Spawning Potential Ratio (sSPR), fishing mortality, recruitment, or spawning stock biomass. The calculated Mohn's Rho statistics and visual inspection of plotted patterns are standard best practices used by the Assessment Team.

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

The Assessment Team used asymptotic standard errors and Markov Chain Monte Carlo (MCMC) to estimate uncertainty for the CSA. The Review Panel thought the asymptotic standard errors were a reasonable approach for quantifying uncertainty for this model. Although MCMC is a justifiable approach, there were some issues with its diagnostics for select parameters (particularly the parameters of the stock-recruitment relationship). Specifically, the chains for these parameters showed very high autocorrelation that indicates the distribution derived from the MCMC chain likely does not fully describe the distributions for those parameters.

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

The Review Panel recommends against using specific estimates of stock biomass, abundance, and exploitation for management purposes because of the sensitivity of the models to several key assumptions. Specifically, the differences in estimates were quite large between CSA models that used the time series for Z from models that only used the average Z value and indicated the estimates of abundance and fishing mortality rates were very sensitive to a range of reasonable assumptions. The surplus production model showed similar issues, but the key assumption appeared to be the initial level of depletion in 1989.

Despite the inability to arrive at a new base model, several patterns seem clear from the data:

1) The indices of abundance for spot appear to be stable or increasing across most of the stock's range.
2) Catch appears to be stable or declining over time.
3) The combination of these two patterns indicates it is likely that fishing mortality rates have also declined over time such that the relative status of the stock in the most recent years is likely better than it was in the late 1980s – early 1990s.
4) Shrimp fishery effort and spot bycatch magnitude appear to be declining. The Stock Assessment Subcommittee should consider adding shrimp bycatch estimates to annual Traffic Light analyses. The new estimates of shrimp bycatch are a notable improvement from previous spot assessments and should be reviewed annually given their substantial contribution to overall spot removals and mortality.

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

The Spawning Potential Ratio (SPR) reference points appeared to be appropriate for the species (30% threshold, 40% target) and are consistent with reference points used for similar species in the region. However, given uncertainties in fishing mortality and biomass estimates exhibited by the sensitivity analyses, stock status cannot be reliably determined. In particular, models with different sets of plausible assumptions resulted in estimates of biomass above and below the limit reference point. The result of whether the stock was overfished in the most recent year depended on how low stock size was at the beginning of the time series. In contrast, all of the models indicated that overfishing is unlikely in the most recent years and that stock size appears to be increasing over the time series.

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

The Panel thoroughly reviewed the research recommendations identified by the Technical Committee, and noted additional research and data collection priorities. Following discussions with the SASC at the Review Workshop, the Panel worked closely with the SASC chair to refine and prioritize a final set of research recommendations, adapted from the stock assessment report and provided here as High or Medium Priorities, within Short-term vs. Long-term research categories.

Short-term

HIGH PRIORITY

- Expand collection of life history data for examination of lengths and age, especially fishery-dependent data sources.
- Organize an otolith exchange and develop an ageing protocol between ageing labs.
- Increase observer coverage for commercial discards, particularly the shrimp trawl fishery. Develop a standardized, representative sampling protocol and pursue collection of individual lengths and ages of discarded finfish.

MEDIUM PRIORITY

- Develop and implement sampling programs for state-specific commercial scrap and bait fisheries in order to monitor the relative importance of Spot. Incorporate biological data collection into program.

- Conduct studies of discard mortality for commercial fisheries. Ask commercial fishermen about catch processing behavior for Sp/Cr when trawl/gillnets brought over the rail to determine if the discard mortality rate used in the assessment is reasonable.
- Conduct studies of discard mortality for recreational fisheries.
- Collect data to develop gear-specific fishing effort estimates and investigate methods to develop historical estimates of effort.

Long-term

HIGH PRIORITY

- Continue state and multi-state fisheries-independent surveys throughout the species range and subsample for individual lengths and ages. Ensure NEFSC trawl survey continues to take lengths and ages. Examine potential factors affecting catchability in long-term fishery independent surveys.
- Continue to develop estimates of length-at-maturity and year-round reproductive dynamics throughout the species range. Assess whether temporal and/or density-dependent shifts in reproductive dynamics have occurred.
- Re-examine historical ichthyoplankton studies for an indication of the magnitude of estuarine and coastal spawning, as well as for potential inclusion as indices of spawning stock biomass in future assessments. Pursue specific estuarine data sets from the states (NJ, VA, NC, SC, DE, ME) and coastal data sets (MARMAP, EcoMon).

MEDIUM PRIORITY

- Identify stocks and determine coastal movements and the extent of stock mixing, via genetic and tagging studies.
- Investigate environmental and recruitment/ natural mortality covariates and develop a time series of potential covariates to be used in stock assessment models.
- Investigate environmental covariates in stock assessment models, including climate cycles (e.g., Atlantic Multi-decadal Oscillation, AMO, and El Nino Southern Oscillation, El Nino) and recruitment and/or year class strength, spawning stock biomass, stock distribution, maturity schedules, and habitat degradation.
- Investigate the effects of environmental changes (especially climate change) on maturity schedules for spot, particularly because this is an early-maturing species, and because the sSPR estimates are sensitive to changes in the proportion mature.
- Investigate environmental and oceanic processes in order to develop better understanding of larval migration patterns into nursery grounds.
- Investigate the relationship between estuarine nursery areas and their proportional contribution to adult biomass. I.e., are select nursery areas along Atlantic coast contributing more to SSB than others, reflecting better juvenile habitat quality?
- Develop estimates of gear-specific selectivity.

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

A benchmark stock assessment is recommended in five years. No assessment updates are called for given challenges with the current model, and the existing annual use of Traffic Light analyses. Despite uncertainty in the assessment model results and an inability to confidently determine stock status, trends in landings and indices do not indicate immediate cause for concern, and therefore do not call for a subsequent new stock assessment in the short-term.

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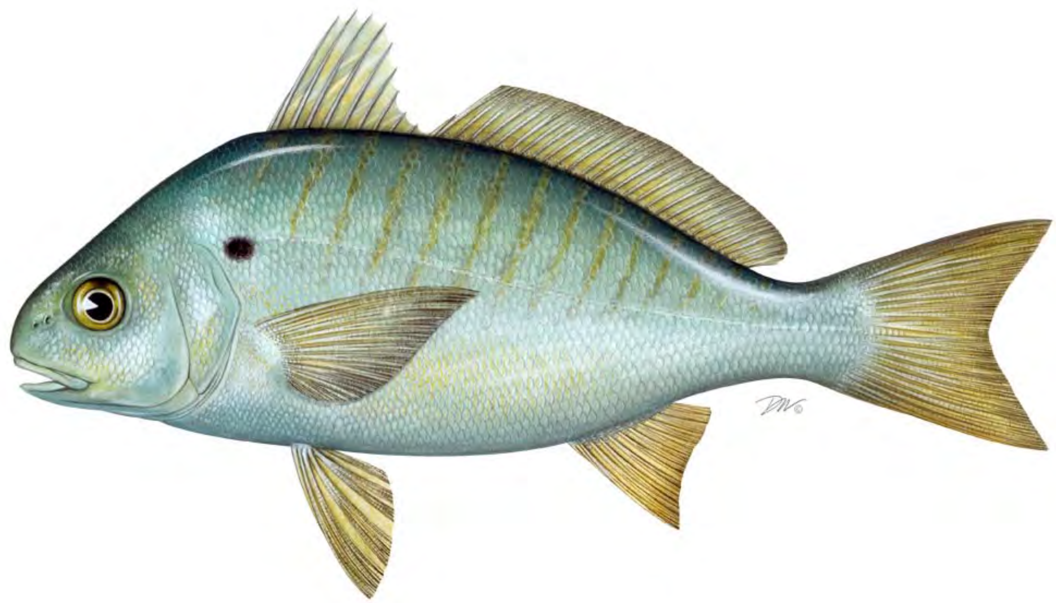
Atlantic States Marine Fisheries Commission

2017 Spot Benchmark Stock Assessment



May 2017

Vision: Sustainably Managing Atlantic Coastal Fisheries

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Atlantic States Marine Fisheries Commission

2017 Spot Benchmark Stock Assessment

May 2017

Prepared by the
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EXECUTIVE SUMMARY

This is the first stock assessment of spot on the Atlantic coast. The management area of spot is the distribution of the resource from New Jersey through Florida (Monroe County). Spot are considered one coastwide stock.

Spot are caught in commercial and recreational fisheries, primarily in the Chesapeake Bay and Mid-Atlantic (New York - Virginia) and South Atlantic (North Carolina - Florida) coastal waters. The majority of annual fishery removals of spot were discards in South Atlantic shrimp trawl fisheries, followed by commercial landings and recreational harvest. Data to estimate discards in South Atlantic shrimp trawl fisheries were available starting in 1989 and the terminal year of data for this assessment was 2014. From 1989-2014, total annual removals of spot from all fishery sources (landings and discards) have ranged from between 4,637 and 57,287 metric tons, or 41 and 1,324 million fish. Removals were relatively large, but variable in the 1990s. Removals since 1997 have been relatively stable, coinciding with the requirement of bycatch reduction devices (BRDs) across shrimp trawl fisheries. The long term mean removals was 12,785 metric tons, or 254 million fish. However, total removals after the peak year that occurred in 1991 averaged 9,399 metric tons, or 158 million fish.

Thirty five fishery-independent surveys that encountered spot were reviewed during the assessment. Biological data from all surveys were used to estimate life history parameters (e.g., growth, maturity). Indices of relative abundance from the NMFS Trawl Survey and the NCDMF Trawl Survey were used in the preferred modified-CSA model. These indices generally show a period of low abundance through the 1990s and early 2000s, followed by increasing abundance in the late 2000s and 2010s. There was a decline across indices in the assessment terminal year (2014).

Both age-0 abundance (914 million fish) and age-1+ abundance (654 million fish) were estimated to be relatively high in 1989. Age-0 abundance remained high through 1991 as age-1+ abundance steadily declined. Total abundance was highly variable through the mid-1990s as age-0 abundance fluctuated drastically. Age-0 abundance (99 million fish) and total abundance (166 million fish) hit a time series lows in 1997. Abundance then fluctuated around an increasing trend through 2013, with the exception of several subsequent poor recruitments from 2006-2009. The 2014 recruitment was relatively poor (205 million fish) resulting in a decline in total abundance, despite increasing age-1+ abundance. Age-1+ abundance in the end of the time series increased close to levels at the beginning of the time series, while age-0 abundance in recent years (excluding the terminal year) increased to about half the magnitude of peak age-0 abundance at the beginning of the time series. Spawning stock biomass followed a similar trajectory as total abundance, generally increasing since 1996 with the exception of the lowest spawning stock biomass of the time series in 2001 (208 metric tons). There was a slight down turn of spawning stock biomass in 2014 (19,032 metric tons), but the estimate was still the second highest of the time series.

Initial fishing mortality was estimated at 1.06 and increased steeply in the next two years. Full fishing mortality then generally fluctuated around a declining trend throughout the time series. Full fishing mortality has remained below 0.50 since 2005. Very low static spawning potential ratios (< 0.2) occurred in the beginning of the time series, when shrimp trawl discards were highest, and during years with large peaks in fishing mortality. Static spawning potential ratios fluctuated around a mean over the last five model years (0.48, 2010-2014) about seven times greater than the mean static spawning potential ratios during years when BRDs were not required (0.07; 1989-1995).

The assessment recommends an overfishing threshold associated with a 30% static spawning potential ratio (F 30%) and a fishing target associated with a 40% static spawning potential ratio (F 40%). The assessment also recommends the equilibrium spawning stock biomass resulting from fishing at F 30% and the recruitment levels estimated from 1996-2014 as a spawning stock biomass threshold and the equilibrium spawning stock biomass resulting from fishing at F 40% and the recruitment levels estimated from 2003-2014 as a spawning stock biomass target. Based on the recommended reference points, overfishing of the Atlantic coast spot stock did not occur in 2014 and the stock was not overfished. The 2014 full fishing mortality was estimated at 0.249, below the threshold (0.5) and target (0.36). The 2014 beginning year spawning stock biomass (2013 end year spawning stock biomass) was estimated at 19,032 metric tons, above the recommended threshold (4,730 metric tons) and target (7,854 metric tons). This stock status determination is reasonable, given the significant decline of discards in South Atlantic shrimp trawl fisheries and the recent increases in relative abundance observed across indices of abundance.

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TERMS OF REFERENCE

For the Spot Benchmark Stock Assessment

Board Approved August 2015

1. Characterize uncertainty of fishery-dependent and fishery-independent data used in the assessment, including the following but not limited to:
    a. Provide descriptions of each data source (e.g., geographic location, sampling methodology, potential explanation for outlying or anomalous data)
    b. Describe calculation and potential standardization of abundance indices.
    c. Discuss trends and associated estimates of uncertainty (e.g., standard errors)
    d. Justify inclusion or elimination of available data sources.
    e. Discuss the effects of data strengths and weaknesses (e.g., temporal and spatial scale, gear selectivity, ageing accuracy, sample size) on model inputs and outputs.
2. Review estimates and PSEs of MRIP recreational fishing estimates. Request participation of MRIP staff in the data workshop process to compare historical and current data collection and estimation procedures and to describe data caveats that may affect the assessment.
3. Develop estimates of spot discards in the South Atlantic shrimp trawl fishery. Develop estimates of bycatch and discards in other fisheries where possible. Characterize uncertainty of all discard and bycatch estimates.
4. Develop models used to estimate population parameters (e.g., F, biomass, abundance) and biological reference points, and analyze model performance.
    a. Describe stability of model (e.g., ability to find a stable solution, invert Hessian)
    b. Justify choice of CVs, effective sample sizes, or likelihood weighting schemes.
    c. Perform sensitivity analyses for starting parameter values, priors, etc. and conduct other model diagnostics as necessary.
    d. Clearly and thoroughly explain model strengths and limitations.
    e. Briefly describe history of model usage, its theory and framework, and document associated peer-reviewed literature. If using a new model, test using simulated data.
    f. If multiple models were considered, justify the choice of preferred model and the explanation of any differences in results among models.
5. State assumptions made for all models and explain the likely effects of assumption violations on synthesis of input data and model outputs. Examples of assumptions may include (but are not limited to):
    a. Choice of stock-recruitment function.
    b. Calculation of M. Choice to use (or estimate) constant or time-varying M and catchability.
    c. Choice of equilibrium reference points or proxies for MSY-based reference points.

   d. Choice of a plus group for age-structured species.
   e. Constant ecosystem (abiotic and trophic) conditions.
6. Characterize uncertainty of model estimates and biological or empirical reference points.
7. Perform retrospective analyses, assess magnitude and direction of retrospective patterns detected, and discuss implications of any observed retrospective pattern for uncertainty in population parameters (e.g., F, SSB), reference points, and/or management measures.
8. Recommend stock status as related to reference points (if available). For example:
   a. Is the stock below the biomass threshold?
   b. Is F above the threshold?
9. Other potential scientific issues:
   a. Compare trends in population parameters and reference points with recent results of the Traffic Light Approach. If outcomes differ, discuss potential causes of observed discrepancies.
   b. Compare reference points derived in this assessment with what is known about the general life history of the exploited stock. Explain any inconsistencies.
10. If a minority report has been filed, explain majority reasoning against adopting approach suggested in that report. The minority report should explain reasoning against adopting approach suggested by the majority.
11. Develop detailed short and long-term prioritized lists of recommendations for future research, data collection, and assessment methodology. Highlight improvements to be made by next benchmark review.
12. Recommend timing of next benchmark assessment and intermediate updates, if necessary relative to biology and current management of the species.

1. Introduction

1.1 Brief Overview and History of Fisheries

Spot (*Leiostomus xanthurus*) are caught in commercial and recreational fisheries, primarily in the Chesapeake Bay and Mid-Atlantic (New York - Virginia) and South Atlantic (North Carolina - Florida) coastal waters. Spot along the Mid-Atlantic coast are generally available to commercial and recreational fisheries from April through October, the bulk being taken from August through October when spot are moving out of estuaries (Pacheco 1962a). In the South Atlantic, spot are caught year round but are most abundant during the fall months (Johnson 2013). Commercially, spot are caught in mixed species or opportunistic fisheries and as bycatch. Historically, haul seines have been used to land the majority of spot, but gillnets have become the dominant gear for spot landings in recent years. During winter, spot are taken in the winter trawl fishery operating off Cape Hatteras, North Carolina (Pearson 1932). Spot bycatch is often discarded at sea or landed as scrap. The North Carolina Division of Marine Fisheries (NCDMF) defines scrap fish as those fish not marketed for human consumption and instead sold for bait, industrial use, or discarded. Spot are a major component of Atlantic coast scrap landings Spot are also one of the most frequent species caught in shrimp trawl fisheries in the South Atlantic (Scott-Denton 2007 and Scott-Denton 2012). Most of these fish are discarded at sea. Generally, a majority of annual recreational catches of spot from hook and line fisheries are harvested. Spot are often kept by recreational anglers to be used as bait, as it is a popular bait species for striped bass recreational fisheries.

1.2 Management Unit Definition

The management area of spot is the Atlantic coast distribution of the resource from New Jersey through Florida (Monroe County).

1.3 Stock Definitions

Spot on the Atlantic coast are considered one coastwide stock due to their migratory behavior (Section 2.1) and the lack of any solid evidence to manage the species on a regional basis (McBride 2014).

1.4 Regulatory History

Historically, any management regulations for spot were left up to the individual states. There have been few regulatory measures enacted by the states for spot (Table 1). States have issued regulations for other species or fisheries that have likely affected spot harvest (Table 2). For example, in North Carolina waters, the elimination of fly-net fishing south of Cape Hatteras (1994), the introduction of bycatch reduction devices (BRDs) in shrimp trawls (1994, by proclamation authority), limits on the incidental catch of finfish by shrimp and crab trawls in inside waters (since 1970s), and culling panels in long haul seines (1999) all likely affected the catch of spot.

The Atlantic States Marine Fisheries Commission's (ASMFC) Fishery Management Plan (FMP) for Spot was adopted in 1987 and includes the states from Delaware through Florida (ASMFC 1987). In reviewing the early plans created under the Interstate Fisheries Management Plan process, the ASMFC found the FMP for Spot to be in need of evaluation and possible revision. Specifically, the ASMFC South Atlantic State/Federal Management Board (Board) found recommendations in the plan to be vague and perhaps no longer valid, and recommended that an amendment be prepared to the FMP for Spot to define the management measures necessary to achieve the goals of the FMP. In August 2009, the Board expanded the initiated amendment to the FMP for Spanish Mackerel to include spot and spotted seatrout, creating the Omnibus Amendment for Spot, Spotted Seatrout and Spanish Mackerel. The goal of the Omnibus Amendment was to update all three plans with requirements specified under the Atlantic Coastal Fisheries Cooperative Management Act (1993) and the Interstate Fishery Management Program Charter (1995). In August 2011, the Board approved the Omnibus Amendment for Spot, Spotted Seatrout, and Spanish Mackerel.

The Omnibus Amendment objectives are to: (1.) Increase the level of research and monitoring on spot bycatch in other fisheries, in order to complete a coastwide stock assessment (2.) Manage the spot population to maintain the spawning stock biomass above the target biomass level. (3.) Develop research priorities that will further refine the spot management program to maximize the biological, social, and economic benefits derived from the spot population. The Omnibus Amendment does not require specific fishery management measures in either the recreational or commercial fisheries for states within the management unit range. However, for years between benchmark stock assessments, the Omnibus Amendment does task the Spot Plan Review Team (PRT) with conducting annual monitoring analysis. This annual analysis has been known as the trigger exercises, where annual statistics were compared to the 10th percentile of the data sets' time series.

In August of 2014, the Board approved Addendum I to the Omnibus Amendment for Spot, Spotted Seatrout, and Spanish Mackerel which altered the method by which the trigger exercises were carried out by the Spot PRT. This Addendum establishes the use of the Traffic Light Approach (Caddy and Mahon 1995, Caddy 1998, Caddy 1999; TLA) within a precautionary management framework for the management of spot. The management framework using the TLA replaces the management triggers as stipulated in the Omnibus Amendment. The Board initiated this addendum at its February 2014 meeting following the development of the TLA report and management memo by the Atlantic Croaker Technical Committee (TC) and Spot PRT. The Spot PRT recommended spot for a benchmark stock assessment with the proposed TLA providing guidance in the interim period. The TLA methodology was extended to develop some additional metrics for comparison to the results of this assessment (Appendix 1, Section 8.3).

The TLA was originally developed as a precautionary management framework for data poor fisheries whereby reference points could be developed that would allow for a reasonable level of resource management. The name comes from assigning a color (red, yellow, or green) to categorize relative levels of different indicators for either a fish population or a fishery. These indicators can be combined to form composite characteristics within similar categories and can include biological indicators, such as growth and reproduction; population level indicators, such as abundance and stock biomass estimates; or fishery indicators, such as harvest/landings and fishing mortality. However, each indicator must be evaluated separately to determine its appropriateness for use in management. In general practice when applying the TLA, the green/yellow boundary is typically set at the long-term mean of the data series reference period (Halliday et al. 2001) of the indicator and the yellow/red boundary is set at 60% of the long-term mean, which would indicate a 40% decline from the series mean. Index values in the intermediate zone can be represented by a mixture of either yellow/green or yellow/red depending on where they fall in the transition zone. Since increasing proportions of red reflect decreasing trends away from the time series mean, the relative proportion of red of the indicator may offer one way of determining if any management response is necessary.

1.5 Assessment History

A formal coastwide stock assessment of spot has not been conducted prior to this assessment. The 1987 FMP recognized the lack of biological and fisheries data necessary for stock assessment and effective management of the resource. A review of available biological data and survey data was conducted through a life history workshop in 2010 to evaluate availability of data for a stock assessment (ASMFC 2010b). It was determined during this workshop that the available data do not support a complex stock assessment model, such as a statistical catch-at-age model, but may support a simpler assessment approach. Commercial and recreational catch and effort data have only been analyzed since 2010 to determine the relationship between landings and abundance via the annual trigger exercises using the TLA.

2. Life History

A review of literature and analyses of available data were conducted to characterize spot life history. For life history analyses, biological samples include paired length-length, length-weight, length-age, and age-maturity data, and sex data. Four commercial, three recreational, and six fishery-independent sources provided these data (Table 3). Descriptions of these sources' sampling and processing methods are provided in the Sections 4 and 5.

2.1 Migration Patterns

Spot larvae have been collected from within estuaries to the edge of the continental shelf (Hildebrand and Cable 1930, Berrien et al. 1978, Lewis and Judy 1983, Warlen and Chester 1985, Hare et al. 1999) from October through May. Larvae were smaller and more numerous offshore (34–128 meters) than inshore (17–26 meters; Berrien et al. 1978, Lewis and Judy 1983, Warlen and Chester 1985). Warlen and Chester (1985) reported that spot larvae may be present at any depth but occurred more frequently near the bottom. However, Lewis and Wilkens (1971) found this to be true only at night. Hare et al. (1999) found spot eggs and yolk sac stage spot at mean depths of 17 meters while older larvae (first and second stage) were typically found at greater mean depths of 20-28 meters.

Direct across-shelf transport has been suggested as the major transport mechanism for larvae of sciaenids and other species along the Mid-Atlantic coast (Nelson et al. 1976, Norcross and Austin 1981, Miller et al. 1984). Spot larvae exhibit this type of cross-shelf transport from the offshore spawning area to nursery habitat in winter and early spring (Govoni and Spach, 1999, Hare et al. 1999). Larval transport from the continental shelf is driven primarily by strong wind events as well as location where larvae were spawned (Hare et al. 1999). However, vertical distribution within the water column has also played a role in the success of larval recruitment, with spot occurring north of Cape Hatteras being transported farther along the Gulf Stream compared to spot transported cross shelf south of Cape Hatteras (Hare et al., 1999). Actual recruitment into estuarine nursery areas from offshore was subject to both vertical movement within tidal cycles as well as fine scale depth patterns within the given estuary (Forward et al. 1999). Spot larvae entered a North Carolina estuary at an average age of 59 days (range 40–74 days) and an average size of 13.6 millimeters (mm; range 11.4 to 15.6 mm; Warlen and Chester 1985). Larvae entered the estuary segregated by age. Recruitment of the new year-class into the Chesapeake Bay occurs in March through May (Norcross 1989). Postlarval spot have been collected in estuarine nursery areas chiefly in April in Delaware Bay (DeSylva et al. 1962), in January and February in the Chesapeake Bay (Welsh and Breder 1923) and North Carolina (Hildebrand and Cable 1930, Tagatz and Dudley 1961, Williams and Deubler 1968, Turner and Johnson 1973, Weinstein 1979, Weinstein and Walters 1981, Lewis and Judy 1983, Warlen and Chester 1985), and from February through May in South Carolina (Shenker and Dean 1979, Bozeman and Dean 1980, Beckman and Dean 1984), Georgia (Music 1974, Music and Pafford 1984), and Florida (Welsh and Breder 1923).

Young-of-year (YOY) spot are largely resident in nursery habitat for the duration of warm weather, but as temperature drops in the fall, they emigrate to deeper estuarine waters and offshore waters (Weinstein and O’Neil 1986). Hildebrand and Schroeder (1928) reported that some YOY overwinter in the deeper waters of the Chesapeake Bay although studies only collected spot from April or May through December in the York River and Chesapeake Bay, respectively (Pacheco 1962b; Markle 1976). YOY spot are found year round in South Carolina in low salinity and brackish waters, but were most abundant during the spring (South Carolina Department of Natural Resources (SCDNR), Unpublished Data).

Adult spot migrate seasonally between estuarine and coastal waters. They enter bays and sounds during spring, but seldom occur as far up-estuary as do the young. They remain in these areas until late summer or fall before moving offshore to spawn or escape low water temperatures (Hildebrand and Schroeder 1928, Roelofs 1951, Dawson 1958, Hoese 1973). A tagging study in Georgia estuaries indicated offshore movement of spot; the longest distance traveled was 118 km (Music and Pafford 1984).

2.2 Diet

The following is a brief summary from the 1987 FMP for Spot (ASMFC 1987), and is included to provide a general description of spot diet. For a more extensive description and references, please refer to the FMP.

Spot are opportunistic bottom feeders that mainly eat polychaetes, small crustaceans and mollusks, and detritus. Spot larvae primarily feed upon copepodid and adult copepods, pteropods, and pelecypods. Juvenile spot, 40–99 mm, fed on micro-bottom surface animals such as ostracods, harpacticoid copepods, ispods, amphipods, minute gastropods, and foraminifera. Isopods, amphipods, and mollusks predominate in the diet of larger spot (>100 mm). Small spot tend to be selective; larger spot are more opportunistic.

2.3 Age

2.3.1 Ageing Methods

Spot have been aged using scales, otoliths, and length frequency analysis. Barger and Johnson (1980) evaluated marks on scales, otoliths, and vertebrae and found that the otoliths possessed the highest potential as age determination structures. Marginal increment analysis indicated that spot annuli on scales were formed in October and November in the Chesapeake Bay (Pacheco 1957), from March through May in North Carolina (DeVries 1982), from April through June in South Carolina (Dawson 1958), and from late February through early April in Georgia (Music and Pafford 1984).

To date, there has not been a formal hard part exchange to evaluate precision or bias of age determinations among agencies ageing spot. There has also not been a formal workshop or efforts to establish a standardized ageing protocol among agencies. Ageing workshops have been held for other species of sciaenids (Atlantic croaker and red drum) and those species have been found to be relatively straightforward to age (ASMFC 2008). Similar protocols have been found to work well with spot.

2.3.1.1 Maryland Department of Natural Resources

The left otolith (the right one is substituted when necessary) is mounted to a glass slide using Crystalbond™ 509, and sectioned using a Buehler IsoMet® Low Speed Saw using two blades separated by a 0.4 mm spacer. The Buehler 15 HC diamond wafering blades are 101.6 mm in diameter and 0.3048 mm thick. The 0.4 mm sections were then mounted on microscope slides and viewed under a microscope to determine the number of annuli. All age structures were read by two readers. If readers did not agree, both readers reviewed the structures together, and if agreement still could not be reached the sample was not assigned an age.

2.3.1.2 Old Dominion University

The otoliths collected through the Virginia Marine Resources Commission's (VMRC) Biological Sampling Program (BSP) are processed and read by the Old Dominion University's (ODU) Center for Quantitative Fisheries Ecology (CQFE). Otoliths are processed following the methods described in Barbieri et al. (1994) with a few modifications. Briefly, the left or right sagittal otolith is randomly selected and attached to a glass slide with Aremco's clear Crystalbond™ 509 adhesive. At least two serial transverse sections are cut through the core of each otolith with a Buehler Isomet low-speed saw equipped with a three-inch, fine-grit Norton diamond-wafering blade. Otolith sections are placed on labeled glass slides and covered with a thin layer of Flo-texx mounting medium.

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

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

2.3.1.3 Virginia Institute of Marine Science

The Multispecies Research Group (MRG) at the Virginia Institute of Marine Science (VIMS) has been ageing spot collected by the group's Chesapeake Bay Multispecies Monitoring and Assessment (ChesMMAP) Trawl Survey and Northeast Area Monitoring and Assessment Program (NEAMAP) Trawl Survey since 2002 and 2007, respectively. Whole otoliths are taken from a subsample of each size class of each species from each tow; these ageing structures are labeled and stored dry at sea.

Upon completion of all field sampling in a given year, each set of whole otoliths of a given species collected by a given survey is assigned a random number, such that location and time of collection are not known during the subsequent processing and assignment of age. Processing protocols for spot follow the methods developed during the ASMFC Atlantic Croaker and Red Drum Ageing Workshop (ASMFC 2008), as they are also similar members of the drum family, Sciaenidae. Specifically, the right whole otolith is selected for each specimen, and a thin (0.3-0.4mm) transverse section is taken through the nucleus of the structure and perpendicular to the sulcal groove. The section is mounted on a glass slide using Crystal-bond™ adhesive.

Each transverse section is viewed under a dissecting microscope (12x magnification), and the number of annuli on the structure is recorded. Each is read independently by three different readers, where one individual is assigned as the "senior" reader. This individual is typically the most experienced in the ageing of the species under consideration. Following the reading of the structures, ages are assigned to each fish (for each of the three reads) based on the number of annuli on the structure and the time of capture. Since mark formation (annuli deposition) typically occurs during the early to mid-summer period, the age of specimens collected prior to June is given by the number of annuli present plus one, while those collected in June or later are assigned an age equal to the number of annuli present.

After ages are assigned to each read, a final age is determined for each fish by taking the mode of the three independent assigned ages for that specimen. If no mode exists (i.e., all three reads generated different ages), the otolith section for that specimen is re-read by each of the three original readers. If this procedure fails again to produce a mode, the sample is discarded. Upon completion of final age assignments, age data are then incorporated into the appropriate survey database.

2.3.1.4 North Carolina Division of Marine Fisheries

Sagittal otoliths are removed, cleaned, and stored dry in plastic vials. Whole otoliths are read from an image on a high resolution monitor coupled with a video camera mounted in a stereo microscope. Ages are assigned based on the number of otolith annuli viewed. The ageing lab biologist conducts a first read of the whole otolith. The samples are then independently read by the species lead biologist. If any differences are not resolved, the data are omitted.

2.3.1.5 South Carolina Department of Natural Resources

In the laboratory, the left sagittae are viewed under low magnification with a binocular microscope (10X) and marked with a soft lead pencil on the core. These are then embedded in epoxide resin in silicon molds. After the resin has polymerized, the embedded otoliths are glued to a card held in a jig attached to the arm of a low speed saw. The otolith is positioned so that a transverse section ~0.5-mm thick can be taken through the core. The Isomet Saw is equipped with a pair of diamond-wafering blades, separated by a plastic washer so that the section can be taken with a single cut. The resulting section is mounted on a labeled microscope slide with Cytoseal-XLY. After polymerization of the mounting medium, slides are stored in boxes until viewing. These are examined with a Nikon SMZU microscope equipped with a Supercircuits model PC - 23C high resolution camera with transmitted light. The video image is captured by a frame grabber board in a personal computer and is subsequently analyzed with the Image-Pro image analysis software. The following measurements are taken on each otolith section:

1) radius—distance in mm from the center of the core to the edge of the section as measured along the sulcus acousticus
2) a_1—distance in mm from the center of the core to the distal edge of the first annulus
3) a_2—distance in mm from the center of the core to the distal edge of the second annulus
4) a_3 to a_n—distance from the center of the core to the distal edge of the third annulus and from the core to the distal edge of the nth annulus
5) marginal increment—distance from the distal edge of the last annulus to the edge of the otolith section

Some spot otoliths vary with respect to diffuse, undefined marking near the core of the otolith. These diffuse areas are not interpreted as being a ring. The first annulus is considered the first well-defined, opaque band that can be traced around the entire section.

2.3.2 Age Characteristics

Spot is a short-lived species, rarely attaining a maximum age of six years (NCDMF 2005). The maximum lifespan of spot appears to be greater along the Mid-Atlantic coast. Maximum ages reported in the literature include: age 4.5 (290 mm TL) in New Jersey (Welsh and Breder 1923), age 5 (237.5 mm FL) in the Chesapeake Bay (Pacheco 1962b), age 6 (355–369 mm FL) in North Carolina, although fish greater than age 3 were rare (DeVries 1981b), age 3 (210–283 mm TL) in Georgia (Music and Pafford 1984), and age 3 in South Carolina (Johnson 2013). Age 0–2 spot were predominate in populations throughout the range (Pacheco 1962b, Joseph 1972, DeVries 1981a, DeVries 1982, Music and Pafford 1984, NCDMF 2005). A summary of available age data by data source is in Table 3**.**

2.4 Growth

Growth of spot is very rapid. Daily growth rates for juvenile spot range from 0.02–0.04 g/day (Peters et al. 1978, Warlen at al. 1979, Weinstein 1983, Currin et al. 1984). An average of 84% of the cumulative growth of spot occurs within the first year, and 99% occurs by the end of the second year (Piner and Jones 2004). The reported range of lengths were similar throughout the Atlantic coast for most previous studies, though spot reach a greater maximum size in the northern part of the range (i.e., north of South Carolina; 0). Maximum sizes reported in the literature were 33 centimeter (cm) in New Jersey (Welsh and Breder 1923), 34.5 cm in Chesapeake Bay (Hildebrand and Schroeder 1928), and 34.6 cm in Core Sound, NC (DeVries 1982). Estimated relative growth is lower in the south and increases with latitude, with the higher growth rates found in the northern latitudes of the Northeast Atlantic (Johnson 1999).

Identifying an appropriate model describing change in length with age is useful given that many stock assessment models rely on an age-length relationship. Estimates of natural mortality for this assessment were also derived from growth model parameters (see Section 2.7). Several growth models were evaluated during the ASMFC Spot Life History Workshop, but no one model consistently outperformed the other. The broad overlap in length ranges observed from adjacent age classes indicate that there is not a well-defined relationship between these characteristics (ASMFC 2010b). A similar analysis was completed during this assessment with additional data collected during recent years. There were ten data sets with paired length and age data (Table 5). Ages ranged from 0-6 with sizes ranging from 4-36 cm total length (TL). All age data derived from scales or lengths were dropped from the analysis. Models compared were the von Bertalanffy, Richard's, Gompertz, and logistic models using the FSA package in R (Ogle 2016, Table 6). The models were fit to all age-length data combined (regardless of presence or absence of sex data), all age-length data with sex data (males and females combined), and all age-length data with sex data by sex. According to Akaike information criterion (AIC), the von Bertalanffy model fit the data best for the entire and reduced data sets (Table 7-Table 10). Analysis of residual sum of squares (ARSS) was used to compare growth between males and females (Chen et al. 1992). The ARSS method provides a procedure for testing whether two or more nonlinear curves are statistically different. There was a significant difference in growth between males and females ($F_{(3,\ 20105)} = 113.3$, $p < 0.0001$). Model predictions, by sex, are in Figure 1 and Figure 2. Residual plots for the von Bertalanffy fit to the data, by sex, are in Figure 3 and Figure 4. Asymptotic average length (L_{inf}) ranged from 34.4-38.5 cm TL depending on the data set (Table 7). Males had the highest L_{inf} value, while the other groups had a narrower range (34.4-35.4 cm). Growth coefficients (k) ranged from 0.220-0.324. These values are a narrower range than estimates for the von Bertalanffy growth parameters from the Spot Life History Workshop which listed L_{inf} values of 30-46 cm and k values of 0.156-0.648 year $^{-1}$ (ASMFC 2010b).

2.5 Meristics and Conversion Factors

2.5.1 Length-Length Relationship

Measurements of spot length are reported in standard length (SL), fork length (FL), and TL, the definitions of which can be found in Table 11**.** Length conversion factors from the literature and those developed for this assessment from available data sources are reported in Table 12**.** All length data compiled for this report were converted to TL (if TL was not available) using the conversion developed from coastwide aggregated data in this assessment prior to use in any life history analyses.

2.5.2 Length-Weight Relationship

Previously estimated length-weight relationships for spot were available for North Carolina (Hester and Copeland 1975), South Carolina (Dawson 1958), and Georgia (Music and Pafford 1984) (Table 13). For this assessment, parameters of the length-weight relationship were modeled using a non-linear power regression with length in mm and weight in grams (g). There were eleven data sets with available length-weight data (Table 3). A subset of the data sets demonstrated typical allometric growth patterns with a highly significant relationship between length and weight (Table 14). There was no significant difference between male and female spot length-weight relationships estimated from these data sets as tested with ARSS (Table 15). All length-weight data were combined for a coastwide conversion (Table 13) to be applied for conversions in this assessment.

2.6 Reproduction

2.6.1 Spawning Seasonality

Spot is a late fall to early spring spawner. Time of spawning for spot has been estimated from gonadal development and the appearance of larval and post-larval fish. Spawning off the Chesapeake Bay, North Carolina, and South Carolina occurs from October to March (Welsh and Breder 1923, Hildebrand and Schroeder 1928, Lippson and Moran 1974, Colton et al. 1979, Hildebrand and Cable 1930, Dawson 1958, Berrien et al. 1978, Lewis and Judy 1983, Warlen and Chester 1985, Flores-Coto and Warlen 1993, Johnson 2013). DeVries (1982) reported that back-calculated lengths at the first annulus for North Carolina spot with one annulus were bimodally distributed with modes at 94-134 mm TL and 172–206 mm TL. This bimodality may represent two peaks in spawning as length frequencies of trawled age-0 spot from North Carolina estuaries showed a bimodal distribution from June to September (Ross 1980, Ross and Carpenter 1983, Ross and Epperly 1985). Peak spawning in North Carolina and South Carolina occurs in December and January (Warlen and Chester 1985) with the bulk of larval and juvenile fish moving into estuarine nursery habitat from January to April (Johnson 2013). In Georgia, spot spawn from October to April (Dahlberg 1972, Mahood et al. 1974, Music 1974; Setzler 1977). There are no references that estimate individual spawning frequency.

2.6.2 Sexual Maturity

Early studies using gross visual assessment of gonads estimated that spot mature at the end of their second year or early in their third year of life (Hildebrand and Cable 1930, Dawson 1958). Other studies have supported spot maturity occurring at an age of two years for most fish

(Hales and Van Den Avyle 1989, Phillips et al. 1989). Recent histological data indicate that spot can begin to mature before reaching one year in age, with 50% maturity for both males and females occurring between age one and two (Johnson 2013). Both males and females reached 100% maturity by age-2 (Johnson 2013). Reported sizes at maturity have ranged from 14.6-21.4 cm TL on the Atlantic coast (Hildebrand and Cable 1930, Dawson 1958, Hales and Van Den Avyle 1989, Phillips et al. 1989, Waggy et al. 2006, Johnson, 2013).

Of the different data sets available for the assessment, seven of the data sets had information on maturity (Table 3). Only SCDNR and VMRC provided paired age-maturity data for maturity estimates. VMRC uses a maturity schedule (Feigenbaum et al. 1985) that does not differentiate between mature and immature fish and, therefore, only SCDNR data were used for maturity-at-age estimates with a logistic regression model. SCDNR uses the Brown-Peterson et al. (2011) maturity schedule. These data were subset to female samples collected from August-December and assessed with histological methods as opposed to macroscopic methods.

Observed and predicted maturity ogives are in Table 16 and Figure 5. Female spot maturity-at-age-1 (January 1 after their first full year) is estimated to be 0.215. Some spot younger than age-1 are estimated to be mature and 50% maturity was estimated to occur at approximately the beginning of September (age-1.75), consistent with the estimates by Johnson (2013). The estimate of 100% maturity occurs when spot are age-4 and is different from the previous studies, including Johnson (2013), that indicate 100% maturity around age-2. This estimate may be a result of low sample size for fish age-2 and older. The average sample size for fish younger than two years is 36.8 and decreases to 5.9 for fish two years and older.

2.6.3 Sex Ratio

Only one study reporting sex ratio for spot was identified. Hata (1985) reported a 1:1 ratio of females to males for spot occurring in the northwestern Gulf of Mexico.

Combined (Table 17) and age-specific (Table 18) sex ratios of spot were calculated by data set. The chi-square (X^2) goodness-of-fit test with Yate's correction for continuity was applied to test whether the observed sex ratios departed from a 1:1 ratio (Zar 1999). The heterogeneity chi-square analysis was also applied to determine if performing a goodness-of-fit test on pooled data (i.e., all commercial and all fisheries-independent data) would be justified. The null hypothesis of the heterogeneity chi-square analysis is that the individual datasets have the same sex ratios.

The sex ratio (female:male) for spot ranged from 1.014 (50.4% female) to 2.729 (73.2% female) among the individual data sets (Table 17). The highest percentages of females were observed in North Carolina's fishery-independent surveys (73.2%) and Virginia's commercial fisheries data (70.5%). The chi-square goodness-of-fit indicated that the sex ratios derived from all datasets significantly deviated from a 1:1 ratio, except for the Southeast Area Monitoring and Assessment Program (SEAMAP) Coastal Trawl Survey data (X^2 = 0.063, p=0.801). The results of the heterogeneity chi-square analysis suggest that there are significant differences in the sex ratios among the individual commercial fisheries datasets (X^2 = 81.2; df = 2; $P < 0.001$) and that these data sets should not be pooled. The sex ratios of the fisheries-independent datasets were also found to be heterogeneous (X^2 = 672.6; df = 5; $P < 0.001$). These results suggest pooling of all data would not be justified.

The sex ratios-at-age indicated a predominance of females at most ages from commercial fisheries data (Table 18). The age-specific sex ratios tended to be higher for the commercial data than the fisheries-independent data. The majority of the age-specific sex ratios and corresponding X^2 values were found to be significantly different from a 1:1 ratio ($P < 0.01$; Table 18).

It should be noted that the months sampled and the available years of data varies among the individual datasets, so the proportion of females by month was also examined across data sets to determine if sex ratios were relatively consistent across months where data was available (Table 19). The proportion female by month was often around 50% across fishery-independent data sets. The proportion of females was greater than 50% in the majority of months across commercial fishery data sets.

2.6.4 Fecundity

Spot, like all of the sciaenids, are batch spawners and there is very limited information on fecundity of this species. Dawson (1958) calculated fecundity gravimetrically for two spot (15.8 and 18.7 cm SL) caught off South Carolina. The estimated the number of eggs >200 micrometers (µm) in diameter to be 77,730 and 83,900, respectively, but it was not known whether these were representative of fully ripe fish. The average size of oocytes undergoing full oocyte maturation (FOM) stage in other sciaenid species typically range from 700–900 µm (Roumillat and Brouwer 2004, Overstreet 1983), so the Dawson fecundity levels may be an overestimation due to the inclusion of oocytes that would not have developed enough to be spawned during that spawning event. Sheridan et al. (1984) listed batch fecundity in spot from the Gulf of Mexico as ranging from 20,900–514,400 oocytes per ovary, with relative fecundity relating poorly to both length and weight.

2.7 Natural Mortality

A variety of indirect methods were applied to available data to derive estimates of natural mortality (*M*). Approaches for estimating both an age-constant *M* and age-specific *M* were considered.

2.7.1 Age-Constant M Approaches

There have been numerous methods developed to estimate age-constant *M* based on the relationship of *M* to various life history characteristics. Some commonly used methods are based on maximum age (T_{max}) of a population (Hoenig 1983, Alagaraja 1984, Hewitt and Hoenig, 2005). Other approaches use von Bertalanffy growth model parameter estimates (L_{inf} and *K*), as well as T_{max} to determine *M* (Alverson and Carney 1975, Pauly 1980, Ralston 1987, Jensen 1996). Recent work by Then et al. (2015) evaluated different estimators of *M* using various combinations of T_{max}, growth model parameters, and water temperature for greater than 200 independent, direct estimates of *M* in order to determine how well the estimators worked in terms of prediction error. They determined that a T_{max} based estimator performed best among all of the estimators evaluated such that $M = 4.889 * T_{max}^{-0.916}$. If T_{max} was not available, the next best estimator was growth based ($M = 4.118 * K^{0.73} * L_{inf}^{-0.33}$). *M* estimates were made using both T_{max} and growth parameter methods for comparison purposes. Since there was a significant difference in growth between males and females, *M* estimates were made using T_{max} and parameter estimates from the von Bertalanffy growth model for all age data combined, all age data with sex data, and age data by sex (Table 20). The Then et al. (2015) T_{max} method produced the same *M* (0.613 year $^{-1}$) for each data set since T_{max} (six) was the same across all data sets. The *M* estimates using growth parameter estimates were markedly lower than the T_{max} estimates, ranging from 0.336– 0.427 year^{-1} depending on the data set (Table 20).

2.7.2 Age-Specific M Approaches

Lorenzen's (2005) method was used to estimate age-specific *M* of spot. This approach requires estimates of the von Bertalanffy growth model parameters (to translate length to age) and the range of ages over which *M* will be estimated. The age-specific estimates of *M* are scaled such that the cumulative *M* across the selected age range is equal to a "target" *M*. This "target" *M* for spot was set equal to the age-constant *M* estimate from the T_{max} method recommended by Then et al. (2015). Since there was a significant difference in growth between males and females, *M* estimates were made using the parameter estimates from the von Bertalanffy growth model for all age data combined, all age data with sex data, and age data by sex (Table 21).

Estimated *M* rates decrease with increasing age as would be expected. The different data sets had very similar mean *M* for ages 1+ (range of 0.306 – 0.396 year $^{-1}$), with the combined data set having the highest *M* (0.396 year $^{-1}$) and males having the lowest *M* (0.306 year $^{-1}$) which was likely due to the lower von Bertalanffy K parameter estimate for males. Age-specific estimates of *M* based on all available data ranged from 0.356 to 0.542 year^{-1} with a mean of 0.396 year^{-1} and a median value of 0.489 year $^{-1}$.

2.8 Discard Mortality

No studies on spot discard mortality rate were identified. A review of recreational angler discard mortality studies found a median discard mortality of 0.11 and a mean of 0.18 across studies (Bartholomew and Bohnsack 2005). The SAS believes a value approximately in the middle of the range between the median and mean (0.15) is an appropriate approximation of the discard mortality rate for spot in recreational fisheries.

A study on Atlantic croaker, a species similar to spot, by Johnson (2003) determined the immediate (15–30 minutes) survival of discards onboard estuarine commercial shrimp trawlers. His results showed that the survival of Atlantic croaker decreased as time on deck increased—from 40% survival for Atlantic croaker that were on deck less than 20 minutes to 8% survival for Atlantic croaker that were on deck longer than 20 minutes. This study does not take into account mortality due to tow time or increased vulnerability to predation and mortality post discarding. Duration of observed tows from the Southeast Shrimp Trawl Observer Program

(Section 4.1.2.4) ranged from twelve minutes to just under nine hours with a median of three hours. Because there is no information from the observer program on the time discards spent on deck and unknown additional mortality from other causes (e.g., stress during long tow durations, increased vulnerability to predation), 100% discard mortality is assumed for spot discarded in commercial fisheries.

3. Habitat Description

3.1 Overview

Spot are found in estuaries and coastal areas from the Gulf of Maine to the Bay of Campeche, Mexico to depths of at least 205 meters, but are most commonly found from the Chesapeake Bay to South Carolina (Smith and Goffin 1973, Bigelow and Schroeder 1953, Dawson 1958, Springer and Bullis 1958, Phillips et al. 1989, Chesapeake Bay Program 1991, Murdy et al. 1997, Mercer 1987). Larval spot are spawned on the continental shelf off the Atlantic coast and use this habitat as they are transported toward the coast and juvenile nursery habitat. Juveniles use estuarine habitat. As they mature, spot are found on the continental shelf during spawning and inshore, estuarine habitat during warm summer and fall months.

3.1.1 Spawning, egg, and larval habitat

Fall migrations of mature spot to offshore waters were reported from Chesapeake Bay (Hildebrand and Schroeder 1928), North Carolina (Roelofs 1951), and South Carolina estuaries (Dawson 1958). During the migration to offshore habitats, some adults may spawn in estuaries and nearshore on the inner continental shelf during the late fall, if water temperatures remain warm enough (Dawson 1958; Lewis and Judy 1983). Smith (1907) stated that, in North Carolina, spot spawn in the sounds and inlets and Hidebrand and Cable (1930) suggested that spawning occurred in close proximity to inlet passes off North Carolina. However, larval distributions of spot indicate that spawning occurs more heavily in offshore waters of the outer continental shelf (26-128 meters) where temperatures are suitable for spawning and egg development (17.5 to 25ºC; Hettler and Powell 1981) than inshore (14.6-20.1 m; Berrien et al. 1978, Lewis and Judy 1983, Warlen and Chester 1985). Govoni and Spach (1999) found that larval spot occurred on both sides of the frontal zone along the Gulf Stream edge indicating spawning on the outer continental shelf in or along the Gulf Stream frontal boundary, with cross-shelf transport of larvae occurring towards the coast and inshore nursery waters. Ripe spot were collected in depths up to 82 meters off South Carolina (Dawson 1958) and 8-10 miles off the Georgia coast (Hoese 1973). Data indicate that spot spawn further offshore and in deeper waters than other sciaenids (Barbieri et al. 1994).

Newly hatched larvae are likely still close to offshore spawning locations, which have been suggested to be up to or beyond 90 kilometers offshore (Flores-Coto and Warlen 1993). Larvae depend on wind and currents (e.g., warm water eddies) for transportation and do much of their developing in the continental shelf waters during the winter (Able and Fahay 2010). In the winter and through early spring, larval spot ingress into estuarine habitats, often into upper regions of an estuary.

3.1.2 Juvenile and adult habitats

Tidal salt marshes and larger estuaries are recognized primary nurseries for spot (Weinstein 1979, Currin et al. 1984), although juvenile spot have been frequently collected on the inner continental shelf (Woodland et al. 2012). Juvenile spot prefer shallow water areas, less than 8 meters, over fine sediment and in tidal marshes (Phillips et al. 1989, Stickney and Cuenco 1982, Chesapeake Bay Program 1991). Juvenile spot are found from polyhaline to tidal fresh water in nursery areas. Although densities of spot were twice as high in polyhaline marshes versus oligohaline marshes in the York River (O'Neil and Weinstein 1987), patterns in other systems suggest that the production of spot may be highest in lower salinity, upper estuarine habitats (Brackin 2002, Ross 2003). The preferred temperature range of juvenile spot is 6–20°C, with a tolerable temperature range extending from 1.2–35.5°C (Parker 1971; Stickney and Cuenco 1982; Phillips et al. 1989, ASMFC 1987). Juvenile spot can tolerate dissolved oxygen (DO) levels as low as 1.3 milligrams/liter (mg/L), but prefer concentration of 5.0 mg/L or higher (ASMFC 1987; Phillips et al. 1989).

Adult spot are bottom-oriented, and require substrates to forage on epifauna and benthic infauna (Chao and Musick 1977). Adults likely prefer muddy substrates to sand or vegetated substrate, which has been reported for juveniles, although offshore adults will likely utilize sand substrates, which are more common outside of estuaries. Adults are likely tolerant of a wide range of DO, but prefer normoxic conditions (> 4.0 mg/L; Chao and Musick 1977). Adult spot are tolerant of salinities up to 60 parts per thousand (ppt, ASMFC 1987; Phillips et al. 1989) and are more abundant in coastal waters and lower estuaries and less abundant in lower salinity areas, compared to juveniles. Survival in adults dropped to 5% when DO was lowered to 0.6 mg/L, which suggests a strong (lethal) effect of DO below 0.8 mg/L (Burton et al., 1980). Recent work has begun to show that spot actively avoid hypoxic areas and even inhabit the margins of these areas (Campbell and Rice 2014). Hypoxic conditions (< 2.0mg/L) are less common offshore, and thus DO is probably less of a concern for adults than for juveniles.

4. Fishery-Dependent Data Sources

4.1 Commercial Data

4.1.1 Commercial Landings

4.1.1.1 Data Collection and Treatment

Commercial landings data are collected by the National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS; aka NOAA Fisheries) and individual state agencies, depending on year and granter of permit(s) (i.e., state and/or federal). Federally permitted dealers and fishermen must report landings to the NMFS using the appropriate reporting process. Individual states may also have reporting requirements for dealers and fishermen landing in-state and some state agencies conduct biological sampling. The types of information and level of detail collected varies among and within the NMFS and various state agencies. Frequency of reporting also has varied over time. The Atlantic Coastal

Cooperative Statistics Program (ACCSP) provides a summary of reporting frequency by state and year on their website (http://www.accsp.org/data-warehouse).

Commercial landings are also maintained at the ACCSP Data Warehouse. The ACCSP provides quality assurance and quality control measures to ensure data are comparable and accurate. For this assessment, commercial landings data were obtained from the ACCSP Data Warehouse and vetted with state agencies (J. Myers, personal communication, January 7, 2016). Commercial landings by gear are available for all states from 1950-present. Though there have been some landings in states north of New Jersey (New York-Massachusetts), they make up such a small proportion of total commercial landings that details of data collection programs in these states are not provided.

4.1.1.1.1 Survey Methods

4.1.1.1.1.1 New Jersey

Commercial landings for spot are obtained from the NMFS reporting. There is no mandatory state reporting of spot in New Jersey.

4.1.1.1.1.2 Delaware

Delaware Division of Fish and Wildlife monitors the commercial fishery through mandatory monthly logbook reporting. Trip-based data collected from these reports include pounds landed by species, area fished, and gear type.

4.1.1.1.1.3 Maryland

The Maryland Department of Natural Resources (MD DNR) has a mandatory reporting system for commercial fishermen that began in 1980. Catch in pounds, days fished, area fished and amount and type of gear used were reported by month prior to 2006. A daily trip log was phased in from 2002 to 2005 with all fishermen using the daily log for the entire year beginning in 2006. Effort data is only available for 1980-1984, 1990 and 1992 – 2014. Maryland relied on the NMFS for collecting commercial landing data prior to 1980.

4.1.1.1.1.4 Virginia Marine Resources Commission

The VMRC's commercial fisheries records include information on both commercial harvest (fish caught and kept from an area) and landings (fish offloaded at a dock) in Virginia. Records of fish harvested from federal waters and landed in Virginia have been provided by the NMFS. The VMRC began collecting voluntary reports of commercial landings from seafood buyers in 1973. A mandatory harvester reporting system was initiated in 1993 and collects trip-level data on harvest and landings within Virginia waters. Data collected from the mandatory reporting program are considered reliable starting in 1994, the year after the pilot year of the program. The Potomac River Fisheries Commission (PRFC) has provided information on fish caught in their jurisdiction and landed in Virginia since 1973.

4.1.1.1.1.5 North Carolina

Prior to 1978, the NMFS collected commercial landings data for North Carolina. In 1978, the NCDMF 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. North Carolina initiated a Trip Ticket Program (NCTTP) in January 1994 in response to a decrease in the NCDMF/NMFS cooperative reporting and due to an increase in demand for complete and accurate trip-level commercial landings statistics by fisheries managers. A trip ticket is a form used by state-licensed fish dealers to document all transfers of fish from the fishermen to the dealer. These forms collect information such as transaction date, area fished, gear used, and the quantity of each species landed from non-scrap landings. Scrap landings are recorded as bait landings on trip tickets but species is not identified. The data obtained through the NCTTP allow for the calculation of fishery-specific effort (i.e., trips, licenses, participants, vessels) and provide a more detailed record of North Carolina's seafood landings.

4.1.1.1.1.6 South Carolina

Landings of spot in South Carolina were collected by the NMFS through the early 1980s. In 2003, SCDNR instituted a wholesale dealer reporting system that provides monthly summaries from wholesale dealers with weight (and value) of fish purchased per species per month. Spot landed as bycatch and sold from the shrimp trawl fishery are also reported through the wholesale dealer reporting system.

4.1.1.1.1.7 Georgia

Commercial landings of all finfish, including spot, from 1950 through 1988 were collected by the NMFS. In 1989, the Georgia Department of Natural Resources (GADNR) instituted mandatory trip-level reporting for commercial fisheries dealers and fishermen.

4.1.1.1.1.8 Florida

During 1950 through 1984, Florida's commercial landings data were collected from seafood dealers on a monthly basis by the NMFS. In late 1984, Florida agencies involved in the management of natural resources, including fisheries (Florida Fish and Wildlife Conservation Commission, FL FWC), established a trip-ticket (TTK) reporting system, known as the Marine Fisheries Information System, designed to monitor the fisheries productions. When the program first started, data were collected by both the NMFS and through the TTK system to enable a comparison of the new data collection system. In 1986, the TTK system became the official commercial fisheries landings data collection system in Florida after it was determined that the monthly dealer summaries and the detailed TTK information were comparable. The TTK program requires all wholesale and retail seafood dealers to report their purchase of saltwater products from commercial fishermen on a trip-level basis. Dealers report the Saltwater Product License number, the wholesale dealer license number, the date of the sale, the gear used (since 1991), trip duration (time away from the dock), area fished (since 1986, but was mandatory from 1994), depth fished, number of traps or number of sets (where applicable), species landed, quantity landed, and price paid per pound for each trip.

4.1.1.1.2 Biological Sampling Methods

4.1.1.1.2.1 New Jersey

No biological sampling of spot from commercial landings has been conducted.

4.1.1.1.2.2 Delaware

No biological sampling of spot from commercial landings has been conducted.

4.1.1.1.2.3 Maryland

Commercial pound nets were sampled by the MD DNR in Maryland's portion of the Chesapeake Bay, and in the mouths of its major tributaries, from the Patuxent River south to the Potomac River. Sampling locations varied each year depending on where the cooperating fishermen's nets were set. The survey has been conducted every year from 1993 to 2014 from late May to early September. Each site was generally sampled once every two weeks, weather, and fisherman's schedule permitting. The commercial fishermen set all nets sampled as part of their regular fishing routine. Net soak time and manner in which they were fished were consistent with the fishermen's day-to-day operations. All spot were measured from each net when possible. In instances when it was not practical to measure all fish, a random sample was measured and the remaining individuals enumerated if possible. From 2008 through 2010 additional samples were obtained at fish dealers. All spot sampled at fish houses were from the pound net fishery, and were measured for length and weighed to the nearest g. All measurements were to the nearest mm TL. The aggregate length frequency is in Figure 6 and annual length sample sizes are in 0. Otoliths, weight to the nearest g, TL in mm and sex were taken during onboard pound net sampling from a subsample of spot beginning in 2007, and during all three years of the fish house survey. The otoliths were processed and aged by MD DNR from 2011 to 2014. The archived 2007 through 2010 otoliths were aged in 2011. Spot sample for age ranged from age-0 to age-2, with the majority being age-1 (Table 23).

4.1.1.1.2.4 Virginia

The VMRC's BSP has been collecting finfish biological data (length, weight, sex, and age) since 1988. The early sampling techniques included manual weighing and measuring of commercially harvested fish and removal of scales.

Several changes in the program have occurred since its inception. These include a switch from mechanical to electronic weighing scales and from manual to electronic fish measuring boards. The switch from mechanical to electronic equipment has increased precision of measurements and allowed a greater rate of sampling. In 1998 the BSP's sampling protocol initiated the removal of otoliths from thirteen important finfish species, including spot. ODU's CQFE Laboratory processes and reads otoliths and provides the VMRC age data for these finfish species.

Biological data sample sizes are in Table 24. Annual and aggregate length frequencies of spot sampled by the BSP are in Figure 7 and Figure 8, respectively. Spot have ranged from 11 to 39 cm TL. Spot sampled for age have ranged from age-0 to age-6, with the majority being age-1 to age-2 (Figure 9).

4.1.1.1.2.5 North Carolina

The NCDMF has sampled marketable landings from major commercial fisheries since 1982. Spot are sampled by gear, market category (in culled catches only), and area fished at local fish houses. Information on area fished and gear type is provided by the vessels captain or crew. As many random samples (usually 50 pound (lb) cartons) as possible were obtained from each market category with more samples being collected from cartons of larger grades since they contained fewer fish. Each sample was weighed to the nearest 0.1 kilogram (kg), individual fish were measured to the nearest mm FL and the total number of individuals was recorded. Annual length frequencies of spot sampled from all non-scrap landings (gears combined) are in Table 25. If the number of individuals in a carton were too numerous to measure, at least 30 were measured and the remainder counted. Subsamples of spot are purchased from the major commercial fisheries to excise otoliths for age determination. Sagittal otoliths have been collected since 1997. Each month, samples (n=10) are distributed across the length range in 20-mm length classes starting at 100 mm FL.

The NCDMF initiated sampling of scrap fish in 1986. Staff samples at least one-half basket (≈12 kg) of the scrap fish from each catch. The sample is sorted by species and weighed (kg). All individuals in the sample are measured for FL or TL to the nearest mm. Annual length frequencies of spot sampled from scrap landings (gears combined) are in Table 26. If the catch of a particular species is exceptionally large, a random subsample of at least 30 individuals is taken for measurement, and the remaining fish are counted.

4.1.1.1.2.6 South Carolina

No biological sampling of spot from commercial landings has been conducted.

4.1.1.1.2.7 Georgia

No biological sampling of spot from commercial landings has been conducted.

4.1.1.1.2.8 Florida

In Florida, biological samples from the commercial fisheries were limited to sample lengths (and, occasionally, to sample weights) of individual spot intercepted through a Trip Interview Program (TIP) at fish houses. While spot is included on the list of species to be sampled, they are only sampled “as available” due to its low priority and the small amounts that are generally landed. Commercial length data of spot were collected since 1992. Annual length sample sizes range from 2 (2005, 2010) to 3,620 (1993; 0). The length frequency from combined gears and years is in Figure 10.

4.1.1.1.3 Catch Estimation Methodology

Reporting of commercial landings in weight is treated as a census, so final reported values are assumed to equal total commercial landings in weight. State-specific commercial landings in weight were converted to numbers with biological sampling data from commercial landings or, if there was no biological sampling of commercial landings, biological sampling of recreational harvest from the Marine Recreational Fisheries Statistics Survey (MRFSS) and/or Marine Recreational Information Program (MRIP; Section 4.2.1). Individual weights or length frequencies and length-weight relationships were used for conversions, depending on the biological data available. Conversion were done at the level of detail permitted by the data to account for differences in size composition and/or mean weight (e.g., by year and gear). Conversions were done for landings from 1981-2014, as there was no fishery-dependent biological sampling prior to these years (recreational sampling began in 1981, see Section 4.2.1).

4.1.1.1.3.1 New Jersey

4.1.1.1.3.1.1 Commercial Landing Numbers

Landings in weight were converted to numbers by applying the wave specific annual average weights estimated for New Jersey from the MRIP and MRFSS, where possible. Average weights by wave from the Mid-Atlantic were used for waves and years when there was no average weight estimated by the MRFSS and MRIP for New Jersey alone. For waves when there is minimal recreational or commercial catches (wave 2 and wave 6, March-April and November-December, respectively) the Mid-Atlantic average weight over all years was used. For waves with no recreational sampling (wave 1; January-February), the Mid-Atlantic average weight over all years from waves 2 and 6 combined was used.

4.1.1.1.3.2 Delaware

4.1.1.1.3.2.1 Commercial Landing Numbers

Landings in weight were converted to numbers using the MRFSS and MRIP mean weight estimates by wave, where possible. If mean weight estimates were not available by wave, the annual estimate was used.

4.1.1.1.3.3 Maryland

4.1.1.1.3.3.1 Commercial Landing Numbers

Maryland spot landings in pounds were converted to numbers using three gear categories, fixed gear, haul seines, and mobile gear (excluding haul seine). Maryland pound net survey data lengths are randomly selected, but weights are not (only take from aged specimens). Spot pound net data was available for 1993-2014, and was used for conversion of weight to numbers for fixed gear for 1993-2008 and 2010- 2014. Maryland fish house sampling data is randomly selected, since fish are weighed and measured on site. Spot were only sampled in 2009 from the fish house survey (all fish were from pound nets), and these data were used to convert the 2009 fixed gear landings.

Virginia length and weight data were available for 1989 through 2014 for several gears and were used to convert Maryland fixed gear landings from 1989-1992 and all Maryland mobile and haul seine landings from 1989 to 2014. All 1981-1989 landing were converted using MRFSS annual mean weights. The ACCSP landings for those years did not include month, so conversions by wave was not possible. Virginia sampling and Maryland landings did not always match up by month. Since Virginia data was used for most conversions, annual landings were used to reduce the complication of matching sampling and landings data by month. ACCSP had several years with landings with gear reported as “NOT CODED”, the Maryland landings (that did not exactly match in total landings) had all gear coded. Some of the NOT CODED category accounted for the majority of landings, therefore, the Maryland proportion of landings by gear was used to place the NOT CODED landings into gear categories prior to conversion to numbers.

4.1.1.1.3.4 Virginia

4.1.1.1.3.4.1 Commercial Landings Numbers

Since 1989, Virginia has had sufficient biological data for spot to predict number of fish landed by size, separated by year, month, and gear. This was done by taking the number of measured and weighed spot in each length bin and using these relative proportions to divide up the total landings in pounds. If there were small sample sizes for any length bins during this time period, the samples were aggregated across all gears. From 1981-1988, when sufficient data were not available, MRFSS values were used to establish the catch frequencies.

4.1.1.1.3.4.2 Total Scrap Landings

Virginia does not subsample their scrap landings. In order to estimate the amount of scrap landings attributed to spot after 1993, data from North Carolina's scrap landings subsampling program were applied. Specifically, the proportion of spot occurring in North Carolina's scrap landings by month and gear were applied to Virginia's total scrap landings by month and gear to estimate scrap landings of spot. For a few years, certain gear-specific samples were not available. In these cases, the proportions were averaged over other gears within each specific month and applied to the landings.

Because VMRC did not begin collecting any information on scrap landings until 1994, it was necessary to hindcast estimates of scrap landings back to 1981. Annual ratios of spot scrap landings to total unclassified finfish landings from 1994–2014 were calculated for Virginia. The median ratio over 1994–2014 was then computed and used to generate hindcast estimates of scrap landings for 1981–1993 by applying this ratio to total unclassified finfish landings during this time period.

4.1.1.1.3.5 North Carolina

4.1.1.1.3.5.1 Commercial Landings Numbers

Numbers of spot landed were determined by calculating the mean number of individuals per sample by market grade and then expanding that number (by market grade and then summed for all market grades) to the total annual landings recorded for all trip tickets.

4.1.1.1.3.5.2 Scrap Landings

Scrap landings have been subsampled since 1994 to determine the species composition of the scrap landings. The total weight of each species in the scrap fish sampled from a trip is calculated by determining the proportion of that species in the subsample and expanding to the respective species' proportional weight of the total scrap fish for the trip. The number of individuals per species in the scrap fish component is calculated by expanding the number of individuals in the sample to represent the total weight of the species for the scrap fish in the samples. Estimates of total scrap fish landings for individual species are determined by applying the tri-annual ratio of marketable fish to scrap fish in the fish house samples to the reported tri-annual marketable landings. The quantity (weight or numbers) and percentage of scrap fish (total or by species) landed by the fishery was determined by applying the seasonal (six-month periods) weight ratio of marketable fish to scrap fish in the fish house samples to the reported seasonal marketable landings from the NCTTP. The estimated scrap fish quantity is for landed fish and does not account for discards at sea. The reported commercial landings of scrap fish (unclassified for scrap or industrial purposes) from the NCTTP were not used because of inconsistencies in dealer reporting. This ratio method of estimating scrap fish assumes marketable fish are accurately reported to the NCTTP. The percent scrap fish reported was computed on a per sampled trip basis, i.e., the percent scrap fish for each sampled trip was determined and the mean was taken across all trips, thereby accounting for sampled trips with no scrap fish. Each sampled catch was viewed as an independent estimate of scrap fish.

Because NCDMF did not begin collecting any information on scrap landings until 1994, it was necessary to hindcast estimates of scrap landings back to 1981. Annual ratios of spot scrap landings to total unclassified finfish landings from 1994–2014 were calculated for North Carolina. The average ratio over 1994–2014 was then computed and used to generate hindcast estimates of scrap landings for 1981–1993 by applying this ratio to total unclassified finfish landings during this time period.

4.1.1.1.3.6 South Carolina

4.1.1.1.3.6.1 Commercial Landing Numbers

There were no surveys that specifically sampled biological data for spot landed by the commercial fishery. While spot were reported commercially, they were generally only reported as total weight of landings by dealer through the Wholesale Dealer reports. There was some fishery dependent biological data available through the MRFSS and MRIP surveys as well as limited data from the South Carolina State Finfish Survey (SC-SFS). The SC-SFS was discontinued in 2012, as the state took over the MRIP survey and the two surveys overlapped.

In order to estimate the number of fish in the commercial landings, annual number of spot were estimated using the length frequency distribution from the recreational harvest, estimated weight at size from the TL to weight relationship from this assessment, and the total annual weight of landings reported in the commercial landings. The protocol required the length frequency be converted to proportion at length into one cm length bins and then the average weight was estimated at each length bin using the length-weight relationship. The total annual landings in weight was then proportioned across the range of TL frequencies and the estimated weight in that bin was then multiplied by the mean weight of that length bin to get the estimated number of spot in that particular length bin. This was done using the annual length frequencies for each year (1981-2014) and matched with the total commercial landings in weight for that year. One major assumption of this method was that the size frequency distribution in the recreational and commercial harvest were similar.

4.1.1.1.3.7 Georgia

4.1.1.1.3.7.1 Commercial Landing Numbers

There are no surveys that collect size, weight or number of spot landed by the commercial fishery. The available data for spot harvested through the commercial fishery include monthly total number of trips, gear used, and total weight landed. This information was not sufficient to estimate numbers of spot landed each year. The only fishery-dependent surveys that collected weights and numbers of spot harvested in Georgia are the MRFSS and MRIP. Therefore, the mean weight of spot harvested recreationally in Georgia was used to determine the total number of spot harvested by the commercial fishery. This was accomplished by dividing the monthly landings in pounds by the mean weight of spot harvested through MRFSS and MRIP in that same month. There were a number of concerns about using recreational information to determine number of harvested spot through the commercial fishery. First concern was that the gears used for each fishery were either different or gear type was not specified for the commercial landings. Another concern was that there were temporal gaps in the MRFSS and MRIP data, not every wave had recorded weights. To compensate for this concern, if there were no observed weights for spot in a month, the number of fish for the commercial landings was not calculated. Most importantly, since there is not a single data point collected on number, size, or weight of spot harvested through Georgia commercial fisheries, there is no way to determine if these estimates generated using this method have any accuracy. The uncertainty surrounding these estimates are very high. For this reason, it was requested that the SAS consider not using these estimates. Since the amount of landings was so low for the state in years for which landings were being converted (1981-2014; Table 29), removing them altogether should have negligible effects on the stock assessment.

4.1.1.1.3.8 Florida

4.1.1.1.3.8.1 Commercial Landings Numbers

The number of spot landed on the east coast of Florida were converted from landings in weight using annual length frequencies obtained from MRFSS recreational samples (1982–1991) and TIP commercial samples from landings made by gillnets (1992–1995) and various gears during 1996–2001 and 2002–2014, as well as a coastwide length-weight relationship. For each length bin during the sampled periods, the conversion was performed as follows:
(1) Estimation of mean weight by applying a weight-length relationship.
(2) Estimation of (i) the sampled weight by multiplying the number of fish sampled with mean weight and (ii) the proportion of sampled weight frequencies.
(3) Estimation of annual landings in weight by multiplying the proportion of sampled weight with total landings weight.
(4) Estimation of annual landings in number by dividing annual landings weight by mean weight.

4.1.1.2 Trends

4.1.1.2.1 Commercial Landings

4.1.1.2.1.1 Catch Rates

Catch rates were not developed from commercial data for modelling due to the availability of several regional fishery-independent surveys.

4.1.1.2.1.2 Total Commercial Landings

Because spot are short-lived and the majority of annual landings often consists of 1-2 year classes, commercial landings from 1950 to present have fluctuated from 638 to 6,586 metric tons (Table 28, Figure 11**)**. Number of spot landed between 1981 and 2014 has ranged between 3.6 and 26.7 million fish (Table 31, Figure 12). Most spot landings occurring in the Chesapeake Bay and South Atlantic states (Table 29). In 2014, 74% of spot were landed in Virginia, 15% in North Carolina, 8% in Maryland, 1% in Delaware, and less than 1% in New Jersey, South Carolina, and Florida. Landings have been negligible from states north of New Jersey. However, landings in these states have increased in recent years. Spot are harvested by a variety of gears including haul seines, pound nets, gillnets, and trawls (Table 30, Figure 11). From the 1950s to the early 1980s, commercial landings were predominately caught in haul seines. In the 1980s, gillnets became the dominant gear contributing to spot landings and has remained so since. In 2014, 77% of commercial landings were caught by gillnets, 8% by haul seines, 8% by fixed nets, 6% by other gears, and less than 1% by trawls.

4.1.1.2.2 Scrap Landings

4.1.1.2.2.1 Catch Rates

Catch rates were not developed from commercial data for modelling due to the availability of several regional fishery-independent surveys.

4.1.1.2.2.2 Total Scrap Landings

Total scrap landings of spot were stable through the 1980s and early 1990s, increased to the highest values of the time series in the late 1990s, and fluctuated around a declining trend through the 2000s and 2010s (Figure 13). Scrap landings were at the lowest levels of the time series in the final two years. North Carolina made the majority of scrap landings through the 1980s and mid-1990s, both states had similar landings through the late 1990s and 2000s, and Virginia made the majority of scrap landings in the most recent years (Table 32).

4.1.1.3 Potential Biases, Uncertainty, and Measures of Precision

4.1.1.3.1 Commercial Landings

Commercial landing reporting is designed to be a census, so there are no measures of precision for these data.

In Georgia, spot landed by trawls may be sold as unsorted mixed fish along with Atlantic croaker, whiting, and small flounder. In these cases, landings are not identified to species level and Georgia’s estimates of spot landings may be underestimated.

Prior to 1986 in Florida, the NMFS collections of landings were most effective for fisheries where the majority of landings were made at the large-volume wholesale dealer outlets. Spot were a low-value species that were landed in small amounts at smaller fish houses so there may have been negative bias (underreporting) in the early commercial landings of spot.

4.1.1.3.2 Scrap Landings

The scrap landings combined from North Carolina and Virginia are likely the minimal estimate from the coastwide scrap fishery. There is currently no scrap landing sampling by other states, but it is believed that North Carolina and Virginia account for the vast majority of Atlantic coast spot scrap landings.

4.1.2 Discards

4.1.2.1 Northeast Fisheries Observer Program

4.1.2.1.1 Survey Methods

The Northeast Fisheries Observer Program (NEFOP) is conducted by the NMFS' Northeast Fisheries Science Center (NEFSC) in order to collect data on catch (harvested and discarded), gear, effort, and biological data during commercial fishing trips from North Carolina to Maine by trained fishery observers. The total catch and a subsample of the total catch from each observation (e.g., towed trawl net) are weighed. The observer program is mandatory for federally-permitted vessels which are selected at random for observation during fishing trips. The program began in 1989. Spot is a third tier priority species for both major gears that encounter spot, Mid-Atlantic gillnets and Mid-Atlantic inshore trawls (NEFSC 2016). See the NEFOP website for additional details (http://nefsc.noaa.gov/fsb/program.html).

4.1.2.1.2 Biological Sampling

Each fish from the catch subsample is counted and measured to the nearest cm. Length sampling of discarded spot has been relatively limited, with no spot measured from trawls and gill nets 14 and 18 years out of 26 years of sampling, respectively (Table 33). Spot discarded from gillnets were slightly larger than spot discarded from trawls (Figure 14 and Figure 15). No spot age samples have been collected.

4.1.2.2 North Carolina Shrimp Trawl Observer Study

4.1.2.2.1 Survey Methods

This study is statewide in all state waters (inshore estuarine and nearshore ocean 0-3 miles) and the primary gear is shrimp otter trawls. The sampling concept is a random design and trip ticket data from previous years is used to estimate coverage by area. Data are available from 2007-2014.

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

When possible the total catch weight is obtained for all tows, otherwise the total catch weight is estimated. All weights are recorded to the nearest kg or g, depending on the size of the sample categories being weighed. Shrimp are separated from each net and a total weight is obtained. Every tow is sampled. This sampling goal is adjusted according to the practicality of obtaining quality subsamples. Latitude and longitude are taken on each tow when the net is hauled back.

4.1.2.2.2 Biological Sampling

For large catches, a one-basket subsample (approximately 32 kg) is taken from each net. Finfish in each subsample is examined as follows: weigh total sample, separate to species, enumerate and weigh total of individual species, for commercially important species measure TL or FL of 30-60 individuals of each species and weigh this smaller subsample. The aggregate length frequency of spot observed is in Figure 16. Beginning in August 2012, the at-net mortality of select species (spot, croaker, and weakfish) was obtained. Observers randomly select 30 individuals from each of the species and record the status (dead or alive) and lengths. This is the first data obtained from the sample to offer a baseline for the at-net mortality of these species.

4.1.2.3 Georgia Large Shrimp Trawl Bycatch Observer Study

4.1.2.3.1 Survey Methods

The Georgia Large Shrimp Trawl Bycatch Observer Study was conducted over an eight year period from 1995 to 1998 and 2001 to 2005. The purpose of the study was to gather bycatch information associated with the shrimp trawl fishery. All NMFS protocols for observer bycatch studies were observed (NMFS 1992). A total of 185 tows were sampled aboard 129 individual trips. Field sampling was conducted on-board commercial shrimp trawling trips in the offshore state waters and in the Exclusive Economic Zone (EEZ) off Georgia (beaches extending to 7 miles offshore), targeting selected species to characterize size, age, and genetic structuring, as well as providing estimates of catch rates by season. After gaining permission from the captains of these vessels, two on-board observers accompanied the captain and crew on a trip. The observers recorded information on each vessel including the vessel code, tow number, date, vessel name, length, identification number, year model, construction, weight, horsepower, and crew size. In addition, records of the economic costs of the trip, such as fuel, oil, ice, food and wages were documented. The type of net used in each application was noted and the specifications on each TED and BRD were recorded. Just prior to deploying the net, the observers recorded the latitude and longitude and the time of day. After completing the tow, the observers again recorded the latitude and longitude as well as the exact time the net was removed from the water. The shrimp, crabs, and fish were then sorted into different groups for examination. The shrimp were weighed and their numbers were estimated when necessary. The fish and crabs were counted and weighed by species.

4.1.2.3.2 Biological Sampling

For the core target species, which includes weakfish, Atlantic croaker, and spot, lengths were recorded for every specimen, while age and genetic samples were collected from a predetermined number of the samples. Sizes of spot ranged from 5.3 to 24.3 cm TL with an average size of 12.8 cm TL. The aggregate length frequency of spot sampled from 1995-2005 is in Figure 17. Otoliths and fin clippings obtained from core target species were sent to the South Carolina Department of Natural Resources for analysis (Ottley et al., 1998).

4.1.2.4 Southeast Shrimp Trawl Observer Program

4.1.2.4.1 Survey Methods

The South Atlantic component of the Southeast Shrimp Trawl Observer Program (SESTOP) began as a voluntary shrimp trawl bycatch observer program implemented from North Carolina to Florida through a cooperative agreement between NMFS, the Gulf and South Atlantic Fishery Management Councils, and the Gulf and South Atlantic Fisheries Foundation, Inc. to characterize catch, as well as evaluate BRDs. Total discards, total shrimp catch, and a subsample (one basket per net, or approximately 32 kg) for species composition and biological sampling is taken from each observed net. Beginning in 2008, the program became mandatory in the South Atlantic and NMFS-approved observers were placed on randomly selected shrimp vessels. The voluntary component of the observer program also continued. Penaeid shrimp (primarily inshore) and rock shrimp (primarily offshore) fisheries in the South Atlantic are covered by the observer program. Observed coverage is allocated by previous effort, or shrimp landings when effort data are not available. Based on nominal industry sea days, observer coverage of South Atlantic shrimp trawl fisheries ranged from 0.2-1.4% and totaled 0.9% from 2007-2010 (see Scott-Denton (2012) Table 1). Number of observed tows are in Table 34. See Scott-Denton (2007) for more details on the voluntary component of the SESTOP and Scott-Denton et al. (2012) for more details on the mandatory SESTOP.

4.1.2.4.2 Biological Sampling

Biological information, such as length and weight of bycatch species, is collected from the subsample of total catch in observed nets. Very limited biological sampling has been conducted for spot. Only 698 spot have been measured for length, caught from just twenty three tows on three trips occurring from October to November in 2003. Lengths ranged from 13 to 23 cm FL (Figure 18). No spot age samples have been collected.

4.1.2.4.3 Trends

Spot is typically one of the most prevalent bycatch species, often outweighing and/or outnumbering individual species of shrimp (see Scott-Denton (2007) Figure 9, Figure 11, Table A2 and Scott-Denton (2012) Table 9, Table 11, Table 12, Figure 6). Discard rates have been variable, but have generally increased over the time series (Figure 22).

4.1.2.5 South Atlantic Shrimp System

4.1.2.5.1 Survey Methods

Detailed catch and effort statistics from commercial shrimp fishing trips were collected and processed by a cooperative effort between the South Atlantic states and, beginning in 1982, the NMFS' Southeast Fisheries Science Center (SEFSC). Data collection began in 1978 in North Carolina and Georgia, 1979 in South Carolina, and 1981 in Florida. Data are available by year, month, state, and port. Florida and North Carolina quit collecting data for the South Atlantic

Shrimp System (SASS) after 1992. The data are maintained by the NMFS. See Gloeckner (2014) for more details on the SASS.

4.1.2.6 Discard Estimation Methods

4.1.2.6.1 Mid Atlantic Trawl and Gillnet Discards

Observer data from the NEFOP were used to develop annual ratios of observed discarded spot to observed landings of all species by gillnets and bottom trawls. Ratios were then applied to reported gillnet and bottom trawl landings of all species to estimate total discards of spot from 1989-2014. The SAS investigated effort data from Vessel Trip Reports (VTRs), but deemed these data unreliable for discard estimates due to data caveats. For example, it was unclear how fishers interpreted certain data fields such as hours fished for trawl nets and whether or not these data fields are interpreted consistently among fishers through time. Orphanides and Palka (2007) also note issues with inconsistent and incomplete gillnet effort from VTRs. VTRs are only required for federally-regulated species.

Commercial landings are reported to the state where they are landed and initial review of the NEFOP data indicated that observed spot discards did not occur on trips landing in ports north of New York. Therefore, all NEFOP observations from trips that landed in ports from North Carolina to New York were used to estimate ratios and ratios were applied to all landings reported from North Carolina to New York. NEFOP data used in this analysis are summarized by year and gear in Table 35 and Table 36. The number of observations by NMFS statistical area (Figure 19) are in Table 37. Spatial distribution of observations are in Figure 20 and Figure 21.

Annual geometric mean ratios of discarded Atlantic croaker to landed Atlantic croaker were used in the 2010 Atlantic Croaker Stock Assessment. These ratios require excluding any trips where the species of interest was not discarded and landed and were deemed unreliable for Atlantic croaker by the Peer Review Panel (ASMFC 2010a). This methodology has the potential to bias ratios high by excluding zero discard trips and bias ratios low by excluding trips where the species was not landed, but was discarded. This method also decreases sample size. For this assessment, annual ratios by major gear type (gillnets and bottom trawls; Table 38) were calculated as the ratio of the mean discards of spot per observation (i.e., tow or net set), in pounds, to the mean landings of aggregated species per observation, also in pounds (Equation 1).

$$Equation\ 1: R = \frac{\bar{D}}{\bar{L}} = \frac{\sum_1^n D_i}{\sum_1^n L_i}$$

This ratio estimator includes all observations with observed landings of any species, including those where no spot were discarded. The variance of the ratio estimator was calculated with Equation 2 (Pollock et al. 1994).

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

It is assumed that discarding rates during observed trips are representative of overall discarding rates in these fisheries. Small sample sizes of positive observations precluded developing ratios at finer resolution (e.g., by state or season).

Annual mean weights were calculated as the total number counted from subsamples divided by the total subsample weight and were applied to the discard estimates in weight to derive discard estimates in numbers. In years with no observer data, averages of adjacent year observations were pooled to estimate ratios. In years with no preceding observer data, averages of the closest two year period were used. Spot discard subsamples from gillnets were particularly sparse, so data were pooled over all years to estimate discards in numbers.

Landings of all species combined by gillnet and bottom trawl gears (Table 39) were provided by ACCSP by year and state landed from North Carolina through New York. Some landings are not available at the gear level (“NOT CODED”). These landings were partitioned into trawl and gillnet landings by calculating the annual proportion of landings by these gear categories and then apply these proportions to the “NOT CODED” landings. Total landings by year and gear are in Table 35 and Table 36.We are assuming that vessels landing north of New York and South of North Carolina discard no spot.

Ratios estimates and variances are in Table 40 and Table 41. A discard mortality rate of 100% is assumed for both gillnet and trawl discards of spot (Section 2.8).

4.1.2.6.2 Shrimp Trawl Discards

Estimates of spot discard rates in South Atlantic shrimp trawl fisheries were developed using discard rate data from the SESTOP to estimate the magnitude of discard rates and the SEAMAP Trawl Survey (Section 5.2) to estimate the trend of discards prior to (1989-2000) and during the observer program. Discard rate estimates were then applied to effort data from state trip ticket programs and the SASS to estimate total discards in these fisheries from 1989-2014 following the methods used by Walter and Isley (2014). The SAS also evaluated the NCDMF observer study data, but the addition of these data resulted in negligible changes to shrimp trawl discard estimates. Only weight data from NCDMF were considered reliable and the SAS was cautioned against using the count data. Due to the negligible impact and lack of count data, the SAS agreed that NCDMF observed data should not be used for South Atlantic shrimp trawl discard estimates.

Only discarded spot are recorded by shrimp trawl observers, so no adjustments are needed to account for fish landed. Observer data were subset to exclude operation codes X, M, H, and J (Appendix 2) because these observations were not considered reliable (e.g., net was dumped overboard without recording catch data). Observations with all other operation codes were included under the assumption that these observations are representative of effort in the shrimp trawl fisheries. Observed nets with disabled BRDs after the requirement of BRDs were also dropped from the analysis. BRDs were required in federal penaeid shrimp fisheries in 1997 under Amendment 2 to the Shrimp Fishery Management Plan for the South Atlantic Region (SAFMC 1996) and federal rock shrimp fisheries in 2005 under Amendment 6 to the Shrimp FMP (SAFMC 2004). State BRD regulations generally fit these time frames.

Trends in catch rates (number of fish/hour fished) of the SEAMAP Trawl Survey and the SESTOP are in Figure 22 and generally track well during overlapping years. Spatial coverage of both surveys overlap throughout most of the sampled ranges (Figure 23). Catch rates by tow from the combined data sets are in Figure 24 and Figure 25.

Discard rates in weight were modelled with the delta-lognormal method (Lo et al. 1992) and discards in numbers were modelled with a negative binomial generalized linear model (GLM). The delta lognormal method combines a lognormal GLM used to predict discard rates of positive observations and a binomial GLM to predict the probability of a positive observation, with effort as an offset variable. The final discard rate is the product of the response variables from these two models. The negative binomial GLM predicts the number of fish caught per observation with effort as an offset variable. Distributions of the response variables for each model are in Figure 26 and Figure 27. Factors considered in the models were year, data set, depth zone, state, and season. Data sets included observer data from the rock shrimp (observer project types W, X, Y) and penaeid shrimp (observer project types A, C) commercial fisheries and fishery-independent data from SEAMAP Trawl Survey tows. Depth zones were less than or equal to 10 meters (=<10m), greater than 10 meters to 30 meters (10-30m), and greater than 30 meters (>30m). All SEAMAP tows were conducted in the shallowest depth zone, while the majority of observer tows were in the shallowest depth zone. State borders were defined by the latitudes used by Scott-Denton et al. (2012). Seasons were December through March (offseason) and April through November (peak season). There are decreases in catch rates during June due to a reduced number of SEAMAP tows (Figure 28), but the seasons were defined to align with shrimp fishing relative to operation in nearshore waters throughout the time series. Shrimp fishing in nearshore waters where catch rates are expected to increase has generally started as early as April and lasted through November. Discard rate data by factor are summarized in Table 42 and Table 43.

Model structure was evaluated with stepwise deletion of factors and the model with the lowest AIC was selected as the final model. Final model summaries are in Table 44-Table 46. All factors were retained for both models (Table 47 and Table 48).

Effort data are available from trip ticket systems from Florida (1986-present), Georgia (2001-present), South Carolina (2004-present), and North Carolina (1994-present) and the SASS from 1978 to the year trip ticket programs were implemented in each state, with the exception of North Carolina. There was a gap from 1992-1993 in North Carolina when data were not available from either a trip ticket program or the SASS. Trip counts were provided by state, year, month, and gear following the methods described in Gloeckner (2014) with a slight modification to eliminate some duplicate reporting issues in Florida (D. Gloeckner, personal communication, April 18, 2016). Code for this "standardized" data query is in Appendix 3. The monthly number of trips in North Carolina in 1993 are estimated as the average of the two adjacent years (1992, 1994). Average hours fished per trip and average number of nets fished per tow by state and year were used from NMFS Sustainable Fisheries Branch (2012) and are originally from trip ticket data. Averages were used before trip ticket data were collected and also for 2011-2014. Fishing hours were calculated as the product of total number of trips, average hours fished per trip, and average number of nets fished per tow. Effort is summarized by state and year in Table 49 and by month in Figure 29. As effort was only available by state, year, and month, some assumptions were made to partition the effort among depth zones and fisheries. The proportions of observations from the observer data by depth zone were applied to overall effort, assuming that the observer data is representative of fishing effort at depth and that fishing effort at depth is static over time. A similar assumption was then made to partition the effort data into fisheries. The proportions of observations in each depth zone allocated to each fishery were applied to the effort data in the respective depth zone. Proportions used to partition effort are in Table 50.

Discard rates were applied to effort estimates summarized by "strata" (i.e., combination of factors included in the model). Standard errors (SEs) of discard estimates made with negative binomial GLMs were estimated with the predict.glm function in the R package stats (R Core Team 2015).

Because there were no observer data before BRDs were required in the penaeid shrimp fishery, discard estimates for penaeid shrimp trawl effort prior to 1997 were adjusted for the reduction in catch due to the required use of certified BRDs on observed tows. Adjustments were based on a weighted average of Atlantic croaker catch reductions in the Gulf of Mexico shrimp trawl fishery estimated depending on the distance of fisheye BRDs from tie-off rings (Helies et al. 2009). The adjustments of spot discard estimates were based on the Atlantic croaker adjustment, as the SAS was unaware of any BRD estimates for spot. 99.6% of observer trips used fisheye BRDs. BRDs in the observed trips ranged from 6 to 21 feet from tie-off rings. Catch reduction estimates were available for BRDs <9 feet (69.7% reduction), 9-10 feet (0% reduction), and 10-11 feet (17.2% reduction) from the tie off rings. There was no estimated reduction for fisheye BRDs greater than 11 feet from the tie-off rings, so the estimate for the 10-11 foot category was used for the proportion of nets greater than 11 feet from the tie-off rings. The proportion of observed trips that fell into the categories of <9 feet, 9-10 feet, 10-11 feet, and >11 feet were 0.22, 0.28, 0.31, and 0.20, respectively. The weighted average adjustment was 0.23 (i.e., discards = unadjusted discards*1/(1-adjustment)). We assumed that observed trips were representative of BRDs used in the fisheries.

All discarded spot were assumed to be dead or to have died post-release (Section 2.8).

4.1.2.7 Discard Trends

4.1.2.7.1 Mid Atlantic Trawl and Gillnet Discards

4.1.2.7.1.1 Total Mid-Atlantic Trawl and Gillnet Discards

Discard estimates are in Table 51 and Table 52 and Figure 30 and Figure 31. Discards from trawls generally make up a larger proportion of the discards than gillnets in Mid-Atlantic fisheries. Discards in numbers of fish for gillnets range between 0 and 59,271 with a median of 2,769, while discards for trawls range between 0 and 25,326,383 with a median of 58,682. Discards in numbers for gillnets range between 0 and 50,021 pounds with a median of 2,336 pounds, while discards for trawls range between 0 and 5,740,647 pounds, with a median of 10,831 pounds. Estimates for both gears are highly variable, with an increasing trend for gillnets and no discernable trend for trawls. The trawl estimates in the first two years are significantly higher than any other year in the time series. There were several very large discard:landings ratios in tows observed these years (one in 1989, five in 1990), inflating the estimates (Table 53). The relative magnitude of the trawl discard estimate for 1989 is similar to the relative magnitude of the NMFS Trawl Survey (Section 5.1) catch rate in 1989 indicating very high relative abundance that was available to these fisheries, though these two sources do not agree on the relative magnitude in the 1990 estimates. The observer data were checked for errors and none could be confirmed, so the SAS agreed that these estimates should not be adjusted.

4.1.2.7.2 Shrimp Trawl Discards

4.1.2.7.2.1 Total Shrimp Trawl Discards

Final discard estimates are in Table 54 and Table 55 and Figure 32 and Figure 33. Mean weights of spot derived from discard number and weight estimates are in Table 56. Discards were relatively high, but decreasing in the early 1990s before BRDs were required. There were particularly high discards of spot in 1991 due to high effort and CPUE (Figure 34). Discards then became relatively stable throughout the 2000s. Despite slightly declining or stable trends in effort during the 2010s, there was an increasing trend in discards. This increase is driven by increasing CPUE over these years. Discard estimates generally follow the same trends as landings by shrimp trawlers (Figure 35).

4.1.2.8 Potential Biases, Uncertainty, and Measures of Precision

4.1.2.8.1 Mid-Atlantic Trawl and Gillnet Discards

Variances of annual ratio estimators were relatively large, resulting in CVs that averaged 0.63 and 0.47 for gillnets and trawls, respectively (Table 40 and Table 41). The relatively large variances were not unexpected given the low sample size of observations and high variances of landings and discards in many years (Table 35 and Table 36). Although variances of these estimates were often large, the estimates make up a small proportion (<3%) of total annual fishery removals (Section 4.3, Figure 59).

4.1.2.8.2 Shrimp Trawl Discards

Shrimp trawl discard estimate 95% confidence intervals are in Table 54 (millions of fish) and Table 55 (metric tons).

4.2 Recreational

Statistics for recreational total catch, catch size composition, and effort were provided by the MRFSS from 1981-2006, MRIP from 2007-2014, and the Southeast Region Headboat Survey (SERHS) from 1981-2014. Additional, though limited, recreational fishery biological sampling has been conducted by several state monitoring programs.

4.2.1 Marine Recreational Fisheries Statistics Survey and Marine Recreational Information Program

Estimates of Atlantic coastal recreational fishing effort (angler hours, number of trips), harvest in numbers and weight, numbers of fish released alive, and catch size composition from 1981-2003 are from the MRFSS and estimates from 2007-2014 are from the MRIP which replaced the MRFSS in 2007.

4.2.1.1 Data Collection and Treatment

4.2.1.1.1 Survey Methods

Data are collected in independent, complementary surveys. The Access Point Angler Intercept Survey (APAIS) and at-sea sampling are designed to collect catch rate data and biological samples. The Coastal Household Telephone Survey (CHTS) and For-Hire Survey (FHS) are designed to collect effort data. Data from the surveys are combined to generate estimates. Angler participation in the MRIP surveys is voluntary. An overview of these surveys from the MRIP website (http://www.st.nmfs.noaa.gov/recreational-fisheries/index) is provided below. See the website and data user handbook at (http://www.st.nmfs.noaa.gov/recreational-fisheries/MRIP-Handbook/MRIP_handbook.pdf) for additional details.

Catch Rate Surveys

APAIS conducts interviews of intercepted anglers at public fishing access sites (e.g., marinas, piers) that collect information on area(s) fished, catch, and angler participation during recreational fishing trips (example questionnaires are available on the MRIP website). Stratified random sampling is used to select access sites in a site registry. Sampling is stratified by state (Florida-Maine), fishing mode, and wave (i.e., bimonthly period). The four fishing modes for stratifying sampling are private boats (including rentals), shoreline (e.g., pier, jetty, etc.), charter boats, and headboats (i.e., party boats). The charter boat and headboat modes were combined as one mode from 1981-1985 and 1981-2003 in the South Atlantic and north of North Carolina, respectively, before being split into separate modes. Headboat anglers in the South Atlantic have not been sampled through APAIS since 1985; data from these anglers are collected by the SERHS (Section 4.2.2). Headboat anglers north of North Carolina have not been sampled by the APAIS since 2004. Catch has been sampled from this mode since 2005 during ride-along, at-sea sampling. Sampling is conducted in six waves, each wave being two consecutive calendar months starting with wave 1 (January and February) and ending with wave 6 (November and December). Sample allocation by wave has varied over time but generally covers all six waves in Florida, with the exception of wave 1 in 1981, all six waves in North Carolina since 1989, waves 2-6 from Georgia-Massachusetts, and waves 2-5 from New Hampshire-Maine. Sampling before 2013 was primarily done during peak daylight hours. In

2013, sampling was allocated to cover non-peak hours. Sampling is post-stratified into marine water areas based on the primary area fished during trips, as reported by anglers. Areas include inshore coastal waters (e.g., bays and tidal rivers), state territorial seas (0-3 miles from the coast), and the EEZ (>3-200 miles from the coast).

The number of spot caught during a trip is recorded as harvested fish observed by the interviewer in whole form (type A catch), fish reported as harvested by the angler but not observed by the interviewer (i.e., bait, filleted, discarded dead on headboats; type B1 catch), and fish reported as released alive (type B2 catch).

Effort Surveys

The CHTS is a stratified random digit dialing telephone survey that includes only households in coastal counties (generally counties within 25-50 miles of coastline, depending on state). The CHTS is stratified by county and wave. Sampling is conducted over a two week period at the end of each wave (last week of the wave and first week of the next wave) and is allocated proportional to county population. The number of telephone interviews conducted during each wave varies based on the amount of fishing activity expected for the season (NMFS, pers. comm.). Information is collected on the number of trips in the previous wave and details about those trips (example questionnaires are available on the MRIP website).

Evaluation of the CHTS found that for-hire modes (headboat and charter boat) were being underrepresented due to the nature of these fisheries (e.g., out of state clients). Beginning in 2005, angler effort on charter boats and headboats from ports north of North Carolina has been sampled through the FHS and several overlapping sampling programs, replacing the CHTS for for-hire modes. The FHS is also a random digit dial telephone survey that uses a vessel directory as a sampling frame. Other overlapping programs include VTRs for New Jersey through Virginia (census logbook) and various state logbook programs.

4.2.1.1.2 Biological Sampling Methods

Length and weight measurements are obtained from type A catch encountered during APAIS intercepts to develop harvest size composition (numbers-at-length) and harvest estimates in weight. Length measurements are FL to the nearest mm and weight measurements are to the nearest tenth of a kg. Information on sample sizes was retrieved from the MRIP and MRFSS raw intercept files. Table 57 include spot length and weight sample sizes obtained during sampling by year.

Beginning in 2004, length measurements have been obtained from type B2 catch encountered during at-sea sampling of headboats (type 9 samples). Sample sizes by year and state are in Table 58.

No age samples (e.g., otoliths) are collected during APAIS sampling or at-sea sampling of headboats.

4.2.1.1.3 Catch Estimation Methods

Effort data from the CHTS and FHS are combined with U.S. Bureau of Census data on population size to estimate the total number of trips in a stratum. The estimated number of trips in a stratum are applied to the spot catch-per-trip for each catch type from APAIS intercepts and at-sea sampling in a stratum to obtain stratum catch estimates. Estimates are summed across strata for total number of spot harvested (A+B1), released alive (B2), or caught (A+B1+B2).

Mean weight of spot weighed during APAIS intercepts for a stratum are applied to the number of harvested spot in the stratum to obtain estimates of harvest in weight. The mean weight of type B1 catch in each stratum is assumed to be the same as type A catch in the stratum. Some strata prior to 2004 have zero harvest estimates in weight and positive harvest estimates in numbers, biasing the weight estimates low. This occurred if all intercepted, harvested fish for the stratum were type B1 catch or if interviewers were unable to obtain weight measurements for type A catch. MRIP methods of imputation using length-weight relationships have been used for addressing missing harvest estimates in weight and there are no strata with missing estimates after 2003. Thirty two strata had zero weight estimates with positive number estimates. To estimate harvest in weight for these strata, individual weight observations for APAIS intercepts were pooled from surrounding strata until a threshold sample size was obtained (n=20). Pooling collapsed over areas, followed by modes, states within sub-region (Mid-Atlantic or South Atlantic), and finally waves until the threshold sample size was reached. Mean weights were calculated and applied to the stratum harvest number estimate to estimate harvest weight. Numbers of harvest weight estimates by pooling level are in Table 59. The original estimate of harvest in numbers, the mean weight from pooling, and the new estimate of harvest in weight are in Table 60.

The proportions of spot measured for length in 1 cm length bins in each stratum are applied to the total number of spot harvested in the stratum to obtain size composition estimates of the harvest in numbers. A custom request was made through MRIP to provide annual size compositions of fish released alive estimated from type 9 length samples collected on headboats. SAS code using the MRIP weighted estimation methodology was provided and annual estimates were generated for years when data were available (2004-2014).

Catch estimate provided by MRFSS and MRIP through the MRIP online data query (NMFS, Fisheries Statistics Division, Silver Spring, MD, pers. comm.) were adjusted for survey design changes through time, according to recommendation by Carmichael and Van Voorhees (2014) and the SEDAR Best Practice Workshop (SEDAR 2016). Adjustments were made by (1) calibrating estimates generated from APAIS intercepts during peak daylight hours only and the MRIP estimation methodology (2004-2012) to 2013 estimates generated from APAIS data collected during peak and non-peak hours and the MRIP estimation methodology, (2) calibrating for-hire estimates generated from CHTS effort data to fire-hire estimates generated from FHS effort data (years are state-specific), and, subsequently, (3) calibrating estimates generated from the MRFSS estimation methodology (1981-2003) to estimates generated from the MRIP estimation methodology (2004-2014). MRFSS estimates from 2004-2007 are already re-estimated with the new estimation methodology when estimates are provided. The combination of for-hire modes from 1981-1985 in the South Atlantic requires splitting the MRFSS estimates into headboat estimates and charter boat estimates so headboat estimates are not double counted when using the preferred SERHS estimates in these years. However, due to the negligible catch estimates from the SERHS (Section 4.2.2), MRFSS for-hire catch estimates in the South Atlantic during 1981-1985 are assumed to be all from charter boats.

Recommendations of Carmichael and Van Voorhees (2014) were followed to calibrate catch estimates for the change in APAIS intercept timing. A ratio of 2013 catch estimated with intercept data from peak hours sampled prior to 2013 to 2013 catch estimated with intercept data from all hours sampled in 2013 was applied to catch estimates from 2004-2012. Ratios were developed at the mode and state level. If a threshold number of intercepts (n=30) were not available at this level, pooling was done until the threshold was reached. Pooling was done by collapsing over states within a sub-region, followed by collapsing over species within a state, followed by collapsing over species and states within a sub-region. If the threshold was still not reached, no adjustments were made to original estimates. Headboat estimates provided by MRIP (i.e., north of NC) were not adjusted because catch rates are developed from at-sea sampling and that sampling design did not change in 2013 (J. Foster, personal communication, March 29, 2016). Catch estimates by pooling levels are in Table 61 and Table 62. The range of ratios for harvest number estimates was 1-4.85 with a mean of 1.53. The range of ratios for harvest weight estimates was 1-8.65 with a mean of 1.60. The range of ratios for released alive estimates was 1-2.60 with a mean of 1.48. For-hire catch estimates from the South Atlantic during 1981-1985 were calibrated using conversion factors (i.e., ratios of effort estimates) developed by Matter et al. (2012), estimates from the South Atlantic during 1986-2002 were calibrated using conversion factors developed by SEDAR (2011), and estimates from the Mid-Atlantic during 1981-2003 were calibrated using conversion factors developed by SEDAR (2008). Estimates were calibrated for the change in estimation methodology according to recommendations of Salz et al. (2012). A ratio of mean catch estimates generated from the two estimation methodologies (i.e., MRIP:MRFSS) during overlapping years (2004-2014) was applied to the MRFSS estimates from 1981-2003. Estimates using the MRFSS estimation methodology were queried from the ACCSP Data Warehouse. Ratios were developed at the broadest scale appropriate for the stock unit (i.e., coastwide), to avoid a deterioration in precision (Salz et al. 2012).

There is a pending change in effort surveys, with the CHTS to be replaced by a mail-based effort survey, but data were not available for this assessment to calibrate estimates generated from CHTS effort data to estimates generated from the new mail effort survey. These data are anticipated sometime in 2018 and should be considered for future updates of this assessment.

To convert recreational releases from numbers to weight, conversion factors were developed from headboat biological sampling (type 9 sampling) from 2004-2014 and annual length-weight relationships developed from the fishery independent biological sampling programs. Numbers of spot released were converted first into lengths using length distributions from the headboat sampling and then converted to weight using year-specific length-weight conversions. For years prior to headboat sampling, a ratio of the average weight of released fish (as calculated from the length frequencies observed on headboats from 2004-2014) to the average weight of harvested fish over that same period was used to estimate the average weight of released fish in years prior to 2004. A ratio of 0.40 was applied to the average weight of harvested fish to calculate the average weight of released fish for the years 1981-2003. The average weight was then applied to coastwide released alive estimates in numbers. This method was also used in the Atlantic Croaker Benchmark Stock Assessment (ASMFC 2010a).

4.2.1.2 Trends

4.2.1.2.1 Recreational Catch Rates (CPUE)

Catch rates were not developed from MRFSS and MRIP data for modelling due to the availability of several regional fishery-independent surveys.

4.2.1.2.2 Recreational Harvest

4.2.1.2.2.1 Total Harvest

Harvest is generally the primary component of MRFSS and MRIP coastwide recreational catch (Figure 36), averaging 65% of annual catch from 1981-2014. Along the Atlantic coast from 1981-2014, annual recreational harvest (type A+B1) of spot has ranged from a low of 4.489 million fish in 1999 to a high of 24.695 million fish in 1983 (Table 63, Figure 36). The harvest has generally declined over the time series. In terms of weight, recreational harvest has ranged between 905 metric tons in 2012 and 3,857 metric tons in 1981 (Table 64, Figure 37). Recreational harvest in 2014 was 8.723 million fish, or 1,328 metric tons. The final, adjusted estimates follow the same trend as the original estimates but are scaled up, on average, by about 2.4 million fish or 405 metric tons (Figure 38 and Figure 39).

The majority of the spot recreational harvest was taken in Virginia and North Carolina (Table 63, Figure 40 and Figure 41), followed by Maryland, South Carolina, Georgia, and Florida. States north of Maryland harvest relatively few spot.

The majority of spot recreational harvest is taken during waves four and five (July-October; Figure 42 and Figure 43) by shore-based anglers and anglers fishing from private or rental boats (Figure 44 and Figure 45). Early in the time series, the majority of spot were harvest from coastal waters, but the majority of harvest since 1986 has generally been from inshore waters (Figure 46 and Figure 47).

4.2.1.2.2.2 Harvest Size Composition

Annual size frequency estimates of coastwide spot harvest are in Figure 48. The figures are subset to a size range between 10 and 31 cm FL, as lengths within this range accounted for at least 1% of the annual harvest for at least one year. The average length of harvested fish generally increased through the 1980s and 1990s (Figure 49). Mean length hit a time series high of 23.2 cm FL in 2004, but has declined since. The mean length of harvested fish in 2014 was 20.4 cm.

4.2.1.2.3 Recreational Releases

4.2.1.2.3.1 Total Releases

Live releases are generally less than recreational harvest in numbers (Figure 36). The estimated number of spot released alive by recreational anglers along the Atlantic coast has been variable, ranging from a low of 2.593 million fish in 2002 to a high of 15.603 million fish in 1981 with a mean of 6.264 million fish (Table 65, Figure 36). Recreational releases in 2014 were estimated at 3.754 million fish. The final, adjusted estimates follow the same trend as the original estimates but are scaled up, on average, by about 1.8 million fish (Figure 50). In terms of weight, recreational releases have ranged from 26 metric tons in 2010 to 156 metric tons in 1981 (Table 66, Figure 51).

Released alive estimates break down similarly to harvest estimates. The majority of fish released alive were captured from North Carolina-Maryland (Figure 52), during waves 3-5 (Figure 53), by shore-based or private or rental boat anglers (Figure 54). The majority of fish released alive throughout the time series were caught in inshore waters (Figure 55).

Fifteen percent of fish released alive were assumed to die post-release as result of factors such as hooking mortality and improper handling (Section 2.8; Table 67).

4.2.1.2.3.2 Release Size Composition

Annual length frequencies of spot released alive by headboat anglers estimated from type 9 biological sampling are in Figure 56. The distributions vary across years with the peak usually occurring between 10 and 20 cm FL.

4.2.1.3 Potential Biases, Uncertainty, and Measures of Precision

The MRIP estimates are based on a stratified random sampling design and so are designed to be unbiased. The proportional standard error (PSE) is provided with MRFSS and MRIP estimates as a measure of precision (Table 68-Table 70). The PSE is the percentage of the SE relative to the catch estimate. PSEs of MRFSS estimates are calibrated similar to catch estimates to address the change in estimation methodology, but the PSE calibration accounts for the additional uncertainty from the estimate of the calibration factor (Salz et al. 2012). A workshop was conducted in 2014 to evaluate acceptable levels of precision for MRFSS and MRIP catch estimates through simulation (ACCSP 2016). PSEs for coastwide catch estimates all fall in or below the general rule of thumb range (40-60%) proposed at this workshop for acceptable levels of precision, with the exception of the released alive estimate in 1981 (72.5%).

4.2.2 Southeast Region Headboat Survey

4.2.2.1 Data Collection and Treatment

4.2.2.1.1 Survey Methods

The SERHS estimates catch (harvest and releases) and effort and provides biological samples of harvested fish from trips on headboats in the South Atlantic (home ports from North Carolina-Florida). The SERHS began in the 1970s, but only data from 1981-2014 were provided. This matches the time series of the catch estimates from other modes of fishing provided by the MRFSS and MRIP. Estimates of released fish from the SERHS are only available since 2004.

There are two, complementary components of the design for this survey. The first was designed as a census logbook program for captain self-reporting of total harvest in numbers and weight, total releases in numbers by disposition (alive, dead, or unknown), and effort on all headboat trips. The logbook program was originally voluntary, but became mandatory. Despite the mandatory nature of the program, there has been known non-reporting that has varied through time. The second component of the survey is intercepts of headboat anglers upon arrival at port following the trip to obtain biological samples from harvested fish. See Brennan (2010) for more details on the SERHS.

4.2.2.1.2 Biological Sampling Methods

Biological sampling is described as a systematic opportunistic sampling of harvest by vessels assigned to port agents. Port agents are instructed to focus on uncommon catches in attempts to collect sufficient sample sizes from all catch. Port agents attempt to sample all vessels they are assigned to proportionally and in a systematic rotation. Fish are measured, weighed and otoliths are collected for ageing.

Only five spot have been sampled for biological data from 1981-2014 and no age structures have been collected from spot.

4.2.2.1.3 Catch Estimation Methods

Catch is summed across headboat logbooks to provide total catch estimates. If necessary, port agents develop correction factors based on records of vessel activity and effort to adjust for non-reporting by applying correction factors to reported catch.

4.2.2.2 Trends

4.2.2.2.1 Recreational Catch Rates (CPUE)

Catch rates were not developed from SERHS data for modelling due to the availability of several regional fishery-independent surveys.

4.2.2.2.2 Recreational Harvest

4.2.2.2.2.1 Total Harvest

Spot are infrequently harvested on South Atlantic headboats and harvest estimates from this survey make a negligible contribution to total fishery removals (Table 71). Only 829 spot were harvested from 1981-2014.

4.2.2.2.3 Recreational Releases

4.2.2.2.3.1 Total Releases

Spot are infrequently caught on South Atlantic headboats and dead release estimates from this survey make a negligible contribution to total fishery removals (Table 72). Only fifteen spot were caught and released from 2004-2014, all with unknown disposition. All of these fish were assumed to die post-release. Due to these negligible numbers during the available time series, releases from 1981-2014 were assumed to be zero.

4.2.2.3 Potential Biases, Uncertainty, and Measures of Precision

No measures of precision were provided with catch estimates.

4.2.3 Maryland Headboat Creel Survey

4.2.3.1 Survey Methods

An onboard headboat creel survey was conducted from 1997-2000 from June through September. The survey focused on Atlantic croaker, spot and weakfish. Anglers were queried as to whether or not they would like to participate in the survey. Each creel clerk surveyed a maximum of six anglers. Total fishing time was determined from the time fishing began until the lines were removed at the last fishing location.

4.2.3.2 Biological Sampling

All spot caught by participating anglers were measured to the nearest mm TL and whether it was harvested or released was recorded.

The time series mean TL of harvested spot was 23.1 cm (n=7,606; Figure 57). Annual mean lengths of harvested spot ranged from 22.0 to 24.3 cm, with sample sizes ranging from 510 to 2,966 fish per year.

The time series mean TL of spot released alive was 15.8 cm (n=480; Figure 57). Annual mean lengths of released spot ranged from 15.3 to 17.2 cm, with sample sizes ranging from 20 to 328 fish per year.

4.2.4 Virginia Marine Resources Commission Marine Sportfish Collection Project

The VMRC's Marine Sportfish Collection Project began in 2007. Chest freezers, bags, and information cards were placed at high activity fishing facilities so that fishermen could donate freshly filleted carcasses with head and tail intact. Bags are collected by the VMRC staff and processed for biological information. Participating anglers receive a shirt, hat, or tape measure as incentive to donate carcasses. When the project began in 2007, freezers where placed at three bait and tackle shops and by 2010 freezers were at seven locations across Capeville, Hampton, Poquoson, Norfolk, and Virginia Beach. Only four spot have been collected through this sampling program (Table 5).

4.2.5 South Carolina Freezer Program

The SCDNR Inshore Fisheries group has run a fish wrack collection program where carcasses of spot were obtained from voluntary contributions of fish "wracks" (the remains of fish after filleting). The samples were collected using freezers for anglers to place the fish wracks in with corresponding catch information at their convenience. A minimum of four freezers were maintained at locations convenient for anglers throughout the Charleston area where fish wracks could be dropped off. Anglers recorded the date and location of where the fish were caught and included this information with the fish wracks. Only length measurements (TL and

SL) were taken for freezer fish since total weight could not be obtained. Sex and maturity were determined through gross morphological examination and otoliths were removed for ageing. Histological samples were not taken since the specimens had been frozen and cellular integrity of the gonad tissue was compromised. Specimens were collected from 2010-2011 (Table 3).

4.3 Total Removals

Total annual removals of spot from all fishery sources (landings and discards) have ranged from between 4,637 and 57,287 metric tons, or 41 and 1,324 million fish (Table 73 and Figure 58). Removals were relatively large, but variable in the 1990s. Removals since 1997 have been relatively stable, coinciding with the requirement of BRDs across shrimp trawl fisheries. The long term mean removals was 12,785 metric tons, or 254 million fish. However, total removals after the peak year that occurred in 1991 averaged 9,399 metric tons, or 158 million fish.

The majority of annual removals were discards in the shrimp trawl fisheries, followed by commercial landings and recreational harvest (Figure 59). Discards from the shrimp trawl fisheries accounted for 31-70% of annual removals depending on year. Commercial landings accounted for 10-40% most years, while recreational harvest typically accounted for approximately 10% each year. The remaining sources of fishery removals were typically 5% or less of total annual removals over the last 20+ years.

5. Fishery-Independent Data

The SAS reviewed 35 fishery-independent surveys that encountered spot (Table 74). Surveys collect biological data used in spot life history analyses (Table 3), as well as catch rate data used to develop indices of relative abundance/biomass. There are several surveys that cover broad geographical areas relative to the stock range and these are believed to be more representative of coastwide relative abundance/biomass than the localized surveys reviewed. These are generally the same surveys that have previously been determined as having utility for assessment of the coastwide Atlantic croaker stock (ASMFC 2010a), as the two species have similar life histories and are often encountered together. These surveys were further narrowed to five surveys that encounter the full age structure of spot which made them candidate surveys for indices of abundance/biomass for the assessment modelling approaches discussed as the SAS reviewed data limitations for spot during the data workshop (e.g., limited size composition information for fishery removals). In anticipation of the potential modelling approaches discussed and review of the first year of complete removal data (i.e., 1989), the SAS requested indices from 1989-2014 in numbers and biomass, as well as surveys split into age-specific (age-0 and age-1+) indices in numbers, when possible. The five selected surveys and indices evaluated and used in this assessment are described in this section.

Additionally, criteria were developed by the SAS for evaluating each survey to determine which should be included in this assessment. The following criteria was used by the SAS to evaluate the surveys:

1. Time series is at least six years long, the age of the oldest spot in the data for this assessment.

2. Time series is continuous and there have been no changes in methodology or gear.
3. Survey operates within the spot geographic range at a time when the fish are typically available.
4. There are a high proportion of positive tows.

These criteria were used as a guide and, when surveys were used to develop indices, the SAS also considered if the index was correlated with other indices, it provided a conflicting signal to other indices or the catch history, or the index was not representative of the stock unit.

5.1 NMFS Trawl Survey

5.1.1 Survey Design & Methods

In 1963, the NMFS NEFSC implemented a multispecies bottom trawl program, which surveys over a large portion of the Atlantic shelf (hereafter referred to as the NMFS Trawl Survey; Avarovitz 1981, Grosslein 1969). The objective of the program is to monitor trends in abundance and distribution, characterize age/length structure, and better understand the biology and ecology of a wide array of finfish and invertebrate species. The survey uses a stratified random design, with strata based on depth (0.0–9.0 m; 9.0–18 m; 18– 27 m; 27–55 m; 55–110 m; 110–188 m; 188–366 m). Both inshore and offshore strata are sampled. The fall survey is an inshore survey that samples sites from Cape Hatteras to Cape Cod. The area within each stratum is subdivided into one-nautical mile blocks that are selected randomly prior to the sampling trip. The sampling gear is a #36 Yankee otter trawl rigged with rollers, 5-fathom legs, and 1,000- pound polyvalent door. A small-mesh cod-end liner (0.5-inch mesh) is used to retain YOY fish.

5.1.2 Sampling Intensity

The fall component has been conducted consistently since 1972. The number of tows per strata and year are in 0. Tow duration is 30 minutes.

5.1.3 Biological and Environmental Sampling

The catch of each tow is identified, counted, weighed, and measured. When the catch of a particular species is large, a subsample of individuals is measured. Data on sex, maturity, stomach contents, and disease are recorded. Latitude, longitude, gear information, salinity, temperature, weather, and hydrographic parameters are recorded.

5.1.4 Evaluation of Survey Data

Data collected from 1972 onward were evaluated. Prior to 1972, the survey protocol changed several times and not all strata were sampled in all years. The survey protocol was standardized beginning in 1972, and with the exception of some vessel changes, has adhered to that protocol since. An evaluation of the proportion of zero catches indicated that the occurrence of spot has been consistent throughout the duration of the survey (Table 76). Zero tows accounted for 50% of the total tows across these years. When the survey was limited to the fall months, when it predominantly encounters spot, and limited to the years 1989-2014, zero tows accounted for 29% of the total tows. Because this survey encounters spot often in a representative geographic range and has a random statistical design, the SAS supported the use of this survey for developing indices of abundance/biomass.

5.1.5 Development of Estimates

Data from the fall months (September–November) and offshore strata were used to develop an index of relative abundance (number per tow) which was split into age-0 (Table 77) and age-1+ (Table 78) indices (Figure 60). The index was split using the age-length key (ALK; 0) from the NEAMAP Trawl Survey to estimate the relative proportions of the two age groups (0 and 1+) annually from the length frequency distributions. The final annual index value for each age group was estimated as the proportion of the total index attributed to that age group. Since there was no age data collected for spot in the NMFS Trawl Survey, the NEAMAP Trawl Survey ALK was used because both were offshore surveys and the geographic range (New York to Cape Hatteras, NC) matched that of the NMFS Trawl Survey. An aggregate index of relative biomass (kg per tow) for all ages was also developed (Figure 61; Table 80). Sampling frequency varied among years and NMFS strata, making it necessary to pool data across strata in order to generate comparable, non-biased metrics of abundance across years. In 2009 there was a change in the sampling protocol for both gear and vessel for the fall survey with the decommissioning of the RV Albatross and the transition to the RV Bigelow for all future surveys. The RV Bigelow is not able to sample the nearshore strata due to the increased draft of this vessel and the mid-shore strata were not sampled as frequently. For continuity of sampling in the nearshore and mid-shore strata, these areas were taken over in 2008 by the NEAMAP Trawl Survey based out of VIMS. Annual estimates of the survey index for spot were reformatted using only the outer offshore strata in order to maintain continuity and effective use of the time series from 1989-2014. Additionally, stratified mean CPUE for the RV Bigelow for 2009-2014 were converted to RV Albatross equivalent units using reported conversion factors from conversion experiments performed between the two vessels doing side by side tows in 2008 (Miller et al. 2010). Pooling of the offshore strata resulted in five pooled strata arranged into five latitudinally separated regions (Region 1 = most northerly, Region 5 = most southerly).

5.1.6 Trends

5.1.6.1 Size Composition

Annual size compositions before splitting the index varied throughout the time series (Figure 62), although on average from 1972-2014 catch was dominated by 16-17 cm TL spot. The length-frequency distributions suggest the survey has primarily encountered spot ages 0+. Young-of-the-year spot (≤ 9 cm TL) and late (mode at 12–13 cm TL) age-0 spot accounted for 0.24-43.4 % of spot annually depending on the year. Prior to 1991, the proportion of YOY fish was higher (9.9%) versus later years (1991-2014, 5.97%). In 2014, the highest proportion of fish was above average at 19 cm TL.

5.1.6.2 Stage-Specific Indices

Abundance was high in the beginning of the time series and remained relatively low in comparison throughout the 1990s and early 2000s for both stages (Figure 60). Abundance for age-0 and age-1+ increased since the mid-2000s to the highest points in the time series in 2012, only to be followed by a decrease in abundance in 2013-2014.

5.1.6.3 Biomass Index

Relative biomass was at its highest in 1989, followed by a low relative biomass through the early 1990s (Figure 61). Biomass was variable through the 2000s, reaching its highest point in 20 years in 2012 followed by another decline and low point in 2014.

5.1.7 Potential biases, Uncertainty, and Measures of Precision

Measures of precision for the index of abundance (CVs) and biomass (SEs) are in Table 77 and Table 80, respectively. An index of total abundance was calculated and then split into age-0 and age-1+ indices, so the CVs reported for these indices are the CVs for the index of total abundance. The CVs for the index of abundance are relatively small, ranging from 0.026 to 0.311 and averaging 0.089.

5.2 SEAMAP Trawl Survey

5.2.1 Survey Design & Methods

The SEAMAP - South Atlantic (SEAMAP-SA) Coastal Survey (previously known as the Shallow Water Trawl Survey; hereafter referred to as the SEAMAP Trawl Survey) began in 1986 and is conducted by the SCDNR Marine Resources Division (MRD). This survey has provided long-term, fisheries-independent data characterizing the seasonal abundance and biomass of all finfish, elasmobranchs, decapod and stomatopod crustaceans, sea turtles, horseshoe crabs, and cephalopods that are accessible by high-rise trawls. The sampling area extends from the coastal zone of the South Atlantic Bight (SAB) between Cape Hatteras, North Carolina, and Cape Canaveral, Florida. The survey uses a stratified random design, where strata are delineated by the 4-m depth contour inshore and the 10-m depth contour offshore. A total of 102 stations are sampled each season within 24 shallow water strata. In previous years (1989–2000), stations in deeper strata—at depths ranging from 10 to 19 m—were also sampled in order to gather data on the reproductive condition of commercially important penaeid shrimp. Those strata were abandoned in 2001 in order to intensify sampling in the shallower depth zone. The R/V Lady Lisa, a 23-m wooden-hulled, double-rigged, St. Augustine shrimp trawler owned and operated by the SCDNR, is used to tow paired 22.9-m mongoose-type Falcon trawl nets, without TEDs. The body of the trawl is constructed of #15 twine with 47.6-mm stretch mesh. The cod end of the net is constructed of #30 twine with 41.3-mm stretch mesh and is protected by chafing gear of #84 twine with 10-cm stretch “scallop” mesh. A 91.4-m three-lead bridle is attached to each of a pair of wooden chain doors, which measure 3.0 m × 1.0 m and to a tongue centered on the headrope. The 26.3-m headrope, excluding the tongue, has one large (60 cm) Norwegian “polyball” float attached top center of the net between the end of the tongue and the tongue bridle cable and two 22.3-cm PVC foam floats located one-quarter of the distance from each end of the net webbing. A 1-ft chain drop-back is used to attach the 89-ft footrope to the trawl door. A 0.6-cm tickler chain, which is 0.9 m shorter than the combined length of the footrope and drop-back, is connected to the door alongside the footrope. Each net is processed separately and assigned a unique collection number.

5.2.2 Sampling Intensity

Multi-legged cruises are conducted in the spring (April–May), summer (July), and fall (October). Trawls are towed for twenty minutes, excluding wire-out and haul-back time, exclusively during daylight hours (1 hour after sunrise to 1 hour before sunset).

5.2.3 Biological and Environmental Sampling

After each tow, the contents of each net are sorted to species or genus, and the total biomass and number of individuals are recorded for all species of finfish, elasmobranchs, decapod and stomatopod crustaceans, cephalopods, sea turtles, xiphosurans, and cannonball jellies. Only total biomass is recorded for all other miscellaneous invertebrates and algae, which are treated as two separate taxonomic groups. Where a large number of individuals of a species occur in a tow, the entire catch is sorted and all individuals of that species are weighed; a random subsample is processed and the total number is estimated. For large trawl catches, the contents of each net are weighed prior to sorting and a randomly chosen subsample of the total catch is then sorted and processed. In every collection, each of the majority of priority species is weighed collectively and individuals are measured to the nearest cm. When a large number of individuals of any of the priority species are collected in a tow, a random subsample consisting of 30 to 50 individuals is weighed and measured.

Spot otoliths were only collected in 2001 from 745 specimens.

5.2.4 Evaluation of Survey Data

The fall component of the SEAMAP Trawl Survey has been conducted consistently since 1989. An evaluation of the proportion of zero tows (37% of all tows) indicates that the SEAMAP Trawl Survey has regularly encountered spot in the spring, summer, and fall components of the survey. Zero tows were more prevalent during the spring component of the survey (41% of all tows). The length-frequency distributions suggest that the majority of spot captured in the spring, summer, and fall components of the survey are age 0+(Figure 65). YOY fish (< 10 cm) were encountered during the fall survey in most years, but not in very high numbers.

5.2.5 Development of Estimates

An index of relative abundance (numbers per tow) was developed and split into age-0 and age-1+ components (Table 77 and Table 78; Figure 63). The index was split using the ALK (0) from age samples taken in 2003. The ALK was then used to estimate the relative proportions of the two age groups (0 and 1+) annually from the length frequency distributions. The final annual index value for each age group was estimated as the proportion of the total index attributed to that age group. An index of relative biomass (kg per tow) was calculated using data from the fall component (September-November) of the SEAMAP Trawl Survey (Figure 64).

5.2.6 Trends

5.2.6.1 Size Composition

Annual size compositions of spot before splitting the index varied throughout the time series (Figure 65), although on average from 1989-2014 ranged from 12-16 cm TL. The length frequency plots indicate that mostly age 0+ spot are caught in this survey, with some YOY (<10 cm) caught during some portions of the year.

5.2.6.2 Stage-Specific Indices

Abundance was low in the beginning of the time series, with a notable peak in the age-1+ index in 1991. Both stage-specific indices remained relatively low throughout the 1990s and early 2000s for both stages (Figure 63). Abundance for age-0 and age-1+ was high in 2005, only to be followed by a decrease in abundance in 2006-2009. The age-0 index had another large peak in 2010 but decreased the following year and remained low until 2014.

5.2.6.3 Biomass Index

The index of relative biomass for spot indicates that abundance was low in 1989 but increased in the early 1990s (Figure 64). From the mid-1990s to the early 2000s abundance remained low. There was a large increase in 2005 followed by almost a decade of ups and downs in abundance.

5.2.7 Potential biases, Uncertainty, and Measures of Precision

Measures of precision for the index of abundance (CVs) and biomass (SEs) are in Table 77 and Table 80, respectively. An index of total abundance was calculated and then split into age-0 and age-1+ indices, so the CVs reported for these indices are the CVs for the index of total abundance. The CVs for the index of abundance range from 0.126 to 0.538 and averaging 0.289.

5.3 NCDMF Trawl Survey

5.3.1 Survey Design and Methods

The Pamlico Sound Survey (hereafter referred to as the NCDMF Trawl Survey), also known as Program 195 (P195), was initiated by the NCDMF in 1987 to provide a long-term, fisheries-independent database for the waters of the Pamlico Sound, eastern Albemarle Sound, and the lower Neuse and Pamlico rivers. The survey samples fifty-two randomly selected stations based on a grid system (one-minute by one-minute grid system equivalent to one square nautical mile). Sampling is stratified by depth and geographic area. Shallow water is considered water between 6 to 12 feet in depth and deep water is considered water greater than 12 feet in depth. The seven designated strata are: Neuse River; Pamlico River; Pungo River; Pamlico Sound east of Bluff Shoal, shallow and deep; and Pamlico Sound west of Bluff Shoal, shallow and deep. As of March 1989, the randomly selected stations have been optimally allocated among the strata based upon all the previous sampling in order to provide the most accurate abundance estimates (PSE < 20) for selected species. A minimum of three stations (replicates) are maintained in each strata. A minimum of 104 stations are sampled each year to ensure maximum areal coverage. Tow duration is 20 minutes at 2.5 knots using the R/V Carolina Coast, which is equipped with double-rigged demersal mongoose trawls. The R/V Carolina Coast is a 44-ft fiberglass hulled double-rigged trawler owned and operated by the NCDMF. The body of the trawl is constructed of #9 twine with 47.6-mm stretch mesh. The cod end of the net is constructed of #30 twine with 38.1-mm stretch mesh. The tailbag is 80 meshes around and 80 meshes long (approximately 3.1 m). A 36.6-m three-lead bridle is attached to each of a pair of wooden chain doors that measure 1.22 m × 0.0610 m and to a tongue centered on the headrope. A 60-cm "polyball" is attached between the end of the tongue and the tongue bridle cable. A 4.76-mm tickler chain that is 0.90 Section B, Page 38 m shorter than the 10.4-m footrope is connected to the door next to the footrope. Trawl door coverage area is 9.51 sq m. The sampling coverage area is 8,152 sq m and the sampling coverage volume is 13,042 cu m. Environmental data are recorded, including temperature, salinity, dissolved oxygen, wind speed, and direction.

5.3.2 Sampling Intensity

The sampling season has undergone some changes since the survey's inception. Beginning in 1991, sampling has been performed over a two-week period, usually the second and third weeks of both June and September. Sampling now occurs only in the Pamlico Sound and associated rivers and bays.

5.3.3 Biological and Environmental Sampling

All species are sorted, and a total number and aggregate weight is recorded for each species. For target species, thirty to sixty individuals are measured, and total aggregate weights are taken. The catches from each of the two towed nets are combined to form a single sample in an effort to reduce variability.

5.3.4 Evaluation of Survey Data

An evaluation of the proportion of zero catches (10% of all tows) indicated that spot have been regularly encountered during the June component of the survey. Because this survey often catches spot, is statistically designed, and represents a portion of the spot geographic range, the SAS supported its use to develop indices of abundance/biomass.

5.3.5 Development of Estimates

An index of relative abundance (numbers per tow) was developed from the June portion of the NCDMF Trawl Survey and split into age-0 and age-1+ components (Figure 66). Due to fast growth of age-0 spot, length separation of these two age groups was most distinct during June. Spot less than 12 cm were considered age-0 fish and those greater than or equal to 12 cm were considered age-1+.

5.3.6 Trends

5.3.6.1 Stage-Specific Indices

Both age-0 and age-1+ abundance indices for spot from the NCDMF Trawl Survey varied throughout the time series. Both were somewhat lower in the 1990s with larger peaks in the mid-2000s. The highest age-0 abundance was in 2008 and the highest age-1+ abundance was in 2006.

5.3.7 Potential biases, Uncertainty, and Measures of Precision

CVs for the age-specific indices of abundance are in Table 77 and Table 78. The CVs for the indices of abundance are similar, averaging 0.177 and 0.183 for the age-0 and age-1+ indices, respectively.

5.4 ChesMMAP Trawl Survey

5.4.1 Survey Design and Methods

The ChesMMAP Trawl Survey has been sampling the mainstem of the Chesapeake Bay, from Poole's Island, Maryland to the Virginian Capes at the mouth of the bay since 2002. This survey is designed to sample the late juvenile and adult stages of the living marine resources in Chesapeake Bay, and as such the timing of sampling is meant to coincide with the seasonal residency of these life stages in the estuary.

The ChesMMAP Trawl Survey area is stratified into five latitudinal regions, and each region is comprised of three depth strata. Depth strata bounds are consistent across regions, and correspond to shallow (3.0m to 9.1m), middle (9.1m to 15.2m), and deep (>15.2m) waters in the bay. Sampling sites are selected for each cruise using a stratified random design; site allocation for a given stratum is proportional to the surface area of that stratum. A four-seam, two-bridle, semi-balloon bottom trawl is towed for 20 minutes at each sampling site with a target speed-over-ground of 3.5kts. The trawl has a 13.7m headline length, and is made of 15.2cm stretch mesh webbing in the body of the net and 7.6cm stretch mesh in the codend. The codend is not outfitted with a liner which enables the net to be towed effectively at relatively high speeds, facilitating the capture of the target late juvenile and adult stages. Trawl wingspread and headline height are measured during each tow.

5.4.2 Sampling Intensity

ChesMMAP conducts 5 cruises annually, during the months of March, May, July, September, and November. A total of 80 sites are sampled per cruise.

5.4.3 Biological and Environmental Sampling

A number of hydrographic variables (profiles of water temperature, salinity, dissolved oxygen, and photosynthetically active radiation [PAR]), atmospheric data, and station identification information are recorded at each sampling site.

Following each tow, the catch is sorted by species and, if appropriate, by size group within a species. Size groups are not predetermined for each species, but rather are defined relative to the size composition of that species for that tow. As such, size designations and ranges of small, medium, and large for a species may vary somewhat among tows. Such an approach facilitates representative subsampling, and therefore proper catch characterization, for each tow.

A subsample of five spot is selected from each size group from each tow for full processing. Specifically, individual TL (mm), whole and eviscerated weight (kg), sex, and maturity stage are recorded. Stomachs are removed for diet analysis and otoliths are removed for age determination. For specimens not taken for full processing, aggregate weight and individual TL measurements (mm) are recorded by size group.

5.4.4 Evaluation of Survey Data

The ChesMMAP survey encounters spot throughout the year except for March, although the amount of tows with zero spot is higher than some of the other surveys considered at 62%. When limited to May-September cruises, the amount of zero tows decreased to 51% and when limited to only stratum occurring in Regions 4 and 5, the amount of zero tows decreased to 37%. The SAS supported the development of indices using ChesMMAP data in May-September and only in regions 4 and 5 for consideration in the modeling approaches.

5.4.5 Development of Estimates

An index of relative abundance (numbers per tow) and an index of biomass (kg per tow) were developed from the May-September portion of the survey from Regions 4 and 5 (Table 80, Figure 68). The index of relative abundance for a given year was split into age-0 and age-1+ components using ALKs generated by the survey's age data on spot for that year. Specifically, the proportion of age-0 and age-1+ spot in the catch was determined using the associated ALK data for that year (Table 82), and these proportions were applied to the overall index to generate indices for age-0 and age-1+ fish, respectively (Table 77 and Table 78, Figure 69).

5.4.6 Trends

5.4.6.1 Size Composition

Most spot captured in the ChesMMAP survey throughout the year range from 14-20 cm TL (Figure 70) and ages 0 and 1 (Figure 71).

5.4.6.2 Stage-Specific Indices

From 2002-2014, age-0 and age-1+ indices indicate that the highest abundance of both age-classes was in 2006 and has been decreasing since then (Figure 69). The terminal year of 2014 experienced very low abundance of both age-0 and age-1+ indices.

5.4.6.3 Biomass Index

The index of relative biomass for spot developed from the May-September component of the ChesMMAP Trawl Survey in regions 4-5 only indicated that the highest biomass occurred in 2005 and has been on a decline since then (Figure 68). Biomass has been consistently low since 2010 and was at its lowest in the whole time series in the terminal year of 2014.

5.4.7 Potential biases, Uncertainty, and Measures of Precision

Measures of precision for the index of abundance (CVs) and biomass (SEs) are in Table 77 and Table 80, respectively. An index of total abundance was calculated and then split into age-0 and age-1+ indices, so the CVs reported for these indices are the CVs for the index of total abundance. The CVs for the index of abundance range from 0.208 to 0.348 and averaging 0.280.

5.5 NEAMAP Trawl Survey

5.5.1 Survey Design and Methods

The NEAMAP Mid-Atlantic/Southern New England Nearshore Trawl Survey (hereafter referred to as the NEAMAP Trawl Survey) has been sampling the coastal ocean from Martha's Vineyard, MA to Cape Hatteras, NC since the fall of 2007.

The survey area is stratified by both latitudinal/longitudinal region and depth. Depth strata between Montauk, NY and Cape Hatteras are 6.1m-12.2m and 12.2m-18.3m, while those in Block Island Sound and Rhode Island Sound are 18.3m-27.4m and 27.4m-36.6m. It is worth noting that, between Montauk and Hatteras, the outer boundary of the NEAMAP Trawl Survey and the inner boundary of the NMFS Trawl Survey align. Both programs sample in Block Island Sound and Rhode Island Sound.

A four-seam, three-bridle, 400x12cm bottom trawl is towed for 20 minutes at each sampling site with a target speed-over-ground of 3.0kts. The gear is of the same size as and nearly identical in design to that used by the NMFS Trawl Survey, only sweep configuration and trawl door type differ between the two programs. Tow times and tow speeds are consistent between the two programs. The net is outfitted with a 2.54cm knotless nylon liner to retain the early life stages of the various fishes and invertebrates sampled by the trawl. Trawl wingspread, doorspread, headline height, and bottom contact are measured during each tow, and those in which net performance falls outside of defined acceptable ranges are either re-towed or excluded from analyses in an effort to maintain sampling consistency.

5.5.2 Sampling Intensity

NEAMAP conducts two cruises per year, one in the spring and one in the fall, mirroring the efforts of the NMFS Trawl Surveys offshore. Spring cruises begin during the third week in April and conclude around the end of May, while the fall surveys span from the third week in September until the beginning of November. Sampling progresses from south to north in the spring and in the opposite direction in the fall, so as to follow the general migratory pattern of the living marine resources of these regions.

Sampling sites are selected for each cruise using a stratified random design; site allocation for a given stratum is proportional to the surface area of that stratum. A total of 150 sites are sampled per cruise, except 160 sites were sampled in the spring and fall of 2009 as part of an investigation into the adequacy of the program's stratification approach.

5.5.3 Biological and Environmental Sampling

A number of hydrographic variables (profiles of water temperature, salinity, dissolved oxygen, and photosynthetically active radiation [PAR]), atmospheric data, and station identification information are recorded at each sampling site.

Following each tow, the catch is sorted by species and, if appropriate, by size group within a species. Size groups are not predetermined for each species, but rather are defined relative to the size composition of that species for that tow. As such, size designations and ranges of small, medium, and large for a species may vary somewhat among tows. Such an approach facilitates representative subsampling, and therefore proper catch characterization, for each tow.

A subsample of five spot is selected from each size group from each tow for full processing. Specifically, individual TL (mm), whole and eviscerated weight (kg), sex, and maturity stage are recorded. Stomachs are removed for diet analysis and otoliths are removed for age determination. For specimens not taken for full processing, aggregate weight and individual TL measurements (mm) are recorded by size group.

5.5.4 Evaluation of Survey Data

NEAMAP has a statistical, randomly stratified design and does encounter spot throughout the year (65% of all tows were zero), specifically during the fall months (55% zeros). While the SAS was concerned about the length of the time series, indices of abundance and biomass were developed for consideration in modeling approaches.

5.5.5 Development of Estimates

An annual index of relative abundance was developed using data from the NEAMAP Trawl Survey by calculating the geometric mean number of spot caught per standard area swept (i.e., 25,000 m^2) for each year. Calculations were restricted to using catch data from the fall cruises and from tows conducted in Regions 06 to 15 (New York Harbor to Cape Hatteras), which represent the season and locations of consistent spot collections. The index of relative abundance for a given year was split into age-0 and age-1+ components using ALKs generated by the survey's age data on spot for that year. Specifically, the proportion of age-0 and age-1+ spot in the catch was determined using the associated ALK data for that year (Table 83), and these proportions were applied to the overall index to generate indices for age-0 and age-1+ fish, respectively (Table 77 and Table 78, Figure 72). Additionally, an index of relative biomass (kg per tow) was developed from the fall months of the survey (September-November) (Table 80, Figure 73).

5.5.6 Trends

5.5.6.1 Size Composition

Most spot captured in the NEAMAP survey throughout the year range from 14-20 cm TL (Figure 74). Data from the fall portion indicates that most spot caught in this survey are ages 0 and 1 (Figure 75).

5.5.6.2 Stage-Specific Indices

Both the age-0 and age-1+ indices for spot caught in the NEAMAP Trawl Survey show little variability throughout the time series with the exception of 2012 (Figure 72). In 2012, the age-1+ index declines to almost zero and the age-0 index shows high abundance in that year.

5.5.6.3 Biomass Index

The index of relative abundance for spot from the NEAMAP Trawl Survey shows some variability with the highest biomass in 2012 and the lowest in the terminal year of 2014 (Figure 73).

5.5.7 Potential biases, Uncertainty, and Measures of Precision

Measures of precision for the index of abundance (CVs) and biomass (SEs) are in Table 77 and Table 80, respectively. An index of total abundance was calculated and then split into age-0 and age-1+ indices, so the CVs reported for these indices are the CVs for the index of total abundance. The CVs for the index of abundance range from 0.113 to 0.278 and averaging 0.214.

5.6 Index Selection

Association of candidate indices was evaluated with Spearman's rank correlation coefficient, or Spearman's rho (ρ). This is a nonparametric test to evaluate association of two ranked variables over time (i.e., indices of abundance). Associations were evaluated between indices within stages as well as within indices between stages, with the age-0 indices being forward lagged by one year to match the year when these year classes would be indexed by the age-1+ index. It was assumed that age 1 fish are the primary age class in the age-1+ indices when evaluating these associations. There are positive associations within the NCDMF Trawl Survey, NMFS Trawl Survey, NEAMAP Trawl Survey, and ChesMMAP Trawl Survey split indices (Table 84). The SEAMAP Trawl Survey split indices were not associated with each other, but the lagged SEAMAP Trawl Survey age-0 index was positively associated with the NMFS and NCDMF Trawl Survey age-1+ indices. Further visual examination of the split SEAMAP Trawl survey indices suggested that this index was not tracking cohorts when split. For example, there are very large peaks of both age-0 and age-1+ fish in 2005. There does not appear to be any support for such a large increase in relative abundance of age-1+ fish from the preceding year age-0 relative abundance. It is suspected that the splitting method does not reliably partition the catch rates of these two age groups. Visual examination of the trend in the ChesMMAP Trawl Survey indices generally suggested a different trend than the other indices being considered and the SAS suspects that this survey is more reflective of localized relative abundance within the Chesapeake Bay. The

SAS also decided not to include the NEAMAP Trawl Survey in base models because of its short time series relative to the NMFS Trawl Survey that operates parallel to this survey and the potential to confound the modelling approaches and overweight the signal of abundance from the Mid-Atlantic region. Instead, the SAS recommended using the NEAMAP Trawl Survey indices in model sensitivity analysis. The NMFS Trawl and NCDMF Trawl Survey indices were selected as split indices for assessment modelling. These surveys are not positively associated with each other, but the SAS believes the signals are collectively representative of coastwide relative abundance.

The NMFS Trawl and SEAMAP Trawl biomass indices were selected as aggregate indices for assessment modelling because they have previously been used in the TLA and are believed to be representative of the coastwide relative biomass.

6. Methods

Available data guided the choice of modelling approaches for this assessment. Biological sampling from the fishery removals, particularly the dead discards, is a major limitation for spot precluding the development of a reliable time series of catch-at-age data. However, there are estimates of fishery removals in biomass and numbers and several regional surveys indexing the abundance of the entire population age structure that can be partitioned into two distinct groups, or stages, with similar life history characteristics. Single-species models in this assessment include a surplus production model performed in ASPIC (Prager 1994) and Excel and a two-stage, forward projecting model (hereafter referred to as the modified-CSA) with similarities to catch survey analysis (CSA; Collie and Sissenwine 1983) and fully age-structured statistical catch-at-age models.

Neither model is spatially explicit and estimate parameters describing the dynamics and condition of the coastwide stock from aggregated coastwide data. The population dynamics were modelled from 1989-2014. The start year was a pragmatic choice, given data used to generate commercial fishery discard estimates, the vast majority of spot fishery removals early in the time series, are available starting in 1989.

6.1 Surplus Production Model

6.1.1 Model Description

The surplus production model was developed as a secondary, supporting model for spot because of its relatively simple modeling approach. Surplus production models combine the effects of recruitment, growth, and mortality into a single function and assume no size or age structure in the population. It requires a time-series of fishery removals and one or more time-series of catch-per-unit effort from a survey. The non-equilibrium Graham-Schaefer, or logistic, form was used to assess spot (ASPIC; Prager 1994). The model assumes that the population is closed, the environment is constant, abundance indices are proportional to the true population abundance, total catch is known without error, the stock responds instantaneously to changes, and that the intrinsic rate of increase (r) and carrying capacity (K) remain constant.

6.1.2 Reference Point Model Description

The surplus production model estimates maximum sustainable yield (MSY) and the associated MSY-based references points of B_{MSY}, the stock biomass associated with MSY, and F_{MSY}, the fishing mortality that maximizes the yield from the population. These absolute values are usually imprecise (Prager 1994) since they require good estimates of catchability (q). Relative biomass (B_{2014}/B_{MSY}) and relative fishing mortality (F_{2014}/F_{MSY}) can be used to determine overfishing and overfished status.

6.1.3 Configuration

A complete description of inputs for the surplus production model can be found in Table 87, but briefly, this analysis used two fishery-independent surveys, the fall portions of the NMFS Trawl and the SEAMAP Trawl Surveys, as well as the complete fishery removals data.

Coastwide fishery removals from 1989-2014 (Table 73, Figure 58, Figure 59) were calculated in weight (metric tons) and were comprised of commercial and recreational landings, recreational dead discards, commercial dead discards from mid-Atlantic gillnet and trawl fisheries, landings from the scrap fishery, and dead discards from the shrimp trawl fishery (see Section 4).

6.1.3.1 Selection and Treatment of Indices

The surplus production model used the fall portions of the relative biomass indices (kg/tow) developed from NMFS Trawl and SEAMAP Trawl Surveys (Table 80, Figure 61, Figure 64). Indices were weighted equally in the model and were found to be positively correlated (r=0.38) but not significantly (P=0.09).

6.1.3.2 Sensitivity Analyses

The SAS conducted sensitivity runs by including the NEAMAP Trawl Survey as an additional relative biomass index, beginning the model in 1992 after the large peaks in the removal time-series, using alternative formulations of the Pella-Tomlinson model, and including the relative biomass index from the NMFS Trawl Survey only. The base run analysis was also performed in Excel to examine differences from and sensitivities to ASPIC.

6.1.3.3 Projections

The population was projected forward 10 years at a harvest level equal to the 2014 harvest.

6.2 Modified-CSA Model

6.2.1 Assessment Model Description

The modified-CSA was originally developed and subsequently modified for several blue crab stock assessments (Miller et al. 2011, VanderKooy 2013). The version used by VanderKooy (2013) was further modified for this assessment. The two stages for spot are recruits (age-0) and post-recruits (age-1+), according to calendar year ages (January 1-December 31). Unlike the original CSA, the modified-CSA model generates estimates that are not conditioned on catch (i.e., catch is not assumed known without error), can fit to multiple indices of abundance for each stage, does not relate the catchability coefficients of the two stages within a survey, allows for fishing to occur on recruits before the survey, and the population dynamics explicitly involves a stock–recruit relationship. The two-stage population structure and an assumed selectivity-at-stage preclude the need for catch-at-age data. Spot are short-lived and the age data that are available indicate that life history characteristics (i.e., growth, maturity) do not vary much between the majority of fish grouped into post-recruits (ages-1 and 2). The model is implemented in AD Model Builder (ADMB) version 11.2 (Fournier et al. 2012). Model code and data input files are in Appendix 4 and Appendix 5, respectively.

General model definitions and model inputs, population and observation model equations, and likelihood components of the model objective function (negative log-likelihood) are in Table 88, Table 89, and Table 90, respectively. Abundance of both stages is predicted in the initial year (1989) and projected forwarded as a function of total mortality (fishing mortality and natural mortality) and annual recruitment. Prior information on the average total mortality of post-recruits over a range of years can be included in the model to provide guidance on the scale of fishing mortality, and, therefore, the scale of abundance. Recruitment each subsequent year is predicted as a function of the previous year, end-year (December 31) spawning stock biomass through a stock-recruit relationship, parameterized in terms of steepness, and lognormally distributed deviations from the expected relationship. Lognormal recruitment deviations on the log scale have a mean of zero and standard deviation that can be estimated or fixed. Lognormally distributed recruitment deviations are bias corrected for transformation from the log space. Beverton-Holt (1957) and Ricker (1954) forms are options for the stock-recruit relationship. A beta prior distribution on steepness of the stock-recruit relationship and spawning stock biomass estimates are new options included for this assessment. Female spawning stock biomass, as opposed to female spawning stock abundance in the blue crab assessments, is assumed to be a proxy for spot reproductive capacity. Recruits that survive their first year (y) join the post-recruits the following year (y+1) and survive as part of subsequent post-recruit abundances (y+1+n) according to the annual total mortality. Initial full, or apical, fishing mortality is an estimated parameter and fishing mortality each subsequent year is estimated as a freely varying deviation from the initial fishing mortality (i.e., deviation vector not restricted to a mean of zero) to allow for freely trending fishing mortality over time (VanderKooy 2013), particularly due to the declining trend in shrimp trawl discards through the first part of the time series. There are no index of abundance data after the terminal year to tune the terminal year fishing mortality estimate, so the terminal year fishing mortality is equal to the geometric mean of the previous two years fishing mortality estimates.

Predicted indices of abundance are calculated as a function of model estimated abundances during the annual timing of the surveys and derived catchability coefficients and compared to observed indices of abundance as a lognormal likelihood component of the objective function. Predicted catch-at-stage is calculated with the Baranov catch equation (i.e., continuous catch throughout the year; Baranov 1918) as a function of the model estimated fishing mortality, then summed across stages, and compared to the observed total fishery removals as a lognormal likelihood component of the objective function. Other components of the objective function include recruitment deviations from the expected stock-recruit relationship, and prior distributions for steepness and average total mortality. Likelihoods components can be either directly weighted by adjusting the weighting "lambdas" or by adjusting input error for data observations (i.e., CVs).

6.2.2 Reference Point Model Description

Static spawning potential ratios (sSPR), fishing mortality rates and spawning stock biomasses at reference sSPRs (e.g., F40% and SSB40%), and MSY-based reference points are calculated from population model estimates (Table 91). sSPR is calculated as the ratio of spawning stock biomass per recruit experiencing annual fishing mortality to the unfished spawning stock biomass per recruit. Fishing mortality rates at sSPRs ranging from 20-40% were calculated, as these are common sSPR reference levels to approximate MSY (Appendix 6). Being a function of annual fishing mortality, the terminal year sSPR is calculated from the geometric mean fishing mortality from the two years prior to the terminal year. Spawning stock biomass reference points associated with reference sSPRs are calculated by projecting the population dynamics to equilibrium under the reference fishing mortality rate and annual recruitment randomly sampled from the model estimated recruitments. These biomass reference points are calculated under the assumption that recruitment estimates being sampled are representative of equilibrium recruitment levels of a stock fished at the reference fishing mortality rate over time. If recruitment estimates are biased low, biomass reference points would be biased low and vice versa. MSY-based reference points include MSY, F_{MSY}, the exploitation rate at MSY (U_{MSY}), and female spawning stock biomass at MSY (SSB_{MSY}). MSY-based reference points are estimated by calculating reference points at a range of F values (0.00-6.00 at increments of 0.01) and finding the fishing mortality rate that maximizes catch in equilibrium conditions, given the model estimated stock-recruitment relationship and yield per recruit calculations.

6.2.3 Configuration and Data

Fishery removals in numbers were aggregated across recreational fisheries (harvest and dead releases from Florida-Connecticut) and commercial fisheries (marketable landings from Florida and South Carolina-New Jersey, scrap landings from North Carolina and Virginia, shrimp trawl dead discards from Florida-North Carolina, and Mid-Atlantic gillnet and trawl dead discards from North Carolina-New York) into one 'fleet'. Total removals are in Table 73 and Figure 58. Removal percentages by fishery are in Figure 59. CVs for removal data were assumed to be 0.05.

Indices of abundance from two surveys, the NCDMF Trawl and NMFS Trawl Surveys, were developed for both stages, resulting in four indices of abundance. Indices were developed from catch in numbers and standardized to means. Indices from the NCDMF Trawl Survey were developed using a length cutoff and indices from the NMFS Trawl Survey were developed by applying an ALK borrowed from the NEAMAP Trawl Survey. These surveys parallel each other along the Atlantic coast, sampling fish as they move from inshore areas (NEAMAP) to offshore areas (NMFS). The NCDMF Trawl Survey indices were developed from June observations only and were compared to model estimated abundance at the middle of June (46% of the year past). The NMFS Trawl Survey indices were developed from fall observations (Sep-Oct) and were compared to model estimated abundance at the end of September (75% of the year past). Both surveys occurred throughout the model time series. Index CVs were derived from design-based estimation of catch rate means and variances. Indices of abundance and CVs are in Table 77, Table 78, Figure 60 and Figure 66. See Section 5 for more details on surveys and development and selection of indices.

Natural mortality-at-stage was fixed at estimates generated from weight-based methods of Lorenzen (2005) and was assumed time-invariant. The natural mortality of post-recruits is an average from ages 2-6 (Section 2.7.2). Post-recruits are assumed fully selected. Partial selectivity of recruits (relative to post-recruits) was fixed at 0.43 and assumed time-invariant. This value was developed by comparing length frequencies of fishery-independent surveys and fishery-dependent sampling from the various fisheries. The effects of each fishery on the overall selectivity (i.e., weighting) were determined by the relative magnitude of the respective fishery's removals to total removals (Appendix 7). Prior information on the average total mortality of post-recruits from 1996-2013 estimated from catch curve analysis (Appendix 8) was updated through the likelihood framework according to data informing fishing mortality estimates in the model. The CV on this prior information was assumed to be 0.05 to anchor the model estimates near the observed total mortality while allowing some flexibility (VanderKooy 2013). Maturity of recruits was estimated from a logistic regression and maturity of post-recruits was assumed to be one (Section 2.6.2). There is variability in information on the maturity of age-1 fish, but most supports age-1 spot maturing by the end of the year (time of spawning in the model). There is also variability in information on sex ratios. The only literature estimate of population sex ratio (female:male) is from the Gulf of Mexico and is 1. Estimates from fishery-independent data from the Atlantic coast range between 1 and 2.79 (Section 2.6.3). Ratios also vary by age and month. Fishery-dependent data are more indicative of a skewed sex ratio in the commercial landings, though there are no sex data from the shrimp trawl observer data. Given the variability of the estimates and the lack of sex data from the shrimp trawl fishery, sex ratios of the population and removals are assumed to be 1. Peak spawning is assumed to occur at the end of the calendar year and recruitment is assumed related to spawning stock biomass from the subsequent year through a Beverton-Holt stock-recruit relationship. The CV of the lognormal error around the expected recruitment was fixed at 0.66 (sd on log scale=0.6) based on a meta-analysis by Beddington and Cooke (1983). Prior information on the steepness of the stock-recruit relationship for spot from a meta-analysis (Appendix 9) was updated through the likelihood framework according to data informing estimation of this parameter in the model. The steepness prior was a beta distribution with parameters p=3.05 and q =1.73 (mean=0.64, CV=0.32). Mean weight-at-stage for spawning stock biomass calculations was developed from the NEAMAP Trawl Survey (Table 92), the only broad regional survey with multiple years of age data, and is assumed time-invariant. No significant differences ($p<0.05$) among annual mean weight within each stage were detected with analysis of variance (ANOVA) for these data (Table 93). Assumed inputs are summarized in Table 88.

There are five leading parameters and forty nine deviations estimated (denoted by ^ in Table 89) from 130 data points, not including CVs, and two priors. All parameters and deviations are estimated in the log space.

6.2.4 Weighting of likelihoods

The methods of Francis (2011) were originally implemented until it was discovered that data conflicts required extreme down weighting of index data, to the point of being uninformative, to achieve standard deviations of standardized residuals (SDSRs) near one. To acknowledge process error, the methods of Francis (2003) were ultimately adopted by adding 0.2 to index CVs representing measurement error (Table 94). This weighting was chosen as the preferred weighting, as the model fit to data with this weighting was deemed a better fit than the model fit to data with weighting that did not acknowledge process error (see next section).

6.2.5 Evaluation of Model Fit

The objective function is minimized to find best fit parameter estimates. Goodness of fit was evaluated by inspecting residuals from model predictions of observed data. Evaluation included visual inspection of residual plots, comparing means of standardized residuals to zero with a t-test, comparing sum of squared residuals (SSR), testing for normality of standardized residuals with a Shapiro-Wilk test, and testing for trends in residual signs (positive or negative) with respect to time with a runs test. Ideal results of evaluation were minimized SSR and normally distributed standardized residuals with no trends or means significantly different than zero. Focus was on fits to index of abundance data as Francis (2011) recommends that these data should have primacy in model fitting.

6.2.6 Characterizing Uncertainty

6.2.6.1 Asymptotic standard errors

The delta method within ADMB was used to generate asymptotic standard errors and CVs of key model parameters and derived values.

6.2.6.2 Sensitivity analysis

Sensitivity of the base model to key assumptions and data choices was evaluated by comparing results of alternative model configurations to the base model. Changes for sensitivity configurations relative to the base model are described below and summarized in Table 95. Each sensitivity configuration will be referred to by the name of the configuration in bold below. Four sensitivities focused on shrimp trawl discard estimates because these made up such a large component of the total removals; the model time series was changed to start in 1992 to exclude the relatively large discard estimates in 1990 and 1991 (**1992 start year**), the relatively large discard estimates were changed to equal the median shrimp trawl discard estimate during years when BRDs were not uniformly required (*259 million fish*; **adjust shrimp discards**), and all shrimp trawl discard estimates were scaled down to 10% (**10% shrimp discards**) and 50% (**50% shrimp discards**) of the base model estimates. The adjusted time series of removals for the sensitivity configurations, where applicable, and the base model time series of removals are in Figure 77. Two sensitivity configurations focused on the assumption about the recruit selectivity relative to post-recruit selectivity; the selectivity was estimated in the model which resulted in an estimate lower than the value assumed for the base model (*0.306*; **low selectivity**) and the selectivity was fixed at the value assuming recruits are vulnerable to fishing mortality for three quarters of the year which was higher than the value assumed for the base model (*0.645*; **high selectivity**). The analysis in Appendix 7 indicates that recruits are not even partially vulnerable to fishing mortality for at least the first few months of the calendar year, so this high value is regarded as the extreme upper bound on selectivity. Though the model estimated a reasonable selectivity for recruits, it was not estimated in the base model because the estimate fluctuated drastically across sensitivity runs and retrospective runs, often being estimated at a bound. Four sensitivity configurations focused on assumptions about mortality; natural mortality was developed using the upper and lower 95% confidence intervals on growth model parameters resulting in a lower natural mortality (*0.537 for recruits and 0.389 for post-recruits*; **low M**) and higher natural mortality (*0.550 for recruits and 0.405 for post-recruits*; **high M**), a prior on total mortality using fishery-dependent data only in catch curve analysis was used for a lower prior scenario (*1.157*; **FD Z prior**), and a prior on total mortality using a weighted catch curve with combined fishery-independent and fishery-dependent data was used for a higher prior scenario (*1.613*; **wt comb Z prior**). Six sensitivity configurations focused on choices and treatment of index data; no adjustments were made to original index CVs to incorporate process error (**no reweight**), the NMFS Trawl Survey indices for both stages were excluded from the model (**no NMFS trawl**), the NCDMF Trawl Survey indices for both stages were excluded from the model (**no NC DMF trawl**), the NEAMAP Trawl Survey indices for both stages were included in the model (**add NEAMAP trawl**), and catchability coefficient of the recruit NMFS Trawl Survey index was allowed to vary after 2004 (**change in NMFS recruit q in 2005**) and after 2008 (**change in NMFS recruit q in 2009**). Catchability was allowed to vary in 2005 based on visual inspection of the trend in residuals for the fit to this index in the base model and in 2009 due to the change of vessel conducting the survey. The final four sensitivity configurations focused on assumptions or treatment of aspects relating to the stock-recruit relationship; the steepness was fixed at 0.99 to specify an uninformative stock-recruit relationship (**h = 0.99**), the steepness was fixed at the mode value estimated in the steepness prior analysis (**h = 0.79**), the mean weight-at-stage used to calculate spawning stock biomass was developed from biological sampling of North Carolina commercial landings (**NCDMF comm mean wts**), and the population sex ratio was changed to 1.62, the value from combined fishery-independent data (**sex ratio**). The sex ratio only affects the stock-recruit parameters and spawning stock biomass estimates, so results from the configuration are only included for the spawning stock biomass estimate comparison. The reweighting methods of Francis (2003) were used for all sensitivity configurations to adjust the input CVs for indices of abundance, with the exception of the **no reweight** sensitivity configuration.

6.2.6.3 Retrospective analysis

A retrospective analysis was completed by comparing base model estimates to model estimates with up to five years of data removed from the end of the time series. A modified (i.e., averaged differences as opposed to summed differences among estimates) Mohn's Rho (Mohn 1999) was calculated for sSPR, fishing mortality, recruitment, and spawning stock biomass estimates. Retrospective plots were visually inspected and modified Mohn's Rhos were compared to general rule of thumb values for modelling short-lived species proposed by Hurtado-Ferro et al. (2015) to identify a retrospective bias.

6.2.6.4 Markov Chain Monte Carlo Simulation

Markov chain Monte Carlo (MCMC) sampling algorithms implemented in ADMB were used to sample from the posterior distribution of bounded model parameters.

6.2.6.5 Likelihood profiles

Likelihood profiling capabilities within ADMB were used to develop likelihood profiles for key unbounded derived values.

7. Results

7.1 Assessment Models

7.1.1 Surplus Production Model

7.1.1.1 Goodness of Fit

The surplus production model fit the NMFS Trawl and SEAMAP Trawl relative biomass indices reasonably well (Figure 78 and Figure 79), although there were concerns about how the model was not capturing the dynamics of the terminal year when abundance indices declined but the estimates in the model did not.

7.1.1.2 Parameter Estimates (include precision of estimates)

The surplus production model estimated that relative biomass (B/B_{MSY}) has been increasing steadily since 1999, the lowest point in the time series. B/B_{MSY} has been above 1.0 since 2006 and the largest relative biomass was in 2011 (Table 96, Figure 80). Relative fishing mortality (F/F_{MSY}) fluctuated in the early part of the time series but has been on decline since the late 1990s. F/F_{MSY} has been below 1.0 since 2002 and the lowest relative fishing mortality was in 2010.

7.1.1.2.1 Exploitation Rates

The surplus production model estimated total fishing mortality throughout the time series (Table 96, Figure 80). Fishing mortality was high and variable from the late 1980s through early 1990s, with the highest fishing mortality occurring in 1991. Since the late 1990s, fishing mortality has steadily declined.

7.1.1.2.2 Abundance or Biomass Estimates

The surplus production model estimated the average biomass (Figure 81). The results showed that the biomass decreased in the middle of the time series but began increasing in the late 1990s to high levels from 2009-2014.

7.1.1.3 Sensitivity Analyses

For sensitivity analyses, adding the NEAMAP Trawl Survey as an additional relative biomass index, abbreviating the time series to 1992-2014, omitting the SEAMAP Trawl Survey index, and performing the analysis in Excel resulted in reference point estimates that were on the same scale as the base run (Table 97**)**. Additionally, ASPIC includes a feature where the exponent can be estimated by the model directly to explore the utility of the Fox or Pella-Tomlinson formulations. The model estimated the parameter to be n=2.35 which was not significantly different from the logistic model (*P*=0.42). Overall, the SAS found the surplus production model to be stable based on these sensitivity runs. Additionally, no sensitivity run found $B2014/B_{MSY}$ to be less than one or $F2014/F_{MSY}$ to be greater than one.

7.1.1.4 Projection Estimates

The population was projected forward for 10 years (2015-2025) at a harvest level equal to 2014 landings of 9,492 metric tons. In the projections, relative biomass and fishing mortality remained stable under current conditions (Figure 82 and Figure 83).

7.1.1.5 Reference Point Model(s)

The estimates of the reference points for the base run of the surplus production model can be found in Table 97 along with the results from the sensitivity runs. In 2014, fishing mortality was 0.0884 and average biomass was 107,300 metric tons. Relative fishing mortality ($F2014/F_{MSY}$) was 0.1824 and has been less than one since 2002. Relative biomass ($B2014/B_{MSY}$) was 1.8610 and has been greater than 1 since 2006.

7.1.2 Modified-CSA Model

7.1.2.1 Goodness of Fit

The model converged on a solution (i.e., positive definite Hessian matrix) with a maximum final gradient of 1.6059e-004. Measures of model fit are in Table 98. The removals are fit well (Figure 84). Residuals for indices generally exhibited the desired properties, though there were some trends in residuals with respect to time for fits to the post-recruit NCDMF Trawl Survey and recruit NMFS Trawl Survey indices, as well as non-normality of the standardized residuals for the fit to the post-recruit NMFS Trawl Survey index (Table 98, Figure 85-Figure 88). Trends in residuals for the fit to the post-recruit NCDMF Trawl Survey index appear to be driven by conflicting signals and the model's tendency to fit closer to the post-recruit NMFS Trawl Survey index due to smaller CVs for the latter. This was thought to be the cause of the trend in residuals in the recruit NMFS Trawl Survey index, as the SDSRs of other indices tended to decrease as the recruit NMFS Trawl Survey index was downweighted. However, late in the assessment process, it was determined that the trend is removed by allowing time-varying catchability for this survey.

7.1.2.2 Parameter estimates

7.1.2.2.1 Leading Parameters and Deviations

Model parameter estimates are in Table 99.

Steepness of the stock-recruit relationship was estimated close to the upper bound (0.98), despite the prior information on this parameter. Unfished spawning stock biomass was estimated at 36,086 metric tons. Given the model's tendency to estimate steepness of the stock-recruit relationship close to the upper bound, the SAS recommends using SPR-based reference points and MSY-based reference points are not reported here. The SAS does believe there is an underlying relationship between recruitment and spawning stock biomass. However, the data do not support reliable estimation of this relationship.

7.1.2.2.2 Abundance and Spawning Stock Biomass

Both recruitment (914 million fish) and post-recruit abundance (654 million fish) are relatively high in 1989 (Table 100, Figure 89-Figure 91). Recruitment remains high through 1991 as post-recruit abundance steadily declines. Total abundance is highly variable through the mid-1990s as recruitment fluctuates drastically. Recruitment and total abundance hit a time series low in 1997. Recruitment and post-recruit abundance then fluctuate around an increasing trend through 2013, with the exception of several subsequent poor recruitments from 2006-2009. The 2014 recruitment was relatively poor resulting in a decline in total abundance, despite increasing post-recruit abundance. Post-recruit abundance in the end of the time series has increased close to levels at the beginning of the time series, while recruitment in recent years (excluding the terminal year) has increased to about half the magnitude of peak recruitments at the beginning of the time series.

Spawning stock biomass follows a similar trajectory as total abundance, generally increasing since 1996 with the exception of the lowest spawning stock biomass of the time series in 2001 (Table 100, Figure 92). There was a slight down turn of spawning stock biomass in 2014, but the estimate was still the second highest of the time series. Post-recruit abundance is a larger component of the total abundance in recent years, resulting in higher spawning stock biomass than during periods of high abundance early in the time series.

7.1.2.2.3 Fishing Mortality and Static Spawning Potential Ratio

Initial fishing mortality was estimated at 1.06 and increased steeply in the next two years (Table 101 and Figure 93). Full fishing mortality then generally fluctuates around a declining trend throughout the time series. There are some exceptionally large peaks in fishing mortality due to upticks in removals, notably in 1991, 1995, and 2001. Full fishing mortality has remained below 0.50 since 2005. The average total mortality from 1996-2013 (1.198) was estimated lower than the prior information (1.356). As an inverse function of fishing mortality, sSPR has fluctuated around an increasing trend throughout the time series (Table 101,Figure 94). Very low sSPR occurred in the beginning of the time series, when shrimp trawl discards were highest, and during years with large peaks in fishing mortality. sSPR has fluctuated around a mean over the last five years (0.48) about seven times greater than the mean sSPR during years when BRDs were not required (0.07; 1989-1995).

7.1.2.2.4 Reference Points

Fishing mortality rates associated with sSPR reference levels (20-40%) are in Table 102. Fishing mortality reference points range from 0.74 (F20%) to 0.36 (F40%).

7.1.2.3 Uncertainty

7.1.2.3.1 Asymptotic Standard Errors

Asymptotic standard errors of model parameters are in Table 99. CVs derived from asymptotic standard errors of model derived population estimates are in Table 100 and Table 101.

Confidence intervals of model derived population estimates are in Figure 90-Figure 94. Estimates of full fishing mortality, sSPR, recruitment, and post-recruit abundance are relatively precise, with mean CVs of 0.11, 0.12, 0.12, and 0.13, respectively. Precision of sSPR estimates tend to increase through time, while precision of recruitment and fishing mortality estimates tends to decrease (Figure 95, Figure 98, and Figure 99). Precision of post-recruit abundance remains relatively stable (Figure 96). CVs are slightly larger for spawning stock biomass estimates, averaging 0.16, though still indicative of relatively precise estimates. Precision of spawning stock biomass estimates is relatively stable with time (Figure 97).

7.1.2.3.2 Sensitivity Analysis

Estimates from sensitivity configurations generally follow the same trend (Figure 100-Figure 119). The **no reweight** configuration estimates a much lower sSPR in 2013 than other configurations due to the model fitting more closely to the NMFS Trawl Survey indices that indicate a sharp decline in abundance over the final two years. As expected, the sensitivities scaling down the shrimp trawl discards estimates (**10% shrimp discards** and **50% shrimp discards**) scaled down abundance. The trend in abundance and the trend and magnitude in fishing mortality and sSPR estimates are relatively insensitive to these changes. The **adjust shrimp discards** configuration results in much smaller recruitment estimates in the years of adjusted removals (1990 and 1991), as lower abundance is expected by the model to account for the reduced removals. Similarly, scaling the selectivity of recruits up (**high selectivity**), scales recruitment and spawning stock biomass down, scales the fishing mortality up, and scales the sSPR estimates down. The most variability in model estimates occurs due to treatment of the indices. This was not to be unexpected, given the somewhat contradictory trends between indices. Most estimates follow the same trend as the base run with some exceptions (i.e., 2013 estimates from the **no reweight** configuration and 1989 estimates from **no NMFS trawl** configuration). Model estimates are relatively insensitive to other configuration changes.

Being per-recruit reference points, the FSPR% reference points are only affected when an input of the per-recruit calculations is changed (e.g., natural mortality; see Table 91). Though a few sensitivity configurations estimate a terminal sSPR below the 95% confidence interval of the base model and the recommended target, all but one (**high selectivity** configuration) estimate the terminal sSPR to be above the threshold (see Section 8.1 for discussion on reference points and Table 103 for F30% threshold estimates). The **high selectivity** configuration is considered an unlikely scenario and represents the extreme upper bound on recruit selectivity.

7.1.2.3.3 Retrospective Analysis

Retrospective plots (Figure 120-Figure 123) show some patterning in estimates, though a consistent retrospective bias is disrupted by estimates from the configuration with 2011 as the terminal year (i.e., three year peel). These estimates reverse trend from the other peels (i.e., underestimates abundance, overestimates fishing mortality). The modified Mohn's Rhos are in Table 104. Modified Mohn's Rho for spawning stock biomass and fishing mortality fall near the bounds proposed by Hurtado-Ferro et al. (2015; -0.22-0.30) as a rule of thumb for values to be concerned about for short-lived species. The value for recruitment estimates exceeds the upper bound, but is driven by the large overestimate in the three year peel model. Dropping this run results in a modified Mohn's Rho (0.27) below the proposed upper bound. Steepness was consistently estimated near the base model estimate from each peel (Table 105).

7.1.2.3.4 MCMC

Two million MCMC samples were drawn from posterior distributions with a burn-in of one thousand samples and a thinning rate of one thousand samples. Samples showed low autocorrelation for the initial condition parameters, but high autocorrelation for parameters of the stock-recruit relationship (steepness, unfished spawning stock biomass; Figure 124-Figure 138). Trace plots indicate stable posterior distributions being sampled for the initial condition parameters, but the presence of a secondary stable region being sampled for the parameters of the stock-recruit relationship. These secondary regions are small relative to the primary stable region being sampled and do not result in bimodality of the density distributions, just more skewed distributions. A similar situation was observed in VanderKooy (2013) for the Western Gulf of Mexico stock.

Autocorrelation is not reduced by increasing the length of the chain (i.e., five million samples with a burn-in of one thousand samples and a thinning rate of one thousand samples; Figure 139 and Figure 140). Autocorrelation is reduced by increasing the thinning rate to ten thousand (Figure 141 and Figure 142), though it is debatable if this is an appropriate solution to approximate precision of the posterior distribution (Link and Eaton 2012). Autocorrelation in the unfished spawning stock biomass estimate is reduced to similar levels as those seen for the initial condition parameters (Figure 143) by fixing steepness and further supports the SAS's recommendation to use SPR-based reference points.

7.1.2.3.5 Likelihood Profile

Likelihood profiling of the terminal year sSPR shows a near identical distribution to the distribution from the asymptotic standard errors (Figure 144).

7.1.2.4 Discussion

The population dynamics predicted with the modified-CSA are heavily influenced by the relatively large magnitude of dead discard estimates from the South Atlantic shrimp trawl fisheries. The decline and stabilization of these discards paired with increasing trends in relative abundance in recent years suggest that the stock is responding favorably to increased regulations in the shrimp trawl fisheries (i.e., requirement of BRDs), which is supported by the model estimates. Though the modified-CSA does generally fit the data well, there are some areas that should serve as focal points for future assessments to improve fits and inconsistencies in the model estimates.

There was borderline indication of retrospective bias, according to general rules of thumb proposed by Hurtado-Ferro et al. (2015). These rules of thumb for short lived species were developed from Pacific sardine with a maximum age of fifteen and the authors note that as species longevity decreases and variability in species dynamics increase, Mohn's rho values and thresholds for concern are expected to increase. Spot have a maximum observed age of six, suggesting that appropriate threshold values for Mohn's rho may be larger than those for a species with a life history similar to Pacific sardine. Hurtado-Ferro et al. (2015) also point out that when biomass is high, the case here for spot, a retrospective pattern may be less problematic and the model results may be less risky for advising management than if biomass were low (i.e., near or below a management threshold). Nonetheless, the direction of the pattern in this assessment (i.e., systematic overestimation of biomass and underestimation of fishing mortality) is of higher concern, from a conservation perspective, and this retrospective pattern should be carefully evaluated in future assessments (Hurtado-Ferro et al. 2015).

Causes of this pattern, though often difficult to pinpoint, should be further explored. Much of this pattern could be due to conflicts in the index of abundance data and the potential change in catchability evaluated with sensitivity analysis. The SAS believes that the indices of abundance from multiple surveys used in the base model represent the coastwide signal of relative abundance better than indices from either survey individually. There were some preliminary attempts to combine the indices into a single index using the methods of Conn (2010), but little effect was observed and the method was not pursued further. The SAS also investigated changing catchability due to improvements in model fit, but believe it is most appropriate to retain time-invariant catchability, given the principal investigators of the survey have calibrated the indices based on side-by-side tow comparisons (Miller et al. 2010). If other causes of a changing catchability can be corroborated (i.e., climate change), modelling these changes would be more defensible.

There is also suspected influence form environmental conditions, particularly temperature, on spot mortality. No appropriate data were identified for this assessment, but identification and incorporation of environmental data time series in future assessment could improve the model's ability to differentiate environmental and density-dependent effects on year class strength. The model results are dependent and sensitive to the assumed selectivity of recruits, as seen with sensitivity analysis. The SAS used the best available estimates, but if additional information becomes available to update this estimate, it would serve future assessments well.

7.1.3 Comparison of Results and Model Selection

The general trends in population estimates from the base surplus production and base modified-CSA models are similar and verify the general dynamics of the stock over the modelled time series, given the input data. It is important to note that there are some major differences between the model estimates and comparison of the magnitude of estimates is not particularly informative. Rather, the objective of the comparison is to check trends in similar estimates provided by two models characterized by very different structures and assumptions. The fishing mortality estimates are in terms of different units (biomass for the surplus production model and numbers for the modified-CSA), but suggest very similar exploitation patterns (Figure 145). The biomass estimates are also in terms of different units (total exploitable biomass for the surplus production model and mature female biomass for the modified-CSA model), but also suggest similar patterns in the response of the reproductive capacity of the stock to exploitation over time (Figure 146). The surplus production model estimates a slower decline in fishing mortality through the 1990s and a slightly more pronounced decline in fishing mortality and increase in biomass in the late 2000s and 2010s.

The modified-CSA is able to incorporate some population structure, allowing more fine-scale changes to be estimated relative to the surplus production model (i.e., high interannual variability in the abundance estimates). The modified-CSA model appears to better capture the interannual variability in abundance and fishing mortality observed from the stock, as indicated by the input data. These different patterns may be due to the surplus production model being more rigid and restrictive, as a function of the constant intrinsic growth rate parameter, in allowing large swings in abundance that occur for stocks like spot that only consist of a few year classes. The terminal year spawning stock biomass estimate from the modified-CSA is more reflective of the decline in relative abundance observed in the indices. Given these points, the SAS recommends the modified-CSA as the preferred modelling approach to inform stock status.

8. Stock Status

8.1 Current Overfishing, Overfished/Depleted Definitions

There are currently no stock status definitions for the Atlantic coast spot stock. The SAS compiled a review of SPR-based reference points (Appendix 6) and recommends an overfishing threshold associated with a 30% sSPR (F 30%) and a fishing target associated with a 40% sSPR (F 40%). These reference point values tend toward precautionary values, acknowledging the potential for high interannual variability in recruitment with an unknown effect from environmental factors and the short life history of spot. Given that sSPR is a per-recruit reference point, a decline in recruitment and/or spawning stock biomass over even a short period could result in adverse impacts to stock condition even if the stock is maintained at relatively high sSPR levels (i.e., greater than the target). Therefore, the SAS also recommends the equilibrium spawning stock biomass resulting from fishing at F 30% and the recruitment levels estimated from 1996-2014 (Table 100) as a spawning stock biomass threshold and the equilibrium spawning stock biomass resulting from fishing at F 40% and the recruitment levels estimated from 2003-2014 (Table 100) as a spawning stock biomass target. The years 1996-2014 and 2003-2014 were chosen as they correspond with the stock fished, on average, at 30% sSPR and 40% sSPR, respectively (Table 101). These years also correspond with the period when BRD requirements were generally implemented and the shrimp trawl discards were at relatively stable levels. Randomly sampled recruitments for the spawning stock biomass threshold and target projections are in Table 106 and Table 107, respectively. Projected spawning stock biomasses and the median over the time series (reference point estimate) are in Figure 147 and Figure 148.

8.2 Stock Status Determination

Based on the recommended reference points, overfishing of the Atlantic coast spot stock did not occur in 2014 and the stock was not overfished. The 2014 full fishing mortality is estimated at 0.249, below the threshold (0.5) and target (0.36). The 2014 sSPR is estimated at 0.507, above the recommended threshold (0.30) and target (0.40). The 2014 beginning year spawning stock biomass (2013 end year SSB) is estimated at 19,032 metric tons, above the recommended threshold (4,730 metric tons) and target (7,854 metric tons). Based on MSY reference points and generic thresholds, the surplus production model status determination (B_{2014}>B_{MSY} and

$F_{2014}<F_{MSY}$) was the same as the modified-CSA determination. This stock status determination is reasonable, given the significant decline of discards in the shrimp trawl fishery and the recent increases in relative abundance observed across indices of abundance.

8.3 Comparison of Assessment Results to the Traffic Light Analysis

The TLA was compared to the assessment results to determine the utility and reliability of using the TLA to inform stock status. The TLA is currently used to inform stock status and the modified-CSA within this assessment is proposed to inform stock status moving forward on an intermittent basis according to future stock assessment schedules. However, the TLA has the potential to inform stock status in the future between stock assessments, so it is important to understand how the approaches compare and contrast. Some additional metrics were developed with the TLA framework (i.e., total fishery removals) to permit comparisons to the modified-CSA results (Appendix 1).

The pattern in the estimates of spawning stock biomass from the modified-CSA model are in agreement with the established abundance metric of the TLA (i.e., adult abundance from the regional SEAMAP Trawl and NMFS Trawl Surveys). Treating spawning stock biomass above the target (not overfished) the same as a TLA proportion red less than 30% (no concern), spawning stock biomass between the target and threshold (not overfished, but below the target) the same as a TLA proportion red between 30% and 60% (moderate concern), and spawning stock biomass below the threshold (overfished) the same as a TLA proportion red greater than 60% (significant concern), the two approaches agree 65% of the time (Table 108, Figure 149). The status from the two approaches is not the opposite (i.e., overfished vs. no concern or vice versa) for any years. The TLA is more conservative in the final two years, suggesting moderate concern, whereas the modified-CSA suggests no concern. There is no recruitment reference point estimated by the modified-CSA, but a qualitative comparison suggests the annual recruitment estimates match the TLA YOY abundance metric proportions well in many years (Figure 150). Specifically, the two approaches agree on relatively weak year classes in 1992, 1995-1996, 1998, 2001, 2003, 2006-2007, and the terminal year (2014). The approaches agree on relatively strong year classes in 1994 and 2010. Notable disagreements occurred for 1989-1991, 1997, 2005, 2011 and 2013. Some of these differences are not surprising given different indices are used in the two approaches and high interannual variability common in juvenile abundance indices.

The harvest metrics from the TLA are not in as close agreement with the modified-CSA sSPR estimates. The established harvest metric from the TLA, as the name suggests, does not include discard information, as there was not a time series of discard estimates established for the TLA. The modified-CSA estimates total fishing mortality across fisheries. Treating sSPR above the target (not overfishing) the same as a TLA proportion red less than 30% (no concern), sSPR between the target and threshold (not overfishing, but above the target) the same as a TLA proportion red between 30% and 60% (moderate concern), and sSPR below the threshold (overfishing) the same as a TLA proportion red greater than 60% (significant concern), the two approaches only agree 15% of the time (Table 109, Figure 151). This is not surprising considering the high proportion of fishery removals used in the modified-CSA attributed to shrimp trawl discards. This is improved slightly when all removals are added to the TLA metric, with agreement 26% of the time (Table 109).

This assessment supports the utility of these analyses as approaches for informing the condition of stock abundance, but highlights the need to further evaluate the incorporation of discards into a fishery removal metric to be used as a comprehensive indicator of fishing pressure between stock assessments with TLA. Given that abundance and fishing mortality are correlated, the abundance measures from both approaches generally agree, and that the abundance and fishing mortality are not independently estimated in the modified-CSA, the harvest metric from the TLA appears to be in disagreement with the other components of the comparison. A potential area of focus could be the appropriate weighting of discards relative to other fishery removals.

9. Research Recommendations and Future Assessments

9.1 Research Recommendations

Short-term

HIGH PRIORITY

- Expand collection of life history data for examination of lengths and age, especially fishery-dependent data sources.
- Organize an otolith exchange and develop an ageing protocol between ageing labs.
- Increased observer coverage for commercial discards, particularly the shrimp trawl fishery. Develop a standardized, representative sampling protocol and pursue collection of individual lengths and ages of discarded finfish.

MEDIUM PRIORITY

- Develop and implement sampling programs for state-specific commercial scrap and bait fisheries in order to monitor the relative importance of Spot. Incorporate biological data collection into program.
- Conduct studies of discard mortality for commercial fisheries. Ask commercial fishermen about catch processing behavior for Sp/Cr when trawl/gillnets brought over the rail.
- Conduct studies of discard mortality for recreational fisheries.
- Collect data to develop gear-specific fishing effort estimates and investigate methods to develop historical estimates of effort.

Long-term

HIGH PRIORITY

- Continue state and multi-state fisheries-independent surveys throughout the species range and subsample for individual lengths and ages. Ensure NEFSC trawl survey continues to take lengths and ages. Examine potential factors affecting catchability in long-term fishery independent surveys.

- Continue to develop estimates of length-at-maturity and year-round reproductive dynamics throughout the species range. Assess whether temporal and/or density-dependent shifts in reproductive dynamics have occurred.
- Re-examine historical ichthyoplankton studies for an indication of the magnitude of estuarine and coastal spawning. Pursue specific estuarine data sets from the states (NJ, VA, NC, SC, DE, ME) and coastal data sets (MARMAP, EcoMon).

MEDIUM PRIORITY

- Identify stocks and determine coastal movements and the extent of stock mixing, via genetic and tagging studies.
- Investigate environmental and recruitment/ natural mortality covariates and develop a time series of potential covariates to be used in stock assessment models.
- Investigate environmental covariates in stock assessment models, including climate cycles (e.g., Atlantic Multi-decadal Oscillation, AMO, and El Nino Southern Oscillation, El Nino) and recruitment and/or year class strength, spawning stock biomass, stock distribution, maturity schedules, and habitat degradation.
- Investigate the effects of environmental changes (especially climate change) on maturity schedules for spot, particularly because this is an early-maturing species, and because the sSPR estimates are sensitive to changes in the proportion mature.
- Investigate environmental and oceanic processes in order to develop better understanding of larval migration patterns into nursery grounds.
- Investigate the relationship between estuarine nursery areas and their proportional contribution to adult biomass. I.e., are select nursery areas along Atlantic coast ultimately contributing more to SSB than others, reflecting better quality juvenile habitat?
- Develop estimates of gear-specific selectivity.

9.2 Recommendation for Timing of Future Stock Assessments

The SAS and PRT recommend that the next assessment be completed five years from the completion of this assessment (i.e., 2022). Though the completion of the spot and Atlantic croaker assessments together was useful for this first assessment of spot, the SAS and PRT recommend a staggered schedule for future spot and Atlantic croaker assessments due to the overlap in personnel.

10. Minority Opinion

There was no minority opinion submitted by any member(s) of the SAS or PRT.

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12. Tables

Table 1. History of Atlantic state regulations specific to spot.

SC	Aggregate bag limit of 50 fish per person per day for small Sciaenidae species for com and rec hook and line gear	2014
FL	Default bag limit for unregulated species is 2 fish or 250 pounds per person per day-whichever is more.	1987
FL	Default bag limit for unregulated species is 2 fish or 100 pounds per person per day-whichever is more.	1989

Table 2. Additional Atlantic state regulations affecting the harvest and bycatch of spot.

State	Regulation	Date
NJ	Weakfish gill-net and pound-net seasonal closures established and trawl minimum mesh reduced (3” diamond)	1992
	Weakfish trawl seasonal closure established, gill-net seasonal closure lengthened, and trawl minimum mesh increased (3.25”)	1995
DE	Weakfish gill-net minimum mesh size (3.125”) and seasonal closures affect the harvest of Atlantic croaker	1995
MD	Weakfish trawl minimum mesh increased to 3.375” square or 3.75” diamond and gill-net and trawl seasonal closure lengthened	1995
	Trawling prohibited in Chesapeake Bay and coastal bays, and within 1 mile of coastal shore	1933
VA	Trawling prohibited in all state waters	1989
	Weakfish commercial gear minimum mesh sizes increased and seasonal closures established or increased	1995

Table 2 *Continued*. **Additional Atlantic state regulations affecting the harvest and bycatch of spot.**

State	Regulation	Date
NC	Minimum mesh size restrictions in shrimp trawl (1.5” tailbag) and crab trawls (3.0”) established	Pre-1975
	Finfish trawling prohibited in internal waters; shrimp and crab trawls limited to 1,000 lb of incidental finfish bycatch per trip	1983
	Shrimp and crab trawls in inside waters limited to 500 lb of incidental finfish from December 1–February 28 and 1,000 lb from March 1–November 30	1991
	Catch of unclassified bait limited to 5,000 lb/vessel/day	1991
	Minimum mesh size restriction in shrimp trawls (1.5” tailbag) and crab trawls (3.0”); shrimp trawls prohibited areas established and headrope length limited to 90 ft	1991
	Fly net minimum stretched mesh size of 3.0” square or 3.5” diamond; fly nets defined as nets having the first body (belly) section consisting of 35 or more continuous meshes of 8.0” or greater (stretched mesh) webbing behind the bottom and top line, with tailbags less than 15 feet in length; tailbags constructed of square mesh may have the terminal 3 feet of mesh hung on a diamond with a minimum stretched mesh length of 2.0”	1992
	Bycatch reduction devices required in all shrimp trawls.	1994
	Fly nets prohibited in ocean waters from Cape Hatteras to NC/SC state line	1994
	Fly net vessels limited to 150 lb weakfish unless all fly nets onboard meet definition; gill nets limited to 150 lb weakfish unless mesh length > 2.875” stretched	1996
	Shrimp and crab trawls in Atlantic Ocean prohibited from possessing incidental finfish December 1–March 31 unless weight of the combined shrimp and crab catch exceeds weight of finfish	1997
	Small mesh (<5.0”) estuarine gill-net attendance requirement, May 1–November 30 in select areas in inside waters	1998
	Mandatory use of long haul cull panels and swipe nets south/west of a line from Bluff Point in Pamlico Sound to Ocracoke Island	1999
	Authorized gear allowed and restrictions applied to the Recreational Commercial Gear License; modified in 2008 to allow mechanical retrieval of shrimp trawl	1999
	Crab trawl minimum mesh size increased to 4” in western Pamlico Sound	2005
	Headrope length internally limited to 90 feet and shrimp trawl prohibited areas established	2006

Table 2 ***Continued*. Additional Atlantic state regulations affecting the harvest and bycatch of spot.**

State	Regulation	Date
SC	Net ban	1987
	Turtle excluder devices required in shrimp trawls in summer	1988
	Turtle excluder devices required in shrimp trawls year-round	1991
	Bycatch reduction devices required in shrimp trawls	1996
GA	Gill nets prohibited (except for shad and diamondback terrapin)	1957
	All sounds closed to large trawl shrimp fishery; TEDs mandated	1990
	Bycatch reduction devices mandatory in large trawl shrimp fishery.	1996
FL	Entangling nets (e.g., trammel and gill nets) prohibited in all state waters	1995
	Directed finfish trawl prohibited; bycatch reduction devices mandatory	1996

Table 3. Biological data available for life history analyses in the spot stock assessment.

Type	Area	Source	Gear	Length-Weight Data	Age - Length Data	Sex Data	Maturity Data	Length Measured
Commercial	Maryland Chesapeake Bay	MD DNR	Pound Net	2008-2014 (n=3,448)	2007-2014 (n=1,354, ages 0-2)	2007-2014 (n=831 F, n=532 M)		TL
Commercial	Virginia	VMRC	Multiple	1991-2014 (n=148,818)	1998-2014 (n=4,967 ,otolith ages 1-6)	1989-2014 (n=9,944 F, n=4,245 M)	1989-2014 (n=9,917 Maturity Stage 1-5)	TL, SL
Commercial	North Carolina	NCDMF	Multiple	1979-2014 (n=7,124)	1979-1997 (n=5,097, scale ages 0-5); 1997-2013 (n=1,631, otolith ages 0-4)	1996-2015 (n=1,086 F, n=646 M)		TL
Commercial	Florida	FWC	Multiple	2000-2014 (n=330)				FL
Recreational	Florida	NMFS (MRFSS)	Hook & Line	1982-2006 (n=1,653)				FL
Recreational	North Carolina	NCDMF	Hook & Line		1992-1996 (n=316 scale age 1-3); 1998-2013 (n=19, otolith ages 1-3)	2000-2013 (n=11 F, n=4 M)		TL
Recreational	South Carolina	SC	Hook & Line		2010-2011 (n=277, ages 0-3)	2010-2011 (n=102 F, n=46 M)	2010-2011 (n=150, Maturity Status I/M)	TL, SL
Fishery Independent	North Carolina	NCDMF	Multiple	1972-2014 (n=10,720)	1979-1997 (n=1,066, scale ages 0-4); 1997-2013 (n=5,610, otolith ages 0-6)	1995-2015 (n=5,155 F, n=1,887 M)		TL
Fishery Independent	Hudson River, NY to Cape Hatteras, NC	NMFS	Trawl	1992-2014 (n=1,008)		1992-2010 (n=455 F, n=257 M)	1992-2014 (n=782, Maturity Status I/M; n=798 Maturity Stage D/I/R/R/S)	FL
Fishery Independent	Hudson River, NY to Cape Hatteras, NC	NEAMAP	Trawl	2007-2014 (n=2,241)		2007-2015 (n=1,185 F, n=957 M)	2007-2015 (n=2,209 Maturity Stage A-D)	FL
Fishery Independent	Maryland and Virginia Chesapeake Bay	ChesMMAP	Trawl	2002-2014 (n=7,337)	2002-2014 (n=7,104, otolith ages 0-4)	2002-2015 (n=3,532 F, n=3,034 M)	2002-2015 (n=6,851 Maturity Stage, various codes)	FL
Fishery Independent	Cape Hatteras, NC to Cape Canaveral, FL	SEAMAP	Trawl	1998-99,2000-01,2009-10 (n=1,455)	2001 (n=731, otolith ages 0-3)	1998-2010 (n=643 F, n=633 M)	1998-2010 (n=873 Maturity Status I/M; n=585 Maturity Stage, various codes)	TL, FL, SL
Fishery Independent	South Carolia	SC	Multiple	Various from 1984-2014 (n=5,440)	1997, 2010-2011 (n=1,050, otolith ages 0-4)	1984-2014 (n=1,265 F, n=749 M)	1984-2014 (n=2,148, Maturity Status I/M)	TL, SL

Table 4. Reported size ranges of spot from previous studies along the Atlantic coast of the United States.

Reference	Region	Length Range (cm)
Welsh and Breder (1923)	NJ - FL	8-33 cm
Hildebrand and Schroeder (1928)	Chesapeake	10-34.5 cm
Hildebrand and Cable (1930)	NC	9-29 cm
Pacheco (1957)	Chesapeake	16-27 cm
Dawson (1958)	SC	8-22.5 cm
DeVries (1982)	NC	6-34.6 cm
Music and Pafford (1984)	GA	11-25 cm
Johnson (2013)	SC	4.5-27 cm

Table 5. Summary of spot paired age-length data by data source based on otolith ages and total length (cm), made available for the stock assessment.

Source		Total length in cm at age						
		0	1	2	3	4	5	6
MD DNR Summer Pound Net Survey (Commercial)	Size Range (cm)	14-25	14-16	18-26				
	Mean (cm)	16	20	23				
	n	217	856	25				
	Percent by age	19.76%	77.96%	2.28%				
MD DNR Fish House Survey (Commercial)	Size Range (cm)	16-23	13-27	21-25				
	Mean (cm)	18	21	23				
	n	14	236	6				
	Percent by age	5.79%	97.52%	2.48%				
NCDMF (Commercial)	Size Range (cm)	9-22	11-27	16-30	22-31	25-31		
	Mean (cm)	15	18	23	27	28		
	n	549	855	170	44	13		
	Percent by age	33.66%	52.42%	10.42%	2.70%	0.80%		
VMRC (Commercial)	Size Range (cm)		13-31	18-34	20-36	26-36	31-36	32-35
	Mean (cm)		23	25	29	30	33	33
	n		2,961	1,552	339	96	15	3
	Percent by age		59.63%	31.25%	6.83%	1.93%	0.30%	0.06%
ChesMMAP Survey (FI)	Size Range (cm)	4-24	7-28	14-30	24-33	23-33		
	Mean (cm)	16	19	23	28	29		
	n	3,837	3,088	155	20	4		
	Percent by age	54.01%	43.47%	2.18%	0.28%	0.06%		
NCDMF (FI)	Size Range (cm)	7-29	11-33	15-31	21-32	24-32	28-32	32-33
	Mean (cm)	16	21	24	27	28	30	32
	n	485	3,036	1,704	308	66	9	2
	Percent by age	8.65%	54.12%	30.37%	5.49%	1.18%	0.16%	0.04%
SEAMAP Survey (FI)	Size Range (cm)	11-22	12-27	16-25	21			
	Mean (cm)	16	18	22	21			
	n	294	415	21	1			
	Percent by age	40.22%	56.77%	2.87%	0.14%			
SCDNR (FI)	Size Range (cm)	4-22	12-27	16-26	23-25	23		
	Mean (cm)	12	21	22	24	23		
	n	693	284	69	3	1		
	Percent by age	66.00%	27.05%	6.57%	0.29%	0.10%		
SCDNR Freezer Survey (R)	Size Range (cm)	16-24	16-29	20-25	33			
	Mean (cm)	19	22	23	33			
	n	68	193	15	1			
	Percent by age	24.55%	69.68%	5.42%	0.36%			
VMRC (R)	Size Range (cm)		22-26	33				
	Mean (cm)		24	33				
	n		3	1				
	Percent by age		75.00%	25.00%				
All Data Combined	Size Range (cm)	3-24	6-31	13-24	19-35	21-36	28-35	32-34
	Mean (cm)	15	20	23	26	29	32	33
	n	6,637	15,041	6,026	997	195	26	5
	Percent by age	25.50%	50.81%	19.69%	3.25%	0.63%	0.08%	0.02%

Table 6. Description of growth models used to estimate the age-length relationship of spot in the stock assessment. Parameters of the same name do not necessarily have the same interpretation across different models.

Growth Model	Equation	Parameters
von Bertalanffy	$L_t = L_\infty \left[1 - e^{-K(t-t_0)}\right]$	*Lt* is length at age *t*, *L*∞ (or L_{inf}) is the theoretical asymptotic average length (if *K* > 0), *K* is growth rate at which the asymptote is approached, and *t*0 is the hypothetical age at which length is zero.
Gompertz	$L_t = L_\infty e^{-e^{-K(t-t_0)}}$	*L*∞ (or L_{inf}) is the theoretical asymptotic average length (if *K* > 0) and *t*0 represents an inflection point on the curve.
Richard's	$L_t = L_\infty \left[1 + \frac{1}{p} e^{-K(t-t_0)}\right]^{-p}$	*L*∞ (or L_{inf}) is the theoretical asymptotic average length (if *K* > 0) and *t*0 represents an inflection point on the curve.
Logistic	$L_t = L_\infty \left[1 + e^{-K(t-t_0)}\right]^{-1}$	*L*∞ (or L_{inf}) is the theoretical asymptotic average length (if *K* > 0) and *t*0 represents an inflection point on the curve.

Table 7. Sample size (n) and parameter estimates and AIC for the von Bertalanffy model fits to spot data sets. There was a significant difference in growth between males and females (ARSS: $F_{3,20105} = 113.31$, $p < 0.0001$).

Data Set	n	Linf (cm)		K		t0		AIC
		Estimate	SE	Estimate	SE	Estimate	SE	
All available ages	22,734	34.4	0.483	0.324	0.012	-1.84	0.036	116,146
Combined male and female ages	20,111	35.4	0.563	0.288	0.012	-2.12	0.045	99,637
Female ages	12,922	34.4	0.584	0.317	0.015	-2.04	0.054	63,766
Male ages	7,189	38.5	1.552	0.220	0.019	-2.42	0.093	35,541

Table 8. Sample size (n) and parameter estimates and AIC for the Richard's growth model fits to spot data sets.

Data Set	n	Lmin (cm)		Lmax (cm)		K		p		Amin	Amax	AIC
		Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE			
All available ages	22,734	15.7	0.084	36.9	0.270	0.369	0.003	1	0.010	0	6	116,352
Combined male and female ages	20,111	16.6	0.120	39.7	0.164	0.306	0.003	1	0.020	0	6	99,857
Female ages	12,922	16.4	0.181	37.8	0.844	0.317	0.010	1	0.035	0	6	64,343
Male ages	7,189	16.2	0.123	47.8	1.150	0.218	0.007	1	0.024	0	6	35,658

Table 9. Sample size (n) and parameter estimates and AIC for the Gompertz growth model fits to spot data sets.

Data Set	n	Linf (cm)		K		t0		AIC
		Estimate	SE	Estimate	SE	Estimate	SE	
All available ages	22,734	31.7	0.295	0.516	0.012	-0.65	0.013	116,177
Combined male and female ages	20,111	32.5	0.339	0.461	0.012	-0.79	0.016	99,664
Female ages	12,922	32.1	0.372	0.487	0.015	-0.83	0.017	63,794
Male ages	7,189	33.9	0.799	0.393	0.019	-0.72	0.045	35,542

Table 10. Sample size (n) and parameter estimates and AIC for the logistic growth model fits for to spot data sets.

Data Set	n	Linf (cm)		K		t0		AIC
		Estimate	SE	Estimate	SE	Estimate	SE	
All available ages	22,734	30.3	0.216	0.713	0.012	-0.07	0.019	116,221
Combined male and female ages	20,111	31.0	0.247	0.638	0.012	-0.15	0.022	99,700
Female ages	12,922	30.7	0.279	0.660	0.016	-0.22	0.024	63,829
Male ages	7,189	31.7	0.543	0.568	0.020	-0.02	0.057	35,545

Table 11. Description of length measurements used for spot.

Measurement	Description
Total Length (max)	Measured from the most anterior point of the fish to the farthest tip of the tail with the tail compressed or squeezed together.
Fork Length (midline)	Measured from the most anterior point of the fish to the rear center edge of the tail.
Standard Length	Measured from the most anterior point of the fish to the end of the vertebral column (caudal peduncle).

Table 12. Length relationships for spot, as reported in the literature and estimated during this assessment.

Reference	Location	Range (mm TL)	N	Relationship	R^2
Dawson (1958)	South Carolina		5,162	SL = 2.000 + 1.2333 TL	0.996
			446	FL = 8.90 + 1.09 SL	0.991
			546	FL = 6.170 + 0.893 TL	0.997
Jorgenson and Miller (1968)	Georgia	14-11	71	TL = -0.606 + 1.2888 SL	0.91
			87	SL = 0.760 + 0.771 TL	0.893
Life History Workshop (2010)	Virginia-Florida	106-370	65,534 (VA)	TL = -0.554 + 1.268 SL	0.949
			65,534	SL = 9.780 + 0.7749 TL	0.949
			745 (SEAMAP)	TL = 6.411 + 0.904 FL	0.984
			745	FL = -4.370 + 1.089 TL	0.984
			745	SL = -7.254 + 0.868 FL	0.97
			745	FL = 12.967 + 1.117 SL	0.97
Stock Assessment (2017)	Coastwide	21-370	43,053	TL = 1.079 FL - 0.843	0.981
			66,494	TL = 1.255 SL + 1.840	0.967

Table 13. The length-weight relationships for Atlantic coast spot (L= total length in mm; W= total weight in grams), as reported in the literature and estimated during this assessment.

Author	Area	N	Size Range	Equation
Hester and Copeland (1975)	North Carolina	356	25-195 (mm TL)	log W = -5.230 + 3.221 log L
Dawson (1985)	South Carolina	4,297	45-205 (mm SL)	log W = -4.54396 + 2.95831 log L
Music and Pafford (1984)	Georgia	325	120-283 (mm TL)	log W = -5.096 + 3.121 log L
Stock Assessment (2017)	Coastwide	22,835	Females: 72-375 (mm TL)	log W = -5.401 + 3.248 log L
		12,320	Males: 67-355 (mm TL)	log W = -5.440 + 3.260 log L
		35,155	Combined sexes: 67-375 (mm TL)	log W = -5.433 + 3.260 log L
		189,460	All available L-W data (mm TL)	log W = -4.636 + 2.916 log L

Table 14. Length-weight relationships for Atlantic coast spot from different data sets using a non-linear power regression in the form: $W=a(L_T)^b$ where L_T = total length (mm); W = weight (g); a = y-intercept; b = slope (regression coefficient).

Data Source	N	Size Range (TL mm)	a	b	r^2
NMFS (FI)	1,008	96-290	4.601×10^{-6}	3.204	0.935
NEAMAP (FI)	2,241	102-290	1.871×10^{-6}	3.377	0.849
ChesMMAP (FI)	7,337	42-335	4.710×10^{-6}	3.200	0.952
SEAMAP (FI)	1,454	87-271	8.533×10^{-6}	3.073	0.956
MD/VA/NC commercial (FD)	159,697	13-390	2.821 x 10-5	2.879	0.830

Table 15. Tests of significance using ARSS between male and female spot length-weight relationship by data set.

Type	Area	Gear	Source	degrees of freedom		*F*-statistic	*P*-value
				numerator	denominator		
Fishery-Independent	NE Atlantic	Trawl	NMFS	2	709	1.022	0.312
Fishery-Independent	NE Atlantic	Trawl	NEAMAP	2	2,139	0.384	0.535
Fishery-Independent	Ches. Bay	Trawl	ChesMMAP	2	6,558	0.019	0.889
Fishery-Independent	SE Atlantic	Trawl	SEAMAP	2	1,272	0.172	0.678
Commercial	Maryland	Pound Net	MDDNR	2	1,360	3.622	0.057
Commercial	Virginia	All	VMRC	2	12,377	1.817	0.178
Commercial	North Carolina	All	NCDMF	2	1,712	1.746	0.187
Commercial	All combined	All	All	2	15,455	2.542	0.111

Table 16. SCDNR histological maturity-at-age data from August-December and predictions and residuals from a logistic regression model (slope = -1.761, inflection = 1.7).

Age	All Observed	Observed Mature	Proportion Mature		Residual
			Observed	Predicted	
0.67	18	1	0.056	0.132	-4.4
0.75	33	0	0.000	0.150	-5.4
0.83	37	5	0.135	0.170	-14.8
0.92	46	14	0.304	0.191	-29.9
1.00	42	3	0.071	0.215	-14.1
1.67	19	5	0.263	0.470	-12.7
1.75	37	15	0.405	0.507	-25.7
1.83	74	61	0.824	0.543	-47.4
1.92	25	20	0.800	0.580	-15.2
2.00	6	2	0.333	0.615	-4.8
2.67	5	2	0.400	0.838	-5.8
2.75	12	7	0.583	0.857	-10.8
2.83	14	10	0.714	0.874	-9.6
2.92	2	2	1.000	0.889	-0.2
3.83	1	1	1.000	0.976	0.0
4.75	1	0	0.000	0.995	-5.3

Table 17. Calculated sex ratios (female:male), sample sizes (n), chi-squared (χ^2) values, and probabilities (*P*) that the spot sex ratio is 1:1 (female:male) by dataset, pooled over ages and available years. Sex ratios were also analyzed using a binomial test with similar results.

Type	Area	Gear	Source	Males n	Female n	Total n	Sex Ratio (F:M)	Chi-squared		Binomial	
								χ^2	*P*	Probability	*P*
Commercial	MD	Pound Net	MDDNR	532	831	1,363	1.56	65.6	<0.01	0.39	<0.01
Commercial	VA	All	VMRC	3,655	8,725	12,380	2.39	2,076.30	<0.01	0.295	<0.01
Commercial	NC	All	NCDMR	633	1,082	1,715	1.71	117.5	<0.01	0.369	<0.01
Fishery-Independent	North Atlantic	Trawl	NMFS	257	455	712	1.77	55.1	<0.01	0.361	<0.01
Fishery-Independent	North Atlantic	Trawl	NEAMAP	957	1,185	2,142	1.24	24.3	<0.01	0.447	<0.01
Fishery-Independent	Chesapeake Bay	Trawl	ChesMMAP	3,029	3,532	6,561	1.17	38.6	<0.01	0.462	<0.01
Fishery-Independent	NC	Trawl	NCDMF	1,879	5,128	77,007	2.79	1506.5	<0.01	0.291	<0.01
Fishery-Independent	South Atlantic	Trawl	SEAMAP	633	642	1,275	1.01	0.1	0.8	0.496	0.82
Fishery-Independent	Coastwide	All		7,500	12,195	19,695	1.62	1119.2	<0.01	0.385	<0.01
Commercial	MD, VA, NC	All		4,820	10,638	15,458	2.21	2,189.70	<0.01	0.312	<0.01
All	Coastwide	All		12,320	22,833	35,153	1.83	3,144.20	<0.01	0.381	<0.01

Table 18. Sex ratio (female:male)-at-age by data set for spot on the Atlantic coast. Computed chi-squared (χ_2) values for age-specific sex ratios were pooled over years and were calculated using Yate's correction for continuity. An asterisk (*) indicates a sex ratio significantly (p-value < 0.05) different than 1.

	Age 0		Age 1		Age 2		Age 3		Age 4		Age 5	
Data Set	Ratio	X^2	Ratio	X^2	Ratio	X^2	Ratio	X^2	Ratio	X^2	Ratio	X^2
MD Commercial	1.037	0.072	1.698	71.6*	1.500	1.2	-	-	-	-	-	-
VA Commercial	-	-	2.620	526.2*	3.098	382.4*	3.671	106.9*	1.879	8.85*	4.000	5.40*
ChesMMAP (FI)	1.108	8.021*	1.207	23.7*	0.943	0.117	0.667	0.60	2.000	-	-	-
SEAMAP (FI)	0.965	0.088	1.109	1.036	2.000	2.333	-	-	-	-	-	-
SCDNR (FI surveys)	1.280	6.627*	2.170	38.02*	2.722	14.3*	2.000	-	1.000	-	-	-
FD Combined	1.139	1.107	2.291	584.5*	3.057	384.8*	3.671	106.9*	1.879	8.85*	4.000	5.40*
FI Combined	1.115	11.18*	1.252	42.1*	1.358	5.16*	0.900	0.052	1.500	-	-	-
Total	1.117	20.3*	1.705	455.9*	2.709	335.2*	3.325	92.7*	1.857	9.33*	4.000	5.40

Table 19. Percent female spot for available datasets, by month, pooled over years.

				Collection		% Female											
Type	**Area**	**Gear**	**Source**	**Period**	**n**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
FI Survey	NE Atlantic	Trawl	NMFS	1992-2010	455				100.0	50.0	50.0	50.0		63.3	70.4		
FI Survey	NE Atlantic	Trawl	NEAMAP	2007-2015	1,185				49.3					58.1			
FI Survey	Ches. Bay	Trawl	ChesMMAP	2002-2015	3,532			72.4		56.6		52.1		53.2	85.9	53.2	
FI Survey	SE Atlantic	Trawl	SEAMAP	1998-2010	642				55.3	50.3		47.2	36.4		48.7	52.3	
Commercial	Maryland	Pound Net	MDDNR	2007-2014	689					69.1	62.2	63.1	63.0	53.1			
Commercial	Maryland	Fish House Survey	MDDNR	2009-2010	142						67.2	43.8	51.3				
Commercial	Virginia	All	VMRC	1989-2014	8,725			83.3	69.7	70.6	73.1	69.9	74.2	69.7	65.0	73.1	
Commercial	North Carolina	All	NCDMF	1996-2015	1,082	40.9	62.5	54.2	53.9	59.4	68.8	62.5	62.2	68.0	69.3	66.7	91.7

Table 20. Estimates of age-constant natural mortality (*M*) of spot using methods from Then et al. (2015) based on maximum age (T_{max}, where $M = 4.899 * T_{max}^{-0.916}$) and the von Bertalanffy growth parameters (VOB, where $M = 4.118 * K^{0.73} * L_{inf}^{-0.33}$). Growth model parameters are described in Table 6.

Data Set	n	L_{inf} (cm TL)	K	T_{max}	Then et al. 2015 T_{max}	Then et al. 2015 VOB
All Age Samples	22,734	34.4	0.324	6	0.613	0.427
Males & Females	20,111	35.4	0.288	6	0.613	0.400
Females	12,922	34.4	0.317	6	0.613	0.422
Males	7,189	38.5	0.220	6	0.613	0.336

Table 21. Estimates of spot age-specific natural mortality (*M*) based on the Lorenzen (2005) method using von Bertalanffy growth parameters (L_{inf}, K, t_o) and scaled to the Then et al. (2015) age-constant estimates.

Age	All Data (n=22,734)	Males and Females (n = 20,111)	Females: n = 12,922	Males: n=7,189
0	0.542	0.503	0..528	0.431
1	0.464	0.434	0.458	0.369
2	0.420	0.393	0.417	0.331
3	0.394	0.367	0.392	0.306
4	0.376	0.352	0.375	0.288
5	0.364	0.338	0.364	0.275
6	0.356	0.330	0.356	0.266
Age 1+ Mean	0.396	0.369	0.394	0.306

Table 22. Annual sample size of spot lengths collected during MD DNR commercial pound net sampling.

Year	n
1993	309
1994	451
1995	158
1996	276
1997	924
1998	60
1999	572
2000	510
2001	126
2002	681
2003	1,354
2004	883
2005	2,818
2006	2,195
2007	519
2008	1,204
2009	614
2010	300
2011	582
2012	1,508
2013	1,302
2014	420

Table 23. Annual sample size of spot age data collected during MD DNR commercial pound net sampling.

Year	Age		
	0	1	2
2007	27	68	3
2008	75	129	2
2009	24	205	3
2010	10	74	7
2011	2	171	0
2012	71	151	4
2013	12	155	0
2014	10	139	12

Table 24. Sample sizes of lengths, individual weights, sex, and age data collected by VMRC's BSP.

Year	Lengths Collected	Weights Colleted	Sex Determined	Structures Taken	Age Determined
1989	6,554	6,682	1,508	0	0
1990	11,497	8,414	2,747	0	0
1991	12,285	9,542	1,540	0	0
1992	15,552	10,662	362	0	0
1993	6,845	5,873	447	0	0
1994	10,213	8,842	384	0	0
1995	10,136	6,732	37	0	0
1996	13,234	9,845	1,028	0	0
1997	10,345	6,918	36	0	0
1998	8,438	4,851	222	173	173
1999	3,102	1,132	349	327	327
2000	3,143	860	400	342	341
2001	3,799	677	417	385	383
2002	8,208	4,566	758	406	405
2003	6,847	6,854	558	422	348
2004	10,068	9,252	464	459	458
2005	8,936	8,945	489	401	400
2006	10,762	10,560	377	384	263
2007	4,003	3,877	342	489	246
2008	2,650	2,587	203	248	197
2009	3,151	3,139	336	360	262
2010	1,667	1,667	334	371	277
2011	4,144	4,144	270	280	225
2012	3,169	3,169	243	297	248
2013	3,941	3,941	319	379	244
2014	5,215	5,215	282	337	276
Total	187,904	148,946	14,452	5,560	5,073

Table 25. Annual length frequency of spot sampled from commercial fishery landings (combined gears, non-scrap) by the NCDMF.

Fork Length (cm)	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
4	0	0	0	0	2	0	0	0	0	0	0	0	0
5	0	0	1	0	0	0	0	0	0	0	0	0	0
6	0	0	2	0	0	0	0	0	0	0	0	0	0
7	1	0	1	0	0	0	0	0	0	0	0	0	0
8	10	1	2	0	3	0	0	0	3	0	0	0	0
9	33	14	31	1	49	1	0	45	12	0	0	3	0
10	118	115	85	35	218	57	7	403	94	0	0	249	1
11	316	235	230	199	352	108	59	662	228	0	0	386	0
12	341	288	343	289	402	68	151	308	290	0	4	102	0
13	457	392	525	351	270	45	112	173	175	0	0	44	2
14	643	585	914	442	235	80	215	136	95	0	0	41	1
15	730	574	1293	669	382	153	478	71	55	1	3	44	2
16	922	709	1444	766	662	393	505	65	181	17	14	128	10
17	1348	1802	2338	1092	995	620	552	109	690	211	250	519	120
18	2182	3652	3839	2285	1975	760	695	398	1241	1069	778	893	589
19	2966	3839	3303	3078	2606	857	1007	1323	2252	2299	1141	1502	1688
20	2347	2086	2153	2902	2380	849	988	2521	2587	2341	1327	2237	2017
21	1211	794	1030	1482	1466	586	589	2516	1898	1396	999	2021	1893
22	502	197	306	545	543	186	290	1441	938	666	955	1855	2075
23	147	18	38	132	115	35	134	608	481	401	936	1590	2061
24	17	4	13	20	23	10	65	205	203	205	587	800	1465
25	3	1	7	1	1	2	16	55	90	40	186	327	799
26	2	1	0	1	1	1	4	1	27	3	46	105	366
27	0	0	1	1	0	0	1	1	6	1	7	67	301
28	2	1	1	0	0	0	2	2	3	1	6	24	163
29	2	0	1	1	0	0	4	4	0	0	2	8	33
30	0	0	0	0	0	1	8	0	0	0	0	4	10
31	0	0	1	0	0	0	9	0	0	0	0	0	4
32	0	0	0	0	3	0	8	0	0	0	0	0	0
33	0	0	0	0	0	0	11	0	3	0	0	0	0
34	0	0	0	0	0	0	7	0	0	0	0	0	0
35	0	0	0	0	0	0	5	0	0	0	0	0	0
36	0	0	0	0	0	0	1	0	0	0	0	0	0
37	0	0	0	0	0	0	1	0	0	0	0	0	0
38	0	0	0	0	0	0	1	0	0	0	0	0	0
39	0	0	0	0	0	0	2	0	0	0	0	0	0

Table 25 *Continued*. **Annual length frequency of spot sampled from commercial fishery landings (combined gears, non-scrap) by the NCDMF.**

Fork Length (cm)	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
4	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	3	0	0	0	0	0	0
11	0	0	0	0	0	0	1	2	0	2	0	1	0
12	0	0	0	0	0	0	1	0	0	0	0	0	0
13	1	0	0	0	1	0	3	1	1	0	0	0	0
14	0	0	2	0	3	0	4	0	6	2	0	0	0
15	2	0	6	1	11	15	21	1	6	7	0	0	0
16	14	4	58	30	37	132	56	17	28	68	5	5	3
17	113	70	142	175	317	602	188	168	141	311	51	33	36
18	608	591	370	648	805	1278	660	736	510	652	352	206	378
19	1403	1549	576	1155	1272	2012	1700	1545	1078	986	972	666	1437
20	2048	1646	817	1286	1889	2653	2258	2123	1788	1409	1156	1113	1949
21	2236	1586	1370	1599	2190	2688	2032	1881	1770	2010	1039	1046	1353
22	1710	1512	2069	1881	2195	2084	1552	1233	1110	1938	571	865	750
23	1264	1662	2418	1860	1555	769	680	629	444	899	114	500	353
24	998	1289	1937	1726	730	141	174	168	131	187	17	163	130
25	487	724	850	1484	369	38	40	40	39	27	5	25	35
26	232	351	315	984	255	15	8	8	8	1	0	4	3
27	124	188	166	634	142	10	1	0	3	2	0	0	2
28	76	136	70	286	64	11	0	1	1	0	0	1	0
29	42	71	29	99	31	7	2	1	1	1	1	1	2
30	24	36	20	34	8	1	2	0	0	0	1	0	0
31	6	12	14	8	0	0	2	0	0	2	0	0	0
32	2	1	19	2	0	0	0	0	0	0	0	0	0
33	0	0	37	1	2	0	1	0	0	1	0	1	1
34	0	0	33	0	0	0	0	0	0	0	0	0	0
35	1	1	13	0	0	0	0	0	0	0	0	0	0
36	1	0	4	0	0	0	0	0	0	0	0	0	0
37	0	0	2	0	0	0	0	0	0	0	0	0	0
38	0	0	1	0	0	0	0	0	0	0	0	0	0
39	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 26. Annual length frequency of spot sampled from scrap landings (combined gears) by the NCDMF.

Fork Length (cm)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
5	0	1	0	0	0	0	0	0	0	0	0	0	0
6	2	4	0	0	0	0	0	0	0	0	0	0	1
7	5	2	0	0	0	0	0	0	0	0	0	0	0
8	66	15	3	20	2	0	1	8	5	14	6	4	0
9	117	24	6	44	6	0	25	24	26	66	28	15	5
10	147	48	10	65	2	36	103	144	108	120	79	67	21
11	167	173	20	52	4	109	190	275	132	181	130	110	49
12	210	406	31	82	25	140	195	277	155	278	174	148	133
13	348	501	52	96	73	107	123	179	160	188	211	142	138
14	429	675	173	246	176	143	115	206	213	215	222	123	107
15	493	768	431	520	237	185	139	231	368	191	261	126	94
16	504	840	526	662	239	202	216	305	480	188	296	159	121
17	410	620	565	607	152	241	197	485	558	210	345	213	209
18	226	305	490	211	92	226	156	672	573	156	307	278	252
19	62	89	206	87	62	153	112	392	276	146	284	196	229
20	5	32	36	67	22	96	51	103	42	43	183	160	176
21	1	6	6	8	7	74	16	18	6	10	86	131	70
22	0	0	1	0	0	15	1	5	1	4	58	85	20
23	0	0	1	0	0	1	2	0	1	3	15	21	8
24	0	0	0	0	0	0	0	0	0	0	3	15	4
25	0	0	0	0	0	0	0	0	0	2	5	5	2
26	0	0	0	0	0	0	0	0	0	0	2	4	1
27	0	2	0	0	0	0	0	0	1	0	1	0	0
28	0	0	0	0	0	0	0	0	0	0	0	1	1
29	0	0	0	0	0	1	0	0	0	0	0	0	1
30	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	1	0	0	0	0

Table 26. ***Continued*. Annual length frequency of spot sampled from scrap landings (combined gears) by the NCDMF.**

Fork Length (cm)	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
5	0	0	0	0	0	0	0	0	0	0	0	0
6	1	0	0	0	0	0	0	0	0	0	0	0
7	0	0	1	0	0	0	0	0	0	0	0	0
8	2	1	0	0	0	1	0	0	0	0	0	0
9	10	19	2	0	0	23	0	3	0	0	0	0
10	42	112	25	9	30	72	11	26	0	7	1	2
11	96	83	89	38	131	57	12	33	18	29	2	5
12	100	68	99	74	135	67	23	40	21	29	7	10
13	85	66	94	167	146	107	21	34	58	12	8	8
14	90	69	126	202	149	95	39	43	47	20	11	11
15	143	156	235	272	207	161	58	48	61	16	3	16
16	172	171	327	253	208	174	99	62	86	15	9	9
17	227	73	249	273	175	213	143	73	63	12	12	25
18	271	54	210	210	113	213	95	45	29	12	11	38
19	163	51	119	95	69	107	24	12	16	13	2	63
20	64	80	49	25	30	37	5	5	2	5	3	22
21	18	29	6	6	8	17	1	2	0	2	0	2
22	7	9	3	1	1	10	1	2	0	0	0	1
23	0	3	4	2	0	1	0	0	0	0	0	0
24	0	3	1	0	0	0	0	0	0	0	0	0
25	0	1	1	0	0	0	0	0	0	1	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	1	0	0	0	0	1	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	1	0	1	1	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0

Table 27. **Spot length sample sizes by gear and year collected from commercial fisheries by the TIP in Florida. (Entangling gear) Net Ban began in 1995 and cast nets became the main commercial gear. For unknown reasons the TIP stopped recording the gears sampled beginning from 2004. So, since 2004, samples are assumed to come from cast nets landings. UNK stands for unknown gear.**

				Gears						
Years	UNK	cast net	crab pot	gill net	lines	seine	trammel	traps	trawl	Grand Total
1992				2361						2361
1993				3620						3620
1994		8		1816						1824
1995		3		387			14		170	574
1996		25								25
1997		311		98	10	1			16	436
1998		97		73	8				4	182
1999		346							99	445
2000		241			1				98	340
2001		103		49				15	183	350
2002	67	385	4			14			25	495
2003		7								7
2004		10								10
2005		2								2
2006		118								118
2007		182								182
2008		91								91
2009		12								12
2010		2								2
2011		43								43
2012		66								66
2013		6								6
2014		78								78
Grand Total	67	2136	4	8404	19	15	14	15	595	11269

Table 28. Coastwide spot commercial landings (metric tons).

Year	Metric Tons	Year	Metric Tons	Year	Metric Tons
1950	4,611	1972	5,066	1994	3,990
1951	5,831	1973	4,726	1995	3,548
1952	6,586	1974	4,548	1996	2,600
1953	3,600	1975	5,778	1997	3,007
1954	3,784	1976	2,477	1998	3,368
1955	3,686	1977	3,201	1999	2,541
1956	5,007	1978	4,328	2000	3,142
1957	4,097	1979	5,065	2001	3,175
1958	4,383	1980	4,634	2002	2,480
1959	4,086	1981	3,403	2003	2,644
1960	4,893	1982	4,736	2004	2,642
1961	3,468	1983	3,246	2005	2,039
1962	3,374	1984	2,676	2006	1,555
1963	2,838	1985	3,255	2007	2,612
1964	3,902	1986	3,157	2008	1,381
1965	2,171	1987	3,675	2009	2,586
1966	2,533	1988	3,123	2010	1,068
1967	4,843	1989	3,213	2011	2,506
1968	2,674	1990	3,010	2012	638
1969	1,766	1991	3,255	2013	1,604
1970	4,422	1992	3,076	2014	2,402
1971	2,676	1993	3,272		

Table 29. Spot commercial landings (metric tons) by state. Red asterisks indicate confidential values.

Year	FL	GA	SC	NC	VA	MD	DE	NJ	NY	CT	MA	RI
1950	41.59		132.18	2,346.11	2,040.44	44.59	4.94	0.64	0.45			
1951	127.23	0.54	1,200.20	2,093.10	2,281.79	58.33	8.03	57.56				4.54
1952	169.05	5.81	825.99	2,516.53	2,683.36	190.46	54.66	140.61				
1953	156.31	3.99	199.58	1,276.73	1,774.59	128.55	20.28	39.01	0.95			
1954	212.60	6.08	226.16	1,084.04	2,010.50	117.12	46.90	79.92	1.00			
1955	163.93	46.72	512.70	860.92	1,791.14	184.88	103.46	22.32				
1956	221.04	18.78	1,897.06	1,167.91	1,454.99	136.30	89.49	20.91				0.05
1957	154.45	29.21	951.59	978.62	1,574.51	267.21	60.01	78.20	2.90			
1958	268.89	17.60	381.88	1,052.74	2,384.26	268.98	7.71	0.54				
1959	468.24	0.14	834.93	1,027.34	1,703.01	38.56	8.94	5.13				
1960	468.47	0.18	1,234.04	1,184.10	1,771.91	226.07	8.26	0.14				
1961	421.21	0.05	1,573.28	932.45	537.01	4.35						
1962	319.65	1.68	1,422.01	552.61	1,065.81	12.20		0.09				
1963	511.15	1.86	1,233.41	415.26	668.96	6.89	0.23					
1964	431.73	1.13	1,436.07	567.53	1,450.50	15.38		0.05				
1965	425.51	4.99	532.52	413.95	794.01	0.27						
1966	546.44	2.40	964.11	495.00	522.90	1.86						
1967	407.51	4.76	1,006.57	1,382.50	1,929.26	112.63		0.05				
1968	501.04	0.91	931.00	714.45	506.21	20.68						
1969	396.71	1.09	205.70	674.85	475.59	9.39		2.90				
1970	634.08	4.22	166.70	693.50	2,663.86	259.73		0.09				
1971	1,311.38	2.63	583.09	539.82	228.43	9.21		1.41				
1972	879.92	14.79	1,029.18	1,769.98	1,338.32	33.43		0.54				
1973	417.58	15.38	659.79	2,448.20	1,168.50	12.29		4.31				
1974	792.79	7.44	162.37	2,543.27	1,021.05	16.78		4.76				
1975	381.33	4.04	676.23	3,764.75	870.41	46.67	7.71	26.54				
1976	242.17	7.94	459.75	1,212.98	540.79	7.44	3.63	1.09	1.41			
1977	466.52	3.22	133.57	1,725.97	846.85	7.44	5.17	9.25	2.54			
1978	450.81	0.14	181.86	2,212.82	1,454.00	14.20	8.85	4.94	0.54			
1979	395.25	0.11	189.82	3,312.77	1,152.69	4.81	8.21	0.82	0.14			
1980	405.11	0.72	186.44	3,220.53	814.11	2.86	2.40	1.09	0.50			
1981	1,269.55	3.50	57.78	1,592.82	465.47	6.44	5.03	2.72				
1982	2,009.97	0.13	28.38	2,231.11	461.49	2.81	1.13	0.82				

Table 29. ***Continued*. Spot commercial landings (metric tons) by state. Red asterisks indicate confidential values.**

Year	FL	GA	SC	NC	VA	MD	DE	NJ	NY	CT	MA	RI
1983	1,027.97	*	108.91	1,339.14	711.27	58.69		0.36				
1984	684.27	*	59.09	1,579.37	333.42	19.60		0.05				
1985	634.95	*	64.75	1,834.25	708.46	3.49	7.80	1.09				
1986	416.79	0.06	297.27	1,521.43	831.84	47.36	39.19	2.99				
1987	428.17	0.69	100.04	1,272.80	1,687.88	114.21	63.55	7.21				
1988	609.75	0.29	170.65	1,397.18	900.53	26.31	17.55	0.73				
1989	519.25	0.16	14.28	1,476.20	1,133.32	52.53	13.15	3.72				
1990	578.66	0.02	17.17	1,567.37	773.33	58.01	11.29	4.10				
1991	476.93	*	14.42	1,382.23	1,151.82	97.99	107.14	24.69				
1992	342.79	0.12	78.00	1,281.91	1,132.90	150.52	43.09	46.36				
1993	374.61	0.58	113.95	1,212.07	1,472.85	82.64	9.98	4.94	0.03		0.01	
1994	454.69	*	130.74	1,332.34	1,936.57	75.41	45.54	14.25				
1995	253.80	0.11	94.86	1,363.88	1,643.21	150.31	28.12	13.68	0.01			
1996	25.59		27.48	1,038.73	1,354.01	116.44	36.71	0.52	0.14			
1997	103.01	*	39.54	1,192.01	1,598.26	54.58	16.19	2.80	0.09			
1998	73.07	*	28.99	1,087.25	1,999.42	102.48	63.67	12.51	*		*	
1999	33.12	*	4.26	1,026.10	1,349.32	101.36	23.38	3.55				
2000	26.30		3.86	1,283.59	1,726.36	80.26	14.65	6.28	0.43			
2001	14.99	*	5.87	1,403.36	1,577.46	128.59	35.50	9.09	0.07		*	
2002	9.35	*	10.26	990.66	1,397.31	62.89	6.25	0.60	2.60			
2003	4.23		7.74	926.86	1,584.14	83.66	34.94	2.72	0.02			
2004	5.87	*	1.20	1,051.05	1,536.25	19.84	26.54	0.75	0.04			
2005	9.59		4.75	777.68	1,122.60	52.16	71.47	0.35	0.20			
2006	10.21	*	2.58	619.04	876.09	15.91	28.55	1.65	1.34			
2007	6.50		2.88	398.74	1,966.46	176.68	58.15	2.03	0.49		*	
2008	4.16	*	0.68	334.06	969.59	56.11	14.81	0.88	0.49			
2009	10.00		10.23	456.54	1,820.98	239.78	32.41	15.45	0.14			
2010	6.10	*	1.79	259.60	501.07	268.53	27.40	2.74	0.62			
2011	15.37		5.52	425.00	1,706.89	283.32	41.79	24.90	3.70	*		
2012	16.67		0.25	222.11	279.35	46.40	8.21	4.51	57.87	0.53		2.59
2013	14.24		1.11	348.63	952.84	144.89	35.90	21.92	73.59	10.32		0.22
2014	7.58	*	2.68	346.86	1,814.05	161.55	54.26	13.50	1.02			*

Table 30. Spot commercial landings (metric tons) by gear.

Year	Haul Seines	Gill Nets	Trawls	Fixed Nets	Other Gears
1950	3,597	296	25	689	3
1951	4,933	354	22	496	26
1952	5,524	482	108	417	54
1953	2,931	272	41	313	43
1954	2,792	385	161	446	1
1955	2,740	412	141	388	4
1956	3,925	442	207	418	15
1957	2,886	506	192	466	47
1958	2,956	739	140	524	23
1959	2,663	642	141	601	40
1960	3,327	711	205	613	38
1961	2,489	515	193	260	11
1962	2,231	572	122	442	8
1963	1,921	638	95	178	6
1964	2,654	771	67	403	7
1965	1,223	590	58	292	8
1966	1,576	692	89	160	16
1967	2,640	924	391	877	12
1968	1,662	629	150	223	10
1969	871	540	179	141	36
1970	1,545	1,571	80	1,154	72
1971	1,134	1,295	126	101	20
1972	2,594	1,423	349	679	22
1973	2,616	910	592	591	17
1974	2,269	1,214	410	619	36
1975	3,918	886	584	374	16
1976	1,516	539	196	213	14
1977	1,539	909	370	357	25
1978	1,663	741	705	764	455
1979	2,610	978	634	444	399
1980	2,468	976	575	210	405
1981	1,323	399	175	236	1,270
1982	1,779	288	235	422	2,012

Table 30. ***Continued.*** **Spot commercial landings (metric tons) by gear.**

Year	Haul Seines	Gill Nets	Trawls	Fixed Nets	Other Gears
1983	1,192	482	159	385	1,028
1984	1,061	478	165	287	686
1985	1,341	852	259	165	638
1986	1,263	1,064	181	227	422
1987	947	1,837	134	303	455
1988	1,252	938	139	168	626
1989	1,040	1,262	161	213	536
1990	1,376	725	121	195	592
1991	1,153	1,505	98	167	332
1992	950	1,776	128	170	51
1993	998	2,060	52	132	29
1994	855	2,753	57	293	31
1995	755	2,304	55	272	161
1996	662	1,606	54	145	134
1997	919	1,797	59	165	68
1998	785	2,239	43	187	113
1999	553	1,792	45	125	26
2000	732	2,207	47	134	22
2001	673	2,163	91	219	29
2002	457	1,753	55	184	31
2003	512	1,806	42	265	19
2004	525	1,918	16	162	21
2005	438	1,433	6	142	21
2006	471	1,014	9	49	12
2007	561	1,819	22	147	64
2008	346	887	11	93	44
2009	293	2,048	30	127	87
2010	197	724	5	77	66
2011	197	1,937	6	140	227
2012	157	345	65	25	47
2013	189	1,099	90	62	164
2014	191	1,847	20	189	154

Table 31. **Spot commercial landings (millions of fish). Conversions were not done for Georgia, North Carolina before 1989, or any states north of New Jersey.**

Year	FL	SC	NC	VA	MD	DE	NJ	Total
1981	8.087	0.388		2.703	0.024	0.022	0.023	11.247
1982	12.803	0.190		3.263	0.031	0.013	0.008	16.308
1983	6.548	0.731		8.256	0.647	0.000	0.003	16.185
1984	4.359	0.018		2.739	0.108	0.000	0.000	7.224
1985	4.044	0.434		4.519	0.039	0.000	0.007	9.043
1986	2.655	1.995		6.540	0.348	0.288	0.027	11.853
1987	2.727	0.671		11.012	0.504	0.000	0.034	14.948
1988	3.884	1.145		5.269	0.193	0.035	0.005	10.531
1989	3.307	0.096	15.683	6.942	0.287	0.153	0.021	26.490
1990	3.686	0.115	16.821	4.261	0.352	0.086	0.041	25.362
1991	3.038	0.097	15.387	6.666	0.545	0.727	0.254	26.715
1992	2.184	0.523	12.685	6.758	0.872	0.272	0.261	23.555
1993	2.386	0.765	11.517	8.240	0.492	0.072	0.040	23.513
1994	2.896	0.877	5.448	10.060	0.407	0.244	0.223	20.156
1995	1.617	0.636	7.516	7.873	0.685	0.128	0.072	18.527
1996	0.143	0.184	5.451	6.440	0.530	0.101	0.002	12.852
1997	0.575	0.265	5.690	8.627	0.342	0.081	0.013	15.595
1998	0.408	0.195	5.392	10.002	0.492	0.338	0.070	16.897
1999	0.185	0.029	4.416	7.275	0.563	0.094	0.015	12.576
2000	0.147	0.026	6.513	8.202	0.395	0.076	0.099	15.457
2001	0.084	0.039	6.272	5.521	0.493	0.179	0.052	12.640
2002	0.052	0.069	4.367	6.087	0.385	0.038	0.003	11.002
2003	0.023	0.052	4.305	6.869	0.399	0.154	0.013	11.815
2004	0.032	0.008	4.664	6.248	0.111	0.141	0.004	11.208
2005	0.052	0.032	3.328	5.072	0.341	0.300	0.001	9.127
2006	0.055	0.017	3.097	4.586	0.095	0.209	0.010	8.070
2007	0.035	0.019	2.428	11.702	0.955	0.322	0.011	15.473
2008	0.023	0.005	1.929	5.454	0.212	0.109	0.011	7.743
2009	0.054	0.069	2.701	9.161	1.181	0.179	0.103	13.447
2010	0.033	0.012	1.496	2.671	1.422	0.197	0.017	5.847
2011	0.083	0.037	2.332	8.461	1.816	0.308	0.158	13.195
2012	0.090	0.002	1.430	1.610	0.329	0.049	0.057	3.568
2013	0.077	0.007	1.909	5.438	0.978	0.185	0.134	8.727
2014	0.041	0.018	1.999	9.520	1.051	0.201	0.056	12.886

Table 32. Scrap landings of spot by state.

Year	NC		VA	
	Millions	Metric Tons	Millions	Metric Tons
1981	3.894	197	0.479	24
1982	5.454	276	0.475	24
1983	3.274	166	0.733	37
1984	3.861	196	0.344	17
1985	4.484	227	0.730	37
1986	3.719	189	0.860	44
1987	3.111	158	1.739	88
1988	3.415	173	0.928	47
1989	3.608	183	1.153	58
1990	3.831	194	0.762	39
1991	3.379	171	1.187	60
1992	3.134	159	1.167	59
1993	2.963	150	1.565	79
1994	5.706	372	1.889	96
1995	1.644	169	3.572	181
1996	6.009	209	2.300	117
1997	5.839	321	1.105	56
1998	3.587	225	3.918	199
1999	2.194	139	2.917	148
2000	1.876	109	1.859	94
2001	1.576	133	1.519	77
2002	0.963	84	0.634	32
2003	1.784	131	1.622	82
2004	1.722	124	1.521	77
2005	0.635	48	0.860	44
2006	0.760	62	2.272	115
2007	2.442	129	2.661	135
2008	2.456	207	1.372	70
2009	1.005	37	0.262	13
2010	0.406	25	0.399	20
2011	1.121	83	0.714	36
2012	0.513	39	1.567	79
2013	0.153	6	0.335	17
2014	0.126	9	0.506	26

Table 33. Number of discarded spot measured for length (fork) by the NEFOP.

Year	Trawls	Gill Nets
1989	140	0
1990	300	0
1991	94	0
1992	0	0
1993	0	0
1994	0	0
1995	0	12
1996	0	1
1997	0	0
1998	0	0
1999	0	0
2000	0	32
2001	110	3
2002	240	0
2003	0	19
2004	0	1
2005	0	0
2006	0	2
2007	1	0
2008	9	0
2009	50	0
2010	78	0
2011	0	0
2012	1	0
2013	1	6
2014	5	0

Table 34. Number of tows observed by the SESTOP by South Atlantic fishery and year.

Year	Fishery	
	Penaeid Shrimp	Rock Shrimp
2001	30	16
2002	14	119
2003	0	177
2004	0	0
2005	158	0
2006	0	22
2007	135	0
2008	239	111
2009	458	19
2010	187	60
2011	320	0
2012	377	0
2013	308	96
2014	174	39

Table 35. NEFOP gillnet observer data from trips encountering spot and total aggregate landings of all species summarized by year. All landings and discard values are in pounds. Values highlighted in yellow are averages of adjacent years or the closest two year period with data.

Year	n Observed Trips	n Observed Sets	Total Observed Landings	Total Observed Discards	Mean Observed Landings	Mean Observed Discards	Observed Landings Variance	Observed Discards Variance	Total Reported Landings
1989	46	376	79,479	302	211	0.80	103,924	5	25,652,524
1990	46	376	79,479	302	211	0.80	103,924	5	24,002,907
1991	46	376	79,479	302	211	0.80	103,924	5	29,094,526
1992	46	376	79,479	302	211	0.80	103,924	5	35,577,345
1993	6	67	5,433	12	81	0.18	15,615	0	43,650,274
1994	40	309	74,046	290	240	0.94	118,692	6	44,036,266
1995	64	489	94,656	445	194	0.91	47,191	11	50,739,022
1996	32	282	64,431	15	228	0.05	72,069	0	69,291,360
1997	39	299	61,243	11	205	0.04	91,721	0	68,001,924
1998	10	43	6,047	25	141	0.58	14,222	3	71,081,469
1999	12	65	7,519	41	116	0.63	100,860	4	60,134,421
2000	12	73	17,000	46	233	0.63	76,590	7	53,612,915
2001	12	81	18,118	6	224	0.07	40,584	0	49,486,118
2002	13	62	13,125	190	212	3.06	84,019	69	44,679,363
2003	5	38	4,561	45	120	1.17	14,626	4	46,294,253
2004	3	19	1,303	35	69	1.82	2,439	61	43,035,622
2005	1	4	788	0	197	0.05	22,147	0	44,817,006
2006	1	7	1,603	1	229	0.20	7,730	0	36,334,649
2007	1	2	333	5	167	2.50	13,945	13	47,407,903
2008	3	30	6,279	5	209	0.16	71,611	0	44,172,162
2009	6	59	9,421	7	160	0.12	67,321	0	46,920,564
2010	3	29	3,142	2	108	0.07	59,914	0	45,500,133
2011	7	46	6,848	92	149	2.00	49,194	71	49,724,296
2012	7	46	6,848	92	149	2.00	49,194	71	43,074,272
2013	4	17	3,706	90	218	5.31	25,452	182	41,490,424
2014	10	83	6,420	85	77	1.02	17,228	25	50,323,940

Table 36. NEFOP trawl observer data from trips encountering spot and total aggregate landings of all species summarized by year. All landings and discard values are in pounds. Values highlighted in yellow are averages of adjacent years.

Year	n Observed Trips	n Observed Tows	Total Observed Landings	Total Observed Discards	Mean Observed Landings	Mean Observed Discards	Observed Landings Variance	Observed Discards Variance	Total Reported Landings
1989	7	67	15,859	3,163	237	47.21	33,506	8,762	102,266,145
1990	10	66	14,111	14,904	214	225.82	95,936	340,475	98,306,719
1991	10	96	75,505	896	787	9.33	2,841,320	561	124,235,440
1992	2	16	14,850	78	928	4.88	1,791,253	162	122,170,085
1993	5	36	11,221	228	312	6.33	64,487	141	122,523,204
1994	3	17	9,397	5	553	0.29	70,928	1	116,584,503
1995	22	179	122,610	416	685	2.32	1,521,473	38	111,100,026
1996	9	55	44,013	72	800	1.31	407,760	13	136,997,042
1997	2	24	79,208	445	3,300	18.54	21,426,228	927	113,737,816
1998	1	18	37,735	45	2,096	2.50	8,432,371	89	151,684,942
1999	3	52	39,878	93	767	1.79	3,055,011	49	124,402,919
2000	2	3	16,048	570	5,349	190.00	27,460,736	73,300	115,098,410
2001	14	67	84,106	46	1,255	0.69	911,833	1	90,445,547
2002	18	91	136,090	45	1,495	0.49	1,116,657	0	80,132,678
2003	22	106	145,557	102	1,373	0.96	1,073,754	4	74,051,714
2004	4	15	9,467	57	631	3.80	187,440	17	106,953,633
2005	5	46	167,852	384	3,649	8.35	37,363,223	1,222	55,072,880
2006	1	6	19,781	0	3,297	0.00	5,791,317	0	71,947,284
2007	16	131	220,367	565	1,682	4.31	12,106,105	519	48,895,736
2008	15	114	161,334	263	1,415	2.31	32,874,979	121	58,543,253
2009	25	164	218,409	350	1,332	2.13	8,222,888	79	71,184,696
2010	9	80	154,000	3,814	1,925	47.68	13,924,724	29,548	47,259,488
2011	12	92	110,180	437	1,198	4.75	2,647,643	690	77,198,373
2012	50	179	143,365	844	801	4.72	776,668	289	65,570,023
2013	75	306	254,069	9,412	830	30.76	3,711,261	44,531	51,079,933
2014	14	70	205,270	2,462	2,932	35.17	33,332,156	17,848	50,734,848

Table 37. Number of observations from NEFOP observer data for spot by NMFS statistical area and gear. A map of statistical areas is in Figure 19.

Stat Area	Gillnets	Trawls
611	0	52
612	2	140
613	0	107
614	92	46
615	0	10
616	0	19
621	92	916
622	0	27
623	0	2
625	1,437	142
626	0	37
631	125	168
632	0	14
635	251	283
636	0	27

Table 38. Gears observed by NEFOP on trips that were used to estimate spot discards.

GILL NET, ANCHORED-FLOATING, FISH
GILL NET, DRIFT-FLOATING, FISH
GILL NET, DRIFT-SINK, FISH
GILL NET, FIXED OR ANCHORED,SINK, OTHER/NK SPECIES
TRAWL,OTTER,BOTTOM,FISH
TRAWL,OTTER,BOTTOM,RUHLE
TRAWL,OTTER,BOTTOM,SCALLOP
TRAWL,OTTER,BOTTOM,TWIN

Table 39. Gears contributing to aggregate landings used to expand ratios to discard estimates. Additional landings recorded as "NOT CODED" were included in the total landings (GILL NETS NC, TRAWLS NC).

GILL NETS	OTHER TRAWLS
GILL NETS, FLOATING ANCHOR	OTTER TRAWL BOTTOM, CRAB
GILL NETS, FLOATING DRIFT	OTTER TRAWL BOTTOM, FISH
GILL NETS, OTHER	OTTER TRAWL BOTTOM, LOBSTER
GILL NETS, RUNAROUND	OTTER TRAWL BOTTOM, OTHER
GILL NETS, SINK ANCHOR	OTTER TRAWL BOTTOM, PAIRED
GILL NETS, SINK DRIFT	OTTER TRAWL BOTTOM, SCALLOP
GILL NETS, STAKE	OTTER TRAWL BOTTOM, SHRIMP
GILL NETS NC	OTTER TRAWL, PEELER
	OTTER TRAWL, RUHLE
	OTTER TRAWL, TWIN
	OTTER TRAWLS
	TRAWLS NC

Table 40. Estimated ratios, variances, and CVs of discarded spot to total aggregate landings of all species from observed gillnets. Values highlighted in yellow are averages of adjacent years or the closest two year period with data.

Year	Ratio	Ratio Variance	Ratio CV
1989	0.000119	2.64E-09	0.4304
1990	0.000119	2.64E-09	0.4304
1991	0.000119	2.64E-09	0.4304
1992	0.000000	0	NA
1993	0.000217	8.77E-09	0.4309
1994	0.000428	5.30E-09	0.1703
1995	0.000412	5.27E-09	0.1760
1996	0.000014	1.76E-11	0.3097
1997	0.000011	4.00E-11	0.5566
1998	0.000035	1.87E-10	0.3923
1999	0.000389	2.40E-08	0.3982
2000	0.000353	2.57E-08	0.4538
2001	0.001027	8.80E-07	0.9135
2002	0.000502	2.06E-07	0.9031
2003	0.000022	1.14E-10	0.4801
2004	0.000013	2.13E-10	1.0812
2005	0.000000	2.92E-14	1.0660
2006	0.000001	6.19E-13	1.0431
2007	0.000007	7.12E-11	1.1835
2008	0.000050	5.60E-10	0.4694
2009	0.000000	0	NA
2010	0.000002	6.63E-12	1.0513
2011	0.000000	0	NA
2012	0.000000	0	NA
2013	0.000252	3.58E-08	0.7515
2014	0.000117	7.62E-09	0.7491

Table 41. **Estimated ratios, variances, and CVs of discarded spot to total aggregate landings of all species from observed trawls. Values highlighted in yellow are averages of adjacent years.**

Year	Ratio	Ratio Variance	Ratio CV
1989	0.014079	1.83E-05	0.3040
1990	0.062590	4.83E-04	0.3512
1991	0.001233	1.51E-07	0.3155
1992	0.000153	1.12E-08	0.6916
1993	0.000852	1E-07	0.3713
1994	0.000016	1.3E-10	0.7223
1995	0.000638	1.85E-08	0.2131
1996	0.000044	3.25E-10	0.4077
1997	0.000406	2.60E-08	0.3968
1998	0.000067	3.69E-09	0.9046
1999	0.000122	5.41E-09	0.6048
2000	0.000227	4.15E-08	0.8968
2001	0.000013	1.16E-11	0.2547
2002	0.000049	3.10E-10	0.3621
2003	0.000000	0	NA
2004	0.000014	2.67E-11	0.3620
2005	0.000205	1.66E-08	0.6288
2006	0.000000	0.00E+00	NA
2007	0.000177	6.91E-09	0.4709
2008	0.000111	2.65E-09	0.4643
2009	0.000086	8.65E-10	0.3425
2010	0.000905	1.45E-07	0.4213
2011	0.000096	3.14E-09	0.5854
2012	0.000456	1.64E-08	0.2809
2013	0.002940	1.43E-06	0.4072
2014	0.000558	6.33E-08	0.4514

Table 42. Number of observations, number of positive observations, proportion positive observations, and mean CPUE (kg per hour fished) of spot by factor level considered in the GLMs for shrimp trawl discard estimates using SEAMAP Trawl Survey and SESTOP data.

season	N	N_pos	prop_pos	mean_CPUE
off	181	163	0.90	6.94
peak	17,107	11,583	0.68	19.93
depth_zone	**N**	**N_pos**	**prop_pos**	**mean_CPUE**
=<10m	16,007	10,927	0.68	21.08
10-30m	671	613	0.91	5.68
>30m	610	206	0.34	1.76
data_set	**N**	**N_pos**	**prop_pos**	**mean_CPUE**
penaeid_shrimp	2,386	2,139	0.90	4.79
rock_shrimp	658	249	0.38	1.69
SEAMAP	14,244	9,358	0.66	23.15
state	**N**	**N_pos**	**prop_pos**	**mean_CPUE**
FL	3,752	2,640	0.70	20.67
GA	3,708	1,996	0.54	7.54
SC	6,102	3,876	0.64	14.03
NC	3,726	3,234	0.87	40.57
year	**N**	**N_pos**	**prop_pos**	**mean_CPUE**
1989	318	201	0.63	28.75
1990	462	310	0.67	48.17
1991	466	343	0.74	60.43
1992	468	290	0.62	23.90
1993	468	300	0.64	15.80
1994	468	269	0.57	19.92
1995	468	309	0.66	29.87
1996	468	281	0.60	9.88
1997	468	227	0.49	20.53
1998	468	329	0.70	7.58
1999	468	259	0.55	5.61
2000	468	235	0.50	11.97
2001	657	476	0.72	11.75
2002	744	392	0.53	5.80
2003	789	532	0.67	18.58
2004	612	380	0.62	17.98
2005	770	556	0.72	31.84
2006	634	402	0.63	21.57
2007	742	472	0.64	5.61
2008	962	610	0.63	13.80
2009	1,148	896	0.78	11.63
2010	919	596	0.65	20.78
2011	992	828	0.83	25.82
2012	1,047	890	0.85	17.88
2013	990	733	0.74	19.31
2014	824	630	0.76	31.07

Table 43. Number of observations, number of positive observations, proportion positive observations, and mean CPUE (numbers per hour fished) of spot by factor level considered in the GLM for shrimp trawl discard estimates using SEAMAP Trawl Survey and SESTOP data.

season	N	N_pos	prop_pos	mean_CPUE
off	181	163	0.90	100.53
peak	16,815	11,291	0.67	350.86
depth_zone	**N**	**N_pos**	**prop_pos**	**mean_CPUE**
=<10m	15,715	10,635	0.68	371.34
10-30m	671	613	0.91	107.22
>30m	610	206	0.34	16.89
data_set	**N**	**N_pos**	**prop_pos**	**mean_CPUE**
penaeid_shrimp	2,379	2,132	0.90	150.07
rock_shrimp	658	249	0.38	16.77
SEAMAP	13,959	9,073	0.65	397.58
state	**N**	**N_pos**	**prop_pos**	**mean_CPUE**
FL	3,719	2,607	0.70	270.89
GA	3,662	1,950	0.53	129.73
SC	5,961	3,735	0.63	263.17
NC	3,654	3,162	0.87	784.52
year	**N**	**N_pos**	**prop_pos**	**mean_CPUE**
1989	318	201	0.63	487.60
1990	462	310	0.67	808.57
1991	466	343	0.74	899.24
1992	468	290	0.62	365.12
1993	468	300	0.64	194.54
1994	468	269	0.57	327.66
1995	468	309	0.66	547.13
1996	468	281	0.60	212.44
1997	253	12	0.05	10.90
1998	398	259	0.65	91.01
1999	468	259	0.55	119.66
2000	468	235	0.50	186.79
2001	657	476	0.72	252.98
2002	744	392	0.53	99.82
2003	789	532	0.67	405.51
2004	612	380	0.62	339.29
2005	770	556	0.72	557.24
2006	634	402	0.63	401.43
2007	742	472	0.64	100.43
2008	961	609	0.63	221.31
2009	1,147	895	0.78	242.47
2010	919	596	0.65	382.52
2011	992	828	0.83	539.31
2012	1,047	890	0.85	313.92
2013	986	729	0.74	320.47
2014	823	629	0.76	569.78

Table 44. Lognormal GLM summary of spot discard rate in weight (kg) from shrimp trawl fisheries.

```
Call:
glm(formula = lnCPUE ~ YEAR + data_set + depth_zone + state +
   season, family = gaussian, data = trips_pr_pos, na.action = na.exclude)
Deviance Residuals:
   Min      1Q   Median      3Q      Max
-5.6426  -1.1672  0.0818   1.1758   6.2999
Coefficients:
                 Estimate Std. Error t value Pr(>|t|)
(Intercept)        0.616356   0.199370   3.092 0.001996 **
YEAR1990          -0.160520   0.155563  -1.032 0.302157
YEAR1991           0.607467   0.152647   3.980 6.95e-05 ***
YEAR1992          -0.040623   0.157693  -0.258 0.796715
YEAR1993          -0.839396   0.156619  -5.359 8.51e-08 ***
YEAR1994          -0.311419   0.160204  -1.944 0.051933 .
YEAR1995          -0.286344   0.155675  -1.839 0.065887 .
YEAR1996          -1.113360   0.158708  -7.015 2.42e-12 ***
YEAR1997          -0.616578   0.166371  -3.706 0.000212 ***
YEAR1998          -1.041126   0.153780  -6.770 1.35e-11 ***
YEAR1999          -1.565368   0.161498  -9.693  < 2e-16 ***
YEAR2000          -1.149601   0.165046  -6.965 3.45e-12 ***
YEAR2001          -0.763366   0.144870  -5.269 1.39e-07 ***
YEAR2002          -1.104388   0.150616  -7.332 2.41e-13 ***
YEAR2003          -0.480957   0.144169  -3.336 0.000852 ***
YEAR2004          -0.684820   0.150092  -4.563 5.10e-06 ***
YEAR2005          -0.707700   0.141981  -4.984 6.30e-07 ***
YEAR2006           0.005537   0.148637   0.037 0.970284
YEAR2007          -1.069100   0.145217  -7.362 1.93e-13 ***
YEAR2008          -0.733061   0.141184  -5.192 2.11e-07 ***
YEAR2009          -0.442210   0.136145  -3.248 0.001165 **
YEAR2010          -0.561131   0.141127  -3.976 7.05e-05 ***
YEAR2011           0.087099   0.136534   0.638 0.523532
YEAR2012           0.036136   0.135996   0.266 0.790466
YEAR2013          -0.303937   0.138043  -2.202 0.027702 *
YEAR2014           0.285651   0.140181   2.038 0.041599 *
data_setrock_shrimp -0.892799   0.250420  -3.565 0.000365 ***
data_setSEAMAP      1.499818   0.051907  28.895  < 2e-16 ***
depth_zone>30m      1.147655   0.273763   4.192 2.78e-05 ***
depth_zone10-30m    0.430202   0.091865   4.683 2.86e-06 ***
stateGA          -0.876792   0.053438 -16.408  < 2e-16 ***
stateNC           0.631736   0.048937  12.909  < 2e-16 ***
stateSC          -0.322651   0.047437  -6.802 1.08e-11 ***
seasonpeak         0.289818   0.148724   1.949 0.051355 .
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for gaussian family taken to be 2.950506)

    Null deviance: 43223  on 11745  degrees of freedom
Residual deviance: 34556  on 11712  degrees of freedom
AIC: 46079

Number of Fisher Scoring iterations: 2
```

Table 45. Binomial GLM summary for spot discard rate in weight (kg) from shrimp trawl fisheries.

```
Call:
glm(formula = success ~ YEAR + data_set + depth_zone + state +
   season, family = binomial(link = "logit"), data = trips_pr,
   na.action = na.exclude, offset = effort)
Deviance Residuals:
  Min     1Q  Median     3Q    Max
-3.738  -1.101   0.569  0.883  2.418
Coefficients:
                     Estimate Std. Error z value Pr(>|z|)
(Intercept)         -0.025634   0.339908  -0.075  0.93988
YEAR1990             0.156883   0.157416   0.997  0.31895
YEAR1991             0.483034   0.161206   2.996  0.00273 **
YEAR1992            -0.089449   0.155144  -0.577  0.56424
YEAR1993             0.007879   0.155814   0.051  0.95967
YEAR1994            -0.289501   0.154189  -1.878  0.06044 .
YEAR1995             0.097886   0.156548   0.625  0.53179
YEAR1996            -0.176228   0.154667  -1.139  0.25454
YEAR1997            -0.678486   0.153792  -4.412 1.03e-05 ***
YEAR1998             0.305887   0.158633   1.928  0.05382 .
YEAR1999            -0.386874   0.153880  -2.514  0.01193 *
YEAR2000            -0.618228   0.153714  -4.022 5.77e-05 ***
YEAR2001             0.342591   0.151703   2.258  0.02393 *
YEAR2002            -0.601331   0.144336  -4.166 3.10e-05 ***
YEAR2003             0.405722   0.148282   2.736  0.00622 **
YEAR2004            -0.188339   0.148523  -1.268  0.20477
YEAR2005             0.130572   0.147451   0.886  0.37587
YEAR2006            -0.069565   0.148226  -0.469  0.63884
YEAR2007            -0.257696   0.145175  -1.775  0.07589 .
YEAR2008            -0.143364   0.143052  -1.002  0.31626
YEAR2009             0.310370   0.143902   2.157  0.03102 *
YEAR2010            -0.123193   0.143296  -0.860  0.38995
YEAR2011             0.794631   0.150625   5.276 1.32e-07 ***
YEAR2012             0.737029   0.151319   4.871 1.11e-06 ***
YEAR2013             0.307538   0.145325   2.116  0.03433 *
YEAR2014             0.383633   0.149715   2.562  0.01039 *
data_setrock_shrimp -1.230365   0.445437  -2.762  0.00574 **
data_setSEAMAP       1.124871   0.088660  12.687  < 2e-16 ***
depth_zone>30m      -2.430597   0.454551  -5.347 8.93e-08 ***
depth_zone10-30m     0.172479   0.173383   0.995  0.31984
stateGA             -1.006508   0.056627 -17.774  < 2e-16 ***
stateNC              0.762613   0.066937  11.393  < 2e-16 ***
stateSC             -0.509512   0.053344  -9.551  < 2e-16 ***
seasonpeak          -0.488308   0.311995  -1.565  0.11756
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 23041  on 17287  degrees of freedom
Residual deviance: 19372  on 17254  degrees of freedom
AIC: 19440

Number of Fisher Scoring iterations: 5
```

Table 46. Negative binomial GLM summary for spot discard rate in numbers from shrimp trawl fisheries.

```
Call:
glm.nb(formula = catch ~ year + season + data_set + state + depth_zone +
   offset(log_eff), data = CPUE_data, init.theta = 0.1946308757,
   link = log)
Deviance Residuals:
   Min      1Q  Median      3Q     Max
-1.8621  -1.4007  -0.7148  -0.1309   5.2769
Coefficients:
                Estimate Std. Error t value Pr(>|t|)
(Intercept)        5.659865   0.325906  17.367  < 2e-16 ***
year1990           0.799449   0.230525   3.468 0.000526 ***
year1991           0.880239   0.230123   3.825 0.000131 ***
year1992          -0.288392   0.230018  -1.254 0.209938
year1993          -0.622286   0.230071  -2.705 0.006842 **
year1994          -0.199967   0.230006  -0.869 0.384640
year1995           0.281341   0.229958   1.223 0.221179
year1996          -0.887417   0.230129  -3.856 0.000116 ***
year1997          -3.324336   0.271444 -12.247  < 2e-16 ***
year1998          -1.256965   0.238318  -5.274 1.35e-07 ***
year1999          -1.312748   0.230263  -5.701 1.21e-08 ***
year2000          -1.056787   0.230182  -4.591 4.44e-06 ***
year2001          -0.061423   0.216617  -0.284 0.776756
year2002          -1.019844   0.213662  -4.773 1.83e-06 ***
year2003           0.328165   0.213281   1.539 0.123909
year2004          -0.687410   0.219107  -3.137 0.001708 **
year2005           0.065884   0.211645   0.311 0.755581
year2006           0.099218   0.217791   0.456 0.648708
year2007          -1.209071   0.212861  -5.680 1.37e-08 ***
year2008          -0.735592   0.206845  -3.556 0.000377 ***
year2009          -0.243182   0.203655  -1.194 0.232462
year2010          -0.318099   0.207185  -1.535 0.124718
year2011           0.853106   0.205926   4.143 3.45e-05 ***
year2012          -0.187737   0.205454  -0.914 0.360851
year2013          -0.010730   0.206417  -0.052 0.958545
year2014           0.452699   0.210126   2.154 0.031222 *
seasonpeak        -0.904388   0.258977  -3.492 0.000480 ***
data_setrock_shrimp -1.183710   0.437108  -2.708 0.006775 **
data_setSEAMAP     1.141451   0.087538  13.039  < 2e-16 ***
stateGA           -1.083271   0.079646 -13.601  < 2e-16 ***
stateNC            1.124155   0.080906  13.895  < 2e-16 ***
stateSC           -0.170220   0.074022  -2.300 0.021484 *
depth_zone>30m    -0.663407   0.454311  -1.460 0.144240
depth_zone10-30m  -0.009523   0.159439  -0.060 0.952375
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for Negative Binomial(0.1946) family taken to be 1.944617)

    Null deviance: 22410  on 16995  degrees of freedom
Residual deviance: 18875  on 16962  degrees of freedom
AIC: 155001
Number of Fisher Scoring iterations: 1
```

Table 47. Model selection summary for spot lognormal (left) and binomial (right) GLMS of discard rate in weight from shrimp trawl fisheries.

Drop	Df	Deviance	AIC	scaled dev.	Pr(>Chi)	Drop	Df	Deviance	AIC	LRT	Pr(>Chi)
none	NA	34,556	46,079	NA	NA	none	NA	19,372	19,440	NA	NA
YEAR	25	37,123	46,870	842	1.92E-161	YEAR	25	19,839	19,857	468	3.97E-83
data_set	2	37,117	46,914	840	4.44E-183	data_set	2	19,517	19,581	146	2.42E-32
depth_zone	2	34,646	46,105	30	2.51E-07	depth_zone	2	19,416	19,480	44	2.18E-10
state	3	37,634	47,075	1,002	5.92E-217	state	3	20,460	20,522	1,089	1.11E-235
season	1	34,568	46,080	4	5.10E-02	season	1	19,374	19,440	3	1.06E-01

Table 48. Model selection summary for spot negative binomial GLM of discard rate in numbers from shrimp trawl fisheries.

drop	Df	Deviance	AIC	Pr(>Chisq)
none	NA	18,875.3	155,001	NA
year	25	18,934.1	156,266	7.27E-262
season	1	18,876.4	155,024	5.94E-07
data_set	2	18,886.0	155,280	4.88E-62
state	3	18,939.9	156,485	1.03753785626662e-322
depth_zone	2	18,875.6	155,004	3.24E-02

Table 49. Summary of shrimp trawl effort data by year and state. Averages are highlighted in yellow.

year	state	hours_fished	trips	avg_hours	avg_gear	year	state	hours_fished	trips	avg_hours	avg_gear
1989	FL	147,659	5,124	17.57	1.64	2002	FL	68,108	2,872	14.46	1.64
1989	GA	646,487	7,711	28.04	2.99	2002	GA	317,808	3,745	28.1	3.02
1989	NC	1,234,260	30,077	18.32	2.24	2002	NC	553,747	12,425	19.21	2.32
1989	SC	393,248	10,192	14.84	2.6	2002	SC	272,943	7,074	14.84	2.6
1990	FL	189,299	6,246	18.48	1.64	2003	FL	106,948	2,763	20.48	1.89
1990	GA	523,746	6,247	28.04	2.99	2003	GA	292,499	3,461	28.36	2.98
1990	NC	802,614	19,558	18.32	2.24	2003	NC	326,112	8,995	15.56	2.33
1990	SC	371,741	9,635	14.84	2.6	2003	SC	226,425	6,293	14.11	2.55
1991	FL	147,733	5,843	15.14	1.67	2004	FL	99,818	2,730	19.98	1.83
1991	GA	849,379	10,131	28.04	2.99	2004	GA	226,756	2,751	27.66	2.98
1991	NC	1,017,306	24,790	18.32	2.24	2004	NC	356,922	7,573	19.72	2.39
1991	SC	533,501	13,827	14.84	2.6	2004	SC	272,049	5,954	17.71	2.58
1992	FL	127,136	4,757	16.1	1.66	2005	FL	94,763	2,649	19.13	1.87
1992	GA	748,436	8,927	28.04	2.99	2005	GA	172,942	2,432	24.27	2.93
1992	NC	389,472	9,491	18.32	2.24	2005	NC	157,026	4,324	16.14	2.25
1992	SC	477,901	12,386	14.84	2.6	2005	SC	139,663	4,131	12.71	2.66
1993	FL	139,354	5,314	16.39	1.6	2006	FL	87,610	2,499	17.27	2.03
1993	GA	752,628	8,977	28.04	2.99	2006	GA	156,168	2,073	24.38	3.09
1993	NC	533,885	13,010	18.32	2.24	2006	NC	227,146	5,587	16.46	2.47
1993	SC	448,346	11,620	14.84	2.6	2006	SC	115,618	3,661	12.1	2.61
1994	FL	167,861	6,484	15.69	1.65	2007	FL	82,025	2,308	16.53	2.15
1994	GA	719,092	8,577	28.04	2.99	2007	GA	124,718	1,651	23.83	3.17
1994	NC	678,297	16,529	18.32	2.24	2007	NC	290,549	6,668	17.57	2.48
1994	SC	391,859	10,156	14.84	2.6	2007	SC	90,831	3,268	10.69	2.6
1995	FL	139,566	5,723	14.87	1.64	2008	FL	64,847	2,147	15.41	1.96
1995	GA	828,838	9,886	28.04	2.99	2008	GA	115,676	1,784	22.13	2.93
1995	NC	694,507	16,924	18.32	2.24	2008	NC	326,774	5,980	21.18	2.58
1995	SC	469,760	12,175	14.84	2.6	2008	SC	92,251	3,531	10.01	2.61
1996	FL	143,918	5,600	13.67	1.88	2009	FL	62,668	2,173	15.34	1.88
1996	GA	651,518	7,771	28.04	2.99	2009	GA	128,305	1,772	23.74	3.05
1996	NC	475,001	11,575	18.32	2.24	2009	NC	249,333	5,744	17.79	2.44
1996	SC	352,503	9,136	14.84	2.6	2009	SC	93,365	3,194	11.33	2.58
1997	FL	119,267	5,314	12.4	1.81	2010	FL	85,296	2,656	15.82	2.03
1997	GA	749,107	8,935	28.04	2.99	2010	GA	141,441	2,224	21.78	2.92
1997	NC	558,470	13,609	18.32	2.24	2010	NC	225,387	5,508	17.05	2.4
1997	SC	435,228	11,280	14.84	2.6	2010	SC	122,570	4,346	11.06	2.55
1998	FL	114,184	5,154	14.48	1.53	2011	FL	83,501	2,745	15.52	1.96
1998	GA	664,932	7,931	28.04	2.99	2011	GA	129,594	1,935	22.55	2.97
1998	NC	389,809	9,499	18.32	2.24	2011	NC	200,784	4,354	18.67	2.47
1998	SC	365,969	9,485	14.84	2.6	2011	SC	88,496	3,176	10.8	2.58
1999	FL	102,769	5,102	13.61	1.48	2012	FL	78,664	2,586	15.52	1.96
1999	GA	603,142	7,194	28.04	2.99	2012	GA	127,852	1,909	22.55	2.97
1999	NC	563,025	13,720	18.32	2.24	2012	NC	284,760	6,175	18.67	2.47
1999	SC	386,072	10,006	14.84	2.6	2012	SC	117,085	4,202	10.8	2.58
2000	FL	69,444	3,666	13.34	1.42	2013	FL	52,230	1,717	15.52	1.96
2000	GA	443,679	5,292	28.04	2.99	2013	GA	86,731	1,295	22.55	2.97
2000	NC	488,849	12,911	18.03	2.1	2013	NC	252,986	5,486	18.67	2.47
2000	SC	367,088	9,514	14.84	2.6	2013	SC	87,409	3,137	10.8	2.58
2001	FL	72,511	3,221	14.07	1.6	2014	FL	62,937	2,069	15.52	1.96
2001	GA	260,741	3,110	28.04	2.99	2014	GA	106,086	1,584	22.55	2.97
2001	NC	397,548	9,808	17.7	2.29	2014	NC	202,813	4,398	18.67	2.47
2001	SC	241,111	6,249	14.84	2.6	2014	SC	87,409	3,137	10.8	2.58

Table 50. Proportions used to partition South Atlantic shrimp trawl effort data. Effort data are partitioned across depth zones first and then within each depth zone across fisheries.

	Depth Zone		
	=<10m	10-30m	>30m
all effort at depth	0.58	0.22	0.20
penaeid effort within depth	1.00	0.93	0.01
rock effort wtihin depth	0.00	0.07	0.99

Table 51. Estimated spot gillnet discards in weight (lbs) and numbers. Lower confidence intervals are truncated at zero due to large variances. Data used to estimate mean weight and discards in numbers were pooled over all years due to small sample size.

Year	Discards (lbs)	Discards LCI (lbs)	Discards UCI (lbs)	n Fish Counted	Total Subsample Weight (lbs)	n Subsamples	Mean Weight (lbs)	Discards (numbers)
1989	3,063	426	5,699	NA	NA	NA	NA	3,629
1990	2,866	399	5,333	NA	NA	NA	NA	3,396
1991	3,474	483	6,464	NA	NA	NA	NA	4,116
1992	0	0	0	NA	NA	NA	NA	0
1993	9,484	1,310	17,659	NA	NA	NA	NA	11,238
1994	18,796	12,395	25,197	NA	NA	NA	NA	22,272
1995	20,858	13,515	28,201	2	8	1	4.000	24,715
1996	931	355	1,508	1	1	1	1.000	1,104
1997	770	0	1,627	NA	NA	NA	NA	913
1998	2,450	528	4,372	NA	NA	NA	NA	2,903
1999	23,110	4,705	41,515	NA	NA	NA	NA	27,384
2000	18,715	1,730	35,701	32	33	4	1.031	22,176
2001	50,021	0	141,409	3	2	2	0.500	59,271
2002	22,175	0	62,226	NA	NA	NA	NA	26,276
2003	1,020	41	1,999	19	8	3	0.421	1,208
2004	573	0	1,812	1	1	1	0.500	679
2005	7	0	22	NA	NA	NA	NA	8
2006	27	0	84	2	1	1	0.700	32
2007	337	0	1,136	NA	NA	NA	NA	400
2008	2,223	136	4,310	NA	NA	NA	NA	2,634
2009	0	0	0	NA	NA	NA	NA	0
2010	111	0	345	NA	NA	NA	NA	132
2011	0	0	0	NA	NA	NA	NA	0
2012	0	0	0	NA	NA	NA	NA	0
2013	10,353	0	25,914	6	2	1	0.383	12,268
2014	5,838	0	14,584	NA	NA	NA	NA	6,917

Table 52. Estimated spot trawl discards in weight (lbs) and numbers. Lower confidence intervals are truncated at zero due to large variances. Values highlighted in yellow are averages of adjacent years or the closest two year period with data.

Year	Discards (lbs)	Discards LCI (lbs)	Discards UCI (lbs)	n Fish Counted	Total Subsample Weight (lbs)	n Subsamples	Mean Weight (lbs)	Discards (numbers)
1989	1,344,507	526,949	2,162,065	140	14	2	0.100	13,445,069
1990	5,740,647	1,708,309	9,772,985	300	68	2	0.227	25,326,383
1991	141,751	52,305	231,197	94	21	2	0.223	634,504
1992	17,379	0	41,417	204	62	30	0.304	57,183
1993	93,537	24,069	163,006	204	62	30	0.304	307,768
1994	1,542	0	3,770	204	62	30	0.304	5,074
1995	59,024	33,867	84,182	204	62	30	0.304	194,210
1996	4,706	869	8,544	204	62	30	0.304	15,484
1997	37,588	7,759	67,417	204	62	30	0.304	123,676
1998	8,751	0	24,583	204	62	30	0.304	28,794
1999	11,098	0	24,523	204	62	30	0.304	36,517
2000	18,678	0	52,179	204	62	30	0.304	61,457
2001	1,033	507	1,559	110	41	28	0.373	2,771
2002	3,333	919	5,747	240	42	37	0.175	19,045
2003	0	0	0	241	42	38	0.176	0
2004	916	253	1,579	241	42	38	0.176	5,220
2005	10,563	0	23,846	241	42	38	0.176	60,181
2006	0	0	0	241	42	38	0.176	0
2007	8,029	468	15,590	1	0	1	0.300	26,763
2008	7,353	525	14,181	9	2	2	0.178	41,361
2009	7,196	2,266	12,125	50	5	2	0.104	69,189
2010	51,590	8,115	95,065	78	13	2	0.160	321,923
2011	6,056	0	13,146	79	13	3	0.163	37,088
2012	24,801	10,868	38,735	1	0	1	0.400	62,003
2013	125,149	23,228	227,069	6	2	2	0.317	395,206
2014	24,348	2,366	46,329	5	2	1	0.300	81,159

Table 53. Comparison of spot discard estimates from trawls in Mid-Atlantic fisheries with and without large discard tows observed in 1989 (1 tow) and 1990 (5 tows). Ratios are the weight of discarded spot to the weight of all species landed.

Estimates with all data

Year	Ratio	Ratio Variance	Ratio CV	Discards (lbs)	Discards (numbers)
1989	0.0141	1.83E-05	0.30	1,344,507	13,445,069
1990	0.0626	4.83E-04	0.35	5,740,647	25,326,383

Estimates excluding anomalous tows in 1989 and 1990

Year	Ratio	Ratio Variance	Ratio CV	Discards (lbs)	Discards (numbers)
1989	0.0045	1.41E-06	0.26	432,981	4,329,810
1990	0.0040	2.20E-06	0.37	365,926	1,614,379

Table 54. Spot discard estimates (millions of fish) from South Atlantic shrimp trawl fisheries with values corresponding to 95% confidence intervals. Unadjusted estimates are estimates before making adjustments due to catch reductions by BRDs.

Year	LCI	Discards	UCI	Unadjusted Discards
1989	423	583	807	454
1990	694	930	1,250	723
1991	953	1,272	1,705	990
1992	154	208	284	162
1993	132	177	240	138
1994	232	311	419	242
1995	399	538	731	419
1996	87	116	157	91
1997	6	9	13	NA
1998	41	56	77	NA
1999	51	69	95	NA
2000	54	73	98	NA
2001	117	152	198	NA
2002	60	78	101	NA
2003	154	199	258	NA
2004	59	77	102	NA
2005	66	85	111	NA
2006	82	107	140	NA
2007	26	34	45	NA
2008	47	59	76	NA
2009	62	77	96	NA
2010	55	69	88	NA
2011	157	197	249	NA
2012	75	94	118	NA
2013	76	96	121	NA
2014	100	127	163	NA

Table 55. Spot discard estimates (metric tons) from South Atlantic shrimp trawl fisheries with values corresponding to 95% confidence intervals. Unadjusted estimates are estimates before making adjustments due to catch reductions by BRDs.

Year	LCI	Discards	UCI	Unadjusted Discards
1989	20,280	27,545	37,543	21,372
1990	13,157	17,239	22,682	13,382
1991	39,320	50,976	66,366	39,634
1992	8,392	11,219	15,083	8,694
1993	4,823	6,387	8,501	4,953
1994	8,682	11,603	15,581	8,990
1995	10,549	13,911	18,435	10,793
1996	3,043	4,051	5,420	3,139
1997	3,556	4,876	6,719	0
1998	2,577	3,386	4,473	0
1999	1,514	2,044	2,776	0
2000	1,793	2,439	3,334	0
2001	3,044	3,861	4,922	0
2002	2,086	2,720	3,564	0
2003	3,660	4,641	5,911	0
2004	2,630	3,413	4,452	0
2005	1,486	1,874	2,378	0
2006	3,453	4,458	5,784	0
2007	1,316	1,677	2,149	0
2008	2,113	2,628	3,289	0
2009	2,623	3,191	3,906	0
2010	1,977	2,473	3,111	0
2011	4,287	5,243	6,450	0
2012	5,330	6,489	7,948	0
2013	2,904	3,569	4,410	0
2014	4,553	5,650	7,050	0

Table 56. Mean weight of spot discarded in South Atlantic shrimp trawl fisheries based on the discard estimates in weight and numbers.

Year	Discard Numbers	Discard Weight (kg)	Annual Mean Weight
1989	583,370,348	27,545,377	0.047
1990	929,664,646	17,238,964	0.019
1991	1,272,210,025	50,975,781	0.040
1992	208,192,851	11,219,290	0.054
1993	177,436,234	6,387,178	0.036
1994	310,993,951	11,603,132	0.037
1995	538,455,701	13,911,437	0.026
1996	116,476,304	4,051,409	0.035
1997	9,229,182	4,875,524	0.528
1998	55,725,316	3,386,127	0.061
1999	69,292,192	2,044,180	0.030
2000	72,777,842	2,439,134	0.034
2001	152,054,525	3,861,087	0.025
2002	77,579,021	2,720,041	0.035
2003	198,910,447	4,640,864	0.023
2004	77,409,152	3,413,310	0.044
2005	85,110,306	1,873,689	0.022
2006	106,681,825	4,457,674	0.042
2007	34,223,459	1,676,660	0.049
2008	59,337,373	2,627,907	0.044
2009	76,673,915	3,190,751	0.042
2010	69,181,376	2,473,140	0.036
2011	196,989,629	5,243,226	0.027
2012	93,779,860	6,488,747	0.069
2013	95,573,541	3,568,750	0.037
2014	127,347,986	5,650,194	0.044

Table 57. **Spot length and weight sample sizes by year obtained during MRFSS and MRIP sampling.**

Year	Length	Weight	Year	Length	Weight
1981	1,514	1,719	1998	2,957	2,930
1982	1,905	1,794	1999	1,964	2,011
1983	3,349	3,090	2000	1,850	1,863
1984	1,281	1,146	2001	2,764	2,800
1985	5,104	4,816	2002	1,656	1,689
1986	5,607	5,249	2003	2,921	2,859
1987	3,955	3,741	2004	4,447	4,475
1988	1,834	1,761	2005	3,422	3,260
1989	3,986	3,835	2006	3,947	3,982
1990	2,742	2,716	2007	3,990	3,973
1991	4,764	5,044	2008	3,611	3,632
1992	3,216	3,349	2009	4,856	4,864
1993	2,470	2,403	2010	2,033	1,990
1994	4,581	4,572	2011	3,312	3,344
1995	2,753	2,550	2012	1,172	932
1996	3,150	2,819	2013	1,731	1,151
1997	3,016	2,942	2014	1,289	857

Table 58. **Spot length sample size from MRIP at-sea sampling of headboats by year and state.**

Year	FL	GA	SC	NC	VA	MD	DE	NJ	Total
2004	0	0	0	9	25	86	0	0	120
2005	0	0	0	6	231	464	0	4	705
2006	0	0	0	31	14	183	0	0	228
2007	0	0	0	3	35	167	3	0	208
2008	0	0	0	57	24	53	16	0	150
2009	0	0	1	13	11	58	1	0	84
2010	0	0	0	2	109	102	3	1	217
2011	0	0	0	7	64	49	5	0	125
2012	0	0	1	3	9	228	6	1	248
2013	0	0	0	7	18	357	0	4	386
2014	0	0	2	40	5	18	1	0	66

Table 59. **Number of recreational harvest weight estimates by pooling level for MRFSS strata with zero harvest weight estimates and positive harvest number estimates.**

Factor Collapsed for Pooling			
Area	Mode	State	Wave
0	1	16	15

Table 60. **Total harvest number estimates without weight, imputed harvest weight estimates, and mean weights for MRFSS strata with zero harvest weight estimates and positive number estimates.**

Year	Numbers	Weight (lbs.)	Mean Weight
1981	0	NA	NA
1982	0	NA	NA
1983	8,975	2,754	0.31
1984	21,046	5,084	0.24
1985	1,807	551	0.30
1986	0	NA	NA
1987	3,343	843	0.25
1988	10,657	3,885	0.36
1989	1,076	310	0.29
1990	2,881	915	0.32
1991	4,769	1,340	0.28
1992	0	NA	NA
1993	50,385	19,864	0.39
1994	35,127	13,869	0.39
1995	1,962	816	0.42
1996	0	NA	NA
1997	0	NA	NA
1998	8,797	4,058	0.46
1999	0	NA	NA
2000	2,597	943	0.36
2001	0	NA	NA
2002	3,953	1,594	0.40
2003	25,408	11,451	0.45

Table 61. **MRIP harvest estimates (numbers and weight) by pooling level for APAIS design change calibration. Headboat estimates were not adjusted (No Ratio) because the design for this mode (at-sea sampling) did not change in 2013.**

Ratio Pooling Level				
No Pooling	Collapse State	Collapse Species	Collapse State and Species	No Ratio
81	43	64	0	28

Table 62. **MRIP released alive (number) estimates by pooling level for APAIS design change calibration. Headboat estimates were not adjusted (No Ratio) because the design for this mode (at-sea sampling) did not change in 2013.**

Ratio Pooling Level				
No Pooling	Collapse State	Collapse Species	Collapse State and Species	No Ratio
81	94	13	0	28

Table 63. **MRFSS and MRIP recreational harvest of spot (millions of fish) by state and coastwide.**

Year	FL	GA	SC	NC	VA	MD	DE	NJ	NY	CT	Coastwide
1981	0.983	0.153	0.692	4.948	14.095	1.167	0.022	0.034	0.054	0.000	22.147
1982	0.904	0.103	1.513	5.072	5.444	3.523	0.101	0.477	0.000	0.000	17.136
1983	0.600	0.138	1.194	6.021	14.748	1.976	0.018	0.000	0.000	0.000	24.695
1984	0.487	0.447	0.891	3.392	1.729	1.079	0.019	0.010	0.000	0.000	8.056
1985	1.060	0.077	2.896	10.828	6.259	1.254	0.000	0.015	0.019	0.000	22.408
1986	0.119	0.170	2.468	3.254	5.019	5.223	0.015	0.012	0.005	0.000	16.285
1987	0.091	0.098	0.738	2.618	4.496	4.196	0.000	0.000	0.000	0.000	12.236
1988	0.816	0.071	2.399	3.146	2.451	0.342	0.003	0.429	0.000	0.000	9.656
1989	0.083	0.043	1.326	3.596	4.522	1.805	0.056	0.001	0.001	0.000	11.433
1990	0.009	0.022	0.175	2.443	6.497	3.352	0.055	0.032	0.000	0.000	12.585
1991	0.332	0.013	0.736	2.849	10.803	2.762	0.186	0.109	0.000	0.000	17.788
1992	0.440	0.032	1.464	1.564	7.680	2.428	0.110	0.025	0.000	0.000	13.743
1993	1.164	0.282	1.775	2.530	3.472	2.829	0.004	0.010	0.001	0.000	12.067
1994	0.169	0.012	1.635	7.292	4.027	2.473	0.114	0.178	0.024	0.000	15.922
1995	0.172	0.035	1.076	4.110	3.280	1.822	0.064	0.004	0.000	0.000	10.563
1996	0.079	0.017	1.750	2.470	1.345	0.748	0.001	0.029	0.000	0.000	6.440
1997	0.039	0.007	0.837	1.772	4.060	1.016	0.155	0.025	0.000	0.000	7.910
1998	0.148	0.008	0.601	3.528	2.437	1.648	0.119	0.000	0.000	0.000	8.489
1999	0.325	0.007	0.986	1.609	0.696	0.842	0.024	0.000	0.000	0.000	4.489
2000	0.050	0.004	0.303	2.367	0.638	1.898	0.082	0.346	0.613	0.000	6.302
2001	0.803	0.005	0.905	4.490	1.253	1.483	0.063	0.000	0.000	0.000	9.001
2002	0.032	0.009	0.484	3.182	1.966	0.851	0.027	0.000	0.000	0.000	6.550
2003	0.104	0.014	0.645	4.669	1.769	4.595	0.037	0.000	0.000	0.000	11.833
2004	0.010	0.002	0.948	5.362	1.560	0.996	0.023	0.000	0.000	0.000	8.902
2005	0.037	0.005	0.486	4.200	4.280	2.093	0.181	0.082	0.000	0.000	11.363
2006	0.013	0.002	1.310	4.551	2.895	3.716	0.279	0.016	0.000	0.000	12.782
2007	0.051	0.004	0.663	4.832	7.357	4.291	0.290	0.000	0.002	0.000	17.491
2008	0.094	0.011	3.197	2.557	6.169	2.293	0.224	0.172	0.000	0.000	14.717
2009	0.048	0.033	0.730	1.728	2.765	2.521	0.347	0.014	0.000	0.000	8.184
2010	0.188	0.002	0.252	1.312	2.042	1.366	0.164	1.134	0.000	0.000	6.460
2011	0.306	0.001	0.764	1.609	3.661	0.907	0.374	0.001	0.000	0.000	7.624
2012	0.125	0.000	1.115	1.255	2.336	0.876	0.147	0.878	0.059	0.000	6.791
2013	0.132	0.007	0.732	1.465	4.288	0.936	0.248	0.329	0.013	0.000	8.150
2014	0.609	0.016	0.466	2.112	3.909	1.254	0.345	0.013	0.000	0.000	8.723

Table 64. MRFSS and MRIP recreational harvest of spot (metric tons) by state and coastwide.

Year	FL	GA	SC	NC	VA	MD	DE	NJ	NY	CT	Coastwide
1981	176	29	82	673	2,566	313	5	3	11	0	3,857
1982	133	11	177	616	853	370	11	48	0	0	2,219
1983	96	16	165	921	1,413	201	2	0	0	0	2,814
1984	69	48	95	367	214	194	3	2	0	0	993
1985	120	7	249	1,762	1,014	109	0	2	2	0	3,266
1986	14	13	257	302	657	710	2	1	1	0	1,958
1987	19	8	128	389	716	932	0	0	0	0	2,193
1988	104	8	344	452	400	45	1	48	0	0	1,403
1989	13	4	163	524	781	438	6	0	0	0	1,930
1990	1	4	28	346	1,167	616	7	3	0	0	2,173
1991	61	2	139	410	1,534	442	30	11	0	0	2,629
1992	95	4	224	228	1,271	481	21	5	0	0	2,329
1993	234	62	261	458	534	456	0	1	0	0	2,008
1994	34	2	265	1,039	657	433	20	18	4	0	2,470
1995	25	4	137	707	589	376	13	1	0	0	1,852
1996	15	3	279	401	274	171	0	6	0	0	1,150
1997	8	1	144	408	706	259	29	5	0	0	1,559
1998	27	1	129	705	480	359	21	0	0	0	1,722
1999	48	1	221	365	137	159	6	0	0	0	937
2000	8	1	73	504	141	379	19	26	74	0	1,224
2001	161	1	196	1,000	285	387	11	0	0	0	2,041
2002	5	2	79	556	467	190	6	0	0	0	1,305
2003	20	3	128	967	493	1,042	8	0	0	0	2,661
2004	1	0	154	1,102	449	252	4	0	0	0	1,962
2005	6	1	79	709	943	404	40	19	0	0	2,201
2006	2	0	231	763	647	584	41	2	0	0	2,271
2007	11	1	86	704	1,305	730	59	0	0	0	2,895
2008	14	2	421	428	1,183	350	29	10	0	0	2,437
2009	8	5	126	264	493	471	59	2	0	0	1,428
2010	34	0	34	188	301	245	25	174	0	0	1,000
2011	50	0	125	248	556	153	59	0	0	0	1,192
2012	17	0	137	160	321	153	22	67	28	0	905
2013	19	1	137	209	602	126	49	54	3	0	1,199
2014	75	2	71	320	579	183	95	3	0	0	1,328

Table 65. MRFSS and MRIP recreational live releases of spot (millions of fish) by state and coastwide.

Year	FL	GA	SC	NC	VA	MD	DE	NJ	NY	CT	Coastwide
1981	0.090	0.008	0.115	1.028	12.428	1.896	0.002	0.036	0.000	0.000	15.603
1982	0.287	0.062	0.512	1.128	2.256	2.344	0.007	1.362	0.000	0.000	7.959
1983	0.261	0.056	0.269	0.911	3.790	1.564	0.000	0.080	0.000	0.000	6.931
1984	0.182	0.025	0.484	1.332	3.629	1.603	0.019	0.000	0.000	0.000	7.273
1985	0.238	0.024	0.720	0.642	2.750	1.026	0.000	0.004	0.031	0.000	5.435
1986	0.014	0.029	0.463	1.141	3.102	4.121	0.000	0.111	0.000	0.000	8.982
1987	0.080	0.040	0.425	0.830	2.399	0.375	0.002	0.000	0.000	0.000	4.150
1988	0.154	0.024	0.154	1.392	1.065	1.001	0.008	0.155	0.000	0.000	3.952
1989	0.031	0.002	0.194	0.734	3.494	1.056	0.056	0.006	0.000	0.000	5.574
1990	0.043	0.006	0.019	1.288	6.131	2.827	0.014	0.020	0.000	0.000	10.349
1991	0.235	0.021	0.141	1.323	9.818	3.060	0.095	0.129	0.000	0.000	14.821
1992	0.090	0.024	0.390	1.178	2.887	0.730	0.017	0.002	0.000	0.000	5.318
1993	0.259	0.067	0.193	0.739	1.914	2.386	0.051	0.000	0.000	0.000	5.609
1994	0.469	0.031	0.449	1.906	2.860	1.523	0.074	0.224	0.011	0.000	7.548
1995	0.376	0.014	0.464	1.447	1.602	0.365	0.020	0.031	0.000	0.000	4.318
1996	0.091	0.007	0.295	1.297	0.800	0.297	0.002	0.055	0.010	0.000	2.855
1997	0.025	0.002	0.343	0.630	1.885	1.920	0.124	0.030	0.000	0.000	4.960
1998	0.082	0.017	0.430	0.909	1.216	0.905	0.106	0.018	0.000	0.000	3.683
1999	0.742	0.015	0.121	0.885	0.472	0.867	0.022	0.000	0.000	0.000	3.124
2000	0.076	0.024	0.162	0.675	0.692	1.515	0.043	0.023	0.221	0.000	3.431
2001	0.104	0.016	0.215	1.598	1.329	0.835	0.018	0.003	0.000	0.000	4.119
2002	0.062	0.028	0.145	0.940	0.673	0.700	0.038	0.004	0.003	0.000	2.593
2003	0.149	0.043	0.324	1.583	1.304	0.957	0.019	0.055	0.000	0.000	4.434
2004	0.012	0.013	0.266	2.103	0.790	0.600	0.054	0.000	0.000	0.000	3.840
2005	0.052	0.031	0.222	2.350	2.231	3.200	0.189	0.010	0.000	0.000	8.284
2006	0.029	0.002	0.530	4.262	1.508	2.257	0.091	0.088	0.000	0.000	8.766
2007	0.034	0.011	0.122	2.199	1.893	2.730	0.036	0.200	0.001	0.000	7.226
2008	0.142	0.039	0.191	2.345	1.595	2.885	0.135	1.088	0.000	0.000	8.419
2009	0.043	0.011	0.414	2.090	1.418	1.076	0.188	0.012	0.000	0.000	5.253
2010	0.026	0.001	0.076	1.549	1.234	1.651	0.082	0.315	0.000	0.000	4.933
2011	0.169	0.015	0.267	1.792	2.574	0.508	0.087	0.001	0.000	0.000	5.413
2012	0.406	0.006	0.146	1.437	1.369	1.651	0.064	0.751	0.050	0.000	5.879
2013	0.111	0.009	0.958	1.314	2.218	2.622	0.214	0.748	0.000	0.001	8.194
2014	0.575	0.027	0.427	0.891	1.174	0.566	0.079	0.015	0.000	0.000	3.754

Table 66. MRFSS and MRIP recreational live releases of spot (metric tons) coastwide.

Year	Coastwide
1981	157
1982	60
1983	44
1984	56
1985	45
1986	73
1987	39
1988	35
1989	58
1990	104
1991	129
1992	50
1993	58
1994	67
1995	42
1996	28
1997	63
1998	42
1999	35
2000	40
2001	56
2002	31
2003	60
2004	29
2005	55
2006	98
2007	69
2008	70
2009	69
2010	27
2011	70
2012	50
2013	95
2014	64

Table 67. Total numbers (millions of fish) and weight (metric tons) of spot caught and released by recreational anglers assumed to die post-release (15%).

Year	Millions	Metric Tons
1981	2.340	157
1982	1.194	60
1983	1.040	44
1984	1.091	56
1985	0.815	45
1986	1.347	73
1987	0.623	39
1988	0.593	35
1989	0.836	58
1990	1.552	104
1991	2.223	129
1992	0.798	50
1993	0.841	58
1994	1.132	67
1995	0.648	42
1996	0.428	28
1997	0.744	63
1998	0.552	42
1999	0.469	35
2000	0.515	40
2001	0.618	56
2002	0.389	31
2003	0.665	60
2004	0.576	29
2005	1.243	55
2006	1.315	98
2007	1.084	69
2008	1.263	70
2009	0.788	69
2010	0.740	27
2011	0.812	70
2012	0.882	50
2013	1.229	95
2014	0.563	64

Table 68. MRFSS and MRIP coastwide recreational harvest of spot (millions of fish) and PSEs.

Year	Mean	PSE
1981	22.147	36.3
1982	17.136	25.4
1983	24.695	41.4
1984	8.056	27.5
1985	22.408	24.2
1986	16.285	25.5
1987	12.236	19.2
1988	9.656	24.8
1989	11.433	15.6
1990	12.585	20.1
1991	17.788	18.7
1992	13.743	23.6
1993	12.067	19.7
1994	15.922	15.3
1995	10.563	22.7
1996	6.440	29.3
1997	7.910	28.1
1998	8.489	21.0
1999	4.489	20.2
2000	6.302	22.2
2001	9.001	20.2
2002	6.550	20.4
2003	11.833	17.6
2004	8.902	12.6
2005	11.363	15.8
2006	12.782	18.3
2007	17.491	15.5
2008	14.717	24.3
2009	8.184	14.3
2010	6.460	18.1
2011	7.624	15.2
2012	6.791	19.5
2013	8.150	7.8
2014	8.723	17.3

Table 69. MRFSS and MRIP coastwide recreational harvest of spot (metric tons) and PSEs.

Year	Mean	PSE
1981	3,857	33.9
1982	2,219	30.2
1983	2,814	41.1
1984	993	29.6
1985	3,266	26.7
1986	1,958	25.9
1987	2,193	22.2
1988	1,403	28.5
1989	1,930	16.9
1990	2,173	22.2
1991	2,629	19.0
1992	2,329	25.4
1993	2,008	19.4
1994	2,470	15.2
1995	1,852	24.9
1996	1,150	30.0
1997	1,559	25.5
1998	1,722	22.8
1999	937	22.6
2000	1,224	25.3
2001	2,041	20.5
2002	1,305	22.2
2003	2,661	18.6
2004	1,962	12.7
2005	2,201	16.9
2006	2,271	19.2
2007	2,895	16.1
2008	2,437	28.2
2009	1,428	15.3
2010	1,000	18.4
2011	1,192	14.4
2012	905	19.6
2013	1,199	7.9
2014	1,328	14.9

Table 70. MRFSS and MRIP coastwide recreational live releases of spot (millions of fish) and PSEs.

Year	Mean	PSE
1981	15.603	72.5
1982	7.959	35.0
1983	6.931	57.8
1984	7.273	32.3
1985	5.435	22.1
1986	8.982	27.1
1987	4.150	20.3
1988	3.952	40.7
1989	5.574	16.4
1990	10.349	19.3
1991	14.821	18.1
1992	5.318	20.0
1993	5.609	20.9
1994	7.548	12.9
1995	4.318	17.5
1996	2.855	19.1
1997	4.960	20.4
1998	3.683	16.3
1999	3.124	20.5
2000	3.431	19.5
2001	4.119	13.9
2002	2.593	16.8
2003	4.434	20.0
2004	3.840	11.8
2005	8.284	14.0
2006	8.766	15.8
2007	7.226	13.9
2008	8.419	14.6
2009	5.253	12.7
2010	4.933	13.4
2011	5.413	12.8
2012	5.879	13.0
2013	8.194	8.1
2014	3.754	9.2

Table 71. Spot harvest estimates (number of fish) from the SERHS.

Year	Harvest	Year	Harvest
1981	363	1998	0
1982	0	1999	1
1983	0	2000	0
1984	0	2001	0
1985	7	2002	0
1986	0	2003	0
1987	35	2004	0
1988	0	2005	35
1989	0	2006	0
1990	57	2007	0
1991	58	2008	0
1992	227	2009	0
1993	28	2010	0
1994	0	2011	0
1995	0	2012	0
1996	0	2013	17
1997	0	2014	1

Table 72. Spot release estimates (number of fish) by disposition from the SERHS.

Year	Dead	Live	Disposition Unknown
2004	0	0	0
2005	0	0	0
2006	0	0	0
2007	0	0	0
2008	0	0	0
2009	0	0	0
2010	0	0	0
2011	0	0	0
2012	0	0	0
2013	0	0	3
2014	0	0	12

Table 73. Coastwide removals of spot combined across fisheries in metric tons and millions of fish. 1989 is the first year removal data from all fisheries are available.

Year	Metric Tons	Millions of Fish
1989	33,598	640
1990	25,364	999
1991	57,287	1,324
1992	16,900	251
1993	12,002	219
1994	18,607	356
1995	19,739	574
1996	8,157	145
1997	9,899	41
1998	8,947	89
1999	5,860	92
2000	7,066	99
2001	9,366	177
2002	6,663	97
2003	10,221	227
2004	8,248	101
2005	6,266	108
2006	8,559	132
2007	7,521	73
2008	6,797	87
2009	7,328	100
2010	4,637	83
2011	9,134	220
2012	8,212	107
2013	6,551	115
2014	9,492	150

Table 74. Surveys considered for developing abundance and biomass indices by the spot SAS for this assessment.

Survey Considered	Time Series Available	Used	Reason Not Used (if applicable)
NJ DFW Delaware River Seine Survey	1980-2014	N	Localized survey, too many zeros
NJ DFW Delaware Bay Trawl Survey	1991-2014	N	Localized survey, fixed design
NJ DFW Ocean Trawl Survey	1989-2014	N	Not representative of whole range
DE DFW 30ft Trawl Survey	1966-1971, 1979-1984, 1990-2014	N	Fixed design, localized survey
DE DFW 17ft Trawl Survey	1978-2014	N	Fixed design, localized survey
MD DNR Chesapeake Blue Crab Trawl Survey	1980, consistent from 1989-2014	N	Fixed design
MD DNR Striped Bass Seine Survey	1966-2014	N	Too many zeros
MD DNR Coastal Bays Trawl Survey	1972-2014, standardized 1989	N	YOY survey, others used instead
MD DNR Coastal Bay Seine Survey	1972-2014	N	Too many zeros
MD DNR Choptank River Gill Net Survey	2013-2014	N	Short time series
VIMS Juvenile Trawl Survey	1988-2014	N	YOY survey
NC P120 (estuarine trawl survey)	1970-2014	N	YOY survey, others used instead
NC P195 (NCDMF Trawl Survey)	1987-2014	Y	NA
NC P915	1987-2014	N	Not representative of stock
NC P135	1990-2014	N	Other survey in this region used
NC P123	1991-2014	N	Other survey in this region used
NC P100		N	Fixed design
NC P430 (pound net survey)	1986-2014	N	Other survey in this region used
NC P433	1979-2014	N	Other survey in this region used
NC P434 (gill net survey)	1982-2014	N	Other survey in this region used
NC P435 (beach seine)		N	Other survey in this region used
NC P537	1978-2014	N	Other survey in this region used
NC P441	1978-2014	N	Other survey in this region used
SC DNR Bears Bluff Shrimp Trawl	1952-1969	N	Localized survey, not representative
SC DNR Trammel Net Survey	1990-2014	N	Localized survey, not representative
SC DNR Electroshock Survey	2001-2014	N	Too many zeros, not representative of stock
SEAMAP Trawl Survey	1990-2014	Y	NA
GA DNR Ecological Monitoring Trawl Survey	1976-2014	N	YOY survey, others more representative

Table 74. ***Continued*. Surveys considered for developing abundance and biomass indices by the spot SAS for this assessment.**

Survey Considered	Time Series Available	Used	Reason Not Used (if applicable)
GA DNR Gill Net Survey	2003-2014	N	Localized survey, not representative
FL FWC Fishery Independent Monitoring Bag Seine Survey	1996-2014	N	Localized survey, not representative
FL FWC Fishery Independent Monitoring Haul Seine Survey	1996-2014	N	Localized survey
FL FWC Fishery Independent Monitoring Trawl Survey	1996-2014	N	Localized survey
NMFS Trawl Survey	1972-2014	Y	NA
NEAMAP Trawl Survey	2007-2014	Y	NA
ChesMMAP Trawl Survey	2002-2014	Y	NA

Table 75. Annual number of trawl tows by strata for the NMFS Trawl Survey.

Year	1OFF	2OFF	3OFF	4OFF	5OFF	Total
1972	9	6	6	4	9	34
1973	17	6	4	4	11	42
1974	7	6	5	4	12	34
1975	6	4	4	4	7	25
1976	4	4	4	4	6	22
1977	4	4	4	4	6	22
1978	4	4	4	4	6	22
1979	4	4	4	4	6	22
1980	3	4	4	4	6	21
1981	4	4	4	4	6	22
1982	4	4	4	4	6	22
1983	4	5	4	4	6	23
1984	4	4	4	4	6	22
1985	4	4	4	4	6	22
1986	4	4	4	4	6	22
1987	4	4	4	4	6	22
1988	4	4	4	4	6	22
1989	4	4	4	4	6	22
1990	6	4	4	5	6	25
1991	4	4	4	4	6	22
1992	4	4	4	4	7	23
1993	4	4	4	4	6	22
1994	4	4	4	4	6	22
1995	4	4	4	4	6	22
1996	4	4	4	4	6	22
1997	4	4	4	4	6	22
1998	4	4	4	4	6	22
1999	4	4	4	4	6	22
2000	4	5	4	4	6	23
2001	4	4	4	4	6	22
2002	5	4	4	4	6	23
2003	4	4	4	4	6	22
2004	4	4	4	4	6	22
2005	4	4	4	4	6	22
2006	4	4	4	4	6	22
2007	4	4	4	4	6	22
2008	4	4	4	4	6	22
2009	5	8	6	4	12	35
2010	6	7	6	6	12	37
2011	13	6	6	11	12	48
2012	6	7	6	6	13	38
2013	9	7	6	6	13	41
2014	8	8	6	6	12	40
Total	220	199	187	188	312	1106

Table 76. Annual proportion of positive tows by strata for spot from the NMFS Trawl Survey using pooled strata scheme.

Year	1OFF	2OFF	3OFF	4OFF	5OFF
1972	0.00	0.00	0.17	0.75	0.33
1973	0.00	0.00	0.25	0.25	0.91
1974	0.00	0.00	0.20	1.00	0.92
1975	0.00	0.00	0.50	0.75	0.86
1976	0.00	0.25	0.25	0.75	0.83
1977	0.50	0.25	1.00	1.00	0.83
1978	0.00	0.00	0.75	0.75	1.00
1979	0.00	0.00	0.50	1.00	1.00
1980	0.00	0.00	0.25	0.50	0.83
1981	0.00	0.75	1.00	0.75	1.00
1982	0.25	0.25	1.00	1.00	0.67
1983	0.25	0.20	0.50	1.00	0.33
1984	0.00	0.25	1.00	1.00	0.83
1985	0.00	0.50	1.00	1.00	1.00
1986	0.00	0.25	1.00	1.00	1.00
1987	0.00	0.00	0.25	0.50	0.83
1988	0.00	0.25	0.25	0.75	0.67
1989	0.00	0.25	1.00	1.00	1.00
1990	0.00	0.25	0.75	0.80	1.00
1991	0.00	0.00	0.75	0.50	0.67
1992	0.00	0.00	0.50	0.25	0.14
1993	0.00	0.00	0.25	0.50	0.17
1994	0.00	0.00	0.50	1.00	0.33
1995	0.25	0.00	1.00	1.00	1.00
1996	0.00	0.00	0.25	1.00	0.67
1997	0.00	0.00	0.75	0.50	0.67
1998	0.00	0.00	0.75	0.75	0.50
1999	0.00	0.00	0.75	0.50	1.00
2000	0.00	0.00	0.00	0.75	0.67
2001	0.00	0.00	0.00	0.25	0.00
2002	0.00	0.25	1.00	0.50	0.50
2003	0.00	0.00	0.75	0.75	1.00
2004	0.00	0.00	0.50	0.50	0.83
2005	0.00	0.25	0.75	0.25	1.00
2006	0.00	0.50	0.75	1.00	1.00
2007	0.00	0.25	1.00	1.00	0.83
2008	0.25	0.50	1.00	1.00	1.00
2009	0.00	0.00	0.67	1.00	1.00
2010	0.50	0.71	1.00	0.83	0.50
2011	0.31	1.00	1.00	0.91	0.92
2012	0.00	0.71	0.67	1.00	1.00
2013	0.33	0.57	0.83	0.00	0.69
2014	0.13	0.13	0.83	0.83	0.58

Table 77. Age-0 indices of abundance and CVs developed for the spot assessment. All indices were in numbers per tow and have been standardized to their mean.

	NCDMF June Trawl		SEAMAP Fall Trawl		NMFS Fall Trawl		ChesMMAP Summer- Fall Trawl		NEAMAP Fall Trawl	
Year	Index	CV	Index	CV	Index	CV	Index	CV	Index	CV
1989	0.5050	0.1455	0.1918	0.3342	3.8526	0.0664				
1990	2.0224	0.1159	0.2627	0.1849	0.6861	0.0553				
1991	0.6570	0.1561	0.3704	0.1959	0.1380	0.2101				
1992	0.1765	0.2103	0.1281	0.2480	0.0444	0.1228				
1993	1.1139	0.1474	0.1500	0.4129	0.0256	0.1661				
1994	0.1948	0.1689	1.2351	0.2547	1.1866	0.1197				
1995	0.0960	0.2106	0.0719	0.1644	0.3425	0.0592				
1996	0.8724	0.1216	0.5658	0.1751	0.2936	0.1165				
1997	0.3996	0.1613	0.1010	0.2576	0.1236	0.1019				
1998	0.3140	0.2354	0.1505	0.2084	0.0718	0.1065				
1999	1.3754	0.2152	0.7167	0.3830	0.6050	0.0363				
2000	0.2787	0.1960	0.0847	0.4089	0.2985	0.0730				
2001	0.5169	0.2223	0.1527	0.2244	0.0005	0.3110				
2002	0.8841	0.1318	0.3398	0.2269	0.2194	0.1152	0.6630	0.3025		
2003	1.8855	0.1601	0.7943	0.4688	0.1398	0.0666	0.7769	0.2909		
2004	1.2624	0.2440	0.2174	0.2759	0.6557	0.0620	1.2951	0.2853		
2005	0.4614	0.1601	9.2655	0.3407	1.6146	0.0538	1.7277	0.2615		
2006	0.1921	0.1928	0.3094	0.1264	0.9300	0.0421	5.2776	0.2577		
2007	0.3853	0.2424	0.1511	0.2627	0.6343	0.1104	0.7931	0.2915	0.5228	0.2586
2008	3.1594	0.2301	0.5208	0.5379	1.1296	0.0487	1.0832	0.3175	1.3452	0.2783
2009	0.4469	0.1822	0.7962	0.2732	1.3712	0.0333	0.2582	0.2671	0.1634	0.1507
2010	1.6853	0.1895	6.8526	0.3420	2.9291	0.0368	0.6741	0.3483	0.5291	0.2697
2011	0.9423	0.1477	0.6487	0.2156	2.5109	0.0374	0.0215	0.2605	0.0938	0.1477
2012	2.4666	0.1047	0.7748	0.1819	4.4639	0.0263	0.2060	0.2800	5.0683	0.2556
2013	2.7690	0.1697	0.6494	0.4163	1.6031	0.0452	0.1876	0.2689	0.2195	0.2384
2014	0.9370	0.1437	0.4987	0.3872	0.1298	0.0697	0.0362	0.2081	0.0580	0.1125

Table 78. Age-1+ indices of abundance and CVs developed for the spot assessment. All indices were in numbers per tow and have been standardized to their mean.

	NCDMF June Trawl		SEAMAP Fall Trawl		NMFS Fall Trawl		ChesMMAP Summer-Fall Trawl		NEAMAP Fall Trawl	
Year	Index	CV	Index	CV	Index	CV	Index	CV	Index	CV
1989	0.8602	0.1757	0.2930	0.3342	3.5809	0.0664				
1990	0.4149	0.2220	0.4260	0.1849	0.6787	0.0553				
1991	0.8793	0.1032	2.9393	0.1959	0.1338	0.2101				
1992	0.4639	0.1408	0.6342	0.2480	0.1151	0.1228				
1993	0.8786	0.0978	1.1321	0.4129	0.0137	0.1661				
1994	0.9277	0.1227	0.8969	0.2547	1.2423	0.1197				
1995	1.5358	0.1334	0.2904	0.1644	0.6403	0.0592				
1996	0.3939	0.1673	0.6332	0.1751	0.2364	0.1165				
1997	0.6283	0.1433	0.0892	0.2576	0.0811	0.1019				
1998	0.4781	0.2664	0.1318	0.2084	0.0986	0.1065				
1999	0.7560	0.1639	0.3033	0.3830	0.7738	0.0363				
2000	1.7494	0.2053	0.5276	0.4089	0.4935	0.0730				
2001	0.6035	0.1573	0.1289	0.2244	0.0004	0.3110				
2002	0.5230	0.1953	0.3614	0.2269	0.2599	0.1152	0.5862	0.3025		
2003	1.2830	0.1671	0.5989	0.4688	0.4962	0.0666	0.6730	0.2909		
2004	0.9074	0.2671	0.5996	0.2759	0.6906	0.0620	0.8006	0.2853		
2005	1.3612	0.2895	4.2248	0.3407	1.1661	0.0538	1.8229	0.2615		
2006	4.2081	0.1248	0.5699	0.1264	1.6101	0.0421	3.9015	0.2577		
2007	0.9282	0.1939	0.3726	0.2627	0.5816	0.1104	1.3534	0.2915	1.0820	0.2586
2008	0.5587	0.3190	1.9167	0.5379	1.0389	0.0487	0.6614	0.3175	0.6773	0.2783
2009	0.6613	0.2073	1.1684	0.2732	1.6489	0.0333	1.4423	0.2671	1.0868	0.1507
2010	0.6246	0.1417	1.5220	0.3420	1.3827	0.0368	0.0976	0.3483	0.9530	0.2697
2011	1.0763	0.1432	0.6718	0.2156	2.7452	0.0374	1.1048	0.2605	1.9066	0.1477
2012	0.7906	0.2175	1.7912	0.1819	4.3593	0.0263	0.0105	0.2800	0.0121	0.2556
2013	1.3604	0.2086	2.6558	0.4163	1.4933	0.0452	0.4441	0.2689	2.2049	0.2384
2014	1.1479	0.1873	1.1214	0.3872	0.4386	0.0697	0.1017	0.2081	0.0772	0.1125

Table 79. Age length key proportions from the NEAMAP Trawl Survey used to estimate age group specific index of relative abundance for the NMFS Trawl Survey.

	Age	
TL_cm	0	1+
3	1	0
4	1	0
5	1	0
6	1	0
7	1	0
8	1	0
9	1	0
10	1	0
11	1	0
12	1	0
13	1	0
14	0.955	0.045
15	0.962	0.038
16	0.939	0.061
17	0.873	0.127
18	0.783	0.217
19	0.754	0.246
20	0.58	0.42
21	0.291	0.709
22	0.115	0.885
23	0.154	0.846
24	0	1
25	0	1
26	0	1
27	0	1
28	0	1
29	0	1

Table 80. Annual indices of biomass and standard errors for each of the surveys developed for the spot assessment.

Year	NMFS Fall (kg/tow)		SEAMAP Fall (kg/tow)		ChesMMAP Summer-Fall (kg/tow)		NEAMAP Fall (kg/tow)	
	Index	SE	Index	SE	Index	SE	Index	SE
1989	58.54	7.65	1.63	0.28				
1990	7.81	2.80	1.62	0.26				
1991	2.46	1.57	17.16	3.84				
1992	0.88	0.94	3.66	0.79				
1993	0.34	0.59	7.91	3.48				
1994	17.89	4.23	5.37	1.50				
1995	6.36	2.52	1.56	0.23				
1996	4.58	2.14	2.72	0.65				
1997	1.53	1.24	0.66	0.17				
1998	1.14	1.07	0.64	0.11				
1999	10.22	3.20	1.11	0.27				
2000	6.25	2.50	3.05	1.48				
2001	0.01	0.08	0.79	0.20				
2002	3.95	1.99	2.00	0.45	2.53	0.55		
2003	3.01	1.74	3.11	0.96	2.98	0.83		
2004	10.80	3.29	3.19	0.92	1.86	0.25		
2005	18.57	4.31	31.99	11.54	4.22	0.56		
2006	13.85	3.72	2.80	0.34	3.16	0.54		
2007	9.72	3.12	1.88	0.44	2.29	0.45	26.64	8.27
2008	14.21	3.77	11.55	7.03	1.22	0.17	25.99	5.38
2009	12.17	3.49	5.77	1.52	2.91	1.46	3.85	1.83
2010	19.53	4.42	17.98	5.97	1.08	0.15	33.96	11.45
2011	26.53	5.15	3.69	0.84	1.00	0.19	3.43	1.20
2012	32.65	5.71	9.29	1.74	0.56	0.19	100.65	19.11
2013	11.95	3.46	14.95	6.78	0.38	0.07	12.58	4.22
2014	2.93	6.06	6.06	2.58	0.34	0.13	0.82	0.32

Table 81. Age length key proportions from the SEAMAP Trawl Survey used to estimate age group specific index of relative abundance.

	Age	
TL_cm	0	1+
9	1	0
10	1	0
11	1	0
12	0.3706	0.6294
13	0.4503	0.5497
14	0.0899	0.9101
15	0.0185	0.9815
16	0	1
17	0	1
18	0	1
19	0	1
20	0	1
21	0	1
22	0	1
23	0	1
24	0	1
25	0	1
26	0	1
27	0	1

Table 82. Age length key proportions from the ChesMMAP Trawl Survey used to estimate age group specific index of relative abundance.

	2002		2003		2004		2005		2006		2007		2008	
LengthCM	Age0	Age1+	Age-0	Age-1+	Age-0	Age-1+	Age-0	Age1+	Age-0	Age-1+	Age-0	Age-1+	Age-0	Age-1+
0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0
2	1	0	1	0	1	0	1	0	1	0	1	0	1	0
3	1	0	1	0	1	0	1	0	1	0	1	0	1	0
4	1	0	1	0	1	0	1	0	1	0	1	0	1	0
5	1	0	1	0	1	0	1	0	1	0	1	0	1	0
6	1	0	1	0	1	0	1	0	1	0	1	0	1	0
7	1	0	1	0	1	0	1	0	1	0	1	0	1	0
8	1	0	1	0	1	0	1	0	1	0	1	0	1	0
9	1	0	1	0	1	0	1	0	1	0	1	0	1	0
10	1	0	1	0	1	0	1	0	1	0	1	0	1	0
11	1	0	1	0	1	0	1	0	1	0	1	0	1	0
12	1	0	1	0	1	0	1	0	1	0	1	0	1	0
13	1	0	1	0	1	0	0.983	0.017	1	0	1	0	0.925	0.075
14	1	0	1	0	0.949	0.051	1	0	0.971	0.029	1	0	0.871	0.129
15	1	0	1	0	0.977	0.023	0.957	0.043	0.905	0.095	1	0	1	0
16	0.923	0.077	0.909	0.091	0.967	0.033	0.927	0.073	0.792	0.208	0	1	0.722	0.278
17	0.833	0.167	0.85	0.15	0.88	0.12	0.893	0.107	0.561	0.439	0.071	0.929	0.359	0.641
18	0.684	0.316	0.755	0.245	0.462	0.538	0.5	0.5	0.431	0.569	0	1	0.341	0.659
19	0.661	0.339	0.725	0.275	0.607	0.393	0.111	0.889	0.244	0.756	0.065	0.935	0.343	0.657
20	0.635	0.365	0.556	0.444	0.103	0.897	0	1	0.037	0.963	0	1	0.04	0.96
21	0.171	0.829	0.2	0.8	0.05	0.95	0	1	0	1	0	1	0.133	0.867
22	0.2	0.8	0	1	0.059	0.941	0	1	0	1	0	1	0	1
23	0	1	0	1	0	1	0	1	0	1	0	1	0	1
24	0	1	0	1	0	1	0	1	0	1	0	1	0	1
25	0	1	0	1	0	1	0	1	0	1	0	1	0	1
26	0	1	0	1	0	1	0	1	0	1	0	1	0	1
27	0	1	0	1	0	1	0	1	0	1	0	1	0	1
28	0	1	0	1	0	1	0	1	0	1	0	1	0	1
29	0	1	0	1	0	1	0	1	0	1	0	1	0	1
30	0	1	0	1	0	1	0	1	0	1	0	1	0	1
31	0	1	0	1	0	1	0	1	0	1	0	1	0	1
32	0	1	0	1	0	1	0	1	0	1	0	1	0	1
33	0	1	0	1	0	1	0	1	0	1	0	1	0	1
34	0	1	0	1	0	1	0	1	0	1	0	1	0	1
35	0	1	0	1	0	1	0	1	0	1	0	1	0	1
36	0	1	0	1	0	1	0	1	0	1	0	1	0	1
37	0	1	0	1	0	1	0	1	0	1	0	1	0	1
38	0	1	0	1	0	1	0	1	0	1	0	1	0	1
39	0	1	0	1	0	1	0	1	0	1	0	1	0	1
40	0	1	0	1	0	1	0	1	0	1	0	1	0	1

Table 82. ***Continued.*** **Age length key proportions from the ChesMMAP Trawl Survey used to estimate age group specific index of relative abundance.**

	2009		2010		2011		2012		2013		2014	
LengthCM	Age-0	Age-1+	Age-0	Age-1+	Age-0	Age1+	Age-0	Age-1+	Age-0	Age-1+	Age-0	Age-1+
0	1	0	1	0	1	0	1	0	1	0	1	0
1	1	0	1	0	1	0	1	0	1	0	1	0
2	1	0	1	0	1	0	1	0	1	0	1	0
3	1	0	1	0	1	0	1	0	1	0	1	0
4	1	0	1	0	1	0	1	0	1	0	1	0
5	1	0	1	0	1	0	1	0	1	0	1	0
6	1	0	1	0	1	0	1	0	1	0	1	0
7	1	0	1	0	1	0	1	0	1	0	1	0
8	1	0	1	0	1	0	1	0	1	0	1	0
9	1	0	1	0	1	0	1	0	1	0	1	0
10	1	0	1	0	1	0	1	0	1	0	1	0
11	1	0	1	0	1	0	1	0	1	0	1	0
12	1	0	1	0	1	0	0.917	0.083	0.9	0.1	1	0
13	0.952	0.048	1	0	1	0	1	0	1	0	1	0
14	0.929	0.071	0.875	0.125	0.5	0.5	0.962	0.038	0.6	0.4	1	0
15	0.615	0.385	0.862	0.138	0	1	1	0	0.5	0.5	1	0
16	0.219	0.781	0.9	0.1	0	1	0.958	0.042	0.205	0.795	0.5	0.5
17	0.057	0.943	0.273	0.727	0	1	0.824	0.176	0.195	0.805	0.529	0.471
18	0.024	0.976	0.048	0.952	0	1	0.75	0.25	0.022	0.978	0.2	0.8
19	0	1	0.043	0.957	0	1	0.25	0.75	0.08	0.92	0.048	0.952
20	0	1	0.143	0.857	0	1	0	1	0	1	0	1
21	0	1	0.5	0.5	0	1	0	1	0.111	0.889	0	1
22	0.045	0.955	0.167	0.833	0	1	0	1	0	1	0	1
23	0	1	0	1	0	1	0	1	0	1	0	1
24	0	1	0	1	0	1	0	1	0	1	0	1
25	0	1	0	1	0	1	0	1	0	1	0	1
26	0	1	0	1	0	1	0	1	0	1	0	1
27	0	1	0	1	0	1	0	1	0	1	0	1
28	0	1	0	1	0	1	0	1	0	1	0	1
29	0	1	0	1	0	1	0	1	0	1	0	1
30	0	1	0	1	0	1	0	1	0	1	0	1
31	0	1	0	1	0	1	0	1	0	1	0	1
32	0	1	0	1	0	1	0	1	0	1	0	1
33	0	1	0	1	0	1	0	1	0	1	0	1
34	0	1	0	1	0	1	0	1	0	1	0	1
35	0	1	0	1	0	1	0	1	0	1	0	1
36	0	1	0	1	0	1	0	1	0	1	0	1
37	0	1	0	1	0	1	0	1	0	1	0	1
38	0	1	0	1	0	1	0	1	0	1	0	1
39	0	1	0	1	0	1	0	1	0	1	0	1
40	0	1	0	1	0	1	0	1	0	1	0	1

Table 83. Age length key proportions from the NEAMAP Trawl Survey used to estimate age group specific index of relative abundance.

	2007		2008		2009		2010		2011	
LengthCM	FallAge-0	FallAge-1+	FallAge-0	FallAge-1+	FallAge-0	FallAge-1+	FallAge-0	FallAge-1+	FallAge-0	FallAge-1+
0	1	0	1	0	1	0	1	0	1	0
1	1	0	1	0	1	0	1	0	1	0
2	1	0	1	0	1	0	1	0	1	0
3	1	0	1	0	1	0	1	0	1	0
4	1	0	1	0	1	0	1	0	1	0
5	1	0	1	0	1	0	1	0	1	0
6	1	0	1	0	1	0	1	0	1	0
7	1	0	1	0	1	0	1	0	1	0
8	1	0	1	0	1	0	1	0	1	0
9	1	0	1	0	1	0	1	0	1	0
10	1	0	1	0	1	0	1	0	1	0
11	1	0	1	0	1	0	1	0	1	0
12	1	0	1	0	1	0	1	0	1	0
13	1	0	1	0	1	0	1	0	1	0
14	1	0	0.95	0.05	1	0	0.933	0.067	0.75	0.25
15	1	0	1	0	1	0	0.86	0.14	0.818	0.182
16	0.952	0.048	0.981	0.019	0.917	0.083	0.907	0.093	0.7	0.3
17	0.947	0.053	1	0	0.5	0.5	0.742	0.258	0.2	0.8
18	0.879	0.121	0.96	0.04	0.308	0.692	0.941	0.059	0.347	0.653
19	0.88	0.12	1	0	0.125	0.875	1	0	0.417	0.583
20	0.5	0.5	0.667	0.333	0	1	0	1	0.267	0.733
21	1	0	0	1	0	1	1	0	0.125	0.875
22	0.5	0.5	0	1	0	1	0	1	0	1
23	0	1	0	1	0	1	0	1	0	1
24	0	1	0	1	0	1	0	1	0	1
25	0	1	0	1	0	1	0	1	0	1
26	0	1	0	1	0	1	0	1	0	1
27	0	1	0	1	0	1	0	1	0	1
28	0	1	0	1	0	1	0	1	0	1
29	0	1	0	1	0	1	0	1	0	1
30	0	1	0	1	0	1	0	1	0	1

Table 83. ***Continued.*** **Age length key proportions from the NEAMAP Trawl Survey used to estimate age group specific index of relative abundance.**

	2012		2013		2014		2015	
LengthCM	FallAge-0	FallAge-1+	FallAge-0	FallAge-1+	FallAge-0	FallAge-1+	FallAge-0	FallAge-1+
0	1	0	1	0	1	0	1	0
1	1	0	1	0	1	0	1	0
2	1	0	1	0	1	0	1	0
3	1	0	1	0	1	0	1	0
4	1	0	1	0	1	0	1	0
5	1	0	1	0	1	0	1	0
6	1	0	1	0	1	0	1	0
7	1	0	1	0	1	0	1	0
8	1	0	1	0	1	0	1	0
9	1	0	1	0	1	0	1	0
10	1	0	1	0	1	0	1	0
11	1	0	1	0	1	0	1	0
12	1	0	1	0	1	0	1	0
13	1	0	1	0	1	0	1	0
14	1	0	1	0	1	0	1	0
15	1	0	1	0	1	0	1	0
16	1	0	0.865	0.135	1	0	0.955	0.045
17	1	0	0.792	0.208	0.88	0.12	1	0
18	1	0	0.636	0.364	0.909	0.091	1	0
19	1	0	0.583	0.417	1	0	1	0
20	1	0	0.143	0.857	0.8	0.2	1	0
21	1	0	0.071	0.929	0.375	0.625	1	0
22	1	0	0.071	0.929	0	1	0	1
23	1	0	0.125	0.875	0	1	0	1
24	0	1	0	1	0	1	0	1
25	0	1	0	1	0	1	0	1
26	0	1	0	1	0	1	0	1
27	0	1	0	1	0	1	0	1
28	0	1	0	1	0	1	0	1
29	0	1	0	1	0	1	0	1
30	0	1	0	1	0	1	0	1

Table 84. **Associations evaluated with Spearman's rho (ρ) between age-0 and age-1+ indices where the age-0 indices have been adjusted forward by one year. Significant p-values (<0.05) are bolded and highlighted in yellow.**

Age 0 Indices Forward Lagged 1 Year	Age 1+ Indices: NCDMF June Trawl			SEAMAP Fall Trawl			NMFS Fall Trawl			ChesMMAP Trawl			NEAMAP Trawl		
	ρ	p-value	n	ρ	p-value	n	ρ	p-value	n	ρ	p-value	n	ρ	p-value	n
NCDMF June Trawl	0.367	**0.04**	26	0.462	**0.01**	26	0.374	**0.03**	26	-0.016	0.53	13	0.238	0.29	8
SEAMAP Fall Trawl	0.595	**0.00**	26	0.141	0.25	26	0.521	**0.00**	26	0.011	0.49	13	0.357	0.19	8
NMFS Fall Trawl	0.314	0.06	26	0.342	0.05	26	0.564	**0.00**	26	-0.165	0.71	13	0.333	0.21	8
ChesMMAP Trawl	0.154	0.32	13	-0.357	0.88	13	-0.084	0.61	13	0.888	**0.00**	13	0.429	0.15	8
NEAMAP Trawl	0.357	0.22	8	0.107	0.42	8	0.000	0.52	8	0.786	**0.02**	8	0.857	**0.01**	8

Table 85. **Associations evaluated with Spearman's rho (ρ) between age-0 abundance indices for spot. Significant p-values (<0.05) are bolded and highlighted in yellow.**

Age 0 Indices	NCDMF June Trawl			SEAMAP Fall Trawl			NMFS Fall Trawl			ChesMMAP Trawl		
	ρ	p-value	n	ρ	p-value	n	ρ	p-value	n	ρ	p-value	n
SEAMAP Fall Trawl	0.466	**0.01**	26									
NMFS Fall Trawl	0.28	0.08	26	0.5904	**0.00**	26						
ChesMMAP Trawl	-0.291	0.84	13	-0.17	0.72	13	-0.154	0.70	13			
NEAMAP Trawl	0.5238	0.10	8	0.2619	0.27	8	0.4762	0.12	8	0.6667	**0.04**	8

Table 86. **Associations evaluated with Spearman's rho (ρ) between age-1+ abundance indices for spot. Significant p-values (<0.05) are bolded and highlighted in yellow.**

Age 1+ Indices	NCDMF June Trawl			SEAMAP Fall Trawl			NMFS Fall Trawl			ChesMMAP Trawl		
	ρ	p-value	n	ρ	p-value	n	ρ	p-value	n	ρ	p-value	n
SEAMAP Fall Trawl	0.1815	0.19	26									
NMFS Fall Trawl	0.3285	0.05	26	0.3716	0.03	26						
ChesMMAP Trawl	0.4341	0.07	13	-0.242	0.79	13	0.1044	0.37	13			
NEAMAP Trawl	0.381	0.18	8	-0.048	0.56	8	0.1905	0.33	8	0.5952	0.07	8

Table 87. Inputs for the spot base surplus production model calculated in ASPIC.

Parameter or Data Input	Value for Spot Base Model	Justification
Run mode	FIT & BOT	ASPIC fits the model and computes estimates of parameters, then runs bootstrapping program
Error type	LOGISTIC YLD SSE	Logistic (Schaefer) model, condition fitting on yield (recommended), sum of squared errors (recommended)
Verbosity	112	Recommended value
Number of bootstrap trials	700	Recommended value between 500-1000
Monte Carlo search enable	0 10000	Disabled as recommended by author
Convergence crit. for simplex	1.0d-8	Recommended value
Convergence crit. for restarts, N restarts	3.0d-8 6	Recommended value
Convergence crit. for estimating effort	1.0d-4	Recommended value
Maximum F allowed in estimating effort	8d0	Default value
Weighting for B1 > K as residual	0d0	0d0 for no penalty
Number of data series	2	NMFS (1), SEAMAP (1)
Statistical weights for data series	1d0 1d0	Equal weighting
B1/K (starting guess)	0.5	Reasonable default value
MSY (starting guess)	28644	1/2 the maximum catch of 57,287 metric tons
K (starting guess)	572870	10x the maximum catch of 57,287 metric tons
q (starting guess)	1.0d-4 5.4d-5	One for each index as the mean CPUE/(2*Max catch)
Estimate flags	1 1 1 1 1	One for each B/K, MSY, K, q1, q2
Bounds (min and max) on MSY	3.6d3 2.3d5	1/8x and 8x the starting guess of MSY (2.9d4)
Bounds (min and max) on K	7.2d4 4.6d6	1/8x and 8x the starting guess of K (5.7d5)
Random number seed	1952385	
Number of years of data	26	1989-2014; Availability of shrimp discards using SEAMAP (first year = 1989) and Mid-Atlantic discards using observer data (first year = 1989). Only one regional survey being considered that starts earlier than 1989 (NMFS).

Table 88. General definitions and inputs (assumed fixed values and data) of the modified-CSA model for spot.

General Definitions	Symbol	Description/Definition
Year index	y	1989-2014
Stage index	a	Stage 1 (recruits) = Age-0; Stage 2 (post-recruits) = Age-1+
Total years in model	k_m	26
Total years for each survey	$k_{I,a}$	NC DMF Trawl = 26, NMFS Trawl = 26
Total years of removal data	k_R	26
Inputs	**Symbol**	**Description/Definition**
Observed index of abundance	$I_{a,y}$	Based on catch rates of age-0 and age-1+ fish from the NC DMF Trawl and NMFS Trawl surveys
Observed fishery removals	R_y	Removals in numbers for each year
Observed average total mortality of post-recruits	Z_{prior}	Average catch curve estimates from 1996-2013 (1.356)
Stage-specific natural mortality	M_a	Fixed based on estimates from a Lorenzen curve ($M_{recruits}$=0.542, $M_{post-recruits}$=0.396)
Fishery selectivity	s_a	Fixed based on external analysis of length frequency data ($s_{recruits}$=0.43, $s_{post\text{-}recruits}$=1)
Probability of spawning	ρ_a	Fixed based on logistic regression for recruits and literature estimates for post-recruits ($\rho_{recruits}$=0.215, ρ_{adults}=1)
Stage-specific average weight (kg)	$\overline{wt}_a$	Fixed based on fall weight-at-age from the NEAMAP Trawl survey ($\overline{wt}_{recruits}$=0.0801, $\overline{wt}_{post-recruits}$=0.1324)
Spawn time	κ	Fixed at 1.0 to coincide with spawning at the end of the year (i.e., December 31)
Survey time	τ_a	Proportion of year passed when survey occurs, fixed based on middle of sampling period (NC DMF Trawl=0.46, NMFS Trawl=0.75)
Population proportion female	ω	Fixed at 0.5 (i.e., female:male sex ratio = 1)
Steepness prior	h_{prior}	Mean estimate from meta-analysis (0.64)
Standard deviation for h	σ_h	Estimate from meta-analysis (0.20)
Coefficient of variation for $I_{a,y}$	$cv_{I,a,y}$	Based on annual estimates from observations on the NC DMF Trawl and NMFS Trawl surveys plus any adjustments for process error
Coefficient of variation for R_y	$cv_{R,y}$	Fixed at 0.05
Coefficient of variation for r_y	cv_r	Fixed at 0.66
Coefficient of variation for Z	cv_Z	Fixed at 0.05

Table 89. Population model equations of the modified-CSA model for spot. Estimated parameters are denoted using hat (^) notation, and predicted values are denoted using breve (˘) notation.

Population Model	Symbol	Description/Definition
Fishing mortality	$F_{a,y}$	$\hat{F}_{1989}$ is estimated for the intial year $F_{a,1989} = s_a\hat{F}_{1989}$; $F_{a,y} = s_a\hat{F}_{1989}e^{\hat{\delta}_{F,y}}$; $\hat{\delta}_{F,y}$ are year specific deviations for all years after the initial year $F_{a,2014} = e^{\left(\left(log\left(F_{a,2012}\right)+log\left(F_{a,2013}\right)\right)/2\right)}$ $F_{a,2014}$ equal to geometric mean of previous two years, as there are no index data from 2015 to tune the $F_{a,2014}$ estimates
Total mortality	$Z_{a,y}$	$Z_{a,y} = M_a + F_{a,y}$
Stage 1 abundance	$N_{0,y}$	$N_{0,1989} = \hat{N}_{0,1989}$ is estimated for the initial year Beverton-Holt SR relationship assumed for subsequent years; $N_{0,y+1} = \frac{SSB_y}{SSB_y\beta+\alpha}e^{\hat{\delta}_{r,y+1}-0.5\sigma_r^2}$; $\hat{\delta}_{r,y+1} \sim N(0,\sigma_r^2)$; $\alpha = \frac{\widehat{SSB}_0(1-\hat{h})}{4\hat{h}r_0}$; $\beta = \frac{5\hat{h}-1}{4\hat{h}r_0}$; $r_0 = \frac{\widehat{SSB}_0}{SSBr_0}$; $SSBr_0 = \omega\rho_0\overline{wt}_{0,0}e^{-\kappa M_0} + \omega\rho_1\frac{e^{-(M_0+\kappa M_1)}}{1-e^{-M_1}}$; $\sigma_r = \sqrt{\log(1+cv_r^2)}$; $\widehat{SSB}_0$ is the unfished SSB, r_0 is the unfished recruitment, σ_r is the standard deviation of lognormal recruitment deviations
Stage 2 abundance	$N_{1,y}$	$N_{1,1989} = \hat{N}_{1,1989}$ is estimated for the initial year $N_{1,y+1} = \sum_{a=0}^{1} N_{a,y}e^{-(M_a+F_{a,y})}$
Female spawning stock biomass	SSB_y	$SSB_y = \sum_{a=0}^{1} \omega\rho_a\overline{wt}_a N_{a,y}e^{-\kappa(M_a+F_{a,y})}$
Predicted catch-at-stage	$\breve{C}_{a,y}$	$\breve{C}_{a,y} = \frac{F_{a,y}}{Z_{a,y}}N_{a,y}[1-e^{-Z_{a,y}}]$
Predicted removals	$\breve{R}_y$	$\breve{R}_y = \sum_{a=0}^{1} \breve{C}_{a,y}$
Predicted stage 1 index of abundance	$\breve{I}_{0,y}$	$\breve{I}_{0,y} = q_0(N_{0,y}e^{-\tau_0(M_0+F_{0,y})})$; $\log(q_0) = \frac{\sum_y \log(\breve{I}_{0,y})-\log(N_{0,y})}{k_{I,0}}$; q_0 is the catchability coefficient for stage 1 fish

Predicted stage 2 index of abundance	$\check{I}_{1,y}$	$\check{I}_{1,y} = q_1(N_{1,y}e^{-\tau_1(M_1+F_{1,y})})$; $\log(q_1) = \frac{\sum_y \log(\check{I}_{1,y}) - \log(N_{1,y})}{k_{I,1}}$; q_1 is the catchability coefficient for stage 2 fish

Table 90. Likelihood components of the modified-CSA model for spot. Predicted values are denoted using breve (˘) notation.

Negative Log-Likelihood	Symbol	Description/Definition
Lognormal indices	$\Lambda_{I,a}$	$\Lambda_{I,a} = \lambda_{I,a}\sum_y [0.5\log(2pi) + 0.5\log(\sigma_{I,a,y}^2) + \log(I_{a,y}) + \frac{[\log(I_{a,y}+\chi) - \log(\check{I}_{a,y}+\chi)]^2}{2\sigma_{I,a,y}^2}]$; $\sigma_{I,a,y} = \sqrt{\log(1+cv_{I,a,y}^2)}$; $\lambda_{I,a}$ is a preset weight factor set to 1.0 χ is fixed at a small value (0.000001) for numerical stability
Lognormal removals	Λ_R	$\Lambda_R = \lambda_R\sum_y [0.5\log(2pi) + 0.5\log(\sigma_{R,y}^2) + \log(R_y) + \frac{[\log(R_y+\chi) - \log(\check{R}_y+\chi)]^2}{2\sigma_{R,y}^2}]$; $\sigma_{R,y} = \sqrt{\log(1+cv_{R,y}^2)}$; λ_L is a preset weight factor set to 1.0 χ is fixed at a small value (0.000001) for numerical stability
Lognormal recruitment deviations	Λ_r	$\Lambda_r = \lambda_r\sum_y [0.5\log(2pi) + 0.5\log(\sigma_r^2) + \log(\hat{\delta}_{r,y}) + \frac{\log(\hat{\delta}_{r,y})^2}{2\sigma_r^2}]$; $\sigma_r = \sqrt{\log(1+cv_r^2)}$; λ_r is a preset weight factor set to 1.0

Prior distribution for h	Λ_h	$\Lambda_h = \lambda_h[(1 - Bprior) * \log(\chi + h_{prior} - h\_lb) + (1 - Aprior) * \log(\chi + h\_ub - h_{prior}) - (1 - Bprior) * \log(\chi + \hat{h} - h\_lb) - (1 - Aprior) * \log(\chi + h\_ub - \hat{h})]$; $Bprior = \tau * \mu$; $Aprior = \tau * (1.0 - \mu)$; h_lb is the lower bound on the steepness parameter estimate (0.00001) h_ub is the upper bound on the steepness parameter estimate (0.99999) χ is fixed at a small value (0.0001) for numerical stability $\mu = \frac{\hat{h} - h\_lb}{h\_ub - h\_lb}$; $\tau = \frac{(\hat{h} - h\_lb) * (h\_ub - \hat{h})}{{\sigma_h}^2} - 1$; λ_h is a preset weight factor set to 1.0

Table 90 ***Continued.*** **Likelihood components of the modified-CSA model for spot. Predicted values are denoted using breve (˘) notation.**

Prior distribution for Z	Λ_Z	$\Lambda_Z = \lambda_Z \left[0.5\log(2pi) + 0.5\log(\sigma_Z^2) + \log(Z_{prior}) + \frac{[\log(Z_{prior}) - \log(\overline{Z_{1,1996-2013}})]^2}{2\sigma_Z^2} \right];$ $\sigma_Z = \sqrt{\log(1 + cv_Z^2)};$ $\overline{Z_{1,1996-2013}}$ is the mean post-recruit Z from 1996-2013 λ_Z is a preset weight factor set to 1.0

Table 91. Reference point calculations for the modified-CSA model for spot.

Reference Point Components	Symbol	Description/Definition
Fishing rate value: F={0, ….6}	F	F is incremented from 0.0 to 6.0 by 0.01, and the reference point calculations are performed at each F value. All final MSY-based reference points are set at the F that maximizes equilibrium removals (Req), while the spawning potential ratio F targets (F_{SPR}) are each set at the F that produces the SPR closest to an input set of targets (SPR={0.2,0.3,0.4})
Projection year for SSB_{SPR} calculations	py	1-100
Unfished female spawning stock biomass per recruit	$SSBr_0$	$SSBr_0 = \omega\rho_0\overline{wt}_0 e^{-\kappa M_0} + \omega\rho_1\overline{wt}_1 \frac{e^{-(M_0+\kappa M_1)}}{1-e^{-M_1}}$
Fished female spawning stock biomass per recruit	$SSBr$	$SSBr = \omega\rho_0\overline{wt}_0 e^{-\kappa(M_0+s_0\mathrm{F})} + \omega\rho_1\overline{wt}_1 \frac{e^{-(M_0+s_0\mathrm{F}+\kappa M_1+\kappa s_1\mathrm{F})}}{1-e^{-\kappa(M_1+s_1\mathrm{F})}}$
Number per recruit	Nr	$Nr = \frac{e^{-(M_0+s_0\mathrm{F})}}{1-e^{-\kappa(M_1+s_1\mathrm{F})}}$
Yield per recruit	Yr	$Yr = \frac{s_0\mathrm{F}}{M_0+s_0\mathrm{F}}\left[1-e^{-(M_0+s_0\mathrm{F})}\right]\overline{wt}_0 + \frac{s_1\mathrm{F}}{M_1+s_1\mathrm{F}}\left[1-e^{-(M_1+s_1\mathrm{F})}\right]\overline{wt}_1$
Equilibrium recruitment	req	$req = \frac{SSBr-\alpha}{\beta SSBr}$ Beverton-Holt SR relationship
Equilibrium number	Neq	$Neq = Nr * req$
Equilibrium female spawning stock biomass	SSB_{eq}	$SSB_{eq} = SSBr * req$
Equilibrium removals	Req	$Req = Yr * req$
Equilibrium exploitation rate	Ueq	$Ueq = \frac{Req}{Neq\overline{wt}_1 + req\overline{wt}_0 \frac{1-e^{-s_0\mathrm{F}}}{1-e^{-s_1\mathrm{F}}}}$
Maximum sustainable yield	MSY	$MSY = \max(Req)$ across all F values
Number at MSY	N_{MSY}	Neq at MSY
Female spawning stock biomass at MSY	SSB_{MSY}	$SSBeq$ at MSY
Fishing rate at MSY	F_{MSY}	F at MSY
Exploitation rate at MSY	u_{MSY}	Ueq at MSY
Static spawning potential ratio	$sSPR$	$sSPR = \frac{SSBr}{SSBr_0}$
Equilibrium female spawning stock biomass at reference SPR	SSB_{SPR}	$SSB_{py} = \omega\rho_0\overline{wt}_0 N_{0,py} e^{-\kappa(M_0+s_0F_{SPR})} + \omega\rho_1\overline{wt}_1 N_{1,py} e^{-\kappa(M_1+s_1F_{SPR})}$; $N_{0,py}$ is randomly selected from model $N_{0,y}$ estimates during a specified reference period $N_{1,py} = N_{0,py-1}e^{-(M_0+s_0F_{SPR})}$; $SSB_{SPR} = median(SSB_{py2}, \ldots\ldots SSB_{py100})$;

Table 92. Spot stage-specific mean weights by data source.

Data Source	Age Range	Age-0 n	Age-0 Ave wt (kg)	Age-0 sd	Age 1+ n	Ages 1+ Ave wt (kg)	Age 1+ sd
NEAMAP	0-3	1,122	0.0801	0.0298	264	0.1324	0.0524
ChesMMAP	0-4	3,129	0.0628	0.0331	1,025	0.1553	0.0701
SEAMAP	0-2	165	0.0580	0.0240	74	0.1191	0.0467
MD DNR Commercial	0-2	14	0.0598	0.0130	50	0.1804	0.0321
VMRC Commercial	1-4	0			1,344	0.2889	0.1062
NCDMF Commercial	0-4	292	0.0733	0.0311	1,011	0.1829	0.0948

Table 93. Test for significant differences ($p<0.05$) with analysis of variance (ANOVA) among annual spot mean weights within stage by data source.

Data Source	Age Group	Significant Difference between Years?
SEAMAP	0	Only one year of data
SEAMAP	1+	Only one year of data
ChesMMAP	0	Yes, p=0.016
ChesMMAP	1+	Yes, p=0.002
NEAMAP	0	No, p=0.994
NEAMAP	1+	No, p=0.374
NC DMF Commercial	0	No, p=0.862
NC DMF Commercial	1+	No, p=0.970
MD DNR Commercial	0	Yes, p=0.028
MD DNR Commercial	1+	No, p=0.119
VMRC Commercial	1+	No, p=0.544

Table 94. CVs for spot indices of abundance used in the modified-CSA model calculated from variance in catch rates (original; observation error) and adjusted according to the methods of Francis (2003) to acknowledge process error (adjusted).

Year	NC DMF Trawl Recruits		NMFS Trawl Recruits		NC DMF Trawl Post-Recruits		NMFS Trawl Post-Recruits	
	Original	Adjusted	Original	Adjusted	Original	Adjusted	Original	Adjusted
1989	0.1455	0.2473	0.0664	0.2107	0.1757	0.2662	0.0664	0.2107
1990	0.1159	0.2312	0.0553	0.2075	0.222	0.2988	0.0553	0.2075
1991	0.1561	0.2537	0.2101	0.2901	0.1032	0.2251	0.2101	0.2901
1992	0.2103	0.2902	0.1228	0.2347	0.1408	0.2446	0.1228	0.2347
1993	0.1474	0.2484	0.1661	0.26	0.0978	0.2226	0.1661	0.26
1994	0.1689	0.2618	0.1197	0.2331	0.1227	0.2346	0.1197	0.2331
1995	0.2106	0.2904	0.0592	0.2086	0.1334	0.2404	0.0592	0.2086
1996	0.1216	0.2341	0.1165	0.2315	0.1673	0.2607	0.1165	0.2315
1997	0.1613	0.2569	0.1019	0.2245	0.1433	0.246	0.1019	0.2245
1998	0.2354	0.3089	0.1065	0.2266	0.2664	0.3331	0.1065	0.2266
1999	0.2152	0.2938	0.0363	0.2033	0.1639	0.2586	0.0363	0.2033
2000	0.196	0.28	0.073	0.2129	0.2053	0.2866	0.073	0.2129
2001	0.2223	0.299	0.311	0.3698	0.1573	0.2544	0.311	0.3698
2002	0.1318	0.2395	0.1152	0.2308	0.1953	0.2795	0.1152	0.2308
2003	0.1601	0.2562	0.0666	0.2108	0.1671	0.2606	0.0666	0.2108
2004	0.244	0.3155	0.062	0.2094	0.2671	0.3337	0.062	0.2094
2005	0.1601	0.2562	0.0538	0.2071	0.2895	0.3519	0.0538	0.2071
2006	0.1928	0.2778	0.0421	0.2044	0.1248	0.2357	0.0421	0.2044
2007	0.2424	0.3143	0.1104	0.2284	0.1939	0.2786	0.1104	0.2284
2008	0.2301	0.3049	0.0487	0.2058	0.319	0.3765	0.0487	0.2058
2009	0.1822	0.2705	0.0333	0.2028	0.2073	0.2881	0.0333	0.2028
2010	0.1895	0.2755	0.0368	0.2034	0.1417	0.2451	0.0368	0.2034
2011	0.1477	0.2486	0.0374	0.2035	0.1432	0.246	0.0374	0.2035
2012	0.1047	0.2257	0.0263	0.2017	0.2175	0.2955	0.0263	0.2017
2013	0.1697	0.2623	0.0452	0.205	0.2086	0.289	0.0452	0.205
2014	0.1437	0.2463	0.0697	0.2118	0.1873	0.274	0.0697	0.2118

Table 95. Description of sensitivity configurations for the sensitivity analysis of the spot modified-CSA model.

Name	Description
1992 start year	Started the model time series in 1992 to remove relatively large shrimp trawl discard estimates prior to this year.
adjust shrimp discards	Changed the relatively large shrimp trawl discard estimates in 1990 and 1991 to the median value of surrounding, pre-BRD estimates (1989, 1992-1996; 259 million fish).
10% shrimp discards	Scaled the shrimp trawl discard estimates for the entire time series down to 10% of the base model estimates. This configuration can represent two scenarios; the base estimates are overestimated by an order of magnitude and the discard mortlaity rate is unchanged from the base model (100%) or the base model estimates are accurate and the discard mortality rate is 10%.
50% shrimp discards	Scaled the shrimp trawl discard estimates for the entire time series down to 50% of the base model estimates. This configuration can represent two scenarios; the base estimates are twice the true values and the discard mortlaity rate is unchanged from the base model (100%) or the base model estimates are accurate and the discard mortality rate is 50%.
low selectivity	The base model estimates recruit selectivity at 0.306. This is lower than the assumed value in the base model (0.43).
high selectivity	The high selectivity value (0.645) is between the value in the base model (0.43) and the value if we did not assume recruits are not vulnerable to capture for the first half of the year (0.86). The SAS does not consider selectivity values greater than 0.645 as plausible values.
low M	M-at-stage vector calculated from weight-at-age using the upper 95% confidence interval values of the growth parameters Linf, K, and t0. This results in M-at-stage (recruits=0.537, post-recruits=0.389) less than the base model M-at-stage (recruits=0.542, post-recruits=0.396).
high M	M-at-stage vector calculated from weight-at-age using the upper 95% confidence interval values of the growth parameters Linf, K, and t0. This results in M-at-stage (recruits=0.550, post-recruits=0.405) greater than the base model M-at-stage (recruits=0.542, post-recruits=0.396).
FD Z prior	Total mortality prior calculated from only FD data as opposed to FD and FI data (Appendix 8). This value (1.157) is lower than the base model prior value (1.356).
wt comb Z prior	Total mortality prior calculated from FD and FI data using a weighted catch curve (Appendix 8). This value (1.613) is greater than the base model prior value (1.356).
no reweight	Use the original CVs provided with indices. Do not allow for process error due to interannual variability in catchability.
no NMFS trawl	Exclude the NNMFS Trawl Survey indices for recruits and post-recruits.
no NCDMF trawl	Exclude the NCDMF Trawl Survey indices for recruits and post-recruits.
add NEAMAP trawl	Include the NEAMAP Trawl Survey indices for recruits and post-recruits. The reason for excluding these indices from the base model was the short time series realtive to the NMFS Trawl Survey indices.
change in NMFS recruit q 2005	Allowed for time-varying catchability (1989-2004=q1, 2005-2014=q2) in the NMFS Trawl Survey recruit index to address the residual trend after 2005. 2005 was selected based on visual evaluation of the resdiual trend.
change in NMFS recruit q in 2009	Allowed for time-varying catchability (1989-2008=q1, 2009-2014=q2) in the NMFS Trawl Survey recruit index to address the residual trend after 2005. 2009 was selected based on the change of vessel conducting the survey.
h = 0.99	Steepness fixed at 0.99 to specify an uninformative stock-recruit relationship (i.e., recruitment deviates around a time series mean).
h = 0.79	Steepness fixed at 0.79, the mode steepness value from the steepness prior analysis (Appendix 9).
NCDMF comm mean wts	Mean weight-at-stage developed from the fall NC DMF commercial catch sampling (recruits=0.0733 kg, post-recruits=0.1829 kg). There are no significant differences among annual mean weight-at-stage from these data and the SEAMAP Trawl Survey only collected one year of age data.
sex ratio	Proportion females = 0.62 (value from combined FI data). Sex ratio only affects stock-recruit parameters and spanwing stock biomass estimates, so results from this configuration are only included on the spawning stock biomass figure.

Table 96. Population parameter estimates from the base spot surplus production model.

Year	Estimated Total F	Estimated Starting Biomass	Estimated Average Biomass	Observed Total Yield	Model Total Yield	Estimated Surplus Production	Estimated F to F_{MSY}	Estimated B to B_{MSY}
1989	0.6180	57400	54370	33600	33600	28050	1.2740	0.9876
1990	0.4760	51850	53250	25360	25360	27980	0.9822	0.8921
1991	1.7290	54470	33130	57290	57290	22160	3.5650	0.9372
1992	0.9220	19340	18340	16900	16900	14980	1.9000	0.3328
1993	0.6260	17420	19170	12000	12000	15520	1.2910	0.2997
1994	0.9600	20940	19390	18610	18610	15670	1.9790	0.3602
1995	1.4830	18000	13310	19740	19740	11390	3.0570	0.3096
1996	0.8160	9644	9998	8157	8157	8863	1.6820	0.1659
1997	1.0220	10350	9682	9899	9899	8608	2.1080	0.1781
1998	1.0800	9059	8286	8947	8947	7463	2.2260	0.1559
1999	0.6970	7575	8408	5860	5860	7564	1.4370	0.1303
2000	0.6880	9279	10270	7066	7066	9075	1.4190	0.1596
2001	0.7990	11290	11720	9366	9366	10220	1.6480	0.1942
2002	0.4440	12140	14990	6663	6663	12640	0.9163	0.2089
2003	0.4780	18120	21380	10220	10220	16890	0.9856	0.3118
2004	0.2620	24800	31540	8248	8248	22160	0.5392	0.4266
2005	0.1280	38700	49130	6266	6266	27210	0.2629	0.6659
2006	0.1240	59640	69290	8559	8559	26910	0.2547	1.0260
2007	0.0880	78000	85720	7521	7521	21690	0.1809	1.3420
2008	0.0700	92160	97030	6797	6797	15500	0.1444	1.5860
2009	0.0710	100900	103100	7328	7328	11280	0.1465	1.7360
2010	0.0430	104800	106900	4637	4637	8308	0.0894	1.8040
2011	0.0850	108500	107700	9134	9134	7699	0.1749	1.8670
2012	0.0770	107100	107100	8212	8212	8205	0.1582	1.8420
2013	0.0610	107100	107700	6551	6551	7676	0.1254	1.8420
2014	0.0880	108200	107300	9492	9492	7991	0.1824	1.8610

Table 97. Parameter estimates from the base and sensitivity runs for the spot surplus production model. The base model included relative biomass indices from the SEAMAP Trawl and NMFS Trawl Surveys and the complete harvest data.

	Base Model 1989-2014	Abbreviated Model 1992-2014	Adding NEAMAP	Fox (n=1)	Pella-Tomlinson (n=2.35)	NMFS only	Excel
MSY	28,190	19,930	30,360	17,240	29,360	33,390	21,070
B_{MSY}	58,120	30,430	59,070	40,210	57,400	67,470	86,171
F_{MSY}	0.485	0.655	0.514	0.429	0.5115	0.495	0.445

Table 98. Measures of model fit from the base modified-CSA model for spot.

Likelihood Component	Negative Log-likelihood	Standardized Residual Mean	Standardized Residual sd	Sum of Squared Standardized Residuals	t-test p-value	Shapiro-Wilk p-value	Runs p-value
NC DMF Post-Recruits	161.83	0.165	3.75	352.78	0.412	0.075	0.005
NMFS Post Recruits	177.34	0.332	4.14	430.85	0.343	0.038	0.423
NC DMF Recruits	128.35	-0.003	3.45	298.01	0.498	0.107	1.000
NMFS Recruits	351.98	0.624	5.57	786.65	0.287	0.081	0.016
Removals	106.25	0.000	1.48	54.61	0.500	0.002	0.005
Total Mortality Prior	1.29	NA	NA	NA	NA	NA	NA
Steepness Prior	2.35	NA	NA	NA	NA	NA	NA
Recruitment Deviations	27.06	-0.301	1.18	35.86	0.108	0.331	0.545
Total	**956.46**	**NA**	**NA**	**1,958.77**	**NA**	**NA**	**NA**

Table 99. Parameter estimates from the base modified-CSA model for spot.

Parameter	Estimate	SE	Parameter	Estimate	SE
log(initial post-recruit N)	6.483	0.14	log(1990 R deviation)	1.313	0.11
log(initial recruit N)	6.818	0.12	log(1991 R deviation)	1.356	0.09
log(initial F)	0.064	0.11	log(1992 R deviation)	-0.583	0.15
log(1990 F deviation)	0.656	0.11	log(1993 R deviation)	0.394	0.15
log(1991 F deviation)	1.268	0.10	log(1994 R deviation)	1.274	0.09
log(1992 F deviation)	0.962	0.10	log(1995 R deviation)	-0.229	0.17
log(1993 F deviation)	0.521	0.12	log(1996 R deviation)	-0.537	0.09
log(1994 F deviation)	-0.210	0.11	log(1997 R deviation)	-1.164	0.14
log(1995 F deviation)	0.772	0.10	log(1998 R deviation)	-0.689	0.11
log(1996 F deviation)	0.454	0.11	log(1999 R deviation)	-0.010	0.09
log(1997 F deviation)	-0.615	0.13	log(2000 R deviation)	-1.071	0.12
log(1998 F deviation)	0.029	0.12	log(2001 R deviation)	-0.811	0.11
log(1999 F deviation)	-0.518	0.11	log(2002 R deviation)	0.793	0.39
log(2000 F deviation)	-0.321	0.12	log(2003 R deviation)	-0.109	0.11
log(2001 F deviation)	1.344	0.11	log(2004 R deviation)	0.103	0.11
log(2002 F deviation)	-0.467	0.12	log(2005 R deviation)	0.209	0.11
log(2003 F deviation)	0.212	0.11	log(2006 R deviation)	-0.598	0.13
log(2004 F deviation)	-0.756	0.12	log(2007 R deviation)	-0.616	0.14
log(2005 F deviation)	-1.058	0.11	log(2008 R deviation)	0.107	0.12
log(2006 F deviation)	-0.761	0.12	log(2009 R deviation)	-0.218	0.13
log(2007 F deviation)	-1.117	0.13	log(2010 R deviation)	0.538	0.11
log(2008 F deviation)	-1.159	0.12	log(2011 R deviation)	0.294	0.12
log(2009 F deviation)	-1.118	0.13	log(2012 R deviation)	0.412	0.12
log(2010 F deviation)	-1.627	0.12	log(2013 R deviation)	0.394	0.14
log(2011 F deviation)	-0.762	0.12	log(2014 R deviation)	-0.553	0.18
log(2012 F deviation)	-1.542	0.13	log(unfished SSB)	10.494	0.08
log(2013 F deviation)	-1.371	0.13	log(steepness)	-0.018	0.02

Table 100. Abundance and end-year spawning stock biomass estimates from the base modified-CSA model for spot. CVs are derived from asymptotic standard errors.

Year	Recruitment (millions of fish)		Post Recruitment (millions of fish)		Spawning Stock Biomass (metric tons)	
	Estimate	CV	Estimate	CV	Estimate	CV
1989	914	0.12	654	0.14	12,929	0.18
1990	1,317	0.09	488	0.13	5,510	0.18
1991	1,352	0.07	359	0.14	1,689	0.14
1992	182	0.14	160	0.12	712	0.20
1993	431	0.08	39	0.15	1,282	0.16
1994	1,135	0.07	120	0.15	6,175	0.10
1995	278	0.15	489	0.09	2,689	0.19
1996	197	0.09	93	0.12	1,253	0.18
1997	99	0.14	67	0.13	2,076	0.18
1998	167	0.11	70	0.15	1,568	0.18
1999	321	0.08	76	0.14	3,025	0.12
2000	117	0.12	169	0.09	3,898	0.15
2001	153	0.09	101	0.11	208	0.21
2002	439	0.09	17	0.16	2,026	0.11
2003	297	0.11	197	0.11	3,197	0.18
2004	378	0.12	134	0.14	5,137	0.15
2005	429	0.11	232	0.13	8,969	0.14
2006	194	0.14	321	0.11	9,463	0.16
2007	191	0.15	222	0.14	7,804	0.17
2008	391	0.12	201	0.14	8,102	0.16
2009	283	0.13	294	0.13	10,459	0.16
2010	605	0.12	281	0.14	12,932	0.14
2011	476	0.12	475	0.12	14,792	0.17
2012	536	0.13	418	0.14	17,251	0.16
2013	528	0.14	507	0.14	19,567	0.17
2014	205	0.17	533	0.15	19,032	0.18

Table 101. Full fishing mortality and static spawning potential ratio estimates from the base modified-CSA model for spot. Terminal year (2014) fishing mortality is the geometric mean of the previous two years (2012-2013) and terminal year static spawning potential ratio is calculated from the terminal year fishing mortality estimate. CVs are derived from asymptotic standard errors.

Year	Full Fishing Mortality		Static Spawning Potential Ratio	
	Estimate	CV	Estimate	CV
1989	1.07	0.11	0.12	0.16
1990	2.06	0.09	0.04	0.17
1991	3.79	0.06	0.01	0.12
1992	2.79	0.08	0.02	0.16
1993	1.80	0.11	0.05	0.19
1994	0.86	0.08	0.17	0.10
1995	2.31	0.08	0.03	0.15
1996	1.68	0.10	0.06	0.16
1997	0.58	0.13	0.26	0.14
1998	1.10	0.11	0.12	0.16
1999	0.64	0.09	0.24	0.10
2000	0.77	0.10	0.19	0.12
2001	4.09	0.08	0.01	0.16
2002	0.67	0.10	0.23	0.11
2003	1.32	0.10	0.09	0.16
2004	0.50	0.12	0.30	0.11
2005	0.37	0.11	0.39	0.09
2006	0.50	0.13	0.30	0.12
2007	0.35	0.14	0.41	0.10
2008	0.33	0.13	0.42	0.10
2009	0.35	0.14	0.41	0.10
2010	0.21	0.13	0.56	0.06
2011	0.50	0.13	0.30	0.12
2012	0.23	0.14	0.53	0.08
2013	0.27	0.15	0.48	0.09
2014	0.25	0.15	0.51	0.08

Table 102. Full fishing mortality reference point estimates for static spawning potential ratio reference levels (i.e., 20-40% SPR) from the base modified-CSA model for spot.

Fishing Mortality Reference Point	Estimate
F20%	0.74
F30%	0.5
F40%	0.36

Table 103. Full fishing mortality reference point estimates for static spawning potential ratio reference levels (i.e., 20-40%) from the base modified-CSA model for spot and all sensitivity configurations.

Model Configuration	F20%	F30%	F40%
base	0.74	0.5	0.36
1992 start year	0.74	0.5	0.36
adjust shrimp discards	0.74	0.5	0.36
10% shrimp discards	0.74	0.5	0.36
50% shrimp discards	0.74	0.5	0.36
low selectivity	0.81	0.54	0.38
high selectivity	0.65	0.45	0.32
low M	0.73	0.5	0.35
high M	0.75	0.51	0.36
FD Z prior	0.74	0.5	0.36
wt comb Z prior	0.74	0.5	0.36
no reweight	0.74	0.5	0.36
no NMFS trawl	0.74	0.5	0.36
no NCDMF trawl	0.74	0.5	0.36
add NEAMAP trawl	0.74	0.5	0.36
change in NMFS recruit q 2005	0.74	0.5	0.36
change in NMFS recruit q in 2009	0.74	0.5	0.36
h = 0.99	0.74	0.5	0.36
h = 0.79	0.74	0.5	0.36
NCDMF comm mean wts	0.71	0.49	0.35
sex ratio	0.74	0.5	0.36

Table 104. Modified Mohn's Rhos (Hurtado-Ferro et al. 2015) for retrospective analysis (5 year peel) of the modified-CSA model for spot. Full fishing mortality and static spawning potential ratio are estimated from the geometric mean full fishing mortality over the two years prior to the terminal year, so calculation are presented for final year estimate (2013) and terminal year derived estimate (2014) for these quantities.

Calculation Year	Recruitment	Spawning Stock Biomass	Full Fishing Mortality	Static Spawning Potential Ratio
Final Year Estimate	0.6029	0.2980	-0.2241	0.2489
Terminal Year Estimate	0.6029	0.2980	-0.0907	0.0964

Table 105. Steepness estimates from retrospective analysis of the base modified-CSA model for spot.

Model Terminal Year	2014	2013	2012	2011	2010	2009
Steepness	0.982	0.977	0.981	0.983	0.982	0.984

Table 106. Randomly sampled recruitment for threshold spawning stock biomass estimate. Recruitment was sampled from model estimated recruitments from 1996-2014.

Projection Year	Recruitment (millions of fish)	Projection Year	Recruitment (millions of fish)	Projection Year	Recruitment (millions of fish)	Projection Year	Recruitment (millions of fish)
1	153	26	378	51	476	76	205
2	99	27	99	52	528	77	297
3	378	28	528	53	476	78	528
4	283	29	536	54	429	79	194
5	191	30	429	55	117	80	191
6	528	31	605	56	321	81	99
7	321	32	429	57	528	82	605
8	321	33	153	58	99	83	429
9	536	34	197	59	476	84	283
10	153	35	297	60	321	85	153
11	476	36	117	61	167	86	194
12	117	37	99	62	99	87	283
13	194	38	439	63	99	88	378
14	191	39	297	64	167	89	297
15	117	40	297	65	476	90	191
16	391	41	283	66	205	91	605
17	429	42	283	67	205	92	153
18	117	43	476	68	476	93	205
19	99	44	283	69	605	94	197
20	197	45	99	70	391	95	194
21	205	46	197	71	283	96	528
22	391	47	153	72	429	97	117
23	191	48	167	73	439	98	536
24	283	49	536	74	391	99	605
25	117	50	117	75	391	100	194

Table 107. Randomly sampled recruitment for target spawning stock biomass estimate. Recruitment was sampled from model estimated recruitments from 2003-2014.

Projection Year	Recruitment (millions of fish)	Projection Year	Recruitment (millions of fish)	Projection Year	Recruitment (millions of fish)	Projection Year	Recruitment (millions of fish)
1	194	26	391	51	536	76	205
2	297	27	297	52	205	77	191
3	391	28	205	53	536	78	205
4	476	29	528	54	391	79	283
5	605	30	283	55	429	80	605
6	205	31	536	56	429	81	297
7	429	32	391	57	205	82	536
8	429	33	194	58	297	83	391
9	528	34	297	59	536	84	476
10	194	35	191	60	429	85	194
11	528	36	429	61	378	86	283
12	429	37	297	62	297	87	476
13	283	38	191	63	297	88	391
14	605	39	191	64	378	89	191
15	429	40	191	65	536	90	605
16	605	41	476	66	205	91	476
17	283	42	476	67	205	92	194
18	429	43	536	68	536	93	205
19	378	44	476	69	536	94	297
20	297	45	378	70	605	95	283
21	205	46	297	71	476	96	205
22	476	47	194	72	391	97	429
23	605	48	378	73	191	98	528
24	476	49	528	74	476	99	536
25	429	50	429	75	476	100	283

Table 108. Comparison of spot stock condition according to the modified-CSA end-year spawning stock biomass and reference point estimates and the TLA proportion of red from the adult abundance metric. Values highlighted in red indicate overfished (modified-CSA) or significant concern (TLA), values highlighted in yellow indicate not overfished, but below the target (modified-CSA) or moderate concern (TLA), and values highlighted in green indicate not overfished (modified-CSA) or no concern (TLA). Bolded values show agreement of condition between the analyses.

Year	Spawning Stock Biomass (metric tons)	Adult Abundance Metric Proportion Red
1989	**12,929**	**0.27**
1990	**5,510**	**0.48**
1991	1,689	0.37
1992	712	0.57
1993	**1,282**	**0.81**
1994	6,175	0.14
1995	2,689	0.55
1996	1,253	0.48
1997	**2,076**	**0.77**
1998	**1,568**	**0.78**
1999	3,025	0.54
2000	**3,898**	**0.70**
2001	**208**	**0.76**
2002	**2,026**	**0.69**
2003	3,197	0.38
2004	**5,137**	**0.52**
2005	**8,969**	**0.00**
2006	**9,463**	**0.27**
2007	**7,804**	**0.34**
2008	**8,102**	**0.00**
2009	**10,459**	**0.12**
2010	**12,932**	**0.29**
2011	**14,792**	**0.00**
2012	**17,251**	**0.00**
2013	19,567	0.31
2014	19,032	0.56

Table 109. Comparison of spot stock condition according to the modified-CSA static spawning potential ratio estimates and the TLA proportion of red from the harvest and total removal metrics. Values highlighted in red indicate overfishing (modified-CSA) or significant concern (TLA), values highlighted in yellow indicate not overfishing, but above the target (modified-CSA) or moderate concern (TLA), and values highlighted in green indicate not overfishing (modified-CSA) or no concern (TLA). Bolded values show agreement of condition between the analyses.

Year	Static Spawning Potential Ratio	Harvest Metric Proportion Red	Total Removals Metric Proportion Red
1989	0.12	0.00	0.26
1990	0.04	0.00	0.30
1991	0.01	0.00	0.25
1992	0.02	0.00	0.03
1993	0.05	0.00	0.00
1994	0.17	0.00	0.04
1995	0.03	0.00	0.05
1996	0.06	0.16	0.05
1997	0.26	0.07	0.03
1998	0.12	0.03	0.01
1999	0.24	0.20	0.07
2000	0.19	0.14	0.06
2001	0.01	0.00	0.01
2002	0.23	0.13	0.11
2003	0.09	0.00	0.01
2004	0.30	0.00	0.01
2005	0.39	0.03	0.09
2006	0.30	0.18	0.13
2007	**0.41**	**0.00**	**0.01**
2008	**0.42**	**0.20**	**0.08**
2009	**0.41**	**0.10**	**0.16**
2010	**0.56**	0.43	**0.26**
2011	0.30	0.17	0.13
2012	**0.53**	0.52	**0.24**
2013	**0.48**	0.30	**0.27**
2014	**0.51**	**0.15**	**0.18**

13. Figures

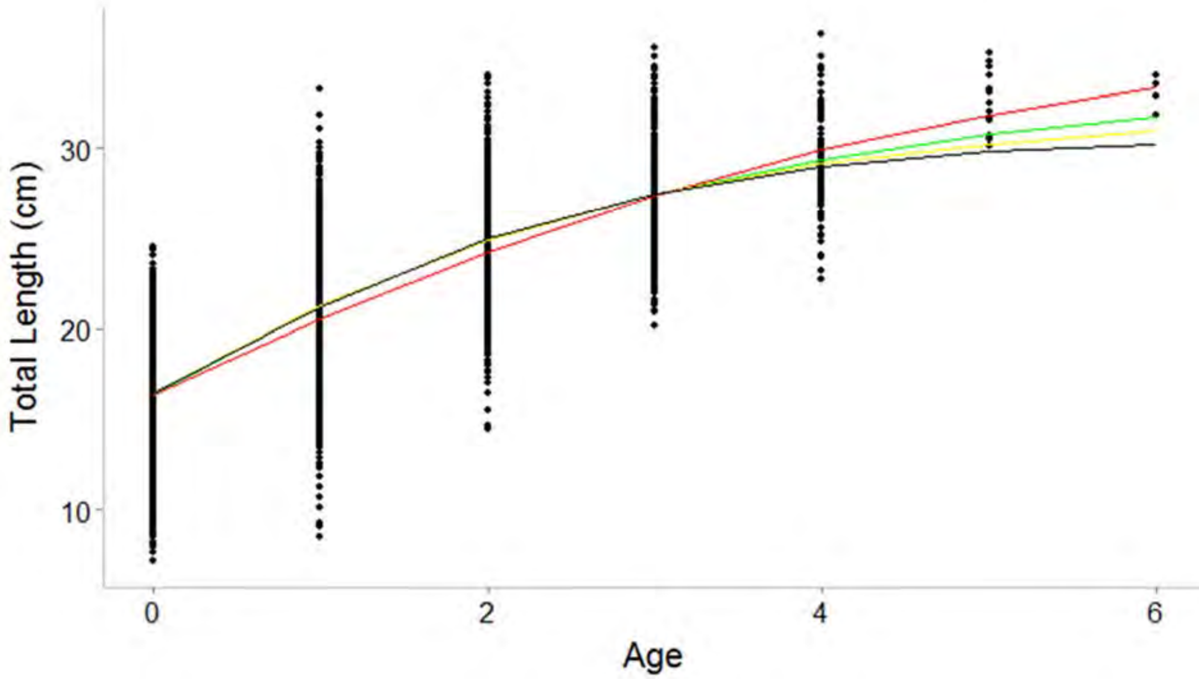


Figure 1. Observed female spot age-at-total length (black circles) and predictions from the von Bertalanffy (green line), Richard's (red line), Gompertz (yellow line), and logistic (black line) growth models.

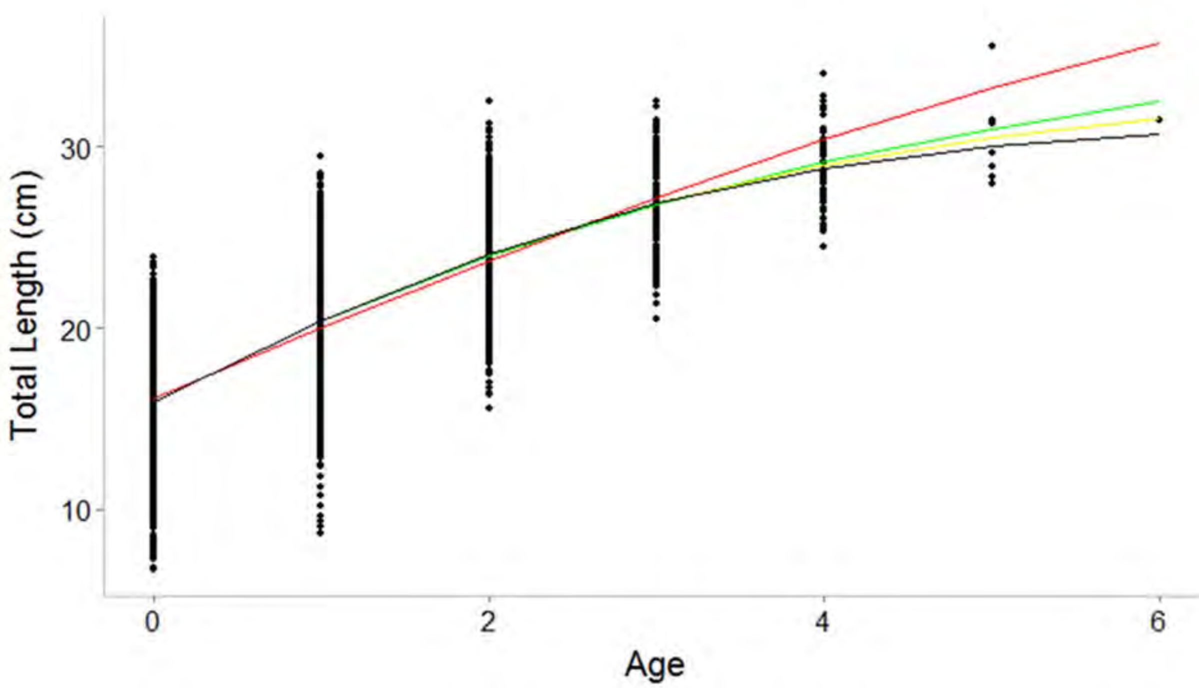


Figure 2. Observed male spot age-at-length (black circles) and predictions from the von Bertalanffy (green line), Richard's (red line), Gompertz (yellow line), and logistic (black line) growth models.

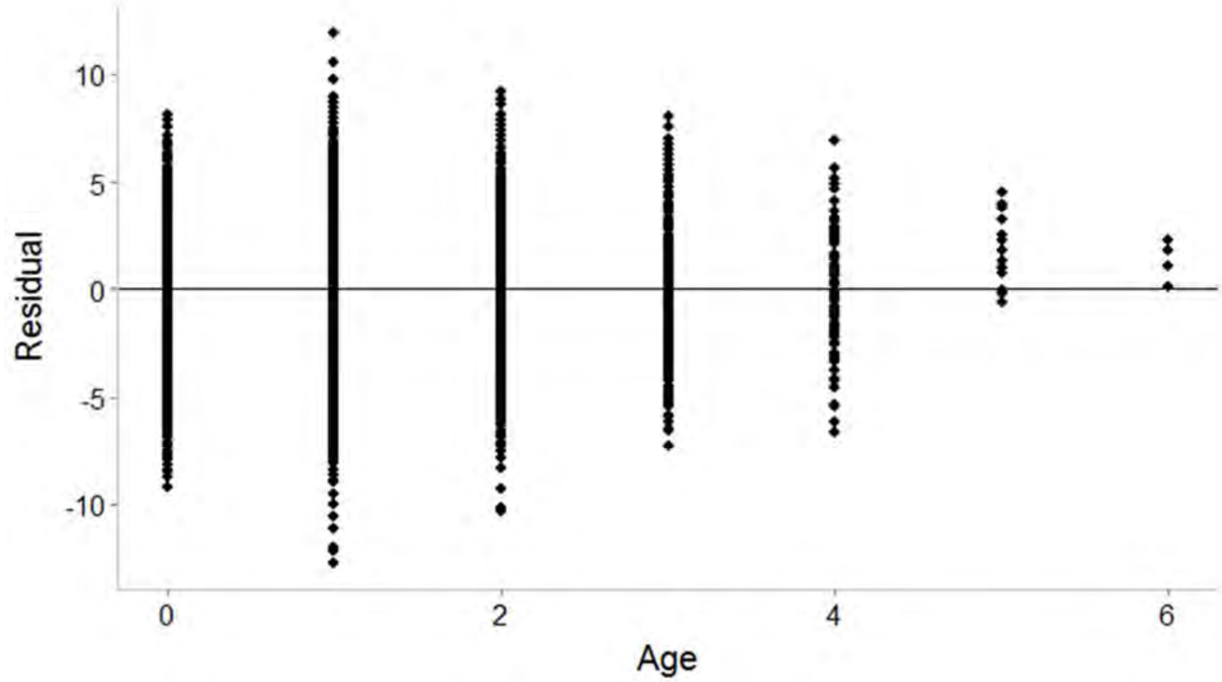


Figure 3. **Residuals of von Bertalanffy growth model fit to observed female spot age-at-total length data.**

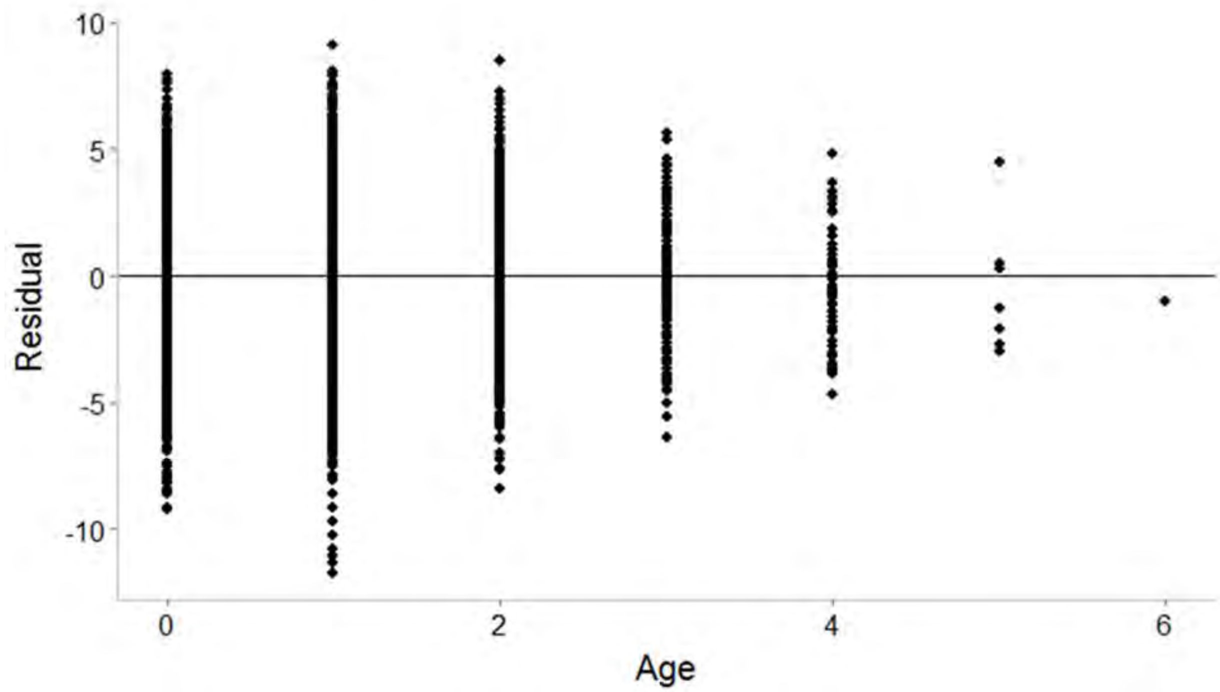


Figure 4. **Residuals of von Bertalanffy growth model fit to observed male spot age-at-length data.**

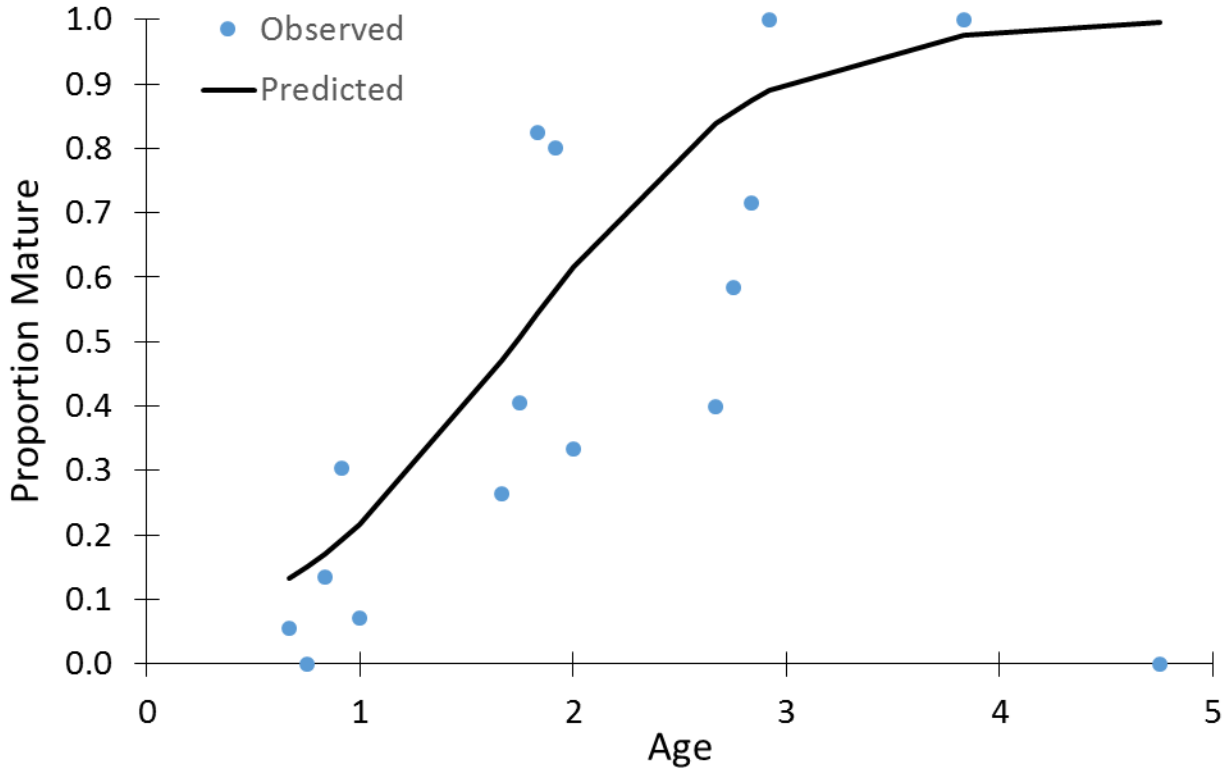


Figure 5. **Observed (blue circles) and predicted (black line) proportion female spot mature-at-age using SCDNR maturity data from August-December. Predicted values are from a logistic regression model (slope = -1.761, inflection = 1.7).**

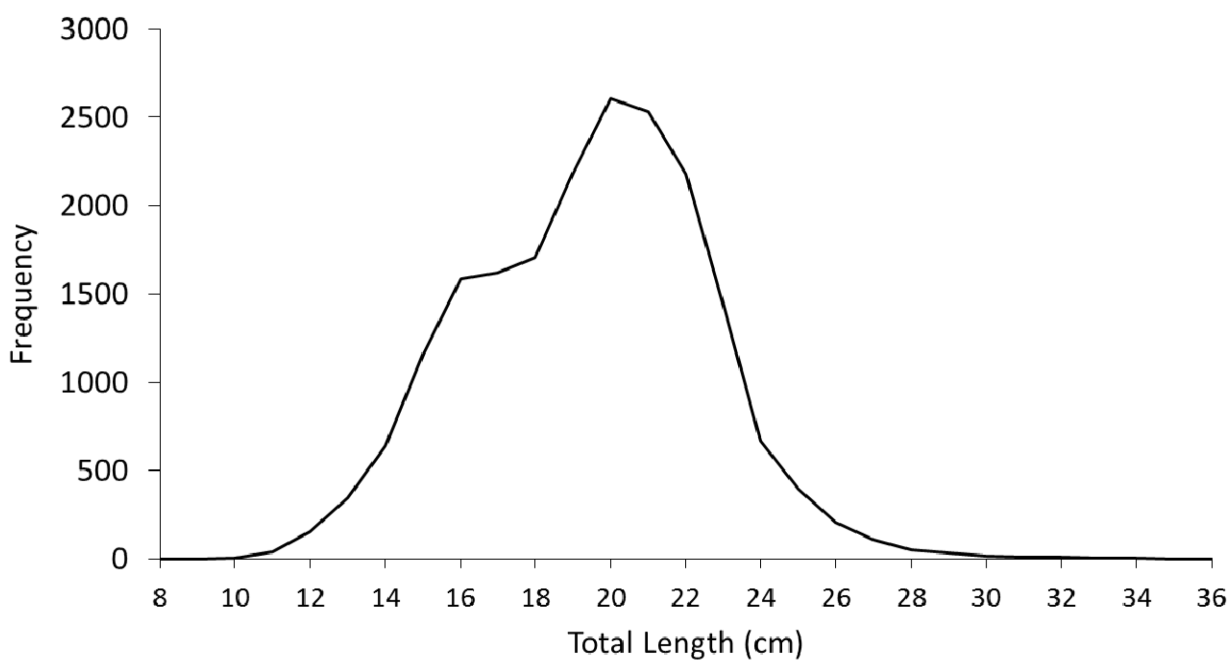


Figure 6. **Aggregate length frequency of spot (mm TL) sampled by the MD DNR from commercial pound nets from 1993-2014.**

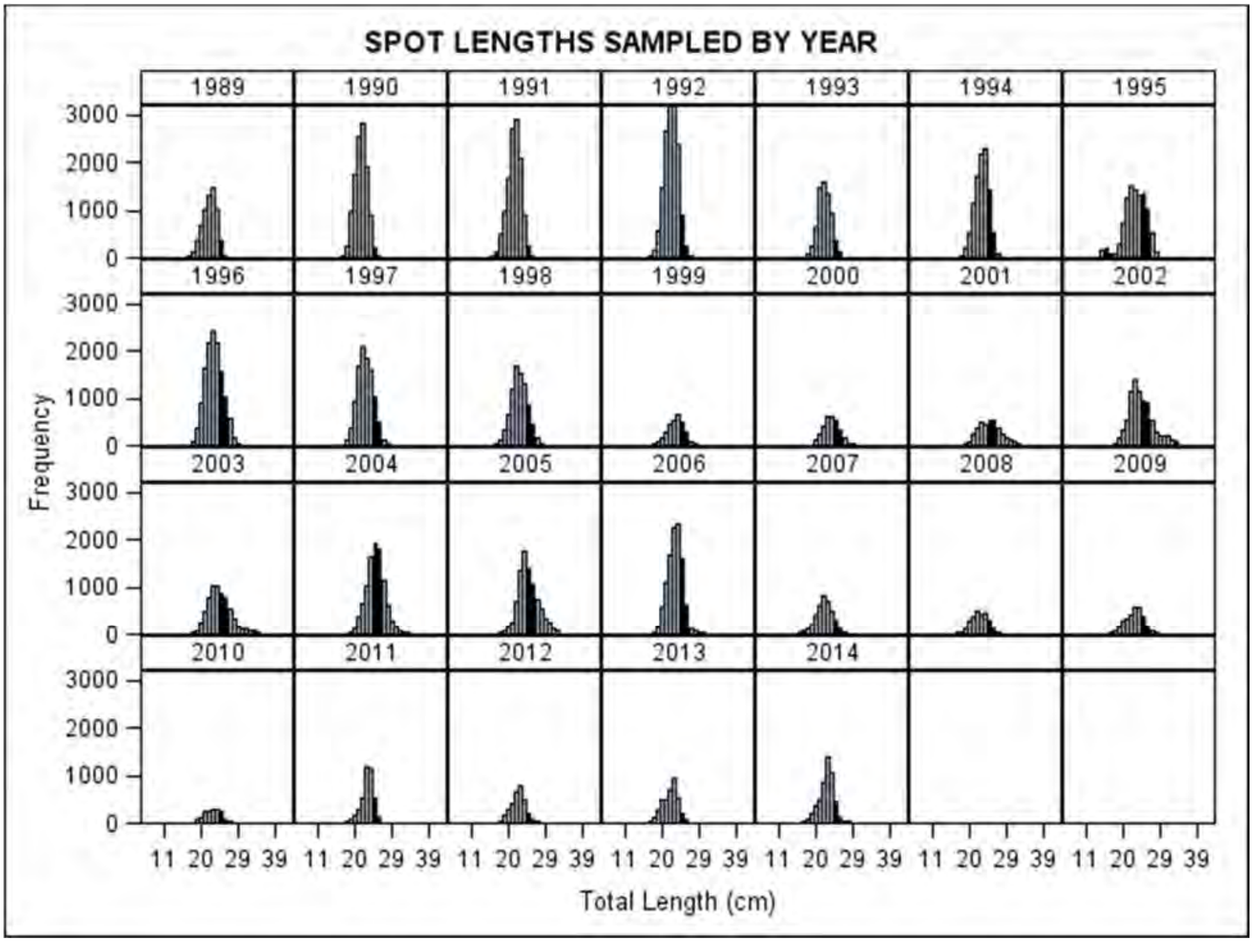


Figure 7. **Annual length frequency of spot sampled by the VMRC's BSP from commercial fisheries.**

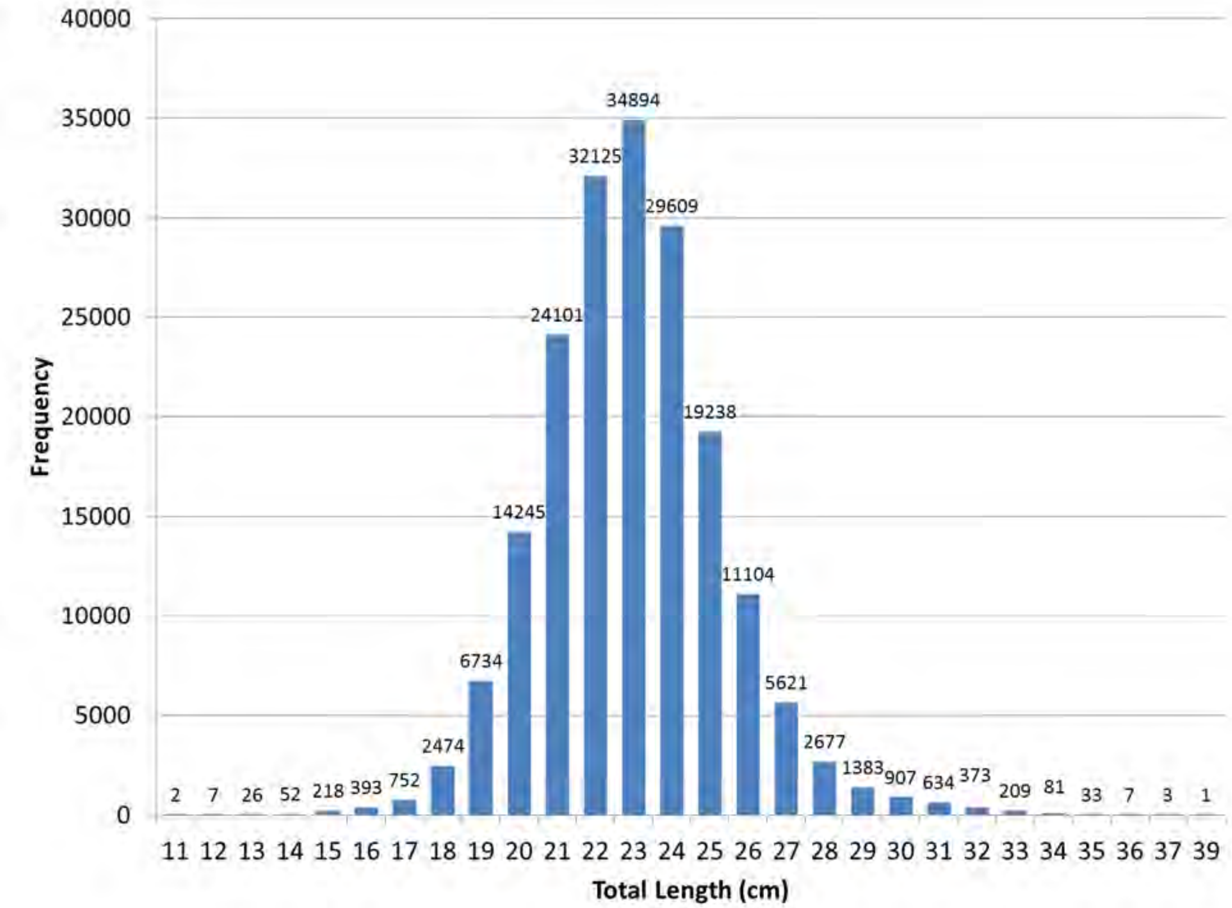


Figure 8. **Aggregate length frequency of spot sampled by the VMRC's BSP from commercial fisheries from 1989-2014.**

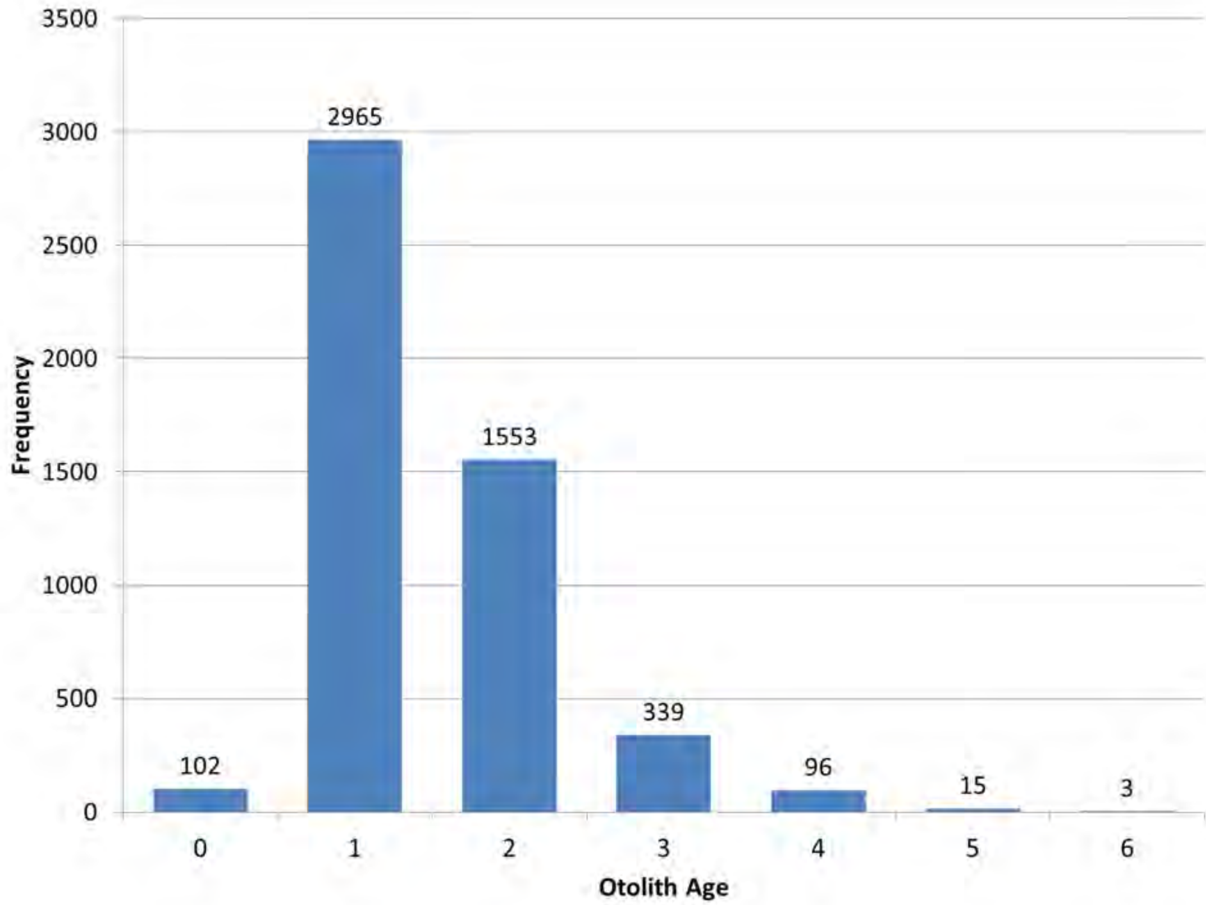


Figure 9. **Aggregate age frequency of spot sampled by the VMRC's BSP from commercial fisheries from 1998-2014.**

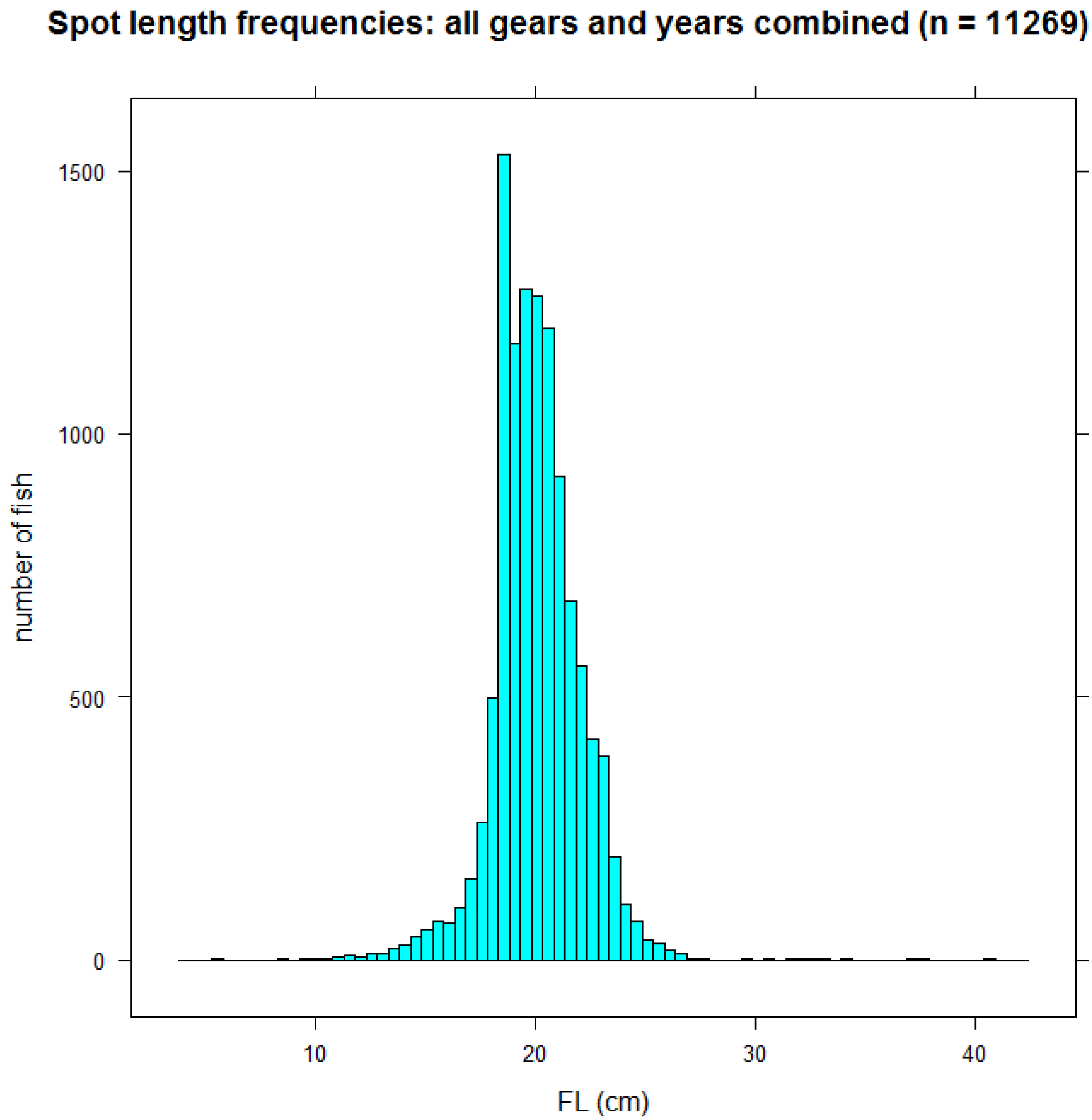


Figure 10. **Length frequency of spot collected by the TIP from commercial fisheries (all gears combined) in Florida from 1992-2014.**

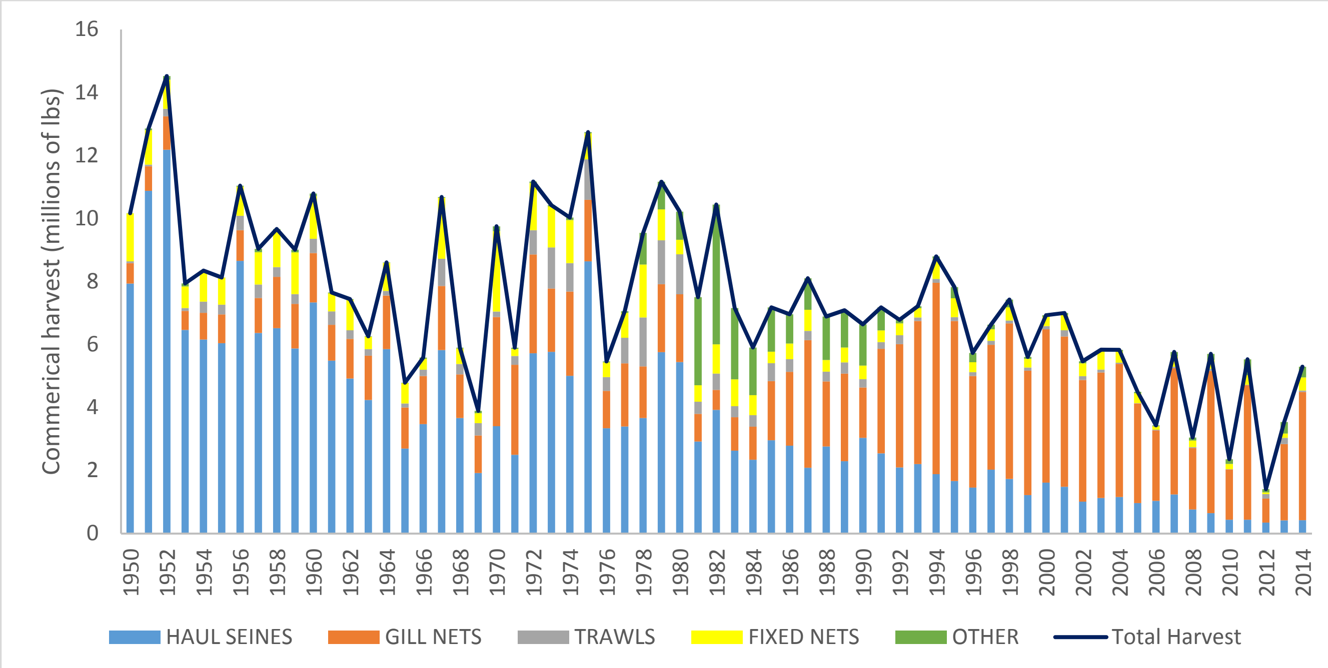


Figure 11. **Coastwide spot commercial landings (millions of pounds) by gear.**

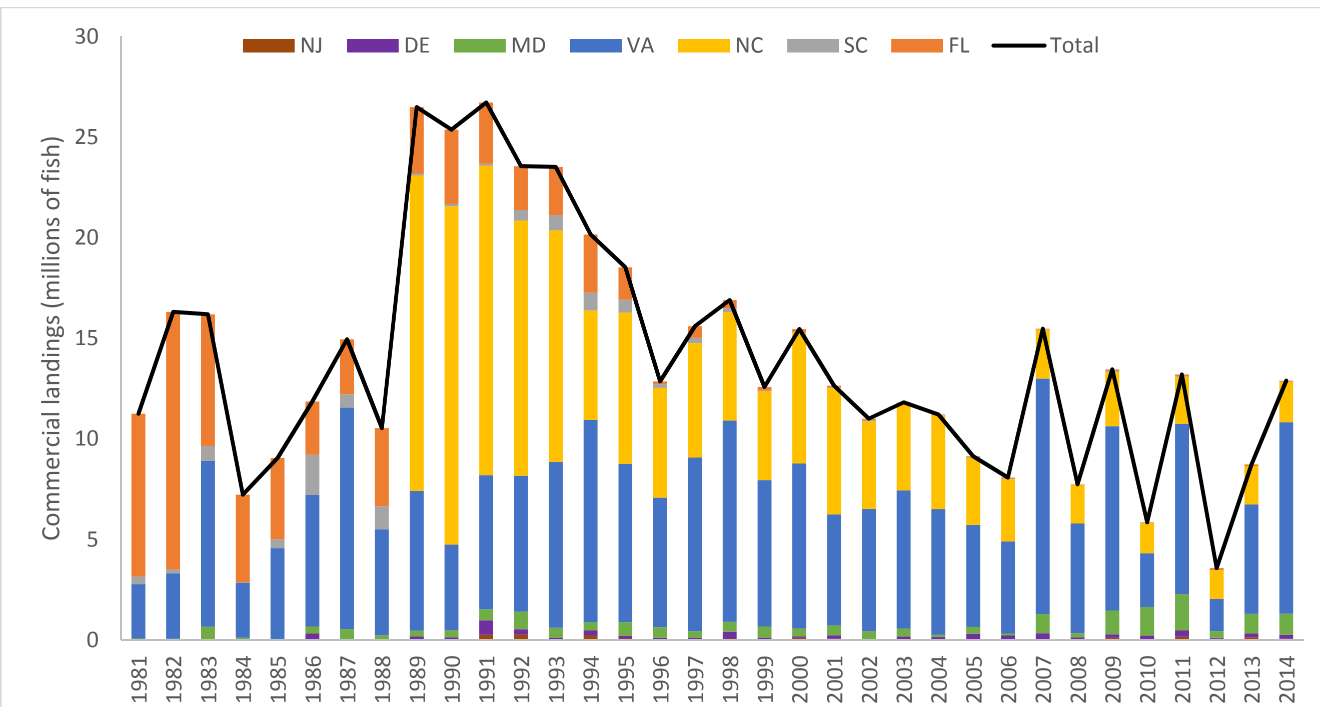


Figure 12. **Spot commercial landings (millions of fish) by state.**

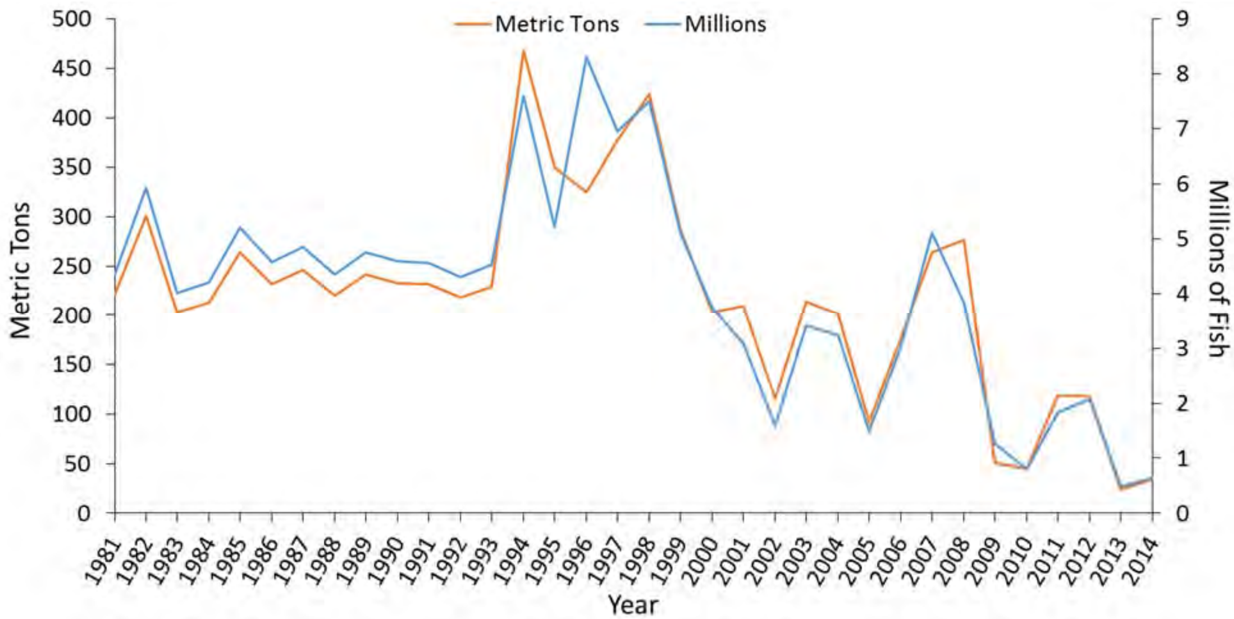


Figure 13. **Annual spot scrap landing estimates in metric tons and millions of fish.**

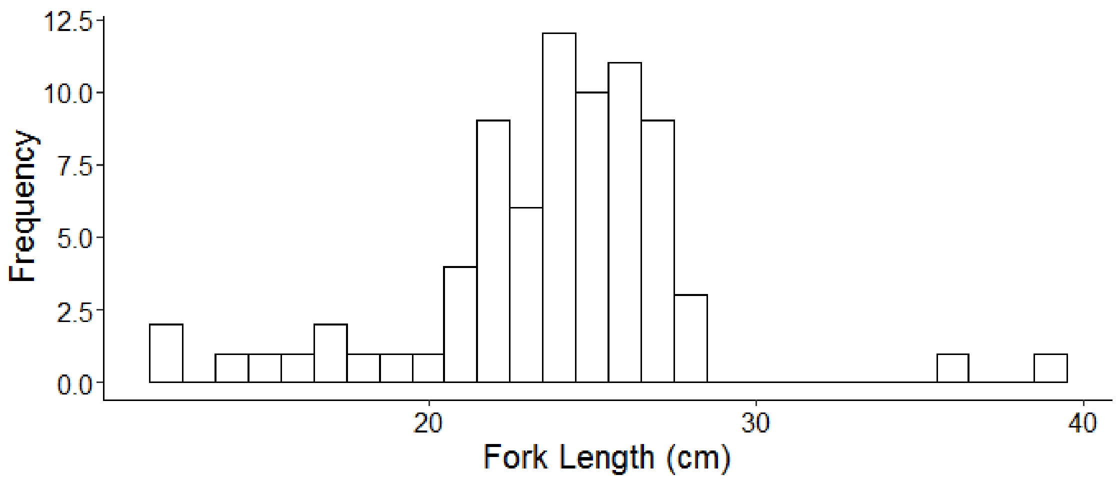


Figure 14. **Length distribution of discarded spot observed in gillnets by the NEFOP.**

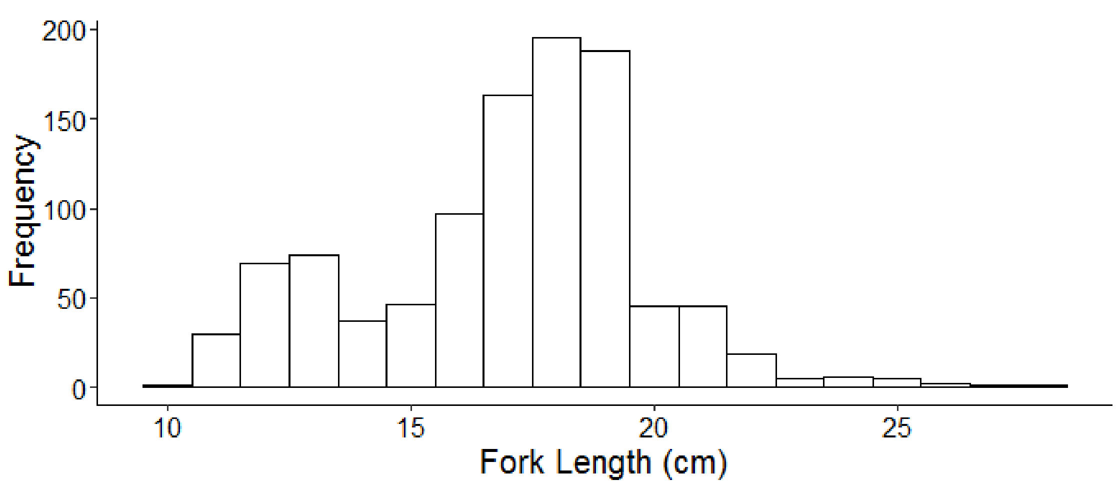


Figure 15. Length distribution of discarded spot observed in trawls by the NEFOP.

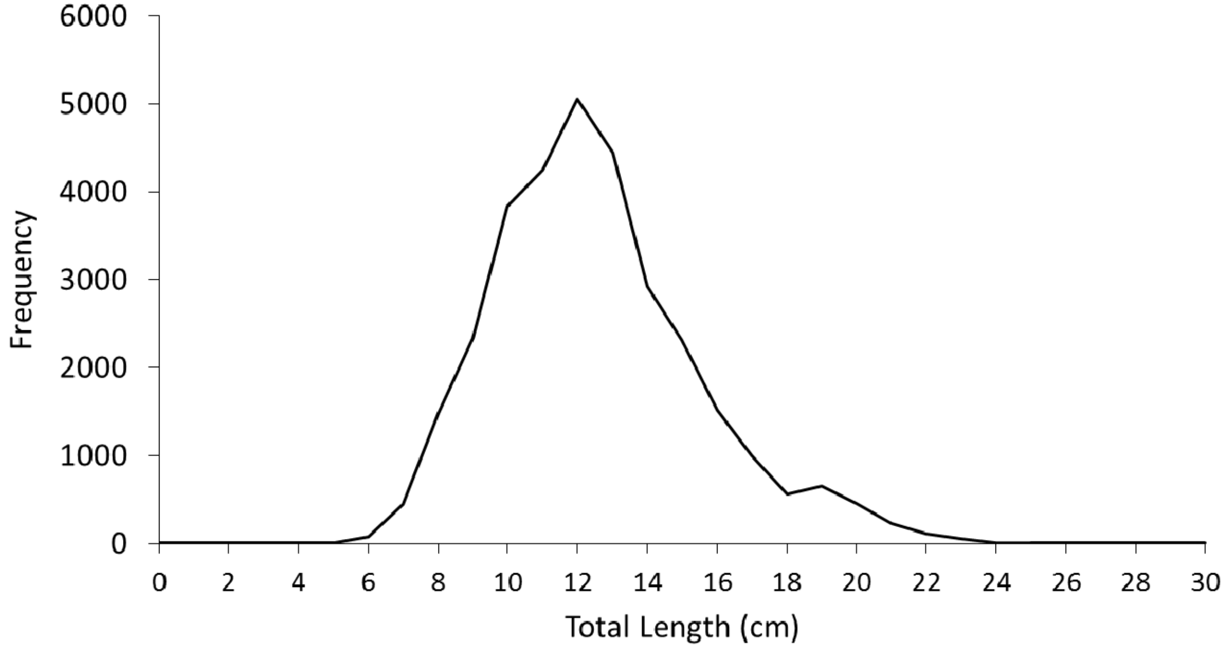


Figure 16. Length frequency of spot observed during the North Carolina Shrimp Trawl Observer Study (2007-2014).

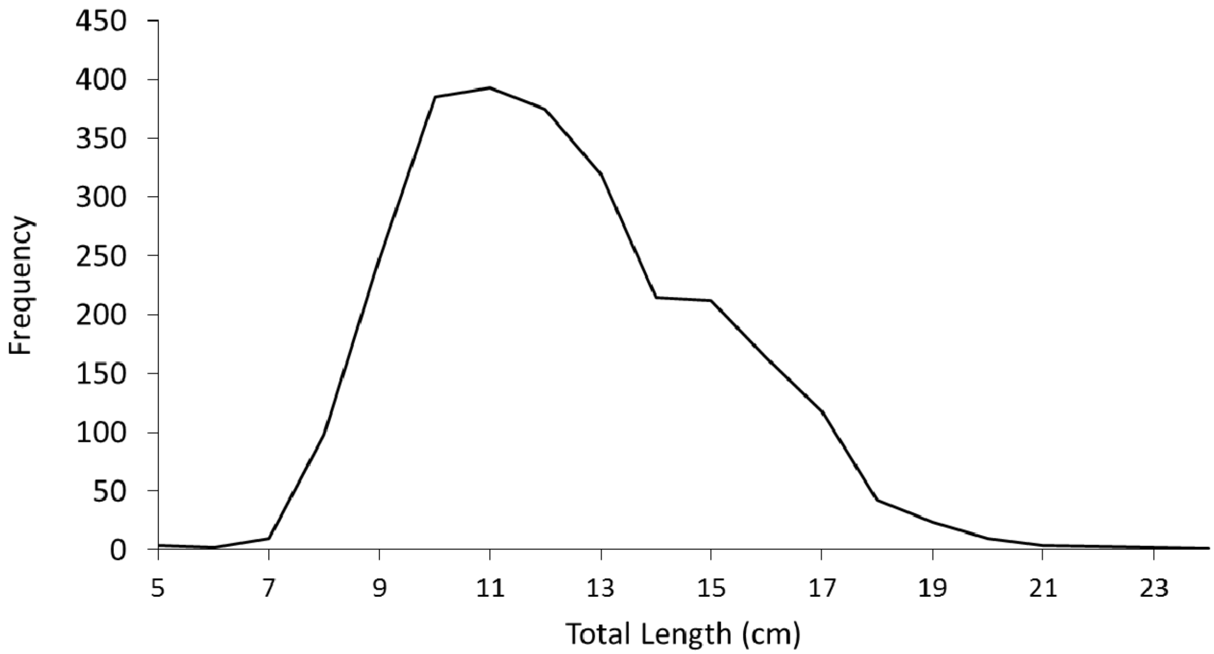


Figure 17. Length frequency of spot observed during the Georgia Large Shrimp Trawl Bycatch Observer Study (1995-2005).

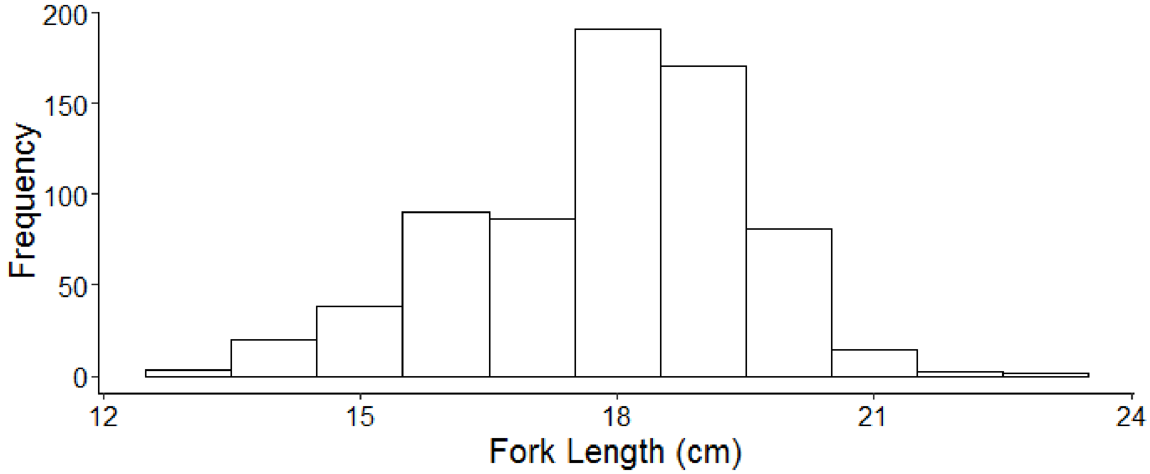


Figure 18. Length distribution of spot measured by the SESTOP. All length samples were collected in 2003.

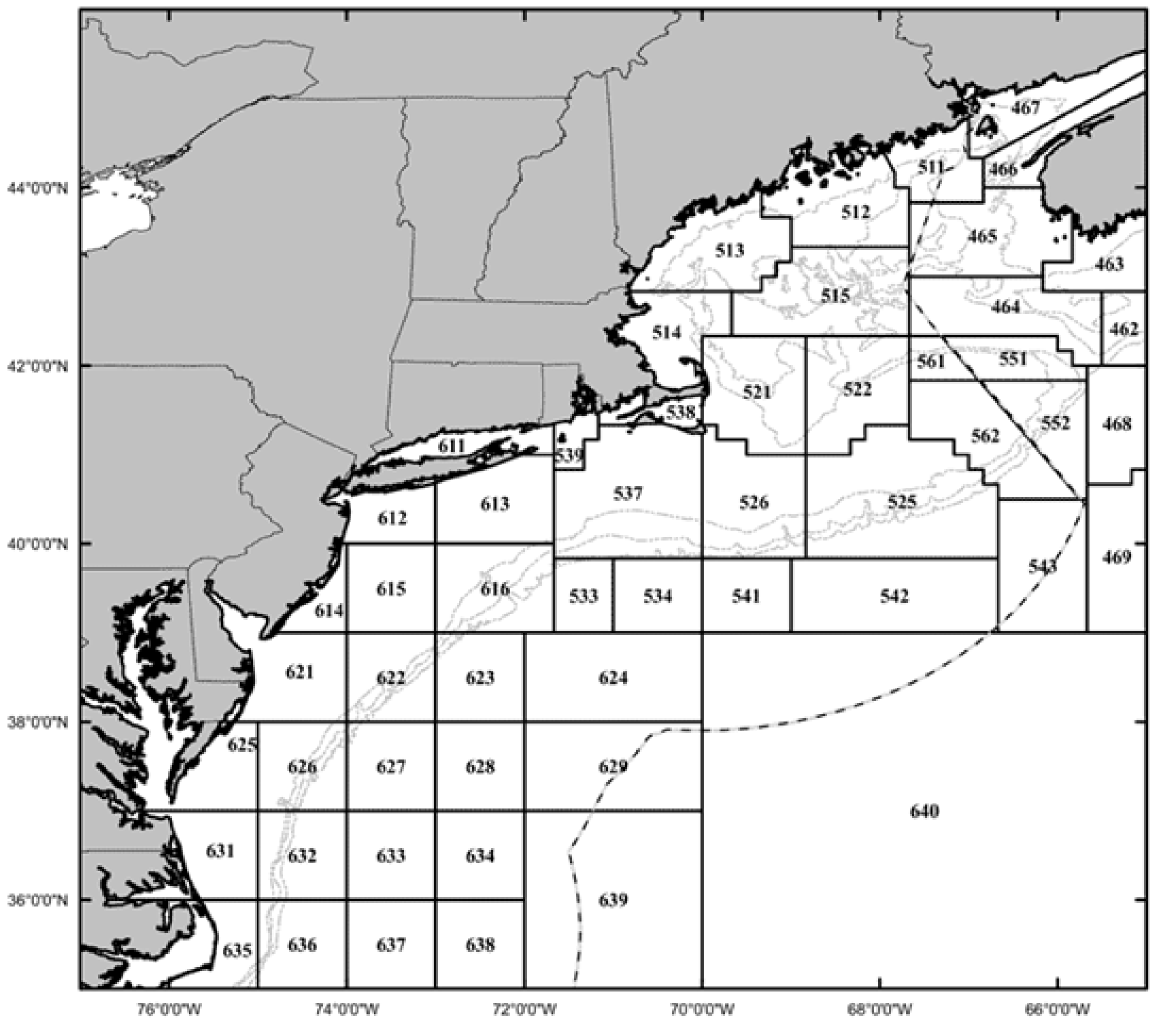


Figure 19. Statistical area used for commercial fisheries data collection by the NMFS in the Northeast Region. The 50, 100 and 500 fa bathymetric lines are shown in

light gray and the U.S. EEZ is indicated by the dashed black line (courtesy of NMFS NEFSC).

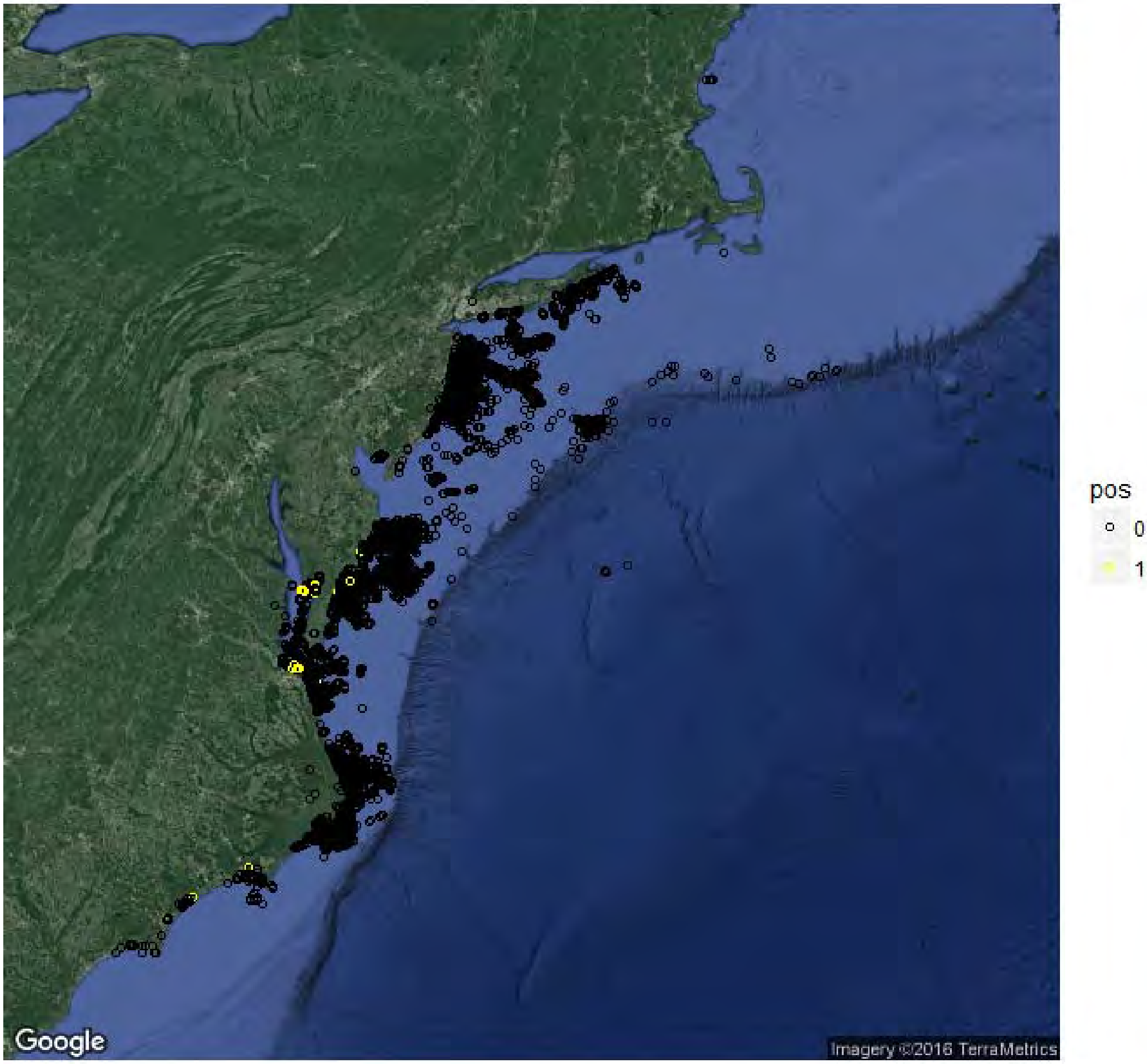


Figure 20. **Gillnet sets observed by the NEFOP. Yellow circles indicate sets where spot were discarded and black circles indicate sets where spot were not discarded.**

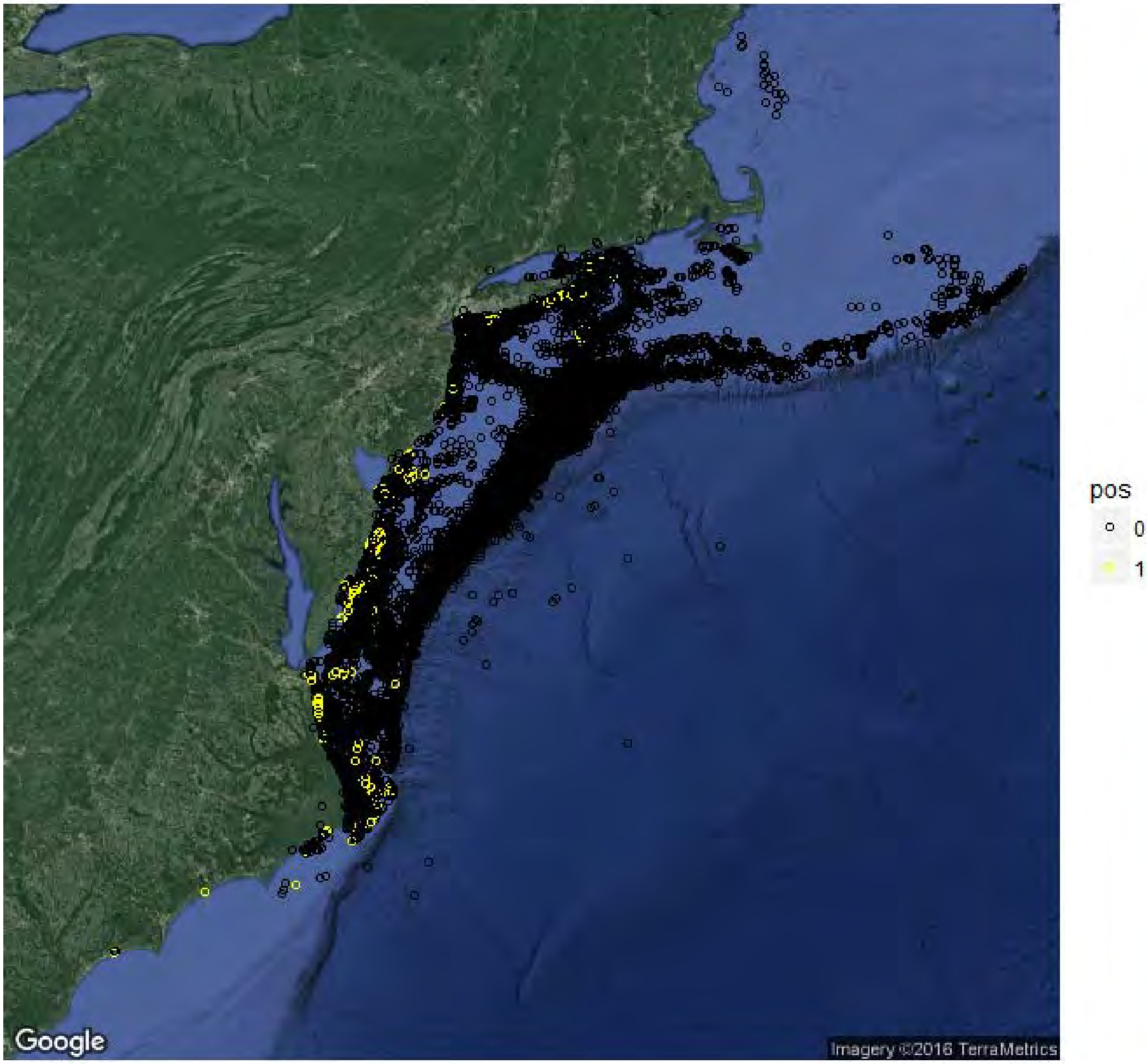


Figure 21. **Trawl tows observed by the NEFOP. Yellow circles indicate tows where spot were discarded and black circles indicate tows where spot were not discarded.**

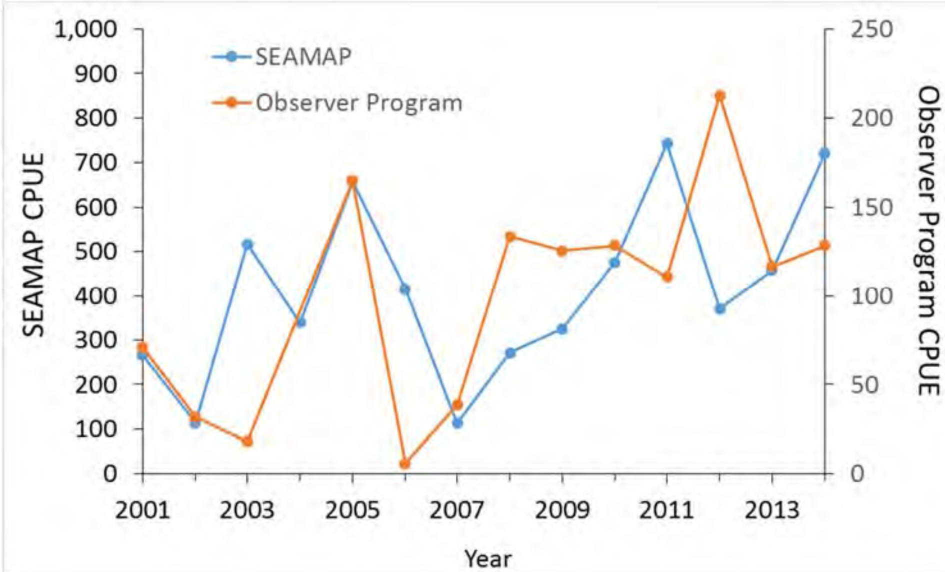


Figure 22. **Annual mean CPUE of spot (number of fish/hour fished) during SEAMAP Trawl Survey tows and observer program tows.**


data_set
SEAMAP
Google
Imagery ©2016 TerraMetrics


data_set
penaeid_shrimp
rock_shrimp
Google
Imagery ©2016 TerraMetrics

Figure 23. **Map of SEAMAP Trawl Survey tows (red circles) and SESTOP observer tows by fishery (yellow circles for the penaeid shrimp fishery and black circles for the rock shrimp fishery).**

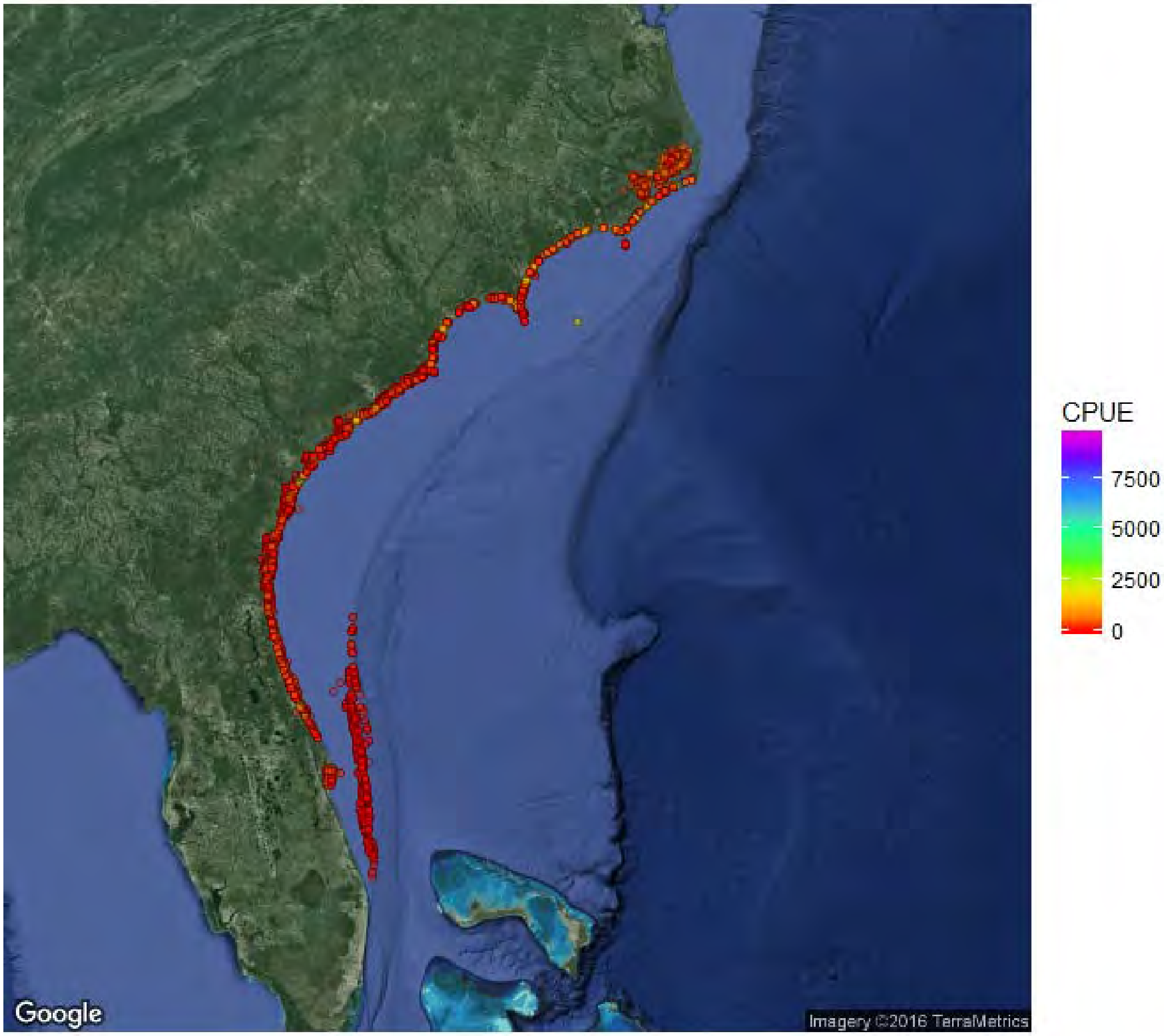


Figure 24. **Tows from SEAMAP Trawl Survey and SESTOP catch rate data set that encountered less than 10,000 spot per hour fished (CPUE).**

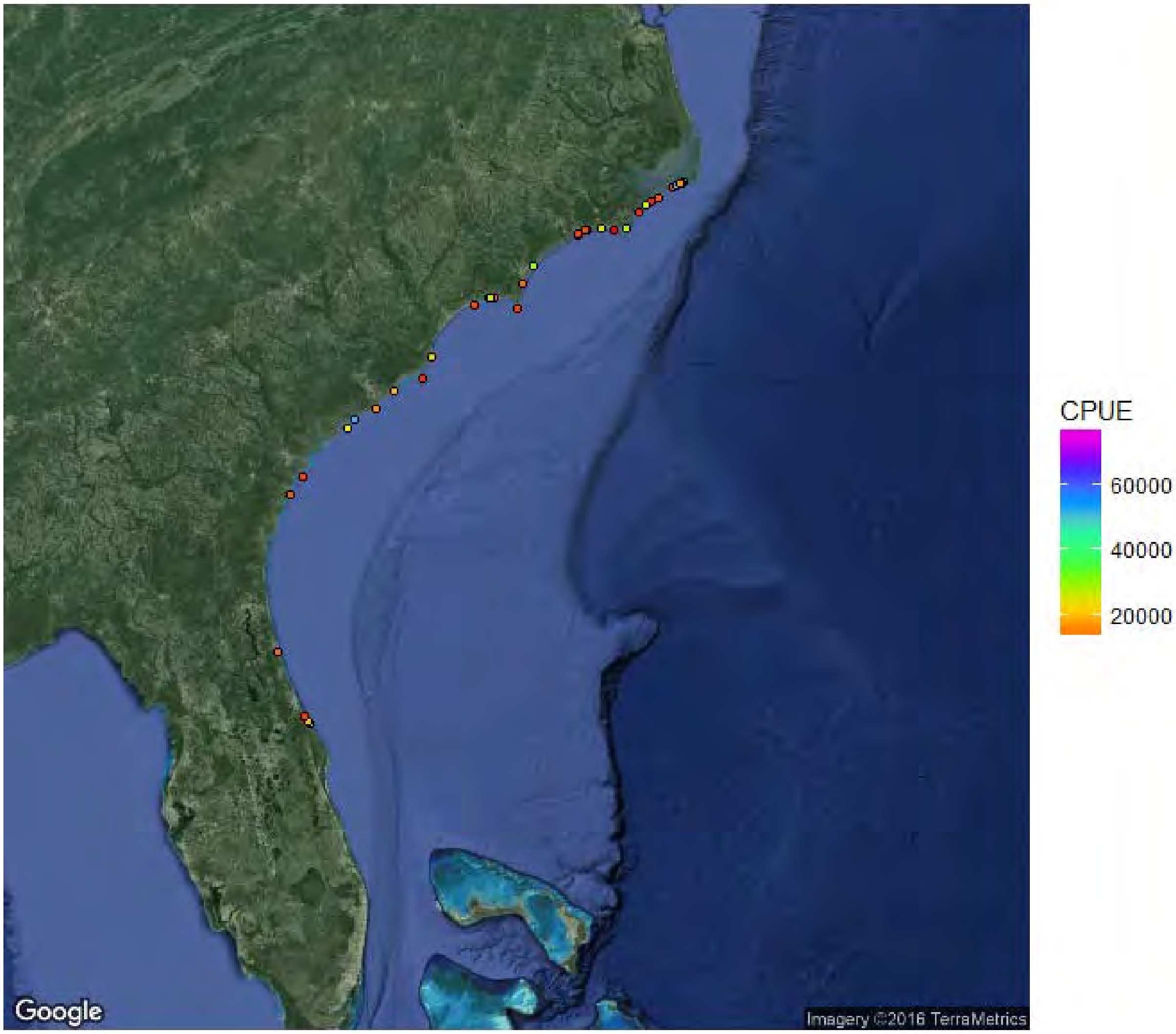


Figure 25. **Tows from SEAMAP Trawl Survey and SESTOP catch rate data set that encountered at least 10,000 spot per hour fished (CPUE).**

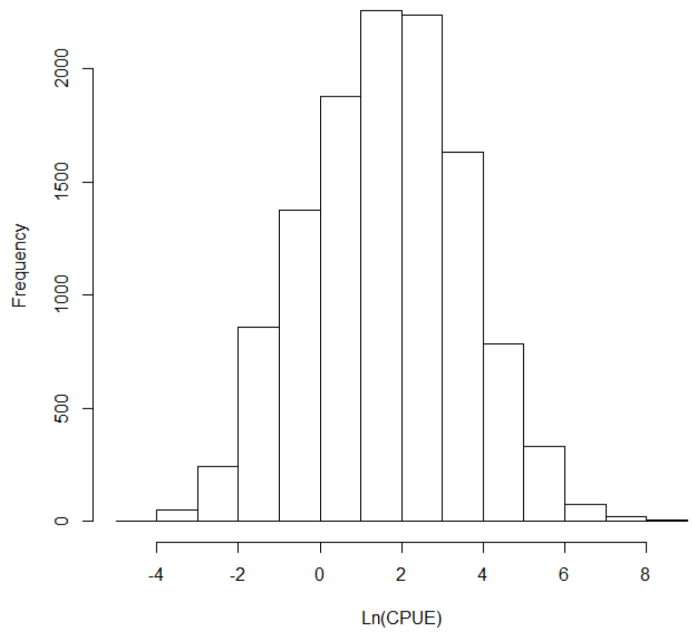


Figure 26. **Distribution of positive spot CPUE observations (weight in kg) from the SEAMAP Trawl Survey and SESTOP on the log scale.**

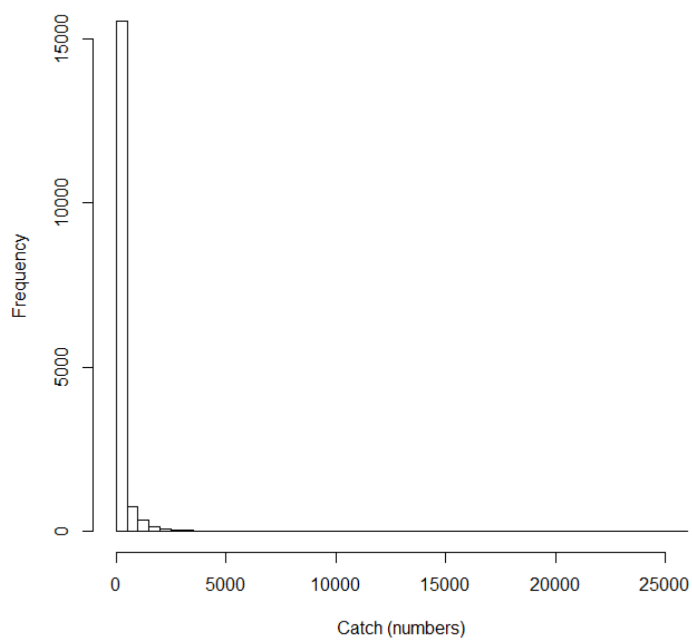


Figure 27. **Distribution of spot discards (numbers) during each observation from the SEAMAP Trawl Survey and SESTOP.**

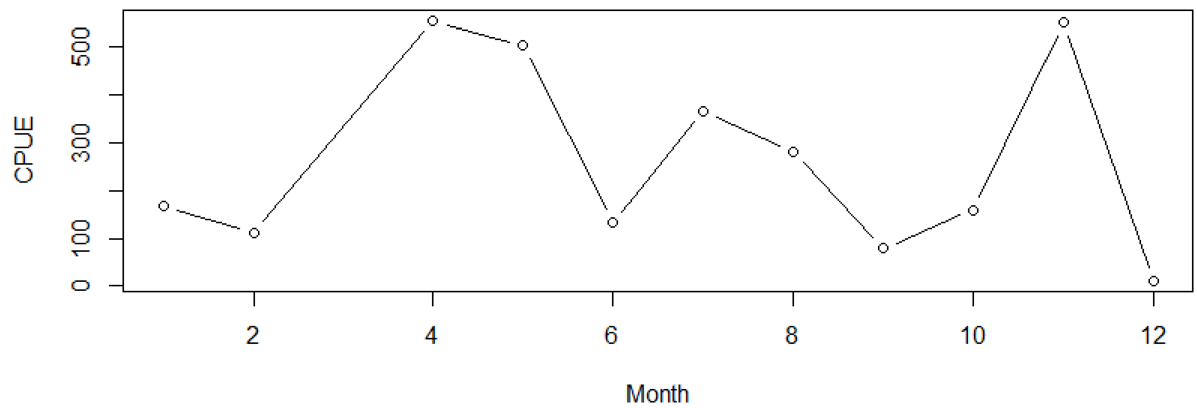


Figure 28. Spot CPUE (numbers) by month from all SEAMAP Trawl Survey and SESTOP catch rate data.

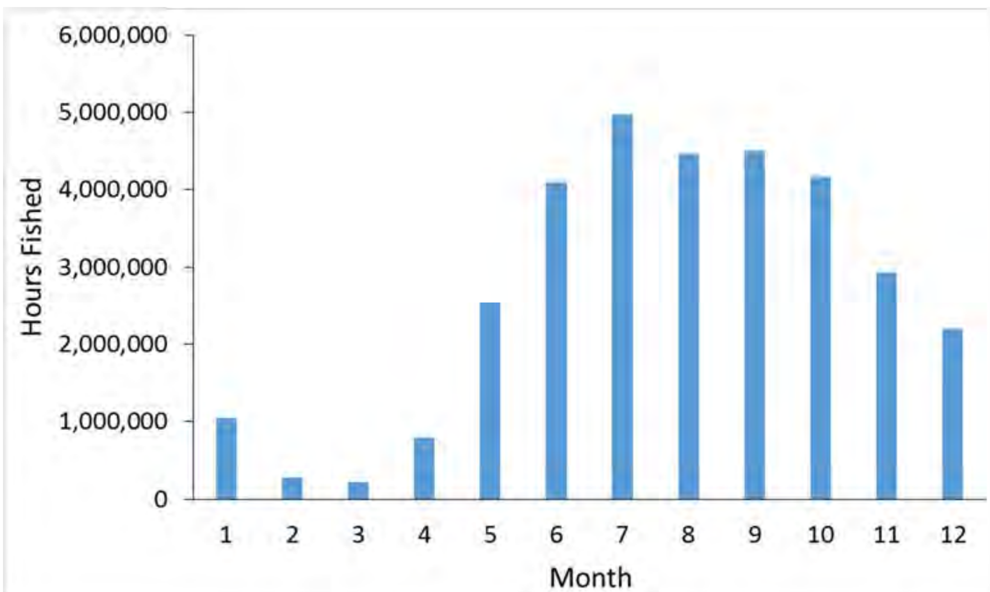


Figure 29. South Atlantic shrimp trawl effort by month.

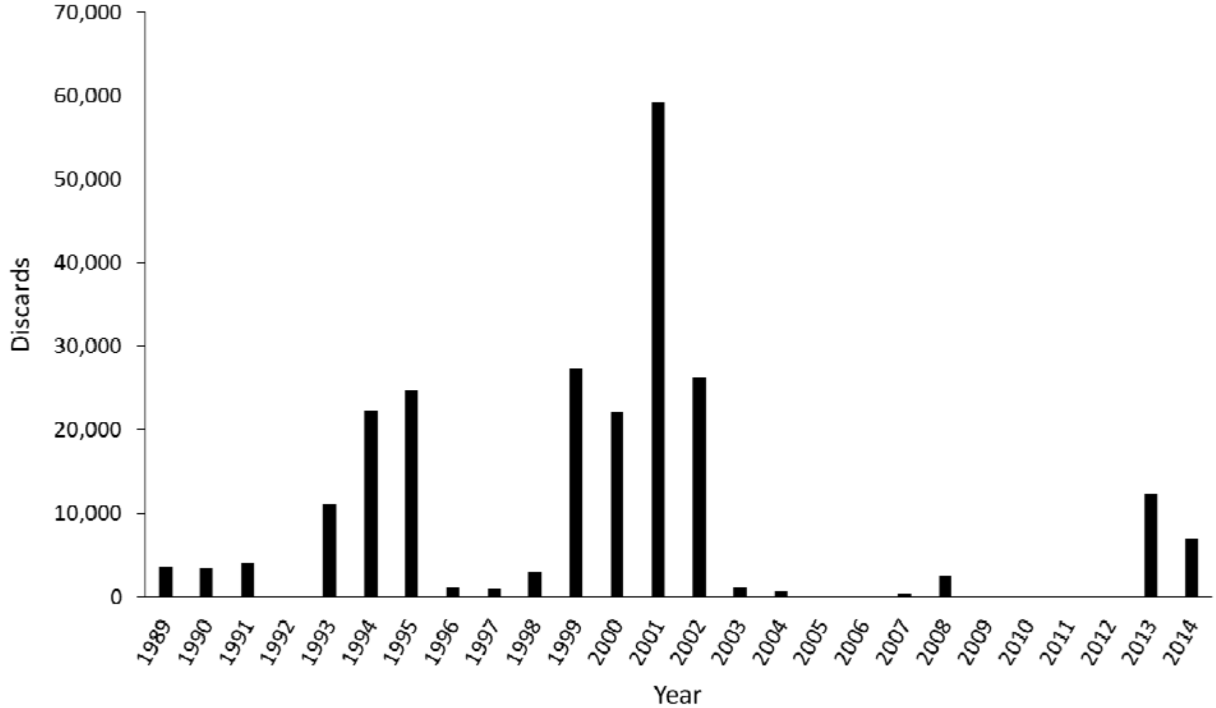


Figure 30. **Spot gillnet discards (number of fish) in Mid-Atlantic fisheries.**

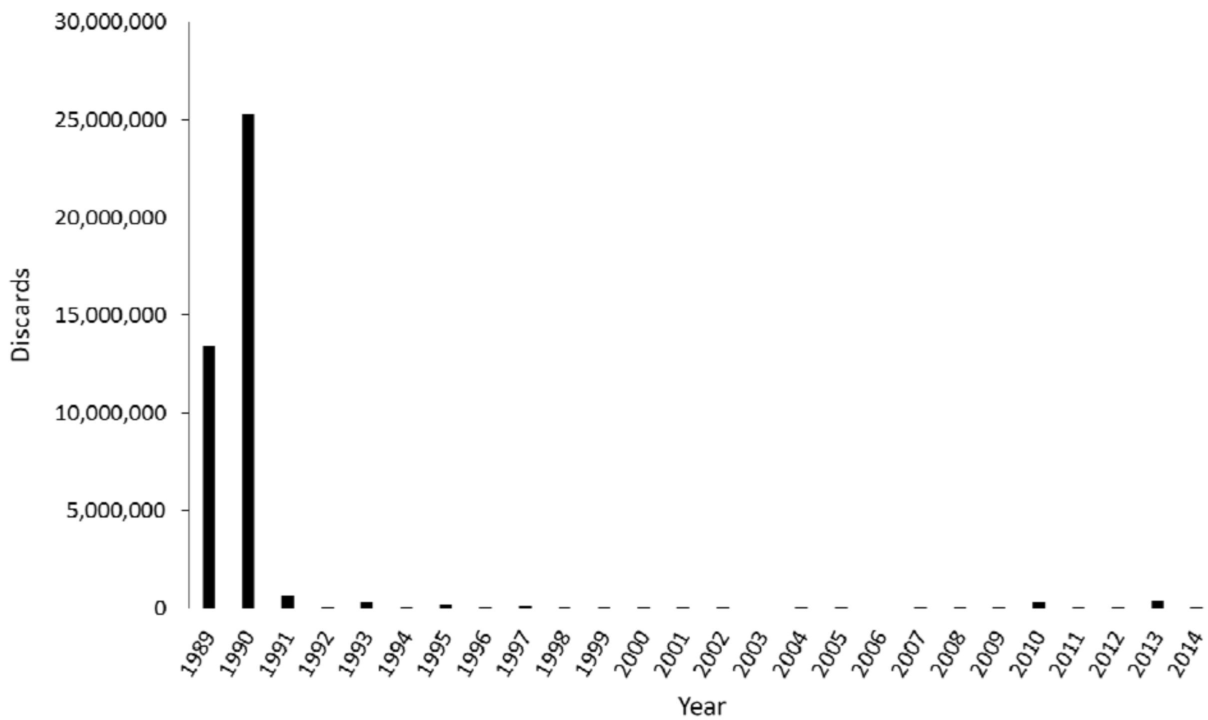


Figure 31. **Spot trawl discards (number of fish) in Mid-Atlantic fisheries.**

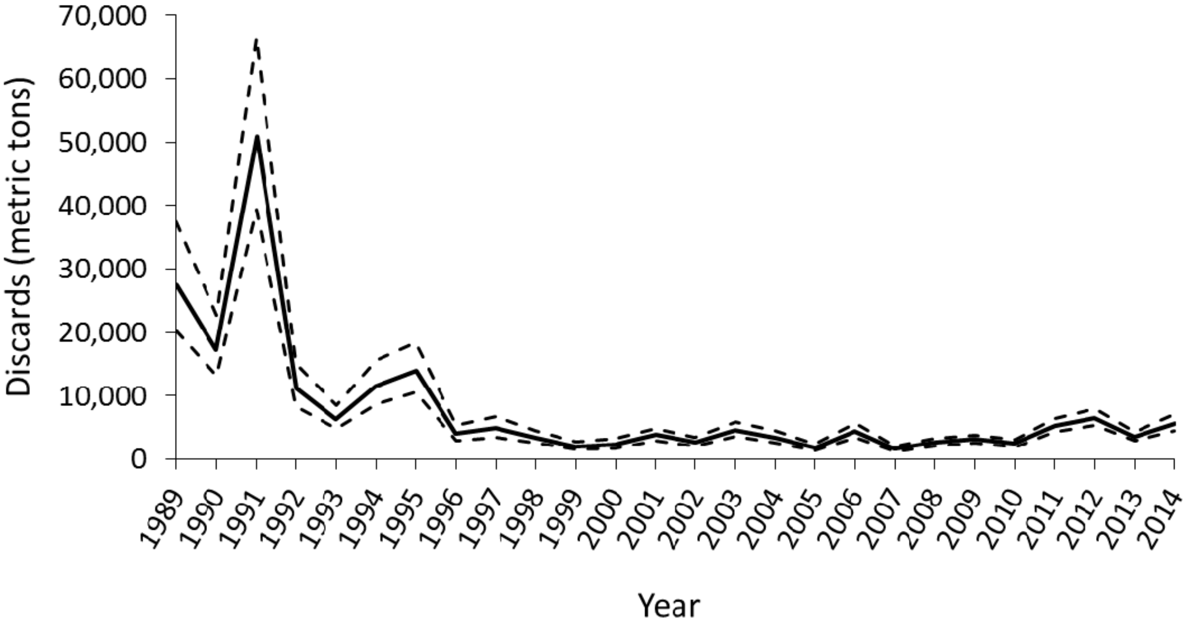


Figure 32. **Spot discard estimates (metric tons, solid line) from South Atlantic shrimp trawl fisheries with 95% confidence intervals (dashed lines).**

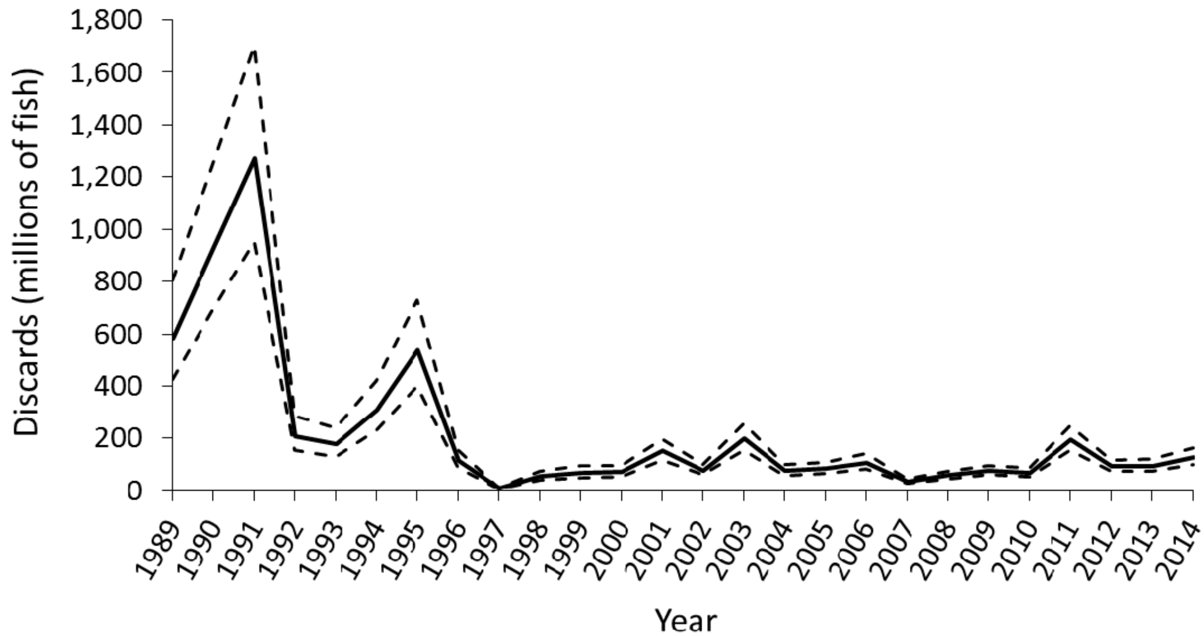


Figure 33. **Spot discard estimates (millions of fish, solid line) from South Atlantic shrimp trawl fisheries with 95% confidence intervals (dashed lines).**

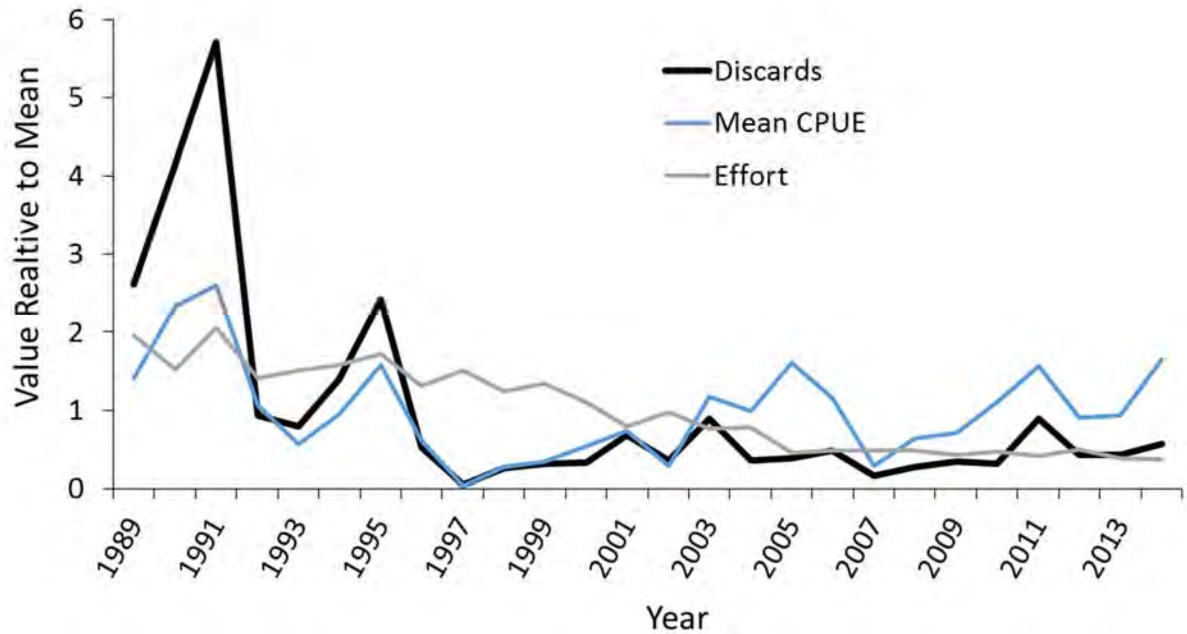


Figure 34. South Atlantic shrimp trawl effort, spot discard estimates (numbers), and mean spot CPUE (number of fish/hour fished) scaled to time series means.

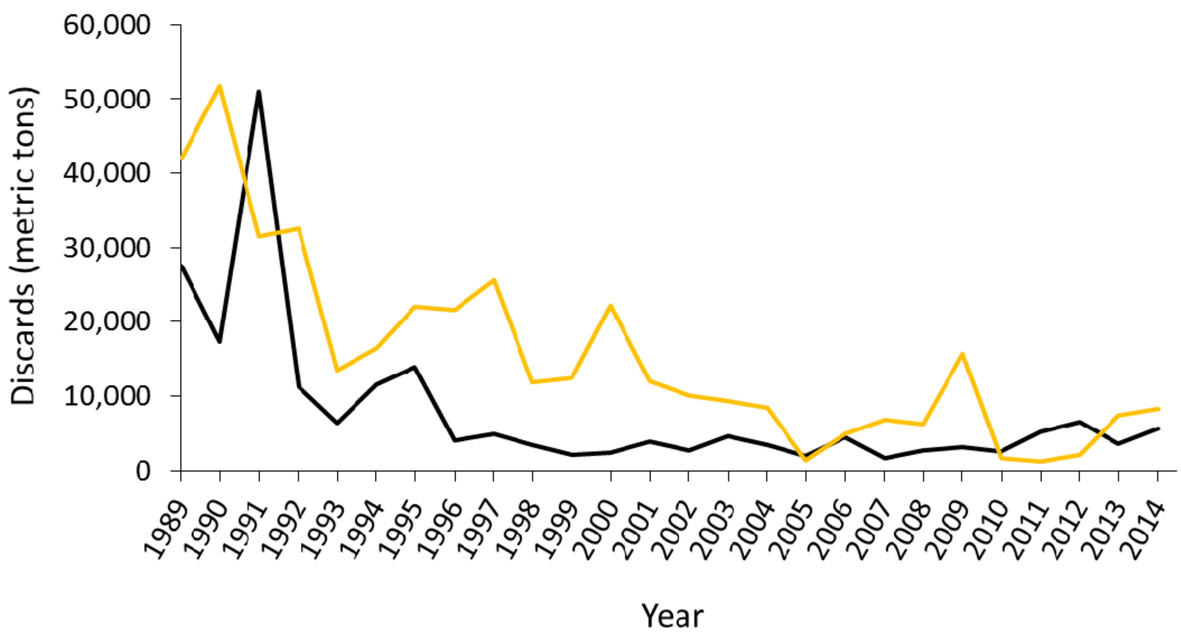


Figure 35. Comparison of spot discard estimates (black line) and spot landings by South Atlantic shrimp trawls (gold line). Landings scale is on secondary axis and values are not included due to confidentiality.

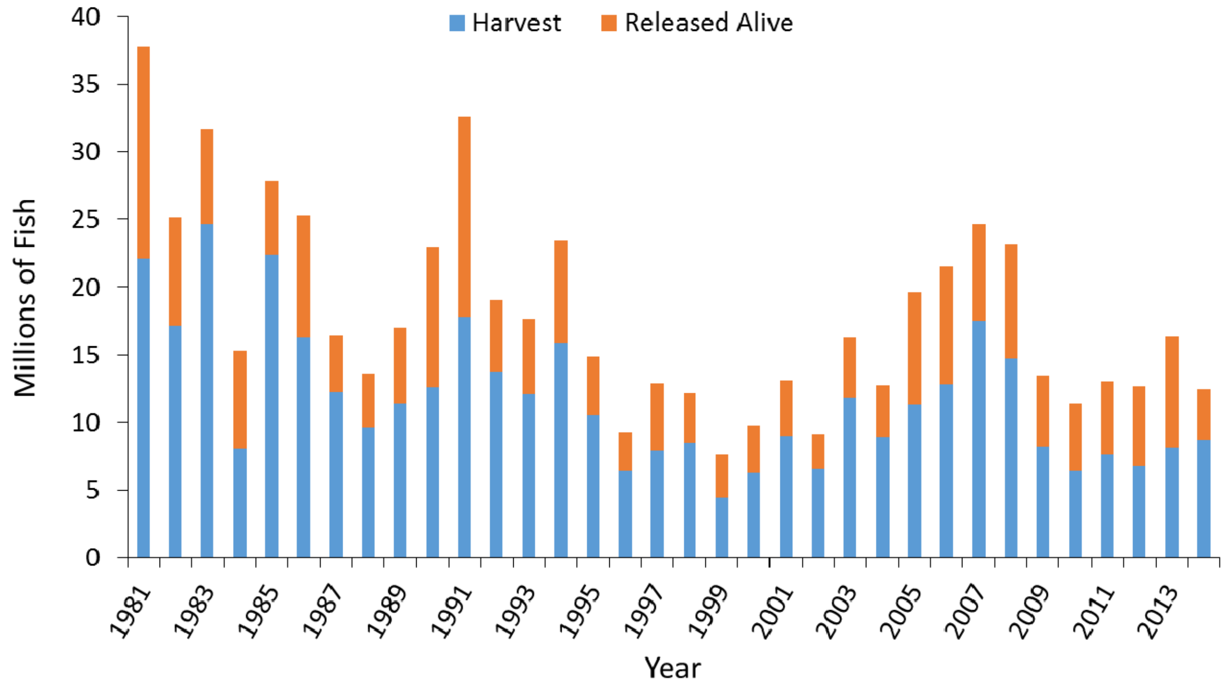


Figure 36. **MRFSS and MRIP coastwide recreational harvest and released alive estimates of spot in millions of fish.**

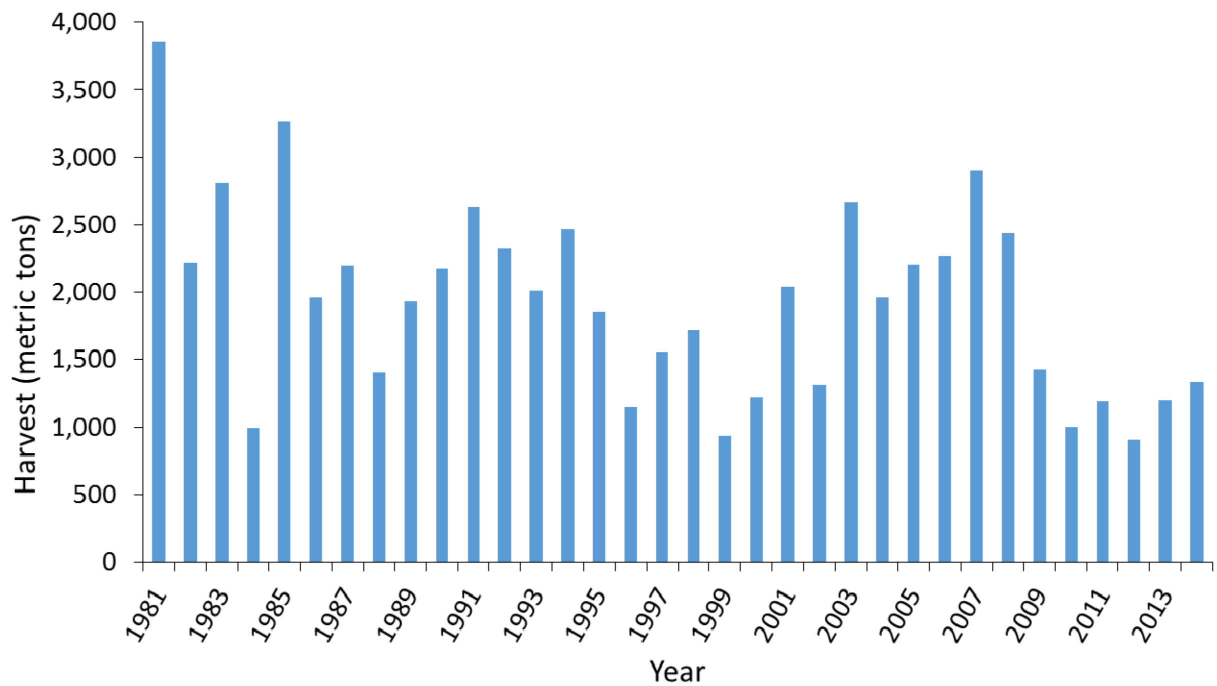


Figure 37. **MRFSS and MRIP coastiwde recreational harvest of spot (metric tons).**

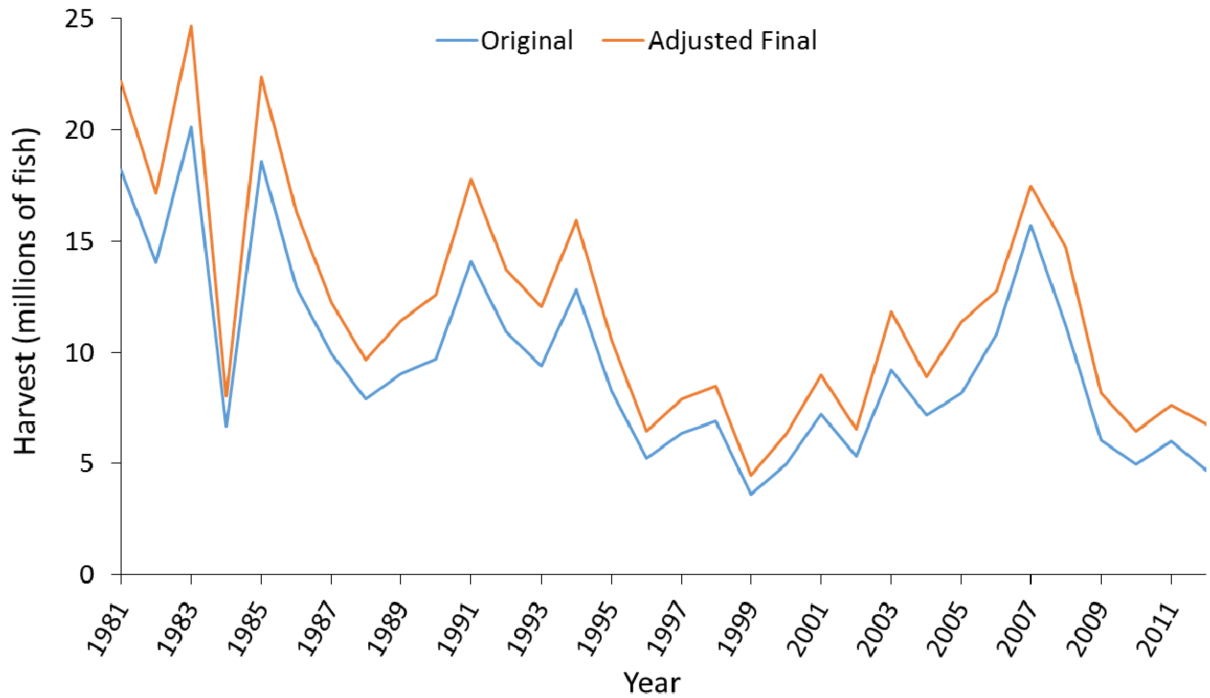


Figure 38. Comparison of MRFSS and MRIP recreational harvest estimates of spot (millions of fish) before (blue line) and after (orange line) adjustments.

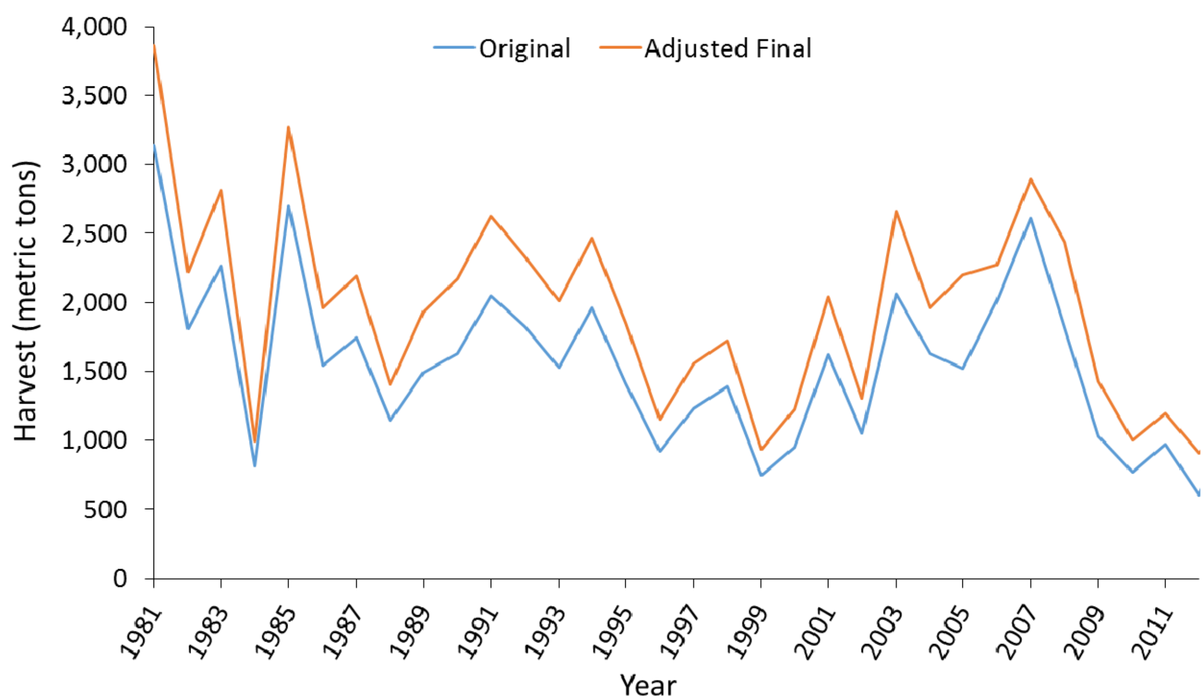


Figure 39. Comparison of MRFSS and MRIP recreational harvest estimates of spot (metric tons) before (blue line) and after (orange line) adjustments.

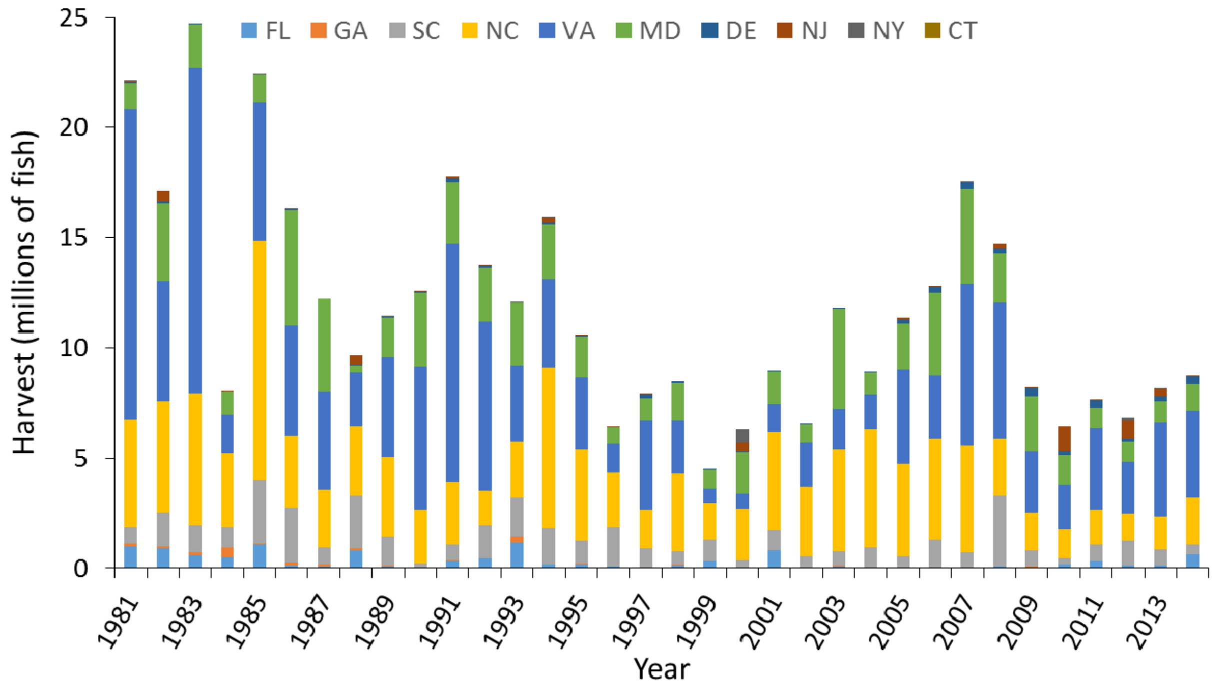


Figure 40. **MRFSS and MRIP recreational harvest estimates of spot (millions of fish) by state and year.**

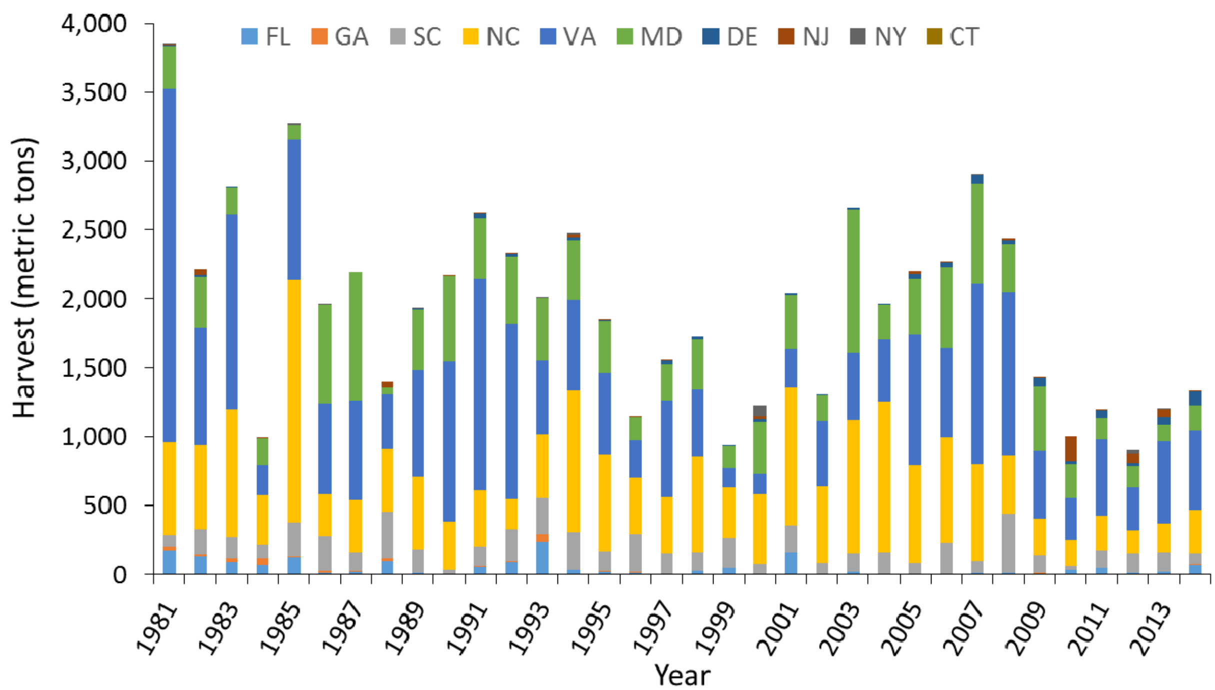


Figure 41. **MRFSS and MRIP recreational harvest estimates of spot (metric tons) by state and year.**

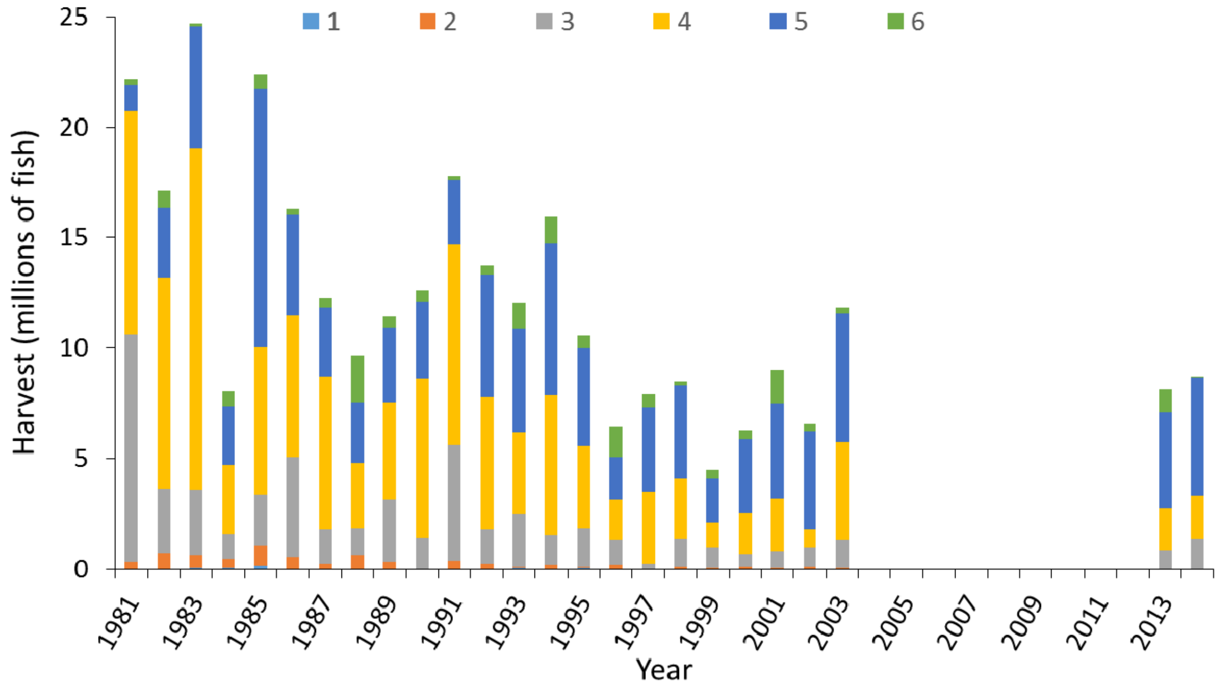


Figure 42. MRFSS and MRIP recreational harvest estimates of spot (millions of fish) by wave and year. Estimates adjusted for the change in the APAIS design (2004-2012) are not provided by wave from the provided SAS code.

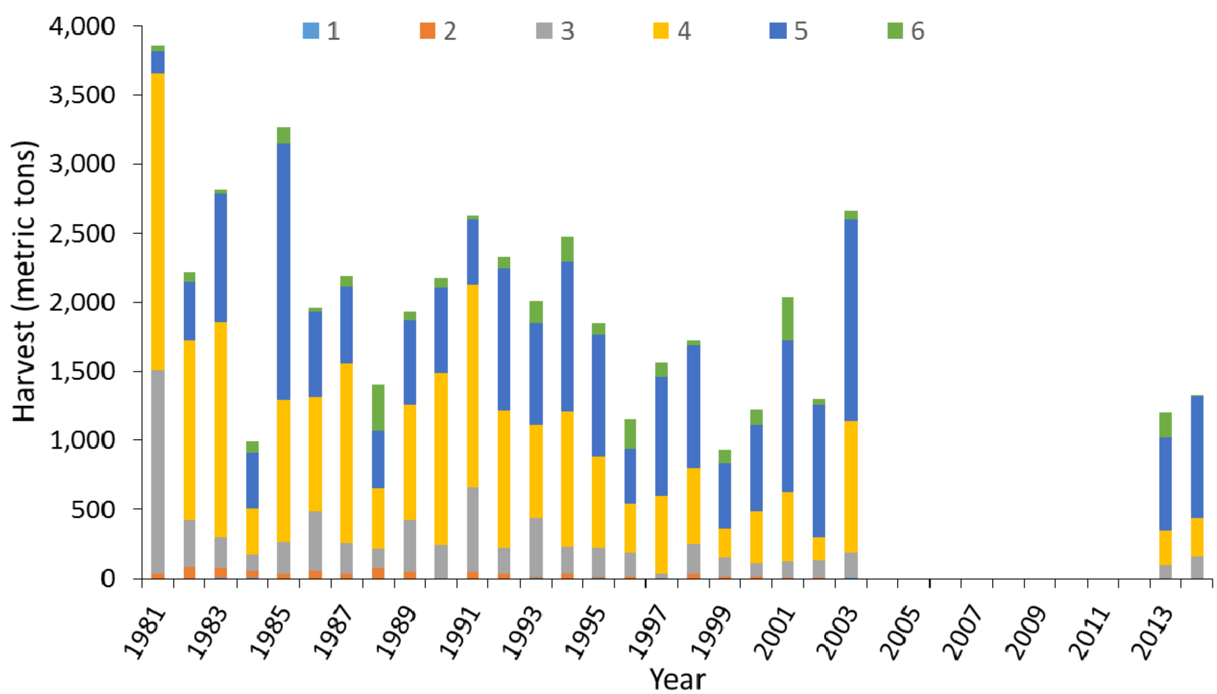


Figure 43. MRFSS and MRIP recreational harvest estimates of spot (metric tons) by wave and year. Estimates adjusted for the change in the APAIS design (2004-2012) are not provided by wave from the provided SAS code.

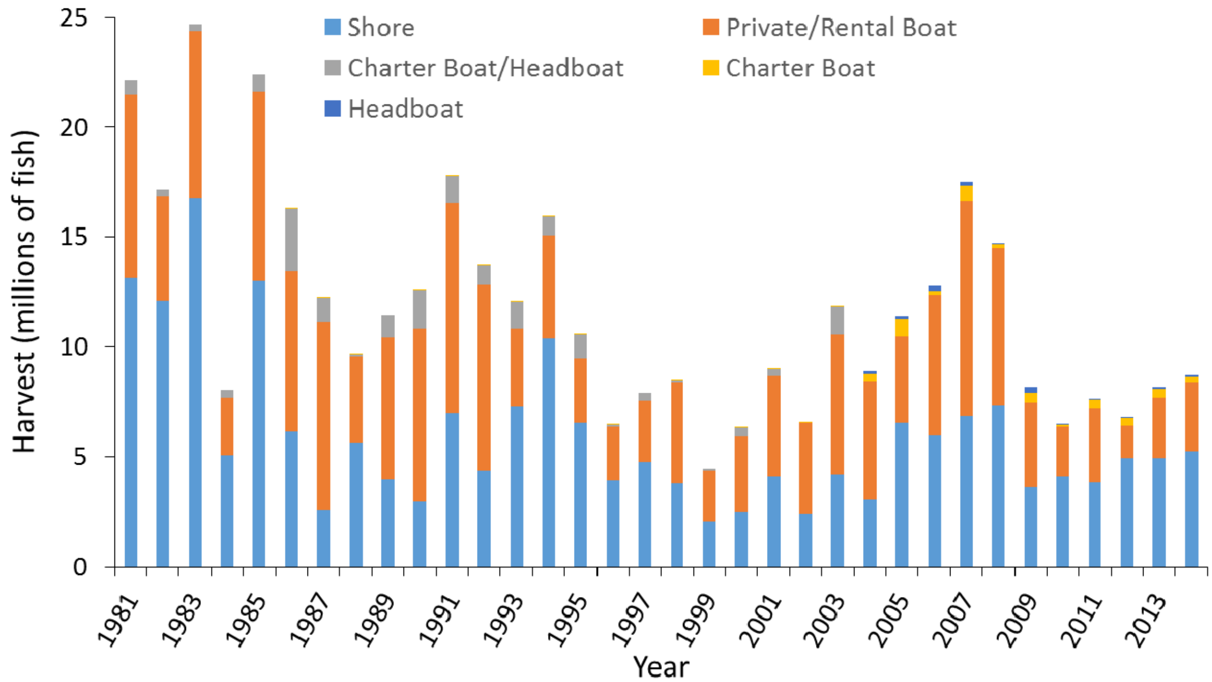


Figure 44. **MRFSS and MRIP recreational harvest estimates of spot (millions of fish) by mode and year.**

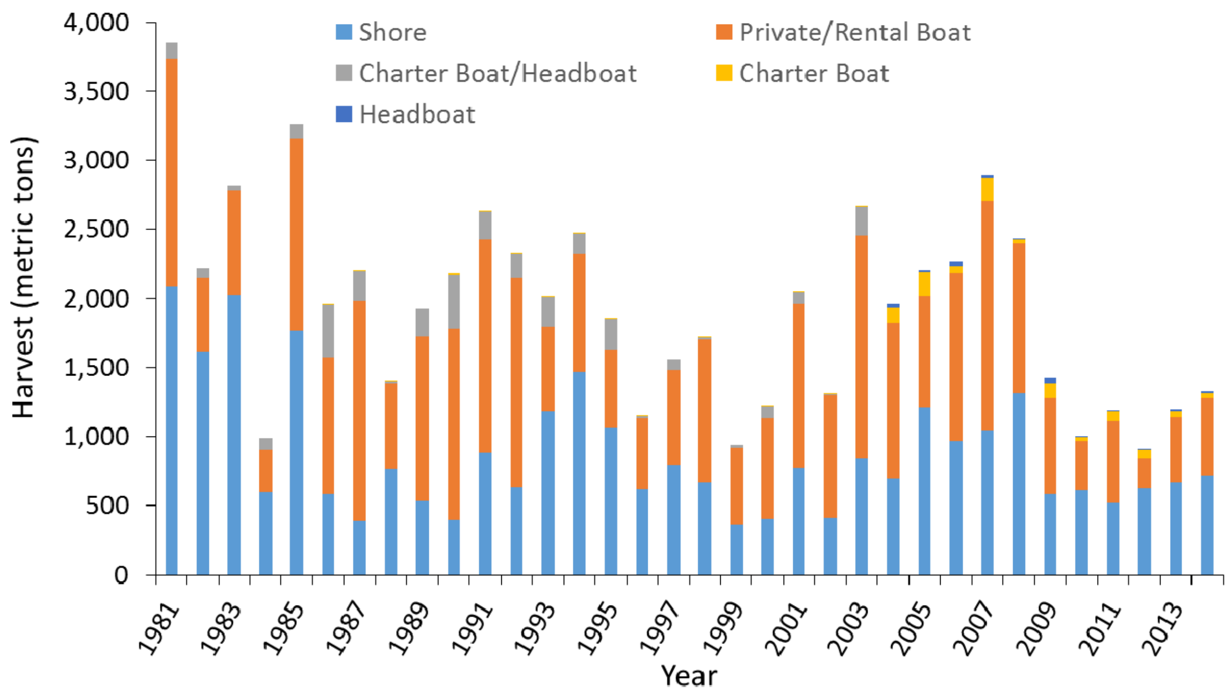


Figure 45. **MRFSS and MRIP recreational harvest estimates of spot (metric tons) by mode and year.**

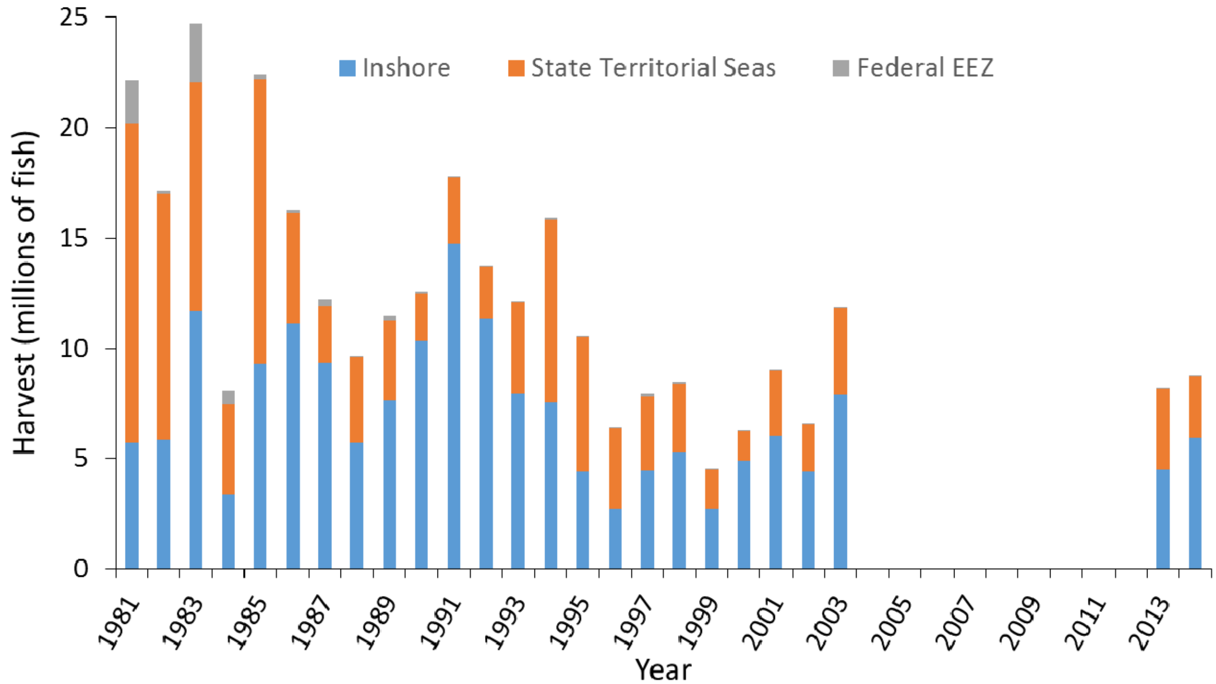


Figure 46. MRFSS and MRIP recreational harvest estimates of spot (millions of fish) by area and year. Estimates adjusted for the change in the APAIS design (2004-2012) are not provided by area from the provided SAS code.

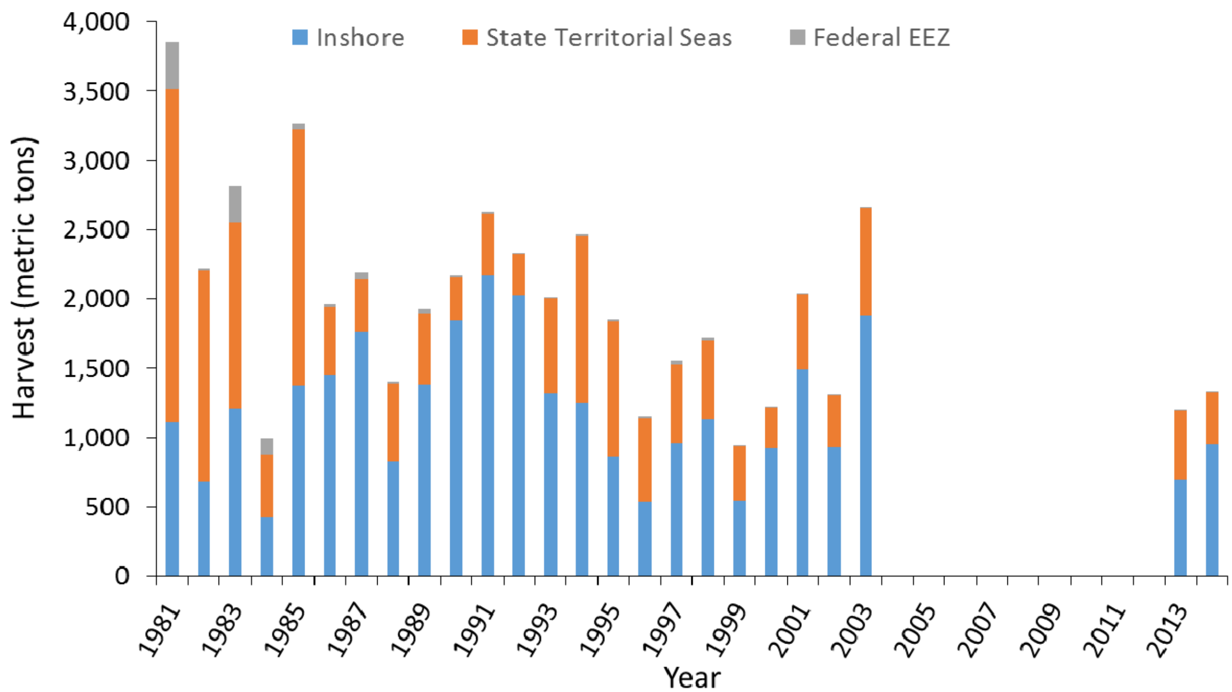


Figure 47. MRFSS and MRIP recreational harvest estimates of spot (metric tons) by area and year. Estimates adjusted for the change in the APAIS design (2004-2012) are not provided by area from the provided SAS code.

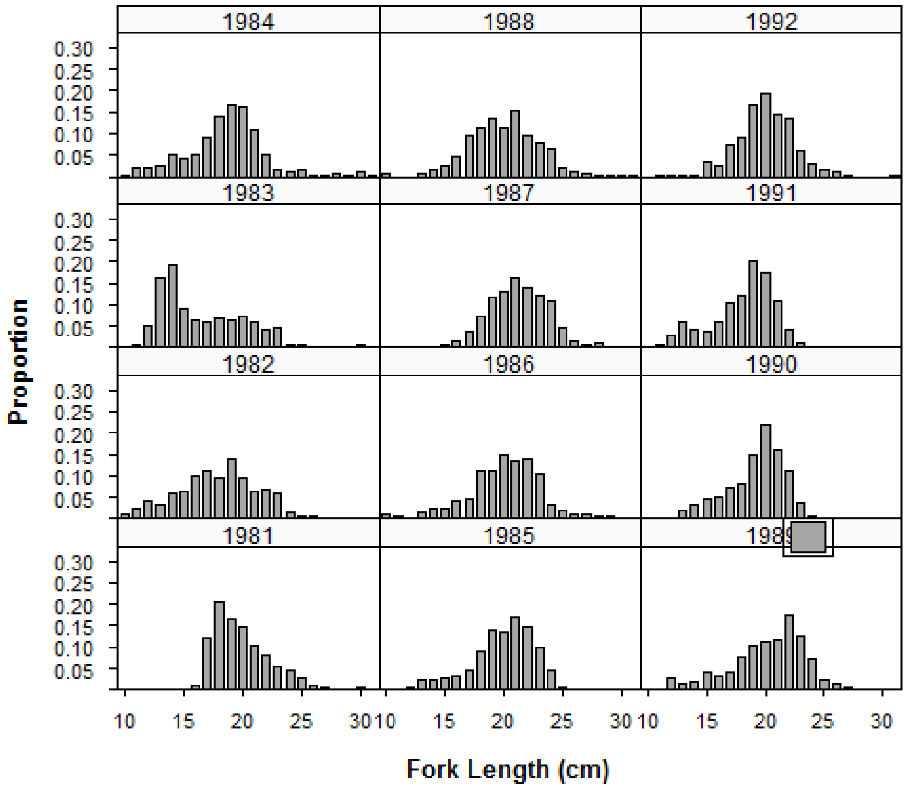


Figure 48. **MRFSS and MRIP recreational harvest length frequency estimates for spot. The x-axes have been subset to exclude lengths that did not account for more than 1% of the annual harvest in any year (<10cm and >31cm).**

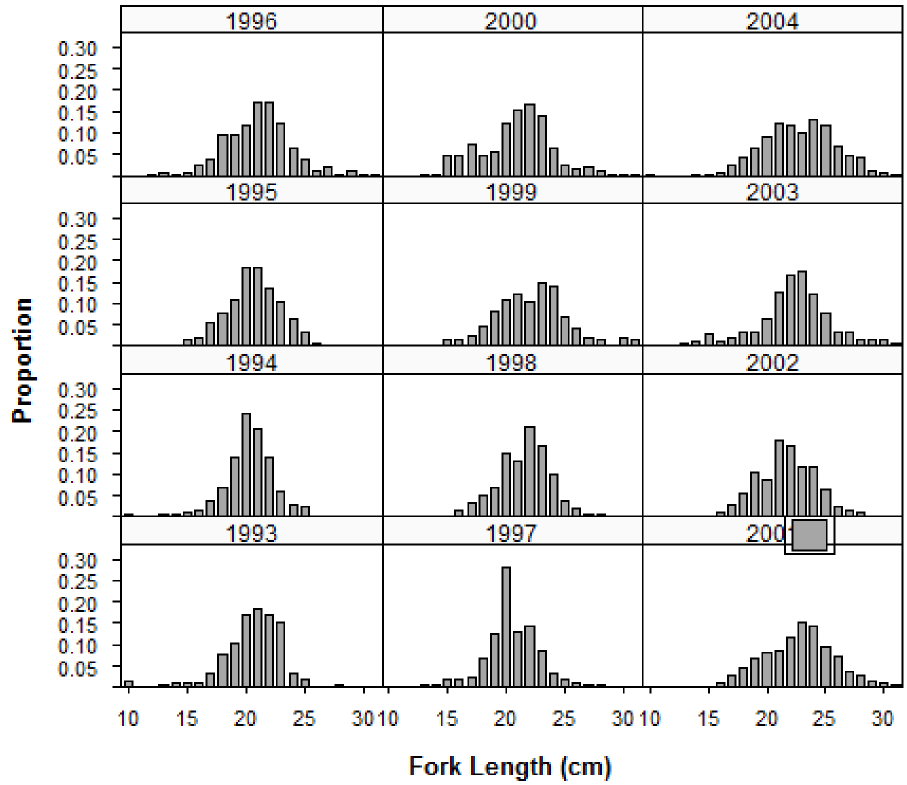


Figure 48. ***Continued.*** **MRFSS and MRIP recreational harvest length frequency estimates. The x-axes have been subset to exclude lengths that did not account for more than 1% of the annual harvest in any year (<10cm and >31cm).**

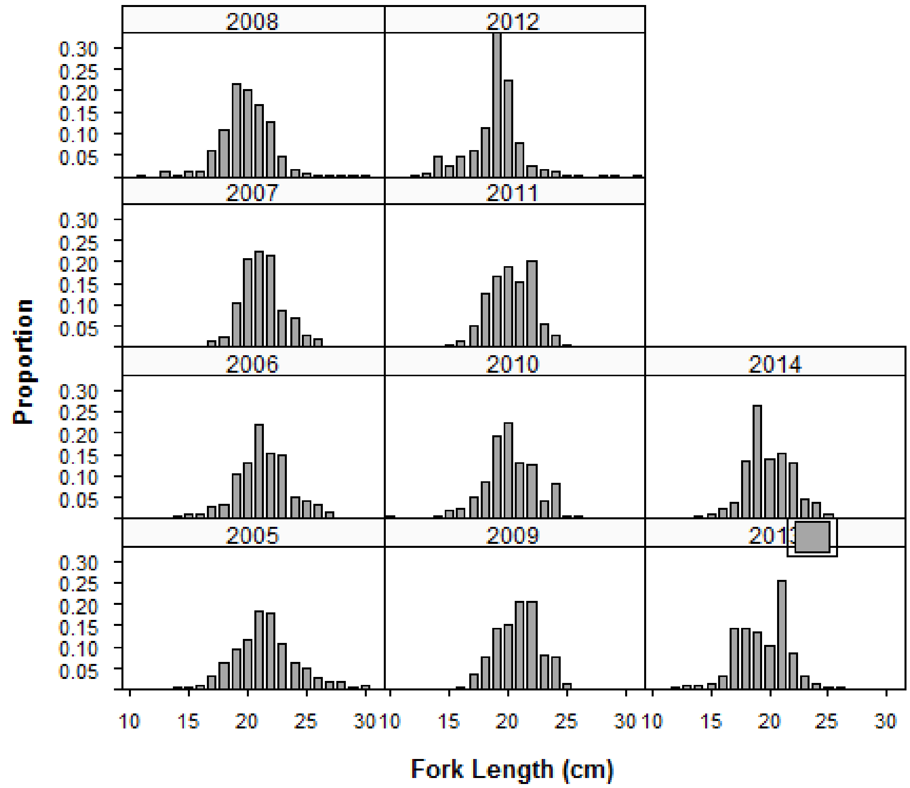


Figure 48. ***Continued.*** **MRFSS and MRIP recreational harvest length frequency estimates. The x-axes have been subset to exclude lengths that did not account for more than 1% of the annual harvest in any year (<10cm and >31cm).**

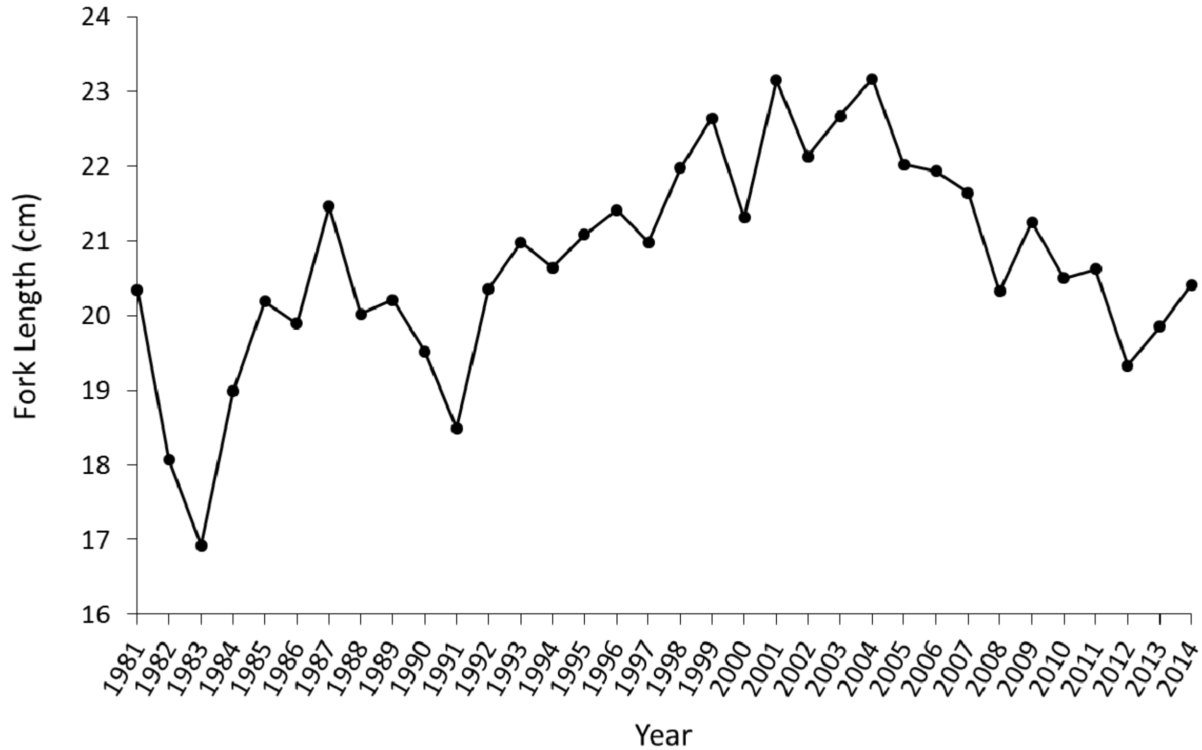


Figure 49. **Annual mean fork length (cm) of spot harvested by recreational anglers on the Atlantic coast.**

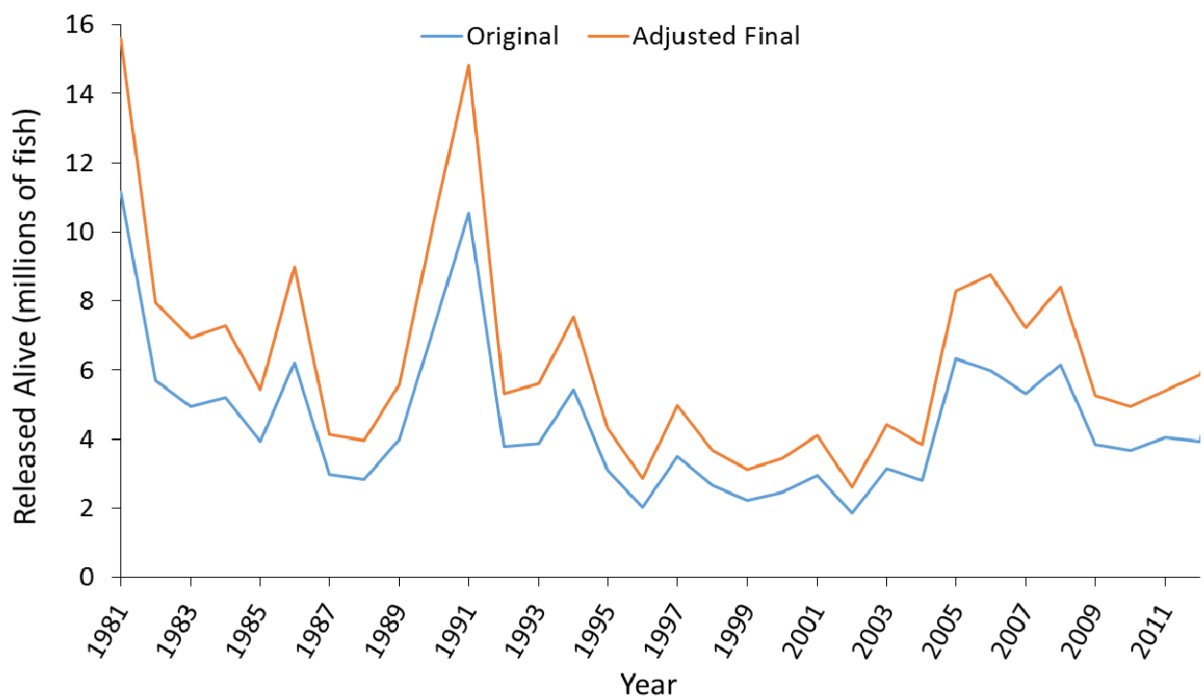


Figure 50. **Comparison of MRFSS and MRIP recreational released alive estimates of spot (millions of fish) before (blue line) and after (orange line) adjustments.**

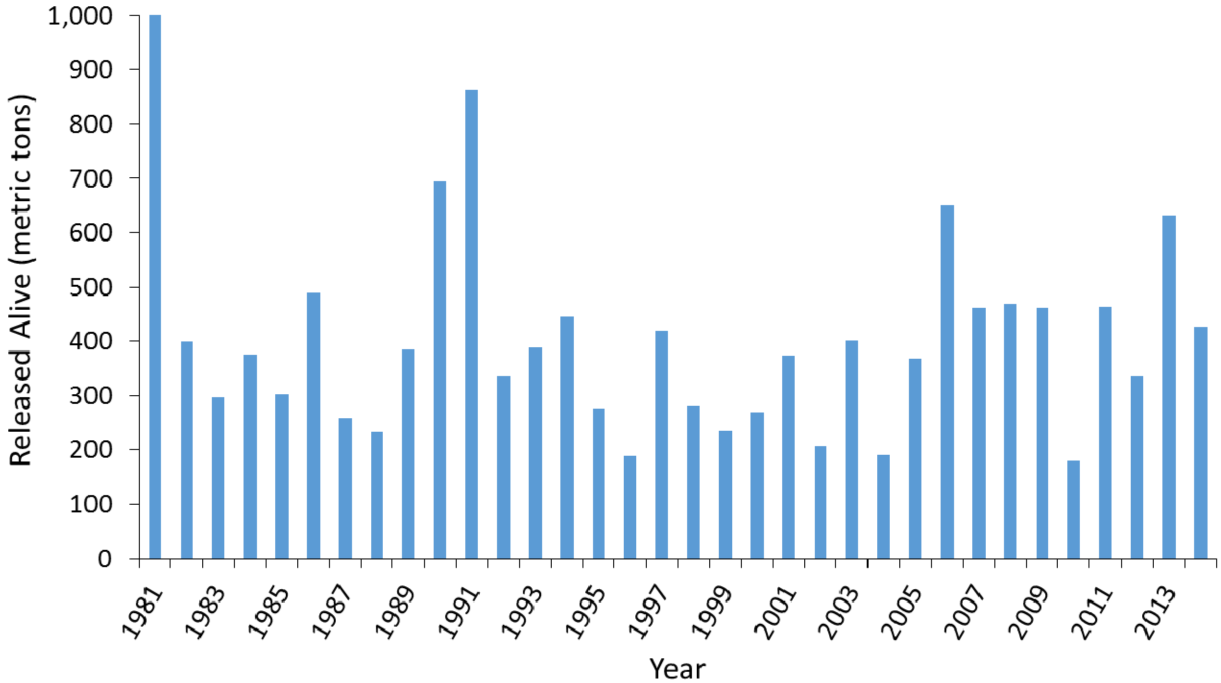


Figure 51. MRFSS and MRIP coastwide recreational live releases of spot (metric tons).

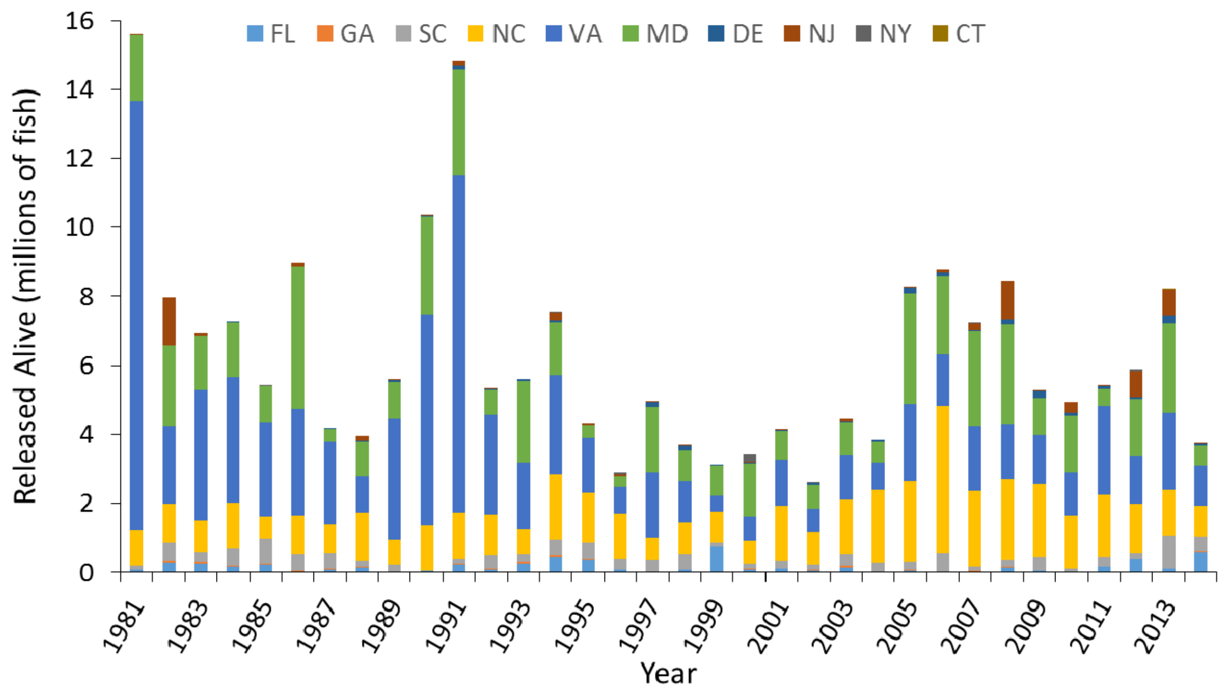


Figure 52. MRFSS and MRIP recreational released alive estimates of spot (millions of fish) by state and year.

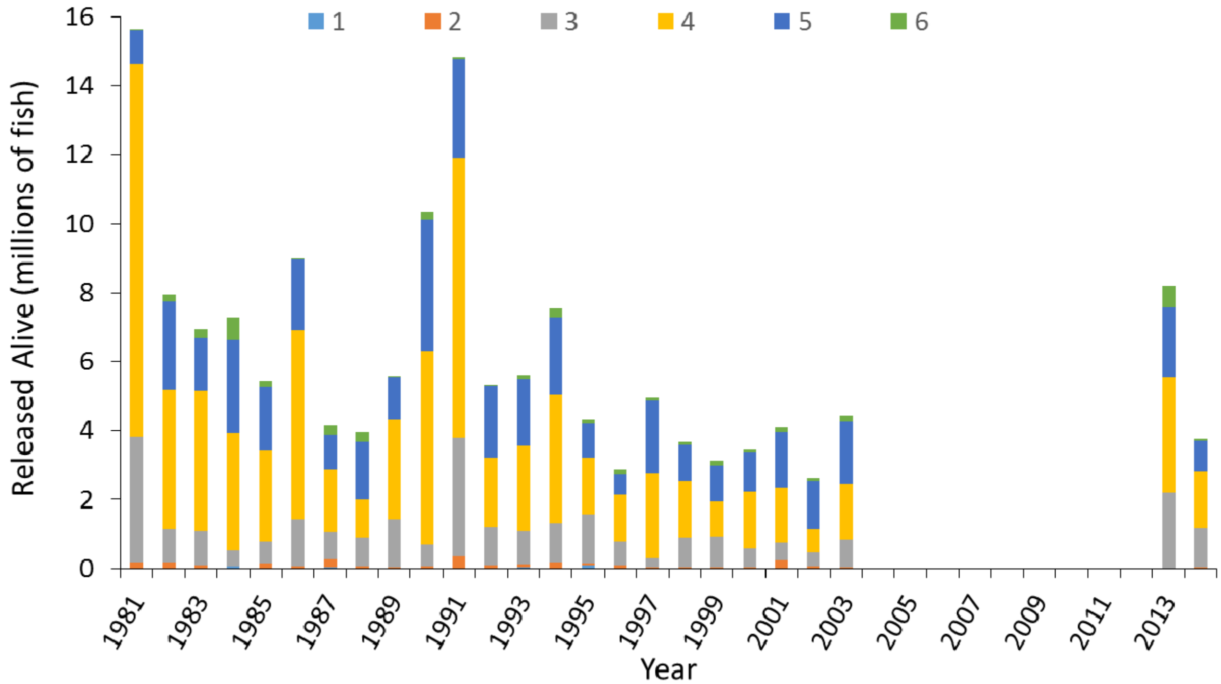


Figure 53. MRFSS and MRIP recreational released alive estimates of spot (millions of fish) by wave and year. Estimates adjusted for the change in the APAIS design (2004-2012) are not provided by wave from the provided SAS code.

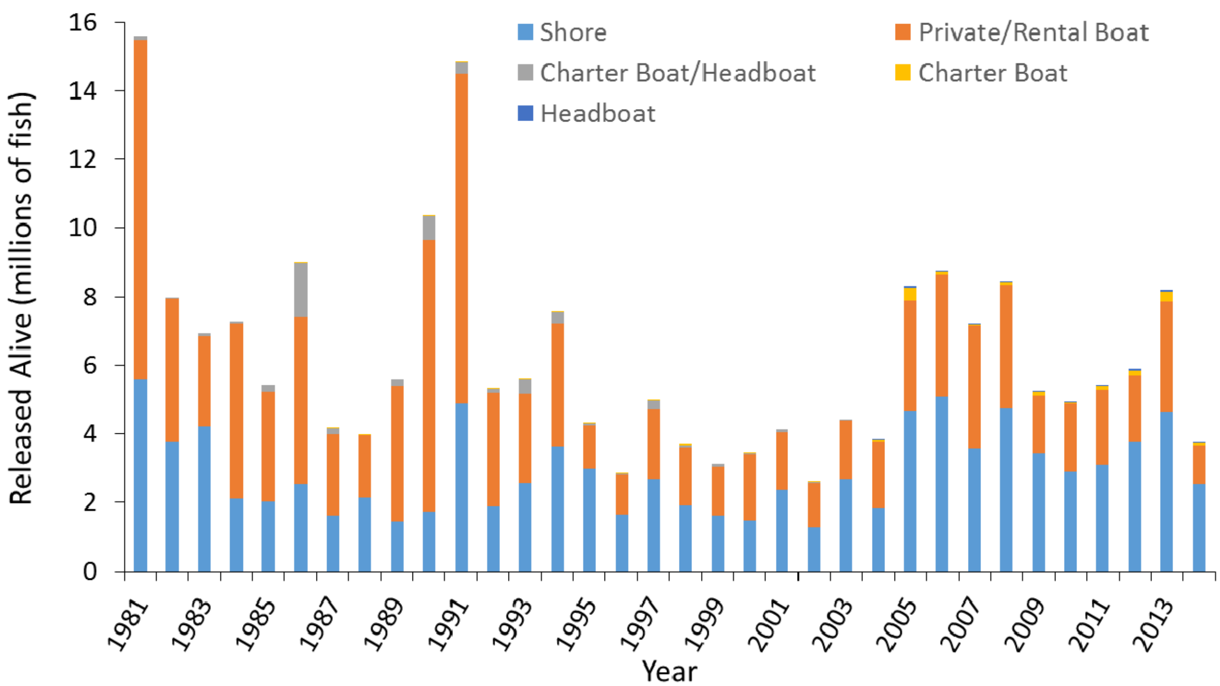


Figure 54. MRFSS and MRIP recreational released alive estimates of spot (millions of fish) by mode and year.

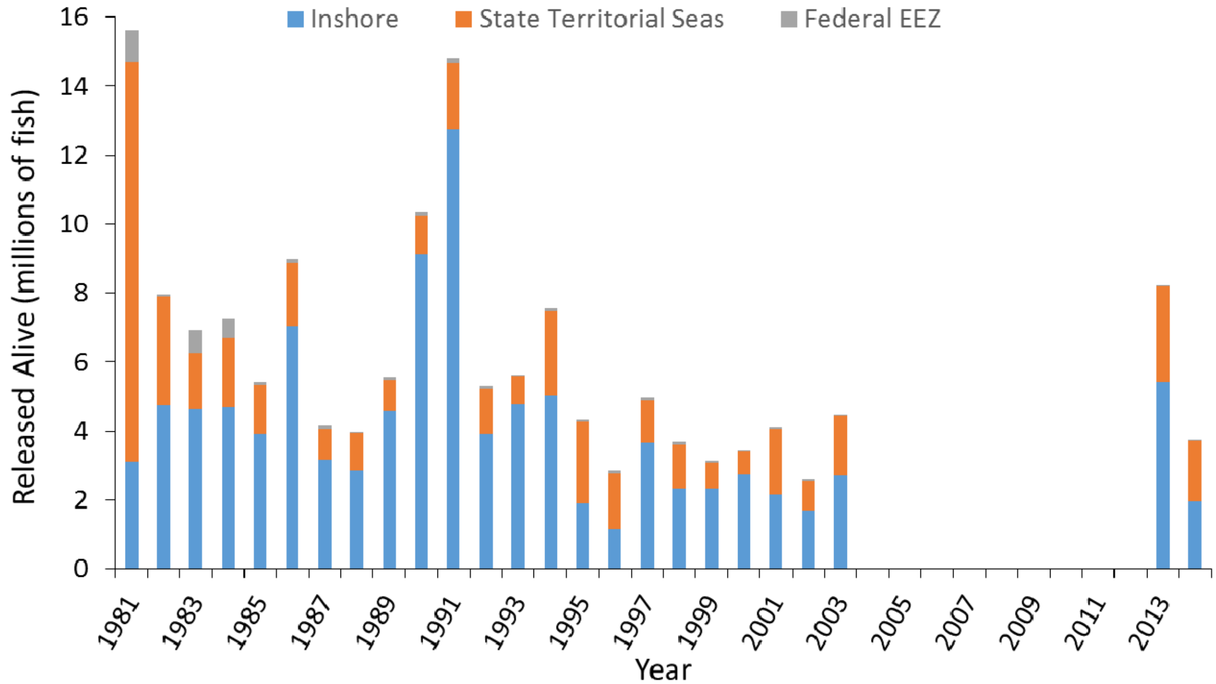


Figure 55. **MRFSS and MRIP recreational released alive estimates of spot (millions of fish) by area and year. Estimates adjusted for the change in the APAIS design (2004-2012) are not provided by area from the provided SAS code.**

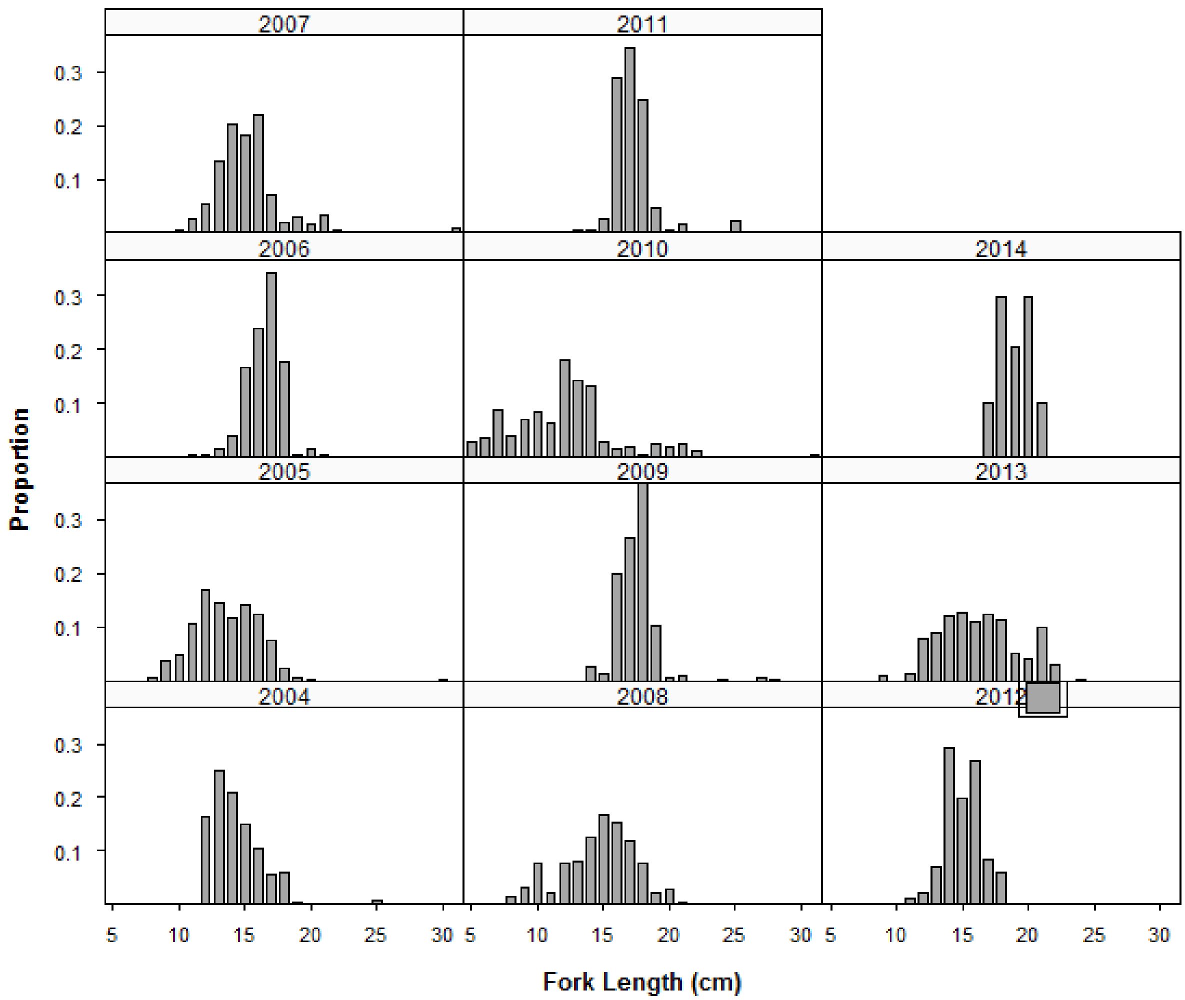


Figure 56. **Annual size compositions of spot caught and released on headboats estimated from MRIP type 9 sampling data.**

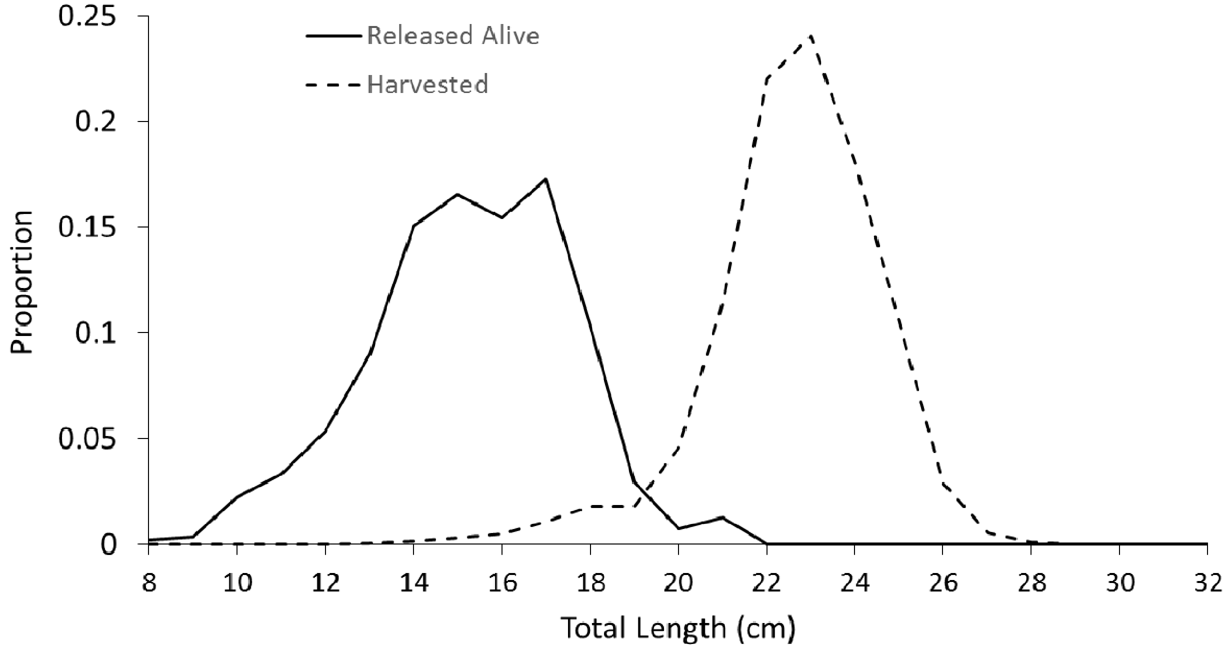


Figure 57. **Aggregate length frequency of spot sampled by the MD DNR Headboat Creel Survey during 1997-2000.**

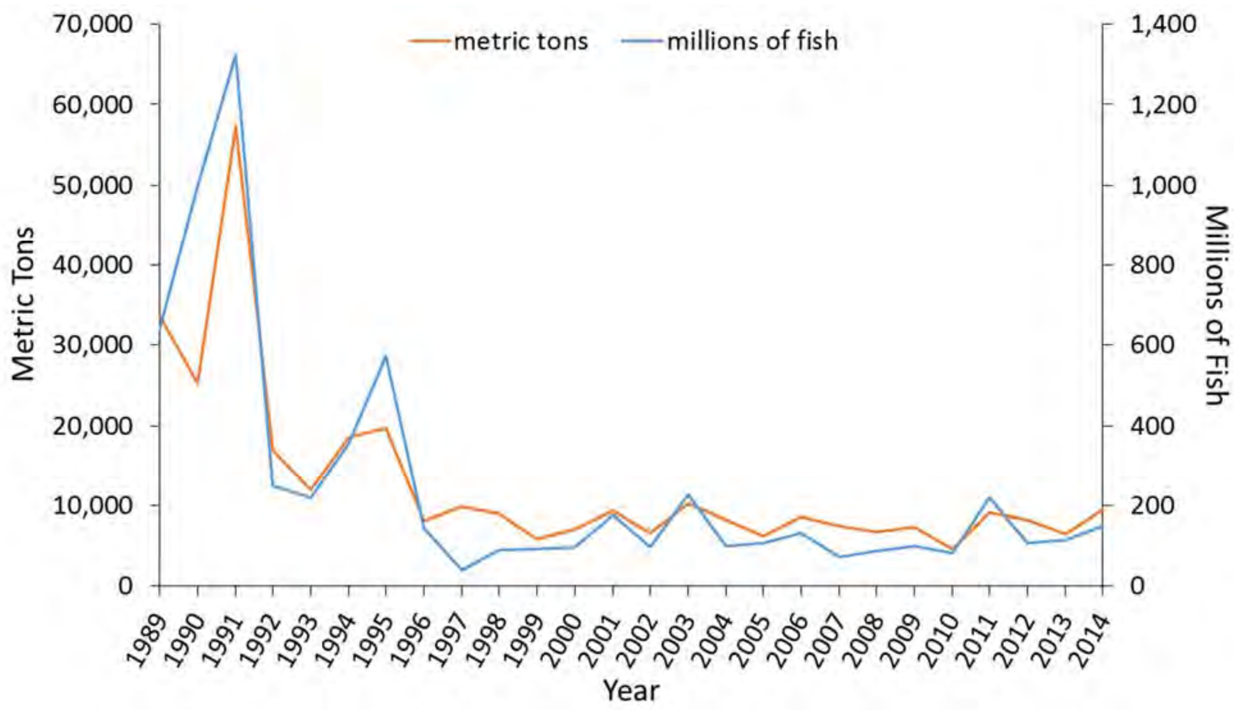


Figure 58. **Coastwide removals of spot combined across fisheries in metric tons (orange line) and millions of fish (blue line). 1989 is the first year removal data from all fisheries are available.**

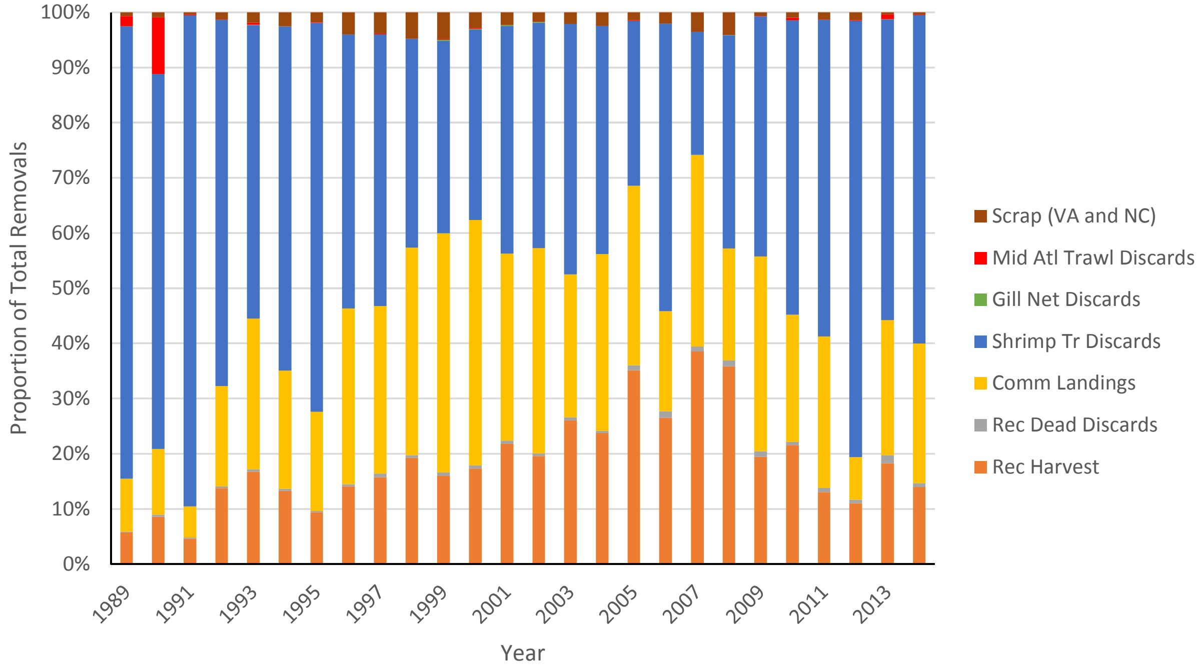


Figure 59. **Annual percentage of total spot removals by fishery source on the Atlantic coast.**

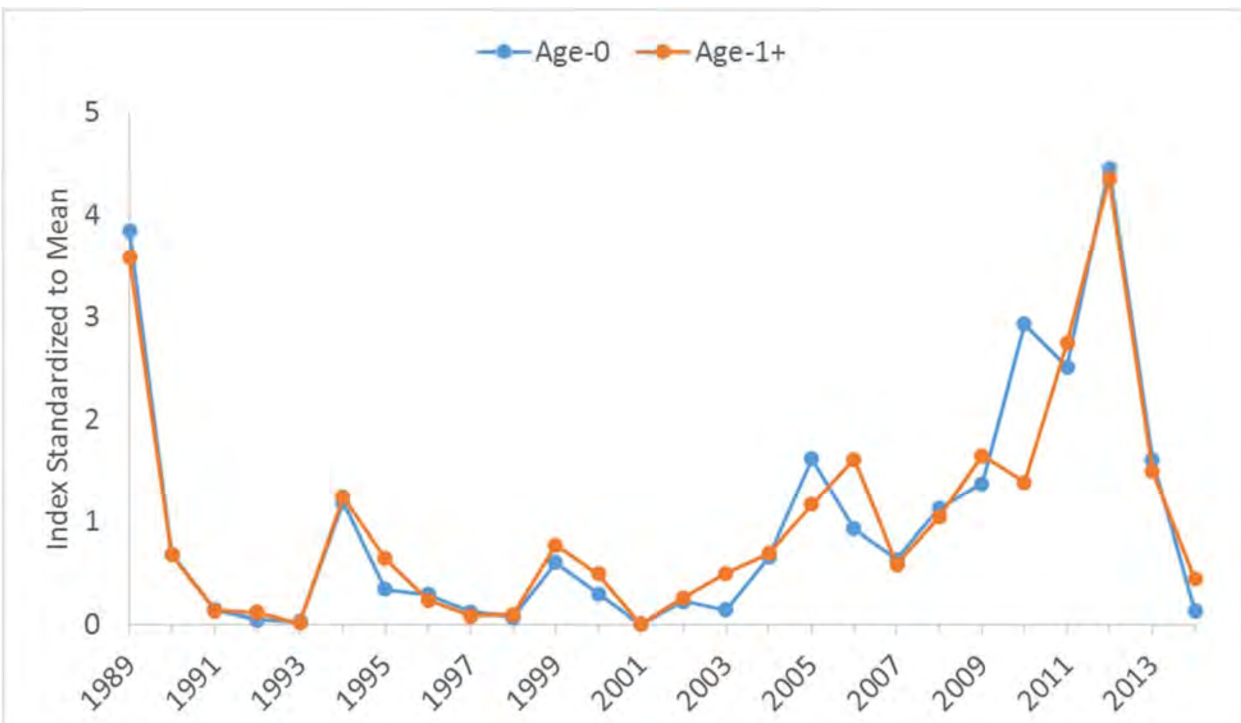


Figure 60. **Age-0 and Age-1+ relative abundance indices developed from the fall months and offshore strata of the NMFS Trawl Survey. Indices were developed in numbers per tow and then standardized to their mean.**

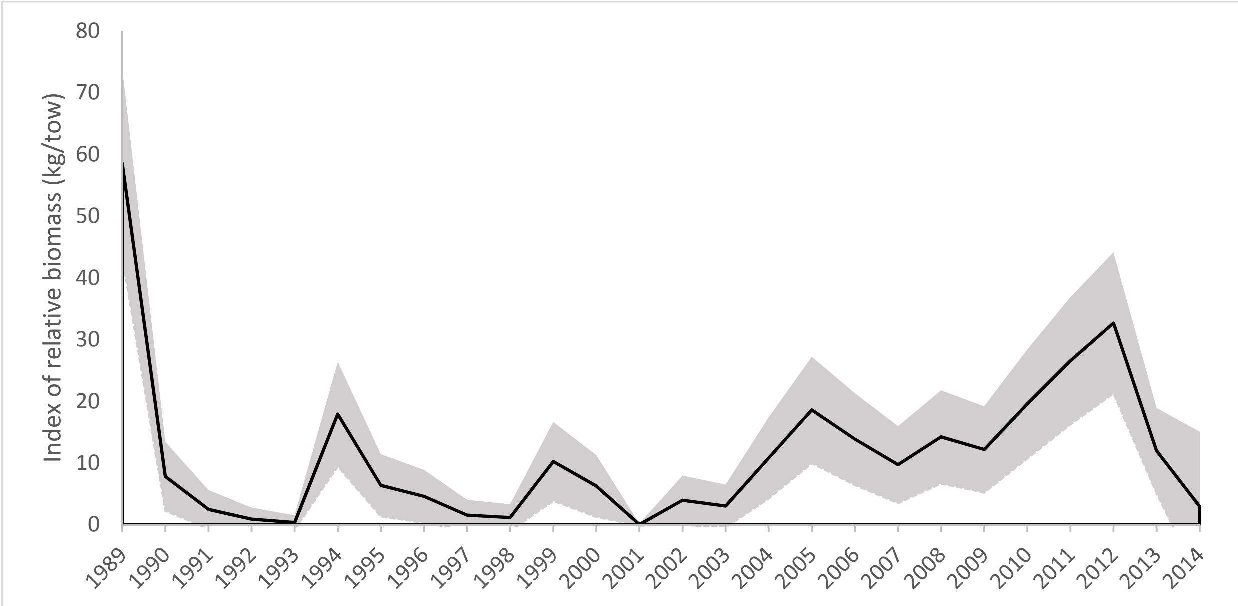


Figure 61. **Index of relative biomass developed from the fall months (September – November) and offshore strata of the NMFS Trawl Survey for 1989-2014 with 95% confidence intervals.**

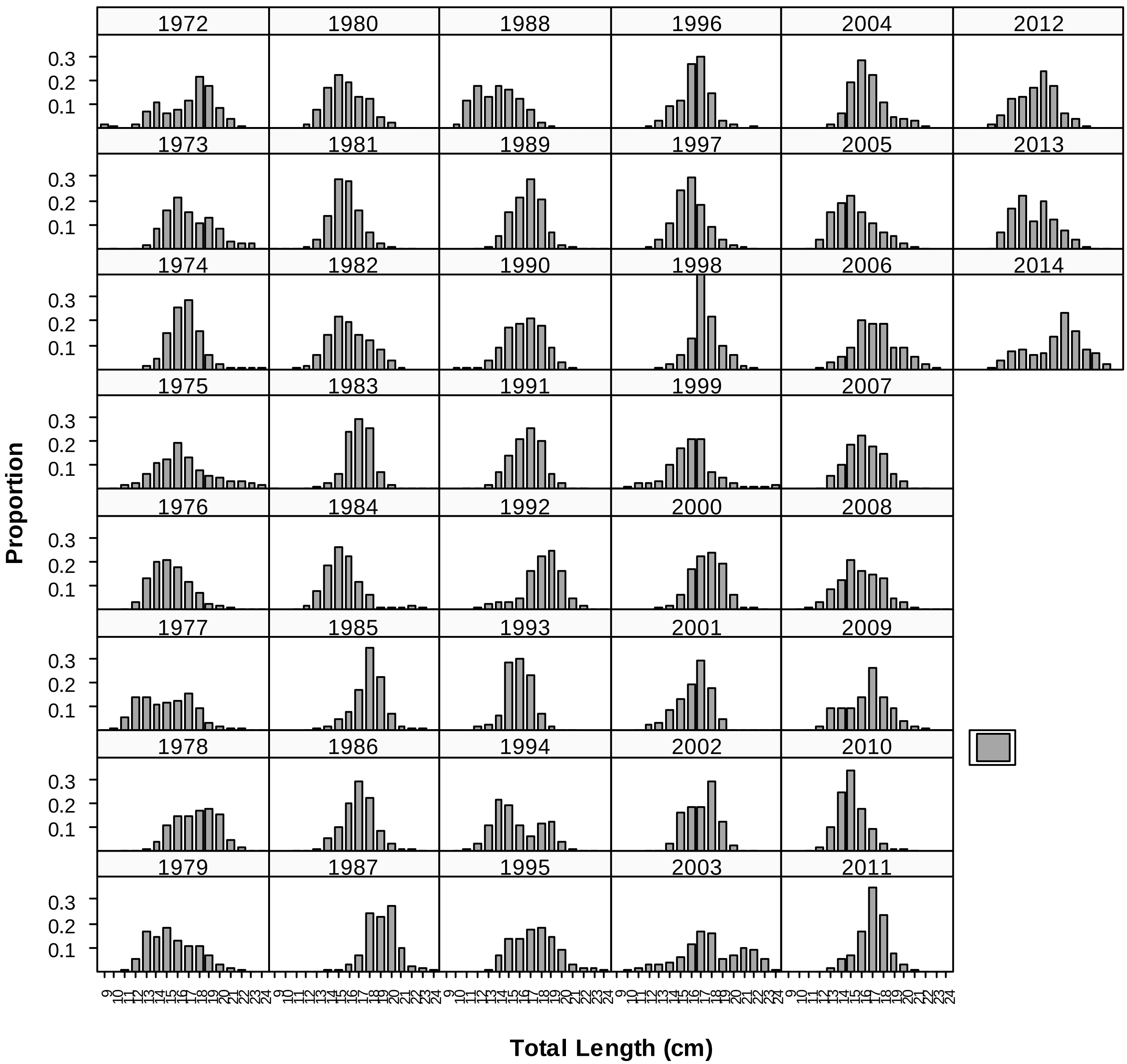


Figure 62. **Annual length frequency of spot caught in the NMFS Trawl Survey from 1972-2014.**

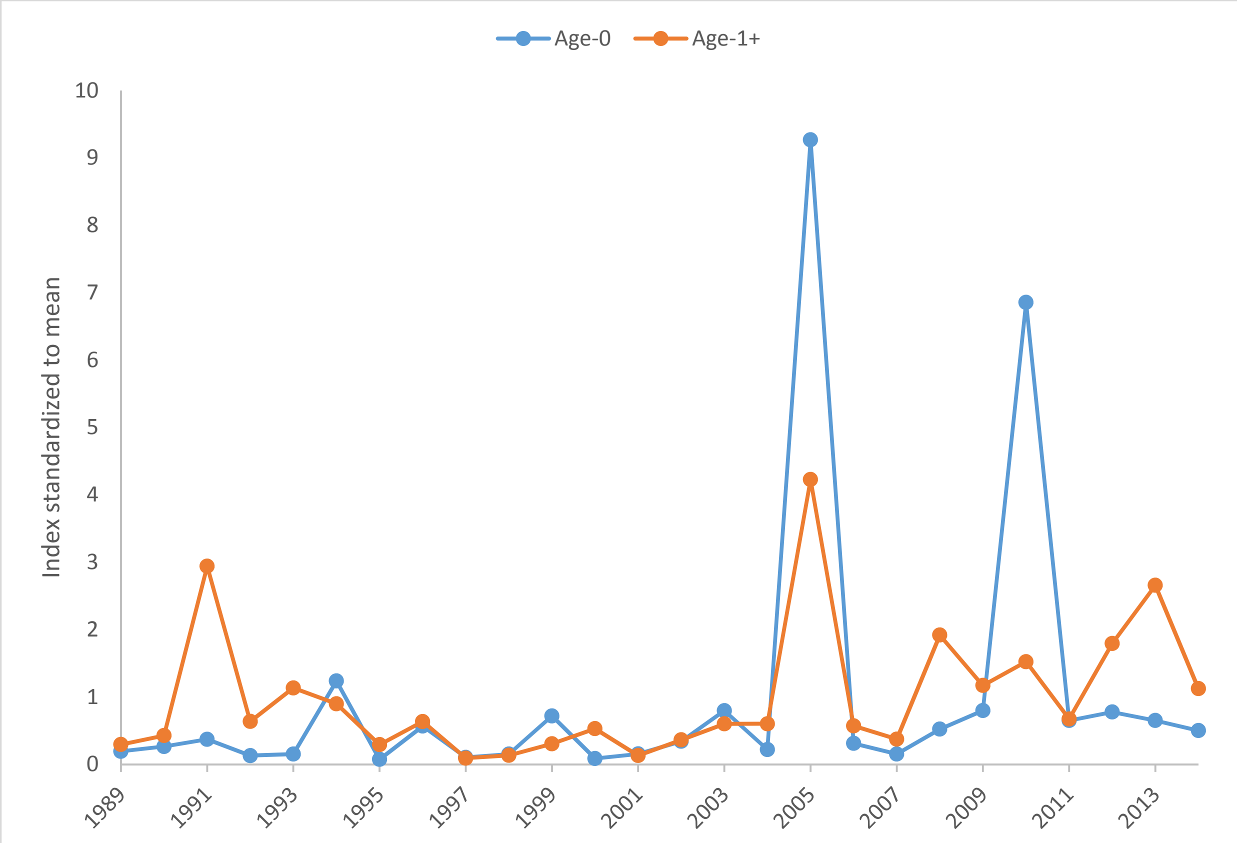


Figure 63. **Age-0 and Age-1+ relative abundance indices developed from the fall months of the SEAMAP Trawl Survey. Indices were developed in numbers per tow and then standardized to their mean.**

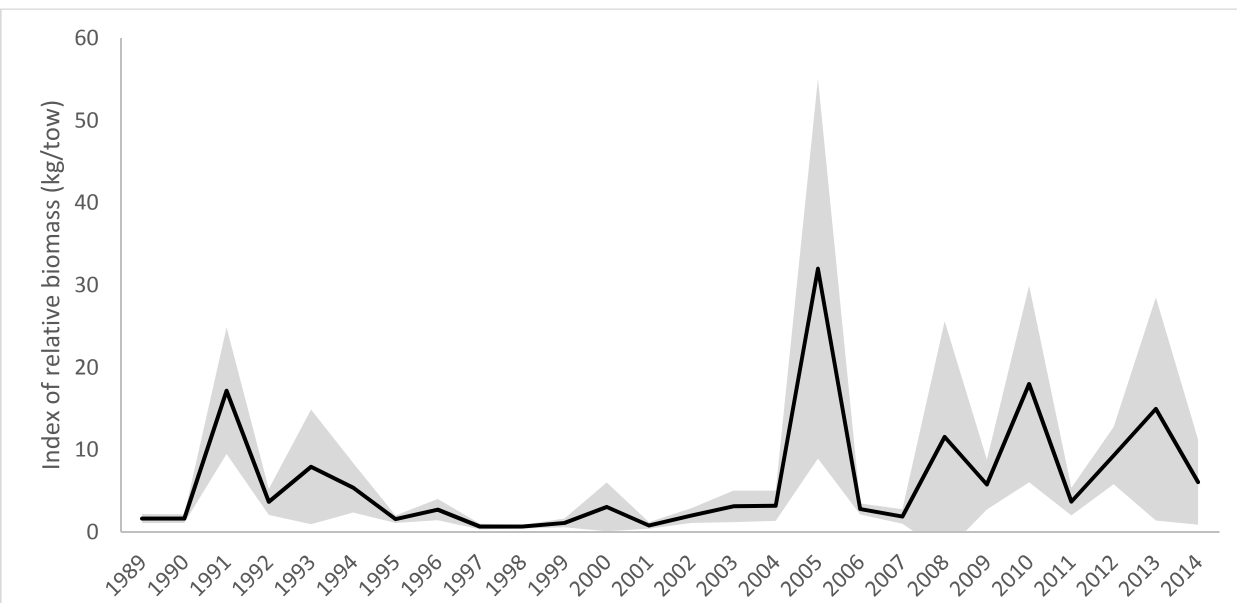


Figure 64. **Index of relative biomass of spot developed from the fall (September-November) months of the SEAMAP Trawl Survey (1989-2014).**

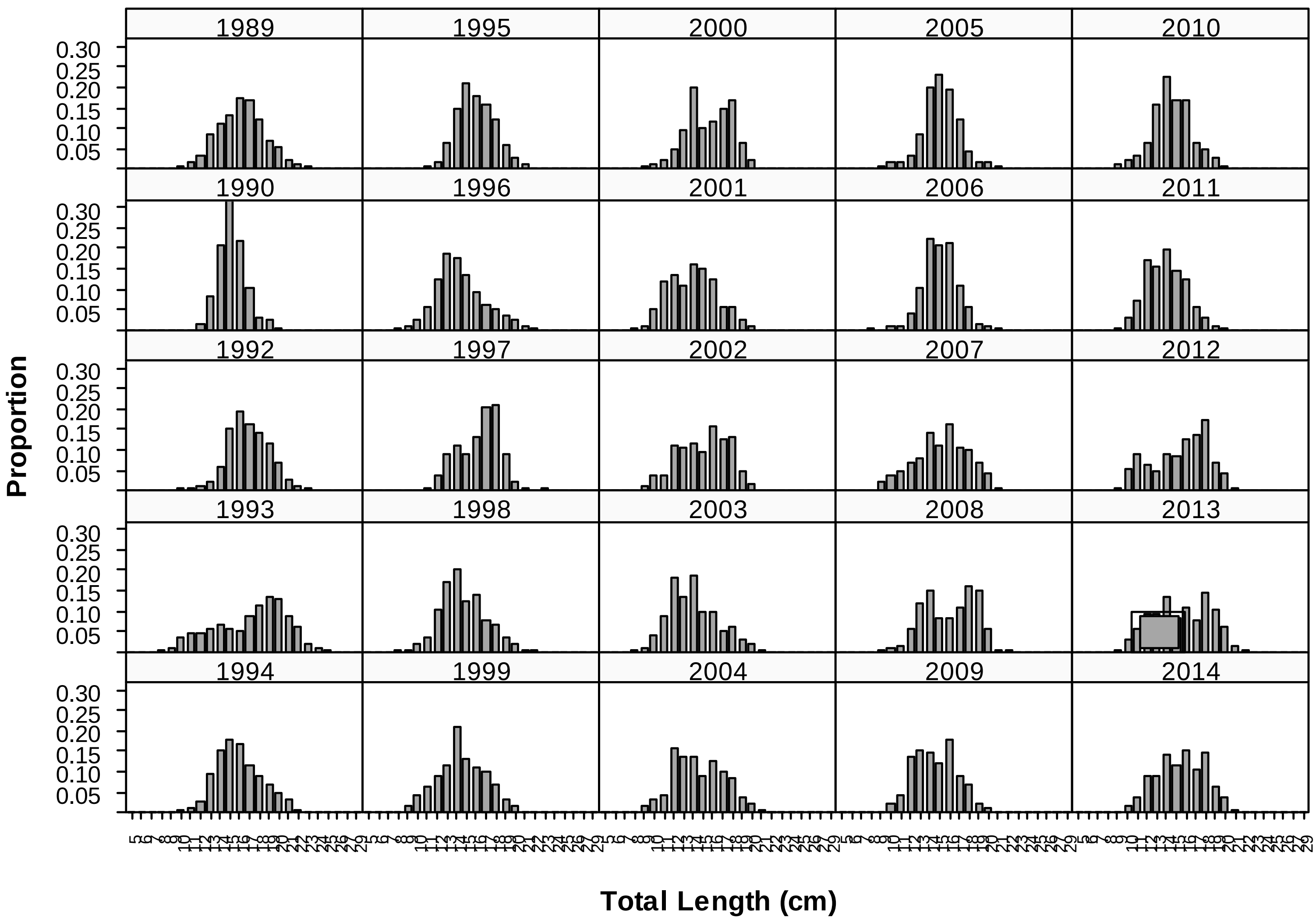


Figure 65. **Annual length frequency of spot caught in the SEAMAP Trawl Survey from 1989-2014. Data from 1991 were not available.**

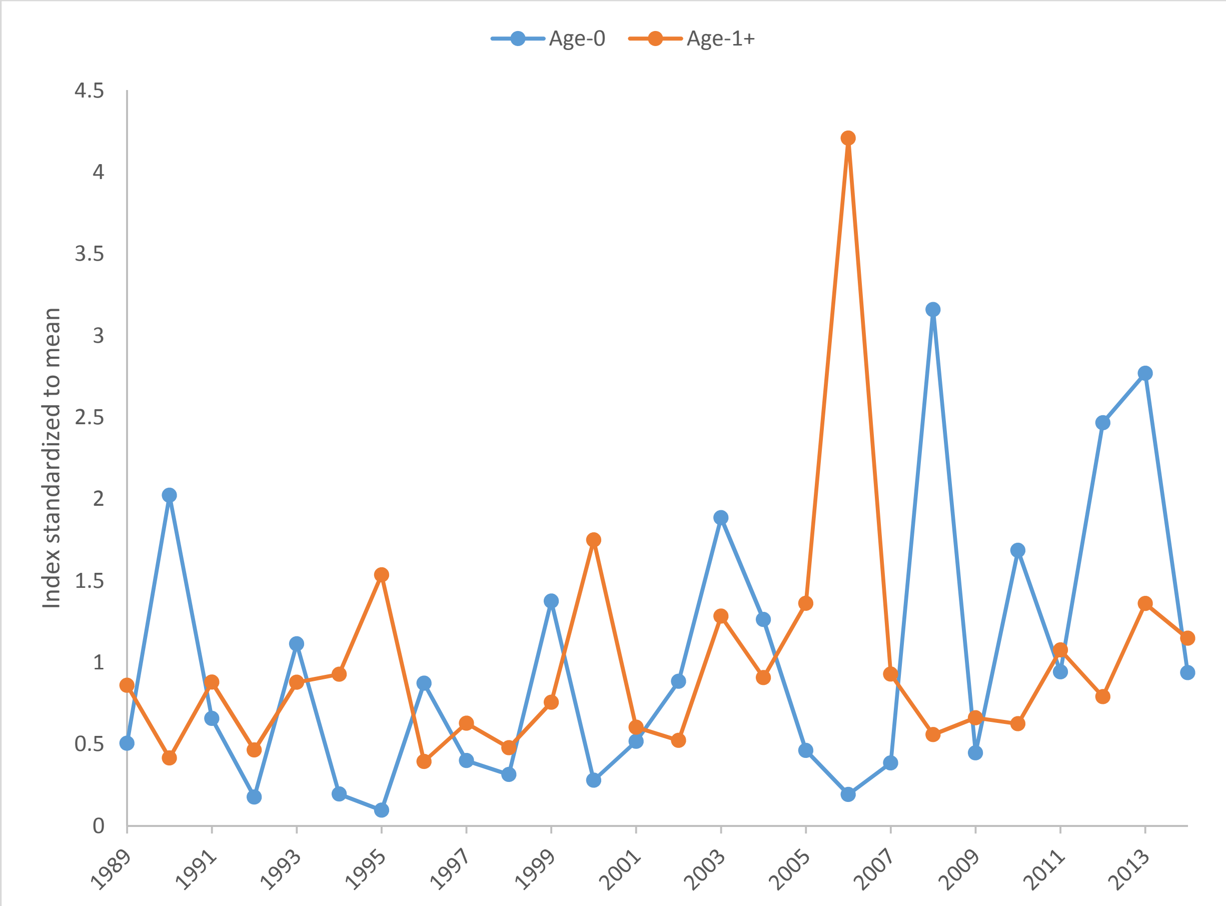
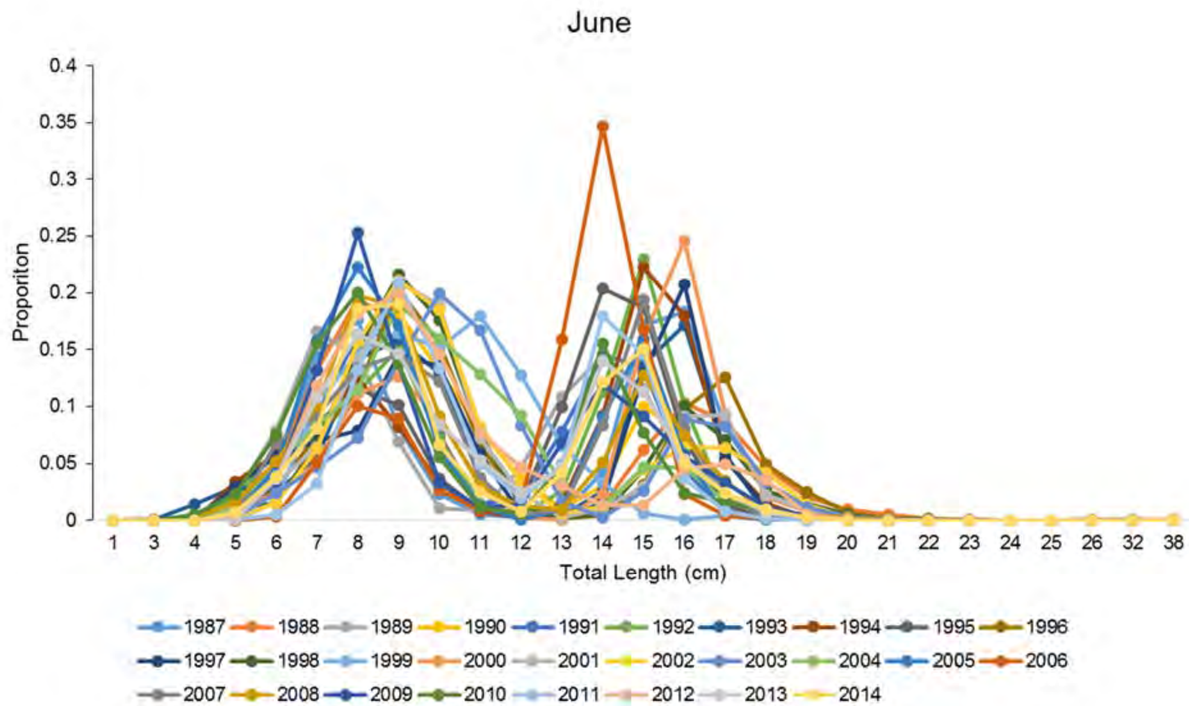


Figure 66. **Age-0 and Age-1+ relative abundance indices developed from the June component of the NCDMF Trawl Survey. Indices were developed in numbers per tow and then standardized to their mean.**



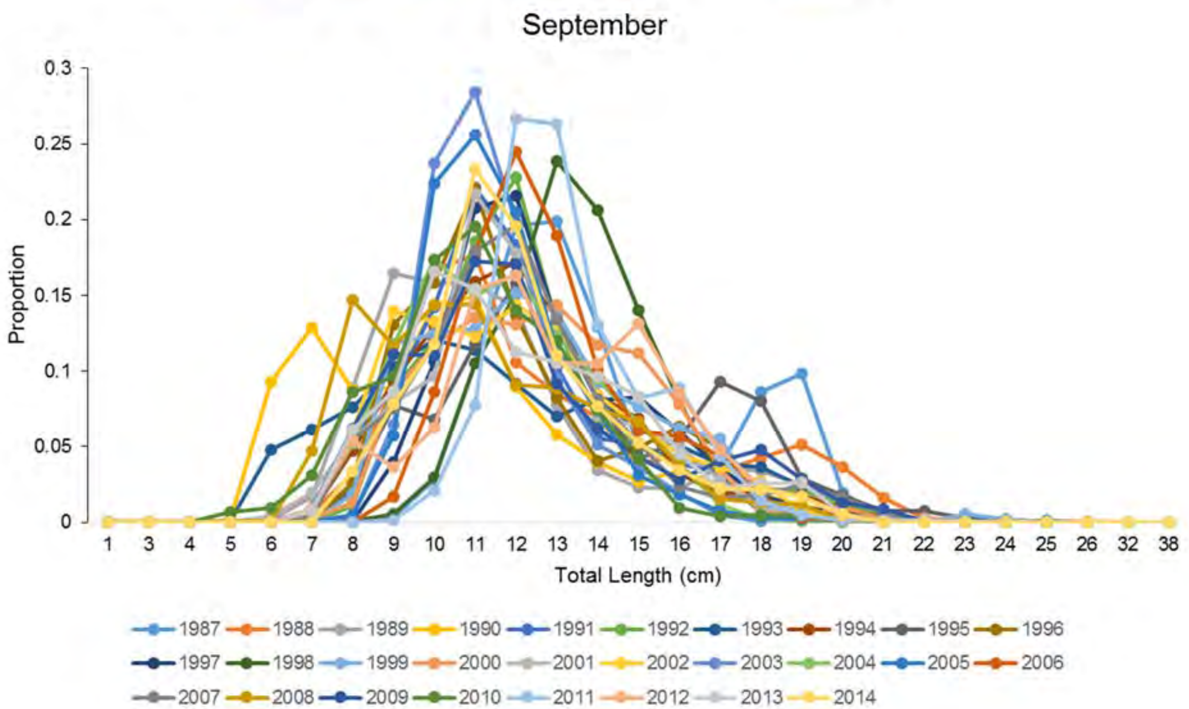


Figure 67. **Annual length frequencies of spot caught in the NC DMF Trawl Survey during June (top figure) and September (bottom figure).**

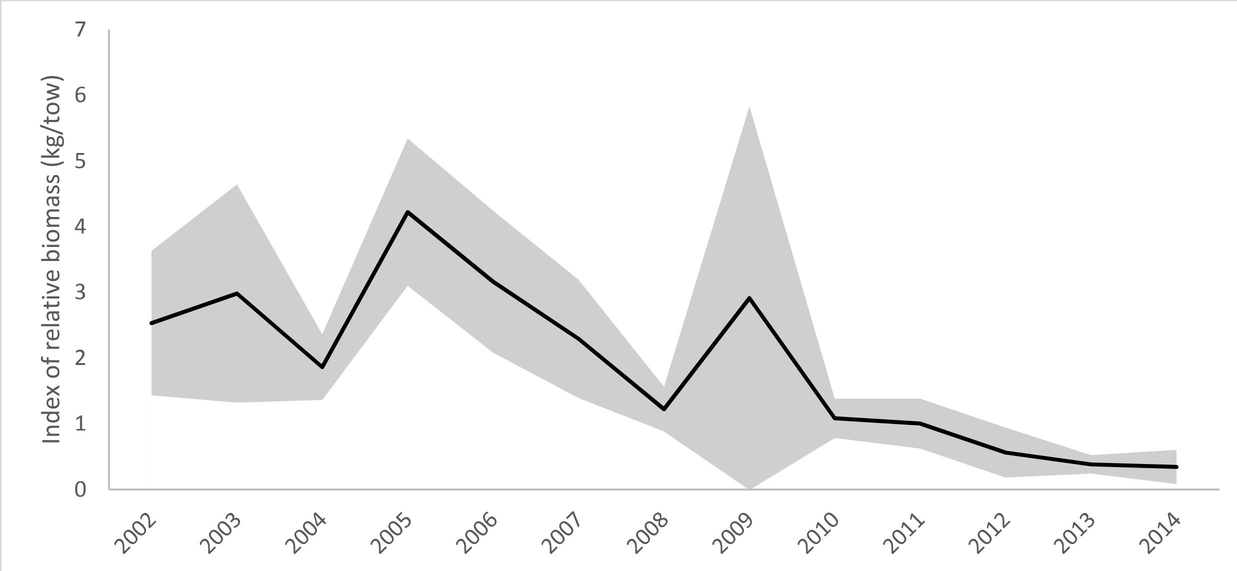


Figure 68. **Index of relative biomass for spot developed from the May-September component of the ChesMMAP Trawl Survey in Regions 4-5 only.**

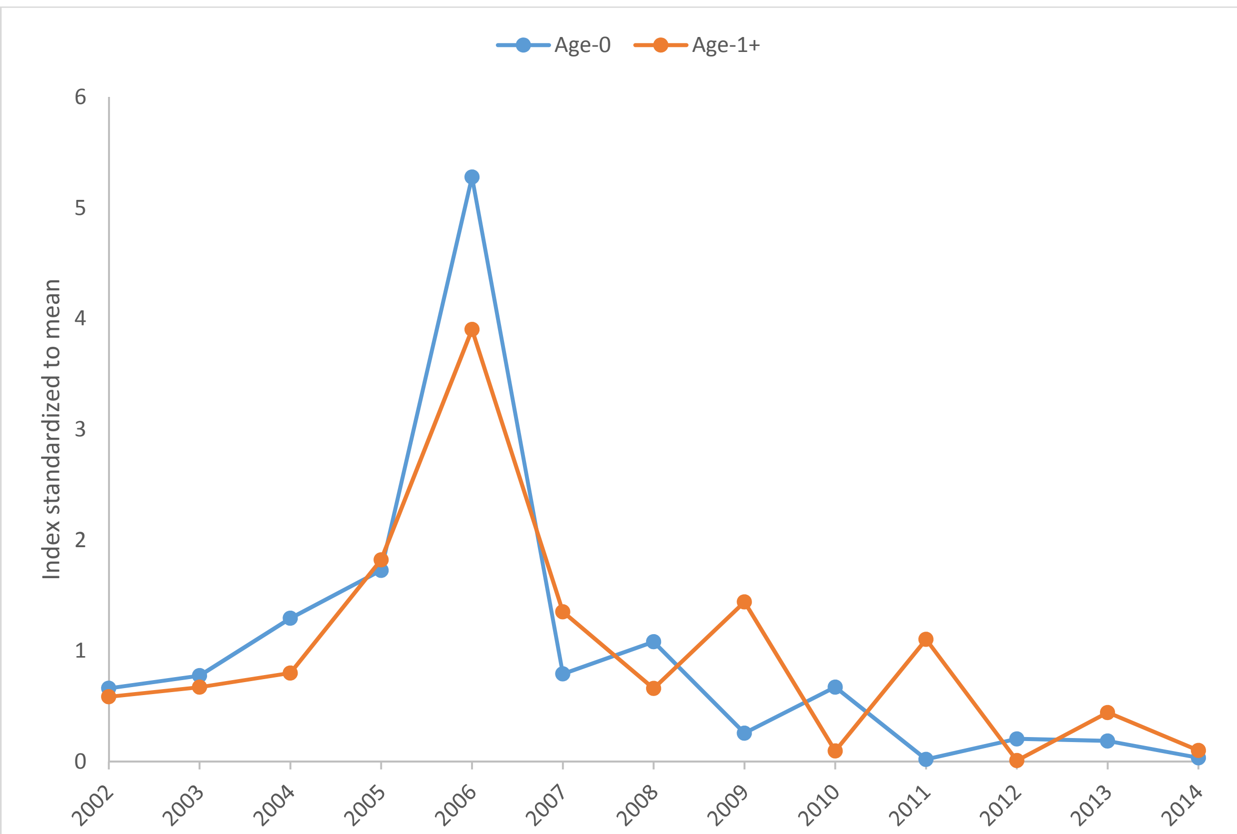


Figure 69. **Index of relative abundance for age-0 and age-1+ spot developed from the ChesMMAP Trawl Survey.**

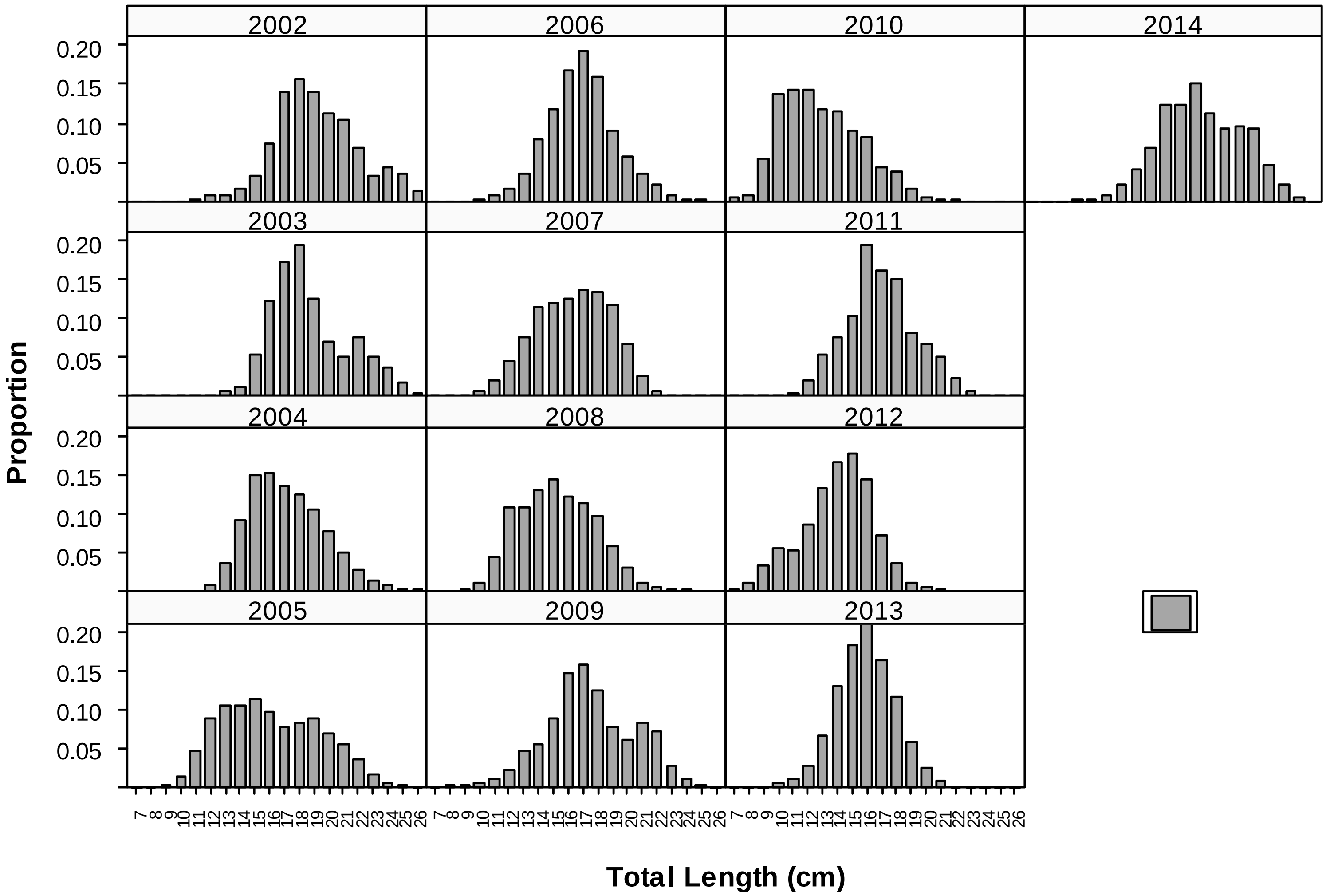


Figure 70. **Length frequency of spot captured in the ChesMMAP Trawl Survey.**

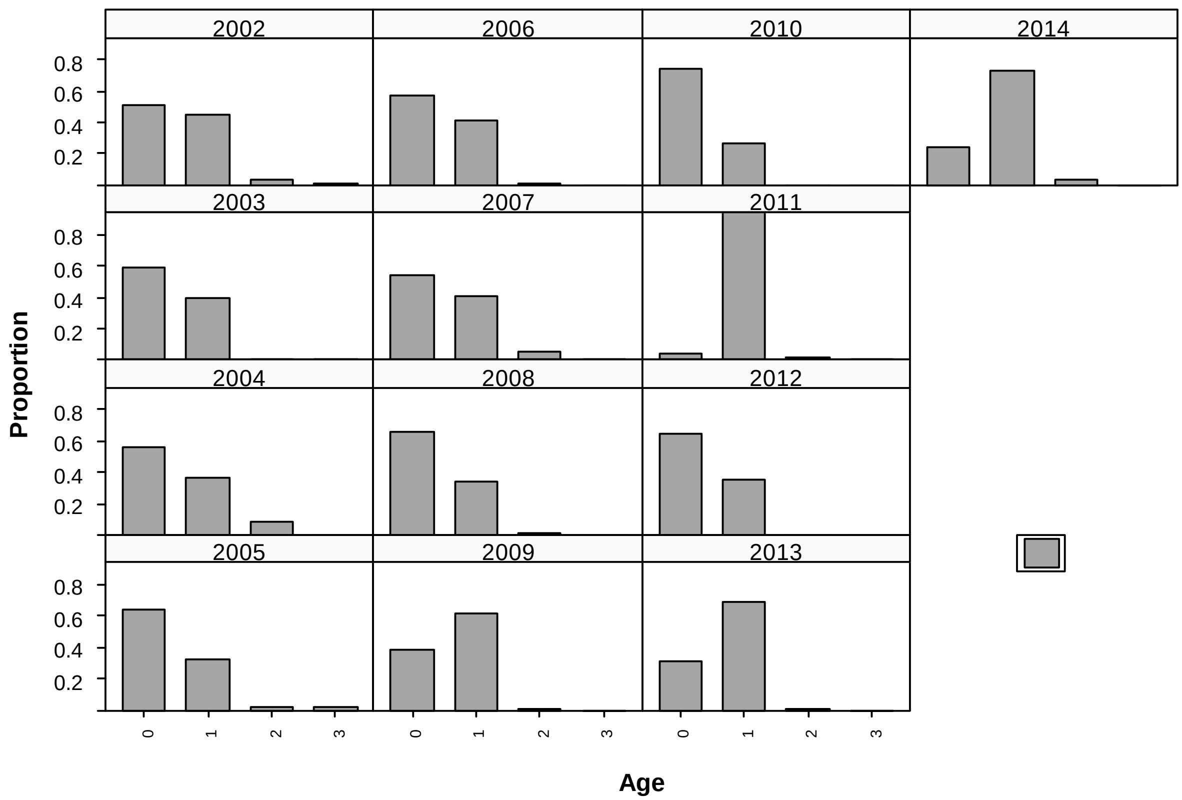


Figure 71. Age frequency of spot captured in the ChesMMAP Trawl Survey for all months.

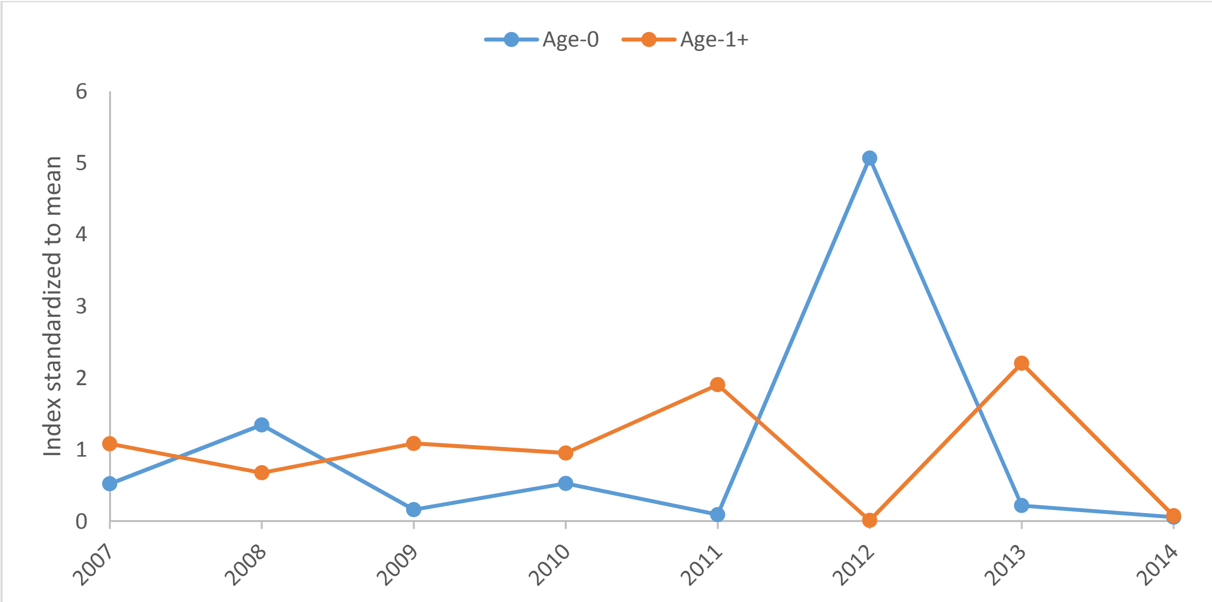


Figure 72. **Index of relative abundance for age-0 and age-1+ spot developed from the NEAMAP Trawl Survey.**

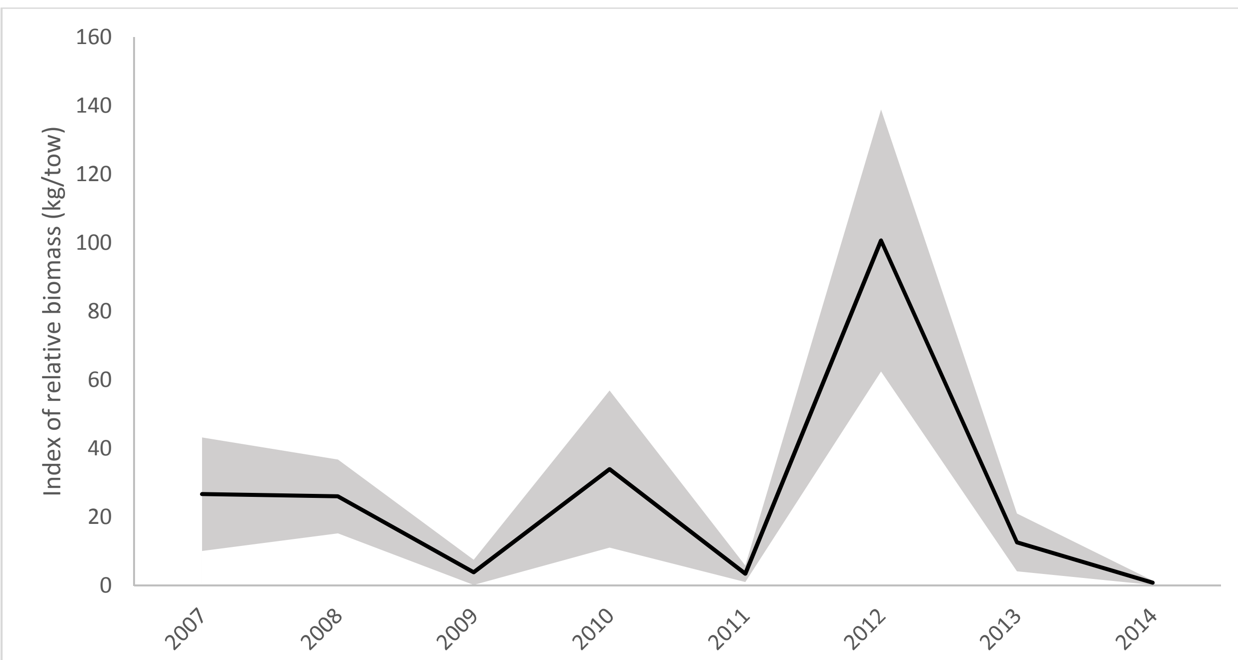


Figure 73. **Index of relative biomass developed from the fall component (September-November) of the NEAMAP Trawl Survey for spot.**

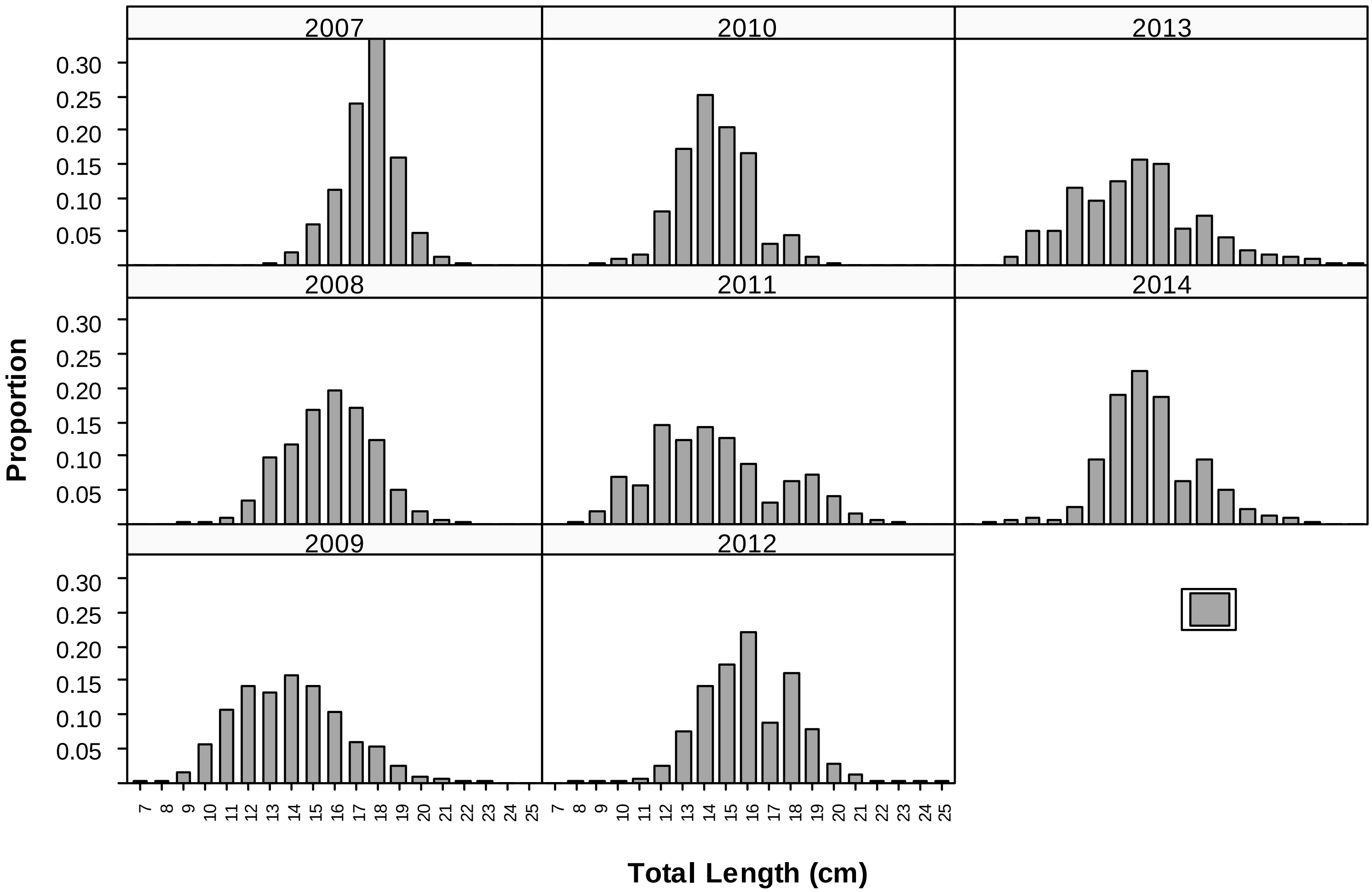


Figure 74. Length frequency of spot caught in the NEAMAP Trawl Survey.

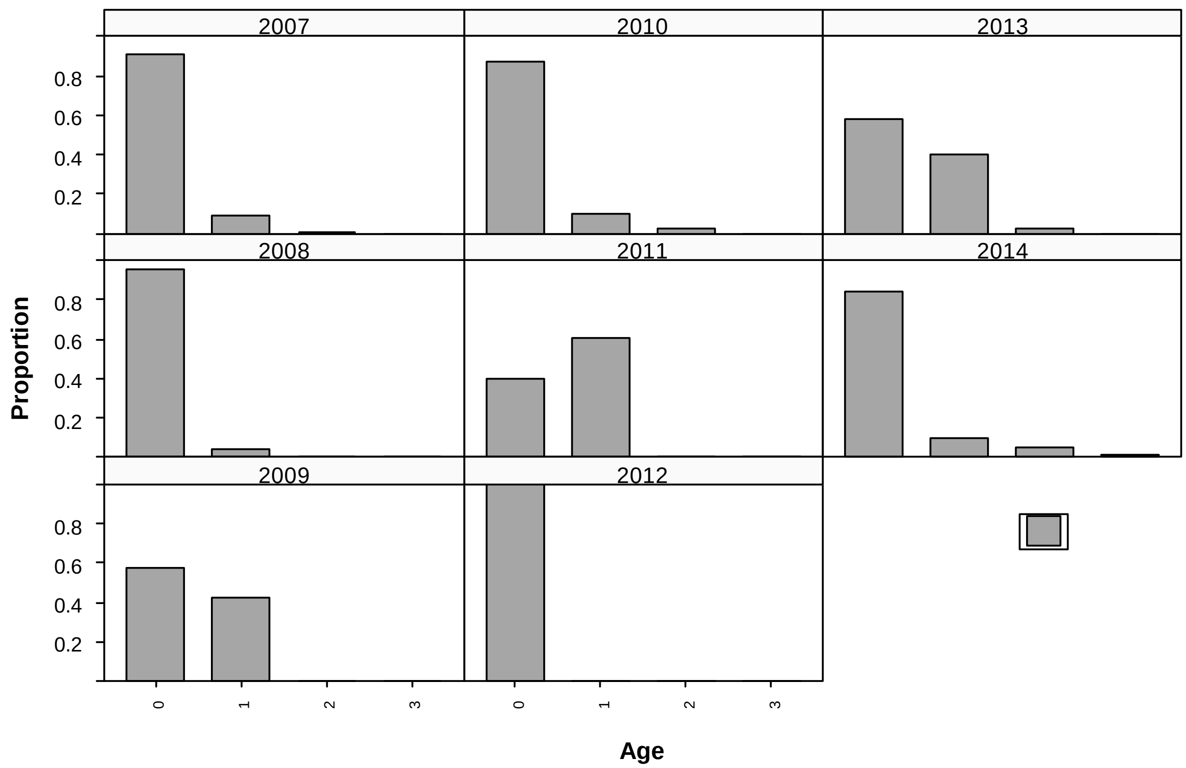


Figure 75. Age frequency of spot caught in the NEAMAP Trawl Survey during the fall component.

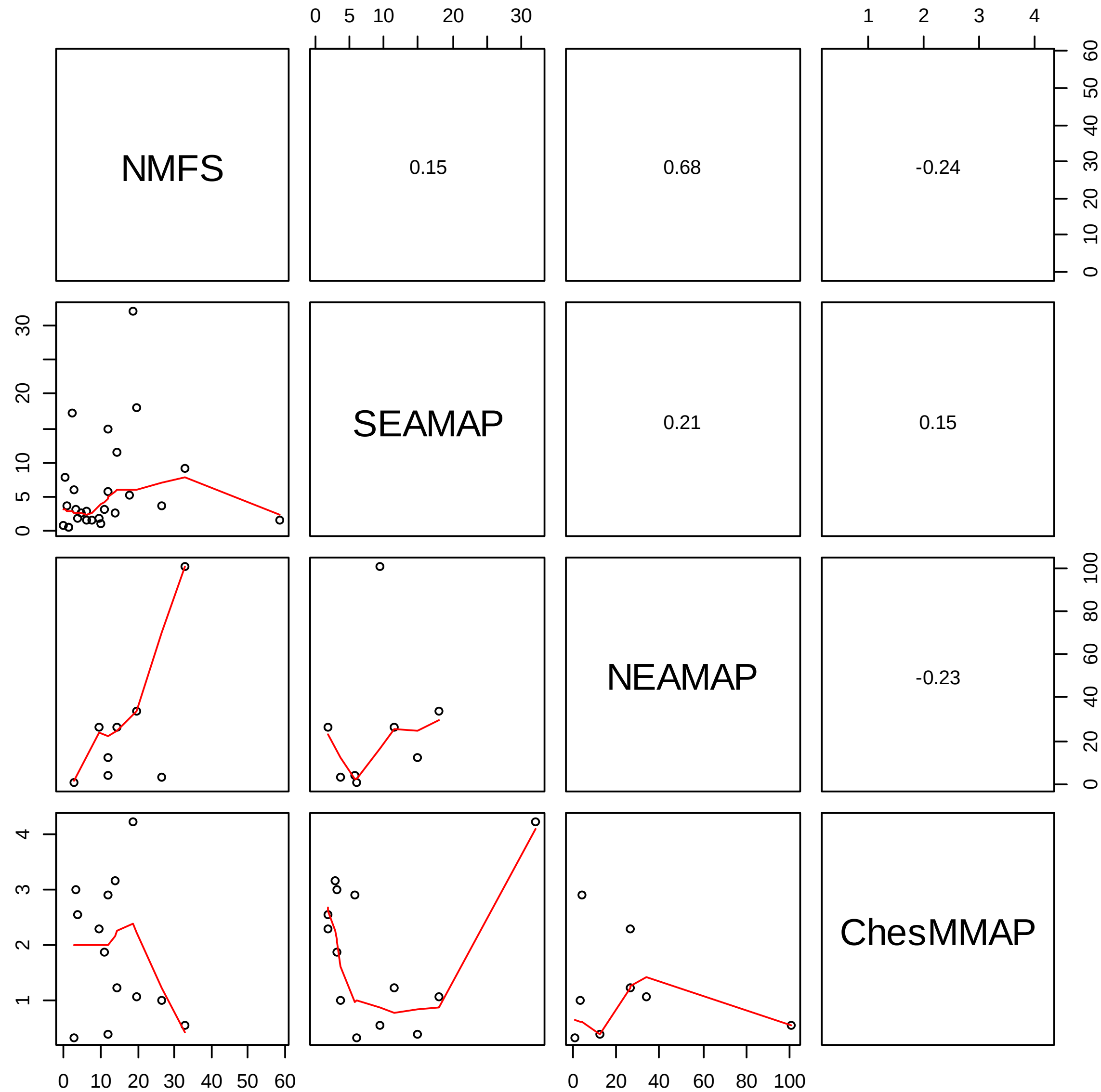


Figure 76. **Correlation coefficients and scatter plots for the aggregate indices considered for spot.**

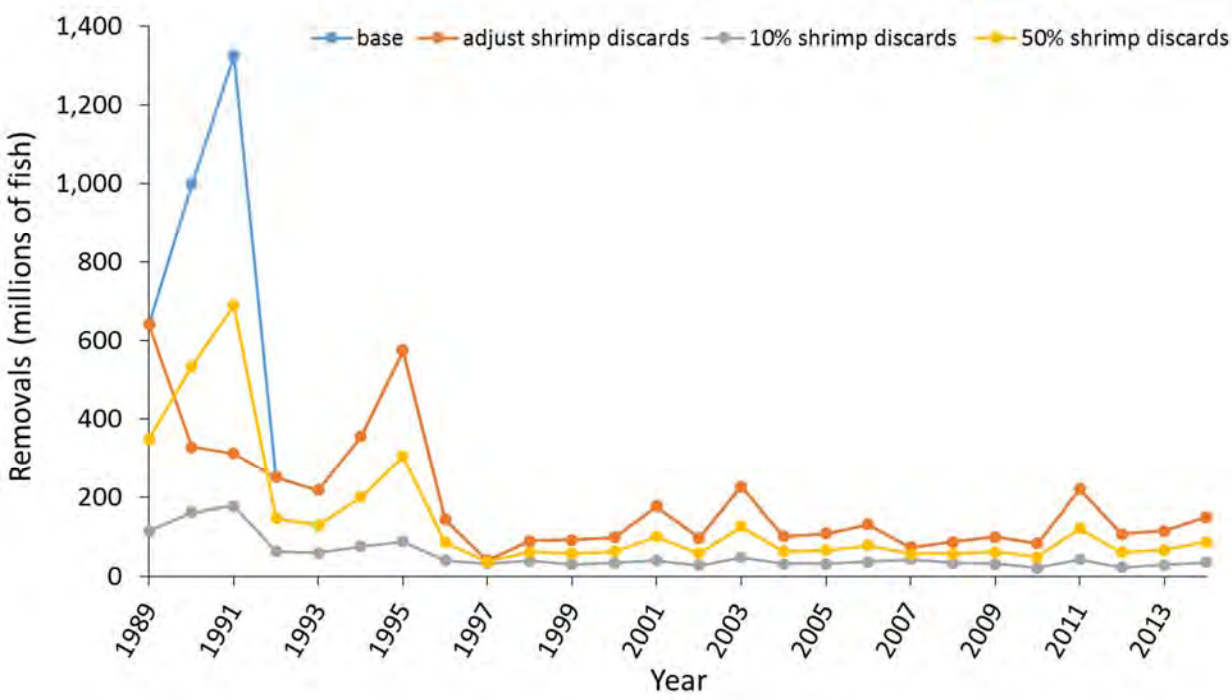


Figure 77. Comparison of removal data time series in the modified-CSA base model and sensitivity configurations for spot with adjusted shrimp trawl discard estimates (see Table 95 for description of sensitivity configurations).

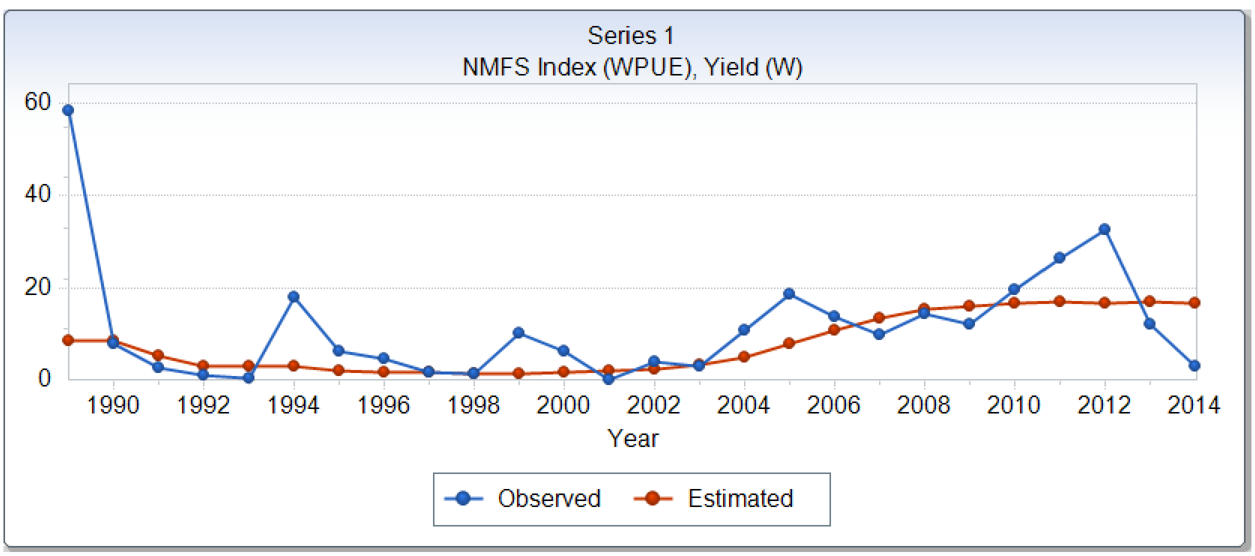


Figure 78. The spot surplus production model fit of the relative biomass index from the NMFS Trawl Survey.

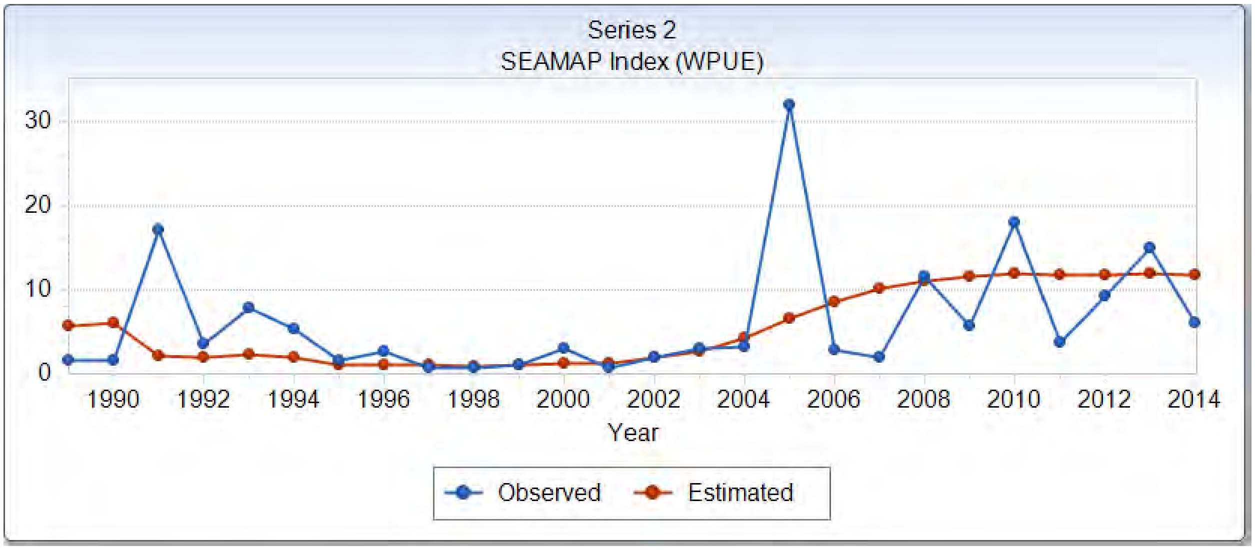


Figure 79. **The spot surplus production model fit of the relative biomass index from the SEAMAP Trawl Survey.**

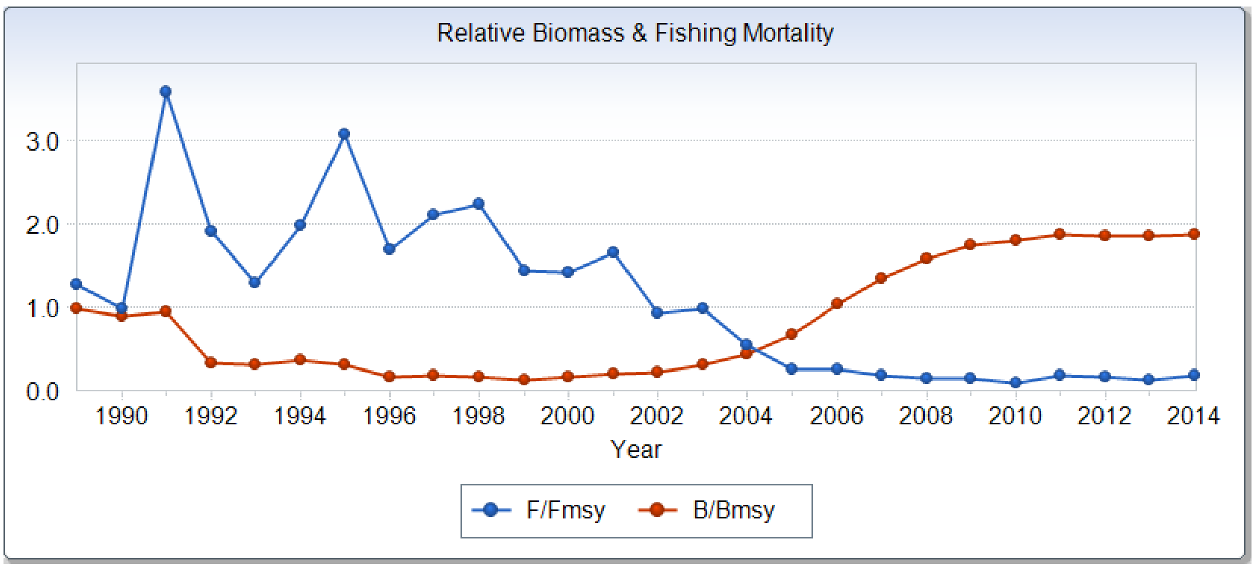


Figure 80. **Estimated relative biomass and fishing mortality of spot from the surplus production model.**

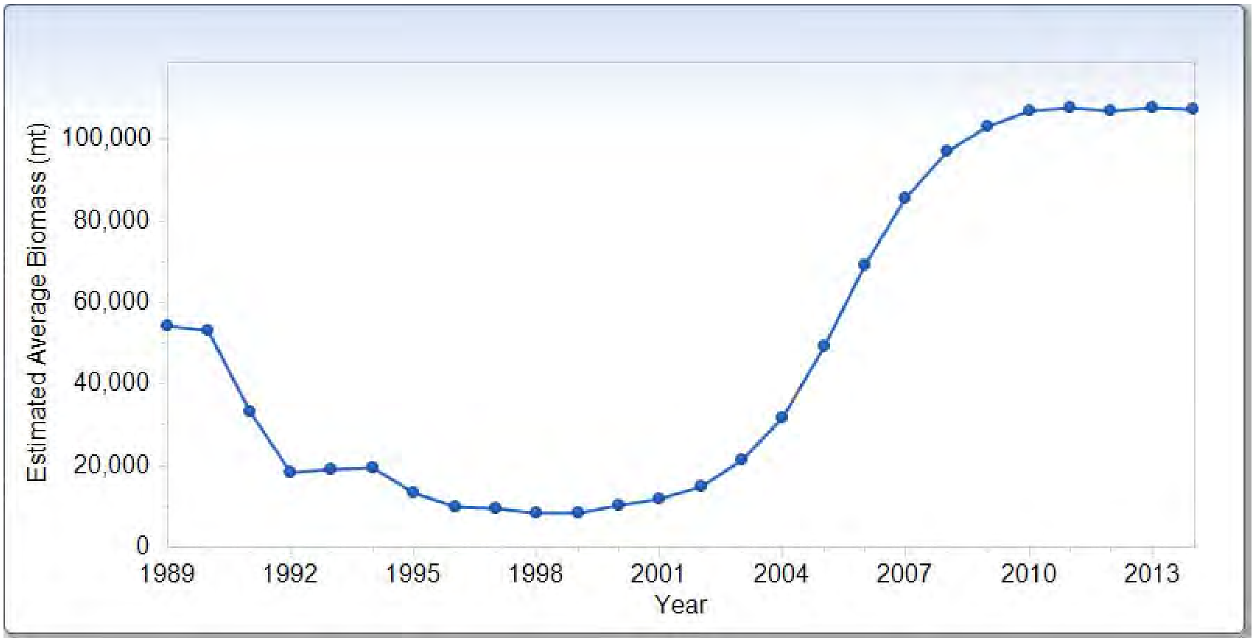


Figure 81. **Estimated average biomass (metric tons) of spot from the surplus production model.**

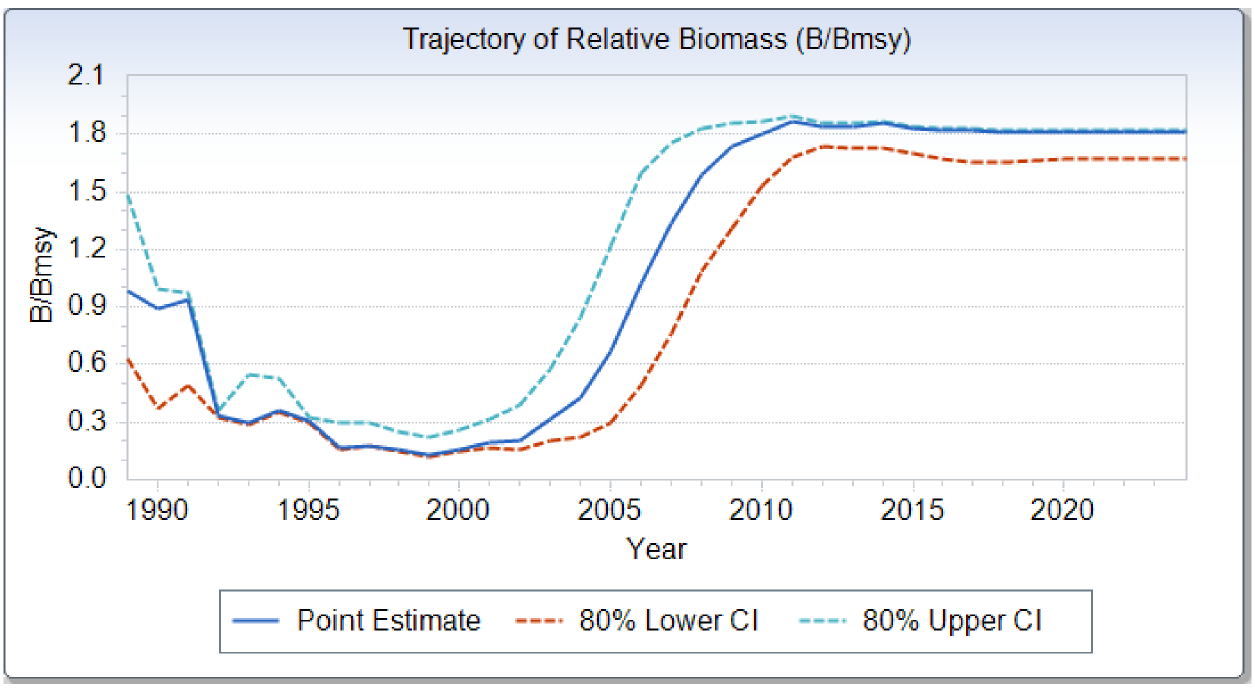


Figure 82. **Estimated relative biomass of spot from the surplus production model 10-year projections based on 2014 removal levels.**

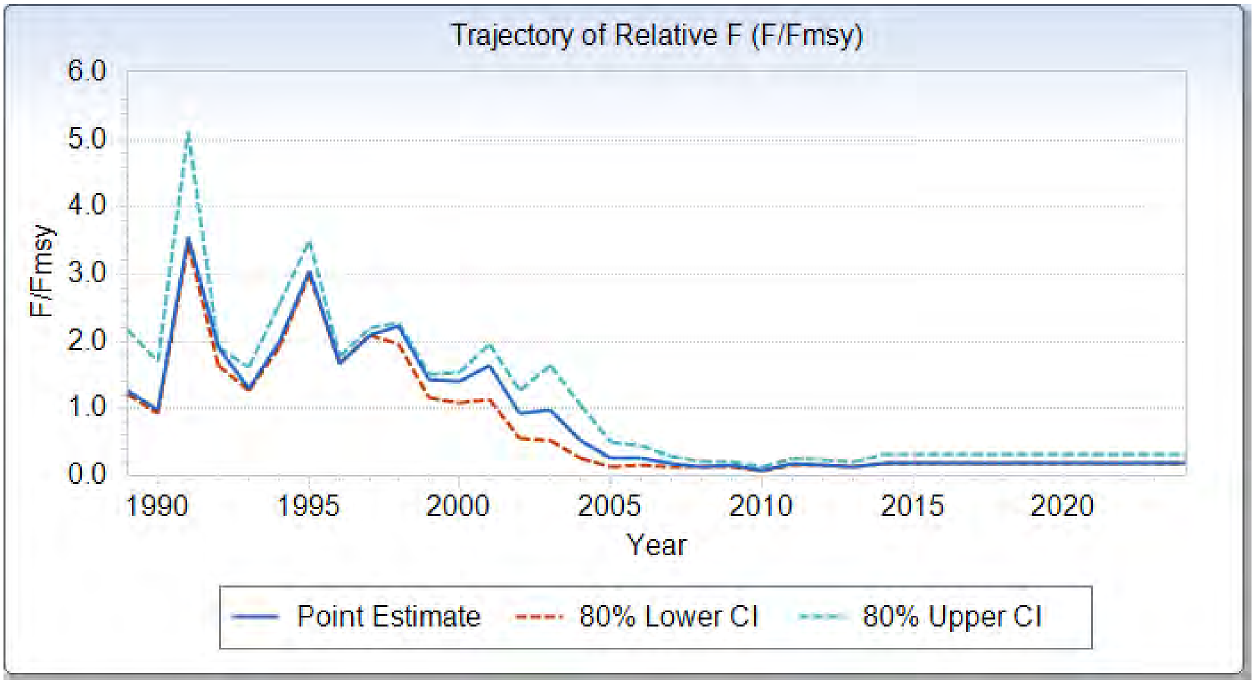


Figure 83. **Estimated relative fishing mortality of spot from the surplus production model 10-year projections based on 2014 removal levels.**

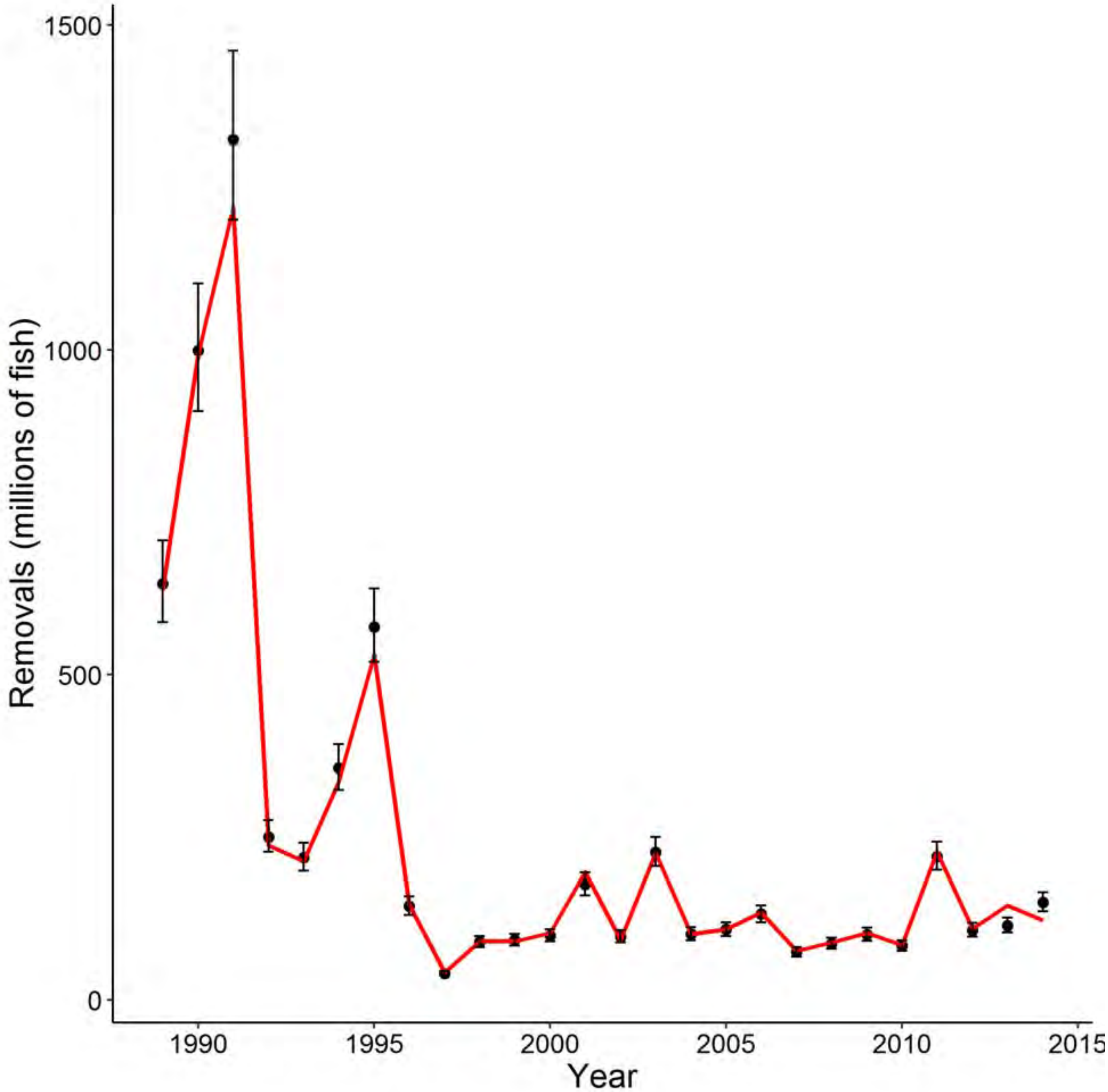


Figure 84. **Base modified-CSA model fit to total fishery removal data. The red line is model predicted removals, the black circles are observed removals, and error bars indicate 95% confidence intervals of observed removals based on assumed input CVs of 0.05.**

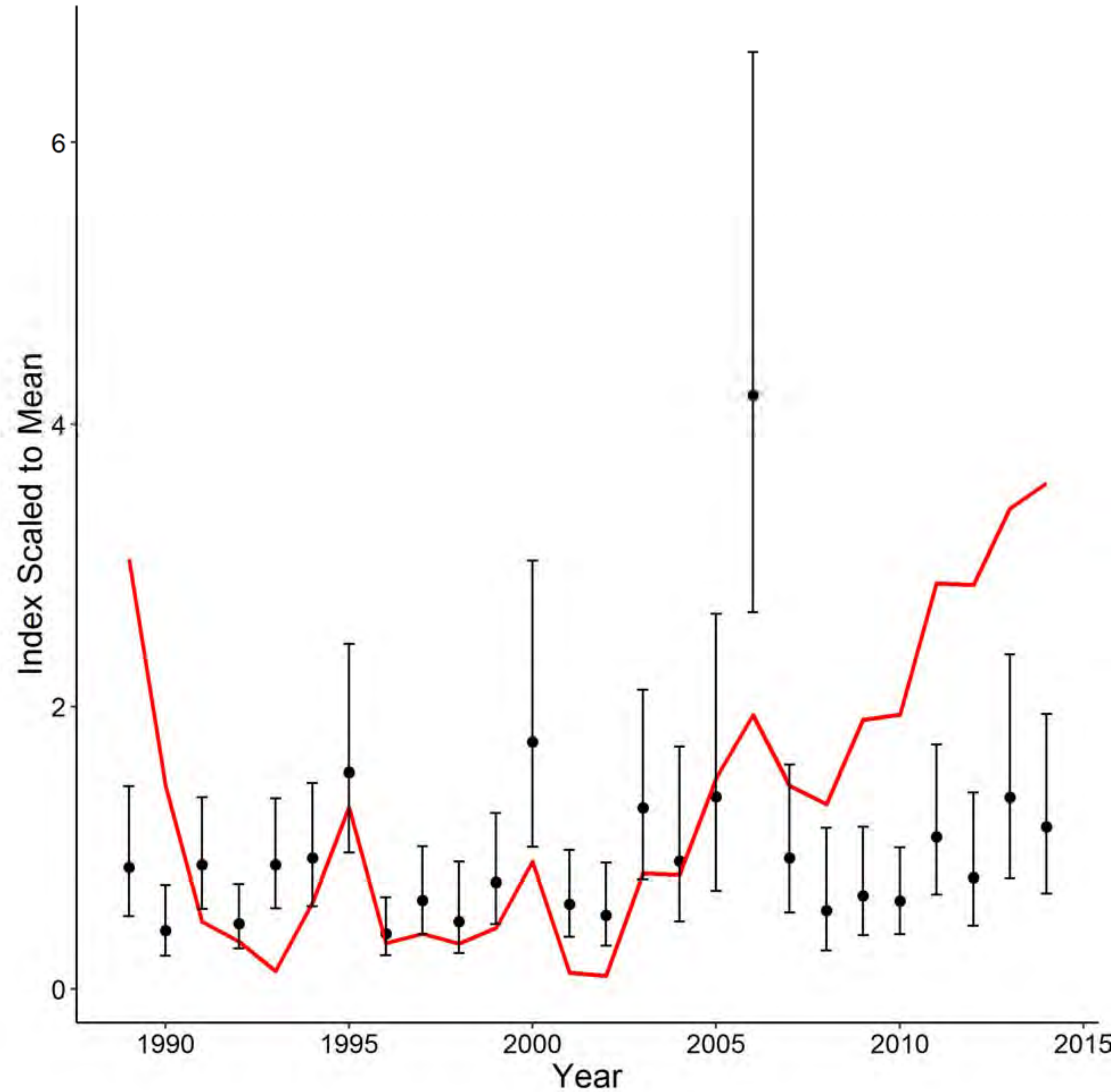


Figure 85. **Base modified-CSA model fit to NCDMF Trawl Survey post-recruit index. The red line is the model predicted index, the black circles are observed index values, and error bars indicate 95% confidence intervals of the observed index values based on the input CVs.**

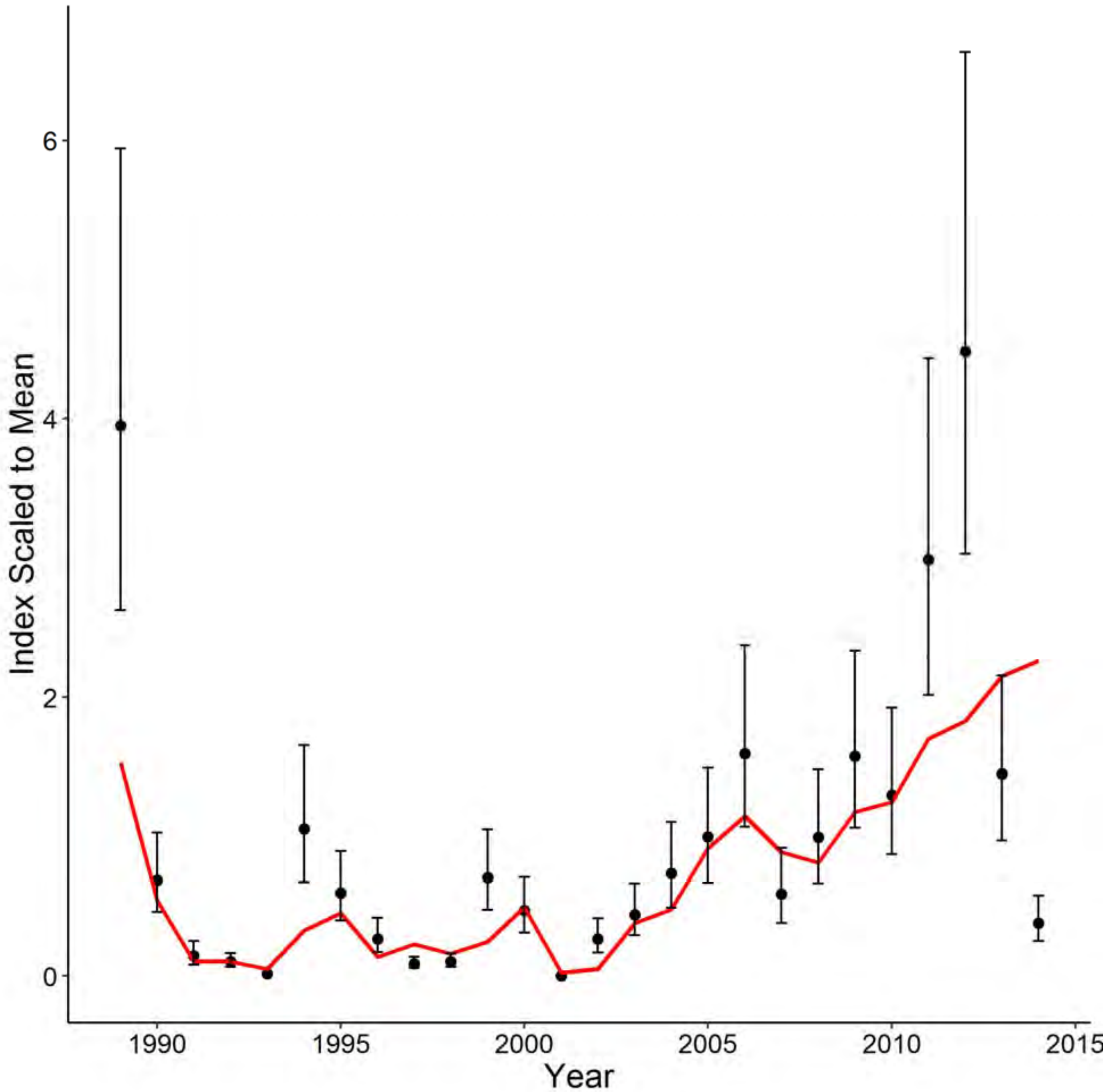


Figure 86. **Base modified-CSA model fit to NMFS Trawl Survey post-recruit index. The red line is the model predicted index, the black circles are observed index values, and error bars indicate 95% confidence intervals of the observed index values based on the input CVs.**

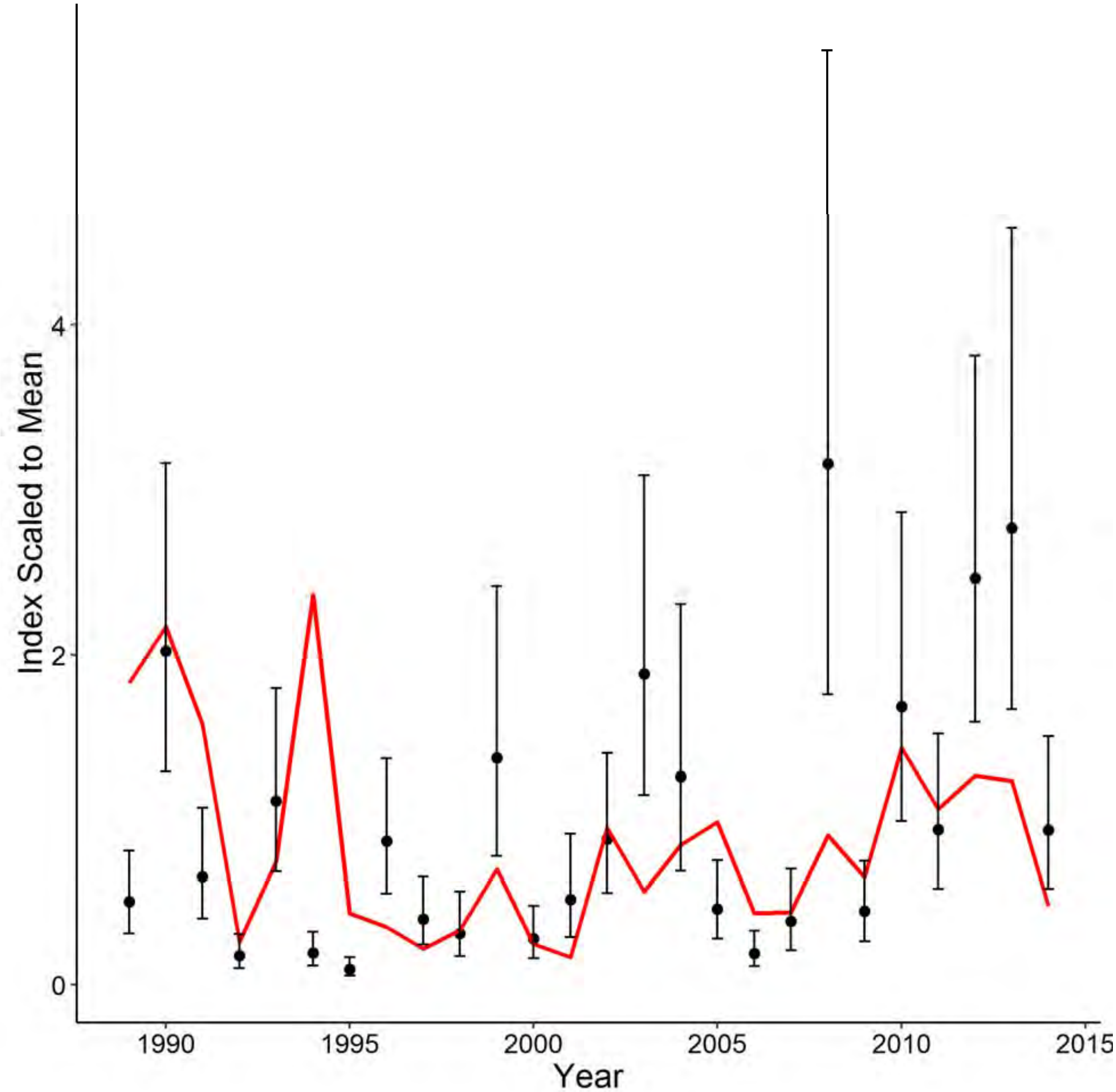


Figure 87. **Base modified-CSA model fit to NCDMF Trawl Survey recruit index. The red line is the model predicted index, the black circles are observed index values, and error bars indicate 95% confidence intervals of the observed index values based on the input CVs.**

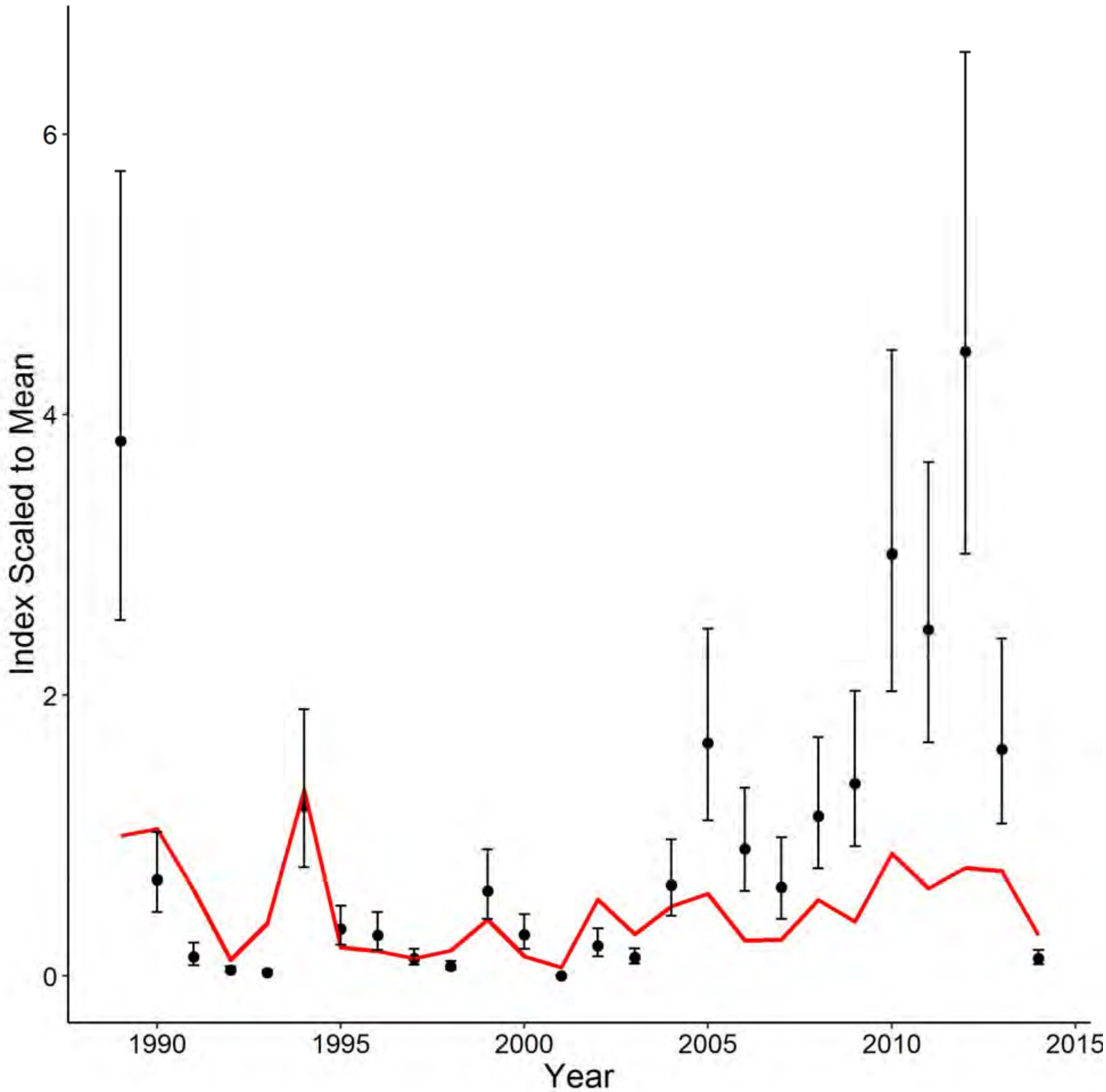


Figure 88. **Base modified-CSA model fit to NMFS Trawl Survey recruit index. The red line is the model predicted index, the black circles are observed index values, and error bars indicate 95% confidence intervals of the observed index values based on the input CVs.**

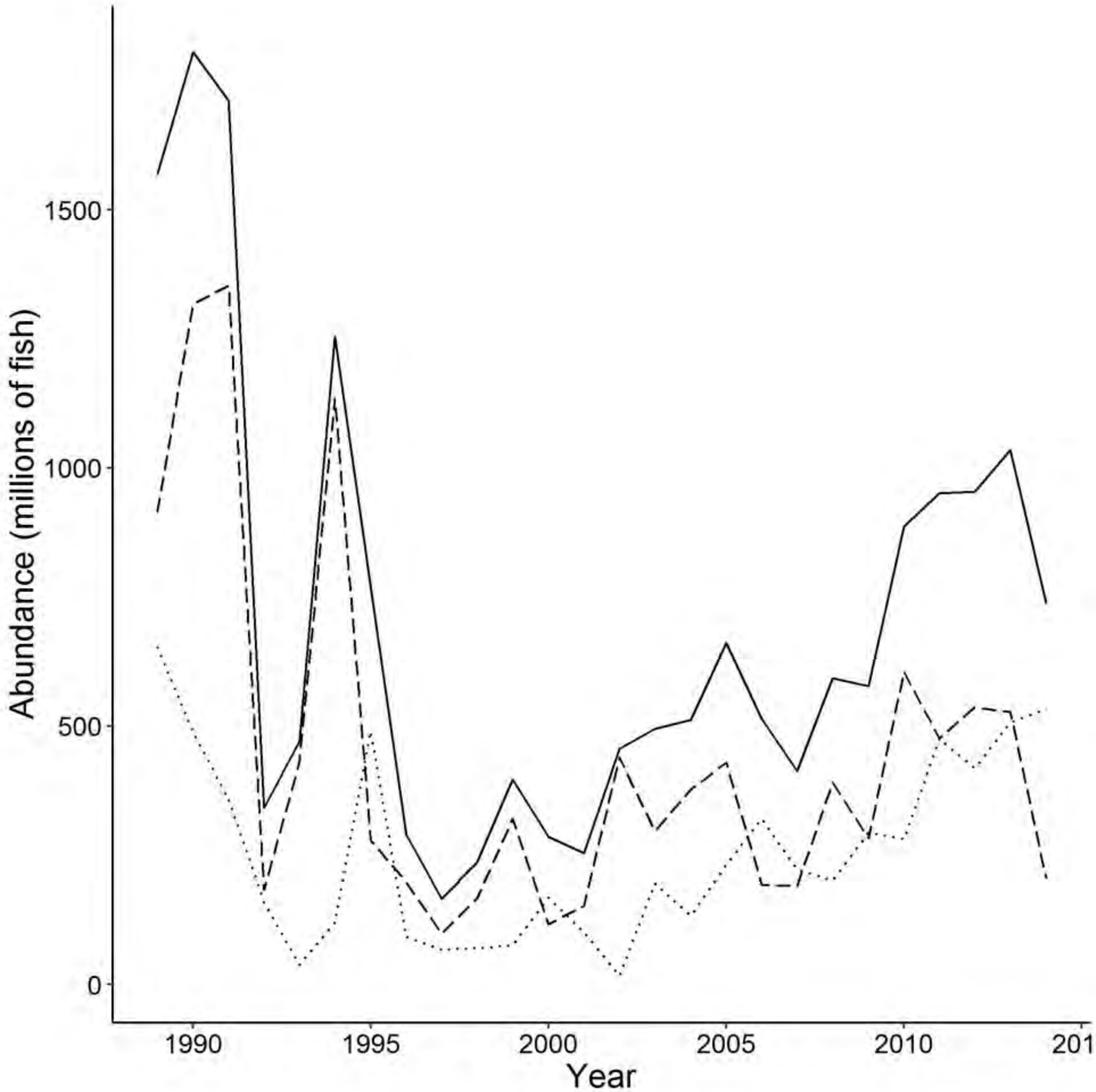


Figure 89. Base modified-CSA model recruitment (dashed line), post-recruit (dotted line), and total abundance (solid line) estimates for spot (millions of fish).

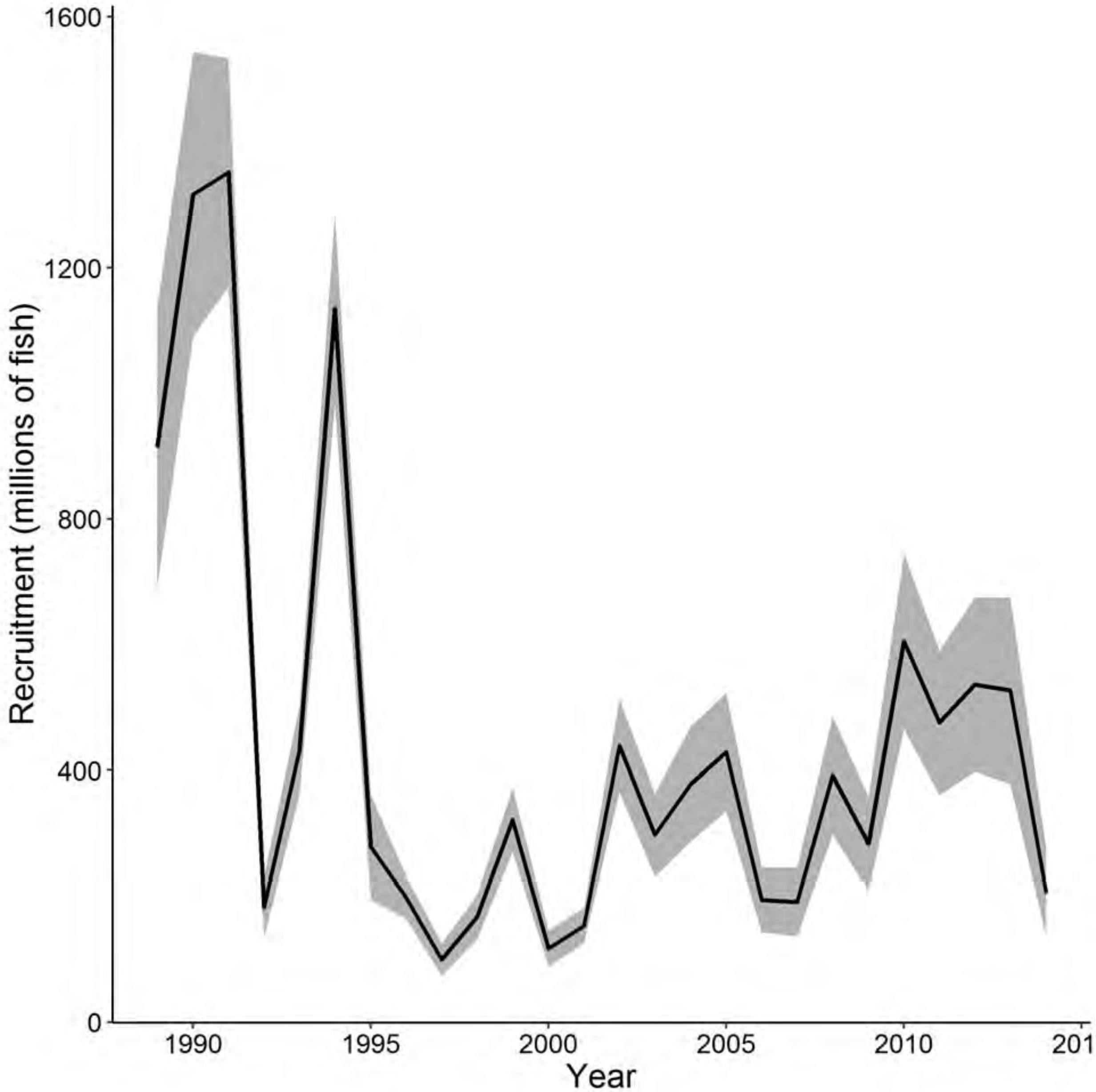


Figure 90. **Base modified-CSA model recruitment estimates for spot (millions of fish) with 95% confidence intervals derived from asymptotic standard errors.**

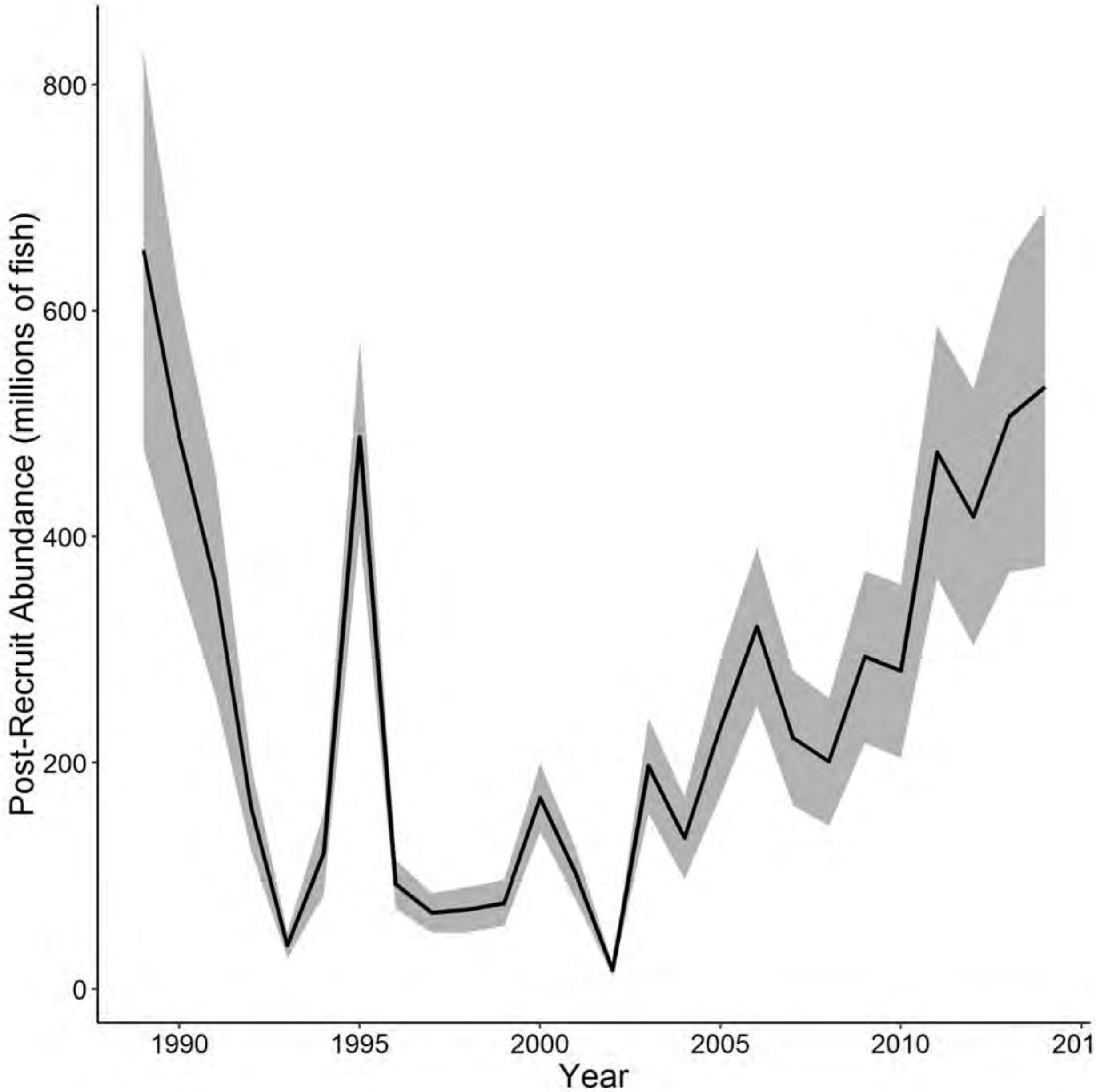


Figure 91. **Base modified-CSA model post-recruit abundance estimates for spot (millions of fish) with 95% confidence intervals derived from asymptotic standard errors.**

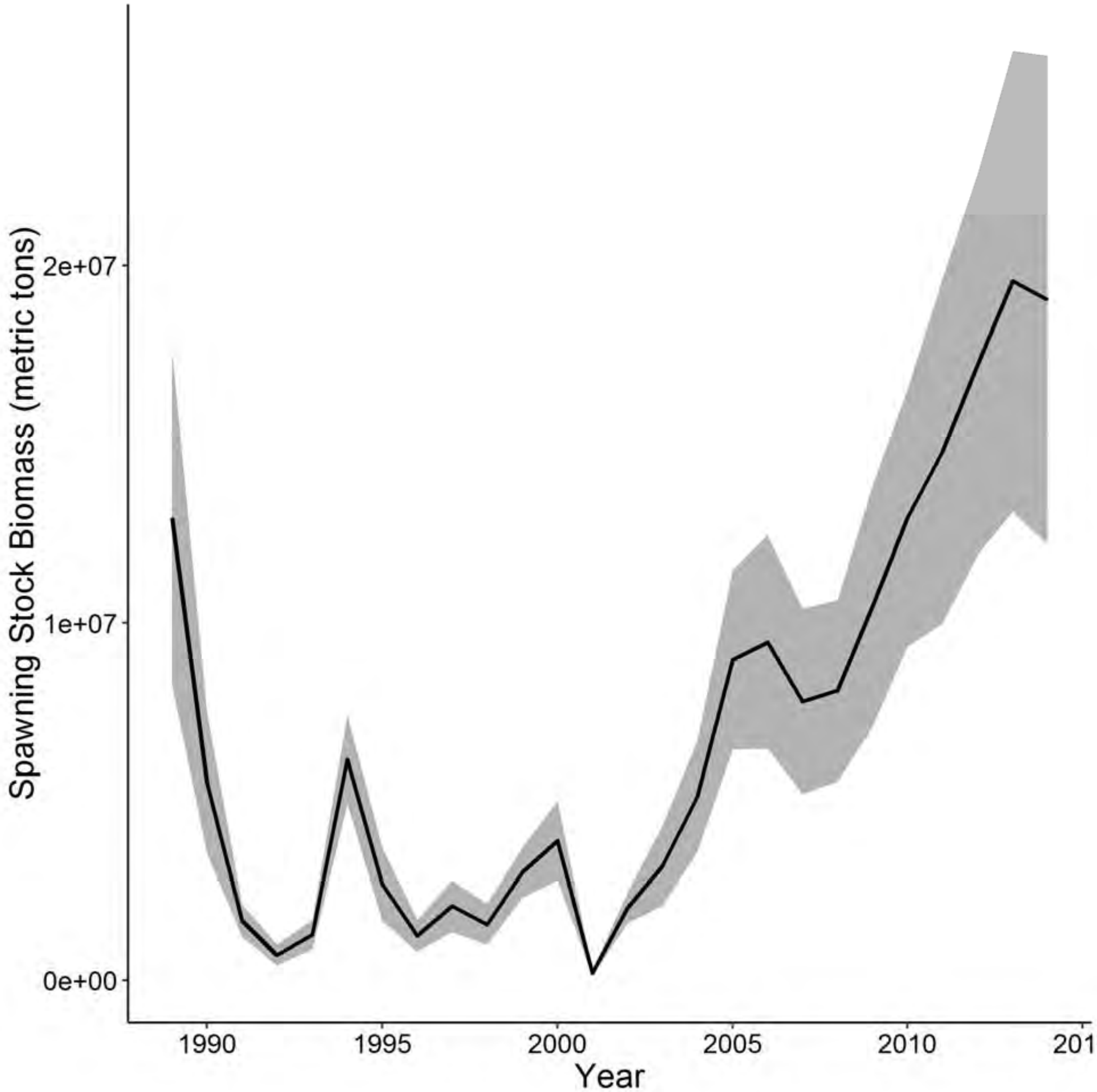


Figure 92. Base modified-CSA model end-year spawning stock biomass estimates for spot (metric tons) with 95% confidence intervals derived from asymptotic standard errors.

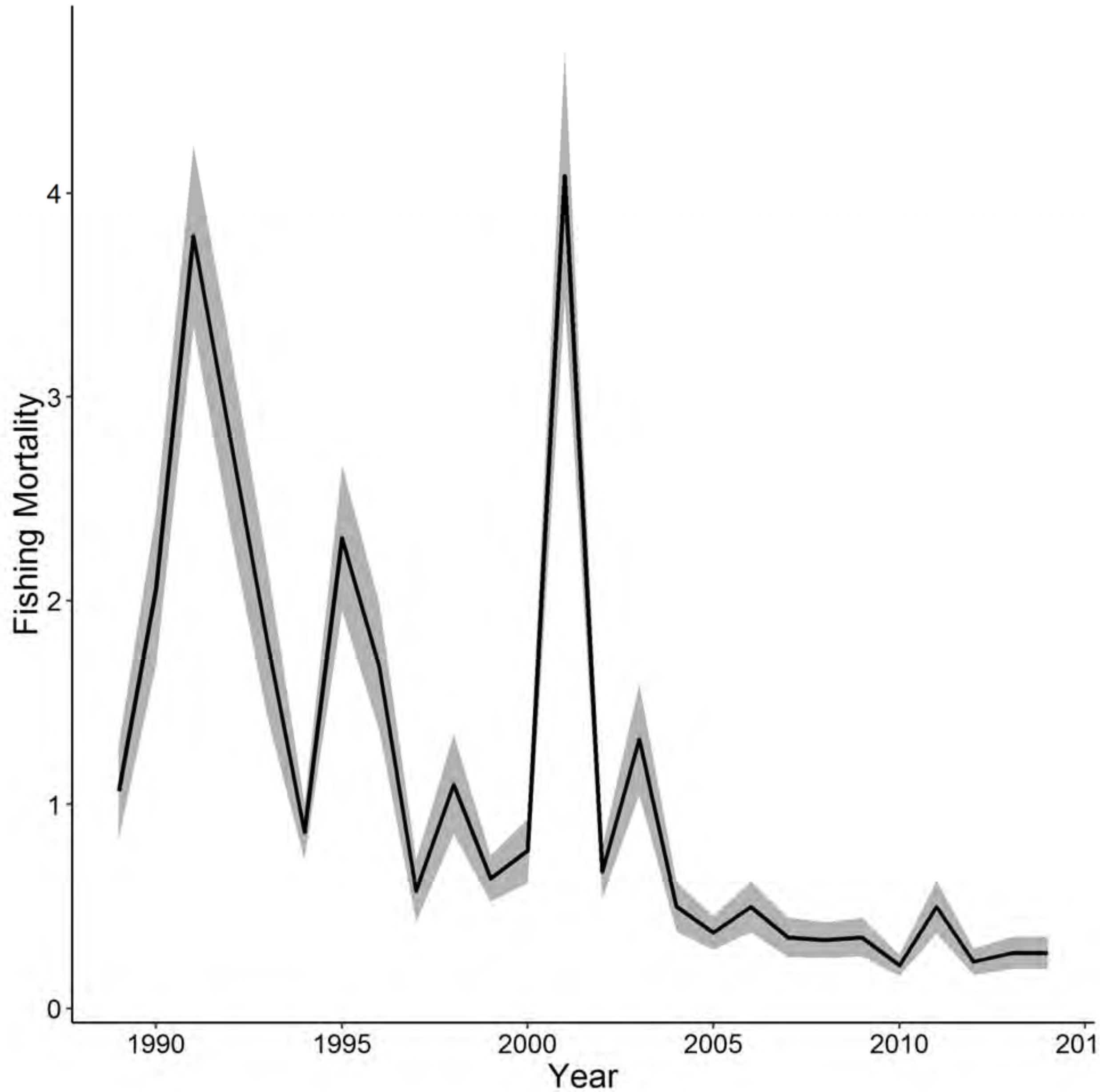


Figure 93. **Base modified-CSA model full fishing mortality estimates for spot with 95% confidence intervals derived from asymptotic standard errors. Terminal year (2014) fishing mortality is the geometric mean of the previous two years (2012-2013).**

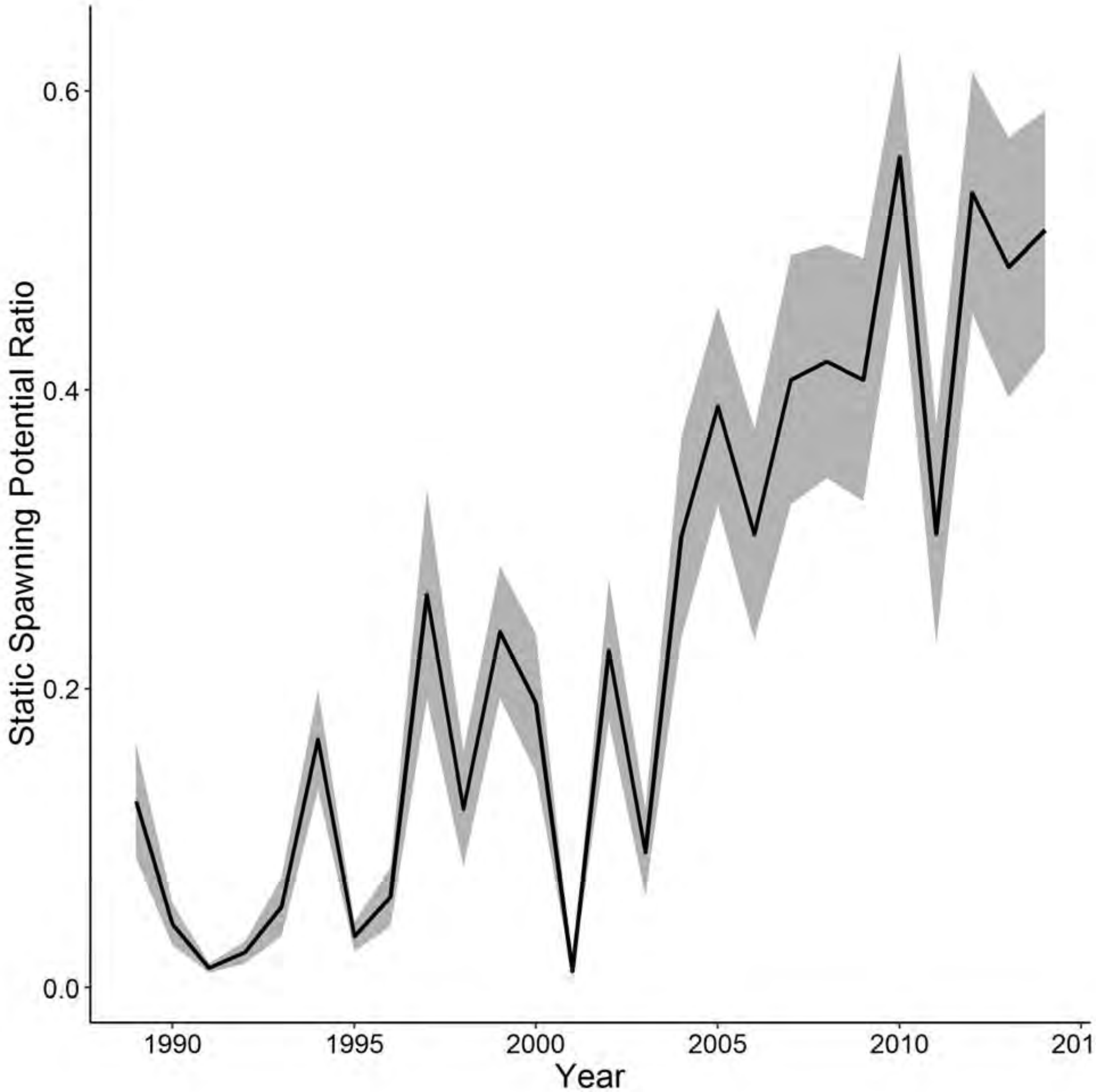


Figure 94. **Base modified-CSA model static spawning potential ratio estimates for spot with 95% confidence intervals derived from asymptotic standard errors. Terminal year (2014) sSPR is estimated from the geometric mean of the previous two years (2012-2013) fishing mortality estimates.**

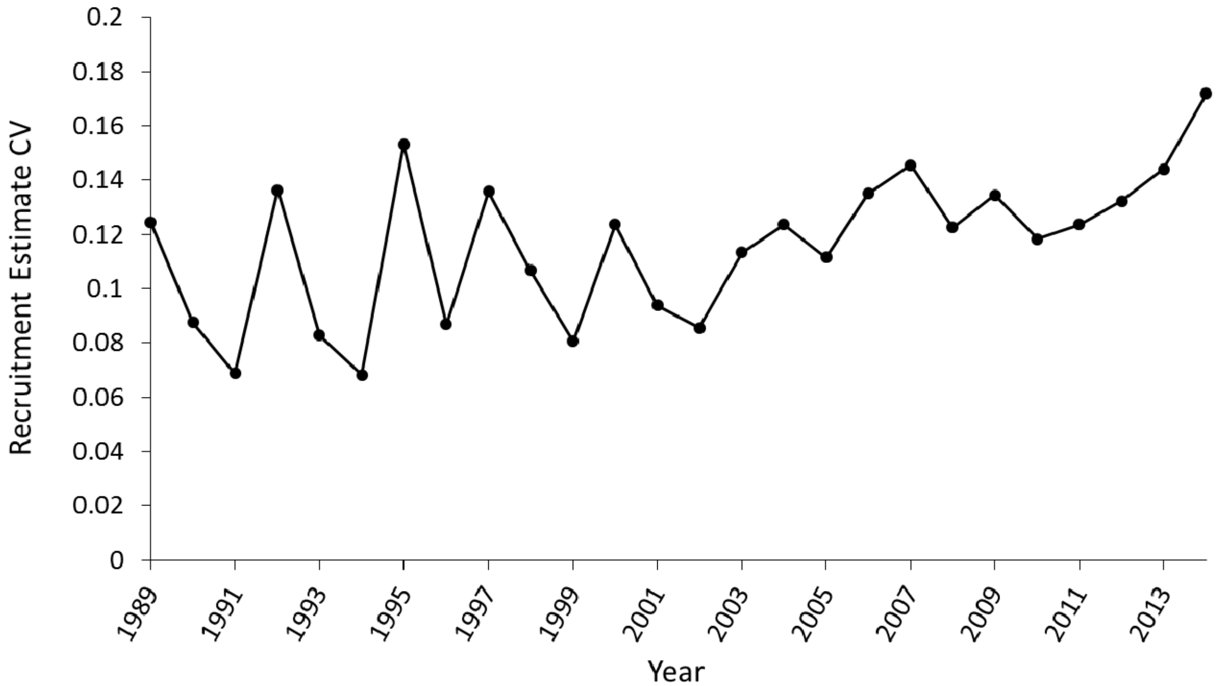


Figure 95. **Base modified-CSA model recruitment estimate CVs for spot derived from asymptotic standard errors.**

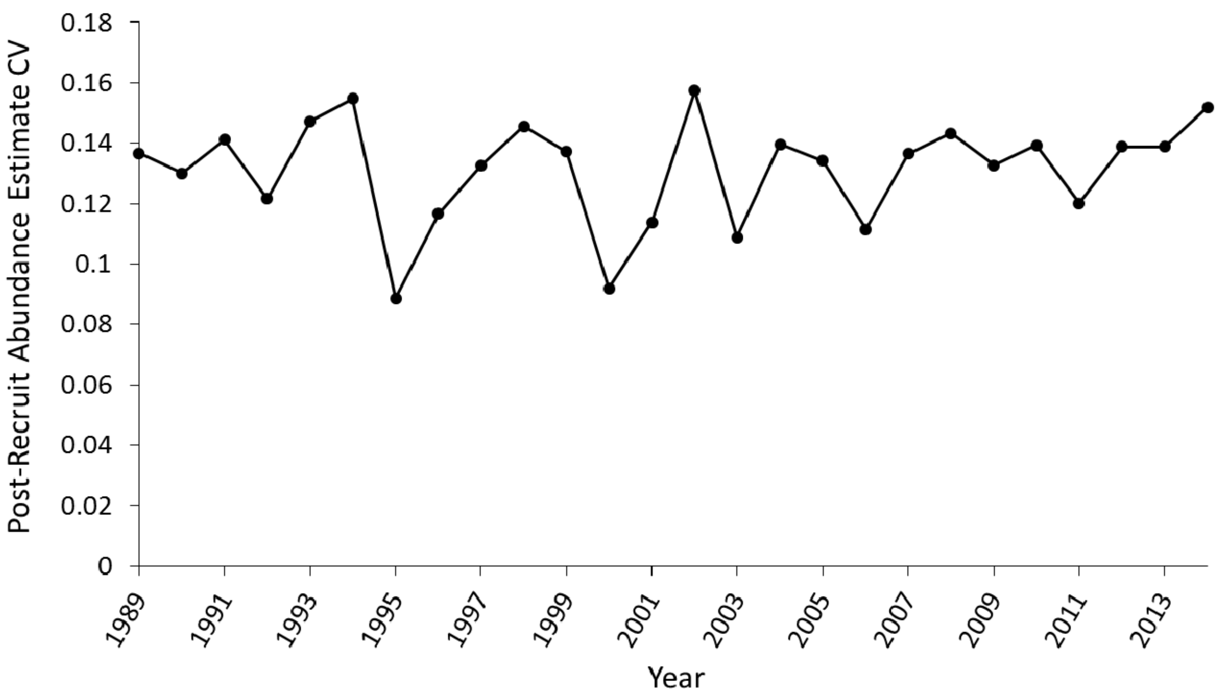


Figure 96. **Base modified-CSA model post-recruit abundance estimate CVs for spot derived from asymptotic standard errors.**

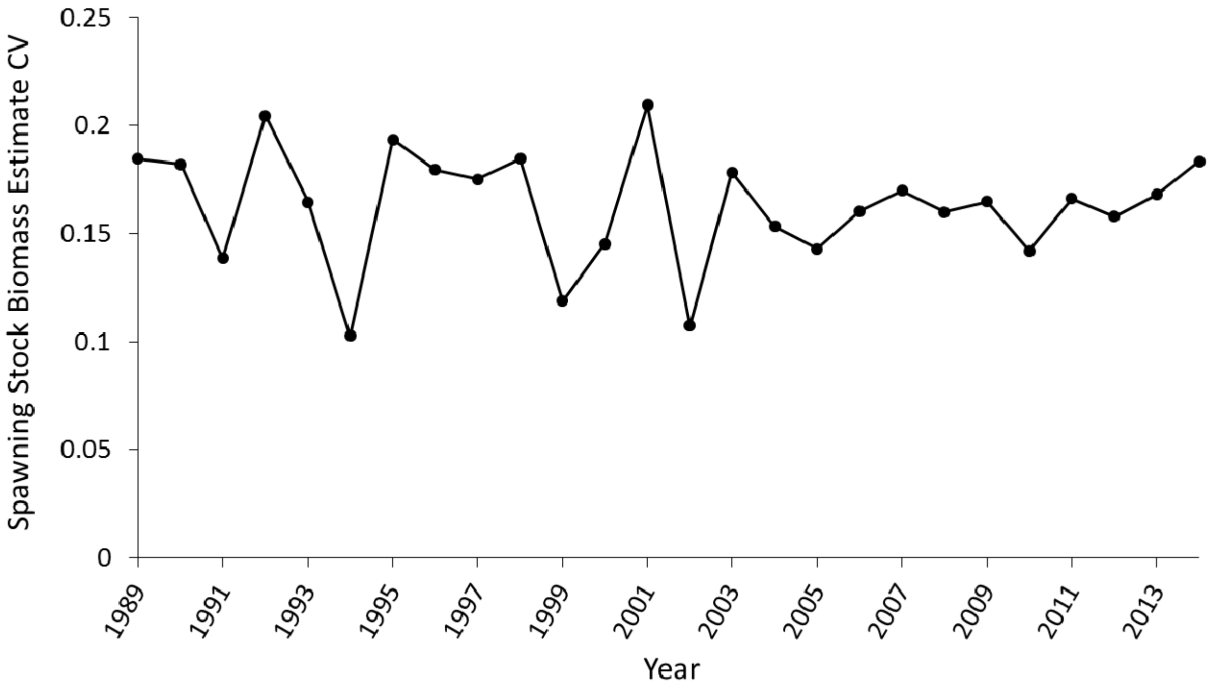


Figure 97. **Base modified-CSA model spawning stock biomass estimate CVs for spot derived from asymptotic standard errors.**

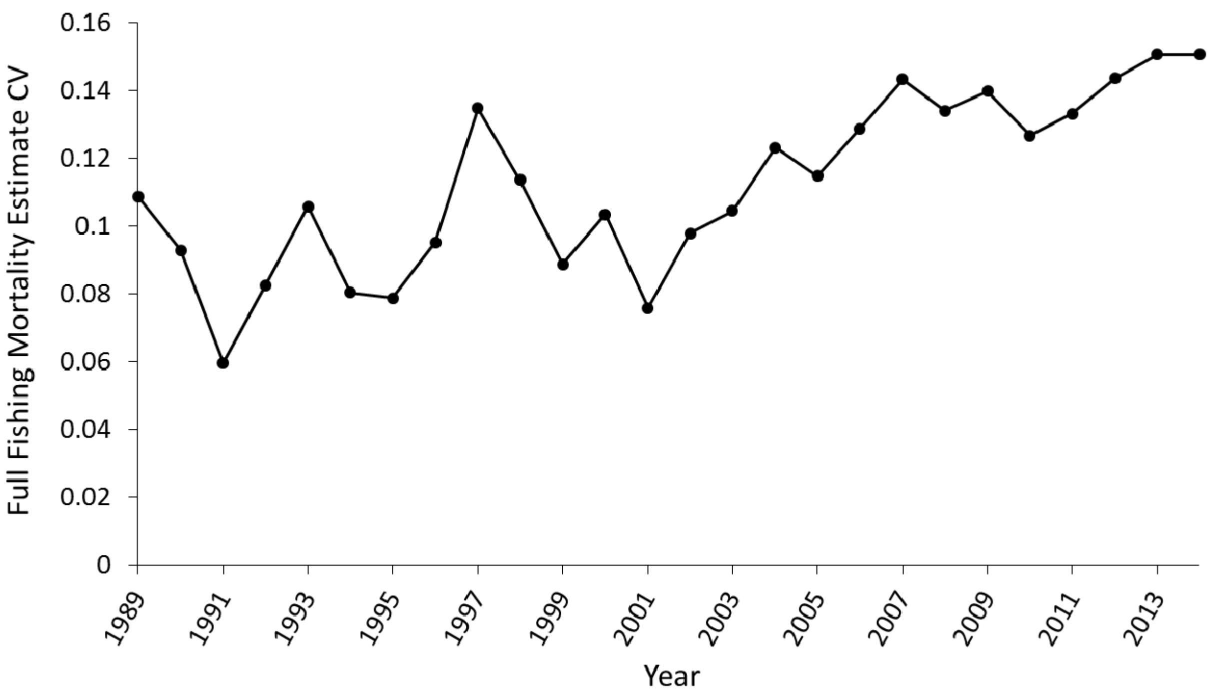


Figure 98. **Base modified-CSA model full fishing mortality estimate CVs for spot derived from asymptotic standard errors.**

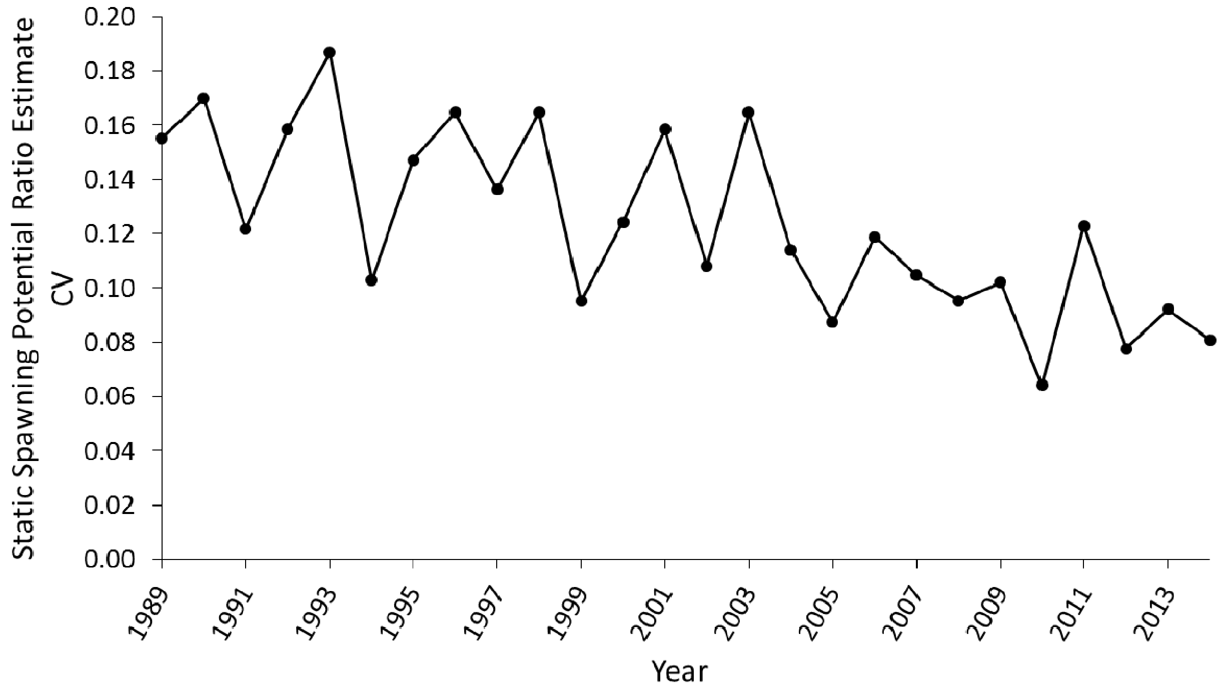


Figure 99. **Base modified-CSA model static spawning potential ratio estimate CVs for spot derived from asymptotic standard errors.**

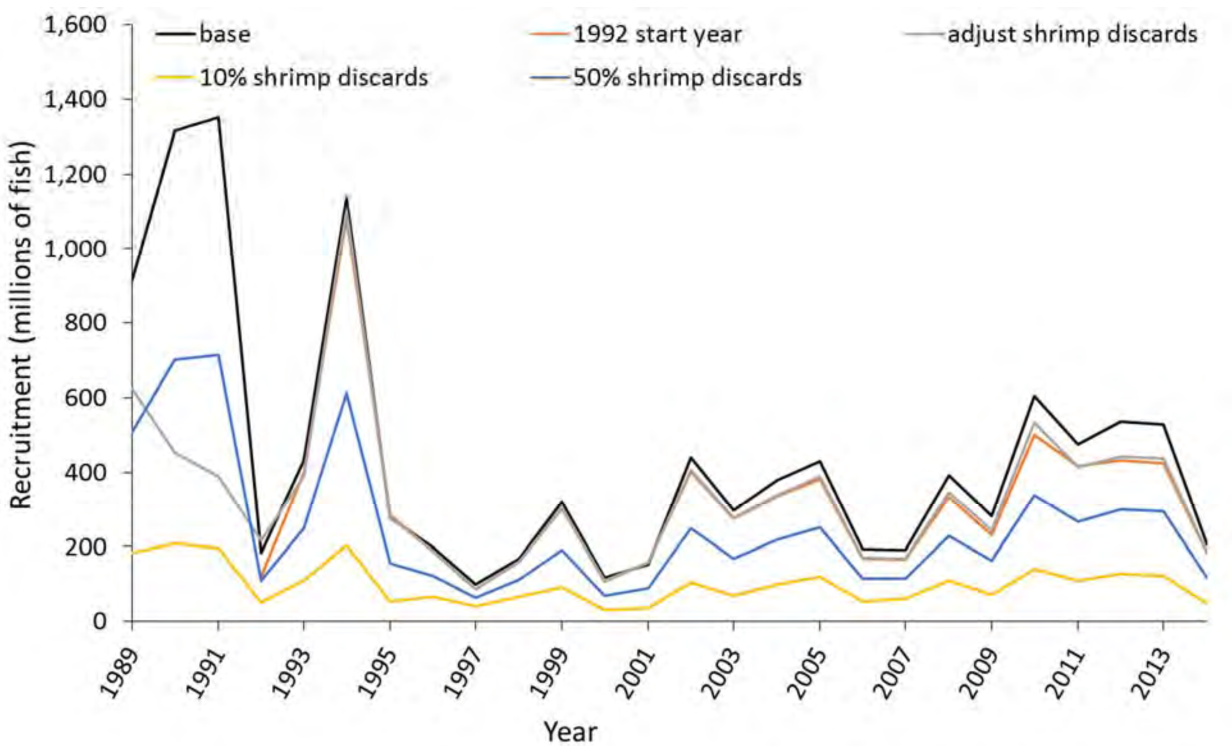


Figure 100. **Recruitment estimates for spot from the base modified-CSA model and sensitivity configurations focusing on shrimp trawl discard estimates (see Table 95 for description of sensitivity configurations).**

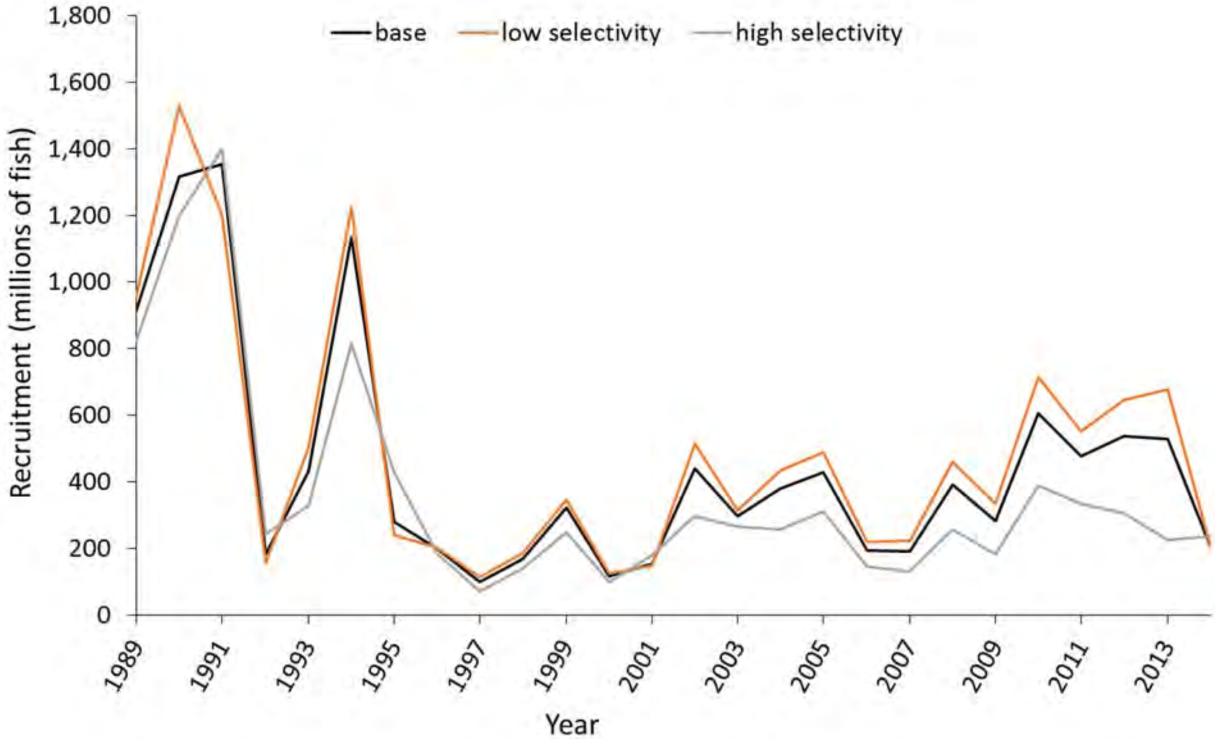


Figure 101. **Recruitment estimates for spot from the base modified-CSA model and sensitivity configurations focusing on recruit selectivity assumptions (see Table 95 for description of sensitivity configurations).**

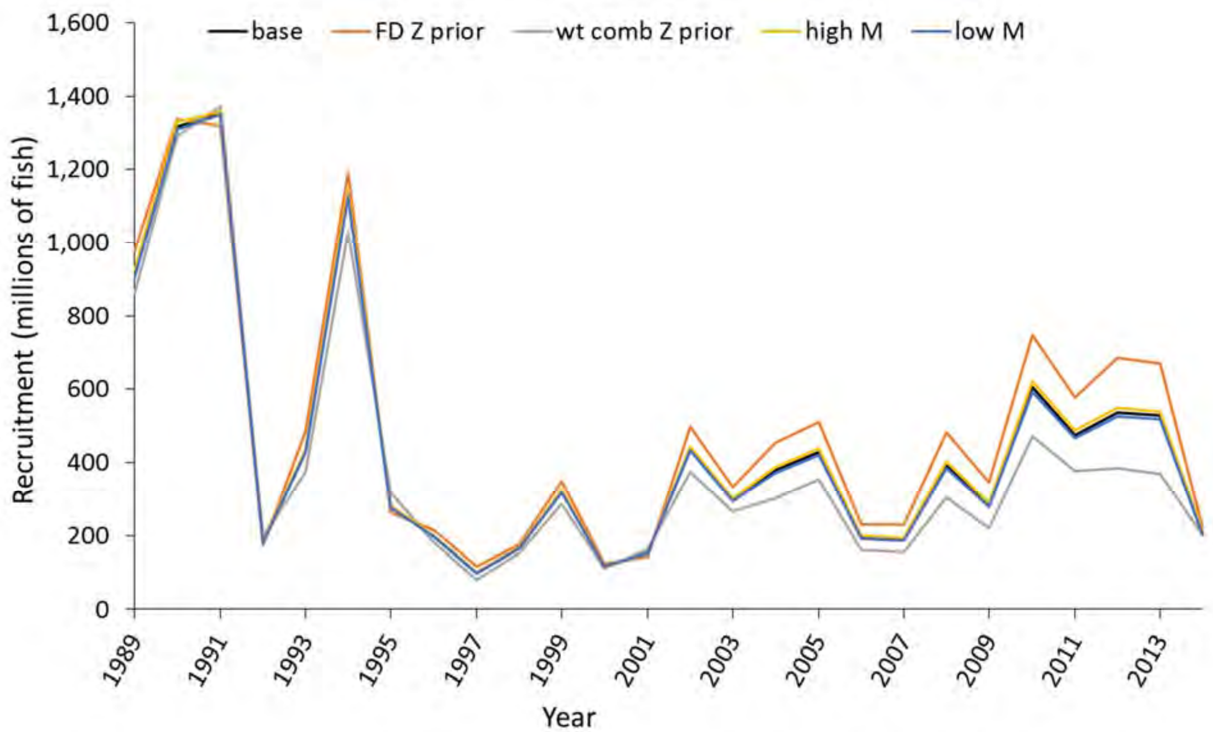


Figure 102. **Recruitment estimates for spot from the base modified-CSA model and sensitivity configurations focusing on assumptions about mortality (see Table 95 for description of sensitivity configurations).**

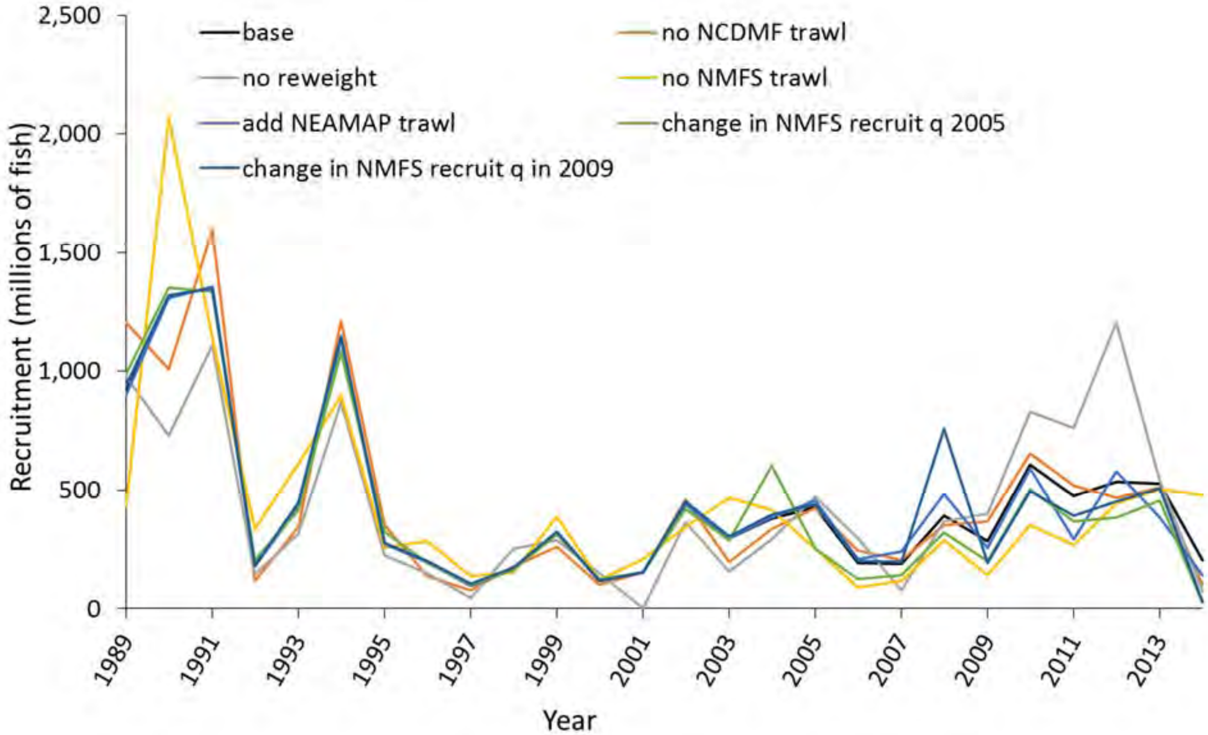


Figure 103. **Recruitment estimates for spot from the base modified-CSA model and sensitivity configurations focusing on choices and treatment of index data (see Table 95 for description of sensitivity configurations).**

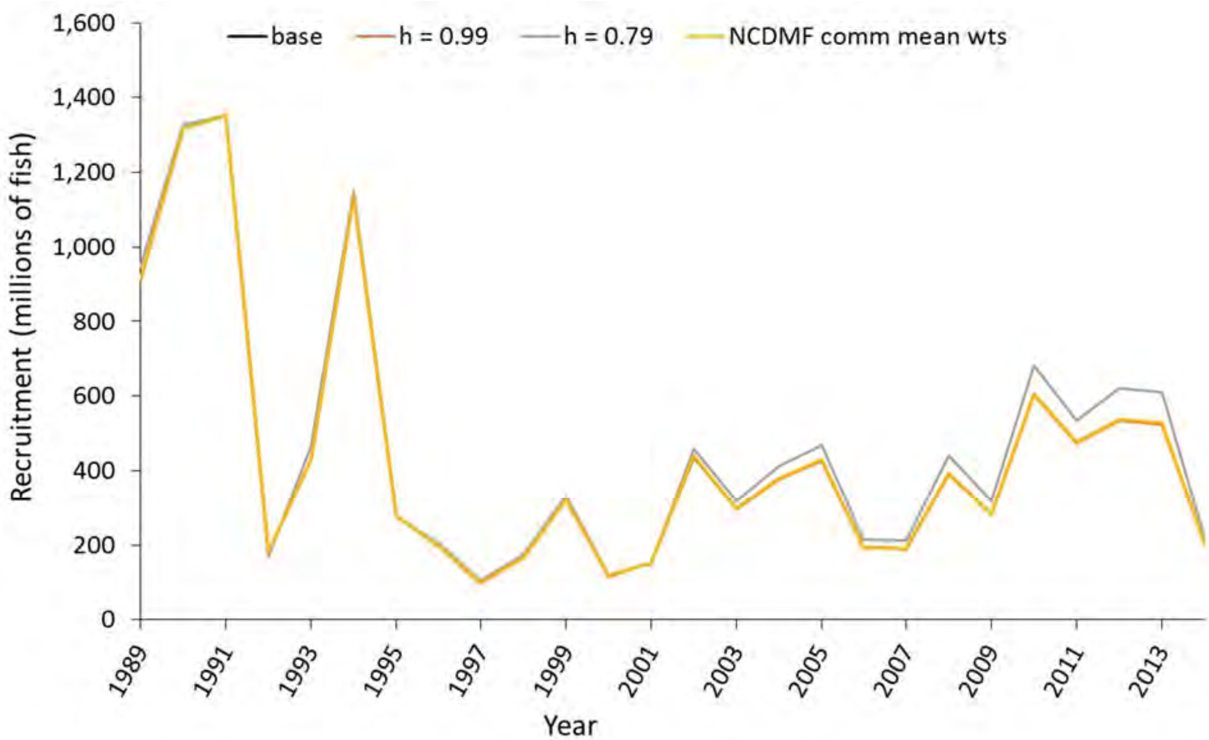


Figure 104. **Recruitment estimates for spot from the base modified-CSA model and sensitivity configurations focusing on aspects relating to the stock-recruit relationship (see Table 95 for description of sensitivity configurations).**

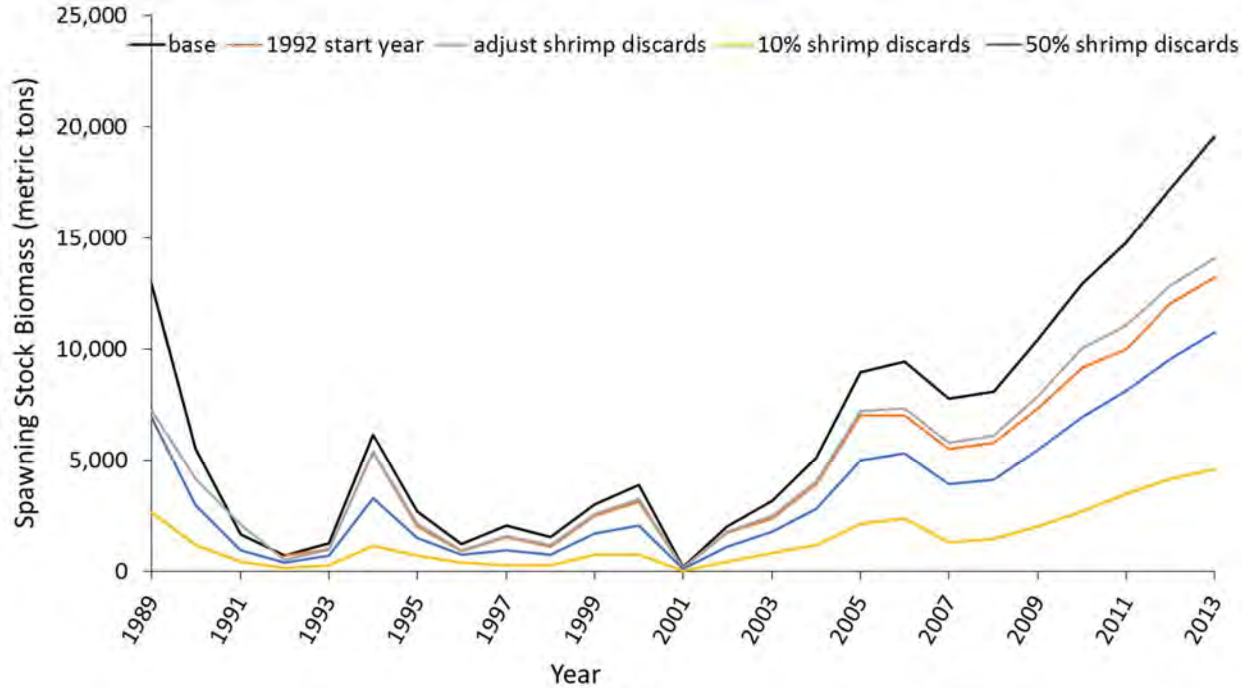


Figure 105. **End-year spawning stock biomass estimates for spot from the base modified-CSA model and sensitivity configurations focusing on shrimp trawl discard estimates (see Table 95 for description of sensitivity configurations).**

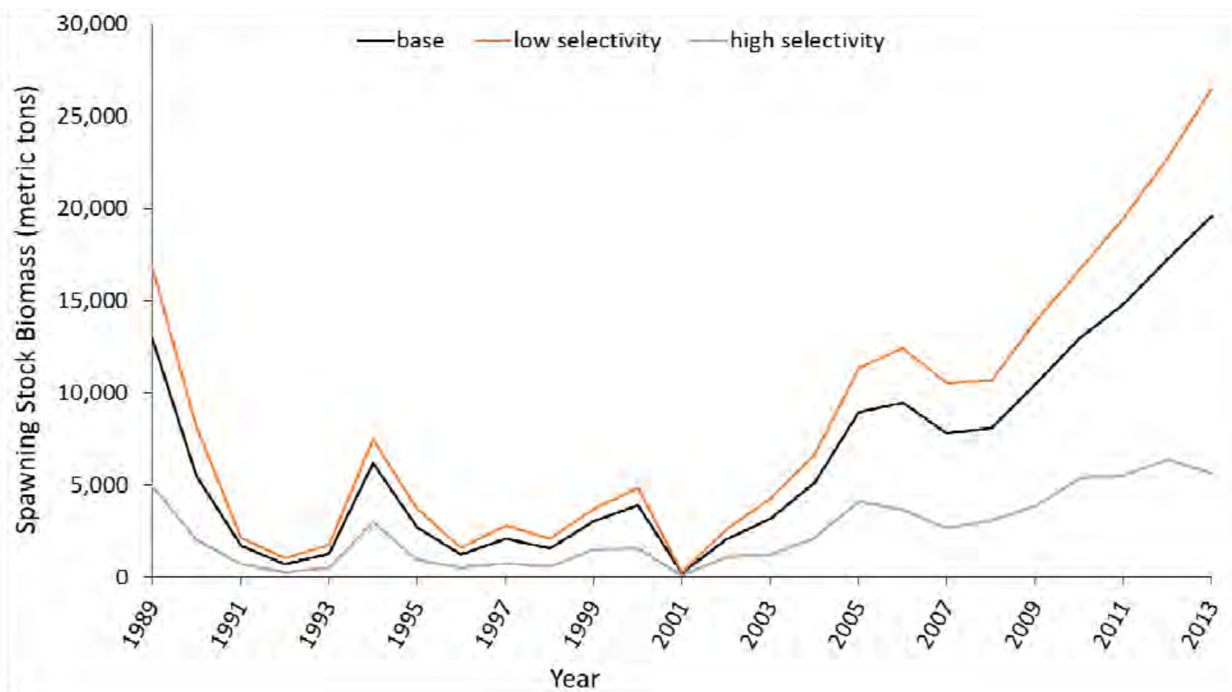


Figure 106. **End-year spawning stock biomass estimates for spot from the base modified-CSA model and sensitivity configurations focusing on recruit selectivity assumptions (see Table 95 for description of sensitivity configurations).**

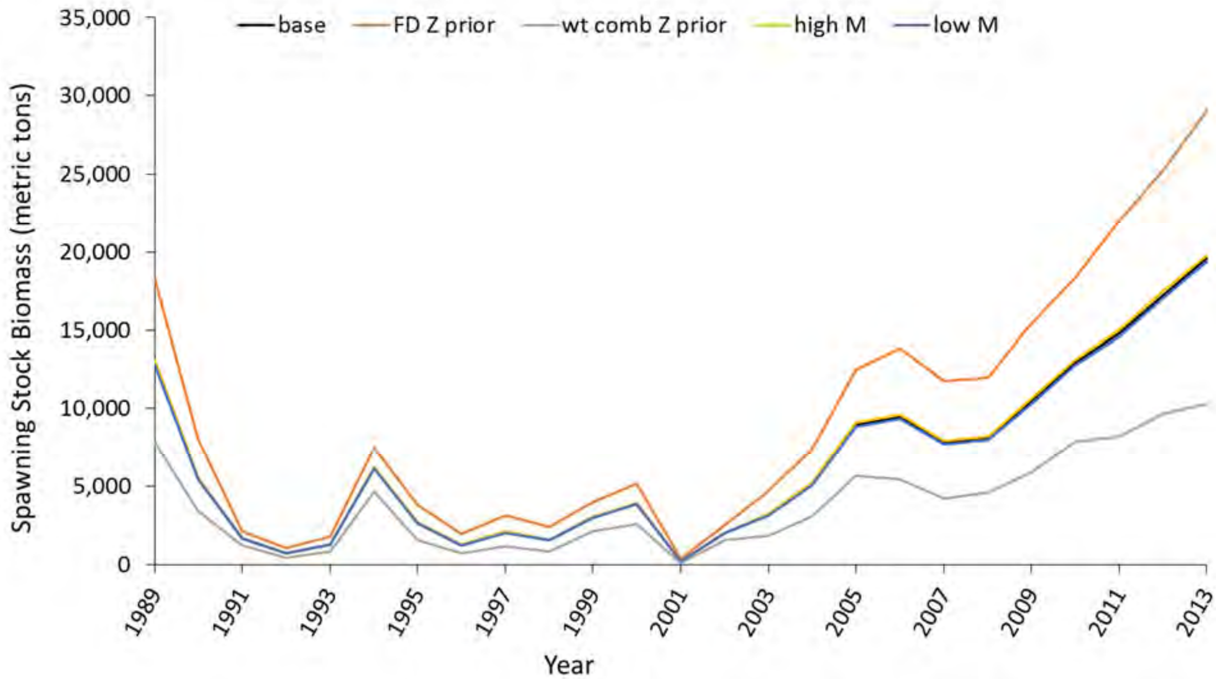


Figure 107. End-year spawning stock biomass estimates for spot from the base modified-CSA model and sensitivity configurations focusing on assumptions about mortality (see Table 95 for description of sensitivity configurations).

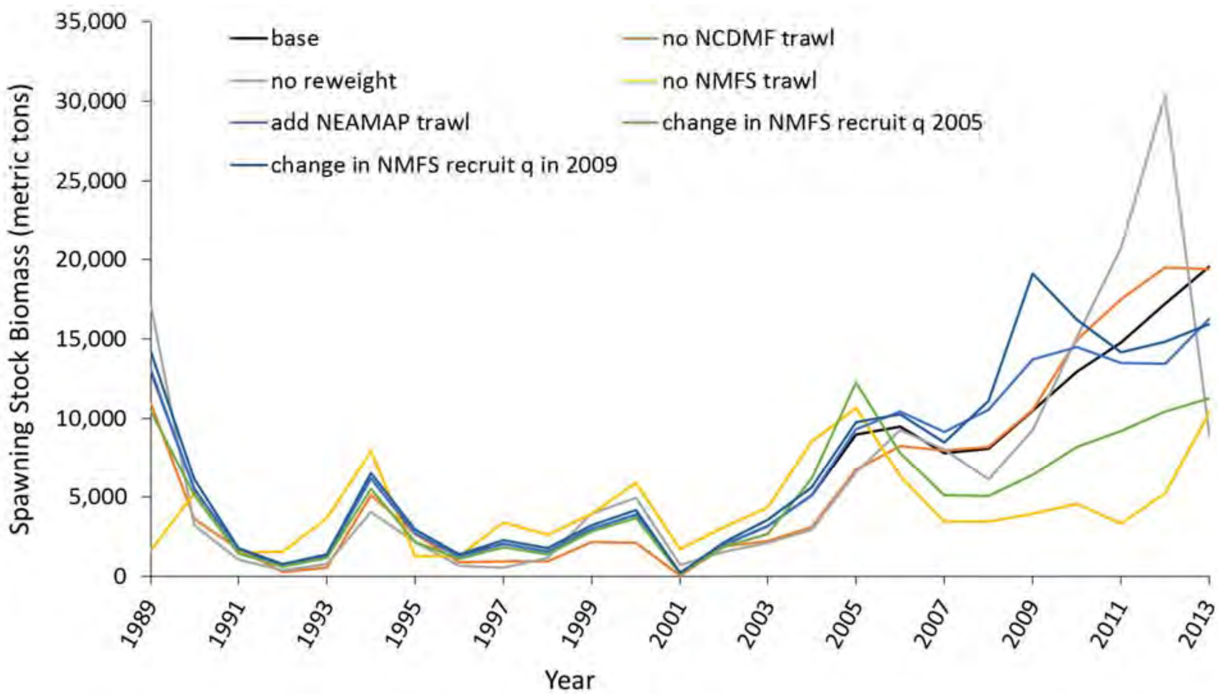


Figure 108. End-year spawning stock biomass estimates for spot from the base modified-CSA model and sensitivity configurations focusing on choices and treatment of index data (see Table 95 for description of sensitivity configurations).

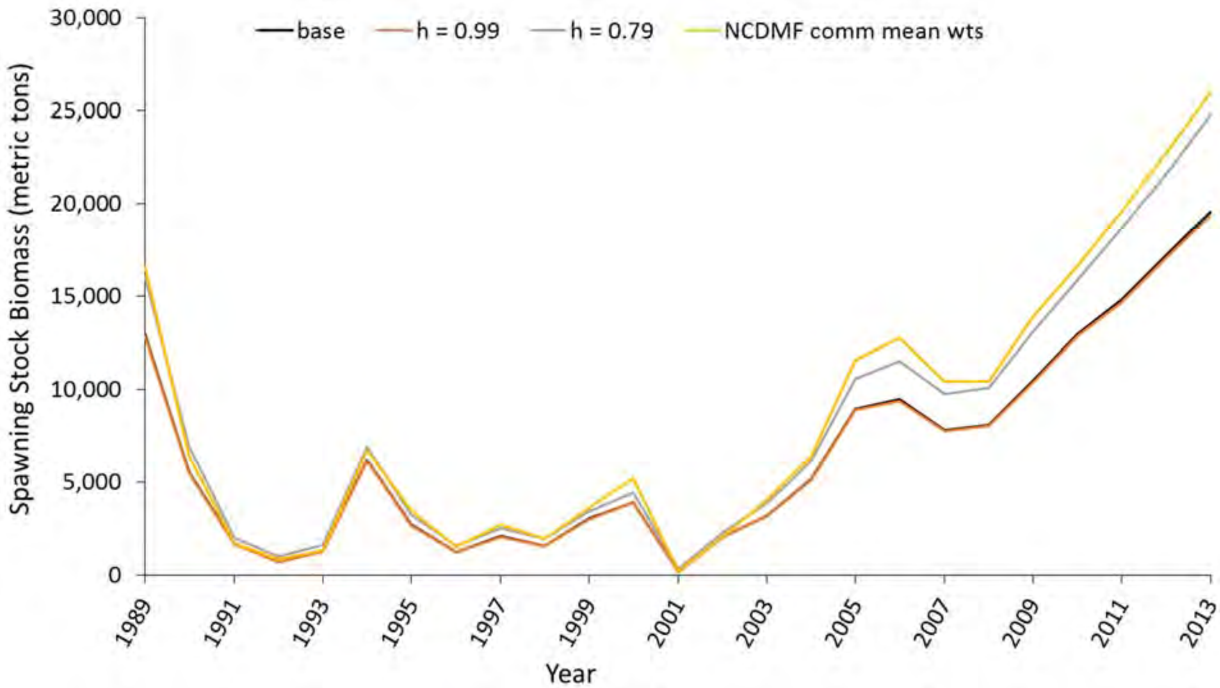


Figure 109. **End-year spawning stock biomass estimates for spot from the base modified-CSA model and sensitivity configurations focusing on aspects relating to the stock-recruit relationship (see Table 95 for description of sensitivity configurations).**

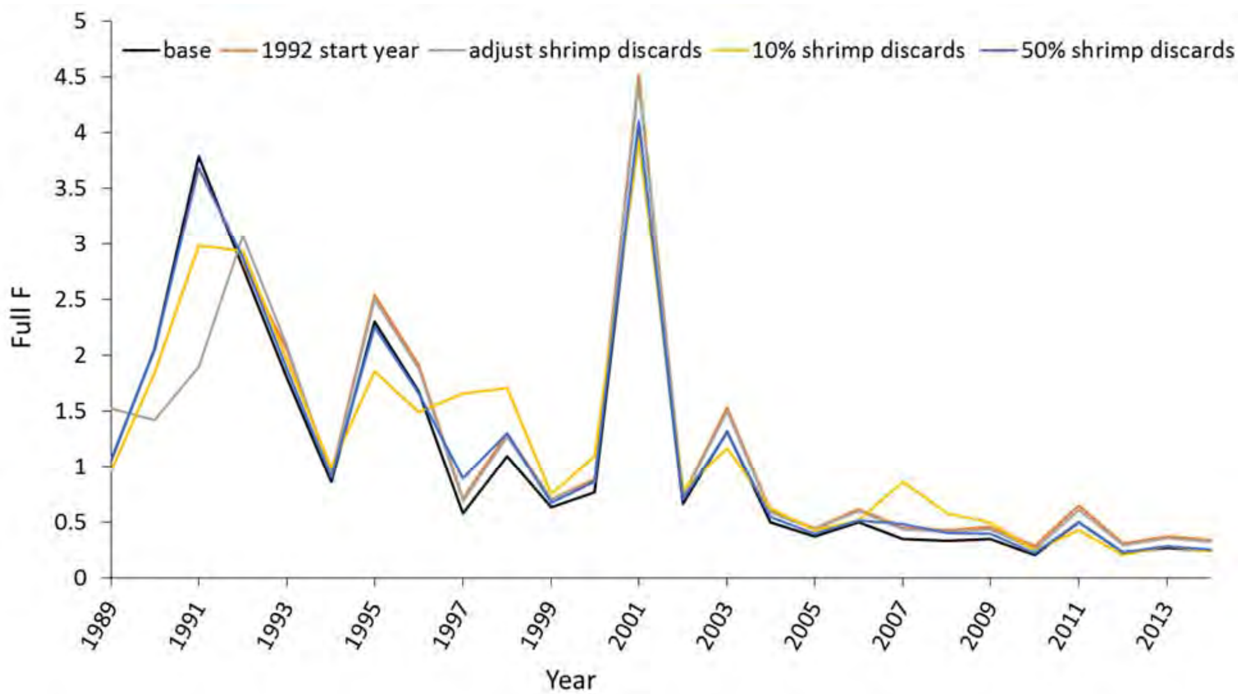


Figure 110. **Full fishing mortality estimates for spot from the base modified-CSA model and sensitivity configurations focusing on shrimp trawl discard estimates (see Table 95 for description of sensitivity configurations).**

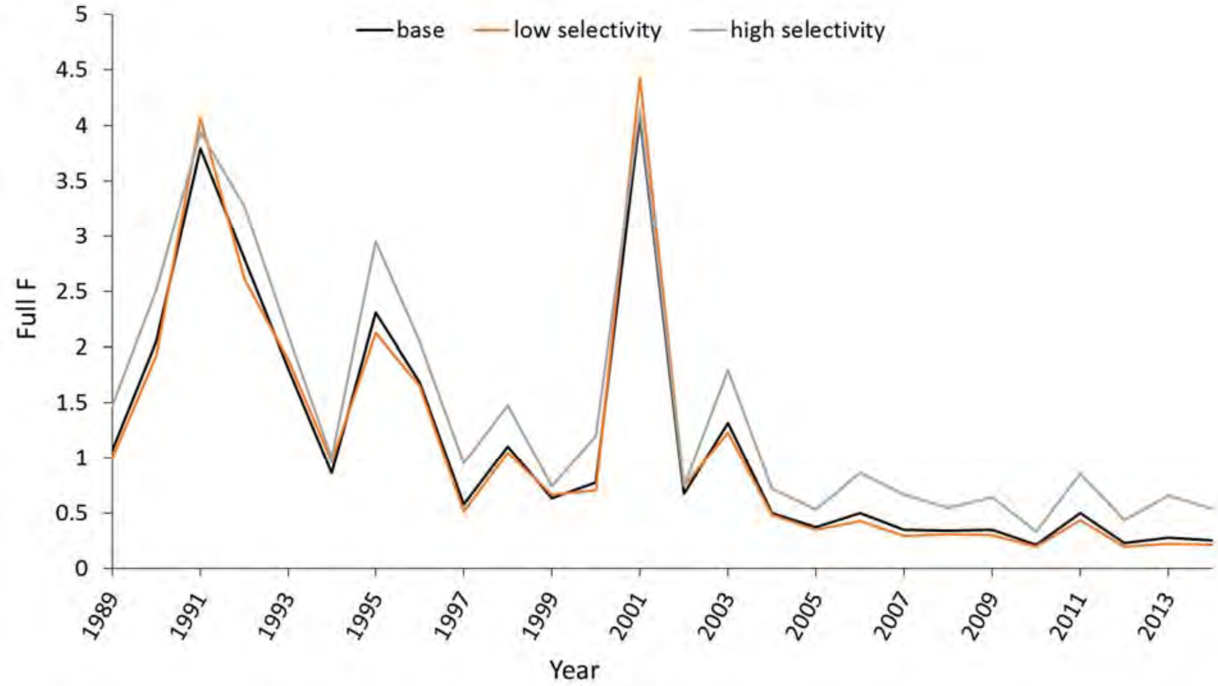


Figure 111. **Full fishing mortality estimates for spot from the base modified-CSA model and sensitivity configurations focusing on recruit selectivity assumptions (see Table 95 for description of sensitivity configurations).**

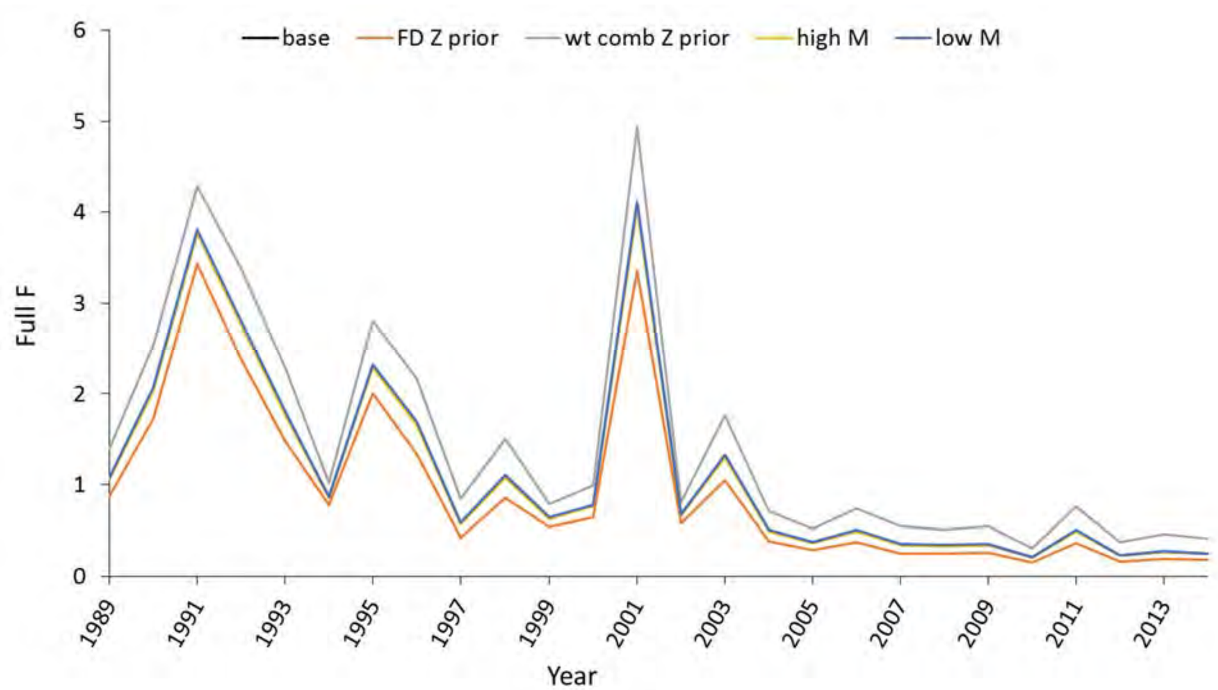


Figure 112. **Full fishing mortality estimates for spot from the base modified-CSA model and sensitivity configurations focusing on assumptions about mortality (see Table 95 for description of sensitivity configurations).**

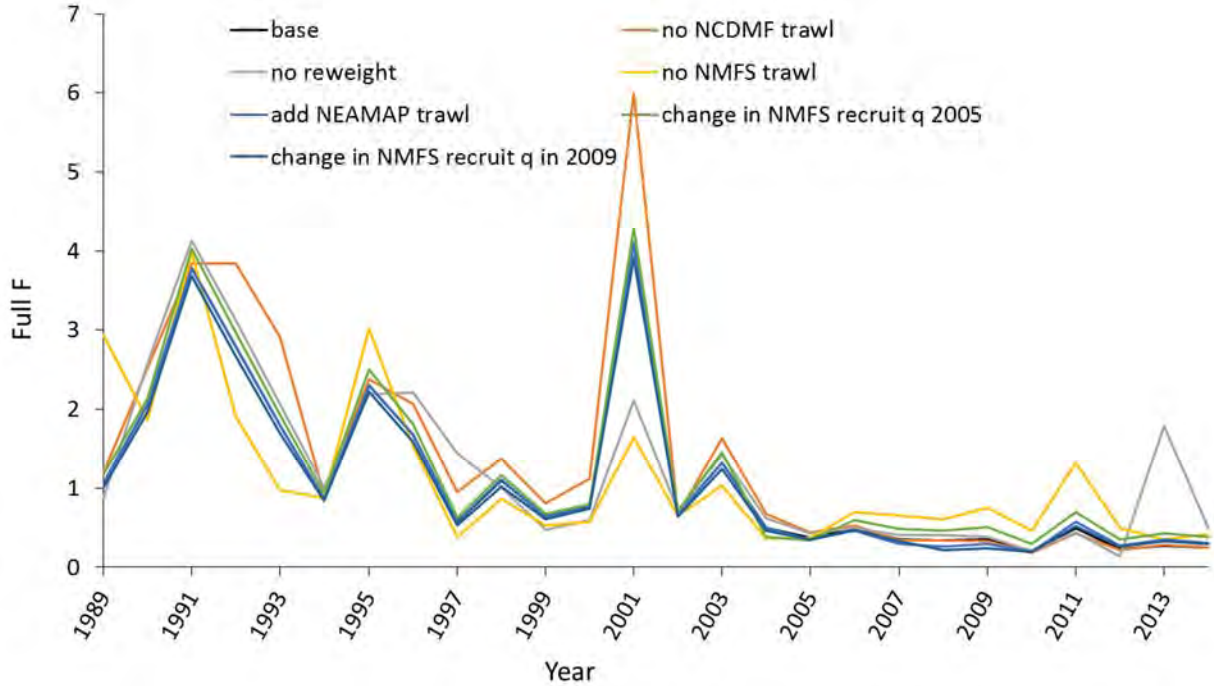


Figure 113. **Full fishing mortality estimates for spot from the base modified-CSA model and sensitivity configurations focusing on choices and treatment of index data (see Table 95 for description of sensitivity configurations).**

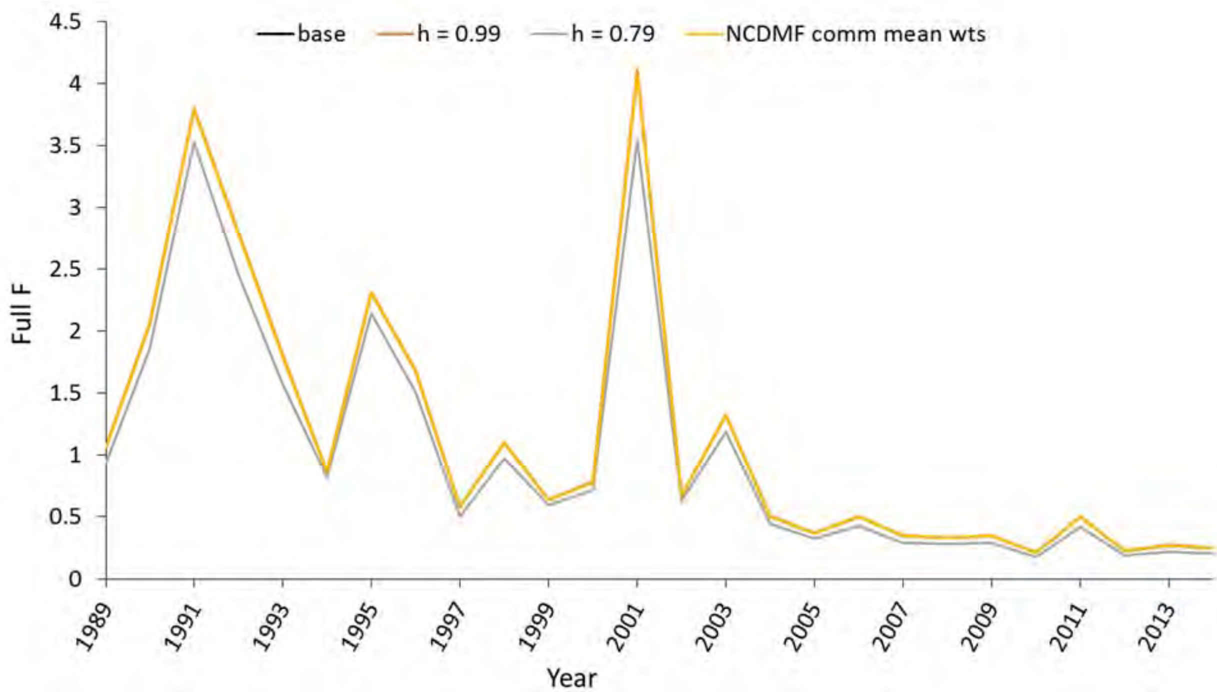


Figure 114. **Full fishing mortality estimates for spot from the base modified-CSA model and sensitivity configurations focusing on aspects relating to the stock-recruit relationship (see Table 95 for description of sensitivity configurations).**

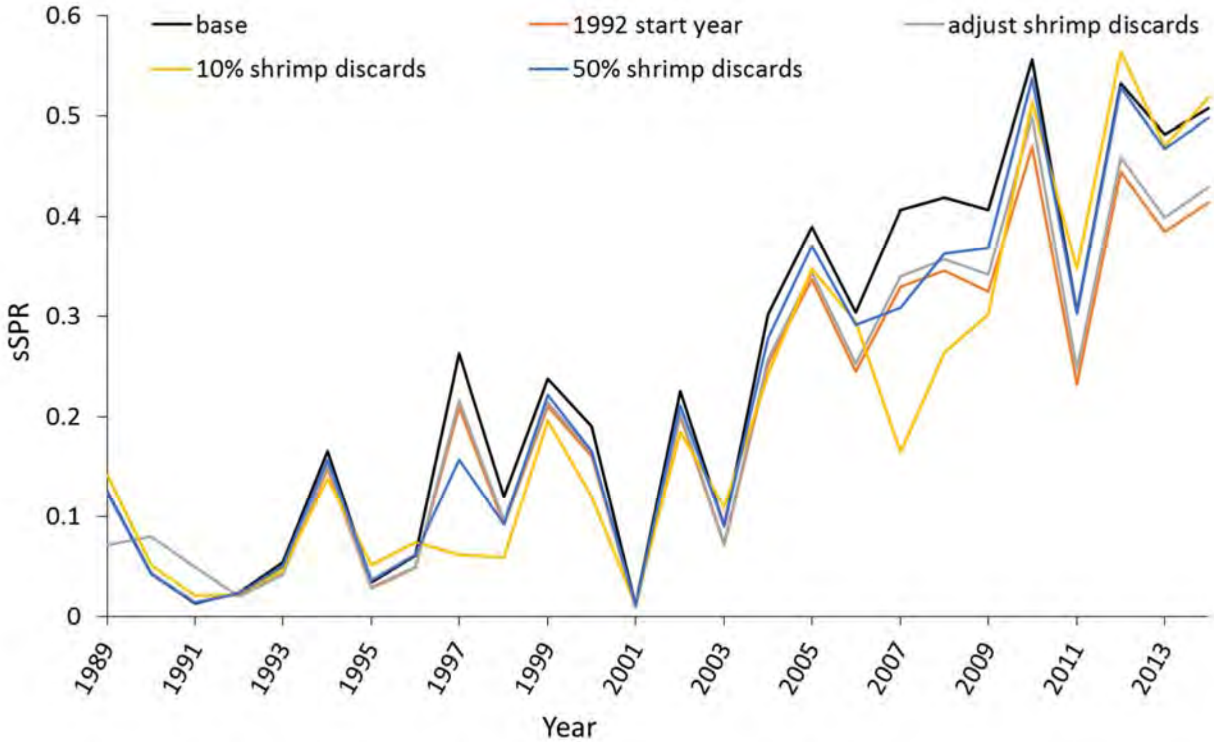


Figure 115. **Static spawning potential ratio estimates for spot from the base modified-CSA model and sensitivity configurations focusing on shrimp trawl discard estimates (see Table 95 for description of sensitivity configurations).**

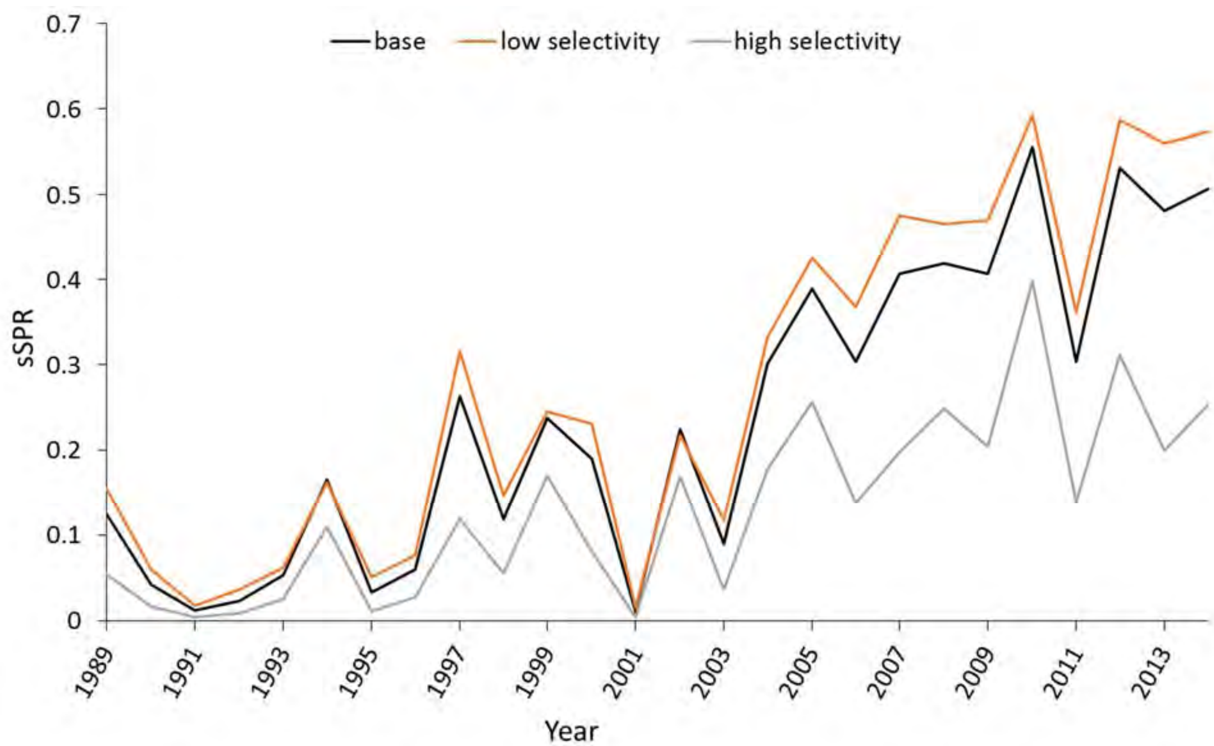


Figure 116. **Static spawning potential ratio estimates for spot from the base modified-CSA model and sensitivity configurations focusing on recruit selectivity assumptions (see Table 95 for description of sensitivity configurations).**

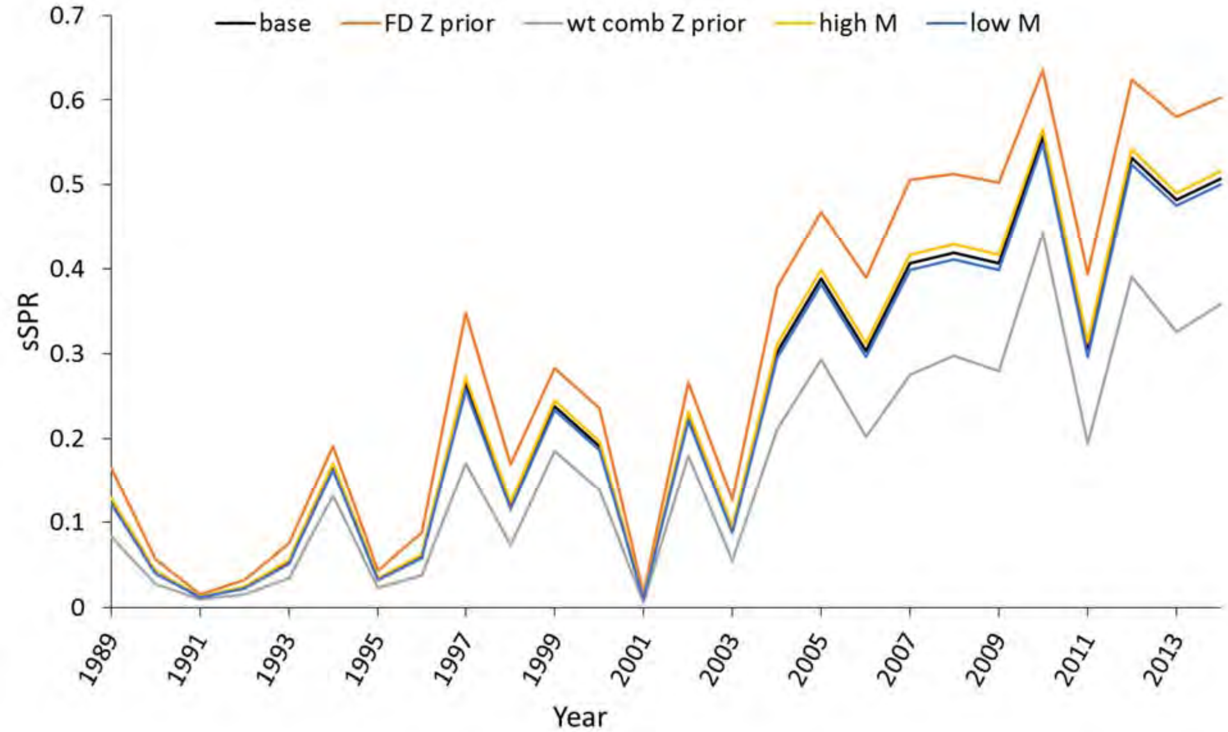


Figure 117. **Static spawning potential ratio estimates for spot from the base modified-CSA model and sensitivity configurations focusing on assumptions about mortality (see Table 95 for description of sensitivity configurations).**

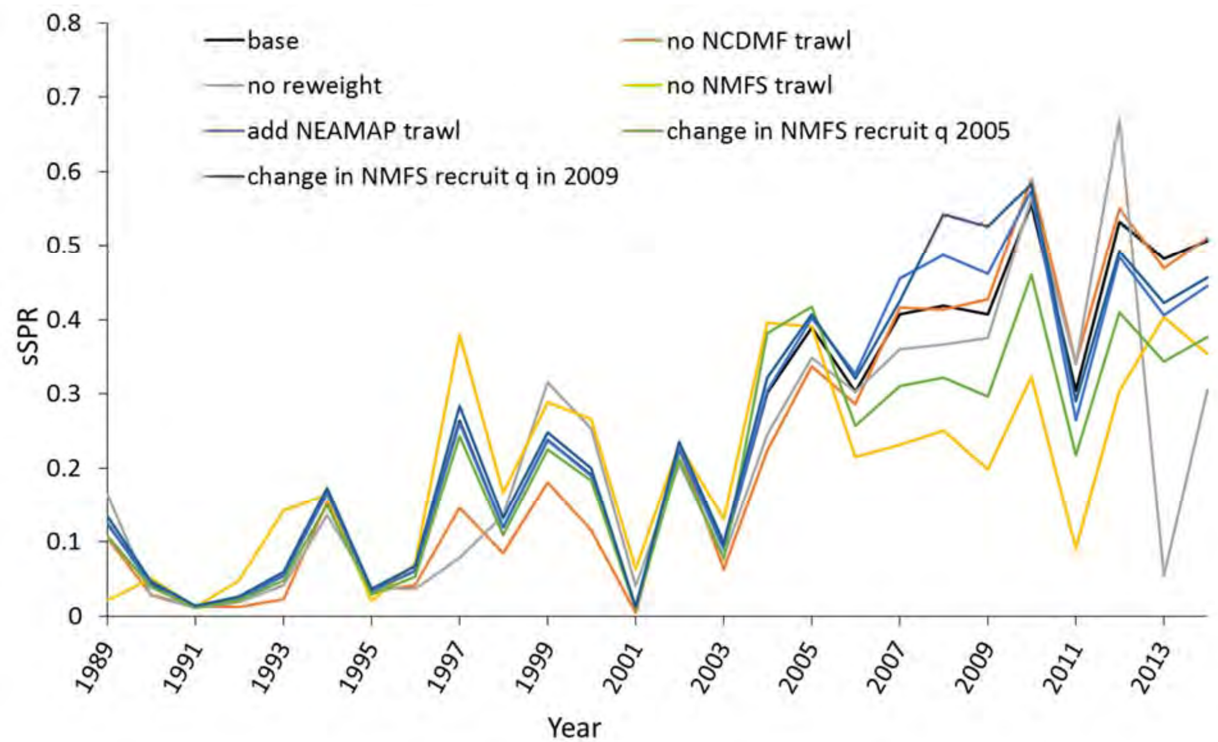


Figure 118. **Static spawning potential ratio estimates for spot from the base modified-CSA model and sensitivity configurations focusing on choices and treatment of index data (see Table 95 for description of sensitivity configurations).**

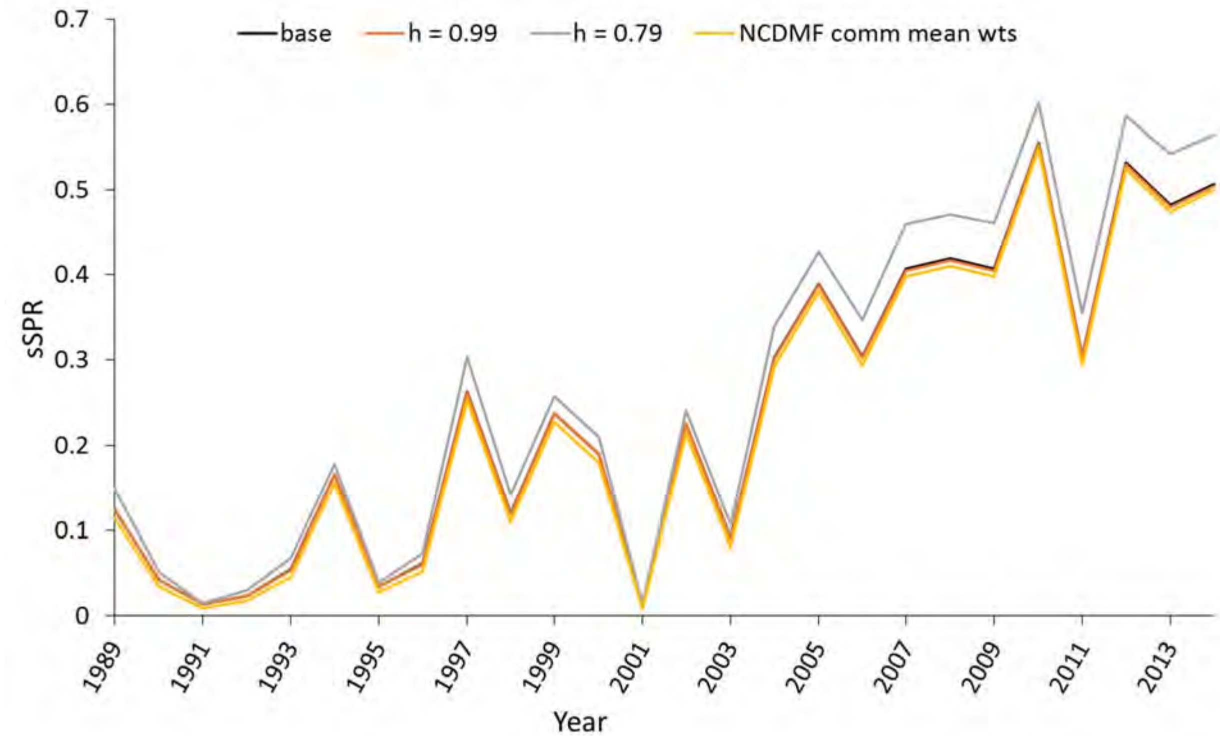


Figure 119. Static spawning potential ratio estimates for spot from the base modified-CSA model and sensitivity configurations focusing on aspects relating to the stock-recruit relationship (see Table 95 for description of sensitivity configurations).

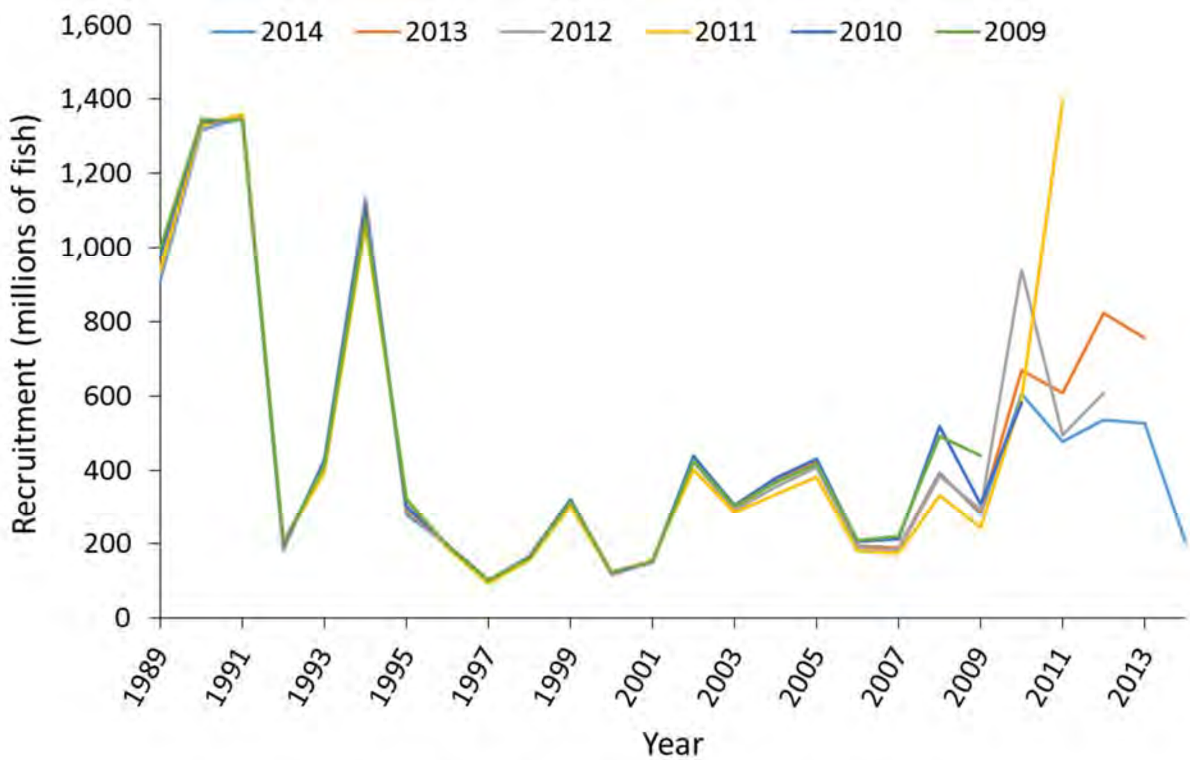


Figure 120. Retrospective plot of recruitment estimates for spot from the base modified-CSA model (2014) and five year peel.

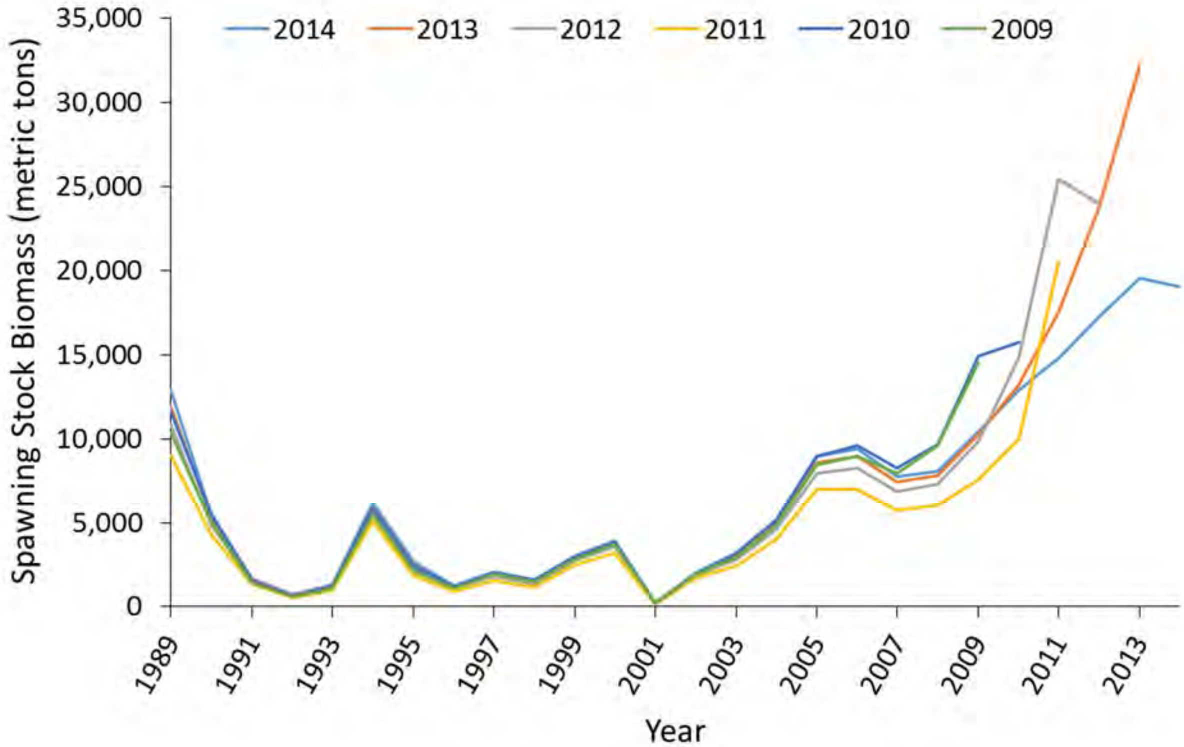


Figure 121. Retrospective plot of end-year spawning stock biomass estimates for spot from the base modified-CSA model (2014) and five year peel.

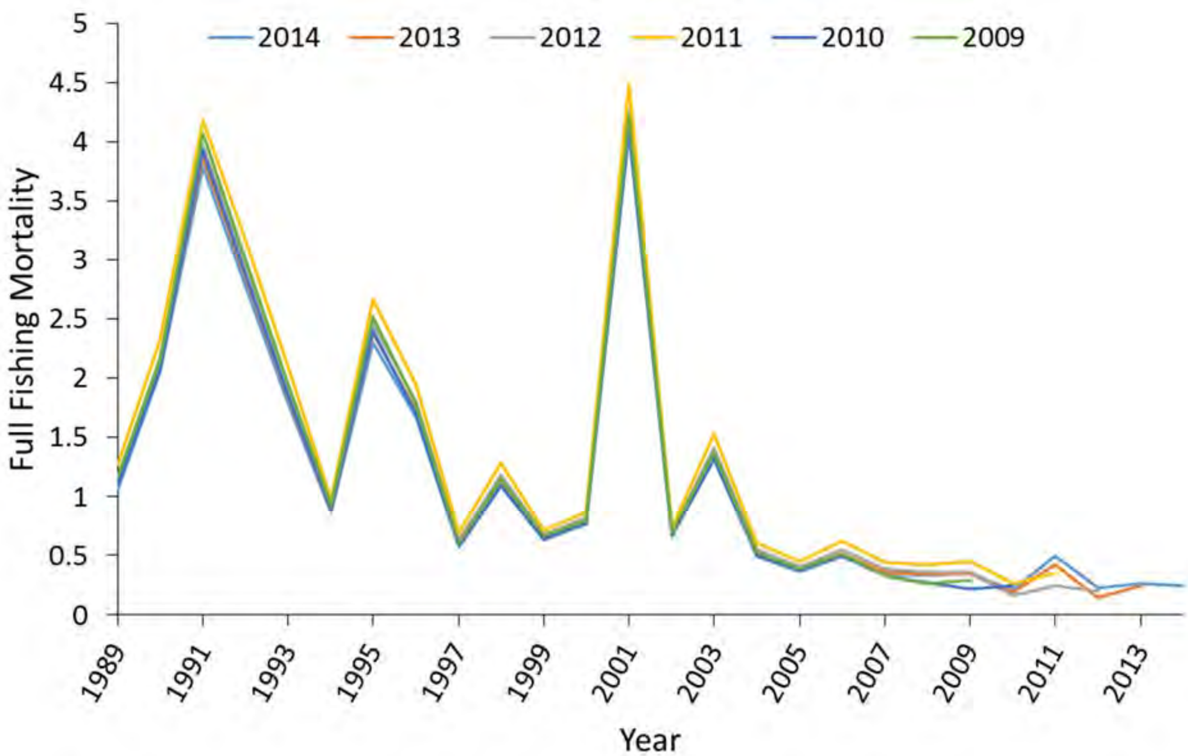


Figure 122. Retrospective plot of full fishing mortality estimates for spot from the base modified-CSA model (2014) and five year peel.

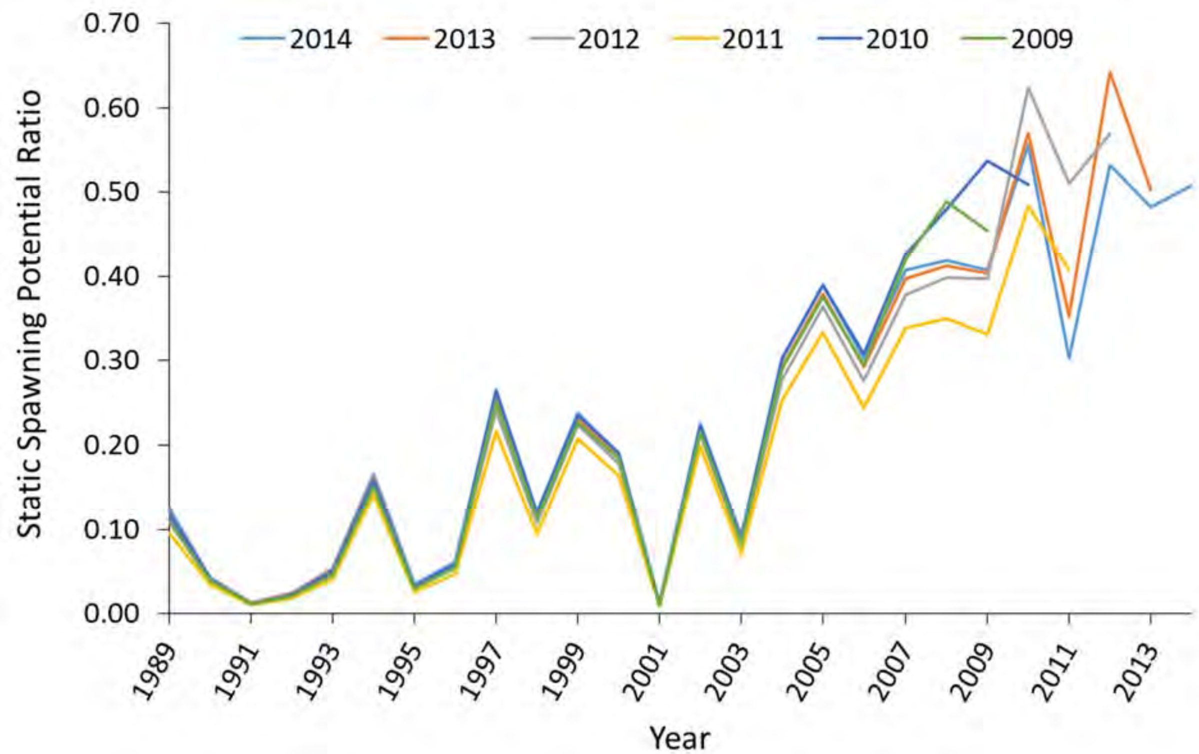


Figure 123. Retrospective plot of static spawning potential ratio estimates for spot from the base modified-CSA model (2014) and five year peel.

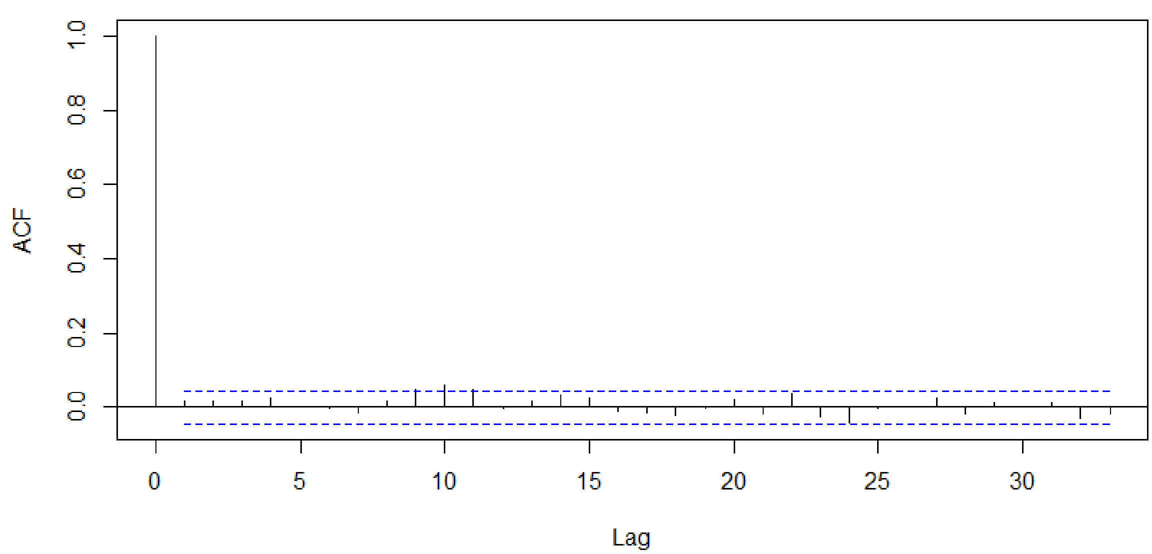


Figure 124. Autocorrelation of MCMC samples for the initial recruitment parameter for spot from the base modified-CSA model. Two million MCMC samples were drawn with a burn-in of one thousand samples and a thinning rate of one thousand samples (final n = 2,000). Dashed blue lines are 95% confidence intervals with values exceeding these lines being statistically different than zero.

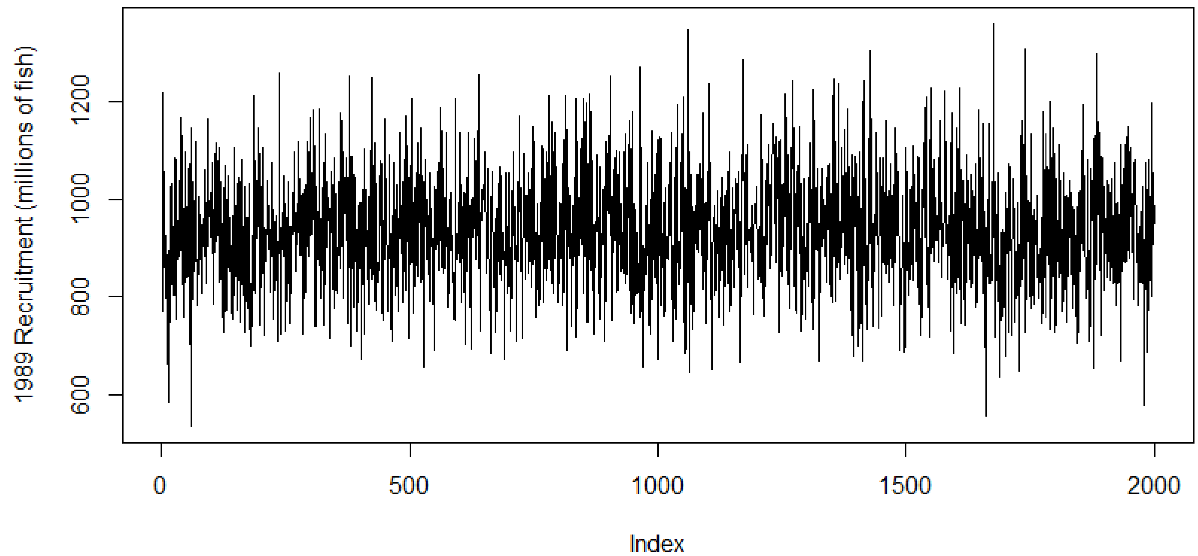


Figure 125. **Trace plot of MCMC samples for the initial recruitment parameter for spot from the base modified-CSA model. Two million MCMC samples were drawn with a burn-in of one thousand samples and a thinning rate of one thousand samples (final n = 2,000).**

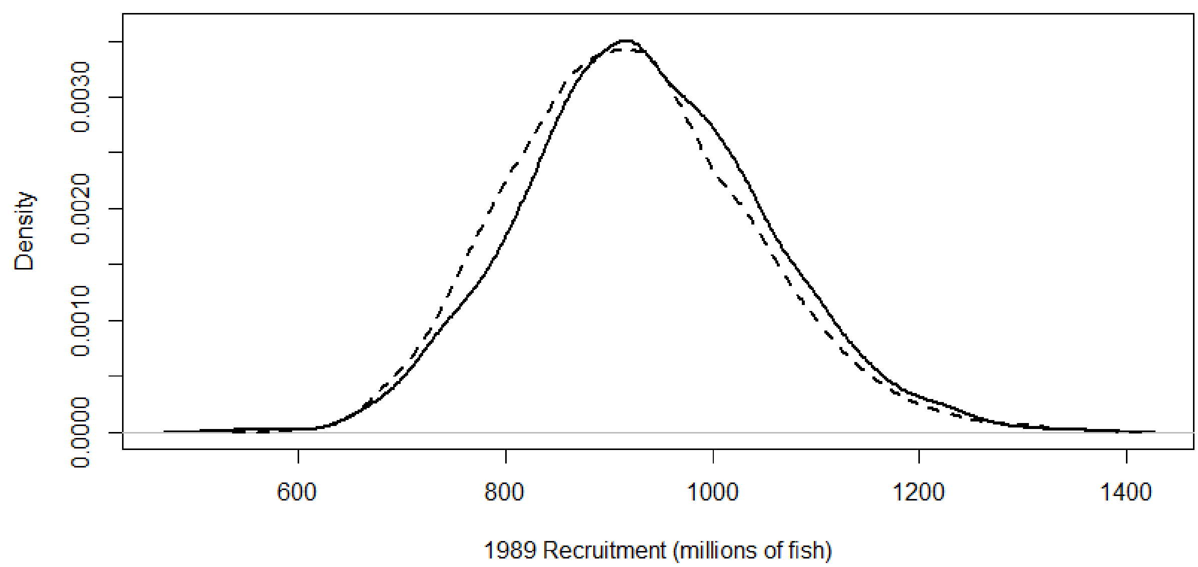


Figure 126. **Density of the base modified-CSA model initial recruitment parameter estimate for spot from MCMC draws (solid line) compared to the maximum likelihood estimate and asymptotic standard errors (dashed line). Two million MCMC samples were drawn with a burn-in of one thousand samples and a thinning rate of one thousand samples (final n = 2,000).**

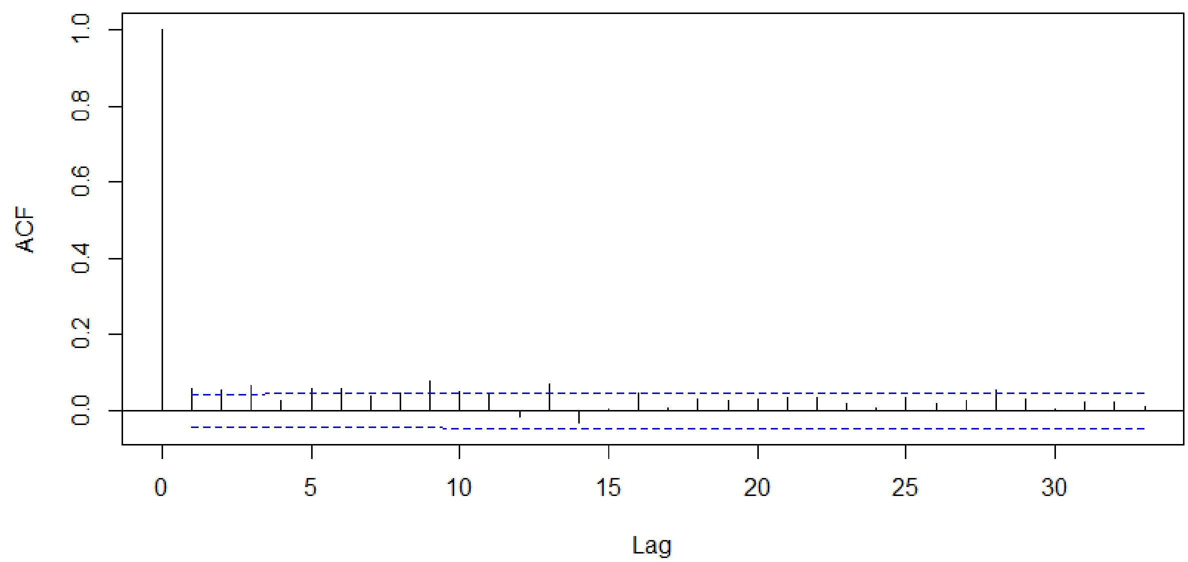


Figure 127. **Autocorrelation of MCMC samples for the initial post-recruit abundance parameter for spot from the base modified-CSA model. Two million MCMC samples were drawn with a burn-in of one thousand samples and a thinning rate of one thousand samples (final n = 2,000). Dashed blue lines are 95% confidence intervals with values exceeding these lines being statistically different than zero.**

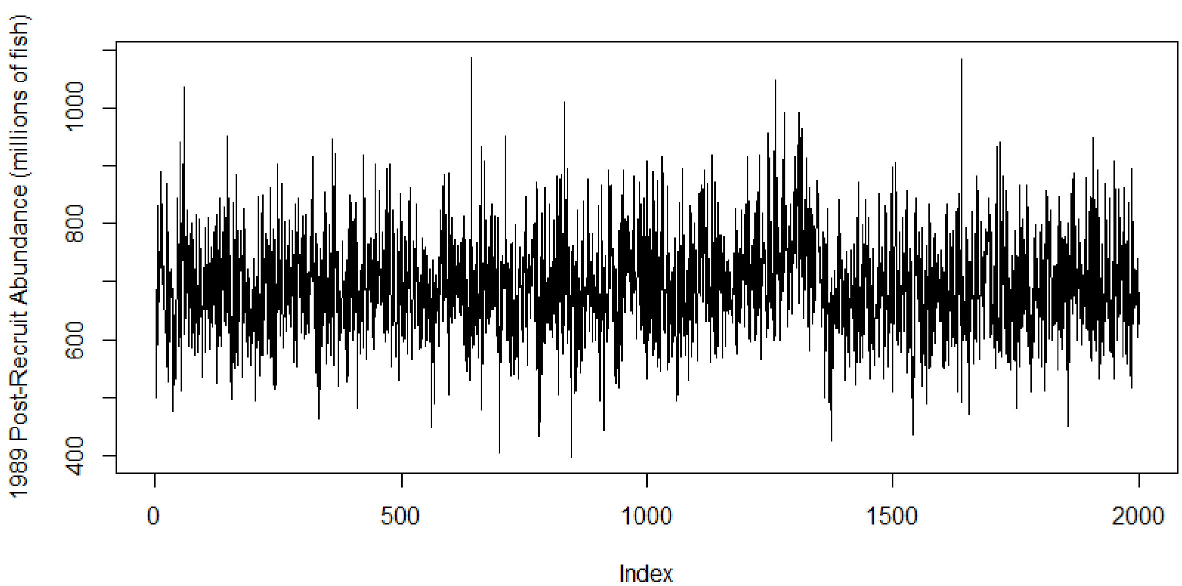


Figure 128. **Trace plot of MCMC samples for the initial post-recruit abundance parameter for spot from the base modified-CSA model. Two million MCMC samples were**

drawn with a burn-in of one thousand samples and a thinning rate of one thousand samples (final n = 2,000).

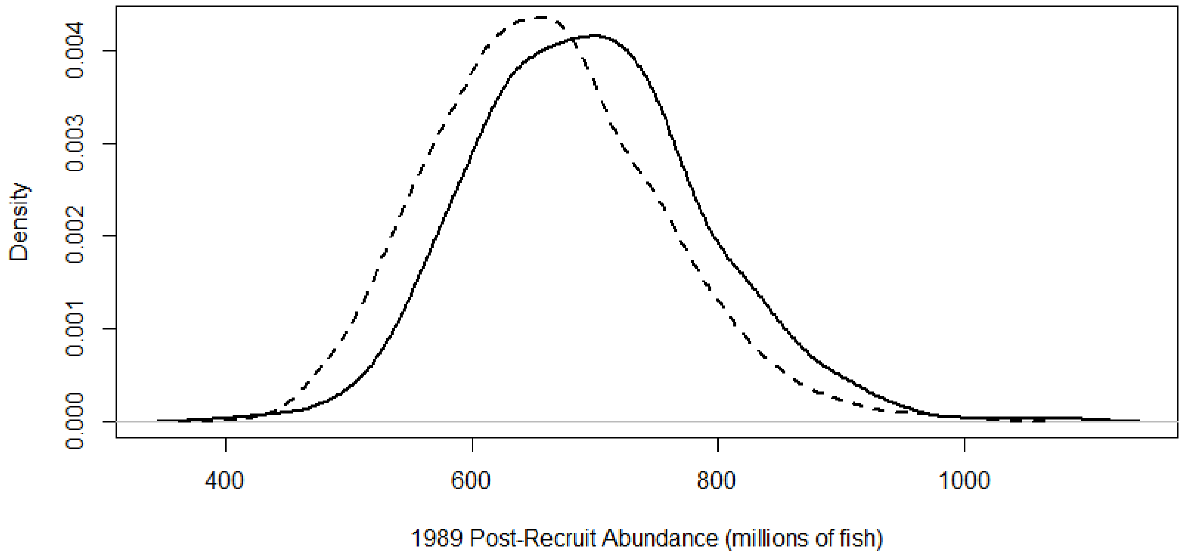


Figure 129. Density of the base modified-CSA model initial post-recruit abundance parameter estimate for spot from MCMC draws (solid line) compared to the maximum likelihood estimate and asymptotic standard errors (dashed line). Two million MCMC samples were drawn with a burn-in of one thousand samples and a thinning rate of one thousand samples (final n = 2,000).

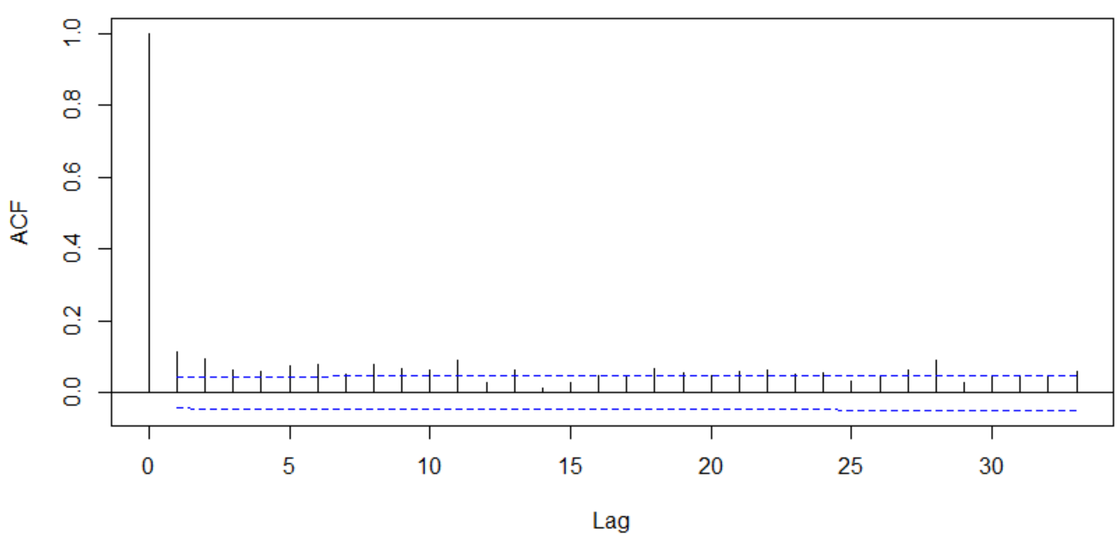


Figure 130. Autocorrelation of MCMC samples for the initial fishing mortality parameter for spot from the base modified-CSA model. Two million MCMC samples were drawn with a burn-in of one thousand samples and a thinning rate of one

thousand samples (final n = 2,000). Dashed blue lines are 95% confidence intervals with values exceeding these lines being statistically different than zero.

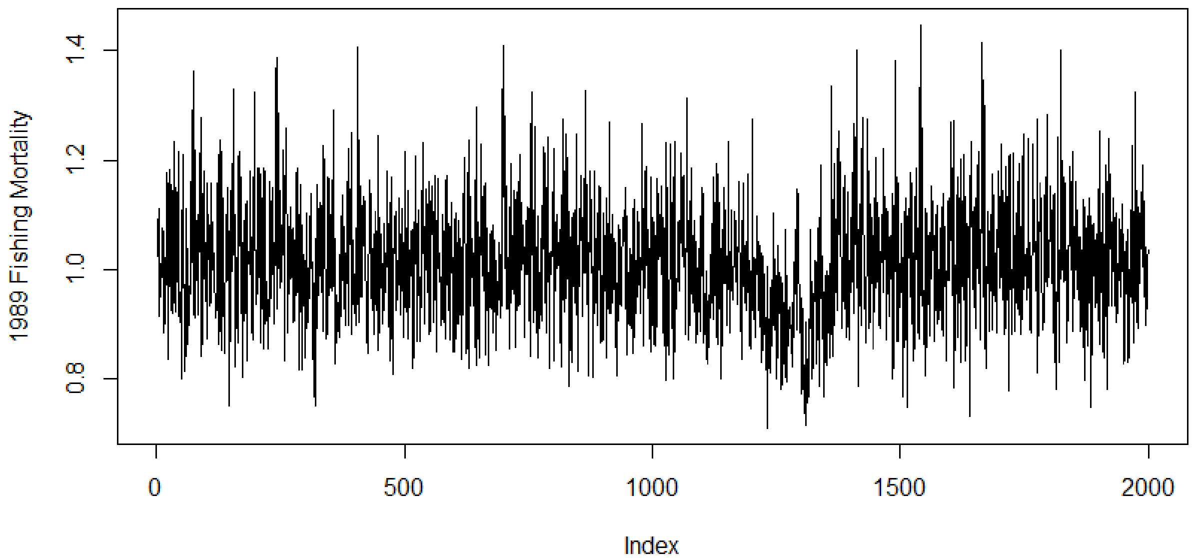


Figure 131. Trace plot of MCMC samples for the initial fishing mortality parameter for spot from the base modified-CSA model. Two million MCMC samples were drawn with a burn-in of one thousand samples and a thinning rate of one thousand samples (final n = 2,000).

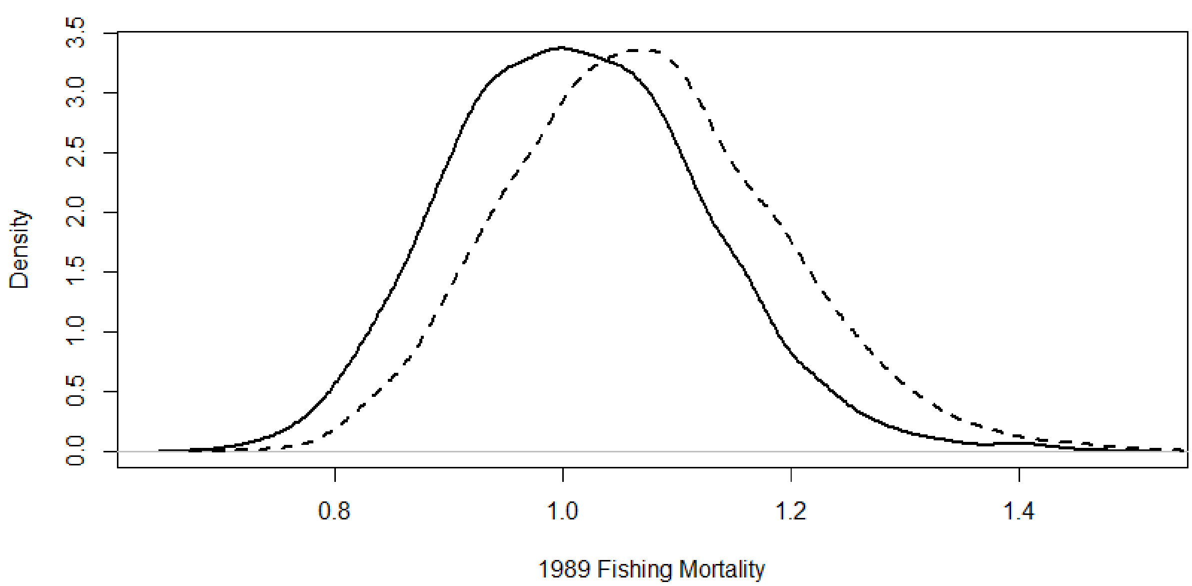


Figure 132. Density of the base modified-CSA model initial fishing mortality parameter estimate for spot from MCMC draws (solid line) compared to the maximum likelihood estimate and asymptotic standard errors (dashed line). Two million MCMC samples were drawn with a burn-in of one thousand samples and a thinning rate of one thousand samples (final n = 2,000).

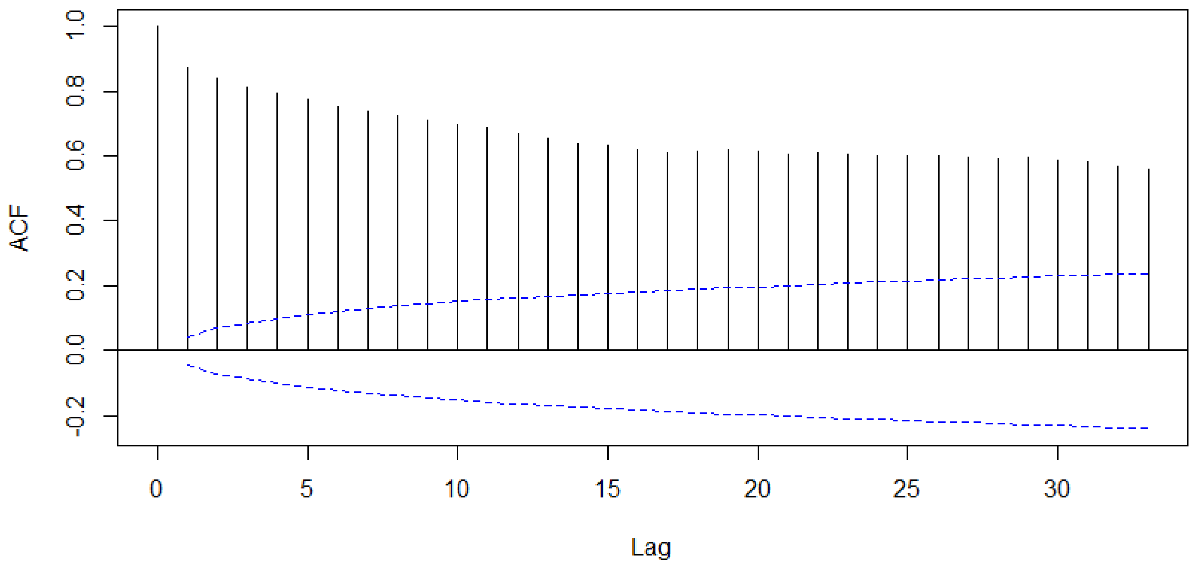


Figure 133. Autocorrelation of MCMC samples for the unfished spawning stock biomass parameter for spot from the base modified-CSA model. Two million MCMC samples were drawn with a burn-in of one thousand samples and a thinning rate of one thousand samples (final n = 2,000). Dashed blue lines are 95% confidence intervals with values exceeding these lines being statistically different than zero.

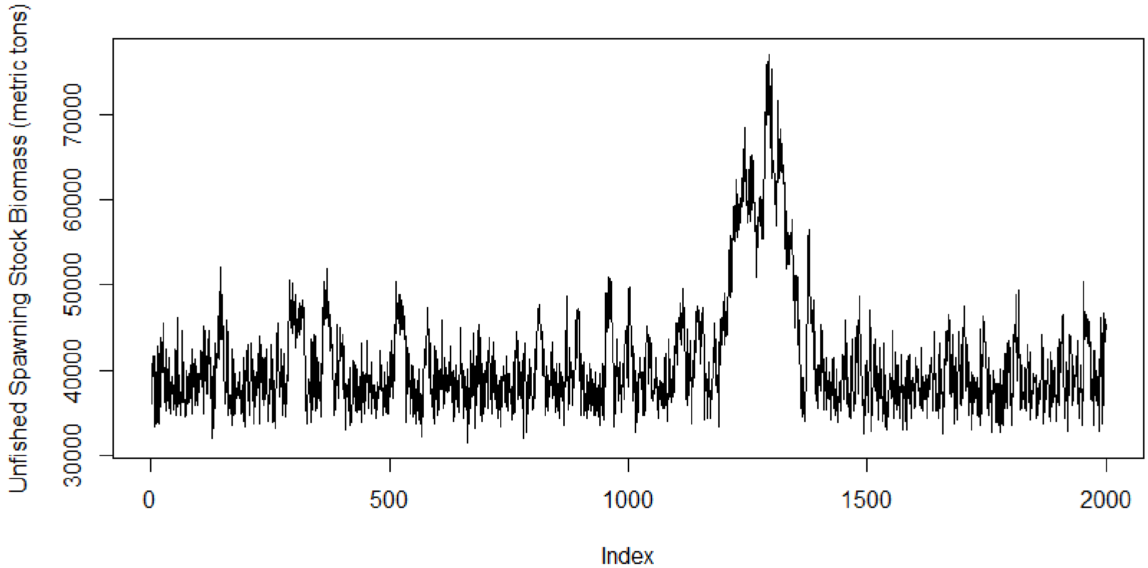


Figure 134. **Trace plot of MCMC samples for the unfished spawning stock biomass parameter for spot from the base modified-CSA model. Two million MCMC samples were drawn with a burn-in of one thousand samples and a thinning rate of one thousand samples (final n = 2,000).**

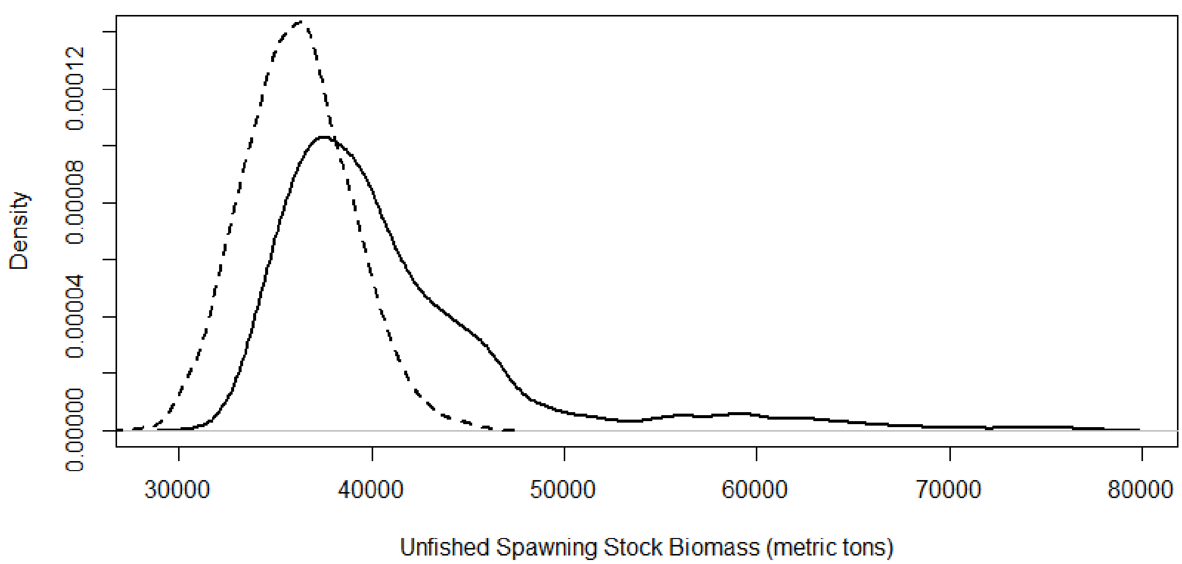


Figure 135. **Density of the base modified-CSA model unfished spawning stock biomass parameter estimate for spot from MCMC draws (solid line) compared to the maximum likelihood estimate and asymptotic standard errors (dashed line). Two million MCMC samples were drawn with a burn-in of one thousand samples and a thinning rate of one thousand samples (final n = 2,000).**

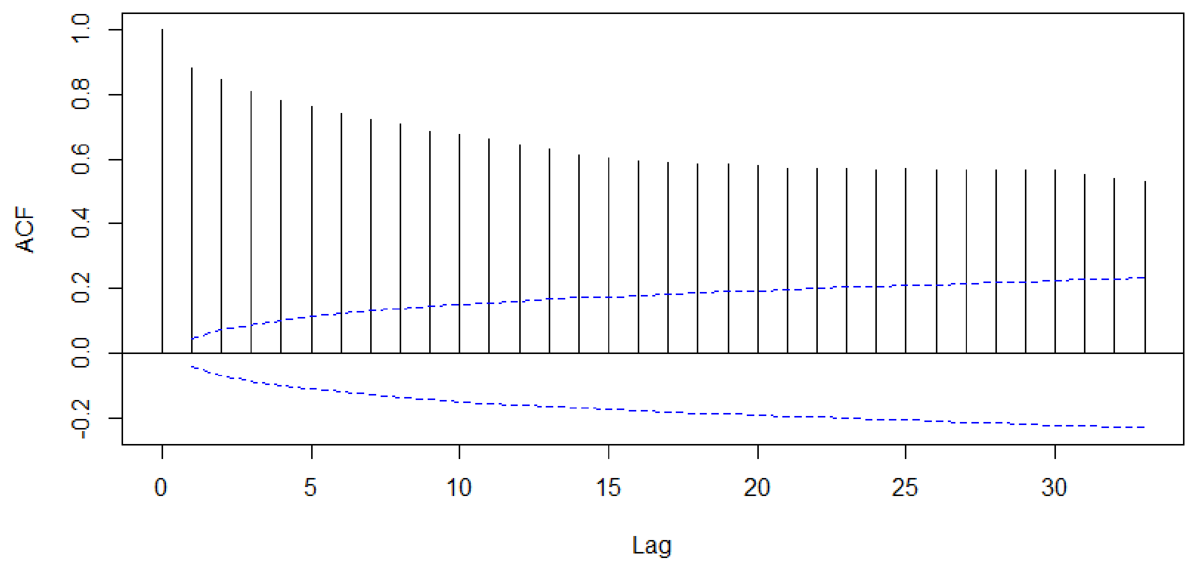


Figure 136. **Autocorrelation of MCMC samples for the steepness parameter for spot from the base modified-CSA model. Two million MCMC samples were drawn with a burn-in of one thousand samples and a thinning rate of one thousand samples (final n = 2,000). Dashed blue lines are 95% confidence intervals with values exceeding these lines being statistically different than zero.**

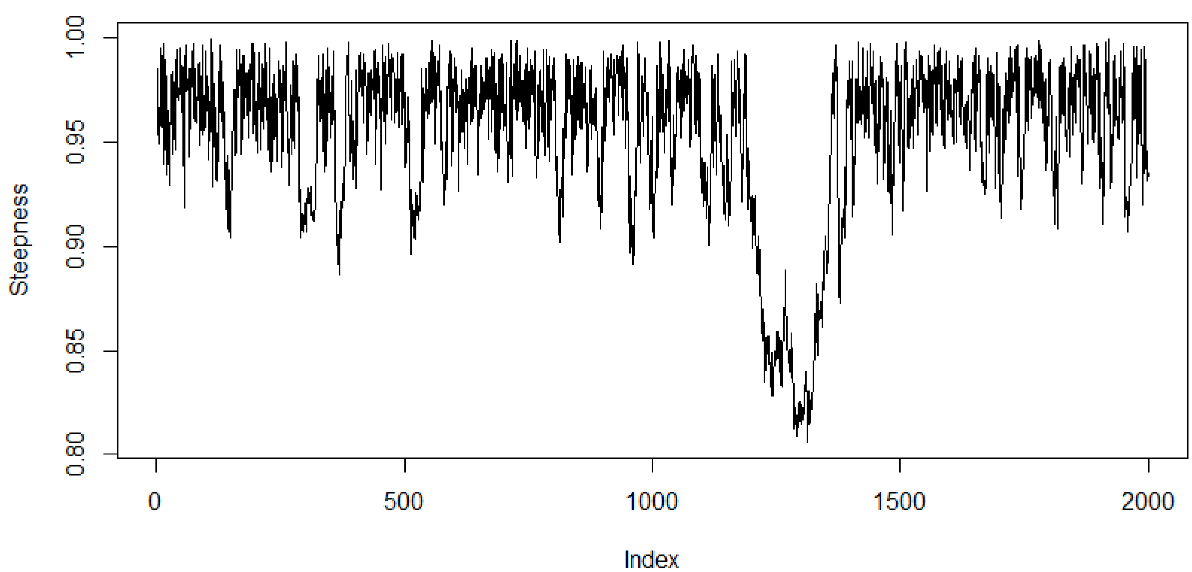


Figure 137. **Trace plot of MCMC samples for the steepness parameter for spot from the base modified-CSA model. Two million MCMC samples were drawn with a burn-in of one thousand samples and a thinning rate of one thousand samples (final n = 2,000).**

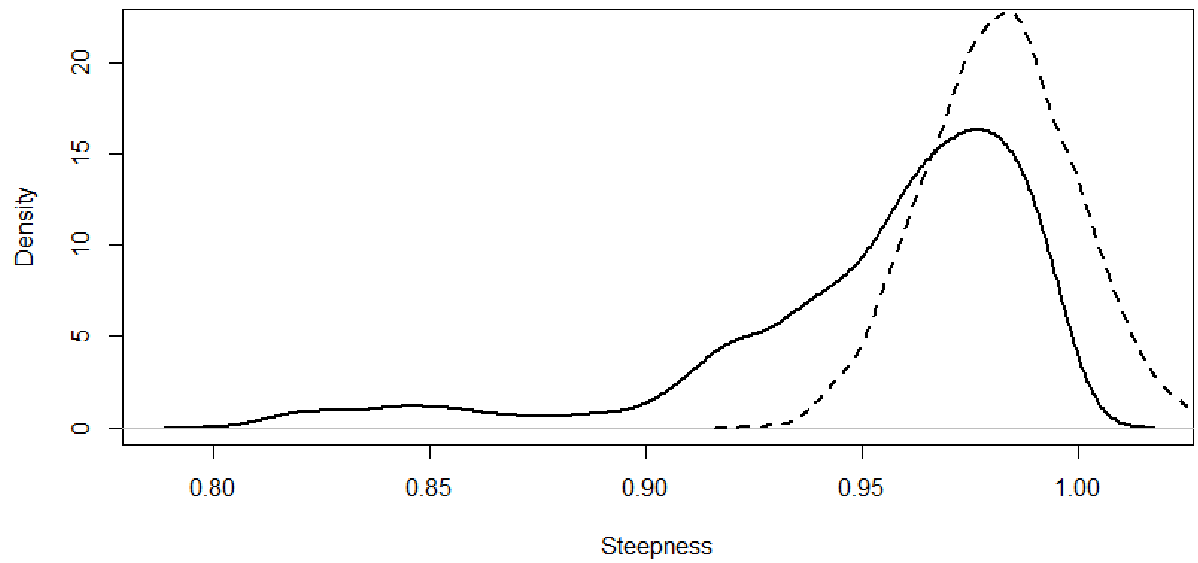


Figure 138. **Density of the base modified-CSA model steepness parameter estimate for spot from MCMC draws (solid line) compared to the maximum likelihood estimate and asymptotic standard errors (dashed line). Two million MCMC samples were drawn with a burn-in of one thousand samples and a thinning rate of one thousand samples (final n = 2,000).**

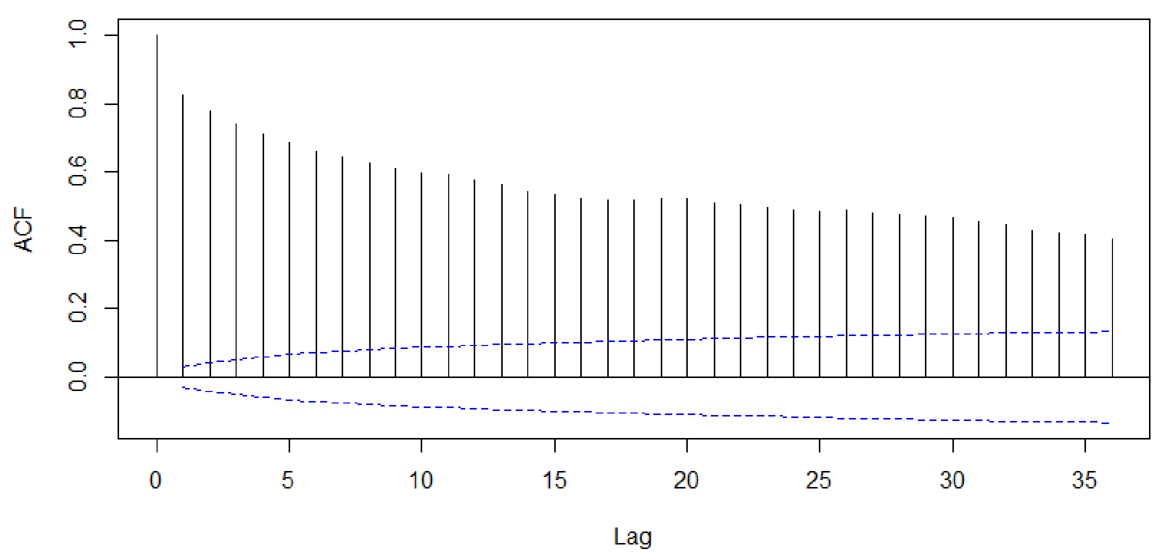


Figure 139. **Autocorrelation of MCMC samples for the unfished spawning stock biomass parameter for spot from the base modified-CSA model. Five million MCMC samples were drawn with a burn-in of one thousand samples and a thinning rate of one thousand samples (final n = 5,000). Dashed blue lines are 95%**

confidence intervals with values exceeding these lines being statistically different than zero.

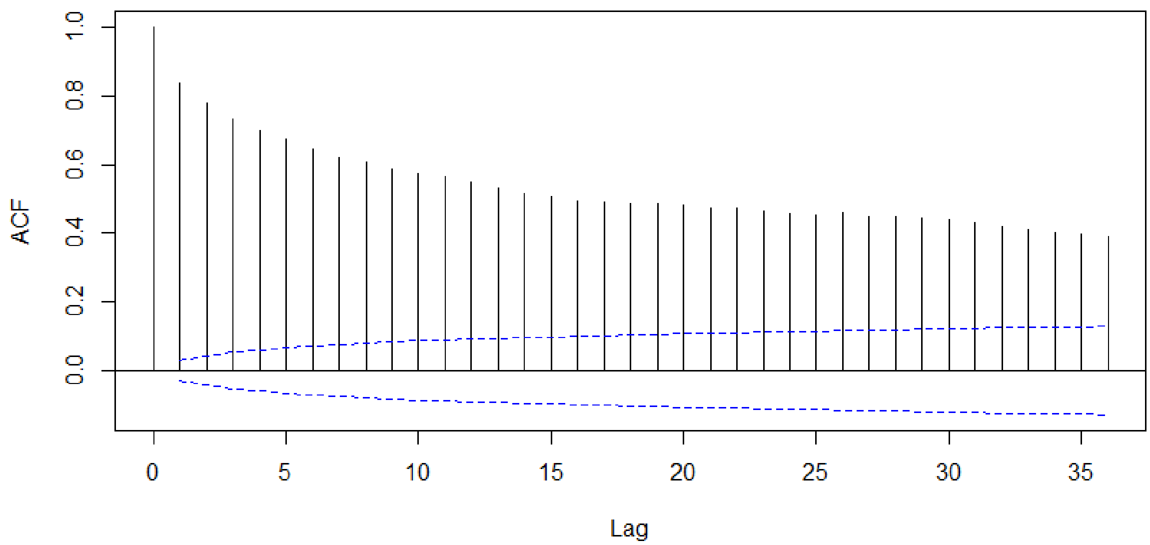


Figure 140. **Autocorrelation of MCMC samples for the steepness parameter for spot from the base modified-CSA model. Five million MCMC samples were drawn with a burn-in of one thousand samples and a thinning rate of one thousand samples (final n = 5,000). Dashed blue lines are 95% confidence intervals with values exceeding these lines being statistically different than zero.**

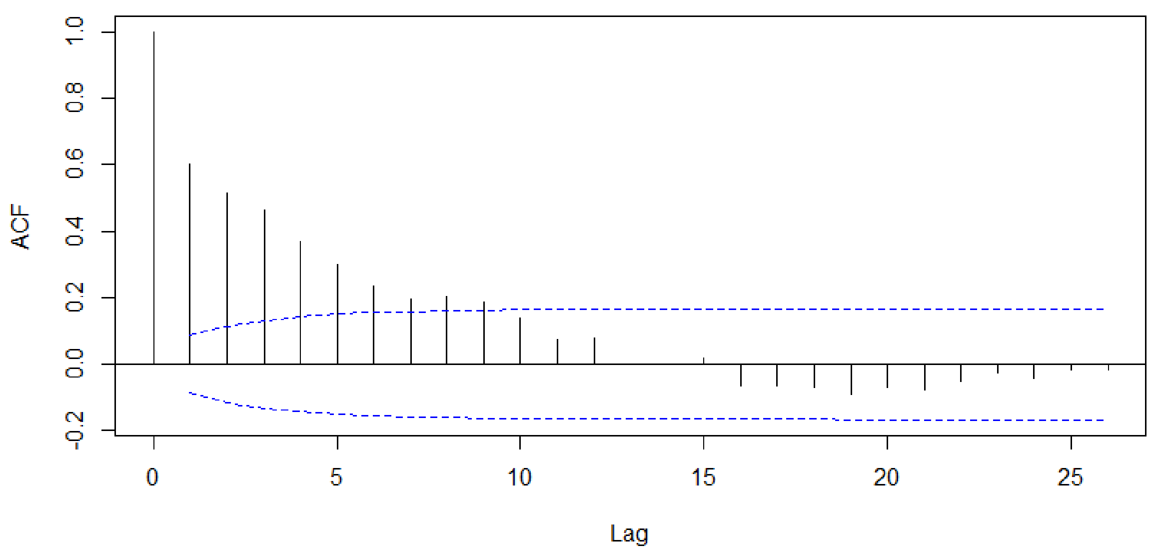


Figure 141. **Autocorrelation of MCMC samples for the unfished spawning stock biomass parameter for spot from the base modified-CSA model. Five million MCMC samples were drawn with a burn-in of one thousand samples and a thinning**

rate of ten thousand samples (final n = 500). Dashed blue lines are 95% confidence intervals with values exceeding these lines being statistically different than zero.

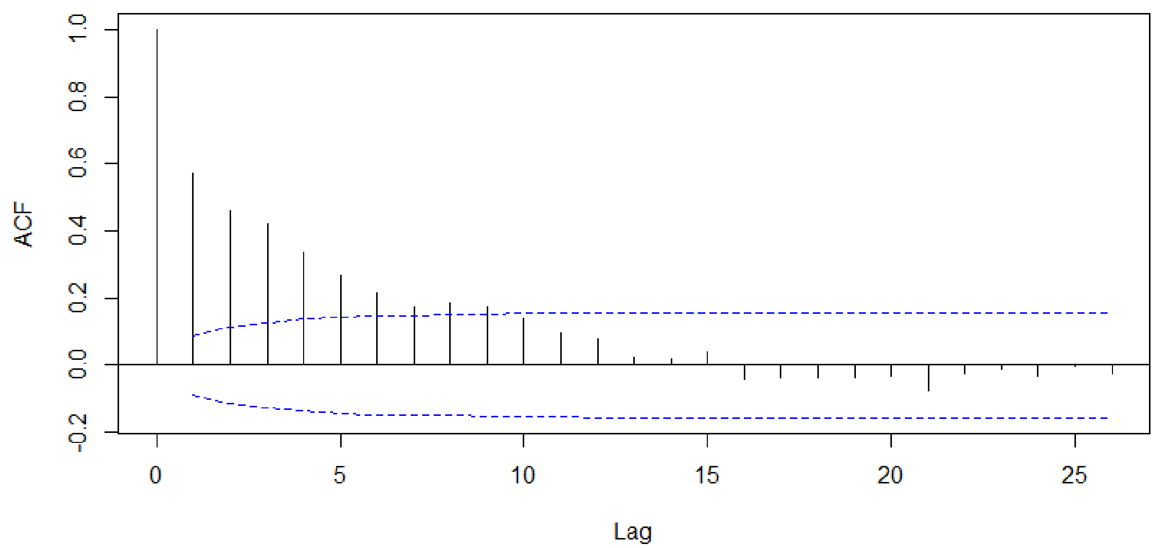


Figure 142. Autocorrelation of MCMC samples for the steepness parameter for spot from the base modified-CSA model. Five million MCMC samples were drawn with a burn-in of one thousand samples and a thinning rate of ten thousand samples (final n = 500). Dashed blue lines are 95% confidence intervals with values exceeding these lines being statistically different than zero.

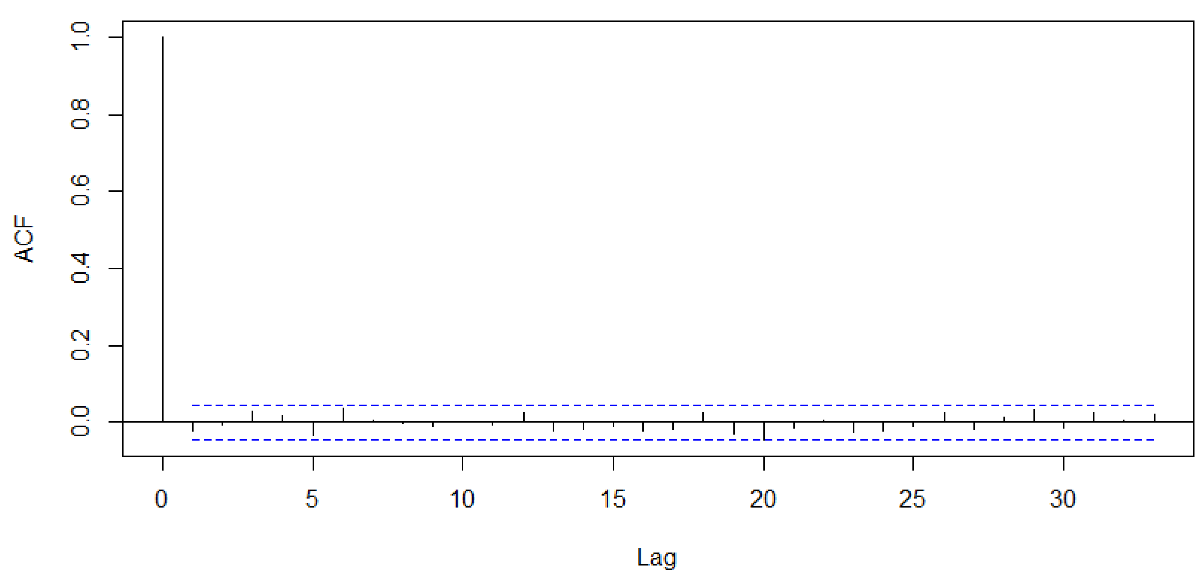


Figure 143. **Autocorrelation of MCMC samples for the unfished spawning stock biomass parameter for spot from the modified-CSA model with the steepness parameter fixed at 0.99. Five million MCMC samples were drawn with a burn-in of one thousand samples and a thinning rate of ten thousand samples (final n = 500). Dashed blue lines are 95% confidence intervals with values exceeding these lines being statistically different than zero.**

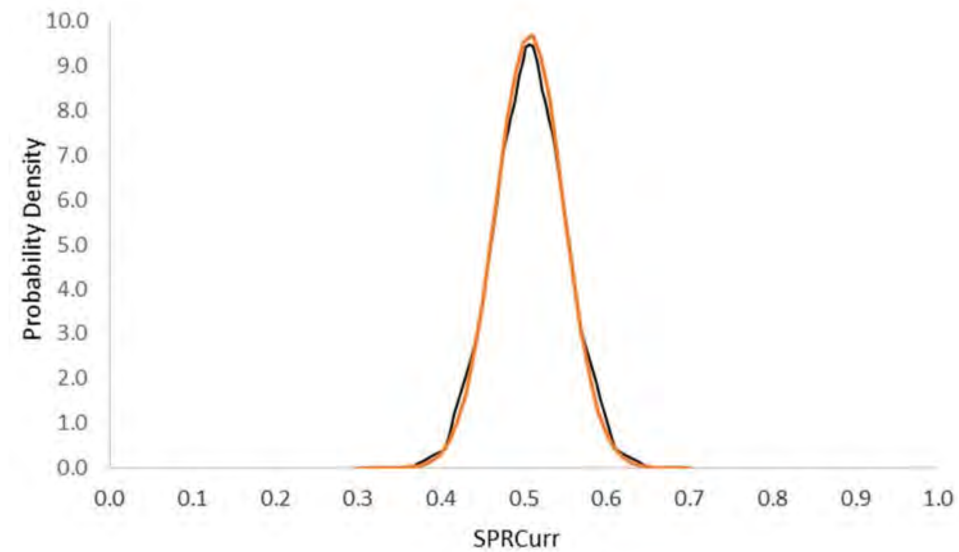


Figure 144. **Likelihood profile of terminal year (2014) static spawning potential ratio estimate for spot from the base modified-CSA model.**

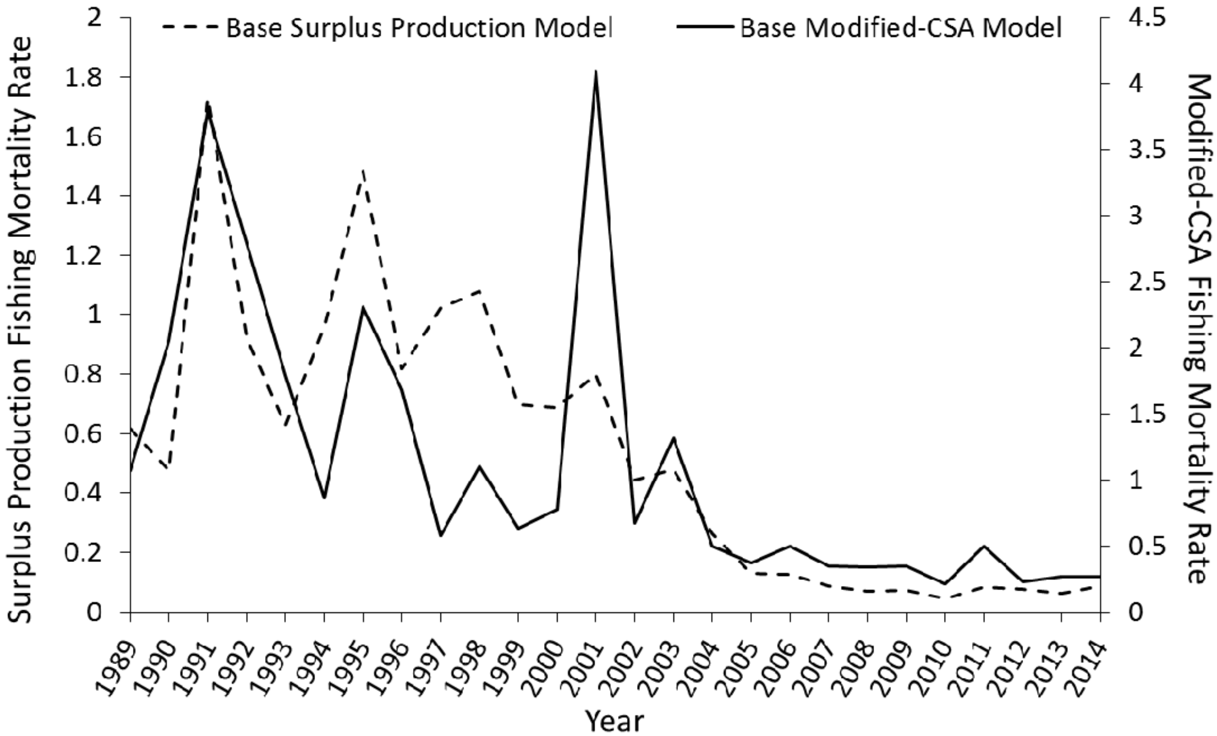


Figure 145. **Fishing mortality estimates for spot from the base surplus production model and modified-CSA model.**

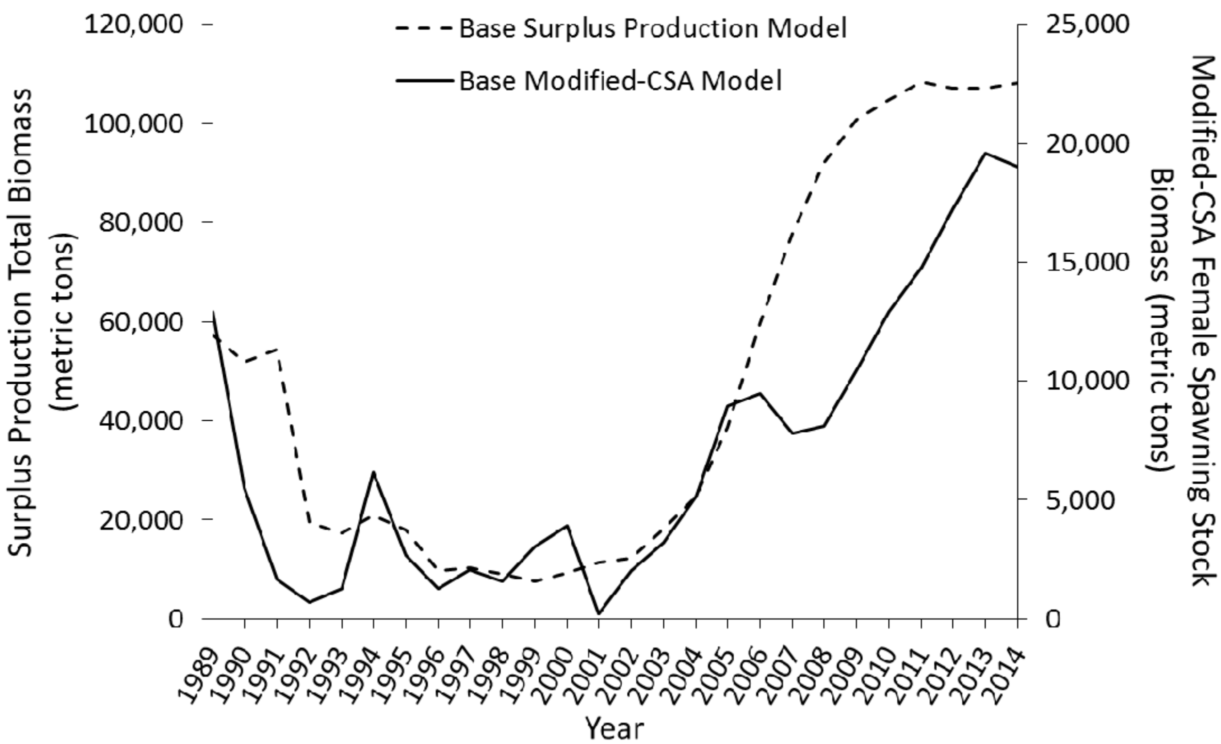


Figure 146. **Total biomass (metric tons) and end-year spawning stock biomass (metric tons) estimates for spot from the base surplus production model and base modified-CSA model, respectively.**

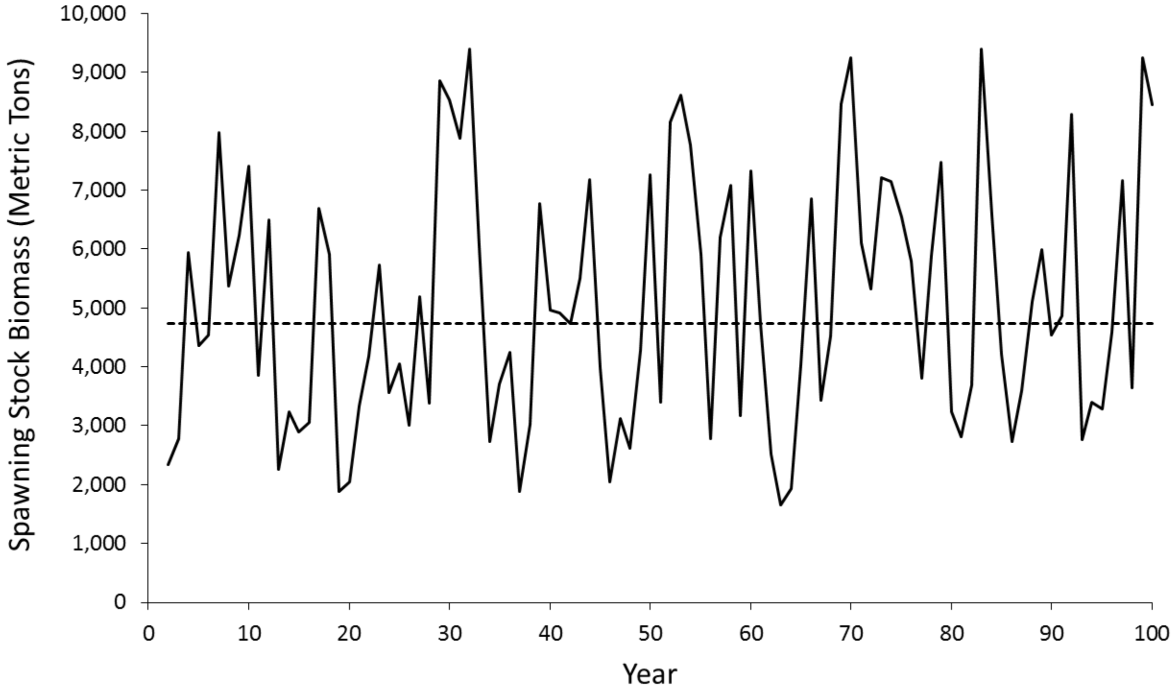


Figure 147. **Projected end-year spawning stock biomass estimates (solid black line) for threshold spawning stock biomass estimate. The median (dashed black line; 4,730 metric tons) estimate is the point estimate for the spawning stock biomass threshold.**

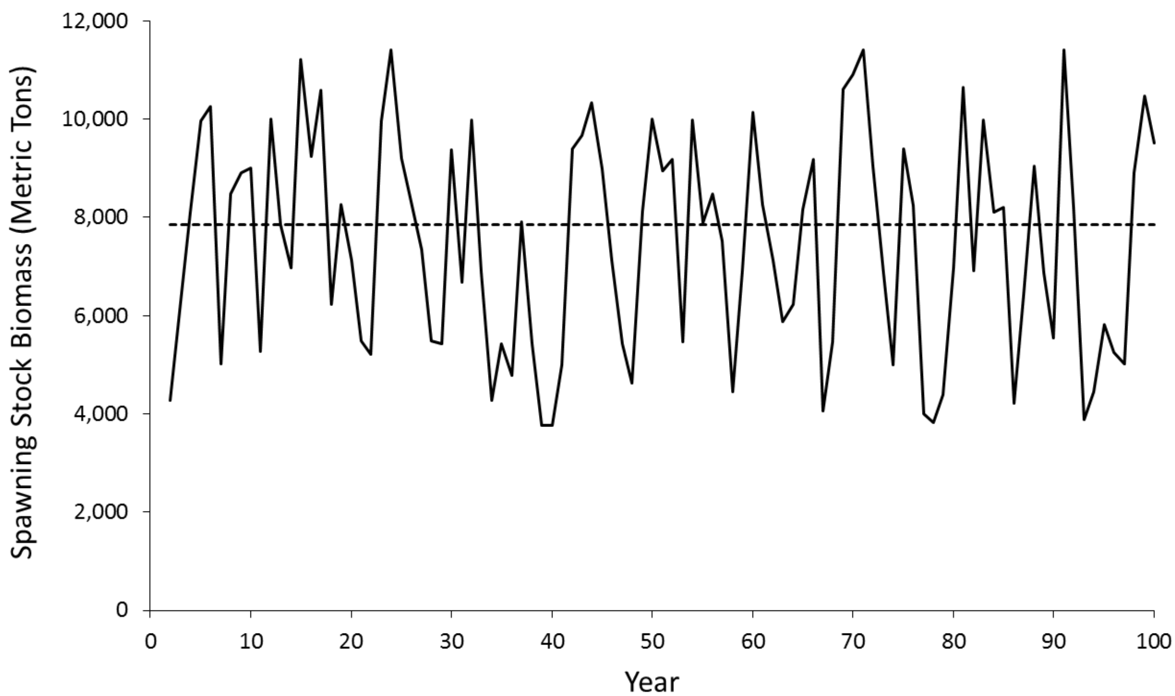


Figure 148. **Projected end-year spawning stock biomass estimates (solid black line) for target spawning stock biomass estimate. The median (dashed black line; 7,854**

metric tons) estimate is the point estimate for the spawning stock biomass target.

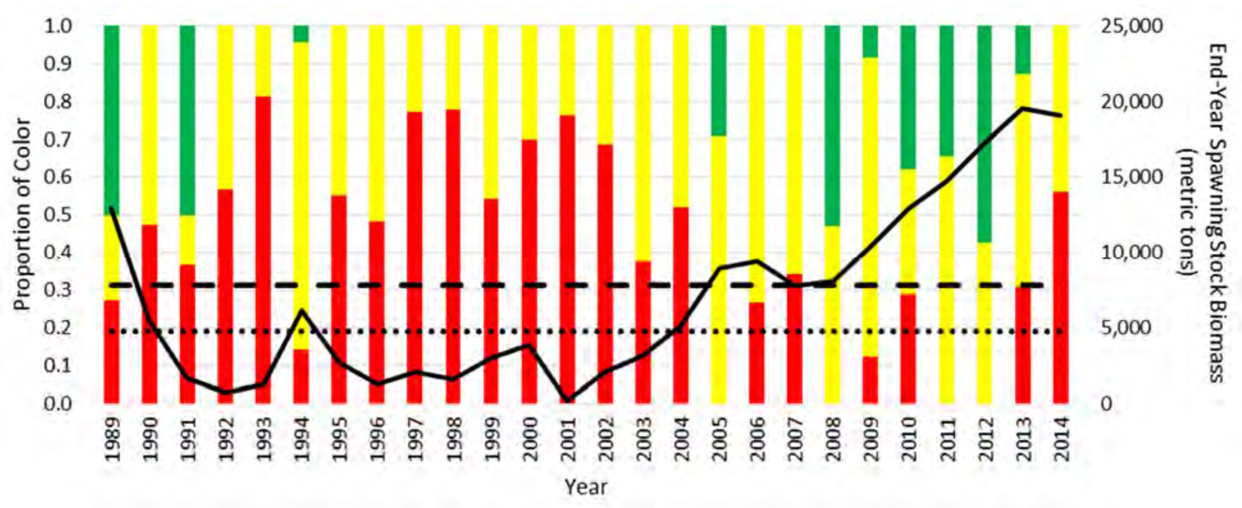


Figure 149. Proportion colors from the spot TLA of the adult abundance metric and end-year spawning stock biomass (solid black line), spawning stock biomass threshold (dotted black line), and spawning stock biomass target (dashed black line) estimates from the base modified-CSA model.

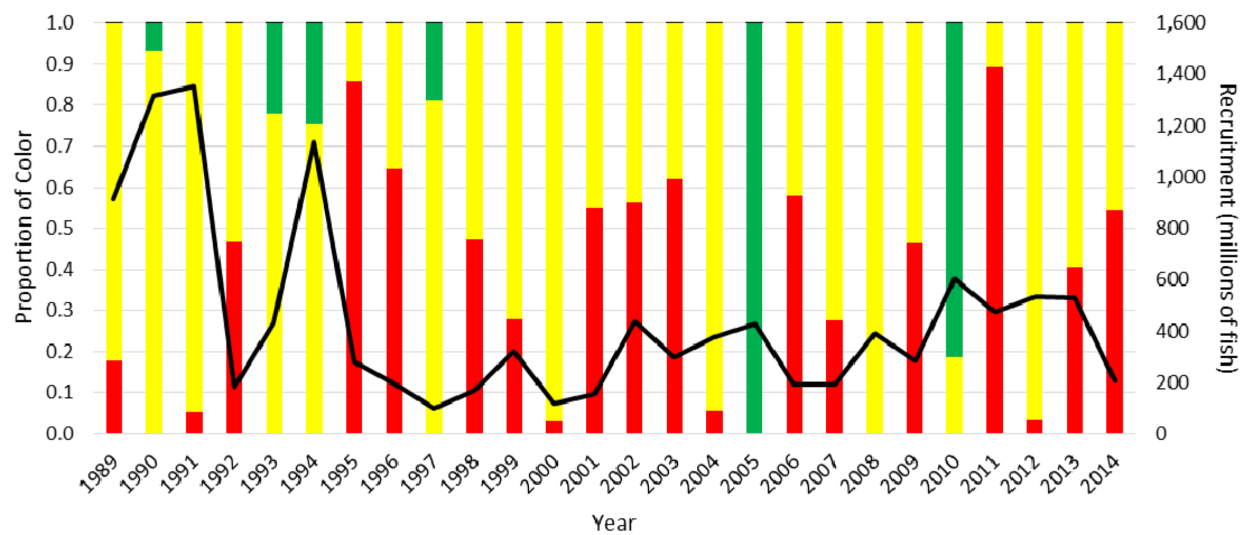


Figure 150. Proportion colors from the spot TLA of the YOY metric and recruitment estimates (solid black line) from the base modified-CSA model.

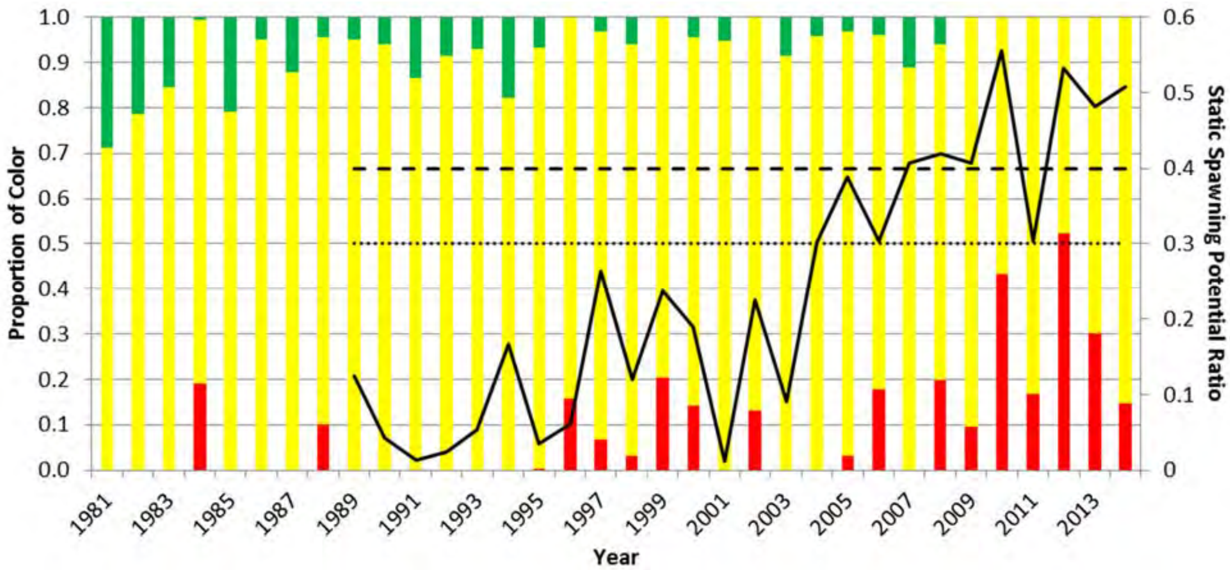


Figure 151. **Proportion colors from the spot TLA of the harvest metric, static spawning potential ratio estimates from the base modified-CSA model (solid black line), and the static spawning potential ratio threshold (dotted black line) and target (dashed black line) recommended in this assessment.**

14. Appendices

Appendix 1. Traffic Light Analysis of Spot: Alternate Model for 2017 ASMFC Stock Assessment

C. McDonough (SCDNR)

The Traffic Light method (TLA) was originally developed (Caddy and Mahon, 1995; Caddy, 1998, 1999) as a precautionary management framework for data poor fisheries whereby reference points could be developed that would allow for a reasonable level of resource management. The name comes from assigning a color (red, yellow, or green) to categorize relative levels of different indicators of the state of either a fish population or a fishery. These indicators can be combined to form composite characteristics within similar categories and can include biological indicators such as growth and reproduction, population level indicators such as abundance and stock biomass estimates, or fishery indicators such as harvest/landings and fishing mortality. However, each indicator must be evaluated separately in order to determine its appropriateness for use in a management scheme.

The purpose of developing the TLA for spot within the assessment was to allow for comparisons to be made to the assessment modelling results and determine how the two approaches would inform understanding of stock condition. It is important to note that while the TLA does provide a management guidance framework based on different index metrics, it does not provide population level parameters such as biomass (B_{msy}) spawning potential ratios (SPR) or fishing mortality (F_{msy}), so its utility for providing stock specific fishery parameters is limited. However, the ability to illustrate trends in different fishery or population parameters (abundance, landings, etc) is useful to compare to more rigorous population models such as the modified-CSA model used in the assessment.

The specific TLA model used is the fuzzy traffic light model. In the fuzzy traffic light model, we use boundary reference points to determine the relative proportion of each color that includes the buffer (yellow) zone based on the upper and lower 95% confidence intervals from the index values for either the entire data series or a pre-determined reference period (Halliday et al., 2001). In the case of this assessment we are using the 1989-2012 as the reference time period as this is the time frame of the data used for the annual management trigger exercises to determine stock status. The current assessment time period covered two more years, 1989-2014. The TLA color proportions were determined by setting the mean index value at 1.0 for yellow and 0.0 for both red and green as this is the exact center of the buffer zone. The 0.5 proportion value for all three colors is set at the mean index value minus the lower 95% confidence interval (CI) (red and left yellow leg) and the mean index value plus the upper CI (green and the right yellow leg). Finally, the value of 1.0 is set for red at the mean index value minus 2X the lower CI or zero, if the index mean minus 2X the lower CI is a negative number. For green the 1.0 value is set at 2X the upper 95% confidence limit. Once the known index values at the proportion values for each color are determined, the relative color proportions for each year can be estimated via linear regression using the annual values of the index. Any negative values are reset to zero and the proportion of yellow are set at 1 minus the color proportion for either red or green in that year. This allows a better illustration of the annual trends within a given color and whether or not values are approaching levels of concern about the reference boundaries.

Composite figures of combined indices can then be created using the color proportion tables from each individual index. These indexes are additive and the total index is re-scaled to 0-1. It is possible to add weighting factors to each index via the color proportion tables if necessary, although in practice indexes are commonly weighted prior to being run through the TLA. This type of composite index is what Halliday et al. (2001) referred to as a Characteristic, while the individual indices that make it up are the Indicators.

For the fishery dependent data there were two separate sets of indicator data. The first was harvest or landings data by weight (in metric tons) and the second was discard data, also by weight in metric tons. The landings data indicators included commercial landings, recreational harvest and scrap fishery landings (NC and VA only). In addition to the data sets used in the annual management trigger exercise, there were also discard indicator data sets that included the south Atlantic shrimp trawl fishery, commercial discards (mid-Atlantic gill net fishery and mid-Atlantic trawl fishery), and recreational discards that became available through the assessment process. These indicator data were included in this exercise to examine the effects on the TLA in relation to the modified-CSA model output. Mortality for the shrimp trawl, gill net and mid-Atlantic trawl fisheries was set at 100% as bycatch discard were typically released dead in these fisheries and there was no other available estimate of discard mortality. The recreational discard mortality was set at 15% as determined by the Stock Assessment Subcommittee at the Assessment workshop. The recreational discard index used was the estimated annual discards lost through mortality. All of the discard indices were treated as part of the total removals from the stock, along with the harvest landings.

The fishery independent indicator data included survey data from the MDDNR, NMFS, and SEAMAP. The modified-CSA model broke each of these indices into two separate components by age for age 0s and age 1+, however the TLA broke them down by adult (NMFS, SEAMAP) and juvenile (MDDNR) surveys. The reference time period (1989-2012) was the same as that used for the fishery dependent data sets. The data sets were split into the different age groups because while spot were considered fully recruited to the fishery at age 1, a certain proportion reach a large enough size each fall to enter into the fishery while still considered age 0 juveniles prior to spawning for the first time. Because of this, the TLA was run on each index for each age group as well as a combined model for all ages.

RESULTS

The majority of removals (95-99% annually) came from commercial landings, recreational harvest, and the southeast shrimp trawl discards (Fig. 1). Annual shrimp trawl discards varied widely, ranging from 22-89% of total removals with a long term mean of 52% annually for 1989-2014. Thus, trends in the TLA were largely driven by these three indices.

The harvest landings data characteristic (commercial and recreational harvest) showed a decline in landings since the mid 1990s, indicated by the increasing proportions of red through 2012 (Fig. 2). Recent years (since 2013) have shown a slight decline in red indicating an increase in harvest. Under the current management trigger guidelines for spot (ASMFC

Omnibus Amendment, 2012) the landings characteristic would not have triggered in 2014 with the three year average proportion of red being below the 30% threshold indicating moderate management concern.

The fishery discard annual total was dominated by the south Atlantic shrimp trawl fishery, accounting for ≤ 97% of all discards in any given year. Annual discards from the shrimp trawl and commercial fisheries have declined since the early 1990s, while recreational discards have been more variable annually. The discard composite characteristic reflected the decline in discards with high proportions of red in the early years and higher proportions of green in later years (indicating declining bycatch (Fig. 3). High discards in the first three years of the series (1989-1991) had red proportions in excess of the 30% threshold.

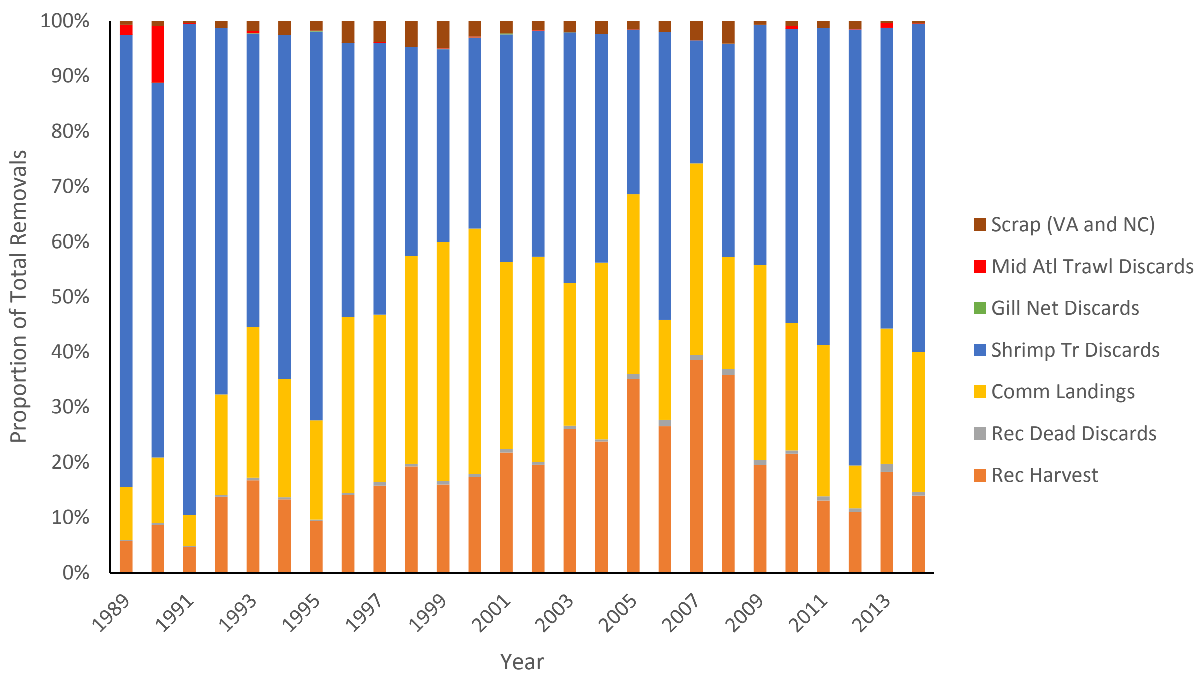


Figure 1. Proportion of annual removals by weight (metric tons) of spot for fishery dependent data by fishery type on the Atlantic coast of the USA from 1989-2014.

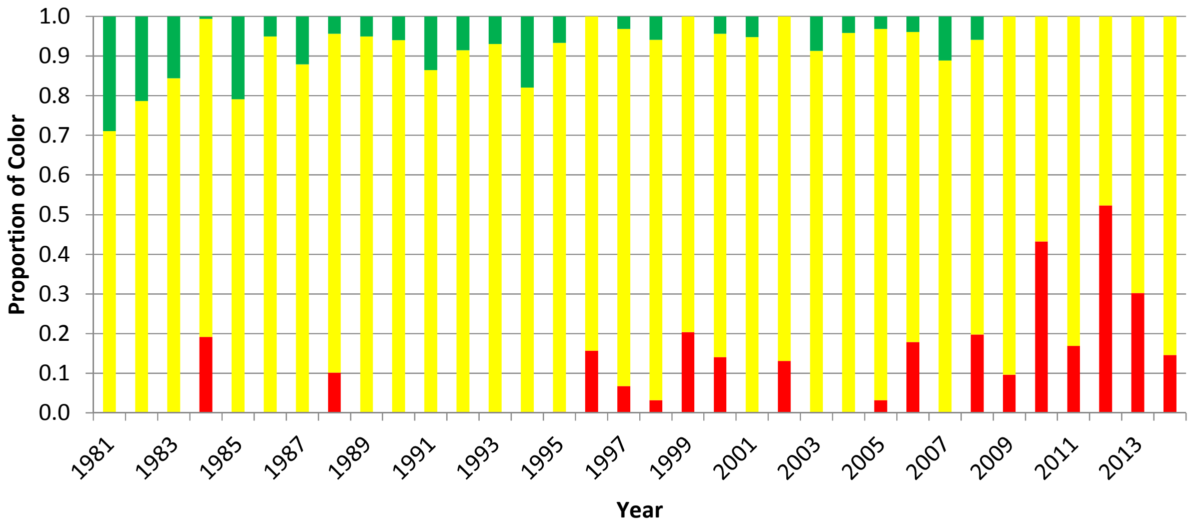


Figure 2. Annual fishery dependent TLA harvest characteristic (commercial, recreational, and scrap fishery landings) for spot on the Atlantic coast of the USA for 1989-2014.

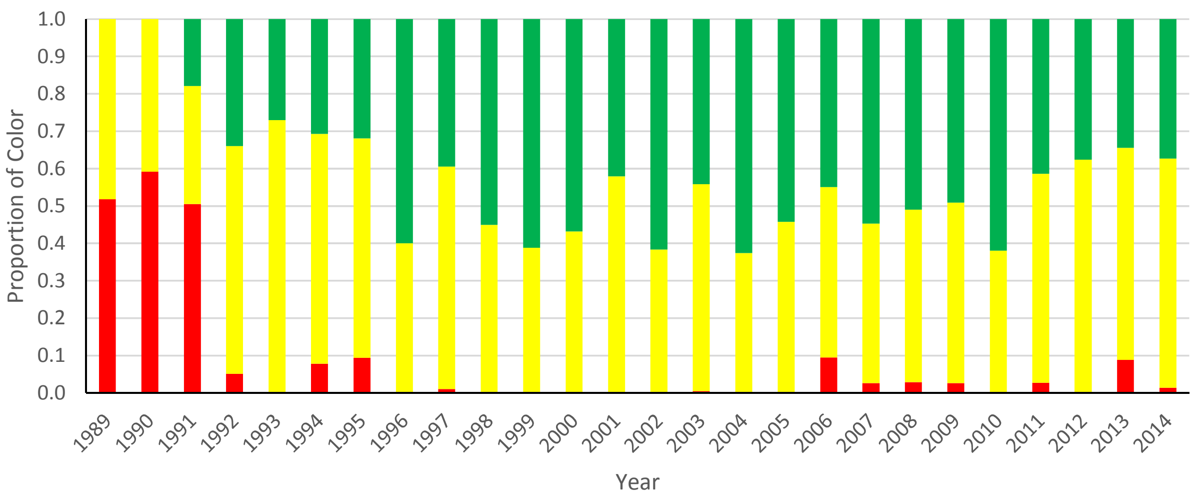


Figure 3. Annual fishery dependent TLA fishery discards characteristic (shrimp trawl fishery, commercial discards and recreational dead discards) for spot on the Atlantic coast of the USA for 1989-2014.

When the landings characteristic was combined with the discards characteristic to form a total removals characteristic, the resulting TLA (Fig. 4) indicated elevated red proportions in the early part of the time series (likely driven by high discards) and an increasing proportion of red since the late 2000s (likely driven by the increase in annual harvest). While this in and of itself was not direct indication of whether spot were being overfished or overfishing was occurring, it does show an increased impact of total removals on spot on the Atlantic coast.

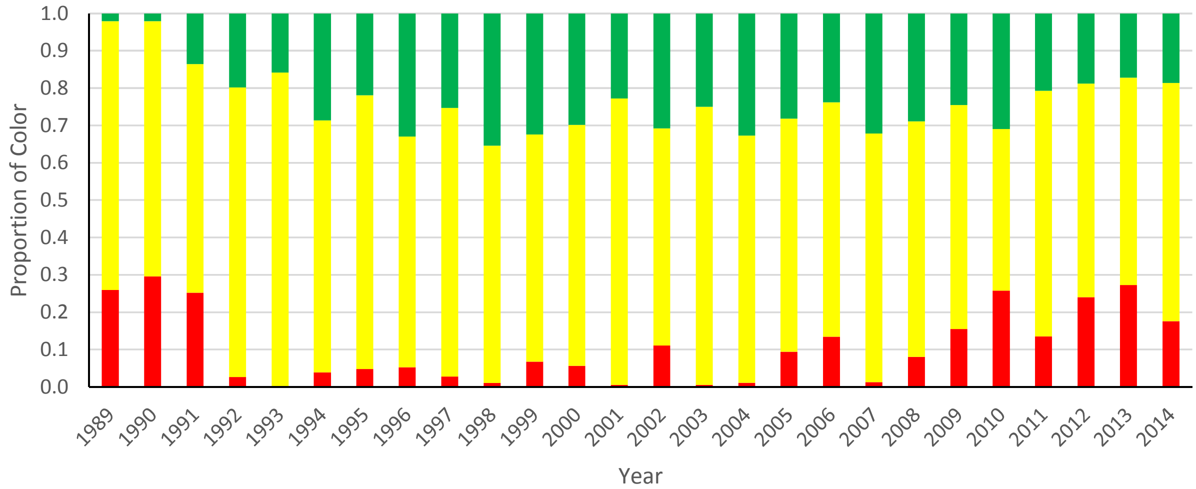


Figure 4. Combined composite TLA characteristic of total annual removals by harvest or fishery discards for spot on the Atlantic coast of the USA for 1989-2014.

The fishery independent survey (NMFS and SEAMAP) characteristic (Fig. 5) indicated high red proportions throughout the 1990s with an increase in green through the 2000s. The last two years showed an increase in red proportions with no triggering of the index since 2005, although it would have triggered in 2014.

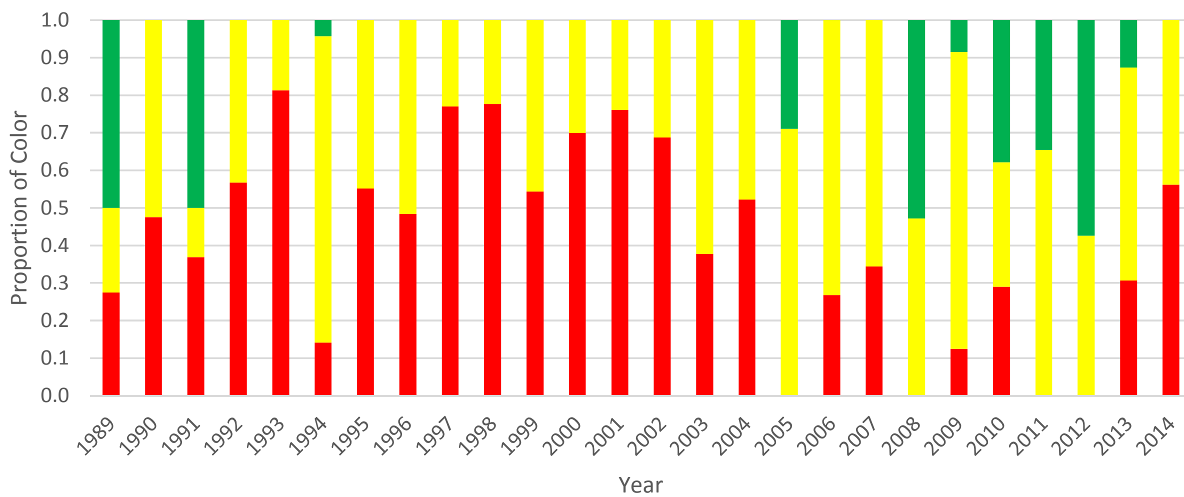


Figure 5. Annual fishery independent TLA composite characteristic for adult (age 1+) spot on the Atlantic coast of the USA using survey data from NMFS and SEAMAP.

The survey index characteristic young of the year spot (Fig.6) showed higher year to year variability in color proportions, likely due to recruitment variability. The higher degree of variability made it more likely that the red proportions would exceed the 30% threshold compared to the adult spot. The MDDNR survey used in the current trigger exercise was the only young of the year survey and increasing proportions of red in this survey reflect the longer term decline in juvenile abundance seen in that survey.

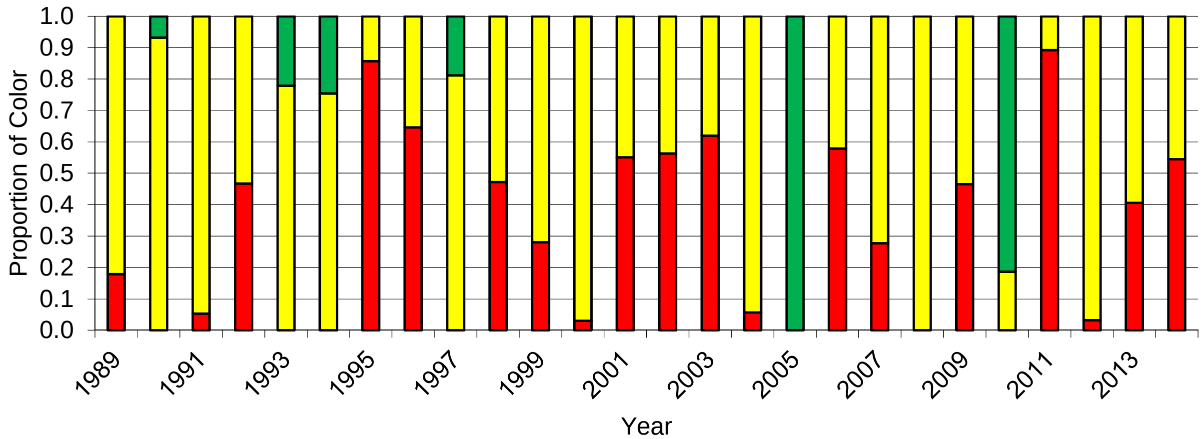


Figure 6. Annual fishery independent TLA composite characteristic for young of the year (age 0) spot on the Atlantic coast of the USA using survey data from MDDNR

FUTURE CONSIDERATIONS

After the current assessment has been completed, the traffic light analysis will have to be reexamined with regards to adjusting the reference period to the time frame of the current assessment and the consideration of adding additional indices to the TLA process. The additional metrics should possibly include the different by-catch estimates (shrimp trawl fishery, commercial discards and recreational discards) as well as possibly including the scrap fishery from Virginia and North Carolina. These indices, coupled with the harvest indicators would produce a characterization of total annual removals from fishery dependent sources. This would be particularly important for the shrimp trawl fishery given the magnitude of the bycatch compared to all other removal sources. For the fishery independent indices, consideration of including the VIMS juvenile trawl survey and NCDMF Program 195 survey might improve the young of the year recruitment characteristic which currently uses just the MDDNR juvenile fish survey. For the adult indices, ChesMMAP and NEAMAP should also be considered. Although, the time series for NEAMAP is still relatively short compared to all the other surveys. A full evaluation of modifying the TLA to improve its representation of both abundance and fishery trends should be considered after completion of the assessment and undertaken by a Spot Technical Committee.

Cited Literature

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ASMFC, 2012. Omnibus Amendment to the Interstate Fishery Management Plans For Spanish Mackerel, Spot, and Spotted Seatrout. http://www.asmfc.org/uploads/file/omnibusAmendment_TechAdd1A_Feb2012.pdf

Caddy, J.F. 1998. A short review of precautionary reference points and some proposals for their use in data-poor situations. FAO Fisheries Technical Paper No. 379, 30pp

Caddy, J.F. 1999. Deciding on precautionary management measures for a stock based on a suite of Limit Reference Points (LRPs) as a basis for a multi-LRP harvest law. NAFO Sci. Council Studies, 32:55-68.

Caddy, J.F. 2002. Limit reference points, traffic lights, and holistic approaches to fisheries management with minimal stock assessment input. Fisheries Research 56:133-137.

Halliday, R.G; L.P. Fanning; and R.K. Mohn. 2001. Use of the Traffic Light Method in Fishery Management Planning. Canadian Science Advisory Secretariat, Research Document No. 108, 41pp.

Seijo, J.C. and J.F. Caddy 2000. Uncertainty in bio-economic reference points and indicators of marine fisheries. Marine and Freshwater Research, 51:477-483.

Appendix 2. Shrimp trawl observer database net performance operation codes.

A - Nets not spread; typically doors are flipped or doors hung together so net could not spread.
B - Gear bogged; the net has picked up a large quantity of sand, clay, mud, or debris in the tail bag possibly affecting trawl performance.
C - Bag obstructed; the catch in the net is prevented from getting into the bag by something (i.e. grass, sticks, turtle, tires, metal/plastic containers etc.) or constriction of net (i.e. twisting of the lazy-line around net).
D - Gear not digging; the net is fishing off the bottom due to insufficient weight or not enough cable let out (etc.).
E - Twisted warp or line; the cables composing the bridle get twisted (from passing over blocks which occasionally must be removed before continuing to fish). Use this code if catch was affected.
F - Gear fouled; the gear has become entangled in itself or with another net. Typically this involves the webbing and some object like a float or chains or lazy line (etc.).
G -Bag untied; bag of net not tied when dragging net.
H - Rough weather. Bags mixed due to rough seas (too dangerous to separate); if the weather is so bad fishing is stopped, then the previous tow should receive this code if the rough conditions affected the catch.
I - Torn, damaged, or lost net; usually results from hanging the net and tearing it loose. The net comes back with large tears etc. if at all. Do not use this code if there are only a few broken meshes. Continue using this code until net is repaired or replaced
J - Dumped catch; tow was made but catch was discarded, perhaps because of too mud. Give reason in comments.
SEDAR38RW01 18
K - Catch not emptied on deck; nets brought to surface, boat changes location, nets redeployed. (explain in comments)
L - Hung up; untimely termination of a tow by a hang. Specify trawl(s) which were hung and caused lost time in Comments.
M - Bags dumped together, catches could not be kept separate.
N - Net did not fish; no apparent cause. Describe reasoning in comments.
O - Gear fouled on submerged object but tow was not terminated. Performance of tow could be affected. Give specifics in Comments.
P - No measurement taken of shrimp and/or total catch.
Q - Main cable breaks and entire rigging lost. Describe in Comments.
R - Net caught in wheel.
S - Tickler chain heavily fouled, tangled, or broken.
T - Other problems. Describe in comments.
U - Turtle excluder gear intentionally disabled.
V – Unknown operation code.
W - Damaged (i.e., bent or broken) excluder gear.
X - BRD intentionally disabled or non-functional. (Damaged) Describe in comments.
Y - Net trailing behind try net.
Z - Successful tow.

Appendix 3. SAS Code for Standardized Shrimp Effort (Trips) Query

```
/******Data for Jennifer Lee**********/
libname SASDATA V8 "N:\FMB\DATA REQUESTS\2016\JEFF KIPP SHRIMP EFFORT";
/***** output directory and year requested *************/


/************************************/
/*EXTRACT STATE TRIP TICKET DATA  FROM ACCSP FOR TRIPS LANDING SHRIMP*/
PROC SQL        ;
        connect to oracle  (user=dgloeckn orapw="gadus6674"  path="SECPR")                              ;
        create table sasdata.ACCSP_TRIPS_SHRIMP_TEMP as

        select * from connection to oracle
 (SELECT A.CONS_RPT_ID, A.TRIP_ID, A.DATA_SUPPLIER,'ACCSP' as FORM_VERSION,
A.UNLOAD_YEAR, A.UNLOAD_MONTH, A.UNLOAD_DAY,A.STATE_CODE, A.COUNTY_CODE,
C.IDENT, C.SUPPLIER_PA_ID,D.COAST_GUARD_NBR, D.STATE_REG_NBR,
A.GEAR_CODE,E.GEAR_NAME, A.AREA_CODE, A.SUB_AREA_CODE, A.DISTANCE_CODE,
B.SPECIES_ITIS, G.COMMON_NAME, B.DISPOSITION_CODE, B.MARKET_CODE, B.GRADE_CODE,
B.LIVE_POUNDS, B.DOLLARS, F.START_YEAR, F.START_MONTH, F.START_DAY,
F.TRIP_NBR, F.SPLIT_TRIP,F.DAYS_AT_SEA, F.FISHING_HOURS, F.SOAK_TIME, F.gear_quantity,
F.COUNTY_CODE AS COUNTY_CODE2,
F.STATE_CODE AS STATE_CODE2, F.AREA_CODE AS AREA_CODE2, F.SUB_AREA_CODE AS
SUB_AREA_CODE2, F.DISTANCE_CODE AS DISTANCE_CODE2, F.GEAR_CODE AS GEAR_CODE2
FROM ACCSPREC.CONSOLIDATED_REPORTS@ACCSP_DBLK A
LEFT JOIN ACCSPREC.CONSOLIDATED_LANDINGS@ACCSP_DBLK B ON (A.CONS_RPT_ID =
B.CONS_RPT_ID)
LEFT JOIN ACCSPREC.PARTICIPANTS@ACCSP_DBLK C ON (A.DEALER_ID = C.PARTICIPANT_ID)
LEFT JOIN ACCSPREC.VESSELS@ACCSP_DBLK D ON (A.VESSEL_ID = D.VESSEL_ID)
LEFT JOIN ACCSPREC.GEARS@ACCSP_DBLK E ON (A.GEAR_CODE = E.GEAR_CODE)
LEFT JOIN ACCSPREC.SPECIES@ACCSP_DBLK G ON (B.SPECIES_ITIS = G.SPECIES_ITIS)
LEFT JOIN (SELECT *
FROM (SELECT A.CONS_RPT_ID, A.DATA_SUPPLIER, B.START_YEAR, B.START_MONTH,
B.START_DAY, B.TRIP_NBR, B.SPLIT_TRIP,
B.DAYS_AT_SEA, C.FISHING_HOURS, C.SOAK_TIME, c.gear_quantity, B.COUNTY_CODE,
B.STATE_CODE, C.AREA_CODE, C.SUB_AREA_CODE,
C.DISTANCE_CODE, C.GEAR_CODE, ROW_NUMBER() OVER (PARTITION BY  A.TRIP_ID,
A.DATA_SUPPLIER ORDER BY A.TRIP_ID, A.DATA_SUPPLIER,
B.TRIP_NBR DESC NULLS LAST,B.DAYS_AT_SEA DESC NULLS LAST, C.FISHING_HOURS DESC
NULLS LAST,D.LIVE_POUNDS DESC NULLS LAST ) AS COUNTS
FROM ACCSPREC.CONSOLIDATED_REPORTS@ACCSP_DBLK A
LEFT JOIN ACCSPREC.TRIPS@ACCSP_DBLK B ON (A.TRIP_ID = B.TRIP_ID)
LEFT JOIN ACCSPREC.EFFORTS@ACCSP_DBLK C ON (A.TRIP_ID = C.TRIP_ID)
LEFT JOIN ACCSPREC.CATCHES@ACCSP_DBLK D ON (A.TRIP_ID = D.TRIP_ID AND C.EFFORT_SEQ =
D.EFFORT_SEQ)) E WHERE E.COUNTS = 1) F ON (A.CONS_RPT_ID = F.CONS_RPT_ID)
WHERE (A.DATA_SUPPLIER = '0013' and a.unload_year between 2004 and 2014 or A.DATA_SUPPLIER =
'0012' and a.unload_year between 1994 and 2014
or A.DATA_SUPPLIER = '0014' and a.unload_year between 1989 and 2014)
AND B.CONS_RPT_ID IN (SELECT CONS_RPT_ID FROM
ACCSPREC.CONSOLIDATED_LANDINGS@ACCSP_DBLK WHERE SPECIES_ITIS IN
            (SELECT SPECIES_ITIS
             FROM ACCSPREC.SPECIES@ACCSP_DBLK
             WHERE COMMON_NAME LIKE '%SHRIMP%'))
union
SELECT A.CONS_RPT_ID, A.TRIP_ID, A.DATA_SUPPLIER,'ACCSP' as FORM_VERSION,
A.UNLOAD_YEAR, A.UNLOAD_MONTH, A.UNLOAD_DAY,A.STATE_CODE, A.COUNTY_CODE,
C.IDENT, C.SUPPLIER_PA_ID,D.COAST_GUARD_NBR, D.STATE_REG_NBR,
A.GEAR_CODE,E.GEAR_NAME, A.AREA_CODE, A.SUB_AREA_CODE, A.DISTANCE_CODE,
```

```
B.SPECIES_ITIS, G.COMMON_NAME, B.DISPOSITION_CODE, B.MARKET_CODE, B.GRADE_CODE,
B.LIVE_POUNDS, B.DOLLARS, F.START_YEAR, F.START_MONTH, F.START_DAY,
F.TRIP_NBR, F.SPLIT_TRIP,F.DAYS_AT_SEA, F.FISHING_HOURS, F.SOAK_TIME, F.gear_quantity,
F.COUNTY_CODE AS COUNTY_CODE2,
F.STATE_CODE AS STATE_CODE2, F.AREA_CODE AS AREA_CODE2, F.SUB_AREA_CODE AS
SUB_AREA_CODE2, F.DISTANCE_CODE AS DISTANCE_CODE2, F.GEAR_CODE AS GEAR_CODE2
FROM ACCSPREC.CONSOLIDATED_REPORTS@ACCSP_DBLK A
LEFT JOIN ACCSPREC.CONSOLIDATED_LANDINGS@ACCSP_DBLK B ON (A.CONS_RPT_ID =
B.CONS_RPT_ID)
LEFT JOIN ACCSPREC.PARTICIPANTS@ACCSP_DBLK C ON (A.DEALER_ID = C.PARTICIPANT_ID)
LEFT JOIN ACCSPREC.VESSELS@ACCSP_DBLK D ON (A.VESSEL_ID = D.VESSEL_ID)
LEFT JOIN ACCSPREC.GEARS@ACCSP_DBLK E ON (A.GEAR_CODE = E.GEAR_CODE)
LEFT JOIN ACCSPREC.SPECIES@ACCSP_DBLK G ON (B.SPECIES_ITIS = G.SPECIES_ITIS)
LEFT JOIN (SELECT *
FROM (SELECT A.CONS_RPT_ID, A.DATA_SUPPLIER, B.START_YEAR, B.START_MONTH,
B.START_DAY, B.TRIP_NBR, B.SPLIT_TRIP,
B.DAYS_AT_SEA, C.FISHING_HOURS, C.SOAK_TIME, c.gear_quantity, B.COUNTY_CODE,
B.STATE_CODE, C.AREA_CODE, C.SUB_AREA_CODE,
C.DISTANCE_CODE, C.GEAR_CODE, ROW_NUMBER() OVER (PARTITION BY  A.TRIP_ID,
A.DATA_SUPPLIER ORDER BY A.TRIP_ID, A.DATA_SUPPLIER,
B.TRIP_NBR DESC NULLS LAST,B.DAYS_AT_SEA DESC NULLS LAST, C.FISHING_HOURS DESC
NULLS LAST,D.LIVE_POUNDS DESC NULLS LAST ) AS COUNTS
FROM ACCSPREC.CONSOLIDATED_REPORTS@ACCSP_DBLK A
LEFT JOIN ACCSPREC.TRIPS@ACCSP_DBLK B ON (A.TRIP_ID = B.TRIP_ID)
LEFT JOIN ACCSPREC.EFFORTS@ACCSP_DBLK C ON (A.TRIP_ID = C.TRIP_ID)
LEFT JOIN ACCSPREC.CATCHES@ACCSP_DBLK D ON (A.TRIP_ID = D.TRIP_ID AND C.EFFORT_SEQ =
D.EFFORT_SEQ)) E WHERE E.COUNTS = 1) F ON (A.CONS_RPT_ID = F.CONS_RPT_ID)
WHERE (A.DATA_SUPPLIER = '0015' and a.unload_year between 1986 and 2014)
AND B.CONS_RPT_ID IN (SELECT CONS_RPT_ID FROM
ACCSPREC.CONSOLIDATED_LANDINGS@ACCSP_DBLK WHERE SPECIES_ITIS IN
                (SELECT SPECIES_ITIS
                 FROM ACCSPREC.SPECIES@ACCSP_DBLK
                 WHERE COMMON_NAME LIKE '%SHRIMP%')) and (a.area_code between '630'
 and '799' and a.area_code not in ('777', '750', '747') and a.area_code||a.sub_area_code not in ('7440001', '7480001')
 or a.area_code||a.sub_area_code in ('0010000','0010009','0020002', '0020009') or a.area_code in ('000') and
a.state_code
  in ('37','45','13') or a.area_code in ('000') and a.state_code
  in ('12') and a.county_code in ('107',
'127',
'035',
'069',
'097',
'007',
'111',
'109',
'095',
'085',
'031',
'011',
'009',
'061',
'099',
'089',
'003',
'093',
'125',
'117',
'025',
```

```
'019')));
disconnect from oracle                                                          ;
QUIT ;
/*SC EFFORT DATA NOT AT ACCSP YET, SO SC SENT US TRIP TICKET DATA FOR 2004-2014 IN A .CSV
FILE*/
/*DATA SASDATA.SCDNR_Shrimp_Data;                          ;
/*     %let _EFIERR_ = 0; /* set the ERROR detection macro variable */
/*      infile 'Z:\SEFSC\SHRIMP\STANDARD EXTRACT\SCDNR_Shrimp_Data_2004-2014_051415.csv'
delimiter = ',' MISSOVER DSD
 lrecl=32767 firstobs=2 ;
        FORMAT
          CONS_RPT_ID      10.
          TRIP_ID          10.
          DATA_SUPPLIER    $4.
          FORM_VERSION     $5.
          UNLOAD_YEAR      4.
          UNLOAD_MONTH     $2.
          UNLOAD_DAY       $2.
          STATE_CODE       $2.
          COUNTY_CODE      $3.
          IDENT            $15.
          SUPPLIER_PA_ID   $30.
          COAST_GUARD_NBR  $11.
          STATE_REG_NBR    $14.
          GEAR_CODE        $3.
          GEAR_NAME        $30.
          AREA_CODE        $3.
          SUB_AREA_CODE    $4.
          DISTANCE_CODE    $1.
          SPECIES_ITIS     $11.
          COMMON_NAME      $50.
          DISPOSITION_CODE $3.
          MARKET_CODE      $2.
          GRADE_CODE       $2.
          LIVE_POUNDS      11.2
          DOLLARS          11.2
          START_YEAR       4.
          START_MONTH      $2.
          START_DAY        $2.
          TRIP_NBR         3.
          SPLIT_TRIP       $1.
          DAYS_AT_SEA      5.
          COUNTY_CODE2     $3.
          STATE_CODE2      $2.
          AREA_CODE2       $3.
          SUB_AREA_CODE2   $4.
          DISTANCE_CODE2   $1.
          GEAR_CODE2       $3.
          Nets_Towed       10.
          Head_Rope_Length_Ft 3.
          Number_Of_Tows   5.
         Tow_Time_Hrs      12.2
          Pots_Pulled      5.
          Soak_Time_Hrs    12.2
          Hrs_Fished       12.2;
        INFORMAT
          CONS_RPT_ID      10.
          TRIP_ID          10.
```

```
  DATA_SUPPLIER    $4.
  FORM_VERSION     $5.
  UNLOAD_YEAR      4.
  UNLOAD_MONTH     $2.
  UNLOAD_DAY       $2.
  STATE_CODE       $2.
  COUNTY_CODE      $3.
  IDENT            $15.
  SUPPLIER_PA_ID   $30.
  COAST_GUARD_NBR  $11.
  STATE_REG_NBR    $14.
  GEAR_CODE        $3.
  GEAR_NAME        $30.
  AREA_CODE        $3.
  SUB_AREA_CODE    $4.
  DISTANCE_CODE    $1.
  SPECIES_ITIS     $11.
  COMMON_NAME      $50.
  DISPOSITION_CODE $3.
  MARKET_CODE      $2.
  GRADE_CODE       $2.
  LIVE_POUNDS      best11.
  DOLLARS          best11.
  START_YEAR       4.
  START_MONTH      $2.
  START_DAY        $2.
  TRIP_NBR         3.
  SPLIT_TRIP       $1.
  DAYS_AT_SEA      5.
  COUNTY_CODE2     $3.
  STATE_CODE2      $2.
  AREA_CODE2       $3.
  SUB_AREA_CODE2   $4.
  DISTANCE_CODE2   $1.
  GEAR_CODE2       $3.
  Nets_Towed       10.
  Head_Rope_Length_Ft 3.
  Number_Of_Tows   best12.
 Tow_Time_Hrs      best12.
  Pots_Pulled      best12.
  Soak_Time_Hrs    best12.
  Hrs_Fished       best12.;
INPUT
  CONS_RPT_ID
  TRIP_ID
  DATA_SUPPLIER    $
  FORM_VERSION     $
  UNLOAD_YEAR
  UNLOAD_MONTH     $
  UNLOAD_DAY       $
  STATE_CODE       $
  COUNTY_CODE      $
  IDENT            $
  SUPPLIER_PA_ID   $
  COAST_GUARD_NBR  $
  STATE_REG_NBR    $
  GEAR_CODE        $
  GEAR_NAME        $
```

```
            AREA_CODE       $
            SUB_AREA_CODE    $
            DISTANCE_CODE    $
            SPECIES_ITIS     $
            COMMON_NAME      $
            DISPOSITION_CODE $
            MARKET_CODE      $
            GRADE_CODE       $
            LIVE_POUNDS
            DOLLARS
            START_YEAR
            START_MONTH      $
            START_DAY        $
            TRIP_NBR
            SPLIT_TRIP       $
            DAYS_AT_SEA
            COUNTY_CODE2     $
            STATE_CODE2      $
            AREA_CODE2       $
            SUB_AREA_CODE2   $
            DISTANCE_CODE2   $
            GEAR_CODE2       $
            Nets_Towed
            Head_Rope_Length_Ft
            Number_Of_Tows
           Tow_Time_Hrs
            Pots_Pulled
            Soak_Time_Hrs
            Hrs_Fished
      ;
      if _ERROR_ then call symput('_EFIERR_',1);
       RUN;

/*STRUCTURE SC DATA FOR MERGE WITH ACCSP DATA*/
/*DATA SASDATA.SCDNR_Shrimp_Data2;
SET SASDATA.SCDNR_Shrimp_Data;
CONS_RPT_ID = TRIP_ID;
IF '0' < STATE_REG_NBR < '2000000' THEN COAST_GUARD_NBR = STATE_REG_NBR;
IF '0' < STATE_REG_NBR < '2000000' THEN STATE_REG_NBR = '';
FORMAT FISHING_HOURS 10.2;
FORMAT SOAK_TIME 10.2;
FORMAT GEAR_QUANTITY 5.;
IF Tow_Time_Hrs > 0 THEN FISHING_HOURS = Tow_Time_Hrs;
IF FISHING_HOURS = . AND Hrs_Fished > 0 THEN FISHING_HOURS = Hrs_Fished;
IF FISHING_HOURS = . AND Soak_Time_Hrs > 0 THEN FISHING_HOURS = Soak_Time_Hrs;
SOAK_TIME = Soak_Time_Hrs;
GEAR_QUANTITY = Nets_Towed;
IF NETS_TOWED = . THEN GEAR_QUANTITY = POTS_PULLED;
DROP NETS_TOWED HEAD_ROPE_LENGTH_FT TOW_TIME_HRS POTS_PULLED SOAK_TIME_HRS
HRS_FISHED Number_Of_Tows;
RUN;



/*CHECK ACCSP DATA FOR DISTRIBUTION OF YEARS*/
/*proc sql;
select unload_year, data_supplier, state_code, sum(live_pounds)
from SASDATA.ACCSP_TRIPS_SHRIMP_TEMP
```

```
group by unload_year, data_supplier, state_code
order by unload_year,  state_code, data_supplier;
quit;

/*1992 AND 1993 INCOMPLETE IN SAS SYSTEM SO USE ALS RECORDS IN ACCSP TO GENERATE
ESTIMATED EFFORT*/
/*PROC SQL      ;
            connect to oracle  (user=dgloeckn orapw="gadus6674"  path="SECPR")                              ;
            create table sasdata.ACCSP_TRIPS_SHRIMP_TEMP_NC as

            select * from connection to oracle
 (               SELECT A.CONS_RPT_ID, A.CONS_RPT_ID AS TRIP_ID, A.DATA_SUPPLIER_ID AS
DATA_SUPPLIER,'ACCSP' as FORM_VERSION,
A.YEAR AS UNLOAD_YEAR, A.MONTH_IN_YEAR AS UNLOAD_MONTH, A.DAY_IN_MONTH AS
UNLOAD_DAY,A.STATE_CODE, A.COUNTY_CODE,
(A.DATA_SOURCE||A.DEALER_ID) AS IDENT, A.CF_LICENSE_NBR AS
SUPPLIER_PA_ID,A.VESSEL_CG_OR_ST_REG AS COAST_GUARD_NBR,A.VESSEL_CG_OR_ST_REG
AS STATE_REG_NBR,
A.GEAR_CODE,E.GEAR_NAME, A.AREA_CODE, A.SUB_AREA_CODE, A.DISTANCE_CODE,
A.SPECIES_ITIS, G.COMMON_NAME, A.DISPOSITION_CODE, A.MARKET_CODE, A.GRADE_CODE,
A.LIVE_POUNDS, A.DOLLARS
FROM accsp_inf2.mv_landings@accsp_dblk A
LEFT JOIN ACCSPREC.GEARS@ACCSP_DBLK E ON (A.GEAR_CODE = E.GEAR_CODE)
LEFT JOIN ACCSPREC.SPECIES@ACCSP_DBLK G ON (A.SPECIES_ITIS = G.SPECIES_ITIS)
WHERE A.state_code = '37' and a.year between 1992 and 1993 AND A.CONS_RPT_ID IN (SELECT
CONS_RPT_ID FROM accsp_inf2.mv_landings@accsp_dblk WHERE SPECIES_ITIS IN
                (SELECT SPECIES_ITIS
                 FROM ACCSPREC.SPECIES@ACCSP_DBLK
                 WHERE COMMON_NAME LIKE '%SHRIMP%')));
disconnect from oracle                                                                                  ;
QUIT ;
/*
PROC APPEND BASE =  sasdata.ACCSP_TRIPS_SHRIMP_TEMP DATA =
sasdata.ACCSP_TRIPS_SHRIMP_TEMP_NC FORCE;
RUN;*/
/*DELETE WEST COAST OF FL*/
proc sql;
delete
from sasdata.ACCSP_TRIPS_SHRIMP_TEMP
where (STATE_CODE = '12' and county_code not in ('107',
'127',
'035',
'069',
'097',
'007',
'111',
'109',
'095',
'085',
'031',
'011',
'009',
'061',
'099',
'089',
'003',
'093',
'125',
```

```
'117',
'025',
'019')) or state_code = '00';
quit;
/*DELETE SC*/
/*proc sql;
delete
from sasdata.ACCSP_TRIPS_SHRIMP_TEMP
where DATA_SUPPLIER = '0013';
quit;
/*APPEND ACCSP DATA AND SC FILE*/
/*PROC APPEND BASE =  sasdata.ACCSP_TRIPS_SHRIMP_TEMP DATA =
SASDATA.SCDNR_Shrimp_Data2 FORCE;
RUN;

libname SASDATA V8 "N:\FMB\DATA REQUESTS\2016\JEFF KIPP SHRIMP EFFORT";
/*CREATE LOOKUP TABLES FROM ACCSP*/
/*CREATE SPECIES LOOKUP*/
PROC SQL;
connect to oracle  (user=dgloeckn orapw="gadus6674"  path="SECPR")                              ;
            create table sasdata.ACCSP_SPECIES_TEMP AS
select * from connection to oracle
(SELECT * FROM ACCSPREC.SPECIES@ACCSP_DBLK);
disconnect from oracle;
QUIT;
/*CREATE GEAR LOOKUP*/
PROC SQL;
connect to oracle  (user=dgloeckn orapw="gadus6674"  path="SECPR")                              ;
            create table sasdata.ACCSP_GEARS_TEMP AS
select * from connection to oracle
(SELECT * FROM ACCSPREC.GEARS@ACCSP_DBLK);
disconnect from oracle                                                  ;
QUIT;
/*CREATE PARTICIPANT LOOKUP*/
PROC SQL;
connect to oracle  (user=dgloeckn orapw="gadus6674"  path="SECPR")                              ;
CREATE TABLE sasdata.ACCSP_PARTICIPANTS_TEMP AS
select * from connection to oracle
(SELECT * FROM ACCSPREC.PARTICIPANTS@ACCSP_DBLK);
disconnect from oracle                                                  ;
QUIT;
/*CREATE VESSEL LOOKUP*/
PROC SQL;
connect to oracle  (user=dgloeckn orapw="gadus6674"  path="SECPR")                              ;
            create table sasdata.ACCSP_VESSELS_TEMP AS
select * from connection to oracle
(SELECT * FROM ACCSPREC.VESSELS@ACCSP_DBLK);
disconnect from oracle                                                  ;
QUIT;
/*CREATE LOOKUP OF NON-FOOD SHRIMP SPECIES*/
PROC SQL;
connect to oracle  (user=dgloeckn orapw="gadus6674"  path="SECPR")                              ;
            create table sasdata.ACCSP_SHRIMP_DROP_SPECIES_XREF AS
select * from connection to oracle
(SELECT *  FROM
DGLOECKN.ACCSP_SHRIMP_DROP_SPECIES_XREF);
disconnect from oracle                                                  ;
QUIT;
```

```
/*DELETE WHERE SPECIES NOT FOOD SHRIMP*/
proc sql;
DELETE FROM sasdata.ACCSP_TRIPS_SHRIMP_TEMP
WHERE SPECIES_ITIS IN (SELECT SPECIES_ITIS FROM
sasdata.ACCSP_SHRIMP_DROP_SPECIES_XREF);
quit;
/*ADD TEXT DISPOSITION DESCRIPTOR*/
data sasdata.ACCSP_TRIPS_SHRIMP_TEMP;
set sasdata.ACCSP_TRIPS_SHRIMP_TEMP;
format disposition $20.0;
run;
/*SET DISPOSITION TO BAIT IF CODED AS BAIT, FOOD FOR ALL OTHERS*/
proc sql;

UPDATE sasdata.ACCSP_TRIPS_SHRIMP_TEMP
SET disposition = 'BAIT'
WHERE DISPOSITION_CODE = '008' OR MARKET_CODE = 'BT' OR GRADE_CODE = '02' or species_itis =
'095603';

UPDATE sasdata.ACCSP_TRIPS_SHRIMP_TEMP
SET DISPOSITION = 'FOOD'
WHERE disposition IS NULL;

/*INSERT DISTINCT TRIP ID IF BLANK*/
UPDATE sasdata.ACCSP_TRIPS_SHRIMP_TEMP
SET TRIP_ID = CONS_RPT_ID WHERE TRIP_ID IS NULL;
quit;

DATA sasdata.ACCSP_TRIPS_SHRIMP_TEMP1;
SET sasdata.ACCSP_TRIPS_SHRIMP_TEMP;
RUN;
/*SORT ACCSP DATA TO DETERMINE TARGET SPECIES*/
PROC SORT DATA = SASDATA.ACCSP_TRIPS_SHRIMP_TEMP1;
BY CONS_RPT_ID IDENT SUPPLIER_PA_ID TRIP_ID UNLOAD_YEAR UNLOAD_DAY
UNLOAD_MONTH STATE_CODE COUNTY_CODE DATA_SUPPLIER DESCENDING LIVE_POUNDS;
RUN;
/*REMOVE DUPLICATE EFFORTS ACROSS SINGLE TRIP*/
PROC SORT IN=SASDATA.ACCSP_TRIPS_SHRIMP_TEMP1
OUT=SASDATA.ACCSP_TRIPS_SHRIMP_TEMP2 NODUPKEY ;
BY UNLOAD_YEAR UNLOAD_DAY UNLOAD_MONTH SUPPLIER_PA_ID IDENT TRIP_ID
CONS_RPT_ID STATE_CODE COUNTY_CODE DATA_SUPPLIER;
RUN ;
/*REMOVE NON-FOOD SHRIMP TARGETED TRIPS*/
PROC SQL;
DELETE FROM SASDATA.ACCSP_TRIPS_SHRIMP_TEMP2
WHERE SPECIES_ITIS NOT IN (SELECT SPECIES_ITIS FROM sasdata.ACCSP_SPECIES_TEMP WHERE
COMMON_NAME LIKE '%SHRIMP%');
QUIT;
/*DETERMINE DISTRIBUTION OF DATA ACROSS STATE, YEAR AND DATA SOURCE*/
/*proc sql;
select distinct state_code,unload_year,  data_supplier
from SASDATA.ACCSP_TRIPS_SHRIMP_TEMP2
order by state_code,unload_year,  data_supplier;
quit;

/*CREATE EFFORT ANALYSIS VARIABLES FROM RECORDED EFFORT*/
DATA SASDATA.ACCSP_TRIPS_SHRIMP_TEMP3;
SET SASDATA.ACCSP_TRIPS_SHRIMP_TEMP2;
```

```
FORMAT NO_START_DATE $1.;/*FORMAT NEW VARIABLE*/
FORMAT TRIPS 10.0; /*FORMAT NEW VARIABLE*/
FORMAT TIME_FISHED 10.2;/*FORMAT NEW VARIABLE*/
FORMAT TIME_UNITS $1.0;/*FORMAT NEW VARIABLE*/
FORMAT DAYS_FISHED 10.2;/*FORMAT NEW VARIABLE*/
FORMAT DAYS_AWAY 10.0;  /*FORMAT NEW VARIABLE*/
IF START_YEAR = . THEN NO_START_DATE = 'Y'; /*insert flag if start date is missing*/
ELSE NO_START_DATE = 'N';/*FLAG IF START DATE PRESENT*/
IF UNLOAD_DAY = '00' THEN UNLOAD_DAY = '01'; /*CORRECT DAY FOR SUMMARY RECORDS*/
IF START_DAY = '00' THEN START_DAY = '01';/*CORRECT DAY FOR SUMMARY RECORDS*/
IF START_month = '00' THEN START_MONTH = UNLOAD_MONTH; /*CORRECT START MONTH IF
SUMMARY DATA*/
FORMAT START_DATE MMDDYY10.; /*FORMAT START DATE VARIABLE*/
FORMAT UNLOAD_DATE MMDDYY10.;/*FORMAT UNLOAD DATE VARIABLE*/
START_DATE = mdy(START_month,START_DAY,START_year); /*CREATE START DATES*/
UNLOAD_DATE = mdy(UNLOAD_month,UNLOAD_DAY,UNLOAD_year);/*CREATE UNLOAD DATES*/
IF STATE_CODE = '12' AND GEAR_CODE = '110' THEN GEAR_NAME = 'SHRIMP
TRAWL';/*STANDARDIZE GEAR NAME*/
IF STATE_CODE = '12' AND GEAR_CODE = '000' THEN GEAR_NAME = 'SHRIMP
TRAWL';/*STANDARDIZE GEAR NAME*/
TRIPS = 1;/*INDICATE EACH TRIP TICKET AS 1 TRIP*/
IF SPLIT_TRIP = 'Y' THEN TRIPS = TRIPS/2; /* IF TRIP IS DIVIDED BETWEEN FISHERMEN THEN
EFFORT IS REPORTED TWICE, SO MUST DIVIDE # TRIPS*/
IF SPLIT_TRIP = 'Y' THEN DAYS_AT_SEA = DAYS_AT_SEA/2; /* IF TRIP IS DIVIDED BETWEEN
FISHERMEN THEN EFFORT IS REPORTED TWICE, SO MUST DIVIDE DAYS AT SEA*/
IF SPLIT_TRIP = 'Y' THEN FISHING_HOURS = FISHING_HOURS/2;/* IF TRIP IS DIVIDED BETWEEN
FISHERMEN THEN EFFORT IS REPORTED TWICE, SO MUST DIVIDE FISHING HOURS*/
IF FISHING_HOURS > 0 AND FISHING_HOURS > DAYS_AT_SEA THEN TIME_UNITS = 'H';/*IF FISHING
HOURS > DAYS AT SEA ASSUME TIME UNITS IS IN HOURS*/
IF FISHING_HOURS > 0 AND FISHING_HOURS > DAYS_AT_SEA THEN TIME_FISHED =
FISHING_HOURS;/*IF FISHING HOURS > DAYS AT SEA ASSUME TIME FISHED IS IN HOURS*/
ELSE TIME_UNITS = 'D';/*IF FISHING HOURS <= DAYS AT SEA THEN TIME UNITS IS IN DAYS*/
IF TIME_UNITS = 'D' AND DAYS_AT_SEA > 0 THEN TIME_FISHED = DAYS_AT_SEA;
IF TIME_FISHED > 0 AND FISHING_HOURS > 0 AND TIME_UNITS = 'H' THEN DAYS_FISHED =
ROUND(((TIME_FISHED/12)+.4),1); /*IF HOURS FISHED IS COLLECTED, USE HOURS FISHED TO
DETERMINE DAYS FISHED*/
IF TIME_UNITS = 'D' THEN DAYS_FISHED = DAYS_AT_SEA;/*IF TIME UNITS IN DAYS THEN DAYS
FISHED IS DAYS AT SEA*/
DAYS_AWAY = (unload_date-start_date)+1; /*DETERMINE DAYS AWAY FROM START AND UNLOAD
DAY*/
IF SPLIT_TRIP = 'Y' THEN DAYS_AWAY = DAYS_AWAY/2;/* IF TRIP IS DIVIDED BETWEEN
FISHERMEN THEN EFFORT IS REPORTED TWICE, SO MUST DIVIDE DAYS AWAY*/
IF DAYS_FISHED = . AND TIME_UNITS = 'D' THEN DAYS_FISHED = DAYS_AWAY; /*IF DAYS FISHED
AND HOURS FISHED NOT COLLECTED, USE DAYS AWAY FOR DAYS FISHED*/
IF TIME_UNITS = 'D' AND TIME_FISHED = . AND DAYS_AWAY > 0 THEN TIME_FISHED =
DAYS_AWAY;/*IF DAYS FISHED AND HOURS FISHED NOT COLLECTED, USE DAYS AWAY FOR
TIME FISHED*/
IF TIME_UNITS = 'D' AND TIME_FISHED = 0 AND DAYS_AWAY > 0 THEN TIME_FISHED =
DAYS_AWAY;/*IF DAYS FISHED AND HOURS FISHED NOT COLLECTED, USE DAYS AWAY FOR
TIME FISHED*/
IF DAYS_FISHED > 45 THEN DAYS_FISHED = 1*TRIPS;/*IF DAYS AT SEA > 45 THEN ASSUME ERROR
IN HOURS AND SET DAYS AT SEA TO 1*/
IF DISPOSITION = 'BAIT' THEN DELETE;/*DELETE BAIT TRIPS*/
IF UNLOAD_MONTH = '12' OR UNLOAD_MONTH = '01' OR UNLOAD_MONTH = '02' THEN SEASON =
'WINTER';/*SET SEASON TO WINTER*/
ELSE SEASON = 'SUMMER';/*SET OTHER MONTHS TO SUMMER*/
RUN;
```

```
/*CREATE STANDARD TABLE STRUCTURE*/
proc sql;
CREATE TABLE SASDATA.ACCSP_LANDINGS_SHRIMP
(DEALER_RPT_ID        NUM,
TRIP_ID         NUM,
DATA_SUPPLIER        CHAR(4),
FORM_VERSION         CHAR(10),
UNLOAD_YEAR          NUM,
UNLOAD_MONTH         CHAR(2),
UNLOAD_DAY CHAR(2),
STATE_CODE   CHAR(2),
COUNTY_CODE          CHAR(3),
IDENT  CHAR(15),
SUPPLIER_PA_ID       CHAR(30),
VESSEL_ID      CHAR(11),
STATE_REG_NBR        CHAR(11),
GEAR_CODE     CHAR(3),
GEAR_NAME    CHAR(50),
AREA_CODE     CHAR(3),
SUB_AREA_CODE        CHAR(4),
DISTANCE_CODE        CHAR(1),
SPECIES_ITIS   CHAR(11),
COMMON_NAME          CHAR(50),
LANDED_LBS   NUM,
DOLLARS        NUM,
TIME_FISHED   NUM,
TIME_UNITS     CHAR(1),
TRIP_START_DATE DATE,
SEASON          CHAR(10),
INSHORE_OFFSHORE    CHAR(10),
SHRIMP_ZONE CHAR(2),
GEAR_CATEGORY        CHAR(50),
START_YEAR   NUM,
START_MONTH          CHAR(2),
START_DAY     CHAR(2),
START_DATE   DATE,
UNLOAD_DATE          DATE,
DAYS_FISHED  NUM,
DAYS_FISHED_CALC    NUM,
TRIPS NUM,
ZONE CHAR(10),
INSHORE_OFFSHORE2 CHAR(10),
DISPOSITION CHAR(10));
quit;
/*INSERT ACCSP DATA INTO STANDARD TABLE STRUCTURE*/
proc sql;
INSERT INTO SASDATA.ACCSP_LANDINGS_SHRIMP
select a.CONS_RPT_ID,
a.TRIP_ID,
a.DATA_SUPPLIER,
a.FORM_VERSION,
a.UNLOAD_YEAR        ,
a.UNLOAD_MONTH,
a.UNLOAD_DAY,
a.STATE_CODE,
a.COUNTY_CODE,
a.IDENT          ,
a.SUPPLIER_PA_ID,
```

```
a.COAST_GUARD_NBR ,
a.STATE_REG_NBR        ,
a.GEAR_CODE,
a.GEAR_NAME  ,
a.AREA_CODE   ,
a.SUB_AREA_CODE,
a.DISTANCE_CODE        ,
a.SPECIES_ITIS,
a.COMMON_NAME,
a.LIVE_POUNDS ,
a.DOLLARS,
A.TIME_FISHED,
A.TIME_UNITS,
a.START_DATE,
A.SEASON ,
'',
'' ,
B.CATEGORY_CODE ,
a.START_YEAR,
a.START_MONTH,
a.START_DAY   ,
a.START_DATE,
a.UNLOAD_DATE,
A.DAYS_FISHED ,
. ,
a.TRIPS,
'',
'' ,
a.DISPOSITION
from SASDATA.ACCSP_TRIPS_SHRIMP_TEMP3 a LEFT JOIN sasdata.ACCSP_GEARS_TEMP B ON
(A.GEAR_CODE = B.GEAR_CODE);
  quit;
/*CREATE SHRIMP DATA FROM SOUTH ATLANTIC SHRIMP (SAS) SYSTEM*/
PROC SQL;
        connect to oracle  (user=dgloeckn orapw="gadus6674"  path="SECPR")                              ;
        CREATE TABLE SASDATA.SAS_MAIN_DATA_EFFORT AS

        select * from connection to oracle
(SELECT TO_NUMBER((A.DATE_LANDED||A.DEALER_NUMBER||A.SCHEDULE_NUMBER)) AS
TEMPID1,
TO_NUMBER((A.DATE_LANDED||A.DEALER_NUMBER||A.SCHEDULE_NUMBER)) AS TEMPID2,
DECODE(A.STATE_LANDED,43,'0013',13,'0014',36, '0012',10,'0015','NONE') AS DATA_SUPPLIER,
'SAS' AS FORM_VERSION,
TO_NUMBER(SUBSTR(A.DATE_LANDED,1,4)) AS UNLOAD_YEAR,
SUBSTR(A.DATE_LANDED,5,2) AS UNLOAD_MONTH,
SUBSTR(A.DATE_LANDED,7,2) AS UNLOAD_DAY,
LPAD(LTRIM(SUBSTR(TO_CHAR(A.STATE_LANDED,'99'),2)),2,'0') AS STATE_LANDED,
LPAD(LTRIM(SUBSTR(TO_CHAR(A.COUNTY_LANDED,'99'),2)),2,'0') AS COUNTY_LANDED,
LPAD(LTRIM(SUBSTR(TO_CHAR(A.COUNTY_LANDED,'999'),2)),3,'0')||TRIM(dealer_number) AS IDENT,
A.SCHEDULE_NUMBER,
TRIM(A.dealer_number) AS DEALER_NUMBER,
A.VESSEL_ID_NUMBER AS VESSEL_ID,
A.VESSEL_ID_NUMBER AS BOAT_ID,
A.GEAR_CODE,
UPPER(B.DESCRIPTION) AS GEAR_NAME,
A.AREA_FISHED,
A.SUBAREA_FISHED AS SUB_AREA,
NULL AS DISTANCE_CODE,
```

```
A.SPECIES_CODE,
UPPER(C.COMMON_NAME) AS SPECIES_NAME,
A.POUNDS_CAUGHT AS LANDED_LBS,
TO_NUMBER((A.UNIT_COST/100)) AS DOLLARS,
NULL AS SEASON,
NULL AS INSHORE_OFFSHORE,
NULL AS SHRIMP_ZONE,
NULL AS GEAR_CATEGORY,
TO_NUMBER(SUBSTR(A.DATE_LANDED,1,4)) AS START_YEAR,
SUBSTR(A.DATE_LANDED,5,2) AS START_MONTH,
SUBSTR(A.DATE_LANDED,7,2) AS START_DAY,
A.CALENDAR_DAYS_FISHED AS DAYS_FISHED,
0 AS DAYS_FISHED_CALC,
((nvl(boat_trips, 0) + nvl(vessel_trips, 0))/10) AS SAS_TRIPS,
DECODE(STATE_LANDED,'36','37','43','45','13','13','10','12','00') AS STATE_LANDED2,
LPAD(LTRIM(E.FIPS_COUNTY_CODE,'0'),3,'0') AS COUNTY_LANDED2,
DECODE(A.GEAR_CODE,'A','090','B','075','C','118','D','110',
'E','110','F','110','G','750','H','020','I','116','J','143','Z','801','000') AS GEAR_CODE2,
LPAD(LTRIM(F.accsp_area,'0'),3,'0') AS AREA_FISHED2,
LPAD(LTRIM(F.accsp_SUBarea,'0'),4,'0') AS SUBAREA_FISHED2,
C.SPECIES_ITIS AS SPECIES_CODE2,
DECODE(nvl(A.SPECIES_CODE,'0'),'0','NONE','B','BAIT','FOOD') AS DISPOSITION
FROM SAS.SAS_MAIN_DATA A
LEFT JOIN SAS.SAS_GEAR_CODE B ON (A.GEAR_CODE = B.GEAR_CODE)
LEFT JOIN SAS.SPECIES_CODE_SAS C ON (A.SPECIES_CODE = C.SAS_CODE)
LEFT JOIN SAS.SAS_ALS_FIPS_COUNTY_XREF E ON (E.ALSSTATE= A.STATE_LANDED
   AND LPAD(E.SASCOUNTY, 2, '0') = LPAD(A.COUNTY_LANDED, 2, '0'))
LEFT JOIN SAS.SAS_AREA_code F ON (to_number(F.area_code) = TO_NUMBER(a.area_fished)
and to_number(F.subarea_code)= TO_NUMBER(a.SUBAREA_FISHED)));
disconnect from oracle                                                    ;
QUIT;
/*DELETE BAIT TRIPS AND YEARS WHERE TRIP TICKET DATA EXIST IN ACCSP and format and
populate trip start and end dates*/
DATA SASDATA.SAS_MAIN_DATA_EFFORT1;
SET SASDATA.SAS_MAIN_DATA_EFFORT;
FORMAT START_DATE MMDDYY10.;
FORMAT UNLOAD_DATE MMDDYY10.;
START_DATE = mdy(START_month,START_DAY,START_year);
UNLOAD_DATE = mdy(UNLOAD_month,UNLOAD_DAY,UNLOAD_year);
IF SPECIES_CODE = '6' THEN DELETE;
IF DISPOSITION = 'BAIT' THEN DELETE;
IF BOAT_ID NE '000000' THEN BOAT_ID = '';
IF BOAT_ID NE '000000' THEN VESSEL_ID = '';
IF STATE_LANDED = '43' AND UNLOAD_YEAR > 2003 THEN DELETE;
IF STATE_LANDED = '13' AND UNLOAD_YEAR > 2000 THEN DELETE;
RUN;
/*SORT SAS DATA BY PRIMARY CATCH AND EFFORT*/
PROC SORT DATA = SASDATA.SAS_MAIN_DATA_EFFORT1;
BY  TEMPID1 SAS_TRIPS DESCENDING DAYS_FISHED DESCENDING LANDED_LBS DESCENDING
UNLOAD_YEAR UNLOAD_MONTH UNLOAD_DAY IDENT DATA_SUPPLIER SCHEDULE_NUMBER;
RUN;
/*REMOVE DUPLICATE EFFORTS FOR A SINGLE TRIP*/
PROC SORT IN=SASDATA.SAS_MAIN_DATA_EFFORT1 OUT=SASDATA.SAS_MAIN_DATA_EFFORT2
NODUPKEY ;
BY TEMPID1 UNLOAD_YEAR UNLOAD_MONTH UNLOAD_DAY IDENT DATA_SUPPLIER
SCHEDULE_NUMBER;
RUN ;
/*REMOVE DATA FROM ACCSP DATA WHERE SAS DATA EXIST*/
```

```
DATA SASDATA.ACCSP_LANDINGS_SHRIMP2;
SET SASDATA.ACCSP_LANDINGS_SHRIMP;
IF STATE_CODE = '12' AND 1980 < UNLOAD_YEAR < 1993 THEN DELETE;
IF STATE_CODE = '37' AND 1977 < UNLOAD_YEAR < 1992 THEN DELETE;
IF STATE_CODE = '13' AND 1977 < UNLOAD_YEAR < 2001 THEN DELETE;
IF STATE_CODE = '45' AND 1977 < UNLOAD_YEAR < 2004 THEN DELETE;
RUN;
/*INSERT SAS DATA INTO STANDARDIZED STRUCTURE*/
PROC SQL;
INSERT INTO SASDATA.ACCSP_LANDINGS_SHRIMP2
SELECT
TEMPID1,
TEMPID2,
DATA_SUPPLIER,
FORM_VERSION,
UNLOAD_YEAR,
UNLOAD_MONTH,
UNLOAD_DAY,
STATE_LANDED2,
COUNTY_LANDED2,
IDENT,
DEALER_NUMBER,
VESSEL_ID,
BOAT_ID,
GEAR_CODE2,
GEAR_NAME,
AREA_FISHED2,
SUBAREA_FISHED2,
DISTANCE_CODE,
SPECIES_CODE2,
SPECIES_NAME,
LANDED_LBS,
DOLLARS,
.,
'',
.,
SEASON,
INSHORE_OFFSHORE,
SHRIMP_ZONE,
GEAR_CATEGORY,
START_YEAR,
START_MONTH,
START_DAY,
START_DATE,
UNLOAD_DATE,
DAYS_FISHED,
DAYS_FISHED_CALC,
SAS_TRIPS,
'',
'',
DISPOSITION
FROM SASDATA.SAS_MAIN_DATA_EFFORT2;
QUIT;

/*CODE STATE OF LANDING AND REMOVE OUT OF STATE PURCHASES AND ADD SEASON TO SAS
DATA*/
DATA SASDATA.ACCSP_LANDINGS_SHRIMP3;
SET SASDATA.ACCSP_LANDINGS_SHRIMP2;
```

```
FORMAT STATE_POSTAL $2.0;
STATE_POSTAL = 'UN';
IF STATE_CODE = '37' THEN STATE_POSTAL = 'NC';
IF STATE_CODE = '45' THEN STATE_POSTAL = 'SC';
IF STATE_CODE = '13' THEN STATE_POSTAL = 'GA';
IF STATE_CODE = '12' THEN STATE_POSTAL = 'FL';
if state_code = '00' and data_supplier = '0015' then delete;
if state_code = '00' and data_supplier = '0014' then delete;
if state_code = '00' and data_supplier = '0013' then delete;
if state_code = '00' and data_supplier = '0012' then delete;
IF UNLOAD_MONTH = '12' OR UNLOAD_MONTH = '01' OR UNLOAD_MONTH = '02' THEN SEASON =
'WINTER';/*SET SEASON TO WINTER*/
ELSE SEASON = 'SUMMER';/*SET OTHER MONTHS TO SUMMER*/
RUN;
/*PULL IN DISTANCE CODES BY AREA FISHED*/
PROC SQL;
connect to oracle  (user=dgloeckn orapw="gadus6674"  path="SECPR")                                    ;
             create table SASDATA.ACCSP_SHRIMP_WATER_LOOKUP AS
select * from connection to oracle
(SELECT *  FROM
DGLOECKN.ACCSP_SHRIMP_WATER_LOOKUP);
disconnect from oracle                                                                  ;
QUIT;
/*UPDATE DISTANCE CODE BASED ON AREA FISHED*/
PROC SQL;
UPDATE SASDATA.ACCSP_LANDINGS_SHRIMP3
SET INSHORE_OFFSHORE = (SELECT distinct INSHORE_OFFSHORE FROM
SASDATA.ACCSP_SHRIMP_WATER_LOOKUP
WHERE AREA = Accsp_landings_shrimp3.area_CODE
  AND sub = accsp_landings_shrimp3.sub_area_code)
WHERE EXISTS (SELECT * FROM SASDATA.accsp_shrimp_water_lookup
WHERE accsp_landings_shrimp3.area_Code = accsp_shrimp_water_lookup.area
  AND accsp_landings_shrimp3.sub_area_code= accsp_shrimp_water_lookup.sub);

/*SET CORRECT AREA FOR AREA||SUB AREA IF DISTANCE CODE IS PROVIDED*/

UPDATE SASDATA.ACCSP_LANDINGS_SHRIMP3
SET INSHORE_OFFSHORE = 'OFFSHORE'
   WHERE AREA_CODE = '' and DISTANCE_CODE IN ('2','3','4','5','8');

UPDATE SASDATA.ACCSP_LANDINGS_SHRIMP3
SET INSHORE_OFFSHORE = 'INSHORE'
   WHERE AREA_CODE = '' and DISTANCE_CODE in ('1', '0');


update SASDATA.accsp_landings_shrimp3
set inshore_offshore = 'OFFSHORE'
where area_code = '711' and sub_area_code in ('9998') and data_supplier = '0013';


update SASDATA.accsp_landings_shrimp3
set inshore_offshore = 'OFFSHORE'
where area_code = '635' and sub_area_code in ('0021','0023');

update SASDATA.accsp_landings_shrimp3
set inshore_offshore = 'OFFSHORE'
where inshore_offshore = '' and state_code not = '37';
```

```
update SASDATA.accsp_landings_shrimp3
set inshore_offshore = 'INSHORE'
where inshore_offshore = '' and state_code = '37';
QUIT;

/*Shrimp zone designations are required IN the output tables.  We assign
   these codes based on (1) the area code, AND (2) by the county of landing*/
/*PULL IN SHRIMP ZONE AND COUNTY XREF TABLE*/
PROC SQL;
connect to oracle  (user=dgloeckn orapw="gadus6674"  path="SECPR")                ;
             create table SASDATA.ACCSP_SHRIMP_COUNTY_ZONE_XREF AS
select * from connection to oracle
(SELECT *  FROM
DGLOECKN.ACCSP_SHRIMP_COUNTY_ZONE_XREF);
disconnect from oracle                                                  ;
QUIT;
/*ASSIGN SHRIMP ZONE BASED ON AREA FISHED*/
PROC SQL;
UPDATE SASDATA.ACCSP_LANDINGS_SHRIMP3
SET SHRIMP_ZONE = (SELECT distinct SHRIMP_ZONE FROM
SASDATA.ACCSP_SHRIMP_WATER_LOOKUP
WHERE AREA = Accsp_landings_shrimp3.area_CODE
  AND sub = accsp_landings_shrimp3.sub_area_code)
WHERE EXISTS (SELECT * FROM SASDATA.accsp_shrimp_water_lookup
WHERE accsp_landings_shrimp3.area_Code = accsp_shrimp_water_lookup.area
  AND accsp_landings_shrimp3.sub_area_code= accsp_shrimp_water_lookup.sub);

/*ASSIGN SHRIMP ZONE BASED ON COUNTY IF WATERBODY IS UNKNOWN*/
UPDATE SASDATA.ACCSP_LANDINGS_SHRIMP3
SET SHRIMP_ZONE = (SELECT distinct SHRIMP_ZONE FROM
SASDATA.ACCSP_SHRIMP_COUNTY_ZONE_XREF
WHERE COUNTY_CODE = ACCSP_LANDINGS_SHRIMP3.COUNTY_CODE
AND STATE_CODE = ACCSP_LANDINGS_SHRIMP3.STATE_CODE)
WHERE shrimp_zone IN ('00','99')
AND (STATE_cODE||COUNTY_CODE) IN (SELECT STATE_cODE||COUNTY_cODE FROM
SASDATA.ACCSP_SHRIMP_COUNTY_ZONE_XREF);

/*ASSIGN S OF HATTERAS TO PROPER WATERBODY*/
UPDATE SASDATA.ACCSP_LANDINGS_SHRIMP3
SET SHRIMP_ZONE = '34'
WHERE SHRIMP_ZONE='00'
  AND (AREA_CODE||SUB_AREA_CODE) IN (SELECT AREA||SUB FROM
SASDATA.ACCSP_SHRIMP_WATER_LOOKUP
  WHERE SUB_AREA_NAME LIKE '%SOUTH%' AND SUB_AREA_NAME LIKE '%HATTERAS%');
  QUIT;

/*ASSIGN TEXT TO ZONE DESIGNATION*/
DATA SASDATA.ACCSP_LANDINGS_SHRIMP4;
SET SASDATA.ACCSP_LANDINGS_SHRIMP3;
FORMAT ZONE $7.0;
IF SHRIMP_ZONE = '24' THEN ZONE = 'SOUTH';
IF SHRIMP_ZONE ='25' THEN ZONE ='SOUTH';
IF SHRIMP_ZONE ='26' THEN ZONE ='SOUTH';
IF SHRIMP_ZONE ='27' THEN ZONE ='SOUTH';
IF SHRIMP_ZONE ='28' THEN ZONE ='SOUTH';
IF SHRIMP_ZONE ='29' THEN ZONE = 'SOUTH';
IF SHRIMP_ZONE ='30' THEN ZONE = 'SOUTH';
IF SHRIMP_ZONE ='31' THEN ZONE = 'CENTRAL';
```

```
IF SHRIMP_ZONE ='32' THEN ZONE = 'CENTRAL';
IF SHRIMP_ZONE = '33' THEN ZONE ='CENTRAL';
IF SHRIMP_ZONE ='34' THEN ZONE = 'NORTH';
IF SHRIMP_ZONE ='35' THEN ZONE ='NORTH';
IF SHRIMP_ZONE = '36' THEN ZONE ='NORTH';
IF ZONE = '' THEN ZONE = 'UNKNOWN';
RUN;
/*ASSIGN ZONE WHERE UNKNOWN*/
PROC SQL;

UPDATE SASDATA.accsp_landings_shrimp4
SET ZONE = 'SOUTH'
WHERE  zONE ='UNKNOWN'  or zone = ''
  AND DATA_SUPPLIER='0015';

UPDATE SASDATA.accsp_landings_shrimp4
SET ZONE = 'CENTRAL'
WHERE  ZONE ='UNKNOWN'  or zone = ''
  AND DATA_SUPPLIER IN ('0014','0013');

UPDATE SASDATA.accsp_landings_shrimp4
SET  ZONE = 'NORTH'
WHERE  ZONE ='UNKNOWN' or zone = ''
  AND DATA_SUPPLIER = '0012' ;
QUIT;
/*ONLY DATA FROM 2001 AND LATER ARE REQUIRED, SO DELETE PREVIOUS YEARS*/
data SASDATA.accsp_landings_shrimp5;
set SASDATA.accsp_landings_shrimp4;
/*if unload_year < 2001 then delete;
/*if state_code = 37 and unload_year < 1994 then delete;*/
run;
/*DETERMINE AVERAGE DAYS FISHED BY YEAR, STATE, ZONE, SEASON, DISTANCE*/
proc sql;
create table sasdata.mean_days as
select unload_year, state_code, zone, season, inshore_offshore, mean(days_fished) as days, min(days_fished) as
lower, max(days_fished) as upper, count(*) as N
from SASDATA.accsp_landings_shrimp5
where days_fished is not null and days_fished > 0
group by unload_year, state_code, zone, season, inshore_offshore;
quit;
/*USE MEAN DAYS FISHED IF DAYS FISHED IS MISSING*/
proc sql;
update SASDATA.accsp_landings_shrimp5
set days_fished = (select round(days+.5)  from sasdata.mean_days where unload_year =
accsp_landings_shrimp5.unload_year and
state_code = accsp_landings_shrimp5.state_code and zone = accsp_landings_shrimp5.zone and
season = accsp_landings_shrimp5.season and inshore_offshore = accsp_landings_shrimp5.inshore_offshore)
where days_fished = . or days_fished = 0;
quit;
/*DETERMINE AVERAGE DAYS FISHED BY STATE, ZONE, SEASON, DISTANCE*/
proc sql;
create table sasdata.mean_days2 as
select state_code, zone, season, inshore_offshore, mean(days_fished) as days, min(days_fished) as lower,
max(days_fished) as upper, count(*) as N
from SASDATA.accsp_landings_shrimp5
where days_fished is not null and days_fished > 0
group by state_code, zone, season, inshore_offshore;
quit;
```

```
/*USE MEAN DAYS FISHED IF DAYS FISHED IS MISSING AND WASN'T FILLED BY STRATA IN
MEAN_DAYS TABLE*/
proc sql;
update SASDATA.accsp_landings_shrimp5
set days_fished = (select round(days+.5) from sasdata.mean_days2 where state_code =
accsp_landings_shrimp5.state_code
and zone = accsp_landings_shrimp5.zone and season = accsp_landings_shrimp5.season
and inshore_offshore = accsp_landings_shrimp5.inshore_offshore)
where days_fished = . or days_fished = 0;
quit;
/*DETERMINE AVERAGE DAYS FISHED BY ZONE, SEASON, DISTANCE*/
proc sql;
create table sasdata.mean_days3 as
select zone, season, inshore_offshore, mean(days_fished) as days, min(days_fished) as lower, max(days_fished) as
upper, count(*) as N
from SASDATA.accsp_landings_shrimp5
where days_fished is not null and days_fished > 0
group by zone, season, inshore_offshore;
quit;
/*USE MEAN DAYS FISHED IF DAYS FISHED IS MISSING AND WASN'T FILLED BY STRATA IN
MEAN_DAYS OR MEAN_DAYS2 TABLES*/
proc sql;
update SASDATA.accsp_landings_shrimp5
set days_fished = (select round(days+.5) from sasdata.mean_days3 where zone = accsp_landings_shrimp5.zone
and season = accsp_landings_shrimp5.season
and inshore_offshore = accsp_landings_shrimp5.inshore_offshore)
where days_fished = . or days_fished = 0;
quit;
/*CHECK DATA TO MAKE SURE THERE ARE NO CELLS NOT FILLED FOR DAYS_FISHED*/
proc sql;
select zone, season, inshore_offshore, count(dealer_rpt_id) as reports
from SASDATA.accsp_landings_shrimp5
where days_fished = . or days_fished = 0
group by zone, season, inshore_offshore;
quit;
/*SET HOURS BY HOURS IF RECORDED, ELSE ASSUME 12 HOURS PER DAY FISHED*/
DATA SASDATA.accsp_landings_shrimp6;
SET SASDATA.accsp_landings_shrimp5;
FORMAT HOURS_FISHED 10.2;
IF TIME_UNITS = 'H' THEN HOURS_FISHED = TIME_FISHED;
ELSE HOURS_FISHED = DAYS_FISHED*12;
RUN;
/*EXPORT COMPLETE EFFORT FILE*/
PROC EXPORT DATA= sasdata.accsp_landings_shrimp6
            OUTFILE= "N:\FMB\DATA REQUESTS\2016\JEFF KIPP SHRIMP
EFFORT\SA_SHRIMP_EFFORT_all_04182016.csv"
   DBMS=csv REPLACE;
run;
/*CREATE EFFORT BY MONTH*/
PROC SQL;
CREATE TABLE sasdata.SA_SHRIMP_EFFORT_MONTH AS
SELECT UNLOAD_YEAR, UNLOAD_MONTH, STATE_POSTAL, GEAR_NAME,  sum(hours_fished) as
HOURS, SUM(TRIPS) AS TRIPS, SUM(DAYS_FISHED) AS DAYS, COUNT(DISTINCT SUPPLIER_PA_ID)
AS DEALERS
FROM sasdata.accsp_landings_shrimp6
GROUP BY UNLOAD_YEAR, UNLOAD_MONTH, STATE_POSTAL, GEAR_NAME;
QUIT;
/*EXPORT EFFORT BY MONTH*/
```

```
PROC EXPORT DATA= sasdata.SA_SHRIMP_EFFORT_MONTH
            OUTFILE= "N:\FMB\DATA REQUESTS\2016\JEFF KIPP SHRIMP
EFFORT\SA_SHRIMP_EFFORT_MONTH_04182016.csv"
   DBMS=csv REPLACE;
run;
/*CREATE ANNUAL EFFORT*/
PROC SQL;
CREATE TABLE sasdata.SA_SHRIMP_EFFORT_ANNUAL AS
SELECT UNLOAD_YEAR, STATE_POSTAL, GEAR_NAME,  sum(hours_fished) as HOURS, SUM(TRIPS) AS
TRIPS, SUM(DAYS_FISHED) AS DAYS, COUNT(DISTINCT SUPPLIER_PA_ID) AS DEALERS
FROM sasdata.accsp_landings_shrimp6
GROUP BY UNLOAD_YEAR, STATE_POSTAL, GEAR_NAME;
QUIT;
/*EXPORT ANNUAL EFFORT*/
PROC EXPORT DATA= sasdata.SA_SHRIMP_EFFORT_ANNUAL
            OUTFILE= "N:\FMB\DATA REQUESTS\2016\JEFF KIPP SHRIMP
EFFORT\SA_SHRIMP_EFFORT_ANNUAL_04182016.csv"
   DBMS=csv REPLACE;
run;
```

Appendix 4. Modified-CSA ADMB Code

```
//#######################################################################
//#######################################################################
//Originally adapted from Chesapeake Bay 2010 blue crab assessment (M. Wilberg 2/28/2011)
//By: W Cooper 2012
//Major changes for GDAR 01:
// 1) Pulled out sex-specific due to limited biostatistical sampling of landings in Gulf
// 2) Added stage-specific mortality, including in ref points
// 3) Added environmental influences on S-R and stage-specific M
// 4) Added retrospective analyses and projections
//Further adapted from GDAR 01 Blue Crab Assessment
//By: J Kipp 2016
//Major changes for ASMFC spot assessment:
// 1) Allow for recruit survey(s) that occur after fish become vulnerable to fisheries
// 2) Added option for spawning stock estimates to be in either biomass (metric tons) or numbers and recruitment
to be a function of spawning stock biomass or spawning stock numbers
// 3) Added beta prior on SR steepness
// 4) Hardwired average Z prior to be over a subset of model years
//#######################################################################
//#######################################################################
TOP_OF_MAIN_SECTION
  //increase number of estimated parameters
  gradient_structure::set_NUM_DEPENDENT_VARIABLES(2000);
  gradient_structure::set_GRADSTACK_BUFFER_SIZE(2000400);
  gradient_structure::set_CMPDIF_BUFFER_SIZE(10000000);
  arrmblsize = 10000000;
  //#######################################################################
  //#######################################################################
DATA_SECTION
  !!USER_CODE ad_comm::change_datafile_name("Spot.dat");  //read in data file
  init_int testing //toggle to turn on/off console output for testing
  init_int fyear //first year of the model run
  init_int lyear //last year of the model run
  init_int retroYears
  init_int projYears
  int timeSteps //number of time steps in a year
  int stages //number of stages/ages to model
  !! timeSteps=1;
  !! stages=2;
  int retroSteps
  int projSteps
  !! retroSteps=retroYears*timeSteps;
  !! projSteps=projYears*timeSteps;
  //Because coded to be multiple time steps per year, need to define an indexing scheme that isn't year-based
  int mTimeSteps // total model time steps for population dynamics
  int startIndex //starting index for the model
  int endIndex //ending index for the model
  !!mTimeSteps = (lyear-fyear+1)*timeSteps; //calculate the time steps in the model
  !!startIndex=1000; //set a value, can be anything > the lag of environment time series
  //substract off the retrospective period
  !!endIndex=startIndex+mTimeSteps-1-retroSteps; //substract 1 since startIndex is first step
  //##################################
  //#Catch Data
  //##################################
  init_int ftcyear //first year of total catch
```

```
 init_int ltcyear //last year of total catch
 int cStartIndex
 int cTimeSteps //catch time steps based on catch years
 !!cTimeSteps = (ltcyear-ftcyear+1)*timeSteps;
 !!cStartIndex = (ftcyear-fyear)*timeSteps+startIndex;
 init_vector com_TC_obs(cStartIndex,cStartIndex+cTimeSteps-1) //total catch
 init_vector C_wgt_obs(cStartIndex,cStartIndex+cTimeSteps-1) //total catch in weight (metric tons) - not currently
included in the objective function
 init_vector C_cv(cStartIndex,cStartIndex+cTimeSteps-1) //catch data CV
 init_int effFlag //flag to use effort time series
 init_vector com_Eff_obs(cStartIndex,cStartIndex+cTimeSteps-1) //total catch
 //##################################
 //#Survey data
 //##################################
 //Adults
 init_int numAdSurv
 init_int fsayear //first year of adult surveys
 init_int lsayear //last year of adult surveys
 int adTimeSteps
 int adStartIndex
 !!adTimeSteps=(lsayear-fsayear+1)*timeSteps;
 !!adStartIndex = (fsayear-fyear)*timeSteps+startIndex;
 init_matrix ad_survey_obs(1,numAdSurv,adStartIndex,adStartIndex+adTimeSteps-1) //Adult survey CPUE
 init_matrix ad_survey_cv(1,numAdSurv,adStartIndex,adStartIndex+adTimeSteps-1) //Survey CVs for adults
 init_vector sa_time(1,numAdSurv) //survey time
 //Recruits
 init_int numRecSurv
 init_int fsryear
 init_int lsryear
 int recTimeSteps
 int recStartIndex
 !!recTimeSteps=(lsryear-fsryear+1)*timeSteps;
 !!recStartIndex = (fsryear-fyear)*timeSteps+startIndex;
 init_matrix re_survey_obs(1,numRecSurv,recStartIndex,recStartIndex+recTimeSteps-1) //Recruit survey CPUE
 init_matrix re_survey_cv(1,numRecSurv,recStartIndex,recStartIndex+recTimeSteps-1) //survey SDs for recruits
 init_vector sr_time(1,numRecSurv)
 //##################################
 //#Fishery params
 //##################################
 init_number p_rec //Proportion of recreational harvest per region
 init_number p_under //Proportion of harvest underreporting per region
 init_number maxF //Max F for F_pen calculation
 init_number maxM //Max M for F_pen calculation
 //##################################
 //#Adult Z estimates as prior
 //##################################
 init_number aveZ
 init_number Z_cv
 //##################################
 //#Life History params
 //##################################
 init_number sratio //Sex ratio
 init_vector M(1,stages) //mortality at age for each stage (e.g., for CS: recruits, post-recruits)
 vector Myr(1,stages) //M rate on per year basis (for ref points)
```

```
 init_vector pSpawn(1,stages) //proportion of females spawning in each season for differential spawning
throughout the year
 init_number sp_time //proportion of the time step before spawning occurs
 init_number h_prior //prior for steepness
 //init_number h_cv //cv of steepness prior
 init_number h_sd //sd of steepness prior
 init_int SRSwitch //switch for recruit function formulation; 1=bev holt, 2=ricker

 init_int fwtyear //first year of mean weights
 init_int lwtyear //last year of mean weights
 int wtTimeSteps
 int wtStartIndex
 !!wtTimeSteps=(lwtyear-fwtyear+1)*timeSteps;
 !!wtStartIndex = (fwtyear-fyear)*timeSteps+startIndex;
 init_matrix mean_wgt(1,stages,wtStartIndex,wtStartIndex+wtTimeSteps-1) //mean weight in kg
 matrix mean_wgt_mt(1,stages,wtStartIndex,wtStartIndex+wtTimeSteps-1) //mean weight in metric tons
 init_number wgt_time //timing for SSB estimates (0=beginning of the year, 1=end of the year)
 init_int SPSwitch //switch for the desired spawning stock units (1=numbers,2=biomass)
LOCAL_CALCS
 //convert M to the appropriate time frame from per year basis
 Myr=M;
 M=M/timeSteps;
 //convert individual mean_wgt from kg to metric tons so population estimates are in metric tons; numbers are in
millions, hence the conversion of kg*1000
 mean_wgt_mt=mean_wgt*1000;
END_CALCS
 //##################################
 //#Environmental time series params/data
 //##################################
 init_int numEnvTS
 init_int feyear //first year of the model
 init_int leyear //last year of the model
 int eTimeSteps
 int eStartIndex //this should be less than the startIndex
 !!eTimeSteps = (leyear-feyear+1)*timeSteps;
 !!eStartIndex = (feyear-fyear)*timeSteps+startIndex;
 init_matrix envObs(1,numEnvTS,eStartIndex,eStartIndex+eTimeSteps-1) //environmental time series (regions,
season,timesteps)
 init_vector env_cv(1,numEnvTS) //environmental time series (regions, season,timesteps)
 init_int envRecTS //time series # that influences recruitment
 init_int envRecLag //lag of recruitment influence
 init_vector envMTS(1,stages) //time series # that influences mortality
 init_vector envMLag(1,stages) //lag in mortality influence
 matrix env(1,numEnvTS,eStartIndex,endIndex+projSteps+1) //add on one for the forward stepping recruitment
 //##################################
 //#Projections
 //##################################
 init_matrix envProj(1,numEnvTS,endIndex+1,endIndex+projSteps+1)
 init_vector effProj(endIndex+1,endIndex+projSteps+1) //START with terminal year since non-estimable F
 //##################################
 //#Parameters (initial val, min, max, phase)
 //##################################
 init_number init_NIni //initial abundance of second stage
 init_vector init_NParams(1,3) //lower bound, upper bound, and phase of estimation for initial abundance
 init_number init_RIni //initial abundance of recruit stage
```

```
init_vector init_RParams(1,3) //lower bound, upper bound, and phase of estimation for initial recruitment
//F params
init_number F_qIni
init_vector F_qParams(1,3)
init_number F_devIni
init_vector F_devParams(1,3)
init_number eff_cvIni
init_vector eff_cvParams(1,3)
//recruitment param
init_number rec_devIni
init_vector rec_devParams(1,3)
init_number rec_cvIni
init_vector rec_cvParams(1,3)
init_number S0Ini
init_vector S0Params(1,3)
init_number steepIni
init_vector steepParams(1,3)
init_number sr_beta_envIni
init_vector sr_beta_envParams(1,3)
init_vector M_beta_envIni(1,stages)
init_vector M_beta_envParams(1,3)
init_number M_cvIni
init_vector M_cvParams(1,3)
init_number selIni_r
init_vector selParams_r(1,3)
init_number selIni_a
init_vector selParams_a(1,3)
//##################################
//#Likelihood Weights
//##################################
init_number com_lambda //survey weight
init_vector sa_lambda(1,numAdSurv) //survey weight
init_vector sr_lambda(1,numRecSurv)
init_number recDev_lambda //survey weight
init_number effort_lambda //survey weight
init_number aveZ_lambda //survey weight
init_number h_lambda //steepness prior weight
//##################################
//#Additional param control flags not addressed in data section
//##################################
init_number biasAdj //Adjustment multiplier for bias correction factor
//##################################
//#Reference point calcs
//##################################
//number for reference point explorations
init_number Fval_init //lowest value of F used in SPR calcs
init_number Fval_max //highest value of F used in SPR calcs
init_number Fval_inc //increment for F
int Fval_num
!!Fval_num=(Fval_max-Fval_init)/Fval_inc+1;
init_int nspr //number of values F-%SPR will be calculated at
init_vector SPR_targ(1,nspr) //Values of SPR for Fval reference point calculations
//##################################
//#EOF Test
//##################################
```

```
 init_int test //check that data read in appropriately
 //##################################
 //#Additional Variables
 //##################################
 //Total harvest including recreational
 vector TC_obs(cStartIndex,cStartIndex+cTimeSteps-1) //total catch
 //Variances for data sets
 vector C_var(cStartIndex,cStartIndex+cTimeSteps-1) //variances of catch
 number Z_var //variance of Z
 matrix ad_survey_var(1,numAdSurv,adStartIndex,adStartIndex+adTimeSteps-1) //variances for adult surveys
 matrix re_survey_var(1,numRecSurv,recStartIndex,recStartIndex+recTimeSteps-1) //variances for recruitment
surveys
 //Define index varaibles
 int y //index variable for time step
 int s //index variable for season
 int r //index variable for region
 int i //index variable
 number year //for report section
 int ispr
 int iter
 int iterMCMC
 !!iterMCMC=0;
 int index
LOCAL_CALCS
 if (SRSwitch==2) steepParams(2)=5.0; //make sure to bound steepness appropriately for Ricker
 for (y=cStartIndex; y<=cStartIndex+cTimeSteps-1; y++){
 C_var(y)=log(C_cv(y)*C_cv(y)+1); //variances of catch
 }
 Z_var=log(Z_cv*Z_cv+1); //variance of Z
 //commercial + recreational catch+prop. underreported
 TC_obs=com_TC_obs*(1.+p_rec+p_under);
 //Calculate variances from CVs
 for (i=1; i<=numAdSurv; i++){
 for (y=adStartIndex; y<=adStartIndex+adTimeSteps-1; y++){
 ad_survey_var(i,y)=log(ad_survey_cv(i,y)*ad_survey_cv(i,y)+1); //variances for adult surveys
 }
 }
 for (i=1; i<=numRecSurv; i++) {
 for (y=recStartIndex; y<=recStartIndex+recTimeSteps-1; y++){
 re_survey_var(i,y)=log(re_survey_cv(i,y)*re_survey_cv(i,y)+1); //variances for recruitment surveys
 }
 }
 for (i=1; i<=numEnvTS; i++){
 for (y=eStartIndex; y<=endIndex; y++){
 env(i,y)=envObs(i,y);
 }
 for (y=endIndex+1; y<=endIndex+projSteps; y++){
 env(i,y)=envProj(i,y);
 }
 }
 if(test!=12345) //check to make sure end of file number is correct
 {
 //if not correct, output the data and exit.
 cout << "Data not reading properly" << endl;
 cout << "Commercial\t" << com_TC_obs << endl;
```

```
 cout << "adults\t" <<ad_survey_obs << endl;
 cout << "recruits\t" <<re_survey_obs << endl;
 cout << "environment\t" <<env << endl;
 cout << "max F\t" <<maxF << endl;
 cout << "max M\t" <<maxM << endl;
 cout << "envMTS\t" <<envMTS << endl;
 cout << "env Lag\t" <<envMLag << endl;
 cout << "ini N\t" <<init_NIni << endl;
 cout << "steepIni\t" <<steepIni << endl;
 cout << "sel params r\t" <<selParams_r<< endl;
 cout << "sel params a\t" <<selParams_a<< endl;
 cout << "EOF test: " << test << endl;
 exit(1);
 }
 END_CALCS
 //######################################################################
 //######################################################################
PARAMETER_SECTION
 //Copy the Parameter estimates to double vals so can put as bounds,phases below
 LOCAL_CALCS
 //template: double xxxMin=log(xxxParams(1)); double xxxMax=log(xxxParams(2)); double
xxxPhase=log(xxxParams(2));
 double log_init_NMin=log(init_NParams(1)); double log_init_NMax=log(init_NParams(2));
 double init_NPhase=init_NParams(3);
 double log_init_RMin=log(init_RParams(1)); double log_init_RMax=log(init_RParams(2));
 double init_RPhase=init_RParams(3);
 double log_F_qMin=log(F_qParams(1)); double log_F_qMax=log(F_qParams(2)); double
 F_qPhase=F_qParams(3);
 double log_F_devMin=log(F_devParams(1)); double log_F_devMax=log(F_devParams(2));
 double F_devPhase=F_devParams(3);
 double log_eff_cvMin=log(eff_cvParams(1)); double log_eff_cvMax=log(eff_cvParams(2));
 double eff_cvPhase=eff_cvParams(3);
 double log_rec_devMin=log(rec_devParams(1)); double log_rec_devMax=log(rec_devParams(2)); double
 rec_devPhase=rec_devParams(3);
 double log_rec_cvMin=log(rec_cvParams(1)); double log_rec_cvMax=log(rec_cvParams(2));
 double rec_cvPhase=rec_cvParams(3);
 double log_S0Min=log(S0Params(1)); double log_S0Max=log(S0Params(2));
 double S0Phase=S0Params(3);
 double log_steepMin=log(steepParams(1)); double log_steepMax=log(steepParams(2));
 double steepPhase=steepParams(3);
 double sr_beta_envMin=sr_beta_envParams(1); double sr_beta_envMax=sr_beta_envParams(2); double
 sr_beta_envPhase=sr_beta_envParams(3);
 double M_beta_envMin=M_beta_envParams(1); double M_beta_envMax=M_beta_envParams(2); double
 M_beta_envPhase=M_beta_envParams(3);
 double log_M_cvMin=log(M_cvParams(1)); double log_M_cvMax=log(M_cvParams(2));
 double M_cvPhase=M_cvParams(3);
 double log_sel_r_Min=log(selParams_r(1)); double log_sel_r_Max=log(selParams_r(2));
 double sel_r_Phase=selParams_r(3);
 double log_sel_a_Min=log(selParams_a(1)); double log_sel_a_Max=log(selParams_a(2));
 double sel_a_Phase=selParams_a(3);
 END_CALCS
 //initial R and N
 //template: (Min,Max,Phase)
 init_bounded_number log_init_N(log_init_NMin,log_init_NMax,init_NPhase)
 init_bounded_number log_init_R(log_init_RMin,log_init_RMax,init_RPhase)
```

```
 //Fishing mortality for each year
 init_bounded_number log_F_q(log_F_qMin,log_F_qMax,F_qPhase)
 init_bounded_vector log_F_dev(startIndex+1,endIndex-1,log_F_devMin,log_F_devMax,F_devPhase) //don't
bother with terminal year deviation
 init_bounded_number log_eff_cv(log_eff_cvMin,log_eff_cvMax,eff_cvPhase)
 //Recruitment params
 init_bounded_dev_vector log_rec_dev(startIndex+1,endIndex,log_rec_devMin,log_rec_devMax,rec_devPhase)
 init_bounded_number log_rec_cv(log_rec_cvMin,log_rec_cvMax,rec_cvPhase)
 //Stock-recruitment parameters
 init_bounded_number log_S0(log_S0Min,log_S0Max,S0Phase)
 init_bounded_number log_steep(log_steepMin,log_steepMax,steepPhase)
 //S-R environmental link parameter
 init_bounded_number sr_beta_env(sr_beta_envMin,sr_beta_envMax,sr_beta_envPhase)
 //Adult environmental link parameter
 init_bounded_vector M_beta_env(1,stages,M_beta_envMin,M_beta_envMax,M_beta_envPhase)
 init_bounded_number log_M_cv(log_M_cvMin,log_M_cvMax,M_cvPhase)
 //Vulnerability at each stage
 init_bounded_number log_sel_r(log_sel_r_Min,log_sel_r_Max,sel_r_Phase)
 init_bounded_number log_sel_a(log_sel_a_Min,log_sel_a_Max,sel_a_Phase)
 //############### Derived parameters ###############//
 //sdreport_matrix for some of these
 sdreport_vector N(startIndex,endIndex+1+projSteps) //abundance
 sdreport_vector R(startIndex,endIndex+1+projSteps) //recruitment
 sdreport_vector SSB(startIndex,endIndex+projSteps) //spawning stock biomass
 vector SP(startIndex,endIndex+projSteps) //number of spawners
 vector TC(startIndex,endIndex+projSteps) //total catch
 vector C_wgt(startIndex,endIndex+projSteps) //catch of recruits in weight
 vector u(startIndex,endIndex+projSteps) //total exploitation rate
 sdreport_vector F(startIndex,endIndex+projSteps) //fishing mortality rate
 vector effort(startIndex,endIndex+projSteps) //fishing mortality rate
 number sel_r //selectivity (partial recruitment) of recruits to the fishery
 number sel_a //selectivity
 matrix Mt(1,stages,startIndex,endIndex+projSteps) //M at time t; don't do for years to account for seasonal M
 vector Z(startIndex,endIndex+projSteps) //total Z
 matrix ad_survey_est(1,numAdSurv,startIndex,endIndex) //estimated adult survey indices
 matrix re_survey_est(1,numRecSurv,startIndex,endIndex) //estimated recruitment survey indices
 vector qa(1,numAdSurv) //catchability for adult surveys
 vector qr(1,numRecSurv) //catchability for recruitment surveys
 number S0
 number mu
 number tau
 number Bprior
 number Aprior
 number steep
 number R0
 number A0
 number alpha //Alpha of the S-R relationship
 number beta //Beta of the S-R relationship
 number rec_var //variance for recruitment deviations
 number eff_var //variance for effort residuals
 number M_var //variance for F deviations
 //Derived variables for reference point calculations
 number Fval //F for SPR calculations
 vector SPR(1,Fval_num) //spawners per recruit (NOT spawning potential ratio)
 number SPR0 //virgin SPR
```

```
number SPR1 //spawner per recruit per year
vector SPR_y(startIndex,endIndex+projSteps) //annual SSB/R
sdreport_vector sSPR(startIndex,endIndex+projSteps) //static SPR
vector NPR(1,Fval_num) //numbers per reruit
vector YPR(1,Fval_num) //yield per recruit
vector SPRatio(1,Fval_num) //spawning potential ratio
vector N_eq(1,Fval_num) //equilibruim numbers
vector SSB_eq(1,Fval_num) //equilibrium SSB
vector R_eq(1,Fval_num) //equilibrium recruitment
vector C_eq(1,Fval_num) //equilibrium catch
vector C_eqSort(1,Fval_num) //sorted equilibrium catch
//Reference points
vector u0_eq(1,Fval_num) //equilibrium explotation rate for age0+
vector u1_eq(1,Fval_num) //equilibrium explotation rate for age1+
vector uAll_eq(1,Fval_num) //equilibrium explotation rate for age0+
vector FSPR_ref(1,nspr) //F%SPR reference points
vector SPRDiff(1,nspr) //temporary array to check if at proper F for SPR calcs
vector Fvec(1,Fval_num) //equilibrium explotation rate for age0+
likeprof_number MSY //MSY estimate
number OFL //Overfishing Limit (Ncurrent*uMSY)
number u0MSY //exploitation rate at MSY for age 0
number u1MSY //exploitation rate at MSY for age 1+
number uMSY //exploitation rate at MSY for age 0+
number FMSY //F rate at MSY
number RMSY //equilibrium recruitment at msy
number NMSY //Number at MSY
number SSBMSY //SSB at MSY
number FLim //F Limit (target)
number NLim //N Limit (target)
number SSBLim //SSB Limit (target)
number cLim //c used in calculation of targets
number FCurr //Current F (geometric mean of last 3 years of model run, not including terminal year)
vector MCurr(1,stages) //Current M (geometric mean of last 3 years of model run)
number NCurr //Current N (geometric mean of last 3 years of model run)
number SSBCurr //Current SSB (geometric mean of last 3 years of model run)
likeprof_number SPRCurr //Current SPR using FCurr and MCurr
number FMSYRatio //Fcurr/FMSY
number NMSYRatio //Ncurr/NMSY
number SSBMSYRatio //SSBCurr/SSBMSY
number UMSYRatio //Ncurr/NMSY
number FFLimRatio //Fcurr/FLimit
number NNLimRatio //Ncurr/NLim
number termToMSY //for F calcs
//variables for likelihood function
vector Lsr(1,numRecSurv) //likelihood components for recruit surveys
vector Lsa(1,numAdSurv) //likelihood components for adult surveys
number Lc //likelihood components for catch time series
number Lz //likelihood components for adult Z estimate (anchors F/N0/R0)
number Lh //likelihood component for steepness prior
number Lrdev //likelihood for recruitment deviations
number Leff //likelihood for effort residuals
number F_pen //penalty for F above the max F
number M_pen //penalty for M above the max M
objective_function_value negLL //negative log-liklihood
//############### Starting parameter values ###############//
```

```
LOCAL_CALCS
 log_init_N=log(init_NIni);
 log_init_R=log(init_RIni);
 log_F_q=log(F_qIni);
 log_F_dev=log(F_devIni);
 log_M_cv=log(M_cvIni);
 log_rec_cv=log(rec_cvIni);
 log_rec_dev=log(rec_devIni);
 log_S0=log(S0Ini);
 log_steep=log(steepIni);
 sr_beta_env=sr_beta_envIni;
 M_beta_env=M_beta_envIni;
 log_sel_r=log(selIni_r);
 log_sel_a=log(selIni_a);
END_CALCS
 //######################################################################
 //######################################################################
PROCEDURE_SECTION
 set_initial_conditions();
 if (testing==1) cout << "End set_initial_conditions()" << endl;
 calculate_abundance_and_catch();
 if (testing==1) cout << "End calculate_abundance_and_catch()" << endl;
 calculate_predicted_indices();
 if (testing==1) cout << "End calculate_predicted_indices()" << endl;
 calculate_objective_function();
 if (testing==1) cout << "End calculate_objective_function()" << endl;
 mcmc();
 if (testing==1) cout << "End mcmc()" << endl;
 if (testing==1) {
 //calculate_sSPR();
 obs_pred();
 MSY_estimates();
 HPD_estimates();
 general_report();
 cout << "Procedure section completed first cycle, now exiting"<< endl;
 exit(1); //exit if in testing phase -- runs model at initial parameter values
 }
 //############### Main Functions ###############
FUNCTION set_initial_conditions
 //convert parameters from the log scale
 S0=exp(log_S0);
 steep=exp(log_steep);
 negLL=0.0;
 M_var=log(exp(log_M_cv)*exp(log_M_cv)+1);
 rec_var=log(exp(log_rec_cv)*exp(log_rec_cv)+1);
 eff_var=log(exp(log_eff_cv)*exp(log_eff_cv)+1);
 sel_r=exp(log_sel_r);
 sel_a=exp(log_sel_a);
 F_pen=0;
 M_pen=0;
 //######## S-R Params ########
 //Calculate virgin SPR, including proportion of recruits spawning
 if(SPSwitch==1){
	A0=sratio*pSpawn(2)*exp(-(M(1)+sp_time*M(2)))/(1.-exp(-(M(2)))) + sratio*pSpawn(1)*exp(-
(sp_time*M(1)));
```

```
 }
 if(SPSwitch==2){
        A0=sratio*pSpawn(2)*mean_wgt_mt(2,startIndex)*exp(-(M(1)+sp_time*M(2)))/(1.-exp(-(M(2)))) +
sratio*pSpawn(1)*mean_wgt_mt(1,startIndex)*exp(-(sp_time*M(1)));
 }
 R0=S0/A0;
 if (SRSwitch==1) { //Beverton-Holt
 alpha = S0*(1-steep)/(4*steep*R0);
 beta = (5*steep-1)/(4*steep*R0);
 }
 if (SRSwitch==2) { //Ricker
 beta = log(5*steep)/(0.8*S0);
 alpha =(exp((5.*log(5.*steep))/4.)*R0)/S0;
 }
 //calculate reference points after setting S-R params so can get FMSY for F projections
 calculate_reference_points();
 //######## M ########
 //compute the yearly M accounting for seasonal differences and environmental differences
 //leave this here to deal with seasonality
 for(y=startIndex; y<=endIndex+projSteps; y++) {
 //only apply deviation + bias correction if active
 Mt(1,y)=M(1);
 if (active(M_beta_env)) Mt(1,y)=M(1)*exp(M_beta_env(1)*env(envMTS(1),y-envMLag(1)))*exp(-0.5*M_var);
 if (y<=endIndex) {
 posfun(maxM-(timeSteps*Mt(1,y)),.000001,M_pen);
 negLL+=100.*M_pen;
 }
 Mt(2,y)=M(2);
 if (active(M_beta_env)) Mt(2,y)=M(2)*exp(M_beta_env(2)*env(envMTS(2),y-envMLag(2)))*exp(-0.5*M_var);
 if (y<=endIndex) {
 posfun(maxM-(timeSteps*Mt(2,y)),.000001,M_pen);
 negLL+=100.*M_pen;
 }
 }
 //######## F ########
 if (effFlag==0) effort=1.0;
 else {
 //set up effort to average and replace all missing data with average
 double avg_effort=mean(com_Eff_obs);
 //for any year prior to effort data, set to avg of all other years
 for (i=startIndex; i<=endIndex; i++) effort(i)=com_Eff_obs(i);
 for (i=endIndex+1; i<=endIndex+projSteps; i++) effort(i)=avg_effort; //effort(endIndex)+effProj(i)*termToMSY;
//deviation off the last year
 effort/=avg_effort; //scale to observed years and not including projected years
 }
 //If want to estimate ave. q instead of 1st year q: change F_dev to bounded_dev_vector and adjust here
 F(startIndex)=exp(log_F_q+log(effort(startIndex)));
 posfun(maxF-(timeSteps*F(startIndex)),.000001,F_pen);
 negLL+=100.*F_pen;
 for(y=startIndex+1; y<endIndex; y++) { //don't include terminal year estimate
 //Computed as F=q*Eff*exp(dev)
 F(y)=exp(log_F_q+log(effort(y))+log_F_dev(y));
 posfun(maxF-(timeSteps*F(y)),.000001,F_pen);
 negLL+=100.*F_pen;
 }
```

```
  //for terminal year, use estimated deviation from previous year to keep scaled together
  F(endIndex)=exp(log_F_q+log(effort(endIndex))+log_F_dev(endIndex-1));
  termToMSY=FMSY-F(endIndex); //effort range from terminal year to MSY; negative if FMSY<termF
  //no F deviations on terminal year or projected years
  for(y=endIndex+1; y<=endIndex+projSteps; y++) {
  F(y)=(F(endIndex)+effProj(y)*termToMSY);
  effort(y)=exp(log(F(y)))/exp(log_F_q);
  }
  F=F/timeSteps;
  //######## Adult Z ########
  for(y=startIndex; y<=endIndex+projSteps; y++) Z(y)=F(y)+Mt(2,y);
FUNCTION calculate_abundance_and_catch
  N(startIndex)=exp(log_init_N);
  R(startIndex)=exp(log_init_R);
  for(y=startIndex; y<=endIndex+projSteps; y++) {
  //spawners also include some animals that were recruits in the beginning of the year
  if(SPSwitch==1){
	SP(y)=sratio*(N(y)*exp(-sp_time*(Mt(2,y)+sel_a*F(y))))*pSpawn(2)+ sratio*(R(y)*exp(-
sp_time*(Mt(1,y)+sel_r*F(y))))*pSpawn(1);
		if (SRSwitch==1) { //Beverton-Holt
		// don't use recruit deviations for projection years
			if (y<endIndex) R(y+1)=(SP(y)/(SP(y)*beta+alpha))*exp(sr_beta_env*env(envRecTS,y+1-
envRecLag))*exp(log_rec_dev(y+1)-biasAdj*0.5*rec_var);
			else R(y+1)=(SP(y)/(SP(y)*beta+alpha))*exp(sr_beta_env*env(envRecTS,y+1-
envRecLag));
		}
		if (SRSwitch==2) { //Ricker
		// don't use recruit deviations for projection years
			if (y<endIndex) R(y+1)=(alpha*SP(y)*exp(-
beta*SP(y)))*exp(sr_beta_env*env(envRecTS,y+1-envRecLag))*exp(log_rec_dev(y+1)-biasAdj*0.5*rec_var);
			else R(y+1)=(alpha*SP(y)*exp(-beta*SP(y)))*exp(sr_beta_env*env(envRecTS,y+1-
envRecLag));
		}
  }
  if(SPSwitch==2){
	SSB(y)=sratio*(N(y)*mean_wgt_mt(2,y)*exp(-wgt_time*(Mt(2,y)+sel_a*F(y))))*pSpawn(2)+
sratio*(R(y)*mean_wgt_mt(1,y)*exp(-wgt_time*(Mt(1,y)+sel_r*F(y))))*pSpawn(1);
		if (SRSwitch==1) { //Beverton-Holt
		// don't use recruit deviations for projection years
			if (y<endIndex)
R(y+1)=((SSB(y)/(SSB(y)*beta+alpha))*exp(sr_beta_env*env(envRecTS,y+1-envRecLag))*exp(log_rec_dev(y+1)-
biasAdj*0.5*rec_var));
			else R(y+1)=((SSB(y)/(SSB(y)*beta+alpha))*exp(sr_beta_env*env(envRecTS,y+1-
envRecLag)));
		}
		if (SRSwitch==2) { //Ricker
		// don't use recruit deviations for projection years
			if (y<endIndex) R(y+1)=((alpha*SSB(y)*exp(-
beta*SSB(y)))*exp(sr_beta_env*env(envRecTS,y+1-envRecLag))*exp(log_rec_dev(y+1)-biasAdj*0.5*rec_var));
			else R(y+1)=((alpha*SSB(y)*exp(-beta*SSB(y)))*exp(sr_beta_env*env(envRecTS,y+1-
envRecLag)));
		}
  }
  //abundance for the next year
  N(y+1)=R(y)*exp(-(Mt(1,y)+sel_r*F(y)))+N(y)*exp(-(Mt(2,y)+sel_a*F(y)));
```

```
 //Baranov catch equation
 TC(y)=N(y)*((sel_a*F(y))/(sel_a*F(y)+Mt(2,y))*(1.-exp(-(sel_a*F(y)+Mt(2,y))))) +
R(y)*((sel_r*F(y))/(sel_r*F(y)+Mt(1,y))*(1.-exp(-(sel_r*F(y)+Mt(1,y)))));
 C_wgt(y)= N(y)*mean_wgt_mt(2,y)*((sel_a*F(y))/(sel_a*F(y)+Mt(2,y))*(1.-exp(-(sel_a*F(y)+Mt(2,y))))) +
R(y)*mean_wgt_mt(1,y)*((sel_r*F(y))/(sel_r*F(y)+Mt(1,y))*(1.-exp(-(sel_r*F(y)+Mt(1,y)))));
	if(SPSwitch==1){
		u(y)=TC(y)/(R(y)*((1-exp(-sel_r*F(y)))/(1-exp(-F(y))))+N(y));
	}
	if(SPSwitch==2){
		u(y)=C_wgt(y)/(R(y)*mean_wgt_mt(1,y)*((1-exp(-sel_r*F(y)))/(1-exp(-
F(y))))+N(y)*mean_wgt_mt(2,y));
	}
	if(SPSwitch==1){
	SPR0=sratio*pSpawn(2)*exp(-(Mt(1,y)+sp_time*Mt(2,y)))/(1.-exp(-(Mt(2,y)))) + sratio*pSpawn(1)*exp(-
(sp_time*Mt(1,y)));
	SPR_y(y)=sratio*pSpawn(2)*exp(-(Mt(1,y)+sel_r*F(y)+sp_time*(Mt(2,y)+sel_a*F(y))))/(1.-exp(-
(Mt(2,y)+sel_a*F(y)))) + sratio*pSpawn(1)*exp(-sp_time*(Mt(1,y)+sel_r*F(y)));
  }
  if(SPSwitch==2){
	SPR0=sratio*pSpawn(2)*mean_wgt_mt(2,startIndex)*exp(-(Mt(1,y)+sp_time*Mt(2,y)))/(1.-exp(-
(Mt(2,y)))) + sratio*pSpawn(1)*mean_wgt_mt(1,startIndex)*exp(-(sp_time*Mt(1,y)));
	SPR_y(y)=sratio*pSpawn(2)*mean_wgt_mt(2,y)*exp(-
(Mt(1,y)+sel_r*F(y)+sp_time*(Mt(2,y)+sel_a*F(y))))/(1.-exp(-(Mt(2,y)+sel_a*F(y)))) +
sratio*pSpawn(1)*mean_wgt_mt(1,y)*exp(-sp_time*(Mt(1,y)+sel_r*F(y)));
 }
 sSPR=SPR_y/SPR0;
 }
 //Calculate year-dependent F/N Reference Point components (i.e., ratios)
 NCurr=mfexp((log(N(endIndex))+log(N(endIndex-1))+log(N(endIndex-2)))/3);
 SSBCurr=mfexp((log(SSB(endIndex-1))+log(SSB(endIndex-2)))/2);
 FCurr=mfexp((log(F(endIndex-1))+log(F(endIndex-2)))/2);
 FMSYRatio=FCurr/FMSY;
 NMSYRatio=NCurr/NMSY;
 SSBMSYRatio=SSBCurr/SSBMSY;
 UMSYRatio=mfexp((log(u(endIndex))+log(u(endIndex-1))+log(u(endIndex-2)))/3)/uMSY;
 cLim=max(1-M(2),0.5);
 if(SPSwitch==1){
	OFL=uMSY*mfexp((log(N(endIndex))+log(N(endIndex-1))+log(N(endIndex-2)))/3); //N is by region, so
need to take mean if more
 }
 if(SPSwitch==2){
	OFL=uMSY*mfexp((log(SSB(endIndex))+log(SSB(endIndex-1))+log(SSB(endIndex-2)))/3);
	SSBLim=cLim*SSBMSY;
 }
 NLim=cLim*NMSY;
 FLim=FMSY;
 if (NCurr <= NLim) FLim=(FMSY*NCurr)/(cLim*NMSY);
 FFLimRatio=FCurr/FLim;
 NNLimRatio=NCurr/NLim;
 MCurr(1)=mfexp((log(Mt(1,endIndex))+log(Mt(1,endIndex-1))+log(Mt(1,endIndex-2)))/3);
 MCurr(2)=mfexp((log(Mt(2,endIndex))+log(Mt(2,endIndex-1))+log(Mt(2,endIndex-2)))/3);
 if(SPSwitch==1){
	SPR0=sratio*pSpawn(2)*exp(-(MCurr(1)+sp_time*MCurr(2)))/(1.-exp(-(MCurr(2)))) +
sratio*pSpawn(1)*exp(-(sp_time*MCurr(1)));
```

```
        SPR1=sratio*pSpawn(2)*exp(-(MCurr(1)+sel_r*FCurr+sp_time*(MCurr(2)+sel_a*FCurr)))/(1.-exp(-
(MCurr(2)+sel_a*FCurr))) + sratio*pSpawn(1)*exp(-sp_time*(MCurr(1)+sel_r*FCurr));
 }
 if(SPSwitch==2){
        SPR0=sratio*pSpawn(2)*mean_wgt_mt(2,startIndex)*exp(-(MCurr(1)+sp_time*MCurr(2)))/(1.-exp(-
(MCurr(2)))) + sratio*pSpawn(1)*mean_wgt_mt(1,startIndex)*exp(-(sp_time*MCurr(1)));
        SPR1=sratio*pSpawn(2)*mean_wgt_mt(2,endIndex)*exp(-
(MCurr(1)+sel_r*FCurr+sp_time*(MCurr(2)+sel_a*FCurr)))/(1.-exp(-(MCurr(2)+sel_a*FCurr))) +
sratio*pSpawn(1)*mean_wgt_mt(1,endIndex)*exp(-sp_time*(MCurr(1)+sel_r*FCurr));
 }
 SPRCurr=SPR1/SPR0;
FUNCTION calculate_predicted_indices
 //########## Recruits #########
 for (i=1; i<=numRecSurv; i++){
 qr(i)=0.0;
 double counter=0.0;
 for(y=startIndex; y<=endIndex; y++) {
 if (y<recStartIndex) continue;
 if(re_survey_obs(i,y)!=-999.) { //check to make sure year is not missing
 if(!last_phase()) {
 //small constant added to recruitment in earlier stages to
 //increase numerical stability
 //NOTE: this formulation now allows for surveys that occur after fish become vulnerable to fisheries
 qr(i)+=log(re_survey_obs(i,y))-log(R(y)*exp(-sr_time(i)*(Mt(1,y)+sel_r*F(y)))+.000001);
 }
 else { //small constant not included in last estimation stage
 qr(i)+=log(re_survey_obs(i,y))-log(R(y)*exp(-sr_time(i)*(Mt(1,y)+sel_r*F(y))));
 }
 counter++;
 }
 }
 //calculate geometric mean
 qr(i)=exp(qr(i)/counter);
 //Calculate predicted index of abundance
 //NOTE: this formulation now allows for surveys that occur after fish become vulnerable to fisheries
 for(y=startIndex; y<=endIndex; y++) {
 re_survey_est(i,y)=qr(i)*(R(y)*exp(-sr_time(i)*(Mt(1,y)+sel_r*F(y))));
 }
 }
 //########## Adults #########
 for (i=1; i<=numAdSurv; i++){
 //calculate catchability for each sex-index combination
 double counter=0.0;
 qa(i)=0.0;
 for(y=startIndex; y<=endIndex; y++) {
 if (y<adStartIndex) continue;
 if(ad_survey_obs(i,y)!=-999.) { //check to make sure year is not missing
 qa(i)+=log(ad_survey_obs(i,y))-log(N(y)*exp(-sa_time(i)*(Mt(2,y)+sel_a*F(y))));
 counter++;
 }
 }
 //calculate geometric mean
 qa(i)=exp(qa(i)/counter);
 //Calculate each predicted index of abundance
 for(y=startIndex; y<=endIndex; y++) {
```

```
 ad_survey_est(i,y)=qa(i)*(N(y)*exp(-sa_time(i)*(Mt(2,y)+sel_a*F(y))));
 }
 }
FUNCTION calculate_objective_function
 double pi=3.141593;
 //calculate adult survey likelihood component
 for (i=1; i<=numAdSurv; i++){
 Lsa(i)=0.0;
 for(y=startIndex; y<=endIndex; y++) {
 if (y<adStartIndex) continue;
 if(ad_survey_obs(i,y)!=-999.) { //check to make sure year is not missing -- some holes

Lsa(i)+=0.5*log(2.*pi)+0.5*log(ad_survey_var(i,y))+log(ad_survey_obs(i,y))+square(log(ad_survey_obs(i,y)+.00000
1)-log(ad_survey_est(i,y)+.000001))/(2*ad_survey_var(i,y));
 }
 }
 Lsa(i)=sa_lambda(i)*Lsa(i);
 }
 //calculate recruit survey likelihood component
 for (i=1; i<=numRecSurv; i++){
 Lsr(i)=0.0;
 for(y=startIndex; y<=endIndex; y++) {
 if (y<recStartIndex) continue;
 if(re_survey_obs(i,y)!=-999.) { //check to make sure year is not missing

Lsr(i)+=0.5*log(2.*pi)+0.5*log(re_survey_var(i,y))+log(re_survey_obs(i,y))+square(log(re_survey_obs(i,y)+.000001)
-log(re_survey_est(i,y)+.000001))/(2*re_survey_var(i,y));
 }
 }
 Lsr(i)=sr_lambda(i)*Lsr(i);
 }
 //calculate total catch likelihood component
 Lc=0.0;
 for(y=startIndex; y<=endIndex; y++) {
 if (y<cStartIndex) continue;
 if(TC_obs(y)!=-999.) { //check to make sure year is not missing
 Lc+=0.5*log(2.*pi)+0.5*log(C_var(y))+log(TC_obs(y))+square(log(TC_obs(y)+.000001)-
log(TC(y)+.000001))/(2*C_var(y));
 }
 }
 Lc=com_lambda*Lc;
 //calculate likelihood component for recruitment deviations

Lrdev=recDev_lambda*(0.5*log(2.*pi)*size_count(log_rec_dev)+0.5*log(rec_var)*size_count(log_rec_dev)+sum(lo
g_rec_dev)+0.5*norm2(log_rec_dev)/rec_var);
 //calculate likelihood component for effort residuals if effort time series is included
 Leff=0.0;
 if (effFlag==1) {
 for(y=startIndex; y<endIndex; y++) {
 Leff+=0.5*log(2.*pi)+0.5*log(eff_var)+log(effort(y))+0.5*square(log(effort(y))-(log(F(y))-log_F_q))/eff_var;
 }
 Leff=effort_lambda*Leff;
 }
 //calculate likelihood component for total Z of adults as prior, read from independent Z estimate
```

```
  Lz=aveZ_lambda*(0.5*log(2.*pi)+0.5*log(Z_var)+log(aveZ)+0.5*square(log(aveZ)-
log(mean(Z(startIndex+7,endIndex-1))))/Z_var); //hardwired (i.e., startIndex+7 instead of just startIndex) for spot
avg Z from 1996-2013
  //calculate likelihood component for SR steepness prior
  mu=(steep-steepParams(1)) / (steepParams(2)-steepParams(1));  // CASAL's v   //borrowed beta prior code from
SS3 which borrowed from CASAL
  tau=(steep-steepParams(1))*(steepParams(2)-steep)/square(h_sd)-1.0;
  Bprior=tau*mu;  Aprior=tau*(1.0-mu);  // CASAL's m and n
  Lh =h_lambda*((1.0-Bprior)*log(0.0001+h_prior-steepParams(1)) + (1.0-Aprior)*log(0.0001+steepParams(2)-
h_prior)-(1.0-Bprior)*log(0.0001+steep-steepParams(1)) - (1.0-Aprior)*log(0.0001+steepParams(2)-steep));
  negLL+=sum(Lsa)+sum(Lsr)+Lc+Lrdev+Leff+Lz+Lh;
FUNCTION calculate_reference_points
  //Reference point variables
  MSY=0.0;
  u1MSY=0.0;
  u0MSY=0.0;
  uMSY=0.0;
  i=0;
  OFL=0.0;
  SPRDiff=1e10;
  //With recruit spawners
  if(SPSwitch==1){
	SPR0=sratio*pSpawn(2)*(exp(-(Myr(1)+sp_time*Myr(2)))/(1.-exp(-(Myr(2))))) + sratio*pSpawn(1)*(exp(-
((sp_time*Myr(1)))));
  }
  if(SPSwitch==2){
	SPR0=sratio*pSpawn(2)*mean_wgt_mt(2,startIndex)*(exp(-(Myr(1)+sp_time*Myr(2)))/(1.-exp(-
(Myr(2))))) + sratio*pSpawn(1)*mean_wgt_mt(1,startIndex)*(exp(-((sp_time*Myr(1)))));
  }
  Fval=Fval_init;
  for(i=1; i<=Fval_num; i++)
  {
  Fvec(i)=Fval; //record the F values
  if(SPSwitch==1){
	SPR(i)=sratio*pSpawn(2)*(exp(-(Myr(1)+sel_r*Fval+sp_time*(Myr(2)+sel_a*Fval)))/(1.-exp(-
(Myr(2)+sel_a*Fval)))) + sratio*pSpawn(1)*(exp(-(sp_time*(Myr(1)+sel_r*Fval))));
  }
  if(SPSwitch==2){
	SPR(i)=sratio*pSpawn(2)*mean_wgt_mt(2,startIndex)*(exp(-
(Myr(1)+sel_r*Fval+sp_time*(Myr(2)+sel_a*Fval)))/(1.-exp(-(Myr(2)+sel_a*Fval)))) +
sratio*pSpawn(1)*mean_wgt_mt(1,startIndex)*(exp(-(sp_time*(Myr(1)+sel_r*Fval))));
  }
  NPR(i)=exp(-(Myr(1)+sel_r*Fval))/(1.-exp(-(Myr(2)+sel_a*Fval)));
  if(SPSwitch==1){
	YPR(i)=(sel_r*Fval)/(sel_r*Fval+Myr(1))*(1.-exp(-(sel_r*Fval+Myr(1)))) +
((sel_a*Fval)/(sel_a*Fval+Myr(2))*(1.-exp(-(sel_a*Fval+Myr(2)))))*NPR(i);
  }
  if(SPSwitch==2){
	YPR(i)=((sel_r*Fval)/(sel_r*Fval+Myr(1))*(1.-exp(-(sel_r*Fval+Myr(1)))))*mean_wgt_mt(1,startIndex) +
(((sel_a*Fval)/(sel_a*Fval+Myr(2))*(1.-exp(-(sel_a*Fval+Myr(2)))))*mean_wgt_mt(2,startIndex))*NPR(i);
  }
  if (SRSwitch==1) R_eq(i)=(SPR(i)-alpha)/(SPR(i)*beta);
  if (SRSwitch==2) R_eq(i)=(log(alpha)+log(SPR(i)))/(beta*SPR(i));
  N_eq(i) = NPR(i)*R_eq(i);
  SSB_eq(i) = SPR(i)*R_eq(i);
```

```
 C_eq(i)=YPR(i)*R_eq(i);
 //calculate exploitation rate
 //age 0+
 u0_eq(i)=(sel_r*Fval)/(sel_r*Fval+Myr(1))*(1.-exp(-(sel_r*Fval+Myr(1))));
 //age 1+
 u1_eq(i)=(sel_a*Fval)/(sel_a*Fval+Myr(2))*(1.-exp(-(sel_a*Fval+Myr(2))));
 //all ages
 if (SPSwitch==1){
 if (i>1) uAll_eq(i)=C_eq(i)/(N_eq(i)+R_eq(i)*((1-exp(-sel_r*Fval))/(1-exp(-Fval))));
 }
 if (SPSwitch==2){
 if (i>1) uAll_eq(i)=C_eq(i)/(N_eq(i)*mean_wgt_mt(2,startIndex)+R_eq(i)*mean_wgt_mt(1,startIndex)*((1-exp(-
sel_r*Fval))/(1-exp(-Fval))));
 }
 //MSY
 if (C_eq(i)>MSY) {
 MSY=C_eq(i);
 FMSY=Fval;
 NMSY=N_eq(i);
 SSBMSY=SSB_eq(i);
 RMSY=R_eq(i);
 u0MSY=u0_eq(i);
 u1MSY=u1_eq(i);
 uMSY=uAll_eq(i);
 }
 //loop through SPR targets and see if at the correct F for each target
 for (ispr=1; ispr<=nspr; ispr++){
 if (square(SPR(i)/SPR0-SPR_targ(ispr)) < SPRDiff(ispr)) {
 SPRDiff(ispr)=square(SPR(i)/SPR0-SPR_targ(ispr));
 FSPR_ref(ispr)=Fval;
 }
 }
 //increment the female F for the SPR
 Fval+=Fval_inc;
 }
 //############### Reporting functions ###############//
FUNCTION mcmc
 //Code to write results of MCMC to file so we can access the chains
 if(mceval_phase()) {
 //Define output file stream for MCMC results
 if(iterMCMC==0) {
 ofstream mcmcout("cmsa_refs.mcmc");
 mcmcout
<<"MSY\t"<<"FMSY\t"<<"NMSY\t"<<"SSBMSY\t"<<"uMSY\t"<<"FLim\t"<<"NLim\t"<<"FMSYRatio\t"<<"NMSYRatio
\t"<<"SSBMSYRatio\t"<<"UMSYRatio\t"<<"FFLimRatio\t"<<"NNLimRatio\t"<<"SPRCurrent"<<endl;
 //print out yearly F and N
 ofstream mcmcout2("cmsa_yearly.mcmc");
 year=fyear;
 for(y=startIndex;y<=endIndex;y++){
 mcmcout2 <<"N"<<year<<"\t";
 year=year+1.0/timeSteps;
 }
 year=fyear;
 for(y=startIndex;y<=endIndex;y++){
 mcmcout2 <<"R"<<year<<"\t";
```

```
 year=year+1.0/timeSteps;
 }
 year=fyear;
 for(y=startIndex;y<=endIndex;y++){
 if( y<endIndex) mcmcout2 <<"F"<<year<<"\t";
 else mcmcout2 <<"F"<<year << endl;
 year=year+1.0/timeSteps;
 }
 ofstream mcmcout3("cmsa_pars.mcmc");
 mcmcout3 <<"N0\t"<<"R0\t"<< "Fq\t"<<"S0\t"<<"h"<<endl;
 iterMCMC++;
 }
 ofstream mcmcout("cmsa_refs.mcmc",ios::app);
 mcmcout

<<MSY<<"\t"<<FMSY<<"\t"<<NMSY<<"\t"<<SSBMSY<<"\t"<<uMSY<<"\t"<<FLim<<"\t"<<NLim<<"\t"<<FMSYRatio<
<"\t"<<NMSYRatio<<"\t"<<SSBMSYRatio<<"\t"<<UMSYRatio<<"\t"<<FFLimRatio<<"\t"<<NNLimRatio<<"\t"<<SPRC
urr<<endl;
 //print out yearly F and N
 ofstream mcmcout2("cmsa_yearly.mcmc",ios::app);
 for(y=startIndex;y<=endIndex;y++){
 mcmcout2 <<N(y) << "\t";
 }
 for(y=startIndex;y<=endIndex;y++){
 mcmcout2 <<R(y) << "\t";
 }
 for(y=startIndex;y<=endIndex;y++){
 if (y<endIndex) mcmcout2 <<F(y) << "\t";
 else mcmcout2 <<F(y) <<endl;
 }
 //print out yearly F and N
 ofstream mcmcout3("cmsa_pars.mcmc",ios::app);
 mcmcout3 <<exp(log_init_N)<<"\t"<<exp(log_init_R)
<<"\t"<<exp(log_F_q)<<"\t"<<exp(log_S0)<<"\t"<<exp(log_steep) << endl;
 }
FUNCTION obs_pred
 ofstream ofs_op("obs_pred_results.dat");
 ofs_op << "survey year sex a_r s_c snum obs cv pred" << endl;
 year=fyear;
 for(y=startIndex; y<=endIndex; y++) {
 //total observed and predicted catch
 ofs_op << "0 "<< year << " t a c 0 " << TC_obs(y) << " " << C_cv(y) << " " << TC(y) << endl;
 //total observed and predicted catch in weight (metric tons)
 ofs_op << "0 "<< year << " t a c_wgt 0 " << C_wgt_obs(y) << " " << "NA" << " " << C_wgt(y) << endl;
 //adult surveys
 for (i=1; i<=numAdSurv; i++)
 ofs_op << i << " "<< year << " 0 a s 0 " << ad_survey_obs(i,y) << " " << ad_survey_cv(i,y) << " " <<
ad_survey_est(i,y) << endl;
 //recruit surveys
 for (i=1; i<=numRecSurv; i++)
 ofs_op << i << " "<< year << " 0 r s 0 " << re_survey_obs(i,y) << " " << re_survey_cv(i,y) << " " << re_survey_est(i,y)
<< endl;
 if (y==startIndex) ofs_op << "0 "<< year << " r r r 0 " << R(y) << " " << "NA" << " " << "NA" << endl;
 else {
        if (SPSwitch==1){
```

```
			if (SRSwitch==1) ofs_op << "0 "<< year << " r r r 0 " << R(y)<< " " << "NA" << " " <<SP(y-1)/(SP(y-
1)*beta+alpha) << endl;
			if (SRSwitch==2) ofs_op << "0 "<< year << " r r r 0 " << R(y)<< " " << "NA" << " " << alpha*SP(y-
1)*exp(-beta*(SP(y-1))) << endl;
		}
		if (SPSwitch==2){
			if (SRSwitch==1) ofs_op << "0 "<< year << " r r r 0 " << R(y)<< " " << "NA" << " " << (SSB(y-
1)/(SSB(y-1)*beta+alpha)) << endl;
			if (SRSwitch==2) ofs_op << "0 "<< year << " r r r 0 " << R(y)<< " " << "NA" << " " << (alpha*SSB(y-
1)*exp(-beta*(SSB(y-1)))) << endl;
		}
  } //recruitment deviations
  year=year+1.0/timeSteps;
  }
FUNCTION HPD_estimates
  ofstream ofs_hpd("HPD_results.dat");
  ofs_hpd << "year Adult Spawners Rec RecSurvey1 TC recM adM F FMSYRatio NMSYRatio SSBMSYRatio FFLimRatio
NNLimRatio u0 u1 uAll SREnv MEnvRec MEnvAd" << endl;
  year=fyear; //for outputting the year if multiple time steps per year
  for(y=startIndex;y<=endIndex+projSteps;y++){
		if(SPSwitch==1){
			ofs_hpd << year << " " << N(y) << " "<< SP(y)<< " " << R(y) << " " <<R(y)*exp(-sr_time(1)*Mt(1,y))
<< " " << TC(y) << " " << Mt(1,y) << " " << Mt(2,y) << " " << F(y)<< " " << F(y)/FMSY<< " " << N(y)/NMSY<< " "<<
F(y)/FLim<< " " << N(y)/NLim<< " "<<
			(sel_r*F(y))/(sel_r*F(y)+Mt(1,y))*(1.-exp(-(sel_r*F(y)+Mt(1,y)))) << " "<<
(sel_a*F(y))/(sel_a*F(y)+Mt(2,y))*(1.-exp(-
			(sel_a*F(y)+Mt(2,y)))) << " "<< u(y) << " " << env(envRecTS,y-envRecLag) << " "<<
env(envMTS(1),y-envMLag(1)) << " " <<
			env(envMTS(2),y-envMLag(2)) << endl;
		}
		if(SPSwitch==2){
			ofs_hpd << year << " " << N(y) << " "<< SSB(y)<< " " << R(y) << " " <<R(y)*exp(-sr_time(1)*Mt(1,y))
<< " " << TC(y) << " " << Mt(1,y) << " " << Mt(2,y) << " " << F(y)<< " " << F(y)/FMSY<< " " << N(y)/NMSY<< " "<<
F(y)/FLim<< " " << N(y)/NLim<< " "<<
			(sel_r*F(y))/(sel_r*F(y)+Mt(1,y))*(1.-exp(-(sel_r*F(y)+Mt(1,y)))) << " "<<
(sel_a*F(y))/(sel_a*F(y)+Mt(2,y))*(1.-exp(-
			(sel_a*F(y)+Mt(2,y)))) << " "<< u(y) << " " << env(envRecTS,y-envRecLag) << " "<<
env(envMTS(1),y-envMLag(1)) << " " <<
			env(envMTS(2),y-envMLag(2)) << endl;
		}
  year=year+1.0/timeSteps;
  }
FUNCTION MSY_estimates
  ofstream ofs_msy("MSY_results.dat");
  {
  //Column headings
  ofs_msy << "Fval\t" << "C_eq\t" << "N_eq\t" << "R_eq\t" << "YPR\t" << "SPR\t" << "SPRatio\t" << "u0_eq\t" <<
"u1_eq\t" << "uAll_eq\t" << endl;
  Fval=Fval_init;
  for(i=1; i<=Fval_num; i++) {
  ofs_msy << Fval << "\t" << C_eq(i) << "\t" << N_eq(i) << "\t" << R_eq(i) << "\t" <<YPR(i) << "\t" << SPR(i) << "\t" <<
  SPR(i)/SPR0 << "\t" << u0_eq(i) << "\t" << u1_eq(i)<< "\t" << uAll_eq(i) << endl;
  Fval+=Fval_inc;
  }
  }
```

```
FUNCTION general_report
 ofstream ofs_gen("gen_results.dat");
 {
 ofs_gen << "Name Value" << endl;
 ofs_gen << "negLL " << negLL <<endl;
 ofs_gen << "Lsa "<< Lsa <<endl;
 ofs_gen << "Lsr "<< Lsr << endl;
 ofs_gen << "Lc "<< Lc << endl;
 ofs_gen << "Lz "<< Lz << endl;
 ofs_gen << "Lh "<< Lh << endl;
 ofs_gen << "Lrdev "<< Lrdev << endl;
 ofs_gen << "Leff "<< Leff << endl;
 ofs_gen << "init_N "<< exp(log_init_N) << endl;
 ofs_gen << "init_R " << exp(log_init_R) << endl;
 for (i=1; i<=numAdSurv; i++) ofs_gen << "qa_i"<<i <<" " << qa(i) << endl;
 for (i=1; i<=numRecSurv; i++) ofs_gen << "qr_i"<<i <<" " << qr(i) << endl;
 ofs_gen << "F_q "<< exp(log_F_q) << endl;
 ofs_gen << "rec_cv "<< exp(log_rec_cv) << endl;
 ofs_gen << "p_rec "<< p_rec << endl;
 ofs_gen << "p_under " << p_under << endl;
 ofs_gen << "SRType " << SRSwitch << endl;
 ofs_gen << "S0 " << exp(log_S0) << endl;
 ofs_gen << "steepness " << exp(log_steep) << endl;
 ofs_gen << "alpha " << alpha << endl;
 ofs_gen << "beta " << beta << endl;
 ofs_gen << "sr_beta_env " << sr_beta_env << endl;
 ofs_gen << "M_beta_env_1 " << M_beta_env(1) << endl;
 ofs_gen << "M_beta_env_2 " << M_beta_env(2) << endl;
 ofs_gen << "sel_1 " << exp(log_sel_r) << endl;
 ofs_gen << "sel_2 " << exp(log_sel_a) << endl;
 ofs_gen << "Mr " << Myr(1) << endl;
 ofs_gen << "Ma " << Myr(2) << endl;
 ofs_gen << "Ma " << Myr(2) << endl;
 ofs_gen << "sp_time " << sp_time <<endl;
 ofs_gen << "MSY " << MSY << endl;
 ofs_gen << "FMSY " << FMSY << endl;
 ofs_gen << "FMSYRatio " << FMSYRatio << endl;
 ofs_gen << "NMSY " << NMSY << endl;
 ofs_gen << "SSBMSY" << SSBMSY << endl;
 ofs_gen << "NMSYRatio " << NMSYRatio << endl;
 ofs_gen << "SSBMSYRatio " << SSBMSYRatio << endl;
 ofs_gen << "RMSY " << RMSY << endl;
 ofs_gen << "u0MSY " << u0MSY << endl;
 ofs_gen << "u1MSY " << u1MSY<< endl;
 ofs_gen << "uMSY " << uMSY<< endl;
 ofs_gen << "UMSYRatio " << UMSYRatio << endl;
 ofs_gen << "FLim " << FLim << endl;
 ofs_gen << "FFLimRatio " << FFLimRatio << endl;
 ofs_gen << "NLim " << NLim << endl;
 ofs_gen << "NNLimRatio " << NNLimRatio << endl;
 ofs_gen << "cLim " << cLim << endl;
 ofs_gen << "OFL " << OFL<< endl;
 ofs_gen << "projYears " << projYears<< endl;
 for(ispr=1; ispr<=nspr; ispr++) {
 ofs_gen << "F"<<SPR_targ(ispr) << "% " << FSPR_ref(ispr)<< endl;
```

```
 }
 }
 //######################################################################
 //######################################################################
REPORT_SECTION
 //Call reporting functions
 //  calculate_sSPR();
 obs_pred();
 MSY_estimates();
 HPD_estimates();
 general_report();
 report << "Likelihood Components" <<endl;
 report << "negLL\t" << negLL <<endl;
 report << "Lsa\t" << Lsa <<endl;
 report << "Lsr\t" << Lsr << endl;
 report << "Lc\t" << Lc << endl;
 report << "Leff\t" << Leff << endl;
 report << "Lz\t" << Lz << endl;
 report << "Lh\t" << Lh << endl;
 report << "Lrdev\t" << Lrdev << endl;
 report << "F_pen\t" << F_pen << endl;
 report << "\nParameter Estimates (NOT log space unless marked)" <<endl;
 report << "init_N\t" << exp(log_init_N) << endl;
 report << "init_R\t" << exp(log_init_R) << endl;
 report << "F\t" << F << endl;
 report << "M_rec\t" << Mt(1) << endl;
 report << "M_ad\t" << Mt(2) << endl;
 report << "AveF\t" << mean(F(startIndex,endIndex-1)) << endl;
 report << "AveZ\t" << mean(Z(startIndex+7,endIndex-1)) << endl;
 report << "AveU\t" << mean(u(startIndex,endIndex)) << endl;
 report << "F_q "<< exp(log_F_q) << endl;
 report << "log_F_dev\t" << log_F_dev << endl;
 report << "mean(log_F_dev)\t" << mean(log_F_dev) << endl;
 report << "rec_dev\t" << exp(log_rec_dev) << endl;
 report << "mean(log_rec_dev)\t" << mean(log_rec_dev) << endl;
 report << "mean(rec_dev)\t" << mean(exp(log_rec_dev)) << endl;
 report << "rec_cv\t" << exp(log_rec_cv) << endl;
 for (i=1; i<=numAdSurv; i++) report << "qa_i"<<i <<"\t" << qa(i) << endl;
 for (i=1; i<=numRecSurv; i++) report << "qr_i"<<i <<"\t" << qr(i) << endl;
 if (SRSwitch==1) //Beverton-Holt
 report << "SR=Beverton-Holt\t" << endl;
 if (SRSwitch==2) //Ricker
 report << "SR=Ricker\t" << endl;
 report << "S0\t" << exp(log_S0) << endl;
 report << "R0\t" << R0 << endl;
 report << "steepness\t" << exp(log_steep) << endl;
 report << "alpha\t" << alpha << endl;
 report << "beta\t" << beta << endl;
 report << "sr_beta_env\t" << sr_beta_env << endl;
 report << "M_beta_env\t" << M_beta_env << endl;
 report << "M_beta_env_rec\t" << M_beta_env(1) << endl;
 report << "M_beta_env_ad\t" << M_beta_env(2) << endl;
 report << "sel\t" << exp(log_sel_r) <<"\t"<< exp(log_sel_a) << endl;
 report << "p_rec\t" << p_rec << endl;
 report << "p_under\t" << p_under << endl;
```

```
 report << "M\t" << Myr << endl;
 report << "rec_cv\t" << exp(log_rec_cv) << endl;
 report << "sp_time\t" << sp_time <<endl;
 report << "mean_wgt_recruits\t" << mean_wgt(1) <<endl;
 report << "mean_wgt_adults\t" << mean_wgt(2) <<endl;
 report << "\nReference Point Calculations" <<endl;
 report << "negLL\t" << negLL <<endl;
 report << "MSY\t" << MSY << endl;
 report << "uMSY\t" << uMSY<< endl;
 report << "NMSY " << NMSY << endl;
 report << "SSBMSY " << SSBMSY << endl;
 report << "UMSYRatio " << UMSYRatio << endl;
 report << "NMSYRatio " << NMSYRatio << endl;
 report << "SSBMSYRatio " << SSBMSYRatio << endl;
 report << "FMSY\t" << FMSY << endl;
 report << "FMSYRatio " << FMSYRatio << endl;
 report << "RMSY\t" << RMSY << endl;
 report << "u0MSY\t" << u0MSY << endl;
 report << "u1MSY\t" << u1MSY<< endl;
 report << "FLim\t" << FLim << endl;
 report << "FFLimRatio\t" << FFLimRatio << endl;
 report << "NLim\t" << NLim << endl;
 report << "NNLimRatio\t" << NNLimRatio << endl;
 report << "cLim\t" << cLim << endl;
 report << "OFL\t" << OFL << endl;
 report << "SPRCurr\t" << SPRCurr<< "\n"<< endl;
 for(ispr=1; ispr<=nspr; ispr++) {
 report << "F"<<SPR_targ(ispr) << "%\t" << FSPR_ref(ispr)<< endl;
 }
 //######################################################################
 //######################################################################
GLOBALS_SECTION
 #include "admodel.h"
 //define constant variable
 const double MathPI = 3.141592654; //or using MI_PI
 const double MathE = 2.71828183;
 //######################################################################
 //######################################################################
RUNTIME_SECTION
 maximum_function_evaluations 25000,25000,20000,20000,20000,20000
 convergence_criteria 1.0e-8
 //Leave space below this line
```

Appendix 5. Modified-CSA Data Input File

```
# Data sources
############################################################
############################################################
#Run in testing mode: runs model at initial values and output some values to console (0=off, 1=on)
 0
#first year / last year for the model simulation (should be same as catch)
 1989 2014
#Retrospective NumYears
 0
#Projection NumYears
 0

##################################
#Removal Data
##################################
#first / last year of total removal time series
 1989 2014
#Total removals (in millions of fish)
#Commercial Landings+Commercial Shrimp Trawl Discards+Mid-Atlantic Gillnet and Trawl Discards+Scrap
Landings+Recreational Harvest+Recreational Dead Releases
 640.34  999.087  1324.14  250.646  218.705  355.827  573.627  144.522  40.546  89.201  92.001  98.869  177.471
         97.162   226.63   101.344  108.398  131.881  73.402   86.931   100.43  83.356  220.493  107.162  114.575
         150.239
#Total removals (in metric tons) - not currently included in the objective function
#Commercial Landings+Commercial Shrimp Trawl Discards+Mid-Atlantic Gillnet and Trawl Discards+Scrap
Landings+Recreational Harvest+Recreational Dead Releases
 33570   25314   57236   16878   11973   18580   19720   8144   9862   8924   5841   7044   9332
         6646    10184   8240    6238    8519    7490    6777   7301   4622   9106   8193   6516
         9471
#Total removals CV (i.e., catch SE/mean catch) applied to likelihood - this value is converted to SE of log(catch)
within the model for the likelihood function
 0.05    0.05    0.05    0.05    0.05    0.05    0.05    0.05    0.05    0.05    0.05    0.05    0.05
         0.05    0.05    0.05    0.05    0.05    0.05    0.05    0.05    0.05    0.05    0.05    0.05
         0.05
#Flag to include effort time series in calcs (adds negLL component for F-deviations) - 0 to exclude, 1 to include
 0
#Effort (if don't have an effort time series, set all equal to 1 for the total number of years)
 1       1       1       1       1       1       1       1       1       1       1       1       1
         1       1       1       1       1       1       1       1       1       1       1       1
         1

##################################
#Survey Data
##################################
###Post-recruit surveys AND CVs###
#Number of post-recruit surveys
 5
#first / last year in post-recruit surveys
#Note: if catch are different lengths of time, use -999. for missing values
# Therefore, this is min and max year for any data
 1989 2014
#Standardized (x/mu)
#Do all surveys as rows first, then all CVs as rows 2nd
#NCDMF Trawl Survey (Program 195; June, >=120mm)
 0.8602  0.4149  0.8793  0.4639  0.8786  0.9277  1.5358  0.3939  0.6283  0.4781  0.7560  1.7494  0.6035
         0.5230  1.2830  0.9074  1.3612  4.2081  0.9282  0.5587  0.6613  0.6246  1.0763  0.7906  1.3604
         1.1479
```

```
#SEAMAP Trawl Survey (Fall)
 0.2930 0.4260 2.9393 0.6342 1.1321 0.8969 0.2904 0.6332 0.0892 0.1318 0.3033 0.5276 0.1289
        0.3614 0.5989 0.5996 4.2248 0.5699 0.3726 1.9167 1.1684 1.5220 0.6718 1.7912 2.6558
        1.1214
#NMFS Trawl Survey (Fall, NEAMAP Aggregate ALK)
 3.9494 0.6895 0.1446 0.1046 0.0163 1.0548 0.5982 0.2674 0.0886 0.1045 0.7080 0.4713 0.0004
        0.2652 0.4425 0.7368 0.9991 1.5952 0.5910 0.9939 1.5753 1.2970 2.9900 4.4850 1.4494
        0.3823
#ChesMMAP Trawl Survey (Annual ALK)
 -999   -999   -999   -999   -999   -999   -999   -999   -999   -999   -999   -999   -999
        0.5862 0.6730 0.8006 1.8229 3.9015 1.3534 0.6614 1.4423 0.0976 1.1048 0.0105 0.4441
        0.1017
#NEAMAP Trawl Survey (Annual ALK)
 -999   -999   -999   -999   -999   -999   -999   -999   -999   -999   -999   -999   -999
        -999   -999   -999   -999   -999   1.0820 0.6773 1.0868 0.9530 1.9066 0.0121 2.2049
        0.0772
#CV(i.e., index SE/mean index) - these value are converted to SE of log(index) within the model for the likelihood
function
#NCDMF Trawl Survey (Program 195; June, >=120mm) CV
#0.1757 0.222  0.1032 0.1408 0.0978 0.1227 0.1334 0.1673 0.1433 0.2664 0.1639 0.2053 0.1573
        0.1953 0.1671 0.2671 0.2895 0.1248 0.1939 0.319  0.2073 0.1417 0.1432 0.2175 0.2086
        0.1873
 0.2662 0.2988 0.2251 0.2446 0.2226 0.2346 0.2404 0.2607 0.2460 0.3331 0.2586 0.2866 0.2544
        0.2795 0.2606 0.3337 0.3519 0.2357 0.2786 0.3765 0.2881 0.2451 0.2460 0.2955 0.2890
        0.2740
#SEAMAP Trawl Survey (Fall)
 0.3342 0.1849 0.1959 0.2480 0.4129 0.2547 0.1644 0.1751 0.2576 0.2084 0.3830 0.4089 0.2244
        0.2269 0.4688 0.2759 0.3407 0.1264 0.2627 0.5379 0.2732 0.3420 0.2156 0.1819 0.4163
        0.3872
#NMFS Trawl Survey (Fall, NEAMAP Aggregate ALK)
#0.0664 0.0553 0.2101 0.1228 0.1661 0.1197 0.0592 0.1165 0.1019 0.1065 0.0363 0.0730 0.3110
        0.1152 0.0666 0.0620 0.0538 0.0421 0.1104 0.0487 0.0333 0.0368 0.0374 0.0263 0.0452
        0.0697
 0.2107 0.2075 0.2901 0.2347 0.2600 0.2331 0.2086 0.2315 0.2245 0.2266 0.2033 0.2129 0.3698
        0.2308 0.2108 0.2094 0.2071 0.2044 0.2284 0.2058 0.2028 0.2034 0.2035 0.2017 0.2050
        0.2118
#ChesMMAP Trawl Survey (Annual ALK)
 -999   -999   -999   -999   -999   -999   -999   -999   -999   -999   -999   -999   -999
        0.3025 0.2909 0.2853 0.2615 0.2577 0.2915 0.3175 0.2671 0.3483 0.2605 0.2800 0.2689
        0.2081
#NEAMAP Trawl Survey (Annual ALK)
 -999   -999   -999   -999   -999   -999   -999   -999   -999   -999   -999   -999   -999
        -999   -999   -999   -999   -999   0.2586 0.2783 0.1507 0.2697 0.1477 0.2556 0.2384
        0.1125
#post-recruit survey time(s)
# NCDMF=0.46 (mid June); SEAMAP=0.83 (end of Oct); NMFS=0.75 (end of Sep); ChesMMAP=0.66 (beg of
Sep); NEAMAP=0.79 (mid Oct)
 0.46   0.83   0.75   0.66   0.79
###recruitment surveys AND CVs###
#Number of recruit surveys
 5
#first /last year in recruit surveys
#Note: if catch are different lengths of time, use -999. for missing values
# Therefore, this is min and max year for any data
 1989 2014
#Standardized (x/mu)
#Do all surveys as rows first, then all CVs as rows 2nd
#NCDMF Trawl Survey (Program 195; June, <120mm)
```

```
 0.505   2.022   0.657   0.177   1.114   0.195   0.096   0.872   0.4     0.314   1.375   0.279   0.517
         0.884   1.885   1.262   0.461   0.192   0.385   3.159   0.447   1.685   0.942   2.467   2.769
         0.937
#SEAMAP Trawl Survey (Fall)
 0.1918  0.2627  0.3704  0.1281  0.1500  1.2351  0.0719  0.5658  0.1010  0.1505  0.7167  0.0847  0.1527
         0.3398  0.7943  0.2174  9.2655  0.3094  0.1511  0.5208  0.7962  6.8526  0.6487  0.7748  0.6494
         0.4987
#NMFS Trawl Survey (Fall, NEAMAP Aggregate ALK)
 3.8123  0.6849  0.1366  0.0428  0.0258  1.2107  0.3357  0.2916  0.1243  0.0699  0.6070  0.2933  0.0005
         0.2169  0.1322  0.6477  1.6572  0.9031  0.6352  1.1398  1.3698  3.0071  2.4664  4.4506  1.6139
         0.1245
#ChesMMAP Trawl Survey (Annual ALK)
 -999    -999    -999    -999    -999    -999    -999    -999    -999    -999    -999    -999    -999
         0.6630  0.7769  1.2951  1.7277  5.2776  0.7931  1.0832  0.2582  0.6741  0.0215  0.2060  0.1876
         0.0362
#NEAMAP Trawl Survey (Annual ALK)
 -999    -999    -999    -999    -999    -999    -999    -999    -999    -999    -999    -999    -999
         -999    -999    -999    -999    -999    0.5228  1.3452  0.1634  0.5291  0.0938  5.0683  0.2195
         0.0580
#CV(i.e., index SE/mean index) - these value are converted to SE of log(index) within the model for the likelihood
function
#NCDMF Trawl Survey (Program 195; June, <120mm)
#0.1455 0.1159  0.1561  0.2103  0.1474  0.1689  0.2106  0.1216  0.1613  0.2354  0.2152  0.196   0.2223
         0.1318  0.1601  0.244   0.1601  0.1928  0.2424  0.2301  0.1822  0.1895  0.1477  0.1047  0.1697
         0.1437
 0.2473  0.2312  0.2537  0.2902  0.2484  0.2618  0.2904  0.2341  0.2569  0.3089  0.2938  0.2800  0.2990
         0.2395  0.2562  0.3155  0.2562  0.2778  0.3143  0.3049  0.2705  0.2755  0.2486  0.2257  0.2623
         0.2463
#SEAMAP Trawl Survey (Fall)
 0.3342  0.1849  0.1959  0.2480  0.4129  0.2547  0.1644  0.1751  0.2576  0.2084  0.3830  0.4089  0.2244
         0.2269  0.4688  0.2759  0.3407  0.1264  0.2627  0.5379  0.2732  0.3420  0.2156  0.1819  0.4163
         0.3872
#NMFS Trawl Survey (Fall, NEAMAP Aggregate ALK)
#0.0664 0.0553  0.2101  0.1228  0.1661  0.1197  0.0592  0.1165  0.1019  0.1065  0.0363  0.0730  0.3110
         0.1152  0.0666  0.0620  0.0538  0.0421  0.1104  0.0487  0.0333  0.0368  0.0374  0.0263  0.0452
         0.0697
 0.2107  0.2075  0.2901  0.2347  0.2600  0.2331  0.2086  0.2315  0.2245  0.2266  0.2033  0.2129  0.3698
         0.2308  0.2108  0.2094  0.2071  0.2044  0.2284  0.2058  0.2028  0.2034  0.2035  0.2017  0.2050
         0.2118
#ChesMMAP Trawl Survey (Annual ALK)
 -999    -999    -999    -999    -999    -999    -999    -999    -999    -999    -999    -999    -999
         0.3025  0.2909  0.2853  0.2615  0.2577  0.2915  0.3175  0.2671  0.3483  0.2605  0.2800  0.2689
         0.2081
#NEAMAP Trawl Survey (Annual ALK)
 -999    -999    -999    -999    -999    -999    -999    -999    -999    -999    -999    -999    -999
         -999    -999    -999    -999    -999    0.2586  0.2783  0.1507  0.2697  0.1477  0.2556  0.2384
         0.1125
#Recruit survey time
# NCDMF=0.46 (mid June); SEAMAP=0.83 (end of Oct); NMFS=0.75 (end of Sep); ChesMMAP=0.66 (beg of
Sep); NEAMAP=0.79 (mid Oct)
#NOTE: now allows for recruit surveys that occur after fish become vulnerable to fisheries
#E.g., re_survey_est(r,i)=qr(r,i)*(R(r)*mfexp(-sr_time(r,i)*(Mt(1,y)+sel(1)*F(y))));
 0.46    0.83    0.75    0.66    0.79

##################################
#Fishery params
##################################
```

#Proportion of recreational harvest per region (from blue crab model, we have recreational removal estimates for spot)
.00
#Proportion under reporting per region
0
#Max F
10
#Max M
4
#Ave Z prior
1.356
#Ave Z CV (i.e., Z SE/mean Z) - this value is converted to SE of log(Z) within the model for the likelihood function
.05

#################################
#Life History params
#################################
#Sex ratio
.5
#Natural mortality per stage (1st = Recruits, 2nd = post-recruits)
0.542 0.396
#Proportion spawning per stage (1st = Recruits, 2nd = post-recruits)
0.215
1
#Proportion of the time step before spawning occurs (0=start of year, 1=end of year)
1
#Steepness for prior
0.64
#sd for steepness prior (i.e., h SE/mean h) - this value is converted to SE of log(h) within the model for the likelihood function
0.20
#SR formulation (Bev Holt=1, Ricker=2)
1
#First and last years of mean weights - added to allow for retrospective analysis
1989 2014
#Mean weight per stage in kg (1st = Recruits, 2nd = post-recruits)
0.0801 0.0801 0.0801 0.0801 0.0801 0.0801 0.0801 0.0801 0.0801 0.0801 0.0801 0.0801 0.0801
0.0801 0.0801 0.0801 0.0801 0.0801 0.0801 0.0801 0.0801 0.0801 0.0801 0.0801 0.0801
0.0801
0.1324 0.1324 0.1324 0.1324 0.1324 0.1324 0.1324 0.1324 0.1324 0.1324 0.1324 0.1324 0.1324
0.1324 0.1324 0.1324 0.1324 0.1324 0.1324 0.1324 0.1324 0.1324 0.1324 0.1324 0.1324
0.1324
#Timing for SSB estimates in the model (0=start of year, 1=end of year)-should match timing of spawning as recruit estimates are dependent on SSB estimates
1
#Desired spawning stock units (1=numbers,2=biomass)
2

#################################
#Environmental time series params/data
#################################
#Number of environmental time series
1
#first / last year for the environmental time series
1988 2014
#Environmental time series

```
 0 0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0
#Environment series CV
 .1
#Time series which influences recruitment:
 1
#Lag in environment influence on recruitment (# time steps)
 1
#Time series that influences mortality (one for each stage):
 1 1
#Lag in enviro influence on mortality (one for each stage):
 0 0

#################################
#Projections time series
#################################
#Environmental time series annomolies for projection years +1 (+1 is for recruit calc)
#Note: must be same number of series as in environment section above with mean=0 (average)
#0 0 0 0 0 0 0 0 0 0 0
 0
#Effort Deviation from year before terminal yr (0) to FMSY (1)
#E.g., 0 .25 .5 .75 1 would be step increase from year before terminal yr F -> FMSY
#.25 .5 .75 1 1 1 1 1 1 1 1
 0

##########################################################
##########################################################
#Parameters and flags
# Format:
# 1st row: initial parameter estimates vector (or stage, e.g., selectivity)
# 2nd row: min bound, max bound, phase of estimatation
# note: if phase <0, then initial value will be held constant
##########################################################
##########################################################
#################################
#Initial values, bounds, and phase
#################################
#init_N (millions of fish)
 1000
 .01 50000 1
#init_R (millions of fish)
#Note: only used if the SR lag (in years) is >0
 1700
 .01 100000 1
################
# F params
################
## F=(q*Effort)*exp(Fdev) where 1st Fdev=0 so q scales to the initial year F
#F q
 1
 .00001 10 2
#F_dev
 1
 .1 5 5
#effort_cv (i.e., F_dev SE/mean F_dev) - this value is converted to SE of log(F_dev) within the model for the likelihood function
 .2
```

```
 .01 1 -1
################
# Recruit params
################
#rec_dev (expected: log(rec_dev)=0 / rec_dev=1)
 1
 .001 40 4
#rec_cv (i.e., rec_dev SE/mean rec_dev) - this value is converted to SE of log(rec_dev) within the model for the likelihood function
 .66
 .3 1 -1
#Stock Recruitment S0
#This value should be in the same units as the desired spawning stock units
 130000
 .1 1000000 3
#S-R steepness
 .79
 0.00001 0.99999 3
########
# Environment params
########
#sr_beta_env (environmental link parameter for recruitment: R=R*exp(sr_beta_env*env) )
 0
 -20 20 -3
#M_beta_env (environmental link parameter for yearly M: Mt=M*exp(M_beta_env*env) )
#note: one for each stage
 0 0
 -20 20 -3
#M_cv
 .1
 .3 1 -1
#Recruit sel (vulnerability)
 0.43
 0.1 1 -1
#Post-recruit sel (vulnerability)
 1.0
 0.1 1 -1

#################################
#Likelihood weights
#################################
#Landings weight lambda
 1.0
#post-recruit survey weight(s) lambda (one value for each)
 1.0 0.0 1.0 0.0 0.0
#Recruit survey weight(s) lambda (one value for each)
 1.0 0.0 1.0 0.0 0.0
#recruitment deviation weight lambda
 1.0
#effort residuals weight lambda
 0.0
#Z prior weight lambda
 1.0
#steepness prior weight lambda
 1.0
#################################
#Additional param control flags not addressed in data section
#################################
```

```
#Bias correction adjustment for predicted recruitment: biasAdj*(0.5*var)
#can turn off by setting=0 or turn on to whatever proportion by setting =1
 1
#################################
#Reference point calcs
#################################
#variables to control F for females used in reference point calculations
#FSPR_init FSPR_max FSPR_increment
 0 6.0 0.01
#SPR targets for calculating F reference points
#number of SPR targets
 5
#targets
 0.05 0.1 0.2 0.3 0.4
#################################
#EOF I/O test
#################################
#EOF number
 12345
```

Appendix 6. What Level of Spawning Potential Ratio (SPR) is a Good Proxy for Spot's MSY? A Report to the ASMFC Spot & Atlantic Croaker Stock Assessment Subcommittee.

Joseph Munyandorero: FWC/FWRI

Overview

When a stage-structured or an age-structured assessment model is completed, biological reference points (BRPs) such as the benchmarks based on the Maximum Sustainable Yield (MSY) should ideally be derived by combining the yield and spawner per-recruit and a spawner–recruit relationship (SRR; Shepherd 1982). Unfortunately, MSY-based prescriptions are seldom trustworthy, largely because they follow from unreliable and nonrobust SRRs. Therefore, BRPs based on age-, stage- or length-structured per-recruit models are often used as proxies of MSY-based BRPs, such F_{MSY}, for both data-rich stocks and data-limited stocks (NMFS 2011; Legault and Brooks 2013; Ault et al. 2008; Hordyk et al. 2015; Munyandorero 2015).

There is a large body of literature on BRPs that are purportedly suitable for precautionary management in terms of either Threshold or Limit Reference Points (LRPs) or Target Reference Points, TRPs (e.g., see Caddy and Mahon 1995; Caddy 1998; Gabriel and Mace 1999; McKown et al. 2008 for reviews). BRPs derived on a cohort or year-class basis typically employ yield per-recruit (YPR) criteria (F_{max}, a fishing mortality maximizing the YPR; and $F_{0.1}$, a fishing mortality at which the marginal increase in YPR is 10% of the marginal increase in YPR when $F = 0$) or spawner per-recruit considerations [typically $F_{x\%}$, a fishing mortality associated with x% (e.g., 40%) of the unfished spawner per-recruit]. The harvest control rules based on them vary according to fisheries jurisdictions (e.g., Caddy 1998). On the U.S. East Coast, Munyandorero (2015) noted that $F_{40\%}$ or $F_{35\%}$ in the US mid-Atlantic and Northeast Atlantic and $F_{15\%}$–$F_{30\%}$ or F_{max} in the US south Atlantic and Gulf of Mexico, have been preferred, respectively, as F_{MSY} proxies. Perhaps that McKown et al.' s (2008) report is the BRPs guideline for the ASMFC managed species.

Since the 1980's, the SRRs became the theoretical basis for BRP derivations in data-rich jurisdictions, but those SRRs are unfortunately unknown or poorly estimated (Fig. A2.1). This is the reason why research in the 1990's especially in the U.S.A focused on combining spawner per-recruit analyses and analyses of (assessment-generated or simulated) stock–recruit data to identify a spawning potential ratio, SPR (i.e., the ratio of the fished spawner per-recruit to the unfished spawner per-recruit), that could be associated with an F level approximating F_{MSY} (Clark 1991, 1993; Goodyear 1993; Mace and Sissenwine 1993; Mace 1994). According to Clark (2002), an ideal SPR target should be devised such that the spawning stock biomass is maintained at a sustainable level, while still providing a reasonable level of catch, perhaps in the form of MSY (Fig. A2.2). Based on these studies, it is generally accepted that:

- A SPR of 35–40% is sustainable for most species (Clark 1993, 2002; Mace and Sissenwine 1993; Mace 1994).
- A SPR of 35–40% may, however, be risk-adverse for species thought to be long-lived and less resilient to fishing (generally with low natural mortality rate M), so a SPR of 50–60% may be appropriate for them (Clark 2002).
- A SPR of 20% may be considered a recruitment-based LRP for average-to-high resilient species (usually short- and moderate-lived species, with moderate-to-high M) and, for little

known stocks, the LRP shout be set at 30% of the unfished spawner per-recruit (Caddy and Mahon 1995).

Case of Spot

Probably that spot is a short-lived species and, therefore, falls into the category of species for which an LRP should be a SPR of 20%. However, this SPR may be risk-adverse, because the corresponding $F_{20\%}$ may be high. For precautionary principle, an LPR between 30 and 40% may be a good option.

Another aspect to be considered relates to the type of "spawner" per-recruit analysis to be used for the LPR derivation. As indicated above, a spawner per-recruit analysis can be age-structured, stage-structured or length-structured and each approach may employ egg production or mass variables. For a given species, each of these analysis combinations may lead to different $F_{x\%}$ (say $F_{40\%}$). In any case, when a full assessment model is conducted, an LPR should be consistent with that model. This is the reason why a composite (i.e., stage-structured) spawning stock per-recruit analysis is recommended (see Munyandorero 2015). The CSA has that flexibility.

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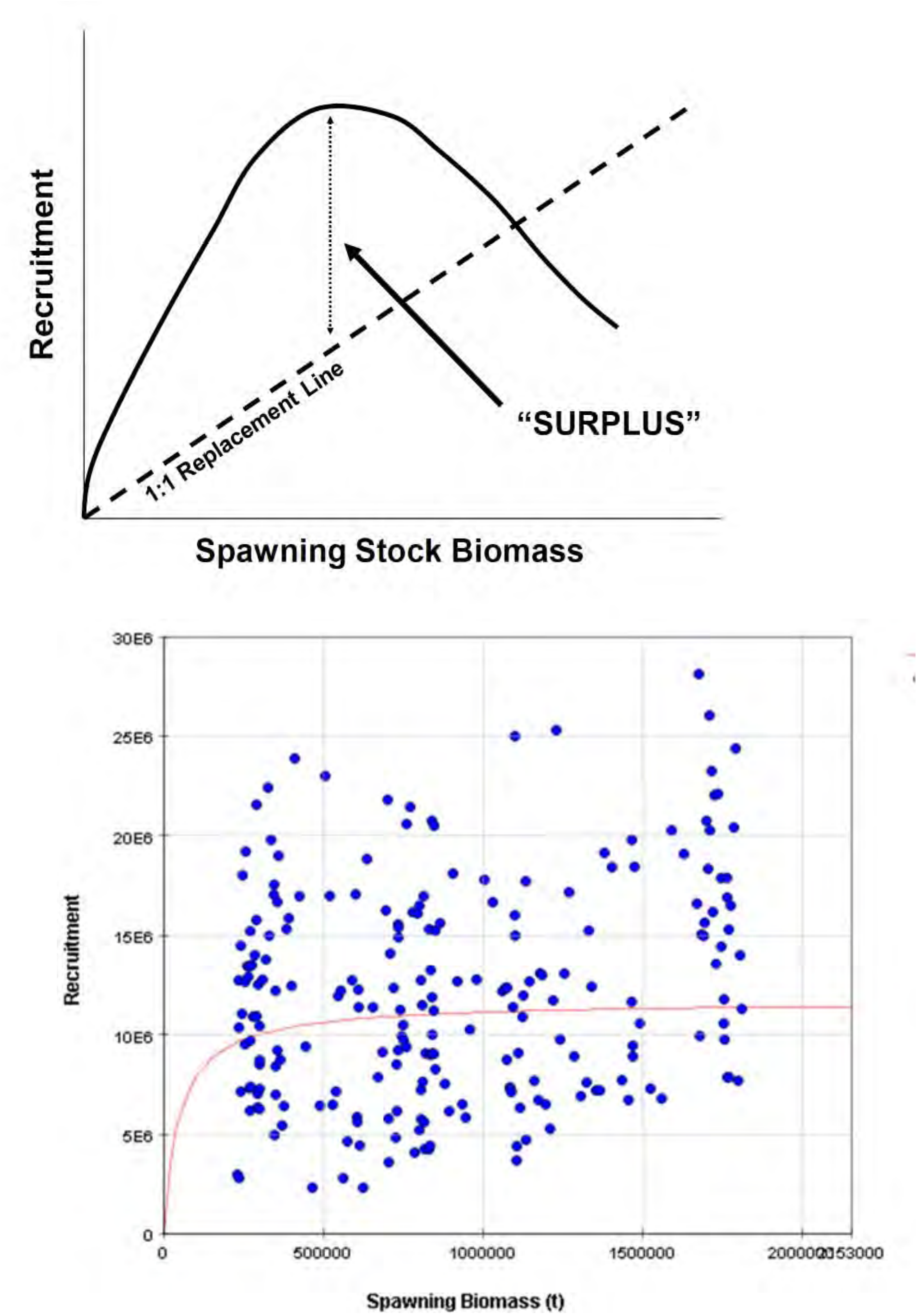

Fig. A2.1 – Theory (top) and reality (bottom) of stock – recruit relationships and stock productivity.

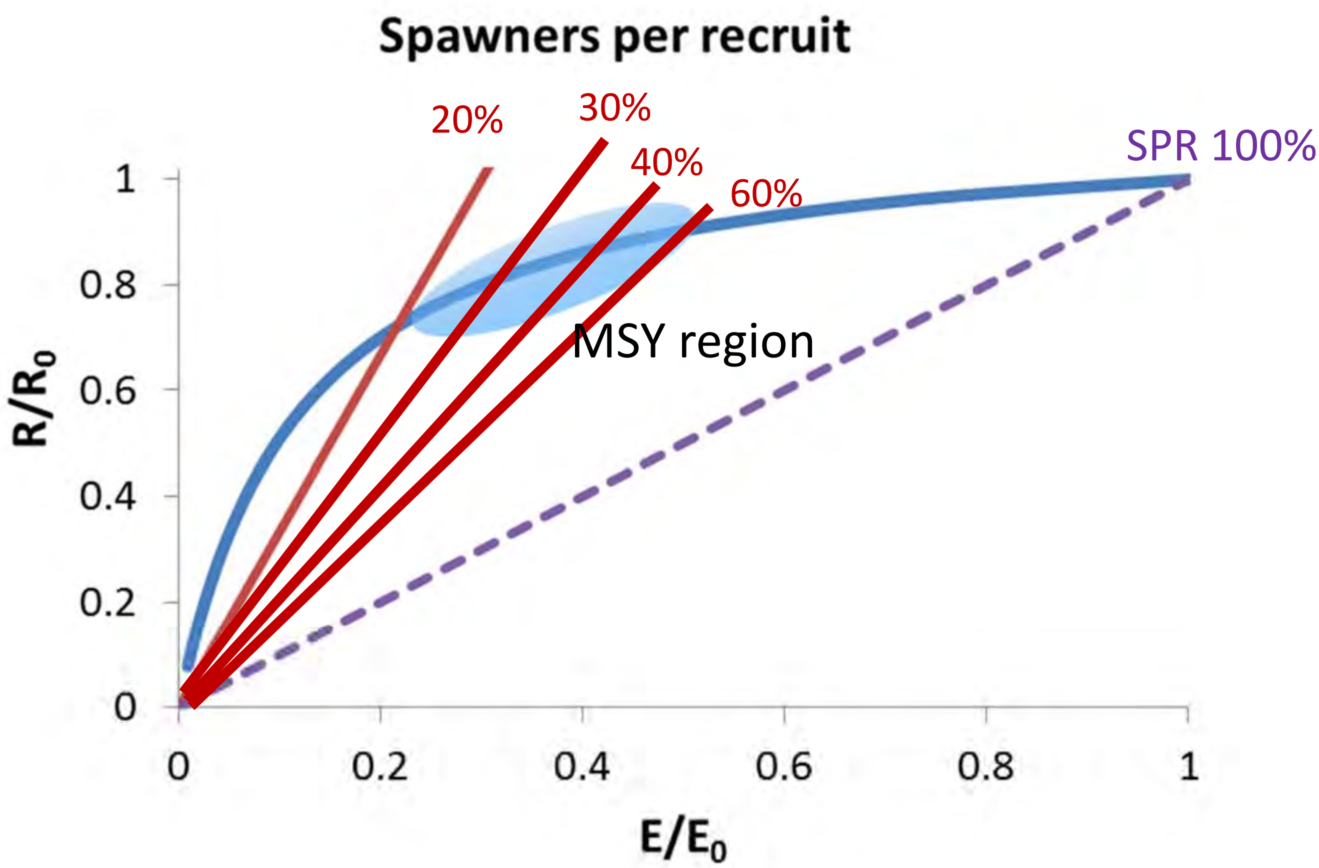

Fig. A2.2 – Theoretical representations of SPR levels for different life-history patterns.

Appendix 7. Selectivity of Age Zero Spot

The proportion of age zero spot available to removal sources was determined by comparing the length frequencies of spot from the removals to the length frequency of age zero spot from fishery independent samples. Only fishery independent lengths from specimens that were determined to be age zero using otolith ages were included in the analysis. All lengths were converted to total length in millimeters where necessary, and length frequencies were constructed using 5mm length bins. Removal types included commercial haul seines, commercial trawls, commercial gill nets, commercial fixed nets, commercial other gear, recreational harvest, recreational release discards, shrimp trawl discards, finfish trawl discards and finfish gill net discards. The length group at which the upper 95% of the removal length frequency remained was used as the cut off value for comparison to the fishery independent age zero length frequency. This was done to eliminate lengths at which incidental catch occurs, but the vast majority of spot at those lengths would not be selected by the gear.

In the first several months of the year, age zero spot are small enough to avoid capture in fishery independent gear, as indicated by 97% of age zero spot being sampled from July through December. The percentage of reported or estimated removals occurring July through December were 70% for the shrimp trawl discards, 91% for combined commercial landings and 90% for recreational harvest. These three removal categories represent 99.6% of total removals. The vast majority of shrimp trawl discards prior to July are likely age one, based on the monthly length frequency distribution.

The selectivity was calculated using length frequencies from July through December combined and dividing this value in half. This assumes age zero spot are not available in the first half of the year. The SAS acknowledges that a very small percentage of age zero spot are selected in the first half of the year. However, it is highly likely a small percentage of age zero spot are not recruited to the fishery independent gears during the July through December timeframe, leading to a slight over estimate of age zero selectivity. The assumption is that these two small errors are equal and offsetting, result in a reliable estimate of the proportion of age zero spot removed by the various fisheries.

Selectivity was calculated for each removal type, and weighted against the average landings from 1994-2014 by removal type. These years represented a timeframe in which removal estimates in numbers were available for all removal types by gear. The weighted portions by removal type were summed to generate a total selectivity from July through December of 0.86. This value was dived by two, yielding an annual age zero spot selectivity value of 0.43.

Cutoff length group in mm, number of lengths, average annual removals in numbers, percentage of total landings and proportion of age zero spot selected by removal type.

	July Through December				July Through December
Removal Type	95% Length Group Cutoff	Number of Lengths	Average Removals	Percentage of Total	Proportion of Age Zero Spot Selected
Commercial Haul Seines	180	20,338	4,012,154	2.70%	0.2528
Commercial Gill Nets	210	78,475	8,045,291	5.41%	0.0290
Commercial Trawls	135	934	518,254	0.35%	0.7303
Commercial Fixed Nets	185	24,005	801,017	0.54%	0.1891
Commercial Other	190	309	207,236	0.14%	0.5390
Shrimp Trawl Discards	90	26,705	124,942,995	84.08%	0.9767
Recreational Landings	170	83,101	9,461,346	6.37%	0.3753
Recreational Discards	110	2,246	528,692	0.36%	0.9226
Finfish Trawl Discards	125	64	75,577	0.05%	0.8258
Finfish Gill Net Discards	225	973	10,062	0.01%	0.0050

Appendix 8. Catch Curve Analysis of Spot for 2017 Stock Assessment

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Catch curve analysis was used to estimate total annual mortality of spot for fishery dependent, fishery independent and the combined data sets where direct age and length data was available. In addition, separate catch curve analysis was also run on model index data from SEAMAP, NEFSC (NMFS) and MRIP using age length keys to convert available length data to age composition data. The catch curve analysis for the MRIP data was performed using the age length key from the fishery dependent data to convert annual length frequency distributions to annual age distributions. Catch curve analysis for SEAMAP and NEFSC were estimated using coastwide ALK'S within each year. The annual total mortality estimates for each data permutation can be seen in Table X. The time period used covered 1996 through 2014 as this represented years where age data was present in the most data sets.

Table A1.1 Estimated annual total mortality from catch curve analysis by data set or type for spot on the Atlantic coast of the United States. *Total number for SEAMAP, NEFSC, and MRIP were based on length frequency expansions of total number with age distributions estimated using age length key conversions.

Year	SEAMAP Z	NEFSC Z	MRIP Z	Fishery Independent	Fishery Dependent	All Data Combined
1996	2.715	2.030	2.133	1.179	1.204	1.379
1997	4.227	1.579	1.396	1.156	1.098	1.303
1998	2.912	1.698	1.305	1.048	1.088	1.237
1999	3.209	2.208	1.511	1.111	1.231	1.339
2000	3.353	2.130	1.754	1.248	1.209	1.401
2001	3.581	2.180	1.860	1.431	1.287	1.527
2002	3.087	2.179	2.065	1.318	1.158	1.370
2003	3.182	1.892	1.679	1.223	1.111	1.298
2004	3.992	2.284	1.806	1.100	0.911	1.071
2005	2.789	2.411	1.457	1.197	0.977	1.139
2006	3.101	2.435	1.820	1.211	1.114	1.303
2007	2.730	2.378	2.284	1.272	1.151	1.331
2008	4.321	2.409	2.678	1.319	1.214	1.445
2009	3.170	2.497	2.433	1.284	1.291	1.466
2010	3.285	2.471	2.342	1.315	1.284	1.464
2011	3.480	2.736	3.507	1.384	1.163	1.467
2012	2.722	2.913	1.482	1.162	1.258	1.385
2013	2.570	2.545	3.548	1.404	1.082	1.478
2014	2.823	2.150	2.244	0.954	1.259	1.328
Z-Range	2.57 - 4.32	1.57 - 2.91	1.31 – 3.55	0.95 -1.43	0.91 – 1.29	1.07 – 1.53
COV	0.305	0.190	0.282	0.098	0.122	0.146
Mean	3.224	2.271	2.069	1.227	1.163	1.354
Median	3.445	2.240	2.43	1.190	1.10	1.30
Age Range	0-4	0-6	0-6	0-6	0-6	0-6
Number	*817,871	*83,440	*138,548,315	9,870	12,460	22,593

In the fishery independent data sets, SEAMAP data had higher Z values than the NEFSC and MRIP data due to a smaller age range (0-4) found in this data set (Figure X.1). Annual Z values were significantly different between SEAMAP and MRIP (paired t-test, P_{MRIP} =0.339) but not with NEFSC (paired t-test, $P_{NEFSC} < 0.001$). The NEFSC and MRIP estimates had similar trends except for two large peaks in the MRIP data in 2011 and 2013 and were not significantly different (pair t-test, P = 0.143).. The peaks in the Z estimate for MRIP in 2011 and 2013 was likely due to the lack of ages 5 and 6 in the age range for those two years.

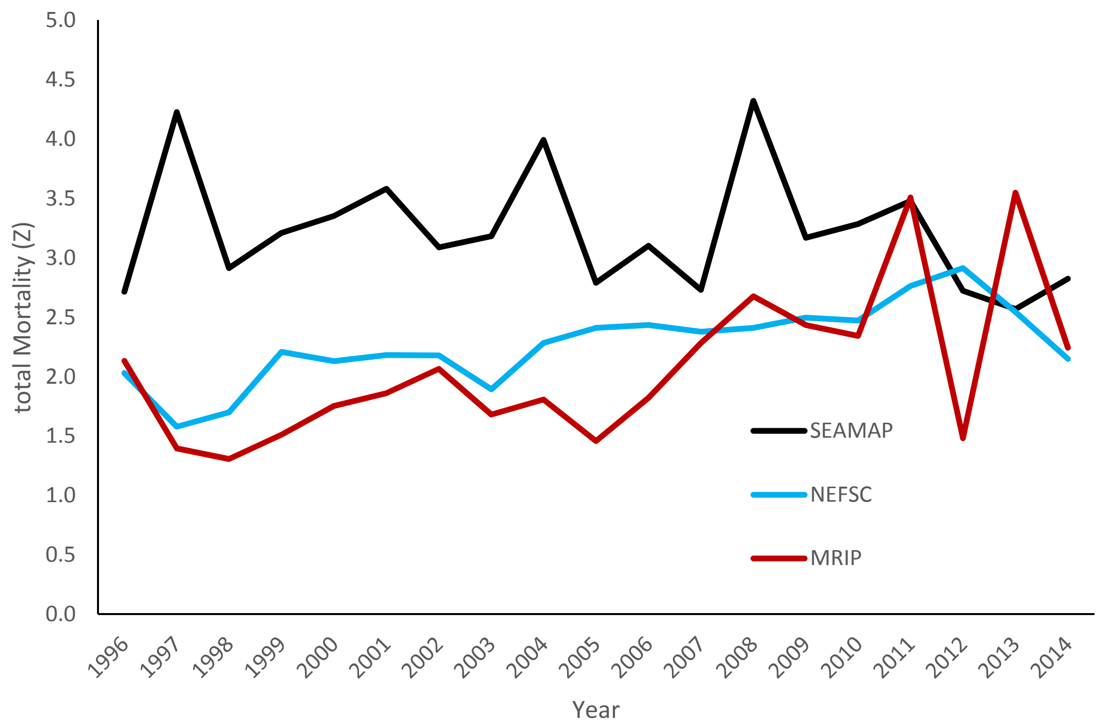

Figure A1.1 Estimated annual total mortality by data set (SEAMAP, NEFSC, MRIP) for spot on the Atlantic coast of the U.S. from assessment data.

The full fishery independent age data set (which also included age data from ChesMMAP, NEAMAP, FWC, and NCDMF) had lower range and mean value than the fishery dependent and full combined age data sets (Table A1.1). Annual trends were very similar across the FI, FD and combined data sets (Figure A1.2), with the mean values and range of Z for the combined data set higher than either the FI or FD data. The annual Z values for FI and FD were not significantly different (paired t-test, $P = 0.068$), so the combined data set was used to set the Z prior levels in the CSA model. However, because there was a significant difference in annual Z values between the combined data with both FI ($P < 0.001$) and FD ($P < 0.001$), separate sensitivity runs were made in the CSA model using the FI and FD values to determine if it effected the model.

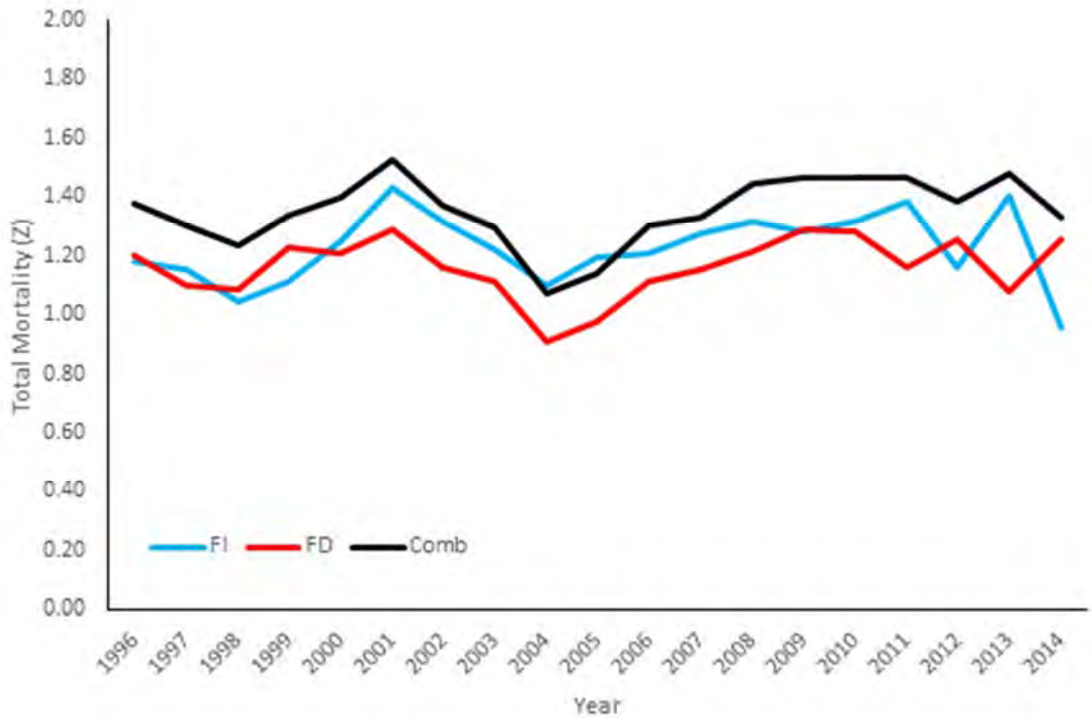

Figure A1.2 Estimated annual total mortality by data type (fishery independent, fishery dependent, combined) for spot on the Atlantic coast of the U.S. from available assessment age data.

Appendix 9. Prior distributions of stock–recruit steepness for the Atlantic croaker (*Micropogonias undulatus*) and Spot (*Leiostomus xanthurus*) populations in the U.S. Atlantic Ocean

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Abstract: The stock–recruit steepness is difficult to estimate. Estimation difficulties are often reduced upon fixing steepness at a "reasonable" value or assigning it a prior distribution. This contribution is devoted to the development of steepness prior distributions for Atlantic croaker and spot inhabiting the U.S. Atlantic coast. To this end, a relationship between slopes at the origin of stock–recruit curves (α) and asymptotic sizes is constructed to infer the plausible values of α, which in turn are combined with species-specific unfished spawning biomass per-recruit (Φ_0). Monte Carlo (MC) simulations are used to propagate uncertainty in growth parameters into natural mortality, Φ_0 and steepness. Under assumptions of Beverton–Holt stock–recruit dynamics, median steepness is 0.78 (80% probable range: 0.68–0.84, mean = 0.76 and mode = 0.79) for Atlantic croaker and 0.66 (80% probable range: 0.33–0.89, mean = 0.64 and mode = 0.79) for spot. If Ricker stock–recruit relationships were assumed, mean and median steepness are 1.68 (80% probable range: 1.1–2.25, mode = 1.78) for Atlantic croaker; for spot, median steepness is 1.58 (80% probable range: 0.35–3.28, mean = 1.03 and mode = 0.52). Two-parameter beta functions are fitted to empirical distributions of the Beverton–Holt stock–recruit steepness for both species. A normal function and a gamma function appear appropriate for fitting the Ricker stock–recruit steepness of Atlantic croaker and spot, respectively. The previous tendency statistics or probable ranges of steepness can guide its estimation. Alternatively, the fitted parameters can be used to select parametric prior for stock–recruit steepness of Atlantic croaker and spot.

Introduction

Contemporary assessments and management of data-rich stocks largely infer from stock–recruit relationships (SRRs). Inferences are made at two levels. First, assessment models include stock-recruit functions designed to govern the recruitment production. Second, nominally sustainable levels (i.e., maximum sustainable yield (MSY)-based benchmarks) and the determination of stock status in principle follow from the combination of (reliable) SRR and per-recruit models (Shepherd, 1982).

Since about the mid-1980s, data-rich stock assessments focused on recasting the stock–recruitment parameters (i.e., maximum recruits per spawner as spawner abundance approaches zero and the degree of compensation) in terms of "steepness" (h; i.e., the fraction of the unexploited recruitment produced by 20% of the unexploited parental stock). This move was adopted because the definition of h was considered biologically meaningful (Hilborn and Mangel, 1997; Haddon, 2001). The previous definition of steepness and related biological and management interpretations are, however, intelligible for and suited to the Bevertion–Holt SRR (BH–SRR). They are difficult to comprehend for other SRRs.

Steepness measures the degree of dependence of average recruitment on the parental stock. For the BH–SRR, it reflects the stock's productivity, whereby its higher values are thought to be associated with highly productive populations, especially at lower density (Beddington and Kirkwood, 2005; Lee et al., 2012; Maunder, 2012; Shertzer and Conn, 2012). In those cases, the stocks are considered to be resilient to harvest. In theory, therefore, intense exploitation and growth-overfishing associated with higher steepness would not affect recruitment or lead to recruitment-overfishing!

Unfortunately, steepness is difficult to estimate. Estimation difficulties arise from reasons such as changes of steepness over time, uninformative fishery data, large fluctuations in recruitment at low stock size, and lack of contrast (i.e., how well the possible range is covered) for the stock–recruit data (Walters and Martell, 2004; Conn et al., 2010; Shertzer and Conn, 2012). For example, in most assessments involving the BH–SRR where steepness is bounded between 0.2 and 1.0, the steepness estimates tend to hit the upper bound irrespective of whether the stock is or is not productive (e.g., Conn et al., 2010; Lee et al., 2012).

Strategies commonly adopted to reduce the estimation difficulties of steepness include: (i) fixing h to an assumed "reasonable" value in a base-model run and conduct sensitivity runs involving alternative values of h; (ii) constraining h between selected lower and upper bounds (e.g., Conn et al., 2010; Anonymous, 2011; Rademeyer et al., 2012); or (iii) developing a prior distribution (penalty function in a maximum likelihood context) for h. The first strategy, along with a fixed natural mortality rate (M), fixes biological reference points, BRPs (Mangel et al., 2013). The second strategy basically is a uniform distribution for h, a "reasonable" estimate of which depends on information contained in fishery data and on possible contrasts that the spawning stock may have exhibited. The third strategy relies on met-population analyses (Myers et al., 1999, 2002; Rose et al., 2001; Shertzer and Conn, 2012; Punt and Dorn, 2014), persistence principles (He et al., 2006), or uncertainty in reproductive and life history parameters (Mangel et al., 2010; Simon et al., 2012; Brodziak et al., 2015). This strategy is somewhat similar to the first strategy when M is fixed, but differ from it in that: (i) given a long and comprehensive time series of fishery data and variable spawning stock, the prior distribution of h can be updated, usually through Bayes' rule, into a posterior distribution; and (ii) the resulting BRPs have distributions.

For the current benchmark assessments of the Atlantic croaker (*Micropogonias undulatus*) and spot (*Leiostomus xanthurus*) stocks in the U.S. Atlantic coast, this note aims to construct plausible prior distributions for stock–recruit steepness of the stocks in question. Analyses combine: (i) the relationship between published stock productivity levels at low stock size and asymptotic lengths; (ii) species-specific parameters on growth and maturity/fecundity (the estimation of M follows from a nonlinear empirical equation in Then et al., 2015); and (iii) the unfished spawning biomass (or number of eggs) per-recruit (Φ_0).

Materials and methods

Basic parameters, relationships and assumptions

The construction of prior distributions of the stock–recruit steepness (h) for Atlantic croaker and spot relies on two main characteristics. First, the slopes at the origin of spawner-recruit curves (α, the maximum recruits per-spawner at lower spawner abundance) is negatively and significantly related to the parameters L_∞ and W_∞ of the von Bertlanffy growth (VBG) equation (Denney et al., 2002; Goodwin et al., 2006; Hall et al, 2006). Therefore, given species-specific values of L_∞ and longevity or W_∞ falling in the range of meta-analytic relationships $\alpha \sim L_\infty$ or $\alpha \sim W_\infty$, plausible species-specific values of α can be estimated. Second, the definition of h reduces to a nonlinear function h of α and the unfished spawning biomass (or number of eggs) per-recruit (Φ_0): $h = f(\alpha, \Phi_0)$ (Mangel et al., 2010, 2013 and references therein).

The previous aspects are accounted for by compiling estimates of α, L_∞, and Φ_0 that have preferably been estimated and published simultaneously. Otherwise, when only α is available, L_∞ values are compiled from various sources including FishBase (http://fishbase.org). Most α values were estimated employing the Ricker SRR (R–SRR)—Myers et al. (1999, 2002) argue that at the limit of small population size, the BH–SRR and R–SRR coincide, having the same α, although they produce different estimates of α once fitted to the same data (Michielsens and McAllister, 2004; Forrest et al., 2010; Galindo-Cortes et al., 2010). In this note, all compiled α values are used irrespective of the standard BH–SRR or standard R–SRR they were derived with, provided the BH–SRR was of the form similar to the equation used below for defining steepness. Furthermore, α estimates for the BH–SRR are preferred over those for R–SRR if they are available for the same stock. The relationship between α and L_∞ is (Fig. 1a, b; $r^2 = 0.67$, $P < 0.001$):

$$\alpha = 856213.7 L_\infty^{-2.9393} \quad (1)$$

The VBG parameters (L_∞, K year^{-1}, and age_0 (years)) and the length–growth scales (a) and exponents (b) for females of Atlantic croaker[1] include those in ASMFC (2010a) and those that have been updated during this assessment benchmark. The growth parameters for females of spot are available during this assessment benchmark only, so they also include those values that have been estimated for both sexes in ASMFC (2010b). Estimated growth parameters are treated as "observed data." Then, the variability in these parameters is considered reflective of scientific uncertainty, but note that the majority of them are linearly and significantly related (Fig. 1c–h). No unique combination made up of each point estimate from their respective sets is preferred *a priori* over other combinations in calculating composite life history metrics, such as M and Φ_0.

Characterizing uncertainty through random samples of growth parameters

Because at least two sets of the observed growth parameters are linearly and significantly related (Fig. 1c–h), the VBG parameters on the one hand, and the length-weight scales and exponents on the other, are jointly simulated as multivariate normal distributions given their empirical mean vectors and covariance matrices. Sampling is performed (number of iterations n = 10000) with the R package MASS (Venables and Ripley, 2002). (A different sampling scheme such as Monte Carlo (MC) simulations assuming uniform distributions would be appropriate if the previous pairs of growth parameters were not linearly related). Except for Atlantic croaker's parameter age_0 versus L_∞, stochastic realizations of various growth parameters are expectedly related linearly (Fig. 2a–h). In particular, isopleths have the highest probability density at about (L_∞, K) = (42 cm, 0.2 year^{-1}) and (a, b) = (0.015, 3.0) for Atlantic croaker and at bout (L_∞, K) = (370 mm, 0.35 year^{-1}) and (a, b) = (3.5×10^{-5}, 3.0) for spot.

During the sampling, some iterations can yield negative values for the parameter a and positive values for the parameter age_0. Such random draws are conducive, respectively, to negative mean weights and negative mean lengths at age-0, which are unfeasible. It is therefore necessary to subset the initial iterations, only keeping draws of L_∞, K, and b associated with positive values of a and negative values of age_0. The number of kept draws is denoted $n+$ and, for each of them, the following quantities are derived or calculated through MC simulations.

Natural mortality

Constant M (Figs. 3a, b) is estimated using the Pauly's nonlinear empirical equation (Then et al., 2015):

$$M = 4.118 K^{0.73} L_\infty^{-0.33} \quad (2a)$$

(Hoenig's updated nonlinear empirical equation can also be used, on the basis of maximum ages that individual studies have recorded). Natural mortality at age (M_{age}) follows from Lorenzen's

[1] The triplets (L_∞, K, age_0) equal to (85.4, 0.0638, −0.0016) and (64.5, 0.2, −3.06) are excluded because they appear to be outliers.

(2000, 2005) natural survival equation at age (S_{age}) for the VBG function (L_∞ is treated as reference length and M relates to L_∞):

$$S_{age} = \left[\frac{L_{age}}{L_{age}+L_\infty(e^K-1)}\right]^{\frac{M}{K}} \quad (2b)$$

where L_{age} is mean length at age estimated with the VBG equation. It follows that $M_{age} = -\log(s_{age})$:

$$M_{age} = \frac{M}{K}\log\left[1+\frac{L_\infty}{L_{age}}(e^K-1)\right] \quad (2c)$$

Figures 3c, d show levels (medians and empirical 95% confidence intervals) and trajectories of natural mortality at age.

Mean weights

The asymptotic weight (W_∞) is given by:

$$W_\infty = aL_\infty^{b} \quad (3a)$$

Mean weight at age (W_{age}) is calculated as:

$$W_{age} = W_\infty\{1 - \exp[-K(age - age_0)]\}^{b} \quad (3b)$$

The unfished spawning stock biomass per-recruit (SSBR)

The unfished SSBR at age (starting from age-0) for females ($\psi_{age.F=0}$) is calculated as:

$$\Psi_{ageF=0} = l_{age}sr_{age}W_{age}\mu_{age}\frac{\sum_{m=1}^{12}\pi_m exp(-\varphi_m M_{age})}{\sum_{m=1}^{12}\pi_m} \quad (4)$$

where sr_{age} is the sex-ratio at age; μ_{age} is the probability mature at age; π_m is the monthly proportion of spawning-capable females; φ_m is the fraction of the year elapsed at the beginning of the spawning month m (calculated assuming that natural mortality by age is uniformly distributed over the year; by convention, φ_1 for the month of January is zero, $\varphi_2 = 1/12$ for the month of February consistent with the elapsed month of January, and so on); and l_{age} is the unfished survivorship to a given age (note: at age-0, $l_{age} = 1$): $l_{age} = l_{age-1}\, exp(-M_{age-1}) = exp(-\sum_0 M_{age-1})$. Figures 3e, f describe the estimated l_a levels and trajectories.

The sex-ratios and probability mature ate age (s_{age}, μ_{age}) as well as the vector φ_m used in Eq. (4) were developed during this assessment benchmarks. Together with the vector π_m, they are treated as deterministic.

The total unfished SBPR (Φ_0) is given by:

$$\Phi_0 = \sum_{age=0}^{T_{max}}\Psi_{ageF=0} \quad (5)$$

where T_{max} is maximum observed age (17 years for Atlantic croaker, 6 years for spot).

Calculating the steepness parameter

The BH–SRR and R–SRR are commonly used in stock assessment models of population dynamics. Here, the steepness (h) is calculated on the ground that its definition relies on a BH–SRR of the form R = αS/(1 + βS), where R is recruitment, S is spawning stock biomass producing R, and α and β are parameters[2]:

$$h = a\Phi_0/(4 + a\Phi_0) \quad (6a)$$

If there is evidence for mechanisms supporting the R–SRR, R = αS exp(−βS), then

$$h = 0.2(a\Phi_0)^{0.8} \quad (6b)$$

[2] If the steepness were defined based on BH–SRRs of the forms R = αS/(β + S) and R = S/(α + βS), h would be expressed as $h = \alpha\Phi_0/(4\beta + \alpha\Phi_0)$ and $h = \Phi_0/(4\alpha + \Phi_0)$, respectively.

The quantity $\alpha\Phi_0$ is the maximum lifetime reproductive rate at low density (Myers et al., 1999, 2002), i.e., the number of recruits produced by a recruit over its lifespan in the absence of fishing (Brooks et al., 2010). It corresponds to the Goodyear (1977, 1980) compensation ratio and is related to steepness (Walters and Martell, 2004; Martell et al. 2008; Brooks et al., 2010; Fig. 4).

Some properties and estimation considerations of the steepness

The range of h is [0.2, 1) for the BH–SRR and [0.2, ∞) for the R–SRR; its domain (i.e., values of $\alpha\Phi_0$) is [1, ∞). The variation of h against $\alpha\Phi_0$ (Fig. 4) indicates that, for the BH–SRR for example, (i) $h = 0.5$ when $\alpha\Phi_0 = 4$; (ii) for $\alpha\Phi_0 > 4$, $h > 0.5$ (e.g., $h = 0.75$ if $\alpha\Phi_0 = 12$ and $h = 0.95$ if $\alpha\Phi_0 = 76$), but $h < 1$ because $\alpha\Phi_0 < 4 + \alpha\Phi_0$ (i.e., 1 should never upper-bound h); and (iii) for $\alpha\Phi_0 < 4$, $h < 0.5$ and $h = 0.2$ when $\alpha\Phi_0 = 1$.

Although the steepness is dimensionless and is considered a tool for comparison across species (e.g., Beddington and Kirkwood, 2005; Kell et al. 2013, Rossberg et al., 2013), the units chosen to calculate Φ_0 influence its magnitude. For example, given α in number of recruits per spawning biomass, values of h based on Φ_0 in g would be higher than those that would be based on Φ_0 in kg. For the BH–SRR in particular, it may be useful to develop Φ_0 with a unit in such a way that the order of magnitude for the $\alpha\Phi_0$ value is comparable with 4 on the denominator (typical values of $\alpha\Phi_0$ are single-digit and double-digit numbers; Figs. 4). For Φ_0 calculated as SSBR, as is here, use of kg is deemed appropriate and is recommended to facilitate comparisons among life histories. The previous remarks suggest that comparison of species of different life histories on the basis of the stock–recruit steepness make sense when their Φ_0 is in the same unit.

Estimating parameters of prior distributions for steepness

The R ExtDist package is used to estimate the parameters that provide the maximum likelihood fit to the empirical steepness distributions as obtained from MC simulations. Specifically, the fitted probability density functions (pdfs) are: (i) the two-parameter beta pdf for the BH–SRR steepness, and (ii) the normal or gamma pdf for the R–SRR steepness.

The forms of the fitted normal, gamma, and two-parameter beta pdfs are, respectively:

$$f(h) = \frac{e^{-\frac{(h-\mu_h)}{\sigma^2}}}{2\sqrt{2\pi}} \quad (7a)$$

$$f(h) = \frac{h^{p-1}e^{-\frac{h}{\theta}}}{\Gamma(p)\theta^p} \quad (7b)$$

$$f(h) = \frac{\Gamma(p+q)}{\Gamma p \Gamma q} h^{p-1}(1-h)^{q-1} \quad (7c)$$

The parameters are the mean μ_h and the standard deviation σ (> 0) for the normal pdf, the shape p (> 0) and the scale θ (> 0) for the gamma pdf, and the shape parameters p and q (> 0) for the two-parameter beta pdf. The mean and variance are given by $p\theta$ and $p\theta^2$ for the gamma pdf and, for the two-parameter beta pdf, by $p/(p + q)$ and $pq/[(p + q)^2(p + q + 1)]$, respectively.

Results

The distributions of the BH–SRR steepness are left skewed for both the Atlantic croaker and Spot (Fig. 5a, b) with MC sample medians of 0.78 (80% probable range: 0.68–0.84) and 0.66 (80% probable range: 0.33–0.89), respectively. The MC sample mean of the BH–SRR steepness is 0.76 (CV = 0.11) for Atlantic croaker and 0.64 (CV = 0.32) for spot.

The parameters of the fitted beta density (Fig. 5a, b) are p = 22.07 (standard error, SE = 0.324) and q = 6.93 (SE = 0.099) for Atlantic croak and p = 3.05 (SE = 0.05) and q = 1.73 (SE = 0.027) for spot.

The R–SRR steepness for Atlantic croaker is normally distributed (Fig. 5c) with an MC sample mean of 1.68 (CV = 0.28; 80% probable range: 1.1–2.25). For spot, the R–SRR steepness is right skewed (Fig. 5d), with an MC sample median of 1.03 and an MC sample mean of 1.58 (80% probable range: 0.35–3.28). The fitting of a gamma pdf to the MC sampled data for this distribution produces p = 1.42 and θ = 0.91 (mean = 0.61; standard deviation = 0.27).

Shertzer and Conn (2012) argue that, if data are informative, "a prior distribution (for steepness) informs the estimation process in that the best estimate occurs at the mode." If so, the modes of the BH–SRR steepness are 0.79 for both Atlantic croaker and spot. The modes of the R–SRR steepness for these species, respectively, are 1.78 and 0.52.

Discussion

This note builds upon a relationship that exits between the slopes at the origin of stock–recruit curves (α) and asymptotic lengths (L_∞). Empirical inferences of α for Atlantic croaker and spot are then made on the ground that their L_∞ values are in the range of the aforementioned relationship. Finally, the calculated α values are combined with the species-specific unexploited spawning biomass per-recruit (Φ_0) to develop the corresponding stock–recruit steepness. The construction of empirical distributions of steepness is made possible through: (i) Monte Carlo simulations of growth parameters, (ii) calculations of constant M using the realized L_∞ and K, and (iii) the propagation of uncertainty in L_∞, K, constant M and length-weight parameters into M-at-length and Φ_0. Therefore, contrary to fully meta-analytic approaches (Myers et al., 1999, 2002; Rose et al., 2001; Shertzer and Conn, 2012; Punt and Dorn, 2014) and methods exclusively based on reproductive and life history parameters (Mangel et al., 2010; Simon et al., 2012; Brodziak et al., 2015), the methodology used here combines results on α and L_∞ gained from other stocks and life history parameters of the species of interest. As such, the proposed approach is hybrid.

Apart from the relationship α ~ L_∞ (which may change depending on the selected pairs), a key step to estimating the steepness is the calculation of Φ_0 (Eq. (5)). Here, a calculation methodology is proposed to account for the protracted nature of the spawning activity for Atlantic croaker and Spot. However, because the incorporation of the reproductive dynamics into equilibrium per-recruit models is challenging, Eq. (4) attempts to address the protracted spawning season through a weighted average of monthly survival rates (i.e., $\frac{\sum_{m=1}^{12} \pi_m exp(-\varphi_m M_{age})}{\sum_{m=1}^{12} \pi_m}$) themselves based on φ_m values; the weights are monthly proportions of spawning-capable females. Such a procedure implies simplifying assumptions that all age-specific schedules are conserved each month and that females in a cohort can survive at the beginning of any month of a year but spawn only during a single month.

The previous weighting of monthly survival rates is flexible in that it can accommodate various configurations depending on species-specific reproductive dynamics in a year. For example, the proportion π_m should simply be set to zero in months during which a species is reproductively inactive. In that case, the resting months would weigh nothing. At another extreme, π_m would equal one if females reproducing in each month all were spawning-capable (the denominator = 12). It is of note that Gabriel et al.'s (1989) equation, applicable for a single month of peak spawning assuming (π_m = 1), is a special case of Eq. (4).

Parametric density functions (normal, gamma, and beta) for steepness are fitted to the empirical steepness distributions to the estimate their parameters. It is anticipated that the fitted parameters can be used to select parametric prior for stock–recruit steepness of Atlantic croaker and spot assuming either the BH–SRR or the R–SRR.

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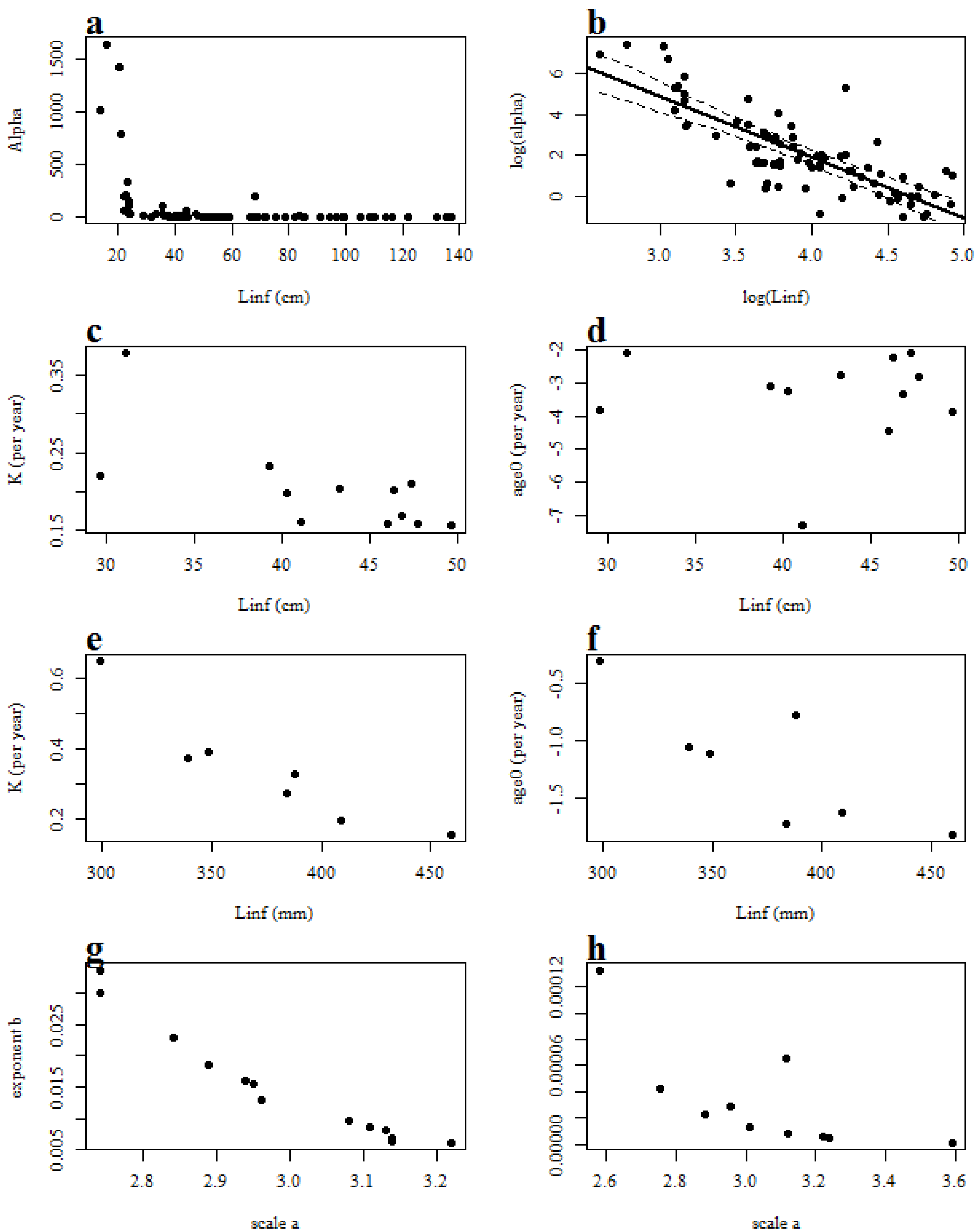

Fig. 1 Relationships between (a, b) "observed" values of alpha and L_∞, on arithmetic and log scale, respectively; (c, d) the VBG parameters K and age_0 for Atlantic croaker, (e, f) for spot; and (g, h) the exponent and the scale of length-weight for Atlantic croaker and spot, respectively.

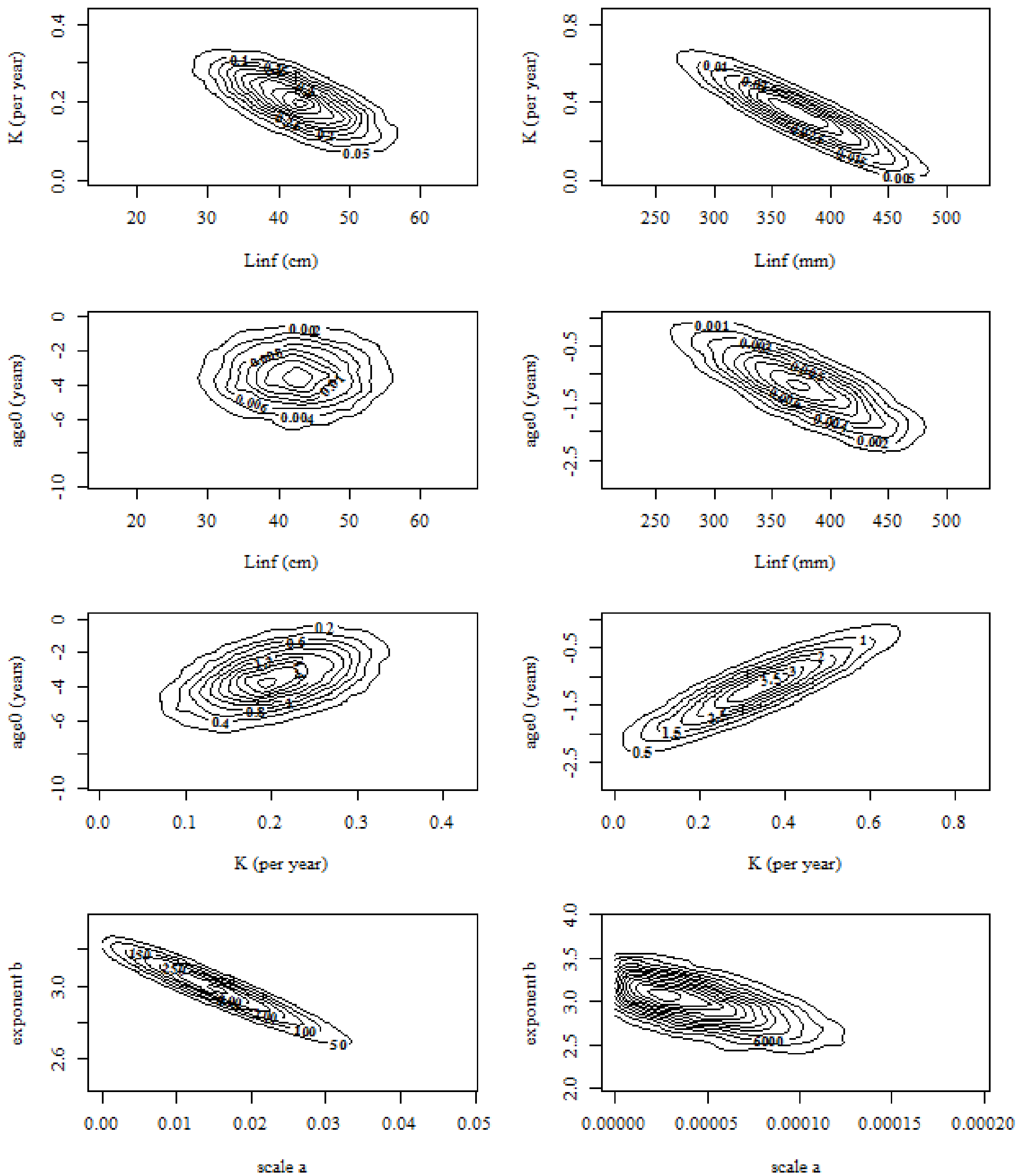

Fig. 2 Isopleth contours showing relationships between the growth parameters for Atlantic croaker (left panel; the number of draws producing the scale *a* > 0 and age-0 < 0, n+, is = 9394) and spot (right panel; n+ = 7632).

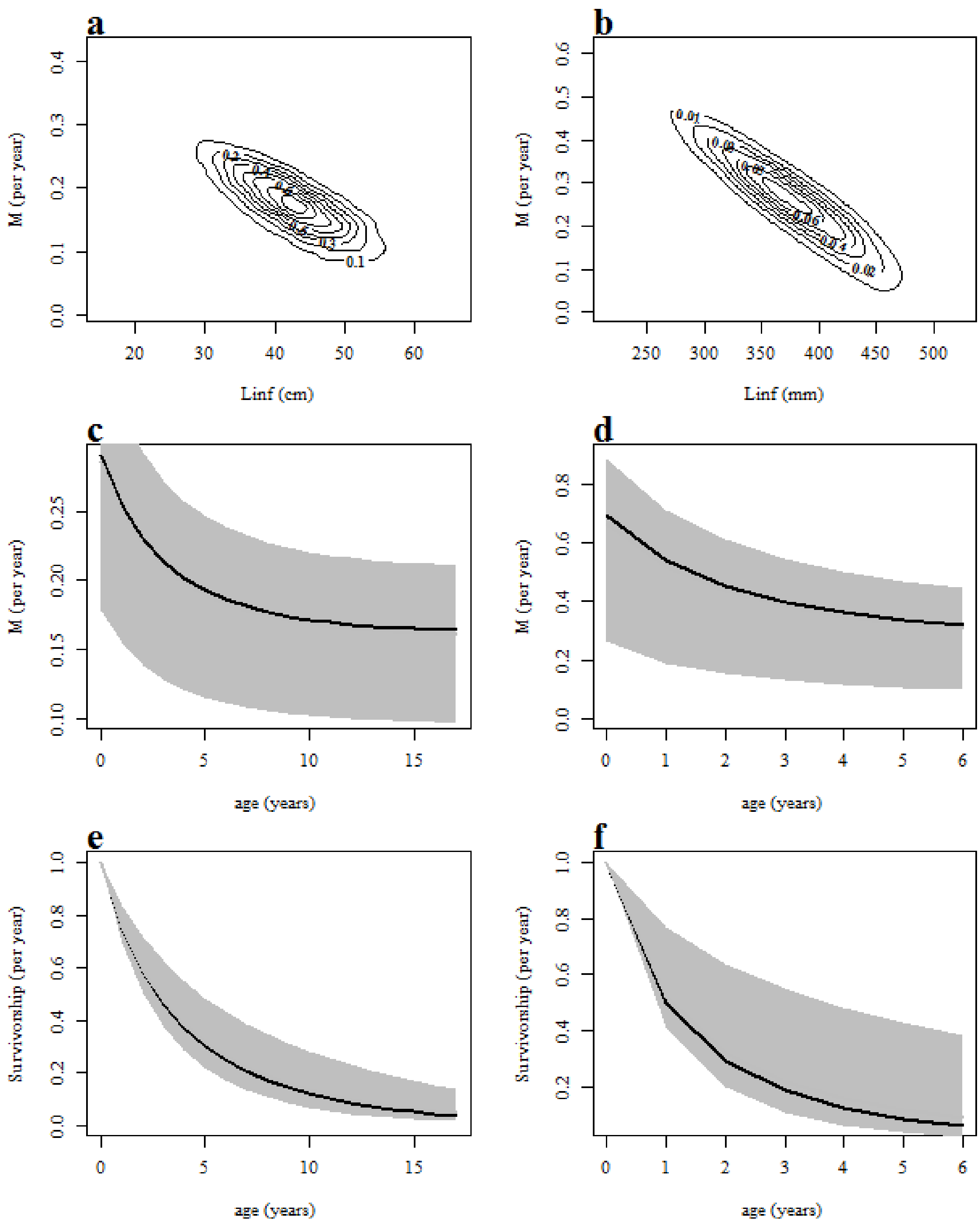

Fig. 3 Relationships between (a, b) the realized natural mortality (*M*) and L_∞; trajectories of median (black line) and 95% confidence intervals (gray color area) of (c, d) age-specific natural mortality and (e, f) survivorship for Atlantic croaker (left panel) and spot (right panel).

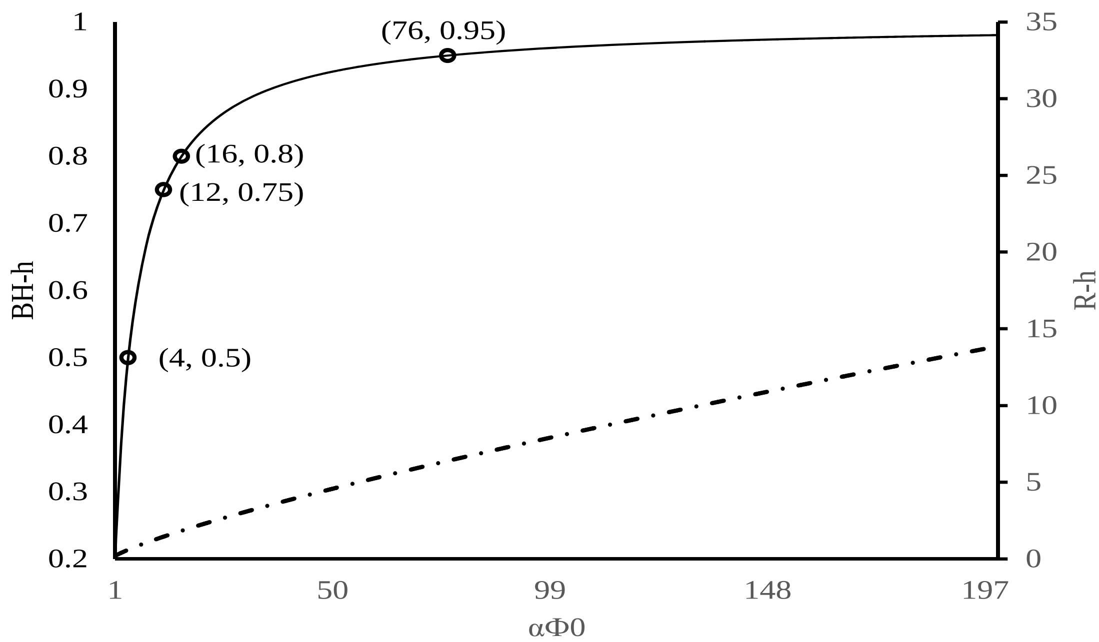

Fig 4 Curves for the BH–SRR steepness (BH–h) and R–SRR steepness (R–h) in relation with the maximum lifetime reproductive rate (a.k.a. Goodyear recruitment compensation ratio), $\alpha\Phi_0$. The selected coordinates for the BH–SRR relate to some commonly-assumed values of steepness.

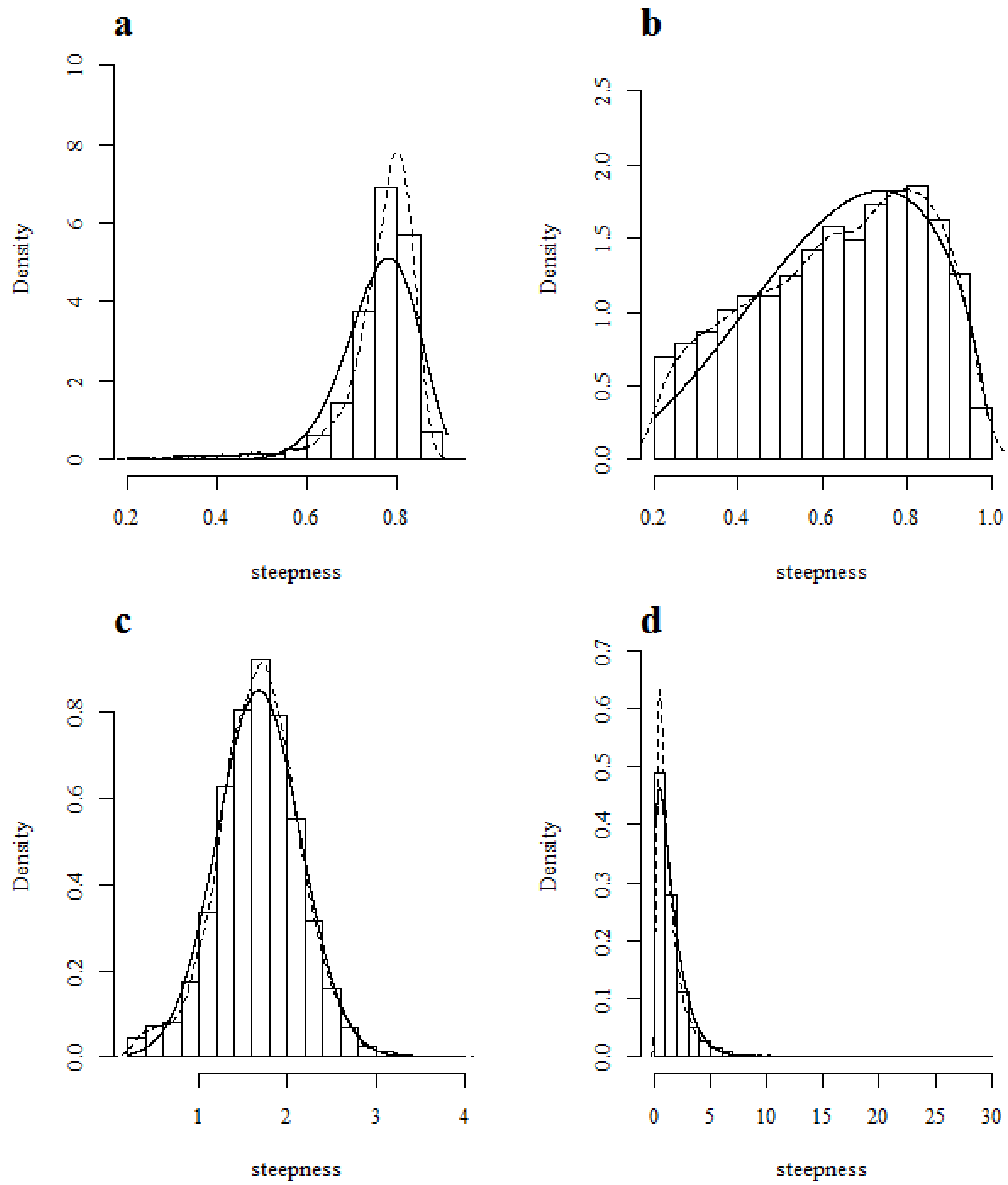

Fig 5 – Frequency histograms of steepness along with empirical (dashed lines) and parametric (solid lines) density functions fitted to those data for (a, b) the BH–SRR and (c, d) the R–SRR for Atlantic croaker (left panel) and spot (right panel) off the U.S. Atlantic coast.