This document contains the latest version of Draft Amendment 2, as revised August 6, 2012. The following sections, highlighted in yellow, have been revised:

1.5.3 Economic Impacts

3.6.2 Fishery-Dependent Data

3.6.2.1 Biological Data

3.6.2.2 Adult Survey Index

4.2.1 Total Allowable Catch (TAC)

4.2.1.1 TAC Specification

4.2.1.2 TAC Setting Method

4.2.1.4 Quota Tranfers

4.2.1.5 Quota Rollover

4.9 RECOMMENDATIONS TO THE SECRETARY FOR COMPLEMENTARY ACTIONS IN FEDERAL JURISDICTIONS

Atlantic States Marine Fisheries Commission

Atlantic Menhaden Management Board

August 8, 2012
9:45 a.m. – 12:45 p.m. and 1:45 – 2:45p.m.
Alexandria, VA

Draft Agenda

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

1. Welcome/Call to Order (*L. Daniel*) — 9:45 a.m.

2. Board Consent — 9:50 a.m.
   - Approval of Agenda
   - Approval of Proceedings from May 2, 2012

3. Public Comment — 9:55 a.m.

4. 2012 Atlantic Menhaden Stock Assessment Update **Action** — 10:00 a.m.
   - Presentation of Stock Assessment Report (*R. Latour*)
   - Technical Committee Reports on Stock Assessment Update (*J. Brust*)
   - Consider acceptance of stock assessment update report for management use

5. Consider Draft Amendment 2 for Public Comment (*M. Waine)* **Action** — 11:30 a.m.
   - Review Draft Amendment Options (*M. Waine)*
   - Advisory Panel Report (*B. Windley)*

6. MSTC Report on Potential MODA Funding Sources (*Staff*) — 2:30 p.m.

7. Other Business/Adjourn — 2:45 p.m.

The meeting will be held at the Crown Plaza, 901 North Fairfax Street, Alexandria, VA 22314; 703-683-6000

MEETING OVERVIEW

Atlantic Menhaden Management Board Meeting
Wednesday, August 8, 2012
9:45 a.m. – 12:45 p.m. and 1:45 – 2:45p.m.
Alexandria, VA

Chair: Louis Daniel (NC) Assumed Chairmanship: 3/11	Technical Committee Chair: Jeff Brust (NJ)	Law Enforcement Committee Representative: Lloyd Ingerson (MD)
Vice Chair: Robert Boyles	Advisory Panel Chair: William Windley (MD)	Previous Board Meeting: May 2, 2012
Voting Members: ME, NH, MA, RI, CT, NY, NJ, DE, MD, PRFC, VA, NC, SC, GA, FL, NMFS, USFWS (17 votes)		

2. Board Consent
- Approval of Agenda
- Approval of Proceedings from May 2, 2012

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. 2012 Atlantic Menhaden Stock Assessment Update (10:00 a.m. -11:30 a.m.) Action
Background • The 2012 update stock assessment was completed in July (**Briefing CD**) • The Technical Committee notes there is a current mismatch in the F and Biomass reference points for Atlantic menhaden (**Briefing CD**) • The Board tasked the Technical Committee to address the topics below. (**Briefing CD**) (1) Highlight any concerns that the TC has regarding the model output and its use for supporting management decisions. (2) Provide additional quantitative or qualitative data that will provide insight to the Board on the status of the menhaden stock (e.g. recruitment levels, catch age composition, survey trends).
Presentations • 2012 Stock Assessment Update Report by E. Williams, SAS Chair • TC Reports on the Stock Assessment Update by J. Brust, TC Chair
Board actions for consideration at this meeting • Accept the Stock Assessment Update Report for management use.

5. Draft Amendment 2 (11:30 a.m. – 12:45 p.m. and 1:45 – 2:30 p.m.) Action
Background • Draft Amendment 2 contains management options to achieve the new fishing mortality reference points implemented through Addendum V in November 2011 **(Briefing CD)**. • The Advisory Panel reviewed Draft Amendment 2 and provided recommendations **(Supplemental Materials)**.
Presentations • Overview of draft Amendment 2 for public comment by M. Waine • Advisory panel report by Bill Windley, AP Chair
Board actions for consideration at this meeting • Approve draft Amendment 2 for public comment.

6. Multispecies Technical Committee Report on Potential MODA Funding Sources (2:30 – 2:45 p.m.)
Background • The Board tasked the MSTC to report on potential funding sources to begin the Multiple Management Objective Decision Analysis (MODA) for Atlantic Menhaden
Presentations • Overview of potential funding sources by Staff

7. Other Business/Adjourn

DRAFT PROCEEDINGS OF THE

ATLANTIC STATES MARINE FISHERIES COMMISSION

ATLANTIC MENHADEN MANAGEMENT BOARD

Crowne Plaza Hotel - Old Town
Alexandria, Virginia
May 2, 2012

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

TABLE OF CONTENTS

INDEX OF MOTIONS

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

2. **Approval of Proceedings of February 7, 2012** by consent (Page 1).

3. **Move that the board use MODA for ecological reference point development as recommended by the Atlantic Menhaden and Multispecies Technical Committee; using the approach detailed in Option 1 in the committee's May 2012 report** (Page 7). Motion by David Pierce; second by Bill McElroy.

4. **Move to postpone the motion until the August meeting and charge the technical committee and staff to research alternative funding options for the MODA project.** (Page 13). Motion by David Nowalsky; second by Steve Meyers. Motion defeated (Page 15).

5. **Move to amend the main motion to add "subject to appropriate funding be determined by the August meeting"** (Page 15). Motion by Ritchie White; second by James Gilmore. Motion carried (Page 16).

   ***ABOVE MOTIONS REWORDED* (Page 16): Move that the board use MODA for ecological reference point development as recommended by the Atlantic Menhaden and Multispecies Technical Committees; using the approach detailed in Option 1 in the committee's May 2012 report; amended to say "subject to appropriate funding be determined by the August meeting".**

6. **Move to remove the ten-year timeframe from Draft Amendment 2** (Page 22). Motion by Pat Augustine; second by Dennis Abbott.

7. **Move to amend the motion to change the ten years to one** (Page 23). Motion by Jack Travelstead; second by Terry Stockwell. Motion carried (Page 25). Carried as the main motion (Page 25).

8. **Motion to amend adding ten years to the main motion; make it one and ten years to be removed** (Page 25). Motion by Dennis Abbott; second by Rep. Peake. Motion defeated (Page 26).

9. **Motion to remove consideration of season, size and gear restrictions under recreational management measures** (Page 30). Motion by Adam Nowalsky; second by Pat Augustine.

10. **Motion to substitute that recreational management measures be put into the adaptive management portion of the amendment** (Page 30). Motion by Doug Grout; second by Bill Adler. Motion carried (Page 30).

11. **Move to eliminate trip limits and gear restrictions from the document** (Page 30). Motion by Jack Travelstead; second by Terry Stockwell. Motion carried (Page 31).

12. **Move to reconsider the vote on Issue Number 1, the timeline for implementing the target fishing mortality rate (Page 38)**. Motion by Bill Goldsborough; second by Pat Augustine. Motion defeated (Page 39).

13. **Motion to adjourn by consent** (Page 41).

ATTENDANCE

Board Members

Terry Stockwell, ME, proxy for P. Keliher (AA)
Steven Train, ME (GA)
Dennis Abbott, NH, proxy for Rep. Watters (LA)
Doug Grout, NH (AA)
G. Ritchie White, NH (GA)
David Pierce, MA, proxy for P. Diodati (AA)
Bill Adler, MA (GA)
Rep. Sarah Peake, MA (LA)
Robert Ballou, RI (AA)
Mark Gibson, RI, Administrative proxy
Bill McElroy, RI (GA)
Rick Bellavance, RI, Proxy for Rep. Martin (LA)
David Simpson, CT (AA)
Dr. Lance Stewart, CT (GA)
James Gilmore, NY (AA)
Steve Heins, NY, Administrative proxy
Pat Augustine, NY (GA)
Brian Culhane, NY, proxy for Sen. Johnson (LA)
Peter Himchak, NJ, proxy for D. Chanda (AA)
Adam Nowalsky, NJ, proxy for Asm. Albano (LA)
Tom Fote, NJ (GA)
David Saveikis, DE (AA)
Roy Miller, DE (GA)
Bernie Pankowski, DE, proxy for Sen.Venables (LA)
Lynn Fegley, MD, proxy for T. O'Connell (AA)
Bill Goldsborough, MD (GA)
Russell Dize, MD, proxy for Sen. Colburn (LA)
Jack Travelstead, VA (AA)
Jim Kellum, VA, proxy for C.Davenport (GA)
Kyle Schick, VA, proxy for Sen. Stuart (LA)
Louis Daniel, NC (AA)
Michelle Duval, NC, Administrative proxy
Mike Johnson, NC, proxy for Sen. Wainwright (LA)
Malcolm Rhodes, SC (GA)
Robert Boyles, Jr., SC (LA)
Spud Woodward, GA (AA)
John Duren, GA (GA)
Aaron Podey, FL (AA)
Steve Meyers, NMFS
Jaime Geiger, USFWS
A.C. Carpenter, PRFC

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

Ex-Officio Members

Jeff Brust, Technical Committee Chair
Mark Robson, Law Enforcement Representative
Bill Windley, Advisory Panel Chair

Staff

Vince O'Shea
Robert Beal
Toni Kerns
Mike Waine
Chris Vonderweidt

Guests

Loren Lustig, PA Gov. Appointee
Mel Bell, SC DNR
Patrick Paquette, MSBA/RFA
Richard Coniff, NY Times
Erica Fuller, Earthjustice
Pam Lyons Gromen, NCMC
Michael Luisi, MD DNR
Alison Fairbrother, Public Trust Project
Jerry Bensen, Menhaden Coalition
Helen Takade-Himacher, EDF
Bob Vanasse, Saving Seafood
Taz Jons, Saving Seafood
Tom McCloy, NJ DFW
Joe Grist, VA MRC
Michelle Duval, NC DMF
Howard Townsend, NOAA
Alexei Sharov, MD DNR
Derek Orner, NMFS
John Clark, DE DFW
Jay Lugar, Marine Stewardship Council
Wilson Laney, USFWS
Clint Waters, MSSA
Robert Geisler, MSSA
Raymond Kane, CHOIR
Rob O'Reilly, VA MRC
Jeff Kaelin, Lund's Fisheries
Benson Chiles, Chiles Consulting, NJ
Steve Ruckman, Ofc. of MD Atty. General
Thomas Miller, FORVA
Theresa Labriola, Pew Env. Grp.
Ben Landry, Omega Protein
Ron Lukens, Omega Protein
Shaun Gehen, KellyDrye Warren, DC

The Atlantic Menhaden Management Board of the Atlantic States Marine Fisheries Commission convened in the Presidential Ballroom of the Crowne Plaza Hotel, Alexandria, Virginia, May 2, 2012, and was called to order at 8:00 o'clock a.m. by Chairman Louis Daniel.

CALL TO ORDER

CHAIRMAN LOUIS DANIEL: Welcome to the Atlantic Menhaden Management Board. This is a four-hour meeting scheduled. We will take breaks. You do have an agenda. There are a lot of meeting materials as well. On the agenda you've the approval of the agenda and the proceedings from our February 8th meeting, which was a marathon as well. Jack.

APPROVAL OF AGENDA AND PROCEEDINGS

MR. JACK TRAVELSTEAD: I assume you're going to ask for approval of the agenda, and I just wanted to add one more item. I think over the last month or so there has been a lot of dialogue about the technical committee possibly looking at more recent science and doing some selectivity analysis or sensitivity analyses on various curves, whether they're dome-shaped or not. I don't understand all the language but I would ask that be added to the agenda in the event the board wants to provide some advice to the technical committee on what they should do in the months ahead.

CHAIRMAN DANIEL: I think that's very appropriate and timely, so I will add that under other business. Anything else on either the agenda or the proceedings from our February 8th meeting? Seeing nothing, I will accept those by consensus as approved.

PUBLIC COMMENT

CHAIRMAN DANIEL:The next item on our agenda is public comment. When I call your name, please come to the microphone, identify yourself and anybody that you're representing. James Price.

MR. JAMES PRICE: I was going to comment on ecological reference points. I don't know whether I should do it now or after the presentation.

CHAIRMAN DANIEL: I'll take it either way. You can wait or you can do it now.

MR. PRICE: All right, I can do it now. My name is James Price, President of the Chesapeake Bay Ecological Foundation. The Foundation supports ASMFC's process to stop menhaden overfishing. However, the commission appears to have decided to delay addressing the problem of ecological depletion of menhaden until 2015 when ecological reference points are supposed to be incorporated into the benchmark assessment and peer review.

Currently fish populations that depend on menhaden for critical forage are suffering from disease and malnutrition in the Chesapeake Bay and along the Atlantic Coast. Predator populations as well as other forage species have dramatically declined because the menhaden can no longer fulfill its ecological role as an important species. Although CBEF has no objection to the commission's attempt to develop ecological reference points for future use in ecosystem-based fisheries management, decisions that involve multispecies management can be applied to address the current problem of ecological depletion of Atlantic menhaden.

There is no logical reason why the ASMFC should wait until 2015 to take action that directly addresses the collapse of the Mid-Atlantic forage base. I also note the ongoing study that we're conducting on striped bass and menhaden indicates that mature female striped bass numbers have dramatically declined; and without increased protection for menhaden the strong 2011 striped bass year class may not have sufficient numbers of menhaden for their ecological needs in 2013.

This is when they will require large numbers of age zero menhaden in their diet. Unless the ASMFC addresses the problem of ecological depletion of menhaden before 2015, the strong 2011 striped bass year class could suffer from disease and malnutrition. This could result in a large economic loss to the fishermen that depend on the healthy striped bass population for the future. Thank you.

CHAIRMAN DANIEL: Thank you, Mr. Price. Robert Geisler.

MR. ROBERT GEISLER: My name is Robert Geisler. I am with the Maryland Saltwater Sportfishing Association. In my career as an industrial engineer there was always controversy about how to establish work effort. There are several authors with books with magical formulas. A time study, which is an actual observation, would quell any controversy.

It takes observation or not formulas to arrive at the right answer. Now the menhaden population is down an additional 88 percent in the last 20 years. Action is overdue. The bait industry is not the place to cut. It provides jobs for thousands of watermen, buyers and shippers, thousands of charterboats, thousands of marinas, boat builders, boat trailers, insurance companies, vehicles for towing, tens of thousands of bait and tackle shops, tens of thousands of restaurants, millions of meals, billions of dollars in state, local, federal fees, taxes and permits.

Will the 37 percent reduction stop the decline? Will it reverse it? The population is so low it might take years to reverse. The prudent action to take is a total moratorium to have the best chance for success. Otherwise, it might take another 20 years of wrangling with formulas, and a moratorium would be the easiest way to enforce the cuts. At a minimum the zeros and ones need to be protected for forage and at least increase the numbers. Thank you.

CHAIRMAN DANIEL: Thank you, sir. One last call for hands; anyone else that wishes to address the board on items not otherwise on the agenda? Seeing no more, we'll move forward. I did want to acknowledge one letter that I received from Omega regarding an April 20th memorandum to Mike Waine regarding their position. That did go out in a supplementary mail-out.

So, just to address the letter that was addressed to me; it was handwritten and I don't think it went to anyone else, but just to make sure that Omega is aware that information was included in some supplementary information and the board has seen your letter. All right, we'll move on to Item 4 on our agenda, which are options to define ecological reference points. Jeff Brust is going to take us through that discussion.

OPTIONS TO DEFINE ECOLOGICAL REFERENCE POINTS

MR. JEFF BRUST: I'll be giving a presentation on how to address the ecological reference point task that the TC has in front of them. This is actually sort of a followup to a presentation that the Multispecies TC gave to the Menhaden Board back in the February meeting. That presentation was on the multiple objective decision analysis process or the MODA process, which was presented as a way for moving forward with addressing this ecological reference point task.

At the time the board was a little hesitant. They wanted some additional information about the MODA process. You asked for a specific problem statement. You requested a budget breakdown and a list of potential funding sources. I will be presenting that information today. In addition, since we only gave you one option for moving forward with this ecological reference point task, we realized that was probably a little shortsighted, so we've come up with a few additional options for moving forward.

If we go back a few years to the May 2010 board meeting, the board tasked the Menhaden Technical Committee with developing a suite of alternative reference points that might include biomass-based reference points and numbers-based reference points, both of which are single species in nature. You also requested that we develop some reference point options that account for predation of menhaden.

This is obviously a multispecies request so we were tasked to work jointly with the Multispecies Technical Committee. Over the next eight or ten months the two technical committees worked together to develop a short list of potential reference point approaches. These were presented to the board at the March 2011 board meeting in a presentation as well as in a guidance document that was included with the briefing materials.

Each of the options that were presented required a specific management goal that we needed information from the board on. The technical committee is not the right body to make management decisions and decide the priorities for management. We brought these to the board and asked for information on which direction you wanted to take.

At the March 2011 meeting the board tasked the Menhaden and Multispecies Technical Committees to move forward with the work on the, quote, multispecies approach as a priority. The management goal for this multispecies approach that was selected was to increase the forage base for predators of menhaden.

Also during that March 2011 meeting the board was informed that if we followed this multispecies approach we're going to require some information from the board, that the board is going to make some tough decisions on the specifics of what they want the predator/prey system to look like.

We needed this information in order for the technical committee to complete their assignment. Some of the things that we were going to need; we need the board to provide some information on appropriate predator-prey ratios in the system; so, do you want ten pounds of menhaden per pound of predators or twenty pounds of menhaden per pound of predators.

Also, we need you to quantify the relative magnitude of the populations. You can do a ten-to-one ratio at ten menhaden and one striped bass or you can do it 10 million menhaden and one striped bass. Not only do we need the ratio but also the relative population sizes. Finally, we need some information on which predators you think are important within the system. Right now the multispecies model has striped bass, weakfish and bluefish, but are there others that you would also like to include; perhaps spiny dogfish or bluefin tuna. The field is wide open.

During that March 2011 meeting the board was not able to address these issues, and since that time the board has been focused on developing the interim reference points which are based on maximum spawning potential. The board has never had time to go back and revisit these questions that we've put in front of you, so the TC doesn't have the information we need to move forward.

The question in front of us is still too broad for the technical committee to answer, and it is going to require some tough decisions by the board. We're talking about value judgments on the different resources, some resource tradeoffs. What are your priorities for the systems, for the predators, for the prey, for the fisheries? It is going to take some collaboration among the different ASMFC management boards for the predator and prey species.

The problem statement that you requested is basically this; you've given us a task but not the information we need to complete it. We presented the MODA back at the February meeting as an option. As I said, there was some hesitancy, and rightly so. From now on I'll be talking about some of the other options that we have in front of us as well as the budget and timeline that you requested.

One of the first options that we came up with was simply for the board to take the task away from the technical committee. You've been working on the interim reference points, the MSP-based reference points. These were supposed to be interim while we developed the ecological reference points; but if the board is comfortable with these MSP-based reference points, then thee is no reason that they have to be, quote, interim reference points.

You could adopt these as your reference points. Also, during the February meeting there was some indication that the board might not fully support multispecies management. If that is the case, is there any need for us to be developing ecosystem reference points. Obviously, this is not the TC's preferred option for moving forward, but it is an option for the board to consider.

The second option would be moving forward with sort of a trial-and-error sort of process. If the technical committee doesn't get specific input from the board on management objectives, the TC would have to develop their own interpretation of what the system could look like, which might sound something like quantifying the amount of menhaden biomass that's necessary to sustain the forage needs of striped bass, bluefish and weakfish at their threshold biomass levels.

Once we have this in mind, we can develop a biomass of menhaden that is necessary to sustain those predator populations at those levels, and we can develop a fishing mortality reference point that maintains the menhaden biomass at that level. More likely than not the first interpretation that we come up with isn't going to be what the board is looking for; so we'll present to you guys, you'll give us some feedback and probably some further direction.

Then the TC will go back and we'll try again. Without careful consideration and some explicit statements of management objectives, this could go back and forth multiple times until we finally come up with something that is acceptable by the board. Obviously, this isn't very effective or efficient; not for the technical committee and not for the board and not for the funding. It's not a technical committee preference.

Even if we are able to develop an acceptable solution, the technical committee is concerned that this is really sort of an ad hoc quick-and-dirty approach to developing ecosystem reference points. There is no real science involved. It is sort of trial and error and it is not going to be very robust when we take it to peer review, so it's likely not going to pass peer review. Again, this isn't a preferred method by the technical committee.

A more appropriate method would be one that identifies management objectives before we try to develop the ecosystem reference points. We have a couple of those in mind. The first of those is the multiple objective decision analysis, or MODA, which we presented to you back in February. The second one is really just sort of a subset of the MODA process.

In both of the processes we would have to develop a working group of the major stakeholders, which might include some management board members, representatives from the bait and reduction fisheries, representatives from the recreational fisheries, and probably environmental groups and any one else that you think would be important to have on board.

For both of the processes the working group would go through a couple of facilitated workshops to help define explicitly and specifically what the management objectives are for menhaden and the predator/prey system. Once we have those specific management objectives, those would go to the technical committee and we would be able to develop some ecosystem-based reference points.

Now, if we move forward with just the facilitated workshops only, we would stop at that level. We'd have specific management objectives. The TC would develop ecosystem reference points. They would come back to the board and you'd select one and we'd move forward. If we keep going with the MODA process, however, the stakeholder working group – there would be some extra steps.

First of all, the stakeholder working group would have to define some performance criteria for these reference points; how would you define a successful management strategy or how much risk would you be willing to accept in achieving those management objectives? Once we have those performance criteria, those would go to the technical committee and also a modeling subgroup where we would take the reference points that are developed.

We would model the system explicitly to see how well each of the different reference point options is able to achieve the management objectives. We might give you a reference point that has a 50 percent chance of achieving your desired goal or we might give you one that has an 80 percent of achieving your desired goal.

That way we would know what is the probability, what is the level of risk you're willing to accept in achieving these management objectives. The suite of reference points and their uncertainty values would go back to the stakeholder working group. They would review them, select hopefully a consensus set for the board's consideration, and then the board would be able to act.

A hypothetical example would be maybe the working group reaches some objectives such as maintaining a self-sustaining menhaden stock, maintaining enough forage of menhaden to support striped bass at the target biomass, and maintain both the bait and reduction fishery at some agreed-upon level per year.

This would go to the technical committee and we'd develop some reference point options such as predator/prey ratios, which might address Objective 2, and depletion from carrying capacity reference points that would address Objective. These would then be passed to the modeling subgroup who would develop the uncertainty values around different harvest levels or predator/prey ratios, which would then go back to the working group.

The results of the MODA process would be a set of very rigorously evaluated ecosystem reference points, which would go to the Menhaden Board, as well as a set of modeling tools that we would be able to use in the future for evaluating perhaps harvest policy or error-checking the single-species models, things like that.

The alternative, if we go with just the facilitated workshops, again we'd probably have one or two workshops with this stakeholder working group. The result would be a set of specific management goals for the menhaden and the predators; and then having these would allow the technical committee to develop the reference points without the trial and error but also without the rigorous testing and the uncertainty around those reference points.

Without this testing, it's less likely that any reference point that is selected would pass peer review. The technical committee's recommendation on how to move forward is obviously the MODA process. I don't think that's a surprise to anyone. It might seem like an academic exercise at first, but it's really the most comprehensive and most rigorous of the options in front of us. It prevents us from flying blindly into this ecosystem management that we're teetering on.

It has explicit stakeholder involvement throughout the process and not just during public comment. The stakeholders and the management board would be the ones who were defining the management objectives; how do we want to move forward with this suite of species? We would get specific and well-define management objectives as well as the acceptable levels of risk around those, and these would be used to help guide the management process.

Again, these are developed not just by the managers but as well by the stakeholders, and they are not developed by the scientists, which is sort of what the trial-and-error process is leaning towards. The reference points that come out of it are rigorously tested and we're able to evaluate their ability to achieve the management objectives.

We'd also be able to evaluate some uncertainty in the system; maybe some unintended consequences of what happens if we drive the striped bass stock even higher than it is or weakfish come back and striped bass go down. Again, it is most defensible at the peer review process.

The MODA process, the term within ASMFC might be new but it is not a new concept. It has been around since – I saw a couple of references that portions of MODA were developed back in the 1970's, others in the late eighties and early nineties. Within the management arena, it has been used for a wide array of conflicting interest issues; not just in fisheries, but there are some applications for fisheries use.

Within ASMFC we've used a similar process to evaluate harvest policies such as the adaptive resource management process for horseshoe crabs and shorebirds as well as Florida is using a similar process to help develop grouper regulations. Those are the options. Looking at the budgets, the multispecies budget is about $20,000 per year.

If we went with the MODA option, in addition to the $20,000 we would be looking at about $150,000 per year and it would probably take about two years to go through the MODA process in full. If we go with just the workshops, it is about $50,000 on top of the current $20,000, and it would take about a year and a half.

To put things in perspective, the ARM process for horseshoe crabs, we have been about $100,000 per year in addition to in-kind money from the Fish and Wildlife and USGS, so neither of these options is really out of the ballpark in terms of cost. If you look at the cost of the fisheries that are involved, this is really a minor amount of money.

The budget breakdown for both of these; the facilitated workshops as well as the MODA process we would need a facilitator, which would cost about $20,000 per year. We would need additional travel funds to the tune of about $30,000 per year. The biggest difference is if we go with the MODA process we're going to need to hire an additional modeler. The $100,000 would cover salary and incidentals and things like that. There is the budget breakdown.

Some pros and cons of the different options; both the MODA and the facilitated workshops, we would get an explicit set of management goals and objectives. We'd have integrated manager and stakeholder involvement. With the MODA process, there would be model development. We'd have these multispecies models that we could use in the future for harvest policy analysis and error checking and things like that.

The reference points that come out of it would be rigorously tested and we'd have uncertainty values around them. Hopefully, we would have some consensus recommendation to the board from the stakeholder working group on how to move forward. Obviously, the MODA costs a lot more and takes a lot more time, but the fallback for using just the workshops is that the reference points are untested, and their ability to pass peer review would be diminished.

Funding sources; it depends on which direction we go. We listed a couple of generic ones up here. NOAA might be a possible funding source; private foundations and trusts; or a mix of stakeholder groups. A couple of similar processes that have happened recently, there is something called Fish Smart for King Mackerel in the South Atlantic that was funded by the Moore Foundation, which is a private foundation; and the Florida Grouper Project that I mentioned earlier was funded through Florida Sea Grant.

We have a list of potentials but there is no need for us starting to address any of them until we have a direction from the board. The timeline; I hate to do this to you but we need an answer quickly. We have a benchmark stock assessment due in 2015, and the most efficient way to move forward would be to take the menhaden model, the multispecies model and the ecosystem reference points that are developed, using those pieces through peer review all at the same time.

The process is going to take a year and a half or two years at the minimum for the actual work, let alone developing these stakeholder working groups, so we sort of need an answer either at this board meeting or at the next board meeting if we're going to meet that 2015 benchmark deadline.

Again, up here I've just listed some of the options. Option 1 is to rescind the task, take it away so we don't have to do it. Option 2, approve the workshop-only concept; Option 3 is to approve the MODA concept. If we don't hear from you either at this meeting or at the next meeting, we're going to have to assume – and you want us to continue working on it, we're going to have to pick up with trial-and-error process. If you tell us, we're going to have to do something. That's the fallback; we've got to do something. That's it, Mr. Chairman.

CHAIRMAN DANIEL: Thank you, Jeff; you make us sound fickle. I think you've done an excellent job laying out the issue, so we do need to make a decision and we do need to have some discussion here. Pat.

MR. PATRICK AUGUSTINE: Mr. Chairman, let's get to the crux of the issue. The issue is money. It's not complicated; we're not going to get anymore. Unless the grants come up, I think we've got to reach out to our folks that seem to be wanting to have us do more. If there are some groups out there in the audience that believe they can come up with some money to fund this program, I think we should either speak up and step up to the plate or we're going to have to take some other approach.

From what you've described, there is no question that the MODA approach is the right way to go; more expensive, more extensive, more complete, and the package at the end of the day will be with us. It will establish a base that we have to establish. Again, unless we can get funding to start with, I don't think it matters what this board decides to do in terms of approving that we go in that direction. Once we approve it we're going to be stuck with it.

If we find in our budget process and the way we're set up for projects for this year and next year, the way funding is going to get tighter and tighter, then we're going to go down a very long path and we're going to scrimp here and scrimp there and come up with a half-baked program at the end of it. I think at the onset let's get a commitment as to where the money is going to come from before we make that decision.

The final comment is, Jeff, you indicated we'd have to go back and forth to the board and TC, back and forth to board. Everything you have presented indicates that we really don't have any options. It's either make the hard decision now and go forward or flip-flop back and forth for the next three or four years and end up I think basically where we are now with the uncertainty with some of the data you're going to be able to put forth. I don't know if you can respond to that; but as I say my concern is that we've got to identify funding sources before we, as a board, I think collectively agree to go down the MODA route.

CHAIRMAN DANIEL: I think that's certainly one significant issue. Pete.

MR. PETER HIMCHAK: Mr. Chairman, I think the technical committee really wants a definite charge out of the board. They were asking for many years are we managing menhaden for the menhaden stock and the menhaden fishery? We've been doing that as single-species management for many years; improved with the MS-VPA. Then with the most recent addendum where we have more restrictive reference points, I think the message is that we're not only managing menhaden for menhaden but we're managing it for a multitude of predators.

Now, is this really ecological reference points or ecosystem-based fisheries management? I don't think it is. I think we have to change our terminology a little bit to say that we're asking the technical committee to manage menhaden for a multitude of species as predators on menhaden. That's a little different than saying menhaden as an ecological component in the ecosystem.

I think what the TC is saying is that, well, you put in more restrictive points, we're trying to build up the SSB, how big do you want the stock to be to maintain X SSB on striped bass, weakfish, bluefish, tuna, et cetera, et cetera. Is that really as far as the TC can take this, and I guess I'll direct to Jeff.

MR. BRUST: Was there a question there, Pete?

MR. HIMCHAK: I guess am I on the right track; is that what you're looking for?

MR. BRUST: Yes, we need to know what predators are you interested in, what level of predators do you want? Those are the two; and if not level of predators, what level of menhaden. We need one or the other; and included in that we should include human use as a predator of menhaden. If you want to include some level of harvest, we need to know what level of harvest you want as well.

CHAIRMAN DANIEL: Followup to that, Pete?

MR. HIMCHAK: Yes. I guess to get to my point is that by constantly referring to it as ecological reference points or ecosystem-based fisheries management, I think we're aspiring to something a little bit more than what we can actually produce. Is that a fair assessment?

MR. BRUST: Sorry, Pete, it's early, try that one again. I am not just doing this because you're down the hall from me.

MR. HIMCHAK: Somebody asked me to define ecosystem-based fisheries management or what an ecological reference point was, and I said that it really is a dream that we're all aspiring to, but basically what we're working on with menhaden is we're not going to get the ecological reference point.

We're going to get a reference point that provides menhaden for the menhaden stock, fishery and a multitude of predators. There is no consideration of menhaden going in the opposite direction in the ecosystem where menhaden is a predator on anything below it or any other value in the ecosystem that we don't even know about. I guess that's the point, so I'm trying to narrow what we're trying to achieve here.

MR. BRUST: All right, is there a definition for ecosystem reference points; no, not really. You could say that what we're looking for is ecosystem based because it includes more than one species. Maybe multispecies are more appropriate. We can't include the entire ecosystem, no. A term that has been kicked around minimum realistic model; so rather than just one, you take in the major players. Maybe that's what we're dealing with.

In terms of moving the other way is menhaden as predators on other things, perhaps one of the stakeholders involved is concerned with water quality, so we would need some certain level of menhaden to maintain water quality at whatever given that there is uncertainty on the role that menhaden play in maintaining water quality, but that might be one of the objectives that is included in the plan. Is this ecosystem reference points, I don't know, I depends on what the definition is. So far I don't think there is one. It is more than single-species management, I guess, is the bottom line.

CHAIRMAN DANIEL: That sounds like an interesting haul. David Pierce.

DR. DAVID PIERCE: All right, Jeff has done a very good job representing the views and recommendations of the menhaden and multispecies technical committees that were tasked by us to do a very important job as described by Jeff, and that's to develop these ecological reference points that account for predation, increasing the forage base for predators of menhaden.

Okay, they've taken this as far as they can take it and now they're looking to us for some guidance, and, frankly, they've done a very good job. They provided us with a few options for us to consider. The option that they are recommending is Option 1 in their report to us regarding the multiple objective decision analysis, the so-called MODA.

Then on Page 3 of their report to us they give us a good list of reasons why we should go in that direction, why we should ask them why we should adopt this approach, and then have them move forward, recognizing the funding considerations. I like what they've offered up for good reasons for us to go with MODA.

I don't pretend to understand all the ins and the outs. Nevertheless, as they say here, it is a good way to have collaborative building of models that account for ecological uncertainty. It indicates that through this means they would not be forced to speculate on board and stakeholder goals for ecosystem. It's a good list; I like it.

I would make a motion, Mr. Chairman, if I may. **I would move that the board use MODA for ecological reference point development as recommended by the Atlantic Menhaden and**

Multispecies Technical Committee; using the approach detailed in Option 1 in the committee's May 2012 report.

CHAIRMAN DANIEL: Everybody understands I think the motion, and I have a second from Bill McElroy. I've got hands up around the room and I'm going to take it in order. I'm going to let this go for a little while and if we keep saying the same things over and over again, I'm going to slow it down, because I've already got a page full, and we've got a lot to do. Ritchie.

MR. G. RITCHIE WHITE: Mr. Chairman, I support the motion. This species is clearly important enough both to the environment and to so many user groups as we continually hear from and to the economy that to go forward with something that is probably not going to pass peer review makes no sense. The chances of when we come out of this that there may be one or more unhappy user groups with the eventual outcome, I think it's critical that we go forward with good, defendable science. I support the motion.

MR. WILLIAM GOLDSBOROUGH: Mr. Chairman, a little clarification on the process on both MODA and how we would use it. I assume that our process would be some version of whatever outcome we got from MODA would then be incorporated into an addendum or an amendment and go through the normal process that included public comment; and yet my understanding of MODA is that it is to reach a consensus among stakeholders.

I wonder what happens to that consensus if in the ensuing public comment we hear a very different story. How do we handle that? I was a little confused because I thought I heard Jeff make reference public comment as part of the MODA process or maybe I missed something there.

MR. BRUST: I think what I said was that the stakeholder groups are involved with the process and not just relegated to public comment. We would have the recreational and commercial fishing industries, environmental groups, managers all together on this working group rather than the way it's usually done is the managers are the ones making the decisions and the stakeholders get one microphone at the back of the room and 20 minutes at the beginning of the meeting. The stakeholders are fully involved, fully vested in the MODA process.

MR. GOLDSBOROUGH: So that would be those stakeholders that are actually part of the process or is it an open process? I'm not sure I get that, because my question still remains in the ensuing public comment periods that we would have – the public comment process we would have; what if there is disagreement in the outcome?

CHAIRMAN DANIEL: Can I make maybe a suggestion because I think the question is to the board do we move forward; and if the answer is yes, then I think we may need to have additional discussion on how it might work.

MR. AUGUSTINE: Point of information, Mr. Chairman. I guess I would like to interject here and ask the hard question. Now, we didn't see any hands raised in the audience of where the funding is going to come from. I support what we're trying to do here and it is very, very important; but I still ask the same question, where is the money going to come from?

Once we have approved this, it's going to have to come from our existing budget, so I guess I would put on the table we stop doing anymore board work on striped bass, American eel, shad, river herring and three or four others, maybe blackfish, and take all that funding – I'm being facetious now – take that funding, eliminate all those meetings for the next couple of years to fund this program for $120,000.

Now maybe some of you will wake up and realize we're about to go on an adventure and we have to go on without any funding. I guess I would like to ask Bob ask can we do this before we take a vote on whether we move forward with this immediately or not.

CHAIRMAN DANIEL: Well, I'm hoping we're going to get down to the point that I hope is made, and that is I spent time yesterday with staff, probably drove them crazy, but trying to understand the current status of the stock; the current biological reference points that we're using, the interim as Jeff described them. I don't have a real strong comfort level on those yet; and so trying to explain to the public – and I think I can do it now, thanks to Genny – but how we can be overfishing and need such a significant reduction in harvest but not be overfished.

That's tough to understand and it's very tough to explain to the public, I think. It would be my thinking that before we move into some extraordinary new analysis, and full respect for the technical committee, shouldn't we understand the basic stock assessment, the basic status of the menhaden stock before we start trying to move into higher order analyses and start including a lot of species.

The questions that the technical committee is asking are fair questions, but who in the world is going to be able to figure out if we're going to include dogfish and striped bass, bluefin tuna, king mackerel, all the various species pounds per predator, pounds of menhaden per pound of predator? I certainly wouldn't know where to start there. So, just to provide an alternate opinion and then also agreeing with Pat; where is the $300,000 going to come from over the next two years?

MR. AUGUSTINE: But back to that point, Mr. Chairman, all the points you've made are very important. The fact of the matter is we're at a point now in this meeting where we're going to make a decision whether we're going to take another approach. Once we've committed to it, unless we rescind that at a later time, we're going to go back and we're going to take a look at what we have to do with the other species and the status of those.

I think, honest to God, we're well beyond those points. Decisions have been made. Whether we like the status of the stock as it has been presented to us, overfishing or not overfishing, the fact of the matter is we're dealing with those facts. The basic point is I really would like to have some kind of evaluation or a point of where some of these funds are going to come from even for the first year. I would love to support this motion, but, quite frankly, I'm going to say no unless you can convince me and us that we have funding to do it and we're not going to scrimp and scrape on this extremely important program.

MR. DOUGLAS GROUT: Mr. Chairman, at a previous board meeting when we voted to go down this road with an interim-based reference point in between, I have to admit that my thought that this ecosystem-based reference point was going to be akin to a biologically based reference point; that the technical committee and the multispecies technical committee were going to come back to us, maybe with some guidance from us, and say from an ecosystem standpoint to maintain enough food for a variety of predators this is what the level is going to be.

What I see this as is this is more of a policy-based reference point and something that we've already gone through with the interim base. We're looking for something that we could put in place to give a little bit more menhaden – assure that there was more menhaden for the predators, but we didn't know exactly how much it was, so we asked the TC for a little help.

They gave us a variety of ranges. We on a policy basis had a selection of a target. We went out to the public with this; and contrary to the way Jeff put it, they a lot more input than just 20 minutes at a mike here. There were 12 public hearings. There were thousands and thousands of e-mails and comments that came in. We had our advisory panel give us advice on which direction to go here.

These were all things that we took into consideration when setting those interim-based reference points. I thought, when I saw this, that the technical committee had some questions here. Identify predator species of interest; I was going to ask the technical committee what are the major predators? We have identified four of them here; are there others?

There is feeding data that will provide us with that. At that point personally I would have said those are the predators that need to go into the model and we need to provide enough menhaden for us to at least be able to manage those species to the threshold and possibly to the target, somewhere in that range, and come back with the multispecies technical model and tell us what is the appropriate level.

To me, if we go into this MODA, it has some benefits here, but who are the stakeholders that we're going to include in here and who are we going to exclude? In our normal policy-based decision-making we include everybody. We give them an opportunity to provide comment through the management process.

If we go with this, clearly unless we're going to allow 40,000 people in on this, which is totally unwieldy, you're going to be excluding some people from this process that thinks it's very important. I think some of the details of this MODA process we need to figure out before we vote this. Who are we going to include in this and where are we going to get the money for it?

To me this is more of going into policy-based reference point rather than ecosystem-based reference points, at least the way I envisioned ecosystem as more on a biologically based reference point, which they tell us, so I'm having difficulty supporting this process until we flesh out who we're going to include and who we aren't.

CHAIRMAN DANIEL: But we do need to get off the dime here. We need to give the technical committee some guidance here, and it's either this – what I'm seeing is it's either accept the motion that is on the floor or take the interim off the reference points title and focus our efforts and energies on coming up with meaningful and understandable biological reference points through the standard processes that we have and deal with and are familiar with. That's where I think we're heading. Jack Travelstead.

MR. TRAVELSTEAD: Mr. Chairman, I don't object to the motion but I think Pat Augustine and others have asked the right question, and that is how are we going to pay for this. I would ask that you allow the staff to comment on what the likelihood is of their finding funding to do this, whether it's in-house or from some other source.

If there is no money, we're spending a lot of time debating something that's not going to happen. That also raises another issue in my mind. If $300,000 is that easy to find, then I'm reminded of some of the other priorities that the technical committee has listed for additional research that is needed.

For years they have been telling us, for instance, that we need an index of adult menhaden abundance, a fishery-independent index; and if we had that, that would solve a lot of the mystery around all of these stock assessments. You know, if $300,000 is that easy to find, why aren't we spending it on high priorities like that kind of information? I'd love to hear from staff on this.

CHAIRMAN DANIEL: Thank you, Jack, good comments. Bob, do you want to address the funding issue that Pat and Jack have raised.

MR. ROBERT E. BEAL: I'll give it a shot. I don't think this will be terribly insightful, but $300,000 is not easy to come by. A motion like this which would commit a portion of that spread out over a couple of years really would play into the commission's priorities for planning for 2013. This would be one of the things that the staff would draft into the action plan and display the tradeoffs between engaging in the MODA process and some of the other priorities that the commission has.

It will be up to the commission and policy board to decide what the priorities are for 2013. I think all the budget discussions that we've heard coming out of Capital Hill and the National Marine Fisheries Service and the like is not good news for 2013. It sounds like the commission's budget under the Atlantic Coastal Act may be down up to a million dollars, so we may have to figure out where to cut areas rather than where to add projects. We may be taking some cuts and considering priorities such as this. How do the commissioners want to balance those tradeoffs, those are going to be the tough decisions that go into planning for 2013.

CHAIRMAN DANIEL: Thank you, Bob. I think that answers the question. We're at nine o'clock, our allotted time for this discussion. I've got at least seven people that set up to speak. Do you want me to go through the list? Okay, Tom Fote.

MR. THOMAS FOTE: I wanted to ask the question before we made a motion to Jeff. One of the things I'm looking at is when they did king mackerel, they looked at an unbiased or take the passion out of it and scientists come up and sit together and basically look at it from a scientific point of view.

I'm wondering if we go to a peer review process, it should be based on science and not feelings of what goes so. If I was looking at how you put this together, it wouldn't be this type of stakeholders. It would be where we basically get to the nitty-gritty facts of what is going on. The other thing is, as everybody else said, the funding here, how do we fund this?

Basically, if it was decided that we wanted to do something like this and maybe go through the scientific process and we needed the money, we could basically put that as part of the motion that unless the money comes forward from someplace – you know, there are a lot of decisions we've made over the last couple of years, blackfish and a few others from the states that we can't fund the thing, so we're losing fish.

It's a crime that we're making commercial and recreational fishermen suffer the penalties. I got here in the early eighties when we had all the funding coming in for striped bass and we were able to do a lot of research and things like that, and that money is no longer available. That is my concern; that is the question I wanted to ask Jeff. When we basically look for a peer review process, shouldn't we be looking at a scientific-based peer review and not putting the passion of how people feel at a public type of meeting?

MR. BRUST: I guess, first of all, while I have the mike, I wanted to apologize. Commissioner Grout called me out, he caught me red-handed. I oversimplified the public and the advisory process. It was a poor choice of words to make a point, and it wasn't meant to minimize the process. I apologize for anyone I rubbed the wrong way. To Commissioner Fote's point, the reference points will be scientifically based.

But the question you're asking us to do is increase the number of menhaden for forage for the predators. We need someone to tell us what level of predators you want. We can't do that. We can tell you – once you give us a predator biomass or a predator number, we can tell you exactly what Doug was looking for, the number of menhaden you need to keep the predators at that biomass, and that is scientifically based. But we aren't the ones who can make the policy decision on how many striped bass do you want, so that's what we're looking for.

CHAIRMAN DANIEL: And I think that's a fair answer and a fair characterization of how the public would be involved in this process if we went in that direction. Thank you for that clarification, and Doug will get over it. (Laughter) Jaime.

DR. JAIME GEIGER: Mr. Chairman, I think we need to separate the question. First of all, what is the most appropriate action that this board needs to take to look at the best science, the best management options, the best biological outcomes; what do we need to do based upon the recommendations of the technical committee and the requirements of the species?

The technical committee has laid out a very good approach, and I believe Option 1 is the most reasonable one we should achieve. I think the first question we need to ask, is this the right thing for the board to do? In my opinion, yes. The second question, I hear questions about the funding. Well, if memory serves me correctly, when we started to recover striped bass in the 1980's, the money wasn't there, but that didn't stop the previous members and some members of this board from making the hard decisions to go forward.

We didn't have the money for the ARM model, but that didn't stop the members of this board and other board members to go forward and make it happen. That is called leadership; that's called using the right science and using the right management to do the right thing. I would respectfully suggest to this board that I think there is an excellent motion on the board.

I know there are lots of questions. I know there will continue to be a lot of questions, but I think it's the role of this board to do the right thing and move forward. Now, in terms of the funding, I think there are a lot of opportunities to look at the available funding. I think like we did in many other species, you don't bite the elephant in one bite.

I think this is going to be a multi-year process. We're cobbling together various types of various federal, private and state funding to make it work and make it work effectively. We did it for the ARM model; we did it for striped bass. We were fortunate to have some congressional appropriations for striped bass that moved us forward. Who is to say what 2013 and 2014 and 2015 are going to look like? Again, it's about priorities, it's about doing the right thing for the species; it's about starting the process. I would urge this board to do the right think. Thank you.

MR. DAVID SIMPSON: I'm opposed to the motion. I think the idea or the concept, the Utopian view of how things should work, maybe that's good, but in practical terms – well, backing up bit. To Doug's point that are we going to change our entire approach to fisheries management to being one of not science-based but policy-based; are we really going to consider changing all of our reference points for all the other species we manage and ask the federal government to change all the reference points for all the species that they manage that come into the mix here, all through the Menhaden Board?

I think we've worked very hard on a number of species to identify objectives for fishery management plans and those have been vetted through a public process and we need to pursue those as they are. Both from that standpoint and from the standpoint of every meeting and every day we face that difficulty of not enough data to support a single-species assessment, and I picture this as a multiplicative thing.

It's the uncertainty of menhaden times the uncertainty of striped bass, which is harvested 90-some percent, approximately 90 percent recreational, which means you're dealing with estimates from a survey; add bluefish, that's 80-

some percent recreational; all of that variance; all the uncertainty, multiply that; and you're asking what species do you want us to allow to eat menhaden is almost how I hear it. You know, I wouldn't know how to do this in the backyard in a pond, never mind in the Atlantic Ocean. I think we're reaching a little beyond our means.

REPRESENTATIVE SARAH K. PEAKE: Mr. Chairman, I'd just like to comment on the funding side of it. I agree with some of the previous speakers where if we believe this is the right direction to go in – and clearly not everybody around the table believes that, but if we believe this is the right direction to move in, I think we should take the vote to support this.

In fact, if I heard the presentation correctly from Jeff, before we can seek outside funding sources, we would need a vote of the board in order to move forward. We need a commitment and the leadership exhibited by this board in order to be able to go to foundations, industry, government, all the sources we would look to to fund this. Worse case scenario, if we voted today and between now our next quarterly meeting we've come up dry or it seems like we are with funding sources, we can revisit it then, but I would hate us to use the excuse of the checkbook to not make the right management and policy decision today.

CHAIRMAN DANIEL: Nail on the head. I've got three more and then that's it. Jim Gilmore.

MR. JAMES GILMORE: Mr. Chairman, I had the same idea as maybe Sarah did but a slightly different version of it. I think Jeff asked before was that they would need essentially approval to go and look for alternate funding. We have a bit of a cart before the horse here. That's one option of doing it.

The other one I thought was maybe to postpone this and give them a separate charge to essentially look for the funding so we could decide if we actually have it or not. I think we could go either way, but I think we need to get the money issue resolved before we're going to be able to vote, and this will give us actually a little more time to think about – I guess the dissenters in the room about it. I'm in support if the MODA. I think in conflict a little bit with Dave, I know we're not there yet and probably not going to be there for a long time, but we've got to start at some point and this is maybe the right time to do it. I think we really need to start addressing the funding part. Thanks.

MR. STEPHEN R. TRAIN: I would like to like this motion. I can probably be talked into it, but I'm wondering if there is any teeth in what we're doing. We started talking about ecosystem-based management and now we've gone to a MODA based on the science, and it's still a one-way street. If we're going to put species in balance, I would think it has got to be a predator/prey relationship both ways, and right now we're just dealing with one of them.

What do we need to do to get to the bluefish population where we want it or the striper population where we want it? I wonder if we're going to manage the species that way. We might have to look the other way around; which one of these species is getting out of balance based on amount of prey available, and do we need to go that way once in a while, too? If we do it on a one-way street, it's not ecosystem-based management at all.

CHAIRMAN DANIEL: Good point. Roy, take us home.

MR. ROY MILLER: That is a big task, Mr. Chairman, but thank you, anyway. I would just like to remind the board that we've been down this road a time or two with other species. Just to follow up a little bit on what Jaime alluded to, when there was a need for funding to fund a horseshoe crab coastal assessment using trawl surveys, we made overtures to both industry and to ecological organizations.

Industry stepped up and contributed and helped us with the funding of that particular survey. For their own reasons, some of the environmental groups did not step up with funding to support that particular survey. I guess in order to vote on this proposal I would have – to vote positively I would have to have some faith that industry would be willing to step up and help with this, particularly if they become stakeholders in the process. Notwithstanding funding that might be available by reprogramming commission funding in the future, I think the slack will have to be picked up by industry. Thank you.

CHAIRMAN DANIEL: All right, I'm going to do my best to summarize where we are; and if I say anything contrary to the maker of the motion, I will give him an opportunity to correct me. I think we've had a good discussion on this issue. It is one that we need to make a decision on now and not continue to batter it about.

There are pros to the MODA analysis, for sure. Again, the money situation and the fact that we don't have the strongest handle on the status of the stock as it is now is difficult. Are you all having a – say again. You want an alternate motion right as I'm trying to clarify what all is going on? All right, go ahead.

MR. ADAM NOWALSKY: Mr. Chairman, I think we've come to the conclusion is that we all want this to happen around the table, but we have reservations for various reasons. In consultation with some of the people sitting next to me, **at this point I'm going to move to table the motion until the August meeting and charge the technical committee and staff to research alternative funding options for this project.**

CHAIRMAN DANIEL: Motion to table seconded by Steve Meyers. Do you need to caucus?

MR. NOWALSKY: In support of this motion, again the intent of this motion is I would really hate to leave here today seeing the original motion voted down. That's the concern is that there has been so much work put into this, we really don't want to see it lost entirely. Therefore, I think given the concerns that have been raised, it would give us a little bit more time.

Mr. Brust indicated that they need guidance to move forward by August to meet the benchmark stock assessment timeline. I think this is a prudent course of action to give us the time, do the research needed so that we can all make the best decision possible in support of the fisheries that we all manage.

MR. BRUST: Obviously, I'm in no position to tell the board how to vote on this, but I just wanted to clarify that the longer that we take to make this decision, the less likely it is that the technical committee is going to make the 2015 benchmark timeline. That's all I wanted to say.

MR. ROBERT H. BOYLES, JR.: Adam, I appreciate the spirit of the motion. I wonder if the technical committee is the right place to research funding alternatives. I think there are other groups, this body, this board, staff. I'm not sure that the technical committee is – I mean, go tell them to go find the money to do this. I just offer that for everybody's consideration.

CHAIRMAN DANIEL: I think the more appropriate language is postpone rather than table, if that's okay with the maker of the motion is to postpone. I think the technical committee and the staff; maybe that helps a little bit. To Jeff's point, we've spent a lot of time discussing this. We've spent an hour and fifteen minutes today going over it. It seems like there is a pretty – I think there is a fairly good consensus around the table; but if we want to wait until August, that is the board's decision. Lynn.

MS. LYNN FEGLEY: I'm sure that I'm going to be out of procedural order, but could we not amend the motion to specifically say that this process won't go forward if funding is not found, and that would allow us to vote now whether we want it or not with the explicit understanding that it won't happen if there is no funding rather than postpone.

MR. DENNIS ABBOTT: That was my point.

MR. HIMCHAK: Mr. Chairman, I don't see the need to postpone a decision. I think the board can make a statement today that it supports a certain pathway of action. To delay until August to start looking around for money, I just don't see the sense in it. You make the statement today and then you actually go out and try and dig up the money.

CHAIRMAN DANIEL: Let me make a suggestion. If we were to – after "committee's May 2011 report, as resources allow" or "as funding permits"; would you be willing to withdraw your motion to postpone if we had that language which addresses Lynn and Dennis' points? I'm not trying to drive the train too far. I'm just trying to come up with a solution.

MR. NOWALSKY: I appreciate the efforts, Mr. Chairman, and I think that this is the right discussion to be having here. I'm amenable to making modifications to amend the original motion to address the point. I'm amenable to going down that road. I'm not ready to withdraw. I will be willing to withdraw the motion assuming we can get to the right amendments to the original motion. I'm not sure we're there right now. I'm not sure what they are.

I think it's contingent upon some funding that we can tangibly point to and say, okay, we're at least going down a road; at least we've got some commitments here. When I look around and I look at all the other species that we talk about prioritizing, we talked about eels and saying, well, if we just had X number of pounds of glass eels, you know, we could get this project done. There are so many things that we all have to deal with. We all sit around this table to deal with so many different species, and this, to me, looks like, okay, we're going to make menhaden – you know, as Mr. Augustine said earlier, we might as well withdraw a lot of other boards for the next two years until we get this single task done. I think it's something we all have to think very hard about. Again, as Mr. Simpson indicated, we want to do this; can we do it?

CHAIRMAN DANIEL: Well, you all have thrown a monkey wrench into my whole plan. I've got a sense of where we are from the discussion, but I'm not certain I know which direction the board will go. If we decide to go and take the interim off of the reference points and continue to focus our efforts on a new benchmark stock assessment that could address the disparities or the disconnects apparently between the biomass reference points and the overfishing reference points, then that is one option. I can't tell if that's a majority opinion around the table. I've heard there are some folks that don't support moving forward with the MODA analysis, and I would be included in one of those.

MR. AUGUSTINE: Point of order, Mr. Chairman. Again, Mr. Chairman, your point is right, but the fact of the matter is we're dealing with two motions on the board. With the discussion around the recent comments that Mr. Nowalsky made was whether we postpone or not; and, quite frankly, I would like to clear the board of those and then take up your motion or your concern about which one we're going to do.

CHAIRMAN DANIEL: And that's fine.

MR. AUGUSTINE: Otherwise, we're going to go back and forth so I'd like to call the question, Mr. Chairman.

MR. STEVE MEYERS: Mr. Chairman, point of order. With respect to the discussion, I am going to recall my second with respect to the gentleman from New Jersey. My point is that we need to have a staff-to-staff discussion about budget and funding broadly with the commission's federal funds. FY 13 and 14 are going to be bears that we're going to have to live with.

I can't go into details because I have no details, but we have to start planning. $300,000 is a lot of money for this commission. We need to understand what that is going to be as an impact. Perhaps we could go ahead with the idea of this MODA, but at the same time we need to come up with a strategy long term as to how we're going to be approaching not just menhaden, bluefish, weakfish, striped bass, everything. With respect to the gentleman, I withdraw the second, but again we need to have that discussion sooner rather than later, please.

CHAIRMAN DANIEL: Yes, I agree. So is there a second to Adam's motion?

MR. AUGUSTINE: Another point of clarification, Mr. Chairman. Based on Mr. Meyers' comments, does that mean that he is suggesting or what is being suggested is that we reword the original motion to include something that Ms. Fegley mentioned as to pending funding or pending a staff-to-staff assessment of available funds? It just seems to me we have to close that loop so we encompass where the funds are going to come from to get this project going. If that isn't possible, I will end up offering a second to the motion.

MR. ABBOTT: Mr. Chairman, I'm really not sure where we are. We're having a discussion on a motion that is not seconded. Either we have a second or we don't have a second; do we have a second?

MR. TRAVELSTEAD: Point of order, Mr. Chairman. Once a motion has been made and seconded and debated by the board, a second can't be withdrawn. You're going to have to vote on it one way or the other.

CHAIRMAN DANIEL: Thank you, Jack. We're going to vote on this motion right now. Whether there are points of order or not, we're going to vote on this motion to postpone. Do you need to caucus? Okay, one minute.

(Whereupon, a caucus was held.)

CHAIRMAN DANIEL: All right, I'm going to read the motion; move to postpone the motion until the August meeting and charge the technical committee and staff to research alternative funding for the MODA project; motion by Mr. Nowalsky; second by Mr. Meyers. All those in favor of the motion raise your right hand, 3; all those opposed; null votes; abstentions, one. **The motion fails which takes us back to the main motion.** Yes, Ritchie.

MR. WHITE: **Motion to amend the main motion to add that appropriate funding be determined by the August meeting.**

CHAIRMAN DANIEL: Is there a second to that motion? Jim Gilmore seconds. Jim.

MR. GILMORE: Ritchie, I was going to do the same thing, but I was going to make it a little bit more formal because I think from what we heard from Jeff before was to charge to the TC to explore the alternate funding, so I don't know if you want to wordsmith that a little bit so it's clearer.

CHAIRMAN DANIEL: I guess, Ritchie, the question would be is it to secure the funding or to have it secured by August or have a report on where the various funds could come from; because I think with the timing that we're looking at, if we come back and we say, yes, we could piecemeal together funding from this source and this source and this source and this source, unless we have the money, that is going to delay us past the benchmark assessment issue; so just to clarify.

MR. WHITE: I think it would be a report back to the board so that the board can make a determination if they're comfortable that we would be able to achieve the money; so it's not to have the money in hand or committed, but a report back to the board from staff, not technical committee, and that hopefully the board members can assist staff in trying to come up with the money.

CHAIRMAN DANIEL: One more, and I swear I'm not trying to delay this, but, Jeff, if we come back in August and you guys have the funding sources identified but we don't have the money, when will you need to have the money and begin the work in order to meet the benchmark stock assessment deadline?

MR. BRUST: Can I say I don't know?

CHAIRMAN DANIEL: Yes.

MR. BRUST: I've never done this before; I don't know how long it's going to take. The process we're looking at is we need to develop the stakeholder working group. We need to have at least one and probably two facilitated workshops. We need to have the results of those sent to the technical committee to develop the reference points.

We need to evaluate and probably expand upon the existing multispecies models to test those reference points, get them back to the working group for any give and take before they can get back to the board. We're looking at two years, probably, at the minimum. There are probably some things that can be done before actually having the funding such as constituting the working group but not meeting with them; identifying perhaps a facilitator but again not having the workshops. It's going to be at least, in my mind, two years of work once we hit the ground, but there are some things that we can do before the funding shows up.

CHAIRMAN DANIEL: Thank you for that clarification. If this motion carries, then essentially the board is endorsing the MODA approach and to move forward; and at the August meeting we would need to come up with our list of species that we're going to support menhaden – you know, our list of dogfish, weakfish, monkfish, king mackerel, cobia, whatever the list is going to be to give the technical committee those specific tasks, so this is basically a heads-up that between now and the August meeting, if we support this motion, we're going to need to come back and give the technical committee very clear direction on how we want to see this thing work; is that fair? Okay, any further discussion? Dave.

MR. SIMPSON: Sorry, I'm not trying to belabor this, but could Jeff answer the question that I still have on my mind is are we going down a path of revisiting our management reference points for all of the predator species?

MR. BRUST: It could come to that, yes, if you give us a list of the predators that you want involved and you tell us what level that you want them at. It could be that you want them at their currently defined target reference points; that would be fine, so you don't have to change those reference points. But if it came back that you wanted striped bass at a different biomass than the current striped bass target biomass, then the Striped Bass Board would then have to go back and revisit and possibly go through an amendment to change that reference point.

CHAIRMAN DANIEL: Clear as 40 weight. All right, Jaime, last word.

DR. GEIGER: Mr. Chairman, again, in honesty I think the opportunity to identify other than reprogramming existing funding either by the commission or by the states by the feds is slim to none for this fiscal year. I think this is just an exercise and kicking the can down the road to give us some cover one way or another.

I hate to be so blunt and candid, but just kick the can down the road to avoid trying to do the right thing. If we vote on the main motion, we will be doing the right thing I think biologically and ecologically; and if we don't and cannot secure the funding or if priorities change, so be it, we will bring this up and reevaluate those priorities and revote. It's as simple as that.

The history of this commission is that we do this all the time. I am very sensitive to the fiscal concerns that have been raised, but I can't predict what is going to happen in 2013 or 2014. I don't think anybody around this table can. Again, people are looking for us to do the right thing biologically for these species. Again, I have no illusions; this is a paradigm shift for this commission. This is a true paradigm shift where we are setting a new direction whether we recognize it or not in the next 15, 20 or 30 years. It's as simple as that.

CHAIRMAN DANIEL: Thank you. All right, take a minute to caucus.

(Whereupon, a caucus was held.)

CHAIRMAN DANIEL: You're voting on the amendment. Question from Robert.

MR. BOYLES: This is a motion to amend?

CHAIRMAN DANIEL: Correct. All right, the motion to amend is on the floor. Motion to amend the main motion to add "subject to appropriate funding be determined by the August meeting." Motion by Mr. White; second by Mr. Gilmore. All those in favor of the motion raise your right hand, 13; those opposed, 3; null votes; abstentions**.** **The motion carries.** The amended motion becomes the main motion. Is there any need for further discussion? Go ahead, Doug.

MR. GROUT: I can either say it before or after because it's to what Jeff was asking for in August.

CHAIRMAN DANIEL: We'll save that. Okay, I'm going to have to read the whole thing now, right? Move that the board use MODA for ecological reference point development as recommended by the Atlantic Menhaden and Multispecies Technical Committees; using the approach detailed in Option 1 in the committee's May 2012 report; amended to say "subject to appropriate funding be determined by the August meeting". All those in favor of the motion raise your right hand, 15; all those opposed; null votes, 1; abstentions, none. **The motion carries**. All right, everybody has got to do their homework for the August meeting and come with list of species. Doug.

MR. GROUT: The question that I think this board needs to ask the technical committee is I heard that we're tasked with coming up with the predator species. I think the technical committee, before we can make a judgment on what would be appropriate for predator species, they have to tell us which species are the major predators on menhaden.

That includes everything from fish to birds and mammals. We'd be doing nothing more than guessing as policy people. The technical committee people can look at the literature, and there has probably been some work done on this when it comes from the standpoint of the Multispecies Technical Committee. We need to have that piece of information in hand at the August meeting for us to make that decision. I would like you to task them with doing that. Is that a possibility, Mr. Chairman?

CHAIRMAN DANIEL: I don't know; let me ask Jeff if that's a possibility?

MR. BRUST: I would say that certainly the technical committee would be willing to do some of the research and help provide some guidance. A little birdie just landed on my shoulder and told me that this is actually one of the pieces that comes out of the MODA process of the stakeholder working group. They are developing the management priorities, the management objectives. What species are included is one of those. I'd be willing to say that the TC is willing to support that, but I don't know if we should be the ones making the decision.

MR. GROUT: No, excuse me, I want to make this clear. I'm not asking you to make the decision. I am asking the technical committee to provide us with biological information so that the board can make that decision. Whether we go down this road or not, we need to clearly make that decision, but I think there are scientists and ecologists on our technical committees that can get that information to tell us which ones are the major predators.

CHAIRMAN DANIEL: Yes, and I think we should task the technical committee with providing us with that information. Certainly, marine mammals are a big component; seabirds are a huge component. We can't keep thinking the Mid-Atlantic. That's what everybody keeps talking about, Mid-Atlantic, and that's a very small component, in my mind, of where the predator fields for menhaden reside.

You're going to need to get the Southern Kingfish Association certainly involved in this, because that's going to be a huge stakeholder group in terms of menhaden use. You're going to have folks up and down the beach – you know, the Spanish mackerel guys, huge component of menhaden bait – all the various fisheries that occur outside of the Mid-Atlantic.

I am not as familiar with the New England, but certainly to get some sense of – there is a very small data base I think on diet analyses that have been done. That has been one of the real concerns about ecosystem-based management is that we don't have those very detailed diet studies for many of these fisheries that we deal with.

We know, certainly, that the majority of the species that we deal with are visually oriented, opportunistic predators. If there are sand lances available, that's what they eat; if there are butterfish available, that's what they eat; if there are menhaden available, that's what they eat. It is very difficult to pinpoint exactly how many menhaden – you know, that's going to be the job, how many menhaden does the striped bass population need, the weakfish population need.

Those are going to be the types of questions and details that if the technical committee can put together for us, the information that at least from the literature shows what are the primary predators on menhaden, I think that will help our situation out a lot to make some decisions and determinations in August, as Doug suggested.

MR. BRUST: Again, I think the technical committee can put together that information, but it is not the board's requirement to develop the list of predators at the August meeting. That will come out of the MODA process, the stakeholder working group, the give and take with the technical committee.

There is not something that needs to be done before the process is started. I believe someone asked me that earlier and I shook my head, yes, that's what needs to be done, but I take that back; I apologize. That is not a task for the board at the August meeting or prior to the August meeting. That will come out of the process as a whole.

CHAIRMAN DANIEL: I think that's inconsistent with what Commissioner Grout is looking for, and I don't know how to resolve that. I don't even know where to go at that point.

MR. MARK GIBSON: Mr. Chairman, I think what was just said is exactly right if I understand this MODA. The process of identifying objectives for optimization within MODA should derive from the stakeholder process. Then the board should look at those and whittle them down to the ones that they believe are manageable based on technical committee advice.

You're going to cast a very wide net here and people are going to come forward with objectives other than food for predators. They're going to have water quality objectives. They are going to have menhaden as FADs or fish-attracting devices for sport fishermen. There are going to be all kinds of objectives and a wide framework.

Then we're going to have to whittle those down based on technical committee advice and say this is the group of objectives we think is manageable within the optimization process that constitutes MODA. I'm willing to come forward with what I think some of my objectives are for the next meeting, but it's not going to be a list of predators.

The idea that we can manipulate menhaden populations through our management of menhaden and generate biomass out there, that is pie in the sky, that's not going to happen. I think we need some clarity as to what, if anything, we need to bring back in August, and I don't think it's a list of predators.

CHAIRMAN DANIEL: Lynn is going to tell us.

MS. FEGLEY: I guess I'm just looking for a point of clarification for Jeff. Back in the alternative reference point guidance document that the MSTC and the TC provided to us a couple of meetings ago, it stated specifically that the MS-VPA was ready for a management strategy evaluation now.

Is it not the purview of the technical group involved with this sort of analysis to set the boundaries on what is possible? In my mind this MODA approach would be used to evaluate tradeoffs on the things that we can model now, which is the multispecies VPA. We have it there.

We're able to examine tradeoffs among the species that are currently modeling. Isn't the tool sitting in front of us and it would be the job of the stakeholders to state their objectives and then we would examine how those objectives would be achieved under the current tools; am I wrong about that?

MR. BRUST: The current multispecies VPA model, unfortunately, is basically a one-way model. We can model how the predators affect menhaden, but there is no process within the model to evaluate how more or less menhaden affect the predators or how the predators affect each other.

One of the things that we have been talking about for quite a while with the MS-VPA is to include that feedback loop. At least the way I see it, the additional modeling done through the MODA process would add that functionality; so that if we have twice as many menhaden, what would happen to the striped bass population and the weakfish population, things like that. Right now we can't do that. We are only modeling what happens to menhaden given a certain level of predators.

CHAIRMAN DANIEL: All right, I'm going to Bill Adler and A.C. and then I'm going to end this conversation, and then I'm going to move this topic to other business if we have time, because we're really running hard up against some pretty tight timelines here. Bill.

MR. WILLIAM A. ADLER: I'll make this quick; add the commercial fishermen and recreational fishermen to the predators and not just bass and the fish. They need to be taken into consideration, too. Thank you.

CHAIRMAN DANIEL: Absolutely! A.C.

MR. A.C. CARPENTER: If we're trying to get to the benchmark assessment in 2015 and we're going to use MODA to get there, I'd suggest the board have a backup plan because I don't see this process being complete in time for that. My backup plan would go back to the biological reference points that we do know how to do and examine them and let's fish to that in the interim.

CHAIRMAN DANIEL: Bless your heart; well said. I think we're going to break on that.

(Whereupon, a recess was taken.)

PUBLIC INFORMATION DOCUMENT TO AMENDMENT 2

CHAIRMAN DANIEL: All right, back to the table, please, we are going to reconvene now. We will try to catch up on a little bit of time here. Right now we need to review the options from the PID along with the public comment summary and the advisory panel's report. For that, I'll turn it over to Mike Waine to review those comments and summaries.

PUBLIC COMMENT SUMMARY

MR. MIKE WAINE: In the interest of time, I'm going to jump right into the public comment summary as I'll go through the options in the document while doing that. There were over 22,000 comments received. A hundred were personalized individual letters; 18 were organization letters; and over 22,000 of the comments were from form or co-signed letters with 13 different letters. We held 12 public hearings in 12 states with roughly 185 attendees.

Issue 1 is the time to achieve the target. A majority of the comments, over 12,000 were for a three-year timeframe. There was support, over a thousand comments for the ten-year timeframe, and over 11,000 comments wanted greater than 50 percent probability of achieving the target, and 72 comments wanted a greater than 75 percent probability to achieve the target, given that timeframe.

I also wanted to mention that there were over 20,000 comments that favored removing the ten-year timeframe from the document while there were over a thousand comments that suggested removing the one-year timeframe from the document. With the reporting, pretty much everybody that commented on reporting was in favor of a more comprehensive and timely reporting system.

Other suggestions were weekly dealer reporting and weekly harvester reporting to the ACCSP data standards and that de minimis status, if it goes through, should not exempt states from reporting; with the general comment that it should be comprehensive, transparent and enforceable.

Moving into the recreational management options, there was a strong favor for status quo as most believed that the recreational landings were insignificant relative to the commercial sector. For the commercial management measures, most people favored quotas as an option, over 21,000 comments; and then there was general favor for all the other options in the document with seasons weighing out more heavily.

Generally people suggested using a suite of management measures that would be able to achieve the target given the timeframe that they specified, so essentially use the options necessary that would be needed to achieve the target in the given timeframe. Just to remind the board, when we took these options out during Addendum V, the favoritism was similar in that over 87,000 of those comments favored quotas in Addendum V.

For de minimis, pretty much everybody that commented on de minimis was in favor of including it in the management plan. They suggested that the criteria should be strict and evaluated annually for status determination and that de minimis states should still have to provide biological monitoring.

I'm going to read through some of the other additional comments that were pretty consistent in all the comments received. Those were implement complementary management measures in federal waters; remove the ten-year option from the timeline; consider the impacts the reductions will have on local communities; industry sees plenty of menhaden and they question the science; conserve menhaden; timeline to achieve the threshold and target should be immediate; manage the reduction and bait fisheries separately; take reductions slowly; remove the one-year option from the timeline to achieve the target; protect menhaden for ecological purposes; the new adult survey conducted in New England should be included in the stock assessment update; allocation should be based on history by state and regulated by the state; moratorium should be considered; consider discard mortality when using trip limits; penalties for violations should be large enough to discourage violators; days at sea should not be considered; reduce the reduction fishery only; perform a full economic and social impact analysis, including other fisheries that rely on menhaden for bait; environment drives the stock change and not fishing; fishing is much more expensive now than it was historically; ecological depletion of menhaden is the main issue; ecological-based reference points are needed; implement management measures to achieve the target in three years; restore menhaden to historic abundance; perform a benchmark stock assessment as soon as possible; the biomass reference points need to match the new fishing mortality reference points; if recreational fishery landings increase substantially, reconsider it for management; a complete social and economic analysis is needed before any recommendations on management options can be made; more information should be gathered before moving forward with the amendment; allocation of any quota should be based on history of each fishery; act now; and not enough landings history information is provided to implement a limited entry program. That's a quick run-through of public comments on the document. Thank you.

CHAIRMAN DANIEL: Thank you, Mike; any questions for Mike on the public comments on the PID? Seeing none, I'll turn to Mr. Windley for the advisory panel's report.

ADVISORY PANEL REPORT

MR. BILL WINDLEY: The advisory panel met via conference call on April 23, 2012, to make recommendations to the board on the public information document for Draft Amendment 2 to the ISFMP for Atlantic menhaden. Panel members in attendance represented the conservation community, commercial harvesters for bait and reduction, bait dealers and recreational fishermen. Starting right out, Issue Number 1, achieving the target timeline; some members suggested using management measures to achieve the Target F in as short a time as possible. Three years or less is a reasonable amount of time to achieve the target.

Including a five-year option for public comment is acceptable, but the ten-year timeframe is not reasonable and should be removed. Some members suggested a ten-year phase-in option should be included as it is often used in the federal council system as it relates to a rebuilding schedule. This allows the process to be implemented over the timeframe allowing the fishing industry to survive the reductions that are being proposed.

Some members suggested achieving this threshold in three years and the target in ten. The probability of achieving the target; some members of the AP were in favor or a 0.75

probability of achieving the threshold and Target F. It was noted that the probabilities are based on the last stock assessment and will change when the update occurs, so some of the AP object to the AP making recommendations on this issue.

Catch reporting; it was suggested that we use ACCSP and their standards for catch monitoring and reporting inherent to the SAFIS system. The changes to the reporting should meet ACCSP data elements and submission standards. Some members suggest daily reporting by harvesters and weekly reporting by dealers, but generally reporting should be as real time as possible. Consider the use of VMS. The reporting should be comprehensive, transparent and enforceable.

Number 3, recreational fishery management tools; the AP recommendation is to consider bait questions on the MRIP intercept surveys. There is concern about the distinction between bait harvested recreationally and bait purchased at a bait shop for recreational purposes. Therefore, reporting by the recreational fishery should only apply to fish that are immediately caught and not menhaden that were purchased for bait.

However, consensus that recreational harvest is less than 1 percent of the total harvest and it is unnecessary to implement management measures if the fishery continues to make up a marginal amount of harvest. There was consensus for status quo on recreational fishery management measures.

Number 4, commercial fishery management tools; status quo, some AP members did not support status quo. Trip Limits; some AP members believe trip limits are not workable for the reduction or bait fishery. A majority of the AP is in favor of keeping the trip limits as an option for management. One member is not in favor of trip limits unless it's an incidental catch allowance in the bait fishery. There is a concern regarding discard mortality as an issue with trip limits.

Gear restrictions; some AP members believe this option should be eliminated for the reduction fishery. Purse seine is the only way to harvest for reduction purposes, so restricting this gear is not a workable option. Some members of the AP support keeping gear restrictions as an option. If gear restrictions are used, it should be appropriate to the fishery and take into account the investments that have been made for specific gears already in use.

Season Closures; there is consensus supporting keeping season closures as an option in the management program. Area closures; some AP members support keeping area closures as an option to protect spawning and or nursery areas. However, other AP members don't consider it an effective tool for F-based management. Quotas; there is consensus from the AP in support of keeping quotas as an option and suboptions. A number of analyses need to be performed if quotas are included as an option. A catch share program would be difficult to implement given the lack of information regarding fishery participation and landings history in the bait fishery.

Effort controls; there is support keeping effort controls as a management option. Some members were concerned about days at sea as an effective effort control measure. Other members thought days at sea could be used to achieve a target F goal. Vessel restrictions should consider both harvester and carrier vessels.

Limited entry; some AP members are not in support of limited entry as a management tool at this time. Other AP members were in support of a limited entry program. There is also support for some mechanism to identify participants in the bait fishery. The AP is fine with including a definition of *de minimis* in the amendment; but regardless of *de minimis* status, every state should be required to report and monitor to the standards developed in the FMP through Amendment 2.

Complementary management measures in federal waters; the board should consider implementation of management options in federal waters as a percentage of the fishery is prosecuted in the EEZ. Social and economic impacts; the AP suggested that an impact section be included before specific management options are chosen through the amendment. The impact section should include an analysis of potential long-term benefits given a change in the management program of Atlantic menhaden. Some individuals submitted written comments and they are included with your package. Thank you.

DISCUSSION OF DRAFT AMENDMENT 2

CHAIRMAN DANIEL: Any questions for Mr. Windley on behalf of the advisory panel? Seeing none, thank you, Mr. Windley, for a very detailed and good report. All right, that brings us down to the Draft Amendment 2. The way that I would like to proceed is to go through this guidance document that we have put together to try to facilitate this discussion.

It's a series of questions on the direction that the board would like to take. I think it's important that we try to maintain as much flexibility in the plan as we possibly can and try not to take out too many things; but at the same time if there are options or ideas that need to be removed that could facilitate staff being able to get the documents prepared, we need to have that discussion. Before I get started with Issue 1; Jack.

MR. TRAVELSTEAD: Just in the way of general comments – and I haven't seen how you're going to proceed with looking at all of the various options, but I would remind the board that we have a stock assessment right now that has a terminal year of 2008, and we really have no understanding at this point of the status of the stock since that year, but we will later this summer when the turn-of-the-crank assessment is done.

With that understanding that our – well, that our understanding of the stock will improve in a few months, I would suggest that we be very cautious about eliminating options at this point in time. I think you've used the word flexibility; I think that's exactly right. Since we don't know the outcome, can't predict the outcome of the turn of the crank, we need to leave ourselves with enough options to be able to react to what that outcome is. I just offer that up as general advice and opinion on where I am on all these various options.

CHAIRMAN DANIEL: Thank you for that and I agree. Anything else before we start? Doug.

MR. GROUT: Just a question for Jeff just so that I can make sure I understand how the tables in the PID work here; Table 1 and Table 2. Because this is sort of a new way in my mind of doing things the way we've done before; as I understand this, Jeff – and correct me if I'm wrong – is we have different probabilities of achieving the threshold or the target based on different landings and then going all the way out to 2017 in here. These are based on the fact that our most recent assessment has the terminal year at 2008; correct?

MR. BRUST: Correct.

MR. GROUT: So when we have the updated stock assessment, these probabilities, where we have more recent data, we will have a terminal year of 2010 or maybe 2011?

MR. BRUST: I believe 2011.

MR. GROUT: 2011; these probabilities are all going to change?

MR. BRUST: Yes.

MR. GROUT: And they're going to have a much higher probability of attaining either the threshold or target with higher landings?

MR. BRUST: I don't know if I can say that at this point.

MR. GROUT: They might be the same?

MR. BRUST: The numbers will change; I don't know if they're going to go up or if they're going to go down. They will change.

MR. GROUT: They might go down, the probabilities?

MR. BRUST: I don't know; it depends on what the stock status is. If the stock has gone down farther, it will probably take – it will be less likely to attain those reference points in the given amount of time. If the stock has come up, then it will be more likely to attain those reference points.

MR. GROUT: But let's say by some miracle there has been no change; the very fact that this is a more recent stock assessment would improve the chances of getting us down to a threshold and to our target fishing mortality rate with a given landings limit? As I understood, the reason these are so low is because it has been a long time since we've had an assessment?

MR. BRUST: No.

MR. GROUT: No, okay, then explain it.

MR. BRUST: The reason these are so low is because these are fishing mortality rates rather than biomass. Okay, the timing of the stock assessment has no play in this other than what our estimate of the biomass is – of what the fishing mortality rate is, right. If the new assessment says if the fishing mortality rate is the same, then a given level of harvest is going to provide the same probability of attaining the reference points. If the stock has gone up and the fishing mortality rate has gone down, we're more likely to – the probabilities will increase and vice versa.

I believe that if the assessment says the fishing mortality rate is the same, then these probabilities won't change. If I could follow up – again, another little birdie on my shoulder here – we do have a certain amount of uncertainty and that will come into play. Because the numbers are that old, we've got some uncertainty of what has happened since 2008.

With the new assessment, we will have less uncertainty so that could affect the value some. Right now we're guessing or we're projecting what has happened between 2008 and 2012, which is the first year of the projection. Once we have more certainty of what the population looks like, then those numbers could change as well.

CHAIRMAN DANIEL: All right, everyone should have a copy of this guidance document in your supplemental materials. What I'd like to do is start moving us through and hope that this goes as smoothly as it went on the phone with staff. I think we need to make some decisions and there are going to be a few decisions in here that I think we need to make just to start sending some information forward and let the public know what direction we're heading. I hate to just say on all these, yes, let's keep everything and not make any decisions at this level.

Given that the current fishing mortality rate, the F in 2008 is 2.28, that exceeds the fishing mortality threshold at the new threshold of F 15 percent of 1.32 and the target of 0.62. We've got to take steps to reduce F to the target level. Step 1 and the first item for the board to consider is should the amendment contain options to achieve the target over one, three, five, ten years or some other number of years?

And just to add to that a little bit and to some of the confusion – and this is something I thought of since we developed this; is it also appropriate or prudent to consider meeting the threshold first and then the target or do we want to go straight to the target? I think with a lot of the uncertainty in the assessment and the unknown results of the upcoming stock assessment and the fact that we're not overfished; do you want to try to achieve that separately or go straight for the target? I think that's the first decision matrix that we need to deal with. Pat.

MR. AUGUSTINE: Mr. Chairman, the document is relatively well put together; but when we talked about how we're going to get there, the timeline to achieve the target, the ten-year thing jumped out and hit me right between the eyeballs. I said, God, why is it even in there. I think it needs to be taken out.

I think when people look at that, it's as though we again are kicking the can down the road, whether it's a real number or not. The other options need to remain in there and I only want to talk to the timeline for achieving the target. That would be it, and I do think the board needs to take multiple years to achieve the target.

Let's see what goes forward as far as other comments are concerned. One, three, five seems logical and reasonable as to it has taken a lot of years to get the status of the stock in its present condition. Again, as you mentioned earlier in the day, Mr. Chairman, we're not sure what the real status is. Do we really have a true assessment? Mr. Travelstead brought up the point it has been 2008; so rather than going too far too fast, bring options out there that are reasonable in the short term in case we are in this real low state of status of the stock.

I do think the message sent to the public is also important here that we're sitting on our thumbs and we are aggressively going to take some action. **The ten years was out of the ballpark. It does equate to what we do through Magnuson and through the councils. I would like to move to remove that.**

CHAIRMAN DANIEL: All right, we've got our first motion to remove the ten-year timeframe from Mr. Augustine and a second from Mr. Abbott. Discussion on that motion? Jack.

MR. TRAVELSTEAD: I think we had over a thousand public comments in support of keeping the ten-year option in. I don't think it should be eliminated. We don't know what the next assessment is going to say. It may say we're no longer overfishing, so I think it's entirely appropriate to keep the ten-year timeframe in.

In fact, eliminating it now just suggests that we're going to ignore the science that's going to be available to us in August. On the other hand, it seemed to me we had an almost unanimous public comment that the one-year timeframe was unrealistic. That's not part of this motion, but I suggest we might eliminate the one year but keep the three, five and ten years as a range that captures everything that we might need to consider in August.

MR. CARPENTER: Mr. Chairman, you raised the point are these for the target or are they for the threshold. If it was for the threshold, I think the one, three and five are fine; but if it's for the target, I think the ten should be left in there. I guess the reason I want to leave the ten in there is because we can fish well below the threshold and have a fairly stable fishery and stock without being right at the target every year. I think the ten-year timeframe is appropriate. I agree with Jack that maybe the one year might be needed to be taken out, but I feel confident that the ten years needs to stay.

MR. TERRY STOCKWELL: Mr. Chair, both Jack and A.C. made the same comments I was going to make. I support the inclusion of the ten-year target and the removal of the one.

MR. JEFF TINSMAN: Mr. Chairman, I support leaving the ten-year timeframe in place for purposes of seeing what kind of harvest level that would support for a couple of reasons. One is we have a very poor stock-recruitment relationship with this stock. We can restrict it tremendously and if environmental conditions aren't right for three, five, seven years, who knows how long, we still don't get that big year class that we need.

The second reason is there is concern about restricting the harvest and the impact that is going to have on availability of bait. I think if we have a longer timeframe and steady restriction on harvesting over that period, it will allow a slightly larger annual harvest. Thank you.

MR. GOLDSBOROUGH: I look at this the same way Pat Augustine did. The ten years jumps out at me. If I'm not mistaken, what Amendment 1 says is that we have to immediately take steps to eliminate overfishing and to achieve the target. That tells me the very least we should do the first year is achieve the threshold and that we ought to be fairly prompt in achieving the target. Ten years in incomprehensible to me, frankly. I think that would justifiably open this commission up to a lot of criticism.

I would remind everybody that we've already waited more than ten years for implementation of Amendment 1 objectives, which call for restoring and protecting menhaden's ecological value. Also, to me it calls into question what we mean by interim reference points. We have decided we were going to adopt interim reference points while we work on another process that at an earlier board meeting; I think last year the TC Chair had told us might take five years, so we're going to set a timetable – we're going to even consider a timetable of ten years for implementing the interim reference points? That just doesn't make any sense to me.

I would also remind the board that in Boston we essentially, by adopting these new reference points – no, we explicitly adopted the strategy to give the stock a shot in the arm. If we stretch that shot in the arm out over ten years, I think we dilute the effect and I think we will be waiting ten years, at the least, before we see any response from the stock. Thank you.

MR. TRAVELSTEAD: **Mr. Chairman, I would move to amend the motion to change the number ten to the number one.**

CHAIRMAN DANIEL: Motion by Jack Travelstead to amend the motion and second by Terry Stockwell to retain the ten-year option and to remove the one-year option. Discussion on the motion? Pete.

MR. HIMCHAK: Mr. Chairman, I support the amendment because, again, the threshold that we've decided upon, we're going to implement that immediately. We're not going to take ten years to work towards that. That's a more restrictive reference point right off the bat. That could be going from 8 percent MSP to 15 percent. Maybe this got lost in a lot of the public hearings, but we have to get below the threshold ASAP and then the target is another issue. I support the amended motion.

MR. ABBOTT: Mr. Chairman, I have no problem with the motion in the sense that we'll probably delete the one year, but then it would be my intention to come back and make another motion to remove the ten-year timeframe. I think that we should have the opportunity to vote on the extreme length of time on one end as well as the minimum length on the other time. I really would like to see the original; either vote it up or down, whichever is the wishes of the board, but substituting the ten for one is just dodging the question of the ten-year timeframe, in my opinion, so that will be my intention.

MR. TRAIN: I support the motion as amended. I think one year is far too aggressive. I saw too many fishermen and boats go out of business for what I considered to be a highly aggressive management strategy in New England on groundfish that was rebuilding because of the timeframe. I would like to see this, as far as fishermen and jobs, be stretched out. If we weren't doing it, I could see being more aggressive; but if we're working towards the target, I think the longer timeframe allows people to stay working.

CHAIRMAN DANIEL: Any other comments on the amendment to the motion? One from the audience.

MS. ERICA FULLER: Thank you for this opportunity to comment on the PID. I am Erica Fuller speaking on behalf of the Herring Alliance. I have two points to make regarding Issue 1. First, I think it's important to clarify that any proposed ten-year step-down approach to achieving the new target is not analogous to a ten-year rebuilding plan under Magnuson.

It would be confusing and incorrect to choose one as a rationale for the other. In a Magnuson Rebuilding Plan the goal is increase biomass to a level that can produce MSY on a continuing basis. The law requires that this occur in as short a time as possible. Ten years is an outside limit; it's not the standard.

Menhaden does not have defined biomass reference points and for that matter is not in a rebuilding plan. In Amendment 2 the schedule refers to a length of time until the target is achieved, and we support the three-year option. The second point is that we are in favor of removing the ten-year schedule to reduce F to the target level.

The ASMFC has a mandatory duty to prevent overfishing and to end it when it occurs. This option will not get the fishing mortality rate below the threshold in the early years of the phase-in and cannot provide a safe buffer against overfishing. Simply put, you will not end overfishing now and you cannot ensure that overfishing won't occur in the future. We feel that continuing analysis of this option would be a waste of resources. We need to manage straight to the target.

CHAIRMAN DANIEL: Thank you. What I'm going to do is – and I may have goofed there and really it's up to the board. We are looking at issues to take out to public hearing so we're not making any final decisions here today. We're just taking the options out for public hearing. I know there is a lot of interest in the audience.

We can take public comment as we make these motions or not. I believe typically we don't do that because we will vote on this again later. I apologize if I've overstepped, but I see a hand and I call on it, but I'm not going to do that anymore today unless there is objection from the board to that. David.

DR. PIERCE: I understand the desire to keep as many options in the document as possible because we'll eventually have a final product to go out to public hearing. We've already gone to a lot of public hearings on the plan information document, and frankly I don't want to go back to public hearing and have the same suite of options in there. It looks stupid.

We should now be in a position to whittle this down a little bit and I frankly support the three and the five and getting rid of the one and ten for good reasons that relate to Table 1 and Table 2 specifically because we'll eventually make a decision as to the probability of getting to where we need to be at certain times.

I am going to be favoring the 75 percent, and frankly I think three and five makes a great deal of sense. It is very sensitive to the public comment that we received, and I think it's a very responsible time period for us to look at. As already mentioned, we're not bound by any particular Magnuson Act; that is, if things go wrong relative to rebuilding, we're not obliged to suddenly cut the fishing mortality down to zero if we're not rebuilding as we think we must. We have flexibility to change for whatever good reason may come up. I'm going to oppose the motion and eventually support a motion that would be for three and five years. That would really limit it for the work of our technical team and give the public a clear indication that we listened to what was said at the public hearings and we have acted.

CHAIRMAN DANIEL: Thank you, Dr. Pierce. All right, the amendment on the table is to change the ten to the one. All those in favor of the amendment raise your right hand –

MR. HIMCHAK: Hold on, Mr. Chairman, we need to caucus.

(Whereupon, a caucus was held.)

CHAIRMAN DANIEL: All right, the motion is move to amend the motion to change the ten years to one. Motion by Mr. Travelstead; second by Mr. Stockwell. All those in favor of the motion raise your right hand, opposed same sign; abstentions; null votes. **The motion carries nine to eight.** We're back on the main motion. Mr. Abbott.

MR. ABBOTT: **I would like to make a motion to amend. I would like to make a motion to amend adding ten years to the main motion; make it one and ten years to be removed.**

CHAIRMAN DANIEL: Are we adding to the amended motion or are we removing ten from the main motion? I think we're removing ten from the main motion.

MR. ABBOTT: Adding; ten year is no longer in the motion.

CHAIRMAN DANIEL: Wait, go back to the main motion, please. The main motion is now – we've had one year removed, so right now the main motion is three, five and ten. No?

MR. WHITE: The main motion is to remove one year.

MR. CARPENTER: We passed an amendment to the motion but now you have to vote on the amended motion, which would be the original motion with the one instead of the ten; vote that up or down and then I think you can take an additional motion.

CHAIRMAN DANIEL: Okay, the main motion is to have the three, five and ten years as the rebuilding; correct? Somebody is saying no and somebody is saying yes. You're telling me we need to vote to remove the one year. Yes.

MR. ABBOTT: I somewhat apologize for making the motion. It surely would have been clearer if we had voted the ten up or down, gone to the one and voted it up or down. We now have a main motion before us which is to remove the one-year timeframe and leave – we're not discussing what we're leaving because whatever is left is left.

However, my motion is to add – I'm making a motion now to amend the main motion. The main motion that is before us is subject to further amendments. I offer the motion to include ten years, which would mean that we would be removing both the one and the ten years. I don't have a second yet.

CHAIRMAN DANIEL: I lost a step, I guess. Sarah seconds the motion. If we vote this up, it would eliminate the one and ten-year options, all right? Dave.

MR. SIMPSON: I have a question and a comment about procedure. I'm deathly afraid we're going to get so tangled up in amendments to amendments and not know what we're voting on. If we could just accept that we had a motion to remove one year and we voted to do that, so that's done and then we –

CHAIRMAN DANIEL: I thought so but according to this crowd, no.

MR. SIMPSON: Right, because we're getting caught up in motions to amend. I think it would be simpler, however, to one at a time decide yes or no; move on to the next thing, yes or no; and so if we could just do that. We've made a decision to remove one year, we're done. Let's have a clean motion that just says let's remove ten years, we're done. Otherwise, I'm afraid we're going to get terribly tangled up.

While I have the mike, I do have a question related to the ten-year option, and that goes all the way back to summer flounder where we took a very large reduction, and that was sort of our introduction back in 1991 to major reductions in a very important fishery, and I'm trying to remember how long it took us to get from where we were fishing the fishing rate of like 1.47, if I remember, down to 0.23.

The Fmax moved around but, Toni, do you recall how long it took us to actually do that? I recall sort of an informal constant harvest strategy to get there, but it was several years. I'm reminding myself of that and others that some of these more challenging things took a little more time than you might imagine.

MR. CARPENTER: I believe that Mr. Abbott is correct that your main motion is what is at the top of the screen. It has not been adopted. It is subject to amendment and he has offered one, so now I think you need to vote on Mr. Abbott's motion; and if that gets passed, then that becomes the main motion. If it doesn't, I think we move back to the main motion. I'd suggest just voting on Mr. Abbott's motion.

CHAIRMAN DANIEL: And that's what we're going to do. The motion is to move to amend the motion to include the ten years by Mr. Abbott and Ms. Peake. All in favor of that motion raise your right hand; opposed same sign; abstentions; null votes. **I've got a tie so the motion fails.** Now what?

All right, so the motion now is to move to remove the one year – I'm not going to take anymore comment – move to remove the one-year timeframe to achieve the target. All those in favor raise your right hand; opposed same sign –

MR. HIMCHAK: Mr. Chairman, could you give us a chance to caucus on this? We haven't voted yet.

CHAIRMAN DANIEL: It's all right. Abstentions, one abstention; null votes. The motion carries; I think it was thirteen to zero to one to zero. All right, so now the amended motion is on the screen, right? So we don't need to approve the motion for the three, five and ten?

MR. MEYERS: Mr. Chairman, a point of order, sir. We need to have a little bit more time to discuss some of these issues internally with a caucus in trying to figure out what motion we're actually voting on, please, sir.

MR. BEAL: I think where we are is you have no motions on the board right now that are in play. The only action that was taken was to remove the one-year option for achieving the targets, so you have the three, the five and the ten still moving forward as direction to plan development team for inclusion in the draft amendment.

CHAIRMAN DANIEL: Okay, so everybody clear on where we are? We have three, five and ten years which are now the options for reaching the target. Is everybody happy with that? Does anybody want to say something about that? Pat.

MR. AUGUSTINE: Yes, Mr. Chairman, I'd simplify it all by making a motion that only the three and five year remain in the options.

CHAIRMAN DANIEL: We just did that and it failed so we've got three, five and ten years. We just had a motion to remove the ten. Robert.

MR. BOYLES: Mr. Chairman, a point of order. I believe that you are correct to the extent that we have accepted a motion to remove one year from the public information document. We have rejected a motion to remove the ten years. That leaves three and five. If we want to deal with removing three or five – excuse me, it leaves three, five and ten. If we want another motion on three or five, I think that we're done.

MR. GROUT: Just a clarification for me on process; we have a PID document that we've sent out and got a variety of information. You have a very nice decision document that we have here. To put something into the amendment, do we need to have a positive vote on options to put into the amendment? Have we had a positive vote to include three and five in there? Don't we need a motion right now to say I move that we include Options 3, 5 and 10 in Amendment 2?

CHAIRMAN DANIEL: That's where I got confused. I got confused with thinking that we were having a motion – we had a motion for one, three, five and ten and there was a motion to amend to remove one, and that's where I got wrapped around the axle. That was my fault. At this point we have taken out one. We've got three, five and ten left.

Now, there was a lot of interest around the table to remove ten, but we had that in the motion and it failed; eight/eight was a failed vote. Right now we've got three, five and ten and that's it, and we're done. Now, Step 2, Issue 1, there are several questions here and I think these are important for us to take into consideration.

I don't know that we need to get into the severe nuts and bolts, but I think we need to take into account that if we achieve the threshold right away with the uncertainty in the stock assessment, with the uncertainty in how the stock is going to respond, we would expect if we double the spawning stock biomass or double biomass that that will have some positive impact on recruitment, but we can't say that because we don't have a stock-recruit relationship. I think we need to keep those points in mind as we move forward is that it may take us some time to realize any measurable gains or improvements in the stock. Is that clear?

So, should the amendment consider a minimum and/or a maximum probability of achieving the target? You have the tables in the PID that actually show you, as Doug brought up earlier in the discussion, the probabilities of achieving that. Should there be equal reductions each year, so will we develop step-wise reductions after we achieve the 15 percent?

Do we want to let the public know that after we achieve the 15 percent, we're going to continue to ratchet down the harvest until we reach the target? Will we wait to see what the 15 percent actually achieves in terms of improved recruitment? We may be so far in the bottom left-hand corner of the stock-recruit relationship that that is why we don't have a stock-recruit relationship.

We also may be in a situation where we have very episodic recruitment and using average recruitment is impracticable. It is going to be very hard to model this population in terms of projections. If you lock yourself into increased reductions every year, you may get up to a point where you've reduced the fishery so much but the stock-recruit relationship compromises the ability of the stock to have any meaningful or show any positive stock responses.

Should more reductions occur in early years; should less reductions occur in early years, more in later years; and should we annually select the amount of reductions that we need as we move forward? Those are some points and some questions that we need to provide some clarification on to the plan development team and the staff. Jack.

MR. TRAVELSTEAD: Those are really difficult questions to answer and there are a lot of questions being asked. I'm almost of the opinion that we need to present as many options as we can once again to the public because we don't know the results of the new stock assessment that will be coming out.

Maybe some of these decisions will be easier later this summer, but right now they're very difficult. I think we present a range of options. My greatest fear is we don't – none of us like overfishing; we want to eliminate it, but we don't want to kill the industry as the process of trying to cure that problem. We've got to present, it seems to me, a range of options for our consideration in August.

MS. FEGLEY: Mr. Chairman, this may be a dumb question but on the last question asking whether the board should annually set the amount of reduction; what would we base that on each year? Maybe that is a question for Jeff. We don't have an annual assessment. Would we base it on an annual JI or what would we base it on?

CHAIRMAN DANIEL: Go ahead, Jeff. I'll let you try and then I've got a comment on that, too.

MR. BRUST: I guess if you selected that, we'd have to come up with something, but at this point I don't think we have anything in our back pocket that we could say, yes, you could use this. There has been some discussion about using the JI as sort of a predictive tool, but we haven't developed anything firm yet.

CHAIRMAN DANIEL: So do you want to keep everything in for now, per Jack's recommendation, and then perhaps once we have the updated stock assessment things will be a little clearer. Okay, the next issue is catch reporting. The reporting structure has led to uncertainties in the bait fishery landings for Atlantic menhaden. There is a white paper that was put together by staff from a meeting where they looked at the unreported bait. It seems like in the last five years or so that has gotten much better.

There doesn't seem to be a huge percentage of unreported bait as was suggested early on. Certainly, the main bait companies are reporting on a pretty regular basis. There are electronic-based reporting options that we could use, so should we consider changing the catch reporting requirements? If the answer is yes, how would we want the harvesters or dealers to report?

MR. JAMES KELLUM: I think Omega has done an good job and the Virginia bait catchers have done a good job in reporting their catch at the end of each week. I think if the pound netters, the gill netters and the purse seiners in New Jersey and the northern states would all adopt a plan to report at the end of each week, it would be a system we could all live with.

CHAIRMAN DANIEL: How does that relate to the ACCSP standards? I mean, if the ACCSP standards are consistent with what Mr. Kellum has indicated, then that would certainly parse this down to a very manageable option. Are we going to require observers in this fishery? If the industry can handle weekly reporting and that's consistent with ACCSP standards, could we just simply indicate that is our intent or do we need to have all these various options in the document? Pete.

MR. HIMCHAK: Well, I can answer part of that. If you envision the situation where you get down into a quota on bait on a state-by-state basis, then certainly the state would have to look at its current monitoring program, and ours is monthly. If we had a quota in the purse seine fishery or all fisheries combined, it would behoove us to make some adjustments in reporting requirements.

But not knowing the extent of any needed reduction, I couldn't comment on that. Now, some fisheries we don't even have required reporting. We'd have to go to the legislature and get a landing license requirement for certain gear types. I don't know how to predict this, but if it came down to a quota we would have to invest in more timely reporting.

CHAIRMAN DANIEL: Yes, you would. Should there be observer coverage requirements for the commercial fishery? Do you want to keep it in there? Yes, no, indifferent? Tom.

MR. FOTE: We sent out a bunch of information. There was basically some good comments when we went out to the public hearings. All fish should be scaled – I think we should just leave the suite in there unless there is something that really needs to come out right now. All we're doing is going to public hearing and we're going to approved this document in August.

We're spending a lot of time on something that I think we're going to revisit in August, anyway, and we're going to spend a lot of time fine tuning it. I think unless there is a glaring thing to remove from the document right now, we should just move forward with a lot of the things except being real picayune about every piece that is in there; unless we saw from the public comment that went out for the PID where we should remove something, and I haven't seen one of those yet.

CHAIRMAN DANIEL: That's fine with me. Pete.

MR. HIMCHAK: I think we're putting off the inevitable here when it gets down to allocation. This amendment is going to say X percent – assuming there is a reduction, whatever it comes out to be, it's going to say the first cut is going to be, well, the recreational sector loses this, the reduction loses this and the bait loses that. Maybe the recreational won't have to do anything. Those are decisions we're headed for.

And then under the bait side you're going to have to look at the years of the bait landings by each state and then start saying, well, each state is going to have to reduce by this much. If the PDT is looking for direction from the board, that's what I would tell them not to do is start looking at reduction versus bait. Is it 50/50, 60/40 and why; age of the fish, value. The economics and social sciences has to weigh in on this. That's going to be Amendment 2; isn't it?

CHAIRMAN DANIEL: And that's where we're headed. That's what we're getting ready to get to here in just a minute. We're doing the easy stuff right now.

MR. HIMCHAK: Well, I guess I'm being a little blunt and just throwing it out.

CHAIRMAN DANIEL: Well, I like blunt. Dave Pierce.

DR. PIERCE: Okay, I think we're on timely and comprehensive catch reporting, Issue 2, correct? Okay, we make it very clear in the public information document that we have some uncertainties in the landing history for Atlantic menhaden; that the current reporting structure and inconsistencies between states have created those uncertainties.

And then we asked the public a number of questions regarding how can we improve what we say needs to be improved? I'm assuming that we will have in this amendment a strategy or a set of strategies that would – and I'm being sensitive to public comments – that we would have in this document that both dealers and fishermen would be required to report; that, indeed, there will be needed electronic reporting options, VMS, the IVR; and that there will be reporting through SAFIS; and that all state dealers will be required to report weekly to be consistent with federal reporting requirements.

In other words, we've asked those questions for a very good reason. It's to plug holes, to plug gaps especially if we end up with a commercial fishery management option that includes quotas. If that's the way we go – and I think we're going to go in that direction. That may be a strongly favorite strategy once all is said and done – we're going to need those very important ways of keeping track of what is being landed.

I can make a motion if you'd like, Mr. Chairman, regarding this particular issue or we can just agree by consensus that this document to be fleshed out, that this amendment will have those particular ways of improving our understanding of what is being caught and what is being landed, and that will lead to a dramatic reduction in the amount of uncertainty of landings.

CHAIRMAN DANIEL: No one objects to that, do they, moving forward with that recommendation from Dr. Pierce? Okay, good;

and if not, we'll move forward to the next issue. Recreational fishing measures; here is your first big decision, I guess, and we can continue to say we're going to restrict the recreational fishermen or we can make the decision that we're not going to consider limiting the recreational catch. Because if we do, I think the staff is going to have to start looking at the impacts of the various bag, season, size and gear restrictions. Dave.

MR. SIMPSON: My thought on this is that we don't need recreational restrictions on this fishery given the relative magnitudes of harvest, but I think the document would benefit from potentially a definition of what recreational fishing is in the simplest terms. That to my mind would be a possession limit probably in numbers and/or a volume; you know, a gallon type of thing because unlike most recreational fisheries, they're not just snagging menhaden.

This could be, depending on the state, a few hundred foot long gill net. I know in Connecticut we've run into real issues of what is recreational and what is commercial. I would suggest an alternative under recreational simply include an alternative that defined recreational fishing with a bag limit of 100 fish or five gallons and throw in a couple of options that are bigger than that, but the idea being to define what recreational fishing is by a volume of catch.

MR. TRAVELSTEAD: I'm not sure if we need recreational measures or not in this amendment, and the reason is I don't know enough about the size of the recreational fishery for menhaden. We read in the document that MRFSS or MRIP isn't very good at collecting that information. It seems to me the amendment would be an opportunity to try to fix that problem if we could somehow seek a modification to MRIP where anglers are asked how they're catching. If they don't bring that stuff back to the dock with them, if they haven't used the bait, they throw it overboard and nobody ever sees it so it's not counted. That's not a regulatory type provision, but it might be some provision that we see under this amendment to get us better information.

CHAIRMAN DANIEL: That's a good point. Ritchie.

MR. WHITE: I think the definition of a recreational fisherman is simple; it's personal use. If a guy is going to use a couple of five-gallon buckets or some people may put out a net, but it's personal use and not sale.

MR. GROUT: Yes, the MRIP asks the questions, it doesn't necessarily have to be anglers. What's the primary purpose of your fishing trip today; was it for fun and relaxation or was it for the sale of fish? If they say the sale of fish, it's gone, and then they'll interview. We do have intercepts of recreational fishermen that aren't necessarily fishing with a rod and reel.

We have them fishing with a net and we get that information. My suggestion is that this be put in – because of the very, very low landings at this particular point in time based on the data we have, that we put this in the adaptive management process, that we could through the addendum process. If recreational landings become significant, implement management measures, but at this point in time I don't see that they warrant us spending a lot of time on this. I would, as I said, recommend that we put this as an item to include in the adaptive management process.

MR. NOWALSKY: **Mr. Chairman, I would like to move to remove consideration of season, size and gear restrictions under recreational management measures** to save the PDT time in evaluating those things when they construct the draft amendment.

CHAIRMAN DANIEL: And that's in lieu of Mr. Grout's recommendation to put them into the adaptive management, which is basically considered but rejected alternatives at this particular point in time, but ones that we could implement down the road and then we wouldn't need to do anything? You want that motion?

MR. NOWALSKY: Based on the four options that were included in the guidance document, I think that the only – in listening to the public comment that was offered at the various hearings, there was discussion about bag limits. There was discussion from Mr. Simpson about bag limits. I think that's reasonable to leave in for discussion moving forward, but it's the only one out of these that I think is really reasonable to ask the PDT to further develop in the draft amendment.

CHAIRMAN DANIEL: All right, is there a second to Adam's motion? Seconded by Mr. Augustine. Discussion? A.C.

MR. CARPENTER: But you're leaving in closed areas as one of the options; is that how I read this motion?

MR. NOWALSKY: I did not see closed – if that was in the PID, then I would have that removed. I'm just referring specific to the guidance document that we had before us and closed areas was not one of the options offered here in the guidance document. If it does exist in the PID now, then I would like to have that also added to this motion.

CHAIRMAN DANIEL: I believe it is in the PID, so good catch. Terry.

MR. STOCKWELL: I'm not opposed to Adam's motion, but I was more inclined to favor Doug's approach. I think 0.05 percent of the total catch; we could be wasting a whole lot of staff time developing options when we have far more important work to do.

MR. HIMCHAK: I would support Doug's concept. Looking at it from a state's point of view, what I envision would be casting netting for personal use. The state would have to invest more into managing a rather insignificant component of a large harvest. I could see delaying taking any recreational measures until the future.

MR. GROUT: **Mr. Chairman, I would move to substitute that recreational management measures be put into the adaptive management portion of the amendment.**

CHAIRMAN DANIEL: Motion by Doug Grout, second by Mr. Adler to substitute the recreational measures to moved to the adaptive management section. Any discussion on the substitute motion? Seeing none, all those in favor of the substitute motion raise your right hand; opposed same sign; null votes; abstentions. **Unanimous, 17/nothing**.

Thank you, Doug, very good suggestion and we appreciate that. The substitute motion becomes the main motion. All those in favor of the main motion raise your right hand; opposed same sign; abstentions; null votes. Same result. All right, Issue 4, commercial fishing measures; we've got a series of tools here that we'd like to discuss.

This is where we may get into some discussions. Should the amendment consider limiting the commercial catch? Well, in order to achieve any reductions in harvest, if we're not going to get them out of the recreational fishery, I don't see how we're going to avoid taking reductions from the commercial fishery. How do you want to do it? The first option is with quotas; so should the amendment consider using quotas to limit the amount of fish allowed to be caught by year or season? Jack.

MR. TRAVELSTEAD: This is a little bit sticky because, for instance, if we ended up with state-by-state quotas, then I suspect you would leave it entirely up to that state or each individual state to use any variety of measures to make sure it does not exceed its quota. That might include trip limits or seasons or area closures.

If you're not talking about state by state, then I think you might want to eliminate some of these. Some of these on a coast-wide basis probably don't make sense. A gear restriction in one state might make sense but not in another. So just thinking coastwide, I think we could eliminate some of these. I don't see gear restrictions, for instance, being that successful.

We probably could eliminate those. Trip limits, I don't see them working very well, quite frankly, either, particularly when you're looking at a gear like a pound net. You don't want people throwing back dead fish and wasting a resource. **If you want a motion, I would offer a motion to eliminate trip limits and gear restrictions as a start.**

CHAIRMAN DANIEL: That would be a good start; so a motion by Jack Travelstead, second by Mr. Adler. Discussion. Terry Stockwell.

MR. STOCKWELL: I would be supportive of removing the gear restrictions but not the trip limits. We have trip limit rules in our state that work very well for a number of reasons, and they're in specific areas. We are able to manage and enforce them. It would be an option that we could always be more restrictive and continue to use but one that I would like to keep in the toolbox. What issue comes to mind that we could remove would be the effort controls. Talking about requiring historic estimates of catch rates, VMS requirements, it seems redundant and complicated. I would be willing to make a motion after I listen to a few more comments.

MR. KELLUM: With all due respect to his comments, I think it would be disastrous in the menhaden industry if we went with any sort of trip limit. Menhaden die very fast, and in our world now some of our sets are great large sets;

nine to ten thousand bushels a set. If we have a trip limit where we can only carry five thousand bushels and we're obligated to set that other four or five thousand bushels free, we're going to have an ecological disaster. That should be stricken because we're really talking about menhaden purse seining here. We can sugarcoat this all we want, but that's what we're talking about. Trips limits need to be stricken right away.

MR. ADLER: Just a way through this; if trip limits are not in the amendment but a state wants to put trip limits in for their reason, are they still able to do such a thing?

CHAIRMAN DANIEL: Absolutely! Mark.

MR. GIBSON: Yes, that was going to be my point. We set a quota, we have imposed trip limits, we have gear restrictions on the size of the purse gear in the bait fisheries, and we intend to do that. I don't have a dog in this fight; it really doesn't matter.

CHAIRMAN DANIEL: Well, let's vote this motion up or down, but then I'd like to get back – this was a little jumping the gun for me. I wanted to get to the quota issues first because there are certain issues there that may reflect on which of the tools we want to retain or eliminate. Is there any further discussion on Mr. Travelstead's motion to remove the trip limits and gear restrictions from the document? Seeing none, all those in favor raise your right hand; opposed same sign; null votes; abstentions**. The motion carries.**

If we don't need to make this decision today – I think we need to – back to Tool 1, and Jack brought up some good points and there several options here that we probably need to clarify at least. Do we want state-by-state quotas or do we want a coast-wide quota? If we have a coast-wide quota, then the allocation argument is really moot, I guess, in that the season would start on a certain date and the commercial industries, be they reduction or bait, would go out and fish for that quota until it's taken.

I think we've got some topics here that we need to have some discussion on, state-by-state allocations between the gear types, but right now looking at about an 80/20 split between the reduction fishery and the bait fishery based on historical landings. Recognizing that those bait landings are going to be reduced, the reduction landings will be reduced; the impacts to the bait fishery, knowing that there has been some underreporting over time.

Also, I asked staff to pass out to you the recent Atlantic herring quotas and landings, where that quota has been reduced by about 50 percent. It may start coming back up a little bit, but I think we need to be cognizant of the significant and real issue that will face the bait industry and the potential impacts to the lobster fishery and the blue crab fishery along the coast.

There are various options in here in this quota. The way this quota is managed is going to have significant impacts on whether or not we have those bait issues or not in terms of quota allocations. With state by state – Jack is right, we go with a state-by-state quota share, you get your quota share, you can use trip limits, area closures, season closures. You can anything you want to as long as you stay within your state-by-state quota share.

Obviously, the states that – you know there are two states that have the lion's share of the landings, and that would really not permit for any kind of expansion or any kind of movement in our bait fisheries. A lot of hands around the table went up. I think that's good; we need to have some discussion on how we want to pare this down. I don't necessarily think we need to get into the bottom bullets; but if we can provide some direction or provide some insight to the public as to what direction we're looking at or at least some specific recommendations, I think that would be helpful for staff and the public. Lynn.

MS. FEGLEY: Just to talk a little bit about quotas and state-by-state allocation, one of the things, first of all, that came up at the last board meeting is there was an issue, if I remember, of Jeff telling us that the time to target could change depending on how you allocate between the bait and the reduction fisheries because the size selectivities of those fleets are different.

At that point I had thought that it would be important for the board to know how that time to target changes depending on how that allocation happens; because if we go state by state, then that decision really rests solely within that single state that is managing the reduction fleet, and it takes out of the hands of the board as a whole. Also, if we're going to go state by state, it worries me a little bit in that we have states that are functioning with artisanal bait fisheries that are essentially passive gears.

They're passive gears, they sit in the water, they're multispecies gears, they're not seeking and finding menhaden. The menhaden come to the gear. For those states that harvest bait that way, it's going to be a little bit harder for them because the only way that they're going to – and it's not that they shouldn't participate in the reduction, but the only way to achieve a substantive reduction would be to start throwing menhaden back or to remove nets from the water and therefore remove all associated fisheries.

I think there are a few things that we need to think through if we go state by state. In any way, shape or form we're going to have to allocate at the end of the day no matter how we do it, but there are some issues there we need to consider. Thank you.

MR. TRAVELSTEAD: Well, either way we go on this we're going to make some allocation decisions. If we go state by state, we've got that allocation to decide; or, if we stay coastwide, we're going to have to look at allocations I guess by gear type. I've long been a proponent of state by state as have a lot of people around this table. It has worked quite well for us; not unanimously, but it has worked quite well for most us over the years.

I think it takes care of Lynn's problem for any state that has a fixed-gear fishery for menhaden. As part of your allocation you decide how you decide how you want to address it. I'm not sure we're going to hear enough today to eliminate either of those two options. I don't see us deciding today we're going to go with state by state. I think we've got to put both of them in there; state by state on the one hand or by gear on the other, coastwide with gear; and then they have something specific to fixed gear that Lynn mentioned as another option.

MR. KYLE SCHICK: I don't see it by fishery as a good option because some fish to both, the bait and the reduction. I think we are really looking at just splitting it; you know, are we going to go on a coastwide by gear or state by state; so probably taking out by fisheries would be a good option to narrow things down. That just makes sense to me.

MR. FOTE: I'm agreeing with Jack; I think we need to leave it in at this time and basically just move on to the next option.

MR. HIMCHAK: Mr. Chairman, I think we need two pieces of information to make this decision. We need to hear from the technical committee to give us advice if a certain proportion – and again this talks about Lynn's comment about the size selectivity in the reduction versus the bait fishery.

Is there a biological reason for, say, 60 percent of the reduction to be shared by one part of the commercial fishery and 40 by the other or should 50/50 had no biological consequence in the overall stock condition; and recognizing that in our bait fishery we're getting three, four, five and six-year-old fish. That is one piece of advice I would like to get from the technical committee.

The other point is from the Committee on Economics and Social Sciences, I think that's critical in our making this decision. I honestly have never – and the reduction fishery, it's value to the nation. I mean, yes, a lot of the people, they like the bait fishery and, of course, it strikes home. They use it, but again we have a bigger picture here to deal with and what are the social and economic consequences of the reductions that we may have to take. Those two pieces of information I'd like to get before we get into any choices here.

CHAIRMAN DANIEL: All right, what I'd like to do is I'd like to take about a five-minute break to have some discussion. This will be our last break but then we'll hopefully run through it, but I need to do some checking on one thing before we move forward.

(Whereupon, a recess was taken.)

CHAIRMAN DANIEL: All right, let's get back to the table, folks.

MR. ADLER: Mr. Chairman, would it be worthwhile to move this along, on Option 6 on quotas, just to leave the A through F into the document. That's all we're doing, which leaves it in the document and then we'll see where it goes from there rather than pick and pick and picking this?

CHAIRMAN DANIEL: Well, that's kind of what I wanted to talk to staff about during the break. Most of the time when we have a public hearing draft – I mean we're past the PID stage now and we're going to public hearing drafts. Those are typically the amendment. There are not a lot of big changes that occur from the draft hearing document to the final amendment.

We've got to give I think a little more guidance to staff in terms of how we want this document to look. For example, under quotas by state/federal waters, I don't think there is a need to keep that one in there. That's going to reduce analysis for staff by taking that one out. If we want to look at state-by-state quotas, I think we all agree that state-by-state quotas, we should look at that, and that there should be table constructed for the document that lays out – and my suggestion – I'm trying to get us off the dime here, folks – three and five years.

If we go back much past five years, we start getting underreporting in the bait landings. They're going to probably be disadvantaged. We need to use more real-time information. The further we go back the more disparate the bait landings become. If we could agree to look at, say, a three- and five-year time series for state-by-state quota allocations, we could have those numbers and those numbers could go out to the public and we could ask for their comments on a state-by-state quota share.

The other option that I think we need to look at is look at the same timeframe, the three- and five-year average allocation between the bait and the reduction fishery, because that's the logical break in terms of the major factions in the fishery, bait and reduction. It's going to be an enormous task I think for the staff, and I'm not sure we even have the information very well established.

To go through and look at by gear when we talk about purse seines, gill nets, pound nets, all these various other smaller fisheries, I just don't see us heading in that direction. That's a tremendous amount of staff time and effort to try to put together that information. It seems like to me that for quotas we've got three major options that we may want to direct staff to flesh out; state by state, by bait and reduction, and then an overall coast-wide quota.

I mean that's what I'm hearing from some of in the industry, an overall coast-wide quota. The season starts May 1st; and once the quota is caught, that's it, they're done; and not distinguish between bait and reduction. That's an option I've heard and that seems like a reasonable one to take one to take out to the public. That may not be what we do, but by going in and taking all these others, we really don't need to have many other additional options than that. With that sort of as a – I think that can get us off the dime a little bit. It can also facilitate discussions on these other issues like limited entry and some of the other options that are in the document. With that, Jack.

MR. TRAVELSTEAD: I think you've captured it, Mr. Chairman, and I'm happy with your suggestions. Also, the staff asked me to clarify my motion eliminating trip limits, and my intent with that motion was to eliminate from consideration the use of coast-wide trip limits; but if a state or a region – if we go with some kind of regional approach who wanted to use a trip limit, I have no objection to that. It was not the intent of my motion to eliminate that possibility.

CHAIRMAN DANIEL: Thank you for that clarification, Jack. Terry.

MR. STOCKWELL: Thank you, Jack, I appreciate that from your most northern neighbor. But coming from the northern range of the stock and with a state having very episodic fishing landings, I'm more than a little anxious about the state-by-state quota concept. I request as we think our way through this for staff to consider addressing the issue. I believe one of the comments was made about an ecologic disaster. If we have another big run of pogies in our neighborhood and we can't harvest them, we will have an ecologic disaster.

MS. FEGLEY: Mr. Chairman, I wonder if there is a way that staff could include – I think that these three options sum up what needs to go in the document. I have some concerns about the coast-wide quota as a whole because I think it puts inside water bait fisheries at a disadvantage. I wonder if staff could include in the document what would happen if we had some sort of coast-wise set-aside for gears that are stationary and multispecies.

Those criteria are important; they have to be stationary and they have to be multispecies. The only way to get that reduction from that gear is to take that gear out of the water or you're throwing back dead menhaden; and if you take the gear out of the water, you're losing all the associated fisheries.

My question is if you were to include a set-aside of something ranging from six to eleven thousand metric tons, what would be the impact on the allocations of the other fisheries. What that does is it allows those states that have these multispecies artisanal fisheries to manage those accordingly. That's my question, if that can go in?

CHAIRMAN DANIEL: I think that's certainly something that needs to be fleshed out and considered. I think another option that could help us in those situations is perhaps some bycatch allowance during closed seasons. That may be something that is reasonable to consider. Nobody is going to go out and abuse it for 500 pounds of menhaden or some type of number.

I don't what the number should be; but if you have menhaden especially in a gill net, they're going to be dead whether your season is closed or not, and so kind of bycatch allowance that would allow for that to avoid those discards, because there will be a lot and they tend to float and they tend to be a mess. Those would be two options I think, Lynn, that would address the concerns with the smaller inside fisheries, if that is satisfactory. Dave Pierce.

DR. PIERCE: Your suggestions were good, Mr. Chairman. I would support what you have offered up, but I would also emphasize what Terry did. Especially up in our neck of the woods in the northern area, we would likely favor and certainly would want some consideration in this document of regional allocations. I think that would address some of our specific concerns. For example, in terms of state by state, there are some states that have actively promoted menhaden fishing. Some states have not.

Like Massachusetts, we have strongly favored curtailing the menhaden fishery in the interest of forage, so we have been dealing with ecological considerations; so to be penalized for our favoring ecological considerations, that wouldn't make sense. That would be contrary to where this board is going relative to how we manage this fishery down the road.

All these options should be in the document with the consideration of region-wide as well. That would also help us in the northern region, in dealing with some of the fisheries that occur in waters that are shared by the different states like Narragansett Bay, Rhode Island, Massachusetts. With region included, I would feel comfortable with the options to be fleshed out in the document.

CHAIRMAN DANIEL: Could that region be, say, New York north? I think the fishery goes to New Jersey, the big reduction and bait fisheries. If you could help define a region, I think that would help staff tremendously.

DR. PIERCE: I haven't got the data in front of me so I'm not sure how landings have varied over the years, three or five years, for example, between states. At this time I'm not confident that I could offer up any region-wide approach that would be anything more than a guess. I would like the plan development team to provide that information and to look at some different options, maybe New York north or some other breakdown. I'm not sure how New York would feel about that. Maybe New York would want to be with New Jersey; I'm not sure.

CHAIRMAN DANIEL: Okay, and what I intend to do is put together a small workgroup of this board to work with the PDT. There may be some things added or taken out, just so you know, between now and August. I certainly would like to have someone from the New England area on that group, so see me after the meeting or else I will assign four or five folks.

I'm going to try to cover the gamut of regions. The staff is going to have a lot of questions; the PDT is going to have a lot of questions between now and the next meeting, and I'd rather not be making all those decisions unilaterally as the chair because it does have multiple ramifications and we're a very minor player in the fishery.

MR. ADLER: I think the region should be included for the reason Dave Pearson had brought it up; but in terms of what you had brought up, I can see us eliminating the by state/federal waters. There is one thing you don't need. I actually would like to see by gear eliminated because they bounce around a lot of times and it just makes it very confusing if you've got to handle ten different ways of handling this fish. Rather than to do that, I would C and D just removed, which would make it a little simpler.

CHAIRMAN DANIEL: And I think that's precisely what I was suggesting to the group, that for the quotas what we would consider is three- and five-year timeframes with the most recent data. I guess it would be the '11 landings data. We'd do a three- and five-year analysis on state-by-state quotas; a coast-wide quota; bait/reduction allocation quotas; and then as the New England guys are looking or the more northern states are looking, maybe a combined state-by-state regional; so maybe if you had a regional quota from New York north and then had state-by-state quotas south of that to avoid some of the issues and concerns that I'm hearing from New England. I don't think you would want to go just regional purely. That would be a problem, but if we had state by state plus regional, that may add to it. That was sort of the direction that I was trying to move the board in that direction of handling it that way. Mark.

MR. GIBSON: Mr. Chairman, In addition to agreeing with what you just said that should any region arise in New England or state by state, I think there is going to need to be a provision for quota transfers in a fairly expedited way, perhaps with the commission as the clearing house, that a lot a fish show up in the Gulf of Maine and not in Narragansett Bay, we may need to move fish around within that region and within the initial state allocation or vice versa if Maine is empty and Narragansett Bay is packed to the brim. If we do end up in a state-by-state situation, we'll need some kind of quota transferability alternative.

CHAIRMAN DANIEL: Yes, I agree with that. Doug.

MR. GROUT: Mr. Chairman, I appreciate the direction we're going in. I had a couple of comments to make sure that certain things were included. Clearly, the question in the decision document of payback overages I think needs to be included as we develop this. Also, I was intrigued by the idea of multiyear specifications and might want to suggest that we might have something looked at that might have a constant harvest strategy between assessments where we'd have a quota that would be consistent until the most recent assessment.

The final comment I have is you had mentioned in your introductory remarks about this particular section using three- and five-year averages. Well, at least up here in the north it has been a long time since we've seen significant adult menhaden. We've seen peanut bunker up there, and it might warrant having at least an option to look at this in a longer timeframe for some of the northern states that may not have had – particularly from Massachusetts north which may not have had that much adult bait landings in the past three and five years just because there haven't been the availability for them. I'd have to look at the landings data but you might want to go back ten or fifteen years just for one option that we consider when we're trying to determine what the quota is.

MR. STOCKWELL: I'd like to underscore Doug's comments on the three- and five-year time period being extremely problematic for the Gulf of Maine. One concept that might be fleshed would be something along the line of a regional set-aside for the Gulf of Maine. We use it in the Atlantic herring with an ability to transfer the unused quota back to the entirety. If the Gulf of Maine was receive an annual allocation, we could ensure that it was harvested by the other states if we did not have access that year.

CHAIRMAN DANIEL: And that certainly seems fair and could be a consistent problem. I'd hate to go back for the major allocations like New Jersey and Virginia, go back too far, but certainly for some smaller – I doubt there is that significant a landings compared to the other fisheries in that area and it would certainly seem to me that we would be able to work something out within the commercial community to provide some type of regional allocation to those areas where they are episodic. I think that's clear direction to the staff to take a look at that to try to satisfy those concerns up north. Pete.

MR. HIMCHAK: Mr. Chairman, I will not raise my hand again during this meeting. As the original caretaker of the bait landings data, we did break it down geographically into four regions throughout the FMP and Amendment 1, so there is a precedent for that particular point. The only other comment I have for the day is what is the progress or what is the timeline for the Committee on Economics and Social Sciences completing their task, which is going to be pretty valuable when we meet at the annual meeting. How are they getting along?

MR. WAINE: We've met with them and they're drafting currently the section that deals with what status quo is on the fishery right now. We're going to be drafting sections through what are now your narrowing options in the document and they will be looking at the economic and social impacts of the specific options that are going to be included in this draft amendment. They've made good progress on the status quo version and now will continue to work through the options that are selected today.

MR. NOWALSKY: Mr. Chairman, do we need an additional motion on this or are we going forward with the expectation that the discussion here as part of the record is how staff will be directed to go ahead and redraw up the document as the final draft amendment for the August meeting?

CHAIRMAN DANIEL: That's the way I'd like to handle it if there is no objection from the board, but I think the direction is pretty clear from the discussions.

MR. NOWALSKY: Okay, to clarify that, would that then also exclude some of the other items in here such as catch shares, ITQ, IFQ, or if it was the desire to remove that, then I'd like to go ahead and make a motion to do so unless your direction addresses that concern.

CHAIRMAN DANIEL: My direction will address that concern. I think we're done talking about quotas; are we? We've eliminated Tool 2 with Jack's clarification that certainly regional trip limits could be established if regional quotas were developed. We've eliminated gear restrictions, so the next is season closures. Do we want to consider seasonal closures?

I see no interest in keeping that in the document so it will be removed from the document. Tool 5, area closures, is there interest in keeping area closures? I'm not sure how that would work, but do we want to flesh that out? Tom.

MR. FOTE: Well, area closures are used in many species and it should be left in there as a tool that we can always look at. There might be specific reasons for closing an area down, so I don't really want to take it out at this point.

CHAIRMAN DANIEL: Well, the other option would be to put it in the adaptive management section as we did some of the others. Would that be satisfactory instead of fleshing it out for this amendment? Is everybody comfortable with that approach, taking Doug's example earlier? I thought it was good. Is that satisfactory to you, Tom? Okay, Dr. Pierce.

DR. PIERCE: Certainly, that's an option to put it in the list of measures that could be taken or used adaptively. I just ask the question do we have information in hand right now relative to where there are areas that should be protected for immature fish and even protection of ecosystem services.

That is a particular point made in the guidance document. I don't have that information in hand, but certainly if it exists that might be something worth exploring again if the data are there and would enable us to do an analysis to augment the other approaches that we are now including. I don't have the answer to that question. I am just wondering if indeed – since we made the point; how do we respond?

CHAIRMAN DANIEL: I don't know that we have that information fine scale enough to have area closures based on that information. I think with that point made, maybe a statement to that effect in the adaptive management section that as the data become available, it may be considered for further protection particularly in nursery areas. Tom.

MR. FOTE: It brought back old memories of Bruce Freeman sitting here explaining – they were looking at corridors along the beach when the small fish were migrating up and down the coast and maybe they shouldn't have been allowed to purse seine on the first years. There was some discussion years ago about basically putting that corridor along the beach for like six-tenths of a mile up and down. Most of the states are closed to reduction anyway so I don't know if it's pertinent, but that was the only conversation I remember going back 15 years ago when we started talking about how we would have closed areas along the beach.

CHAIRMAN DANIEL: Good historical information. Lynn.

MS. FEGLEY: Mr. Chairman, I guess I'm having angst about season closures for much the same reason of area closures. To be clear, if we're going to do quotas, then every managed entity a seasonal closure would still be applicable in order to control a quota; but if we're thinking about area closures, something an area that should be protected should only be protected during a certain time. I don't know that removing season temporal closures is necessarily if we want to take that out of our toolbox right now, and maybe that should slide in with – I hate to throw a monkey wrench in it, but I'm uneasy about pulling that out right now.

CHAIRMAN DANIEL: I think that can go in adaptive management. If there is any queasiness from anybody, it can go into adaptive management that will allow us to bring it up at any time. If there is no objection, any of the ones that we're saying we're removing just automatically goes into the adaptive management, and that way we don't lose any options in framework, but we're not going to flesh them out and we're going to streamline the document some. Is that okay?

All right, next is effort controls; days fished, vessel size, fleet size, upgrade size capacity of the vessels; adaptive management? Adaptive management. Limited entry, adaptive management or do you want to just get rid of that one? Jack.

MR. TRAVELSTEAD: Get rid of it completely. If we go with state by state, a state might want to look at that, but I can't imagine in the short timeframe we have we're going to devise a limited entry program for this fishery along the entire coast? It's just not realistic.

CHAIRMAN DANIEL: I agree. Can we just get rid of that one? Is there any objection to that? You said you weren't going to raise your hand again.

MR. HIMCHAK: I had no objection to removing it on a coast-wide basis, but just recognize we've already put in a limited entry program in the purse seine fishery.

CHAIRMAN DANIEL: That's cool. Doug.

MR. GROUT: Mr. Chairman, my belief has always been any time you get into quota management, you have to have that tool in the toolbox, the limited entry. You may not need it right away, but I would suggest maybe putting it – as least my opinion would be to put it in adaptive management, but the rest of this board may have a different opinion on that.

CHAIRMAN DANIEL: The only way it would be eliminated is if it was a consensus; so if there is no consensus on eliminating it, it will go into adaptive management would be my suggestion. I don't think anybody will jump and down and yell and scream about that, I hope. Issue 5, de minimis; I think we've all got a lot of experience with de minimis.

Should we have de minimis criteria for this plan? I'm seeing nods around the table, yes, so we'll need to come up with some criteria that qualify for de minimis. Now, for de minimis, just for clarity, do we want to do reduction de minimis and bait de minimis? If you just do a combination de minimis I think most all of us will be de minimis with the exception of Virginia and New Jersey. I know North Carolina would be.

If we look at de minimis in terms of if you have a reduction fishery, which is Virginia, obviously they're not going to be de minimis on reduction. The bait fishery, if look at the bait fishery, there will be a lot of us that are not de minimis if you just look at bait. Do you want to look at it both ways or just look at it by the bait fishery de minimis? Dave.

MR. SIMPSON: I don't like to think about it in terms of what the product is used for as you're characterizing it. It's more the gear type that is being used and I'd like to think we could define certain types of gears, as Lynn was alluding to, that might qualify as de minimis or a certain size gill net that if you're smaller than that, then you wouldn't have to have weekly monitoring or whatever the criteria are, but you could establish what might be very modest use for local consumption, that sort of thing.

CHAIRMAN DANIEL: A little squirrel told me that we probably don't have the data to that level of specificity in order to – I mean, it sounds like a really interesting idea to address some of the smaller fisheries and some of the bycatch concerns that may arise from of the fisheries. If they're de minimis, then perhaps it would eliminate the problems that we may have with some of the smaller fixed gears. That's a good idea, but I don't know if we have the data to analyze that.

MR. SIMPSON: Yes, I think that almost reinforces the point that it's so small that it's below the detection level. I think a group could arrive at a size of a gill net that they say that's not going to change the menhaden management world. It's a few hundred pounds or a thousand pounds of bait a day or something like that.

We're trying to avoid trip limits, but just kind of characterize what are essentially artisanal, very small operations that aren't going to become growth industries and try to manage those that are less intensive – in a less intensive way than for big purse seine fisheries and real volume fisheries.

CHAIRMAN DANIEL: I think that would be unique to this plan to do it that way, but we're already in a paradigm shift and we're already going down a different direction. Is there objection to looking at it that way? If there was going to be a fishery where we were going to look at it, with the dominance of the snapper rigs and purse seine vessels in the harvest, trying to provide at least some characterization of some the smaller fisheries and assign them as such seems like a reasonable concept to look at. Roy.

MR. MILLER: Mr. Chairman, I think we need to simplify this a little bit and just look at the bait fishery for this particular purpose as a whole. Thank you.

CHAIRMAN DANIEL: Any other thoughts on de minimis? Doug.

MR. GROUT: Keep it simple or at least have an option that keeps it simple. If we want to task the PDT with developing something like Dave has suggested, that's fine with me as long as we have the option of keeping I simple enough so that we just base it on landings, whether it be bait landings or coast-wide landings below a certain amount you could qualify for de minimis.

MS. FEGLEY: Mr. Chairman, I guess I'll throw this out there, and we should keep de minimis simple. I have again a little bit of queasiness about dividing by bait and reduction rather than by rig. I think if you do de minimis criteria by rig, what will happen is that those states – and, yes, Maryland is one of them – that have artisanal bait fisheries that are large compared to those other artisanal bait fisheries, those states will be above the de minimis level, but they will have no recourse – they don't have anywhere else to go in managing a reduction than in those multispecies stationary gears.

Those states will have to ask that those stationary gears be removed from the water, which means they're removing other fishery opportunities; or, ask that dead menhaden be discarded. We need to keep it simple but I think some analysis of how de minimis is going to place the onus of the bait fishery reductions needs to be considered.

CHAIRMAN DANIEL: Anything else on de minimis? I'm hearing do a coast-wide de minimis analysis and a reduction/bait de minimis analysis, so no by gear analysis. That may be something for the workgroup to consider and think about; and maybe in time if we – I'd like to think about that a little more myself and how that may impact some of the fisheries. Anything else on the amendment for the public hearing draft? We got there quicker than I thought we would at the start. Bill Goldsborough.

MR. GOLDSBOROUGH: Mr. Chairman, I believe earlier in the meeting we experienced substantial confusion around the table with Issue Number 1; so much so that I don't think we arrived at a result that reflects the majority views of this board or is responsive to the public comment or even the AP input.

I think we can do better so I'd like to make a motion to reconsider the vote on Issue Number 1, the timeline for implementing the target fishing mortality rate. I believe since Maryland was on the prevailing side of that vote that this motion is in order, assuming I get a second.

CHAIRMAN DANIEL: Motion to reconsider the timeline to achieve the target; second by Mr. Augustine. Discussion on the motion? Yes, sir.

MR. AUGUSTINE: I think Mr. Goldsborough is absolutely correct. There was a very strong position on this. It may not seem important to some folks but I do think when we had that many respondents and the advisory panel supported, I think we're just missing a point of two bodies, particularly the advisory panel that believes we really should move in that direction.

I don't see any harm done by doing it. If push comes to shove and we have to extend it beyond the numbers that we're working with, the three and five that are in there, so be it. We can adjust but to send a strong message back out to all the folks who took a serious interest in this document and how it was developed and positions that they structured coming back to us in the best interests of the fishery and its value to us, I think we're missing our point. I definitely support this motion.

CHAIRMAN DANIEL: Thus the second. Sarah.

REPRESENTATIVE PEAKE: Mr. Chairman, I support this motion as well. If I'm correct in my understanding, it's a motion to reconsider our prior vote. We're not jumping right to the timeline but a motion to reconsider. I would ask my fellow commissioners to support it as well. One of the main reasons for a motion to reconsider is if there is confusion at the time of the vote.

I think there may have been some confusion. I know I heard New Jersey asking for time to caucus. I'm not sure that their vote was ever counted. Any number of ways you look at it, Representative Abbott and I were following along with the procedural stuff, but we're sort of legislative junkies.

Unfortunately, I think that his motion and my second may have just muddied the waters more; so if you will, this is sort of a way to turn back the clock and try to put the string back on the ball, hit the reset button and say let's do this over again to make sure that the intent of the commission and all of its members really understood. Thank you for bringing forward this motion to reconsider.

CHAIRMAN DANIEL: Any other comments on the motion to reconsider? Adam.

MR. NOWALSKY: Just to be clear, Mr. Chairman, we're considering the final motion to remove one year because there were a lot of motions made; so just for clarity, that is what we're reconsidering here. The final motion was to remove one year from the timelines and that is what we're reconsidering at this time?

CHAIRMAN DANIEL: That's correct. Pete, you keep doing it.

MR. HIMCHAK: Well, this is pretty important. Confusion notwithstanding, the final outcome of the initial vote on Issue 1, we understand what that was. Yes, we were confused during the caucuses, but that was inconsequential to the desired outcome that we already got. I don't support this motion to rehash what we took an hour and a half to unsort. And I will not raise my hand again.

CHAIRMAN DANIEL: All right, can we vote on this to reconsider? All we're doing is voting to reconsider and then I'll take a very quick motion to do whatever if the motion carries. All right, all those in favor to reconsider raise your right hand; opposed same sign. **It fails as a tie.** I think I counted them right.

BOARD MEMBER: The Chair can break the tie.

CHAIRMAN DANIEL: I can! No, I'm not. All right, so we've got three, five and ten. There is from my perspective a little comfort in the ten. The only reason I say that is not for the public perception that we're going to wait ten years to reach the target; but just looking at the stock assessment and looking at the projections and looking at the concerns that we may not see one of one of these extraordinary recruitment events in five, seven, ten years, we may not achieve the target simply because of the environmental consequences around the stock, and so we may not have that control.

At least that to me gives some justification for maintaining a longer timeframe and whether we select that at the end is going to be up to the board and public hearings. Just because it remains in the document doesn't mean that is what the end result will be. Is there any other discussion on the draft amendment? Bill.

MR. ADLER: May I make a motion at this time to accept the draft amendment as amended for public discussion?

CHAIRMAN DANIEL: No, we're not at that point yet. Bill, we don't need that motion for this meeting. We're just giving guidance to staff. We'll review the draft and approve it at the August meeting. Bill.

MR. GOLDSBOROUGH: Mr. Chairman, I had two comments in the form of requests to staff, assuming the board agrees, for some language in the draft amendment. First of all, with respect to federal waters, recognizing that a substantial amount of this fishery takes place in federal waters over which we have no jurisdiction, might it not be prudent to include some language in the draft amendment to the effect that it would be our intent to work with the councils to seek consistency with the measures we put in place through Amendment 2?

CHAIRMAN DANIEL: That would be a recommendation to the secretary, I think, wouldn't it?

MR. GOLDSBOROUGH: Would it not be prudent to put some language in the draft amendment to the effect that it's our intent to do that?

CHAIRMAN DANIEL: Yes, that will be in there.

MR. GOLDSBOROUGH: Thank you. My second request has to do with the language in the PID on socio-economics. At the last board meeting when we discussed this I raised the issue that the language at that point had only to do with short-term socio-economic impacts and that there are a range of other impacts that needed to be included.

It was my understanding that they were going to be added and they weren't. For example, we know the stock has been declining for 25 years and over that time period we've had substantial socio-economic impacts. Presumably, what are the impacts if we don't stop that decline? Another has to do with the whole intent of this exercise which is to boost the stock, in which case presumably there would be positive socio-economic impacts, and they're not referenced in there either. It's just a request that we beef up that socio-economic impacts section to include the full range.

CHAIRMAN DANIEL: We will do our best to accommodate that request. Anything else; any further direction to staff? If not, what I would like to do is I'd like to keep it as a small group. I believe Mr. Boyles is the vice-chairman of the Menhaden Board; so if it suits the board I would like to have Robert, Jack, Lynn, Dave Pierce and Pete to be a little subcommittee of this board to kind of review and give guidance to the PDT and staff if the need arises.

Is that a reasonable distribution and interests for folks? Any objection to that list? If you have it, let me know after the meeting and I'll try to make some accommodations but I'd really like to keep it to five including myself. I think that's plenty big.

OTHER BUSINESS

CHAIRMAN DANIEL:All right, the last item is Jack had an other business issue that he wanted to bring before the board.

MR. TRAVELSTEAD: This is the issue of what guidance, if any, we need to provide to the technical committee on information that they look at in doing the next assessment. I'm aware there has been a lot of dialogue between staff, some congressional folks. I think Sam Rauch was even involved. It might be helpful to start if perhaps Vince or Bob Beal could update us or summarize what has occurred recently; and then if you'd come back to me, I'll explain what I'd like to see happen and then we could have some discussion.

EXECUTIVE DIRECTOR JOHN V. O'SHEA: Last Wednesday afternoon the Acting AA for the National Marine Fisheries Service, Sam Rauch; Dr. Richard Merrick, the senior scientist for NOAA Fisheries; and myself met with Mr. Whitman. I think to summarize the meeting, Mr. Whitman's primary concern was that the science function of ASMFC look carefully at available information; that is what he was concerned about.

We told him in response to a letter that he had written and we responded to and all the members of the board received, that we were going to have an in-person meeting of the stock assessment subcommittee that is working on the update. He was pleased to hear that and he thanked us for that. Sam Rauch indicated that he was going to direct the Beaufort Lab folks to run sensitivity analyses on the recruitment function of dome-shaped versus plateau. Mr. Whitman was appreciative of that. That was basically the summary of the meeting. Thank you.

CHAIRMAN DANIEL: And that's my understanding of where we are at this time. Also, just to add to that, some of the requests at having the technical committee look at some of Dr. Sulikowski's work and the aerial surveys, recognizing that there is just one year of data so far in that survey, but what kind of information can be gleaned from that and at least give it a review at the technical committee meeting.

One of the things, you know, we agreed to do the face-to-face first meeting with the idea that – and that was fine, but we are moving more and more towards these webinar type functions and it does save us a lot of money and a lot of travel time. I know that there is a big difference between face to face and because this one was so volatile, I felt like we need to go ahead and get off the dime and make that decision. I don't want us to start backtracking into having more and more of the face-to-face meetings and indicate that the webinars aren't effective because I believe the technical folks would tell you that they're very effective and certainly less time-consuming than a lot of traveling. That's kind of where at this point, Jack, from my understanding and Vince's recollection was as mine was. He had got another comment.

EXECUTIVE DIRECTOR O'SHEA: Well, a correction; I said the recruitment selectivity and it's the selectivity of the reduction fishery.

CHAIRMAN DANIEL: Thank you for that clarification. Jack.

MR. TRAVELSTEAD: I appreciate, for one, your decision to have that face-to-face meeting as the first meeting of the TC. I think that will be very helpful. All I'm looking for is some willingness of the TC to look at those pieces of information. I recognize that the Sulikowski work is one year.

It's hard to make decisions based on one year; but if the board could be informed later this summer as to how sensitive the models are to that information, that would inform us as to whether or not it's worth doing that kind of survey on an annual basis. The industry has come forward; they did this work; they presented the information. It is just one year.

You can't make a lot of decisions based on one year's worth of data; but if we knew that the model was somehow significantly sensitive to that kind of information, then that might be something we want to pursue or ask the industry to continue to do for us in the future. That's all I'm looking for.

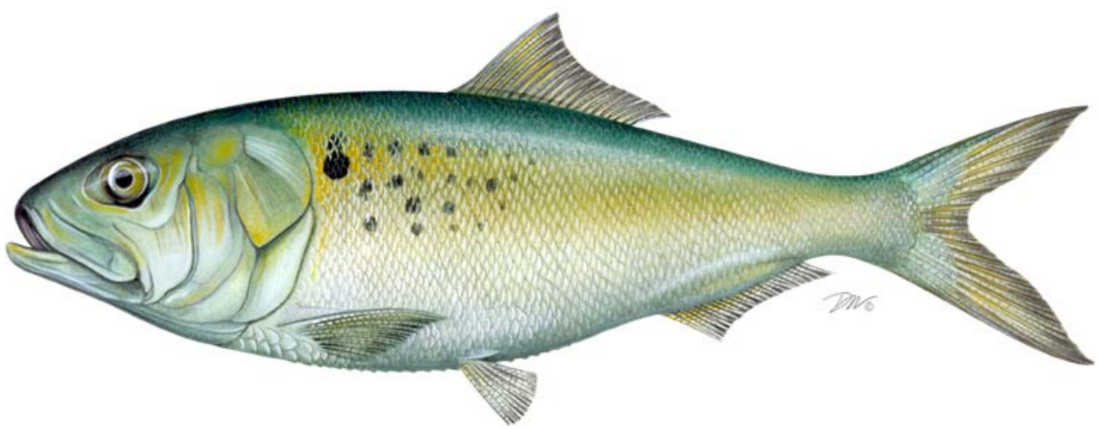
ADJOURNMENT

CHAIRMAN DANIEL: Thank you, and I think we'll be able to have that discussion later in the summer. Anything else to come before the Atlantic Menhaden Board? If not, thank you for your indulgence and your participation. We will stand adjourned.

(Whereupon, the meeting was adjourned at 12:25 o'clock p.m., May 2, 2012.)

Atlantic States Marine Fisheries Commisison

2012 Atlantic Menhaden Stock Assessment Update



July 2012

Working towards healthy, self-sustaining populations for all Atlantic coast fish species or successful restoration well in progress by the year 2015

Atlantic States Marine Fisheries Commission

2012 Atlantic Menhaden Stock Assessment Update

Submitted to the Atlantic Menhaden Management Board
July 2012

Prepared by the
ASMFC Atlantic Menhaden Stock Assessment Subcommittee

Dr. Erik Williams (Chair), National Marine Fisheries Service
Mr. Jeff Brust, New Jersey Department of Environmental Protection Bureau of Marine Fisheries
Dr. Matt Cieri, Maine Department of Marine Resources
Dr. Robert Latour, Virginia Institute of Marine Science
Mr. Micah Dean, Massachusetts Division of Marine Fisheries
Dr. Behzad Mahmoudi, Florida Fish and Wildlife Research Institute
Mr. Jason McNamee, Department of Environmental Management Marine Fisheries Section
Dr. Geneviève Nesslage, Atlantic States Marine Fisheries Commission
Dr. Amy Schueller, National Marine Fisheries Service
Dr. Alexei Sharov, Maryland Department of Natural Resources
Mr. Joseph Smith, National Marine Fisheries Service

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Executive Summary

The purpose of this assessment was to update the 2010 Atlantic menhaden benchmark with recent data from 2009-2011. No changes in structure or parameterization were made to the base model run. Corrections made to data inputs were minor and are described in the body of this report. Additional sensitivity analyses and landings projections were conducted.

Updated data included reduction, bait, and recreational landings, samples of annual size and age compositions from the landings, the coastwide juvenile abundance index (JAI), and the Potomac River Fisheries Commission (PRFC) pound net index. Also, a new matrix of age- and time-varying natural mortality estimates was obtained from the 2012 update of the MSVPA-X model.

Abundance of menhaden has remained at similar levels as reported in the 2010 benchmark assessment. Total abundance in 2011 was estimated to be 7.84 billion fish. Generally low recruitment has occurred since the early 1990s. The most recent estimate for 2011 (4.03 billion) is the second lowest recruitment value for the entire time series, but is likely to be modified in the future as more data from the cohort are added to the analysis. Population fecundity (SSB, number of maturing ova) was variable across the time series, but has declined since the 1990s to a 2011 terminal year estimate of 13 trillion eggs.

Fishing mortality estimates suggest a high degree of variability, but in general the reduction fishery has experienced declining fishing mortality rates since the mid-1960s, while the bait fishery has experienced increasing fishing mortality rates since the 1980s. Reduction fishing mortality rates have risen, though, in the last two years of the assessment (2010-2011). The estimate of full fishing mortality in 2011 was 4.5.

The current overfishing definition is a fecundity-per-recruit threshold of $F_{15\%}$. The current fecundity-based overfished definition is a threshold of $SSB_{MED.T}$ (half of SSB_{MED}). Benchmarks were calculated using all years, 1955-2011. The ratio of Full F in the terminal year to the overfishing benchmark ($F_{2011}/F_{15\%}$) was greater than 1. The ratio of SSB in the terminal year to the SSB benchmark ($SSB_{2011}/SSB_{threshold}$ was greater than 1. **Therefore overfishing is occurring, but the stock is not overfished. However, the TC warns that there is a technical mismatch between the current overfishing and overfished reference points.** The TC recommends that, given the Board has adopted an $F_{15\%}$ overfishing definition, a matching overfished definition of $SSB_{15\%}$ should be adopted as well.

Retrospective pattern analysis suggested that this model is not robust to addition of new data. An underestimation of F and overestimation of SSB was evident during the 2010 benchmark stock assessment; however, these patterns became more worrisome during this update when a switch in direction of the pattern was observed such that F was overestimated and SSB was underestimated in recent years. It is unclear exactly what is causing this retrospective pattern, but it appears that some data sources have developed discordance since 2003.

Overall, the retrospective pattern and a number of other issues cast considerable doubt on the accuracy of the estimates from this update stock assessment. The TC warns that additional data analysis and modeling work are necessary to resolve these model structure and performance issues. An expedited benchmark assessment during which the TC can more fully examine many of the issues raised above is warranted. Although the Technical Committee could not come to consensus on the utility of the terminal year point estimates of F and SSB for management advice, there was consensus that the status determinations were likely robust. In other words, the ratio of $F_{2011}/F_{15\%}$ is likely greater than 1.0 (overfishing is occurring), and $SSB_{2011}/ SSB_{MED.T}$ is likely greater than 1.0 (the stock is not overfished), but the exact magnitude of these ratios could not be determined.

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1 Introduction

The purpose of this assessment was to update the 2010 Atlantic menhaden (*Brevoortia tyrannus)* benchmark (ASMFC 2010) with recent data. No changes in structure or parameterization were made to the base run. Corrections made to data inputs were minor and are described in this report. Additional sensitivity analyses and projections were conducted.

2 Regulatory History

The Commission has coordinated interstate management of Atlantic menhaden in state waters (0-3 miles) since 1981. Management authority in the exclusive economic zone (EEZ, 3-200 miles from shore) lies with NOAA Fisheries.

In 1988, the Commission initiated a revision to the FMP. The plan revision included a suite of objectives to improve data collection and promote awareness of the fishery and its research needs, including six management triggers used to annually evaluate the menhaden stock and fishery. In 2001, Amendment 1 was passed, providing specific biological, social, economic, ecological, and management objectives for the fishery.

Addendum I (2004) addressed biological reference points for menhaden, the frequency of stock assessments, and updating the habitat section currently in Amendment 1.

Addendum II instituted a harvest cap on Atlantic menhaden by the reduction fishery in Chesapeake Bay. This cap was established for the fishing seasons in 2006 through 2010. The Atlantic Menhaden Technical Committee determined the following research priorities to examine the possibility of localized depletion of Atlantic menhaden in Chesapeake Bay: determine menhaden abundance in Chesapeake Bay; determine estimates of removal of menhaden by predators; exchange of menhaden between bay and coastal systems; and larval studies (determining recruitment to the Bay).

Addendum III was initiated in response to a proposal submitted by the Commonwealth of Virginia that essentially mirrors the intent and provisions of Addendum II. It placed a five-year annual cap on reduction fishery removals from Chesapeake Bay. The cap, based on the mean landings from 2001 – 2005, was in place from 2006 through 2010. Addendum III also allowed a harvest underage in one year to be added to the next year's quota. The maximum cap in a given year is 122,740 metric tons. Though not required by the plan, other states have implemented more conservation management measures in their waters. Addendum IV (2009) extends the Chesapeake Bay harvest cap three additional years (2011-2013) at the same cap levels as established in Addendum III.

Addendum V, approved in November 2011, establishes a new F threshold and target rate (based on MSP) with the goal of increasing abundance, spawning stock biomass, and menhaden availability as a forage species.

3 Life History

3.1 Age

The seminal study on ageing Atlantic menhaden was conducted by June and Roithmayr (1960) at the NMFS Beaufort Laboratory; their specimens were collected mostly from purse-seine landings during 1952-1956. They validated rings on the scales of menhaden as reliable age marks based on timing of scale ring deposition and marginal increment analyses; accordingly, Atlantic menhaden are assigned ages based on a March 1 "birthdate". Menhaden field sampling protocols remain relatively unchanged from the 1950s. Information on precision of age estimates, paired scale:otolith (earstones) age estimates, and longevity are dealt with more thoroughly in Section 2.3 of the 2010 benchmark assessment report (ASMFC 2010).

3.2 Weight

Regressions of weight (W in g) on fork length (FL in mm) for port samples of Atlantic menhaden were fit based on the natural logarithm transformation:

$$\ln W = a + b \ln FL \qquad \text{(Eq. 1);}$$

and were corrected for transformation bias (root MSE) when retransformed back to the form:

$$W = a(FL)^b \qquad \text{(Eq. 2).}$$

As in previous menhaden assessments, regressions of fork length (mm) on age (yr) were based on the von Bertalanffy growth curve:

$$FL = L_\infty(1 - \exp(-K(age - t_0))) \qquad \text{(Eq. 3).}$$

Von Bertalanffy fits were made with the size at age data aligned by cohort (year class). Because of concerns that density-dependent growth is a characteristic of the cohort, cohort-based analyses were thought to be a better approach. Attempts were made to fit the von Bertalanffy growth equation to each year class from 1947 (age-8 in 1955) to 2011 (age-0 in 2011). For most cohorts, a full range of ages were available (1955-2004). For the incomplete cohorts at the beginning of the time period (1947-1955), all fits converged, although specific parameter estimates became progressively unrealistic for the earlier years (especially 1947-1949). Similarly, incomplete cohorts for the recent time period (2005-2011) generally converged with the exception of the last two years (2010-2011).

Annual estimates of fork length at-age were interpolated from the cohort-based von Bertalanffy growth fits to represent the start of the fishing year (March 1) for use in estimating population fecundity (Table 1). Similarly, annual estimates of length-at-age were interpolated to represent the middle of the fishing year (September 1) and converted to weight-at-age (Eq. 2) for use in the statistical catch-at-age models when comparing model estimated catch to observed catch (Table 2, Table 3).

3.3 Fecundity

Often reproductive capacity of a stock is modeled using female weight-at-age, primarily because of lack of fecundity data. To the extent that egg production is not linearly related to female weight, indices of egg production (fecundity) are better measures of reproductive output of a stock of a given size and age structure. Additionally, fecundity better emphasizes the important contribution of older and larger individuals to population egg production. Thus in this stock assessment update (as in the most recent benchmark assessment for Atlantic menhaden [ASMFC 2010]), modeling increases in egg production with size is preferable to female biomass as a measure of reproductive ability of the stock.

Atlantic menhaden are relatively prolific spawners. Predicted fecundities are:

$$\text{number of maturing ova} = 2563 * e^{0.015*FL},$$

according to the equation derived by Lewis et al. (1987).

As in the previous benchmark assessment of Atlantic menhaden (2010; Section 2.5), the percentage of first-time spawners in the population is assumed to be 12.5% mature for age-2 fish and 85.1% mature for age-3 fish.

Most historical fecundity studies of Atlantic menhaden have concentrated on acquiring gravid females off the coast of North Carolina during the fall fishery when most age classes in the stock tend to be available (Higham and Nicholson 1964, Dietrich 1979, Lewis et al. 1987). Repeating these studies in contemporary times will be difficult relative to the acquisition of adequate number of specimens. The last menhaden factory in North Carolina, Beaufort Fisheries Inc., closed in winter 2004-05. Moreover, the North Carolina Marine Fisheries Commission recently moved to prohibit purse seining for reduction purposes 0-3 miles from the state’s coastline (http://portal.ncdenr.org/web/mf/proclamation-m-25-2012). Thus, procuring specimens from traditional fall fishing grounds may be challenging. The need for additional information collection on fecundity and maturity is underlined further in Research Recommendations.

For a more thorough discussion on historical studies on fecundity of Atlantic menhaden, refer to Section 2.5 of ASMFC (2010).

3.4 Natural Mortality

Time-varying natural morality at age generated from the Expanded Multispecies VPA (MSVPA-X) was updated for this assessment through 2010. See report in Appendix 5 for details. The age-specific natural mortality rate was assumed constant over time for the years 1955-1981 and was based on the average of estimates from the MSVPA-X analysis for the years 1982-2010. The natural mortality rate for 2011 was the projected natural mortality from the MSVPA-X.

A comparison between the 2009 and 2012 model runs of total M2 estimates (summed across the 3 modeled predators) showed that overall changes to menhaden M2 were minimal between old and new runs. However, for the oldest age class (6+) large changes in the M2 were noted (see Appendix 5). While these differences are minor when compared to the overall magnitude of the predation mortality on younger ages, this difference could be a contributing factor to the ongoing retrospective problem found in the most recent menhaden update (see section 7.2.5).

4 Fishery-Dependent Data Sources

4.1 Commercial Reduction Fishery

In January 2005 the penultimate menhaden reduction factory on the US east coast, Beaufort Fisheries Inc., in Beaufort, NC, closed permanently. Since then, Omega Protein Inc. at Reedville, VA, is the sole remaining industrial processor of Atlantic menhaden on the Eastern Seaboard. The extant reduction fleet at Reedville is comprised of about ten vessels (approx. 165-200 ft in length). Most of their fishing activity is centered in the Virginia portion of Chesapeake Bay and Virginia's ocean waters; however, in summer the fleet ranges north to northern New Jersey and in fall south to Cape Hatteras, North Carolina. Occasionally, a few smaller purse-seine vessels that fish in Chesapeake Bay for menhaden for bait unload their catch at the Omega Protein factory when the bait demand is soft or when their catch is too small for the bait market.

4.1.1 Data Collection Methods

Methods of acquiring fishery-dependent data for the Atlantic menhaden purse-seine reduction fishery remain relatively unchanged since the recent benchmark stock assessment (ASMFC 2010). Briefly, landings by the reduction fleet by fishing year (March 1 through February 28 of the following year) have been maintained by the NMFS Beaufort Laboratory since 1955. Landings are reported to the Beaufort Laboratory monthly; daily vessel unloads are provided in thousands of standard fish (1,000 standard fish = 670 lbs), which are converted to kilograms.

The biostatistical data, or port samples, for length- and weight-at-age are available from 1955 through 2011, and represent one of the longest and most complete time series of fishery data sets in the nation. The NMFS employs a full-time port agent at Reedville to sample catches at dockside throughout the fishing season for age and size composition of the catch.

The Captains Daily Fishing Reports (CDFRs, or daily logbooks) itemize purse-seine set locations and estimated at-sea catch; they are mailed to the Beaufort Laboratory weekly. Vessel compliance is 100%. CDFR data for the Atlantic menhaden fleet are available for 1985-2011. Beginning in 2009, CDFR forms are optically scanned as they are received at the Beaufort Laboratory. Preliminary data on fishery removals by area are available shortly after they are scanned, facilitating timely monitoring of the "Chesapeake Bay Cap" (see Section 4.1.2 below).

4.1.2 Commercial Reduction Landings

A complete chronology of Atlantic menhaden landings, dating back through the late nineteenth century, is presented in the previous benchmark stock assessment (ASMFC 2010, Section 4.1.2). Herein, recent landings are discussed beginning in 2005. Between 2005 and 2008 (terminal year for the previous benchmark assessment) only the factory at Reedville, VA, operated. Landings ranged from 141,100 t (2008) to 174,500 t (2007), and averaged 155,000 t (Figure 1, Table 5). Reduction landings in 2008 accounted for 75% of total coastwide landings of Atlantic menhaden (bait and reduction combined), down from 80% in 2007 and 86% in 2006. During 2009 to 2011, reduction landings ranged from 143,800 t (2009) to 183,100 t (2010), and averaged 167,000 t.

Reduction landings in 2011 accounted for 76% of total coastwide landings of Atlantic menhaden (bait and reduction combined), down from 81% in 2010 and 78% in 2009.

In some respects, purse-seine landings for reduction during 2008-2010 belie the recent abundance of Atlantic menhaden in lower Chesapeake Bay and vicinity. During those respective summers, and to some extent in summer 2011, fish factory managers periodically imposed daily and/or weekly landings quotas on the vessels unloading at Reedville, VA. The quotas were enacted because during many fishing weeks, catches exceeded the factory's processing capacity. The most severe restrictions occurred during the summers of 2008 and 2009 when vessels were often limited to daily landings not to exceed 700-800 thousand standard fish (approx. 213-243 t, or about one-half the capacity of their fish holds).

Beginning in 2006 and through 2013, the harvest of Atlantic menhaden for reduction in Chesapeake Bay has been 'capped' by ASMFC (Addenda III and IV to Amendment 1 of the FMP) at 109,020 t per year (with penalties for overages and credits for underages). The fishery has not exceeded the annual cap through 2011. For comparative purposes, during 1990-1999 removals of Atlantic menhaden from Chesapeake Bay by the reduction fleet averaged 145,700 t per year; during 2000-2005 removals averaged 104,400 t; and during 2006-2011 removals averaged 75,400 t.

4.1.3 Commercial Reduction Catch-at-Age

Detailed sampling of the reduction fishery permits landings in biomass to be converted to landings in numbers-at-age. Port sampling provides an estimate of mean weight and the age distribution of fish caught. Estimates of numbers of fish landed are derived by dividing weekly landings by the mean weight of fish sampled. The age proportion of the weekly port samples then allows numbers-at-age to be estimated. Developing the catch matrix at the port/week/area-caught level of stratification provides for considerably greater precision than is typical for most stock assessments.

On average, 2,631 Atlantic menhaden from the reduction fishery have been processed annually for size and age composition over the past three fishing seasons, 2009-11. In the two most recent years, age-2 Atlantic menhaden, comprising 50% (2011) and 49% (2010) of the total numbers of fish landed, have slightly outnumbered age-1 fish (42% in 2011 and 40% in 2010) in the catch-at-age matrix (Table 4). In 2009 the age composition of the coastwide landings for reduction was 1% age-0s, 48% age-1s, 31% age-2s, and 20% age-3+; in 2010, it was 2% age-0s, 40% age-1s, 49% age-2s, and 9% age-3+; and in 2011, it was 42% age-1s, 50% age-2s, and 8% age-3+. The higher proportion of age-1s in the catch in recent years suggests improved recruitment during 2009-2011 versus 2005-2008 (except for 2006 when the 2005 year class entered the fishery; 40% of the catch-at-age in numbers).

4.1.4 Potential Biases, Uncertainty, and Measures of Precision

The topics and data derivations for this section, as well as the ageing error matrix for the catch-at-age, are unchanged and assumed the same as in the benchmark stock assessment (ASMFC 2010).

4.2 Commercial Bait Fishery

4.2.1 Data Collection Methods

Commercial bait landings have been reported through a variety of state and federal reporting systems from 1985 to the present (Table 5).

4.3 Commercial Bait Landings

Coastwide bait landings of Atlantic menhaden increased during the period 1985 to 1995, declined slightly over the next decade, and grew rapidly in recent years (
Figure 2). During 1985 to 1989 bait landings averaged 30.5 thousand mt, and landings peaked at 36.3 thousand mt in 1988. During the 1990s bait landings averaged 37.8 thousand mt, with peak landings of 42.8 thousand mt in 1993. Between 2000 and 2007 average bait landings for the coast increased again to 35.8 thousand mt, with a peak of 42.8 thousand mt in 2007. Between 2008 and 2011 average landings increased more than 30% from the previous time period, to 46.7 thousand mt, peaking in 2011 at 54.8 thousand mt. Historically, the "snapper rig" (small purse seine) fishery in Chesapeake Bay and the purse-seine fishery off New Jersey have dominated the bait landings; these two fisheries account for more than 67% of the total bait harvest during 2007-2011.

In recent years (2007-2011) bait landings have averaged 28% of the total coastwide Atlantic menhaden landings (including landings for reduction; Figure 1). This is up from an average of 13% of total landings for the period 1985-2000. The relative increase of menhaden for bait as a percent of coastal landings since the late 1990s is attributed to better data collection in the Virginia 'snapper rig' bait seine fishery, the decline in coastal reduction landings because of plant closures, and increased interest in menhaden for bait purposes because of recent quota reductions for Atlantic herring, a preferred bait for the lobster fishery.

4.3.1 Commercial Bait Catch-at-Age

Biological sampling of the bait harvest for size and age continued in 2008-2011 using the target sample sizes by state and gear established in 1994 (Table 6). All age samples are processed by the NMFS Beaufort Laboratory.

4.3.2 Potential biases, Uncertainty, and Measures of Precision

Underreporting is known to occur, with the greatest sources expected to be personal use harvest and direct sales to commercial and recreational fishermen. More comprehensive reporting criteria over the years have improved bait harvest estimates, and the level of underreporting is considered to be minimal relative to the magnitude of reported landings (ASMFC 2012b).

4.3.3 Commercial Bait Catch Rates (CPUE)

Pound net landings collected by the Potomac River Fisheries Commission (PRFC) were used to develop a fishery-dependent index of relative abundance for adult menhaden. Pound nets are a stationary, presumably nonselective, fishing gear. PRFC pound nets are set in the Potomac River adjacent Chesapeake Bay; among other fishes, they catch menhaden primarily ages-1 through -3. Other than the reduction landings, these data represent the only other available information that can be used to infer changes in relative abundance of adult menhaden along the east coast of the U.S.

The updated base model index (1976-2011) was based on annual ratios of pounds of fish landed to total pound net days fished. Raw catch and effort data were available for 1976-1980 and 1988-2011. Recently, the PRFC was able to obtain and computerize more detailed data on pound net landings and effort, which allowed index values to be calculated for 1964-1975 and 1981-1987. To generate estimates of pound net landings (PN) for the missing years, a linear regression was fitted to annual PN and published landings (PB):

$$PN = 219035.8 + 0.953 \cdot PB,$$

which had an R^2 value of 0.996 and was highly significant ($p < 0.001$, $n = 26$). During 1964–1993, there were no restrictions on the number of licenses sold to fishers operating in the Potomac River, however after 1993, the number of licenses was capped at 100 (A. C. Carpenter, PRFC, personal communication). Therefore, to generate estimates of pound net days fished (DF) for the missing years, a second linear regression was fitted to DF as a function of the number of licenses (L):

$$DF = 3094.2 + 17.944 \cdot L,$$

which had an R^2 value of 0.485 and was significant at an α-level of 0.104 ($n = 11$). The shorter period of overlap among DF and L and greater variability associated with the regression increases the uncertainty of the index for the reconstructed years, but not for the most recent years (1988–2011). This index was constructed in the same manner as those used for the 2003 and 2006 menhaden assessments, and it shows a variable trend over time with low values in the 1960s-1970s, peak values in the early 1980s, and intermediate values in recent years (Figure 3). The only difference between the benchmark and update assessment was for the years 2004-2008. These years of data were incorrect when provided to the SAS during the last benchmark assessment. However, the error did not change the overall trend of the index (Figure 3). The corrected data were used in this update assessment.

4.4 Recreational Fishery

4.4.1 Data Collection Methods

The Marine Recreational Fisheries Statistics Survey (MRFSS) contains estimated Atlantic menhaden catches from 1981-2003 and the Marine Recreational Information Program (MRIP) contains estimated Atlantic menhaden catches from 2004-2011. These catches were downloaded from http://www.st.nmfs.noaa.gov/st1/recreational/queries/index.html using the query option.

See MRFSS/MRIP online for discussion of survey methods:
http://www.st.nmfs.noaa.gov/st1/recreational/overview/overview.html#meth

4.4.2 Biological Sampling Methods and Intensity

Insufficient biological samples were available to develop a recreational catch at age matrix. See Section 4.3.5 for a discussion of the treatment of recreational landings.

4.5 Recreational Landings

Estimated recreational catches are reported as number of fish harvested (Type A+B1) and released alive (Type B2; Table 7 and Table 8, respectively). The fundamental cell structure for estimating recreational catches is by state [Maine – Florida], mode of fishing [beach/bank, manmade, shore, private/rental, charter], fishing area [inland, ocean (<=3mi), ocean (>3mi)], and wave [six 2-month periods]. Using the same methods as the 2010 benchmark assessment, the average weight was applied by region to total harvest (A+B1+0.5*B2) in numbers to obtain harvest in weight (Table 9). To provide estimates of harvest (Type A+B1) in weight, the catch records were retained at the basic cell level for which both harvest in numbers and harvest in weights were available. These landings were then pooled by region (NE, MA, SA), and the ratio was used to obtain an average weight by region. The assumption that the size (mean weight) of the B2 caught fish was similar to that of the A+B1 fish was made.

To put these removals into perspective, reduction landings have been on the order of 170,000 mt during the last decade, bait landings around 40,000 mt during the last decade, and recreational landings on the order of 200-400 mt during the last decade. In general, the recreational landings represent less than about 1% of the combined bait and reduction landings.

Recreational landings did change during 2004-2008 from the values used in the benchmark assessment due to the switch in estimation to the new MRIP methodology (Figure 4). The change in landings was small and given that recreational landings represent less than 1% of total landings, the values provided through MRIP were used in place of the values MRFSS provided during the last benchmark assessment. The values from MRIP represent the best available estimates and starting in 2013 MRFSS estimates will no longer be provided.

4.5.1 Recreational Discards/Bycatch

To determine total harvest, an estimate of release mortality to apply to the B2 caught fish is necessary. Under the assumption that many of these recreationally caught fish were by castnet, the judgment of the data workshop participants was that a 50% release mortality rate was a reasonable value. Based on this value, the total number of fish dying due recreational fishing (A+B1+0.5*B2) is summarized in Table 10.

4.5.2 Recreational Catch Rates (CPUE)

Available recreational data was insufficient to calculate recreational catch rates.

4.5.3 Recreational Catch-at-Age

As in the benchmark, recreational landings were combined with bait landings, and the bait catch-at-age matrix was expanded to reflect these additional landings in numbers applied regionally and then combined.

4.5.4 Potential biases, Uncertainty, and Measures of Precision

Uncertainty associated with recreational landings (MRFSS/MRIP) is substantial, but probably no worse than for bait. The MRFSS/MRIP provides estimates of PSE (proportional standard error) as a measure of precision in Table 10. These values range between 15% and 40% with some exceeding 50%. Values under 20% are considered to be "good". Potential biases are unknown.

5 Fishery-Independent Data

Fishery-independent data sources used in the benchmark and update assessments include state seine surveys that ostensibly target other species of juvenile fish, but also capture juvenile menhaden.

5.1 State seine surveys

5.1.1 Data collection

Data collected from seine surveys conducted within several states along the east coast of the U.S. were used to develop indices of relative abundance for juvenile menhaden. The primary objective of these seine surveys is to measure the recruitment strength of species other than menhaden, that is, the underlying sampling protocols were designed to target juvenile striped bass, alosines, or other fishes and species complexes. Although menhaden are a bycatch species in these surveys, the seine catch-per-haul data represent the best available information for the construction of a menhaden juvenile abundance index (JAI).

The calculation of the menhaden JAI was based on data from the following state seine surveys:

- North Carolina alosine seine survey (1972-2011)
- Virginia striped bass seine survey (1967-1973, 1980-2011)
- Maryland striped bass seine survey (1959-2011)
- Connecticut seine survey (1987-2011)
- New Jersey seine survey (1980-2011)
- New York seine survey (1986-2011)
- Rhode Island seine survey (1988-2011)

The North Carolina Alosine seine survey (Program 100S) has operated continuously from 1972-present in the Albemarle Sound and surrounding estuarine areas. The survey targets juvenile alosine fishes and sampling is conducted monthly from June through October.

The Virginia striped bass seine survey was conducted from 1967-1973 and 1980-present. The survey targets juvenile striped bass following a fixed station design, with most sampling occurring monthly from July through September and occasional collections in October and November. In 1986 the bag seine dimensions were changed from 2 m x 30.5 m x 6.4 mm to the "Maryland" style seine with the dimensions 1.2 m x 30.5 m x 6.4 mm. Rivers sampled in the southern Chesapeake Bay system include the James, Mattaponi, Pamunkey, Rappahannock, and York rivers.

The Maryland striped bass seine survey targets juvenile striped bass and has operated continuously from 1959-present. Survey stations are fixed and sampled repeatedly in three rounds in July, August, and September with a beach seine of dimensions 1.2 m x 30.5 m x 6.4 mm. Permanent stations within the northern Chesapeake Bay system are sampled in five regions: Choptank River, Head of Bay, Nanticoke River, Patuxent and Potomac River.

The New Jersey seine survey targets a variety of fishes and has operated continuously in the Delaware River from 1980-present. The sampling scheme has been modified over the years but the core survey area, sampling locations, and field time frame (June-November) have remained consistent. The current sampling protocol, which was established in 1998, consists of 32 fixed stations sampled twice a month from June through November within three distinct habitats: Area 1 – brackish tidal water; Area 2 – brackish to fresh tidal water; Area 3 – tidal freshwater. A beach seine with dimensions 1.8 m x 30.5 m x 6.4 mm is used for sampling. For the juvenile index calculation, data from Area 3 were omitted due to the rare occurrences of menhaden in tidal freshwater.

The Connecticut seine survey targets juvenile alosines in the Connecticut River and has continuously operated from 1987-present. Sampling occurs monthly from July through October with a beach seine of dimensions 2.44 m x 15.2 m x 0.5 cm. Approximately 14 hauls are taken annually in the Deep, Essex, Glastonbury, and Salmon Rivers.

The Rhode Island seine survey targets a variety of fishes in Narragansett Bay and has operated continuously from 1988-present. A total of 18 fixed stations are sampled from June through October using a beach seine with dimensions 3.05 m x 61 m.

The New York seine survey targets a variety of fishes in western Long Island Sound and has operated continuously from 1984-present. Sampling occurs with a 61 m beach seine primarily from May through October within three areas: Jamaica Bay, Little Neck Bay, and Manhasset Bay.

5.1.2 Biological Sampling

Length data (in mm) were available for the seine surveys conducted by North Carolina, Virginia, Maryland, and New Jersey; little or no length data are available for the seine surveys conducted by Connecticut, and Rhode Island.

5.1.3 Ageing Methods

For state seine surveys (North Carolina, Virginia, Maryland, New Jersey, and New York) with length data, catch-per-haul data were adjusted based on the convention cut-off sizes by month for juvenile menhaden adopted by the Atlantic menhaden Technical Committee in March 2003. Juvenile length cutoffs were defined as: June 1-June 30, 110 mm FL; July 1-August 15, 125 mm FL; and August 16-November 30, 150 mm FL.

5.1.4 Coastwide Juvenile Abundance Index

A coastwide index of juvenile menhaden abundance was developed by combining the state-specific seine data into a single dataset. As noted in the most recent menhaden stock assessment, examination of the raw catch-per-haul data for each state indicated that each data set contained a high proportion of zero catches, or alternatively, a low proportion of hauls where at least one juvenile menhaden was captured (ASMFC 2010). Zero catches can arise for many reasons, and it was reasoned that the use of an active sampling gear combined with the schooling nature of menhaden was the likely cause (Maunder and Punt 2004). Although a variety of strategies can be used to deal with zero catches, in the most recent stock assessment a delta approach was adopted where the probability of obtaining a zero catch and the catch rate, given that the catch is non-zero, were modeled separately (Maunder and Punt 2004). The general form of a delta model is:

$$\Pr(Y = y) = \begin{cases} w & y = 0 \\ (1-w)\,f(y) & \text{otherwise} \end{cases}$$

Based on analyses described in the most recent assessment report, the probability of obtaining a zero observation was modeled using the binomial distribution and the distribution used to model the non-zero catches was assumed to be lognormal (ASMFC 2010). The delta-lognormal GLM used to develop the coastwide juvenile relative abundance index included *year*, *month*, and *state* as fixed factors. All statistical analyses were conducted using the software package R, version 2.11.0 (R Development Core Team, 2010).

5.1.5 Trends

The trend of the index is generally low during the 1960s, high from the mid 1970s to mid 1980s, and low to moderate from the mid 1980s to the present (Figure 5). Over the past 20 years, noteworthy strong year-classes occurred in 1999 and 2005.

5.1.6 Potential Biases, Uncertainty, and Measures of Precision

Because of the schooling nature of Atlantic menhaden combined with the fact that these seine surveys were originally designed to measure the abundance of other species, it is possible that the menhaden catch data are not truly representative abundance.

6 Methods

In this section, one modeling approach from the last benchmark assessment was updated, the Beaufort Assessment Model (BAM). During the last benchmark assessment, BAM was recommended as the preferred assessment model.

6.1 Base Model

The Beaufort Assessment Model (BAM) used for this assessment update is a statistical catch-at-age model (Quinn and Deriso 1999) implemented with the AD Model Builder software (Fournier et al. 2012).

6.1.1 Spatial and Temporal Coverage

The BAM model is not a spatially-explicit model; rather it assumes one coastal population of Atlantic menhaden. Catches are reported by fishery and state, but are assumed to come from one population. The abundance index data for Atlantic menhaden are assumed to be measures of the coastwide population, as reflected by the age-specific selectivity vector applied to each survey.

The BAM model for Atlantic menhaden employs annual time steps, modeling the years 1955-2011. The 1955 starting year reflects the first year of catch-at-age data.

6.1.2 Treatment of Indices

Two sources of information were used for abundance indices in the BAM model. Fishery-dependent PRFC pound net data were used to develop a CPUE adult abundance index. The assumed age-specific selectivity schedule was 0.25 for age-1, 1.0 for age-2, 0.25 for age-3, and 0.0 for all other ages. The level of error in this index was uncertain, thus the coefficient of variation was assumed to be 0.5. In the BAM model, the estimates of the product of total numbers of fish at the midpoint of the year, a single catchability parameter, and the selectivity schedule were fit to the PRFC pound net index value in that same year. The error in this abundance index was assumed to follow a lognormal distribution. Note that beginning in 2010, NMFS Beaufort personnel, with the assistance of PRFC staff, have acquired and "aged" port samples for PRFC pound nets (27 fish aged in 2010, 56% age-1s, 26% age-2s; 59 fish aged in 2011, 49% age-1s, 32% age-2s). As this is an assessment update, these data were not incorporated into the update data set.

The other abundance index used in the BAM model comes from a series of state-specific seine surveys. These surveys, although designed for other species, also capture primarily juvenile menhaden, primarily age-0s. In the model the juvenile abundance index (JAI) was treated as an age-0 CPUE recruitment index, by fitting the product of the model estimated annual age-0 numbers at the beginning of the year and a single catchability parameter to the computed index values. The error in the JAI index was assumed to follow a lognormal distribution.

6.1.3 Parameterization

The ADMB model code and input data file are attached as Appendices A.2 and A.3. A summary of the model equations may be found in Table 11. The formulation's major characteristics are summarized as follows:

Natural mortality: The age-specific natural mortality rate was assumed constant over time for the years 1955-1981 and was based on the average of estimates from the MSVPA-X analysis for the years 1982-2010 (MSVPA-X discussed in Section 3.4 and Appendix 5). The natural mortality rate for 2011 was the projected natural mortality from the MSVPA-X.

Stock dynamics: The standard Baranov catch equation was applied. This assumes exponential decay in population size because of fishing and natural mortality processes.

Growth/Maturity/Fecundity: Percent of females mature was fixed in the model. Female size- and fecundity-at-age varied annually.

Recruitment: Recruitment to age-0 was estimated in the assessment model for each year with a set of annual deviation parameters, conditioned about a mean and estimated in log-space.

Biological benchmarks: Biological benchmark calculation is described below in Section 6.2.

Fishing: Two commercial fisheries were modeled individually: reduction and bait. Separate fishing mortality rates and selectivity-at-age patterns were estimated for each fishery.

Selectivity functions: Selectivity was fit parametrically using a logistic model for both the reduction fishery and the bait fishery. Selectivity was assumed constant for the entire time period in the assessment model.

Discards: Discards were believed to be negligible and were therefore ignored in the assessment model.

Abundance indices: The model used two indices of abundance that were modeled separately: a juvenile (age-0) index series (1959–2011) and a pound net CPUE index series (1964–2011).

Fitting criterion: The fitting criterion was a total likelihood approach in which total catch, the observed age compositions, and the patterns of the abundance indices were fit based on the assumed statistical error distribution and the level of assumed or measured error (see Section 6.1.4 below).

6.1.4 Weighting of Likelihoods

The likelihood components in the BAM model include separate bait and reduction landings, bait and reduction catch-at-age data, a PRFC CPUE pound net index, and a seine survey-derived JAI index. For each of these components a statistical error distribution was assumed as follows:

Likelihood Component	Error Distribution	Error Levels
Reduction Landings	Lognormal	Constant CV value equal to 0.03
Bait Landings	Lognormal	Constant CV value equal to 0.15 in early years and 0.05 in later years
Reduction Catch-at-Age	Multinomial	Annual number of trips sampled ranged from 278 to 1340
Bait Catch-at-Age	Multinomial	Annual number of trips sampled ranged from 1 to 100
PFRC Pound Net Index	Lognormal	Constant CV value equal to 0.5
Seine Survey JAI Index	Lognormal	Annual CV values from 0.14 to 1.38

No additional weights were applied to the likelihood components; the measured or assumed error levels formed the basis for the relative fit among the components.

6.1.5 Estimating Precision

The BAM model was implemented in the AD Model Builder software, which allowed for easy calculation of the inverse Hessian approximated precision measures. However, in this case where some key values were fixed (e.g., natural mortality), it is believed that precision measures from the inverse Hessian matrix are probably underestimates of the true precision. Instead, a parametric bootstrap procedure was used to estimate uncertainty. Input data sources were re-sampled using the measured or assumed statistical distribution and error levels in the table above. All the data sources in the table above were re-sampled in 2,000 bootstrap iterations.

The landings, JAI index, and PRFC index were all re-sampled using multiplicative lognormal error using the *CV*s specified in the model input for each respective component. Uncertainty in the landings and indices was applied using a parametric bootstrap. The age compositions were recreated for each year by distributing the number of fish sampled for each year to each age based on the probability observed.

6.2 Sensitivity Analyses

A total of five sensitivity runs and a retrospective analysis were completed with the BAM model. Sensitivity runs are represented by those involving input data and those involving changes to the model configuration.

6.2.1 Sensitivity to Input Data

Three sensitivity runs were conducted to examine various effects to changes in the input data. The following is a list of these sensitivity runs.

Run number	Sensitivity Examined
menhad-007	Omit the JAI index data
menhad-008	Omit the PRFC pound net index data
menhad-009	Effective N for reduction and bait fishery age compositions in all years was set to the median effective N calculated for each respective fishery

A sensitivity run with the JAI index data removed was performed (menhad-007), and a sensitivity run with the PRFC pound net index data removed was completed (menhad-008). Both of these sensitivity runs were completed in order to explore the model's behavior when a data source was removed. This helps to provide information on model response to a specific data source and aids in diagnosing the apparent data conflict between the two indices in the most recent years.

Additionally, a sensitivity run was completed where the effective sample size in each year was set at the median effective sample size from the base run for each fishery. This effectively down-weighted the age composition data in order to provide information on model response to this particular data source and addressed an important concern from the benchmark stock assessment review panel.

6.2.2 Sensitivity to Model Configuration

Two sensitivity runs were conducted to examine the effects of changes in the model configuration. The following is a list of these sensitivity runs.

Run number	Sensitivity Examined
menhad-003	Assumed and estimated dome-shaped selectivity in last time period (1994-2011) for the reduction fishery; bait fishery selectivity remained logistic
menhad-006	Assumed and estimated dome-shaped selectivity in last time period (1994-2011) for both the reduction and bait fisheries

The reduction fishery has experienced major changes over its history, most notably a steady decline in number of fish plants and vessels and also a contraction of geographic coverage. Currently, one reduction plant with about ten vessels operates at Reedville, VA. This contraction of the fishery may have had some effects on the shape of the selectivity applied to the reduction fishery in recent years. A sensitivity run was completed to allow for dome-shaped selectivity in the most recent time period (1994-2011) via the inclusion of a double-logistic selectivity function for the reduction fishery (menhad-003).

In previous stock assessments for Atlantic menhaden a dome-shaped selectivity function was applied to the bait fishery. This assumption was discussed and examined during the last benchmark assessment workshop in 2010. After comparison of age data between the reduction and bait fisheries, it was decided that the two fisheries should have similarly shaped selectivity functions. Thus for consistency with that finding, a sensitivity run was completed to allow for dome-shaped selectivity in the most recent time period (1994-2011) via the inclusion of a double-logistic selectivity function for both the reduction and bait fisheries (menhad-006).

6.2.3 Retrospective Analyses

Retrospective analyses were completed by running the BAM model in a series of runs sequentially omitting years 2011 to 2001, as indicated below:

Run number	**Sensitivity Examined**
menhad-010	Retrospective analysis with modeling ending in 2010
menhad-011	Retrospective analysis with modeling ending in 2009
menhad-012	Retrospective analysis with modeling ending in 2008
menhad-013	Retrospective analysis with modeling ending in 2007
menhad-014	Retrospective analysis with modeling ending in 2006
menhad-015	Retrospective analysis with modeling ending in 2005
menhad-016	Retrospective analysis with modeling ending in 2004
menhad-017	Retrospective analysis with modeling ending in 2003
menhad-018	Retrospective analysis with modeling ending in 2002
menhad-019	Retrospective analysis with modeling ending in 2001
menhad-020	Retrospective analysis with modeling ending in 2000

6.3 Reference Point Estimation – Parameterization, Uncertainty, and Sensitivity Analysis

Since the 2010 benchmark assessment, the Atlantic Menhaden Management Board adopted $F_{30\%}$ and $F_{15\%}$ as the menhaden management *F*-based overfishing target and threshold, respectively. *F*-based biological reference points were calculated in this update using average vectors from 1955-2011. The vectors used to calculate the *F*-based biological reference points included a vector of average fecundity, a vector of average M, and a catch weighted average selectivity vector.

The target and threshold population fecundity (SSB_{MED} and $SSB_{MED.T}$) reference points currently used for menhaden management were also calculated using the methods from the 2009 benchmark assessment. **However, the TC warns that there is a technical mismatch between the current overfishing and overfished reference points. See Appendix 3 for details concerning the mismatch and presentation of a more appropriate biomass-based reference point.**

7 Results of Base BAM Model

7.1 Goodness of Fit

Goodness-of-fit was governed in the BAM assessment model by the likelihood components in the objective function (Table 11). The relative fit among the likelihood components was governed by the error levels for each data source (see section 6.1.4). During the assessment workshop, goodness of fit was also judged for each data source through examination of the model residuals. No adjustments were made to the error levels of the data sources or to the external weights for the likelihood components. They remained fixed at the levels applied during the 2010 benchmark stock assessment.

Observed and model-predicted landings for the reduction fishery (1955–2011; Figure 6) and the bait fishery (1985–2011; Figure 7) were compared for the base model run. Reduction fishery landings, which are known fairly precisely, fit very well. The more poorly estimated bait landings show some deviations, but overall represent a good fit. Commercial reduction and commercial bait landings fit similarly during the last benchmark assessment in 2010 and this update assessment (Figure 8, Figure 9). Patterns in the annual comparisons of observed and predicted proportion catch-at-age for the reduction fishery (Figure 10) indicate a good overall model fit to the observed data. The bubble plot for the reduction fishery (Figure 11) indicates that the model fit overestimates age-0 in the most recent years. Patterns in annual comparisons of observed and predicted proportion catch-at-age for the bait fishery and associated bubble plots (Figure 12, Figure 13) indicate a good overall model fit to the observed data. Fits to the age composition data were similar between the last benchmark and current update assessment (Figure 14, Figure 15).

Observed and predicted coastwide juvenile abundance indices were compared for the base model run (1959–2011; Figure 16). The residual pattern suggests that the JAI index data did not fit well in years prior to 1978 as compared to the most recent years. Visual examination of the fit suggests that the overall pattern fit reasonably well, with the BAM model capturing the observed index values for the low-high-low recruitment pattern suggested for the years 1959-1973, 1974-1986, and 1987-2011, respectively. Fits to the observed JAI data were very similar between the last benchmark assessment in 2010 and the current update assessment with the largest differences in fit occurring during the most recent couple of years (Figure 17).

The observed and predicted PRFC pound net CPUE index (1964–2011; Figure 18) values do not fit as well as the JAI index values. The pattern of fit is similar in that the general high-low patterns are captured, but the relative fit within the time series is better in the early years and worse in the most recent years. The model estimates smaller numbers of fish in all but one of the last 13 years compared to the relative index values. Fits to the observed PRFC data were similar between the last benchmark assessment in 2010 and the current update assessment with the largest differences in fit occurring during the early 1980s and during the most recent couple of years (Figure 19).

7.2 Parameter Estimates

7.2.1 Selectivities and Catchability

Fishing mortality was related to an overall level of fishing and the selectivity (or availability) of menhaden to the two fisheries (reduction and bait). For both fisheries time invariant, two-parameter logistic functions were applied. Model estimates of selectivity (availability) for these fisheries were compared graphically in Figure 20 and Figure 21. The results for both fisheries suggest very similar estimates of selectivity, with age-4 almost fully selected and age-5 and older fully selected. The biggest differences are in the amount of age-1 and age-2 fish that are selected. The reduction fishery selectivity estimates a higher proportion of age-1 and -2 fish available for capture compared to the bait fishery. The selectivities estimated for this update assessment were similar to the selectivities estimated during the last benchmark assessment for the commercial reduction fishery (Figure 22) and were slightly different for the commercial bait fishery with small increases in the selectivity of age 2 and 3 fish (Figure 23).

The base BAM model estimates a single, constant catchability parameter for each of the abundance indices, reflecting the assumption that catchability for these CPUE indices is believed to be constant through time. This seems to be a reasonably good assumption for the fishery-independent JAI abundance index since it is based on consistent, scientific survey collections, albeit the surveys are at fixed shore stations and ostensibly target other species. For the fishery-dependent PRFC pound net index, a sensitivity run was completed during the 2010 benchmark assessment in order to examine a random walk process in catchability. The results of the sensitivity run completed during the 2010 benchmark assessment were stable with changes in catchability for the PRFC index, and thus the constant catchability assumption was upheld. Therefore, a sensitivity run exploring changes in selectivity was not redone for this update assessment.

7.2.2 Exploitation Rates

Total full fishing mortality rates were estimated within BAM (Figure 24, Figure 25). Highly variable fishing mortalities were noted throughout the entire time series, with a slight decline in fishing mortality from the mid-1960s to the early 1980s. Since the mid-1980s the fishing mortality rate has been quite variable, ranging between some of the highest and lowest values in the entire time series. The fishery-specific full fishing mortality rates are shown in Table 12, Figure 26, and Figure 27. The estimates suggest a high degree of variability, but in general the reduction fishery has experienced declining fishing mortality rates since the mid-1960s, while the bait fishery has experienced increasing fishing mortality rates since the 1980s (Table 12, Table 13). However, reduction fishery fishing mortality rate has risen in the last two years of the assessment (2010-2011). The total full fishing mortality rate and the fishery-specific full fishing mortality rates estimated for the update assessment were very similar to the full fishing mortality rates estimated from the 2010 benchmark assessment (Figure 28, Figure 29, Figure 30). Finally, F rates can vary substantially among age groups (Table 14). Selectivity on age-1 is small, greater on age-2, almost fully selected at age-3, and generally fully selected at older ages.

7.2.3 Abundance, Fecundity, and Recruitment Estimates

The base BAM model estimated population numbers-at-age (ages 0-8) for 1955–2011 (Table 15, Figure 31). From these estimates, along with growth and reproductive data (Section 3), different estimates of reproductive capacity were computed. Addendum 1 adopted population fecundity as the preferred measure of reproductive output. Population fecundity (SSB, number of maturing ova) was variable, but in general declined from high levels in the late 1960s, increased through the 1990s, then declined through 2011. (Table 16, Figure 32). The largest values of population fecundity were present in 1955 and 1961, resulting from two very strong recruitment events in 1951 and 1958 as noted in earlier stock assessments (Ahrenholz et al. 1987; Vaughan and Smith 1988; Vaughan et al. 2002b; ASMFC 2004). Throughout the time series, the age-3 fish produced most of the total estimated number of eggs spawned annually (Figure 33).

Age-0 recruits of Atlantic menhaden (Figure 34, Table 17) were high during the late 1950s, especially the 1958 year-class. The annual estimated recruitment values are shown in Figure 35 and were similar to recruitment values estimated during the last benchmark assessment in 2010 (Figure 36). Recruitment was generally poor during the 1960s and high during the late 1970s and early 1980s. The late 1970 and early 1980s values are comparable to the late 1950s (with the exception of the extraordinary 1958 year-class). Generally low recruitment has occurred since the early 1990s. There is a hint of a potential long-term cycle from this historical pattern of recruitment, but not enough data are present to draw any conclusions regarding the underlying cause at this point (Figure 34, Figure 35, Figure 36). The most recent estimate for 2011 is quite low and likely to be modified in the future as more data from the cohort (age-1 in 2012, age-2 in 2013, etc.) are added to the analysis. The current estimate of recruits to age-0 in 2011 (4.03 billion) is the second lowest recruitment value for the entire time series.

A plot of the model-estimated fecundity (mature ova) to the recruits at age-0 indicated a weak relationship (Figure 37). Additional discussion on dynamics of recruit per egg is presented in ASMFC (2010) section 8.2.3. Figure 37 also shows the median recruitment and fecundity-per-recruit estimates which were used to determine the benchmarks for Atlantic menhaden during the last benchmark assessment in 2010 (see ASMFC 2010 for more details).

7.3 Sensitivity Analyses

The results of the five sensitivity runs suggest that the base BAM model is stable with respect to the induced changes for three of the runs (Figure 38, Figure 39, Figure 40, Figure 41, Figure 42, Figure 43). The largest changes in population estimates relative to base model estimates resulted from sensitivity runs involving effective sample size on the age composition data and the selectivity function for both the commercial reduction and bait fisheries from 1994-2011. These changes had the greatest effects on the fishing mortality, fecundity, and biomass estimates (Figure 38, Figure 40, Figure 41), as well as for the fit to the PRFC index (Figure 43). The recruitment estimates were very similar among sensitivity runs (Figure 39), and the fits to the JAI index was also similar among sensitivity runs (Figure 42).

The negative log likelihood for the base BAM model and the sensitivity runs are in Table 19.

The resulting benchmarks appeared to be stable for three of the explored sensitivity runs. The run which included median effective sample size on the age composition data had benchmarks that were slightly different (Table 18; also see Appendix 3). The benchmarks calculated for the sensitivity runs with dome-shaped selectivity functions for the commercial fisheries from 1994-2011 were not directly comparable due to selectivity differences.

7.3.1 Retrospective Analyses

Patterns and biases in the results of a retrospective analysis over time were apparent (Figure 44-Figure 53). The fishing mortality for the terminal year of the assessment was underestimated in the 2000-2005 period and overestimated in 2006-2011, indicating presence of retrospective bias. Results indicate that the terminal full fishing mortality rate is highly variable (Figure 44 and Figure 50) with Mohn's rho equaling 0.42 (Legault 2009). The bias in F estimates expressed as a ratio to the most recent (2011) run F estimates varied from -0.6 to 0.9 (Figure 50). The resulting recruitment, fecundity, and biomass showed consistent biases or patterns in opposite directions (Figure 45-Figure 47 and Figure 51-Figure 53). Mohn's rho equaled 1.17 for recruitment and 1.83 for fecundity. In addition, the fits to the JAI and PRFC indices also showed biases or patterns when completing the retrospective analyses (Figure 48, Figure 49).

The magnitude of stock status outcomes varied considerably in this set of retrospective model runs. In particular, the ratios of full fishing mortality in the terminal year to $F_{15\%}$ ranged from 0.5 to 3.36, to $F_{30\%}$ ranged from 1.06 to 7.11 (Table 18). In particular, the ratios of spawning stock biomass (fecundity) in the terminal year to $SSB_{MED.T}$ ranged from 1.23 to 6.42 within this range of retrospective runs (Table 18).

The negative log likelihood for the base BAM model and the retrospective runs are in Table 20.

7.4 Uncertainty Analysis

The parametric bootstrap procedure was run for 2,000 iterations. The resulting estimates from these runs have been summarized in Figure 24, Figure 32**,** Figure 34, Table 12, Table 16, and Table 17, showing the 90% confidence region. In general the bootstrap results suggest fairly symmetrical error distributions about the base run results.

7.5 Reference Point Results - Parameter Estimates and Sensitivity

The base BAM model estimates for current benchmarks and terminal year values are listed in Table 21 for benchmark calculation. **The base BAM model estimated the current stock status as not overfished ($SSB_{2011}/SSB_{threshold}$ > 1.0) and overfishing is occurring ($F_{2011}/F_{benchmark}$ > 1.0). Note that use of an SSB reference point that is appropriately matched to the currently adopted $F_{15\%}$ would change the overfished status (see Appendix 3).**

Fecundity-per-recruit and yield-per-recruit (mt) estimates as a function of total full fishing mortality rates are shown in Figure 54 and Figure 55 for benchmarks calculated using the years 1955-2011 (see also Appendix 3). These plots are offered as a reference for comparison between fishing mortality rates. For example, using the years 1955-2011 for benchmark calculation, the terminal year full fishing mortality rate estimate (F_{2011}) of 4.50 is below $F_{6\%}$ (Figure 54). The entire time series of full fishing mortality and fecundity relative to $F_{15\%}$ and $F_{30\%}$ based benchmarks are shown in Figure 56 and Figure 57 using the years 1955-2011 for benchmark calculation.

For additional sensitivity and uncertainty analyses, see Appendix 3.

8 Stock Status

Threshold reference points are the basis for determining stock status (i.e., whether overfishing is occurring or a stock is overfished). When the fishing mortality rate (*F*) exceeds the *F*-threshold, then overfishing is occurring. When the reproductive output (measured as spawning stock biomass or population fecundity) falls below the biomass-threshold, then the stock is overfished, meaning there is insufficient mature female biomass (SSB) or egg production (population fecundity) to replenish the stock.

8.1 History of Atlantic Menhaden Reference Points

8.1.1 Amendment 1 Benchmarks

The reference points in Amendment 1, adopted in 2001, were developed from the historic spawning stock per recruit (SSB/R) relationship. As such, F_{MED} was selected as $F_{threshold}$ (representing replacement level of stock, also known as F_{REP}) and was calculated by inverting the median value of R/SSB and comparing to the SSB/R curve following the method of Sissenwine and Shepherd (1987). The spawning stock biomass corresponding to $F_{threshold}$, was calculated as a product of median recruitment and SSB/R at F_{MED}, from equilibrium YPR analysis, which became the SSB_{target}. The threshold for SSB ($SSB_{threshold}$) was calculated to account for natural mortality [(1-*M*)*SSB-target, where *M*=0.45]. In Amendment 1, the F_{target} was based on F_{MAX} (maximum fishing mortality before the process of recruitment overfishing begins).

8.1.2 Addendum 1 Benchmarks

Based on the 2003 benchmark stock assessment for Atlantic menhaden, the benchmarks were modified by the ASMFC in Addendum 1 as recommended by the Technical Committee (ASMFC 2004). The TC recommended using population fecundity (number of maturing or ripe eggs; SSB) as a more direct measure of reproductive output of the population compared to the weight of mature females. For Atlantic menhaden, older menhaden release more eggs than younger menhaden per unit of female biomass. By using the number of eggs released, more reproductive importance is given to older fish in the population than accounted for simply by female biomass. They also recommended modifications to the fishing mortality (*F*) target and threshold. The TC recommended continued use of F_{MED} to represent F_{REP} as the $F_{threshold}$, but estimated it using fecundity per recruit rather the SSB per recruit. Because the analysis calculated an F_{MAX} (target) that was greater than F_{MED} (and may be infinite), they recommended instead that F_{target} be based on the 75^{th} percentile of observed SSB/R values. This approach was consistent with the approach used for the $F_{threshold}$. For biomass (or egg) benchmarks, the TC recommended following the approach of Amendment 1.

8.1.3 Addendum V Benchmarks

Addendum V, approved in November 2011, establishes a new interim fishing mortality threshold and target (based on maximum spawning potential or MSP) with the goal of increasing abundance, spawning stock biomass, and menhaden availability as a forage species. Recognizing that development of specific multispecies reference points to achieve this management objective might take several years, the Board began the process to develop and implement interim reference points. The Technical Committee was tasked with identifying ad-hoc reference point options that would support the approved management objective until a full investigation and evaluation of multispecies reference points could be conducted. One of the options was based on the concept of maximum spawning potential (MSP), and in November 2011, Addendum V was approved which established interim fishing mortality reference points based on MSP. The interim limit and target equate to 15% and 30% MSP, respectively. Thus, fishing mortality benchmarks of $F_{15\%}$ and $F_{30\%}$ MSP were calculated based on the fecundity per recruit analysis.

Addendum V made no changes to the biomass reference points. However, the TC recommends adoption of an SSB target and threshold that is more appropriate and consistent with the $F_{15\%}$ and $F_{30\%}$ approach (see Appendix 3).

8.2 Current Overfishing, Overfished/Depleted Definitions

The current overfishing definition is a fecundity-per-recruit threshold of $F_{15\%}$ and a target of $F_{30\%}$. The current fecundity-based overfished definition is a target of SSB_{MED} and a threshold of $SSB_{MED.T}$ (half of SSB_{MED}). Benchmarks are calculated using all years, 1955-2011.

8.3 Stock Status Determination

8.3.1 Overfishing Status

Full $F/F_{15\%}$ for the terminal year was greater than 1 (Table 21; Figure 56). Hence, based on this criterion, **overfishing is occurring**. The sensitivity runs, excluding the retrospective analysis, all suggest overfishing is occurring in the terminal year (Table 18), and all of the bootstrap runs completed for the uncertainty analysis result in a stock status of overfishing is occurring (see Appendix 3). Thus, the stock status seems stable for the model changes explored and the uncertainty specified during this update assessment. However, several issues raise concern about the status of the stock relative to this benchmark. First, a retrospective pattern has continued to result in potential bias in the estimation of F in the terminal year. Second, there is relatively large variation in F among years, and overfishing was occurring in almost all of the years used in this assessment (1955-2011). With respect to the target F, the stock has never been at or below target F.

8.3.2 Overfished Status

SSB/SSB_{limit} for the terminal year was greater than 1 (Table 21; Figure 58) Hence, based on this criterion, **the stock is not overfished**. The bootstrapped values of SSB for the most part fall into the region that is considered not to be overfished, although a small portion of the values do fall into the region that is considered to be overfished (see Appendix 3). None of the sensitivity runs suggest the stock is overfished (Table 18). Thus, the stock status seems stable for the model changes explored and the uncertainty specified during this update assessment. Note, however, that use of an SSB reference point that is appropriately matched to the currently adopted $F_{15\%}$ would change the overfished status (see Appendix 3).

8.3.3 Uncertainty

Uncertainty of the status of stock relative to the two benchmarks was investigated using several approaches. First, sensitivity runs were made to explore the effect on benchmarks by changes in assumptions from the base run (Table 18). While the sensitivity runs inform model behaviors, they should not be considered plausible runs. Next, sensitivity of the estimates was investigated based on a bootstrapped analysis within the BAM model (Figure 56, Figure 57, and Appendix 3). Stock status determination, based on the benchmarks as specified in Addendum I and Addendum V, seemed to be stable with respect to uncertainty.

Although the Technical Committee could not come to consensus on the utility of the terminal year point estimates of F and SSB for management advice, there was consensus that the status determinations were likely robust. In other words, the ratio of $F_{2011}/F_{15\%}$ is likely greater than 1.0 (overfishing is occurring), and $SSB_{2011}/ SSB_{MED.T}$ is likely greater than 1.0 (the stock is not overfished), but the exact magnitude of these ratios could not be determined. This statement in supported both quantitatively and qualitatively. Quantitatively, results of the sensitivity runs (albeit limited) and bootstrap analysis indicated the results of stock status were robust to uncertainty in the data and parameterization as specified in this update. Qualitatively, the 2009 benchmark stock assessment concluded that overfishing was occurring, and Addendum V reference points significantly reduced the overfishing threshold (from approximately $F_{8\%}$ to $F_{15\%}$). As harvest levels have increased since 2008 and there has been no significant increase in stock size, overfishing is still likely occurring.

9 Projections

Projections using constant landings scenarios were run in order to explore options to achieve 1) the fishing mortality threshold immediately and 2) the fishing mortality target over a range of 3, 5, and 10 years. Decisions regarding the structure and inputs for the projection analysis were discussed by the TC during a meeting on January 9, 2012. The brief documentation and methods below reflect those decisions; for further documentation see the resulting white paper (ASMFC 2012a).

9.1 Methods

Data inputs and outputs from the base run of BAM were used as the basis for all of the projections within this document. The starting conditions of the projection analysis included initial numbers-at-age, which were the estimated numbers-at-age at the end of 2011, N_a, from the bootstrap runs, which allowed for the inclusion of uncertainty. Recruitment was projected without an underlying stock-recruitment function and was based on the median recruitment from 1990-2010 estimated from the base run of BAM. Variability was incorporated into recruitment as a nonparametric bootstrap based on the annual deviations from the median in the base run of the BAM during the specified time period (1990-2010), which reflects variability in the more recent years. The median age varying natural mortality and weight vectors from 1990-2010 were projected into the future. Selectivity was constant across time for the base run of the BAM model and was thus constant in the projections. Selectivity was the weighted average selectivity from the bait and reduction fisheries.

Annual landings levels were input for the simulation and the annual fishing mortality rate, *F*, was solved for within the model. Commercial reduction and bait landings for 2012 were input as the mean of the landings from 2009-2011. Starting in 2013, management was instituted with a constant level of total landings, which was projected for several years. Total projected landings included 75, 100, 125, 150, 175, 200, and 225 thousand metric tons. Total landings were allocated such that 75% were allocated to the reduction fishery and 25% were allocated to the bait fishery. This allocation was based on the proportion of bait landings to the total coastwide landings of Atlantic menhaden for the most recent years. The allocation presented here (75:25) is for illustrative purposes only; the question of future allocations between the reduction and bait fisheries is a question that managers will need to address and provide guidance to the TC.

Each constant landings scenario was repeated 2,000 times. Outputs included the median and 5^{th} and 95^{th} percentiles for spawning stock size (ova), *F*, recruitment, and landings over time. Spawning stock size for each year was the sum of the number of fish at each age times the vector of median age-specific reproductive values from 1990-2010. The reproductive vector was the product of the proportion female, the maturity vector, and the median fecundity vector. Landings (1,000s mt) over time was a model input, as discussed above. Additional outputs included the probability of *F* being less than the specified target of 0.62 and less than the specified threshold of 1.34 over time given the constant landings input.

9.2 Results

As expected, the higher the landings, the lower the probability of *F* being less than the threshold and target (Table 22, Table 23). However, the range in *F* was fairly broad for a given level of constant landings (Figure 59 - Figure 72). At the low end of fixed landings considered (75,000 and 100,000 mt) the fishing mortality rapidly declines and the probability of 100% for F being below overfishing limit is achieved by the year 2016 or 2017. The rate of decline in F slows down and the range of possible F values for a given year increases as the amount of constant landings goes up. In some cases, the *F* could not be estimated or was estimated at an extremely high value, sometimes even hitting the bound of 25. In the scenarios with landings equaling 225,000 mt, the F often reached a bound, but still could not produce 225,000 mt in landings, indicating that the stock is unable to sustain this level of landings under the assumed stock productivity parameters (selected variability in recruitment, growth and natural mortality).

There is an overall general trend of rise in population fecundity through time, which varies from tenfold increase of median fecundity estimate at 75,000 mt constant landings to less than two fold increase at 225,000 mt constant annual landings.

Variability in recruitment was a major driving factor for these projections and was one of the most uncertain components of the projections. The recruitment uncertainty carried through all of the results.

9.3 Important notes to managers

These projections are only presented as an example of possible outcomes. They do not account for all possible sources of uncertainty and are primarily intended to show long term effects of constant catch policy. Furthermore, when projections are used to determine what level of landings would be appropriate to reduce overfishing, the Atlantic Menhaden Management Board needs to determine the acceptable level of risk (% probability of F being over the limit) because the projections provide an estimate of a chance for the variable to be of certain value, rather than the exact number for each year. In addition, the Atlantic Menhaden Management Board needs to decide how landings will be allocated between the reduction and bait fisheries, a decision may impact the estimated *F* for a given constant landings value.

The retrospective pattern observed during this update assessment suggests that the results from the assessment may be biased, thus projection results, which start with terminal year estimates from the assessment, may also be biased. However, the significance of such bias for projections results has not been investigated yet by the Technical Committee. If the projections are biased, then the Atlantic Menhaden Management Board should be cautious when using this for management advice, especially if providing values for quotas for the fisheries.

All results from this analysis are conditional on the assumptions made about management implementation uncertainty. Management uncertainty was assumed to be zero because no information is available for the Atlantic menhaden fishery on this type of uncertainty. If the assumption of zero uncertainty is violated, there may be effects on the projection results. The effect of management uncertainty will depend on the ability of management to maintain the limits on harvest or mortality rates within the chosen range.

It is important to note that the projections included many sources of uncertainty and their cumulative effects are represented by the wide range of possible values of F, SSB and other parameters that are illustrated on projection graphs by the upper (95% of observed values) and lower (5%) limits. It is important to keep in mind that although the general trend of expected population dynamics is generally described by the median values, the actual values for each projected year could fall anywhere in the range shown. Therefore the actual trajectory of SSB, for example, is likely to look like a series of ups and downs within the estimated range rather than a steady rise or decline as shown by the median curve.

In addition, these projections did not include structural uncertainty. Structural uncertainty means that results are conditional on the functional forms and assumptions made regarding population dynamics, selectivity, recruitment, etc. The major source of the uncertainty in the projection is recruitment. Projections were based on assumption that 1) recruitment variability for the projected period will remain similar to that observed during last two decades, and 2) there is no functional relationship between the stock size and recruitment within the range of both metrics observed during selected period. The introduction of formal stock recruitment function into the recruitment forecasting procedure may affect stock trajectories, in particular the rate of population growth when starting with low spawning biomass, but will not affect the possible range of recruitment. Another assumption adding to the overall uncertainty is the shape of the fishery-weighted selectivity over time. If allocations between the two fisheries are different in the future, the weighted selectivity vector will also be different and projection results will be affected.

10 Issues and Concerns for Management

The CIE review panel of the 2010 benchmark stock assessment raised some concerns not addressed during an update stock assessment. Therefore, several important criticisms of the 2010 benchmark stock assessment continue to apply to this update assessment. They include the following:

1. Overweighting of the age composition data.
2. Lack of spatial modeling to address changes in the fishery over time.
3. Lack of a coastwide adult abundance index.

In addition, two model performance issues mentioned during the 2010 benchmark assessment have subsequently worsened and have become a serious concern for this update, namely:

4. Poor fit to the PRFC index.
5. Strong retrospective pattern.

These unaddressed criticisms and issues make interpreting the results of this stock assessment update challenging.

In order to address Criticism 1, overweighting of the age composition data, a sensitivity run with lower sample sizes for the age composition data was completed, effectively down weighting the age composition data. This run resulted in lower F and higher SSB estimates compared to the base run; however, down weighting the age composition data did not substantially improve the model fits to the JAI or PRFC indices, suggesting that other likelihood components may also be improperly weighted and/or the indices are not truly representative of the population. The timeframe for the update assessment was insufficient to address these uncertainties. The direction and magnitude of bias in the results remains unknown.

Criticism (2) above, lack of spatial modeling, is probably the most important criticism with respect to management advice. The trend we have seen over the whole time series for the menhaden reduction fishery is one of spatial contraction of the range of the fishery and decrease in landings. Menhaden do exhibit an age/size stratification during summer in which the larger and older fish tend to migrate farther north relative to their smaller and younger counterparts that stay farther south along the Atlantic coast (Nicholson 1972; Nicholson 1978; Ahrenholz 1991). The reduction fishery operates solely out of Virginia, ranging north to New Jersey and south to Cape Hatteras; thus, the larger and older fish occurring north of about Long Island, NY, are unavailable to the reduction fishery. When this type of availability pattern occurs it is often modeled using a dome-shaped selectivity function. However, the bait fishery has had increasing catches, particularly in recent years and mostly off the New Jersey coast. While there is some suggestion of a dome-shaped selectivity in the bait fishery based in Chesapeake Bay and adjacent waters, a logistic shaped selectivity maybe more appropriate for the bait fishery in the Mid-Atlantic and New England.

The 2010 benchmark assessment review panel recommended modeling the population via a northern and southern fishery with a spatial break somewhere along the Delmarva Peninsula. The reviewers further recommended allowing for dome-shaped selectivity in the southern fishery. Because this analysis was limited to a strict update assessment, the two-area feature was not incorporated into the model at this time. However, a sensitivity run was completed allowing a freely estimated, dome-shaped selectivity curve for both the reduction and bait fisheries after 1994, when the coastwide fishery spatially contracted. Imposing a dome-shaped selectivity curve would generally reduce estimated fishing mortality rates and subsequently increase SSB, as this sensitivity run indicates; however, this particular sensitivity run produced unrealistic estimates (especially, time-series high SSB estimates) that were considered implausible by the technical committee. Although the direction of the bias is not unexpected, the magnitude of the bias is still unknown and additional work is needed during the benchmark assessment to align the spatial structure of the model with that of the stock and fishery.

Criticism (3) above, lack of a coastwide adult index of abundance, is an ongoing, serious problem for this stock assessment. As a result of not having a coastwide abundance index, we are forced to seek out more spatially limited measures of adult abundance (e.g., the PRFC pound net index). This leads to issue (4) above, the poor fit of the PRFC index. The update assessment model appears to be insensitive to the only adult index that informs the model, at least in recent years. The upward trend in the PRFC pound net index in the last few years is not matched by the model derived index and is in conflict with the trend seen in the coastwide GLM based JAI index.

An additional concern raised during the evaluation of the update stock assessment model was the presence of a strong retrospective pattern in F and SSB, issue (5) above. An underestimation of F and overestimation of SSB was evident during the 2010 benchmark stock assessment; however, these patterns became worrisome during this update when a switch in direction of the pattern was observed (such that F was overestimated and SSB underestimated in recent years), and when the pattern did not disappear with additional years of data. The strong retrospective pattern suggests that this model is not robust to addition of new data. The results suggest that terminal year fishing mortality may be overestimated and that fecundity and biomass may be underestimated. It is unclear exactly what is causing this retrospective pattern, but it appears that some data sources have developed discordance since 2003.

Overall, the five criticisms indicated above cast considerable doubt on the accuracy of the estimates from this update stock assessment. Retrospective analysis suggested that in the last 5-6 years fishing mortality and overfishing status may be biased high, while fecundity and overfished status may be biased low. Two sensitivity runs (reduced effective sample size and dome-shaped selectivity) also produced lower estimates of fishing mortality and higher estimates of fecundity than the base and other sensitivity runs. However, the base run and three sensitivity analyses produced similar estimates of recruitment, population size, biomass, fecundity, and fishing mortality across the historical time series (back to 1955), indicating these results were not affected by the changes explored in those specific sensitivity runs. Note that the sensitivity runs conducted for this update assessment were not intended to be an exhaustive array of investigations, rather a select set to identify and characterize important sources of uncertainty.

Regarding stock status, the TC notes that the overfished status reported here is based on the current $SSB_{MED.T}$ reference point adopted by the FMP. However, there is a theoretical mismatch between the $F_{15\%}$ overfishing definition recently adopted by the Board and the $SSB_{MED.T}$ in the FMP. The TC recommends that if the Board wishes to adopt an $F_{15\%}$ overfishing definition, that a matching overfished definition ($SSB_{15\%}$) be adopted as well. In addition, although MSP based reference points were identified as a viable interim option by the Technical Committee, the TC wants to point out that selected reference points were not designated to achieve a specific management goal.

Although the Technical Committee could not come to consensus on the utility of the terminal year point estimates of F and SSB for management advice, there was consensus that the status determinations were likely robust. In other words, the ratio of $F_{2011}/F_{15\%}$ is likely greater than 1.0 (overfishing is occurring), and $SSB_{2011}/ SSB_{MED.T}$ is likely greater than 1.0 (the stock is not overfished), but the exact magnitude of these ratios could not be determined. This statement in supported both quantitatively and qualitatively. Quantitatively, results of the sensitivity runs (albeit limited) and bootstrap analysis indicated the results of stock status were robust to uncertainty in the data and parameterization as specified in this update. Qualitatively, the 2009 benchmark stock assessment concluded that overfishing was occurring, and Addendum V reference points significantly reduced the overfishing threshold (from approximately $F_{8\%}$ to $F_{15\%}$). As harvest levels have increased since 2008 and there has been no significant increase in stock size, overfishing is still likely occurring.

The Technical Committee concluded that projections based on the current assessment are likely biased because of 1) the observed retrospective pattern, and 2) the lack of feedback between stock size and recruitment. The observed retrospective pattern suggests that the terminal year results from the assessment, and therefore the starting values for the projection may be biased, thus projection results may also be biased. Additionally, the TC made the assumption that recruitment was constant with some variability, and thus there is no feedback from stock size to the number of recruits. The rate of increase over time presented in the projection results is therefore influenced by this assumption, as is the probability of being over the threshold and limit reference points. This assumption of constant recruitment into the future is unrealistic for an r-selected, environmentally driven species like Atlantic menhaden. The Technical Committee concluded that, given these limitations, the projection results provide information on stock response given harvest reductions but should not be used to establish harvest limits for the fishery. As an alternative to using projections to set harvest limits, the Technical Committee has compiled the default “rules” used by several regional Fishery Management Councils on how harvest limits are set in data poor situations (Appendix 4). It should be noted that, at this time, these are provided only as information for the Management Board; the Technical Committee has not had time to review these as a group to determine which (if any) would be appropriate for use in managing the Atlantic menhaden stock.

The TC warns that additional data analysis and modeling work are necessary to resolve these model performance issues. Some of the criticisms (e.g., # 3 above) cannot be addressed without additional, long-term data collection programs; others could potentially be addressed through improvements to the base assessment model. An expedited benchmark assessment during which the TC can more fully examine many of the issues raised above is warranted.

11 Research and Modeling Recommendations for Benchmark

Recommendations from the 2010 and 2012 Assessments

Many of the research and modeling recommendations from the last benchmark stock assessment remain relevant for this update stock assessment. Research recommendations are broken down into two categories: data and modeling. While all recommendations are high priority, the first recommendation is the highest priority. Each category is further broken down into recommendations that can be completed in the short term and recommendations that will require long term commitment.

<u>Annual Data Collection</u>

Long term:

1. **[Highest Priority]** Develop a coastwide fishery independent index of adult abundance at age to replace or augment the existing Potomac River pound net index in the model. Possible methodologies include an air spotter survey, or an industry-based survey with scientific observers on board collecting the data. In all cases, a sound statistical design is essential (involve statisticians in the development and review of the design; some trial surveys may be necessary). **NOTE:** An industry funded feasibility study conducted in 2011 further supported the need for this work (Sulikowski et al 2012). A subcommittee of the Menhaden Technical Committee began discussions for development of a coastwide aerial survey in 2008. At the time of this update assessment, a contract has been awarded to develop the survey design, with results expected by the end of 2012. The Technical Committee is in consensus that an index of adult abundance is the highest priority research recommendation but recognizes that implementation of the survey will require significant levels of funding.
2. Work with industry to collect age structure data outside the range of the fishery.
3. Validate MSVPA model parameters through the development and implementation of stomach sampling program that will cover major menhaden predators along the Atlantic coast. Validation of prey preferences, size selectivity and spatial overlap is critically important to the appropriate use of MSVPA model results.

Short term:

1. Continue current level of sampling from bait fisheries, particularly in the mid-Atlantic and New England.
2. Investigate interannual maturity variability via collection of annual samples of mature fish along the Atlantic coast.

3. Recover historical tagging data from paper data sheets.
4. Continue annual sampling of menhaden from the PRFC pound net fishery to better characterize age and size structure of catch.
5. Compare age composition of PRFC catch with the age composition of the reduction bait fishery catch in Chesapeake Bay. Upon completion of comparative analysis develop most efficient and representative method of sampling for age structure.
6. Consider developing an adult index, similar to PRFC CPUE index, using MD, VA, NJ and RI pound net information.
7. Explore additional sources of information that could be used as additional indices of abundance for juvenile and adult menhaden (ichthyoplankton surveys, NEAMAP, etc.).

<u>Assessment Methodology</u>

Long term:

1. Develop a spatially-explicit model, once sufficient age-specific data on movement rates of menhaden are available.
2. Develop multispecies statistical catch-at-age model to estimate menhaden natural mortality at age.

Short term:

1. Thoroughly explore causes of retrospective pattern in model results.
2. Explore alternative treatments of the reduction and bait fleets (e.g., spatial split, alternative selectivity configurations) in the BAM to reflect latitudinal variability in menhaden biology (larger and older fish migrating farther north during summer).
3. Review underlying data and evaluate generation of JAI and PRFC indices.
4. Perform likelihood profiling analysis to guide model selection decision-making.
5. Examine the variance assumptions and weighting factors of all the likelihood components in the model.
6. Re-evaluate menhaden natural mortality-at-age and population response to changing predator populations by updating and augmenting the MSVPA (e.g., add additional predator, prey, and diet data when available).
7. Incorporate maturity-at-age variability in the assessment model.

<u>Future Research</u>

1. Evaluate productivity of different estuaries (e.g., replicate similar methodology to Ahrenholz et al. 1987).
2. Collect age-specific data on movement rates of menhaden to develop regional abundance trends.
3. Determine selectivity of PRFC pound nets.
4. Update information on maturity, fecundity, spatial and temporal patterns of spawning and larval survivorship.
5. Investigate the effects of global climate change on distribution, movement, and behavior of menhaden.

12 Recommendations from the 2010 Peer Review Panel

The Review Panel of the last benchmark stock assessment had additional short and long term research recommendations which are detailed below. The short- and long-term recommendations are in order of priority.

Short term (improvements for the next benchmark review)

a. The Panel recommends that future model specifications include a capped effective sample size at 200, allow the gaps in the pound net index and bait fishery age composition where data are not available, modify the reduction and bait fleets to northern and southern fleets, and allow time-varying domed shaped selectivity for the southern region.
b. Fishing mortality should be calculated as full F. The N-weighted fishing mortalities relative to the N-weighted F-reference points do not provide correct interpretation with regard to overfishing.
c. The Panel has concerns about the use of F_{MED} and the fecundity associated with it as reference points. The concern is that there was no information on the relationship of the target and threshold fecundity in relation to virgin fecundity levels. Recommend examination of alternative reference points which provide more protection to SSB or fecundity than F_{MED}.
d. Examine weighting of datasets in the model. As a starting point, some experts assert that the input variance assumptions should be consistent with the estimated variance of residuals. In the base model the effective sample sizes for catch-at-age data are far too high and consequently estimates of uncertainty are too low.
e. The Panel recommends the Assessment Team's alternative use of the juvenile indices: combining relative abundance data from groups of adjacent states according to the similarity of trends in the state-specific time series; and cumulatively-combining these indices within the model. This allows for different regional patterns of recruitment to provide a stock-wide recruitment pattern.
f. Examine the timing of fisheries and indices in the model. Many of the fisheries are seasonal and need to be timed appropriately with the abundance indices. Incorrect timing may affect model fits.

Long Term

a. Develop a coast-wide adult menhaden survey. Possible methodologies include an airspotter survey, a hydro-acoustic survey, or an industry-based survey with scientific observers on board collecting the data. In all cases, a sound statistical design is essential (involve statisticians in the development and review of the design; some pilot surveys may be necessary).

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14 Tables

Table 1. Fork length (mm) at age on March 1 (beginning of fishing year) estimated from year class von Bertalanffy growth parameters.

Year	0	1	2	3	4	5	6	7	8
1955	110.6	158.6	222.1	264.5	277.7	296.5	296.1	322.1	289.7
1956	92.3	149.9	222.5	269.6	289.9	302.3	312.5	323.1	334.7
1957	119.7	138.5	211.2	265.4	298	307.9	317.4	322.6	323.3
1958	95.1	155.1	207.6	254.9	294.2	315	320.5	326.8	329
1959	140	132.9	211.8	254.2	286.1	313.6	325.2	329.4	332.6
1960	104.4	169.9	195	253.8	285.5	308.3	326.6	331.3	335.7
1961	126.2	151.9	220.5	242.5	284.9	306.7	324.2	335.3	334.9
1962	130.5	163.9	220.6	261	278.9	308	320.9	335.4	341.2
1963	136	169.4	219.5	264.7	293.4	306.7	325	330.5	343.5
1964	138.5	171.7	225.4	256.4	293.1	319.2	328	337.7	337
1965	130.8	172.4	225.9	261.1	280.7	311.3	339.9	344.3	347.1
1966	137.2	162.4	227.2	263.2	283.9	296.9	322.9	356.5	356.8
1967	143.2	176	217.1	268.2	288.9	298.5	307.6	330.4	369.7
1968	149.9	168.7	234.7	262.1	298.8	306.6	307.8	314.6	335.3
1969	144.5	175.5	216.2	274.9	299	321.7	318.8	313.7	319.3
1970	122.8	183.2	221.9	259.6	302.5	329.4	338.9	327.2	317.5
1971	123.5	173	243.1	262.8	299.1	321.4	354.3	351.7	332.9
1972	82	161.1	241.7	285.3	298.8	335.1	334.4	374.8	361.3
1973	116.7	144.6	220.9	282.8	315.1	330.5	367.9	343.2	391.7
1974	101.7	152.2	221.9	264.7	307.3	336	358.3	397.9	349.3
1975	104.3	139.1	207.5	261.8	296.9	322	350.8	382.9	425.1
1976	84.3	133.1	196.8	246.8	282.4	320.5	330.7	361.3	404.5
1977	91.1	123.4	181.9	237.6	274.7	293.1	337.7	335.9	368.6
1978	107.6	127.9	184.2	220.9	266.4	294.6	298.6	350.4	339.1
1979	104.9	134.8	186.3	227.4	252.1	286.7	308.7	301.4	359.7
1980	92.7	127.9	181	229.1	258.2	277.1	301.1	318.8	302.8
1981	88.5	129.1	170.1	218.4	260.6	280	297.1	311.2	326
1982	99	128.6	186.2	207.6	248.5	283.6	295.5	313.1	318.3
1983	110.9	131.9	190.1	227.4	241	272.9	300.5	306.5	325.9
1984	97	136	185.9	232.9	257	270.7	292.5	312.9	314.4
1985	93.3	130.3	180.2	227.1	262.7	278.3	297.1	308.4	322
1986	98.3	128.1	183.5	217.4	258.7	283.4	293.7	320.6	321.2
1987	101.2	133.7	183	222.8	248.8	282.8	297.8	304.7	341.6
1988	95.8	132.6	188.2	222.9	251.9	275.2	301.3	307.8	312.7
1989	114	140.4	184	226.5	251.7	273.3	297.5	315.5	314.8
1990	114.7	155.4	204.2	223.2	253.3	272.7	289.1	316.2	326.3

Table 1. (*continued*).

Year	0	1	2	3	4	5	6	7	8
1991	127.3	148	213.5	244.6	253.1	272.1	287.9	300.8	332
1992	101.8	164.4	200.7	249.3	270.2	276	285.3	299	309.4
1993	127.2	142.8	219.4	239.2	271.4	286.3	293.4	294.5	307
1994	84.5	162.3	206.1	256	267.2	285	296.6	306.7	301
1995	86.9	144.3	217.1	250.7	280.4	287.7	293.5	303	316.8
1996	76.3	138.1	224.6	256.1	282.2	296.6	302.6	298.6	307.1
1997	101.2	130.4	211.9	271.1	284	304.3	307.4	313.5	301.8
1998	137.3	142.3	206.7	259.4	298.1	304	319.9	314.6	321.5
1999	107.8	169.5	206.1	254	289.9	313.7	318.2	330.8	319.4
2000	87	158.9	222.3	251.5	283.5	309.4	322.7	328.3	338.6
2001	125.1	149.2	228.9	262.5	283.8	301.8	322	328	335.5
2002	108.2	170	227.6	270.5	293.2	306.9	313.2	330.1	331
2003	125	153.7	226.7	269.3	295.3	316.7	323.3	320.3	335.3
2004	91.9	159.1	216.6	257	291.4	310.1	334.5	334.9	324.7
2005	103.9	137.2	211.9	254.6	273.2	303.2	318.9	348.2	343.3
2006	113.1	151.7	201.3	249.3	277.6	281.9	309.4	324.2	358.6
2007	126.2	160.2	214.7	241.5	275.7	291.6	286.5	312.7	327.3
2008	139.4	166.8	221.6	250.4	266.6	294.5	300	289	314.5
2009	118.2	165.3	221.2	255.7	270.6	282.3	307.7	305.1	290.3
2010		171	210.4	252.6	274.7	282.1	292.1	317.1	308.2
2011			219.4	247.7	270.7	285.3	288.6	298.2	323.8

Table 2. Weight (g) at age on September 1 (middle of fishing year) estimated from annual weight-length parameters and annual lengths at age.

Year	0	1	2	3	4	5	6	7	8
1955	21.2	66.1	191.5	332.3	387.5	476.8	474.8	618.8	442.8
1956	12	55.8	194.2	356.7	448.7	511.9	568.6	631.7	706.1
1957	25.9	41.6	163.5	342.6	499.2	554.5	612.4	645.4	649.8
1958	12.4	61.2	158.6	310	494.6	618.3	654.1	697	712.8
1959	43.1	36.4	166.3	301.5	443.6	598.2	673.6	702.6	724.9
1960	15.7	79.6	126.2	303.5	449.5	580.6	703.2	737.4	770.8
1961	29.7	55.1	190	260.8	445.3	568.6	683.7	765.1	762
1962	38.3	77.2	193.1	324.1	397.6	539.8	612.8	702.6	740.3
1963	42.1	85	194.3	353.4	490.5	565.4	680.6	717.7	811.8
1964	45.9	90.8	215.1	323.4	494.2	648.1	706.2	774.5	769.1
1965	36.5	88.2	209	332.1	418.4	581.6	770.7	802.7	823.6
1966	43.5	73.5	208.7	329.8	417.4	479.5	622.8	847	849.1
1967	47	91.6	180.8	358.2	455.9	506.7	558.3	704.2	1013.1
1968	57.4	83.5	238.3	338.3	513.2	557	563.9	604.7	739.7
1969	55	101.8	197.4	422.2	550.8	694.6	674.7	641.4	678.3
1970	31.6	111	202.5	331.2	535.5	699.4	764.7	684.9	623.4
1971	32.2	90.9	259	329.3	490.3	611.9	826.2	807.4	682.1
1972	8.4	69.4	247	414.9	479.4	686.5	681.7	974.8	868.6
1973	27.5	52.9	193.1	410.7	571.3	661	917.6	742.2	1110.9
1974	16.5	58.7	192.3	334.8	535.4	709.2	868.1	1206.4	801.3
1975	17.8	44.3	157.5	329.6	490.8	634.8	833.5	1099.7	1532.6
1976	8.5	37.8	135.8	284.2	441.7	667.1	739.5	986.9	1427.3
1977	10.8	29.4	106.1	256.9	415.2	514.2	822.2	807.9	1098.2
1978	19.1	33.5	110.4	199.7	368.2	511.4	534.1	901.3	809.4
1979	17.5	39.8	115.1	221.4	310.3	473	602.7	556.9	994.5
1980	11.8	33.9	105.6	228.7	338	426.4	559.6	675	570.4
1981	9.7	33.6	83.4	190.1	340.4	431.6	524.9	611.6	712.6
1982	16.2	36.9	117.7	165.5	291.2	440.7	501.4	601.3	633.4
1983	22.3	38.3	119.6	208.9	250.4	369	498.6	530.2	642
1984	15.4	44.1	116.9	236.4	321.4	377.9	481.5	594.3	602.8
1985	13	36.8	101.2	208.4	328.1	393	482	541.5	619.8
1986	13.9	32.7	105.2	182.3	320.4	430.7	483.5	643	646.8
1987	16.6	40.1	108.1	201.4	285.3	427.8	503.5	541.5	776.6
1988	13.9	38.5	115.2	195.3	286.2	377.6	501.3	535.9	562.8
1989	21.9	43.5	105.5	208.6	295.3	386.6	510.6	619.2	615
1990	22.6	60.9	148.3	198.1	299.2	380.7	460.5	616.7	683.1

Table 2. (*continued*)

Year	0	1	2	3	4	5	6	7	8
1991	33.2	53.4	168.9	259.2	288.7	362.5	433	497	677.9
1992	15.3	71.5	135.9	272.7	353	378	420.6	488.9	546.2
1993	32.5	47	184.2	242.5	362.5	429.8	464.4	470.3	536.3
1994	8.3	69	149.5	301.5	346.5	427	485.4	541.1	509.6
1995	9.6	47.5	171.4	269.7	383.3	415.7	442.4	489.4	562.9
1996	6	41.5	201.3	308.5	422.2	496.7	530.1	507.8	556.1
1997	15.5	35.1	168.8	374.3	435.2	543.7	562.1	599	529.7
1998	41.8	46.8	154.5	319.4	498	530.2	624.2	592.1	634.2
1999	19.1	80.5	149.5	290.7	441.9	567.7	593.9	672.4	601.5
2000	9.6	65.1	188.6	279	407.9	538.4	615.2	649.6	716.2
2001	31.8	54.9	207.1	317.3	404.3	489.2	598.2	633.3	679.8
2002	21.8	87	213.1	361.6	463.1	532.3	566.7	665.6	671.3
2003	32.3	62.6	218.1	379.1	509.8	637.8	681.5	661.5	766.2
2004	12.3	67.9	177.8	303.4	449.1	545.2	690.7	693.3	629.1
2005	19.1	44.1	162.9	283	349.9	478.4	557	725.2	694.9
2006	23.5	58.3	139.8	270.4	377.3	395.4	527.5	609	831.7
2007	35	70.8	168.1	237.5	351.3	414.2	393.3	509.4	582.5
2008	46.4	79.6	187.1	270.4	326.3	440.3	465.7	416	536.9
2009	27.3	75.4	181.9	282.3	335.1	380.6	494.2	481.6	414.3
2010	26	83.3	156.8	273.9	354	383.9	427	548.9	503
2011	25.2	62.6	175.4	254.8	334.9	393.5	407.6	451.2	581

Table 3. Weight (g) at age on September 1 (middle of fishing year) estimated from annual weight-length parameters and annual lengths.

Year	0	1	2	3	4	5	6	7	8
1955	36.2	124.3	274.3	390.3	451.5	523.3	610.8	681.9	674.8
1956	25.2	105.1	267.1	428.1	498.1	558.8	601.7	633	710.4
1957	41.2	91.3	230.8	413.4	553.1	595.6	645.8	668.9	649.8
1958	22.8	109.9	231.7	382.2	555.5	655.8	686.9	719.8	728.9
1959	60.5	75.2	231.4	373.5	507.5	643.9	697.1	726.6	739.2
1960	32.2	129.6	189.6	375.4	513.3	636.2	738.3	752.7	789.3
1961	48.3	116	258.4	336.7	512.9	618.3	727.6	789.9	771.3
1962	60.1	131	267.1	394.1	466.5	591	644.3	731.1	754.8
1963	63.5	145.6	257.7	424.9	567.3	635	727.1	742.6	835.6
1964	67.1	150.4	281.1	380.3	550.2	721.1	767.2	811.7	786.5
1965	53	145.8	275.5	386.3	462.2	621.2	835.8	853.3	852.3
1966	66.8	121.9	278.1	387.7	455.6	509.7	648.2	899.7	887.3
1967	62.1	157.6	252.4	434.2	507.2	535.7	581.5	722.8	1063.5
1968	74.7	128.1	316.8	424.3	583.3	596.3	583.3	620.6	751.8
1969	83.3	152.8	268.9	500	649.2	759.4	705.9	655.1	689.9
1970	58.7	185.4	269.3	419.1	595.1	790.4	814.4	705.8	631.7
1971	50.6	169.4	341.9	406.3	589.4	654.5	905.8	844.3	695.9
1972	24.7	122.7	328.9	493.1	566.4	800	713.2	1048.6	897.8
1973	43.1	121.1	263.3	475.2	636.9	752.9	1039.3	764.4	1175.1
1974	28.7	103.4	263	408.7	582	764	968.3	1344.6	817.8
1975	27.1	84.5	214.8	379.8	560.5	666.2	877	1204.4	1682.8
1976	17.3	67.4	192.4	345.3	474.1	732.6	761.3	1023	1543.4
1977	20.2	64.4	151.3	317.3	471.6	533	878.5	821.9	1126.2
1978	28.4	68.7	163.2	252.6	420.4	556.1	543.8	944	817.6
1979	24.8	68.7	168.8	279.1	366.8	516.4	638.4	562.1	1028.2
1980	21.7	56.6	148.1	288.8	391.6	482	593.8	702.3	573.1
1981	19.5	68.2	118.8	239.7	396.9	475.8	575.8	637.1	732.7
1982	26.7	76.2	167.7	212.4	341	486.7	533.9	643	650.7
1983	31.4	70.8	171.6	258.4	303.4	414.5	534	553.5	675.8
1984	25.6	71.9	165.8	291.7	368.6	440.4	525.8	623.9	621
1985	22.6	68.4	139.3	260.6	374.2	430.8	546	579.3	641.6
1986	24.3	64.4	149.8	230.7	375.2	470.7	516.2	715.8	683
1987	26.6	75.5	153.6	249.4	338.2	476.8	533.3	566	847.6
1988	27.8	69.4	159.9	241.3	329.2	429.6	541.5	556.9	580.4
1989	39.1	91.1	150.3	256.1	341.1	427.5	567.7	657.1	632.2
1990	35.8	113.1	208.5	248.2	340.4	419.4	494	670.6	713.7

Table 3. (*continued*)

Year	0	1	2	3	4	5	6	7	8
1991	52	92.8	224.1	309.7	334.8	393.4	461.9	521.5	723.5
1992	28.3	123.1	186.4	318.7	392.3	420.5	445	512	565.8
1993	49.8	93.4	243.6	294.7	396	457.6	501.1	488.5	553.9
1994	23.5	118.8	214.3	355.7	395	450.3	504.8	572.6	523.3
1995	22.6	112.6	229.7	331.8	423.1	453.4	456.3	501.1	586.3
1996	17	96.5	288.8	371.6	483.5	529.8	564.3	517.7	564.7
1997	28.8	87.6	246.6	447	491	594.2	585.9	625.8	536
1998	60.3	93.9	227.2	390.9	547	574.4	662.1	608.2	654.1
1999	39.1	131.1	214	354.9	496.6	597.8	627.1	699.9	612.1
2000	27.1	131.5	252.7	345.5	456.5	577.9	633.4	674.5	736.3
2001	55	125.1	280.6	382.9	462.1	522	624.5	643.7	697.6
2002	40.4	149.4	290.1	422.1	526.3	581	588.9	683.6	677.6
2003	49.5	121.7	277	440.1	557.5	701.6	725.3	678	779.9
2004	25.3	113.9	238.6	339.2	482.6	572.9	738.6	722.8	638.4
2005	37.1	88.6	214.5	328.6	369.5	495.8	572.7	760.5	714.6
2006	43.8	112.5	193.7	321.5	411.2	407.1	537.6	619.3	862.4
2007	56	127.2	219.6	280.6	390.9	434.4	399.2	514.3	588
2008	61	132.7	241.3	309.7	359.7	473.5	479.2	419.4	539.6
2009	54.1	112.9	230	320.2	360.2	403.4	519.5	489.9	416
2010	52.3	137.7	205.6	309.5	378.4	399.4	442.5	568.2	508.2
2011	43.7	114.5	202	309.5	358	408	416.8	461.3	595.2

Table 4. Percent age composition of Atlantic menhaden from coastwide reduction fishery catch-at-age matrix, 2005-2011.

Year	0	1	2	3	4	5	6	7	8
2005	2	12	59	24	3	<1	-	-	-
2006	1	40	40	16	3	<1	-	-	-
2007	<1	26	65	7	1	<1	-	-	-
2008	1	9	68	18	3	<1	-	-	-
2009	1	48	31	18	3	<1	-	-	-
2010	2	40	49	7	3	<1	-	-	-
2011	-	42	50	7	1	<1	-	-	-

Table 5. Coastwide reduction and bait landings, 1940-2011.

	Reduction Fishery		Reduction Fishery	Bait Fishery
Year	Landings (1000 t)	Year	Landings (1000 t)	Landings (1000 t)
1940	217.7	1985	306.7	26.7
1941	277.9	1986	238	28
1942	167.2	1987	327	30.6
1943	237.2	1988	309.3	36.3
1944	257.9	1989	322	31
1945	295.9	1990	401.2	30.8
1946	362.4	1991	381.4	36.2
1947	378.3	1992	297.6	39
1948	346.5	1993	320.6	42.8
1949	363.8	1994	260	39.1
1950	297.2	1995	339.9	42.4
1951	361.4	1996	292.9	35.3
1952	409.9	1997	259.1	36.5
1953	593.2	1998	245.9	39.4
1954	608.1	1999	171.2	36.2
1955	641.4	2000	167.2	35.3
1956	712.1	2001	233.7	36.3
1957	602.8	2002	174	37.1
1958	510	2003	166.1	33.8
1959	659.1	2004	183.4	35.5
1960	529.8	2005	146.9	38.8
1961	575.9	2006	157.4	26.5
1962	537.7	2007	174.5	42.8
1963	346.9	2008	141.1	47.4
1964	269.2	2009	143.8	39.1
1965	273.4	2010	183.1	45.3
1966	219.6	2011	174	54.8
1967	193.5			
1968	234.8			
1969	161.6			
1970	259.4			
1971	250.3			
1972	365.9			
1973	346.9			
1974	292.2			
1975	250.2			
1976	340.5			
1977	341.1			
1978	344.1			
1979	375.7			
1980	401.5			
1981	381.3			
1982	382.4			
1983	418.6			
1984	326.3			

Table 6. Number of fish sampled from Atlantic menhaden landed for bait, 1985-2011.

	Purse Seine				Poundnet				Totals		
Year	NE	MA	CB	SA	NE	MA	CB	SA	Purse Seine	Poundnet	Grand
1985	600	0	0	170	0	0	0	30	770	30	800
1986	40	0	0	340	0	0	0	40	380	40	420
1987	0	0	0	220	0	0	0	0	220	0	220
1988	0	0	0	10	0	0	0	0	10	0	10
1989	20	0	0	10	0	0	0	0	30	0	30
1990	0	0	0	10	0	0	10	0	10	10	20
1991	0	0	0	78	0	0	0	0	78	0	78
1992	0	0	30	40	0	0	0	0	70	0	70
1993	29	0	10	130	0	0	0	0	169	0	169
1994	80	320	0	139	0	0	10	0	539	10	549
1995	130	59	96	77	0	0	0	0	362	0	362
1996	15	187	137	18	0	0	0	0	357	0	357
1997	0	110	136	67	0	0	100	0	313	100	413
1998	0	225	295	106	0	0	0	10	626	10	636
1999	0	192	299	47	0	0	0	0	538	0	538
2000	0	273	231	39	0	0	0	0	543	0	543
2001	0	677	275	10	0	0	0	0	962	0	962
2002	0	155	471	76	0	0	0	0	702	0	702
2003	0	108	309	10	0	0	0	0	427	0	427
2004	0	28	326	0	0	0	0	0	354	0	354
2005	0	4	318	0	0	0	0	0	322	0	322
2006	28	223	203	0	0	10	20	0	454	30	484
2007	122	477	374	0	190	10	80	0	973	280	1,253
2008	199	629	314	0	140	50	80	0	1,142	270	1,112
2009	27	377	481	0	40	10	110	0	885	160	1,045
2010	0	421	298	18	70	0	150	0	737	220	957
2011	0	448	327	0	0	0	260	0	775	260	1,035
Total	1,290	4,913	4,930	1,615	440	80	820	80	12,748	1,420	13,868

Table 7. Recreational harvest (Type A+B1) in numbers of Atlantic menhaden in the recreational fishery by region (New England, Middle Atlantic, and South Atlantic states), 1981-2011.

Year	MA	NE	SA	Overall
1981	117,957	248,063	77,841	443,861
1982	3,362	218,033	546,377	767,772
1983	26,033	175,877	382,531	584,441
1984	315,659	101,279	259,739	676,677
1985	266,892	227,162	101,710	595,764
1986	736,270	557,216	13,463	1,306,949
1987	365,506	463,769	142,006	971,281
1988	892,562	252,015	280,735	1,425,312
1989	192,875	258,202	182,656	633,733
1990	234,232	250,855	343,572	828,659
1991	856,362	374,938	390,179	1,621,479
1992	288,409	1,098,238	1,266,057	2,652,704
1993	268,992	354,034	84,017	707,043
1994	222,665	133,236	279,250	635,151
1995	777,497	142,589	85,272	1,005,358
1996	50,410	181,925	297,759	530,094
1997	227,652	98,781	135,071	461,504
1998	54,785	187,577	78,273	320,635
1999	742,075	54,578	289,447	1,086,100
2000	47,274	131,385	99,969	278,628
2001	147,773	17,389	985,208	1,150,370
2002	200,812	233,814	515,634	950,260
2003	217,042	21,153	1,669,518	1,907,713
2004	77,698	7,153	1,789,096	1,873,947
2005	66,226	5,547	1,467,118	1,538,891
2006	672,228	59,850	2,400,491	3,132,569
2007	298,455	480,196	1,818,868	2,597,519
2008	1,180,160	373,798	726,104	2,280,062
2009	108,563	91,556	1,307,950	1,508,069
2010	263,773	56,832	1,491,377	1,811,982
2011	560,406	22,643	1,097,325	1,680,374

Table 8. Recreational released alive (Type B2) in numbers of Atlantic menhaden in the recreational fishery by region (New England, Middle Atlantic, and South Atlantic states), 1981-2011.

Year	MA	NE	SA	Overall
1981	0	14,269	71,401	85,670
1982	9,314	0	378,801	388,115
1983	539	5,313	805,522	811,374
1984	44,582	5,435	534,245	584,262
1985	46,767	8,020	338,916	393,703
1986	30,881	3,372	97,581	131,834
1987	36,935	6,102	58,805	101,842
1988	29,641	22,082	41,840	93,563
1989	11,980	10,677	162,420	185,077
1990	43,491	27,470	108,288	179,249
1991	265,965	66,991	22,600	355,556
1992	697	96,997	22,737	120,431
1993	13,642	27,526	177,890	219,058
1994	12,424	18,771	4,117	35,312
1995	99,622	17,830	9,125	126,577
1996	2,082	3,139	391	5,612
1997	1,458	861	6,165	8,484
1998	3,209	3,628	10,219	17,056
1999	1,119	51,974	369,179	422,272
2000	57,934	0	81,727	139,661
2001	714	1,276	413,752	415,742
2002	91,225	18,221	387,996	497,442
2003	17,352	0	613,070	630,422
2004	4,326,150	52,149	387,179	4,765,478
2005	9,784	5,476	339,041	354,301
2006	270,205	114,971	1,119,853	1,505,029
2007	237,299	16,774	465,573	719,646
2008	71,499	13,107	74,687	159,293
2009	12,685	960	642,738	656,383
2010	67,672	10,161	522,416	600,249
2011	1,602	11,348	231,078	244,028

Table 9. Total catch (A+B1+0.5*B2) in weight (1,000 metric tons) of Atlantic menhaden in the recreational fishery (MRFSS/MRIP) by region (New England, Middle Atlantic, and South Atlantic states), 1981-2011.

Year	MA	NE	SA	Total
1981	0.0265	0.0798	0.0088	0.11504
1982	0.0018	0.0682	0.0567	0.12667
1983	0.0059	0.0558	0.0605	0.12225
1984	0.0759	0.0325	0.0406	0.14906
1985	0.0652	0.0723	0.0209	0.1584
1986	0.1689	0.1747	0.0048	0.34844
1987	0.0863	0.1459	0.0132	0.24543
1988	0.2039	0.0822	0.0233	0.30938
1989	0.0447	0.0824	0.0203	0.14741
1990	0.0575	0.0827	0.0307	0.17089
1991	0.2223	0.1277	0.0309	0.38094
1992	0.0649	0.3585	0.0985	0.52184
1993	0.0620	0.1150	0.0133	0.19029
1994	0.0514	0.0446	0.0217	0.1177
1995	0.1859	0.0474	0.0069	0.24019
1996	0.0116	0.0574	0.0230	0.09189
1997	0.0513	0.0310	0.0106	0.09298
1998	0.0127	0.0592	0.0064	0.07831
1999	0.1669	0.0252	0.0365	0.2286
2000	0.0171	0.0411	0.0109	0.06906
2001	0.0333	0.0056	0.0919	0.1308
2002	0.0554	0.0759	0.0547	0.18601
2003	0.0507	0.0066	0.1523	0.20964
2004	0.5035	0.0104	0.1528	0.66671
2005	0.0160	0.0026	0.1261	0.14472
2006	0.1814	0.0367	0.2282	0.44627
2007	0.0937	0.1527	0.1581	0.4046
2008	0.2732	0.1189	0.0588	0.45097
2009	0.0258	0.0288	0.1256	0.18017
2010	0.0669	0.0194	0.1351	0.22131
2011	0.1261	0.0089	0.0935	0.22844

Table 10. Total catch (A+B1+0.5*B2) in numbers of Atlantic menhaden in the recreational fishery (MRFSS/MRIP) by region (New England, Middle Atlantic, and South Atlantic states), 1981-2011.

Year	MA	NE	SA	Overall	PSE
1981	117,957	255,198	113,542	486,696	27.26
1982	8,019	218,033	735,778	961,830	35.6
1983	26,303	178,534	785,292	990,128	38.8
1984	337,950	103,997	526,862	968,808	35.2
1985	290,276	231,172	271,168	792,616	36
1986	751,711	558,902	62,254	1,372,866	33.59
1987	383,974	466,820	171,409	1,022,202	15.82
1988	907,383	263,056	301,655	1,472,094	31.19
1989	198,865	263,541	263,866	726,272	18.63
1990	255,978	264,590	397,716	918,284	14.47
1991	989,345	408,434	401,479	1,799,257	20.07
1992	288,758	1,146,737	1,277,426	2,712,920	31.12
1993	275,813	367,797	172,962	816,572	20.48
1994	228,877	142,622	281,309	652,807	18.88
1995	827,308	151,504	89,835	1,068,647	28.28
1996	51,451	183,495	297,955	532,900	48.94
1997	228,381	99,212	138,154	465,746	31.62
1998	56,390	189,391	83,383	329,163	28.82
1999	742,635	80,565	474,037	1,297,236	57.96
2000	76,241	131,385	140,833	348,459	27.95
2001	148,130	18,027	1,192,084	1,358,241	26.96
2002	246,425	242,925	709,632	1,198,981	21.27
2003	225,718	21,153	1,976,053	2,222,924	16.03
2004	2,240,773	33,228	1,982,686	4,256,686	102.14
2005	71,118	8,285	1,636,639	1,716,042	23.99
2006	807,331	117,336	2,960,418	3,885,084	18.11
2007	417,105	488,583	2,051,655	2,957,342	17.17
2008	1,215,910	380,352	763,448	2,359,709	19.21
2009	114,906	92,036	1,629,319	1,836,261	15.93
2010	297,609	61,913	1,752,585	2,112,107	13.34
2011	561,207	28,317	1,212,864	1,802,388	27.06

Table 11. General definitions, input data, population model, and negative log-likelihood components of the BAM forward-projecting statistical age-structured model used for Atlantic menhaden.

General Definitions	Symbol	Description/Definition
Year index: y = {1955,..,2011}	y	
Age index: a = {0,...,8+}	a	
Fishery index: f = {1 reduction, 2 bait}	f	
Input Data	**Symbol**	**Description/Definition**
Fishery Weight-at-age	$w^f_{a,y}$	Computed from size at age from fishery samples
Population Weight-at-age	$w^p_{a,y}$	Computed from size at age back-calculated to beginning of year
Maturity-at-age	m_a	From data workshop with recent added samples
Fecundity-at-age	$\gamma_{a,y}$	From data workshop
Observed age-0 CPUE y = {1959,...,2011}	$U_{1,y}$	Based on numbers of age-0 fish from various seine samples (selected/combined Assessment Workshop)
Observed pound net CPUE y = {1964,...,2011}	$U_{2,y}$	Based on pound net landings of menhaden per set from the Potomac River Fisheries Commission
Selectivity for U_2	s'_a	Fixed at 0.25 for a = {1, 3}, 1.0 for a = {2}, and 0 for a = {0,4,...,8+}
Coefficient of variation for U	c_U	Based on annual estimates from samples for U_1, fixed at 0.5 for U_2
Observed age compositions	$p_{f,a,y}$	Computed as percent age composition at age (a) for each year (y) and fishery (f)
Age composition sample sizes	$n_{f,y}$	Number of trips sampled in each year (y) from each fishery (f)
Observed fishery landings	$L_{f,y}$	Reported landings in weight for each year (y) from each fishery (f)
Coefficient of variation for L_f	c_{L_f}	Fixed at 0.03 for L_1 and 0.15 (early years) and 0.05 (recent years) for L_2
Observed natural mortality	$M_{a,y}$	From MSVPA-X model, constant in years 1955-1981, projected for 2011

Table 11. (c*ontinued*).

Population Model	Symbol	Description/Definition
Fishery selectivity	$s_{f,a}$	Assumed constant for all years (y) $s_a = \frac{1}{1+\exp(-\eta_1[a-\alpha_1])}$ $s_a = \left[\frac{1}{1+\exp(-\eta_{1,2}[a-\alpha_{1,2}])}\right]\left[1-\frac{1}{1+\exp(-\eta_{2,2}[a-\alpha_{2,2}])}\right]\left[\frac{1}{\max(s_a)}\right]$ where η's and α's are estimated parameters. The base BAM model assumed logistic selectivity for both reduction and bait fisheries.
Fishing mortality (fully selected)	$F_{f,a,y}$	$F_{f,a,y} = s_a F_{f,y}$ where $F_{f,y}$s are estimated parameters
Total mortality	$Z_{a,y}$	$Z_{a,y} = M_{a,y} + \sum_{f=1}^{2} F_{f,a,y}$
Fecundity per recruit at $F = 0$	ϕ_y	$\phi_y = \sum_{a=0}^{8+} N_{a,y} m_a \gamma_{a,y} 0.5 \Big/ N_{0,y}$ where $N_{a+1,y} = N_{a,y}\exp(-Z_{a,y})$ and $N_{8+,y} = N_{7,y}\exp(-Z_{7,y})/[1-\exp(-Z_{8+,y})]$
Population numbers Population fecundity	$N_{a,y}$ ε_y	$N_{a+1,1955} = N_{a,1955}\exp(-Z_{a,1955})$ $N_{8+,1955} = N_{7,1955}\exp(-Z_{7,1955})/[1-\exp(-Z_{8+,1955})]$ $\varepsilon_y = \sum_{a=0}^{8+} N_{a,y} m_a \gamma_a 0.5$ $N_{0,y} = R_y$ $N_{a+1,y+1} = N_{a,y}\exp(-Z_{a,y})$ $N_{A,y} = N_{A-1,y-1}\exp(-Z_{A-1,y-1}) + N_{A,y-1}\exp(-Z_{A,y-1})$ where R_y are annual recruitment parameters.

Table 11. (c*ontinued*).

Population Model (*cont.*)	**Symbol**	**Description/Definition**
Population biomass	B_y	$B_y = \sum_{a=0}^{8+} N_{a,y} w_a^p$
Predicted catch-at-age	$\hat{C}_{f,a,y}$	$\hat{C}_{f,a,y} = \frac{F_{f,a,y}}{Z_{a,y}} N_{a,y} \left[1 - \exp\left(-Z_{a,y}\right)\right]$
Predicted landings	$\hat{L}_{f,y}$	$\hat{L}_{f,y} = \sum_{a=0}^{8+} \hat{C}_{f,a,y} w_a^f$
Predicted age composition	$\hat{p}_{f,a,y}$	$\hat{p}_{f,a,y} = \hat{C}_{f,a,y} \Big/ \sum_{a=0}^{8+} \hat{C}_{f,a,y}$
Predicted age-0 CPUE	$\hat{U}_{1,y}$	$\hat{U}_{1,y} = N_{0,y} q_1$ where q_1 is a catchability parameter
Predicted pound net CPUE	$\hat{U}_{2,y}$	$\hat{U}_{2,y} = \sum_{a=0}^{8+} N_{a,y} s'_a q_2$ where q_2 is a catchability parameter
Negative Log-Likelihood	**Symbol**	**Description/Definition**
Multinomial age composition	Λ_f	$\Lambda_f = -\lambda_f n_{f,y} \sum_{a=0}^{8+} \left(p_{f,a,y} + x\right) \log\left(\hat{p}_{f,a,y} + x\right) - \left(p_{f,a,y} + x\right) \log\left(p_{f,a,y} + x\right)$ where λ_f is a preset weighting factor and x is fixed at an arbitrary value of 0.001
Lognormal indices	Λ_f	$\Lambda_f = \lambda_f \sum_y \frac{\left[\log\left(U_{f,y} + x\right) - \log\left(\hat{U}_{f,y} + x\right)\right]^2}{2c_U^2}$ where λ_f is a preset weighting factor and x is fixed at an arbitrary value of 0.001
Lognormal landings	Λ_f	$\Lambda_f = \lambda_f \sum_y \frac{\left[\log\left(L_{f,y} + x\right) - \log\left(\hat{L}_{f,y} + x\right)\right]^2}{2c_{L_f}^2}$ where λ_f is a preset weighting factor and x is fixed at an arbitrary value of 0.001

Table 12. Estimated annual total full fishing mortality rates, full fishing mortality rates for the commercial reduction fishery, and full fishing mortality rates for the commercial bait fishery from the base BAM model.

Year	full F	full F reduction	full F bait
1955	1.41	1.36	0.05
1956	2.74	2.57	0.17
1957	2.46	2.2	0.26
1958	1.54	1.44	0.1
1959	2.01	1.87	0.13
1960	0.92	0.84	0.08
1961	1.1	1.05	0.06
1962	2.14	1.98	0.16
1963	3.3	2.88	0.42
1964	4.07	3.32	0.75
1965	6.84	5.2	1.64
1966	5.29	4.27	1.02
1967	3.89	3.15	0.74
1968	3.45	3.06	0.39
1969	2.74	2.27	0.47
1970	3.19	2.43	0.76
1971	1.7	1.47	0.23
1972	3.06	2.87	0.19
1973	2.86	2.52	0.34
1974	2.85	2.51	0.34
1975	2.71	2.15	0.56
1976	3.05	2.59	0.46
1977	2.57	2.15	0.42
1978	2.49	2.09	0.4
1979	2.25	2.06	0.18
1980	2.59	2.23	0.36
1981	2.13	1.82	0.31
1982	1.64	1.45	0.19
1983	2.11	1.9	0.21
1984	2.75	2.5	0.25
1985	2.88	2.18	0.7
1986	1.43	1.07	0.36
1987	1.52	1.28	0.24
1988	2.03	1.66	0.37
1989	2.9	2.32	0.59
1990	2.46	2.02	0.45

Year	full F	full F reduction	full F bait
1991	4.15	3.37	0.78
1992	3.38	2.25	1.13
1993	1.92	1.4	0.52
1994	1.26	0.97	0.29
1995	1.87	1.53	0.35
1996	1.38	1.09	0.29
1997	1.42	1.16	0.26
1998	2.17	1.67	0.49
1999	2.19	1.47	0.72
2000	1.57	1.03	0.54
2001	1.69	1.3	0.39
2002	1.8	1.3	0.51
2003	1.64	1.09	0.55
2004	1.49	1.03	0.47
2005	1.4	0.94	0.46
2006	1.68	1.26	0.42
2007	1.86	1.12	0.73
2008	1.5	0.89	0.62
2009	1.9	1.23	0.67
2010	2.81	1.68	1.13
2011	4.5	2.43	2.07

Table 13. Estimated annual total full fishing mortality rates from the base BAM model and percentiles from the bootstrap runs.

Year	Base BAM model	5th percentile	50th percentile	95 percentile
1955	1.41	0.97	1.49	2.99
1956	2.74	1.84	3.01	5.75
1957	2.46	1.7	2.76	4.52
1958	1.54	1.08	1.68	2.91
1959	2.01	1.51	2.18	3.31
1960	0.92	0.77	0.95	1.25
1961	1.1	0.92	1.12	1.45
1962	2.14	1.75	2.23	2.96
1963	3.3	2.48	3.54	5.37
1964	4.07	3.1	4.41	6.71
1965	6.84	5.27	7.59	11.31
1966	5.29	3.67	5.96	10.09
1967	3.89	2.97	4.25	6.38
1968	3.45	2.89	3.73	4.97
1969	2.74	2.22	3.02	4.28
1970	3.19	2.53	3.49	5.06
1971	1.7	1.4	1.82	2.45
1972	3.06	2.48	3.31	4.6
1973	2.86	2.33	3.08	4.26
1974	2.85	2.2	3.1	4.57
1975	2.71	2.1	2.94	4.42
1976	3.05	2.4	3.32	4.72
1977	2.57	1.92	2.8	4.28
1978	2.49	1.73	2.74	4.59
1979	2.25	1.51	2.42	4.36
1980	2.59	1.7	2.89	4.72
1981	2.13	1.47	2.32	4.14
1982	1.64	1.17	1.79	2.83
1983	2.11	1.51	2.28	3.81
1984	2.75	1.8	3.1	5.47
1985	2.88	1.98	3.27	5.29
1986	1.43	1.07	1.55	2.39
1987	1.52	1.19	1.63	2.39
1988	2.03	1.53	2.22	3.38
1989	2.9	2.03	3.2	5.24
1990	2.46	1.83	2.66	4.2

Year	Base BAM model	5th percentile	50th percentile	95 percentile
1991	4.15	2.75	4.65	9.1
1992	3.38	2.55	3.74	6.08
1993	1.92	1.59	2.08	2.89
1994	1.26	1.08	1.34	1.73
1995	1.87	1.65	1.99	2.49
1996	1.38	1.2	1.46	1.81
1997	1.42	1.24	1.49	1.85
1998	2.17	1.8	2.31	3.1
1999	2.19	1.72	2.36	3.36
2000	1.57	1.24	1.68	2.33
2001	1.69	1.4	1.8	2.38
2002	1.8	1.35	1.97	2.89
2003	1.64	1.23	1.78	2.78
2004	1.49	1.22	1.6	2.24
2005	1.4	1.15	1.49	1.99
2006	1.68	1.36	1.8	2.47
2007	1.86	1.46	2.01	2.88
2008	1.5	1.21	1.62	2.23
2009	1.9	1.52	2.05	2.89
2010	2.81	2.19	3.02	4.26
2011	4.5	3.09	4.85	7.81

Table 14. Estimated full fishing mortality rates at age from the base BAM model.

	Age								
Year	0	1	2	3	4	5	6	7	8
1955	0.01	0.13	0.78	1.32	1.4	1.41	1.41	1.41	1.41
1956	0.02	0.26	1.49	2.56	2.73	2.74	2.74	2.74	2.74
1957	0.02	0.22	1.3	2.3	2.45	2.46	2.46	2.46	2.46
1958	0.01	0.14	0.84	1.44	1.53	1.54	1.54	1.54	1.54
1959	0.02	0.19	1.09	1.88	2	2.01	2.01	2.01	2.01
1960	0.01	0.08	0.49	0.86	0.91	0.92	0.92	0.92	0.92
1961	0.01	0.1	0.61	1.03	1.1	1.1	1.1	1.1	1.1
1962	0.02	0.2	1.16	2	2.13	2.14	2.14	2.14	2.14
1963	0.03	0.29	1.72	3.07	3.29	3.3	3.3	3.3	3.3
1964	0.03	0.34	2.03	3.77	4.05	4.07	4.07	4.07	4.07
1965	0.05	0.53	3.27	6.31	6.81	6.84	6.84	6.84	6.84
1966	0.04	0.43	2.62	4.9	5.26	5.29	5.29	5.29	5.29
1967	0.03	0.32	1.93	3.6	3.87	3.88	3.89	3.89	3.89
1968	0.03	0.31	1.81	3.21	3.43	3.45	3.45	3.45	3.45
1969	0.02	0.23	1.38	2.54	2.73	2.74	2.74	2.74	2.74
1970	0.02	0.25	1.53	2.94	3.18	3.19	3.19	3.19	3.19
1971	0.01	0.15	0.88	1.58	1.69	1.7	1.7	1.7	1.7
1972	0.03	0.29	1.67	2.87	3.05	3.06	3.06	3.06	3.06
1973	0.02	0.25	1.5	2.66	2.85	2.86	2.86	2.86	2.86
1974	0.02	0.25	1.49	2.66	2.84	2.85	2.85	2.85	2.85
1975	0.02	0.22	1.33	2.51	2.7	2.71	2.71	2.71	2.71
1976	0.02	0.26	1.56	2.83	3.03	3.05	3.05	3.05	3.05
1977	0.02	0.22	1.3	2.38	2.55	2.56	2.57	2.57	2.57
1978	0.02	0.21	1.26	2.31	2.48	2.49	2.49	2.49	2.49
1979	0.02	0.21	1.21	2.1	2.24	2.25	2.25	2.25	2.25
1980	0.02	0.22	1.34	2.41	2.58	2.59	2.59	2.59	2.59
1981	0.02	0.18	1.09	1.98	2.11	2.12	2.13	2.13	2.13
1982	0.01	0.14	0.86	1.52	1.63	1.64	1.64	1.64	1.64
1983	0.02	0.19	1.12	1.96	2.1	2.11	2.11	2.11	2.11
1984	0.02	0.25	1.47	2.56	2.73	2.75	2.75	2.75	2.75
1985	0.02	0.22	1.37	2.66	2.87	2.88	2.88	2.88	2.88
1986	0.01	0.11	0.68	1.32	1.42	1.43	1.43	1.43	1.43
1987	0.01	0.13	0.77	1.41	1.51	1.52	1.52	1.52	1.52
1988	0.02	0.17	1.01	1.88	2.02	2.03	2.03	2.03	2.03
1989	0.02	0.23	1.43	2.69	2.89	2.9	2.9	2.9	2.9
1990	0.02	0.2	1.23	2.28	2.45	2.46	2.46	2.46	2.46

Table 14 (*continued*).

	Age								
Year	0	1	2	3	4	5	6	7	8
1991	0.03	0.34	2.06	3.84	4.13	4.15	4.15	4.15	4.15
1992	0.02	0.23	1.49	3.09	3.36	3.38	3.38	3.38	3.38
1993	0.01	0.14	0.89	1.77	1.91	1.92	1.92	1.92	1.92
1994	0.01	0.1	0.61	1.16	1.25	1.26	1.26	1.26	1.26
1995	0.01	0.15	0.93	1.73	1.86	1.87	1.87	1.87	1.87
1996	0.01	0.11	0.67	1.27	1.37	1.38	1.38	1.38	1.38
1997	0.01	0.12	0.71	1.32	1.41	1.42	1.42	1.42	1.42
1998	0.02	0.17	1.05	2	2.16	2.17	2.17	2.17	2.17
1999	0.01	0.15	0.97	2	2.18	2.19	2.19	2.19	2.19
2000	0.01	0.11	0.69	1.43	1.56	1.57	1.57	1.57	1.57
2001	0.01	0.13	0.81	1.56	1.68	1.69	1.69	1.69	1.69
2002	0.01	0.13	0.83	1.66	1.79	1.8	1.8	1.8	1.8
2003	0.01	0.11	0.72	1.5	1.63	1.64	1.64	1.64	1.64
2004	0.01	0.11	0.67	1.37	1.48	1.49	1.49	1.49	1.49
2005	0.01	0.1	0.62	1.28	1.39	1.4	1.4	1.4	1.4
2006	0.01	0.13	0.8	1.55	1.67	1.68	1.68	1.68	1.68
2007	0.01	0.12	0.78	1.69	1.85	1.86	1.86	1.86	1.86
2008	0.01	0.09	0.62	1.37	1.5	1.5	1.5	1.5	1.5
2009	0.01	0.13	0.82	1.74	1.89	1.9	1.9	1.9	1.9
2010	0.02	0.18	1.17	2.55	2.79	2.81	2.81	2.81	2.81
2011	0.02	0.26	1.77	4.07	4.48	4.5	4.5	4.5	4.5

Table 15. Estimated numbers of Atlantic menhaden (billions) at the start of the fishing year from the base BAM model..

	Age								
	0	1	2	3	4	5	6	7	8
1955	33.68	4.87	2.31	0.27	0.88	7.35E-08	2.94E-02	2.61E-09	5.21E-10
1956	33.19	10.64	1.75	0.53	0.04	1.29E-01	1.11E-08	4.55E-03	4.85E-10
1957	19.33	10.37	3.39	0.2	0.02	1.58E-03	5.17E-03	4.54E-10	1.86E-04
1958	75.38	6.06	3.42	0.47	0.01	1.19E-03	8.33E-05	2.80E-04	1.01E-05
1959	7.95	23.8	2.16	0.75	0.06	1.45E-03	1.58E-04	1.14E-05	3.96E-05
1960	15.17	2.5	8.12	0.37	0.06	5.03E-03	1.21E-04	1.35E-05	4.34E-06
1961	9.16	4.82	0.94	2.51	0.09	1.54E-02	1.24E-03	3.06E-05	4.53E-06
1962	9.22	2.9	1.78	0.26	0.5	1.74E-02	3.17E-03	2.62E-04	7.40E-06
1963	7.24	2.9	0.98	0.28	0.02	3.56E-02	1.27E-03	2.37E-04	2.01E-05
1964	8.88	2.26	0.89	0.09	0.01	4.43E-04	8.11E-04	2.96E-05	5.99E-06
1965	7.22	2.75	0.66	0.06	0	7.68E-05	4.68E-06	8.79E-06	3.86E-07
1966	9.99	2.2	0.67	0.01	0	7.59E-07	5.06E-08	3.16E-09	6.20E-09
1967	5.09	3.07	0.59	0.02	0	1.87E-07	2.37E-09	1.62E-10	3.00E-11
1968	8.18	1.58	0.92	0.04	0	6.71E-07	2.38E-09	3.09E-11	2.50E-12
1969	13.25	2.54	0.48	0.08	0	7.31E-06	1.32E-08	4.80E-11	6.74E-13
1970	6.34	4.15	0.83	0.06	0	3.80E-05	2.91E-07	5.40E-10	1.99E-12
1971	17.23	1.98	1.33	0.09	0	8.34E-05	9.66E-07	7.59E-09	1.41E-11
1972	10.91	5.44	0.7	0.28	0.01	1.98E-04	9.43E-06	1.12E-07	8.82E-10
1973	13.16	3.4	1.68	0.07	0.01	3.00E-04	5.73E-06	2.80E-07	3.35E-09
1974	17.23	4.11	1.09	0.19	0	3.10E-04	1.06E-05	2.08E-07	1.03E-08
1975	29.2	5.39	1.32	0.12	0.01	9.15E-05	1.11E-05	3.89E-07	8.00E-09
1976	23.32	9.16	1.78	0.18	0.01	3.01E-04	3.76E-06	4.66E-07	1.67E-08
1977	23.92	7.29	2.9	0.19	0.01	1.62E-04	8.81E-06	1.13E-07	1.45E-08
1978	24.42	7.5	2.41	0.4	0.01	2.71E-04	7.72E-06	4.30E-07	6.22E-09
1979	43.78	7.66	2.5	0.34	0.02	4.94E-04	1.39E-05	4.06E-07	2.29E-08
1980	28.78	13.74	2.56	0.38	0.02	1.42E-03	3.22E-05	9.29E-07	2.87E-08
1981	55.9	9.02	4.52	0.34	0.02	1.07E-03	6.57E-05	1.53E-06	4.55E-08
1982	26.73	17.58	3.09	0.76	0.03	1.37E-03	7.92E-05	4.98E-06	1.19E-07
1983	40.78	5.07	3.75	0.45	0.07	2.71E-03	1.56E-04	9.82E-06	6.32E-07
1984	55.46	8.57	1.15	0.47	0.03	4.89E-03	1.94E-04	1.19E-05	8.02E-07
1985	40.05	14.1	2.18	0.12	0.02	1.12E-03	1.91E-04	7.91E-06	5.20E-07
1986	25.33	10.69	3.74	0.24	0	6.09E-04	3.83E-05	6.84E-06	3.01E-07
1987	14.63	6.61	3.21	0.82	0.03	5.79E-04	8.91E-05	5.86E-06	1.09E-06
1988	27.56	4.23	2.16	0.68	0.11	4.26E-03	7.85E-05	1.26E-05	9.83E-07
1989	7.19	8.27	1.44	0.38	0.06	8.40E-03	3.51E-04	6.68E-06	1.16E-06
1990	13.17	2.64	2.94	0.18	0.01	1.90E-03	2.84E-04	1.24E-05	2.76E-07

Table 15 (*continued*).

	Age								
	0	1	2	3	4	5	6	7	8
1991	17.24	4.91	1	0.46	0.01	7.67E-04	1.01E-04	1.52E-05	6.80E-07
1992	13.12	6.24	1.63	0.07	0.01	1.04E-04	7.48E-06	1.00E-06	1.59E-07
1993	8.63	5.35	2.46	0.21	0	1.24E-04	2.23E-06	1.62E-07	2.52E-08
1994	14.44	3.21	2.17	0.55	0.02	1.70E-04	1.14E-05	2.08E-07	1.75E-08
1995	8.02	5.19	1.33	0.65	0.1	3.70E-03	3.04E-05	2.07E-06	4.10E-08
1996	8.53	2.61	1.99	0.29	0.07	9.80E-03	3.54E-04	2.95E-06	2.05E-07
1997	6.43	2.85	1.04	0.56	0.05	1.07E-02	1.57E-03	5.72E-05	5.10E-07
1998	9.76	2.25	1.15	0.28	0.09	7.41E-03	1.68E-03	2.47E-04	9.12E-06
1999	9.1	3.19	0.87	0.23	0.02	6.69E-03	5.47E-04	1.26E-04	1.93E-05
2000	3.72	2.91	1.27	0.18	0.02	1.64E-03	4.77E-04	3.97E-05	1.06E-05
2001	7.79	1.35	1.26	0.37	0.03	2.43E-03	2.19E-04	6.40E-05	6.74E-06
2002	12.61	2.64	0.56	0.31	0.05	3.09E-03	2.80E-04	2.56E-05	8.28E-06
2003	9.72	3.87	1.01	0.13	0.04	4.72E-03	3.19E-04	2.92E-05	3.52E-06
2004	6.32	3.34	1.52	0.26	0.02	4.32E-03	5.86E-04	4.01E-05	4.12E-06
2005	14.32	2.03	1.21	0.39	0.04	2.39E-03	6.06E-04	8.49E-05	6.40E-06
2006	9.66	4.42	0.73	0.33	0.06	5.67E-03	3.65E-04	9.51E-05	1.43E-05
2007	5.59	3.04	1.59	0.16	0.04	6.73E-03	6.34E-04	4.25E-05	1.27E-05
2008	10.48	1.83	1.14	0.37	0.02	3.52E-03	6.30E-04	6.03E-05	5.25E-06
2009	8.81	3.35	0.69	0.31	0.05	2.17E-03	4.59E-04	8.48E-05	8.82E-06
2010	7.8	2.79	1.21	0.15	0.03	4.46E-03	1.89E-04	4.07E-05	8.29E-06
2011	4.03	2.62	0.99	0.19	0.01	1.05E-03	1.61E-04	6.98E-06	1.81E-06

Table 16. Estimated annual fecundity (billions of eggs) from the base BAM model and percentiles from the bootstrap runs.

Year	Base BAM model	5th percentile	50th percentile	95 percentile
1955	102151.8	48649.8	98848.26	157141.9
1956	61339.73	23109	58345.02	101081.1
1957	28073.84	14209.07	25770.46	48612.99
1958	36984.24	18359.35	33923.01	58891.1
1959	51319.12	24393.07	48015.01	80319.07
1960	48873.04	33337.33	46921.62	65333.29
1961	118281.3	92877.26	118000.1	142083.4
1962	67100.69	48116.77	66166.32	85069.11
1963	27508.07	18491.08	26896.42	35950.83
1964	9718.88	5862.37	9313.8	14192.22
1965	6500.38	4150.41	6165.04	8955.56
1966	3957.4	2661.5	3768.85	5451.2
1967	3944.79	1927.8	3676.76	6877.95
1968	7413.53	5385.99	7137.89	9589.47
1969	7178.88	4681.16	6684.17	9202.52
1970	7383.83	5088.57	6990.85	9390.17
1971	13549.67	9973.63	13187.58	17024.19
1972	27500.18	19877.4	26729.04	34011.74
1973	13811.02	9782.85	13046.87	17787.85
1974	16206.55	10723.4	15326.37	21403.16
1975	12407.83	7388.99	11790.34	17662.89
1976	13788.54	9000.36	13154.63	18476.19
1977	14894.24	10287.77	14152.71	19535.1
1978	18828.19	11104.93	17779.64	27092.04
1979	19243.04	9181.46	18136.14	30846.98
1980	20562.58	9445.76	19675.43	35018.24
1981	20392.96	11342.31	19120.39	32970.54
1982	28394.78	13314.49	26390.93	45259.81
1983	28999.48	17390.25	27248.84	42835.69
1984	21877.47	9770.45	20577.09	34742.87
1985	10364.88	4931.42	9558.1	18319.32
1986	16568.12	9978.18	15640.06	25024.09
1987	35104.65	21898.83	34004.96	47749.11
1988	33249.29	20879.41	31806	44780.27
1989	19935.37	10913.67	18861.16	29211.09
1990	16671.75	11201.98	16036.83	23353.8

Table 16 (*continued*).

Year	Base BAM model	5th percentile	50th percentile	95 percentile
1991	24471.07	12843.18	23559.52	35961.12
1992	8876.69	4389.41	8239.5	15311.54
1993	18923.46	13160.5	17950.9	24087.39
1994	37219.34	28515.79	35720.27	44223.26
1995	45216.37	37036.2	43760.21	50906.05
1996	30935.49	25622.43	29729.57	34334.84
1997	45718.16	39911.09	44632.95	50281.58
1998	30711.2	24831.03	29781.09	35606.01
1999	17499.81	12465.4	16914.97	22165.58
2000	16396.6	11659.19	15888.69	21328.95
2001	29593.6	22538.97	28954.09	36708.14
2002	27754.16	20748.3	26514.49	34540.18
2003	17552.86	10453.71	16367.23	25472.7
2004	22344.43	14742.52	21627.33	29397.85
2005	27506.7	20529.04	26712.08	33690.81
2006	23007.35	17231.11	22259.63	28153.2
2007	16899.65	12620.38	16244.56	20940.34
2008	24131.03	17852.14	23431.98	30384.94
2009	22737.49	17009.56	21857.34	27757.72
2010	14567.67	10429.2	14061.59	18782.07
2011	13333.82	9382.16	13071.02	17736.5

Table 17. Estimated annual recruitment of age-0 (billions) fish from the base BAM model and percentiles from the bootstrap runs.

Year	Base BAM model	5th percentile	50th percentile	95 percentile
1955	33.68	25.21	33.39	42.98
1956	33.19	23.38	32.81	42.65
1957	19.33	9.78	19.04	28.57
1958	75.38	64.3	76.19	87.45
1959	7.95	3.1	7.8	13.04
1960	15.17	10.84	15	19.62
1961	9.16	6.96	9.06	11.47
1962	9.22	7.45	9.13	10.9
1963	7.24	5.93	7.2	8.56
1964	8.88	7.36	8.78	10.49
1965	7.22	5.56	7.16	8.91
1966	9.99	8.43	9.94	11.42
1967	5.09	4.23	5.05	5.93
1968	8.18	6.67	8.09	9.8
1969	13.25	11.52	13.19	14.88
1970	6.34	4.74	6.25	7.82
1971	17.23	14.71	17.09	19.71
1972	10.91	8.35	10.84	13.48
1973	13.16	9.96	13.05	16.46
1974	17.23	13.65	17.01	20.91
1975	29.2	24.28	28.94	35.02
1976	23.32	17.63	23.01	29.34
1977	23.92	16.03	23.7	32.63
1978	24.42	16.83	24.1	34.25
1979	43.78	30.18	42.66	57.78
1980	28.78	17.54	28.09	40.34
1981	55.9	39.25	54.83	73.31
1982	26.73	13.79	26.28	41.53
1983	40.78	27.21	39.87	55.84
1984	55.46	40.29	54.92	70.34
1985	40.05	26.82	39.39	52.72
1986	25.33	17.44	24.93	34.4
1987	14.63	10	14.63	19.88
1988	27.56	22.26	27.36	33.01
1989	7.19	4.41	7.03	10.02
1990	13.17	9.39	13.05	17.06

Table 17 (*continued*).

Year	Base BAM model	5th percentile	50th percentile	95 percentile
1991	17.24	14.18	17.14	20.24
1992	13.12	11.12	13.05	15.16
1993	8.63	7.43	8.6	9.84
1994	14.44	13.36	14.4	15.52
1995	8.02	7.11	7.98	8.9
1996	8.53	7.49	8.52	9.65
1997	6.43	5.16	6.39	7.84
1998	9.76	7.86	9.74	11.65
1999	9.1	7.37	8.97	10.69
2000	3.72	2.73	3.66	5.08
2001	7.79	5.67	7.66	9.66
2002	12.61	9.89	12.55	15.29
2003	9.72	7.48	9.62	12.14
2004	6.32	4.9	6.29	7.87
2005	14.32	12.04	14.23	16.65
2006	9.66	7.77	9.48	11.44
2007	5.59	4.29	5.55	7.1
2008	10.48	8.57	10.5	12.46
2009	8.81	7.18	8.78	10.88
2010	7.8	6.3	7.86	10
2011	4.03	3.25	4.06	5.08

Table 18. Results from base BAM model, sensitivity runs, and retrospective analysis. Fishing mortality (F) is full F and population fecundity (SSB) is in billions of mature ova. Subscripts denote the following MED: median; MED.T: threshold associated with the median; and term: terminal year, which is 2011 for the six rows. * denotes that benchmark calculation is not directly comparable with the base run because of differences in selectivity.

Run	R_{MED}	SSB_{MED}	$SSB_{MED.T}$	SSB_{term} /$SSB_{MED.T}$	$F_{15\%}$	$F_{30\%}$	F_{term} /$F_{15\%}$	F_{term} /$F_{30\%}$
Base run	12.61	19092	9546	1.4	1.34	0.62	3.36	7.22
*cR dome-shaped selectivity	12.52	18090	9045	1.39	1.25	0.64	3.31	6.51
omit JAI	12.72	18365	9182	1.47	1.34	0.62	3.54	7.6
omit PRFC	12.61	19140	9570	1.32	1.34	0.62	3.82	8.2
median effective N	11.96	22043	11021	1.26	1.18	0.57	3.26	6.74
*cR and cB dome-shaped selectivity	14.84	23575	11787	3.67	1.09	0.65	1.51	2.52
Retrospective 2010	12.85	18337	9169	1.23	1.33	0.62	3.31	7.11
Retrospective 2009	13.09	17594	8797	1.88	1.33	0.62	2.75	5.9
Retrospective 2008	13.12	18198	9099	2.2	1.32	0.62	1.56	3.35
Retrospective 2007	13.09	17180	8590	1.48	1.31	0.61	2.3	4.93
Retrospective 2006	13.14	17679	8839	2.5	1.3	0.61	1.46	3.13
Retrospective 2005	13.26	17560	8780	4.77	1.3	0.61	0.63	1.34
Retrospective 2004	13.25	17318	8659	3.06	1.3	0.61	0.94	2
Retrospective 2003	13.26	17077	8539	2.74	1.29	0.6	0.91	1.95
Retrospective 2002	13.89	17940	8970	4.31	1.27	0.6	0.89	1.89
Retrospective 2001	14.58	18570	9285	6.42	1.26	0.6	0.5	1.06
Retrospective 2000	14.6	18266	9133	2.41	1.26	0.59	0.85	1.81

Table 19. The negative log likelihood for the base BAM model and the sensitivity runs.

Run	total	JAI	pound net	cR landings	cB landings	cR age comps	cB age comps	SR fit	SRend
Base run	2457	245	19.46	11.32	1.94	2035.4	125.6	17.7	0.83
cR dome-shaped selectivity	2398	247	19.22	10.44	1.87	1982.2	118.8	17.7	0.74
omit JAI	2191	0	19.91	11.67	1.75	2010.2	122.9	21.2	3.36
omit PRFC	2437	245	0	11.56	2	2034.1	126.4	17.7	0.84
median effective N	424	153	19.45	1.26	0.13	169.12	66.58	14.1	0.25
cR, cB dome-shaped selectivity	2337	245	26.19	8.02	2.25	1945	92.9	17.2	0.78

Table 20. The negative log likelihood for the base BAM model and the retrospective runs.

Ending year	total	JAI	pound net	cR landings	cB landings	cR age comps	cB age comps	SR fit	SRend
Base run	2457	245.3	19.46	11.32	1.94	2035.4	125.57	17.65	0.83
2010	2395	239	19.24	11.22	1.82	2002.2	103.21	17.45	0.67
2009	2357	238.4	19.31	11.15	1.77	1974.5	93.42	17.66	0.58
2008	2324	230.4	17	11.12	1.78	1954.4	91.26	17.19	0.82
2007	2275	205	16.13	10.91	1.78	1934.1	88.34	17.11	1.16
2006	2222	194.3	13.59	10.75	1.77	1902.2	79.22	17.82	2.07
2005	2192	190.2	12.69	10.52	1.77	1887.4	73.24	15.86	0.63
2004	2173	188	12.63	10.38	1.75	1872.2	71.8	15.64	0.45
2003	2144	185.1	12.43	10.17	1.71	1849.4	69.97	15.07	0
2002	2097	182.9	11.88	9.67	1.64	1809.3	65.58	15.26	0.52
2001	2055	165	12.93	9.62	1.53	1787.2	63.57	14.3	0.62
2000	2019	169.7	11.73	9.45	1.59	1753.2	59.67	13.69	0.06

Table 21. Summary of benchmarks and terminal year (2011) values estimated for the base BAM model. Fishing mortality rate is full F, and SSB is fecundity in billions of mature ova. Benchmarks were calculated using the time period 1955-2011.

Benchmarks and Terminal Year Values	Base BAM Model Estimates 1955-2011
Median Age-0 Recruits (billions)	12.61
$F_{30\%}$	0.62
$F_{15\%}$	1.34
F_{2011}	4.5
$F_{2011}/F_{30\%}$	7.22
$F_{2011}/F_{15\%}$	3.36
Target: SSB_{MED}	19,092
Threshold (Limit):	
$SSB_{MED.thresh}$	9,546
SSB_{2011}	13,334
$SSB_{2011}/SSB_{threshold}$	1.4

Table 22. The probability of the fishing mortality rate (F) being less than the THRESHOLD over time for given constant landing scenarios. Total landings are partitioned with 75% to the commercial reduction fishery and 25% to the commercial bait fishery.

Landings (1000s mt)	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
75	0.00	0.09	0.86	0.99	1.00	1.00	1.00	1.00	1.00	1.00
100	0.00	0.01	0.50	0.89	0.97	1.00	1.00	1.00	1.00	1.00
125	0.00	0.00	0.19	0.58	0.81	0.92	0.97	0.99	0.99	1.00
150	0.00	0.00	0.04	0.25	0.47	0.62	0.74	0.83	0.90	0.93
175	0.00	0.00	0.01	0.06	0.16	0.27	0.36	0.44	0.51	0.57
200	0.00	0.00	0.00	0.01	0.02	0.06	0.10	0.12	0.14	0.17
225	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.02	0.02

Table 23. The probability of the fishing mortality rate (F) being less than the TARGET over time for given constant landing scenarios. Total landings are partitioned with 75% to the commercial reduction fishery and 25% to the commercial bait fishery.

Landings (1000s mt)	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
75	0.00	0.00	0.24	0.83	0.98	1.00	1.00	1.00	1.00	1.00
100	0.00	0.00	0.02	0.37	0.72	0.90	0.97	0.99	1.00	1.00
125	0.00	0.00	0.00	0.06	0.28	0.49	0.65	0.78	0.87	0.91
150	0.00	0.00	0.00	0.01	0.04	0.11	0.21	0.31	0.38	0.46
175	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.04	0.06	0.08
200	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01
225	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

15 Figures

Figure 1. Annual menhaden reduction and bait landings (1,000 t), 1940-2011.

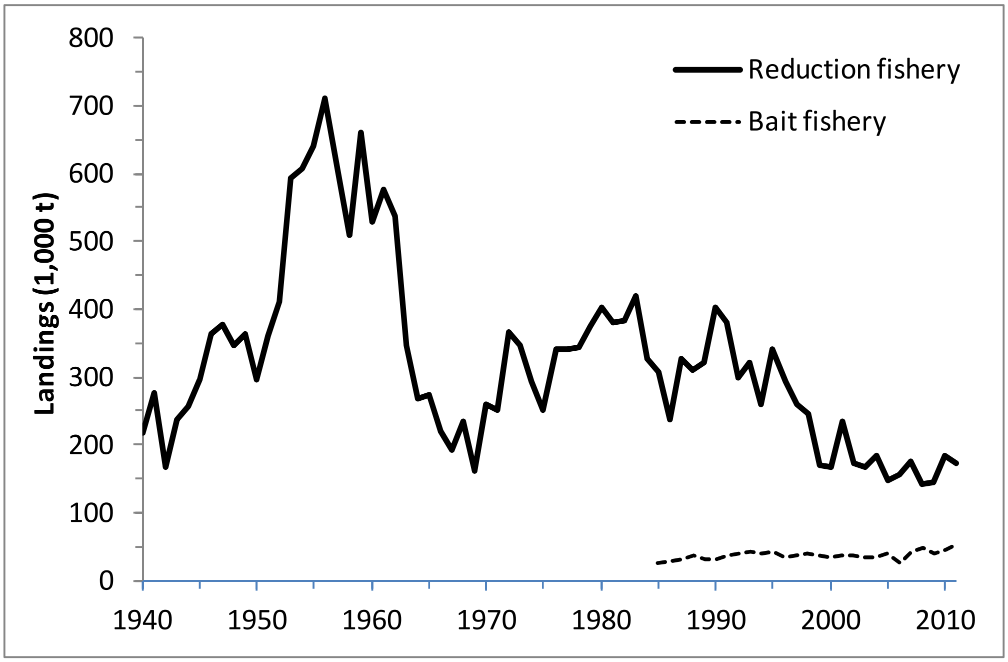


Figure 2. Annual menhaden bait landings (1,000 t), 1985-2011.

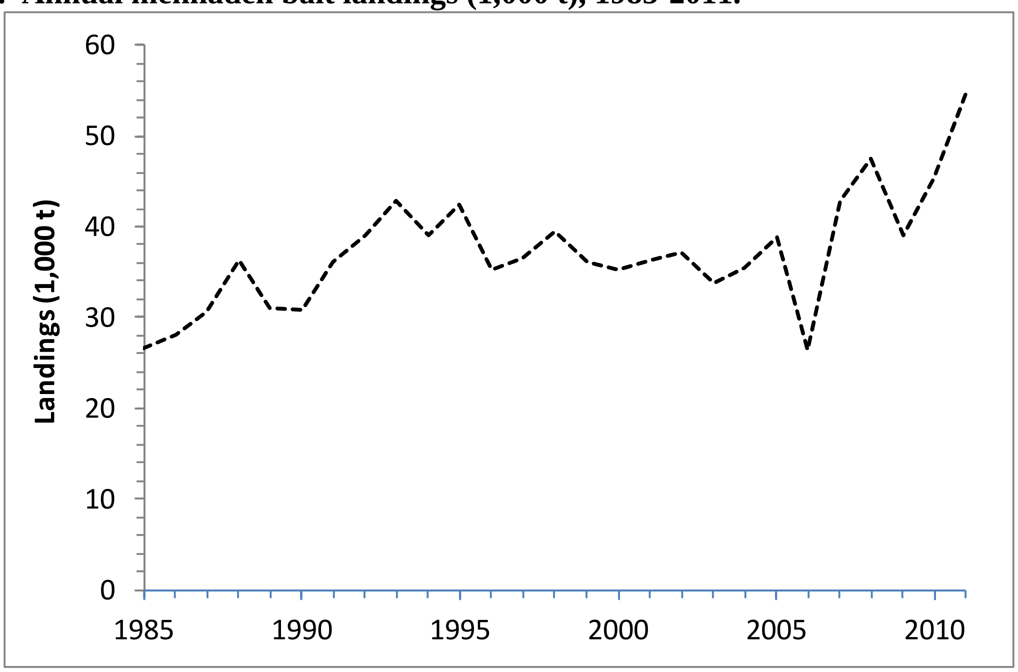
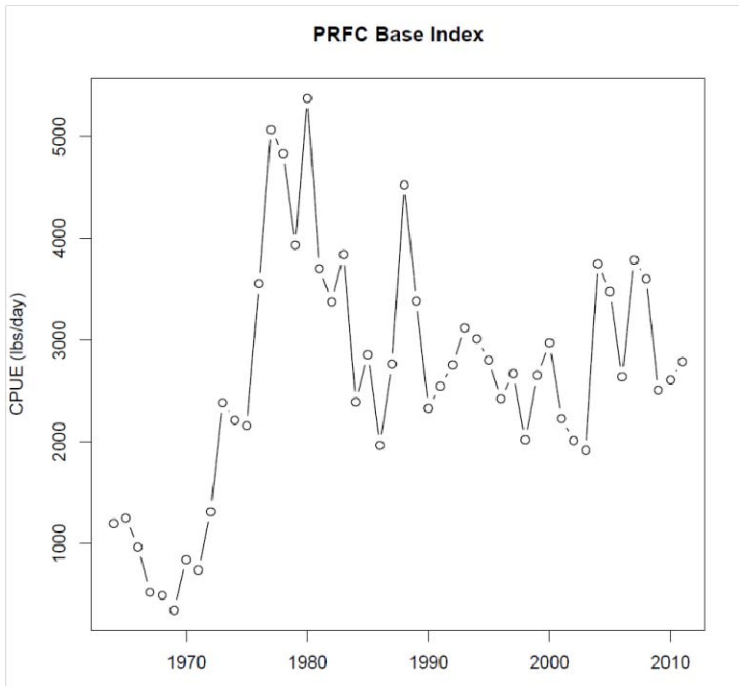


Figure 3. Top: PRFC adult Atlantic menhaden (primarily ages-1 through 3) index of relative abundance derived from annual ratios of pounds landed and pound net days fished. CPUE for the years 1964-1975 and 1981-1987 were estimated from regressions of published landings (to obtain annual landings) and licenses (to obtain total annual days fished). Bottom: Comparison of PRFC index between 2010 benchmark and 2012 update assessments; the red line represents the index used in the benchmark, 1964-2008, and the blue line indicates the updated and corrected index, 1964-2011.



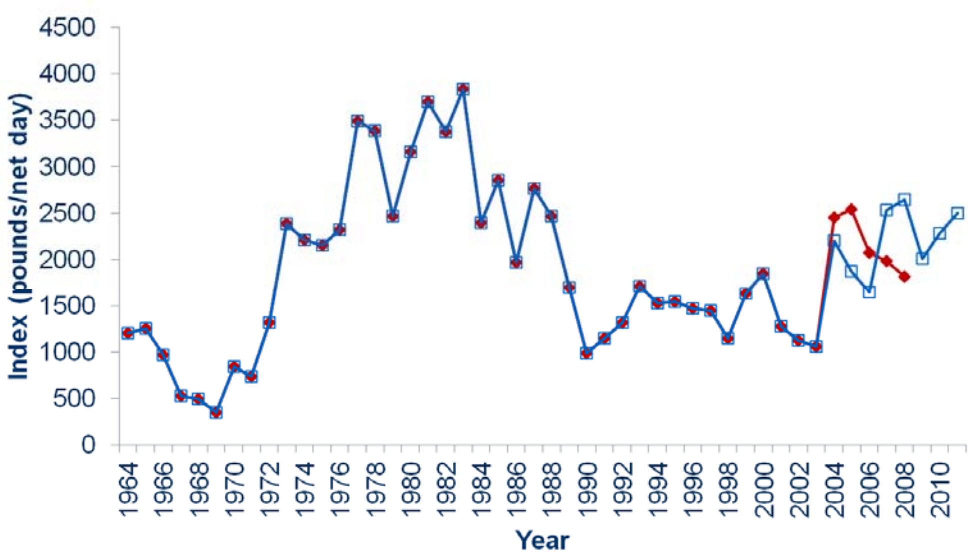


Figure 4. Recreational landings (1000s mt) from the benchmark assessment (dashed line) and for the update assessment (solid line). Differences in landings from 2004-2008 occurred because of a move from MRFSS to MRIP for those years. The current update assessment used MRFSS values from 1981-2003 and MRIP values from 2004-2011.

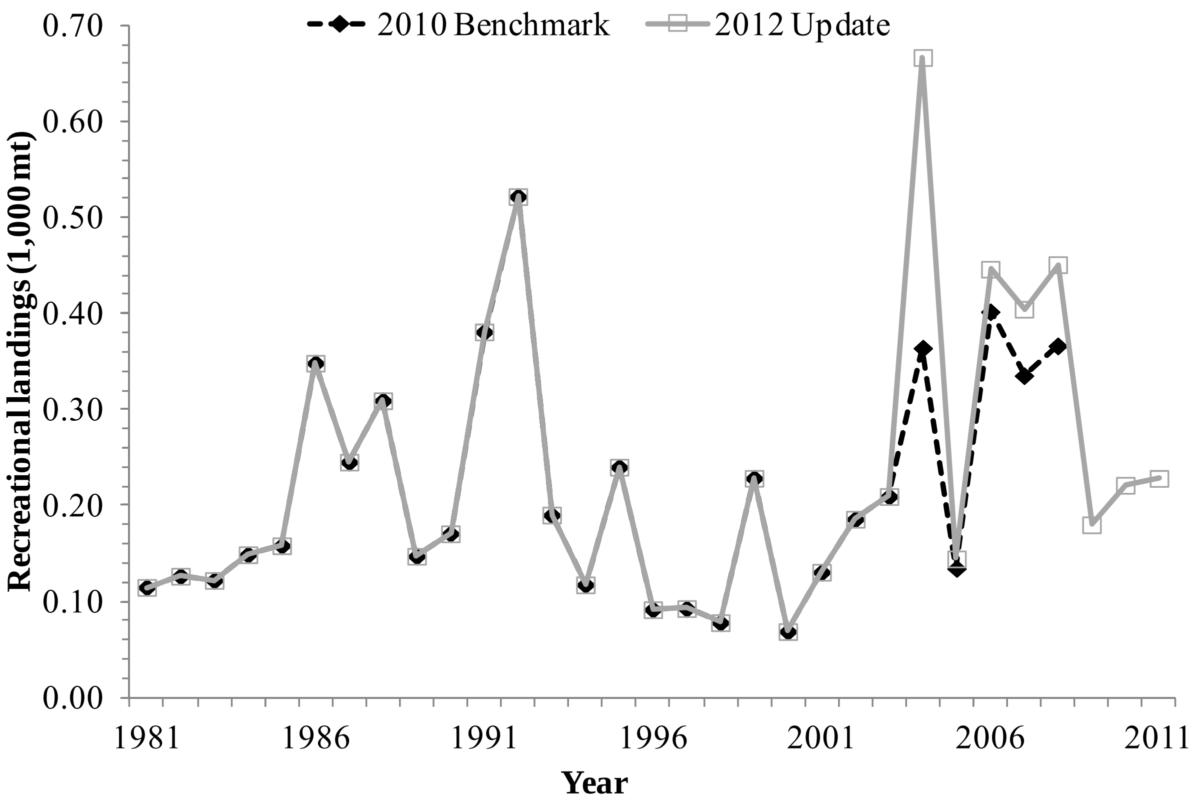


Figure 5. Coastwide juvenile abundance index (black line) based on the delta-lognormal GLM with fixed factors year, month, and state fitted to seine catch-per-haul data for 1959-2011 from all states combined. Coefficients of variations (CV; grey line) were calculated from jackknifed derived SEs.

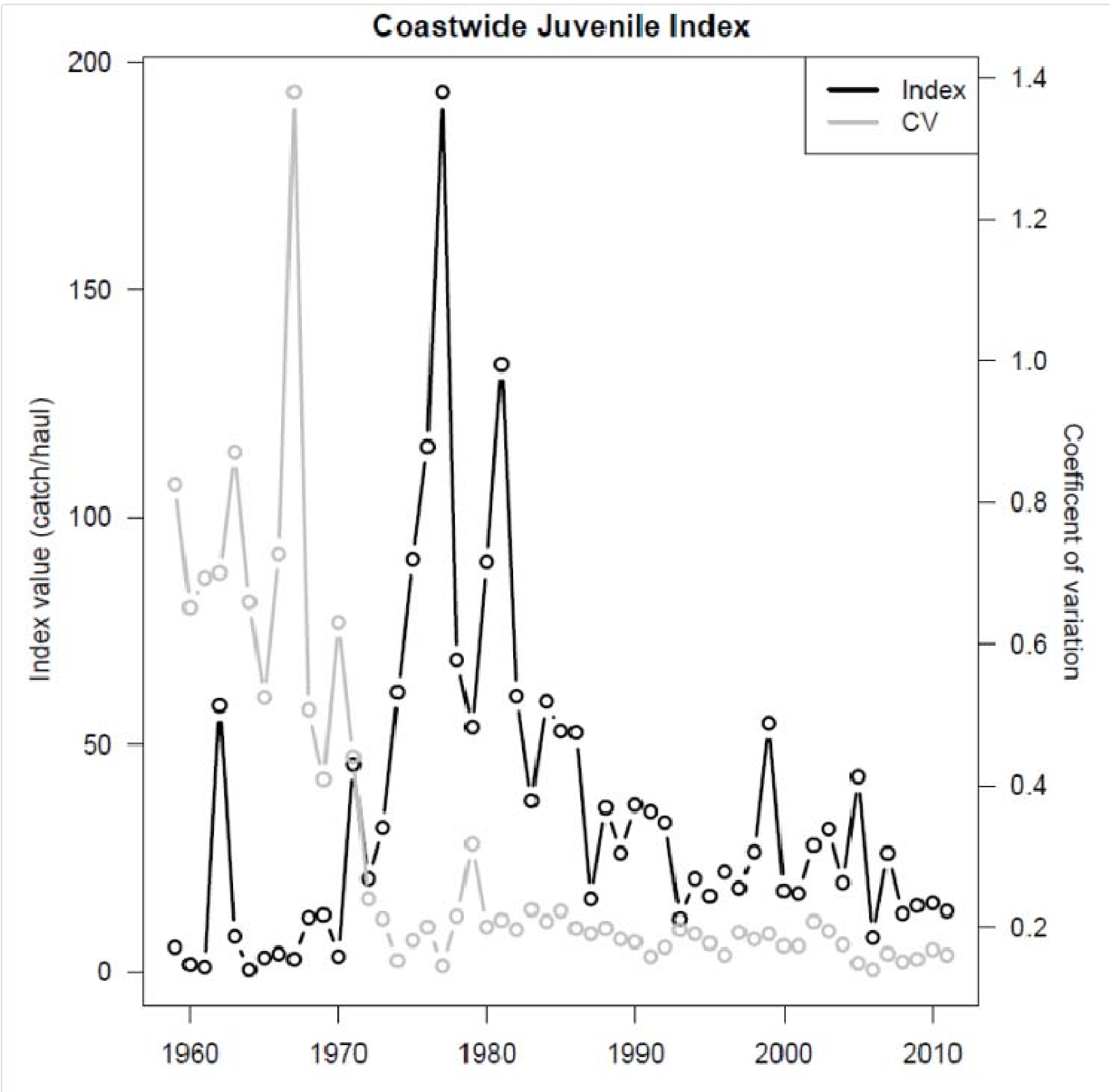


Figure 6. Observed (open circles) and predicted (connected points) landings in 1,000 metric tons of Atlantic menhaden by the commercial reduction fishery from the base BAM model.

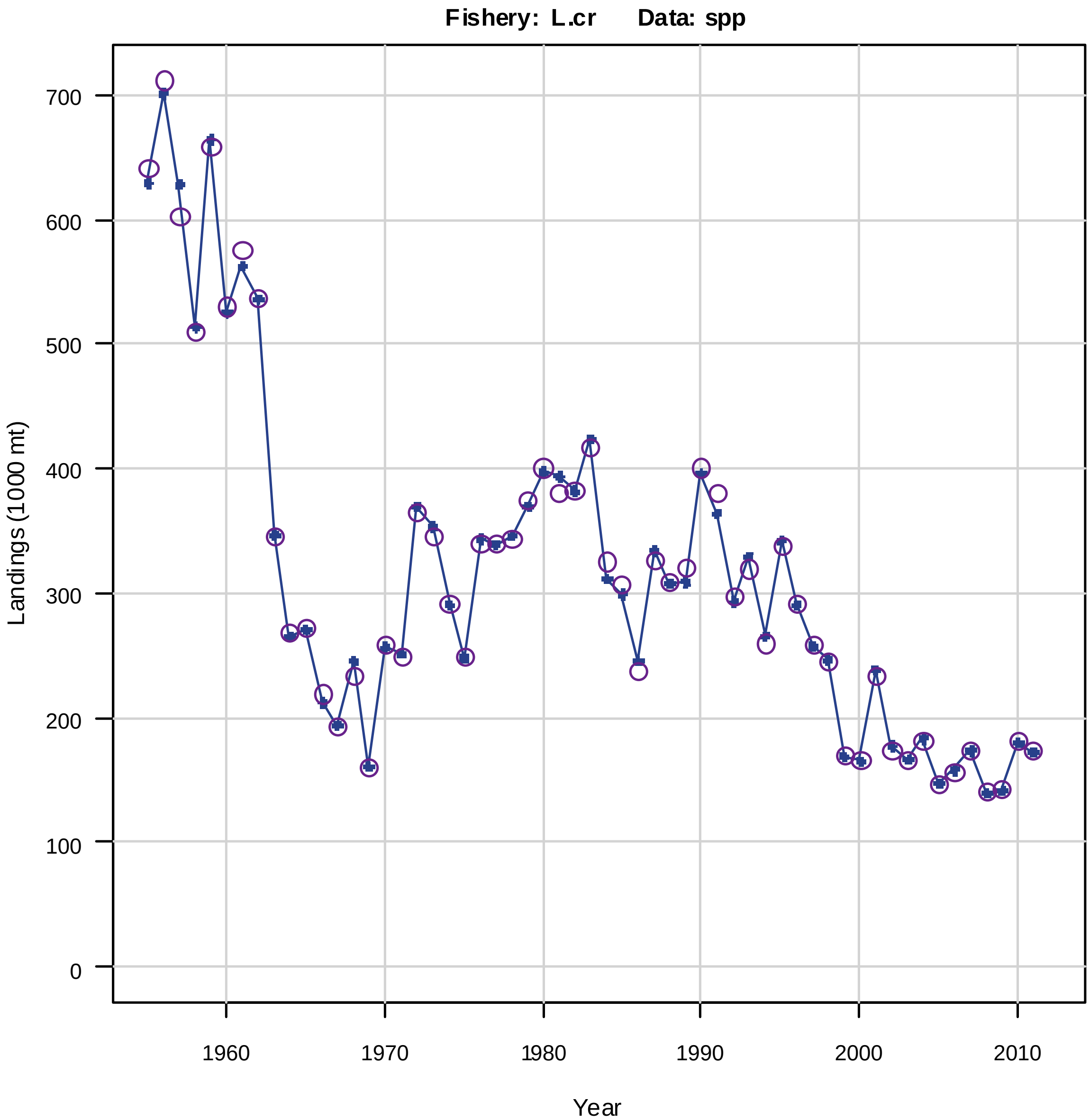


Figure 7. Observed (open circles) and predicted (connected points) landings in 1000 metric tons of Atlantic menhaden by the bait fishery from the base BAM model.

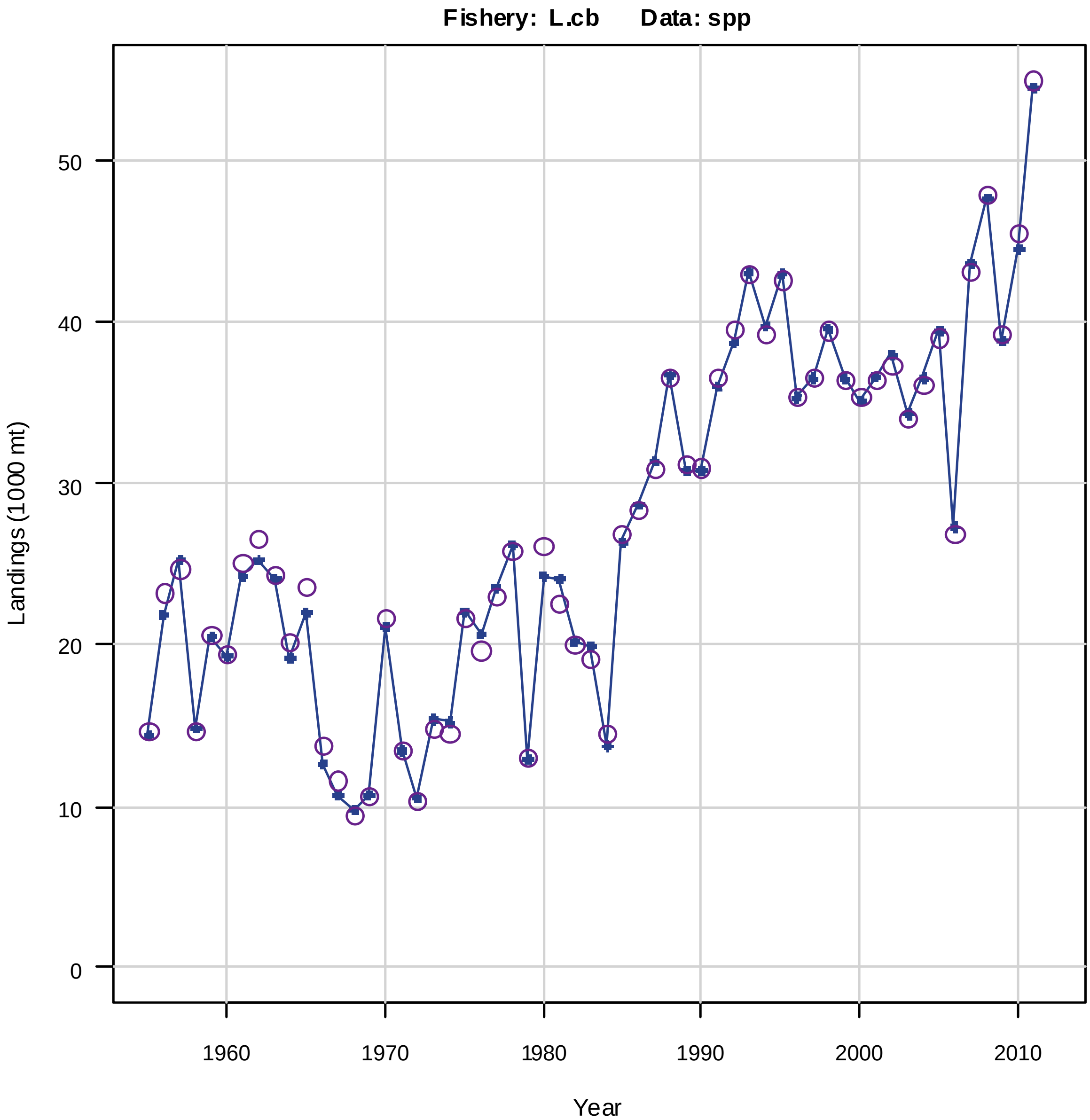


Figure 8. Observed (open circles) and predicted (connected points) landings in 1,000 metric tons of Atlantic menhaden by the commercial reduction fishery from the base BAM model for the 2010 benchmark assessment (red) and the current update assessment (blue).

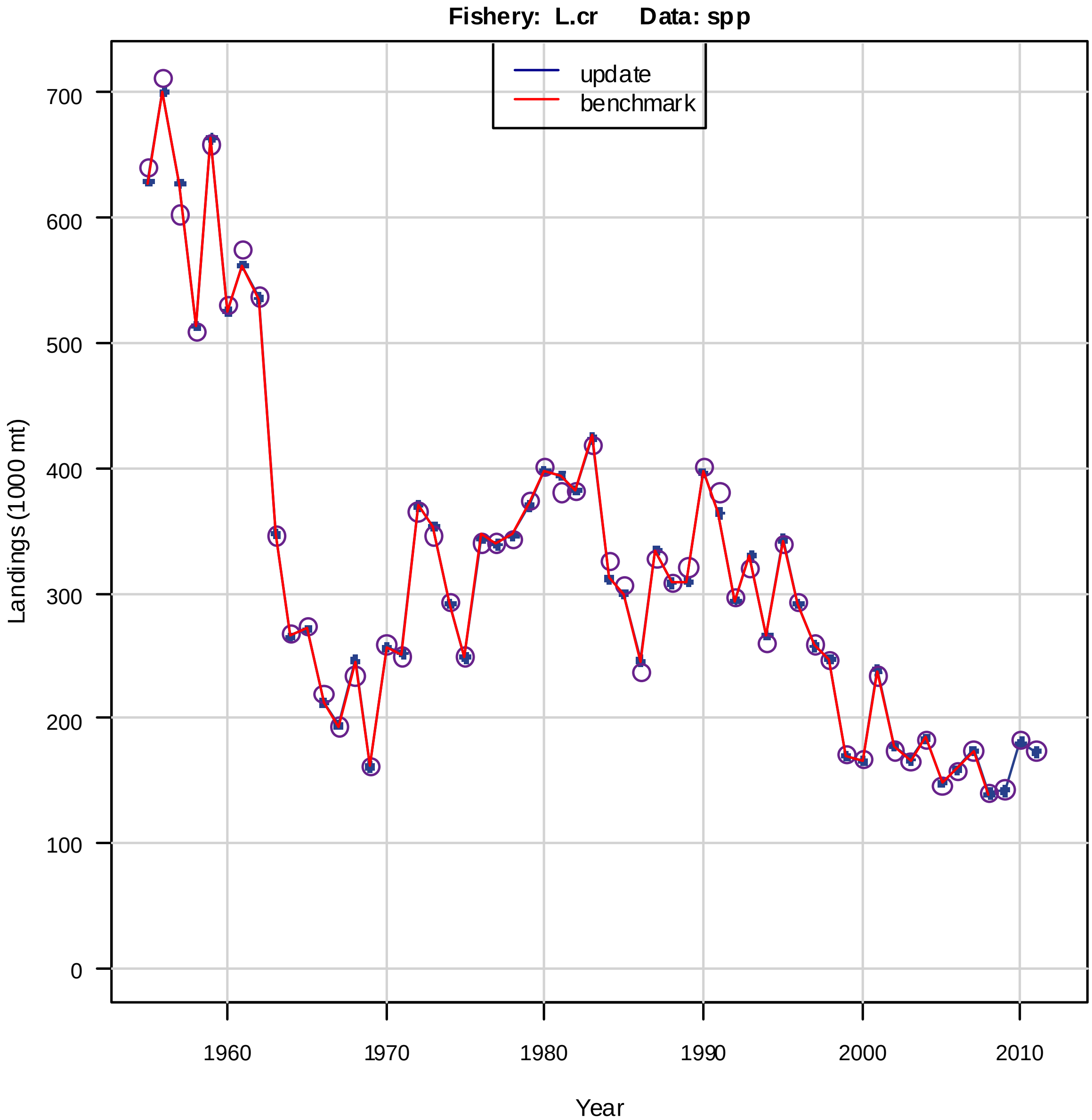


Figure 9. Observed (open circles) and predicted (connected points) landings in 1,000 metric tons of Atlantic menhaden by the commercial bait fishery from the base BAM model for the 2010 benchmark assessment (red) and the current update assessment (blue).

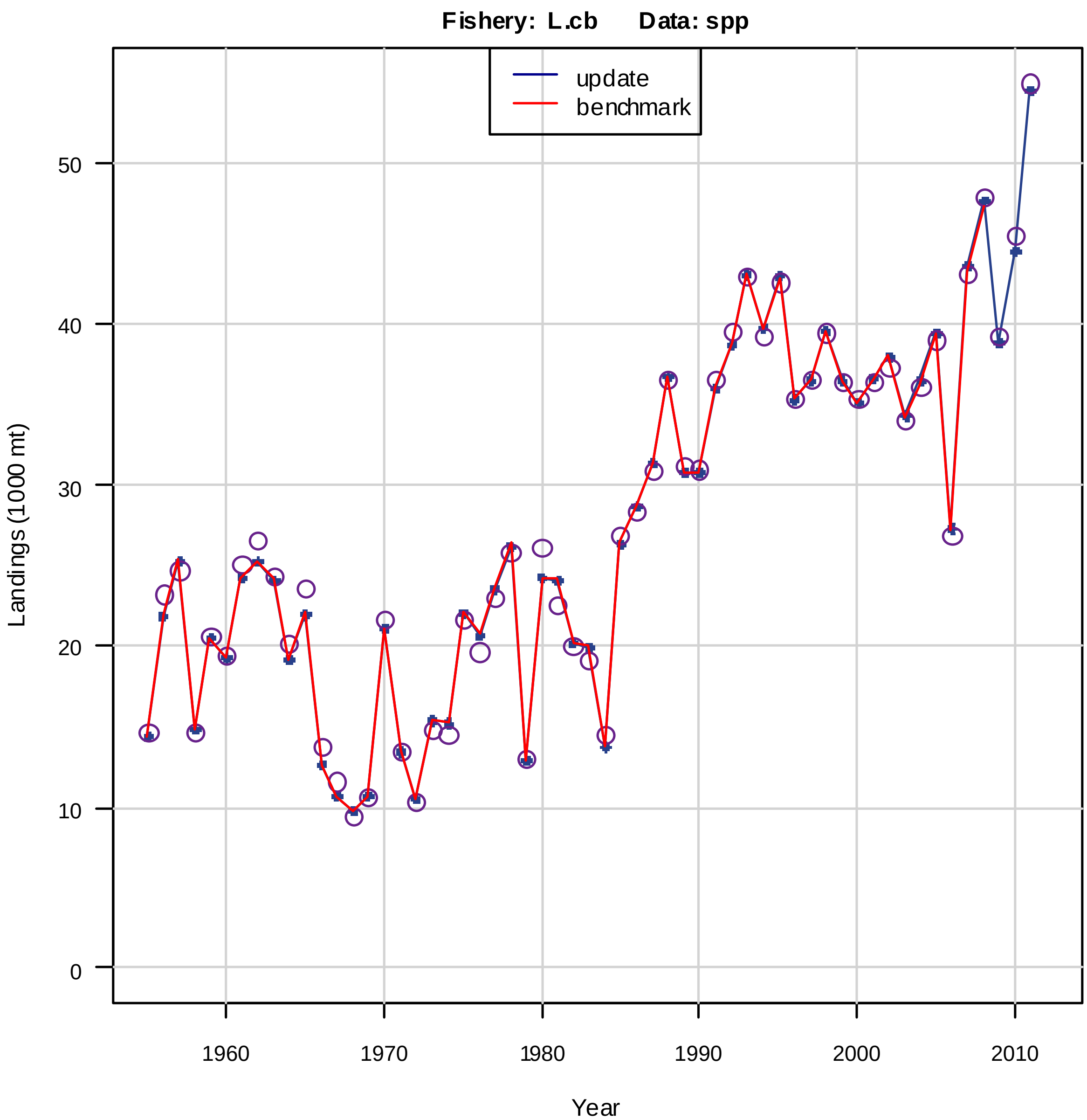


Figure 10. Annual observed (open circles) and predicted (connected points) proportions at age for Atlantic menhaden from the commercial reduction fishery from the base BAM model. The number of trips sampled (N) is indicated for each year.

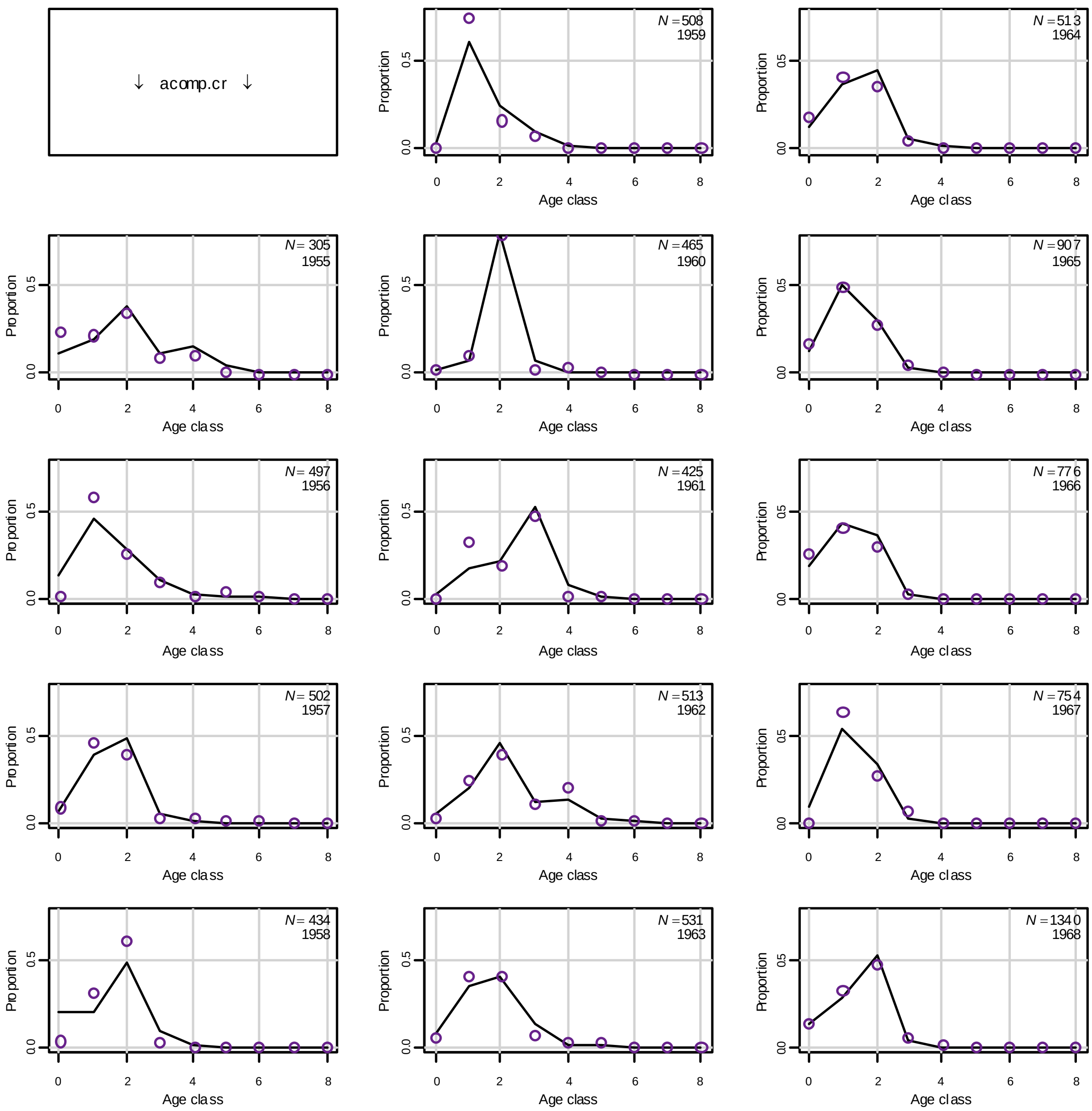


Figure 10. (*continued*).

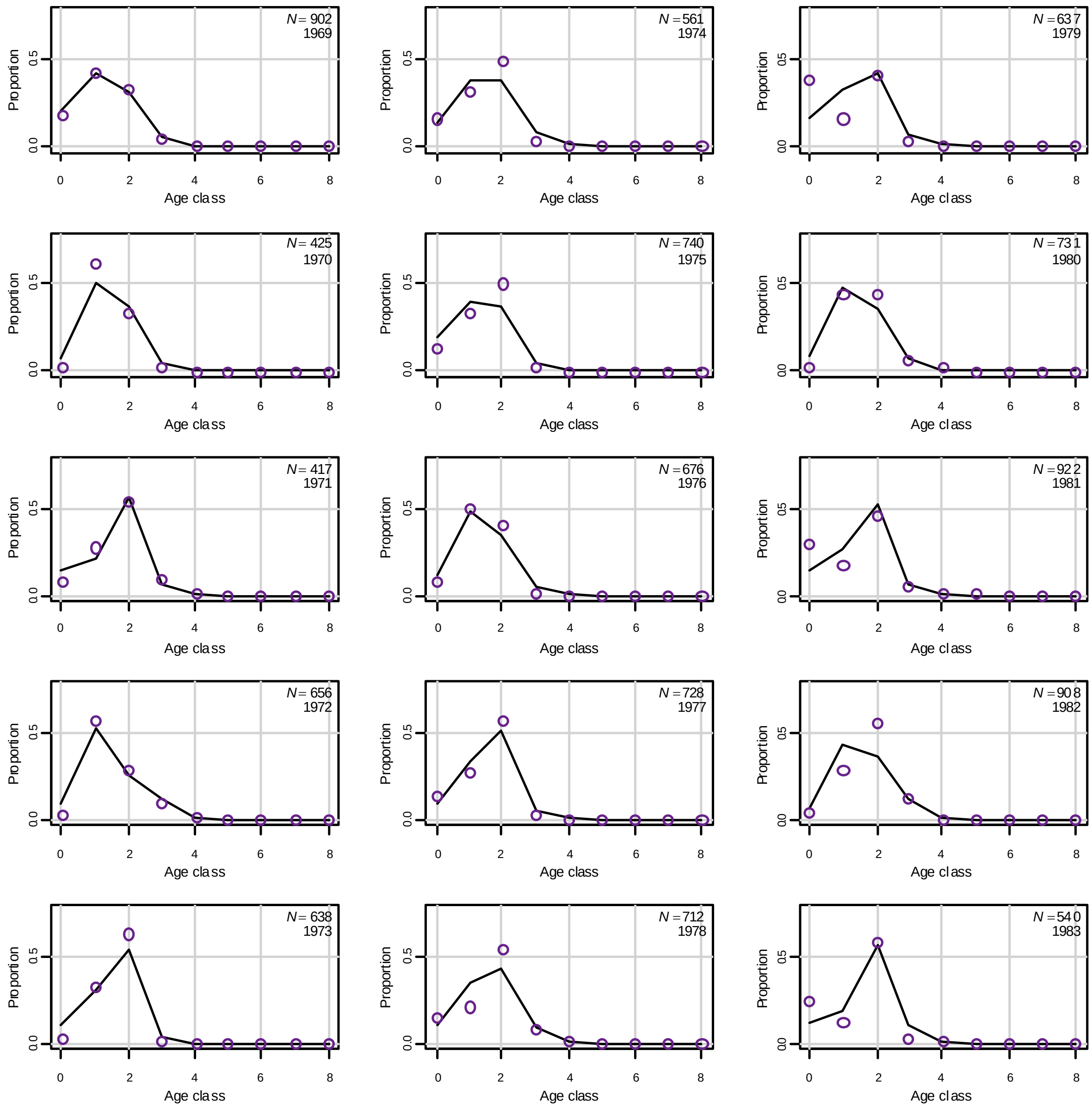


Figure 10. (*continued*).

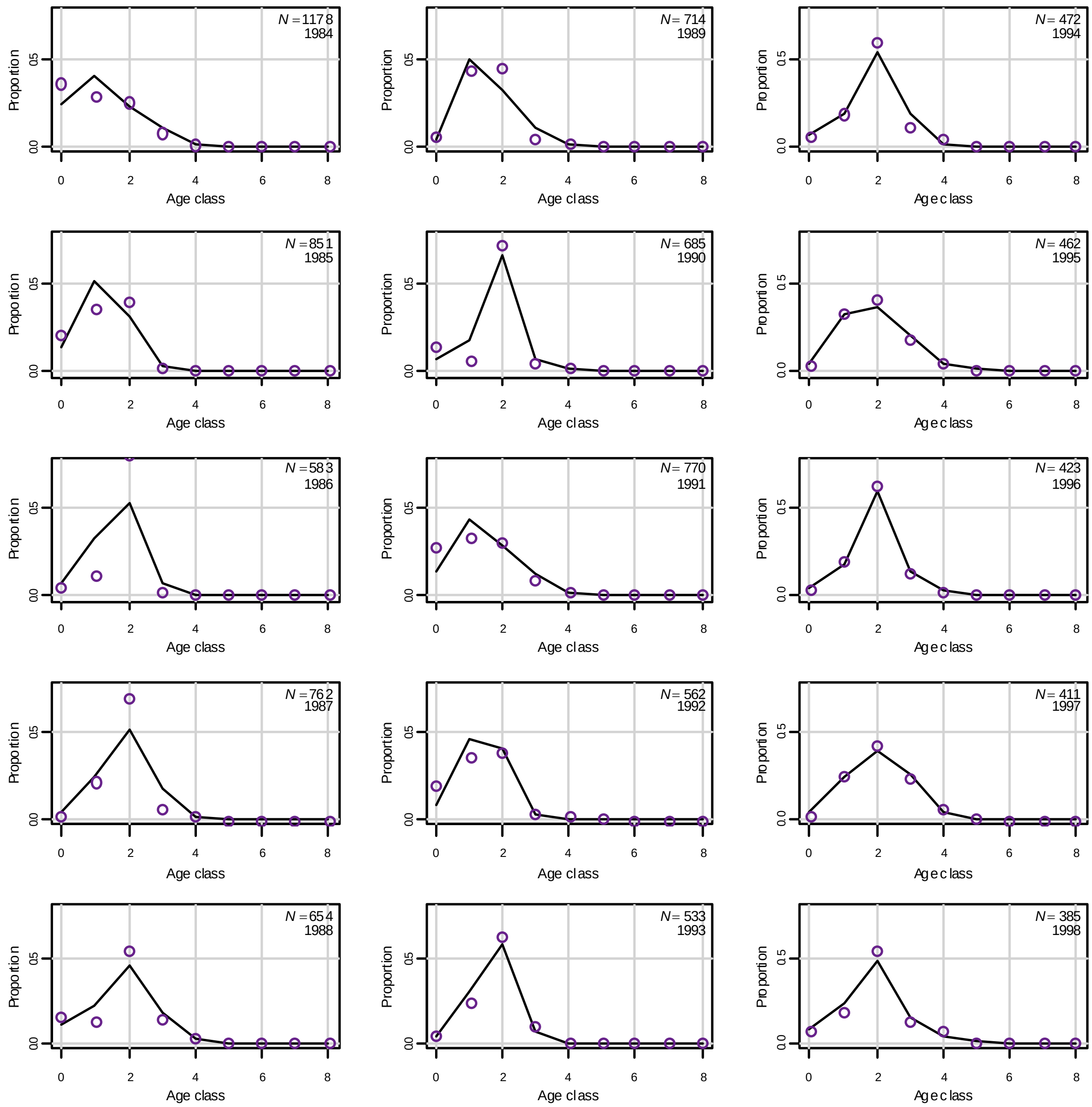


Figure 10. (*continued*).

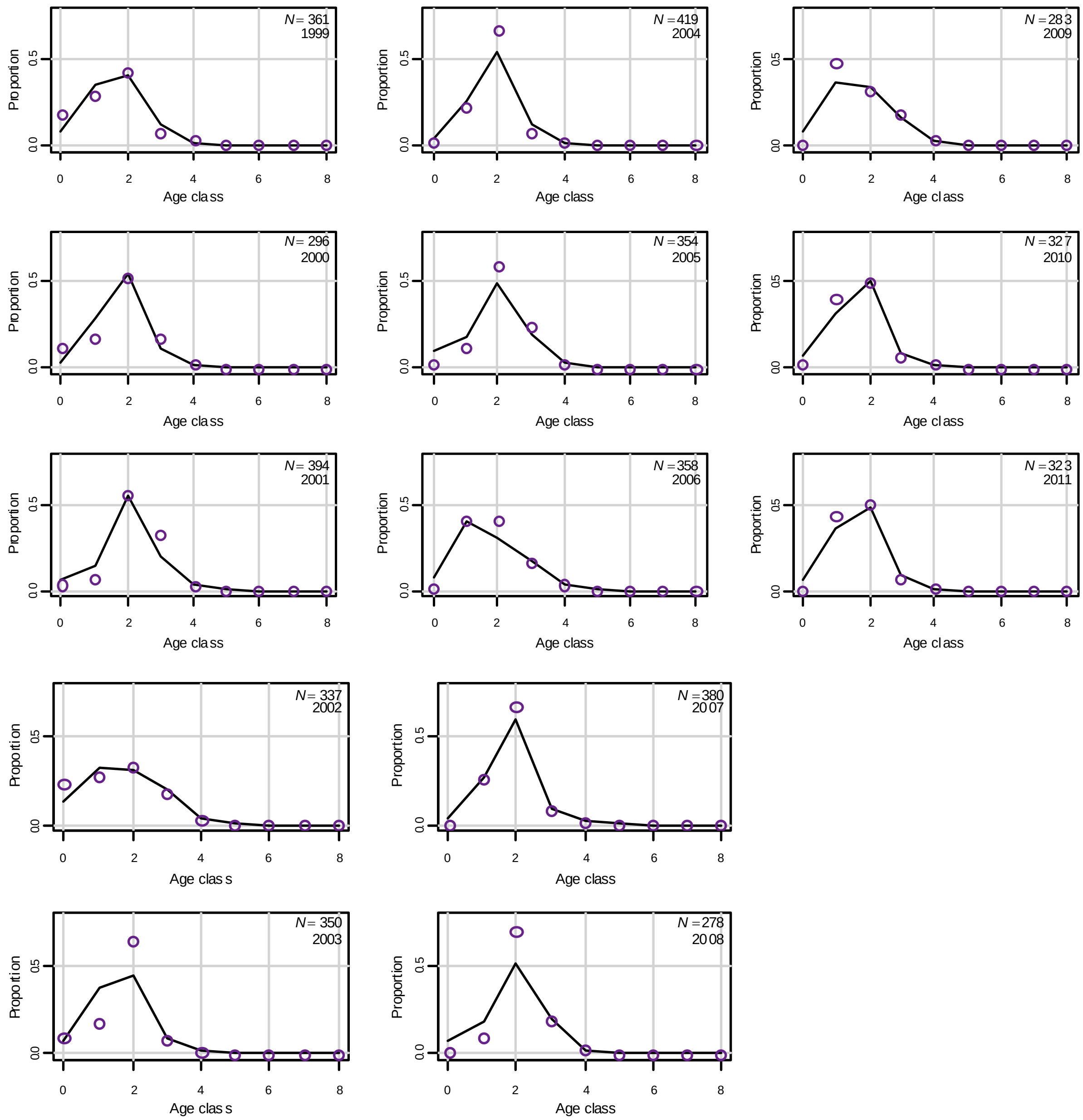


Figure 11. Bubble plot of Atlantic menhaden commercial reduction fishery catch-at-age residuals from the base BAM model. Area of circles is relative to the size of the residual and blue (dark) circles indicate an overestimate by the BAM model.

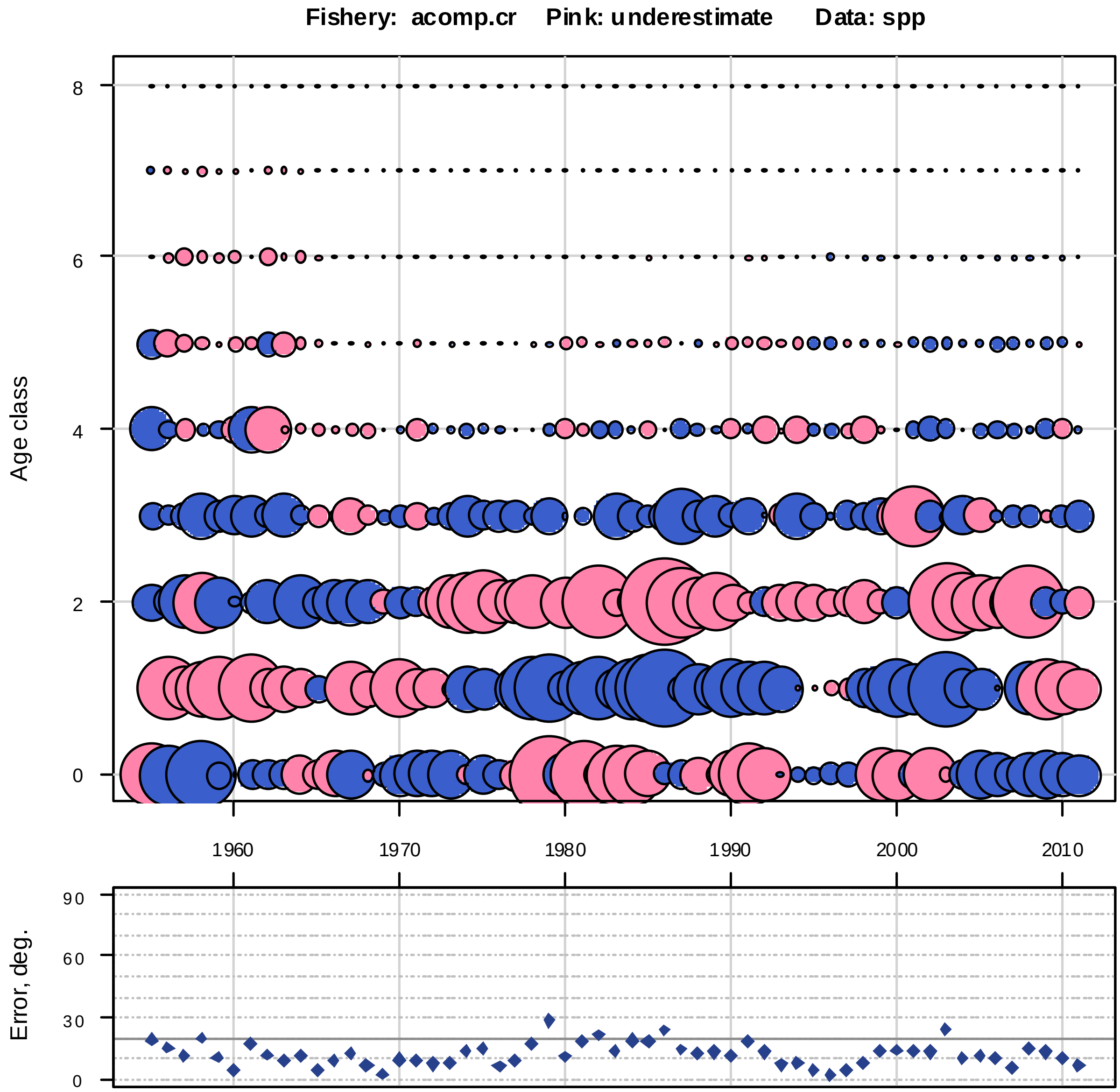


Figure 12. Annual observed (open circles) and predicted (connected points) proportions at age for Atlantic menhaden from the bait fishery from the base BAM model. The number of trips sampled (N) is indicated for each year.

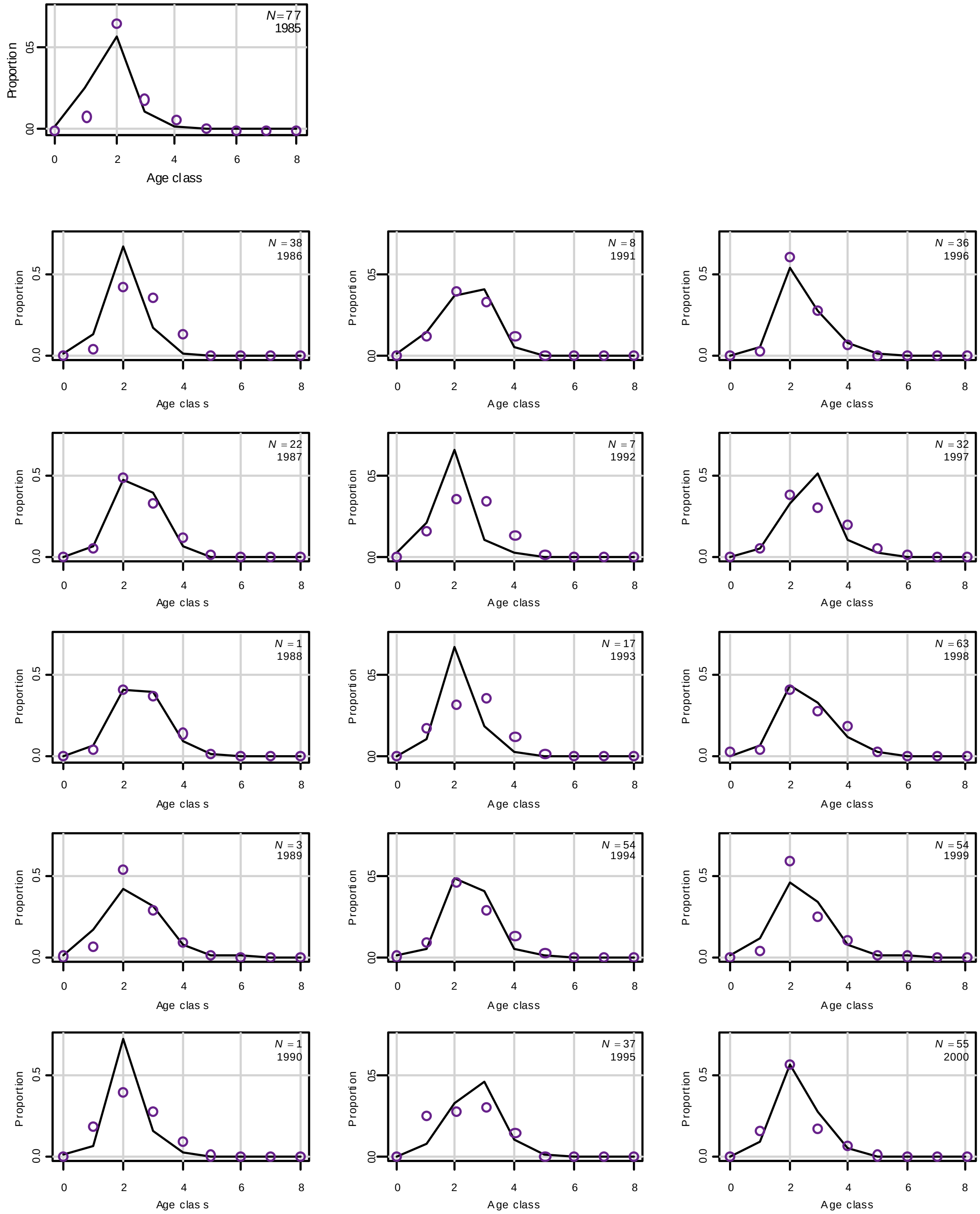


Figure 12. (*continued*).

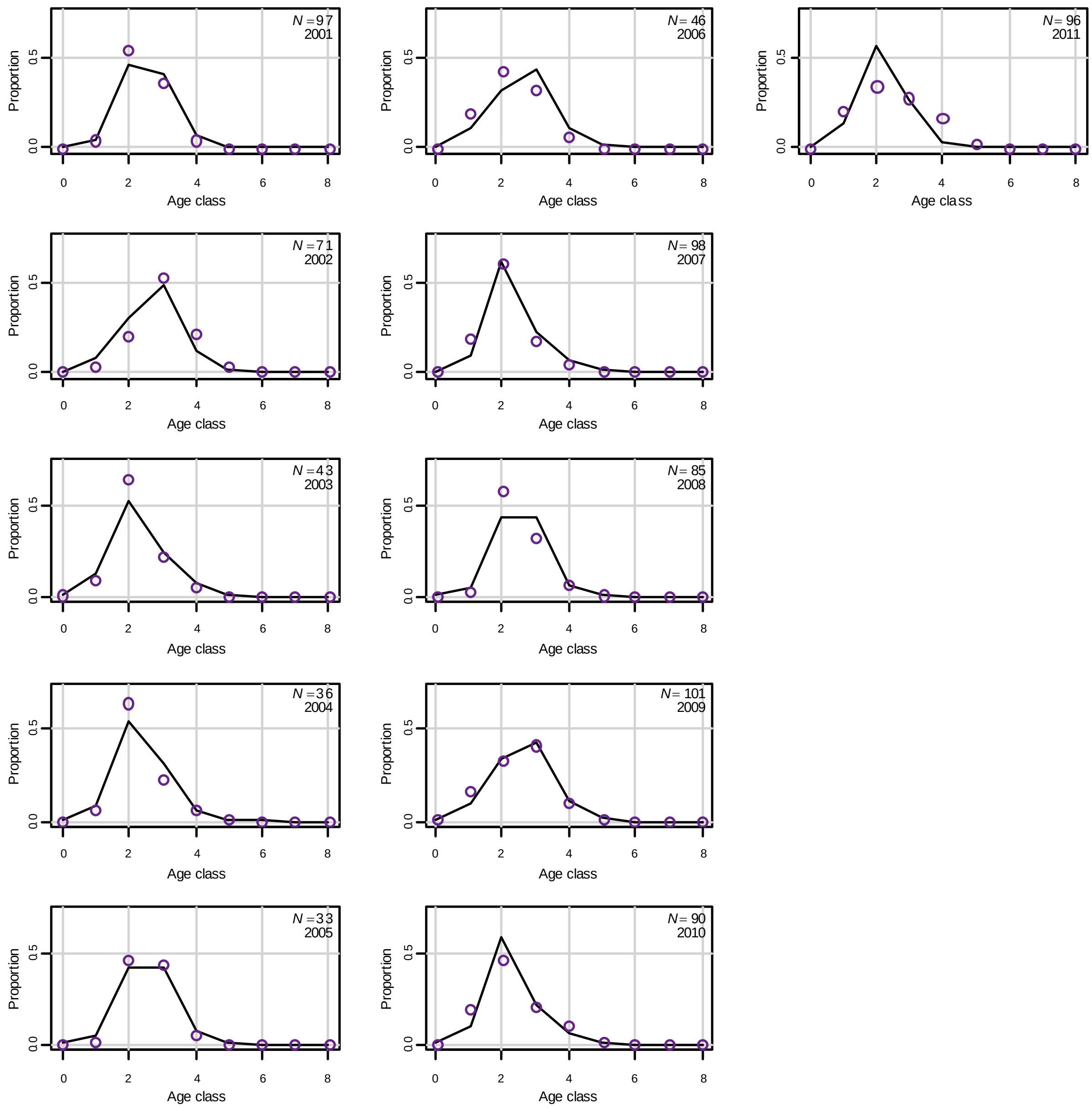


Figure 13. Bubble plot of Atlantic menhaden bait fishery catch-at-age residuals from the base BAM model. Area of circles is relative to the size of the residual and blue (dark) circles indicate an overestimate by the BAM model.

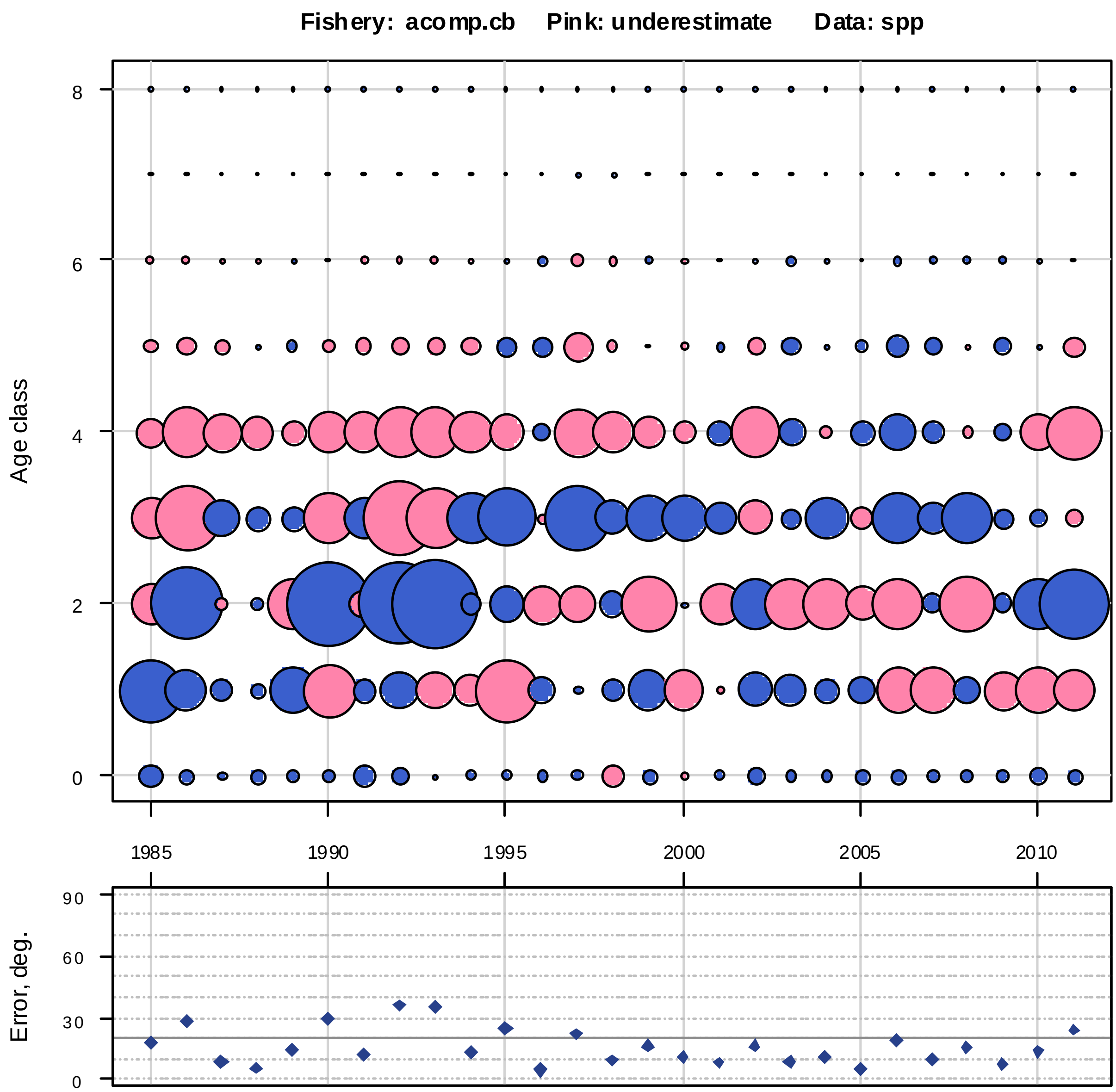


Figure 14. Annual observed (open circles) and predicted (lines) proportions at age for Atlantic menhaden from the commercial reduction fishery from the base BAM model for the last benchmark assessment (red) and the current update assessment (black). The number of trips sampled (*N*) is indicated for each year.

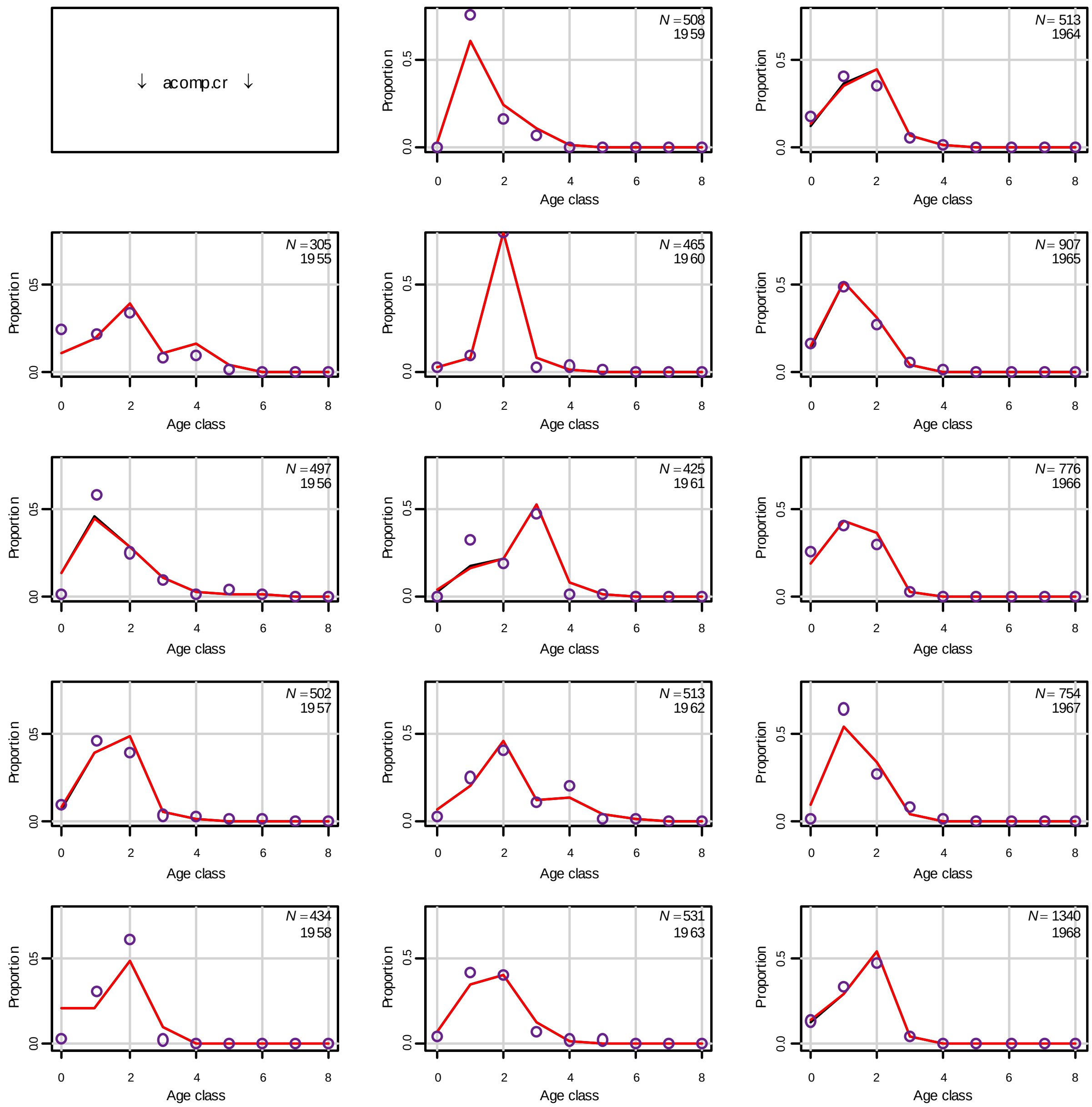


Figure 14. (*continued*).

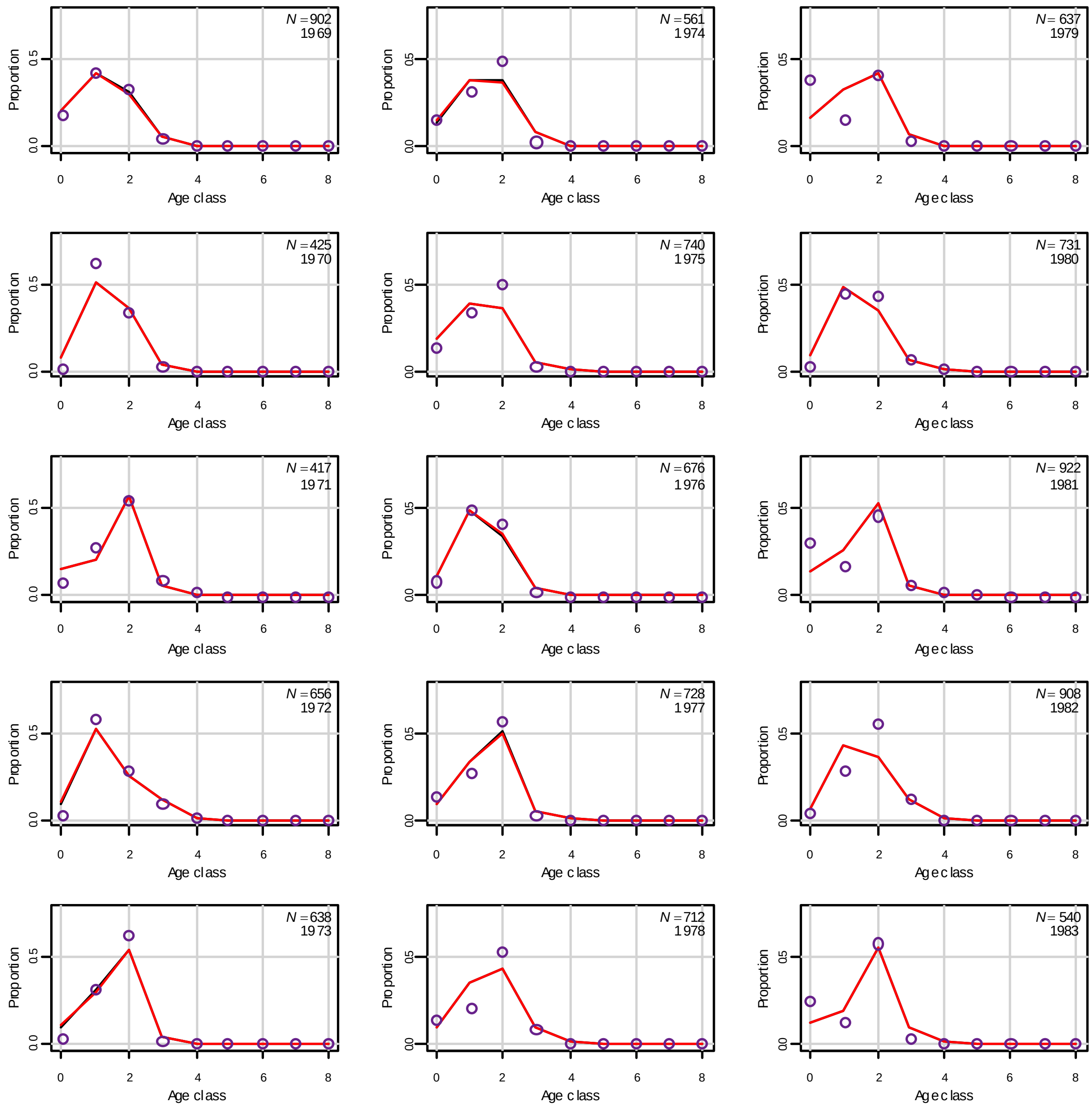


Figure 14. (*continued*).

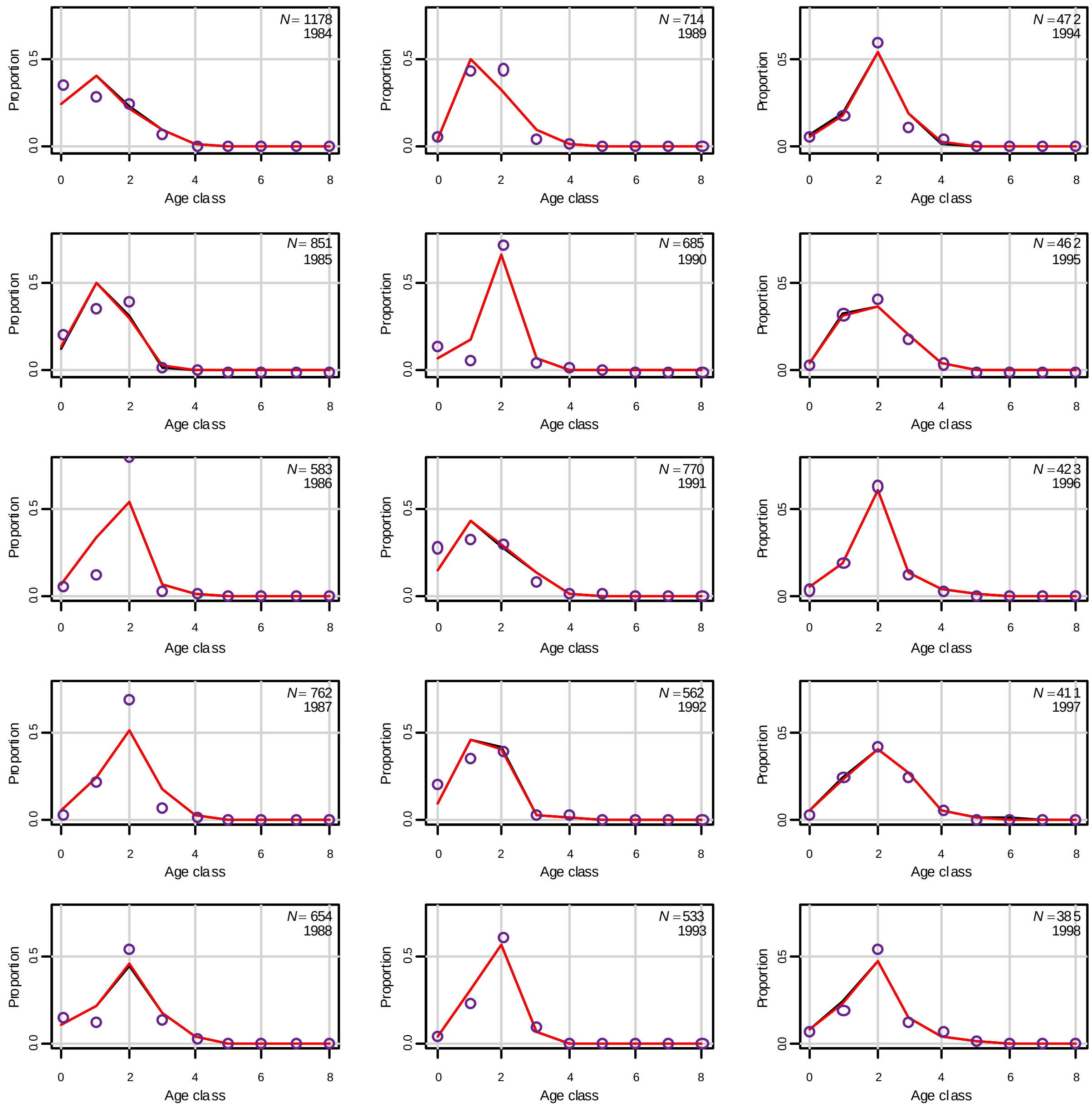


Figure 14. (*continued*).

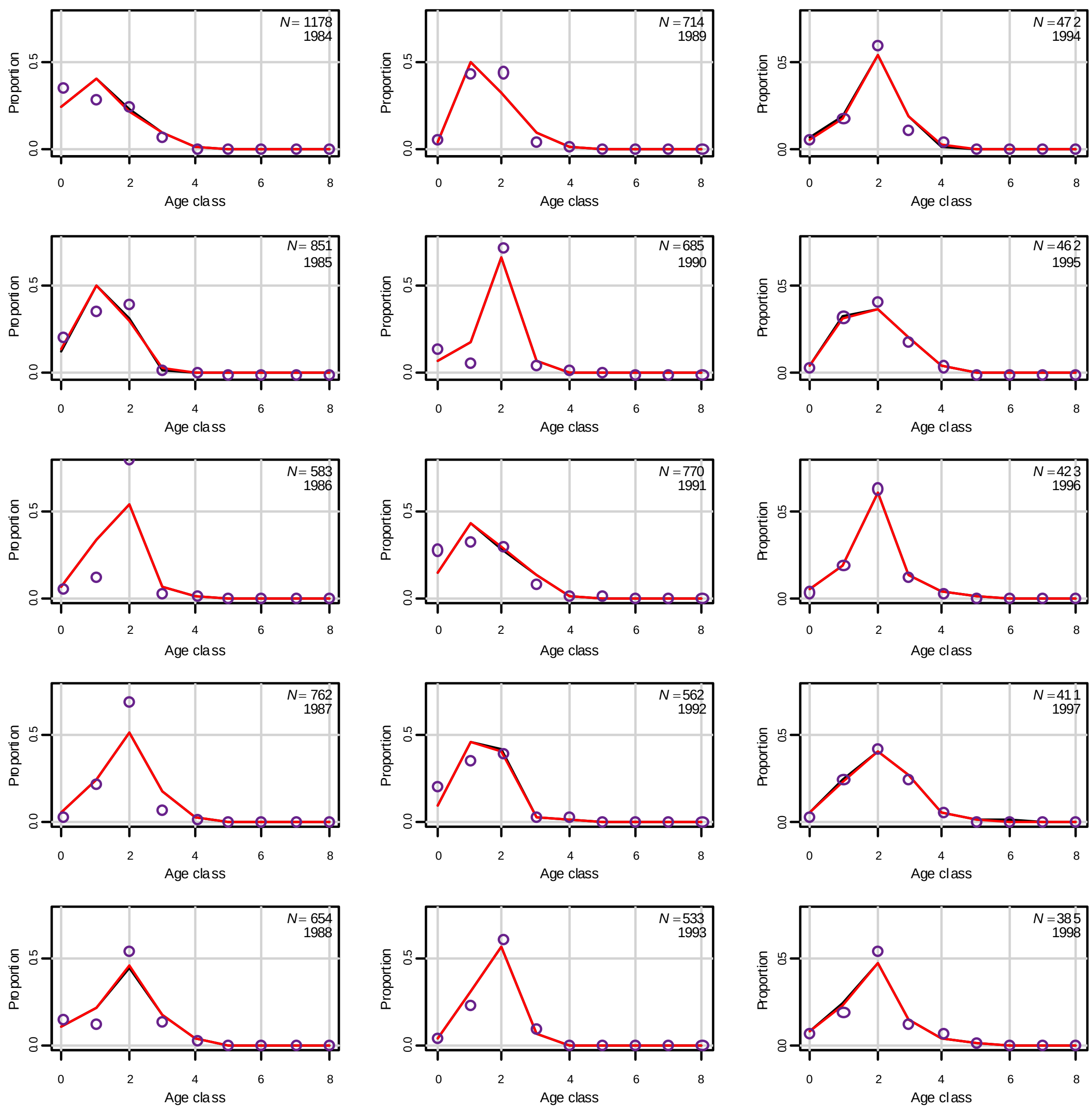


Figure 14. (*continued*).

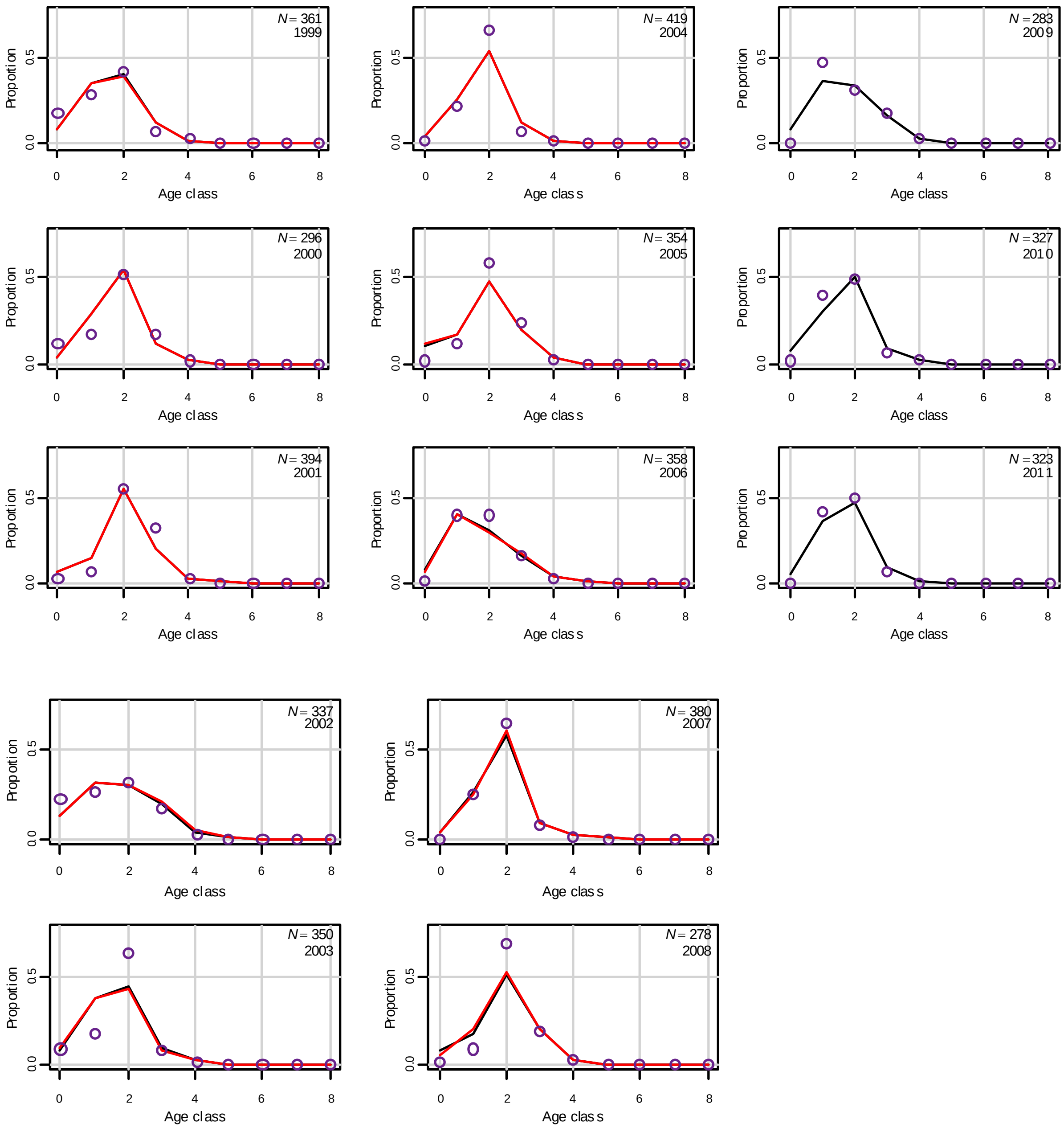


Figure 15. Annual observed (open circles) and predicted (lines) proportions at age for Atlantic menhaden from the commercial bait fishery from the base BAM model for the last benchmark assessment (red) and the current update assessment (black). The number of trips sampled (*N*) is indicated for each year.

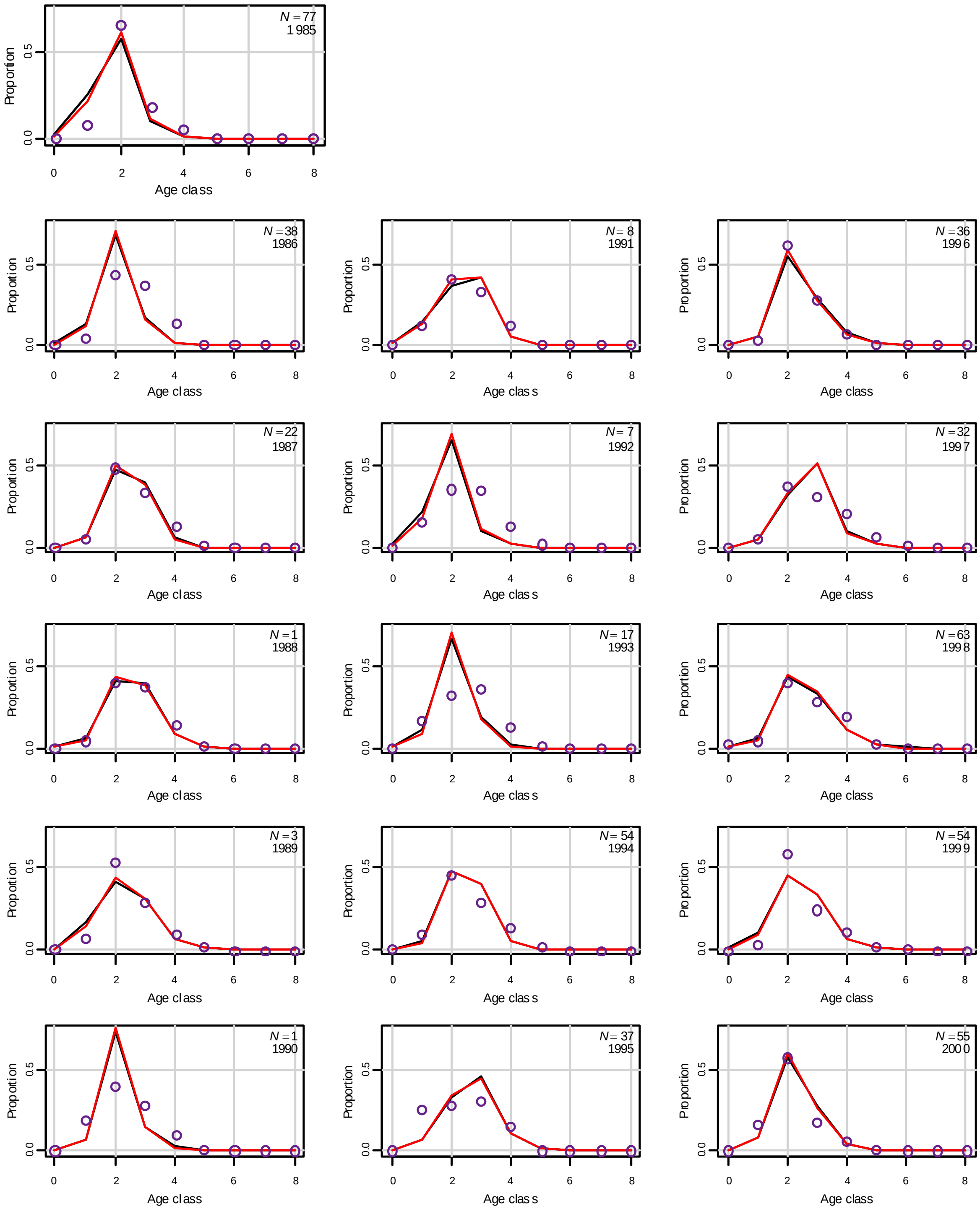


Figure 15. (*continued*).

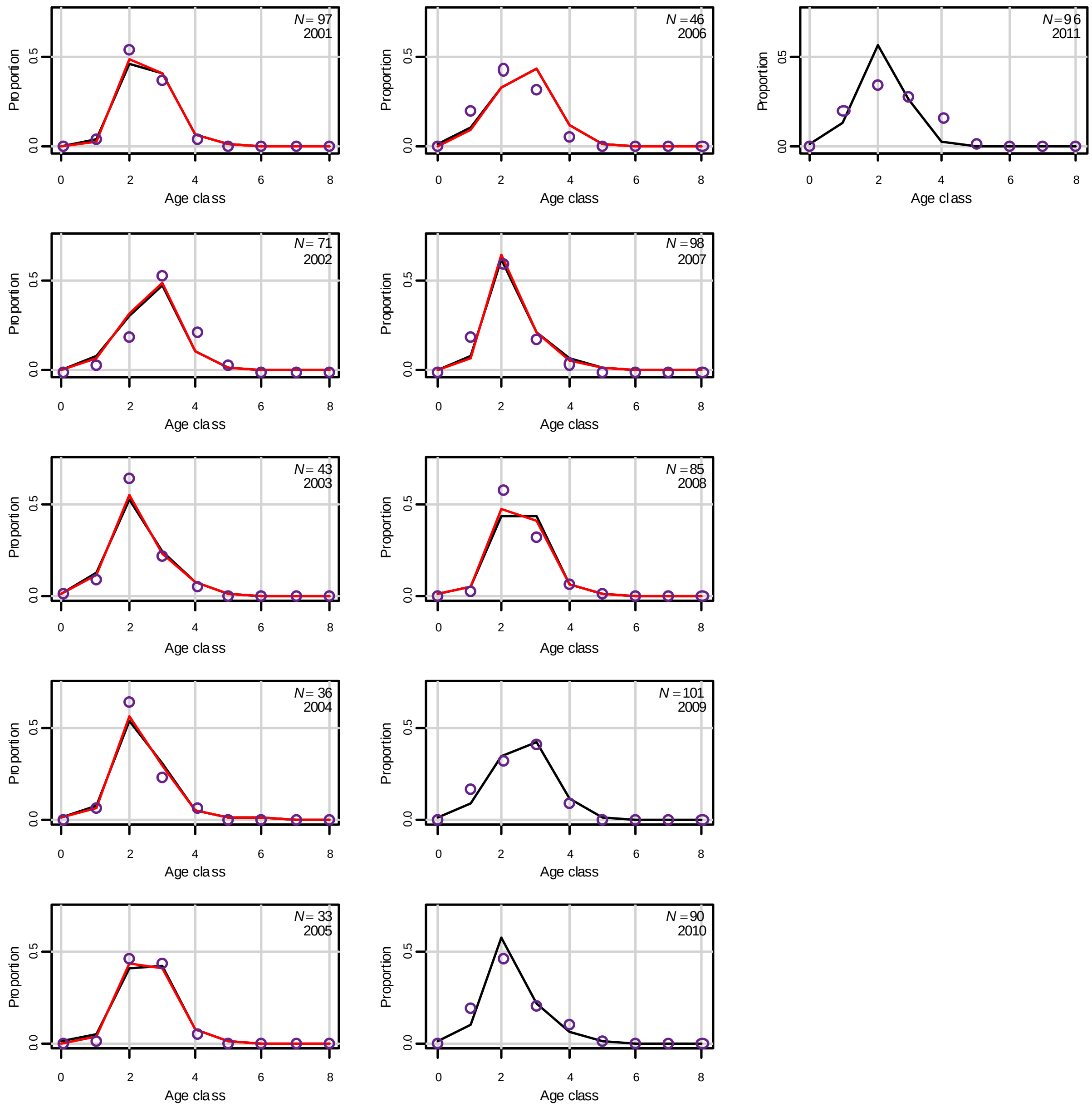


Figure 16. Observed (open circles) and predicted (connected points) juvenile abundance index values for Atlantic menhaden from the base BAM model. Bottom panel indicates pattern and magnitude of log-transformed residuals of model fit.

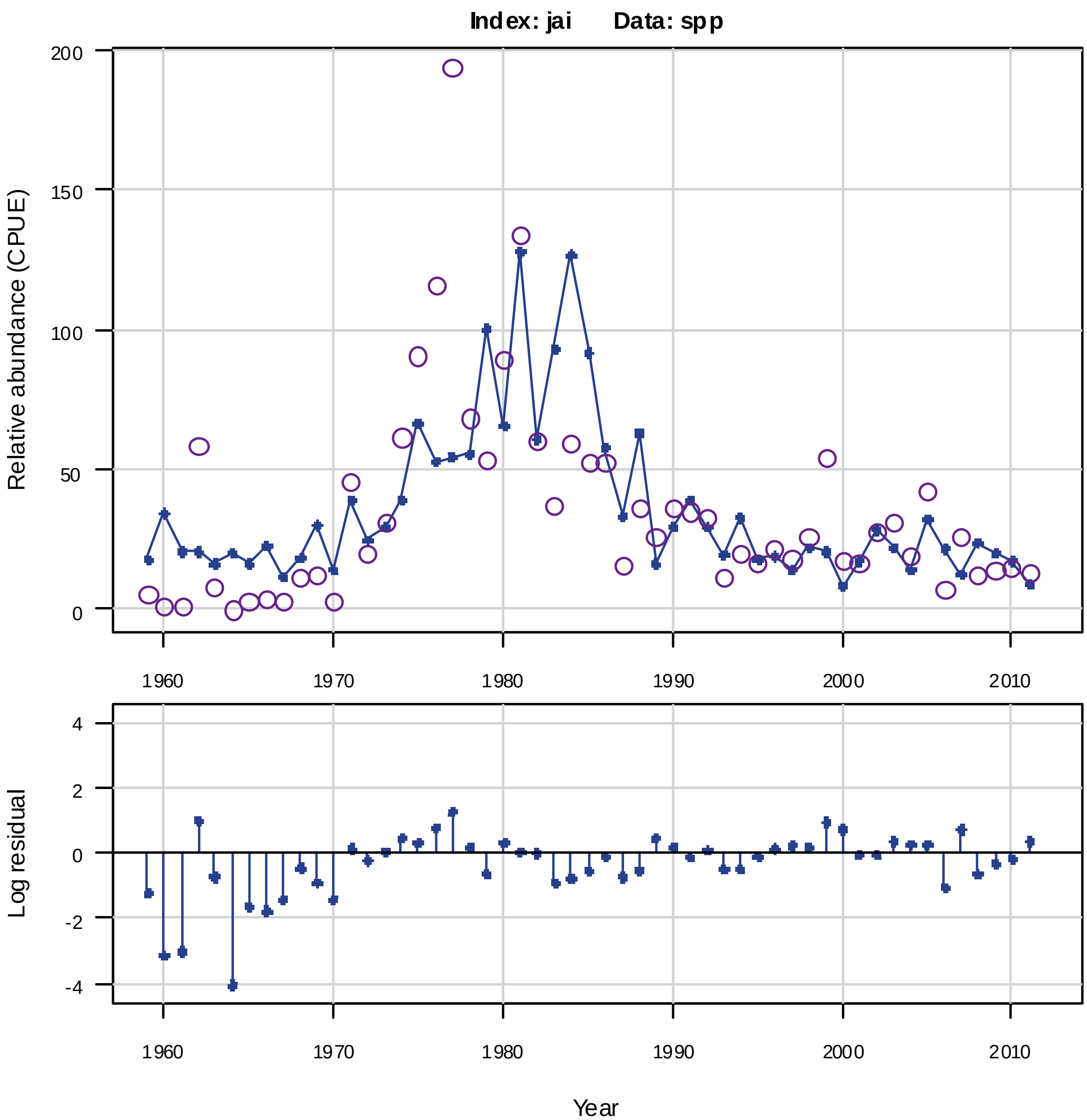


Figure 17. Observed (open circles) and predicted (connected points) juvenile abundance index values for Atlantic menhaden from the base BAM model for the benchmark assessment from 2010 (red) and this update assessment (blue).

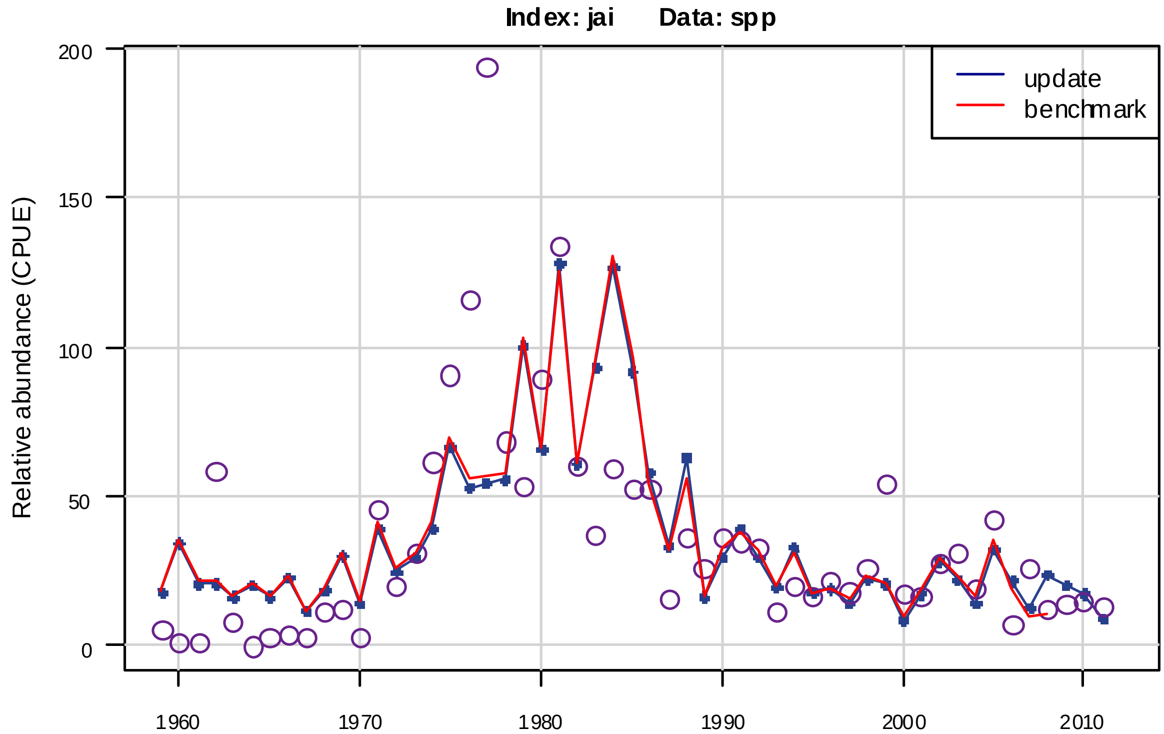


Figure 18. Observed (open circles) and predicted (connected points) PRFC pound net CPUE index values for Atlantic menhaden from the base BAM model. Bottom panel indicates pattern and magnitude of log-transformed residuals of model fit.

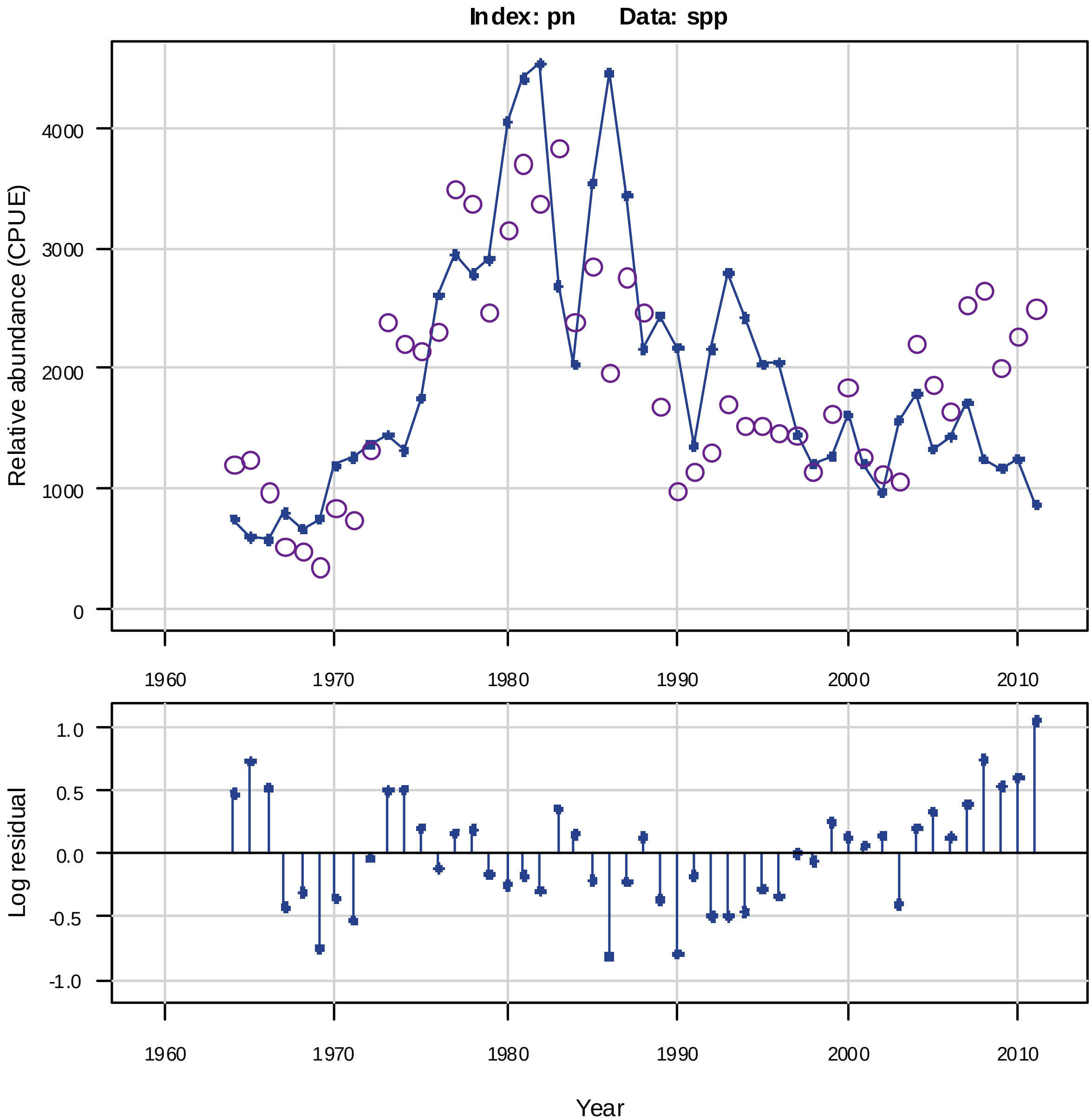


Figure 19. Observed (open circles) and predicted (connected points) PRFC pound net CPUE index values for Atlantic menhaden from the base BAM model for the benchmark assessment from 2010 (red) and this update assessment (blue).

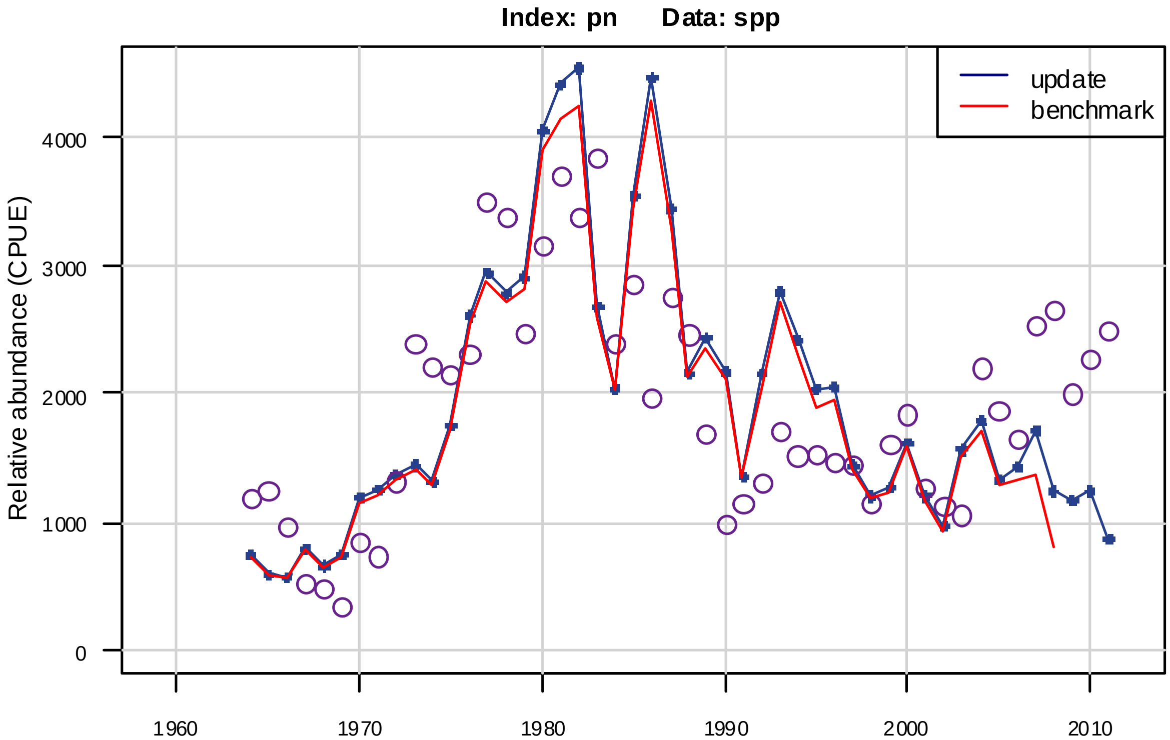


Figure 20. Estimated age-specific selectivity pattern for the Atlantic menhaden commercial reduction fishery from the base BAM model.

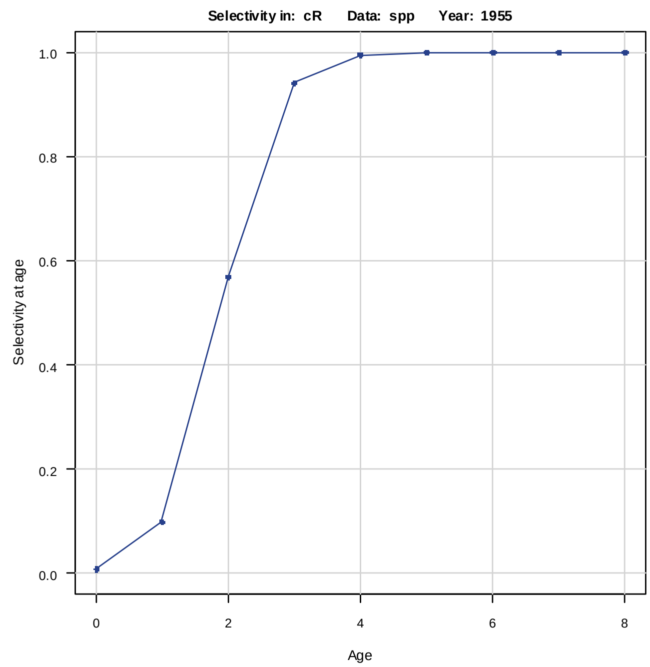


Figure 21. Estimated age-specific selectivity pattern for the Atlantic menhaden bait fishery from the base BAM model.

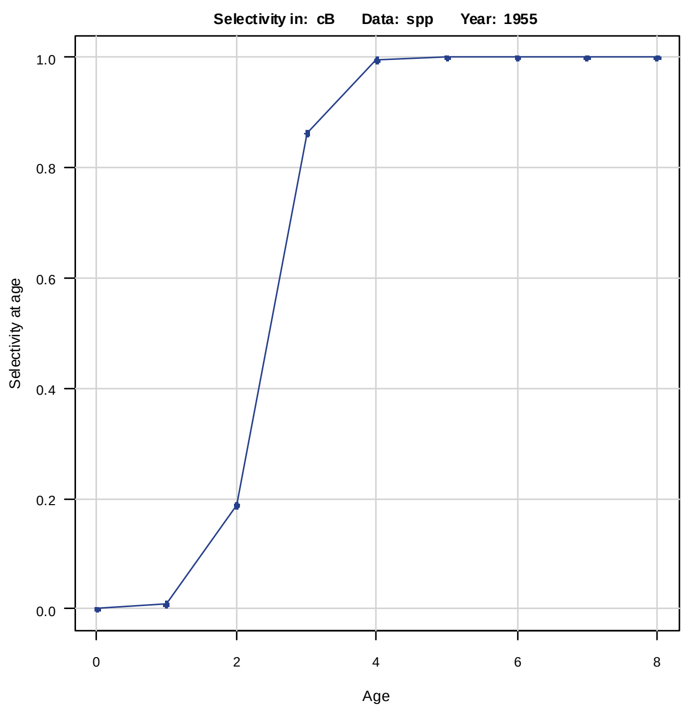


Figure 22. Estimated age-specific selectivity pattern for the Atlantic menhaden commercial reduction fishery from the base BAM model for the update assessment (blue) and the 2010 benchmark assessment (red).

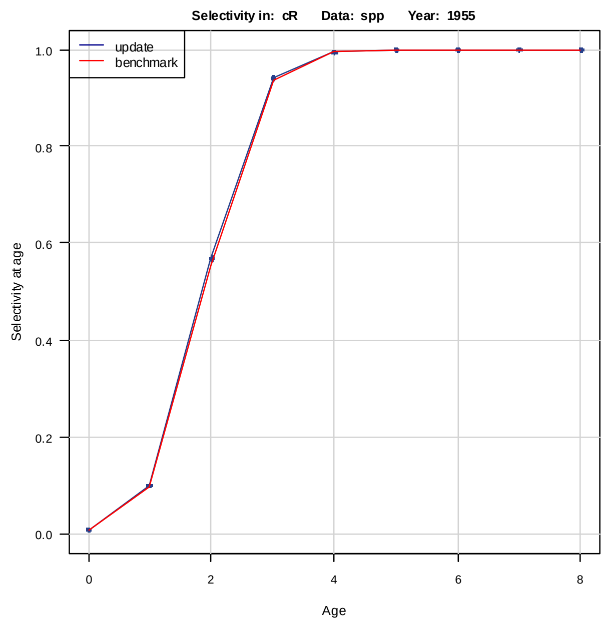


Figure 23. Estimated age-specific selectivity pattern for the Atlantic menhaden bait fishery from the base BAM model for the update assessment (blue) and the 2010 benchmark assessment (red).

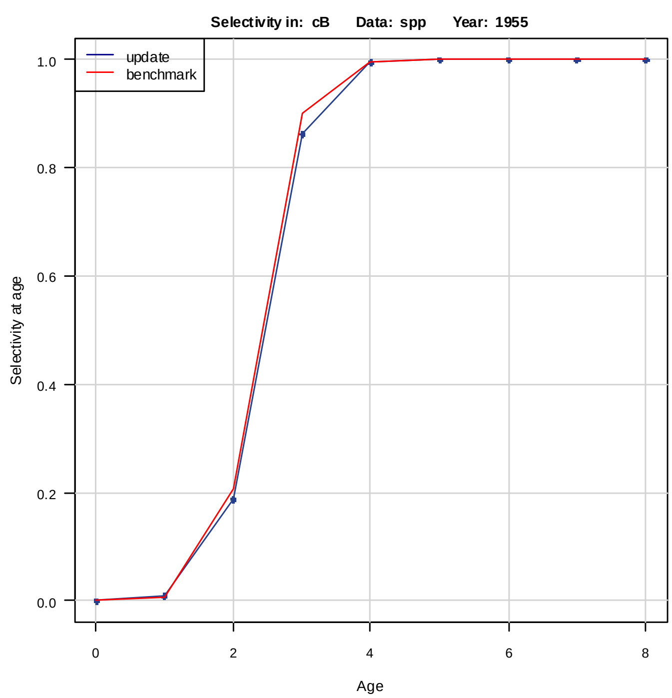


Figure 24. Estimated annual full fishing mortality rate from the base BAM model (connected points). Shaded area represents the 90% confidence interval of the bootstrap runs.

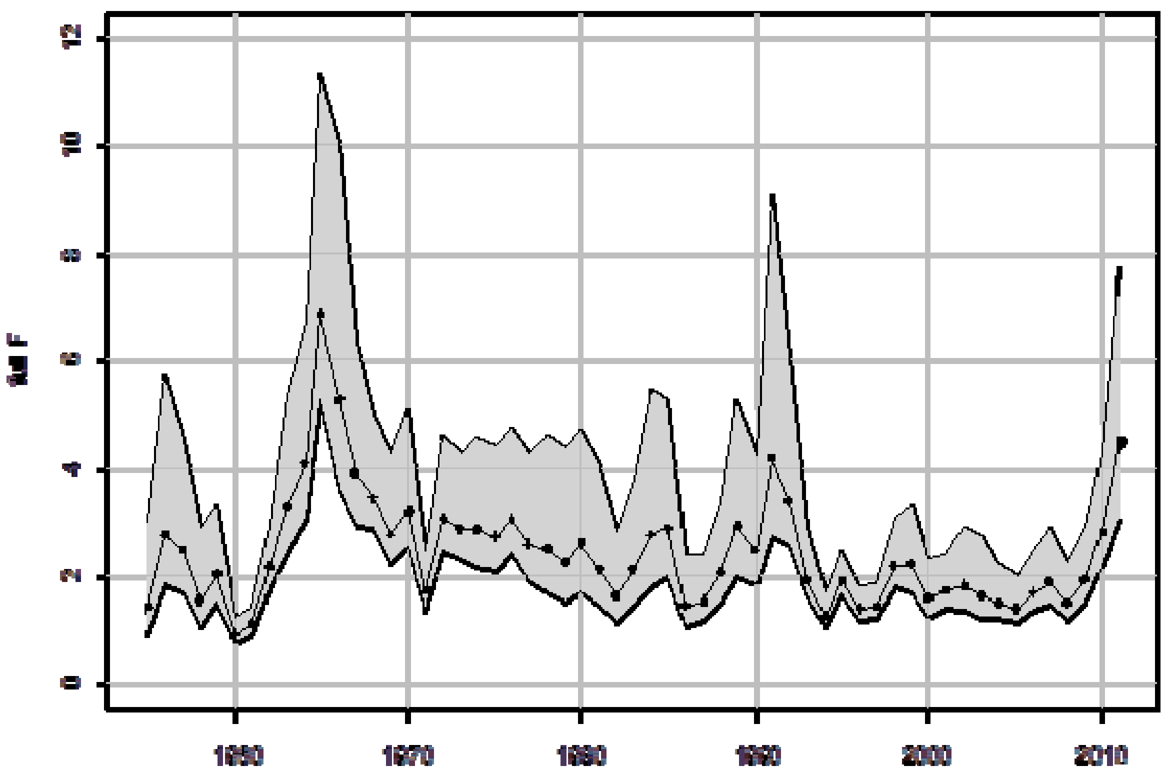


Figure 25. Estimated annual full fishing mortality rate from the base BAM model (connected points).

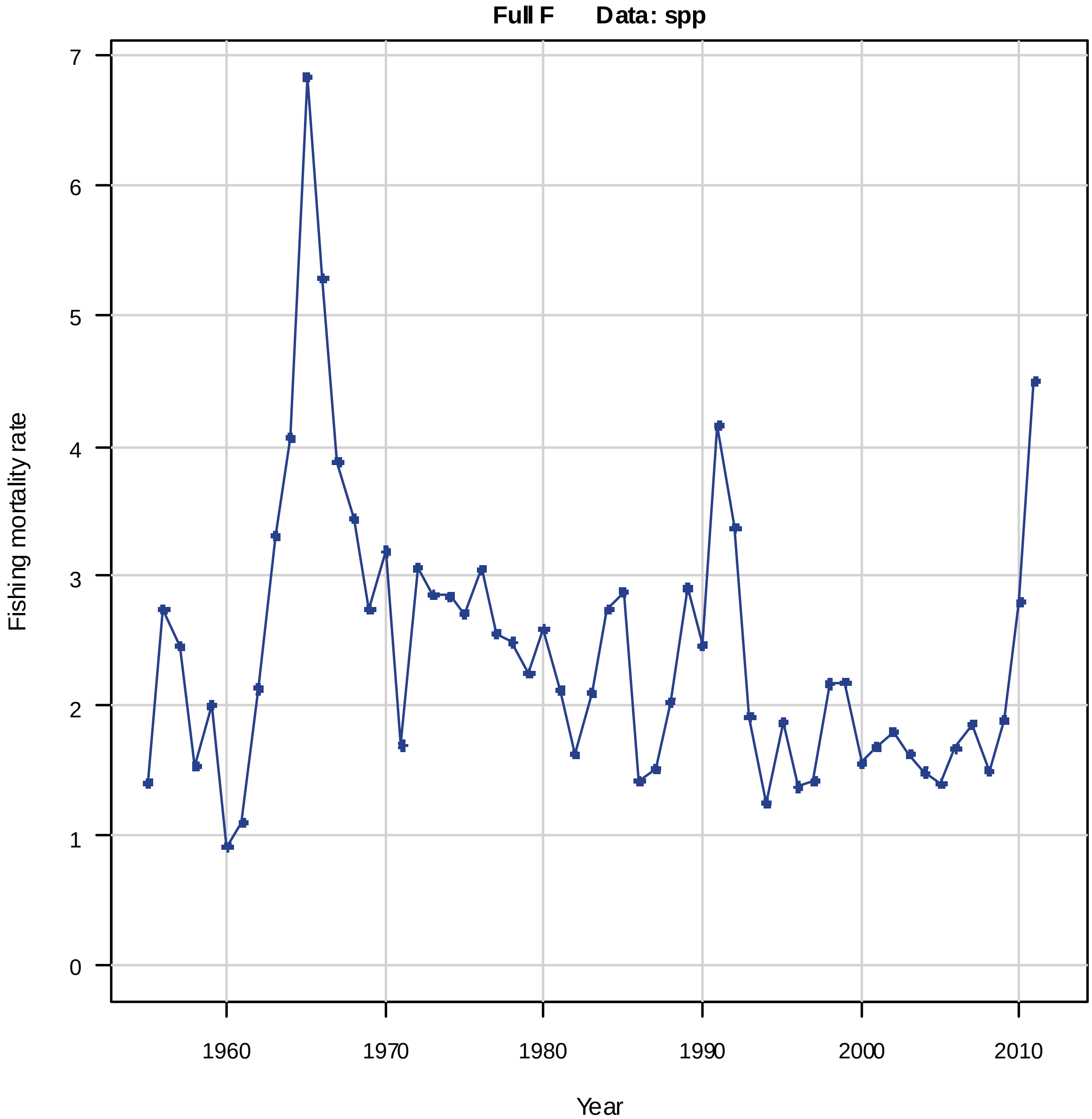


Figure 26. Estimated annual full fishing mortality rates for the commercial reduction fishery from the base BAM model.

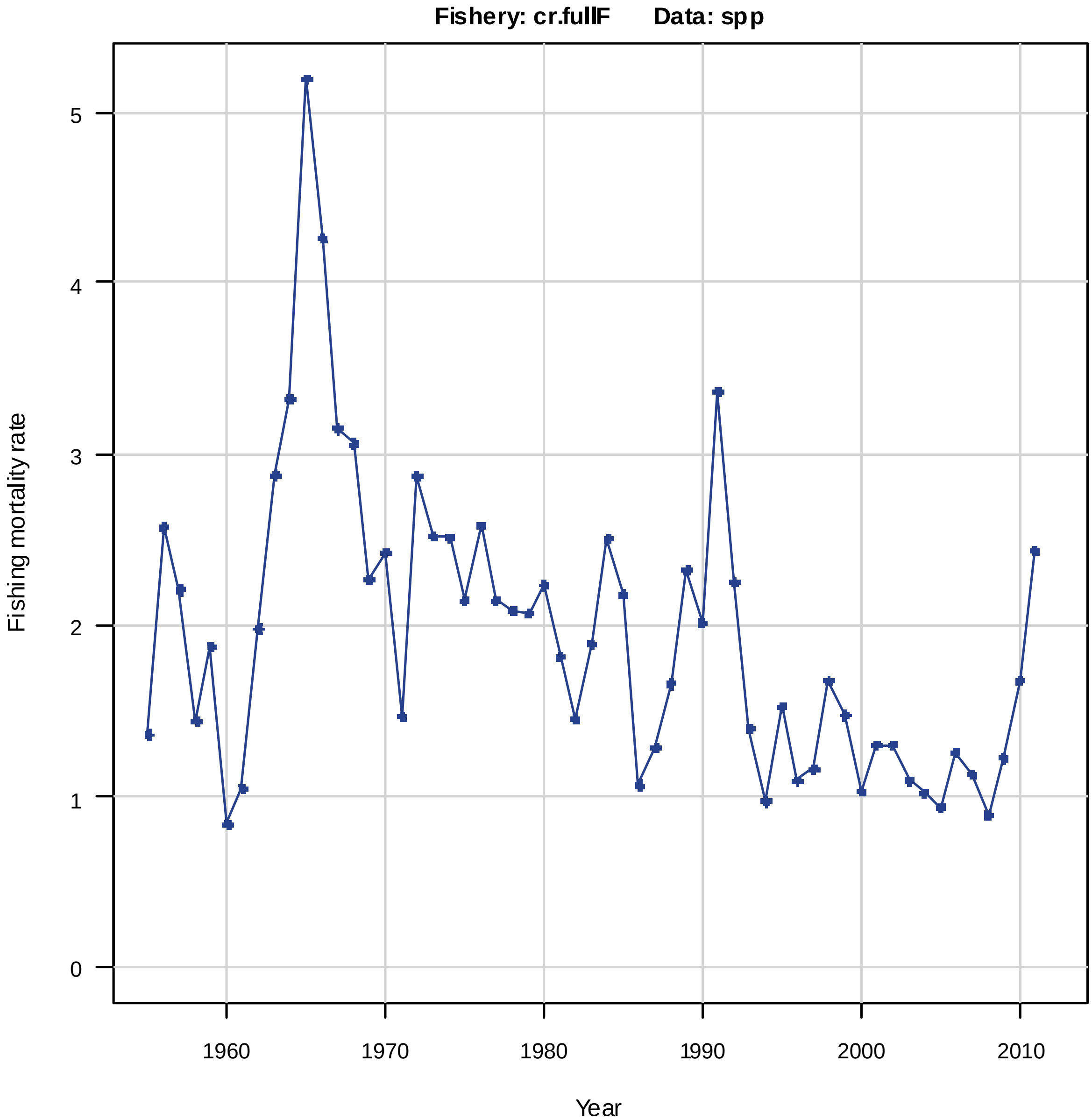


Figure 27. Estimated annual full fishing mortality rates for the bait fishery from the base BAM model.

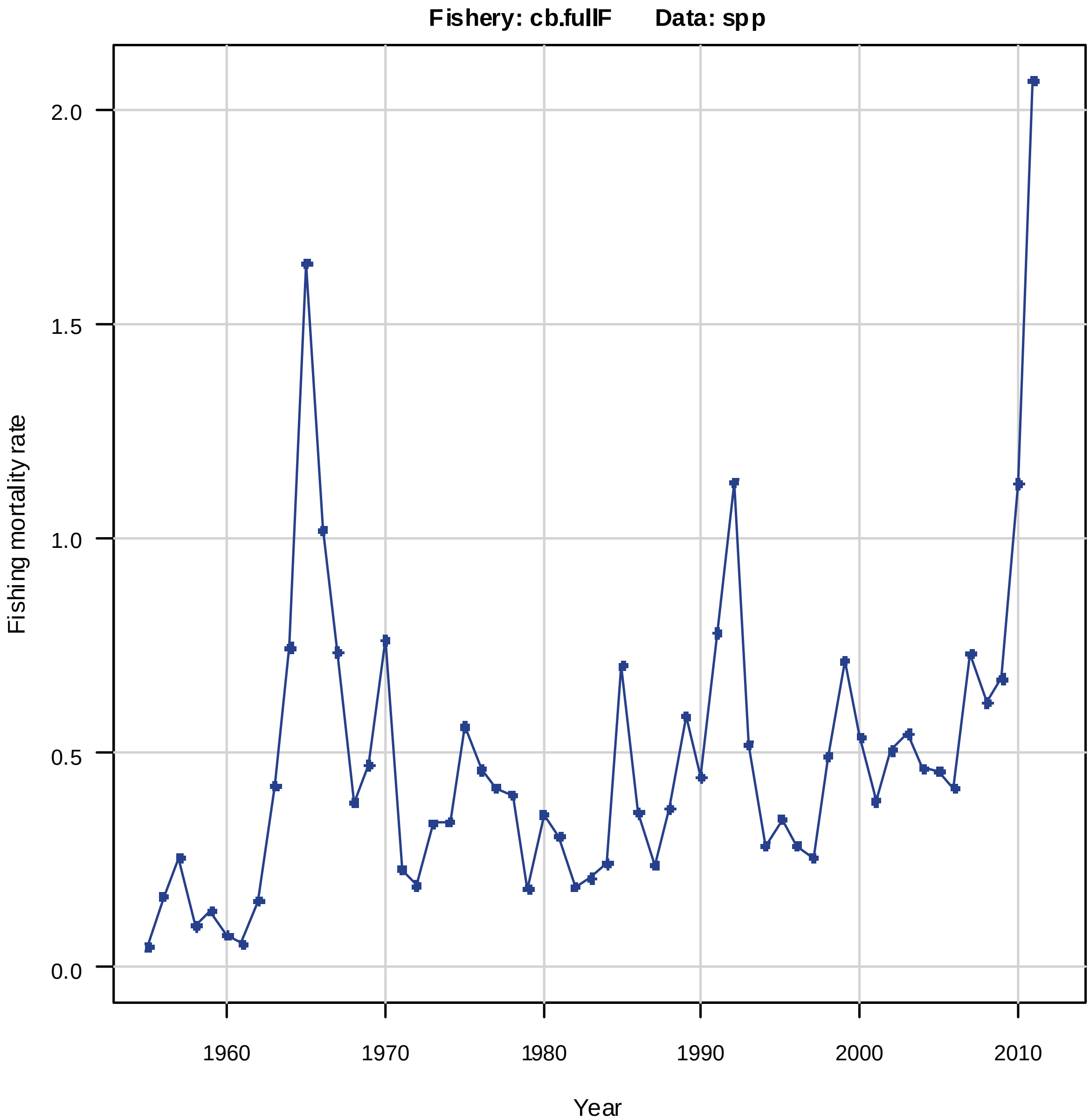


Figure 28. Estimated annual full fishing mortality rates, full F, for combined reduction and bait fisheries from the base BAM model for this update assessment (blue) and the 2010 benchmark assessment (red).

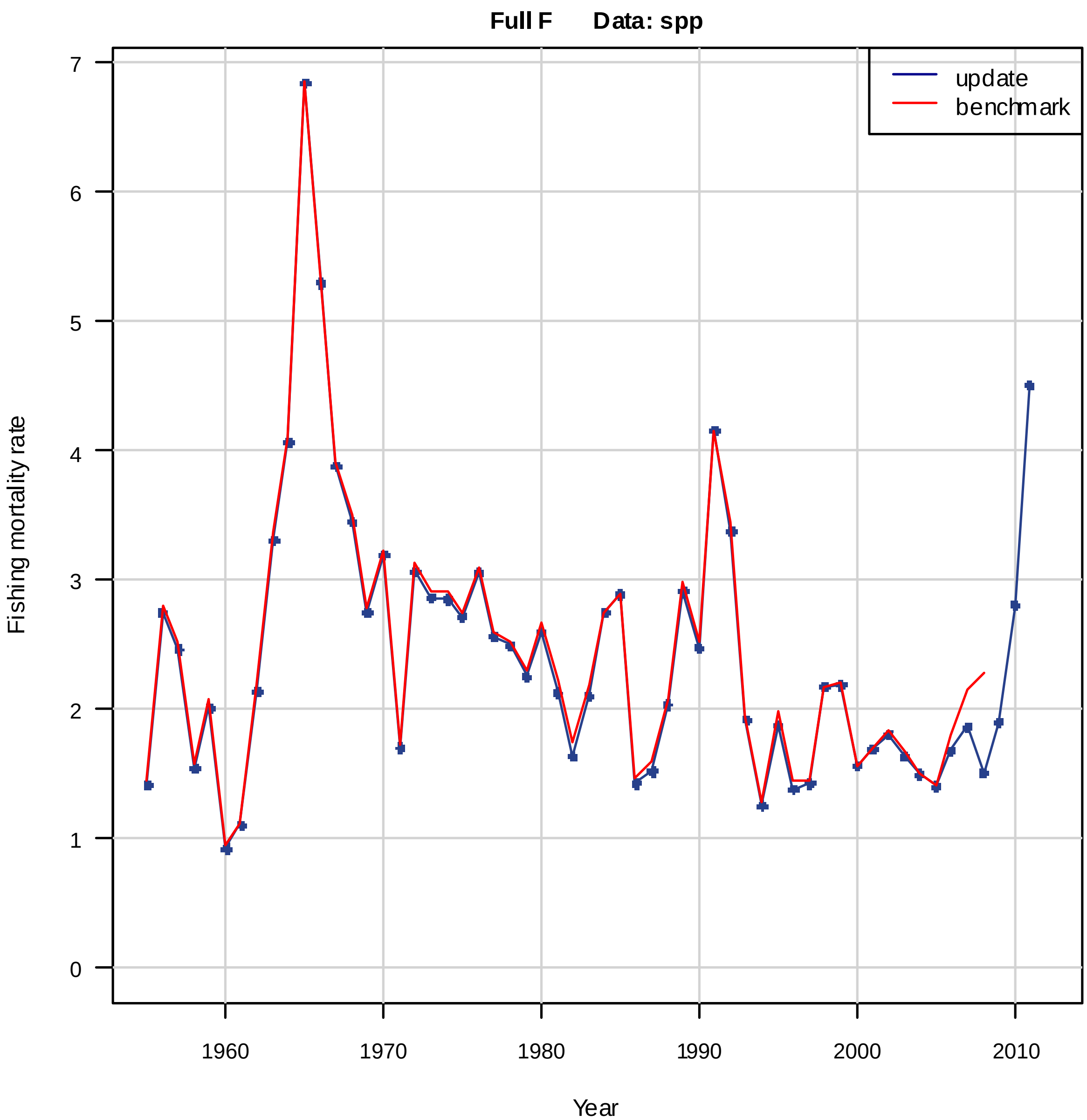


Figure 29. Estimated annual full fishing mortality rates for the commercial reduction fishery from the base BAM model for this update assessment (blue) and the 2010 benchmark assessment (red).

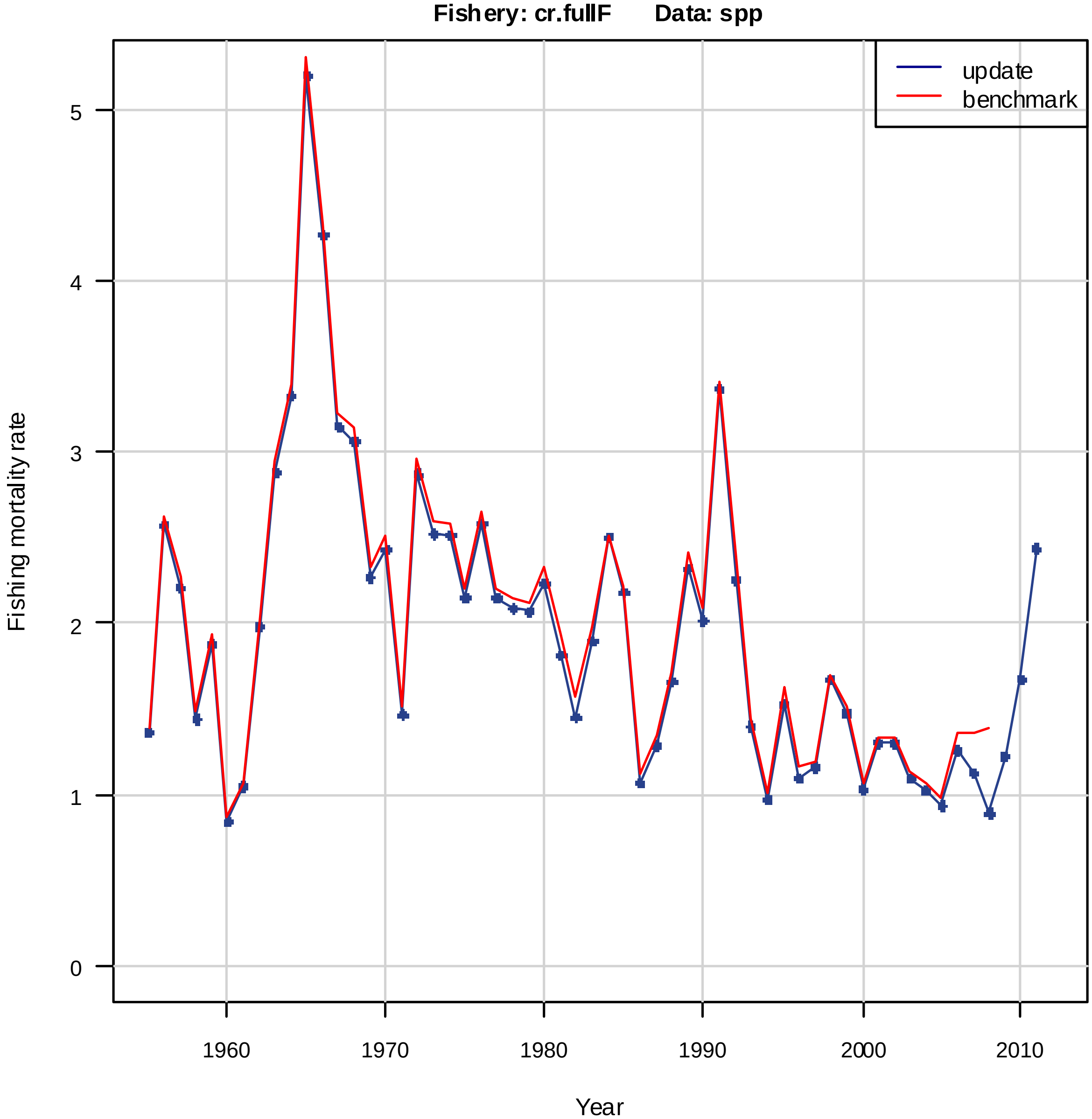


Figure 30. Estimated annual full fishing mortality rates for the bait fishery from the base BAM model for this update assessment (blue) and the 2010 benchmark assessment (red).

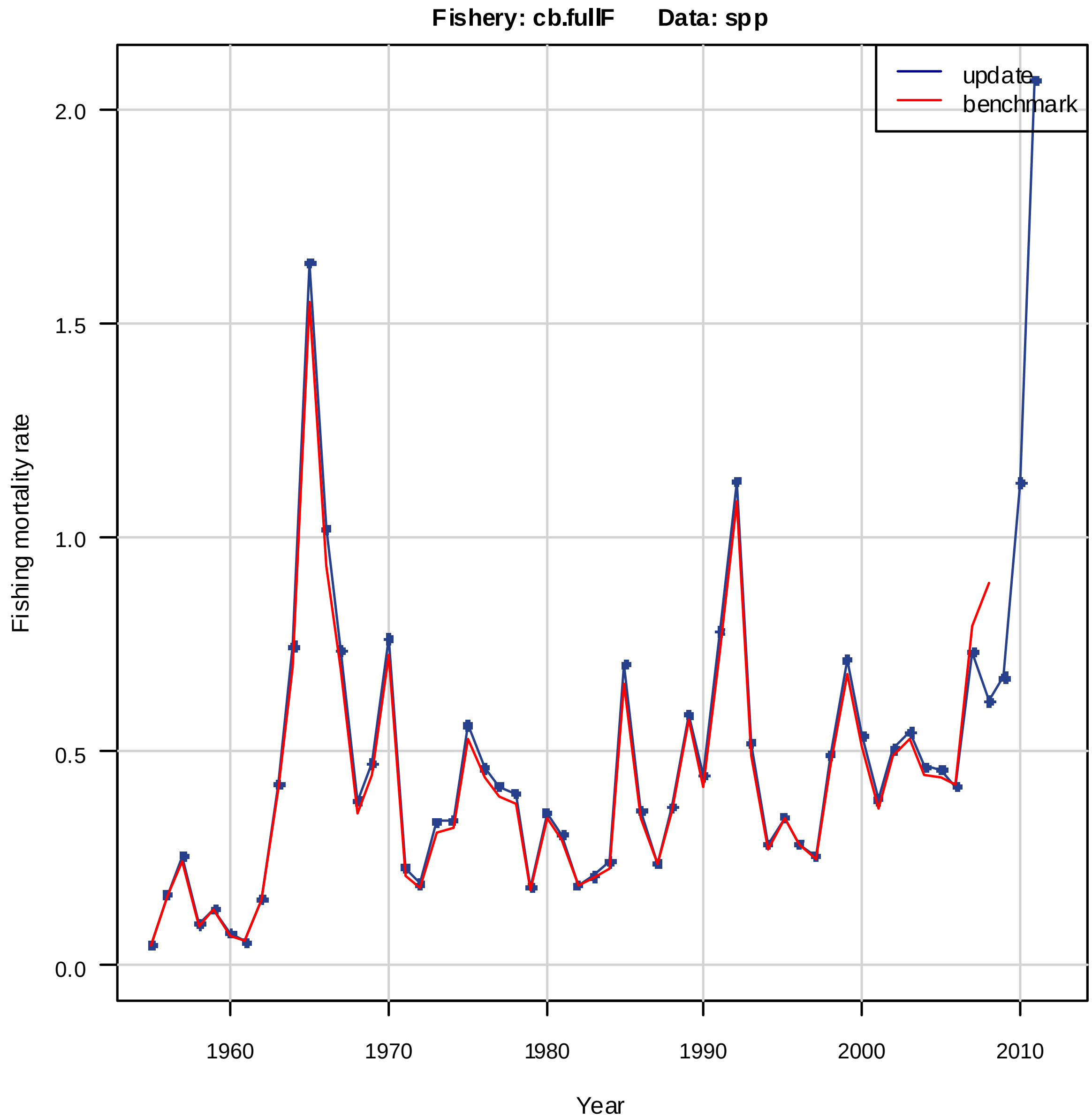


Figure 31. Estimated numbers at age of Atlantic menhaden (billions) at the start of the fishing year from the base BAM model.

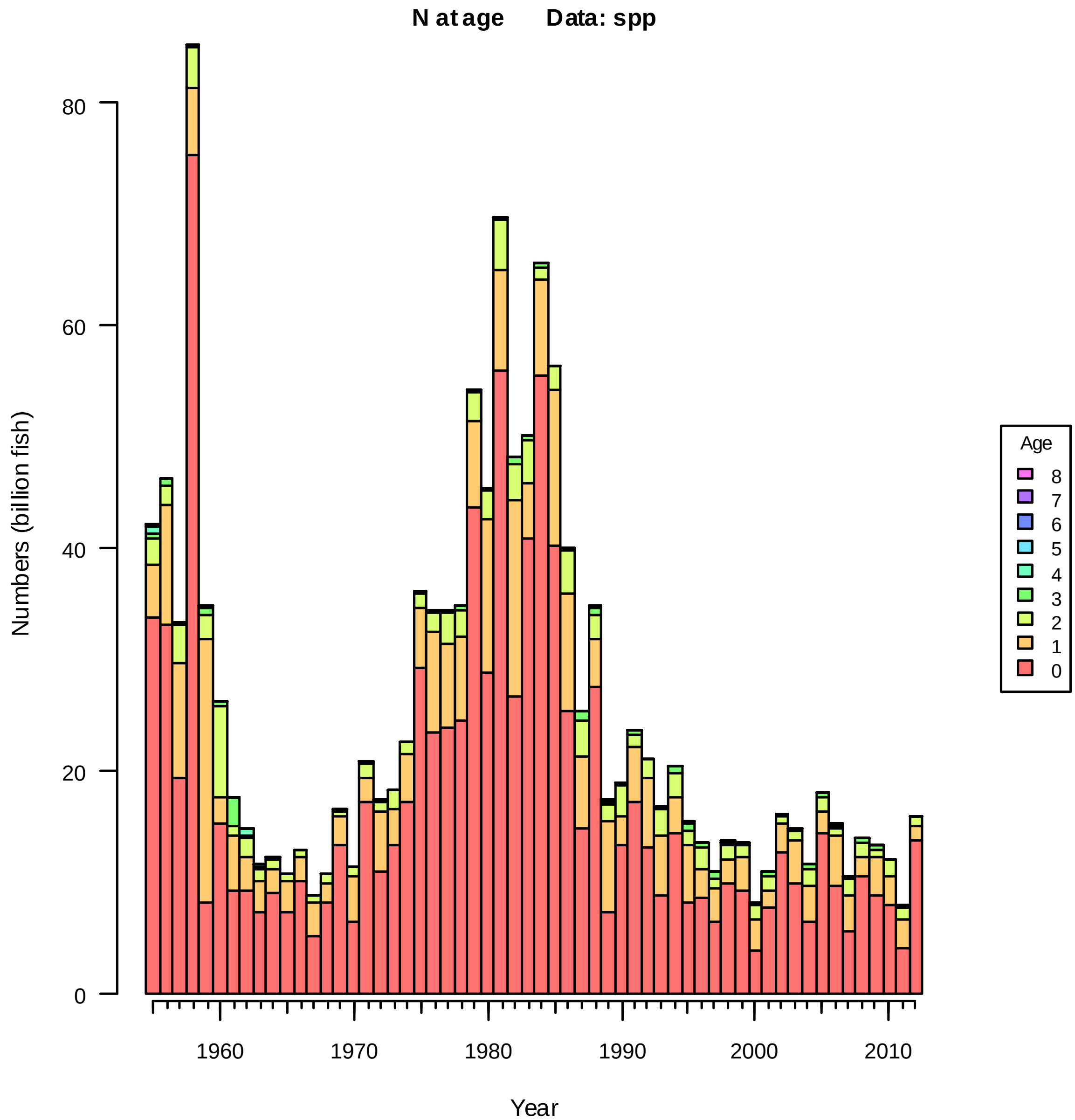


Figure 32. Estimated annual fecundity (billions of eggs) from the base BAM model (connected points). Shaded area represents the 90% confidence interval of the bootstrap runs.

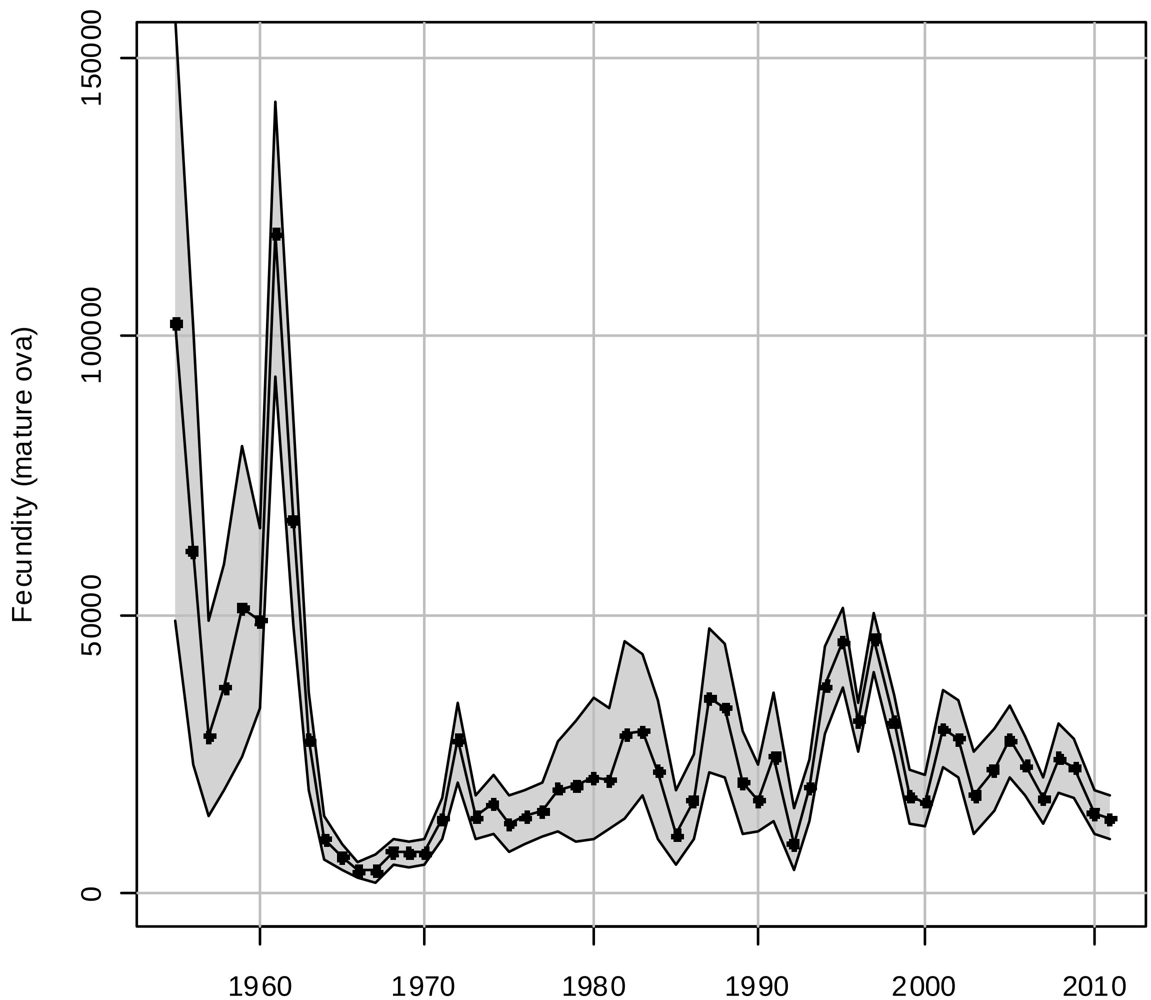


Figure 33. Estimated total fecundity (billions of mature ova) at age of Atlantic menhaden at the start of the fishing year from the base BAM model.

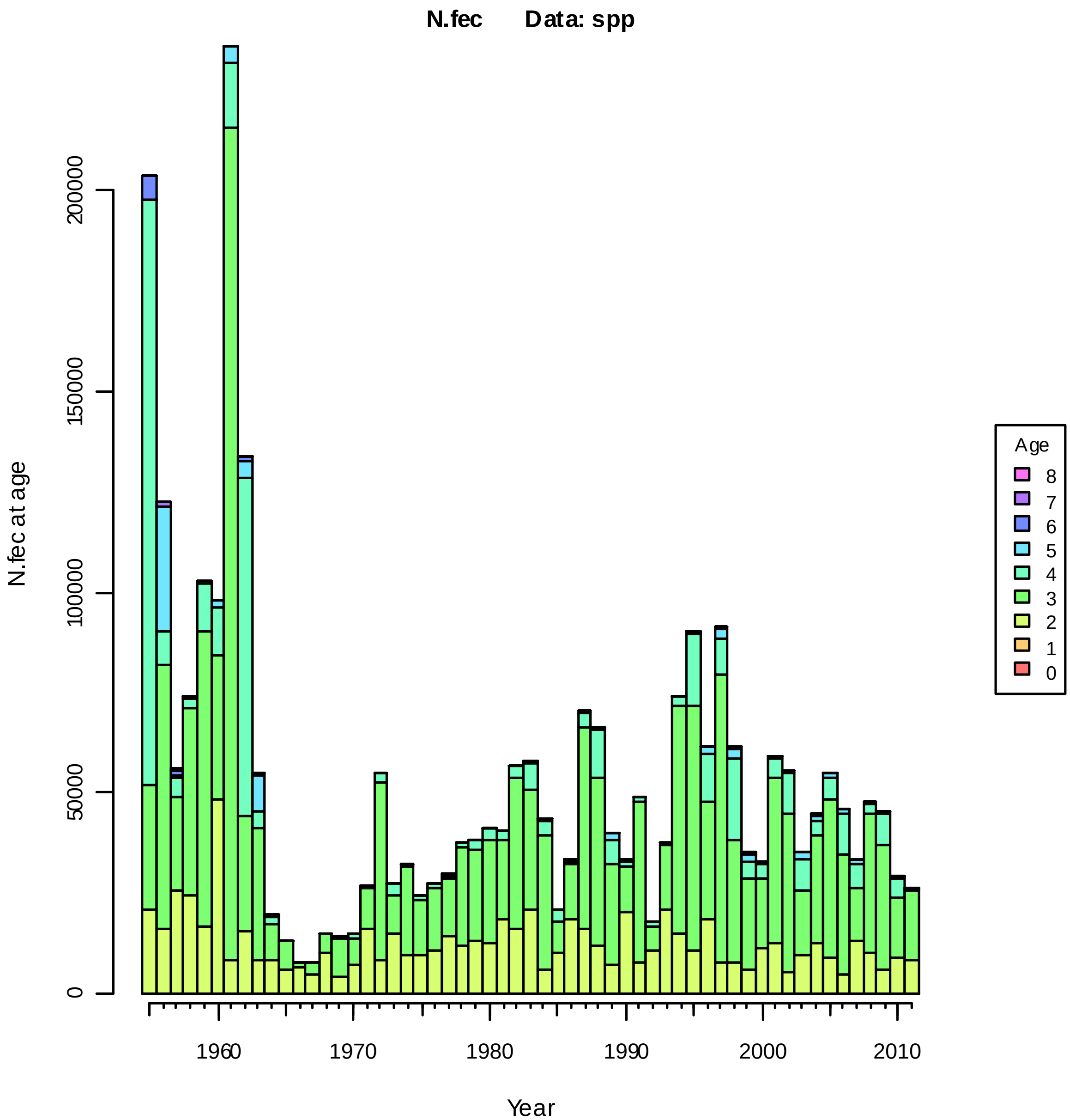


Figure 34. Estimated annual recruitment to age-0 (billions) from the base BAM model (connected points). Shaded area represents the 90% confidence interval of the bootstrap runs.

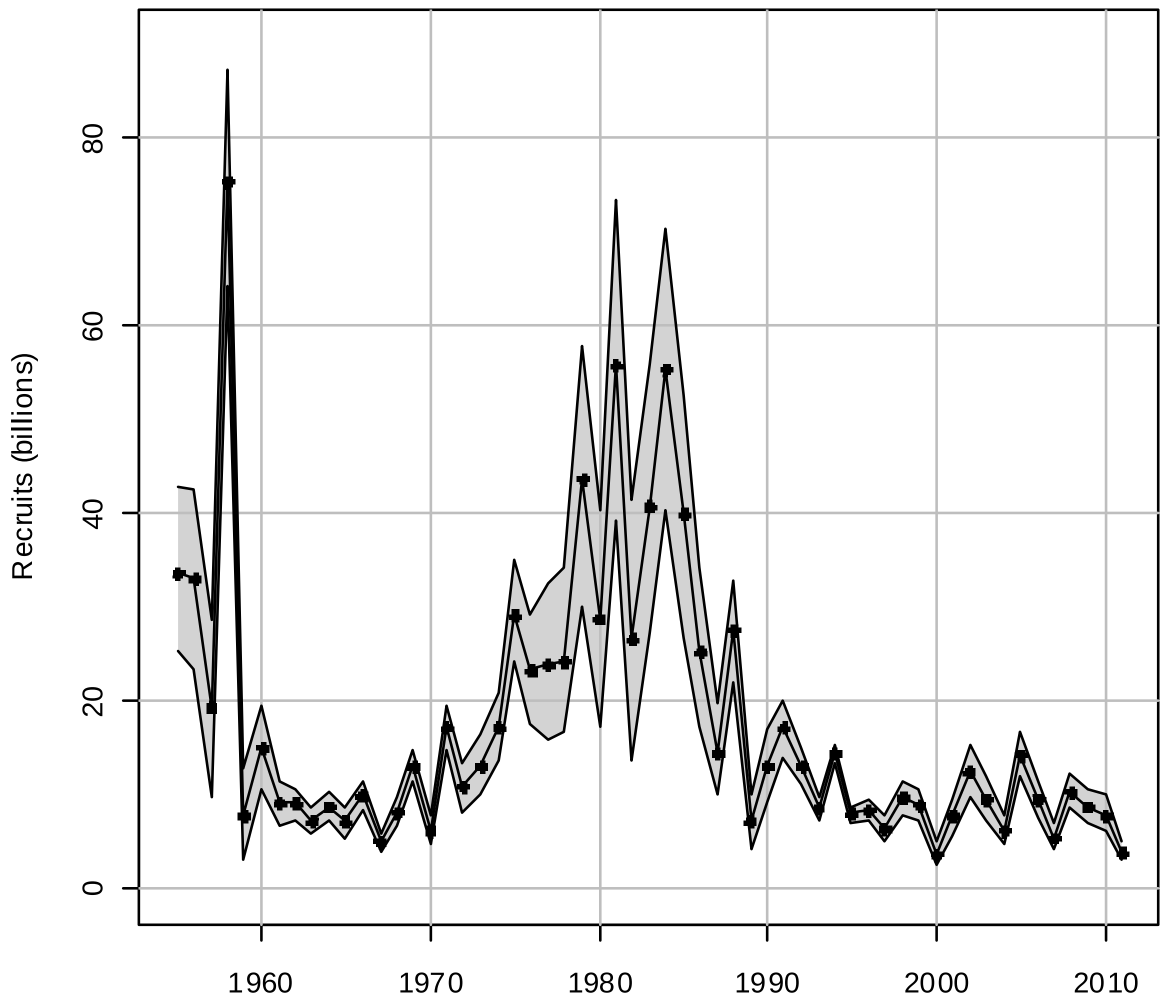


Figure 35. Estimated annual recruitment to age-0 (billions) from the base BAM model (connected points). The recruitment estimate for 2012 shown in this figure is a projection based on the long term geometric mean.

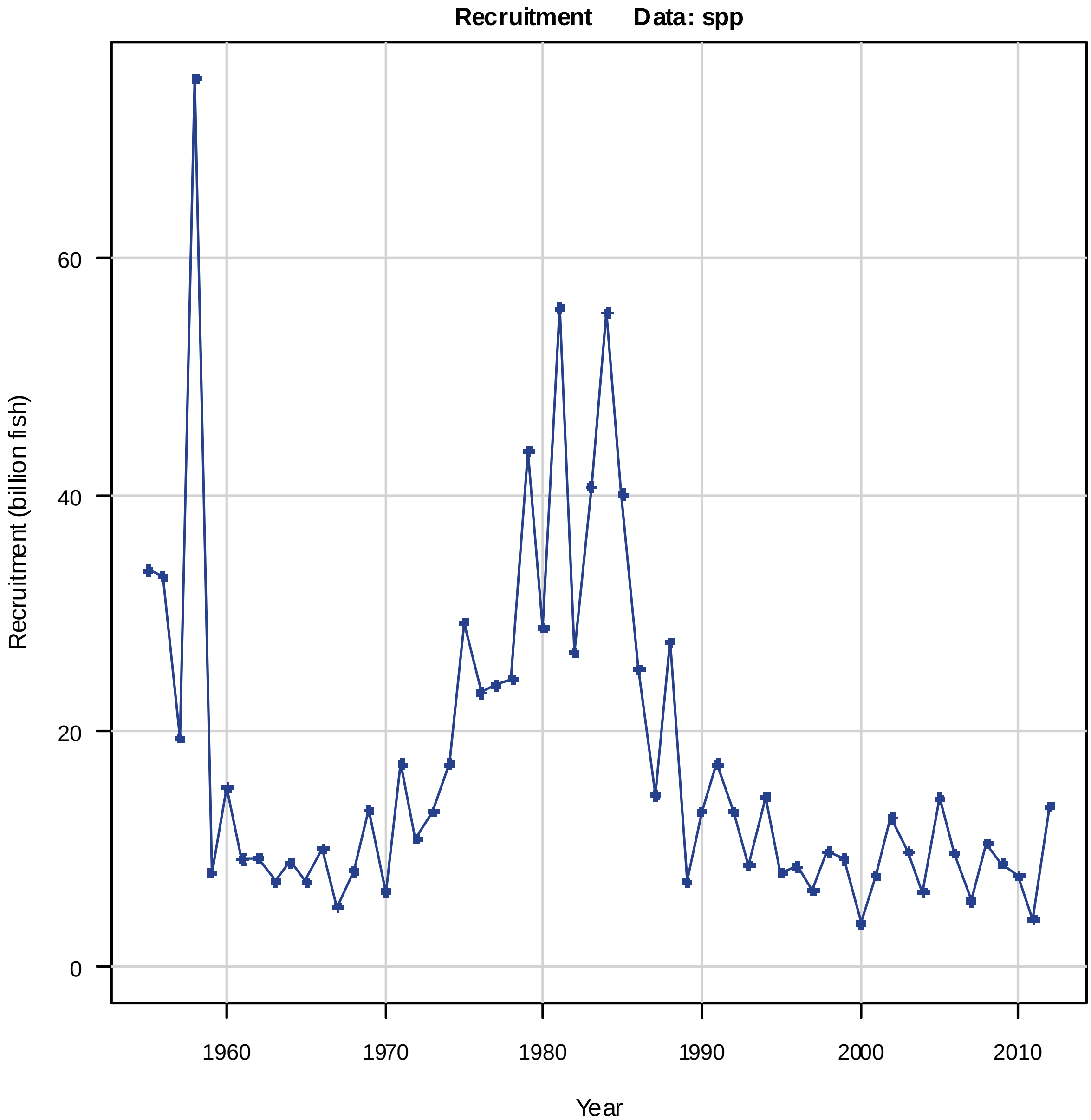


Figure 36. Estimated annual recruitment to age-0 (billions) from the base BAM model for the update assessment (blue) and for the last benchmark assessment in 2010 (red). The recruitment estimate for 2012 (blue) and 2009 (red) shown in this figure are projections based on the long term geometric mean.

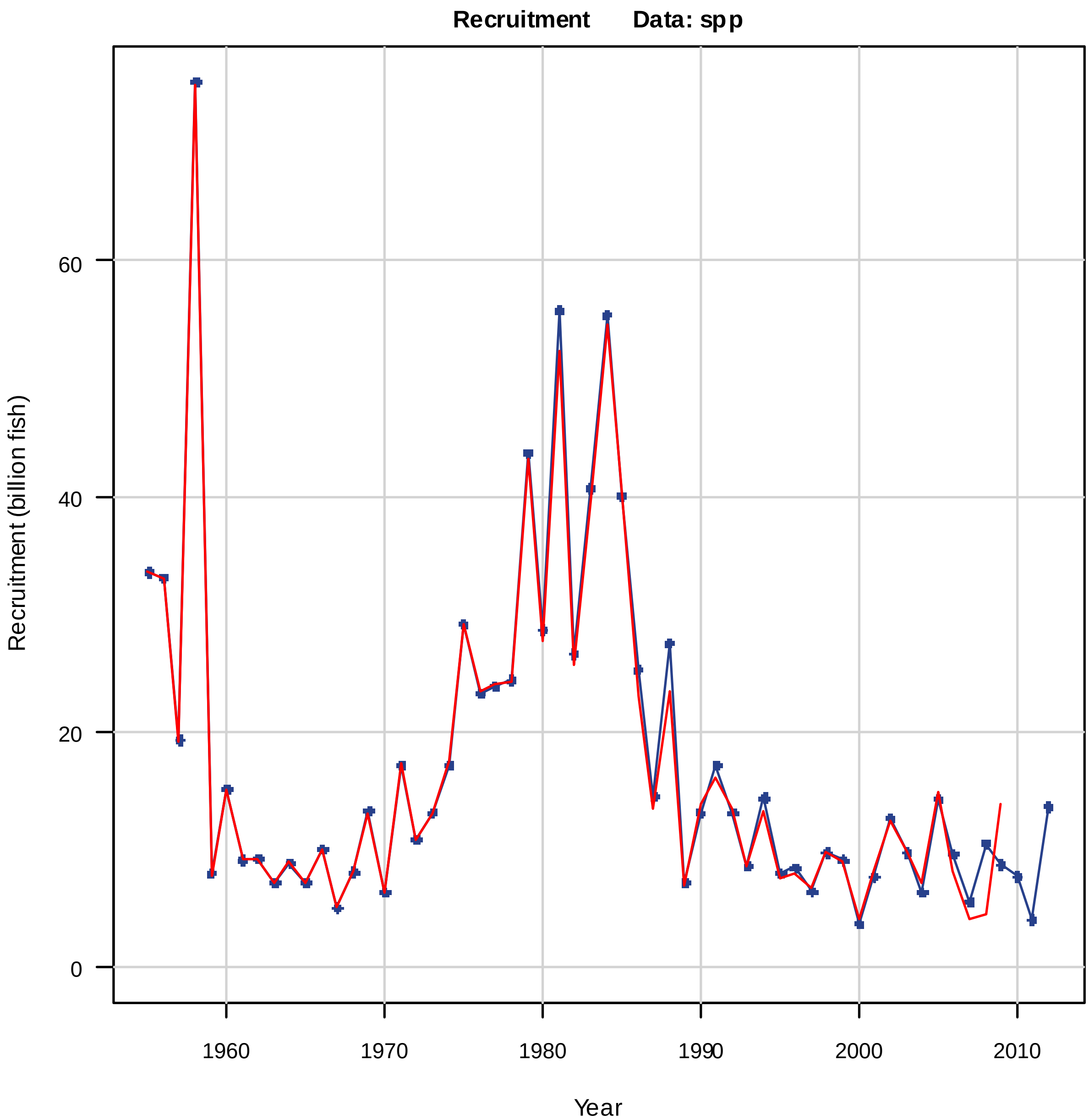


Figure 37. Estimated spawning stock (billions of mature ova) and recruitment (billions of age-0 fish) from the base BAM model (points). Lines indicate the median recruitment (horizontal) and the 50th and 75th percentile of spawners-per-recruit.

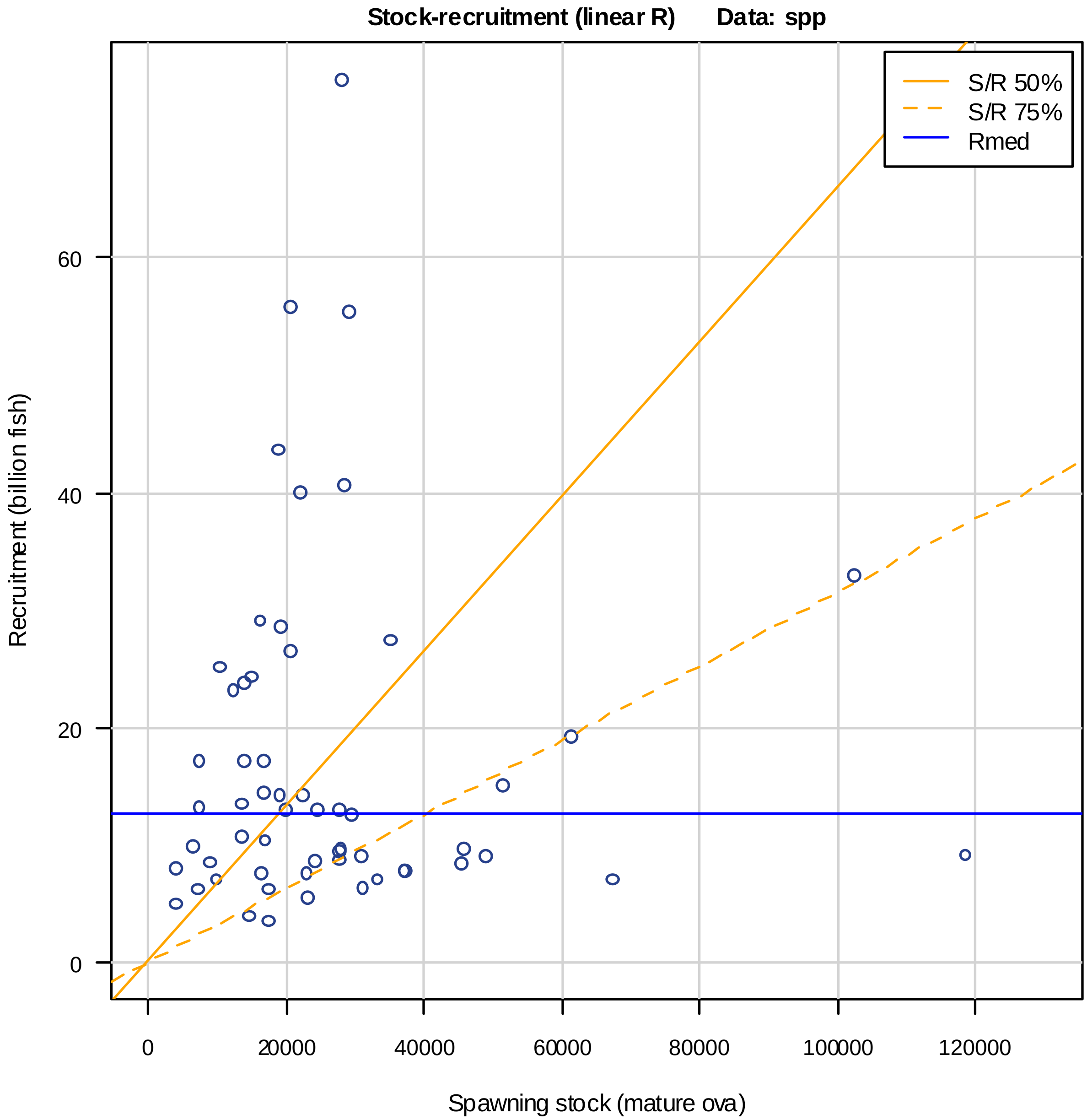


Figure 38. Estimated annual full fishing mortality rates from the base BAM model (connected open circles) and various sensitivity runs.

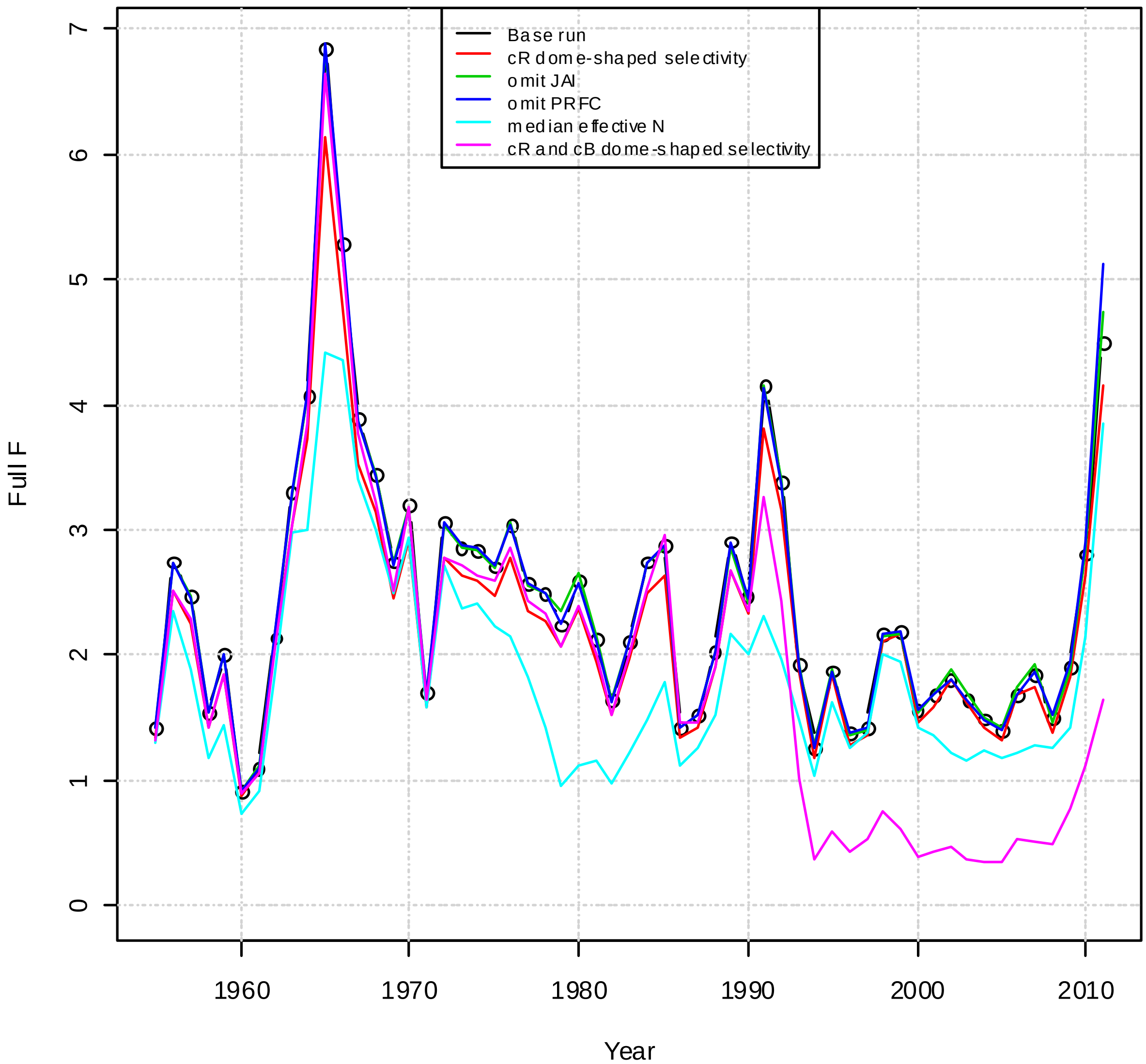


Figure 39. Estimated annual recruitment of age-0 fish (billions) from the base BAM model (connected open circles) and various sensitivity runs.

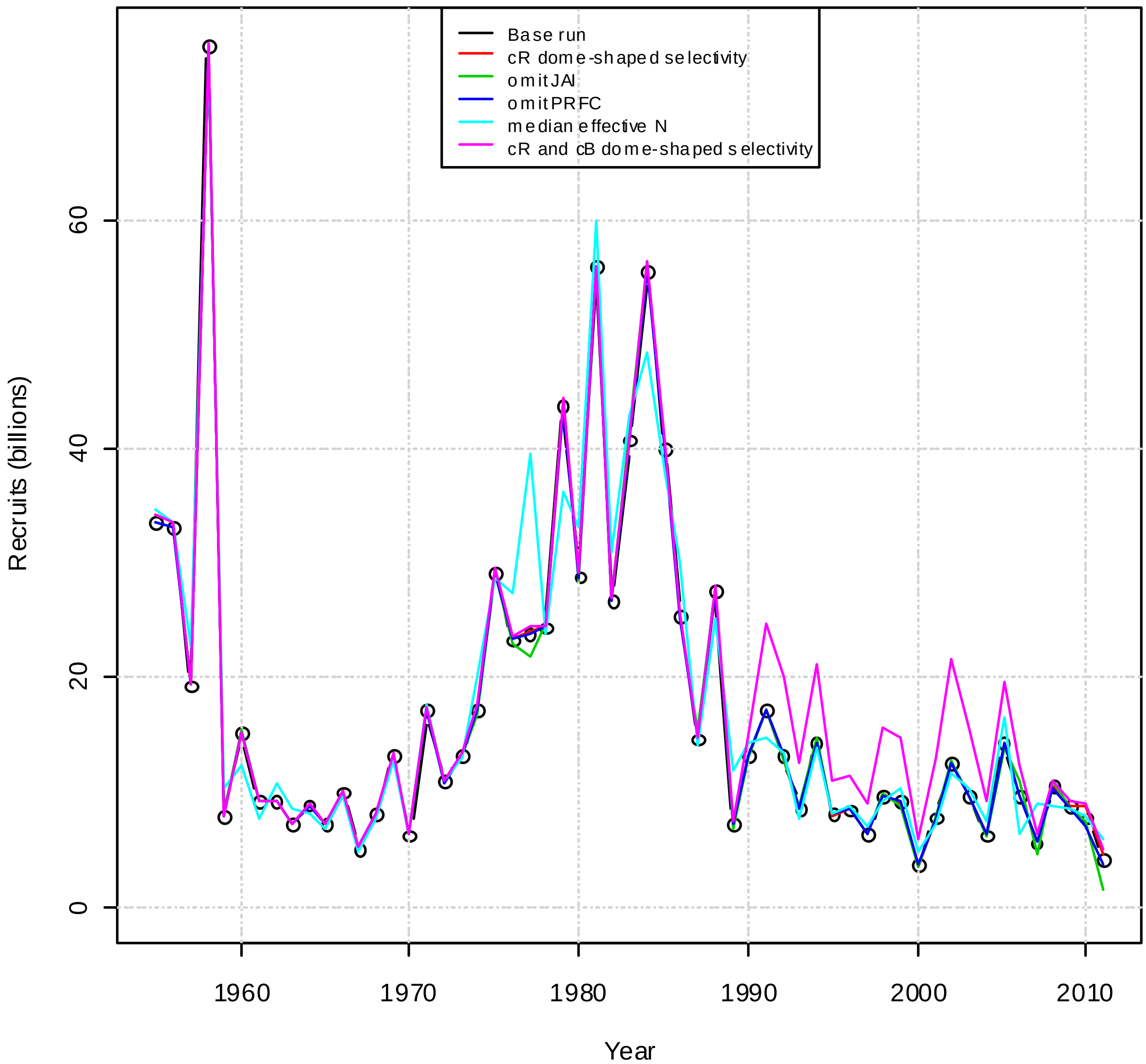


Figure 40. Estimated annual fecundity (billions of mature eggs) from the base BAM model (connected open circles) and various sensitivity runs.

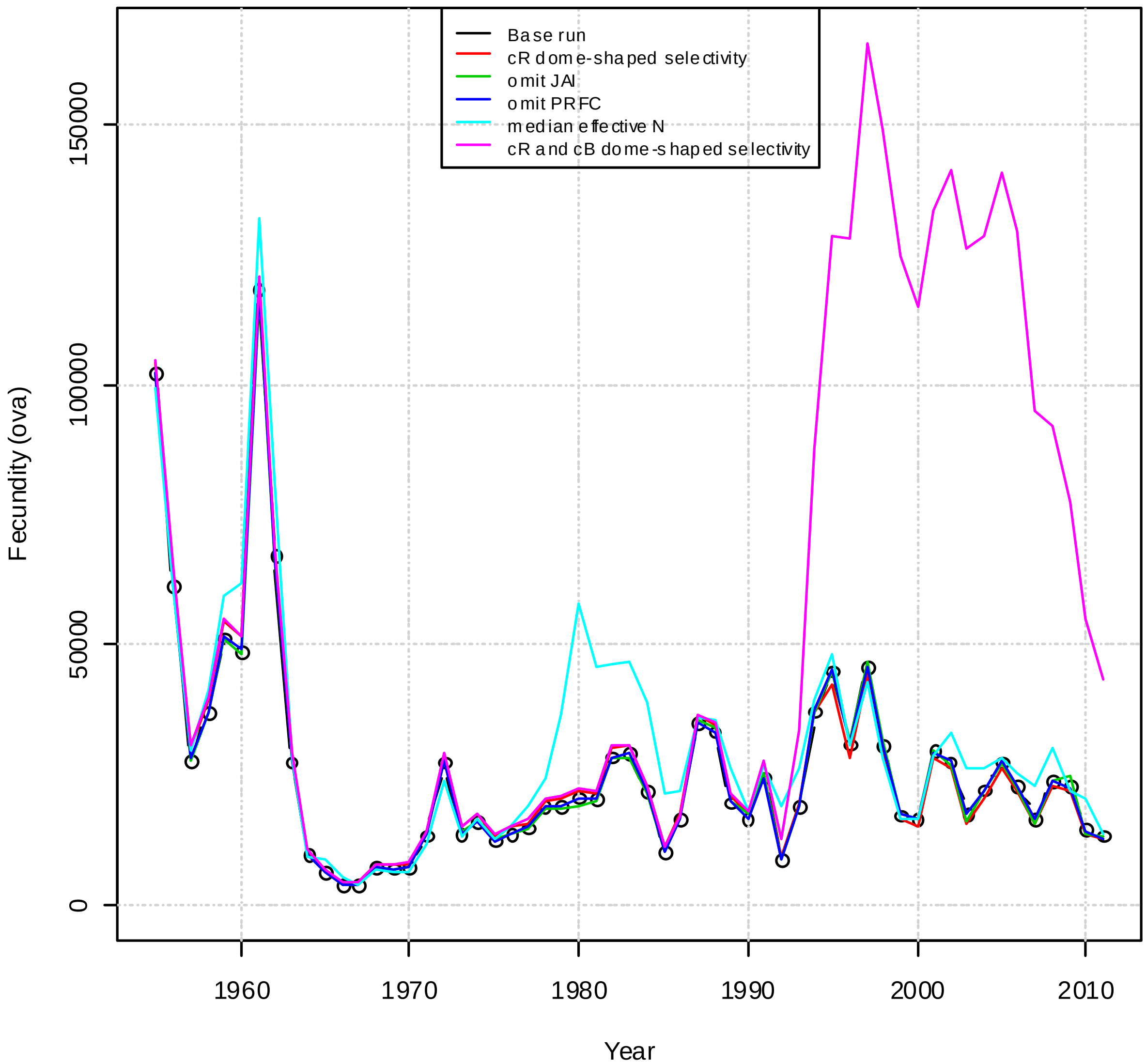


Figure 41. Estimated annual biomass (1,000 mt) from the base BAM model (connected open circles) and various sensitivity runs.

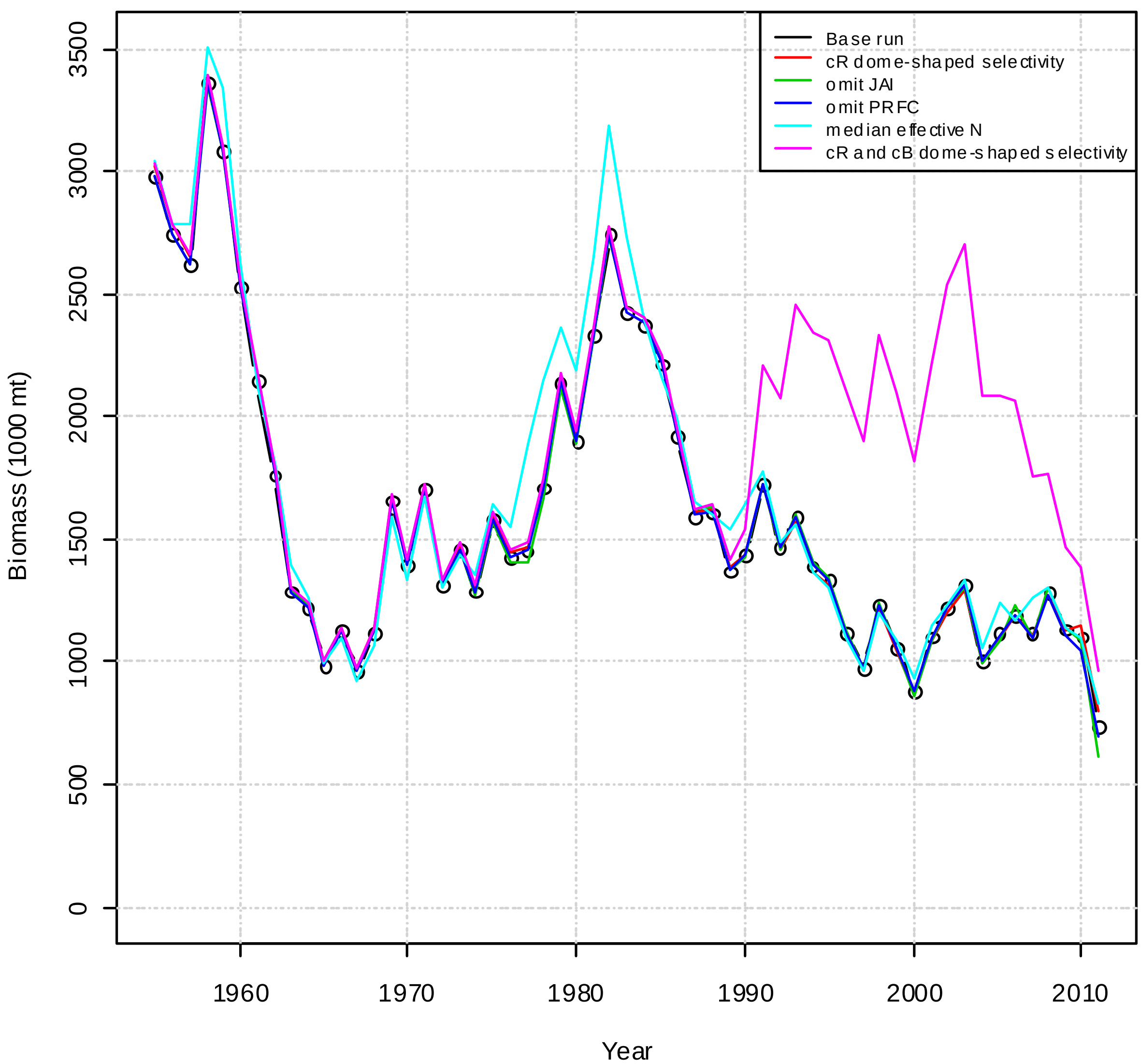


Figure 42. Fit to the observed juvenile abundance index from the base BAM model and various sensitivity runs. The open points are the observed values.

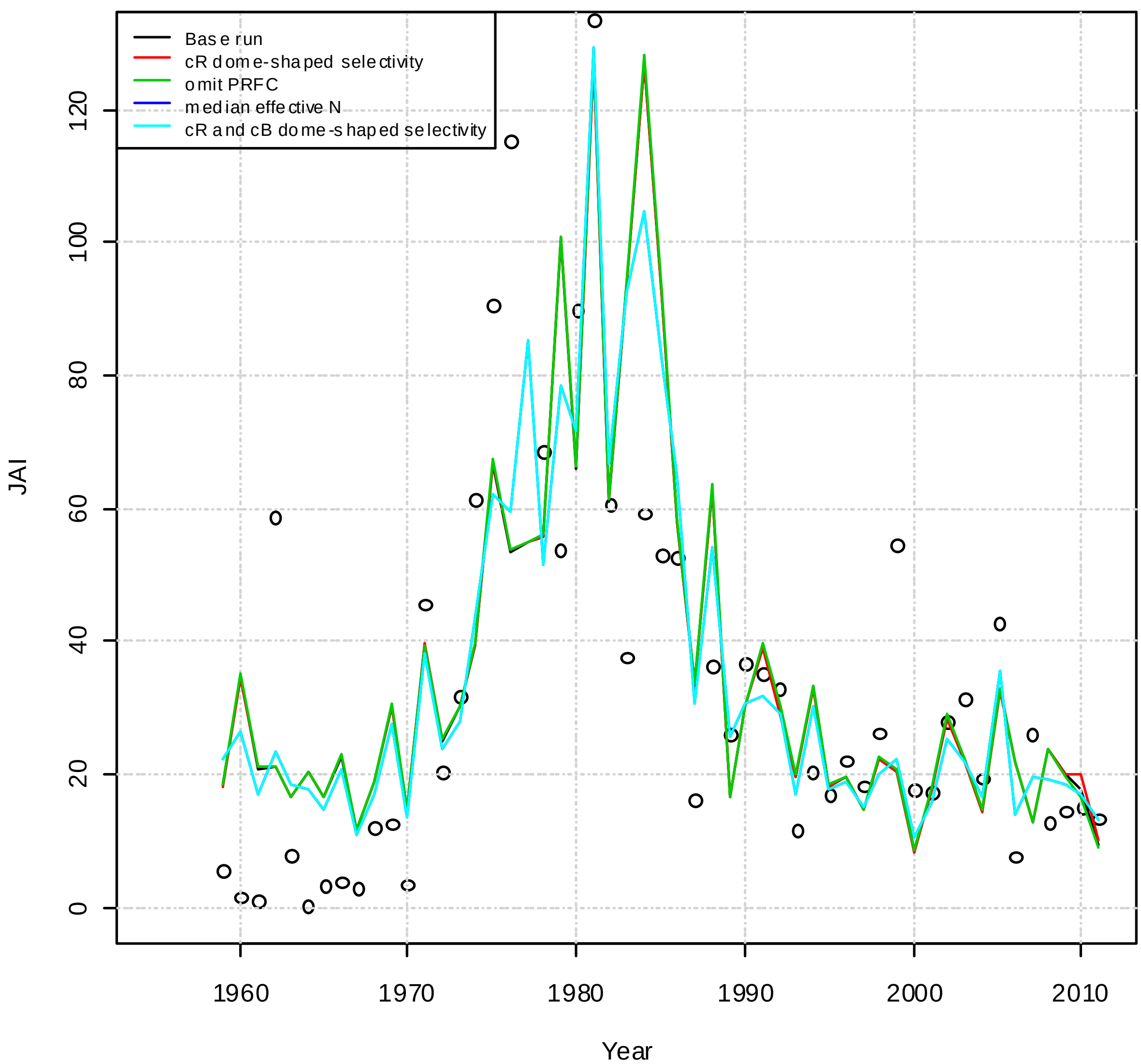


Figure 43. Fit to the observed pound net index from the base BAM model and various sensitivity runs. The open points are the observed values.

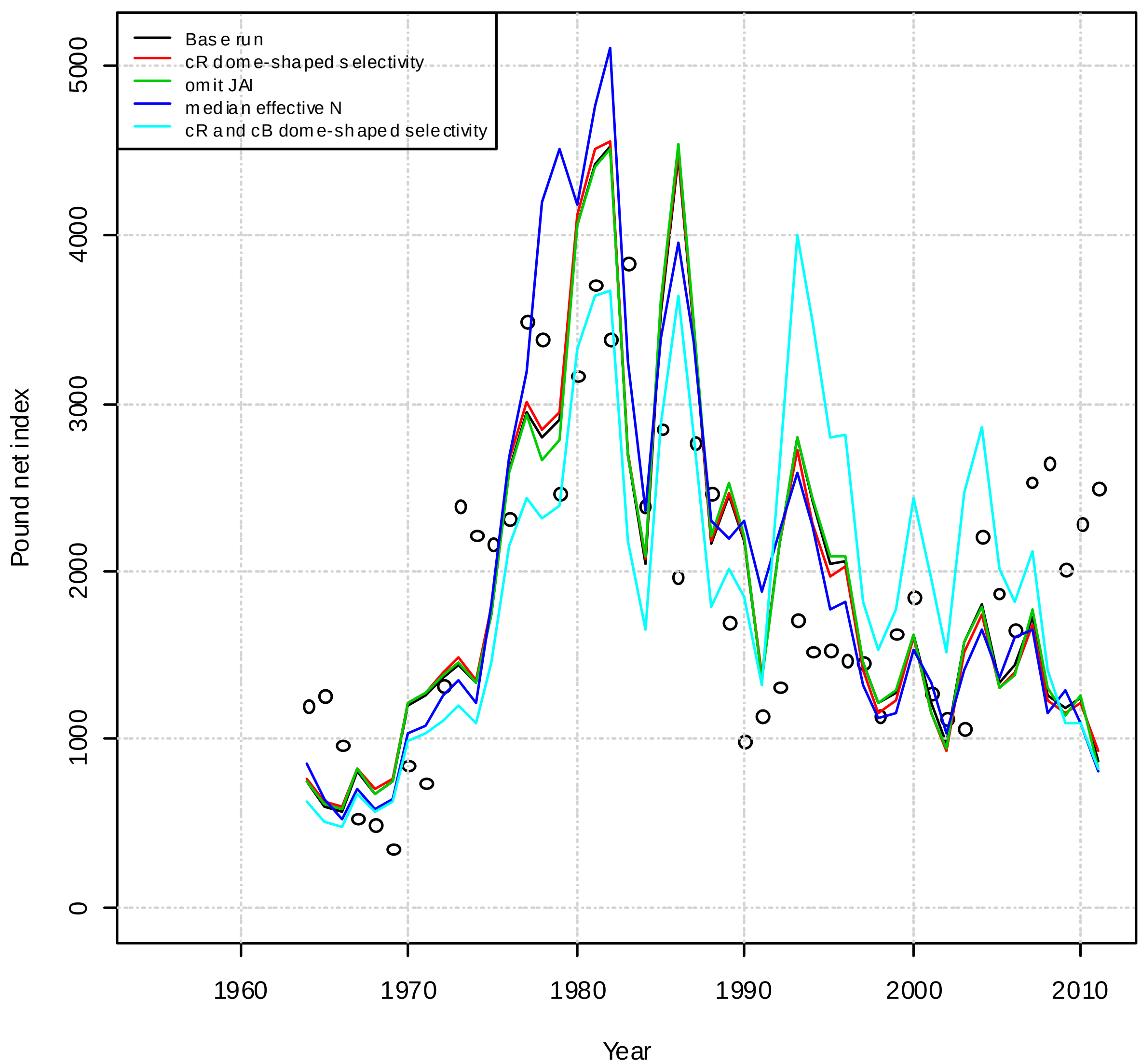


Figure 44. Estimated annual full fishing mortality rates from the base BAM model (connected open circles) and retrospective analysis runs. The last year of data used in the model run is indicated in the legend.

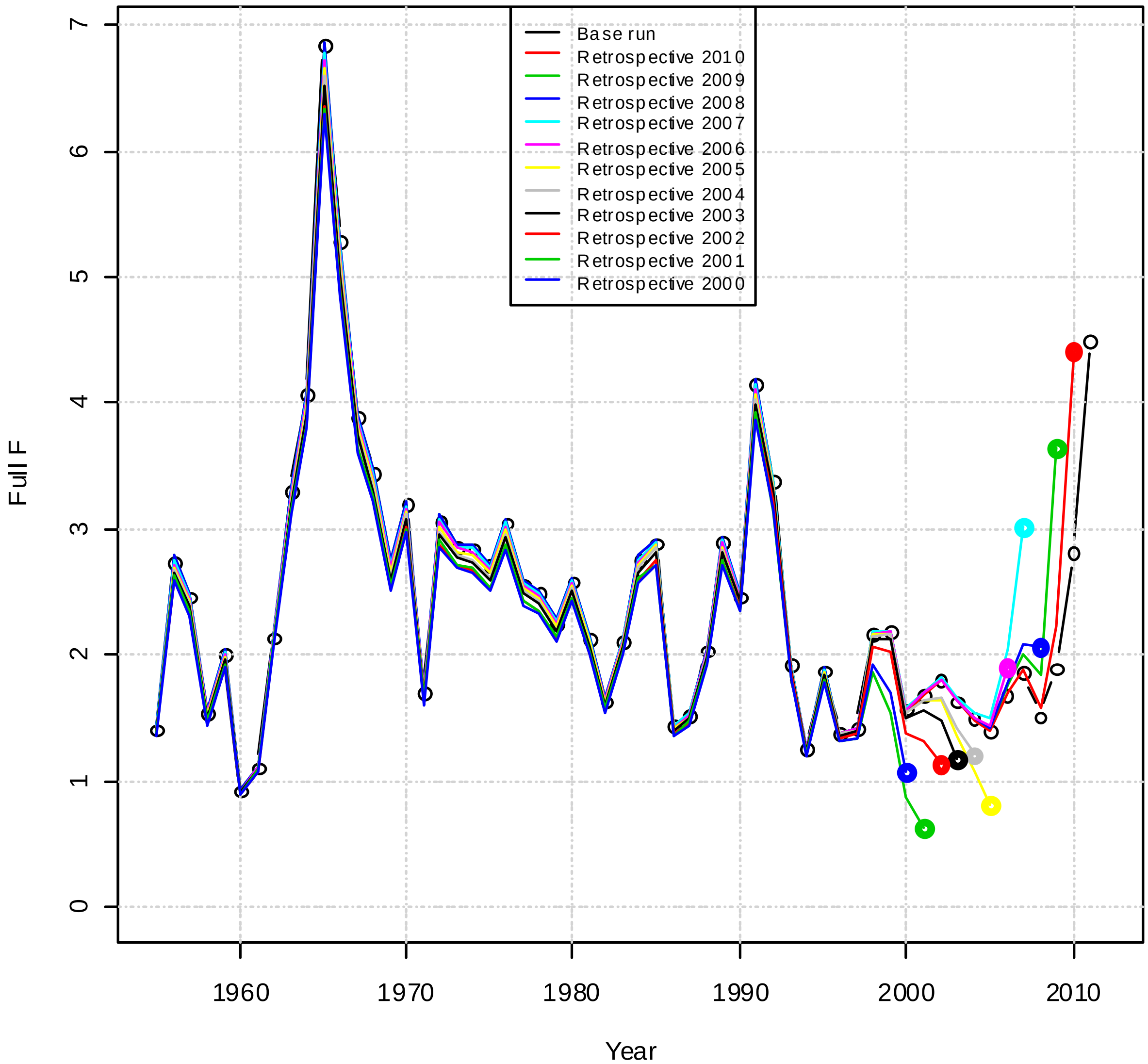


Figure 45. Estimated annual recruitment of age-0 fish (billions) from the base BAM model (connected open circles) and retrospective analysis runs. The last year of data used in the model run is indicated in the legend.

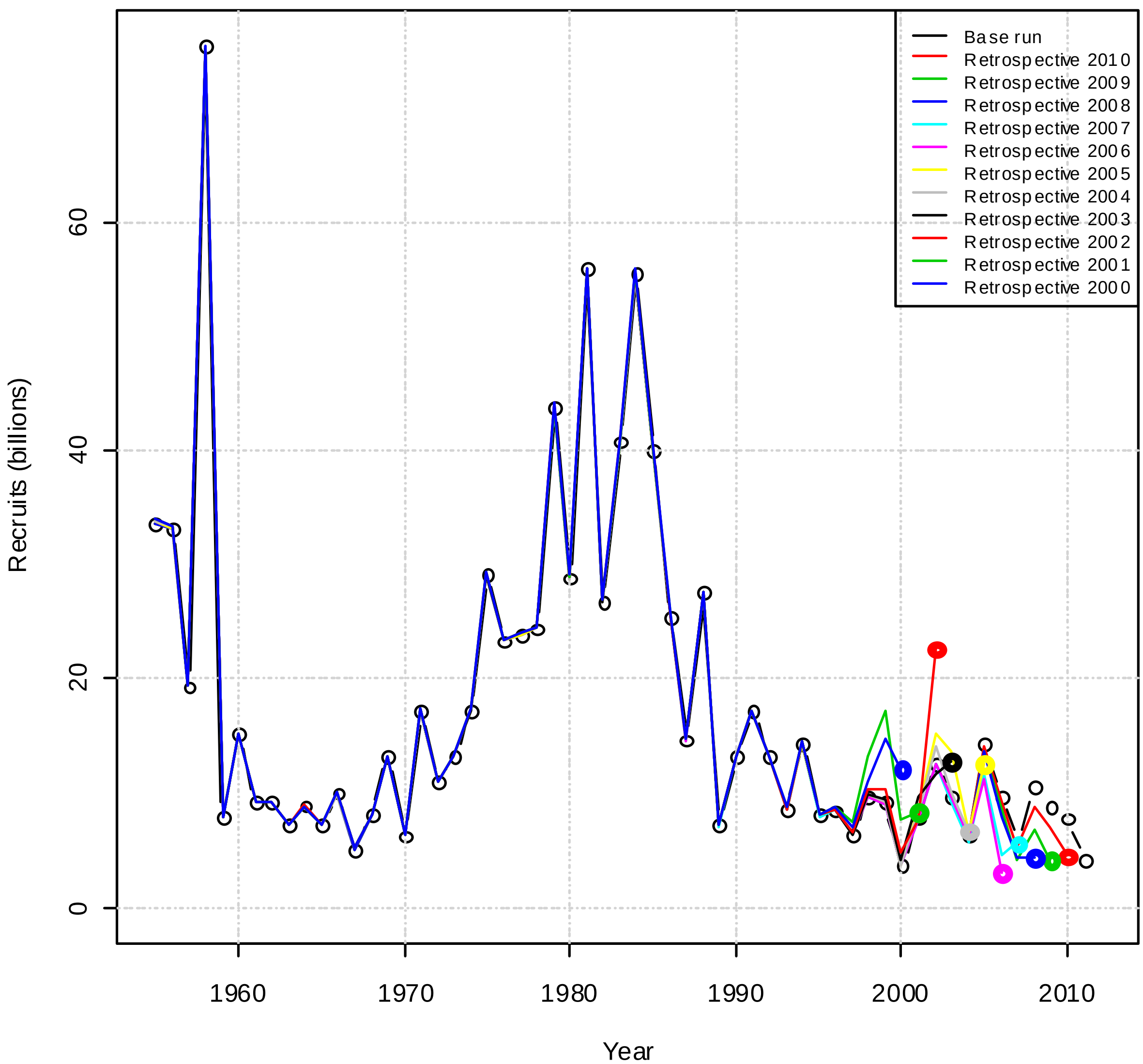


Figure 46. Estimated annual population fecundity (billions of mature ova) from the base BAM model (connected open circles) and retrospective analysis runs. The last year of data used in the model run is indicated in the legend.

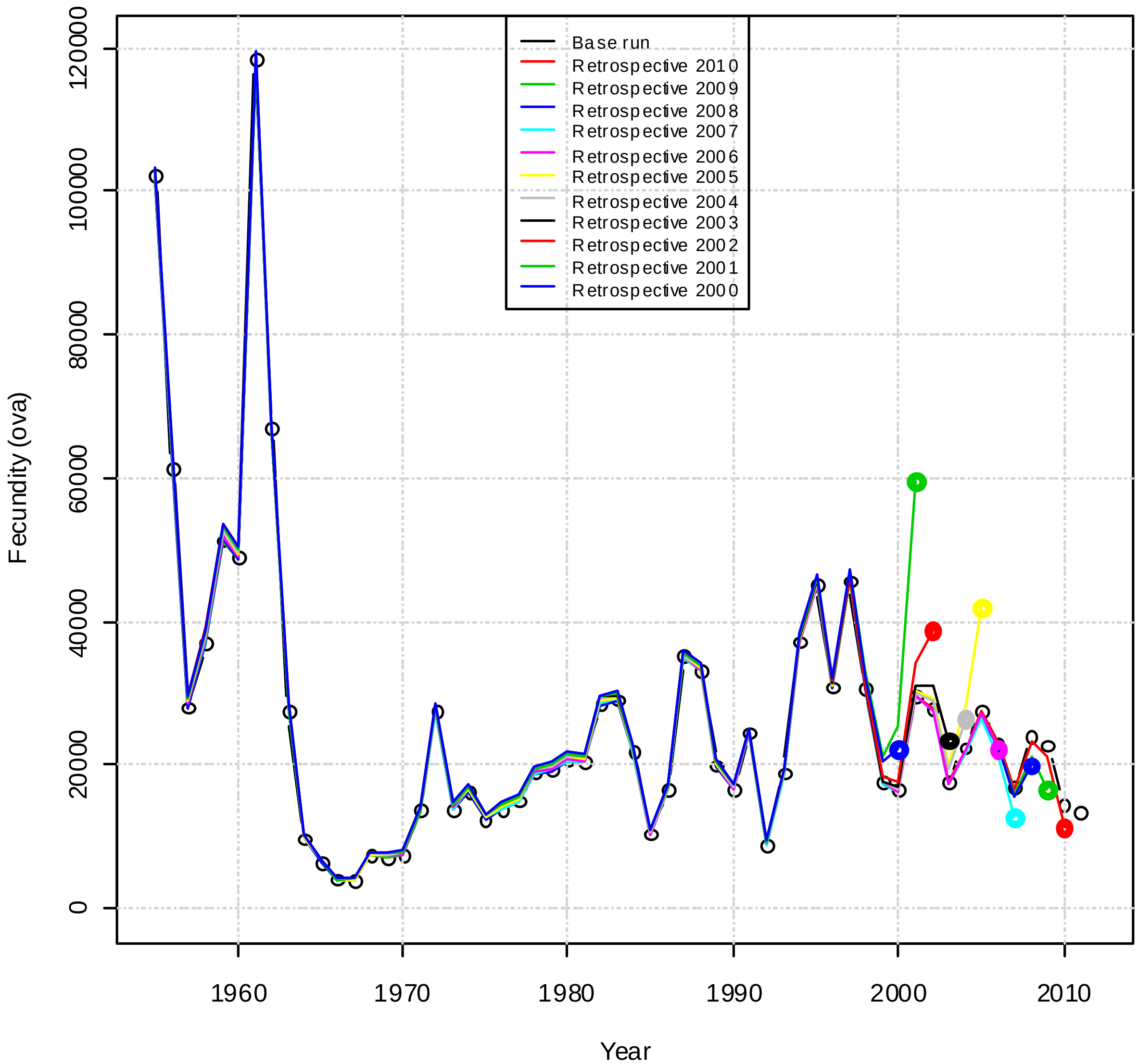


Figure 47. Estimated annual population biomass (1,000s mt) from the base BAM model (connected open circles) and retrospective analysis runs. The last year of data used in the model run is indicated in the legend.

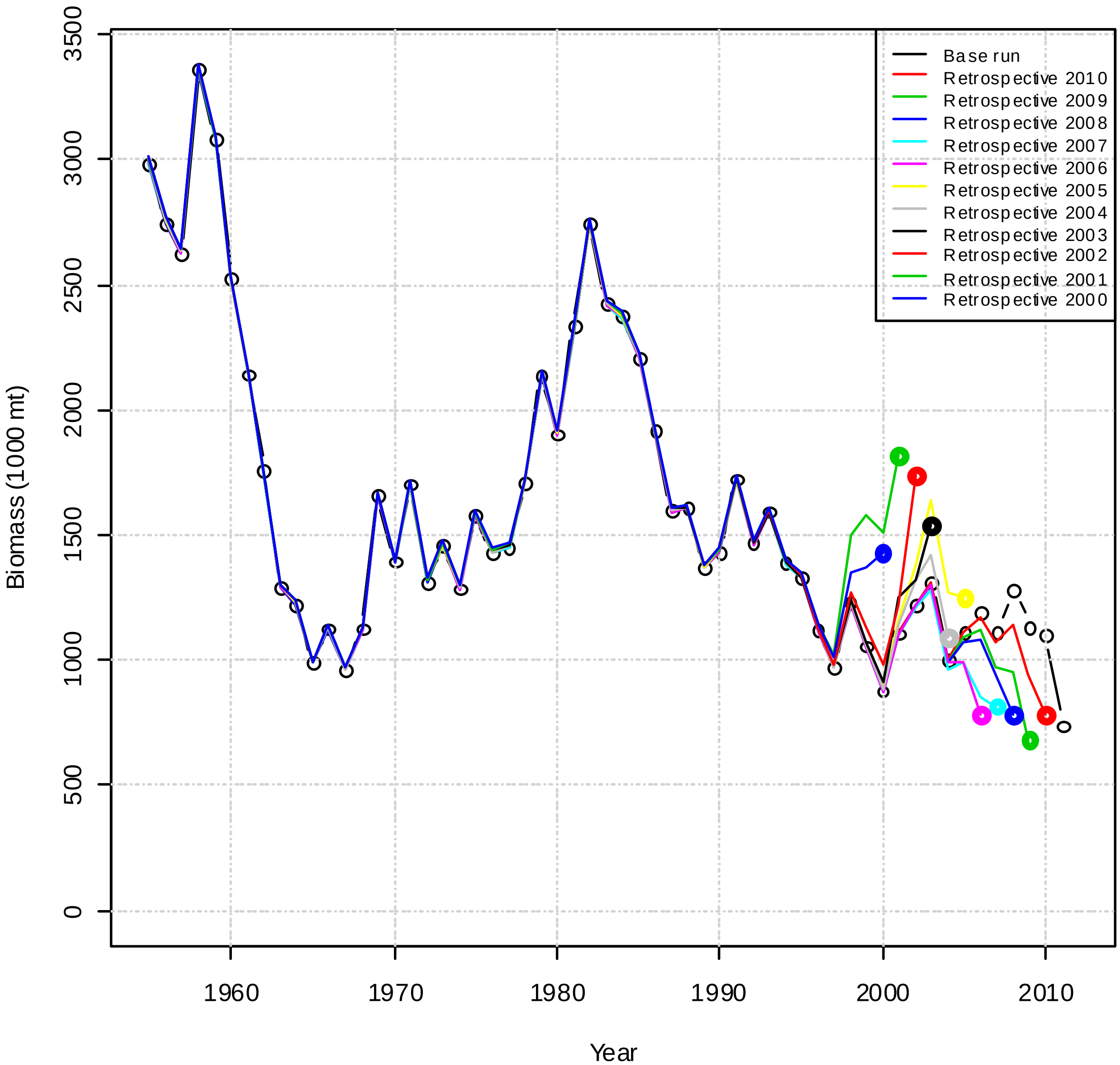


Figure 48. Fit to the JAI index from the base BAM model (connected open circles) and retrospective analysis runs. The last year of data used in the model run is indicated in the legend.

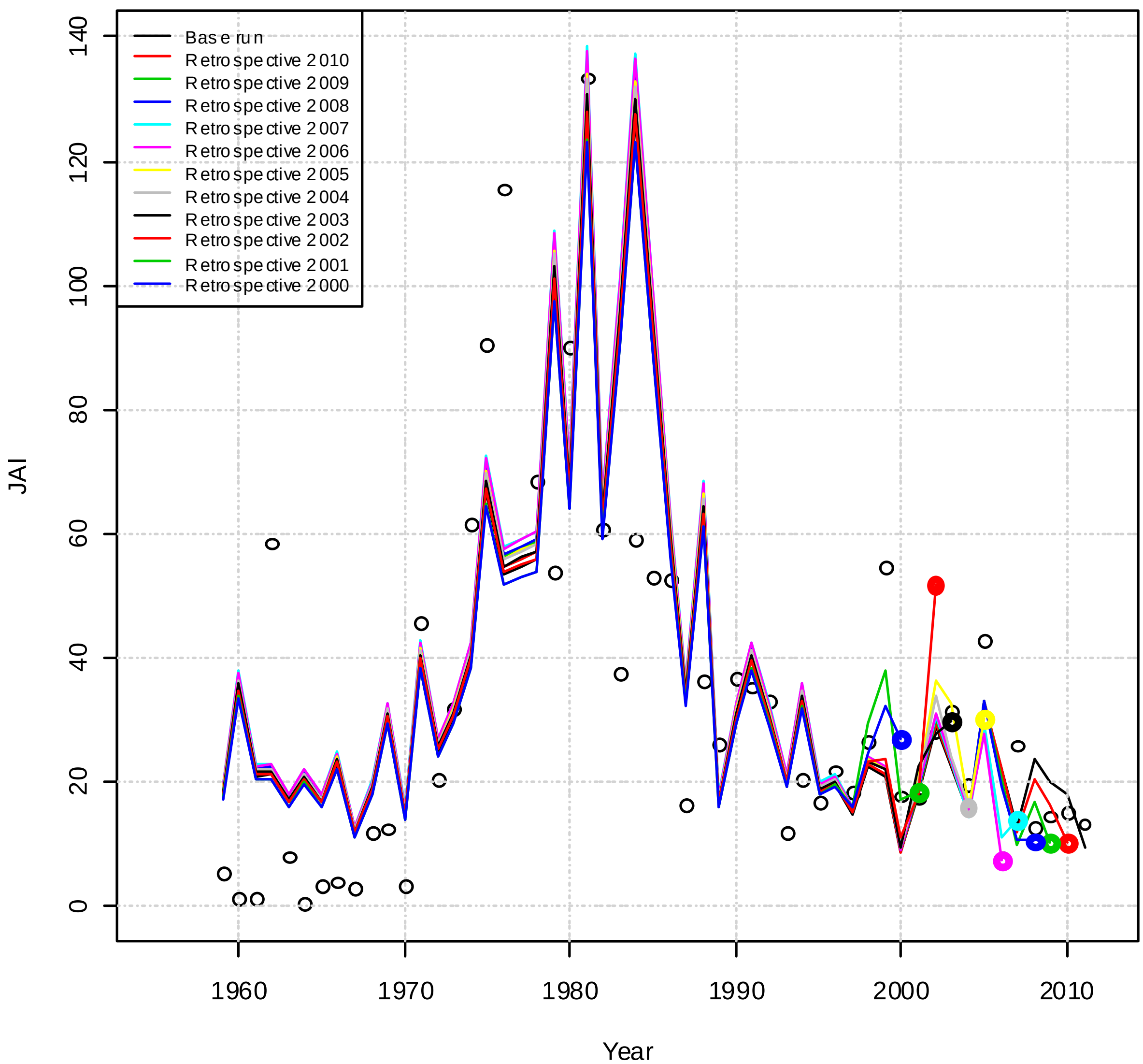


Figure 49. Fit to the pound net index from the base BAM model (connected open circles) and retrospective analysis runs. The last year of data used in the model run is indicated in the legend.

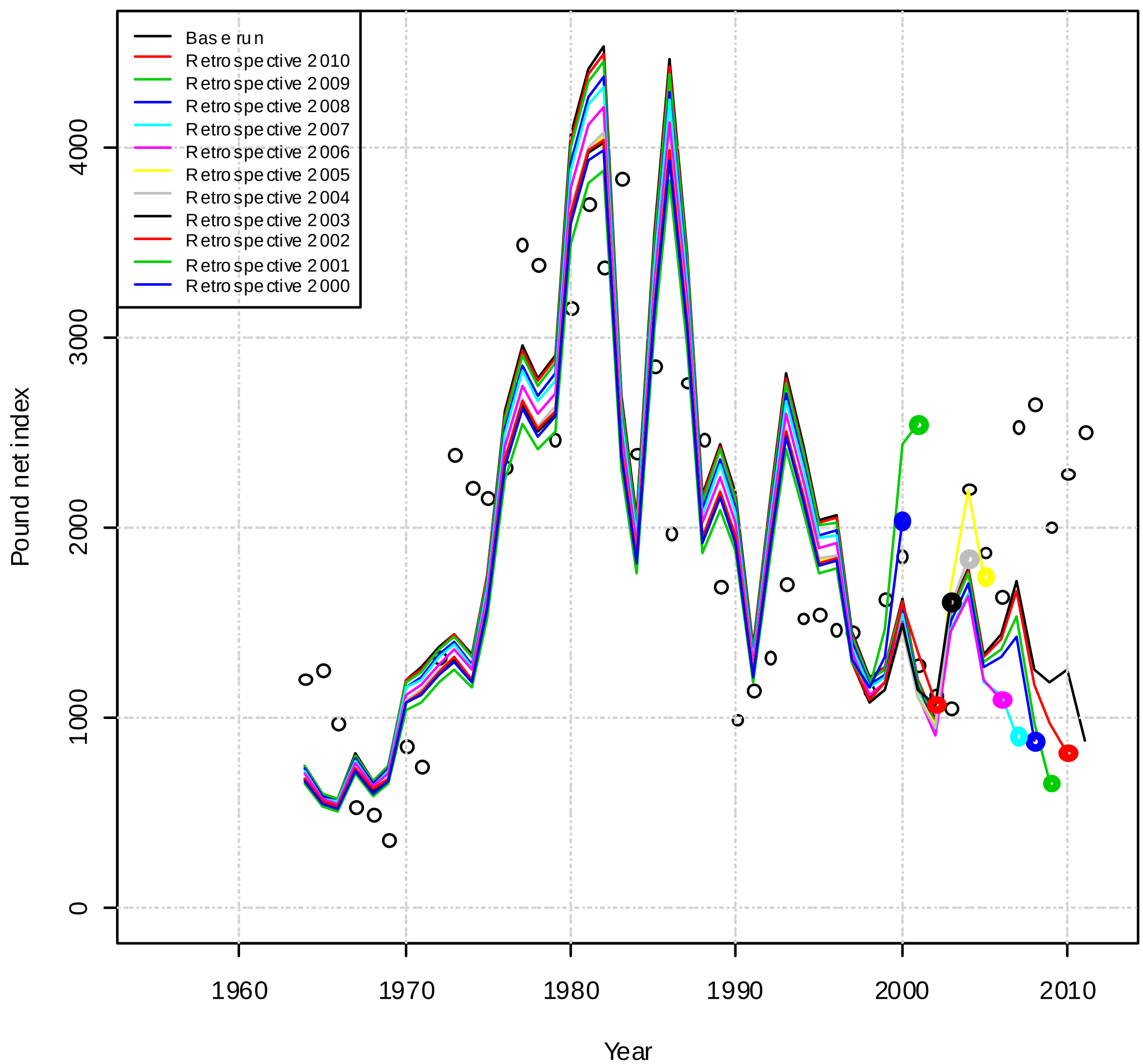


Figure 50. Relative change in full F from the base BAM model with a terminal year of 2011 compared to the retrospective analysis runs. The last year of data used in the model run is the year indicated on the x-axis.

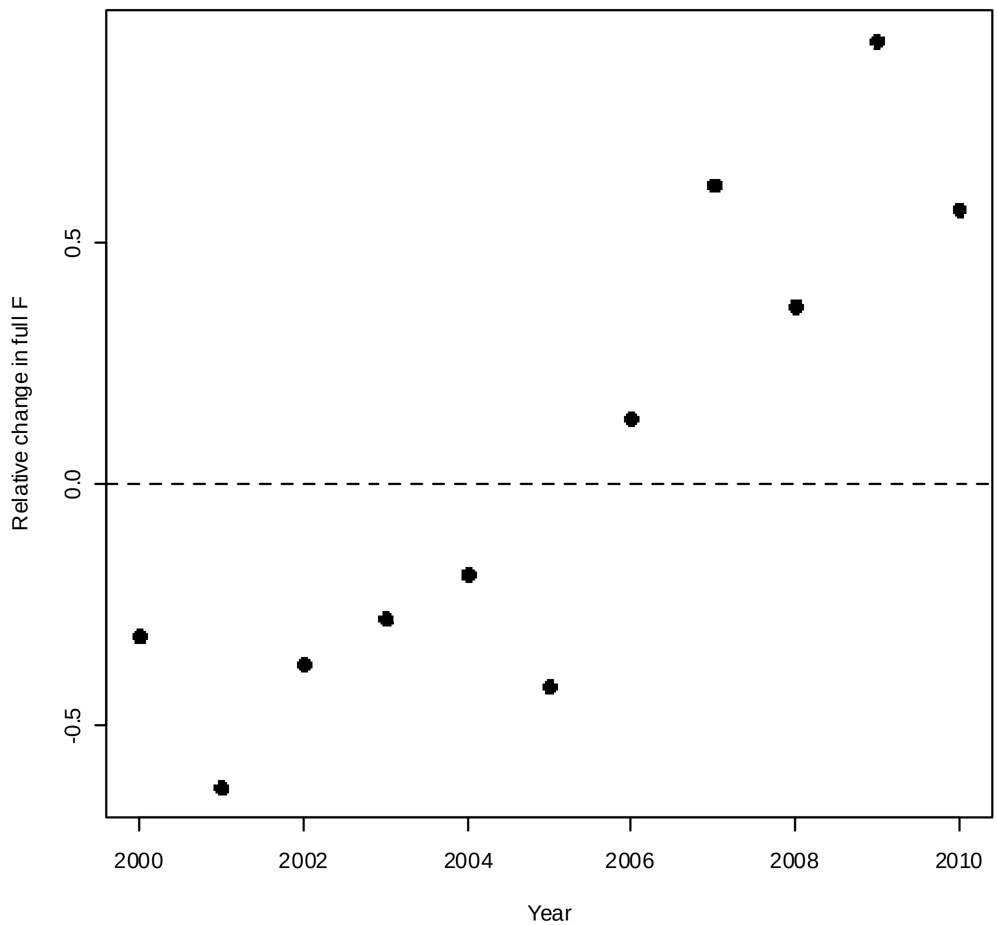


Figure 51. Relative change in recruitment from the base BAM model with a terminal year of 2011 compared to the retrospective analysis runs. The last year of data used in the model run is the year indicated on the x-axis.

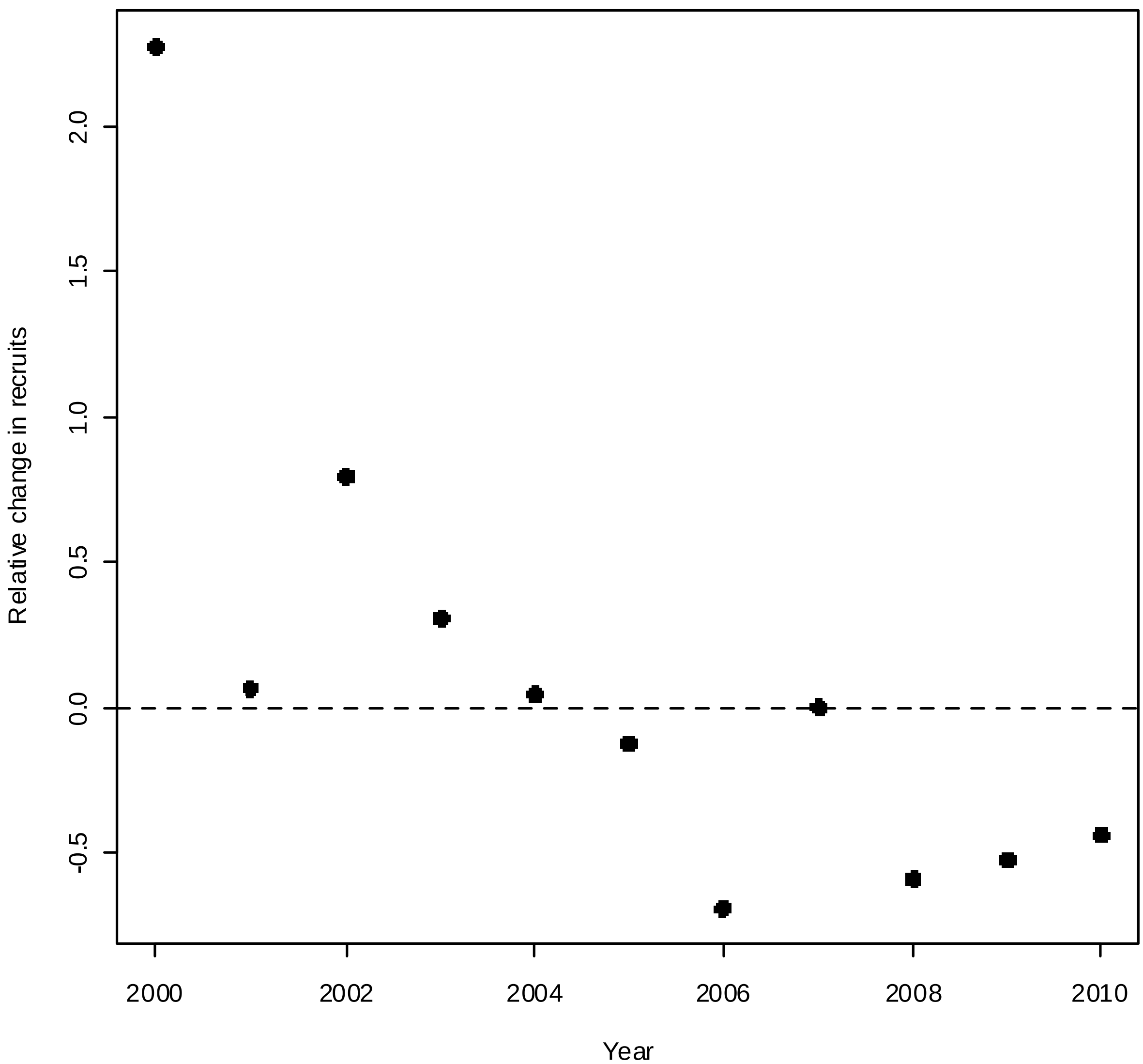


Figure 52. Relative change in fecundity from the base BAM model with a terminal year of 2011 compared to the retrospective analysis runs. The last year of data used in the model run is the year indicated on the x-axis.

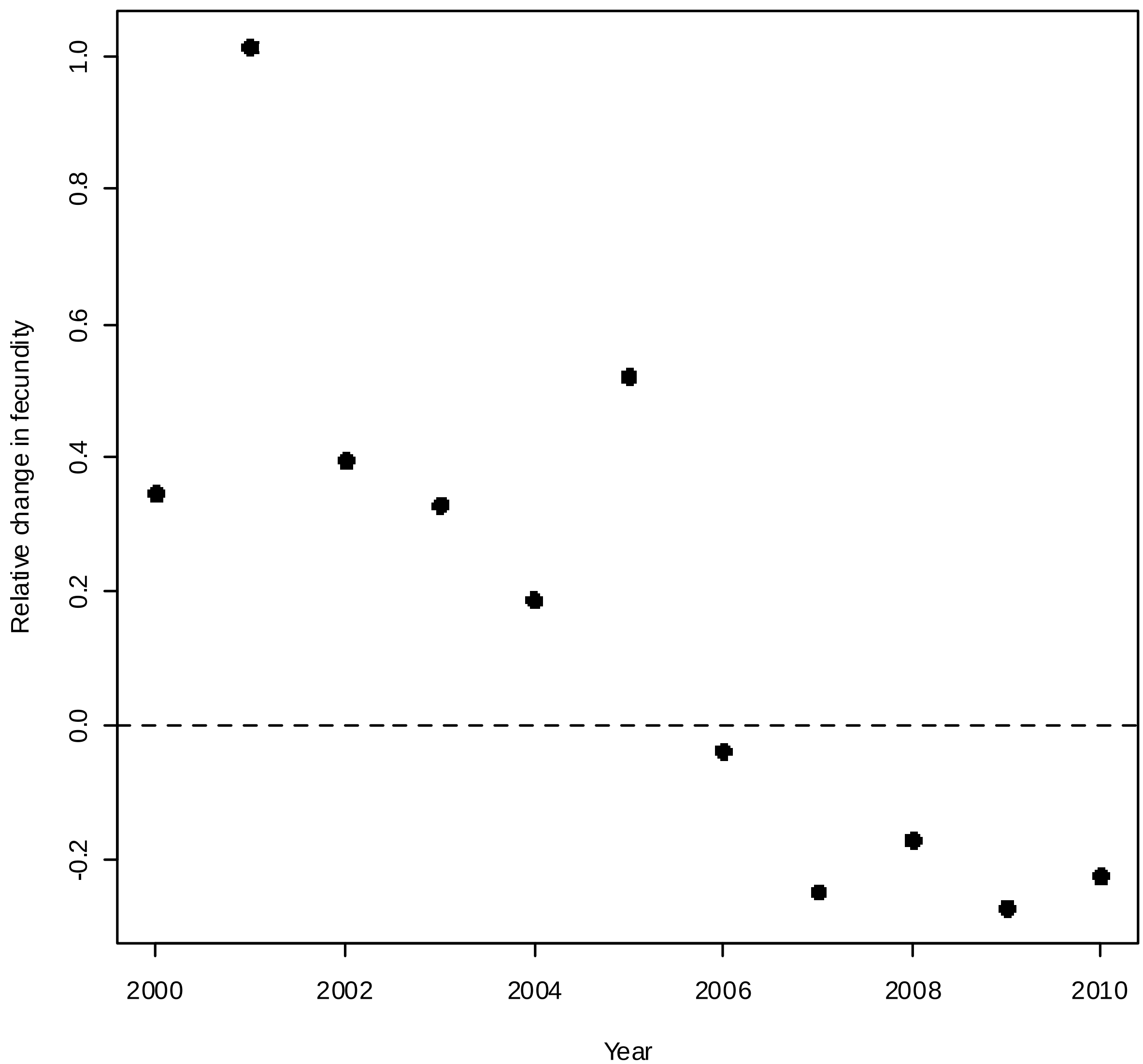


Figure 53. Relative change in biomass from the base BAM model with a terminal year of 2011 compared to the retrospective analysis runs. The last year of data used in the model run is the year indicated on the x-axis.

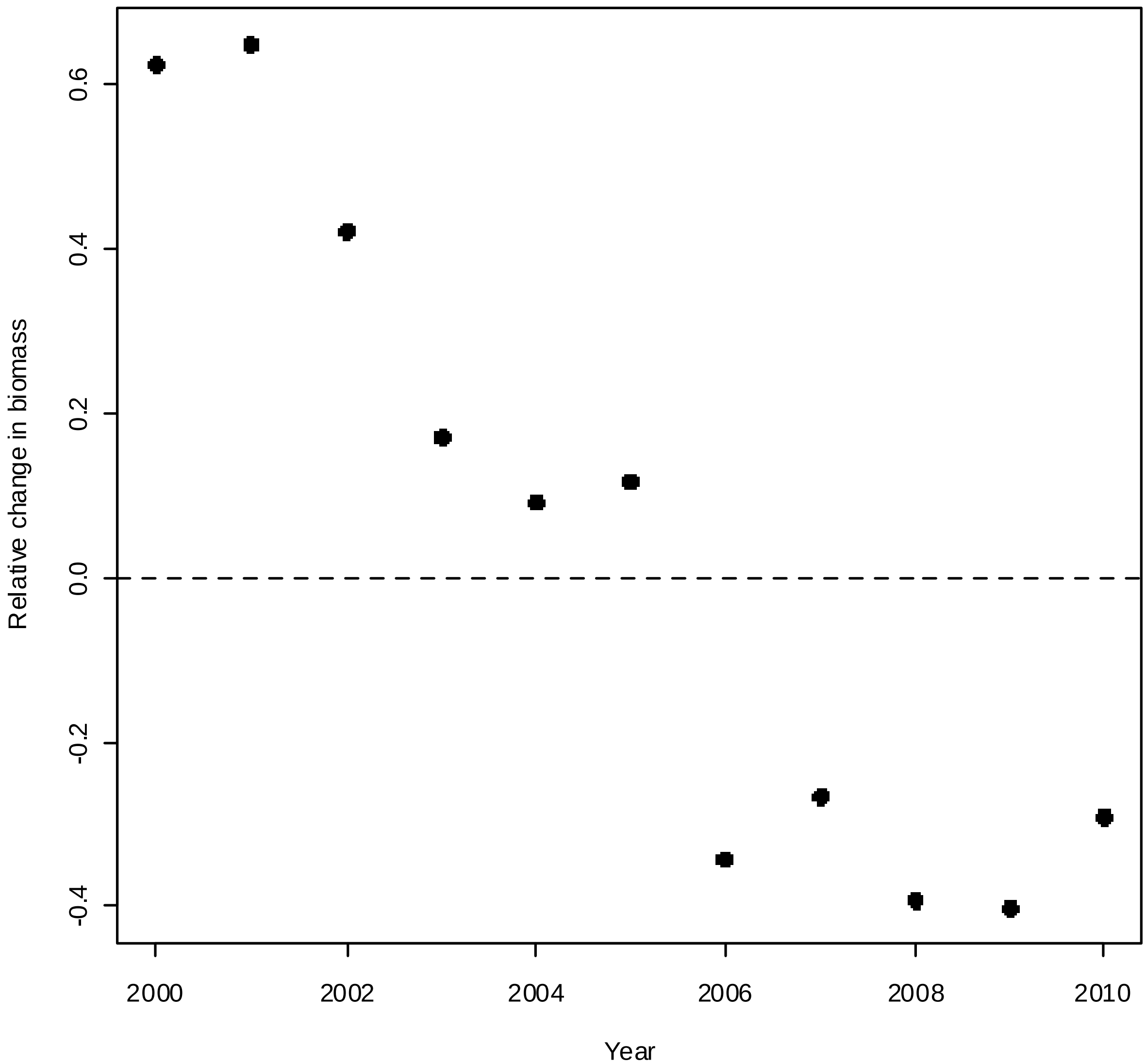


Figure 54. Estimates of the proportional (re-scaled to max of 1.0) fecundity-per-recruit as a function of the total full fishing mortality rate from the base BAM model using the years 1955-2011 for benchmark calculations.

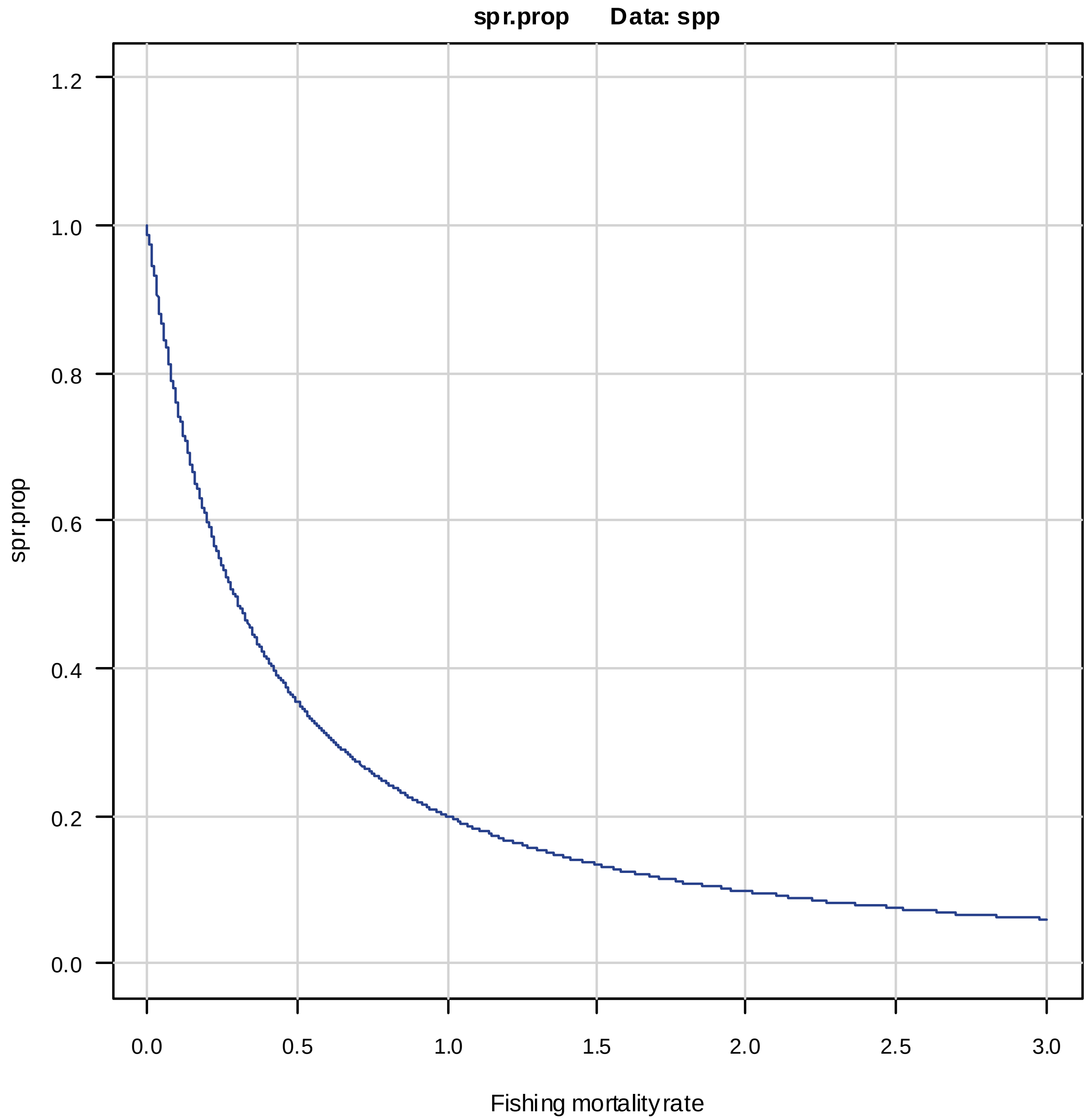


Figure 55. Estimates of the yield-per-recruit (mt/million) as a function of the total full fishing mortality rate from the base BAM model using the years 1955-2011 for benchmark calculations.

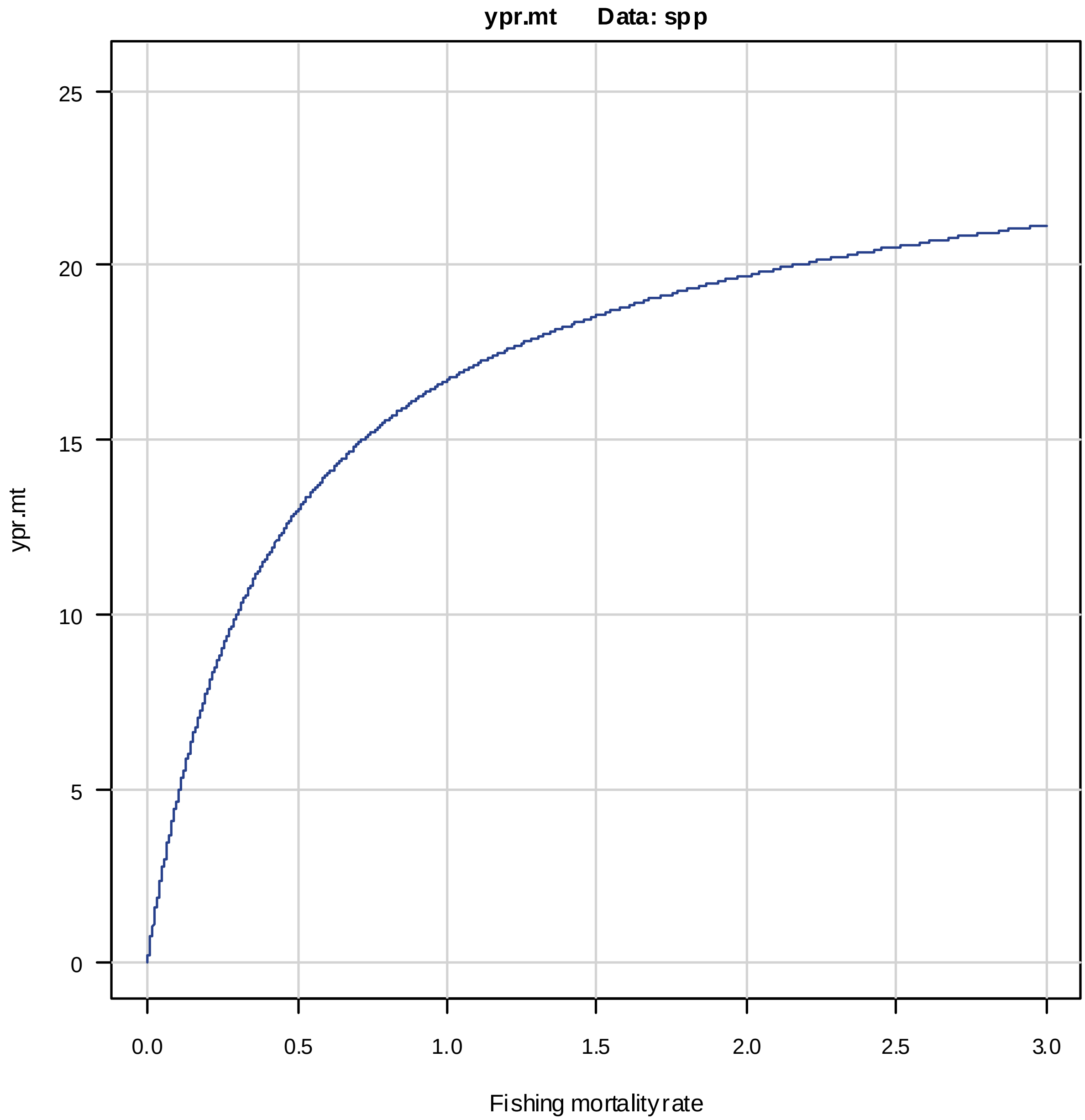


Figure 56. Estimates of the total full fishing mortality rate relative to the F15% benchmark (fishing limit value) from the base BAM model (connected points) using benchmarks calculated over 1955-2011. Shaded area represents the 90% confidence interval of the bootstrap runs.

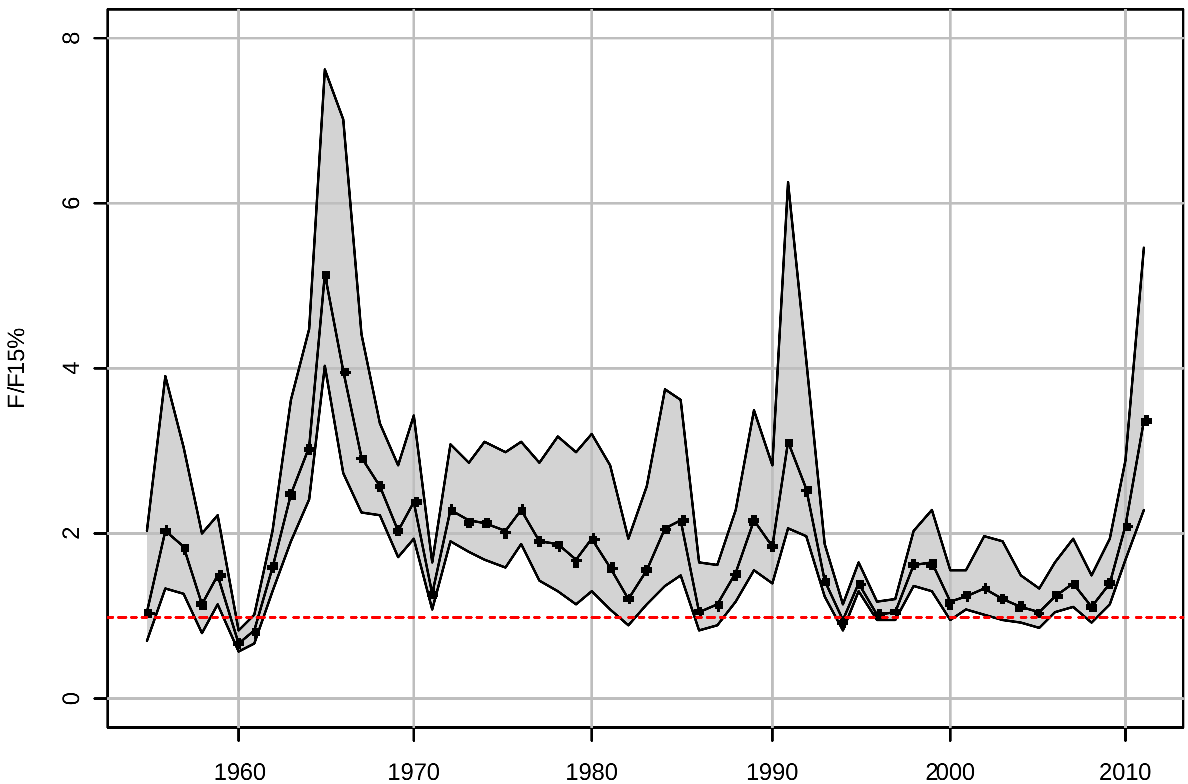


Figure 57. Estimates of the total full fishing mortality rate relative to the F30% benchmark (fishing target) from the base BAM model (connected points) using benchmarks calculated over 1955-2011. Shaded area represents the 90% confidence interval of the bootstap runs.

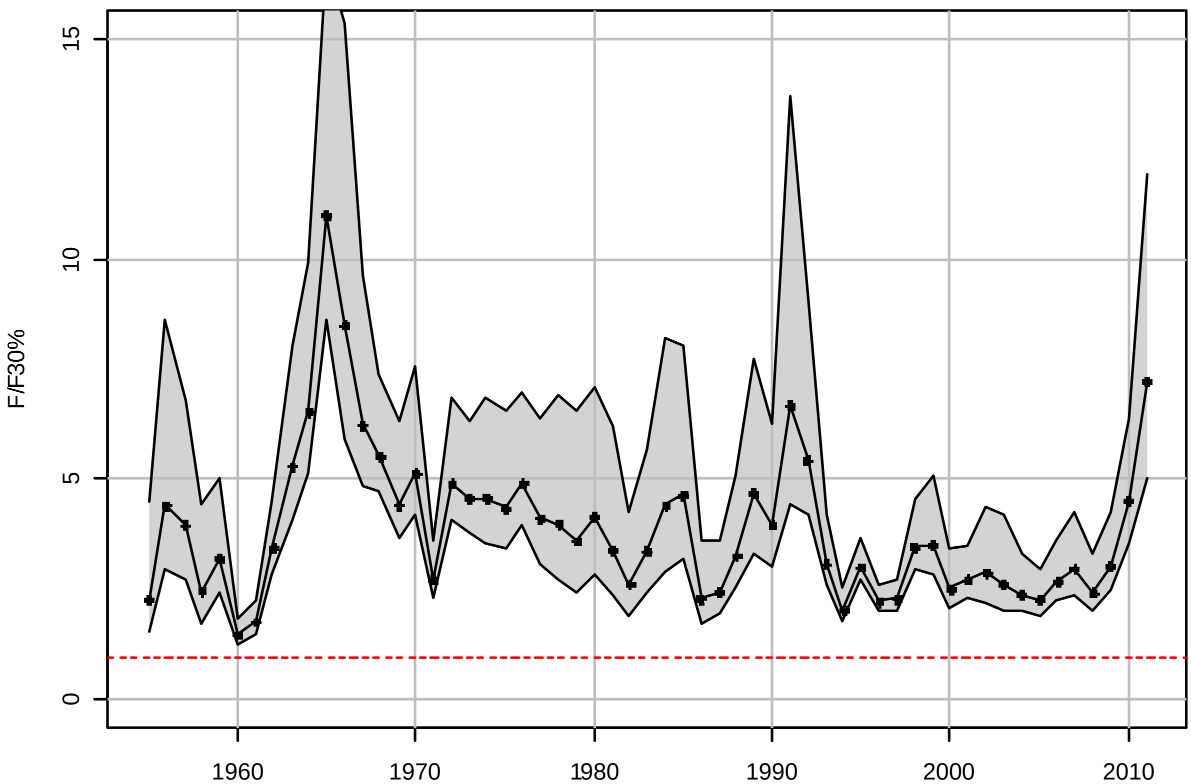


Figure 58. Annual fecundity compared to target and limit (threshold).

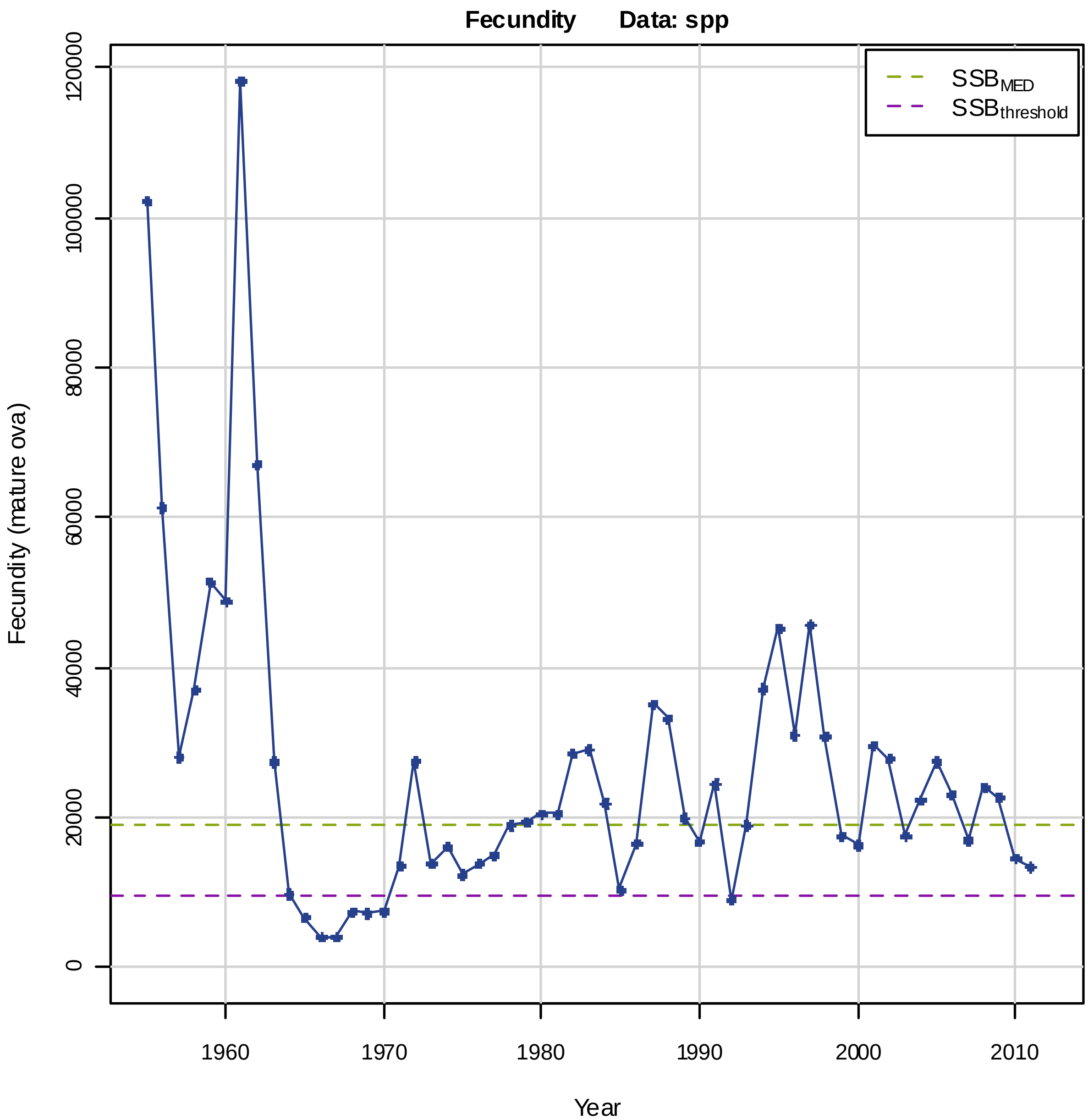


Figure 59. Fecundity, recruits, fishing mortality (F), and landings over time based on constant landings of 75,000 mt with 25% allocated to the bait fishery and 75% allocated to the reduction fishery.

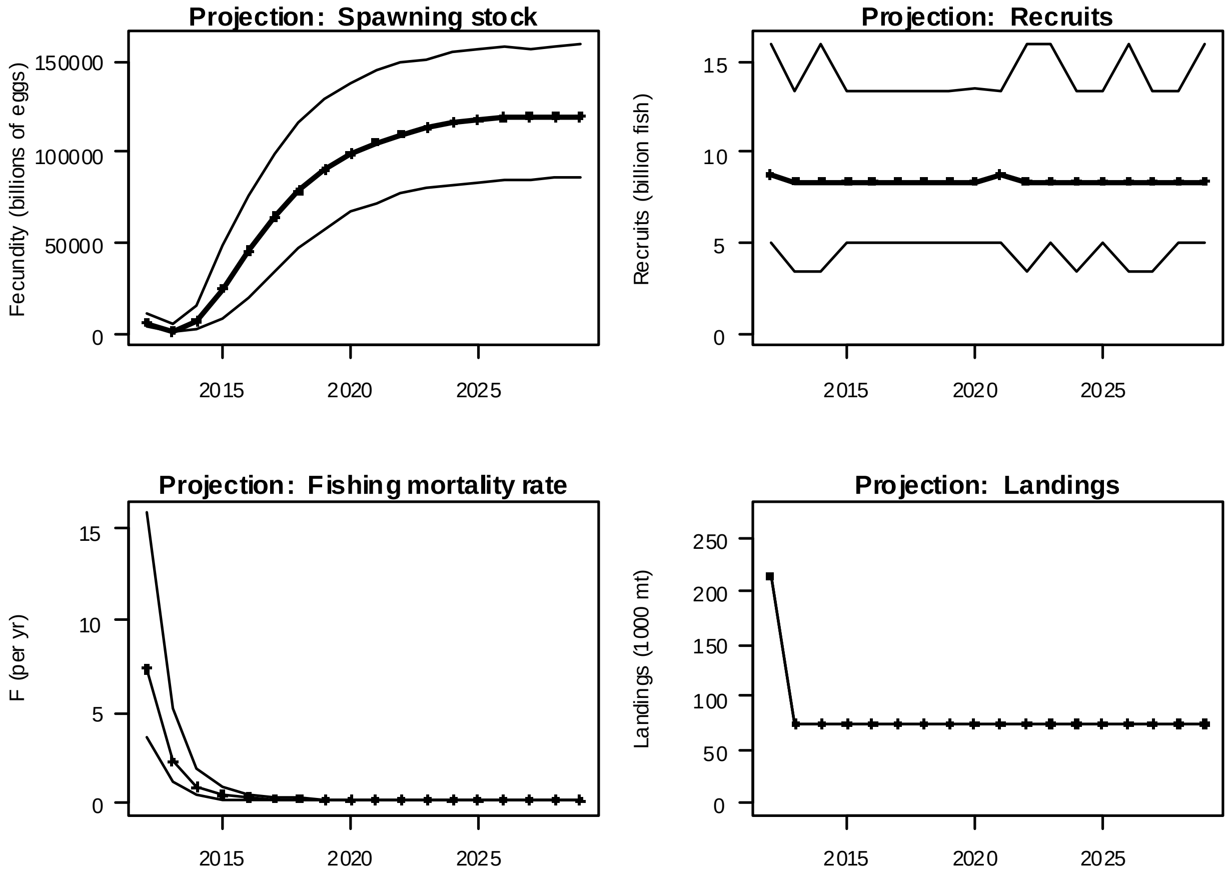


Figure 60. Cumulative distribution of fishing mortality rates for 2012 to 2023 based on constant landings of 75,000 mt with 25% allocated to the bait fishery and 75% allocated to the reduction fishery. The blue line denotes the threshold and the red line denote the target.

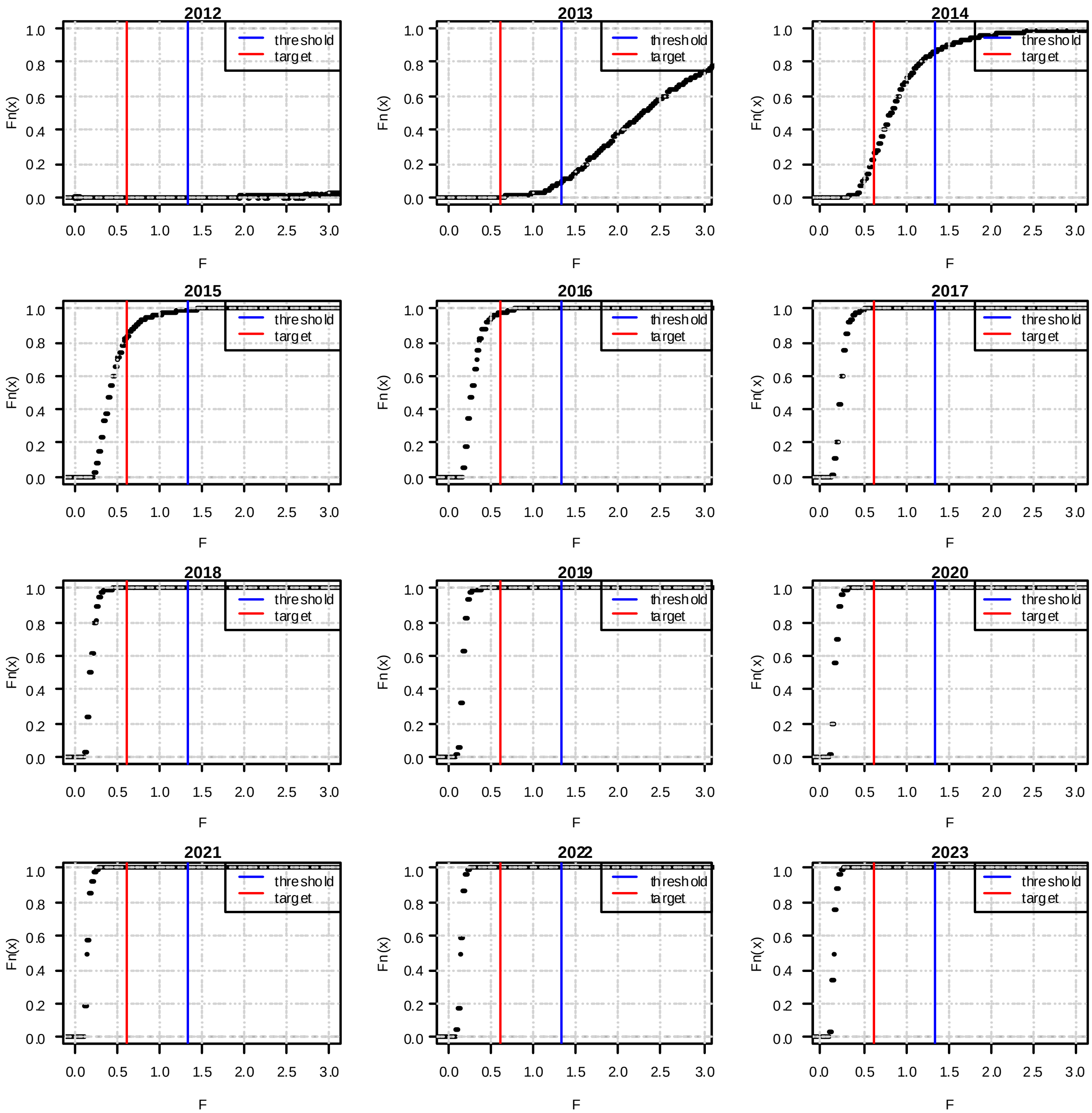


Figure 61. Fecundity, recruits, fishing mortality (F), and landings over time based on constant landings of 100,000 mt with 25% allocated to the bait fishery and 75% allocated to the reduction fishery.

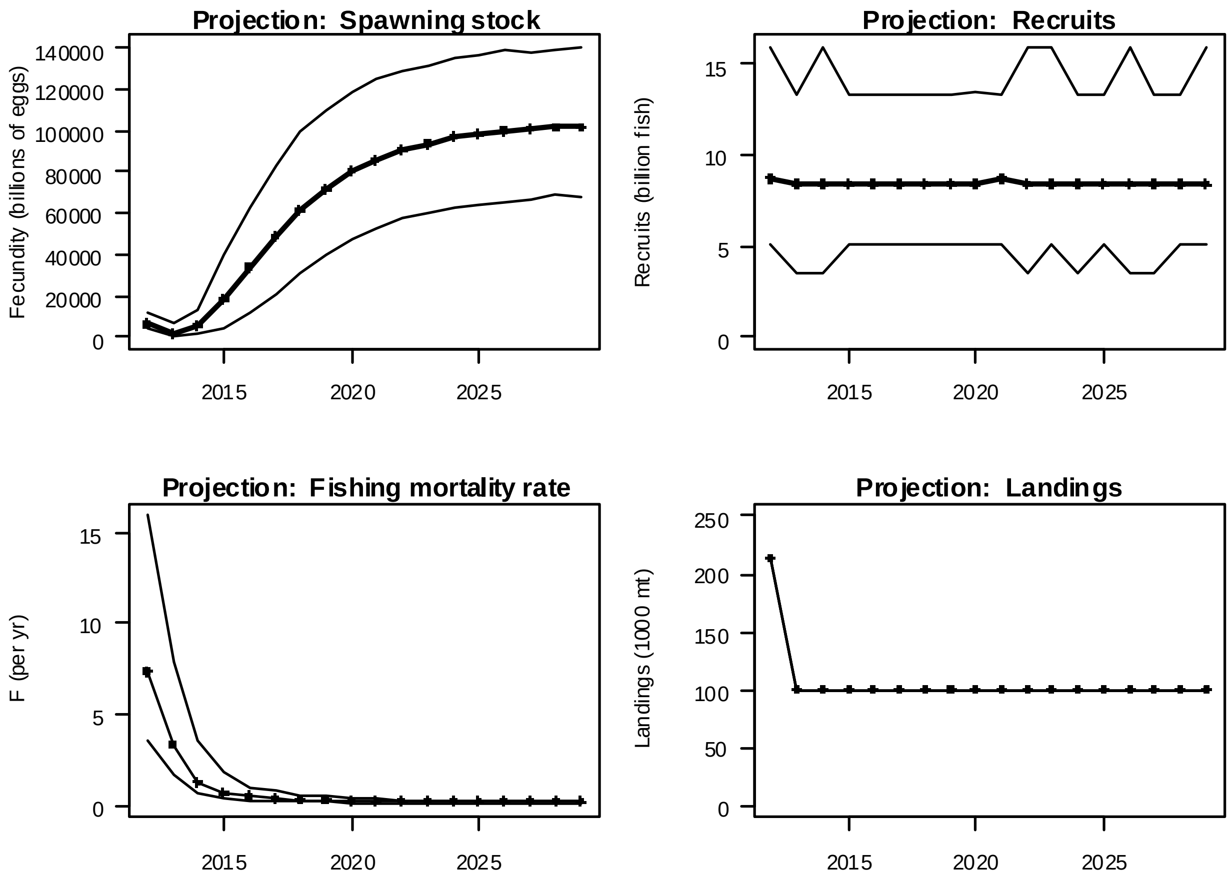


Figure 62. Cumulative distribution of fishing mortality rates for 2012 to 2023 based on constant landings of 100,000 mt with 25% allocated to the bait fishery and 75% allocated to the reduction fishery. The blue line denotes the threshold and the red line denotes the target, and where the lines cross the distribution is the probability that the given landings will be below a specified *F* in that year.

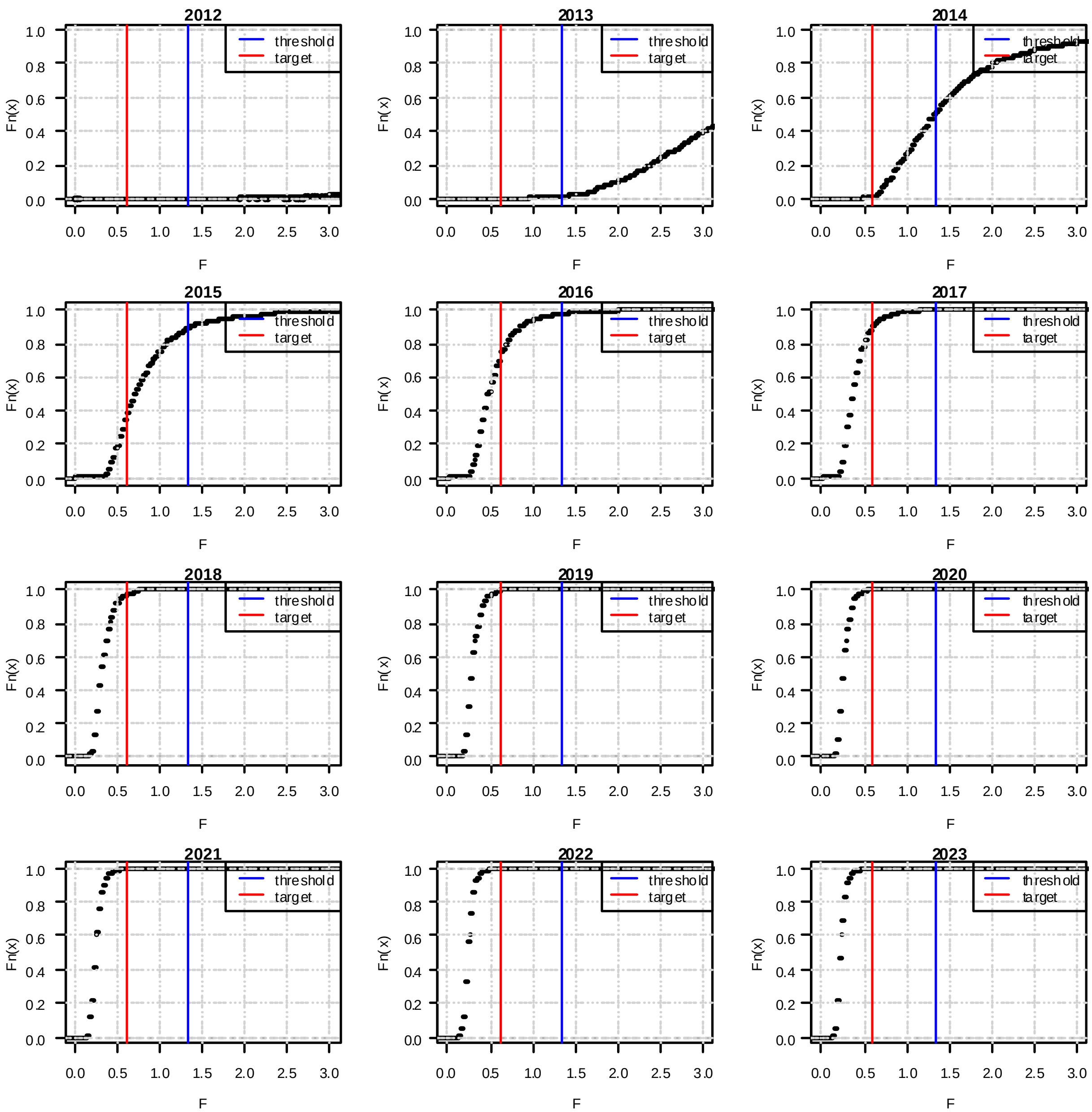


Figure 63. Fecundity, recruits, fishing mortality (F), and landings over time based on constant landings of 125,000 mt with 25% allocated to the bait fishery and 75% allocated to the reduction fishery.

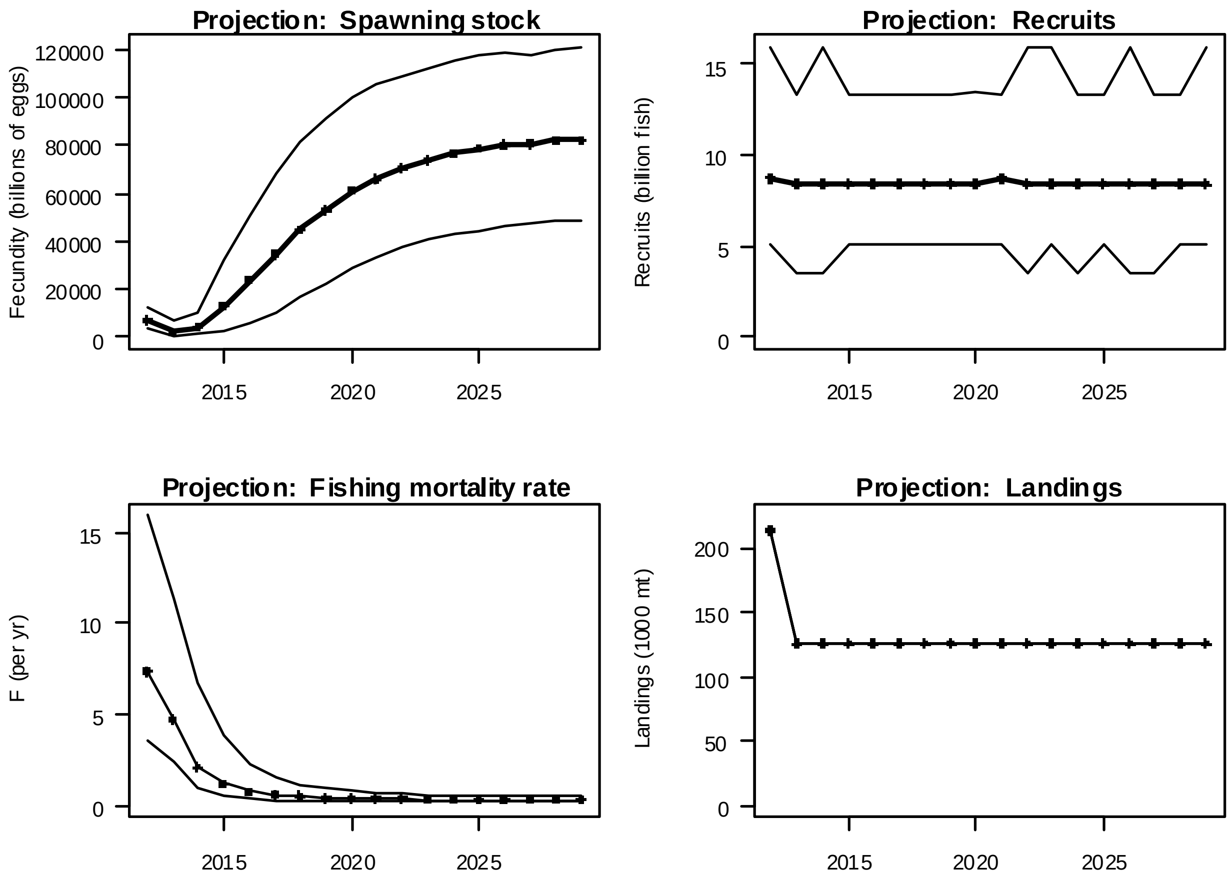


Figure 64. Cumulative distribution of fishing mortality rates for 2012 to 2023 based on constant landings of 125,000 mt with 25% allocated to the bait fishery and 75% allocated to the reduction fishery. The blue line denotes the threshold and the red line denotes the target, and where the lines cross the distribution is the probability that the given landings will be below a specified *F* in that year.

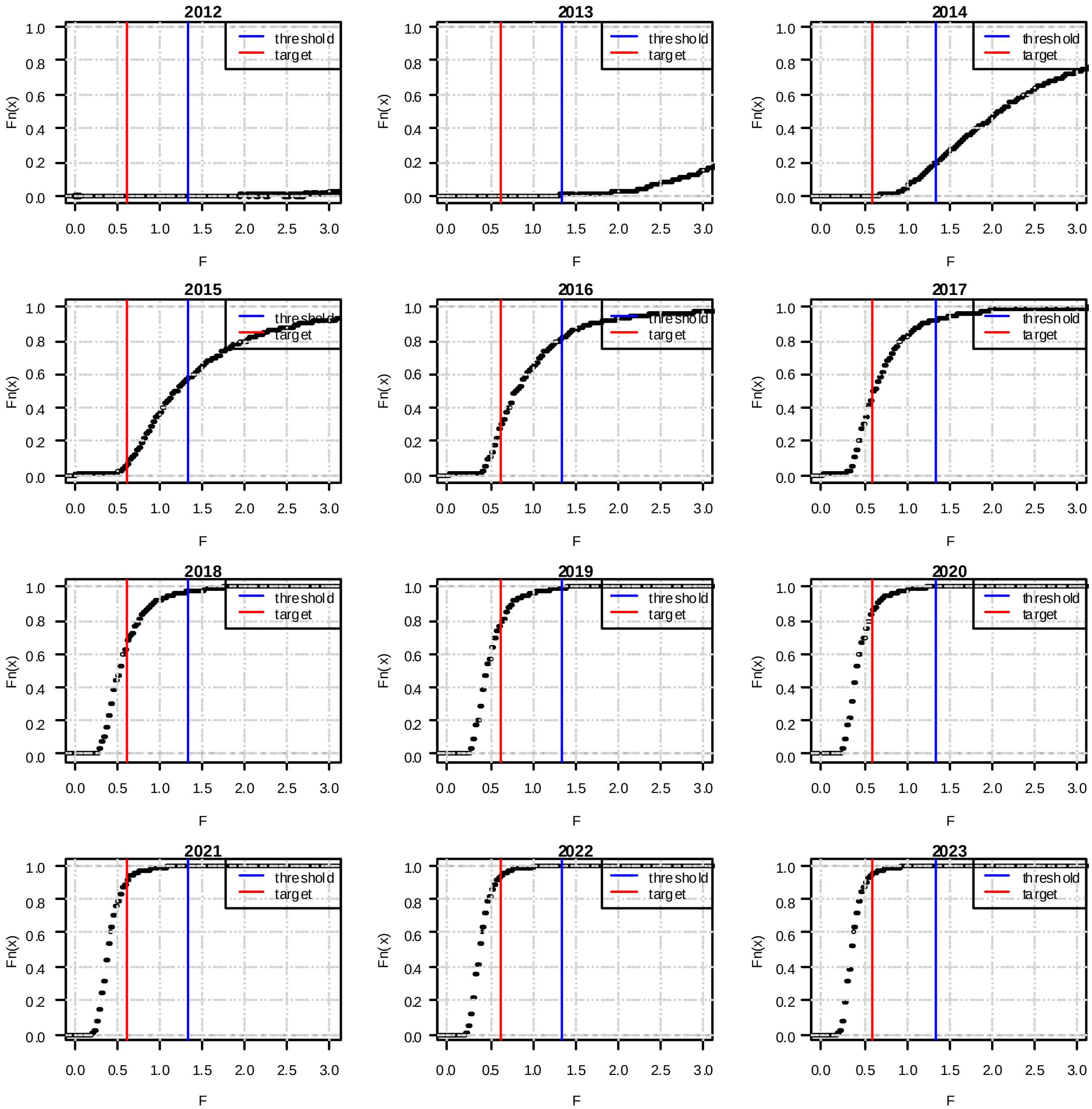


Figure 65. Fecundity, recruits, fishing mortality (F), and landings over time based on constant landings of 150,000 mt with 25% allocated to the bait fishery and 75% allocated to the reduction fishery.

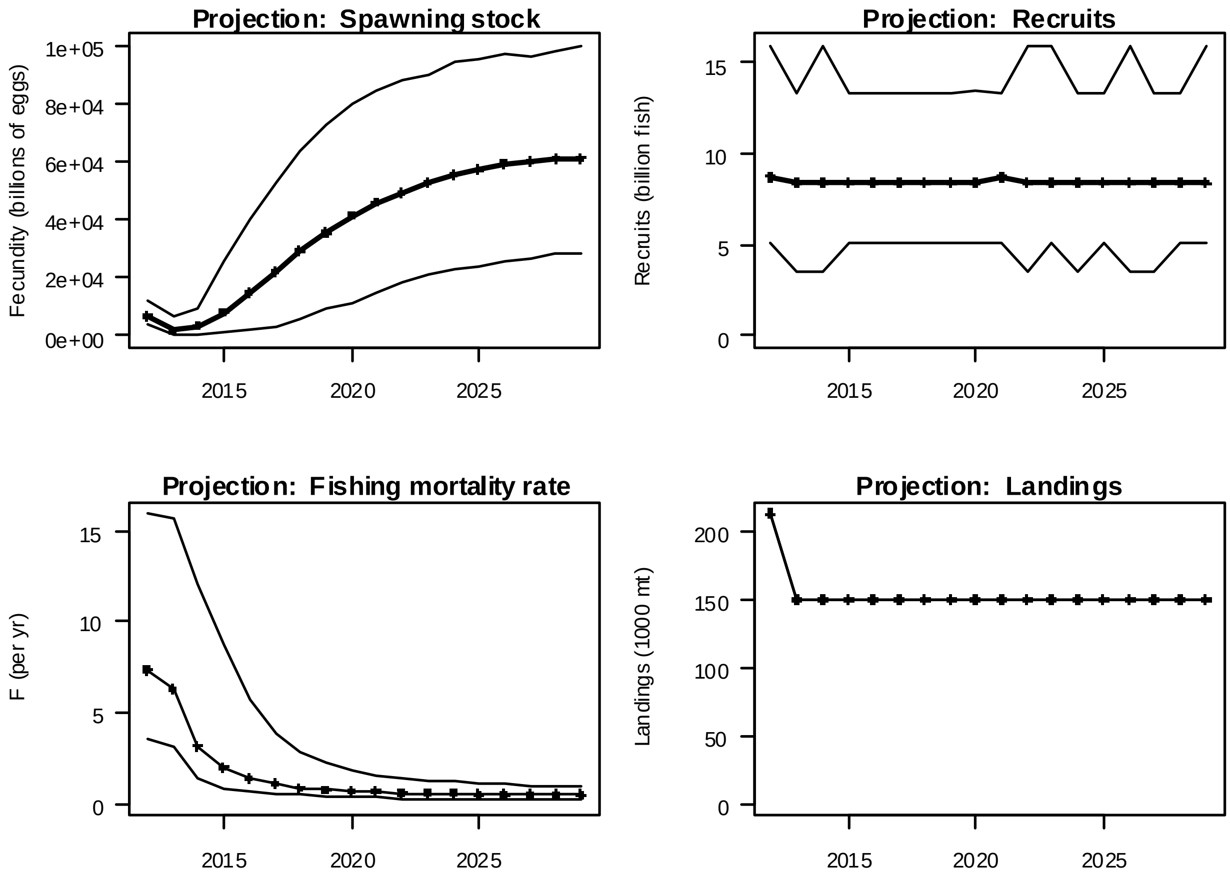


Figure 66. Cumulative distribution of fishing mortality rates for 2012 to 2023 based on constant landings of 150,000 mt with 25% allocated to the bait fishery and 75% allocated to the reduction fishery. The blue line denotes the threshold and the red line denotes the target, and where the lines cross the distribution is the probability that the given landings will be below a specified *F* in that year.

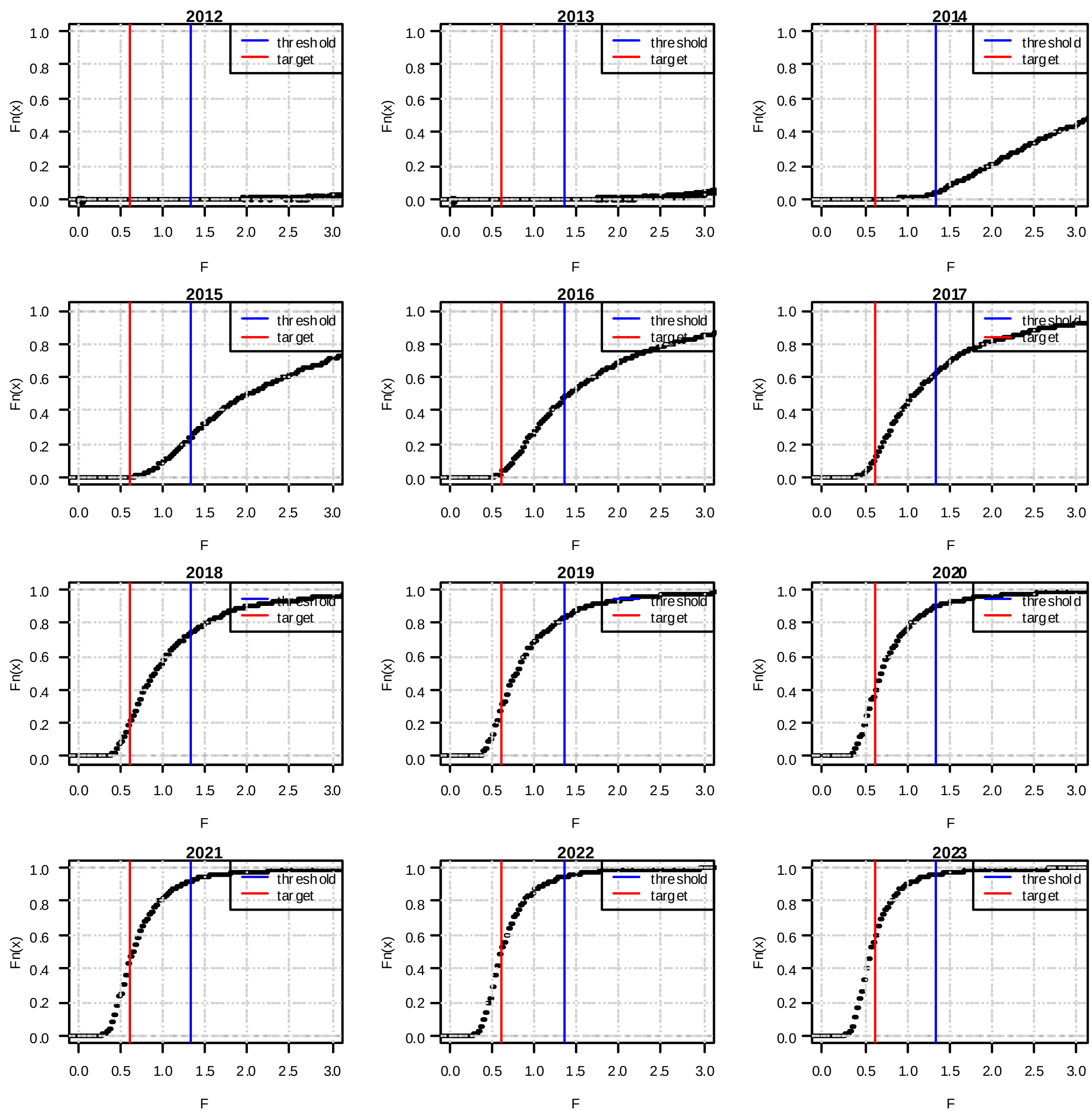


Figure 67. Fecundity, recruits, fishing mortality (F), and landings over time based on constant landings of 175,000 mt with 25% allocated to the bait fishery and 75% allocated to the reduction fishery.

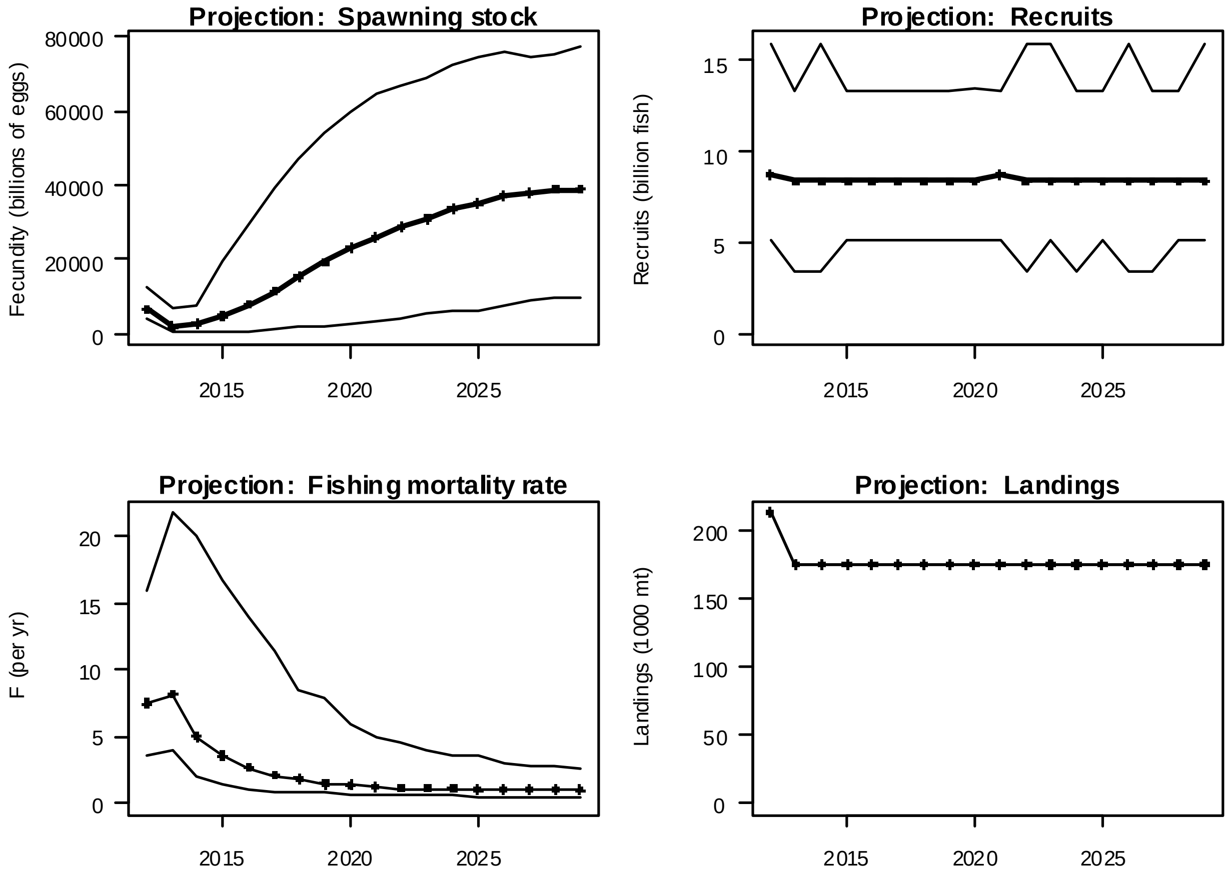


Figure 68. Cumulative distribution of fishing mortality rates for 2012 to 2023 based on constant landings of 175,000 mt with 25% allocated to the bait fishery and 75% allocated to the reduction fishery. The blue line denotes the threshold and the red line denotes the target, and where the lines cross the distribution is the probability that the given landings will be below a specified *F* in that year.

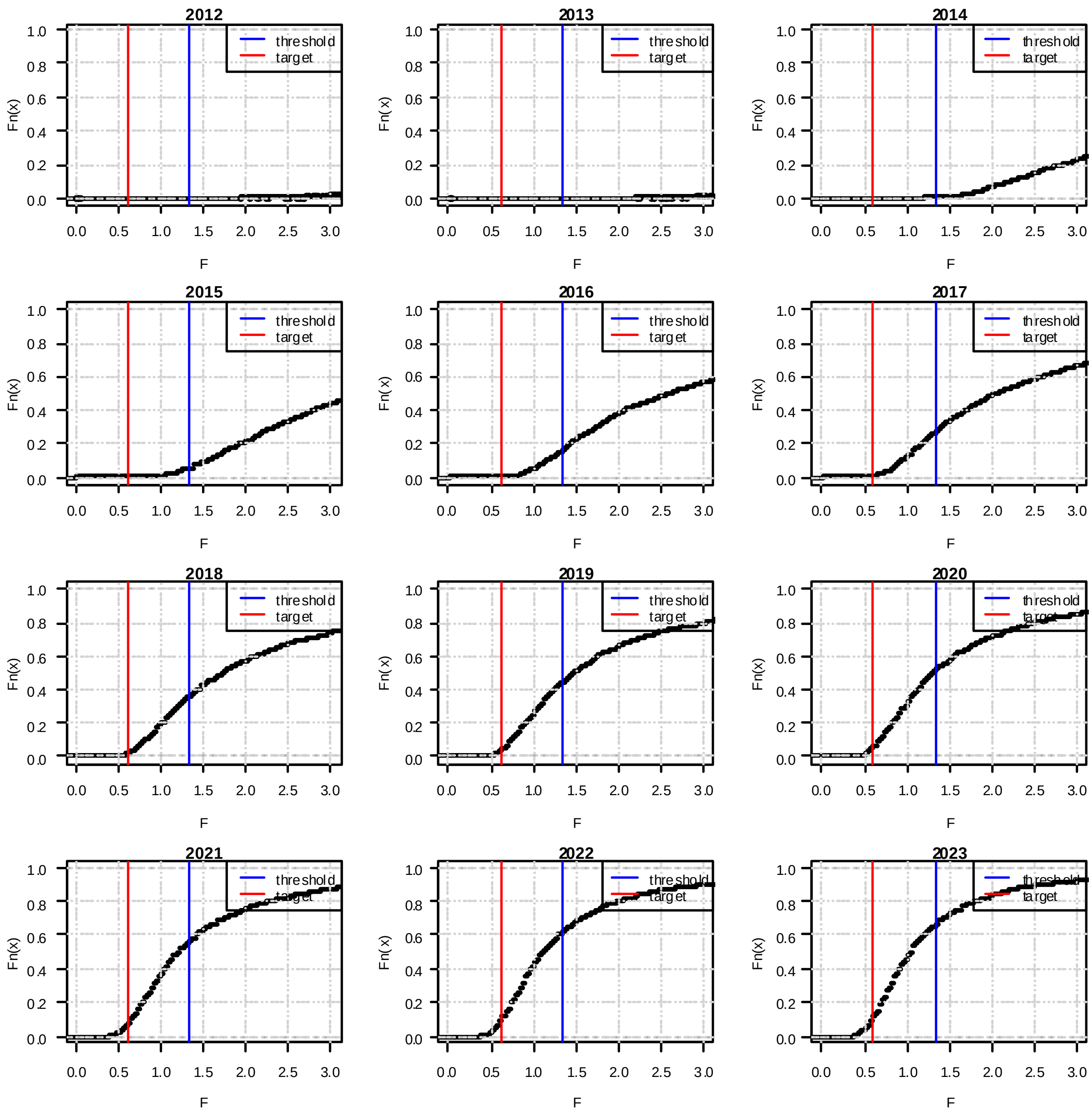


Figure 69. Fecundity, recruits, fishing mortality (F), and landings over time based on constant landings of 200,000 mt with 25% allocated to the bait fishery and 75% allocated to the reduction fishery.

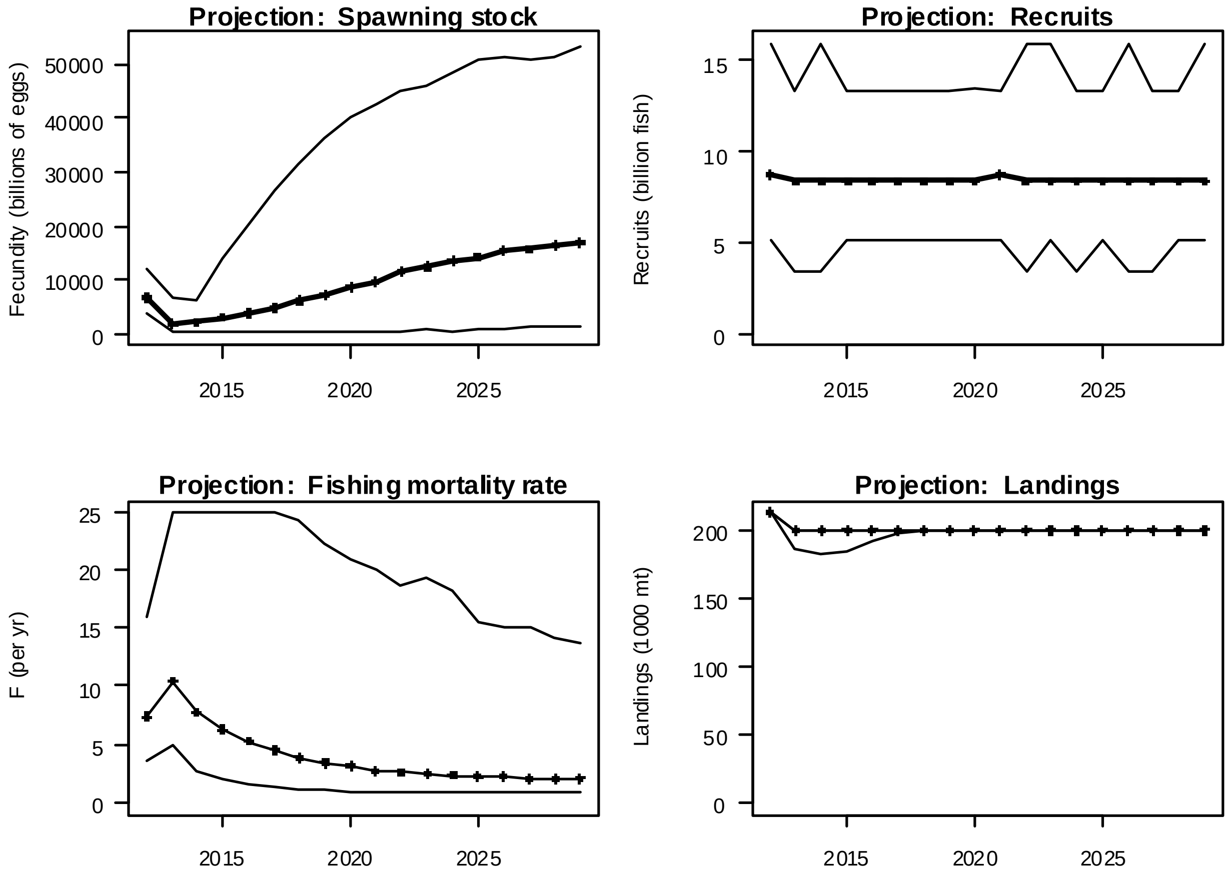


Figure 70. Cumulative distribution of fishing mortality rates for 2012 to 2023 based on constant landings of 200,000 mt with 25% allocated to the bait fishery and 75% allocated to the reduction fishery. The blue line denotes the threshold and the red line denotes the target, and where the lines cross the distribution is the probability that the given landings will be below a specified *F* in that year.

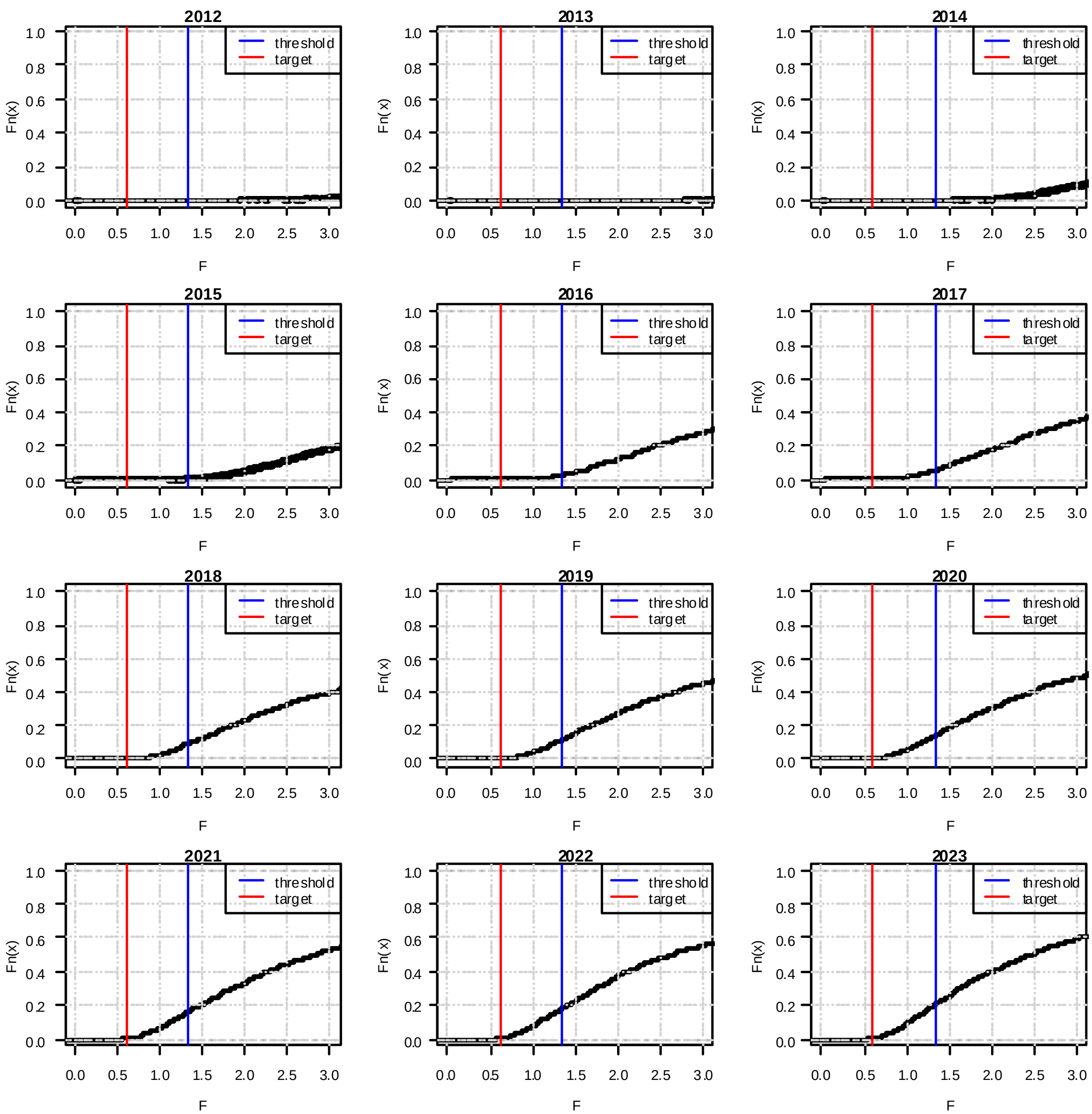


Figure 71. Fecundity, recruits, fishing mortality (F), and landings over time based on constant landings of 225,000 mt with 25% allocated to the bait fishery and 75% allocated to the reduction fishery.

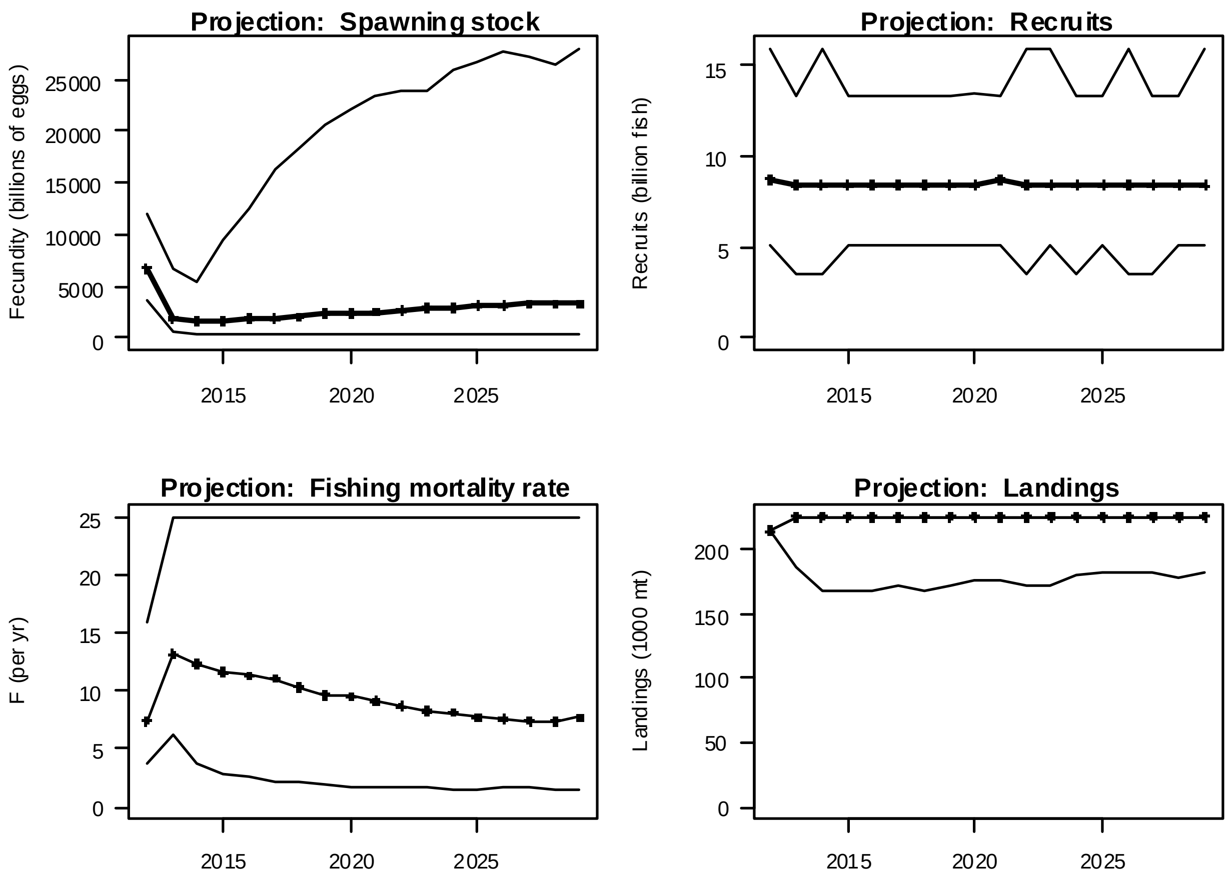
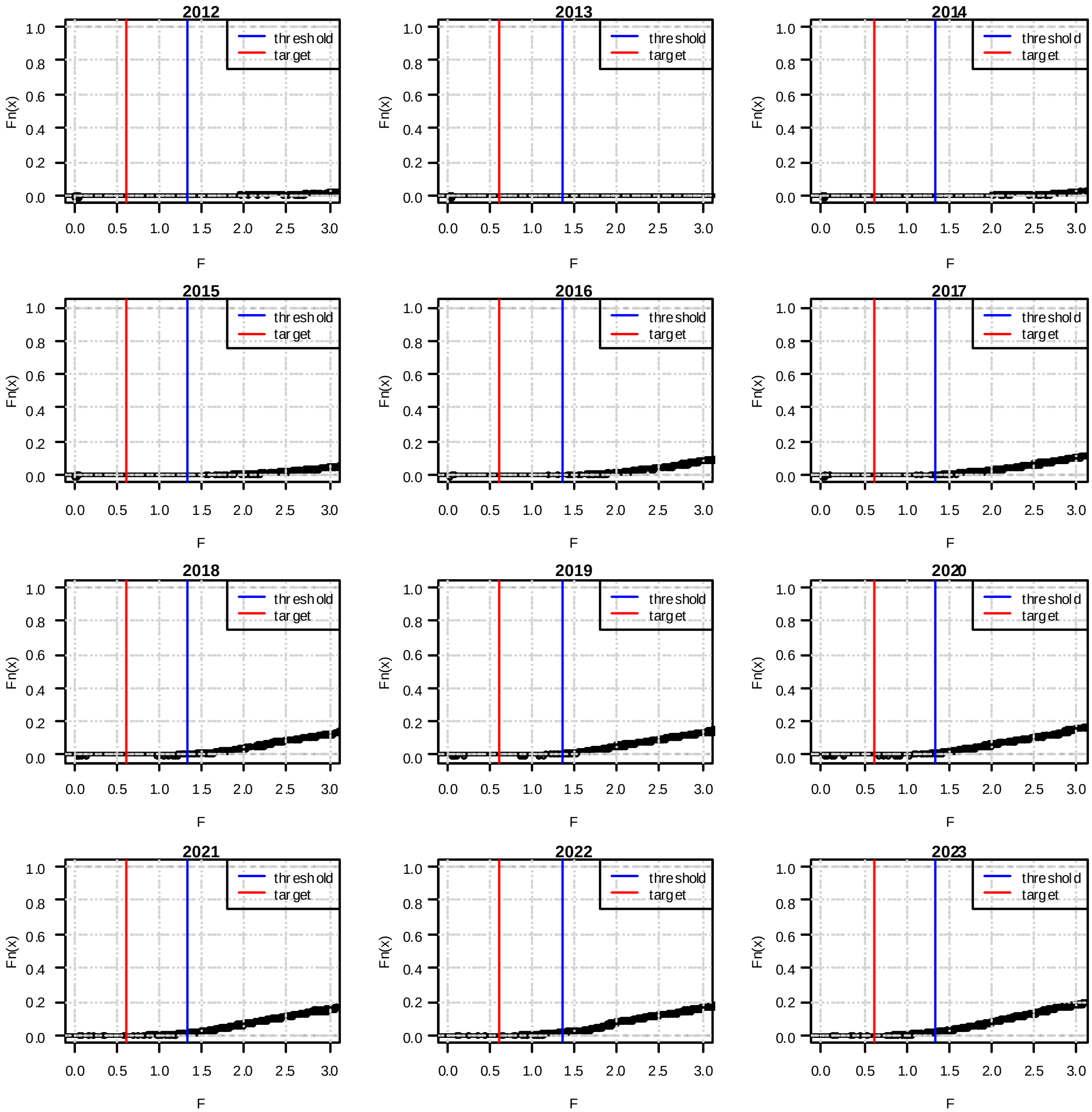


Figure 72. Cumulative distribution of fishing mortality rates for 2012 to 2023 based on constant landings of 225,000 mt with 25% allocated to the bait fishery and 75% allocated to the reduction fishery. The blue line denotes the threshold and the red line denotes the target, and where the lines cross the distribution is the probability that the given landings will be below a specified *F* in that year.



16 Appendix 1 – BAM dat file

```
##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
## Data Input File
## ASMFC Assessment: Atlantic Menhaden
##
##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>

#starting and ending year of model
1955
2011
#Starting year to estimate recruitment deviation from S-R curve
1955
#3 phases of constraints on recruitment deviations: allows possible heavier constraint in early and late period, with lighter constraint in the middle
#ending years of recruitment constraint phases
1956
2009
#4 periods of changing selectivity for reduction fishery: yr1-1963, 1964-1975, 1976-1993, 1994-2011
#ending years of regulation period
1963
1975
1993

#starting and ending years to use for benchmark calculations
1955
2011

#Number of ages (last age is plus group)
9
##vector of agebins, last is a plus group
0 1 2 3 4 5 6 7 8

#max value of F used in spr and msy calculations
3.0
#number of iterations in spr calculations
30001
#number of iterations in msy calculations
30001
#Number years at end of time series over which to average sector Fs, for weighted selectivities
57
#multiplicative bias correction of recruitment (may set to 1.0 for none or negative to compute from recruitment variance)
-1.0
```

```
#number yrs to exclude at end of time series for computing bias correction (end rec devs may
have extra constraint)
0

##time-invariant vector of % maturity-at-age for females (ages 0-8+)
0	0	0.125	0.851	1	1	1	1	1
##time-invariant vector of % maturity-at-age for males (ages 0-8+)
1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
#time-variant vector of proportion female (ages 0-8+)
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5
#time of year (as fraction) for spawning: mid-April=115d/365d
0.0
#age-dependent natural mortality at age
1.140	0.889	0.683	0.574	0.519	0.482	0.455	0.455	0.455

#age-independent natural mortality (used only to compute MSST=(1-M)SSBmsy)
0.45
#age and year specific natural mortality
1.140	0.889	0.683	0.574	0.519	0.482	0.455	0.455	0.455
1.140	0.889	0.683	0.574	0.519	0.482	0.455	0.455	0.455
1.140	0.889	0.683	0.574	0.519	0.482	0.455	0.455	0.455
1.140	0.889	0.683	0.574	0.519	0.482	0.455	0.455	0.455
1.140	0.889	0.683	0.574	0.519	0.482	0.455	0.455	0.455
1.140	0.889	0.683	0.574	0.519	0.482	0.455	0.455	0.455
1.140	0.889	0.683	0.574	0.519	0.482	0.455	0.455	0.455
1.140	0.889	0.683	0.574	0.519	0.482	0.455	0.455	0.455
1.140	0.889	0.683	0.574	0.519	0.482	0.455	0.455	0.455
1.140	0.889	0.683	0.574	0.519	0.482	0.455	0.455	0.455
1.140	0.889	0.683	0.574	0.519	0.482	0.455	0.455	0.455
1.140	0.889	0.683	0.574	0.519	0.482	0.455	0.455	0.455
1.140	0.889	0.683	0.574	0.519	0.482	0.455	0.455	0.455
1.140	0.889	0.683	0.574	0.519	0.482	0.455	0.455	0.455
1.140	0.889	0.683	0.574	0.519	0.482	0.455	0.455	0.455
1.140	0.889	0.683	0.574	0.519	0.482	0.455	0.455	0.455
1.140	0.889	0.683	0.574	0.519	0.482	0.455	0.455	0.455
1.140	0.889	0.683	0.574	0.519	0.482	0.455	0.455	0.455
1.140	0.889	0.683	0.574	0.519	0.482	0.455	0.455	0.455
1.140	0.889	0.683	0.574	0.519	0.482	0.455	0.455	0.455
1.140	0.889	0.683	0.574	0.519	0.482	0.455	0.455	0.455
1.140	0.889	0.683	0.574	0.519	0.482	0.455	0.455	0.455
1.140	0.889	0.683	0.574	0.519	0.482	0.455	0.455	0.455
1.140	0.889	0.683	0.574	0.519	0.482	0.455	0.455	0.455
1.140	0.889	0.683	0.574	0.519	0.482	0.455	0.455	0.455
1.140	0.889	0.683	0.574	0.519	0.482	0.455	0.455	0.455
1.140	0.889	0.683	0.574	0.519	0.482	0.455	0.455	0.455
```

1.650	1.400	1.067	0.814	0.655	0.539	0.451	0.451	0.451
1.543	1.293	0.969	0.746	0.619	0.532	0.462	0.462	0.462
1.347	1.118	0.829	0.650	0.556	0.494	0.452	0.452	0.452
1.301	1.106	0.831	0.651	0.555	0.490	0.448	0.448	0.448
1.334	1.093	0.843	0.667	0.565	0.493	0.447	0.447	0.447
1.228	0.988	0.775	0.625	0.538	0.478	0.435	0.435	0.435
1.189	0.909	0.724	0.596	0.521	0.466	0.432	0.432	0.432
0.982	0.799	0.655	0.568	0.517	0.484	0.440	0.440	0.440
0.968	0.766	0.614	0.539	0.501	0.475	0.460	0.460	0.460
0.985	0.765	0.614	0.540	0.503	0.480	0.455	0.455	0.455
0.877	0.698	0.568	0.508	0.480	0.462	0.450	0.450	0.450
0.978	0.761	0.598	0.523	0.488	0.465	0.448	0.448	0.448
1.015	0.783	0.597	0.519	0.485	0.466	0.448	0.448	0.448
1.108	0.802	0.602	0.524	0.492	0.474	0.460	0.460	0.460
1.088	0.815	0.590	0.507	0.474	0.455	0.444	0.444	0.444
1.040	0.786	0.586	0.498	0.460	0.437	0.426	0.426	0.426
1.102	0.784	0.588	0.502	0.463	0.440	0.421	0.421	0.421
1.127	0.771	0.577	0.502	0.470	0.453	0.434	0.434	0.434
1.005	0.730	0.553	0.491	0.466	0.452	0.442	0.442	0.442
1.069	0.756	0.578	0.512	0.484	0.470	0.455	0.455	0.455
1.168	0.832	0.607	0.523	0.489	0.468	0.459	0.459	0.459
1.059	0.821	0.617	0.522	0.478	0.450	0.436	0.436	0.436
1.129	0.910	0.685	0.567	0.509	0.473	0.442	0.442	0.442
1.168	0.922	0.689	0.572	0.515	0.478	0.453	0.453	0.453
1.144	0.895	0.697	0.595	0.543	0.512	0.472	0.472	0.472
1.108	0.860	0.671	0.583	0.540	0.512	0.495	0.495	0.495
1.132	0.878	0.692	0.603	0.559	0.533	0.501	0.501	0.501
1.138	0.891	0.699	0.609	0.566	0.539	0.523	0.523	0.523
1.074	0.862	0.689	0.596	0.547	0.516	0.493	0.493	0.493
1.027	1.017	0.769	0.619	0.544	0.505	0.484	0.484	0.484

##Spawner-recruit parameters
#switch for S-R function to use Ricker (1) or Beverton-Holt (2)
2
#steepness (fixed or initial guess)
0.99
#standard error of steepness (from meta-analysis)
0.2
#log_R0 - log virgin recruitment
2.7
R autocorrelation
0.0

##--><>--><>--><>-- Weight-at-age in the fishery (g) --><>--><>--><>--><>--><>--><>--><>--><>

36.2	124.3	274.3	390.3	451.5	523.3	610.8	681.9	674.8
25.2	105.1	267.1	428.1	498.1	558.8	601.7	633.0	710.4
41.2	91.3	230.8	413.4	553.1	595.6	645.8	668.9	649.8
22.8	109.9	231.7	382.2	555.5	655.8	686.9	719.8	728.9
60.5	75.2	231.4	373.5	507.5	643.9	697.1	726.6	739.2
32.2	129.6	189.6	375.4	513.3	636.2	738.3	752.7	789.3
48.3	116.0	258.4	336.7	512.9	618.3	727.6	789.9	771.3
60.1	131.0	267.1	394.1	466.5	591.0	644.3	731.1	754.8
63.5	145.6	257.7	424.9	567.3	635.0	727.1	742.6	835.6
67.1	150.4	281.1	380.3	550.2	721.1	767.2	811.7	786.5
53.0	145.8	275.5	386.3	462.2	621.2	835.8	853.3	852.3
66.8	121.9	278.1	387.7	455.6	509.7	648.2	899.7	887.3
62.1	157.6	252.4	434.2	507.2	535.7	581.5	722.8	1063.5
74.7	128.1	316.8	424.3	583.3	596.3	583.3	620.6	751.8
83.3	152.8	268.9	500.0	649.2	759.4	705.9	655.1	689.9
58.7	185.4	269.3	419.1	595.1	790.4	814.4	705.8	631.7
50.6	169.4	341.9	406.3	589.4	654.5	905.8	844.3	695.9
24.7	122.7	328.9	493.1	566.4	800.0	713.2	1048.6	897.8
43.1	121.1	263.3	475.2	636.9	752.9	1039.3	764.4	1175.1
28.7	103.4	263.0	408.7	582.0	764.0	968.3	1344.6	817.8
27.1	84.5	214.8	379.8	560.5	666.2	877.0	1204.4	1682.8
17.3	67.4	192.4	345.3	474.1	732.6	761.3	1023.0	1543.4
20.2	64.4	151.3	317.3	471.6	533.0	878.5	821.9	1126.2
28.4	68.7	163.2	252.6	420.4	556.1	543.8	944.0	817.6
24.8	68.7	168.8	279.1	366.8	516.4	638.4	562.1	1028.2
21.7	56.6	148.1	288.8	391.6	482.0	593.8	702.3	573.1
19.5	68.2	118.8	239.7	396.9	475.8	575.8	637.1	732.7
26.7	76.2	167.7	212.4	341.0	486.7	533.9	643.0	650.7
31.4	70.8	171.6	258.4	303.4	414.5	534.0	553.5	675.8
25.6	71.9	165.8	291.7	368.6	440.4	525.8	623.9	621.0
22.6	68.4	139.3	260.6	374.2	430.8	546.0	579.3	641.6
24.3	64.4	149.8	230.7	375.2	470.7	516.2	715.8	683.0
26.6	75.5	153.6	249.4	338.2	476.8	533.3	566.0	847.6
27.8	69.4	159.9	241.3	329.2	429.6	541.5	556.9	580.4
39.1	91.1	150.3	256.1	341.1	427.5	567.7	657.1	632.2
35.8	113.1	208.5	248.2	340.4	419.4	494.0	670.6	713.7
52.0	92.8	224.1	309.7	334.8	393.4	461.9	521.5	723.5
28.3	123.1	186.4	318.7	392.3	420.5	445.0	512.0	565.8
49.8	93.4	243.6	294.7	396.0	457.6	501.1	488.5	553.9
23.5	118.8	214.3	355.7	395.0	450.3	504.8	572.6	523.3
22.6	112.6	229.7	331.8	423.1	453.4	456.3	501.1	586.3
17.0	96.5	288.8	371.6	483.5	529.8	564.3	517.7	564.7
28.8	87.6	246.6	447.0	491.0	594.2	585.9	625.8	536.0

60.3	93.9	227.2	390.9	547.0	574.4	662.1	608.2	654.1
39.1	131.1	214.0	354.9	496.6	597.8	627.1	699.9	612.1
27.1	131.5	252.7	345.5	456.5	577.9	633.4	674.5	736.3
55.0	125.1	280.6	382.9	462.1	522.0	624.5	643.7	697.6
40.4	149.4	290.1	422.1	526.3	581.0	588.9	683.6	677.6
49.5	121.7	277.0	440.1	557.5	701.6	725.3	678.0	779.9
25.3	113.9	238.6	339.2	482.6	572.9	738.6	722.8	638.4
37.1	88.6	214.5	328.6	369.5	495.8	572.7	760.5	714.6
43.8	112.5	193.7	321.5	411.2	407.1	537.6	619.3	862.4
56.0	127.2	219.6	280.6	390.9	434.4	399.2	514.3	588.0
61.0	132.7	241.3	309.7	359.7	473.5	479.2	419.4	539.6
54.1	112.9	230.0	320.2	360.2	403.4	519.5	489.9	416.0
52.3	137.7	205.6	309.5	378.4	399.4	442.5	568.2	508.2
43.7	114.5	202.0	309.5	358.0	408.0	416.8	461.3	595.2

##--><>--><>--><>-- Weight-at-age for the spawning population - start of year (g) --><>--><>--><>--><>

21.2	66.1	191.5	332.3	387.5	476.8	474.8	618.8	442.8
12.0	55.8	194.2	356.7	448.7	511.9	568.6	631.7	706.1
25.9	41.6	163.5	342.6	499.2	554.5	612.4	645.4	649.8
12.4	61.2	158.6	310.0	494.6	618.3	654.1	697.0	712.8
43.1	36.4	166.3	301.5	443.6	598.2	673.6	702.6	724.9
15.7	79.6	126.2	303.5	449.5	580.6	703.2	737.4	770.8
29.7	55.1	190.0	260.8	445.3	568.6	683.7	765.1	762.0
38.3	77.2	193.1	324.1	397.6	539.8	612.8	702.6	740.3
42.1	85.0	194.3	353.4	490.5	565.4	680.6	717.7	811.8
45.9	90.8	215.1	323.4	494.2	648.1	706.2	774.5	769.1
36.5	88.2	209.0	332.1	418.4	581.6	770.7	802.7	823.6
43.5	73.5	208.7	329.8	417.4	479.5	622.8	847.0	849.1
47.0	91.6	180.8	358.2	455.9	506.7	558.3	704.2	1013.1
57.4	83.5	238.3	338.3	513.2	557.0	563.9	604.7	739.7
55.0	101.8	197.4	422.2	550.8	694.6	674.7	641.4	678.3
31.6	111.0	202.5	331.2	535.5	699.4	764.7	684.9	623.4
32.2	90.9	259.0	329.3	490.3	611.9	826.2	807.4	682.1
8.4	69.4	247.0	414.9	479.4	686.5	681.7	974.8	868.6
27.5	52.9	193.1	410.7	571.3	661.0	917.6	742.2	1110.9
16.5	58.7	192.3	334.8	535.4	709.2	868.1	1206.4	801.3
17.8	44.3	157.5	329.6	490.8	634.8	833.5	1099.7	1532.6
8.5	37.8	135.8	284.2	441.7	667.1	739.5	986.9	1427.3
10.8	29.4	106.1	256.9	415.2	514.2	822.2	807.9	1098.2
19.1	33.5	110.4	199.7	368.2	511.4	534.1	901.3	809.4
17.5	39.8	115.1	221.4	310.3	473.0	602.7	556.9	994.5
11.8	33.9	105.6	228.7	338.0	426.4	559.6	675.0	570.4
9.7	33.6	83.4	190.1	340.4	431.6	524.9	611.6	712.6

16.2	36.9	117.7	165.5	291.2	440.7	501.4	601.3	633.4
22.3	38.3	119.6	208.9	250.4	369.0	498.6	530.2	642.0
15.4	44.1	116.9	236.4	321.4	377.9	481.5	594.3	602.8
13.0	36.8	101.2	208.4	328.1	393.0	482.0	541.5	619.8
13.9	32.7	105.2	182.3	320.4	430.7	483.5	643.0	646.8
16.6	40.1	108.1	201.4	285.3	427.8	503.5	541.5	776.6
13.9	38.5	115.2	195.3	286.2	377.6	501.3	535.9	562.8
21.9	43.5	105.5	208.6	295.3	386.6	510.6	619.2	615.0
22.6	60.9	148.3	198.1	299.2	380.7	460.5	616.7	683.1
33.2	53.4	168.9	259.2	288.7	362.5	433.0	497.0	677.9
15.3	71.5	135.9	272.7	353.0	378.0	420.6	488.9	546.2
32.5	47.0	184.2	242.5	362.5	429.8	464.4	470.3	536.3
8.3	69.0	149.5	301.5	346.5	427.0	485.4	541.1	509.6
9.6	47.5	171.4	269.7	383.3	415.7	442.4	489.4	562.9
6.0	41.5	201.3	308.5	422.2	496.7	530.1	507.8	556.1
15.5	35.1	168.8	374.3	435.2	543.7	562.1	599.0	529.7
41.8	46.8	154.5	319.4	498.0	530.2	624.2	592.1	634.2
19.1	80.5	149.5	290.7	441.9	567.7	593.9	672.4	601.5
9.6	65.1	188.6	279.0	407.9	538.4	615.2	649.6	716.2
31.8	54.9	207.1	317.3	404.3	489.2	598.2	633.3	679.8
21.8	87.0	213.1	361.6	463.1	532.3	566.7	665.6	671.3
32.3	62.6	218.1	379.1	509.8	637.8	681.5	661.5	766.2
12.3	67.9	177.8	303.4	449.1	545.2	690.7	693.3	629.1
19.1	44.1	162.9	283.0	349.9	478.4	557.0	725.2	694.9
23.5	58.3	139.8	270.4	377.3	395.4	527.5	609.0	831.7
35.0	70.8	168.1	237.5	351.3	414.2	393.3	509.4	582.5
46.4	79.6	187.1	270.4	326.3	440.3	465.7	416.0	536.9
27.3	75.4	181.9	282.3	335.1	380.6	494.2	481.6	414.3
26.0	83.3	156.8	273.9	354.0	383.9	427.0	548.9	503.0
25.2	62.6	175.4	254.8	334.9	393.5	407.6	451.2	581.0

##--><>--><>--><>-- Fecundity-at-age - not adjusted for maturity (g) --><>--><>--><>--><>

13463	27660	71747	135469	165103	219032	217740	321215	197636
10233	24296	72102	146296	198365	238715	278272	326059	387985
15428	20472	60931	137238	224019	259559	299712	323917	327225
10666	26237	57710	117364	211476	289036	313736	344903	356689
20917	18821	61418	116011	187290	282759	336617	358600	376132
12263	32755	47772	115336	185702	261358	343690	368737	394034

17011	25036	70012	97435	183960	254960	331452	391833	389392
18151	29948	70150	128512	168105	259983	315659	392635	427908
19711	32553	68999	135948	208853	255173	335926	364507	443039
20457	33674	75370	119892	207922	307939	351183	406166	401612
18237	34048	75932	128808	172836	273148	420039	448402	467517
20068	29310	77431	132904	181346	220185	325457	538380	540608
21964	35909	66557	143144	195394	225602	258464	364216	656569
24285	32187	86618	130604	226649	254766	259346	287397	391507
22385	35628	65678	158388	227292	319609	305825	283479	308310
16182	40033	71523	125826	239545	358396	413289	346808	300046
16345	34342	98269	132074	227586	318080	521103	500891	378173
8763	28730	96288	185087	226597	390623	386319	708822	578342
14754	22426	70424	178248	289225	364405	639178	441371	912764
11782	25141	71533	135920	257501	396200	553580	1001315	483573
12253	20637	57577	130162	220146	320777	494628	799846	1507572
9077	18868	49093	103812	177278	313545	365766	578387	1105788
10058	16325	39217	90510	157887	207920	406384	395594	645832
12879	17450	40638	70425	139391	212757	225751	491521	414559
12366	19345	41904	77701	112508	189067	263044	235543	565097
10294	17459	38722	79681	123164	163676	234456	305897	240762
9663	17774	32855	67809	127673	170870	220932	272912	340566
11321	17653	41867	57673	106595	180427	215633	280868	303798
13532	18542	44385	77593	95158	153582	232534	254408	340344
10981	19719	41641	84316	121001	148589	206248	280104	286135
10385	18098	38260	77328	131778	166631	220916	261679	321083
11194	17507	40211	66869	124164	179809	209812	314420	317127
11694	19044	39900	72507	107028	178377	223223	247684	430450
10781	18729	43140	72525	112059	159064	235350	259482	279125
14167	21067	40486	76556	111879	154549	222090	290944	288137
14328	26370	54852	72906	114475	153221	195960	294199	342191

17301	23607	63019	100508	114209	151802	192481	233508	372828
11794	30181	52052	107864	147453	160861	185035	227120	265781
17271	21825	68848	92673	150265	187929	208910	212599	256089
9100	29252	56433	119239	141157	184363	219109	255020	234350
9443	22337	66500	110187	171898	191874	209152	241463	296939
8052	20339	74449	119511	176526	219312	240032	226078	256774
11702	18123	61582	149569	181602	246020	257940	282628	237196
20099	21649	56881	125462	224089	244805	310820	287369	318397
12914	32600	56379	115806	198170	283248	302967	366460	308808
9448	27803	71927	111449	180157	265805	324435	352755	411527
16749	24031	79355	131544	181048	237106	320982	350990	393221
12987	32813	77921	148231	208483	255753	281249	362328	367363
16723	25692	76840	145560	215084	296236	327068	312738	391655
10172	27874	65996	121075	202863	268489	387280	389664	334063
12172	20064	61521	116790	154373	241983	306415	475127	441406
13970	24940	52516	107766	164962	175774	265745	331510	555314
17011	28337	64217	95875	160275	203292	188400	279302	347428
20748	31291	71159	109691	139713	212289	230685	195515	286783
15094	30613	70713	118748	148526	176822	259034	249020	199427
2563	33330	60171	113248	157875	176326	204895	298233	260813
2563	2563	68863	105264	148654	184971	194311	224680	329526

##--><>--><>--><>-- Juvenile Abundance Index from seine surveys --><>--><>--><>--><>--><>

##Switch to use single index (=1) or let model combine indices (not equal to 1)

1
##Starting and ending years of time series, respectively
1959
2011
##Observed CPUE (numbers) and CV vectors, respectively
5.491734867 1.534904649 1.076431123 58.49198267 7.981097225 0.35919016
3.247040557 3.961176354 2.935460962 11.99799361 12.59130939 3.527680041
45.66921052 20.408 31.768 61.500 90.67782902 115.4876118 193.2720334
68.54676898 53.83551253 90.01464586 133.6273607 60.73340475 37.55812116
59.35820177 52.88549569 52.74099064 16.23705165 36.27840019 26.12079688
36.6717888 35.33512979 32.96361429 11.81244874 20.45342909 16.78943714
21.99224431 18.40753229 26.40169637 54.66091353 17.9452847 17.27377949
27.99333855 31.4852824 19.51574823 42.83586482 7.670375404 26.03329246
12.78954984 14.57326323 15.08972551 13.39590218
0.825771029 0.65102718 0.693498008 0.700055169 0.870469319 0.659286488
0.524139237 0.727360555 1.378414886 0.506140876 0.408322838 0.630359596
0.440986753 0.239 0.212 0.152 0.181651923 0.19898857 0.145517735
0.215161259 0.316513403 0.200730196 0.21002599 0.196650846 0.224923611
0.206726223 0.222313732 0.197158985 0.189717662 0.19791558 0.182516329
0.17930702 0.157287034 0.172143806 0.195243429 0.190494429 0.178044763
0.160901394 0.192580693 0.183430456 0.189749333 0.17337474 0.174111664
0.207722682 0.19491029 0.176160697 0.148973832 0.138549198 0.162734644
0.150567815 0.154886058 0.168381506 0.16091767

##--><>--><>--><>-- Juvenile Abundance Indices (4 groups) from seine surveys --><>--><>--
><>--><>--><>
##Series 1 Observed CPUE (numbers) and CV vectors, respectively
##must have zeros in place of missing values and all series must be the same length as single index above
##this is the first pca which includes NC, VA, MD, and NJ
11.22236324 3.810815272 2.454395881 145.4116619 19.21190751 0.912880198
7.664551774 9.709131271 4.816096224 9.54805575 10.71565941 3.670002203
46.52267774 8.385763603 8.675398659 13.60809331 21.68499099 36.03533635
47.9972427 20.79606107 33.69199196 35.77239409 61.4170975 22.18331719
14.95832472 33.94508329 30.450203 29.14765001 13.96951388 31.89998324
19.30337276 29.16463299 22.80238979 14.14661101 6.509984223 15.17569029
14.6478255 10.19497052 12.87027351 8.41088298 22.94038778 5.249502305
6.175214786 5.740289035 9.774880827 4.209639331 25.32354302 5.24906146
5.965354555 5.903325195 5.790499148 11.64416909 7.347340044
0.827327143 0.624641534 0.689540863 0.68186415 0.857998483 0.644916586
0.507367753 0.725246191 1.324318264 0.49092314 0.403332086 0.584119269
0.437848642 0.247553927 0.218169417 0.150318895 0.183799148 0.208396777
0.140888537 0.209386317 0.331029776 0.203209149 0.218999882 0.208750268
0.237426726 0.222041593 0.235828175 0.208853941 0.193845915 0.230292034
0.207729318 0.208286098 0.166036424 0.174472623 0.211501457 0.219711709

0.200614413 0.1783482 0.222785647 0.20710356 0.205126879 0.177415462
0.221658495 0.206586884 0.200632268 0.172754398 0.160026835 0.164505125
0.161476058 0.148338709 0.151362405 0.176032138 0.16434461
##Series 2 Observed CPUE (numbers) and CV vectors, respectively
##this is the second pca which includes NY, RI, and CT
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
12.83630273 0 50.74708419 2.817741794 21.37008409 30.32209573
38.44188855 68.16488424 205.1397687 21.77823001 31.73125384 9.207271953
71.13961393 52.90854248 194.8673195 249.3451522 120.4190692 99.1709621
416.0385222 273.5613528 182.0206876 52.72150685 11.85976458 273.9825802
6.25279857 35.40534735 3.243542377 4.977913035
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
0.717595862 0 0.864701992 0.475363734 0.505377615 0.504660343
0.479697559 0.499317118 0.485946106 0.534964142 0.497585705 0.444626636
0.437916177 0.502891836 0.451746654 0.488411478 0.439086388 0.414100414
0.460747837 0.467153269 0.461933647 0.454053612 0.397312665 0.434577534
0.631797479 0.571418097 0.467509485 0.481292493
##Series 3 Observed CPUE (numbers) and CV vectors, respectively
##Not updated...
0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 62.6893134 259.2783574
51.8810532 12.2443508 30.9959456 14.1435884 2.3832303 1.5905358
5.8567029 8.145969 13.1786803 7.4515134 6.3196687 1.2897558
10.3979867 13.436357 3.5883454 8.64925 3.8668316 26.4074946
2.6622985 1.089944 2.0327237 1.9672035 0.3815253 12.2755695
1.6988698 1.4698375 1.1856853 5 5 5
0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0.6100114 0.7673876
0.4563601 0.5643986 0.3666978 0.3004134 0.5151165 0.3213347
0.3180115 0.2841494 0.2579026 0.2837902 0.2688518 0.4544062
0.3454617 0.2981172 0.3135442 0.321363 0.2960134 0.3096394
0.2708529 0.3130682 0.3179908 0.3103309 0.3233245 0.258085
0.2679273 0.2771044 0.2998046 0.3 0.3 0.3
##Series 4 Observed CPUE (numbers) and CV vectors, respectively
##Not updated...
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 0 5.798786 36.682552 114.432077 88.413428
457.305185 720.60668 125.110058 76.98277 31.049442 270.940064
252.012355 1990.351097 180.398169 586.980987 234.406695 881.609674
1533.95439 557.335098 27.657342 7.583182 452.320643 23.885976
25 25 25

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 0 0.484021 0.4013174 0.4930011 0.5355576
0.5371519 0.5340335 0.4895519 0.575322 0.5688208 0.5077108
0.5219801 0.4456174 0.5576982 0.6027831 0.4460296 0.6735579
0.578154 0.56118 0.5660324 0.5055432 0.5770563 0.747471
0.5 0.5 0.5

##--><>--><>--><>-- PRFC pound net index --><>--><>--><>--><>--><>--><>--><>--><>--
><>
##Starting and ending years of time series, respectively
1964
2011
##Observed CPUE (numbers) and CV vectors, respectively
1200.034827 1253.47176 968.6025307 526.5643746 491.3551115 350.0381583
844.3270832 738.4494723 1318.00342 2388.332307 2213.956559 2156.071384
2320.080977 3493.875143 3384.639318 2470.892705 3164.768854 3703.970913
3379.37838 3837.60589 2392.945932 2854.073898 1967.828042 2765.947626
2465.256195 1692.525183 986.646892 1148.029682 1315.305353 1710.162139
1524.597216 1538.066769 1467.940839 1448.316981 1144.909144 1626.076021
1845.551788 1277.655637 1120.800936 1055.591783 2205.259804 1872.553586
1643.624096 2534.952645 2646.751512 2008.635962 2283.734811 2498.894641
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5
#0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2
0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2
0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2
0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2

##--><>--><>--><>-- Commercial Reduction fishery --><>--><>--><>--><>--><>--><>--><>
#Starting and ending years of landings time series, respectively
1955
2011
##Observed landings (1000 mt) and assumed CVs
641.4 712.1 602.8 510 659.1 529.8 575.9 537.7 346.9 269.2 273.4 219.6
193.5 234.8 161.6 259.4 250.3 365.9 346.9 292.2 250.2 340.5 341.1 344.1
375.7 401.5 381.3 382.4 418.6 326.3 306.7 238 327 309.3 322 401.2
381.4 297.6 320.6 260 339.9 292.9 259.1 245.9 171.2 167.2 233.7 174
166.1 183.4 146.9 157.4 174.5 141.1 143.8 183.1 174
0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03
0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03
0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03

0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03
0.03 0.03 0.03 0.03
##Number and vector of years of age compositions for hook and line fishery
57
1955 1956 1957 1958 1959 1960 1961 1962 1963 1964 1965 1966 1967
1968 1969 1970 1971 1972 1973 1974 1975 1976 1977 1978 1979
1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991
1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003
2004 2005 2006 2007 2008 2009 2010 2011
##sample sizes of age comps by year (first row observed N, second row effective N: effective may be set to observed)
15009 17963 18389 14303 17938 12783 12898 15458 12716 10286 18955 15486 14653
25888 14858 8239 8118 6198 6348 5361 7262 6401 7266 7025 6231
7046 8870 8552 11279 11594 8507 5826 7548 7349 6374 6790 7614
5440 5348 4862 4504 4275 3982 3688 3468 3068 4102 3654 3108
3759 3102 3300 3759 3204 2461 2710 2721
305 497 502 434 508 465 425 513 531 513 907 776 754
1340 902 425 417 656 638 561 740 676 728 712 637
731 922 908 540 1178 851 583 762 654 714 685 770
562 533 472 462 423 411 385 361 296 394 337 350
419 354 358 380 278 283 327 323
#age composition samples (year,age)
0.244021051 0.216174805 0.339151289 0.085737126 0.098527746 0.01219106
0.003397508 0.00059956 0.000199853
0.010187608 0.581584368 0.253242777 0.089628681 0.012581417 0.042253521
0.008072148 0.00189278 0.0005567
0.085322747 0.455598456 0.387786177 0.02757083 0.020175105 0.011528631
0.010495405 0.001196367 0.000326282
0.039012795 0.315598126 0.601412291 0.026497937 0.006362302 0.005872894
0.003355939 0.0018178 0.000139831
0.002118526 0.754418242 0.159000948 0.072531639 0.006244076 0.002230027
0.002285778 0.00083626 0.000334504
0.025971994 0.101228194 0.795900806 0.027536572 0.036845811 0.00852695
0.002894469 0.000860518 0.000234687
7.75374E-05 0.320384586 0.19384353 0.46553462 0.007366054 0.011320462
0.001085524 0.00031015 7.75374E-05
0.02458274 0.244857032 0.397399405 0.103441584 0.201643162 0.014620261
0.011709147 0.001423211 0.000323457
0.054895792 0.410460087 0.401966182 0.069445537 0.025481715 0.02965002
0.005898545 0.001887534 0.000314589
0.174995139 0.407155357 0.349893059 0.048318102 0.010402489 0.004569318
0.003791561 0.000777756 0.000194439
0.170509101 0.49042469 0.277341071 0.051173833 0.008018992 0.0012134
0.000791348 0.000474809 5.27565E-05

0.260687072	0.410887253	0.301433553	0.02363425	0.00290585	0.000258298	6.45745E-05	6.45745E-05	0
0.007029757	0.643393393	0.26992902	0.073983074	0.005187005	0.00047775	0	0	0
0.134386588	0.328723733	0.469483931	0.057207973	0.009309333	0.000849815	3.86279E-05	0	0
0.182124108	0.428859873	0.327500337	0.055054516	0.006259254	0.000201911	0	0	0
0.015293118	0.620706396	0.337783712	0.023303799	0.002912975	0.000121374	0	0	0
0.075141661	0.271741808	0.541019956	0.091155457	0.018354274	0.002586844	0	0	0
0.029202969	0.572442723	0.284930623	0.101000323	0.011132623	0.001129397	0	0	0
0.030403277	0.31931317	0.625393825	0.020951481	0.003780718	0.00015753	0	0	0
0.158552509	0.319903003	0.495243425	0.02443574	0.001305727	0.000746129	0	0	0
0.138116221	0.332966125	0.502478656	0.023271826	0.003029468	0.000137703	0	0	0
0.083580691	0.490860803	0.408373692	0.014685205	0.002343384	0.000156226	0	0	0
0.131865107	0.273503097	0.566689608	0.022711631	0.004817619	0.000412939	0	0	0
0.148327402	0.215231317	0.541637011	0.083701068	0.010106762	0.00113879	0	0	0
0.385714286	0.160995185	0.414285714	0.033065811	0.005617978	0.000321027	0	0	0
0.026539881	0.443514051	0.437553222	0.066846438	0.020720976	0.004257735	0.000425773	0	0
0.298049825	0.175402999	0.454627438	0.055799797	0.011949047	0.003832713	0.000338181	0	0
0.035898036	0.289522919	0.547708138	0.11950421	0.005144995	0.001870907	0.000116932	0.000116932	0
0.244613884	0.131217306	0.581700505	0.028991932	0.012057807	0.001241245	8.86603E-05	0	8.86603E-05
0.364757633	0.288683802	0.25142315	0.076505089	0.014145248	0.004312575	0.000172503	0	0
0.210625294	0.35554772	0.404795487	0.014574518	0.011753644	0.002115656	0.000587682	0	0
0.051493306	0.117233093	0.796429797	0.025575009	0.005492619	0.003261243	0.000514933	0	0
0.018550417	0.217967404	0.685835431	0.065588976	0.010865244	0.000927521	0.000265006	0	0

0.157028167	0.131038236	0.53639951	0.139610831	0.032385359	0.00326575	0.000136073	0.000136073	0
0.056941176	0.438901961	0.440313725	0.041254902	0.018039216	0.004392157	0.000156863	0	0
0.142709867	0.061561119	0.719734904	0.050515464	0.019587629	0.005743741	0.000147275	0	0
0.278434463	0.326503809	0.2987917	0.080246914	0.011951668	0.003414762	0.000656685	0	0
0.194669118	0.354227941	0.3875	0.032169118	0.025	0.005330882	0.000735294	0.000183824	0
0.04262479	0.237801458	0.616563844	0.093475416	0.006917181	0.002430361	0.000186951	0	0
0.059440559	0.184080625	0.595639654	0.110654052	0.045043192	0.005141917	0.000205677	0	0
0.034635879	0.32482238	0.40874778	0.188055062	0.0410746	0.002664298	0	0	0
0.030877193	0.191578947	0.621988304	0.127251462	0.026432749	0.001871345	0	0	0
0.025364139	0.247865394	0.426418885	0.238322451	0.051732798	0.009040683	0.00125565	0	0
0.072396963	0.18356833	0.536605206	0.12527115	0.072396963	0.008947939	0.000813449	0	0
0.183626405	0.28509657	0.426635918	0.077543961	0.023637936	0.003170943	0.000288268	0	0
0.118318123	0.173728814	0.518252934	0.170143416	0.016949153	0.002933507	0	0	0
0.034365099	0.065074336	0.552035096	0.325127955	0.022422618	0.000974896	0	0	0
0.22194855	0.263546798	0.323481117	0.169129721	0.02134647	0.000547345	0	0	0
0.086872587	0.182754183	0.640604891	0.076898327	0.011261261	0.001287001	0.00032175	0	0
0.018355946	0.21867518	0.666666667	0.077414206	0.017823889	0.000798085	0	0	0
0.018703644	0.121573686	0.590454692	0.237665269	0.028700419	0.00290229	0	0	0
0.012121212	0.396363636	0.398181818	0.161212121	0.031212121	0.000606061	0	0	0
0.001330141	0.256451184	0.653099229	0.074487896	0.013833466	0.000798085	0	0	0
0.013732834	0.09082397	0.683832709	0.184769039	0.025280899	0.001872659	0	0	0
0.005941539	0.477313524	0.310089318	0.177185978	0.026978785	0.002490856	0.000000000	0.000000000	0.000000000

```
0.015130872  0.400268268  0.489815526  0.066563349  0.027669655  0.000552330
        0.000000000  0.000000000  0.000000000
0.000000000  0.423873050  0.499423133  0.065985197  0.008974268  0.001744352
        0.000000000  0.000000000  0.000000000

##--><>--><>--><>-- Commercial Bait fishery --><>--><>--><>--><>--><>--><>--><>
#Starting and ending years of landings time series, respectively
1955
2011
##Observed landings (1000 mt) and assumed CVs (includes MRFSS landings)
14.638849  23.252443  24.706525  14.688427  20.584228  19.443850
        25.067948  26.579637  24.390235  20.233646  23.619581  13.722410
        11.610436  9.460088  10.607452  21.642142  13.471437  10.348269
        14.768668  14.539331  21.691221  19.628598  23.091326  25.865743
        13.019076  26.114873  22.553758  19.988213  19.187072  14.480761
        26.819892  28.327247  30.875023  36.559491  31.167033  30.969148
        36.610655  39.566498  42.989747  39.252885  42.626679  35.402869
        36.625869  39.444272  36.424157  35.371754  36.436071  37.242311
        34.056661  36.135930  38.977165  26.900390  43.205670  47.823131
        39.285798  45.478444  54.984197
0.15  0.15  0.15  0.15  0.15  0.15  0.15  0.15  0.15  0.15  0.15  0.15  0.15
      0.15  0.15  0.15  0.15  0.15  0.15  0.15  0.15  0.15  0.15  0.15  0.15
      0.15  0.15  0.15  0.15  0.15  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  0.05
#0.20 0.20  0.20  0.20  0.20  0.20  0.20  0.20  0.20  0.20  0.20  0.20  0.20
      0.20  0.20  0.20  0.20  0.20  0.20  0.20  0.20  0.20  0.20  0.20  0.20
      0.20  0.20  0.20  0.20  0.20  0.10  0.10  0.10  0.10  0.10  0.10  0.10
      0.10  0.10  0.10  0.10  0.10  0.10  0.10  0.10  0.10  0.10  0.10  0.10
      0.10  0.10  0.10  0.10  0.10  0.10  0.10  0.10
##Number and vector of years of age compositions for bait fishery
27
1985  1986  1987  1988  1989  1990  1991  1992  1993  1994  1995  1996  1997
      1998  1999  2000  2001  2002  2003  2004  2005  2006  2007  2008  2009
2010  2011
##sample sizes of age comps by year  (first row observed N, second row effective N: effective may be set to observed)
770  380  220  10  30  10  78  70  169  539  362  357  313
     626  538  543  962  702  427  354  322  454  973  842  1005
899  955
77   38   22   1   3   1   8   7   17   54   37   36   32
     63   54   55   97   71   43   36   33   46   98   85   101  90
96
#age composition samples (year,age)
0.003  0.085  0.651  0.187  0.062  0.010  0.002  0.000  0.000
```

0.002	0.054	0.430	0.365	0.135	0.013	0.002	0.000	0.000
0.002	0.048	0.481	0.332	0.124	0.012	0.001	0.000	0.000
0.002	0.051	0.411	0.377	0.144	0.014	0.002	0.000	0.000
0.002	0.069	0.531	0.291	0.096	0.010	0.001	0.000	0.000
0.004	0.198	0.396	0.286	0.104	0.010	0.001	0.000	0.000
0.001	0.121	0.405	0.333	0.125	0.013	0.002	0.000	0.000
0.003	0.151	0.356	0.346	0.129	0.014	0.002	0.000	0.000
0.005	0.173	0.317	0.359	0.129	0.014	0.002	0.000	0.000
0.002	0.096	0.463	0.282	0.136	0.019	0.001	0.000	0.000
0.000	0.255	0.275	0.310	0.160	0.000	0.000	0.000	0.000
0.000	0.029	0.615	0.285	0.068	0.002	0.000	0.000	0.000
0.000	0.049	0.380	0.308	0.198	0.054	0.011	0.000	0.000
0.029	0.046	0.408	0.286	0.193	0.031	0.006	0.000	0.000
0.001	0.041	0.589	0.242	0.111	0.014	0.002	0.000	0.000
0.006	0.163	0.570	0.179	0.071	0.009	0.002	0.000	0.000
0.002	0.046	0.538	0.363	0.044	0.006	0.001	0.000	0.000
0.000	0.029	0.197	0.522	0.220	0.031	0.001	0.000	0.000
0.005	0.084	0.645	0.221	0.044	0.002	0.000	0.000	0.000
0.000	0.058	0.649	0.227	0.058	0.007	0.001	0.000	0.000
0.000	0.014	0.472	0.448	0.058	0.007	0.001	0.000	0.000
0.000	0.196	0.427	0.314	0.060	0.002	0.000	0.000	0.000
0.000	0.187	0.594	0.175	0.041	0.002	0.001	0.000	0.000
0.000	0.021	0.582	0.322	0.067	0.008	0.000	0.000	0.000
0.002	0.162	0.327	0.411	0.091	0.007	0.000	0.000	0.000
0.000	0.200	0.465	0.212	0.111	0.011	0.001	0.000	0.000
0.000	0.204	0.337	0.275	0.163	0.021	0.000	0.000	0.000

```
#####################Parameter values and initial
guesses###################################################################################
########
###Selectivity parameters.
###Initial guess must be within boundaries.
# Initial guesses initialized near solutions from preliminary model runs
# age at size limits (12, 20 inches)= 1.42, 3.62
# zero in slope2 provides logistic selectivity

1.4 #selpar_L50_cR
3.3 #selpar_slope_cR
6.0 #selpar_L502_cR
0.0  #selpar_slope2_cR

2.2 #selpar_L50_cB
3.9 #selpar_slope_cB
6.5 #selpar_L502_cB
```

0.0 #selpar_slope2_cB

1.14 #selpar_L50_cPN
7.62 #selpar_slope_cPN
1.72 #selpar_L502_cPN
7.77 #selpar_slope2_cPN

##################Likelihood Component Weighting###
##Weights in objective fcn
1.0 #landings
1.0 #age comps
1.0 #JAI index
1.0 #PN index
1.0 #S-R residuals
0.0 #constraint on early recruitment deviations
1.0 #constraint on ending recruitment deviations
0.0 #penalty if F exceeds 3.0 (reduced by factor of 10 each phase, not applied in final phase of optimization)
0.0 #weight on tuning F (penalty not applied in final phase of optimization)
1.0 #weight for penalty to keep JAI combination weights summing to 1.0

###
##log catchabilities (initial guesses)
-1.8 #JAI survey
6.4 #PN survey

#exponent for JAI cpue index
1.0

#JAI combination weights
0.25
0.25
0.25
0.25

#rate increase switch: Integer value (choose estimation phase, negative value turns it off)
-1
##annual positive rate of increase on all fishery dependent q due to technology creep
0.0
DD q switch: Integer value (choose estimation phase, negative value turns it off)
-1

##density dependent catchability exponent, value of zero is density independent, est range is (0.1,0.9)
0.0
##SE of density dependent catchability exponent (0.128 provides 95% CI in range 0.5)
0.128
#Age to begin counting D-D q (should be age near full exploitation)
2
#Random walk switch:Integer value (choose estimation phase, negative value turns it off)
-3
#Variance (sd^2) of fishery dependent random walk catchabilities (0.03 is near the sd=0.17 of Wilberg and Bence
0.03

##log mean F (initial guesses)
0.2 #commercial reduction
-1.2 #commercial bait
#Initialization F as a proportion of first few assessment years (set to 1.0 without evidence otherwise)
1.0

#Tuning F (not applied in last phase of optimization)
1.5
#Year for tuning F
2011

#threshold sample sizes (greater than or equal to) for age comps
1.0 #cR
1.0 #cB

#switch to turn priors on off (-1 = off, 1 = on)
-1

##
######################################
#Ageing error matrix (columns are true age 1-20, rows are ages as read for age comps)

#1	0	0	0	0	0	0	0	0
#0	1	0	0	0	0	0	0	0
#0	0	1	0	0	0	0	0	0
#0	0	0	1	0	0	0	0	0
#0	0	0	0	1	0	0	0	0
#0	0	0	0	0	1	0	0	0
#0	0	0	0	0	0	1	0	0
#0	0	0	0	0	0	0	1	0
#0	0	0	0	0	0	0	0	1

0.989574885 0.010425115 3.41132E-08 8.71309E-12 4.9779E-12 3.69962E-10
1.06845E-07 1.57149E-05 0.000623385
0.010425115 0.979149769 0.036041469 2.7224E-05 5.8031E-07 8.37634E-07
1.08755E-05 0.000198104 0.001951093
2.07379E-12 0.010425115 0.927916994 0.089249633 0.001764541 0.000311433
0.000471017 0.001762145 0.006387882
0 2.07379E-12 0.036041469 0.821446286 0.163648594 0.019751402 0.008711424
0.010519756 0.017424063
0 0 3.41132E-08 0.089249633 0.669172569 0.226878066 0.069393527
0.042182061 0.039598326
0 0 0 2.7224E-05 0.163648594 0.506116523 0.24003818 0.113684332
0.074981978
0 0 0 8.71314E-12 0.001764541 0.226878066 0.362749737 0.206038939
0.118305185
0 0 0 0 5.8031E-07 0.019751402 0.24003818 0.251197896
0.155534864
0 0 0 0 4.97791E-12 0.000312271 0.078586951 0.374401052
0.585193224

##
##999 #end of data file flag

17 Appendix 2 – BAM code

```
//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
//##
//##  ASMFC Assessment: Atlantic Menhaden, October 2009
//##
//##  Erik Williams, NMFS, Beaufort Lab
//##  Erik.Williams@noaa.gov
//##
//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>

DATA_SECTION
//Create ascii file for output
//!!CLASS ofstream report1("menhadresults.rep",ios::out);  //create file for output

!!cout << "Starting Atlantic Menhaden Assessment Model" << endl;

// Starting and ending year of the model (year data starts)
init_int styr;
init_int endyr;

//Starting year to estimate recruitment deviation from S-R curve
init_int styr_rec_dev;
!!cout << styr_rec_dev <<endl;
//possible 3 phases of constraints on recruitment deviations
init_int endyr_rec_phase1;
init_int endyr_rec_phase2;

//3 periods of size regs: styr-83 no restrictions, 1984-91 12-inch TL, 1992-08 20-in TL
init_int endyr_period1;
init_int endyr_period2;
init_int endyr_period3;

//starting and ending years to use for benchmark calculations
init_int styr_bench;
init_int endyr_bench;

//Total number of ages
init_int nages;

// Vector of ages for age bins
init_ivector agebins(1,nages);

//number assessment years
number nyrs;
number nyrs_rec;
```

```
//this section MUST BE INDENTED!!!
 LOCAL_CALCS
   nyrs=endyr-styr+1.;
   nyrs_rec=endyr-styr_rec_dev+1.;
 END_CALCS

//Max F used in spr and msy calcs
init_number max_F_spr_msy;
//Total number of iterations for spr calcs
init_int n_iter_spr;
//Total number of iterations for msy calcs
init_int n_iter_msy;
//Number years at end of time series over which to average sector F's, for weighted selectivities
init_int selpar_n_yrs_wgted;
//bias correction (set to 1.0 for no bias correction or a negative value to compute from rec
variance)
init_number set_BiasCor;
//exclude these years from end of time series for computing bias correction
init_number BiasCor_exclude_yrs;

//Female maturity and proportion female at age
init_vector maturity_f_obs(1,nages);           //proportion females mature at age
init_vector maturity_m_obs(1,nages);           //proportion males mature at age
init_vector prop_f_obs(1,nages);               //proportion female at age

init_number spawn_time_frac; //time of year of peak spawning, as a fraction of the year
// Natural mortality
init_vector set_M(1,nages); //age-dependent: used in model
init_number set_M_constant; //age-independent: used only for MSST
init_matrix set_M_mat(styr,endyr,1,nages); //age and year specific M
//Spawner-recruit parameters (Initial guesses or fixed values)
init_number set_SR_switch;
init_number set_steep;
init_number set_steep_se;
init_number set_log_R0;
init_number set_R_autocorr;

//--><>--><>--><>-- Weight-at-age in the fishery (g) --><>--><>--><>--><>--><>--><>--><>--
><>
init_matrix wgt_fish_g(styr,endyr,1,nages);

//--><>--><>--><>-- Weight-at-age for the spawning population - start of year (g) --><>--><>--
><>--><>
init_matrix wgt_spawn_g(styr,endyr,1,nages);
```

```
//-->><>--><>--><>-- Fecundity-at-age - not adjusted for maturity (g) --><>--><>--><>--><>
init_matrix fec_eggs(styr,endyr,1,nages);

//-->><>--><>--><>-- Juvenile Abundance Index from seine surveys --><>--><>--><>--><>--
><>
init_int JAI_cpue_switch;
//CPUE
init_int styr_JAI_cpue;
init_int endyr_JAI_cpue;
init_vector obs_JAI_cpue(styr_JAI_cpue,endyr_JAI_cpue);   //Observed CPUE
init_vector JAI_cpue_cv(styr_JAI_cpue,endyr_JAI_cpue);    //CV of cpue

//-->><>--><>--><>-- Juvenile Abundance Indices from seine surveys --><>--><>--><>--><>--
><>
//CPUE, must have zeros in place of missing values
init_vector obs_JAI1_cpue(styr_JAI_cpue,endyr_JAI_cpue);   //Observed CPUE 1
init_vector JAI1_cpue_cv(styr_JAI_cpue,endyr_JAI_cpue);    //CV of cpue 1
init_vector obs_JAI2_cpue(styr_JAI_cpue,endyr_JAI_cpue);   //Observed CPUE 2
init_vector JAI2_cpue_cv(styr_JAI_cpue,endyr_JAI_cpue);    //CV of cpue 2
init_vector obs_JAI3_cpue(styr_JAI_cpue,endyr_JAI_cpue);   //Observed CPUE 3
init_vector JAI3_cpue_cv(styr_JAI_cpue,endyr_JAI_cpue);    //CV of cpue 3
init_vector obs_JAI4_cpue(styr_JAI_cpue,endyr_JAI_cpue);   //Observed CPUE 4
init_vector JAI4_cpue_cv(styr_JAI_cpue,endyr_JAI_cpue);    //CV of cpue 4

//-->><>--><>--><>-- PRFC pound net index --><>--><>--><>--><>--><>--><>--><>--><>--
><>
//CPUE
init_int styr_PN_cpue;
init_int endyr_PN_cpue;
init_vector obs_PN_cpue(styr_PN_cpue,endyr_PN_cpue);   //Observed CPUE
init_vector PN_cpue_cv(styr_PN_cpue,endyr_PN_cpue);    //cv of cpue

//-->><>--><>--><>-- Commercial Reduction fishery --><>--><>--><>--><>--><>--><>--><>
// Landings  (1000 mt)
init_int styr_cR_L;
init_int endyr_cR_L;
init_vector obs_cR_L(styr_cR_L,endyr_cR_L); //vector of observed landings by year
init_vector cR_L_cv(styr_cR_L,endyr_cR_L);    //vector of CV of landings by year

// Age Compositions
init_int nyr_cR_agec;
init_ivector yrs_cR_agec(1,nyr_cR_agec);
init_vector nsamp_cR_agec(1,nyr_cR_agec);
init_vector neff_cR_agec(1,nyr_cR_agec);
init_matrix obs_cR_agec(1,nyr_cR_agec,1,nages);
```

```
//-->><>-->><>-->><>-- Commercial Bait fishery -->><>-->><>-->><>-->><>-->><>-->><>-->><>-->><>
// Landings (1000 mt)
init_int styr_cB_L;
init_int endyr_cB_L;
init_vector obs_cB_L(styr_cB_L,endyr_cB_L);
init_vector cB_L_cv(styr_cB_L,endyr_cB_L);    //vector of CV of landings by year

// Age compositions
init_int nyr_cB_agec;
init_ivector yrs_cB_agec(1,nyr_cB_agec);
init_vector nsamp_cB_agec(1,nyr_cB_agec);
init_vector neff_cB_agec(1,nyr_cB_agec);
init_matrix obs_cB_agec(1,nyr_cB_agec,1,nages);

//###########################################################################
#
//##################Parameter values and initial guesses
#################################
//Initial guesses of estimated selectivity parameters
init_number set_selpar_L50_cR;
init_number set_selpar_slope_cR;
init_number set_selpar_L502_cR;
init_number set_selpar_slope2_cR;

init_number set_selpar_L50_cB;
init_number set_selpar_slope_cB;
init_number set_selpar_L502_cB;
init_number set_selpar_slope2_cB;

init_number set_selpar_L50_PN;
init_number set_selpar_slope_PN;
init_number set_selpar_L502_PN;
init_number set_selpar_slope2_PN;

//--weights for likelihood components-----------------------------------------------------------------------
--------
init_number set_w_L;
init_number set_w_ac;
init_number set_w_I_JAI;
init_number set_w_I_PN;
init_number set_w_rec;            //for fitting S-R curve
init_number set_w_rec_early;        //additional constraint on early years recruitment
init_number set_w_rec_end;        //additional constraint on ending years recruitment
```

init_number set_w_fullF;   //penalty for any Fapex>3(removed in final phase of optimization)
init_number set_w_Ftune;   //weight applied to tuning F (removed in final phase of optimization)
init_number set_w_JAI_wgts;   //weight for penalty to keep JAI combination weights summing to 1.0

////--index catchability--
init_number set_logq_JAI;   //catchability coefficient (log) for MARMAP RVC
init_number set_logq_PN;   //catchability coefficient (log) for MARMAP CVT

init_number set_JAI_exp;   //exponent for cpue index

//--JAI index combination weights--
init_number set_wgt_JAI1;
init_number set_wgt_JAI2;
init_number set_wgt_JAI3;
init_number set_wgt_JAI4;

//rate of increase on q
init_int set_q_rate_phase; //value sets estimation phase of rate increase, negative value turns it off
init_number set_q_rate;
//density dependence on fishery q's
init_int set_q_DD_phase; //value sets estimation phase of random walk, negative value turns it off
init_number set_q_DD_beta;   //value of 0.0 is density indepenent
init_number set_q_DD_beta_se;
init_int set_q_DD_stage;   //age to begin counting biomass, should be near full exploitation

//random walk on fishery q's
init_int set_q_RW_phase;   //value sets estimation phase of random walk, negative value turns it off
init_number set_q_RW_PN_var;   //assumed variance of RW q

////--F's--------------------------------
init_number set_log_avg_F_cR;
init_number set_log_avg_F_cB;
init_number set_F_init_ratio; //defines initialization F as a ratio of that from first several yrs of assessment

//Tune Fapex (tuning removed in final year of optimization)
init_number set_Ftune;
init_int set_Ftune_yr;

```
//threshold sample sizes for age comps
init_number minSS_cR_agec;
init_number minSS_cB_agec;

//switch to turn priors on off (-1 = off, 1 = on)
init_number switch_prior;

//ageing error matrix (columns are true ages, rows are ages as read for age comps)
init_matrix age_error(1,nages,1,nages);

// #######Indexing integers for year(iyear), age(iage) ###############
int iyear;
int iage;
int ff;
int quant_whole;

number sqrt2pi;
number g2mt;                    //conversion of grams to metric tons
number g2kg;                    //conversion of grams to kg
number g2klb;                   //conversion of grams to 1000 lb
number mt2klb;                  //conversion of metric tons to 1000 lb
number mt2lb;                   //conversion of metric tons to lb
number dzero;                   //small additive constant to prevent division by zero

init_number end_of_data_file;
//this section MUST BE INDENTED!!!
 LOCAL_CALCS
   if(end_of_data_file!=999)
   {
     for(iyear=1; iyear<=1000; iyear++)
     {
       cout << "*** WARNING: Data File NOT READ CORRECTLY ****" << endl;
       cout << "" <<endl;
     }
   }
   else
   {
    cout << "Data File read correctly" << endl;
   }
 END_CALCS

//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--
><>--><>--><>
```

```
PARAMETER_SECTION
//////---------------------------------------------------------------------------------------

  matrix wgt_fish_kg(styr,endyr,1,nages);
  matrix wgt_fish_mt(styr,endyr,1,nages);
  matrix wgt_spawn_kg(styr,endyr,1,nages);
  matrix wgt_spawn_mt(styr,endyr,1,nages);

  matrix wgt_cR_mt(styr,endyr,1,nages);      //wgt of cR landings in 1000 mt
  matrix wgt_cB_mt(styr,endyr,1,nages);      //wgt of cB landings in 1000 mt

  matrix pred_cR_agec(1,nyr_cR_agec,1,nages);
  matrix ErrorFree_cR_agec(1,nyr_cR_agec,1,nages); //age comps prior to applying ageing error
matrix
  matrix pred_cB_agec(1,nyr_cB_agec,1,nages);
  matrix ErrorFree_cB_agec(1,nyr_cB_agec,1,nages);

  //nsamp_X_allyr vectors used only for R output of comps with nonconsecutive yrs, given
sample size cutoffs
  vector nsamp_cR_agec_allyr(styr,endyr);
  vector nsamp_cB_agec_allyr(styr,endyr);

//effective sample size applied in multinomial distributions
  vector neff_cR_agec_allyr(styr,endyr);
  vector neff_cB_agec_allyr(styr,endyr);

//Computed effective sample size for output (not used in fitting)
  vector neff_cR_agec_allyr_out(styr,endyr);
  vector neff_cB_agec_allyr_out(styr,endyr);

//-----Population-------------------------------------------------------------------------
  matrix N(styr,endyr+1,1,nages);           //Population numbers by year and age at start of yr
  matrix N_mdyr(styr,endyr,1,nages);        //Population numbers by year and age at mdpt of yr:
used for comps and cpue
  matrix N_spawn(styr,endyr,1,nages);       //Population numbers by year and age at peaking
spawning: used for SSB
  init_bounded_vector log_Nage_dev(2,nages,-5,5,1); //log deviations on initial abundance at age
  //vector log_Nage_dev(2,nages);
  vector log_Nage_dev_output(1,nages);             //used in output. equals zero for first age
  matrix B(styr,endyr+1,1,nages);           //Population biomass by year and age at start of yr
  vector totB(styr,endyr+1);              //Total biomass by year
  vector totN(styr,endyr+1);              //Total abundance by year
  vector SSB(styr,endyr);                ///Total spawning biomass by year
  vector rec(styr,endyr+1);              //Recruits by year
  vector pred_SPR(styr,endyr);             //spawning biomass-per-recruit (lagged) for Fmed calcs
```

```
  vector prop_f(1,nages);                  //Proportion female by age
  vector maturity_f(1,nages);              //Proportion of female mature at age
  vector maturity_m(1,nages);              //Proportion of female mature at age
  matrix reprod(styr,endyr,1,nages);
  vector wgted_reprod(1,nages);            //average reprod in last few years
//
////---Stock-Recruit Function (Beverton-Holt, steepness parameterization)----------
  init_bounded_number log_R0(1,10,1);      //log(virgin Recruitment)
  //number log_R0;
  number R0;                               //virgin recruitment
  init_bounded_number steep(0.21,0.99,-3);   //steepness
//  number steep;  //uncomment to fix steepness, comment line directly above
  init_bounded_dev_vector log_rec_dev(styr_rec_dev,endyr,-5,5,1); //log recruitment deviations
  //vector log_rec_dev(styr_rec_dev,endyr);
  vector log_rec_dev_output(styr,endyr+1);          //used in output. equals zero except for yrs in
log_rec_dev
  number var_rec_dev;                      //variance of log recruitment deviations
                                  //Estimate from yrs with unconstrainted S-R(XXXX-XXXX)
  number BiasCor;                          //Bias correction in equilibrium recruits
  init_bounded_number R_autocorr(-1.0,1.0,2);  //autocorrelation in SR
  number S0;                               //equal to spr_F0*R0 = virgin SSB
  number B0;                               //equal to bpr_F0*R0 = virgin B
  number R1;                               //Recruits in styr
  number R_virgin;                         //unfished recruitment with bias correction
  vector SdS0(styr,endyr);                 //SSB / virgin SSB

////---Selectivity-------------------------------------------------------------------------

//Commercial reduction-------------------------------------------------
  matrix sel_cR(styr,endyr,1,nages);
  init_bounded_number selpar_slope_cR1(0.5,10.0,1); //period 1
  init_bounded_number selpar_L50_cR1(0.5,4.0,1);
  init_bounded_number selpar_slope2_cR1(0.0,10.0,-1); //period 1
  init_bounded_number selpar_L502_cR1(0.0,6.0,-1);
  vector sel_cR1_vec(1,nages);

  init_bounded_number selpar_slope_cR2(0.5,10.0,-2); //period 2
  init_bounded_number selpar_L50_cR2(0.5,4.0,-2);
  init_bounded_number selpar_slope2_cR2(0.0,10.0,-3); //period 2
  init_bounded_number selpar_L502_cR2(0.0,6.0,-3);
  vector sel_cR2_vec(1,nages);

  init_bounded_number selpar_slope_cR3(0.5,10.0,-2); //period 3
  init_bounded_number selpar_L50_cR3(0.5,4.0,-2);
  init_bounded_number selpar_slope2_cR3(0.0,10.0,-3); //period 3
```

```
  init_bounded_number selpar_L502_cR3(0.0,6.0,-3);
  vector sel_cR3_vec(1,nages);

  init_bounded_number selpar_slope_cR4(0.5,10.0,-2); //period 4
  init_bounded_number selpar_L50_cR4(0.5,4.0,-2);
  init_bounded_number selpar_slope2_cR4(0.0,10.0,-3); //period 4
  init_bounded_number selpar_L502_cR4(0.0,6.0,-3);
  vector sel_cR4_vec(1,nages);

//Commercial bait-------------------------------------------------
  matrix sel_cB(styr,endyr,1,nages);
  init_bounded_number selpar_slope_cB(0.5,10.0,1);
  init_bounded_number selpar_L50_cB(0.5,4.0,1);
  init_bounded_number selpar_slope2_cB(0.5,10.0,-1);
  init_bounded_number selpar_L502_cB(0.0,6.0,-1);
  vector sel_cB_vec(1,nages);

//Commercial bait-------------------------------------------------
  matrix sel_PN(styr,endyr,1,nages);
  number selpar_slope_PN; //period 1
  number selpar_L50_PN;
  number selpar_slope2_PN; //period 1
  number selpar_L502_PN;
  vector sel_PN_vec(1,nages);

  //effort-weighted, recent selectivities
  vector sel_wgted_L(1,nages);  //toward landings
  vector sel_wgted_tot(1,nages);//toward Z

//-------CPUE Predictions--------------------------------
  vector obs_JAI_cpue_final(styr_JAI_cpue,endyr_JAI_cpue);     //used to store cpue used in
likelihood fit
  vector JAI_cpue_cv_final(styr_JAI_cpue,endyr_JAI_cpue);
  vector pred_JAI_cpue(styr_JAI_cpue,endyr_JAI_cpue);         //predicted JAI U
  vector N_JAI(styr_JAI_cpue,endyr_JAI_cpue);         //used to compute JAI index
  vector pred_PN_cpue(styr_PN_cpue,endyr_PN_cpue);         //predicted PN U
  matrix N_PN(styr_PN_cpue,endyr_PN_cpue,1,nages);         //used to compute PN index

//------Index exponent--------------------------------
  init_bounded_number JAI_exp(0.01,1.0,-3);

//------Index combination weights--------------------------------
  init_bounded_number wgt_JAI1(0.001,1.0,-3);
  init_bounded_number wgt_JAI2(0.001,1.0,-3);
  init_bounded_number wgt_JAI3(0.001,1.0,-3);
```

```
  init_bounded_number wgt_JAI4(0.001,1.0,-3);
  number JAI_wgt_sum_constraint;

////---Catchability (CPUE q's)-------------------------------------------------------
  init_bounded_number log_q_JAI(-10,10,1);
  init_bounded_number log_q_PN(-10,10,1);
  init_bounded_number q_rate(0.001,0.1,set_q_rate_phase);
  //number q_rate;
  vector q_rate_fcn_PN(styr_PN_cpue,endyr_PN_cpue);        //increase due to technology creep
(saturates in 2003)

  init_bounded_number q_DD_beta(0.1,0.9,set_q_DD_phase);
  //number q_DD_beta;
  vector q_DD_fcn(styr,endyr);    //density dependent function as a multiple of q (scaled a la
Katsukawa and Matsuda. 2003)
  number B0_q_DD;                //B0 of ages q_DD_age plus
  vector B_q_DD(styr,endyr);      //annual biomass of ages q_DD_age plus

  init_bounded_vector q_RW_log_dev_PN(styr_PN_cpue,endyr_PN_cpue-1,-
3.0,3.0,set_q_RW_phase);
  vector q_PN(styr_PN_cpue,endyr_PN_cpue);

//---Landings in numbers (total or 1000 fish) and in wgt (klb)------------------------------------------
-------
  matrix L_cR_num(styr,endyr,1,nages);            //landings (numbers) at age
  matrix L_cR_mt(styr,endyr,1,nages);            //landings (1000 mt) at age
  vector pred_cR_L_knum(styr,endyr); //yearly landings in 1000 fish summed over ages
  vector pred_cR_L_mt(styr,endyr);  //yearly landings in 1000 mt summed over ages

  matrix L_cB_num(styr,endyr,1,nages);             //landings (numbers) at age
  matrix L_cB_mt(styr,endyr,1,nages);             //landings (1000 mt) at age
  vector pred_cB_L_knum(styr,endyr);      //yearly landings in 1000 fish summed over ages
  vector pred_cB_L_mt(styr,endyr);       //yearly landings in 1000 mt summed over ages

  matrix L_total_num(styr,endyr,1,nages);               //total landings in number at age
  matrix L_total_mt(styr,endyr,1,nages);               //landings in 1000 mt at age
  vector L_total_knum_yr(styr,endyr);                  //total landings in 1000 fish by yr summed
over ages
  vector L_total_mt_yr(styr,endyr);                   //total landings (1000 mt) by yr summed over
ages

////---Fmed calcs--------------------------------------------------------------------------
  number quant_decimal;
  number quant_diff;
  number quant_result;
```

```
  number R_med;                              //median recruitment for chosen benchmark years
  vector R_temp(styr_bench,endyr_bench);
  vector R_sort(styr_bench,endyr_bench);
  number SPR_med;                            //median SSB/R (R = SSB year+1) for chosen SSB years
  number SPR_75th;
  vector SPR_temp(styr_bench,endyr_bench);
  vector SPR_sort(styr_bench,endyr_bench);
  number SSB_med;                            //SSB corresponding to SSB/R median and R median
  number SSB_med_thresh;                     //SSB threshold
  vector SPR_diff(1,n_iter_spr);
  number SPR_diff_min;
  number F_med;                              //Fmed benchmark
  number F_med_target;
  number F_med_age2plus;                     //Fmed benchmark
  number F_med_target_age2plus;
  number L_med;

////---MSY calcs---------------------------------------------------------------------------
  number F_cR_prop;       //proportion of F_sum attributable to reduction, last
X=selpar_n_yrs_wgted yrs, used for avg body weights
  number F_cB_prop;       //proportion of F_sum attributable to bait, last X yrs
  number F_temp_sum;      //sum of geom mean Fsum's in last X yrs, used to compute
F_fishery_prop

  vector F_end(1,nages);
  vector F_end_L(1,nages);
  number F_end_apex;

  number SSB_msy_out;           //SSB (total mature biomass) at msy
  number F_msy_out;             //F at msy
  number msy_mt_out;            //max sustainable yield (1000 mt)
  number msy_knum_out;          //max sustainable yield (1000 fish)
  number B_msy_out;             //total biomass at MSY
  number R_msy_out;             //equilibrium recruitment at F=Fmsy
  number spr_msy_out;           //spr at F=Fmsy

  vector N_age_msy(1,nages);         //numbers at age for MSY calculations: beginning of yr
  vector N_age_msy_mdyr(1,nages);    //numbers at age for MSY calculations: mdpt of yr
  vector L_age_msy(1,nages);         //catch at age for MSY calculations
  vector Z_age_msy(1,nages);         //total mortality at age for MSY calculations
  vector F_L_age_msy(1,nages);       //fishing mortality landings (not discards) at age for MSY
calculations
  vector F_msy(1,n_iter_msy);        //values of full F to be used in equilibrium calculations
```

```
  vector spr_msy(1,n_iter_msy);      //reproductive capacity-per-recruit values corresponding to F values in F_msy
  vector R_eq(1,n_iter_msy);         //equilibrium recruitment values corresponding to F values in F_msy
  vector L_eq_mt(1,n_iter_msy);     //equilibrium landings(1000 mt) values corresponding to F values in F_msy
  vector L_eq_knum(1,n_iter_msy);     //equilibrium landings(1000 fish) values corresponding to F values in F_msy
  vector SSB_eq(1,n_iter_msy);       //equilibrium reproductive capacity values corresponding to F values in F_msy
  vector B_eq(1,n_iter_msy);         //equilibrium biomass values corresponding to F values in F_msy

  vector FdF_msy(styr,endyr);
  vector SdSSB_msy(styr,endyr);
  number SdSSB_msy_end;
  number FdF_msy_end;

  vector wgt_wgted_L_mt(1,nages);  //fishery-weighted average weight at age of landings
  number wgt_wgted_L_denom;        //used in intermediate calculations

  number iter_inc_msy;             //increments used to compute msy, equals 1/(n_iter_msy-1)

////--------Mortality------------------------------------------------------------------
  vector M(1,nages);                       //age-dependent natural mortality
  number M_constant;                       //age-indpendent: used only for MSST
  matrix M_mat(styr,endyr,1,nages);
  vector wgted_M(1,nages);                 //weighted M vector for last few years
  matrix F(styr,endyr,1,nages);
  vector Fsum(styr,endyr);                 //Full fishing mortality rate by year
  vector Fapex(styr,endyr);                //Max across ages, fishing mortality rate by year (may differ from Fsum bc of dome-shaped sel
  matrix Z(styr,endyr,1,nages);

  vector E(styr,endyr);                    //Exploitation rate
  vector F_age2plus(styr,endyr);           //population weighted age 2+ F
  vector F_cR_age2plus(styr,endyr);        //population weighted age 2+ F
  vector F_cB_age2plus(styr,endyr);        //population weighted age 2+ F

  init_bounded_number log_avg_F_cR(-5,2.0,1);
  init_bounded_dev_vector log_F_dev_cR(styr_cR_L,endyr_cR_L,-10.0,5.0,2);
  matrix F_cR(styr,endyr,1,nages);
  vector F_cR_out(styr,endyr); //used for intermediate calculations in fcn get_mortality
  number log_F_dev_init_cR;
  number log_F_dev_end_cR;
```

```
  init_bounded_number log_avg_F_cB(-10,0.0,1);
  init_bounded_dev_vector log_F_dev_cB(styr_cB_L,endyr_cB_L,-10.0,5.0,2);
  matrix F_cB(styr,endyr,1,nages);
  vector F_cB_out(styr,endyr); //used for intermediate calculations in fcn get_mortality
  number log_F_dev_init_cB;
  number log_F_dev_end_cB;

  init_bounded_number F_init_ratio(0.05,2.0,-1);

//---Per-recruit stuff----------------------------------------------------------------------------------
  vector N_age_spr(1,nages);         //numbers at age for SPR calculations: beginning of year
  vector N_age_spr_mdyr(1,nages);    //numbers at age for SPR calculations: midyear
  vector L_age_spr(1,nages);         //catch at age for SPR calculations
  vector Z_age_spr(1,nages);         //total mortality at age for SPR calculations
  vector spr_static(styr,endyr);     //vector of static SPR values by year
  vector F_L_age_spr(1,nages);       //fishing mortality of landings (not discards) at age for SPR
calculations
  vector F_spr(1,n_iter_spr);        //values of full F to be used in per-recruit calculations
  vector F_spr_age2plus(1,n_iter_spr);  //values of F age2+ to be used in per-recruit calculations
  vector spr_spr(1,n_iter_spr);      //reproductive capacity-per-recruit values corresponding to F
values in F_spr
  vector L_spr(1,n_iter_spr);        //landings(mt)-per-recruit (ypr) values corresponding to F
values in F_spr

  vector N_spr_F0(1,nages);          //Used to compute spr at F=0: at time of peak spawning
  vector N_bpr_F0(1,nages);          //Used to compute bpr at F=0: at start of year
  vector N_spr_initial(1,nages);     //Initial spawners per recruit at age given initial F
  vector N_initial_eq(1,nages);      //Initial equilibrium abundance at age
  vector F_initial(1,nages);         //initial F at age
  vector Z_initial(1,nages);         //initial Z at age
  number spr_initial;                //initial spawners per recruit
  vector spr_F0(styr,endyr);         //Spawning biomass per recruit at F=0
  vector bpr_F0(styr,endyr);         //Biomass per recruit at F=0
  number wgted_spr_F0;

  number iter_inc_spr;               //increments used to compute msy, equals
max_F_spr_msy/(n_iter_spr-1)


////-------Objective function components-------------------------------------------------------------------
--------
  number w_L;
  number w_ac;
  number w_I_JAI;
```

```
  number w_I_PN;
  number w_rec;
  number w_rec_early;
  number w_rec_end;
  number w_fullF;
  number w_Ftune;
  number w_JAI_wgts;

  number f_JAI_cpue;
  number f_PN_cpue;

  number f_cR_L;
  number f_cB_L;

  number f_cR_agec;
  number f_cB_agec;

  number f_PN_RW_cpue; //random walk component of indices

  //Penalties and constraints. Not all are used.
  number f_rec_dev;              //weight on recruitment deviations to fit S-R curve
  number f_rec_dev_early;        //extra weight on deviations in first recruitment stanza
  number f_rec_dev_end;          //extra weight on deviations in first recruitment stanza
  number f_Ftune;                //penalty for tuning F in Ftune yr.  Not applied in final optimization
phase.
  number f_fullF_constraint;     //penalty for Fapex>X
  number f_JAI_wgts;

  number f_priors;               //prior information on parameters

  objective_function_value fval;
  number fval_unwgt;

//--Dummy variables ----
  number denom;                  //denominator used in some calculations
  number numer;                  //numerator used in some calculations
  vector temp_agevec(1,nages);
  number dum1;

//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
INITIALIZATION_SECTION


//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
```

```
//##-->><>-->><>-->><>-->><>-->><>-->><>-->><>-->><>-->><>-->><>-->><>-->><>-->><>
GLOBALS_SECTION
  #include "admodel.h"          // Include AD class definitions
  #include "admb2r.cpp"    // Include S-compatible output functions (needs preceding)

//##-->><>-->><>-->><>-->><>-->><>-->><>-->><>-->><>-->><>-->><>-->><>-->><>-->><>
RUNTIME_SECTION
 maximum_function_evaluations 1000, 4000,8000, 10000;
 convergence_criteria 1e-2, 1e-5,1e-6, 1e-7;

//##-->><>-->><>-->><>-->><>-->><>-->><>-->><>-->><>-->><>-->><>-->><>-->><>-->><>
//##-->><>-->><>-->><>-->><>-->><>-->><>-->><>-->><>-->><>-->><>-->><>-->><>-->><>
PRELIMINARY_CALCS_SECTION

// Set values of fixed parameters or set initial guess of estimated parameters
  M=set_M;
  M_constant=set_M_constant;
  M_mat=set_M_mat;
  steep=set_steep;
  R_autocorr=set_R_autocorr;

  log_q_JAI=set_logq_JAI;
  log_q_PN=set_logq_PN;

  JAI_exp=set_JAI_exp;

  wgt_JAI1=set_wgt_JAI1;
  wgt_JAI2=set_wgt_JAI2;
  wgt_JAI3=set_wgt_JAI3;
  wgt_JAI4=set_wgt_JAI4;

  q_rate=set_q_rate;
  q_rate_fcn_PN=1.0;
  q_DD_beta=set_q_DD_beta;
  q_DD_fcn=1.0;
  q_RW_log_dev_PN.initialize();

  if (set_q_rate_phase<0 & q_rate!=0.0)
  {
     for (iyear=styr_PN_cpue; iyear<=endyr_PN_cpue; iyear++)
     {   if (iyear>styr_PN_cpue & iyear <=2003)
         {//q_rate_fcn_cL(iyear)=(1.0+q_rate)*q_rate_fcn_cL(iyear-1); //compound
            q_rate_fcn_PN(iyear)=(1.0+(iyear-
styr_PN_cpue)*q_rate)*q_rate_fcn_PN(styr_PN_cpue);  //linear
         }
```

```
    if (iyear>2003) {q_rate_fcn_PN(iyear)=q_rate_fcn_PN(iyear-1);}
  }
} //end q_rate conditional

w_L=set_w_L;
w_ac=set_w_ac;
w_I_JAI=set_w_I_JAI;
w_I_PN=set_w_I_PN;
w_rec=set_w_rec;
w_fullF=set_w_fullF;
w_rec_early=set_w_rec_early;
w_rec_end=set_w_rec_end;
w_Ftune=set_w_Ftune;
w_JAI_wgts=set_w_JAI_wgts;

log_avg_F_cR=set_log_avg_F_cR;
log_avg_F_cB=set_log_avg_F_cB;
F_init_ratio=set_F_init_ratio;

log_R0=set_log_R0;

selpar_L50_cR1=set_selpar_L50_cR;
selpar_slope_cR1=set_selpar_slope_cR;
selpar_L502_cR1=set_selpar_L502_cR;
selpar_slope2_cR1=set_selpar_slope2_cR;

selpar_L50_cR2=set_selpar_L50_cR;
selpar_slope_cR2=set_selpar_slope_cR;
selpar_L502_cR2=set_selpar_L502_cR;
selpar_slope2_cR2=set_selpar_slope2_cR;

selpar_L50_cR3=set_selpar_L50_cR;
selpar_slope_cR3=set_selpar_slope_cR;
selpar_L502_cR3=set_selpar_L502_cR;
selpar_slope2_cR3=set_selpar_slope2_cR;

selpar_L50_cR4=set_selpar_L50_cR;
selpar_slope_cR4=set_selpar_slope_cR;
selpar_L502_cR4=set_selpar_L502_cR;
selpar_slope2_cR4=set_selpar_slope2_cR;

selpar_L50_cB=set_selpar_L50_cB;
selpar_slope_cB=set_selpar_slope_cB;
selpar_L502_cB=set_selpar_L502_cB;
selpar_slope2_cB=set_selpar_slope2_cB;
```

```
 selpar_L50_PN=set_selpar_L50_PN;
 selpar_slope_PN=set_selpar_slope_PN;
 selpar_L502_PN=set_selpar_L502_PN;
 selpar_slope2_PN=set_selpar_slope2_PN;

sqrt2pi=sqrt(2.*3.14159265);
//g2mt=0.000001;        //conversion of grams to metric tons
g2mt=1.0;
g2kg=0.001;          //conversion of grams to kg
mt2klb=2.20462;       //conversion of metric tons to 1000 lb
mt2lb=mt2klb*1000.0;  //conversion of metric tons to lb
g2klb=g2mt*mt2klb;    //conversion of grams to 1000 lb
dzero=0.00001;        //additive constant to prevent division by zero

SSB_msy_out=0.0;

iter_inc_msy=max_F_spr_msy/(n_iter_msy-1);
iter_inc_spr=max_F_spr_msy/(n_iter_spr-1);

maturity_f=maturity_f_obs;
maturity_m=maturity_m_obs;
prop_f=prop_f_obs;

//Fill in sample sizes of comps sampled in nonconsec yrs.
//Used primarily for output in R object

    nsamp_cR_agec_allyr=missing;
    nsamp_cB_agec_allyr=missing;

    neff_cR_agec_allyr=missing;
    neff_cB_agec_allyr=missing;

    for (iyear=1; iyear<=nyr_cR_agec; iyear++)
      {
       if (nsamp_cR_agec(iyear)>=minSS_cR_agec)
       {
         nsamp_cR_agec_allyr(yrs_cR_agec(iyear))=nsamp_cR_agec(iyear);
         neff_cR_agec_allyr(yrs_cR_agec(iyear))=neff_cR_agec(iyear);
       }
      }
    for (iyear=1; iyear<=nyr_cB_agec; iyear++)
      {
       if (nsamp_cB_agec(iyear)>=minSS_cB_agec)
       {
```

```
            nsamp_cB_agec_allyr(yrs_cB_agec(iyear))=nsamp_cB_agec(iyear);
            neff_cB_agec_allyr(yrs_cB_agec(iyear))=neff_cB_agec(iyear);
          }
        }

//fill in Fs for msy and per-recruit analyses
  F_msy(1)=0.0;
  for (ff=2;ff<=n_iter_msy;ff++)
  {
    F_msy(ff)=F_msy(ff-1)+iter_inc_msy;
  }
  F_spr(1)=0.0;
  for (ff=2;ff<=n_iter_spr;ff++)
  {
    F_spr(ff)=F_spr(ff-1)+iter_inc_spr;
  }

//fill in F's, Catch matrices, and log rec dev with zero's
  F_cR.initialize();
  L_cR_num.initialize();
  F_cB.initialize();
  L_cB_num.initialize();

  F_cR_out.initialize();
  F_cB_out.initialize();

  L_total_knum_yr.initialize();
  L_total_mt_yr.initialize();

  log_rec_dev_output.initialize();
  log_Nage_dev_output.initialize();
  log_rec_dev.initialize();
  log_Nage_dev.initialize();


//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
TOP_OF_MAIN_SECTION
  arrmblsize=20000000;
  gradient_structure::set_MAX_NVAR_OFFSET(1600);
  gradient_structure::set_GRADSTACK_BUFFER_SIZE(2000000);
  gradient_structure::set_CMPDIF_BUFFER_SIZE(2000000);
  gradient_structure::set_NUM_DEPENDENT_VARIABLES(500);
```

```
//>--><>--><>--><>--><>
//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
PROCEDURE_SECTION

 R0=mfexp(log_R0);

 //cout<<"start"<<endl;
 get_weight_at_age();
 get_reprod();
 get_weight_at_age_landings();
 //cout<< "got weight at age of landings"<<endl;
 get_spr_F0();
 //cout << "got F0 spr" << endl;
 get_selectivity();
 //cout << "got selectivity" << endl;
 get_mortality();
 //cout << "got mortalities" << endl;
 get_bias_corr();
 //cout<< "got recruitment bias correction" << endl;
 get_numbers_at_age();
 //cout << "got numbers at age" << endl;
 get_landings_numbers();
 //cout << "got catch at age" << endl;
 get_landings_wgt();
 //cout << "got landings" << endl;
 get_catchability_fcns();
 //cout << "got catchability_fcns" << endl;
 get_indices();
 //cout << "got indices" << endl;
 get_age_comps();
 //cout<< "got age comps"<< endl;
 evaluate_objective_function();
 //cout << "objective function calculations complete" << endl;

FUNCTION get_weight_at_age
  //compute mean length (mm) and weight (whole) at age
    wgt_fish_kg=g2kg*wgt_fish_g;                          //wgt in kilograms
    wgt_fish_mt=g2mt*wgt_fish_g;                          //mt of whole wgt: g2mt converts g to
mt
    wgt_spawn_kg=g2kg*wgt_spawn_g;                          //wgt in kilograms
    wgt_spawn_mt=g2mt*wgt_spawn_g;                          //mt of whole wgt: g2mt converts g
to mt

FUNCTION get_reprod
```

```
  //product of stuff going into reproductive capacity calcs
  for (iyear=styr; iyear<=endyr; iyear++)
  {
    //reprod(iyear)=elem_prod((elem_prod(prop_f,maturity_f)+elem_prod((1.0-
prop_f),maturity_m)),wgt_spawn_mt(iyear));
    //reprod(iyear)=elem_prod((elem_prod(prop_f,maturity_f)+elem_prod((1.0-
prop_f),maturity_m)),fec_eggs(iyear));
    reprod(iyear)=elem_prod(elem_prod(prop_f,maturity_f),fec_eggs(iyear));
  }

  //compute average natural mortality
  wgted_M=M_mat(endyr)*0.0;
  for(iyear=(endyr-selpar_n_yrs_wgted+1); iyear<=endyr; iyear++)
  {
    wgted_M+=M_mat(iyear);
  }
  wgted_M=wgted_M/selpar_n_yrs_wgted;

  //average reprod for last few years for eq calculations
  wgted_reprod=reprod(endyr)*0.0;
  for(iyear=(endyr-selpar_n_yrs_wgted+1); iyear<=endyr; iyear++)
  {
    wgted_reprod+=reprod(iyear);
  }
  wgted_reprod=wgted_reprod/selpar_n_yrs_wgted;

FUNCTION get_weight_at_age_landings

  wgt_cR_mt=wgt_fish_mt;
  wgt_cB_mt=wgt_fish_mt;

FUNCTION get_spr_F0

  for (iyear=styr; iyear<=endyr; iyear++)
  {
    //at mdyr, apply half this yr's mortality, half next yr's
    N_spr_F0(1)=1.0*mfexp(-1.0*M_mat(iyear,1)*spawn_time_frac); //at peak spawning time
    N_bpr_F0(1)=1.0;      //at start of year
    for (iage=2; iage<=nages; iage++)
    {
      //N_spr_F0(iage)=N_spr_F0(iage-1)*mfexp(-1.0*(M(iage-1)));
      dum1=M_mat(iyear,iage-1)*(1.0-spawn_time_frac) + M_mat(iyear,iage)*spawn_time_frac;
      N_spr_F0(iage)=N_spr_F0(iage-1)*mfexp(-1.0*(dum1));
      N_bpr_F0(iage)=N_bpr_F0(iage-1)*mfexp(-1.0*(M_mat(iyear,iage-1)));
    }
```

```
   N_spr_F0(nages)=N_spr_F0(nages)/(1.0-mfexp(-1.0*M_mat(iyear,nages))); //plus group (sum
of geometric series)
   N_bpr_F0(nages)=N_bpr_F0(nages)/(1.0-mfexp(-1.0*M_mat(iyear,nages)));

   spr_F0(iyear)=sum(elem_prod(N_spr_F0,reprod(iyear)));
   bpr_F0(iyear)=sum(elem_prod(N_bpr_F0,wgt_spawn_mt(iyear)));
  }

  N_spr_F0(1)=1.0*mfexp(-1.0*wgted_M(1)*spawn_time_frac); //at peak spawning time
  for (iage=2; iage<=nages; iage++)
  {
   dum1=wgted_M(iage-1)*(1.0-spawn_time_frac) + wgted_M(iage)*spawn_time_frac;
   N_spr_F0(iage)=N_spr_F0(iage-1)*mfexp(-1.0*(dum1));
  }
  N_spr_F0(nages)=N_spr_F0(nages)/(1.0-mfexp(-1.0*wgted_M(nages))); //plus group (sum of
geometric series
  wgted_spr_F0=sum(elem_prod(N_spr_F0,wgted_reprod));

FUNCTION get_selectivity

//// ------- compute landings selectivities by period

  for (iage=1; iage<=nages; iage++)
  {
    sel_cR1_vec(iage)=(1./(1.+mfexp(-1.*selpar_slope_cR1*(double(agebins(iage))-
                selpar_L50_cR1))))*(1.-(1./(1.+mfexp(-1.*selpar_slope2_cR1*
                (double(agebins(iage))-(selpar_L50_cR1+selpar_L502_cR1)))))); //double logistic

    sel_cR2_vec(iage)=(1./(1.+mfexp(-1.*selpar_slope_cR2*(double(agebins(iage))-
                selpar_L50_cR2))))*(1.-(1./(1.+mfexp(-1.*selpar_slope2_cR2*
                (double(agebins(iage))-(selpar_L50_cR2+selpar_L502_cR2)))))); //double logistic

    sel_cR3_vec(iage)=(1./(1.+mfexp(-1.*selpar_slope_cR3*(double(agebins(iage))-
                selpar_L50_cR3))))*(1.-(1./(1.+mfexp(-1.*selpar_slope2_cR3*
                (double(agebins(iage))-(selpar_L50_cR3+selpar_L502_cR3)))))); //double logistic

    sel_cR4_vec(iage)=(1./(1.+mfexp(-1.*selpar_slope_cR4*(double(agebins(iage))-
                selpar_L50_cR4))))*(1.-(1./(1.+mfexp(-1.*selpar_slope2_cR4*
                (double(agebins(iage))-(selpar_L50_cR4+selpar_L502_cR4)))))); //double logistic

    sel_cB_vec(iage)=(1./(1.+mfexp(-1.*selpar_slope_cB*(double(agebins(iage))-
                selpar_L50_cB))))*(1.-(1./(1.+mfexp(-1.*selpar_slope2_cB*
                (double(agebins(iage))-(selpar_L50_cB+selpar_L502_cB)))))); //double logistic

    sel_PN_vec(iage)=(1./(1.+mfexp(-1.*selpar_slope_PN*(double(agebins(iage))-
```

```
                selpar_L50_PN))))*(1.-(1./(1.+mfexp(-1.*selpar_slope2_PN*
                (double(agebins(iage))-(selpar_L50_PN+selpar_L502_PN)))))); //double logistic
 }
 sel_cR1_vec=sel_cR1_vec/max(sel_cR1_vec); //re-normalize double logistic
 sel_cR2_vec=sel_cR2_vec/max(sel_cR2_vec); //re-normalize double logistic
 sel_cR3_vec=sel_cR3_vec/max(sel_cR3_vec); //re-normalize double logistic
 sel_cR4_vec=sel_cR4_vec/max(sel_cR4_vec); //re-normalize double logistic
 sel_cB_vec=sel_cB_vec/max(sel_cB_vec); //re-normalize double logistic
 sel_PN_vec=sel_PN_vec/max(sel_PN_vec); //re-normalize double logistic

//-----------fill in years--------------------------------------------

 for (iyear=styr; iyear<=endyr; iyear++)
 {  //time-invariant selectivities
   sel_cB(iyear)=sel_cB_vec;
   sel_PN(iyear)=sel_PN_vec;
 }
 //Period 1:
 for (iyear=styr; iyear<=endyr_period1; iyear++)
 {
   sel_cR(iyear)=sel_cR1_vec;
 }

 //Period 2:
 for (iyear=endyr_period1+1; iyear<=endyr_period2; iyear++)
 {
   //sel_cR(iyear)=sel_cR2_vec;
   sel_cR(iyear)=sel_cR1_vec;
 }

 //Period 3
 for (iyear=endyr_period2+1; iyear<=endyr_period3; iyear++)
 {
   //sel_cR(iyear)=sel_cR3_vec;
   sel_cR(iyear)=sel_cR1_vec;
 }

 //Period 4
 for (iyear=endyr_period3+1; iyear<=endyr; iyear++)
 {
   //sel_cR(iyear)=sel_cR4_vec;
   sel_cR(iyear)=sel_cR1_vec;
 }

FUNCTION get_mortality
```

```
  Fsum.initialize();
  Fapex.initialize();
  F.initialize();
  ////initialization F is avg of first 3 yrs of observed landings
  log_F_dev_init_cR=sum(log_F_dev_cR(styr_cR_L,(styr_cR_L+2)))/3.0;
  log_F_dev_init_cB=sum(log_F_dev_cB(styr_cB_L,(styr_cB_L+2)))/3.0;

  for (iyear=styr; iyear<=endyr; iyear++)
  {
   //-------------
   if(iyear>=styr_cR_L & iyear<=endyr_cR_L)
     {F_cR_out(iyear)=mfexp(log_avg_F_cR+log_F_dev_cR(iyear));}
   if (iyear<styr_cR_L)
     {F_cR_out(iyear)=mfexp(log_avg_F_cR+log_F_dev_init_cR);}
   F_cR(iyear)=sel_cR(iyear)*F_cR_out(iyear);
   Fsum(iyear)+=F_cR_out(iyear);

   //-------------
   if(iyear>=styr_cB_L & iyear<=endyr_cB_L)
       {F_cB_out(iyear)=mfexp(log_avg_F_cB+log_F_dev_cB(iyear));}
   if (iyear<styr_cB_L)
     {F_cB_out(iyear)=mfexp(log_avg_F_cB+log_F_dev_init_cB);}
   F_cB(iyear)=sel_cB(iyear)*F_cB_out(iyear);
   Fsum(iyear)+=F_cB_out(iyear);

   //Total F at age
   F(iyear)=F_cR(iyear); //first in additive series (NO +=)
   F(iyear)+=F_cB(iyear);

   Fapex(iyear)=max(F(iyear));
   Z(iyear)=M_mat(iyear)+F(iyear);
  }  //end iyear

FUNCTION get_bias_corr
  //may exclude last BiasCor_exclude_yrs yrs bc constrained or lack info to estimate
  var_rec_dev=norm2(log_rec_dev(styr_rec_dev,(endyr-BiasCor_exclude_yrs))-
            sum(log_rec_dev(styr_rec_dev,(endyr-BiasCor_exclude_yrs)))
            /(nyrs_rec-BiasCor_exclude_yrs))/(nyrs_rec-BiasCor_exclude_yrs-1.0);
  if (set_BiasCor <= 0.0) {BiasCor=mfexp(var_rec_dev/2.0);}   //bias correction
  else {BiasCor=set_BiasCor;}


FUNCTION get_numbers_at_age
//Initialization
  S0=spr_F0(styr)*R0;
```

```
  if(set_SR_switch>1) //Beverton-Holt
  {
   R_virgin=(R0/((5.0*steep-1.0)*spr_F0(styr)))*
             (BiasCor*4.0*steep*spr_F0(styr)-spr_F0(styr)*(1.0-steep));
  }
  if(set_SR_switch<2) //Ricker
  {
   R_virgin=R0/spr_F0(styr)*(1+log(BiasCor*spr_F0(styr))/steep);
  }
  B0=bpr_F0(styr)*R_virgin;

  temp_agevec=wgt_fish_mt(styr);

B0_q_DD=R_virgin*sum(elem_prod(N_bpr_F0(set_q_DD_stage,nages),temp_agevec(set_q_D
D_stage,nages)));

  F_initial=sel_cR(styr)*mfexp(log_avg_F_cR+log_F_dev_init_cR)+
          sel_cB(styr)*mfexp(log_avg_F_cB+log_F_dev_init_cB);
  Z_initial=M+F_init_ratio*F_initial;

//Initial equilibrium age structure
  N_spr_initial(1)=1.0*mfexp(-1.0*Z_initial(1)*spawn_time_frac); //at peak spawning time;
  for (iage=2; iage<=nages; iage++)
    {
     N_spr_initial(iage)=N_spr_initial(iage-1)*
               mfexp(-1.0*(Z_initial(iage-1)*(1.0-spawn_time_frac) +
Z_initial(iage)*spawn_time_frac));
    }
  N_spr_initial(nages)=N_spr_initial(nages)/(1.0-mfexp(-1.0*Z_initial(nages))); //plus group
//    N_spr_F_init_mdyr(1,(nages-1))=elem_prod(N_spr_initial(1,(nages-1)),
//                             mfexp((-1.*(M(nages-1)+ F_initial))/2.0));

  spr_initial=sum(elem_prod(N_spr_initial,reprod(styr)));

  if(set_SR_switch>1) //Beverton-Holt
  {
   if (styr=styr_rec_dev) {R1=(R0/((5.0*steep-1.0)*spr_initial))*
             (4.0*steep*spr_initial-spr_F0(styr)*(1.0-steep));} //without bias correction (deviation
added later)
   else {R1=(R0/((5.0*steep-1.0)*spr_initial))*
             (BiasCor*4.0*steep*spr_initial-spr_F0(styr)*(1.0-steep));} //with bias correction
  }
  if(set_SR_switch<2) //Ricker
  {
```

```
    if (styr=styr_rec_dev) {R1=R0/spr_initial*(1+log(BiasCor*spr_initial)/steep);} //without bias
correction (deviation added later)
    else {R1=R0/spr_initial*(1+log(BiasCor*spr_initial)/steep);} //with bias correction
  }

  if(R1<0.0) {R1=1.0;} //Avoid negative popn sizes during search algorithm


//Compute equilibrium age structure for first year
  N_initial_eq(1)=R1;
  for (iage=2; iage<=nages; iage++)
  {
    N_initial_eq(iage)=N_initial_eq(iage-1)*
      mfexp(-1.0*(Z_initial(iage-1)*(1.0-spawn_time_frac) + Z_initial(iage)*spawn_time_frac));
  }
  //plus group calculation
  N_initial_eq(nages)=N_initial_eq(nages)/(1.0-mfexp(-1.0*Z_initial(nages))); //plus group

//Add deviations to initial equilibrium N
  N(styr)(2,nages)=elem_prod(N_initial_eq(2,nages),mfexp(log_Nage_dev));

  if (styr=styr_rec_dev) {N(styr,1)=N_initial_eq(1)*mfexp(log_rec_dev(styr_rec_dev));}
  else {N(styr,1)=N_initial_eq(1);}

  N_mdyr(styr)(1,nages)=elem_prod(N(styr)(1,nages),(mfexp(-1.*(Z_initial(1,nages))*0.5)));
//mid year
  N_spawn(styr)(1,nages)=elem_prod(N(styr)(1,nages),(mfexp(-
1.*(Z_initial(1,nages))*spawn_time_frac))); //peak spawning time

  SSB(styr)=sum(elem_prod(N_spawn(styr),reprod(styr)));

  temp_agevec=wgt_fish_mt(styr);

B_q_DD(styr)=sum(elem_prod(N(styr)(set_q_DD_stage,nages),temp_agevec(set_q_DD_stage,n
ages)));

//Rest of years
  for (iyear=styr; iyear<endyr; iyear++)
  {
    if(iyear<(styr_rec_dev-1)) //recruitment follows S-R curve exactly
    {
        //add dzero to avoid log(zero)
        if(set_SR_switch>1) //Beverton-Holt
        {
          N(iyear+1,1)=BiasCor*mfexp(log(((0.8*R0*steep*SSB(iyear))/(0.2*R0*spr_F0(iyear)*
```

```
        (1.0-steep)+(steep-0.2)*SSB(iyear)))+dzero));
      }
      if(set_SR_switch<2) //Ricker
      {
       N(iyear+1,1)=mfexp(log(BiasCor*SSB(iyear)/spr_F0(iyear)*mfexp(steep*(1-
SSB(iyear)/(R0*spr_F0(iyear))))+dzero));
      }
      N(iyear+1)(2,nages)=++elem_prod(N(iyear)(1,nages-1),(mfexp(-1.*Z(iyear)(1,nages-1))));
      N(iyear+1,nages)+=N(iyear,nages)*mfexp(-1.*Z(iyear,nages));//plus group
      N_mdyr(iyear+1)(1,nages)=elem_prod(N(iyear+1)(1,nages),(mfexp(-
1.*(Z(iyear+1)(1,nages))*0.5))); //mid year
      N_spawn(iyear+1)(1,nages)=elem_prod(N(iyear+1)(1,nages),(mfexp(-
1.*(Z(iyear+1)(1,nages))*spawn_time_frac))); //peak spawning time
      SSB(iyear+1)=sum(elem_prod(N_spawn(iyear+1),reprod(iyear+1)));
      temp_agevec=wgt_fish_mt(iyear+1);

B_q_DD(iyear+1)=sum(elem_prod(N(iyear+1)(set_q_DD_stage,nages),temp_agevec(set_q_DD
_stage,nages)));

   }
   else   //recruitment follows S-R curve with lognormal deviation
   {
      //add dzero to avoid log(zero)
      if(set_SR_switch>1) //Beverton-Holt
      {
       N(iyear+1,1)=mfexp(log(((0.8*R0*steep*SSB(iyear))/(0.2*R0*spr_F0(iyear)*
        (1.0-steep)+(steep-0.2)*SSB(iyear)))+dzero)+log_rec_dev(iyear+1));
      }
      if(set_SR_switch<2) //Ricker
      {
       N(iyear+1,1)=mfexp(log(SSB(iyear)/spr_F0(iyear)*mfexp(steep*(1-
SSB(iyear)/(R0*spr_F0(iyear))))+dzero)+log_rec_dev(iyear+1));
      }
      N(iyear+1)(2,nages)=++elem_prod(N(iyear)(1,nages-1),(mfexp(-1.*Z(iyear)(1,nages-1))));
      N(iyear+1,nages)+=N(iyear,nages)*mfexp(-1.*Z(iyear,nages));//plus group
      N_mdyr(iyear+1)(1,nages)=elem_prod(N(iyear+1)(1,nages),(mfexp(-
1.*(Z(iyear+1)(1,nages))*0.5))); //mid year
      N_spawn(iyear+1)(1,nages)=elem_prod(N(iyear+1)(1,nages),(mfexp(-
1.*(Z(iyear+1)(1,nages))*spawn_time_frac))); //peak spawning time
      SSB(iyear+1)=sum(elem_prod(N_spawn(iyear+1),reprod(iyear+1)));
      temp_agevec=wgt_fish_mt(iyear+1);

B_q_DD(iyear+1)=sum(elem_prod(N(iyear+1)(set_q_DD_stage,nages),temp_agevec(set_q_DD
_stage,nages)));
   }
```

```
 }


   //last year (projection) has no recruitment variability
   if(set_SR_switch>1) //Beverton-Holt
   {
     N(endyr+1,1)=mfexp(log(((0.8*R0*steep*SSB(endyr))/(0.2*R0*spr_F0(endyr)*
             (1.0-steep)+(steep-0.2)*SSB(endyr)))+dzero));
   }
   if(set_SR_switch<2) //Ricker
   {
     N(endyr+1,1)=mfexp(log(SSB(iyear)/spr_F0(iyear)*mfexp(steep*(1-
SSB(iyear)/(R0*spr_F0(iyear))))+dzero));
   }
   N(endyr+1)(2,nages)=++elem_prod(N(endyr)(1,nages-1),(mfexp(-1.*Z(endyr)(1,nages-1))));
   N(endyr+1,nages)+=N(endyr,nages)*mfexp(-1.*Z(endyr,nages));//plus group
   //SSB(endyr+1)=sum(elem_prod(N(endyr+1),reprod));


//Time series of interest
  rec=column(N,1);
  SdS0=SSB/S0;
  for (iyear=styr; iyear<=endyr; iyear++)
  {
   pred_SPR(iyear)=SSB(iyear)/rec(iyear+1);
  }

FUNCTION get_landings_numbers //Baranov catch eqn
  for (iyear=styr; iyear<=endyr; iyear++)
  {
    for (iage=1; iage<=nages; iage++)
    {
      L_cR_num(iyear,iage)=N(iyear,iage)*F_cR(iyear,iage)*
        (1.-mfexp(-1.*Z(iyear,iage)))/Z(iyear,iage);
      L_cB_num(iyear,iage)=N(iyear,iage)*F_cB(iyear,iage)*
        (1.-mfexp(-1.*Z(iyear,iage)))/Z(iyear,iage);
    }

    pred_cR_L_knum(iyear)=sum(L_cR_num(iyear));
    pred_cB_L_knum(iyear)=sum(L_cB_num(iyear));
  }

FUNCTION get_landings_wgt

////---Predicted landings------------------------
```

```
  for (iyear=styr; iyear<=endyr; iyear++)
  {
   L_cR_mt(iyear)=elem_prod(L_cR_num(iyear),wgt_cR_mt(iyear));     //in 1000 mt
   L_cB_mt(iyear)=elem_prod(L_cB_num(iyear),wgt_cB_mt(iyear));     //in 1000 mt

   pred_cR_L_mt(iyear)=sum(L_cR_mt(iyear));
   pred_cB_L_mt(iyear)=sum(L_cB_mt(iyear));
  }

FUNCTION get_catchability_fcns
 //Get rate increase if estimated, otherwise fixed above
  if (set_q_rate_phase>0.0)
  {
      for (iyear=styr_PN_cpue; iyear<=endyr_PN_cpue; iyear++)
      {   if (iyear>styr_PN_cpue & iyear <=2003)
          {//q_rate_fcn_cL(iyear)=(1.0+q_rate)*q_rate_fcn_cL(iyear-1); //compound
             q_rate_fcn_PN(iyear)=(1.0+(iyear-
styr_PN_cpue)*q_rate)*q_rate_fcn_PN(styr_PN_cpue);  //linear
          }
          if (iyear>2003) {q_rate_fcn_PN(iyear)=q_rate_fcn_PN(iyear-1);}
      }
  } //end q_rate conditional

 //Get density dependence scalar (=1.0 if density independent model is used)
  if (q_DD_beta>0.0)
  {
   B_q_DD+=dzero;
   for (iyear=styr;iyear<=endyr;iyear++)
       {q_DD_fcn(iyear)=pow(B0_q_DD,q_DD_beta)*pow(B_q_DD(iyear),-q_DD_beta);}
        //{q_DD_fcn(iyear)=1.0+4.0/(1.0+mfexp(0.75*(B_q_DD(iyear)-0.1*B0_q_DD))); }
  }

FUNCTION get_indices
//---Predicted CPUEs------------------------
 //combined JAI index
  if(JAI_cpue_switch==1)
  {
   obs_JAI_cpue_final=pow(obs_JAI_cpue,JAI_exp);
   JAI_cpue_cv_final=JAI_cpue_cv;
  }
  else
  {

obs_JAI_cpue_final=(obs_JAI1_cpue*wgt_JAI1+obs_JAI2_cpue*wgt_JAI2+obs_JAI3_cpue*w
gt_JAI3+obs_JAI4_cpue*wgt_JAI4)
```

```
                  /(wgt_JAI1+wgt_JAI2+wgt_JAI3+wgt_JAI4);
   obs_JAI_cpue_final=pow(obs_JAI_cpue_final,JAI_exp);

JAI_cpue_cv_final=(JAI1_cpue_cv*wgt_JAI1+JAI2_cpue_cv*wgt_JAI2+JAI3_cpue_cv*wgt_JAI3+JAI4_cpue_cv*wgt_JAI4)
                  /(wgt_JAI1+wgt_JAI2+wgt_JAI3+wgt_JAI4);
  }

 //JAI survey
  for (iyear=styr_JAI_cpue; iyear<=endyr_JAI_cpue; iyear++)
  {   //index in number units
     N_JAI(iyear)=N(iyear,1);
     pred_JAI_cpue(iyear)=mfexp(log_q_JAI)*N_JAI(iyear);
  }

 //PN index
  for (iyear=styr_PN_cpue; iyear<=endyr_PN_cpue; iyear++)
  {   //index in number units
     N_PN(iyear)=elem_prod(N_mdyr(iyear),sel_PN(iyear));
     pred_PN_cpue(iyear)=mfexp(log_q_PN)*sum(N_PN(iyear));
  }

FUNCTION get_age_comps

 //Commercial reduction
  for (iyear=1;iyear<=nyr_cR_agec;iyear++)
  {
    ErrorFree_cR_agec(iyear)=L_cR_num(yrs_cR_agec(iyear))/
                     sum(L_cR_num(yrs_cR_agec(iyear)));
    pred_cR_agec(iyear)=age_error*ErrorFree_cR_agec(iyear);
  }

 //Commercial bait
  for (iyear=1;iyear<=nyr_cB_agec;iyear++)
  {
    ErrorFree_cB_agec(iyear)=L_cB_num(yrs_cB_agec(iyear))/
                     sum(L_cB_num(yrs_cB_agec(iyear)));
    pred_cB_agec(iyear)=age_error*ErrorFree_cB_agec(iyear);
  }

////------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------
FUNCTION get_weighted_current
  F_temp_sum=0.0;
  F_temp_sum+=mfexp((selpar_n_yrs_wgted*log_avg_F_cR+
```

```
    sum(log_F_dev_cR((endyr-selpar_n_yrs_wgted+1),endyr)))/selpar_n_yrs_wgted);
 F_temp_sum+=mfexp((selpar_n_yrs_wgted*log_avg_F_cB+
    sum(log_F_dev_cB((endyr-selpar_n_yrs_wgted+1),endyr)))/selpar_n_yrs_wgted);

 F_cR_prop=mfexp((selpar_n_yrs_wgted*log_avg_F_cR+
    sum(log_F_dev_cR((endyr-
selpar_n_yrs_wgted+1),endyr)))/selpar_n_yrs_wgted)/F_temp_sum;
 F_cB_prop=mfexp((selpar_n_yrs_wgted*log_avg_F_cB+
    sum(log_F_dev_cB((endyr-
selpar_n_yrs_wgted+1),endyr)))/selpar_n_yrs_wgted)/F_temp_sum;

 log_F_dev_end_cR=sum(log_F_dev_cR((endyr-
selpar_n_yrs_wgted+1),endyr))/selpar_n_yrs_wgted;
 log_F_dev_end_cB=sum(log_F_dev_cB((endyr-
selpar_n_yrs_wgted+1),endyr))/selpar_n_yrs_wgted;

 F_end_L=sel_cR(endyr)*mfexp(log_avg_F_cR+log_F_dev_end_cR)+
     sel_cB(endyr)*mfexp(log_avg_F_cB+log_F_dev_end_cB);

 F_end=F_end_L;
 F_end_apex=max(F_end);

 sel_wgted_tot=F_end/F_end_apex;
 sel_wgted_L=elem_prod(sel_wgted_tot, elem_div(F_end_L,F_end));

 wgt_wgted_L_denom=F_cR_prop+F_cB_prop;
 wgt_wgted_L_mt=F_cR_prop/wgt_wgted_L_denom*wgt_cR_mt(endyr)+
       F_cB_prop/wgt_wgted_L_denom*wgt_cB_mt(endyr);

FUNCTION get_msy

 //compute values as functions of F
 for(ff=1; ff<=n_iter_msy; ff++)
 {
  //uses fishery-weighted F's
  Z_age_msy=0.0;
  F_L_age_msy=0.0;

  F_L_age_msy=F_msy(ff)*sel_wgted_L;
  Z_age_msy=wgted_M+F_L_age_msy;

  N_age_msy(1)=1.0;
  for (iage=2; iage<=nages; iage++)
  {
   N_age_msy(iage)=N_age_msy(iage-1)*mfexp(-1.*Z_age_msy(iage-1));
```

```
  }
  N_age_msy(nages)=N_age_msy(nages)/(1.0-mfexp(-1.*Z_age_msy(nages)));
  N_age_msy_mdyr(1,(nages-1))=elem_prod(N_age_msy(1,(nages-1)),
                          mfexp((-1.*Z_age_msy(1,(nages-1)))*spawn_time_frac));
  N_age_msy_mdyr(nages)=(N_age_msy_mdyr(nages-1)*
                  (mfexp(-1.*(Z_age_msy(nages-1)*(1.0-spawn_time_frac) +
                        Z_age_msy(nages)*spawn_time_frac) )))
                  /(1.0-mfexp(-1.*Z_age_msy(nages)));

  spr_msy(ff)=sum(elem_prod(N_age_msy_mdyr,wgted_reprod));


  //Compute equilibrium values of R (including bias correction), SSB and Yield at each F
  if(set_SR_switch>1) //Beverton-Holt
  {
   R_eq(ff)=(R0/((5.0*steep-1.0)*spr_msy(ff)))*
          (BiasCor*4.0*steep*spr_msy(ff)-wgted_spr_F0*(1.0-steep));
  }
  if(set_SR_switch<2) //Ricker
  {
   R_eq(ff)=R0/spr_msy(ff)*(1+log(BiasCor*spr_msy(ff))/steep);
  }
  if (R_eq(ff)<dzero) {R_eq(ff)=dzero;}
  N_age_msy*=R_eq(ff);
  N_age_msy_mdyr*=R_eq(ff);

  for (iage=1; iage<=nages; iage++)
  {
   L_age_msy(iage)=N_age_msy(iage)*(F_L_age_msy(iage)/Z_age_msy(iage))*
              (1.-mfexp(-1.*Z_age_msy(iage)));
  }


  SSB_eq(ff)=sum(elem_prod(N_age_msy_mdyr,wgted_reprod));
  B_eq(ff)=sum(elem_prod(N_age_msy,wgt_fish_mt(endyr)));
  L_eq_mt(ff)=sum(elem_prod(L_age_msy,wgt_wgted_L_mt));
  L_eq_knum(ff)=sum(L_age_msy);
 }

 msy_mt_out=max(L_eq_mt);

 for(ff=1; ff<=n_iter_msy; ff++)
 {
  if(L_eq_mt(ff) == msy_mt_out)
    {
```

```
      SSB_msy_out=SSB_eq(ff);
      B_msy_out=B_eq(ff);
      R_msy_out=R_eq(ff);
      msy_knum_out=L_eq_knum(ff);
      F_msy_out=F_msy(ff);
      spr_msy_out=spr_msy(ff);
     }
  }

//------------------------------------------------------------------------------------------------------------------
-----------------------------------------------------------------------
FUNCTION get_miscellaneous_stuff

  //compute total landings- and discards-at-age in 1000 fish and klb
  L_total_num.initialize();
  L_total_mt.initialize();

  L_total_num=(L_cR_num+L_cB_num); //catch in number fish
  L_total_mt=L_cR_mt+L_cB_mt;   //landings in klb whole weight

  for(iyear=styr; iyear<=endyr; iyear++)
  {
      L_total_mt_yr(iyear)=sum(L_total_mt(iyear));
      L_total_knum_yr(iyear)=sum(L_total_num(iyear));

      B(iyear)=elem_prod(N(iyear),wgt_fish_mt(iyear));
      totN(iyear)=sum(N(iyear));
      totB(iyear)=sum(B(iyear));
  }
  B(endyr+1)=elem_prod(N(endyr+1),wgt_fish_mt(endyr));
  totN(endyr+1)=sum(N(endyr+1));
  totB(endyr+1)=sum(B(endyr+1));

//  steep_sd=steep;
//  fullF_sd=Fsum;

  if(F_msy_out>0)
    {
     FdF_msy=Fapex/F_msy_out;
     FdF_msy_end=FdF_msy(endyr);
    }
  if(SSB_msy_out>0)
    {
     SdSSB_msy=SSB/SSB_msy_out;
     SdSSB_msy_end=SdSSB_msy(endyr);
```

```
   }

  //fill in log recruitment deviations for yrs they are nonzero
  for(iyear=styr_rec_dev; iyear<=endyr; iyear++)
  {
   log_rec_dev_output(iyear)=log_rec_dev(iyear);
  }
  //fill in log Nage deviations for ages they are nonzero (ages2+)
  for(iage=2; iage<=nages; iage++)
  {
   log_Nage_dev_output(iage)=log_Nage_dev(iage);
  }

  //Compute the exploitation rate for ages 1+ and pop wgtd F for ages 2+
   for(iyear=styr; iyear<=endyr; iyear++)
   {

E(iyear)=sum(L_cR_num(iyear)(2,nages)+L_cB_num(iyear)(2,nages))/sum(N(iyear)(2,nages));

F_age2plus(iyear)=((F_cB(iyear)(3,nages)+F_cR(iyear)(3,nages))*N(iyear)(3,nages))/sum(N(iye
ar)(3,nages));
     F_cR_age2plus(iyear)=(F_cR(iyear)(3,nages)*N(iyear)(3,nages))/sum(N(iyear)(3,nages));
     F_cB_age2plus(iyear)=(F_cB(iyear)(3,nages)*N(iyear)(3,nages))/sum(N(iyear)(3,nages));
   }


//----------------------------------------------------------------------------------------------------------
----------------------------------------------------------------------
FUNCTION get_per_recruit_stuff

 //static per-recruit stuff

 for(iyear=styr; iyear<=endyr; iyear++)
 {
   N_age_spr(1)=1.0;
   for(iage=2; iage<=nages; iage++)
   {
     N_age_spr(iage)=N_age_spr(iage-1)*mfexp(-1.*Z(iyear,iage-1));
   }
   N_age_spr(nages)=N_age_spr(nages)/(1.0-mfexp(-1.*Z(iyear,nages)));
   N_age_spr_mdyr(1,(nages-1))=elem_prod(N_age_spr(1,(nages-1)),
                         mfexp(-1.*Z(iyear)(1,(nages-1))*spawn_time_frac));
   N_age_spr_mdyr(nages)=(N_age_spr_mdyr(nages-1)*
                    (mfexp(-1.*(Z(iyear)(nages-1)*(1.0-spawn_time_frac) +
Z(iyear)(nages)*spawn_time_frac) )))
```

```
                    /(1.0-mfexp(-1.*Z(iyear)(nages)));
   spr_static(iyear)=sum(elem_prod(N_age_spr_mdyr,reprod(iyear)))/spr_F0(iyear);
  }


  cout << "sel_wgted_L = " << sel_wgted_L  << endl;
  cout << "wgted_M     = " << wgted_M  << endl;
  cout << "wgted_reprod = "  << wgted_reprod << endl;
  cout << "wgt_wgted_L_mt = " << wgt_wgted_L_mt << endl;

  //compute SSB/R and YPR as functions of F
  for(ff=1; ff<=n_iter_spr; ff++)
  {
   //uses fishery-weighted F's, same as in MSY calculations
   Z_age_spr=0.0;
   F_L_age_spr=0.0;

   F_L_age_spr=F_spr(ff)*sel_wgted_L;

   Z_age_spr=wgted_M+F_L_age_spr;

   N_age_spr(1)=1.0;
   for (iage=2; iage<=nages; iage++)
   {
    N_age_spr(iage)=N_age_spr(iage-1)*mfexp(-1.*Z_age_spr(iage-1));
   }
   N_age_spr(nages)=N_age_spr(nages)/(1-mfexp(-1.*Z_age_spr(nages)));
   N_age_spr_mdyr(1,(nages-1))=elem_prod(N_age_spr(1,(nages-1)),
                             mfexp((-1.*Z_age_spr(1,(nages-1)))*spawn_time_frac));
   N_age_spr_mdyr(nages)=(N_age_spr_mdyr(nages-1)*
                    (mfexp(-1.*(Z_age_spr(nages-1)*(1.0-spawn_time_frac) +
Z_age_spr(nages)*spawn_time_frac) )))
                    /(1.0-mfexp(-1.*Z_age_spr(nages)));
   F_spr_age2plus(ff)=F_L_age_spr(3,nages)*N_age_spr(3,nages)/sum(N_age_spr(3,nages));
   spr_spr(ff)=sum(elem_prod(N_age_spr,wgted_reprod));
   L_spr(ff)=0.0;
   for (iage=1; iage<=nages; iage++)
   {
    L_age_spr(iage)=N_age_spr(iage)*(F_L_age_spr(iage)/Z_age_spr(iage))*
                (1.-mfexp(-1.*Z_age_spr(iage)));
    L_spr(ff)+=L_age_spr(iage)*wgt_wgted_L_mt(iage); //in mt
   }
  }

FUNCTION get_effective_sample_sizes
```

```
    neff_cR_agec_allyr_out=missing;
    neff_cB_agec_allyr_out=missing;

    for (iyear=1; iyear<=nyr_cR_agec; iyear++)
      {if (nsamp_cR_agec(iyear)>=minSS_cR_agec)
        { numer=sum( elem_prod(pred_cR_agec(iyear),(1.0-pred_cR_agec(iyear))) );
          denom=sum( square(obs_cR_agec(iyear)-pred_cR_agec(iyear)) );
            if (denom>0.0) {neff_cR_agec_allyr_out(yrs_cR_agec(iyear))=numer/denom;}
            else {neff_cR_agec_allyr_out(yrs_cR_agec(iyear))=-missing;}
        } else {neff_cR_agec_allyr_out(yrs_cR_agec(iyear))=-99;}
      }

    for (iyear=1; iyear<=nyr_cB_agec; iyear++)
      {if (nsamp_cB_agec(iyear)>=minSS_cB_agec)
        { numer=sum( elem_prod(pred_cB_agec(iyear),(1.0-pred_cB_agec(iyear))) );
          denom=sum( square(obs_cB_agec(iyear)-pred_cB_agec(iyear)) );
            if (denom>0.0) {neff_cB_agec_allyr_out(yrs_cB_agec(iyear))=numer/denom;}
            else {neff_cB_agec_allyr_out(yrs_cB_agec(iyear))=-missing;}
        } else {neff_cB_agec_allyr_out(yrs_cB_agec(iyear))=-99;}
      }
//-----------------------------------------------------------------------------------------------------------------
-----------------------------------------------------------------------

FUNCTION get_Fmed_benchmarks

 //sorting function for recruitment and SPR values (slow algorithm, but works)
 R_temp=rec(styr_bench,endyr_bench);
 SPR_temp=pred_SPR(styr_bench,endyr_bench);
 for(int jyear=endyr_bench; jyear>=styr_bench; jyear--)
 {
  R_sort(jyear)=max(R_temp);
  SPR_sort(jyear)=max(SPR_temp);
  for(iyear=styr_bench; iyear<=endyr_bench; iyear++)
  {
   if(R_temp(iyear)==R_sort(jyear))
   {
    R_temp(iyear)=0.0;
   }
   if(SPR_temp(iyear)==SPR_sort(jyear))
   {
    SPR_temp(iyear)=0.0;
   }
  }
 }
```

```
 // compute the quantile using quant_whole (declared in the data section)
 // which computes the floor integer of a decimal number
 //median
 quant_decimal=(endyr_bench-styr_bench)*0.5;
 quant_whole=(endyr_bench-styr_bench)*0.5;
 quant_diff=quant_decimal-quant_whole;
 R_med=R_sort(styr_bench+quant_whole)*(1-
quant_diff)+R_sort(styr_bench+quant_whole+1)*(quant_diff);
 SPR_med=SPR_sort(styr_bench+quant_whole)*(1-
quant_diff)+SPR_sort(styr_bench+quant_whole+1)*(quant_diff);
 //cout << "quant_decimal = " << quant_decimal << endl;
 //cout << "quant_whole = " << quant_whole << endl;
 //cout << "quant_diff = " << quant_diff << endl;
 //cout << "result = " << quant_whole*(1-quant_diff)+(quant_whole+1)*quant_diff << endl;
 //cout << "R_med = " << R_med << endl;
 //cout << "R_sort = " << R_sort << endl;
 //cout << "R = " << R_temp << endl;

 //75th quantile
 quant_decimal=(endyr_bench-styr_bench)*0.75;
 quant_whole=(endyr_bench-styr_bench)*0.75;
 quant_diff=quant_decimal-quant_whole;
 SPR_75th=SPR_sort(styr_bench+quant_whole)*(1-
quant_diff)+SPR_sort(styr_bench+quant_whole+1)*(quant_diff);
 //cout << "quant_decimal = " << quant_decimal << endl;
 //cout << "quant_whole = " << quant_whole << endl;
 //cout << "quant_diff = " << quant_diff << endl;
 //cout << "result = " << quant_whole*(1-quant_diff)+(quant_whole+1)*quant_diff << endl;

 //find F that matches SPR_med = F_med
 SPR_diff=square(spr_spr-SPR_med);
 SPR_diff_min=min(SPR_diff);
 for(ff=1; ff<=n_iter_spr; ff++)
 {
  if(SPR_diff(ff)==SPR_diff_min)
  {
   F_med=F_spr(ff);
   F_med_age2plus=F_spr_age2plus(ff);
   L_med=L_spr(ff)*R_med;
  }
 }
 SSB_med=SPR_med*R_med;
 SSB_med_thresh=SSB_med*0.5;
```

```
 //get the target that corresponds to Fmed, based on 75th quantile of SPR scatter
 SPR_diff=square(spr_spr-SPR_75th);
 SPR_diff_min=min(SPR_diff);
 for(ff=1; ff<=n_iter_spr; ff++)
 {
  if(SPR_diff(ff)==SPR_diff_min)
  {
   F_med_target=F_spr(ff);
   F_med_target_age2plus=F_spr_age2plus(ff);
  }
 }

FUNCTION evaluate_objective_function
 fval=0.0;
 fval_unwgt=0.0;

////---likelihoods---------------------------

////---Indices-------------------------------
 f_JAI_cpue=0.0;
 for (iyear=styr_JAI_cpue; iyear<=endyr_JAI_cpue; iyear++)
 {
  f_JAI_cpue+=square(log((pred_JAI_cpue(iyear)+dzero)/
     (obs_JAI_cpue_final(iyear)+dzero)))/(2.0*log(1.0+square(JAI_cpue_cv_final(iyear))));
 }
 fval+=w_I_JAI*f_JAI_cpue;
 fval_unwgt+=f_JAI_cpue;

 f_PN_cpue=0.0;
 for (iyear=styr_PN_cpue; iyear<=endyr_PN_cpue; iyear++)
 {
  f_PN_cpue+=square(log((pred_PN_cpue(iyear)+dzero)/
     (obs_PN_cpue(iyear)+dzero)))/(2.0*log(1.0+square(PN_cpue_cv(iyear))));
 }
 fval+=w_I_PN*f_PN_cpue;
 fval_unwgt+=f_PN_cpue;

////---Landings-------------------------------

 f_cR_L=0.0; //in 1000 mt
 for (iyear=styr_cR_L; iyear<=endyr_cR_L; iyear++)
 {
   f_cR_L+=square(log((pred_cR_L_mt(iyear)+dzero)/
    (obs_cR_L(iyear)+dzero)))/(2.0*log(1.0+square(cR_L_cv(iyear))));
 }
```

```
  fval+=w_L*f_cR_L;
  fval_unwgt+=f_cR_L;

  f_cB_L=0.0; //in 1000 mt
  for (iyear=styr_cB_L; iyear<=endyr_cB_L; iyear++)
  {
   f_cB_L+=square(log((pred_cB_L_mt(iyear)+dzero)/
       (obs_cB_L(iyear)+dzero)))/(2.0*log(1.0+square(cB_L_cv(iyear))));
  }
  fval+=w_L*f_cB_L;
  fval_unwgt+=f_cB_L;

//////---Age comps-------------------------------
  f_cR_agec=0.0;
  for (iyear=1; iyear<=nyr_cR_agec; iyear++)
  {
   if (nsamp_cR_agec(iyear)>=minSS_cR_agec)
    {
   f_cR_agec-=neff_cR_agec(iyear)*
          sum(elem_prod((obs_cR_agec(iyear)+dzero),
            log(elem_div((pred_cR_agec(iyear)+dzero),
              (obs_cR_agec(iyear)+dzero)))));
   }
  }
  fval+=w_ac*f_cR_agec;
  fval_unwgt+=f_cR_agec;


  f_cB_agec=0.0;
  for (iyear=1; iyear<=nyr_cB_agec; iyear++)
  {
   if (nsamp_cB_agec(iyear)>=minSS_cB_agec)
    {
   f_cB_agec-=neff_cB_agec(iyear)*
          sum(elem_prod((obs_cB_agec(iyear)+dzero),
            log(elem_div((pred_cB_agec(iyear)+dzero),
              (obs_cB_agec(iyear)+dzero)))));
   }
  }
  fval+=w_ac*f_cB_agec;
  fval_unwgt+=f_cB_agec;

////-----------Constraints and penalties--------------------------------
  f_rec_dev=0.0;
  f_rec_dev=norm2(log_rec_dev);
```

```
f_rec_dev=pow(log_rec_dev(styr_rec_dev),2);
for(iyear=(styr_rec_dev+1); iyear<=endyr; iyear++)
{f_rec_dev+=pow(log_rec_dev(iyear)-R_autocorr*log_rec_dev(iyear-1),2);}
fval+=w_rec*f_rec_dev;


f_rec_dev_early=0.0; //possible extra constraint on early rec deviations
if (styr_rec_dev<endyr_rec_phase1)
  {
   f_rec_dev_early=pow(log_rec_dev(styr_rec_dev),2);
   for(iyear=(styr_rec_dev+1); iyear<=endyr_rec_phase1; iyear++)
   {f_rec_dev_early+=pow(log_rec_dev(iyear)-R_autocorr*log_rec_dev(iyear-1),2);}
  }
fval+=w_rec_early*f_rec_dev_early;

f_rec_dev_end=0.0; //possible extra constraint on ending rec deviations
if (endyr_rec_phase2<endyr)
  {
   for(iyear=(endyr_rec_phase2+1); iyear<=endyr; iyear++)
   {f_rec_dev_end+=pow(log_rec_dev(iyear)-R_autocorr*log_rec_dev(iyear-1),2);}
  }
fval+=w_rec_end*f_rec_dev_end;

f_Ftune=0.0;
if (!last_phase()) {f_Ftune=square(Fapex(set_Ftune_yr)-set_Ftune);}
fval+=w_Ftune*f_Ftune;

//code below contingent on four phases
f_fullF_constraint=0.0;
if (!last_phase())
{for (iyear=styr; iyear<=endyr; iyear++)
    {if (Fapex(iyear)>3.0){f_fullF_constraint+=mfexp(Fapex(iyear)-3.0);}}
 if (current_phase()==1) {w_fullF=set_w_fullF;}
 if (current_phase()==2) {w_fullF=set_w_fullF/10.0;}
 if (current_phase()==3) {w_fullF=set_w_fullF/100.0;}
}

fval+=w_fullF*f_fullF_constraint;

//Random walk components of fishery dependent indices
f_PN_RW_cpue=0.0;
for (iyear=styr_PN_cpue; iyear<endyr_PN_cpue; iyear++)
   {f_PN_RW_cpue+=square(q_RW_log_dev_PN(iyear))/(2.0*set_q_RW_PN_var);}
fval+=f_PN_RW_cpue;
```

```
  //JAI combination weights penalty to sum to 1.0
  f_JAI_wgts=0.0;
  f_JAI_wgts=square(1.0-(wgt_JAI1+wgt_JAI2+wgt_JAI3+wgt_JAI4));
  fval+=w_JAI_wgts*f_JAI_wgts;

  f_priors=0.0;
  f_priors=norm2(log_Nage_dev);
  f_priors+=square(steep-set_steep)/square(set_steep_se);
  f_priors+=square(R_autocorr-set_R_autocorr);
  f_priors+=square(q_DD_beta-set_q_DD_beta)/square(set_q_DD_beta_se);

  if(switch_prior==1)
  {
   fval+=f_priors;
  }
  //cout << "fval = " << fval << "  fval_unwgt = " << fval_unwgt << endl;


REPORT_SECTION

  //cout<<"start report"<<endl;
  get_weighted_current();
  //cout<<"got weighted"<<endl;
  get_msy();
  //cout<<"got msy"<<endl;
  get_miscellaneous_stuff();
  //cout<<"got misc stuff"<<endl;
  get_per_recruit_stuff();
  //cout<<"got per recruit"<<endl;
  get_effective_sample_sizes();
  get_Fmed_benchmarks();

  //><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--
><>--><>--><>--><>
  report << "Likelihood " << "Value " << "Weight" << endl;
  report << "JAI_index " << f_JAI_cpue << " " << w_I_JAI << endl;
  report << "PN_index " << f_PN_cpue << " " << w_I_PN << endl;
  report << "reduction_agec " << f_cR_agec << " " << w_ac << endl;
  report << "L_reduction " << f_cR_L << " " << w_L << endl;
  report << "bait_agec " << f_cB_agec << " " << w_ac << endl;
  report << "L_bait " << f_cB_L << " " << w_L << endl;
  report << "R_dev " << f_rec_dev << " " << w_rec << endl;
  report << "R_dev_early " << f_rec_dev_early << " " << w_rec_early << endl;
  report << "R_dev_end " << f_rec_dev_end << " " << w_rec_end << endl;
  report << "F_tune " << f_Ftune << " " << w_Ftune << endl;
```

```
 report << "fullF_constraint " << f_fullF_constraint << " " << w_fullF << endl;
 report << "priors " << f_priors << " " << switch_prior << endl;
 report << "TotalLikelihood " << fval << endl;
 report << "UnwgtLikelihood " << fval_unwgt << endl;
 report << "Error levels in model" << endl;
 report << "JAI_cv " << JAI_cpue_cv << endl;
 report << "PN_cv " << PN_cpue_cv << endl;
 report << "L_reduction_cv " << cR_L_cv << endl;
 report << "L_bait_cv " << cB_L_cv << endl;
 report << "NaturalMortality Vector" << endl;
 report << "Age " << agebins << endl;
 report << "M_vector " << M << endl;
 report << "NaturalMortality Matrix " << endl;
 report << "Year " << agebins << endl;
 for(iyear=styr; iyear<=endyr; iyear++)
 {
  report << iyear << " " << M_mat(iyear) << endl;
 }
 report << "Steepness " << steep << endl;
 report << "R0 " << R0 << endl;
 report << "Recruits" << endl;
 report << "Year";
 for(iyear=styr; iyear<=endyr; iyear++)
 {
  report << " " << iyear;
 }
 report << endl;
 report << "Age-0_recruits " << column(N,1) << endl;
 report << "Age-1_recruits " << column(N,2) << endl;
 report << "SSB" << endl;
 report << "Year";
 for(iyear=styr; iyear<=endyr; iyear++)
 {
  report << " " << iyear;
 }
 report << endl;
 report << "FEC " << SSB << endl;
 //report << "SSB " << FEC << endl;
 report << "Lagged_R " << column(N,1)(styr+1,endyr) << endl;

//    cout<< mfexp(log_len_cv)<<endl;
//  report << "TotalLikelihood " << fval << endl;
 #include "menhad_make_Robject012.cxx"   // write the S-compatible report
```

18 Appendix 3. Concerns and additional analyses regarding reference points

Statement of the problem

The current overfished definition in the Atlantic menhaden FMP is SSB_{MED} as a target and 50% of SSB_{MED} as a threshold. Since the 2010 benchmark assessment, the Atlantic Menhaden Management Board adopted $F_{30\%}$ and $F_{15\%}$ as the menhaden management *F*-based overfishing target and threshold, respectively. The target and threshold population fecundity (SSB_{MED}) reference point currently used for menhaden management is presented in the body of this report using the methods from the 2009 benchmark assessment. **However, the TC warns that there is a technical mismatch between the current overfishing and overfished reference points. Logically, $SSB_{15\%}$ and $SSB_{30\%}$ (threshold and target, respectively) should be adopted if the Board wishes to define overfishing using $F_{30\%}$ and $F_{15\%}$ benchmarks.** Additional calculations and sensitivity runs were performed to estimate $SSB_{30\%}$ and $SSB_{15\%}$ and compare those estimates with other reference points – see below. Note SSB in this report implies fecundity, or mature ova.

Notes on methods

$SSB_{30\%}$ and $SSB_{15\%}$ reference points associated with $F_{30\%}$ and $F_{15\%}$ were calculated using the same vectors of average fecundity, M, and catch-weighted selectivity in addition to a value of median recruitment using the years 1955-2011. The uncertainty in the terminal year stock status indicators is expressed using the results of the 2,000 bootstrap runs of the base BAM model.

F-based biological reference points in the main body of this update report were calculated using average vectors from 1955-2011. The TC requested several analyses examining the reference points calculated across a shorter, more recent time period as a sensitivity analysis. The vectors used to calculate the *F*-based biological reference points included a vector of average fecundity, a vector of average M, and a catch weighted average selectivity vector.

Note F_{MED} is no longer being used for management, but is provided in Table 24 for continuity comparison with the 2010 assessment.

Supplemental results

Estimates of $SSB_{30\%}$ and $SSB_{15\%}$ and some exploration of the sensitivity of these results to model configuration are presented in Table 24 and Table 25. **If $SSB_{15\%}$ were adopted for management, the stock would be overfished.** The retrospective analysis, which re-estimates benchmarks annually, demonstrates that overfishing has been occurring during six of the last 12 years (Table 24) and that the population was overfished during nine of the last 12 years when using fecundity-per-recruit based benchmarks.

The entire time series of $SSB_{30\%}$ and $SSB_{15\%}$ and associated bootstrap confidence intervals are shown in Figure **73** and Figure **74** using the years 1955-2011 for benchmark calculation. Phase plots of the last ten years of fecundity-per-recruit-based estimates are shown in Figure 75 using the years 1955-2011 for benchmark calculation. The results based on fecundity-per-recruit based benchmarks indicate that the fecundity estimates for the terminal year are all below the threshold (limit) using the years 1955-2011 (Figure **76**).

Sensitivity to reference time period
Fecundity-per-recruit and yield-per-recruit (mt) estimates as a function of total full fishing mortality rates are shown in Figure **77** and Figure **78**Figure **78** for benchmarks calculated using the years 1990-2011. These plots are offered as a reference for comparison between fishing mortality rates. For example, using the years 1990-2011 for benchmark calculation, the terminal year full fishing mortality rate estimate (F_{2011}) of 4.50 is below $F_{7\%}$.

The entire time series of $SSB_{30\%}$ and $SSB_{15\%}$ and associated bootstrap confidence intervals are shown in Figure **79** and Figure **80** using the years 1990-2011 for benchmark calculation. Phase plots of the last ten years of estimates are shown in Figure **81** using the years 1990-2011 for benchmark calculation. The results based on fecundity-per-recruit based benchmarks indicate that the fecundity estimates for the terminal year are all below the threshold (limit) using the years 1955-2011 (Figure **82**).

Appendix 3 – Tables

Table 24. Results from base BAM model, sensitivity runs, and retrospective analysis. Median recruitment to age-0 (billions) is labeled as R_{MED}, fishing mortality (F) is full F, and population fecundity (SSB) is in billions of mature ova. Subscripts denote the following MED: median; MED.T: threshold associated with the median; and term: terminal year, which is 2011 for the six rows. * denotes that benchmark calculation is not directly comparable with the base run because of differences in selectivity.

Run	R_{MED}	F_{MED}	$F_{MED.T}$	SSB_{MED}	$SSB_{MED.T}$	F_{term} /F_{MED}	SSB_{term} /$SSB_{MED.T}$	$F_{15\%}$	$F_{30\%}$	$SSSB_{15\%}$	$SSB_{30\%}$	F_{term} /$F_{15\%}$	F_{term} /$F_{30\%}$	SSB_{term} /$SSB_{15\%}$	SSB_{term} /$SSB_{30\%}$
Base run	12.61	2.06	1.02	19092	9546	1.83	1.4	1.34	0.62	30551	61100	3.36	7.22	0.44	0.22
*cR dome-shaped selectivity	12.52	1.95	0.97	18090	9045	1.77	1.39	1.25	0.64	30326	60650	3.31	6.51	0.41	0.21
omit JAI	12.72	2.15	0.97	18365	9182	1.88	1.47	1.34	0.62	30809	61618	3.54	7.6	0.44	0.22
omit PRFC	12.61	2.06	1.02	19140	9570	2.07	1.32	1.34	0.62	30561	61123	3.82	8.2	0.41	0.21
median effective N	11.96	1.51	0.85	22043	11021	2.07	1.26	1.18	0.57	28993	57989	3.26	6.74	0.48	0.24
*cR and cB dome-shaped selectivity	14.84	1.4	0.33	23575	11787	1.04	3.67	1.09	0.65	35953	71906	1.51	2.52	1.2	0.6
Retrospective 2010	12.85	2.17	0.96	18337	9169	1.71	1.23	1.33	0.62	31342	62686	3.31	7.11	0.36	0.18
Retrospective 2009	13.09	2.29	0.99	17594	8797	1.71	1.88	1.33	0.62	32014	64027	2.75	5.9	0.52	0.26
Retrospective 2008	13.12	2.23	0.96	18198	9099	0.9	2.2	1.32	0.62	32300	64599	1.56	3.35	0.62	0.31
Retrospective 2007	13.09	2.32	0.95	17180	8590	1.09	1.48	1.31	0.61	32406	64812	2.3	4.93	0.39	0.2
Retrospective 2006	13.14	2.27	0.99	17679	8839	0.95	2.5	1.3	0.61	32627	65251	1.46	3.13	0.68	0.34
Retrospective 2005	13.26	2.29	1.02	17560	8780	0.37	4.77	1.3	0.61	33006	66008	0.63	1.34	1.27	0.63
Retrospective 2004	13.25	2.3	1	17318	8659	0.49	3.06	1.3	0.61	33009	66020	0.94	2	0.8	0.4
Retrospective 2003	13.26	2.32	0.98	17077	8539	0.47	2.74	1.29	0.6	32983	65963	0.91	1.95	0.71	0.35
Retrospective 2002	13.89	2.26	0.98	17940	8970	0.58	4.31	1.27	0.6	34252	68498	0.89	1.89	1.13	0.56
Retrospective 2001	14.58	2.26	0.97	18570	9285	0.29	6.42	1.26	0.6	35757	71518	0.5	1.06	1.67	0.83
Retrospective 2000	14.6	2.26	0.97	18266	9133	0.43	2.41	1.26	0.59	35483	70970	0.85	1.81	0.62	0.31

Table 25. Summary of benchmarks and terminal year (2011) values estimated for the base BAM model. Fishing mortality rate is full F, and SSB is fecundity in billions of mature ova. The benchmarks were calculated using two time periods: 1955-2011 and 1990-2011.

Benchmarks and Terminal Year Values	**Base BAM Model Estimates 1955-2011**	**Base BAM Model Estimates 1990-2011**
Median Age-0 Recruits (billions)	12.61	8.96
Threshold (Limit): F_{MED}	2.06	1.51
Target: $F_{MED.target}$	1.02	1.04
$F_{30\%}$	0.62	0.7
$F_{15\%}$	1.34	1.53
F_{2011}	4.5	4.5
F_{2011}/F_{MED}	1.83	2.5
$F_{2011}/F_{30\%}$	7.22	6.43
$F_{2011}/F_{15\%}$	3.36	2.94
Target: SSB_{MED}	19,092	25,186
Threshold (Limit): $SSB_{MED.thresh}$	9,546	12,593
$SSB_{30\%}$	61,100	49,537
$SSB_{15\%}$	30,551	24,767
SSB_{2011}	13,334	13,334
$SSB_{2011}/SSB_{threshold}$	1.4	1.05
$SSB_{2011}/SSB_{30\%}$	0.22	0.27
$SSB_{2011}/SSB_{15\%}$	0.44	0.54

Appendix 3 - Figures

Figure 73. Estimates of the population fecundity (SSB) relative to the limit SSB15% from the base BAM model (connected points) using benchmarks calculated over 1955-2011. Shaded area represents the 90% confidence interval of the bootstrap runs.

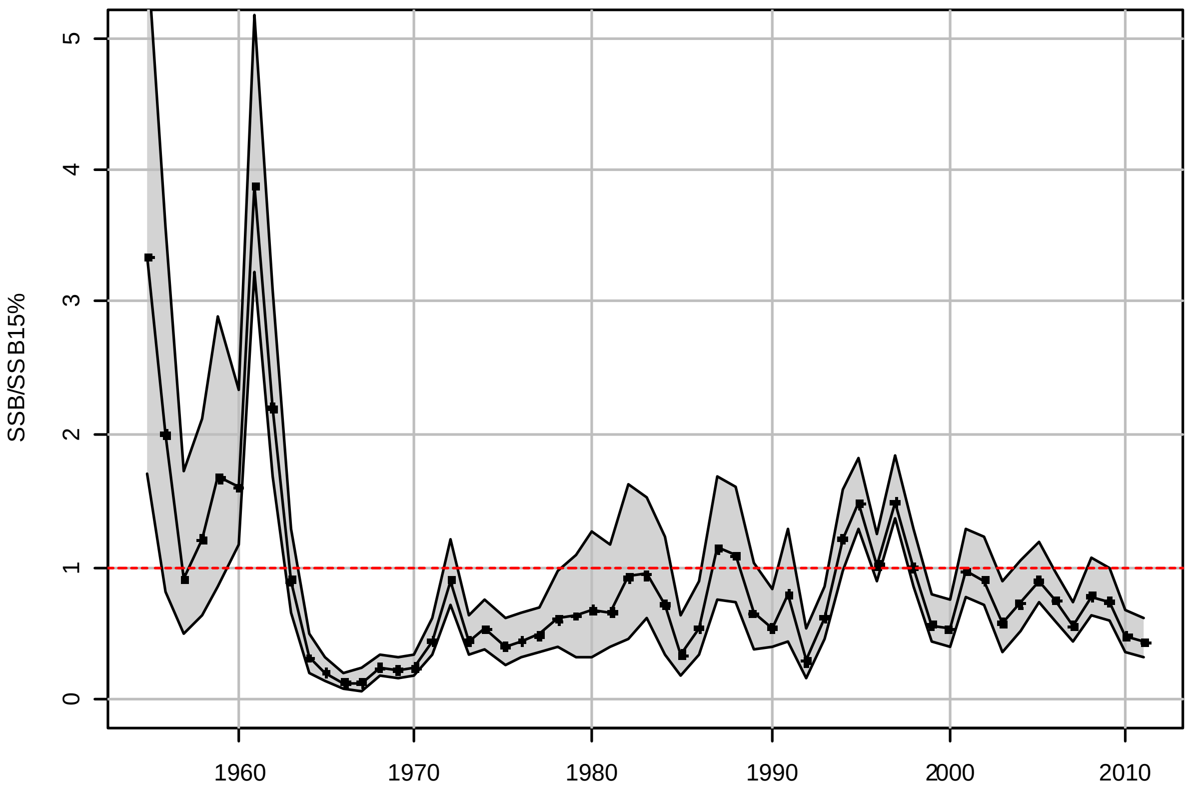


Figure 74. Estimates of the population fecundity (SSB) relative to the target SSB30% from the base BAM model (connected points) using benchmarks calculated over 1955-2011. Shaded area represents the 90% confidence interval of the bootstrap runs.

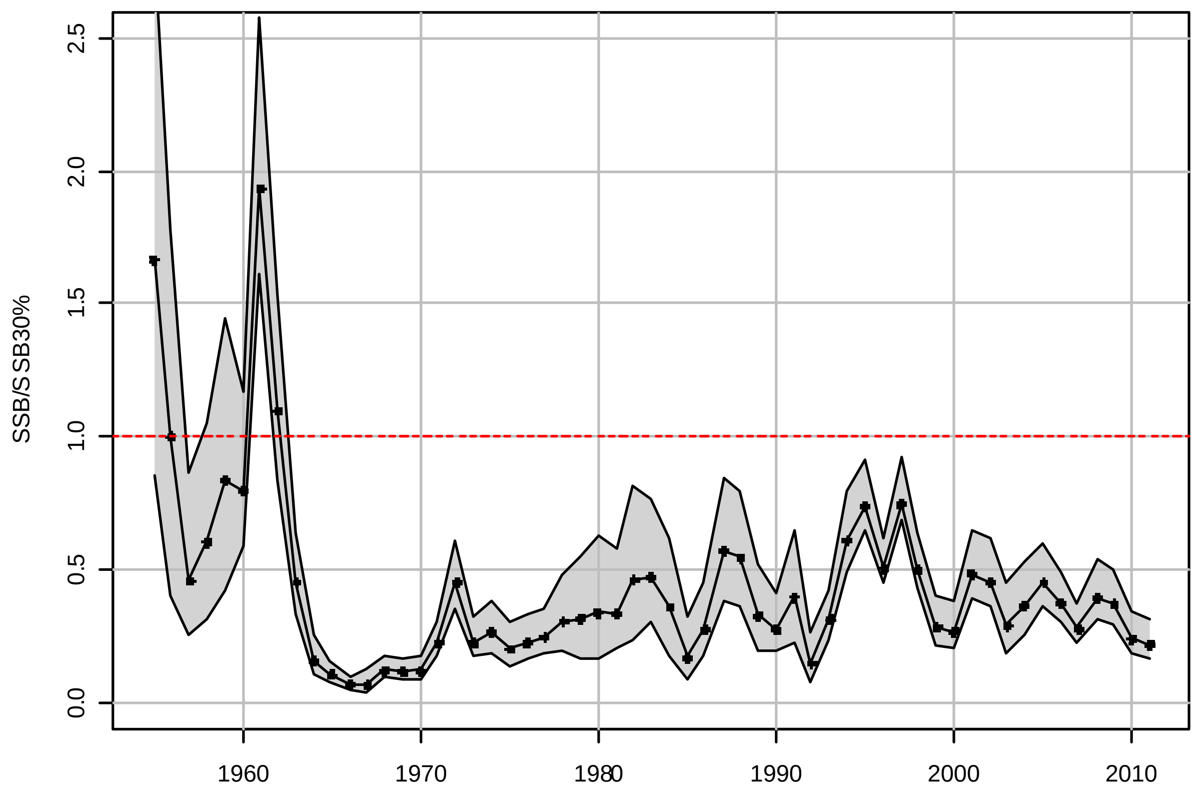


Figure 75. Phase plot of recent estimates of the population fecundity (mature ova in billions) and total full fishing mortality rate from the base BAM model with fecundity-per-recruit based benchmarks calculated using the years 1955-2011. Solid vertical and horizontal lines indicate the targets and limits for each respective axis. Double digit number in circles indicates the year of the point estimate (e.g. 08 = 2008).

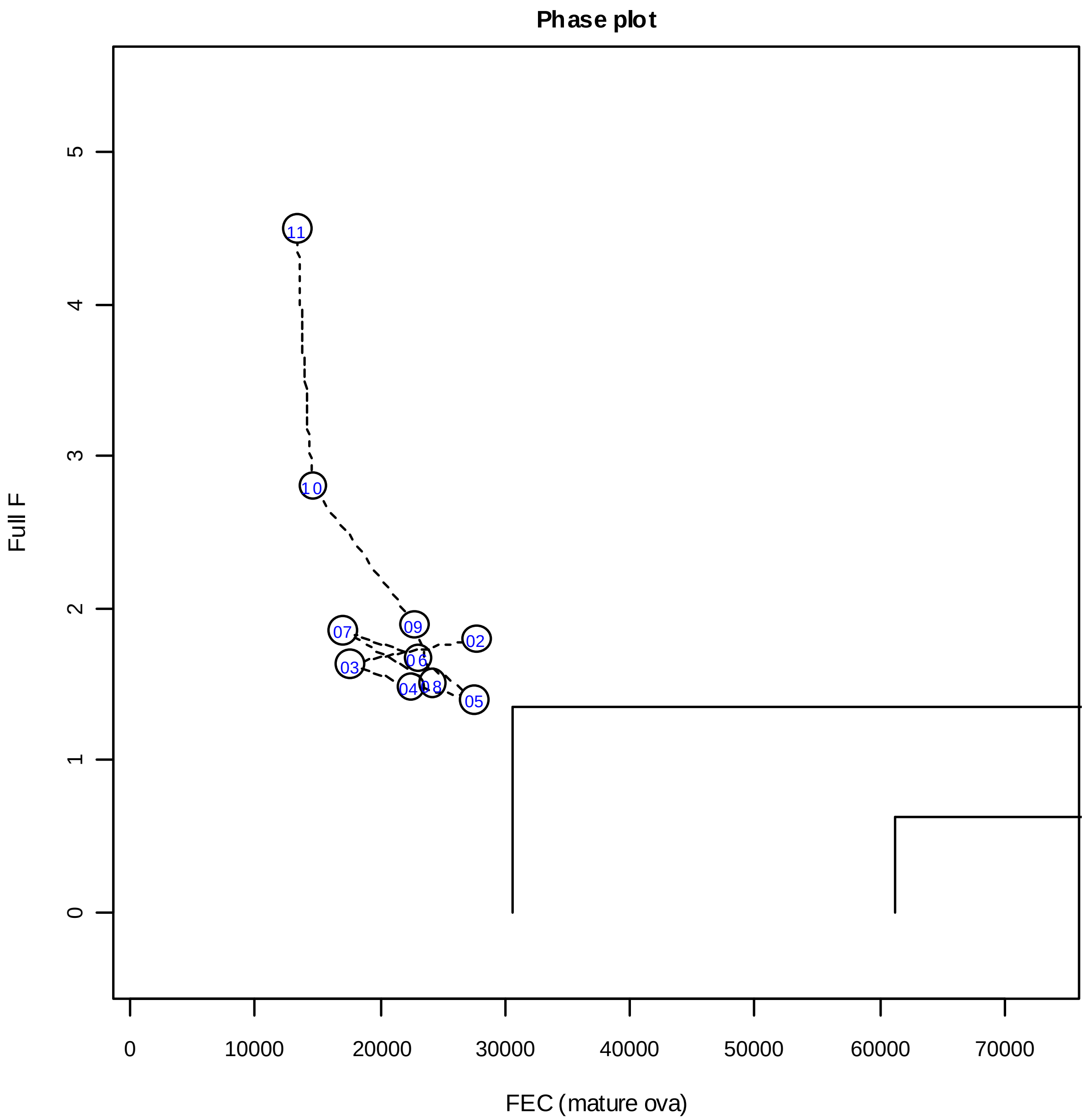


Figure 76. Scatter plot of the 2011 estimates relative to the F15% benchmarks (limits) from the 2,000 bootstrap estimates from the base BAM model. All years 1955-2011 were used to calculate the benchmarks.

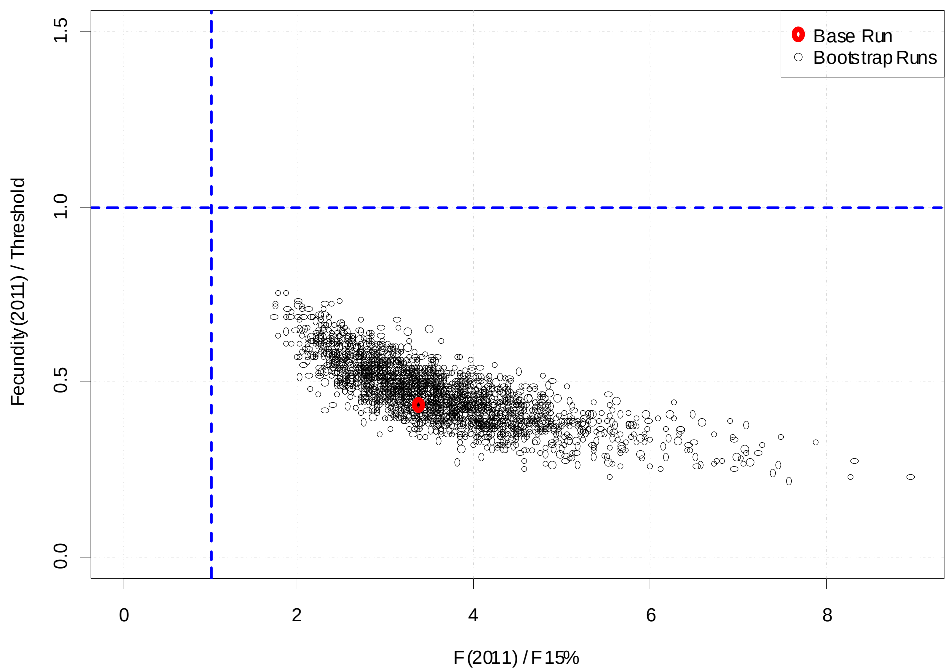


Figure 77. Estimates of the proportional (re-scaled to max of 1.0) fecundity-per-recruit as a function of the total full fishing mortality rate from the base BAM model using the years 1990-2011 for benchmark calculations.

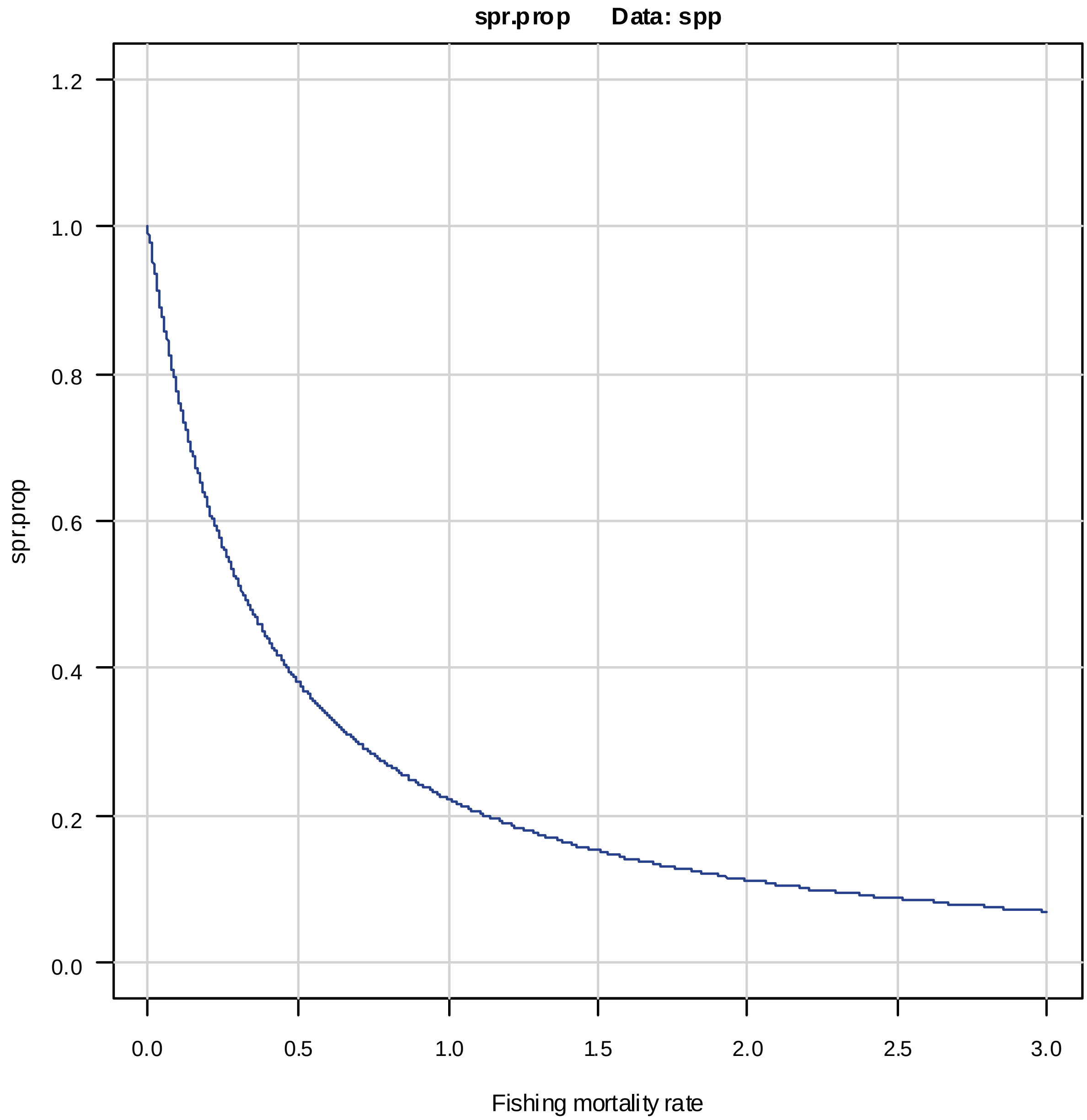


Figure 78. Estimates of the yield-per-recruit (mt/million) as a function of the total full fishing mortality rate from the base BAM model using the years 1990-2011 for benchmark calculations.

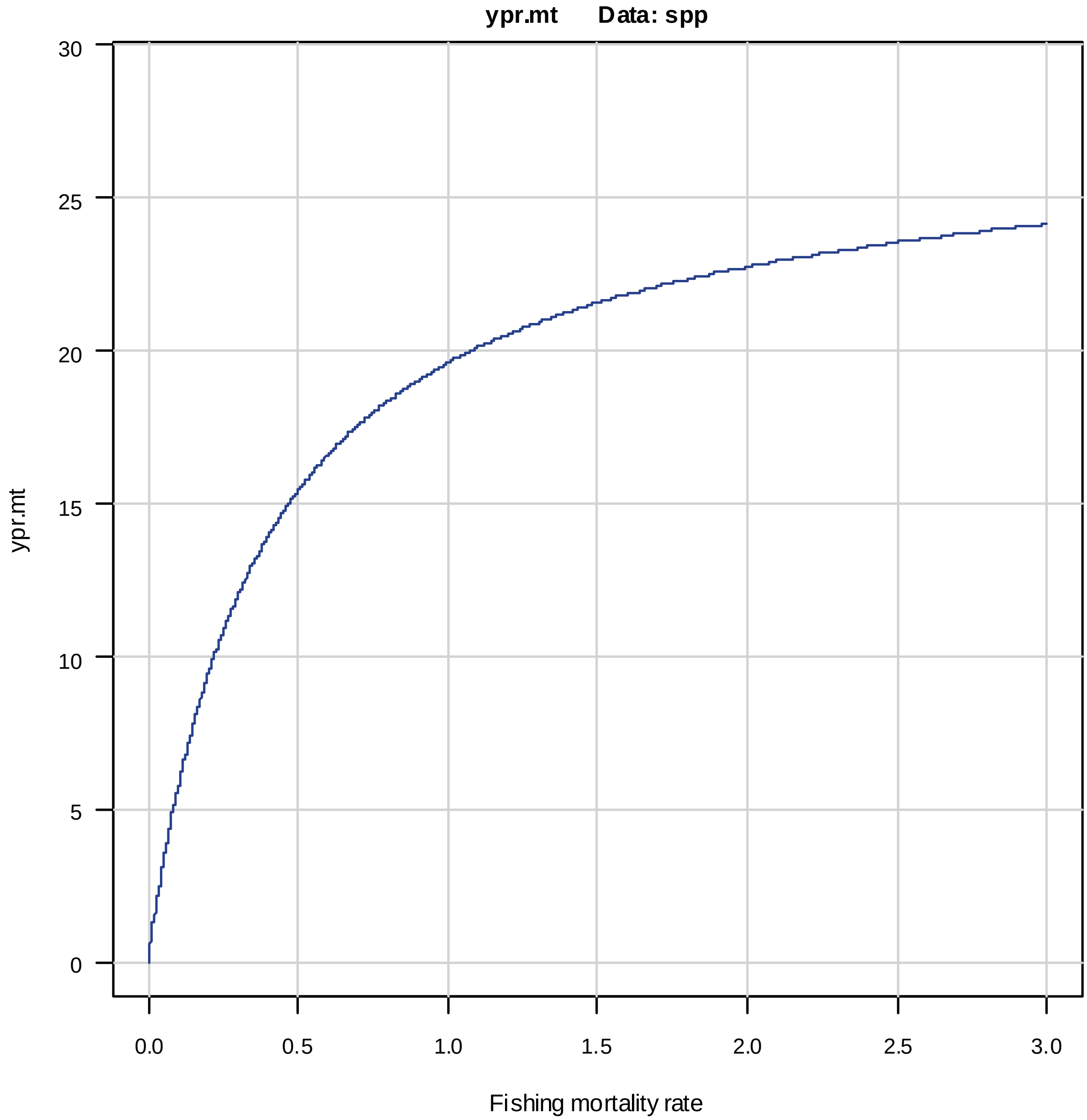


Figure 79. Estimates of the total full fishing mortality rate relative to the F15% benchmark (fishing limit value) from the base BAM model (connected points) using benchmarks calculated over 1990-2011. Shaded area represents the 90% confidence interval of the bootstrap runs.

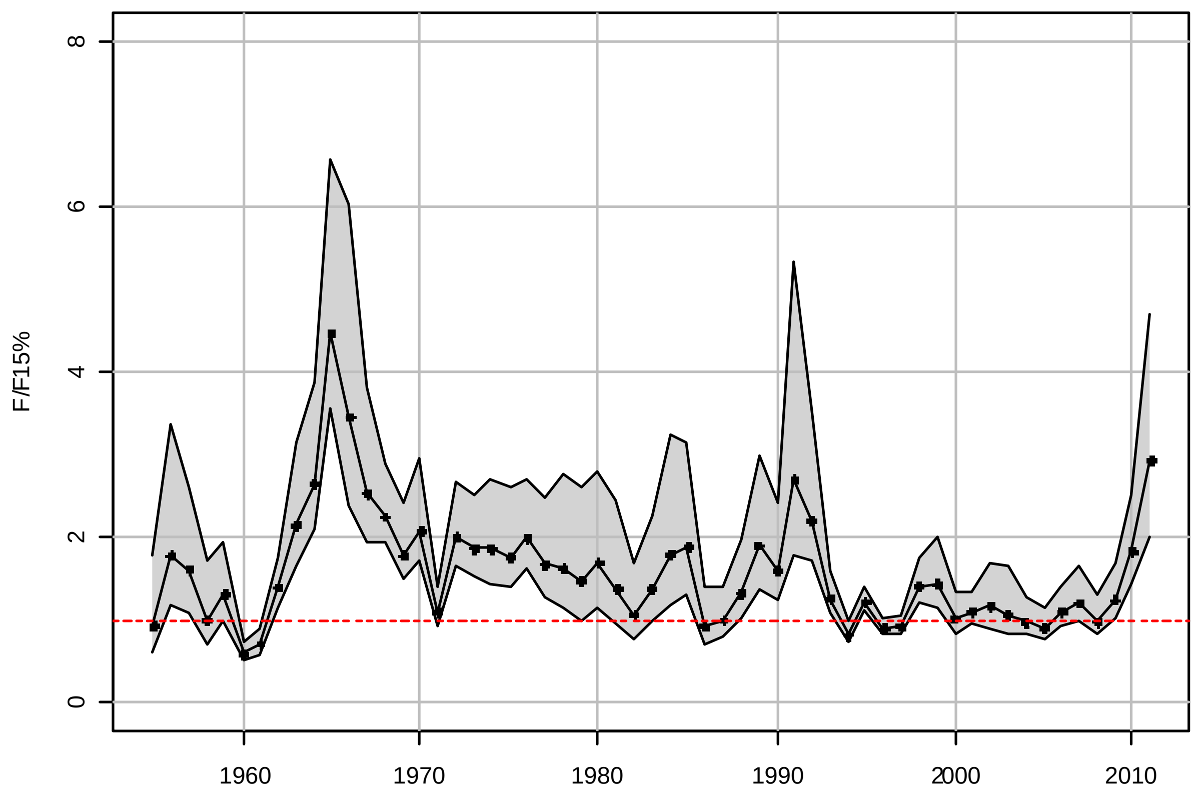


Figure 80. Estimates of the population fecundity (SSB) relative to the target SSB30% from the base BAM model (connected points) using benchmarks calculated over 1990-2011. Shaded area represents the 90% confidence interval of the bootstrap runs.

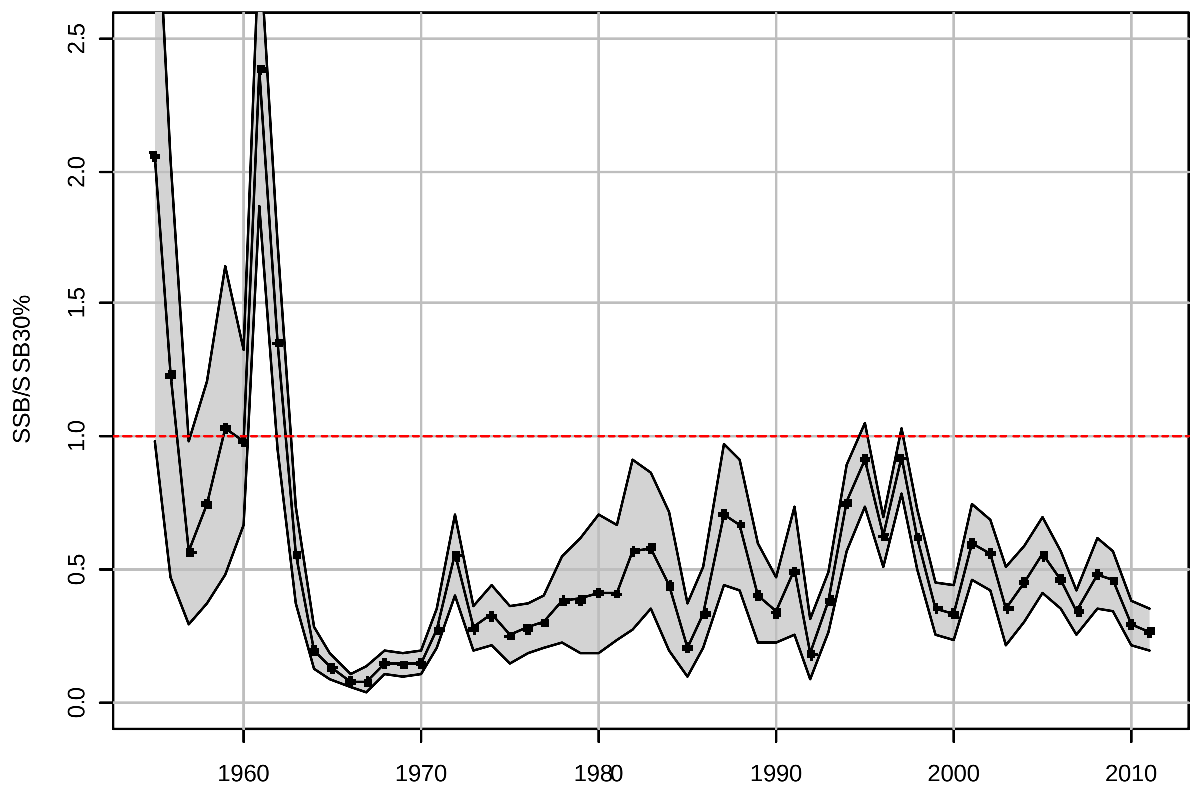


Figure 81. Phase plot of recent estimates of the population fecundity (mature ova in billions) and total full fishing mortality rate from the base BAM model with fecundity-per-recruit based benchmarks calculated using the years 1990-2011. Solid vertical and horizontal lines indicate the targets and limits for each respective axis. Double digit number in circles indicates the year of the point estimate (e.g. 08 = 2008).

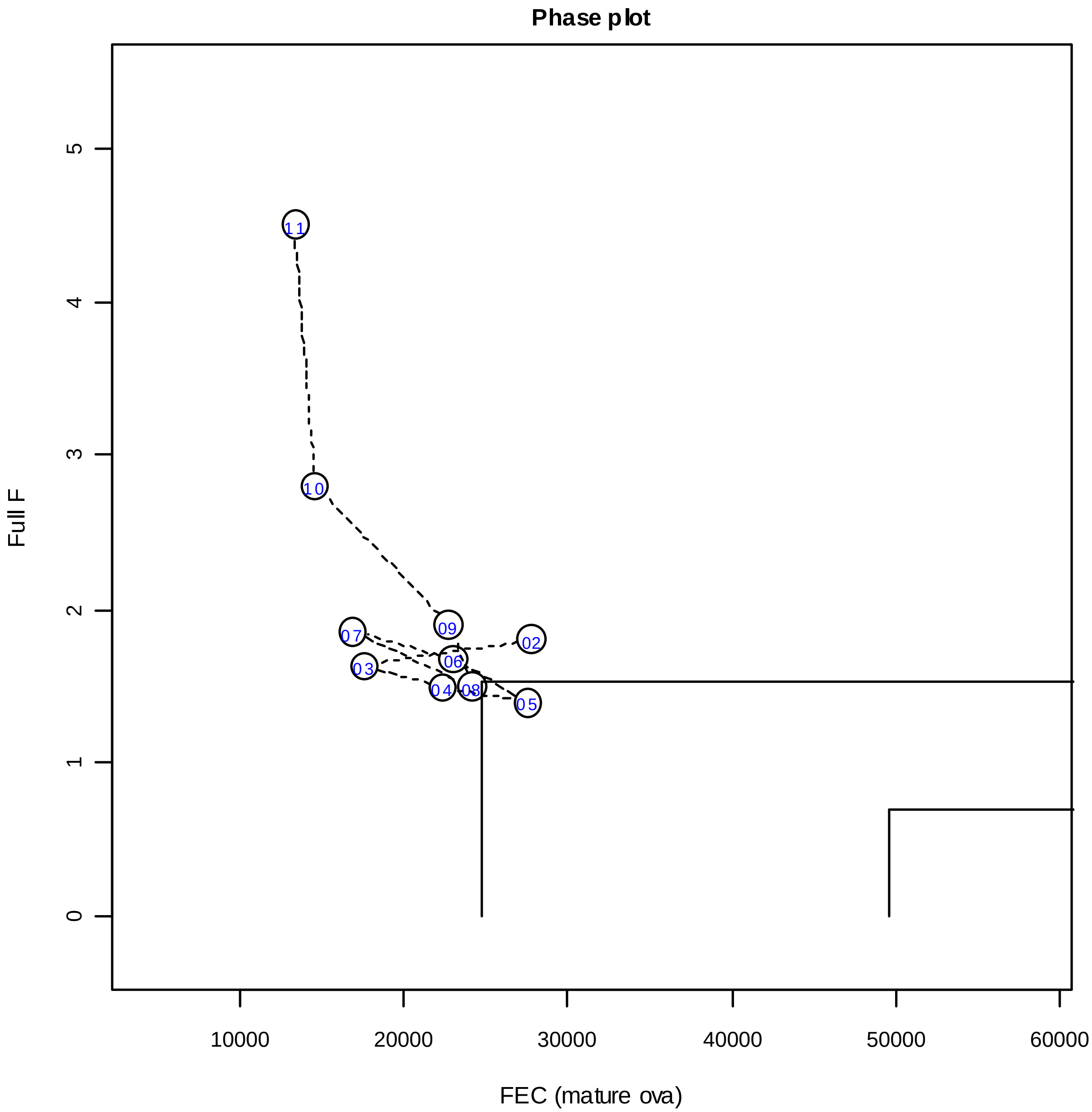
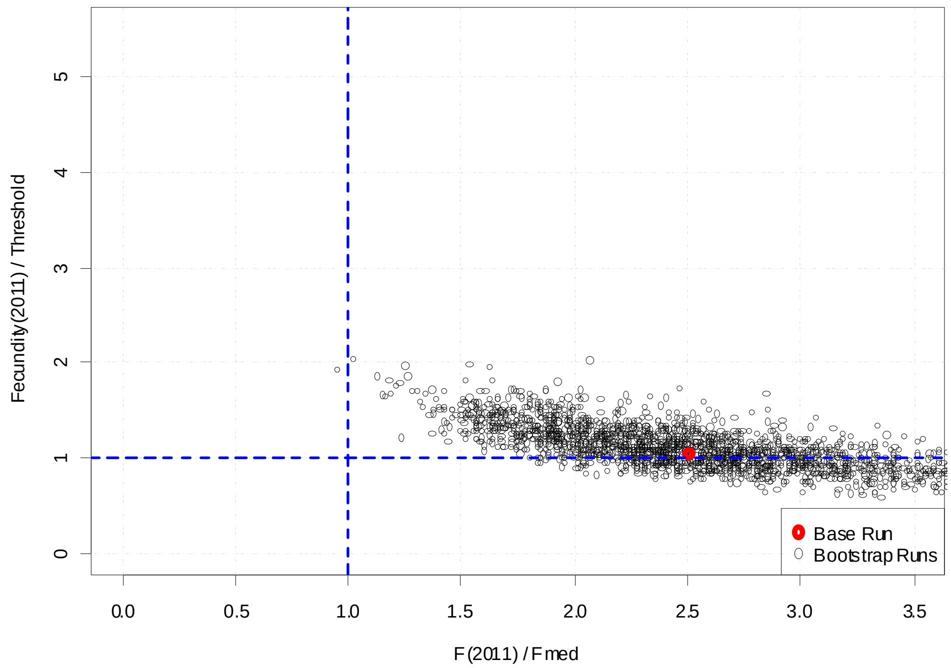


Figure 82. Scatter plot of the 2011 estimates relative to the FMED benchmarks (limits) from the 2,000 bootstrap estimates from the base BAM model using truncated years 1990-2011 (lower panel) to calculate benchmarks.



19 Appendix 4. Alternative approaches to set harvest limits in data poor situations

Table 26. Summary of ad-hoc "rules" used by Fishery Management Councils to set harvest limits in data poor situations.

Council	Species group	Multiplier	Comments
New England	Atlantic herring	1	Not OF, OF not occurring
New England	Red crab	1	Based on stock status
Carribean		0.85	Used to set ABC and ACL
New England	Groundfish	0.75	
Pacific		0.75	Used to set ABC
Pacific	Groundfish	0.5	Used to set OY
Pacific	Coastal pelagics	0.25	Used to set ABC

Table 27. Estimated harvest levels (thousand MT) for a range of uncertainty correction factors.

Probability of ending overfishing decreases as you move towards a multiplier of 1

Average	Multiplier					
	1	0.9	0.8	0.75	0.5	0.25
3-year	213.5	192.2	170.8	160.2	106.8	53.4
5-year	209.5	188.5	167.6	157.1	104.7	52.4

20 Appendix 5. 2012 Update of the Expanded Multispecies Virtual Population Analysis

INTRODUCTION

Background

The Expanded Multispecies Virtual Population Analysis (MSVPA-X) was developed by ASMFC and peer reviewed during SARC 42 in 2006 (Garrison et al. 2010, NEFSC 2006b). The 2006 base run utilized the best available single-species assessment and diet data for important predator (striped bass, bluefish, weakfish) and prey (menhaden, other prey) species for the period 1982–2002 from the mid-Atlantic region. An update assessment for the MSVPA-X occurred in 2008 during which all data source were updated through 2006 (ASMFC 2008). The MSVPA-X was partially updated in 2009 with new predator and menhaden input data through 2008 in preparation for the 2010 menhaden benchmark assessment. Major predator and prey data sources were used to update the MSVPA-X again in preparation for the 2012 menhaden update as described in this report.

Overview of changes to base run configuration

In addition to updating the model with new data, the following minor but necessary configuration changes were made to the 2012 base run: weight-at-age estimates for weakfish were revised and several striped bass indices were removed from the striped bass XSA.

DATA INPUT AND MODEL PARAMETERIZATION

Atlantic menhaden

Commercial Landings and Catch-at-Age (CAA)

Reduction fishery: Reduction fishery CAA was updated in the MSVPA-X through 2010. Landings from the reduction fishery have been provided to and summarized by the NMFS Beaufort Laboratory since 1955. The Beaufort Laboratory has also conducted biological sampling for the reduction fishery since 1955, based on a two-stage cluster design. This sampling is conducted over the range of the fishery, both temporally and geographically. Sampling protocols and estimation of catch at age are described in the latest benchmark assessment for Atlantic menhaden for ASMFC (ASMFC 2010b) and have not changed.

Bait fishery: Bait fishery CAA was updated in the MSVPA-X through 2010. Landings from the bait fishery have been provided by the individual coastal states since 1985. Landings were adjusted for missing Virginia snapper vessel landings (1993-1997) as described in the 2008 update (ASMFC 2008). Sampling protocols and estimation of CAA are described in the latest benchmark assessment for Atlantic menhaden for ASMFC (ASMFC 2010b) and have not changed. Because sampling is much less intense than for the reduction fishery, estimated catch-at-age for the bait fishery is subject to greater uncertainty.

Tuning indices

Fishery-independent surveys: An aggregated juvenile abundance index was developed from six state seine surveys, namely NC, VA, MD, NJ, NY, CT, and RI (Figure A5. 1).

The methodology for developing these individual indices and combining them into a coastwide juvenile abundance index is described in the recent benchmark assessment for Atlantic menhaden for ASMFC (ASMFC 2010b) and has not changed.

Potomac River Fisheries Commission pound net index: This index is pounds per net days fished, and the methods from the recent benchmark assessment for Atlantic menhaden (ASMFC 2010b) were used to update the index for this MSVPA-X update (Figure A5. 2).

Striped bass

Catch-at-age, weight-at-age, and tuning indices for striped bass used in this update of the MSVPA-X were taken from the most recent ASMFC striped bass update assessment (ASMFC 2011).

Catch-at-age

Catch-at-age was estimated using standard methods (NEFSC 2008). Commercial landings-at-age were estimated by applying corresponding length-frequency distributions and age-length keys to the reported number of fish landed by the commercial fishery in each state. Length-frequencies of recreational landings were based on a combination of Marine Recreational Fisheries Statistics Survey (MRFSS) length samples and volunteer angler logbooks. State specific age-length keys were applied, where possible, to length frequencies to estimate number of fish-at-age landed by the recreational fishery. Age composition of the recreational discards was estimated using lengths available from volunteer angler logbooks and American Littoral Society data. State specific methods for estimating age composition of commercial landings, recreational landings, and recreational discards are provided in individual state compliance reports to ASMFC.

Annual weight- and size-at-age

Annual estimates of striped bass weights at age in the coast-wide population were reported in Barker (2005) and Barker and Warner (2007). The coast-wide WAA calculations were based on individual fishery elements for each state that reported landings and biological characteristics. The coast-wide WAA was calculated for each age as the weighted mean of the fish at that age in each fishery, where weights were the proportion of each fishery contribution (in numbers) to the coast-wide catch for that age.

Year specific size-at-age was calculated using year specific mean weight-at-age (Barker and Warner, 2007) and length weight relationship:

$$W_a = e^{-7.792+2.982\ln L_a}$$

where W_a is mean weight (lb) at age a and L_a is mean total length (inches) at age a. Size-at-age for 2007-2008 was not updated and was assumed the same as 2006. Size-at-age for 2009-2010 was updated.

Tuning indices

All abundance indices included in the 2011 striped bass update were included in the MSVPA-X as either age-specific or age-aggregated indices. Young of year (age-0) indices included those from Maryland, Virginia, New Jersey, and New York. Juveniles (age-1) indices were available for Maryland and New York. Adult indices included the New Jersey trawl (ages 2–13+), Delaware River electrofishing spawning stock indices (ages 2–13+), Maryland spawning survey (ages 2 – 15+), Connecticut trawl (ages 4-6), and the coastwide MRFSS aggregate (ages 2–13+) total catch rate index.

Connecticut's age-specific recreational CPUE index was not reproducible and was thus eliminated from the XSA. The NEFSC spring inshore survey was not used in the striped bass update and was thus removed from the XSA. The New York ocean haul seine survey and the Massachusetts commercial CPUE surveys ended in recent years and cannot be updated; these indices should be removed from the XSA during the next update. The Delaware trawl survey was mistakenly retained in this run as well and will be removed when the model is next updated.

Weakfish

Catch-at-age

Catch-at-age data are supplied either individually by state, or by estimating catch-at-age from length-frequency data and applying regional length-weight and age-length relationships as appropriate (ASMFC 2006c, Part A; NEFSC 2009). For the SARC-reviewed MSVPA-X model (NEFSC 2006b), the fishery catch-at-age matrix included commercial and recreational landings, and recreational discard estimates. Commercial discard estimates were not included in the catch-at-age matrix until the 2008 MSVPA-X update (ASMFC 2008). For the 2012 MSVPA-X update, catch-at-age again includes removals from all four sectors (commercial and recreational harvest and discards) covering the period 1982 to 2010 for ages 1 through 6+.

A benchmark stock assessment for weakfish in 2009 revised and updated estimates of harvest at age for the period 1981 to 2006 (Table A5. 1; see NEFSC 2009 for details). Recent (2007-2010) recreational harvest estimates and catch-at-age were calculated as in the 2009 stock assessment; however, because of some changes in fishery regulations and data availability, commercial data were treated using slightly different methods than in the past. For the SARC review and 2008 update, commercial harvest weight was converted to numbers at size using state-year-season-gear specific biological samples where available. Recently, population declines and regulation changes have severely limited weakfish harvest, and the number of biological samples has dropped dramatically. As a result, harvest weight from 2008-2010 was converted to numbers at size using region-wide sample data (region-year-season). Commercial discards for 2008-2010 were calculated using multi-year ratios from the 2009 stock assessment for appropriate gear-species combinations, but implementation of trip limits in 2010 required calculation of additional discards for that year. The NMFS Commercial Fisheries Database System (CFDBS) was queried for trips that landed weakfish from 2005-2009. The trip limit from 2010 was applied to these trips to estimate harvest had the trip limit been in place in those years. The ratio of "restricted" 2005-2009 harvest to reported 2005-2009 harvest was calculated and applied to 2010 reported harvest to estimate harvest if the trip limits had not been in effect. The difference between 2010 reported harvest and estimated "unrestricted" harvest was added to the discard estimates developed from the multi-year gear-species combinations.

Tuning indices

The most recent weakfish stock assessment that uses VPA as the preferred method (ASMFC 2006) was tuned using fishery dependent CPUE from the federal recreational fisheries survey. A more recent weakfish assessment included additional indices for tuning the VPA, but VPA was not selected as the preferred assessment model (NEFSC 2009). The 2012 MSVPA update therefore uses only the recreational fishery dependent indices to tune the weakfish model. An age aggregated index of CPUE for ages 2+ was developed using catch (numbers) per private/rental boat trip in the Mid-Atlantic region. The Mid-Atlantic region is the center of the weakfish stock, and the private/rental sector is a highly mobile fleet, able to maintain contact with the stock throughout the season (*i.e.* the index is less likely to be biased by lack of spatial overlap during certain seasons) (ASMFC 2006c). In addition, age specific indices of harvest per unit effort (HPUE) were developed for ages 3-6+ using the same criteria (number per Mid-Atlantic private/rental boat trip).

Annual weight- and size-at-age

As with the 2008 update, annual size- and weight-at-age estimates for the 2012 update were calculated using year-specific von Bertalanffy parameters developed by Vaughan (unpublished data) for the period from 1990-1999 based upon otolith data (Kahn 2002 and D. Vaughn, SEFSC, pers. comm) and 2001 to 2010 (NEFSC 2009; J. Brust, pers. comm.). The 1992 estimates were applied for the period from 1982 to 1991. For 2000, estimates from 1999 and 2001 were averaged. When reviewing inputs from previous MSVPA-X model runs (Garrison et al. 2011, NEFSC 2006b, ASMFC 2008) several inconsistencies were noted in the weakfish weights at age. For the 2012 update, the entire time series of weight at age was updated using the estimated weight at age from the 2009 weakfish benchmark stock assessment (NEFSC 2009)(Table A5. 2, Table A5. 3).

Bluefish

Biomass estimates for the 2009 MSVPA-X base run were derived from the 2009 ASAP age-structured model (1982-2008 values from Table 5 in ASMFC 2009b). Biomass estimates for the 2012 update were taken from the 2011 bluefish stock assessment update (1982-2010 values from Table 11 in NEFSC 2011a). The time series of total bluefish biomasses are shown in Figure A5. 3.

An analysis of bluefish diet information based upon the NEFSC food habits database (http://www.nefsc.noaa.gov/pbio/fwdp/databases.html#survey) indicated significant breaks in bluefish diets in three size/age classes: 10-30 cm (ages 0-1), 30-60 cm (ages 2-3), and >60 cm (ages 4+) (ASMFC 2008). These three size classes were used in the MSVPA-X model to account for ontogenetic changes in feeding selectivity and consumption parameters. The proportion of the total biomass in each age class was estimated from the age-specific ASAP biomass estimates from the 2011 bluefish stock assessment update (Table 11 in NEFSC 2011a; i.e., for each of the three size classes, the sum of annual biomasses within the size class ÷ total biomass across all years and ages). For the 2012 update, these input values were: Size 1 = 0.0451; Size 2 = 0.1553; Size 3 = 0.7996.

Other prey (non-menhaden)

Macrozooplankton

Crangonid shrimps, mysids, and other large zooplankton are primary prey items for young age classes of each predator species. However, no new estimates of macrozooplankton density have been published since Monaco and Ulanowicz (1997). Biomass estimates for macrozooplankton derived during the 2006 MSVPA-X configuration (NEFSC 2006b) were retained for this update.

Benthic invertebrates

The three primary benthic invertebrate taxa important in the diets of weakfish, bluefish, and striped bass are gammarid amphipods, isopods, and polychaetes. Regional density estimates for these benthic invertebrate taxa were developed from a systematic benthic sampling program of the U.S. Atlantic continental shelf described in Wigley and Theroux (1981) and Theroux et al. (1998). While these estimates of benthic invertebrate biomass are based upon several decades old data, there is not a more recent broadscale estimate of benthic biomass available over the U.S. Atlantic continental shelf. The resulting total estimated biomass of benthic invertebrates is 3,357,000 mt (NEFSC 2006b) and has been retained in the 2012 update. The size structure of the benthic invertebrate taxa was inferred from general descriptions of the observed size ranges in these habitats (NEFSC 2006b).

Benthic crustaceans

The "other prey" group called benthic crustaceans in the MSVPA-X includes blue crab, American lobster, rock crab, and Jonah crab. These species make up a small, but consistent, proportion of the diet of striped bass, bluefish, and weakfish (NEFSC 2006b). Revised lobster biomass estimates produced during the 2009 benchmark assessment have shifted the primary contributor to this grouping of other prey from blue crab to lobster. In the 2012 base run, revised estimates of total annual total benthic crustacean biomass were obtained by summing estimates for all four species (Table A5. 4).

<u>Blue crabs:</u> Blue crab population estimates were available only for the largest, commercially important populations of blue crab in Chesapeake Bay, Delaware Bay, and North Carolina sounds. Estimated biomass was summed across all three areas. Blue crab found in predator stomachs do not exceed the size of approximately 60 mm (R. Latour, VIMS ChesMMAP, pers. comm.); therefore, only total biomass of blue crab <=60 mm in size was included in the analysis.

Estimates of biomass of age 0 (<60 mm carapace width) blue crab in Chesapeake Bay were obtained from the 2011 Chesapeake Bay stock assessment (Miller et al.

2011). This assessment used a sex-specific, multiple survey model to develop integrated estimates of management reference points and stock status, incorporating observation and process error and producing annual estimates of absolute abundance, biomass, and fishing mortality rates from 1979 through 2006.

For Delaware Bay, estimates of recruit biomass (<120 mm crabs) were obtained from the 2011 blue crab assessment for Delaware Bay (Wong 2010). This assessment was based on a catch-survey model (Collie and Sissenwine 1983), incorporating observation and process error and producing annual estimates of absolute abundance, biomass, and fishing mortality rates from 1979 through 2010. An average size frequency distribution from the Chesapeake Bay was applied to Delaware Bay recruit estimates to obtain biomass of crabs <=60 mm carapace width.

Stock assessment of blue crab in North Carolina was conducted by Eggleston et al, 2004. A Collie - Sissenwine catch survey model was used to estimate absolute abundance of recruits (CW<127 mm) and post-recruits (CW=>127 mm). Total abundance estimates for 1988-2002 were distributed by 10 mm size groups using an average size frequency distribution observed in Chesapeake Bay. Finally, mean weights at size were applied to number of crabs per size group to produce biomass by size. No population estimates were available for the 1982-2001 period. Abundance in this time period was calculated by taking the fraction of annual harvest relative to the 2002 harvest and multiplying it by the 2002 abundance estimate. No population estimates were available for the 2003-2010 period. Population size estimates for these years was obtained by dividing the total annual harvest by the average exploitation rate observed in 1997-2002 period (0.73) and multiplying the ratio of current to 2002 biomass by the 2002 abundance estimate. Total biomass was allocated by size groups as described above.

Lobster: Abundance estimates for lobster were obtained from the 2009 American lobster stock assessment and (ASMFC 2009a). This assessment used a statistical length-, sex-, and season-structured model to estimate recruitment, abundance, and biomass of lobster 53-227 mm carapace length in each of three stock units. For each sex and season, total abundance of lobster in the 78 mm carapace length bin (≥ 78 mm and <83 mm) was multiplied by the weight of lobster by size bin, sex, and stock area. The 78 mm bin most closely corresponds with the "pre-recruit" class (i.e., the length bin from which lobsters are most likely to recruit to the fishery in a given year) used to estimate lobster biomass in the previous Collie-Sissenwine model and inform the 2008 MSVPA. Total weight of males and females in each season were summed across stock units.

Rock and Jonah Crab: For rock and Jonah crabs, there is no detailed assessment data from which to derive information on total biomass. However, the NEFSC bottom trawl survey samples and quantifies (number and weight) both species. Raw trawl survey data were obtained from 2001 – 20010 and seasonal (winter, spring and fall) catch rates (number and biomass per tow) were developed annually. Catch rates were not developed on a regional basis, as was done in 2005 – one catch rate was developed for an entire survey for a particular season. Similar to the procedure for bay anchovy, the catch rates were converted into minimum trawlable biomass estimates assuming a trawl swept-area of 0.0315 km^2 (NEFSC 2006b), a total survey area of 150,382 km^2 (area includes Chesapeake Bay even though not sampled), a gear efficiency of 100%, and using the biomass data for each tow instead of a calculated mean weight (the latter was done in 2005). Annual total biomass estimates were the most variable in the spring, greater than six-fold differences, and least variable in the winter. Combined rock and Jonah crab biomass estimates for 2002-2010 were averaged across seasons.

Other Clupeid Data

The sum of Atlantic herring, Atlantic thread herring, Spanish sardine, and scad estimated biomasses were summed to create the "other clupeid" non-menhaden prey group (Table A5. 5).

Atlantic herring: Recent results from an age-based assessment model, including population abundance estimates, were provided by Matt Cieri (ME, pers. comm) for use in the 2012 base run. Formerly, reported Atlantic herring landings were divided by 0.05 (assuming F~0.05). These new estimates are more precise (and generally lower) than the previous crude estimates used in the 2006 SARC review of MSVPA-X (NEFSC 2006b).

Atlantic thread herring, Spanish sardine, and scad: As in the 2008 MSVPA model, the sardine/herring complex (Atlantic thread herring, Spanish sardine, scaled sardine, and scads) biomass estimate for was calculated by summing total recreational (north, mid, and south Atlantic from MRFSS data sets) and commercial landings from (ME to FL). The catch (88mt, an annual average for the 2008-2010 period) was then converted to biomass (1,759mt) using an assumed exploitation rate of 0.05 (F=0.1 and Z=1.2).

Medium forage fish – butterfish and squids

The biomass estimates for butterfish were taken from the most recent approved stock assessment document (NEFSC 2010; Table B26).

The biomass estimates for *Loligo* were taken from the last approved stock assessment document (NEFSC 2011b; Table B25). The biomass estimates for *Illex* squid were developed by taking the average weight per tow from the total annual tows from the NEFSC trawl survey (NEFSC, personal communication), dividing that value by a tow area of 0.0389358 km^2, multiplying that value by a total stock area of 146,324 km^2, and then dividing by 1,000 to convert to metric tons.

Bay anchovy

Estuary Biomass Calculations**:** During a majority of the year, bay anchovy biomass in the estuary is relatively constant; however, during the late summer and fall following recruitment, anchovy biomass increases dramatically as age-0 fish undergo rapid growth (Newberger and Houde 1995). Based on survey data collected in 1993, Rilling and Houde (1999) estimated baywide (Chesapeake Bay) biomass during June and July to be approximately 23,000 metric tons. More recently, Jung and Houde (2004) estimated baywide anchovy abundance over a number of years (1995 – 2000) and seasons (spring, summer and fall) with their results showing extreme seasonal and annual variability.

The average bay anchovy estuary biomass, by season, was calculated using data from both published reports. The new data (Jung and Houde 2004) altered the seasonal estuary estimates from the 2005 MSVPA assessment (Figure A5. 4) – new seasonal estuary estimates are as follows: winter – 10,300 mt; spring – 10,300 mt; summer – 23,400 mt; fall – 104,000.

Coastal Biomass Calculations: The New Jersey Ocean Trawl survey database was used to develop bay anchovy biomass estimates to apply to near shore coastal waters. During the survey, the total weight of each species is measured in kg and the length of all individuals, or a representative sample by weight for large catches, is measured to the nearest cm following each tow. Minimum trawlable biomass estimates were developed assuming a 100% gear efficiency using the following equation:

$$B = (cA/a) / e \qquad \text{(from Sparre and Venema 1998)}$$

where: B is absolute biomass, c is mean catch per tow, A is total survey area, a is area swept per tow; e is the net efficiency. Minimum trawlable biomass estimates were developed on an annual and seasonal basis. The mean biomass estimate for the timeseries (1989 – 2006) was used to determine the total seasonal biomass estimate along the New Jersey coast. The seasonal trends for bay anchovy off the New Jersey coast are similar to those for Chesapeake Bay, although the absolute biomass values are quite different (Figure A5. 4).

Annual estuary and coast indices: Bay anchovy data from various fishery-independent survey datasets (7 total) were used to develop annual estuary specific indices for Chesapeake Bay and Delaware Bay and a grand Estuary Index to apply to all other coastal estuaries. The data were Z-transformed to normalize and standardize all datasets. The transformed indices were then weighted in order to combine indices and create a grand index for the Chesapeake Bay and Delaware Bay. The estuary specific indices were then re-weighted and combined for a grand Estuary Index that would be applied to the other estuaries (Figure A5. 5). Data from the NJ Ocean Trawl survey and the SEAMAP survey were used to develop the yearly Coastal bay anchovy index. As with the estuary indices, the data were Z-transformed and weighted to develop a single annual coastwide index (Figure A5. 5).

Annual and seasonal indices: The seasonal estuary biomass estimates developed by Rilling and Houde (1999) and Jung and Houde (2004) and were determined from data collected in 1993 and 1995-2000. Since a single seasonal biomass estimate was developed, the 93/95-00 data were used as the 'reference period' to then scale the annual (1982 – 2006) Estuary indices to the average 93/95-00 index to determine the annual seasonal biomass estimates. First, annual seasonal densities (biomass km^{-2}) were calculated for each of the estuaries along the coast – Buzzards Bay, Long Island Sound, Hudson River Estuary, Delaware Bay, Chesapeake Bay, Neuse River and Pamlico Sound

(GIS tools were used to determine estuary and coastal water area – km^2). The density inside Chesapeake Bay was assumed to be similar to that in other estuaries, but the appropriate scaled index value was applied to the appropriate estuary to develop the seasonal densities (ex. formula: [season biomass * scaled index value] / regional area). The calculated seasonal densities were then multiplied by the respective estuaries total area (km^2) to determine the annual seasonal biomass estimate for each estuary. All of the individual estuary estimates were summed to determine the total estuary bay anchovy biomass.

A similar procedure was followed with the coastal estimates. For consistency with the estuary estimates, we scaled the annual coastal estimates to the 93/95-00 reference period to determine the annual seasonal biomass estimates – note: from 1982 through 1988, coastal biomass estimates are constant and are equivalent to the 93/95-00 reference period because the coastal surveys used in this analysis has not begun until 1989. We determined the annual seasonal densities (biomass km^{-2}) for the New Jersey coast and the remaining coastal waters (out to 10 nautical miles from shore) and assumed the density along the Jersey coast was similar to that along other parts of the coast and applied the appropriate scaled index value to develop the seasonal densities. As with the estuaries estimates, the calculated densities were multiplied by the corresponding coastal total area and then all of the coastal areas were summed to get the total coastal bay anchovy biomass. The total estuary and coastal estimates were then summed to develop the overall annual seasonal bay anchovy biomass.

Sciaenids

Spot and croaker were updated with new estimates through 2010. Total annual spot and croaker biomass estimates were summed to create the "other prey" class called "sciaenids".

Croaker. Estimated trends in croaker biomass for 1982-1987 were obtained from assessment results (ASMFC 2005). Biomass estimates from 1988-2010 were obtained from Katie Drew (ASMFC, pers. comm.) based on an update of the most recent stock assessment (ASMFC 2010a). Note these estimates do not include shrimp bycatch.

Spot. Spot biomass estimates for 1982-2010 were calculated as in the 2008 MSVPA-X update.

Predator diets

Diet data were updated during the 2008 assessment (ASMFC 2008). The same prey preference and spatial overlap parameters were used in this 2012 update. These parameters need to be carefully re-evaluated and updated during the next update or benchmark of the MSVPA-X.

Temperature
The same temperature data were used as in the 2008 update. Recent years were assumed to be the same as 2008. These inputs need to be updated during the next update or benchmark of the MSVPA-X.

RESULTS

Atlantic menhaden

This section compares MSVPA-X model output for Atlantic menhaden from two project runs; the 2009 run (1982-2008) and 2012 base run (1982-2010). Total population abundance (ages 1+) of Atlantic menhaden remained mostly unchanged in this update (Figure A5. 6) with the notable exception of increased abundances in the recent period. As always, estimates in the terminal year are most uncertain.

Estimates of the predation component of natural mortality (M2) on Atlantic menhaden by year and predator averaged across ages 0 to 2 are presented in (Figure A5. 7-Figure A5. 9). Overall predation mortality for the overlapping years of these new and old runs was not very different with the exception of weakfish; revised weight-at-age increased the estimates of historical removals. Overall, though, the change is only slight when compared to the overall rate of predation morality on menhaden by both bluefish and striped bass.

Estimates of total M2 (summed across the 3 modeled predators) were then compared for ages 0-6+ menhaden between the 2009 and 2012 model runs (Figure A5. 10). Despite the increase in weakfish weight at age and consumption, overall changes to the M2 were minimal between old and new runs. However, for the oldest age class (6+) large changes in the M2 were noted (Figure A5. 11), while these differences are minor when compared to the overall magnitude of the predation mortality on younger ages, this difference could be a contributing factor to the ongoing retrospective problem found in the most recent menhaden update.

In summary, total population abundance and predation mortality are similar in trend and magnitude between old and new or updated runs. However notable differences were observed, suggesting more intensive analysis is warranted.

Striped bass

A comparison of striped bass population estimates (ages 0+) from the MSVPA-X 2009 base run (data from 1982 through 2008, inclusive) and 2012 base run (data from 1982 through 2010, inclusive) are nearly identical through 1999 (Figure A5. 12). Trends in abundance after 1999 are similar, though between 2000 and 2004 the 2012 base run estimates are on average 10% lower than estimates from the 2009 base run, whereas between 2006 and 2008 the 2012 base run estimates are on average 15% greater than the 2009 base run estimates. The differences in total abundance coincide with differences in estimates of age 0 abundance (Figure A5. 13) for the two runs during those same time periods. Estimates of striped bass SSB from the two configurations of the MSVPA-X are identical (or nearly so) through 1995 (Figure A5. 14). Between 1996 and 2002 the 2012 base run estimates of SSB are on average 5% greater than those from the 2009 base run, whereas between 2003 and 2006 the 2012 base run estimates are on average 5% below estimates from the 2009 base run. Estimates of SSB in 2007 and 2008 from the two model runs trend in opposite directions (and differ by approximately 20%) – the trend in SSB for the final two years of the 2012 base run continues downward. Estimates of fishing mortality between the two configurations of the MSVPA-X are nearly identical through 2001 (Figure A5. 15). After 2001, though both MSVPA-X configurations show an increasing trend in F, the 2012 base run consistently estimates F at levels higher than the 2008 configuration (on average, 17% higher).

Trends in age 1+ abundance between the 2012 base run and the single species 2011 striped bass update stock assessment (Table 11 from ASMFC 2011) are nearly identical (Figure A5. 16). The 2012 MSVPA-X base run estimates are however in general lower than the single species estimates (on average 18% lower, but as much as 47% lower), with the exception of estimates from 1997 through 2003 when the 2012 base run estimates are either identical to or slightly greater than the single species estimates. Differences in population size estimates are attributed to the difference in structure of assessment models (XSA in MSVPA-X versus statistical catch-at-age).

Estimates of menhaden consumed by striped bass are similar between the two MSVPA-X configurations with the notable exception of consumption in the terminal year of the 2009 base run, in which consumption of menhaden in the 2012 configuration is twice that estimated in the 2009 configuration (**Figure A5.** 17, Figure A5. 18). Principal components of striped bass diet in the 2012 base run include: bay anchovies, benthic invertebrates, clupeids, and menhaden. Medium forage fish, a notable component of striped bass diet in the 2009 base run, are a negligible portion of striped bass diet in the 2012 base run, primarily as result of reduced medium forage fish abundances across the entire time series in the 2012 configuration.

Weakfish

Comparisons of the results for the weakfish single species analysis are made for the 2009 and 2012 base runs of the MSVPA-X model. Results of the 2009 benchmark stock assessment for weakfish (NEFSC 2009) are not included in the comparison because the Weakfish Technical Committee had concerns with the age-structured VPA model, and the VPA was not selected as the preferred model.

Weakfish abundance estimates for the 2009 and 2012 runs of the MSVPA-X are nearly identical until 2004 (Figure A5. 19). Abundance was high in the early to mid 1980s, reaching a peak in 1985 before declining by over 50% by 1989. The population rebounded over the next five years but has exhibited a nearly exponential decline since 1996. Since 2004, results of the 2012 run are lower than those from the 2009 model run. Average abundance for the period 2006-2010 is approximately 3% of the abundance during 1982-1986.

Estimated fishing mortality rates were also similar between the 2009 and 2012 MSVPA-X model runs (Figure A5. 20). Fishing mortality rates were variable, but generally exceeded 1.0 from 1982 to 1989, falling to between 0.5 and 1.0 for 1990 to 1994. F reached the time series minimum (F = 0.30) in 1995 before increasing rapidly to over 2.0 by 2003. Since 2004, results from the 2012 run have been greater than F values estimated during the 2008 update. One of the concerns expressed by the Weakfish Technical Committee with the single species age structured model during the recent weakfish benchmark assessment (ASMFC 2006; NEFSC 2009) was the assumption of constant natural mortality. Increased fishing mortality rates estimated from the age-structured model during periods of increased harvest restrictions suggested that natural mortality was not constant. The trends in F from the MSVPA-X models are similar in pattern to those from the weakfish single species assessments. An alternative view proposed by the Weakfish Technical Committee would be to combine calculated F estimates with input M rates (M = 0.25) to portray a trend in total mortality, Z. Regardless, it should be noted that the MSVPA-X, as per the SARC peer reviewers' comments (NEFSC 2006b), cannot and should not serve as an indicator of single species status.

Updated weights at age are generally higher than those used during the 2008 MSVPA-X update, resulting in generally higher SSB estimates for the 2012 run (Figure A5. 21). Regardless of the difference in scale, the temporal pattern in weakfish spawning stock biomass is similar between the 2009 and 2012 MSVPA-X model runs and generally follow the pattern of abundance. High levels of SSB during the early 1980s declined during the latter part of the decade before rebounding gradually during the early 1990s. SSB has declined since 1997 to the lowest levels on record in 2010.

As with the other parameters, estimated age-0 recruitment trends were similar between the 2009 and 2012 model runs until 2004 (Figure A5. 22). Since 2004, recruitment from the 2012 run is lower than from the 2009 run.

The overall pattern in consumption by weakfish is similar between the 2009 and 2012 MSVPA-X model runs (Figure A5. 23). Primary diet items include bay anchovies, benthic invertebrates, and macro-zooplankton. Menhaden has not been an appreciable component of weakfish diet since the early 1990s. The two largest differences between the 2009 and 2012 runs are that the overall scale approximately doubled for the 2012 run, and the relative absence of medium forage in the 2012 run compared to 2008. The increase in scale is largely due to using updated weight at age vectors in 2012 which greatly increased the estimated biomass of weakfish during the early part of the time series. Significant reductions in estimated availability (abundance) of medium forage are the primary driving factor behind the reduced consumption of this prey category.

After the assessment runs were completed, some potential errors were observed in the weight at age time series. Weights at age, particularly for older fish, are lower than expected based on raw data. It is likely the inconsistency is due to using fitted size and weight at age data rather than using raw data; however it is also possible that the error is due to a conversion error or other type of error. Higher weights at age would provide increased estimates of spawning stock biomass and consumption (which is driven by biomass). The impact on estimated predation mortality for menhaden, however, would be minimal since menhaden are only a small component of weakfish diet (Figure A5. 23) and the biomass of weakfish relative to other predators is very small (Figure A5. 24). The weakfish size and weight at age data will be thoroughly reviewed during the MSVPA-X benchmark stock assessment.

Bluefish

Trends in bluefish biomass are similar between the 2009 and 2012 base runs (Figure A5. 3). Each begins with high biomass (>300,000 mt) in the 1980s and steadily declines to a low (~100,000 mt) in the mid-1990s. Biomass then increases to a moderate level in more recent years, to levels between 150,000-200,000 metric tons (Figure A5. 3). A comparison of biomass trends among the three modeled predators can be found in Figure A5. 24.

Diet composition of bluefish is similar between the MSVPA-X runs (Figure A5. 25, **Figure A5.** 26). The 2012 base run results suggest that size 1 bluefish (10-30 cm) are primarily consuming bay anchovies, benthic invertebrates, and macro zooplankton (Figure A5. 25). Menhaden are important parts of size 2 and 3 bluefish diets, as are bay anchovies and clupeids (Figure A5. 25). Total consumption of menhaden by bluefish (and other predators) is illustrated in Figure A5. **27**. Medium forage fish, a notable component of sizes 2 and 3 bluefish diet in the 2009 base run, are a negligible portion of bluefish diet in the 2012 base run, primarily as result of reduced medium forage fish abundances across the entire time series in the 2012 configuration. The 2012 base run results suggest that bluefish are consuming menhaden and bay anchovies in place of medium forage fish (Figure A5. 25).

MODELING AND RESEARCH RECCOMMENDATIONS

Below is an abbreviated list of short (for 2015 benchmark) and long-term modeling and research needs to support upkeep and development of the MSVPA.

Short-term

- Convert MSVPA code from VB to ADMB and build associated output graphing code in R
- Carefully re-review all model input calculations and assumptions
- Modifications to MSVPA configuration:
    - Add additional explicitly modeled predators, biomass predators, and “other prey”, as necessary/possible
    - Summarize diet studies results into a synthetic view of seasonal and spatial variation in diets to both parameterize models and identify data gaps and update parameterization of prey preferences/diet ranks/spatial overlap
    - Model bluefish in MSVPA via XSA (rather than as a biomass input) and convert weakfish to a biomass predator
    - Parameterize feedback between prey and predator growth

- Compare/contrast with ICES MSVPA results.

Long-term

- Transition to statistical MS model
- Validate diet parameters used in all these approaches by conducting a coast wide diet and abundance study (i.e., an Atlantic coast "year of the stomach") especially for nearshore sites during all seasons.

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Tables

Table A5. 1. Weakfish catch at age (thousands of individuals).

	Age					
Year	**1**	**2**	**3**	**4**	**5**	**6+**
1982	9,914.2	12,967.0	5,473.0	2,778.2	721.6	639.5
1983	8,004.0	12,869.1	5,822.7	2,780.0	568.2	424.1
1984	10,444.2	14,736.9	6,521.1	3,045.3	484.5	254.5
1985	14,153.2	11,262.3	3,246.1	1,171.0	212.9	55.1
1986	18,610.7	15,778.4	4,942.4	1,823.7	264.1	52.1
1987	16,256.3	14,343.1	4,347.1	1,485.2	145.4	11.0
1988	8,161.9	16,140.8	10,545.3	6,092.0	1,050.5	70.7
1989	3,705.0	5,304.9	4,333.5	2,922.3	626.2	84.6
1990	9,510.1	4,890.1	2,093.6	1,204.8	591.4	89.1
1991	9,795.9	5,825.6	2,750.0	1,373.6	463.4	57.3
1992	5,179.5	6,046.0	2,211.0	1,255.0	527.8	65.0
1993	4,974.8	6,357.0	2,179.8	1,138.6	401.1	48.2
1994	3,761.9	4,347.4	3,561.0	1,563.5	204.1	39.8
1995	4,336.3	3,727.7	3,566.7	1,637.8	198.1	54.3
1996	2,498.8	2,689.5	5,033.3	3,174.2	1,379.3	100.1
1997	1,716.4	2,394.2	2,913.2	5,522.0	1,523.1	410.2
1998	1,270.6	2,138.3	3,983.1	2,019.2	2,928.8	909.5
1999	1,412.6	1,300.4	2,256.6	3,326.0	725.7	1,145.0
2000	1,377.0	1,727.1	1,985.7	1,663.7	1,528.2	403.0
2001	2,420.7	2,953.1	1,474.1	1,219.9	658.7	485.9
2002	2,591.7	1,070.5	2,695.7	823.9	388.2	231.5
2003	335.6	949.9	959.7	718.4	209.5	254.2
2004	852.3	1,511.9	667.8	115.8	49.7	38.4
2005	334.3	1,771.5	1,255.2	191.5	10.2	27.1
2006	747.3	637.3	959.2	252.9	15.5	11.9
2007	386.3	725.5	324.5	125.4	23.4	5.8
2008	599.2	670.2	247.2	80.8	6.2	1.7
2009	439.5	498.8	139.2	16.4	3.7	1.8
2010	487.1	508.3	106.3	4.8	2.0	0.4

Table A5. 2. Variable size at age for weakfish (cm).

	Age						
Year	0	1	2	3	4	5	6+
1982	5.3	14.22	26.65	36.73	44.92	51.57	56.97
1983	5.3	14.22	26.65	36.73	44.92	51.57	56.97
1984	5.3	14.22	26.65	36.73	44.92	51.57	56.97
1985	5.3	14.22	26.65	36.73	44.92	51.57	56.97
1986	5.3	14.22	26.65	36.73	44.92	51.57	56.97
1987	5.3	14.22	26.65	36.73	44.92	51.57	56.97
1988	5.3	14.22	26.65	36.73	44.92	51.57	56.97
1989	5.3	14.22	26.65	36.73	44.92	51.57	56.97
1990	5.3	14.22	26.65	36.73	44.92	51.57	56.97
1991	5.3	14.22	26.65	36.73	44.92	51.57	56.97
1992	5.3	14.22	26.65	36.73	44.92	51.57	56.97
1993	5.3	15.63	23.96	31.22	37.54	43.05	47.84
1994	5.3	19.36	26.62	33.02	38.66	43.62	47.99
1995	5.3	19.67	25.3	30.41	35.05	39.25	43.07
1996	5.3	19.14	25.29	30.82	35.79	40.26	44.29
1997	5.3	24.51	29.39	33.84	37.9	41.61	44.99
1998	5.3	20.28	26.24	31.61	36.44	40.79	44.71
1999	5.3	18.47	26.02	32.66	38.48	43.59	48.07
2000	5.3	17.57	26.49	34.2	40.85	46.59	51.54
2001	5.3	16.66	26.96	35.74	43.22	49.59	55.01
2002	5.3	19.42	28.4	36.18	42.91	48.73	53.77
2003	5.3	18.73	29.27	38.15	45.66	51.99	57.33
2004	5.3	23.13	30.67	37.35	43.26	48.49	53.12
2005	5.3	22.6	29.63	35.57	40.6	44.85	48.44
2006	5.3	23.99	30.7	36.22	40.77	44.52	47.61
2007	5.3	23.99	30.7	36.22	40.77	44.52	47.61
2008	5.3	25.89	32.23	36.39	41.12	50.14	78.21
2009	5.3	26.34	29.60	33.88	39.95	49.99	76.67
2010	5.3	25.86	29.21	32.65	45.45	55.73	81.02

Table A5. 3. Variable weight at age for weakfish (kg).

Year	Age 0	1	2	3	4	5	6+
1982	0.106	0.212	0.307	0.483	1.076	3.033	3.033
1983	0.078	0.19	0.368	0.885	1.4	2.86	2.862
1984	0.095	0.189	0.379	0.758	1.583	2.536	2.536
1985	0.077	0.267	0.579	1.235	1.75	3.06	3.055
1986	0.152	0.262	0.758	1.759	2.819	3.173	3.173
1987	0.087	0.236	0.524	1.234	2.127	2.536	2.536
1988	0.09	0.179	0.398	0.796	1.494	3.026	3.026
1989	0.109	0.186	0.383	0.769	1.417	3.348	3.348
1990	0.06	0.104	0.407	0.865	1.399	1.945	1.945
1991	0.036	0.215	0.543	0.971	1.446	1.925	1.925
1992	0.027	0.181	0.477	0.875	1.326	1.79	1.79
1993	0.036	0.132	0.292	0.509	0.769	1.058	1.058
1994	0.069	0.181	0.346	0.556	0.8	1.067	1.067
1995	0.071	0.153	0.265	0.407	0.572	0.755	0.755
1996	0.066	0.152	0.276	0.433	0.617	0.822	0.822
1997	0.139	0.239	0.366	0.515	0.681	0.862	0.862
1998	0.078	0.17	0.298	0.457	0.642	0.846	0.846
1999	0.059	0.166	0.329	0.538	0.783	1.051	1.051
2000	0.059	0.166	0.329	0.538	0.783	1.051	1.051
2001	0.043	0.182	0.425	0.751	1.134	1.548	1.548
2002	0.092	0.265	0.52	0.836	1.191	1.566	1.566
2003	0.067	0.249	0.544	0.924	1.356	1.809	1.809
2004	0.116	0.279	0.512	0.802	1.134	1.493	1.493
2005	0.101	0.237	0.431	0.674	0.953	1.257	1.257
2006	0.133	0.287	0.5	0.762	1.064	1.392	1.392
2007	0.174	0.388	0.675	1.015	1.388	1.776	1.776
2008	0.152	0.362	0.653	1.005	1.398	1.811	1.811
2009	0.136	0.341	0.631	0.983	1.376	1.79	1.79
2010	0.109	0.311	0.608	0.978	1.393	1.83	1.83

Table A5. 4. Benthic crustacean biomass estimates by season (mt).

	Season 1	Season 2	Season 3	Season 4
1982	17,808	17,557	17,568	17,724
1983	14,784	14,539	15,790	16,419
1984	20,753	20,444	23,566	23,695
1985	19,850	19,487	19,368	19,684
1986	17,033	16,699	17,841	17,940
1987	19,664	19,341	20,008	20,762
1988	19,839	19,523	22,266	22,817
1989	27,728	27,365	27,509	28,351
1990	25,584	25,213	25,752	26,514
1991	25,460	25,069	24,909	25,620
1992	20,297	19,914	19,979	21,026
1993	23,154	22,760	24,355	25,339
1994	21,158	20,700	20,952	21,812
1995	21,984	21,520	21,518	22,601
1996	22,206	21,738	22,990	24,162
1997	25,532	25,011	25,719	26,742
1998	21,017	20,473	20,822	22,380
1999	24,105	23,533	24,980	25,617
2000	21,599	20,994	18,021	19,324
2001	18,714	18,212	19,385	20,260
2002	21,780	21,241	20,127	21,458
2003	18,812	18,305	19,611	20,763
2004	20,433	19,876	19,704	21,007
2005	20,924	20,366	20,395	21,238
2006	21,578	21,030	19,082	20,129
2007	18,366	17,889	18,249	19,426
2008	22,750	22,273	22,633	23,810
2009	22,444	21,968	22,327	23,504
2010	23,337	22,861	23,221	24,397

Table A5. 5. Other clupeid biomass estimates by season (mt).

	Season 1	Season 2	Season 3	Season 4
1982	110,416	110,416	110,416	110,416
1983	109,847	109,847	109,847	109,847
1984	111,803	111,803	111,803	111,803
1985	134,136	134,136	134,136	134,136
1986	169,316	169,316	169,316	169,316
1987	194,636	194,636	194,636	194,636
1988	194,190	194,190	194,190	194,190
1989	238,739	238,739	238,739	238,739
1990	333,739	333,739	333,739	333,739
1991	430,538	430,538	430,538	430,538
1992	512,740	512,740	512,740	512,740
1993	582,657	582,657	582,657	582,657
1994	567,693	567,693	567,693	567,693
1995	621,144	621,144	621,144	621,144
1996	773,173	773,173	773,173	773,173
1997	758,926	758,926	758,926	758,926
1998	759,705	759,705	759,705	759,705
1999	713,108	713,108	713,108	713,108
2000	853,894	853,894	853,894	853,894
2001	786,066	786,066	786,066	786,066
2002	665,084	665,084	665,084	665,084
2003	655,634	655,634	655,634	655,634
2004	669,065	669,065	669,065	669,065
2005	628,571	628,571	628,571	628,571
2006	676,261	676,261	676,261	676,261
2007	667,825	667,825	667,825	667,825
2008	594,332	594,332	594,332	594,332
2009	590,650	590,650	590,650	590,650
2010	585,890	585,890	585,890	585,890

Figures

Figure A5. 1. Coastwide juvenile abundance index (black line) based on the delta-lognormal GLM with fixed factors year, month, and state fitted to seine catch-per-haul data for 1959-2011 from all states combined. Coefficients of variations (CV; grey line) were calculated from jackknifed derived SEs.

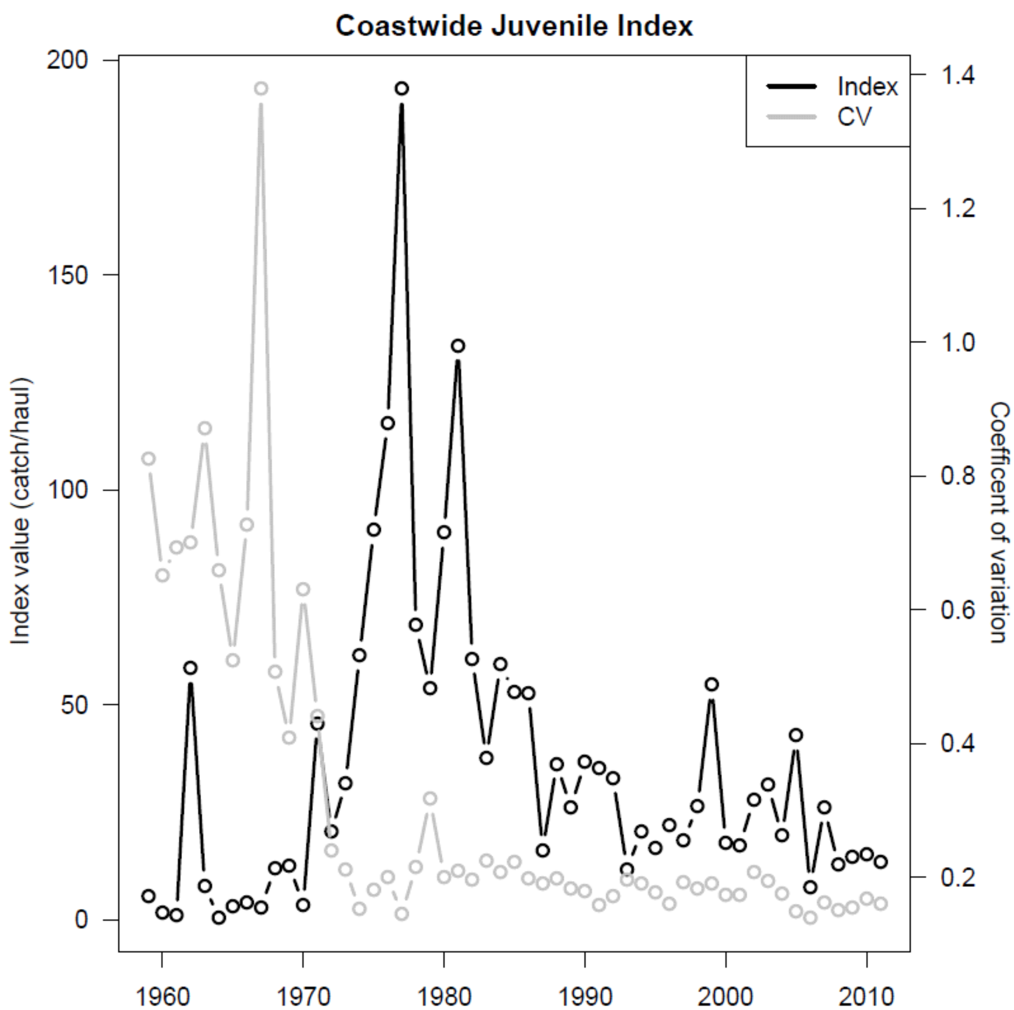


Figure A5. 2. PRFC adult Atlantic menhaden (primarily ages-1 through 3) index of relative abundance derived from annual ratios of pounds landed and pound net days fished. CPUE for the years 1964-1975 and 1981-1987 were estimated from regressions of published landings (to obtain annual landings) and licenses (to obtain total annual days fished).

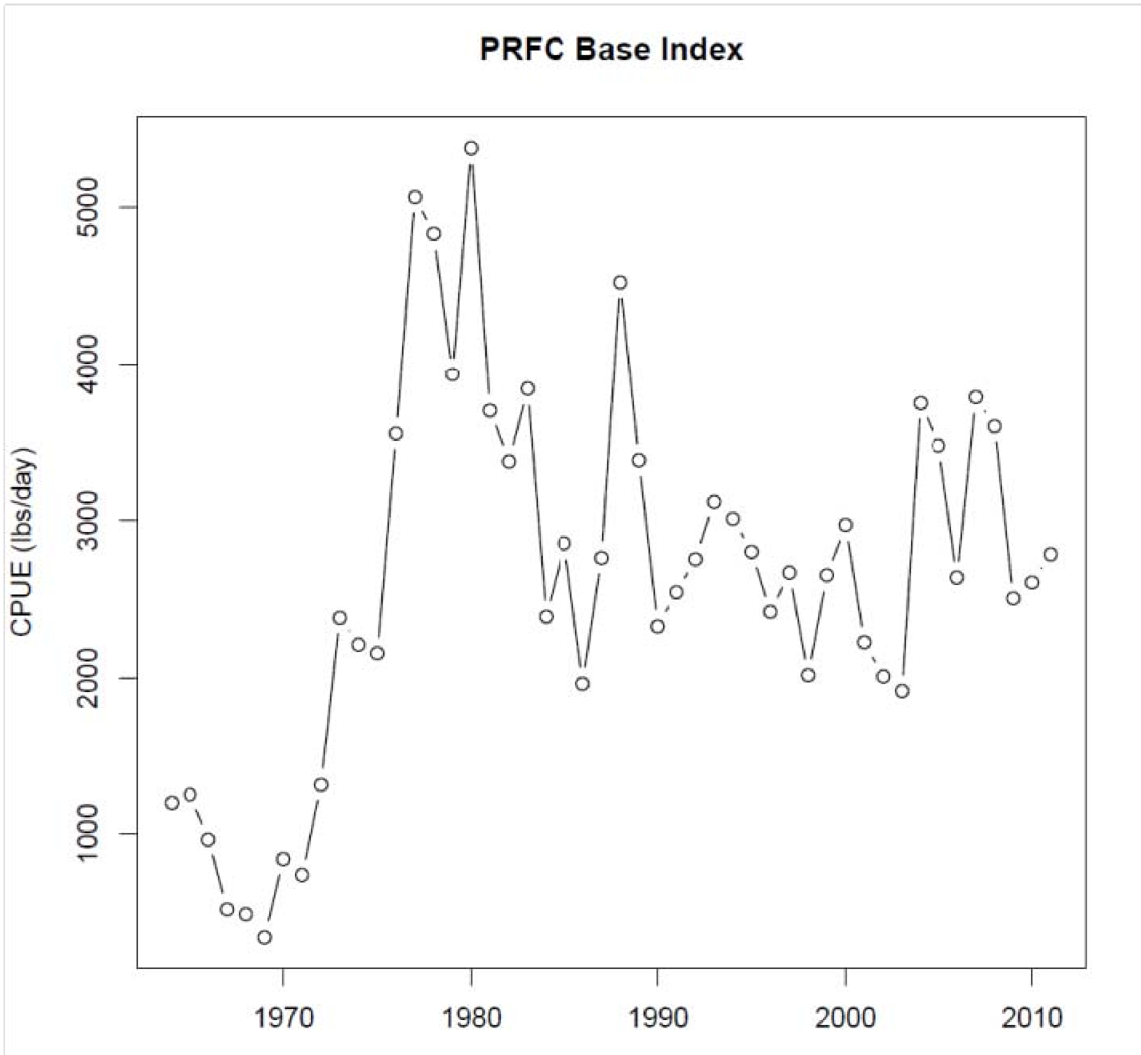


Figure A5. 3. Bluefish biomass trends – a comparison between the 2009 and 2012 base runs.

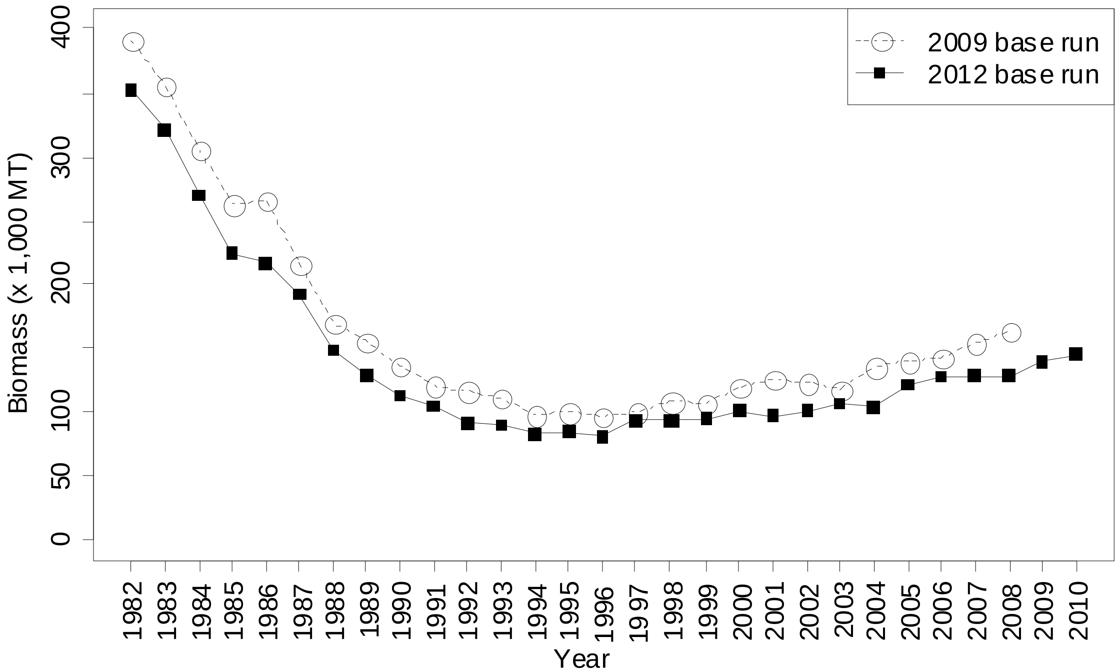
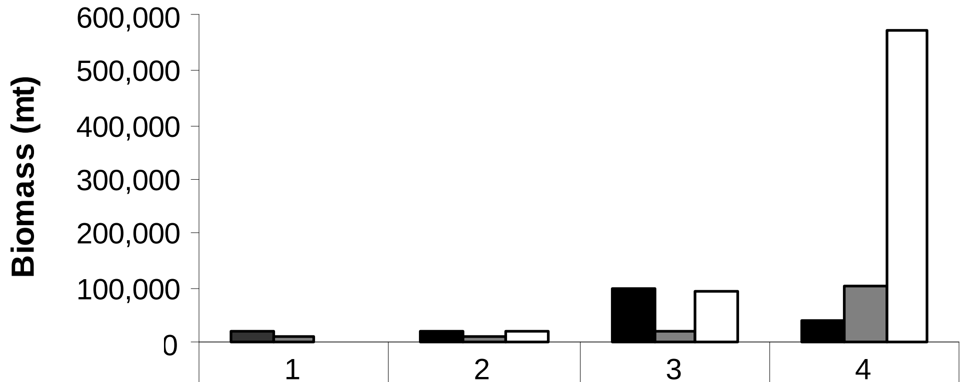


Figure A5. 4. Seasonal bay anchovy biomass (mt) estimates for the Chesapeake Bay developed for the 2005 and 2007 assessment (Rilling and Houde, 1999; Jung and Houde 2004) and the New Jersey coast.



	1	2	3	4
Ches. Bay 05	23,000	23,000	100,000	40,000
Ches. Bay 07	10,300	10,300	23,400	104,000
NJ Coast	108	23,371	91,396	573,413

Figure A5. 5. Z-transformed and weighted survey indices combined to create an annual grand Estuary and Coastal indices for bay anchovy.

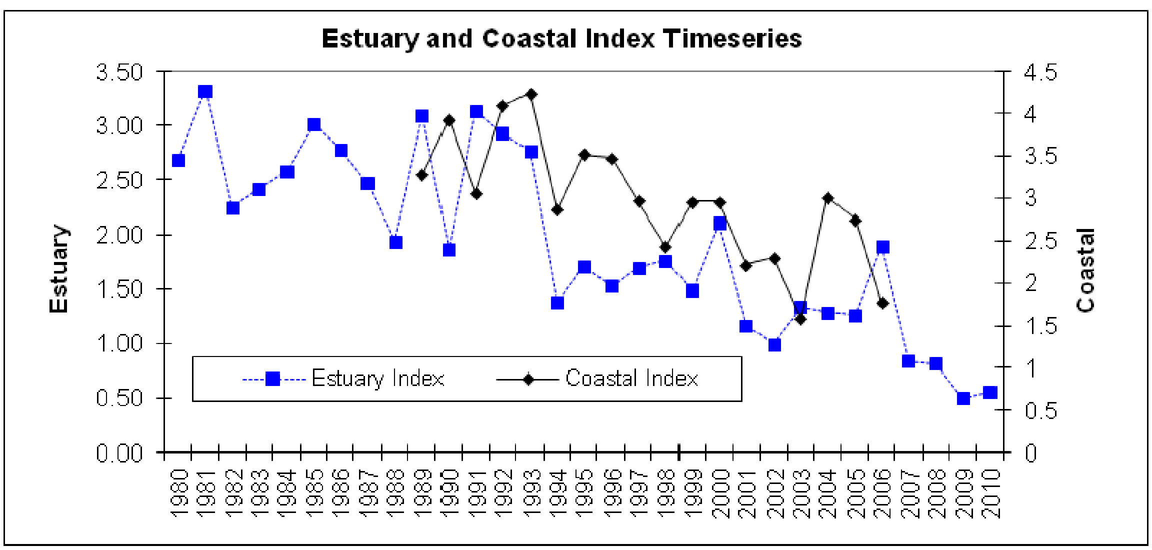


Figure A5. 6. Age 1+ abundance (x 1 million fish) of Atlantic menhaden estimated by the 2009 and 2012 base runs.

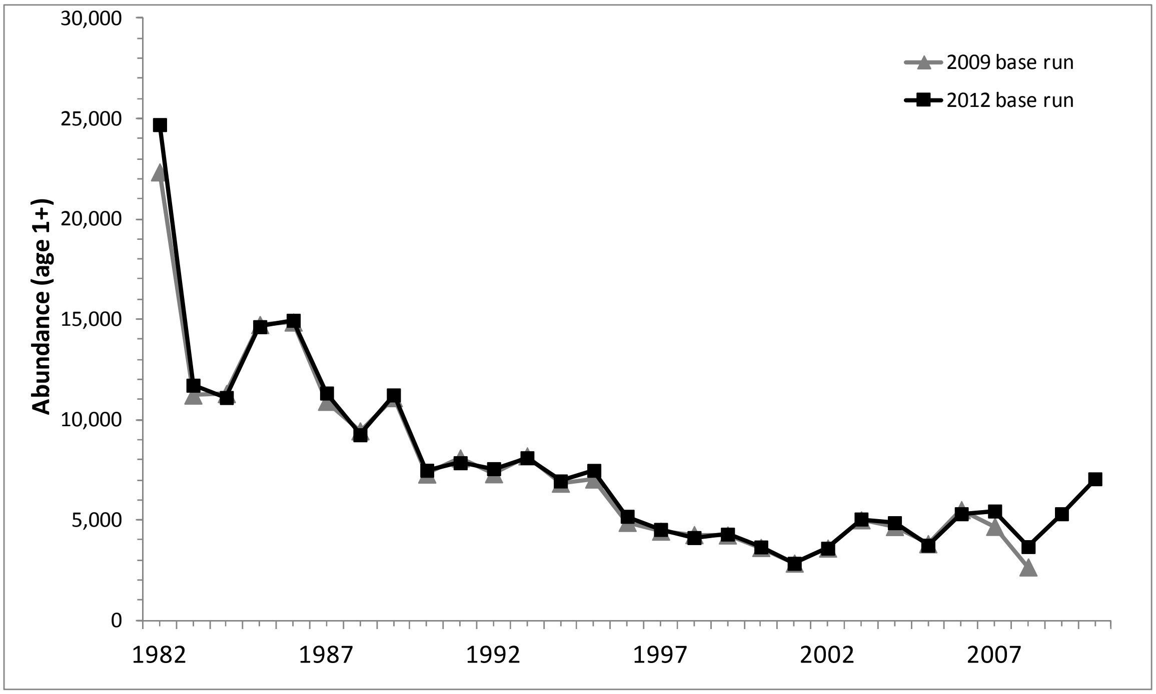


Figure A5. 7. A comparison between assessment update estimates of the bluefish predation component of natural mortality (M2) on Atlantic menhaden averaged across ages 0 to 2.

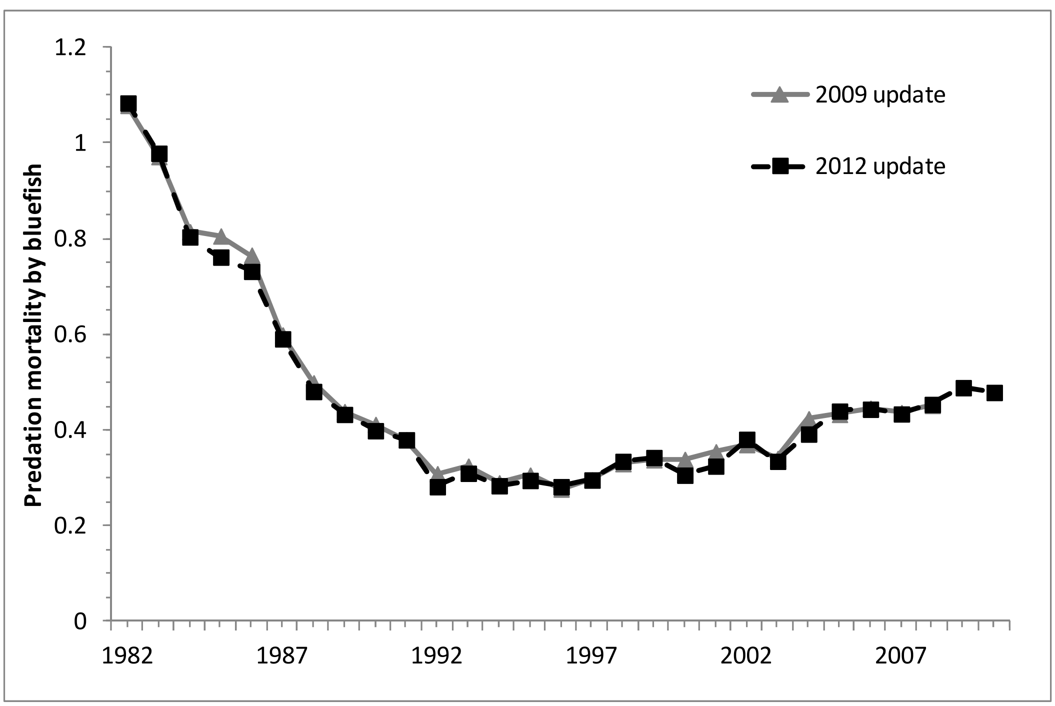


Figure A5. 8. A comparison between assessment updates of the striped bass predation component of natural mortality (M2) on Atlantic menhaden averaged across ages 0 to 2.

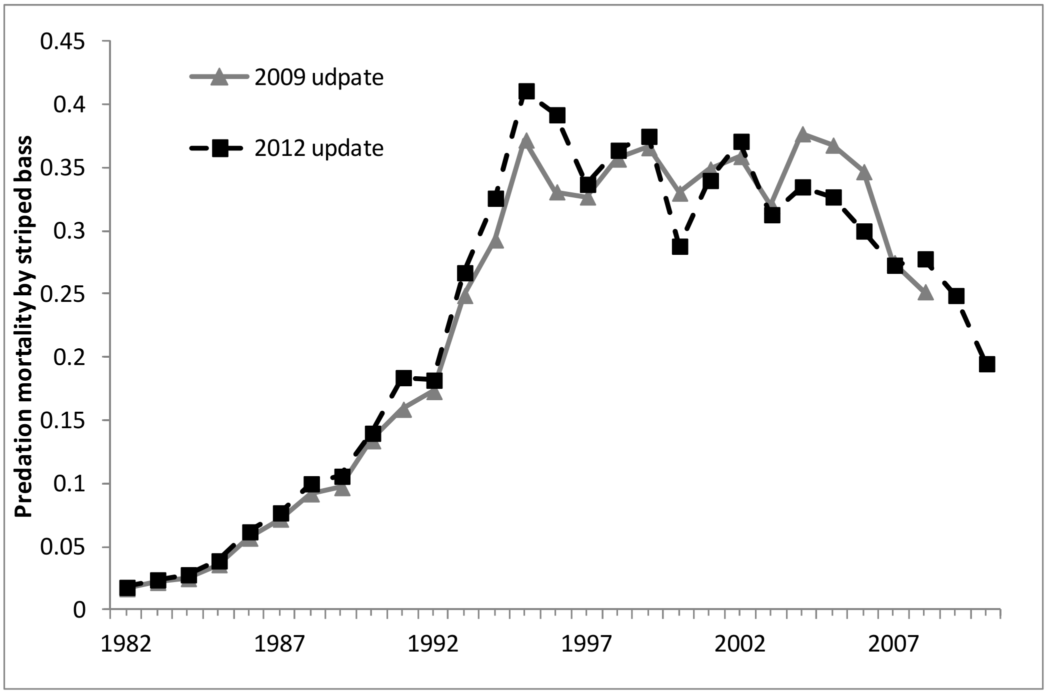


Figure A5. 9. A comparison between assessment updates of the weakfish predation component of natural mortality (M2) on Atlantic menhaden averaged across ages 0 to 2.

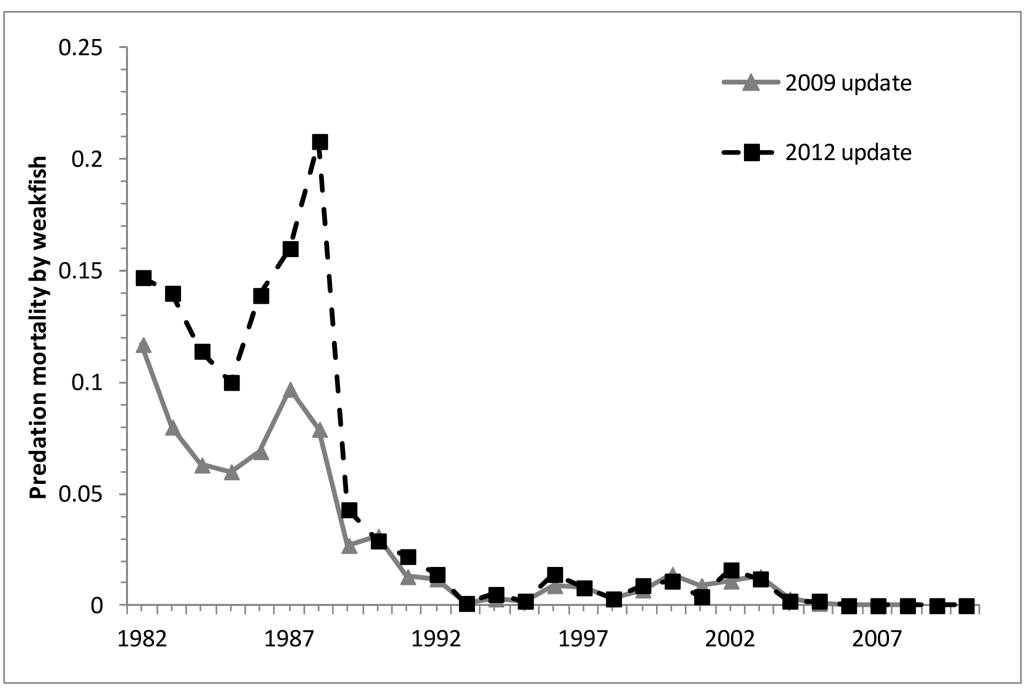


Figure A5. 10. A comparison between assessment updates of estimates of the predation component of natural mortality (M2) on Atlantic menhaden for all predators averaged across ages 0 to 6+.

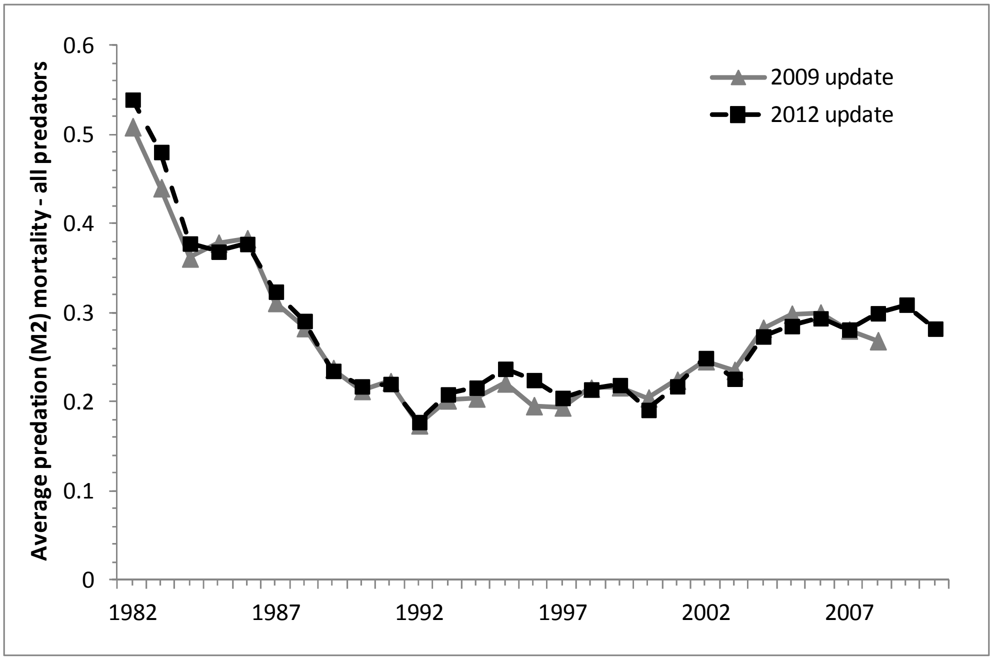


Figure A5. 11. A comparison between assessment updates of estimates of the predation component of natural mortality (M2) by all predators on 6+ Atlantic menhaden.

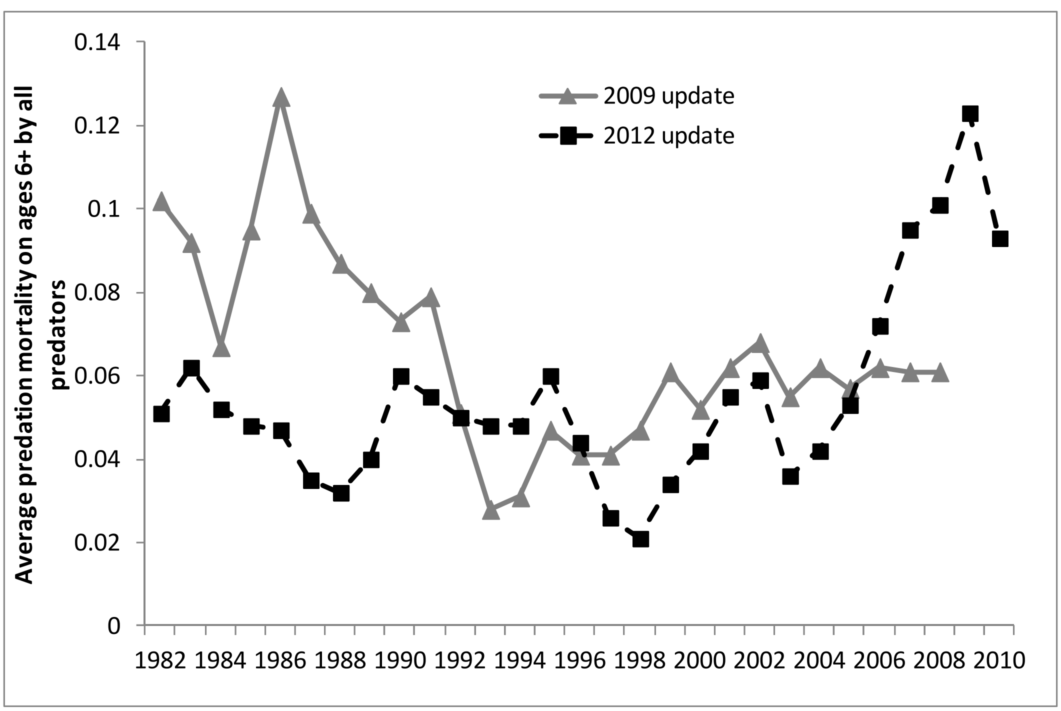


Figure A5. 12. Abundance estimates (ages 0+) of striped bass from two configurations of the MSVPA-X.

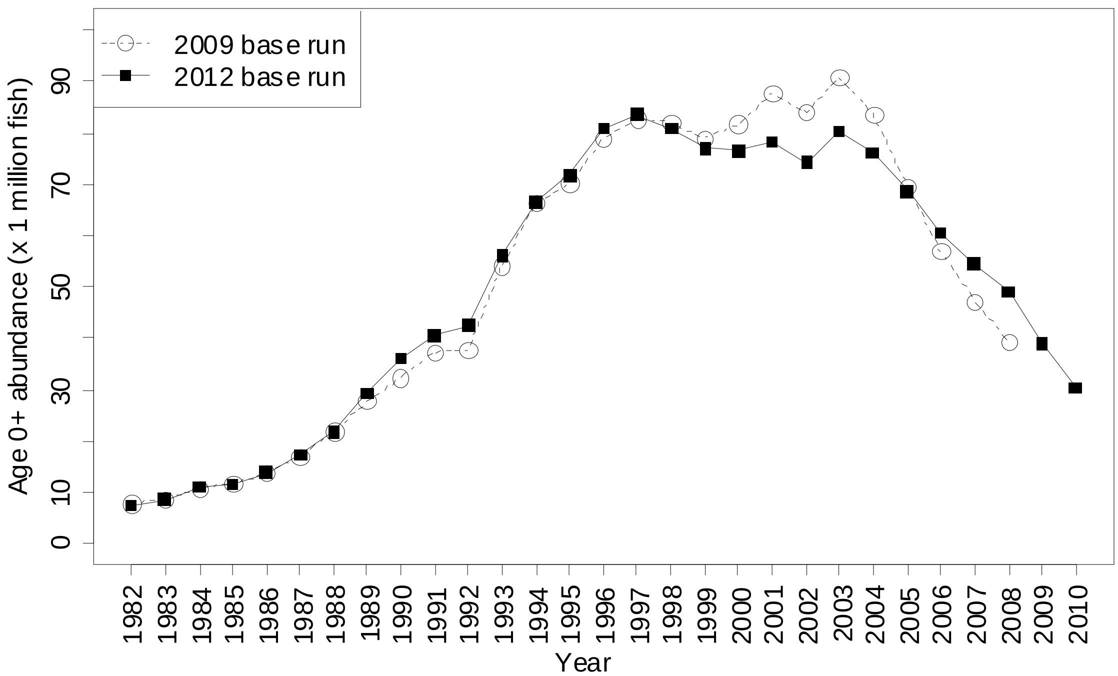


Figure A5. 13. Recruitment estimates (abundance of age 0 fish) of striped bass from two configurations of the MSVPA-X.

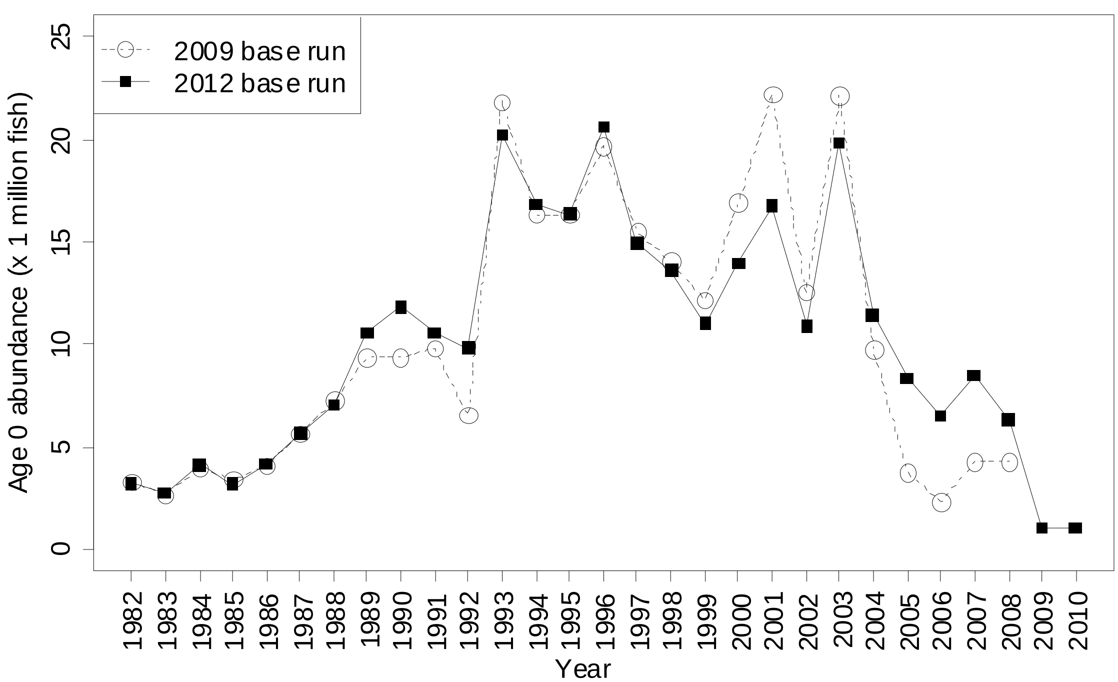


Figure A5. 14. Spawning stock biomass (SSB) of striped bass from two configurations of the MSVPA-X.

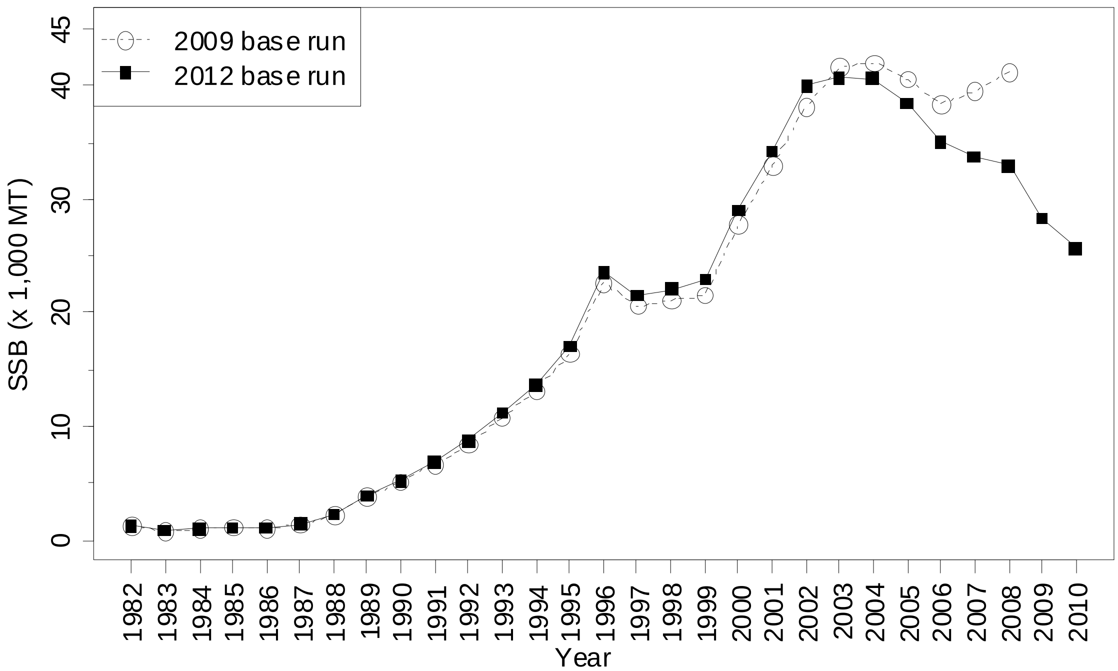


Figure A5. 15. Average fishing mortality (F) of striped bass from two configurations of the MSVPA-X.

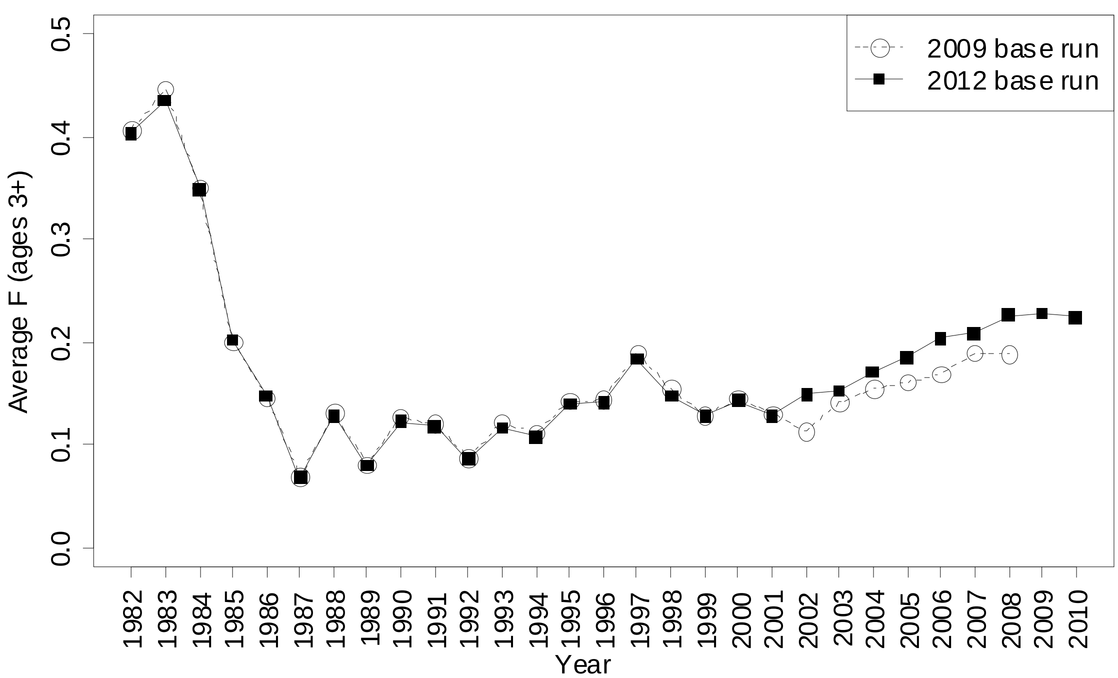


Figure A5. 16. Abundance estimates (ages 1+) of striped bass from two configurations of the MSVPA-X as well as from the most recent single species striped bass stock assessment.

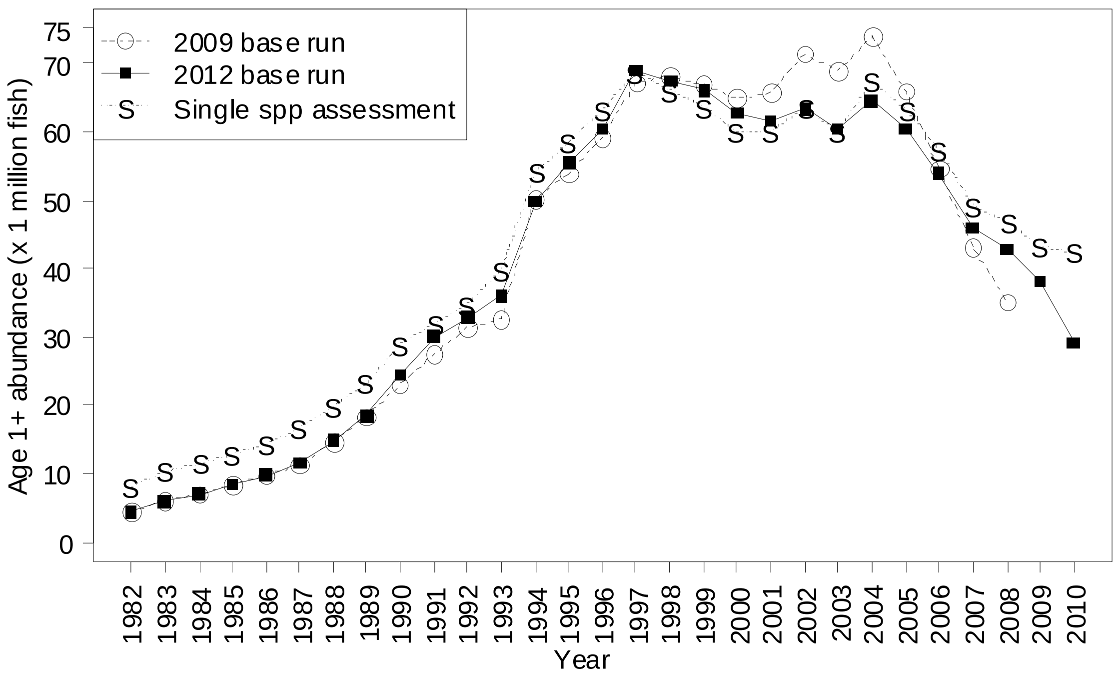
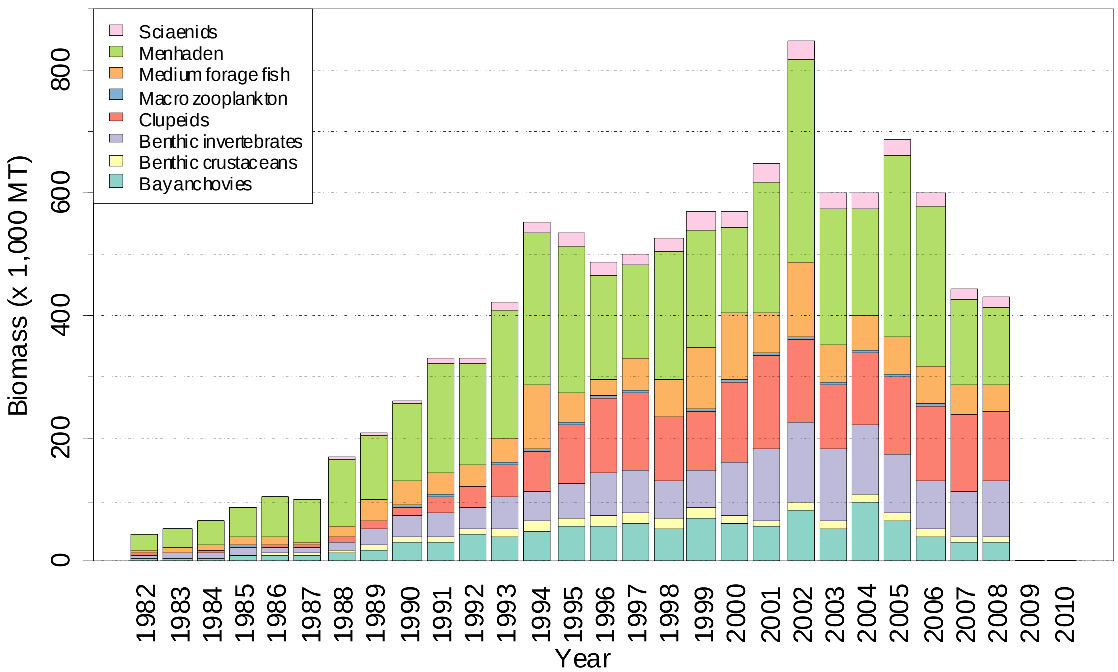


Figure A5. **17. Comparison of prey consumption by striped bass between two configurations of the MSVPA-X.**

2009 base run



2012 base run

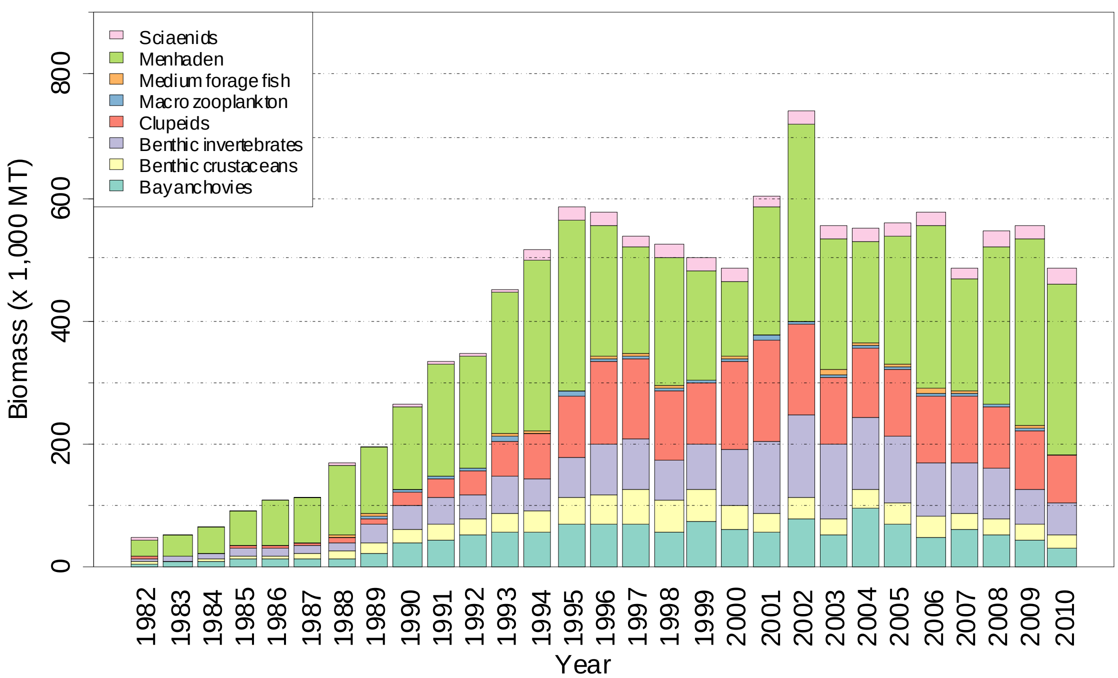


Figure A5. 18. Total consumption of menhaden by striped bass for two configurations of the MSVPA-X.

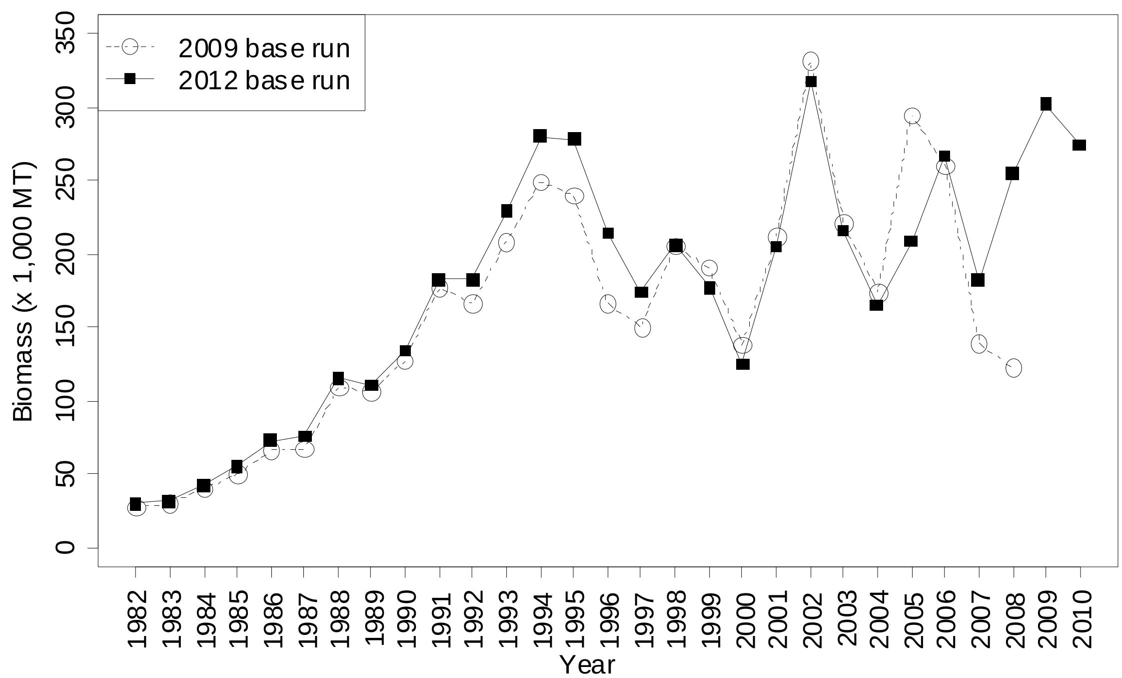


Figure A5. 19. Estimated weakfish abundance 1982-2010 for two configurations of the MSVPA-X.

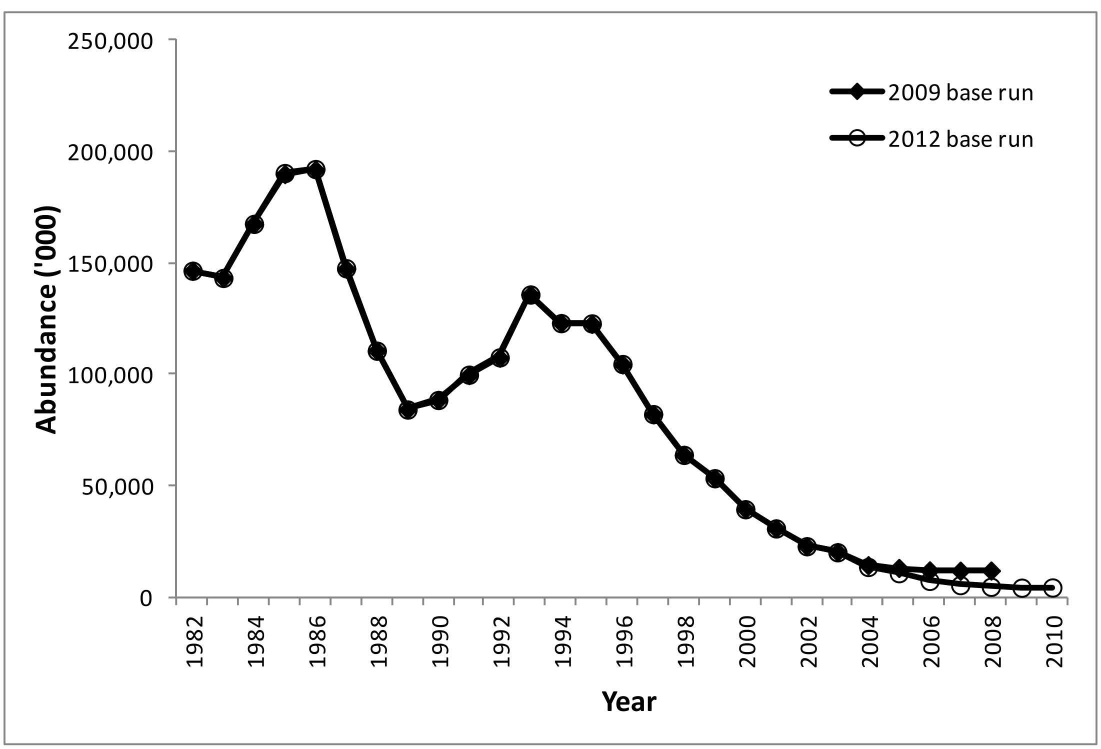


Figure A5. 20. Estimated fishing mortality rates for weakfish 1982-2010 for two configurations of MSVPA-X.

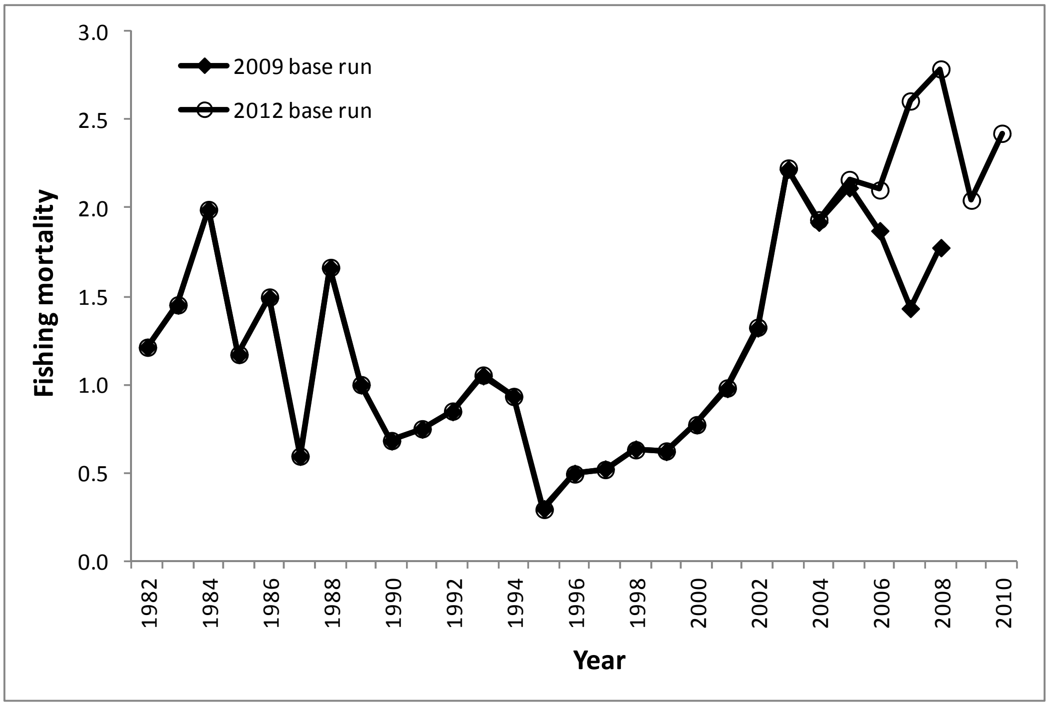


Figure A5. 21. Estimated weakfish spawning stock biomass (SSB) 1982-2010 for two configurations of MSVPA-X.

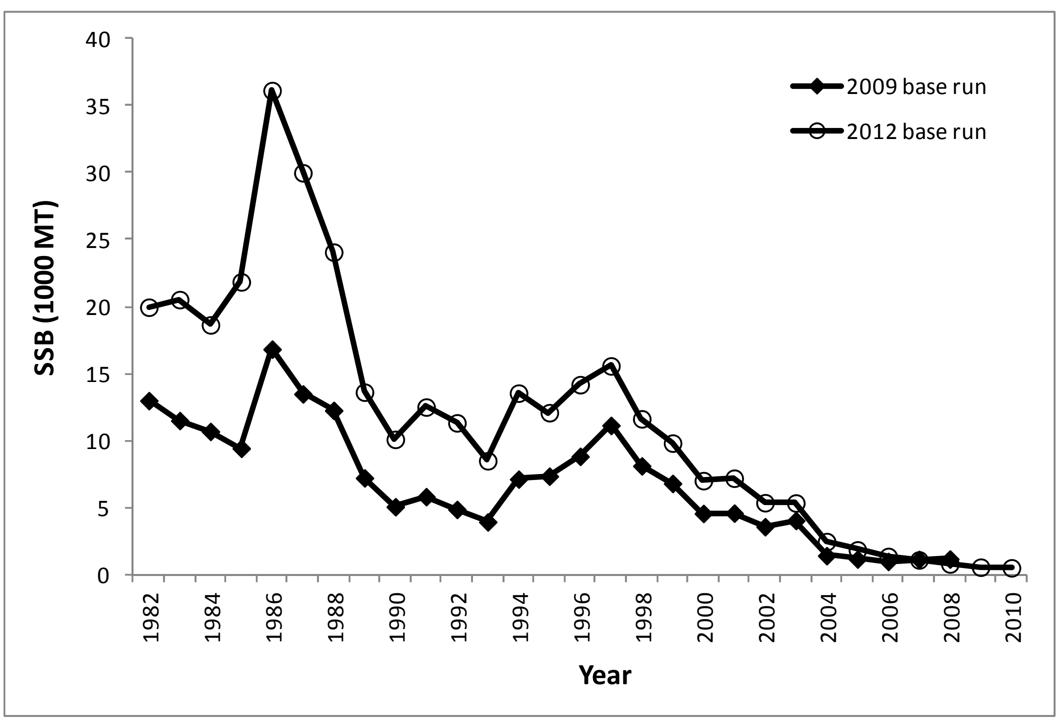


Figure A5. 22. Estimated weakfish recruitment (age-0) 1982-2010 for two configurations of the MSVPA-X.

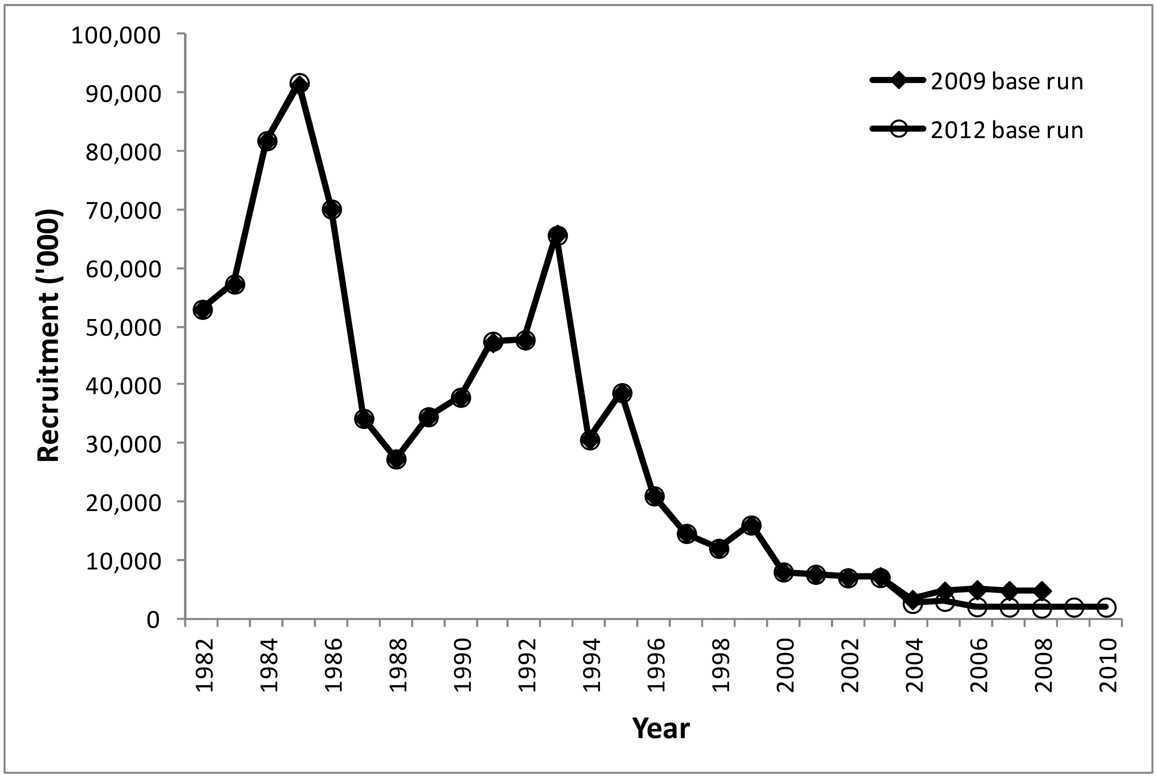
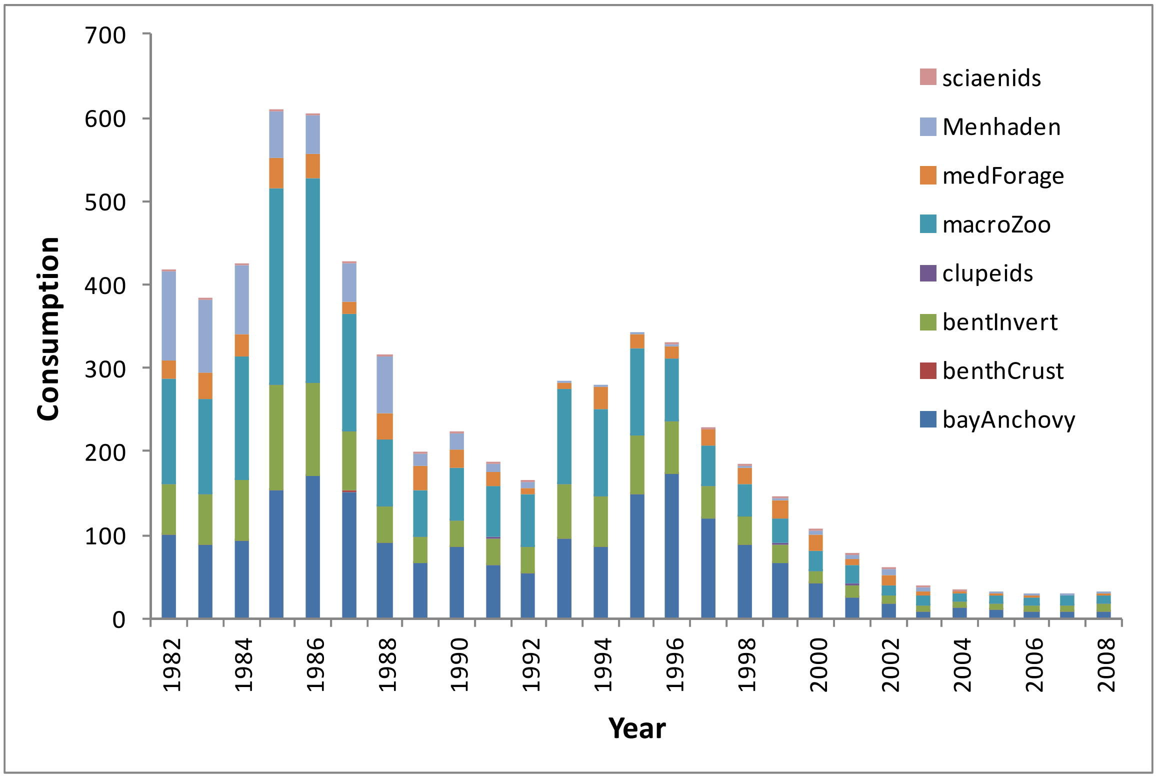


Figure A5. 23. Consumption of various prey species by weakfish 1982-2010 for the 2009 (top) and 2012 (bottom) updates.



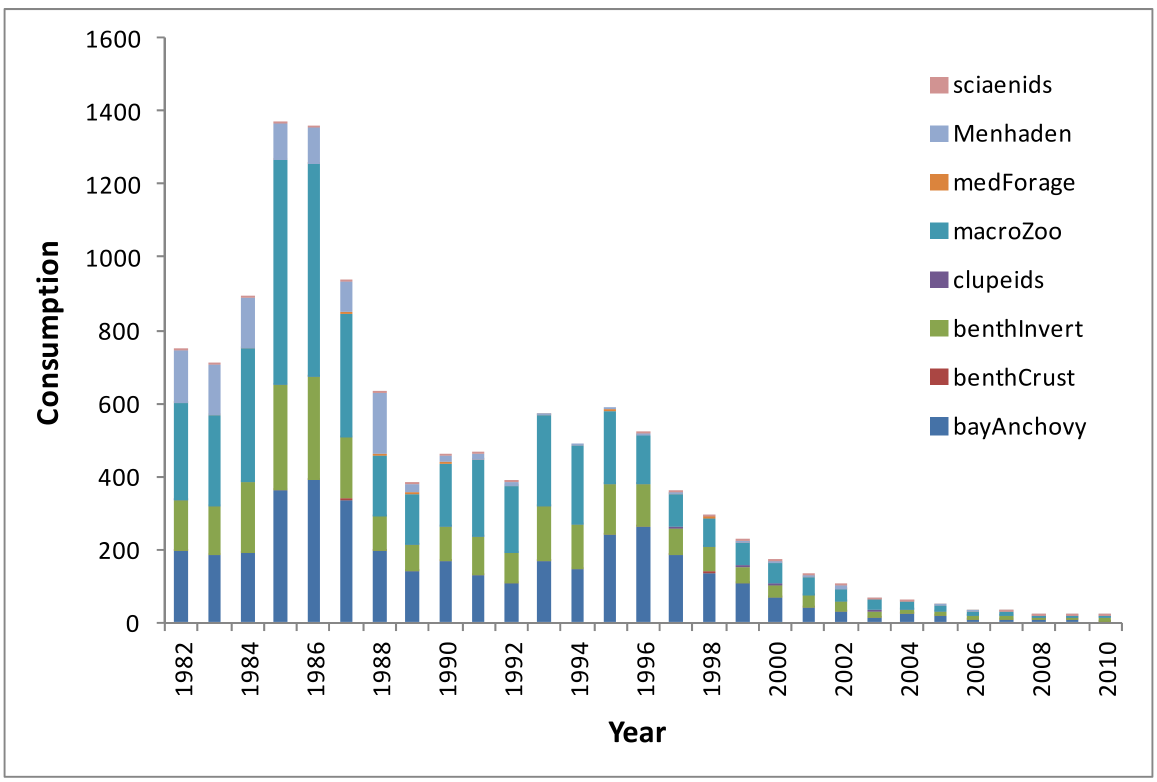


Figure A5. 24. Comparison of estimated biomass trends among three modeled predators in the MSVPA-X (2012 base run), 1982-2010.

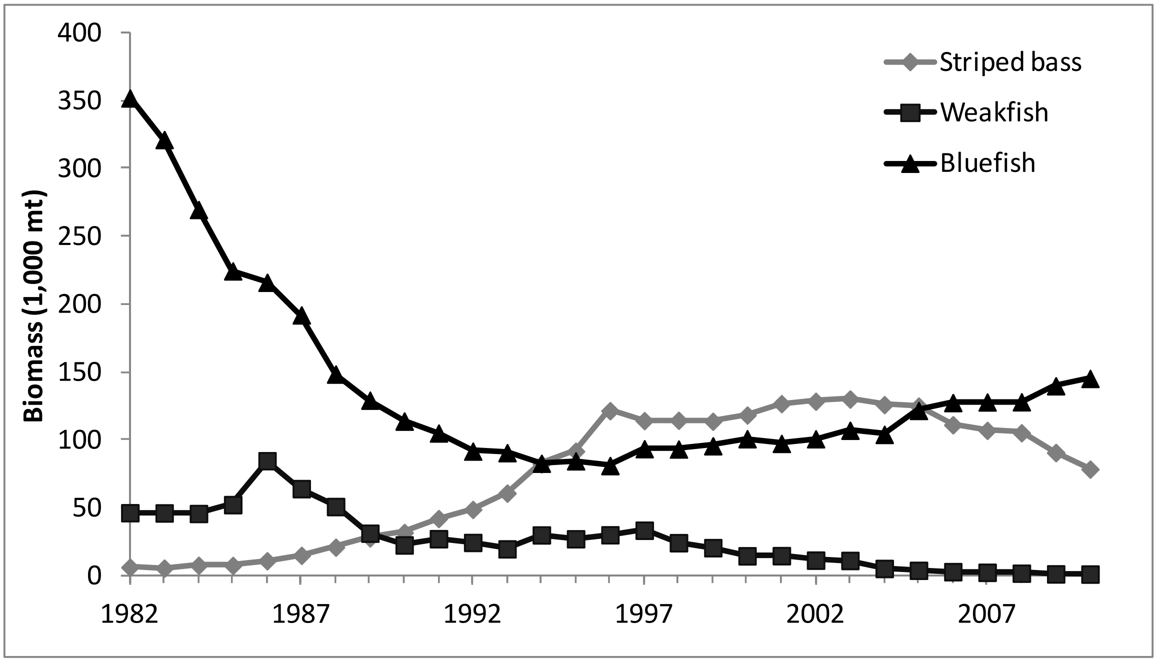


Figure A5. 25. Bluefish diet composition from two configurations of the MSVPA-X.

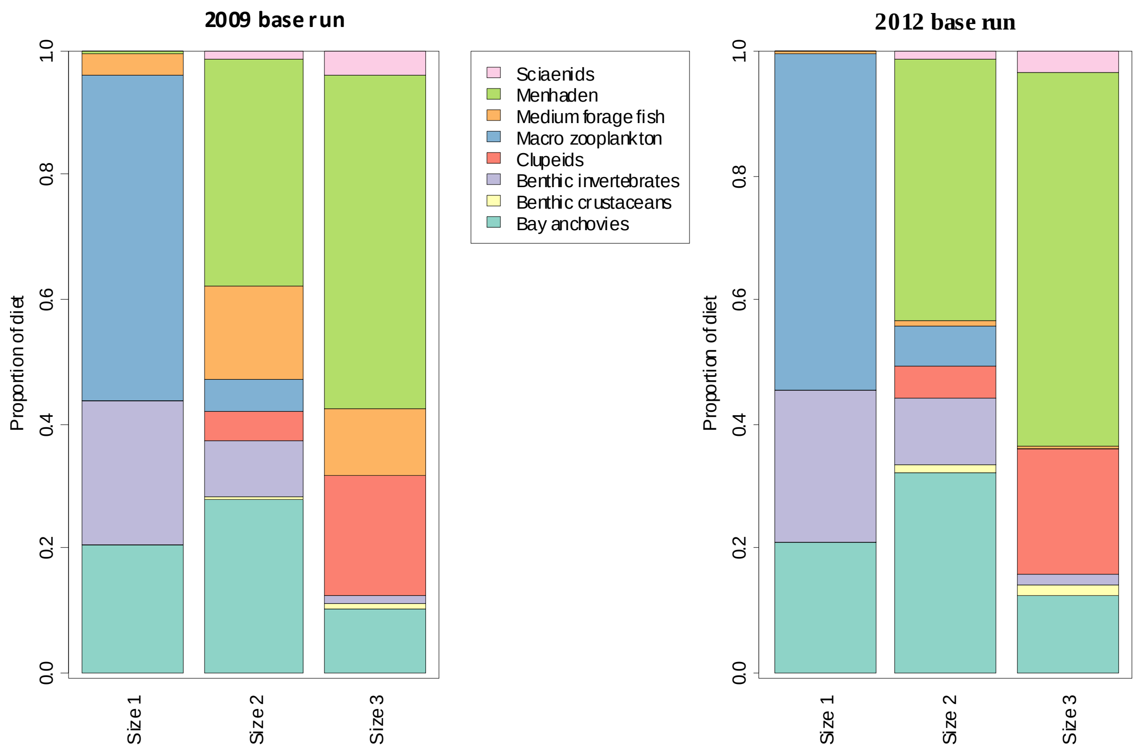


Figure A5. 26. Comparison of prey consumption by bluefish between two configurations of the MSVPA-X.

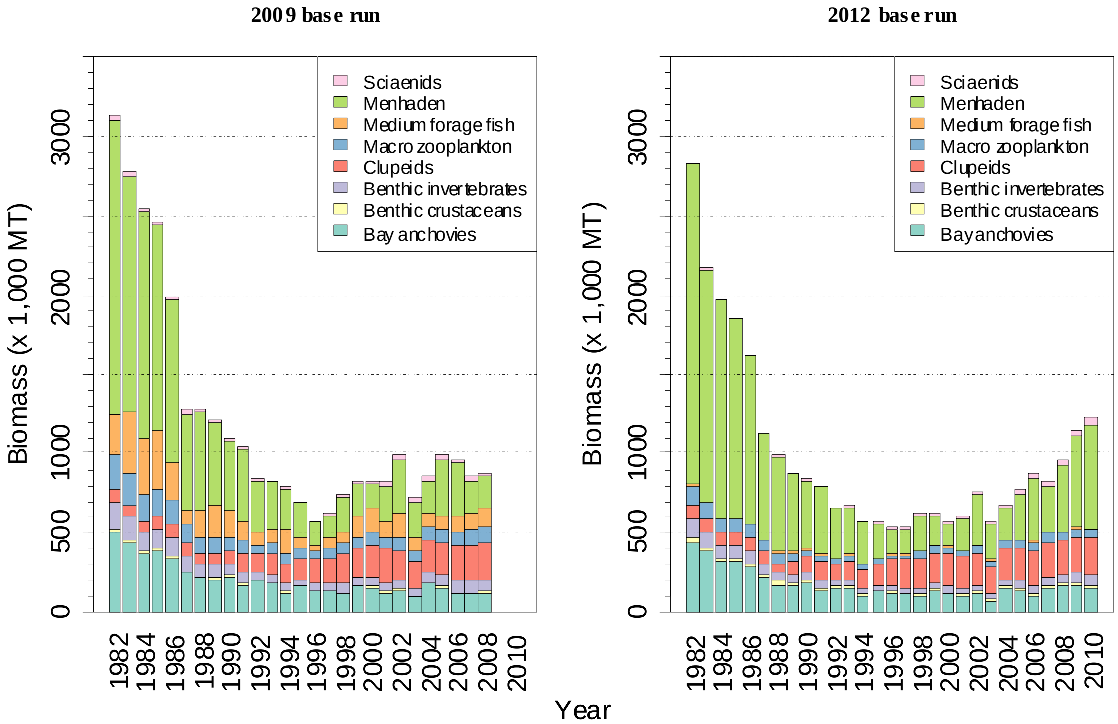
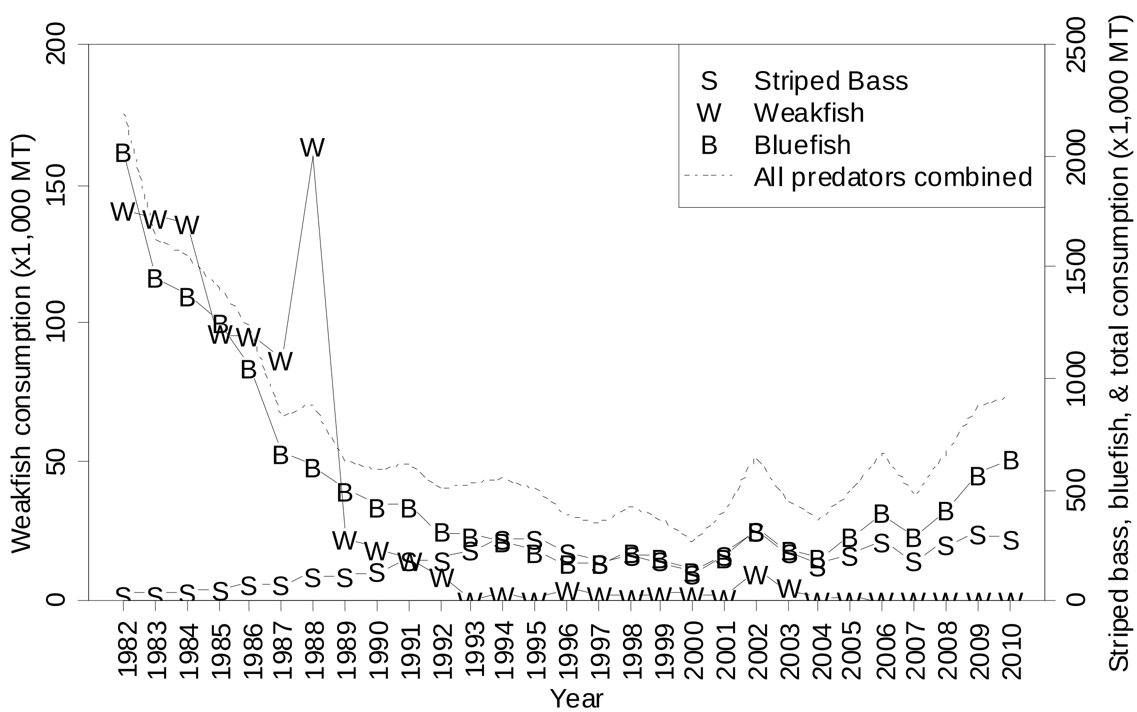


Figure A5. 27. Comparison of menhaden consumed by the three predators in the MSVPA-X (2012 base run). Weakfish consumption is plotted on the left-hand axis; striped bass, bluefish, and total consumption (striped bass + weakfish + bluefish) are plotted on the right--hand axis.



Atlantic States Marine Fisheries Commission

1050 N. Highland Street • Suite 200A-N • Arlington, VA 22201
703.842.0740 • 703.842.0741 (fax) • www.asmfc.org

MEMORANDUM

July 24, 2012

To: **Atlantic Menhaden Management Board**

From: **Jeffrey Brust, Atlantic Menhaden Technical Committee Chairman**

Subject: **Response to "Technical Clarification" Memo**

Statement of the problem

The current overfished definition in the Atlantic menhaden FMP is SSB_{MED} as a target and 50% of SSB_{MED} as a threshold. Since the 2010 benchmark assessment, the Atlantic Menhaden Management Board adopted $F_{30\%}$ and $F_{15\%}$ as the menhaden management *F*-based overfishing target and threshold, respectively. **The TC warns that there is a technical mismatch between the current overfishing and overfished reference points. The TC recommends that if the Board wishes to manage the stock with an $F_{15\%}$ overfishing definition, then a matching overfished definition ($SSB_{15\%}$) should be adopted as well.**

This memo presents a comparison of $SSB_{15\%}$ and $SSB_{30\%}$ with current SSB_{MED} reference points. See also Appendix 3 of the 2012 update assessment report.

Notes on methods

The term "spawning stock biomass", or "SSB", in the update report and this memo refers to fecundity, or mature ova, *not* the biomass of mature adult menhaden. $SSB_{30\%}$ and $SSB_{15\%}$ reference points associated with $F_{30\%}$ and $F_{15\%}$ were calculated using the same vectors of average fecundity, M, and catch-weighted selectivity in addition to a value of median recruitment using the years 1955-2011. The uncertainty in the terminal year stock status indicators is expressed using the results of the 2,000 bootstrap runs of the base BAM model.

Results

Estimates of $SSB_{30\%}$ and $SSB_{15\%}$ and some exploration of the sensitivity of these results to model configuration are presented in Table 1 and Table 2. **If $SSB_{15\%}$ were adopted for management, the stock would be overfished.** The retrospective analysis, which re-estimates benchmarks annually, demonstrates that if $F_{15\%}$ and $SSB_{15\%}$ benchmarks are used, overfishing has been occurring during six of the last 12 years (Table 1) and the population was overfished during nine of the last 12 years.

The entire time series of $SSB_{30\%}$ and $SSB_{15\%}$ and associated bootstrap confidence intervals are shown in Figure 1 and Figure 2 using the years 1955-2011 for benchmark calculation. Phase plots of the last ten years of fecundity-per-recruit-based estimates are shown in Figure 3 using the years 1955-2011 for benchmark calculation. The results based on $SSB_{30\%}$ and $SSB_{15\%}$ benchmarks indicate that the SSB estimates for the terminal year are all below the threshold (limit) using the years 1955-2011 (Figure 4).

Healthy, self-sustaining populations for all Atlantic coast fish species or successful restoration well in progress by the year 2015

Table 1. Results from base BAM model, sensitivity runs, and retrospective analysis. Median recruitment to age-0 (billions) is labeled as R_{MED}, fishing mortality (F) is full F, and population fecundity (SSB) is in billions of mature ova. Subscripts denote the following MED: median; MED.T: threshold associated with the median; and term: terminal year, which is 2011 for the six rows. * denotes that benchmark calculation is not directly comparable with the base run because of differences in selectivity. This table is the same as Table 22 in the update report.

Run	R_{MED}	F_{MED}	$F_{MED.T}$	SSB_{MED}	$SSB_{MED.T}$	F_{term} /F_{MED}	SSB_{term} /$SSB_{MED.T}$	$F_{15\%}$	$F_{30\%}$	$SSSB_{15\%}$	$SSB_{30\%}$	F_{term} /$F_{15\%}$	F_{term} /$F_{30\%}$	SSB_{term} /$SSB_{15\%}$	SSB_{term} /$SSB_{30\%}$
Base run	12.61	2.06	1.02	19092	9546	1.83	1.4	1.34	0.62	30551	61100	3.36	7.22	0.44	0.22
*cR dome-shaped selectivity	12.52	1.95	0.97	18090	9045	1.77	1.39	1.25	0.64	30326	60650	3.31	6.51	0.41	0.21
omit JAI	12.72	2.15	0.97	18365	9182	1.88	1.47	1.34	0.62	30809	61618	3.54	7.6	0.44	0.22
omit PRFC	12.61	2.06	1.02	19140	9570	2.07	1.32	1.34	0.62	30561	61123	3.82	8.2	0.41	0.21
median effective N	11.96	1.51	0.85	22043	11021	2.07	1.26	1.18	0.57	28993	57989	3.26	6.74	0.48	0.24
*cR and cB dome-shaped selectivity	14.84	1.4	0.33	23575	11787	1.04	3.67	1.09	0.65	35953	71906	1.51	2.52	1.2	0.6
Retrospective 2010	12.85	2.17	0.96	18337	9169	1.71	1.23	1.33	0.62	31342	62686	3.31	7.11	0.36	0.18
Retrospective 2009	13.09	2.29	0.99	17594	8797	1.71	1.88	1.33	0.62	32014	64027	2.75	5.9	0.52	0.26
Retrospective 2008	13.12	2.23	0.96	18198	9099	0.9	2.2	1.32	0.62	32300	64599	1.56	3.35	0.62	0.31
Retrospective 2007	13.09	2.32	0.95	17180	8590	1.09	1.48	1.31	0.61	32406	64812	2.3	4.93	0.39	0.2
Retrospective 2006	13.14	2.27	0.99	17679	8839	0.95	2.5	1.3	0.61	32627	65251	1.46	3.13	0.68	0.34
Retrospective 2005	13.26	2.29	1.02	17560	8780	0.37	4.77	1.3	0.61	33006	66008	0.63	1.34	1.27	0.63
Retrospective 2004	13.25	2.3	1	17318	8659	0.49	3.06	1.3	0.61	33009	66020	0.94	2	0.8	0.4
Retrospective 2003	13.26	2.32	0.98	17077	8539	0.47	2.74	1.29	0.6	32983	65963	0.91	1.95	0.71	0.35
Retrospective 2002	13.89	2.26	0.98	17940	8970	0.58	4.31	1.27	0.6	34252	68498	0.89	1.89	1.13	0.56
Retrospective 2001	14.58	2.26	0.97	18570	9285	0.29	6.42	1.26	0.6	35757	71518	0.5	1.06	1.67	0.83
Retrospective 2000	14.6	2.26	0.97	18266	9133	0.43	2.41	1.26	0.59	35483	70970	0.85	1.81	0.62	0.31

Table 2. Summary of benchmarks and terminal year (2011) values estimated for the base BAM model. Fishing mortality rate is full F, and SSB is fecundity in billions of mature ova. The benchmarks were calculated using two time periods: 1955-2011 and 1990-2011. This table is the same as Table 23 in the update report.

Benchmarks and Terminal Year Values	Base BAM Model Estimates 1955-2011	Base BAM Model Estimates 1990-2011
Median Age-0 Recruits (billions)	12.61	8.96
Threshold (Limit): F_{MED}	2.06	1.51
Target: $F_{MED.target}$	1.02	1.04
$F_{30\%}$	0.62	0.7
$F_{15\%}$	1.34	1.53
F_{2011}	4.5	4.5
F_{2011}/F_{MED}	1.83	2.5
$F_{2011}/F_{30\%}$	7.22	6.43
$F_{2011}/F_{15\%}$	3.36	2.94
Target: SSB_{MED}	19,092	25,186
Threshold (Limit):		
$SSB_{MED.thresh}$	9,546	12,593
$SSB_{30\%}$	61,100	49,537
$SSB_{15\%}$	30,551	24,767
SSB_{2011}	13,334	13,334
$SSB_{2011}/SSB_{threshold}$	1.4	1.05
$SSB_{2011}/SSB_{30\%}$	0.22	0.27
$SSB_{2011}/SSB_{15\%}$	0.44	0.54

Figure 1. Estimates of the population fecundity (SSB) relative to the limit $SSB_{15\%}$ from the base BAM model (connected points) using benchmarks calculated over 1955-2011. Shaded area represents the 90% confidence interval of the bootstrap runs. This figure is the same as Figure 73 in the update report.

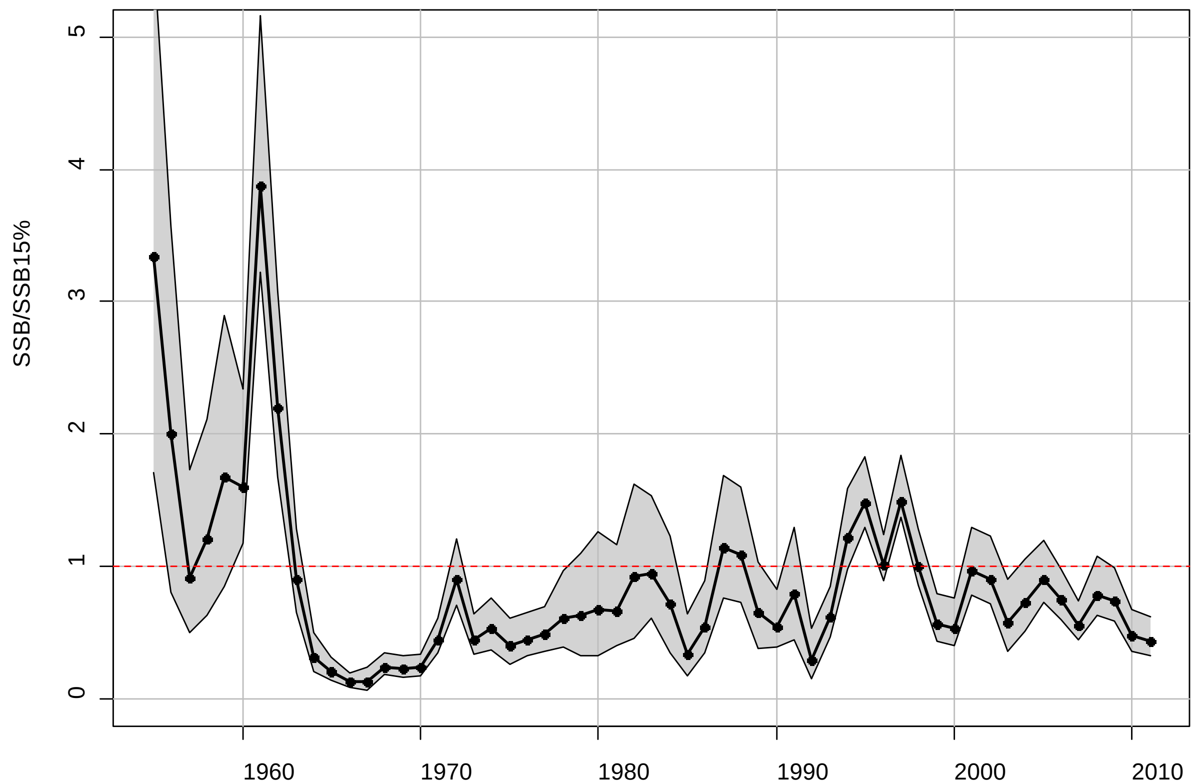


Figure 2. Estimates of the population fecundity (SSB) relative to the target $SSB_{30\%}$ from the base BAM model (connected points) using benchmarks calculated over 1955-2011. Shaded area represents the 90% confidence interval of the bootstrap runs. This figure is the same as Figure 74 in the update report.

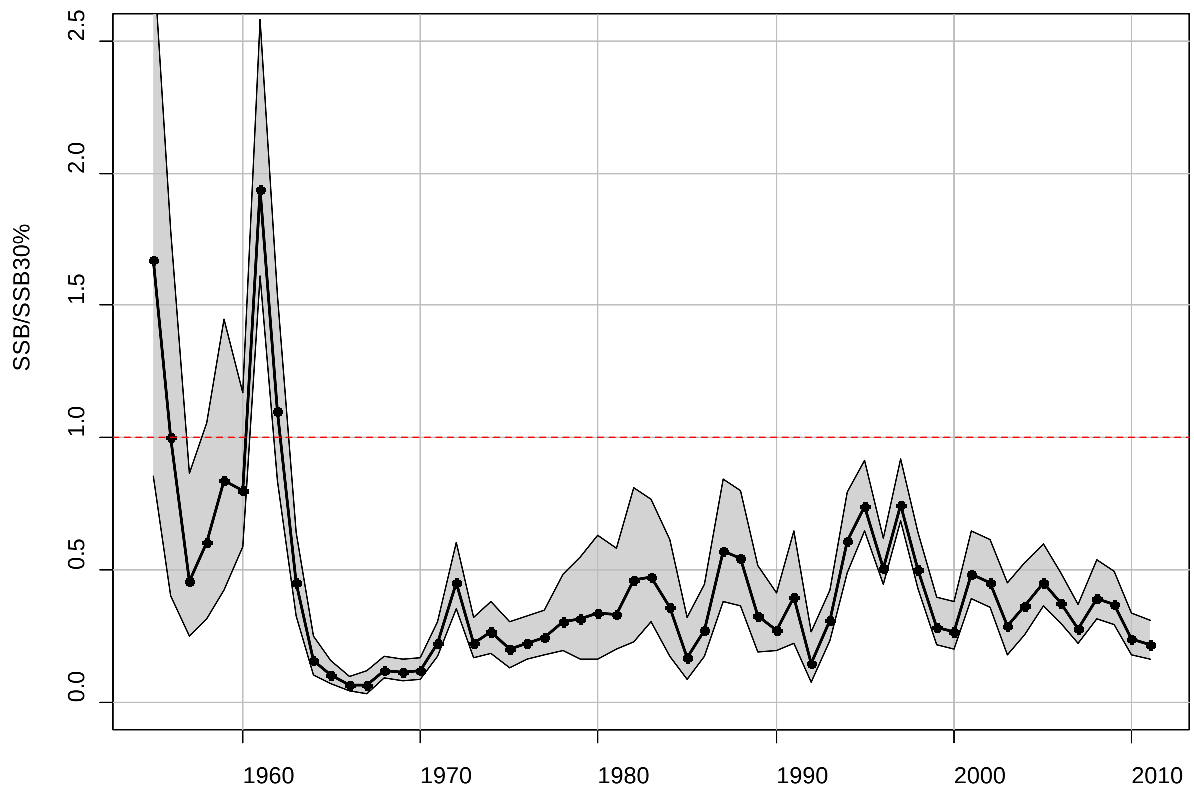


Figure 3. Phase plot of recent estimates of SSB (FEC, or billions of mature ova) and total full fishing mortality rate from the base BAM model with fecundity-per-recruit based benchmarks calculated using the years 1955-2011. Solid vertical and horizontal lines indicate the targets and limits for each respective axis. Double digit number in circles indicates the year of the point estimate (e.g. 08 = 2008). This figure is the same as Figure 75 in the update report.

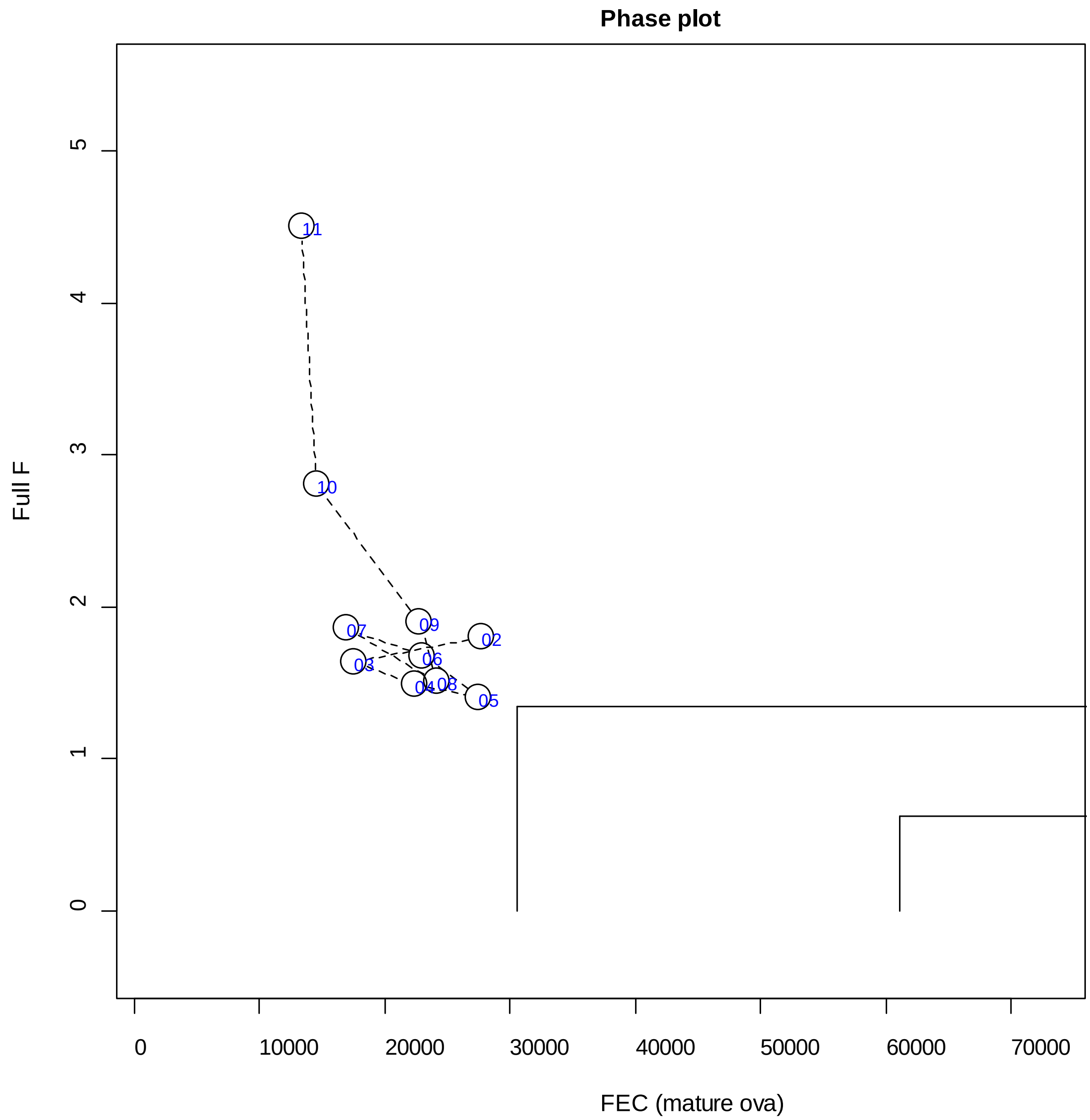
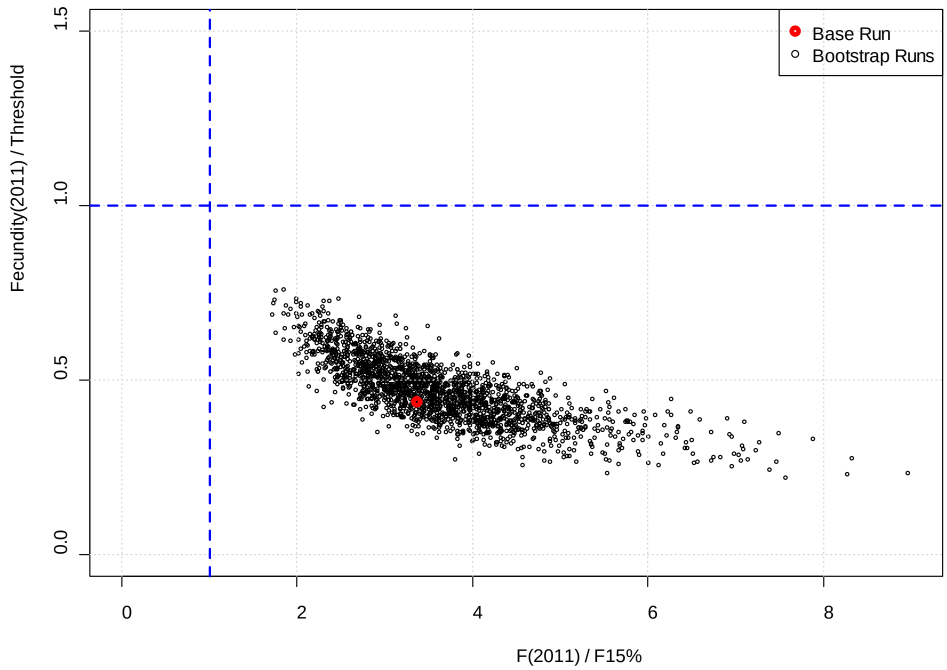


Figure 4. Scatter plot of the 2011 estimates relative to the $F_{15\%}$ and $SSB_{15\%}$benchmarks (limits) from the 2,000 bootstrap estimates from the base BAM model. All years 1955-2011 were used to calculate the benchmarks. This figure is the same as Figure 75 in the update report.



Atlantic States Marine Fisheries Commission

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MEMORANDUM

July 24, 2012

To: **Atlantic Menhaden Management Board**

From: **Jeffrey Brust, Atlantic Menhaden Technical Committee Chairman**

Subject: **Response to "Technical Clarification" Memo**

On June 21, 2012, the Atlantic Menhaden Technical Committee received a memo (M12-050) from Dr. Louis Daniel, Chair of the Atlantic Menhaden Management Board tasking the TC to address certain areas of concern prior to the August 2012 Board meeting. The concerns stem from a number of issues identified during the stock assessment update that undermine the TC's confidence in the assessment results to provide management advice. The Board's request focused the TC's attention on identifying the major concerns with the assessment, and providing alternatives for moving forward under the Amendment 2 framework. The specific requests, and the TC responses, are described in detail below.

Board task 1:
Complete the Assessment Update for inclusion in the briefing materials for the Board.

TC Response:
The stock assessment update is complete. The full report, including text, tables, figures, and appendices, is available with the August 2012 meeting materials.

Board task 2:
Highlight any concerns that the TC has regarding the model output and its use for supporting management decisions.

TC Response:
The five main concerns identified by the Technical Committee are:

- Overweighting of the age composition data.
- Lack of spatial modeling to address changes in the fishery over time.
- Lack of a coastwide adult abundance index.
- Poor fit to the PRFC index.
- Strong retrospective pattern.

The first three were identified by the 2009 peer review panel as potential short comings of the model which could not be addressed during the update process, while the remaining two undermine the TC's confidence in the terminal year estimates. The five issues together cast considerable doubt on the accuracy of the estimates from this update stock assessment. Additional details on these five issues and their implications are discussed in Section 10 of the stock assessment update report.

Board task 3a:
Provide additional quantitative or qualitative data that will provide insight to the Board on the status of the menhaden stock (e.g. recruitment levels, catch age composition, survey trends).

TC Response:

<u>Assessment</u>
The TC's overall level of comfort with the underlying data sources and results used in this assessment has not changed appreciably during this update. However, treatment of data sources within the model deserves close attention during the next benchmark. The TC offers the following statements regarding the update data sources to help guide management:

- Reduction landings trends are reliable.
  - Note the ASMFC-imposed 109,020 t per year annual cap in Chesapeake Bay has never been exceeded.
  - Note also that since 2008, the Reedville reduction plant has self-imposed daily and/or weekly vessel landings quotas because catches often exceeded the factory's processing capacity.
- Catch-at-age for the reduction fishery is reliable.
  - Given enough consecutive years of data, good year classes can be identified and year class strength can be tracked over time.
- Commercial bait landings trends are less reliable, but are unlikely to match or exceed reduction landings.
  - Commercial bait landings have risen across the time series and reached a record high in 2011.
- There is still no coastwide adult survey to provide fishery-independent information about coastwide trends in the stock.
- The MSVPA-X indicated that forage demands from increasing bluefish and striped bass stocks have increased consumption rates on menhaden.
- The TC is concerned about the representativeness of the PRFC and JAI indices in reflecting true changes in stock conditions.

Retrospective bias problems identified during the assessment update are not unique to the BAM (i.e., this is not the result of a coding error or a minor parameterization issue within BAM). The problem may not be resolved without careful review, vetting, and re-analysis of input data sources and model structure.

The TC cannot agree on the issue of correcting for retrospective pattern given the directional changes in bias over the last 11 years.

<u>Stock status and reference points</u>

Although the Technical Committee could not come to consensus on the utility of the terminal year point estimates of F and SSB for management advice, there was consensus that the status determinations were likely robust. In other words, the ratio of $F_{2011}/F_{15\%}$ is likely greater than 1.0 (overfishing is occurring), and $SSB_{2011}/SSB_{MED.T}$ is likely greater than 1.0 (the stock is not overfished), but the exact magnitude of these ratios could not be determined. This statement in supported both quantitatively and qualitatively. Quantitatively, results of the sensitivity runs (albeit limited) and bootstrap analysis indicated the results of stock status were robust to uncertainty in the data and parameterization as specified in this update. Qualitatively, the 2009 benchmark stock assessment concluded that overfishing was occurring, and Addendum V reference points significantly reduced the overfishing threshold (from approximately $F_{8\%}$ to $F_{15\%}$). As harvest levels have increased since 2008 and there has been no significant increase in stock size, overfishing is still likely occurring.

The TC notes that there is a theoretical mismatch between the $F_{15\%}$ overfishing definition recently adopted by the Board and the $SSB_{MED.T}$ in the FMP (*i.e.* the fishing mortality and biomass reference points are in different "currency"). The TC recommends that if the Board wishes to adopt an $F_{15\%}$ overfishing definition, that a matching overfished definition ($SSB_{15\%}$) be adopted as well. This issue is further discussed in Appendix 3 of the stock assessment update report.

Reference points evaluated in the stock assessment update report are intended to be interim reference points while the Technical Committee addresses the Board task of developing ecosystem reference points. Although MSP based reference points were identified as a viable interim option by the Technical Committee, the TC has not had the opportunity to evaluate whether the selected reference points achieve a specific management objective other than generically increasing Atlantic menhaden biomass. The TC reiterates its support for the Multiple Objective Decision Analysis (MODA) process to help the Board identify specific management objectives necessary for development of ecosystem reference points.

Board task 3b:
Also, provide recommendations on potential steps to achieve the Board selected biological reference points.

TC Response: During the February 2012 Management Board meeting, the Technical Committee presented preliminary results of projection analysis that estimated the probability of achieving the Board selected reference points over a range of time frames (1 to 5 years) under different constant harvest scenarios. The analysis was expected to be re-run following completion of the 2012 stock assessment update, and the results would be presented to the Board for potential use in setting harvest levels under Amendment 2. However, given the uncertainty in the results of the update stock assessment, the Technical Committee has concluded that, although, the projection results provide information on stock response given harvest reductions, they should not be used to establish harvest limits for the fishery.

As an alternative to using projections to set TACs, ad hoc approaches are used by several regional Fishery Management Councils for species with poor assessment data or uncertain stock assessment results. Typically, in these situations, most Councils use their landings/catch data as the only reliable means of setting harvest limits. A document entitled "Calculating Acceptable Biological Catch for Stocks that have reliable Catch Data Only" was recently published (ORCS 2011), and serves as guidance to set interim removal levels under these conditions.

To summarize the ORCS report; generally an average of the last 3-5 years of landings are used as this reflects recent history. A precautionary multiplier is then applied to decrement the average landings and set a harvest limit. Decision of the appropriate multiplier is cautiously decided based on factors such as life history, ecological function, stock status, and an understanding of exploitation. Typically this multiplier can range from 0.85 to 0.25 (Table 1).

Table 1. Summary of ad-hoc approaches used by Fishery Management Councils to set harvest limits in data poor situations.

Council	Species group	Multiplier	Comments
New England	Atlantic herring	1	Not OF, OF not occurring
New England	Red crab	1	Based on stock status
Carribean		0.85	Used to set ABC and ACL
New England	Groundfish	0.75	
Pacific		0.75	Used to set ABC
Pacific	Groundfish	0.5	Used to set OY
Pacific	Coastal pelagics	0.25	Used to set ABC

In the New England approach, the multiplier was chosen at 1.0 suggesting catch be maintained at current levels. The rationale was that the stock was not overfished and overfishing was not likely to be occurring. Other evidence, such as size at age, also indicated that the overall stock status was good. Further, landings were well monitored and discards of the target stock were low.
In the case of the Pacific Fishery Management Council the multiplier was set at 0.25. This number reflected the importance of herring as forage for stellar Sea Lions and other endangered mammals, the high level of exploitation, and the fact that Pacific Herring spawn in discreet and vulnerable aggregations (when they are targeted by the fishery).

It should be noted that the multiplier is never set at a value >1.0; indicating that catch should not be allowed to increase in these uncertain situations. Table 2 provides some additional decision making framework information that goes into the choice of a multiplier.

Table 2. The method table showing possible actions for determining ABC based on different fishery impact categories and expert opinion. Taken from the workshop report of the 2nd National SSC meeting (From ORCS, 2011).

Historical Catch	Expert Judgment	Possible Action
Nil, not targeted	Inconceivable that catch could be affecting stock	Not in fishery; Ecosystem Component; SDC not required
Small	Catch is enough to warrant including stock in the fishery and tracking, but not enough to be of concern	Set ABC and ACL above historical catch; Set ACT at historical catch level. Allow increase in ACT if accompanied by cooperative research and close monitoring.
Moderate	Possible that any increase in catch could be overfishing	ABC/ACL = f(catch, vulnerability) So caps current fishery
Moderately high	Overfishing or overfished may already be occurring, but no assessment to quantify	Set provisional OFL = f(catch, vulnerability); Set ABC/ACL below OFL to begin stock rebuilding

ABC = Acceptable Biological Catch
ACL = Annual Catch Limit
ACT = Annual Catch Target
OFL = Overfishing Level

For Atlantic menhaden; the stock is likely experiencing overfishing given the recent changes in reference points (ASMFC 2012). Overall, Atlantic menhaden have low vulnerability given their short life history, age at spawning, rapid growth, and fecundity. However, menhaden also serve as forage for other valuable commercial and recreationally important species. While landings history data are good, some significant uncertainties remain in recruitment due to natural variability. As such Table 3 outlines some possible options using a 3 or 5 year average of the catch, with the addition of potential multipliers to be used on those catch values. Typically Councils and their SSC's dictate the multipliers in 0.25 increments, given the other uncertainties involved.

Table 3. Estimated harvest levels (thousand MT) for a range of uncertainty correction factors.

Probability of reducing overfishing decreases moving towards a multiplier of 1.

Average	Multiplier					
	1	0.9	0.8	0.75	0.5	0.25
3-year	213.5	192.2	170.8	160.2	106.8	53.4
5-year	209.5	188.5	167.6	157.1	104.7	52.4

It should be noted that, at this time, these are provided only as information for the Management Board; the Technical Committee has not had time to review these as a group to determine which (if any) would be appropriate for use in managing the Atlantic menhaden stock.

Reference

ORCS-Berkson, J., L. Barbieri, S. Cadrin, S. L. Cass-Calay, P. Crone, M. Dorn, C. Friess, D. Kobayashi, T. J. Miller, W. S. Patrick, S. Pautzke, S. Ralston, M. Trianni. 2011. Calculating Acceptable Biological Catch for Stocks That Have Reliable Catch Data Only (Only Reliable Catch Stocks – ORCS). NOAA Technical Memorandum NMFS-SEFSC-616, 56 P.

Atlantic States Marine Fisheries Commission

Draft Amendment 2 to the Interstate Fishery Management Plan for Atlantic Menhaden

ASMFC Vision Statement:
Healthy, self-sustaining populations for all Atlantic coast fish species or successful
restoration well in progress by the year 2015.

Revised August 6, 2012

August, 2012

DRAFT DOCUMENT FOR BOARD REVIEW

Amendment 2 to the Interstate Fishery Management Plan for
Atlantic Menhaden

Prepared by

Atlantic States Marine Fisheries Commission
Atlantic Menhaden Plan Development Team

Plan Development Team Members:
Jason McNamee, RI Department of Environmental Management Marine Fisheries Section
Harry Rickabaugh, Maryland Department of Natural Resources
Joe Grist, Virginia Marine Resources Commission
Derek Orner, National Marine Fisheries Service
Mike Waine (Chair), Atlantic States Marine Fisheries Commission

This is a report of the Atlantic States Marine Fisheries Commission pursuant to U.S. Department of Commerce, National Oceanic and Atmospheric Administration Award Nos. XXXXXXXXX.

DRAFT

DRAFT DOCUMENT FOR BOARD REVIEW

The Atlantic States Marine Fisheries Commission seeks your input on Draft Amendment 2 to the Atlantic Menhaden Fishery Management Plan

The public is encouraged to submit comments regarding this document during the public comment period. Comments must be received by **5:00 PM (EST) on XXXXX.** Regardless of when they were sent, comments received after that time will not be included in the official record. The Atlantic Menhaden Management Board will consider public comment on this document before finalizing Amendment 2 at their October meeting.

You may submit public comment in one or more of the following ways:

1. Attend public hearings held in your state or jurisdiction, if applicable.
2. Refer comments to your state's members on the Atlantic Menhaden Board or Atlantic Menhaden Advisory Panel, if applicable.
3. Mail, fax, or email written comments to the following address:

Mail: Mike Waine
Atlantic States Marine Fisheries Commission
1050 N. Highland Street, Suite 200 A-N
Arlington VA. 22201

Email: mwaine@asmfc.org
(Subject: Amend 2)
Phone: (703) 842-0740
Fax: (703) 842-0741

If you have any questions please call Mike Waine at (703) 842-0740.

DRAFT

DRAFT DOCUMENT FOR BOARD REVIEW

The timeline for completion of Amendment 2 is as follows:

	Feb 2012	Mar 2012	Apr 2012	May 2012	June 2012	July 2012	Aug 2012	Sept 2012	Oct 2012
Approval of Draft PID by Board	**X**								
Public review and comment on PID		**X**	**X**						
Board review of public comment; Board direction on what to include in Draft Amendment 2				**X**					
Preparation of Draft Amendment 2					**X**	**X**			
Review and approval of Draft Amendment 2 by Board							**X**		
Public review and comment on Draft Amendment 2								**X**	
Board review of public comment on Draft Amendment 2									**X**
Review and approval of the final Amendment 2 by the Board, Policy Board and Commission									**X**

DRAFT

EXECUTIVE SUMMARY

The executive summary highlights all the sections of Draft Amendment 2 that contain a management decision. The summary is intended to be a shortened version of the document distributed at public hearings.

1.0 INTRODUCTION

The Atlantic States Marine Fisheries Commission (ASMFC) is developing an amendment to its Interstate Fishery Management Plan (FMP) for Atlantic Menhaden (*Brevoortia tyrannus)* under the authority of the Atlantic Coastal Fisheries Cooperative Management Act (ACFCMA). The Commission, through the coastal states of Maine through Florida, is responsible for managing Atlantic menhaden. ASMFC has coordinated interstate management of Atlantic menhaden in state waters (0-3 miles) since 1981. Atlantic menhaden is currently managed under Amendment 1 and Addenda I-V to the Fishery Management Plan (FMP). Amendment 2 to the Interstate Fishery Management Plan for Atlantic menhaden replaces Amendment 1 to the 1981 FMP for Atlantic menhaden. This document contains all applicable management options still in implementation from Amendment 1 and all five addenda. Management authority in the exclusive economic zone (EEZ, 3-200 miles from shore) lies with NOAA Fisheries.

1.1 BACKGROUND INFORMATION

1.1.1 Statement of the Problem

The 2010 Atlantic menhaden benchmark stock assessment Peer Review Panel noted that menhaden population abundance had declined steadily and recruitment had been low since the last peak observed in the early 1980s. Fishing at the fishing mortality (F) threshold reference point in the terminal year (2008) has resulted in approximately 8% of the maximum spawning potential (MSP). Therefore, the Panel recommended alternative reference points be considered that provide greater protection for spawning stock biomass (SSB) or population fecundity relative to the unfished level. In November 2011, the Atlantic Menhaden Management Board responded to that recommendation and adopted new F reference points via Addendum V. The new reference points are more conservative than the previous to account for the following: (1) while menhaden are not overfished the number of fish in the population has been declining, (2) while menhaden are important for many fisheries they also provide important ecological services, (3) strong recruitment classes may be dependent on favorable environmental conditions, and (4) recent science suggest conserving a larger percentage of the spawning stock is an important consideration for forage species such as menhaden. The new F threshold is $F_{15\%MSP}$ and the new F target is $F_{30\%MSP}$. Full $F/F_{15\%MSP}$ for the terminal year (2011) was greater than 1, therefore, overfishing is occurring. Addendum V states that when overfishing is occurring the Board will take steps to reduce F to the target level. In order to reduce overfishing to the target, the Board needs to consider changes in the management tools used to regulate the fishery.

The new F reference points adopted by the Board are intended to be interim reference points while the Commission's Multispecies Technical Committee develops ecological-based reference points (ERP). The ERPs will take some time to develop due to the complexity of modeling predator-prey relationship in marine species that rely on menhaden for forage (e.g., striped bass, bluefish, weakfish). In either case (biological or ecological reference points) the intent is to manage Atlantic menhaden at sustainable levels to support fisheries and meet predator demands through sufficient SSB to prevent stock depletion and protect against recruitment failure.

2.5 BIOLOGICAL REFERENCE POINTS

Threshold reference points are the basis for determining stock status (i.e., whether overfishing is occurring or a stock is overfished). When the fishing mortality rate (*F*) exceeds the *F*-threshold, then overfishing is occurring; the rate of removal of fish by the fishery exceeds the ability of the stock to replenish itself. When the reproductive output (measured as spawning stock biomass or population fecundity) falls below the biomass-threshold, then the stock is overfished, meaning there is insufficient mature female biomass (SSB) or egg production (population fecundity) to replenish the stock.

Current Overfishing, Overfished/Depleted Definitions

The current overfishing definition is a fecundity-per-recruit threshold of $F_{15\%MSP}$ and a target of $F_{30\%MSP}$. The current fecundity-based overfished definition is a target of SSB_{MED} and a threshold of $SSB_{MED.T}$ (half of SSB_{MED}). Benchmarks are calculated using all years, 1955-2011. Reference points are recalculated during an update and benchmark stock assessment, see the latest stock assessment for point estimates of reference points and stock status determination (ASMFC, 2012).

SSB Reference Points

As noted, the current overfished definition is SSB_{MED} as a target and 50% of SSB_{MED} as a threshold. Since the 2010 benchmark assessment, the Atlantic Menhaden Management Board adopted $F_{30\%MSP}$ and $F_{15\%MSP}$ as the menhaden management *F*-based overfishing target and threshold, respectively. **The TC warns that there is a technical mismatch between the current overfishing and overfished reference points. The TC recommends that if the Board wishes to manage the stock with an $F_{15\%MSP}$ overfishing definition, then a matching overfished definition ($SSB_{15\%MSP}$) should be adopted as well.**

The Board may consider a change to the SSB biological reference points through Amendment 2.

Option A: Status Quo. The current fecundity-based overfished definition is a target of SSB_{MED} and a threshold of $SSB_{MED.T}$ (half of SSB_{MED}).

Option B: The fecundity-based overfished definition is a target of $SSB_{30\%MSP}$ and a threshold of $SSB_{15\%MSP}$.

2.6.2 Stock Rebuilding Schedules

SSB Rebuilding Schedule

The Board shall take action to rebuild the Atlantic menhaden stock to at least the target SSB level in a time frame that shall be no longer than 10 years.

F Rebuilding Schedule

Through Amendment 2, the Board will take immediate actions to end overfishing. However, because the reductions in F are more substantial to achieve the F target, the Board is considering a three, five and ten year schedule to reduce F to the target level. Depending on the schedule for reducing F, a time stepped approach may be used in which F would be reduced in smaller increments until the target is reached. If the target F is to be achieved on a shorter time frame, annual reductions in landings may be more substantial than if the F was achieved over a longer time period.

Option A: The Board is not required to specify a time frame to rebuild the Atlantic menhaden stock to the target F level.

Option B: The Board shall take action to rebuild the Atlantic menhaden stock to at least the target F level in a time frame that shall be no longer than 3 years.

Option C: The Board shall take action to rebuild the Atlantic menhaden stock to at least the target F level in a time frame that shall be no longer than 5 years.

Option D: The Board shall take action to rebuild the Atlantic menhaden stock to at least the target F level in a time frame that shall be no longer than 10 years.

3.6 SUMMARY OF MONITORING PROGRAMS

In order to achieve the goals and objectives of Amendment 2, the collection and maintenance of quality data is necessary.

3.6.1 Catch and Landings Information

The reporting requirements for the Atlantic menhaden fishery are based in part on Captains Daily Fishing Reports (CDFRs). The ASMFC, NMFS, US Fish & Wildlife Service, the New England, Mid-Atlantic, and South Atlantic Fishery Management Councils, and all the Atlantic coastal states have developed a coastwide fisheries statistics program (Atlantic Coastal Cooperative Statistics Program). A minimum set of reporting requirements based on a trip-level for fishermen and dealers has been developed as the minimum standard for data collection on the Atlantic coast. Nothing in the proposed program would prohibit a state/agency from requiring more detailed information on a trip basis if so desired.

3.6.1.1 Commercial Catch and Effort Data Collection Program(s)

The ACCSP commercial data collection program is a mandatory, trip-based system with all fishermen and dealers required to report a minimum set of standard data elements (refer to the Atlantic Coast Fisheries Data Collection Standards for details).

All menhaden purse seine and bait seine vessels (or snapper rigs) shall be required to submit the Captain's Daily Fishing Reports (CDFRs) through the Standard Atlantic Fisheries Information System (eTrips), an ACCSP standards compliant electronic reporting system.

Reduction Fishery

Daily vessel unloads (in thousands of standard fish) are emailed daily to the NMFS. Captains Daily Fishing Reports (CDFRs) from the Reedville menhaden fleet are used to estimate in-season removals from Chesapeake Bay (Chesapeake Bay Cap). CDRFs are deck logbooks maintained by the Virginia reduction purse-seine vessels. Total removals by area are calculated at the end of the fishing season. At-sea catches from the CDFRs are summed by vessel, and compared to total vessel unloads from company catch records. Individual at-sea sets are then multiplied by an adjustment factor (company records/ at-sea estimates). Adjusted catches by set are converted to metric tons, and accumulated by fishing area. Catch totals are reported by ocean fishing areas (New Jersey, Delaware, and Maryland in the EEZ, Virginia and North Carolina), while catches inside and outside Chesapeake Bay are delineated by the Chesapeake Bay Bridge Tunnel.

NMFS port agent samples purse-seine catches at dockside in Reedville, VA, throughout the fishing season (May through December), providing data for age composition determination.

Bait Fishery
The current catch reporting requirements for the Atlantic menhaden fisheries do not provide timely or complete data for use by managers and scientists, particularly the bait fishery. The summary of current reporting requirements, by state, are provided in Table 15.

3.6.1.2 Quota Monitoring

Quota monitoring, whether coastal, or state-by-state, is dependent upon the strength of state specific monitoring programs, as described in Section 3.6.1.

Option A. Status Quo
- Utilize current monitoring systems, as described in *Section 3.6.1.1.,* in existence, no additional requirements.
- Does not improve timeliness or completeness of data collection.

Option B. Approved State Methodology for Monitoring
- Must be approved by the Board as a valid method for monitoring (high probability of success)
- ability to monitor fisheries landings to within 7 days of actual landing dates.

Option C. Require SAFIS dealer weekly reporting system
- Due Tuesday by midnight, available by 6am Wednesday consolidated (lag 1-10 days)
- Consistent with NE dealers reporting requirements
- Difficult to implement in states with established harvester-dependent reporting, not dealer-dependent reporting.
- Not difficult to implement in states that use ACCSP eTrips.

Option D. Require SAFIS ETrips fisherman daily reporting system
- Due by 10pm, available by 6am next day for consolidation
- Limiting factor, computer access and familiarity of fisherman

Option E. SAFIS weekly with trigger to SAFIS eTrips when approaching quota maximum (85% trigger)
- Utilize weekly system until it is projected that 85% of the quota will be attained, then require daily reporting system until close of fishery (or end of season), whichever comes first.

3.6.2 Fishery-Dependent Data

3.6.2.1 Biological Data

The Beaufort Laboratory of the Southeast Fisheries Science Center (NMFS) conducts biostatistical sampling of the Atlantic menhaden reduction fishery (Smith 1991). The program began preliminary sampling in the Mid-Atlantic and Chesapeake Bay areas during 1952-1954 and has continued uninterrupted since 1955, sampling the entire range of the Atlantic menhaden purse-seine reduction fishery. Detailed descriptions of the sampling procedures and estimates gathered through the program are cited in Smith (1991).

The biostatistical data, or port samples, for length- and weight-at-age are available from 1955 through 2011, and represent one of the longest and most complete time series of fishery data sets in the nation (Table 1). The NMFS employs a full-time port agent at Reedville, VA to sample catches at dockside throughout the fishing season for age and size composition of the reduction catch.

Table 1. Number of ten fish samples from the reduction fishery landings at Reedville, VA from 2007-2011.

Year	2007	2008	2009	2010	2011
Number of ten-fish samples acquired in VA Reduction Fishery	379	277	283	327	323

Biological sampling of the Atlantic menhaden bait harvest for size was initially scrutinized by the Atlantic Menhaden Advisory Committee (AMAC; predecessor of the Atlantic Menhaden Technical Committee) in the early 1990s. Target sample sizes from the menhaden bait fisheries by state and gear were established by the AMAC in 1994 (Table 2). Table 3 presents recent bait harvest sampled by year, state and gear during 2007-2011. All age samples are processed by the NMFS Beaufort Laboratory.

Table 2. Target number of ten fish samples as established in 1994 for the bait harvest.

State	Target # of 10-fish samples
Massachusetts & Maine Combined (RI*)	37
New Jersey	50
Virginia	41
North Carolina	14
Total	142

*Bait purse-seine crews at the time were fishing in Naragansett Bay (RI), but landing catch in Swansea, MA.

Table 3. Number of ten fish samples by year, state, and gear, sampled from the bait harvest from 2007-2011.

	VA		PRFC		NJ		RI/MA		ME		Total	
Year	purse seine	pound net	purse seine	pound net	purse seine	pound net	purse seine	pound net	purse seine	pound net	Purse seine	pound net
2007	47	8	0	0	61	1	17	19	0	0	125	28
2008	37	8	0	0	73	5	12	14	16	0	138	27
2009	57	11	0	0	44	1	3	4	0	0	104	16
2010	36	12	0	3	55	0	0	7	0	0	91	22
2011	37	17	0	9	51	0	0	0	0	0	88	26

The Board may consider mandatory biological sampling requirements to meet the data needs of Atlantic menhaden stock assessments.

Option A. Status quo. Biological sampling requirements are not a mandatory element of the FMP.

Option B. The TC will review and recommend the targeted number of ten fish samples to be collected by state, and based on the TC's recommendation the Board may select specific biological monitoring requirements for Amendment 2.

3.6.2.2 Adult Survey Index

PRFC Pound Net Index

Pound net landings collected by the Potomac River Fisheries Commission (PRFC) are used to develop a fishery-dependent index of relative abundance for adult menhaden. Pound nets are a stationary, and presumably nonselective, fishing gear. PRFC pound nets are set in the Potomac River adjacent Chesapeake Bay; among other fishes, they catch menhaden primarily ages-1 through -3. Other than the reduction landings, these data represent the only other available information that can be used to infer changes in relative abundance of adult menhaden along the east coast of the U.S.

The index (1976-2011) is based on annual ratios of pounds of fish landed to total pound net days fished. Raw catch and effort data are available for 1976-1980 and 1988-2011. Recently, the PRFC was able to obtain and computerize more detailed data on pound net landings and effort, which allowed index values to be calculated for 1964-1975 and 1981-1987.

The Board may consider mandatory fishery-dependent sampling requirements to meet the data needs of Atlantic menhaden stock assessments.

Option A. Status quo. Fishery-dependent sampling requirements for an adult survey index are not a mandatory element of the FMP.

Option B. Require all states that have a pound net fishery, to keep catch/effort data (i.e., pounds landed, number of nets fished, number of days fished per net) for potential development of a CPUE index of adults across the range of Atlantic menhaden. Additional biological data would be required including age and length samples to determine the selectivity of those fisheries.

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4.2 COMMERCIAL FISHERY MANAGEMENT MEASURES

4.2.1 Total Allowable Catch (TAC)

Option A. Status quo. Harvest will not be restricted through the use of a TAC.

Option B. Harvest will be restricted through the use of a TAC. (*If selected see Sections 4.2.1.1 through 4.2.1.7*).

4.2.1.1 TAC Specification

The Atlantic Menhaden Management Board will set an annual or multi-year TAC based on the following procedure.

The Atlantic Menhaden TC will annually review the best available data including, but not limited to, commercial and recreational catch/landing statistics, current estimates of fishing mortality, stock status, survey indices, assessment modeling results, and target mortality levels. The TC will calculate quota options based on the Board selected method of setting a quota (see *Section 4.2.1.2*). The Board will set an annual TAC with the option of setting a multi-year TAC, reviewed annually.

The directed fishery for Atlantic menhaden will be closed when the Plan Development Team Chair projects the catch will exceed OPTION% of the TAC. States have the responsibility to close the Atlantic menhaden commercial fishery in their state once the quota (or a percentage thereof) has been reached.

Acknowledging that any changes selected in reporting requirements (Section 3.6.1.2) may take time to implement completely, the Board may select a lower closing percentage to account for late reports at the time of season closure.

Option A. 85%
Option B. 90%
Option C. 95%
Option D. The Board will specify annually or multi-year, a percentage of the TAC to base closures on.

4.2.1.2 TAC Setting Method

Achieving the F threshold and target will require the implementation of management measures that lower landing levels compared to recent years.

Option A: Projections from 2012 Stock Assessment Update

The constant landings scenarios in (Table 4 and Table 5; below) are based on the current overfishing status in 2011. Intuitively, lower landing levels have a higher probability of achieving the threshold, whereas higher landing levels have a lower probability of achieving the threshold. These projections assume constant landings, meaning if a specific landing level is maintained from one year to the next the probability of achieving the threshold increases. These principles also apply to the probabilities of achieving the target over a given time frame as detailed in Table 5. The projections illustrate how the F reference points may be achieved if the board chooses to adopt a TAC based on a constant landings approach.

To give these constant landing scenarios a frame of reference, the average total landings of Atlantic Menhaden over the last 3 years was 213.5 thousand metric tons.

However, given the uncertainty in the results of the stock assessment update, the Technical Committee has concluded that, although, the projection results provide information on stock response given harvest reductions, they should not be used to establish harvest limits for the fishery.

Table 4. Constant landing projections based on the 2012 stock assessment update. The probability of the fishing mortality rate (F) being less than the THRESHOLD over time for given constant landing scenarios. Total landings are partitioned with 75% to the commercial reduction fishery and 25% to the commercial bait fishery.

Landings (1000s mt)	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
75	0	0.09	0.86	0.99	1	1	1	1	1	1
100	0	0.01	0.5	0.89	0.97	1	1	1	1	1
125	0	0	0.19	0.58	0.81	0.92	0.97	0.99	0.99	1
150	0	0	0.04	0.25	0.47	0.62	0.74	0.83	0.9	0.93
175	0	0	0.01	0.06	0.16	0.27	0.36	0.44	0.51	0.57
200	0	0	0	0.01	0.02	0.06	0.1	0.12	0.14	0.17
225	0	0	0	0	0.01	0.01	0.01	0.01	0.02	0.02

Table 5. Constant landing projections based on the 2012 stock assessment update. The probability of the fishing mortality rate (F) being less than the TARGET over time for given constant landing scenarios. Total landings are partitioned with 75% to the commercial reduction fishery and 25% to the commercial bait fishery.

Landings (1000s mt)	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
75	0	0	0.24	0.83	0.98	1	1	1	1	1
100	0	0	0.02	0.37	0.72	0.9	0.97	0.99	1	1
125	0	0	0	0.06	0.28	0.49	0.65	0.78	0.87	0.91
150	0	0	0	0.01	0.04	0.11	0.21	0.31	0.38	0.46
175	0	0	0	0	0	0.01	0.02	0.04	0.06	0.08
200	0	0	0	0	0	0	0	0.01	0.01	0.01
225	0	0	0	0	0	0	0	0	0	0

Option B: Projections from 2010 Benchmark Stock Assessment

The constant landings scenarios explored (Table 6 and Table 7; below) are based on the overfishing status in 2008. Intuitively, lower landing levels have a higher probability of achieving the threshold, whereas higher landing levels have a lower probability of achieving the threshold. These projections assume constant landings, meaning if a specific landing level is maintained from one year to the next the probability of achieving the threshold increases. These principles also apply to the probabilities of achieving the target over a given time frame as detailed in Table 7. The projections illustrate how the F reference points may be achieved if the board chooses to adopt a TAC based on a constant landings approach.

The 2010 benchmark stock assessment passed peer review and was accepted for management use by the Board. The starting points for the projections outlined below were based on the population parameters estimated in the terminal year (2008) from the benchmark assessment. However, the projection analysis was not part of the peer review process.

To give these constant landing scenarios a frame of reference, the average total landings of Atlantic Menhaden over the last 3 years was 213.5 thousand metric tons.

Table 6. Constant landing projections based on the 2010 benchmark stock assessment. The probability of the fishing mortality rate (F) being less than the THRESHOLD over time for given constant landing scenarios. Total landings are partitioned with 75% to the commercial reduction fishery and 25% to the commercial bait fishery.

Landings (1000s mt)	2009	2010	2011	2012	2013	2014	2015	2016	2017
75	0	0	0	0.01	0.56	0.89	1.00	1.00	1.00
100	0	0	0	0.01	0.40	0.74	0.93	0.99	1.00
125	0	0	0	0.01	0.28	0.55	0.78	0.91	0.96
150	0	0	0	0.01	0.17	0.37	0.56	0.73	0.84
175	0	0	0	0.01	0.10	0.22	0.35	0.47	0.56
200	0	0	0	0.01	0.05	0.11	0.17	0.22	0.28
225	0	0	0	0.01	0.02	0.05	0.07	0.08	0.09

Table 7. Constant landing projections based on the 2010 benchmark stock assessment. The probability of the fishing mortality rate (F) being less than the TARGET over time for given constant landing scenarios. Total landings are partitioned with 75% to the commercial reduction fishery and 25% to the commercial bait fishery.

Landings (1000s mt)	2009	2010	2011	2012	2013	2014	2015	2016	2017
75	0	0	0	0.0	0.21	0.62	0.91	0.99	1.00
100	0	0	0	0.0	0.09	0.35	0.66	0.88	0.96
125	0	0	0	0.0	0.02	0.15	0.38	0.59	0.76
150	0	0	0	0.0	0.01	0.05	0.14	0.27	0.40
175	0	0	0	0.0	0.00	0.01	0.04	0.07	0.11
200	0	0	0	0.0	0.00	0.00	0.00	0.01	0.02
225	0	0	0	0.0	0.00	0.00	0.00	0.00	0.00

Option C. Ad-hoc approach to setting TACs.

As an alternative to using projections to set TACs, ad hoc approaches are used by several regional Fishery Management Councils for species with poor assessment data or uncertain stock assessment results. Typically, in these situations, most Councils use their landings/catch data as the only reliable means of setting harvest limits. A document entitled "Calculating Acceptable Biological Catch for Stocks that have reliable Catch Data Only" was recently published (ORCS 2011), and serves as guidance to set interim removal levels under these conditions.

To summarize the ORCS report; generally an average of the last 3-5 years of landings are used as this reflects recent history. A precautionary multiplier is then applied to decrement the average landings and set a harvest limit. Decision of the appropriate multiplier is cautiously decided based on factors such as life history, ecological function, stock status, and an understanding of exploitation. Typically this multiplier can range from 0.85 to 0.25 (Table 8).

Table 8. Summary of ad-hoc approaches used by Fishery Management Councils to set harvest limits in data poor situations.

Council	Species group	Multiplier	Comments
New England	Atlantic herring	1	Not OF, OF not occurring
New England	Red crab	1	Based on stock status
Carribean		0.85	Used to set ABC and ACL
New England	Groundfish	0.75	
Pacific		0.75	Used to set ABC
Pacific	Groundfish	0.5	Used to set OY
Pacific	Coastal pelagics	0.25	Used to set ABC

In the New England approach, the multiplier was chosen at 1.0 suggesting catch be maintained at current levels. The rationale was that the stock was not overfished and overfishing was not likely to be occurring. Other evidence, such as size at age, also indicated that the overall stock status was good. Further, landings were well monitored and discards of the target stock were low.
In the case of the Pacific Fishery Management Council the multiplier was set at 0.25. This number reflected the importance of herring as forage for stellar Sea Lions and other endangered mammals, the high level of exploitation, and the fact that Pacific Herring spawn in discreet and vulnerable aggregations (when they are targeted by the fishery).

It should be noted that the multiplier is never set at a value >1.0; indicating that catch should not be allowed to increase in these uncertain situations. Table 9 provides some additional decision making framework information that goes into the choice of a multiplier.

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Table 9. The method table showing possible actions for determining ABC based on different fishery impact categories and expert opinion. Taken from the workshop report of the 2nd National SSC meeting (From ORCS, 2011).

Historical Catch	Expert Judgment	Possible Action
Nil, not targeted	Inconceivable that catch could be affecting stock	Not in fishery; Ecosystem Component; SDC not required
Small	Catch is enough to warrant including stock in the fishery and tracking, but not enough to be of concern	Set ABC and ACL above historical catch; Set ACT at historical catch level. Allow increase in ACT if accompanied by cooperative research and close monitoring.
Moderate	Possible that any increase in catch could be overfishing	ABC/ACL = f(catch, vulnerability) So caps current fishery
Moderately high	Overfishing or overfished may already be occurring, but no assessment to quantify	Set provisional OFL = f(catch, vulnerability); Set ABC/ACL below OFL to begin stock rebuilding

ABC = Acceptable Biological Catch
ACL = Annual Catch Limit
ACT = Annual Catch Target
OFL = Overfishing Level

For Atlantic menhaden; the stock is likely experiencing overfishing given the recent changes in reference points (ASMFC 2012). Overall, Atlantic menhaden have low vulnerability given their short life history, age at spawning, rapid growth, and fecundity. However, menhaden also serve as forage for other valuable commercial and recreationally important species. While landings history data are good, some significant uncertainties remain in recruitment due to natural variability. As such Table 10 outlines some possible options using a 3 or 5 year average of the catch, with the addition of potential multipliers to be used on those catch values. Typically Councils and their SSC's dictate the multipliers in 0.25 increments, given the other uncertainties involved.

Table 10. Estimated harvest levels (thousand MT) for a range of uncertainty correction factors.

Probability of reducing overfishing decreases moving towards a multiplier of 1.

Average	Multiplier					
	1	0.9	0.8	0.75	0.5	0.25
3-year	213.5	192.2	170.8	160.2	106.8	53.4
5-year	209.5	188.5	167.6	157.1	104.7	52.4

Option D. Projections or Ad-hoc approach

The Board will set the TAC based on the best available science (e.g., projection analysis), but if the projections are not recommended for use by the TC, the Board may set a quota based on the ad-hoc approaches used by the Regional Councils and detailed in Option D.

4.2.1.3 TAC Allocation

If a TAC management approach is selected, it may be allocated to the bait and reduction fisheries separately, or it may be allocated based on total landings (bait and reduction fisheries combined). The following allocation options A, B, and C have sub-options to be considered to further specify how the TAC should be, or should not be, sub-allocated.

OPTION A. Menhaden commercial TAC to be managed on a coastwide basis.
(if chosen, go to suboptions A)

OPTION B. Menhaden commercial TAC to be managed on a regional basis.
(if chosen, go to suboptions B)
Regions
New England Region (ME-CT)
Mid-Atlantic Region (NY-MD Coast)
Chesapeake Bay Region (VA, PRFC, MD Bay)
South Atlantic Region (NC-FL)

OPTION C. Menhaden commercial TAC to be managed on a state-by-state basis.
(if chosen, go to suboptions C)
States
ME-FL

SUBOPTIONS A: Menhaden commercial TAC to be managed on coastwide basis.

SUBOPTION A.1: Menhaden coastal commercial TAC not to be allocated by fishery.
(if chosen, TAC allocation section complete)

SUBOPTION A.2: Menhaden coastal commercial TAC to be allocated by fishery; bait and reduction.
(if chosen, go to suboptions A.2)

SUBOPTIONS A.2: Menhaden coastal commercial TAC to be allocated by fishery; bait and reduction.

Suboptions	Bait	Reduction
A.2.1: Average 3 years (2009-2011)	0.2155	0.7845
A.2.2: Average 5 years (2007-2011)	0.2194	0.7806
A.2.3: Average 7 years (2005-2011)	0.1962	0.8038
A.2.4: Highest 3 years (2005-2011)	0.2163	0.7837

These time frames are reflective of the most recent improvements to the bait fishery landing reporting systems. Since 2005, only one reduction fishery plant was in operation.

Suboptions A.2.1, A.2.2., and A.2.3. are based on the average historical landings for the time frame specified.

Suboption A.2.4 is based on an average of the highest 3 years of landings, by fishery, since 2005.

SUBOPTIONS B: Menhaden commercial TAC to be managed on a regional basis.

SUBOPTION B.1: Menhaden coastal commercial TAC not to be allocated by fishery, only by region.
(if chosen, go to suboptions B.1)

SUBOPTION B.2: Menhaden coastal commercial TAC to be allocated by fishery, and by region.
(if chosen, go to suboptions B.2)

SUBOPTIONS B.1: Menhaden coastal commercial TAC not to be allocated by fishery, only by region

Suboptions	New England (ME-CT)	Mid-Atlantic (NY-MD Coast)	Chesapeake Bay (VA, PRFC, MD-Bay)	South Atlantic (NC-FL)
B.1.1: Average 3 years (2009-2011)	1%	11%	87%	1%
B.1.2: Average 5 years (2007-2011)	2%	10%	88%	0%
B.1.3: Average 7 years (2005-2011)	1%	9%	89%	0%
B.1.4: Highest 3 years (2005-2011)	2%	11%	87%	0%

These time frames are reflective of the most recent improvements to the bait fishery landing reporting systems. Since 2005, only one reduction fishery plant was in operation in Virginia, so the Chesapeake Bay region would receive the 100% of the reduction fishery allocation.

Suboptions B.1.1, B.1.2., and B.1.3. are based on the average historical landings for the time frame specified.

Suboption B.1.4 is based on an average of the highest 3 years of landings, by fishery, since 2005.

SUBOPTIONS B.2: Menhaden coastal commercial TAC to be allocated by fishery, and then the bait portion of the quota by region (two parts)

Part 1: Fishery Suboptions	Bait	Reduction
B.2.1.1: Average 3 years (2009-2011)	0.2155	0.7845
B.2.1.2: Average 5 years (2007-2011)	0.2194	0.7806
B.2.1.3: Average 7 years (2005-2011)	0.1962	0.8038
B.2.1.4: Highest 3 years (2005-2011)	0.2163	0.7837

These time frames are reflective of the most recent improvements to the bait fishery landing reporting systems. Since 2005, only one reduction fishery plant was in operation in Virginia.

Suboptions B.2.1.1, B.2.1.2., and B.2.1.3. are based on the average historical landings for the time frame specified.

Suboption B.2.1.4 is based on an average of the highest 3 years of landings, by fishery, since 2005.

Part 2: Regional Bait Allocation Suboptions	New England (ME-CT)	Mid-Atlantic (NY-MD Coast)	Chesapeake Bay (VA, PRFC, MD-Bay)	South Atlantic (NC-FL)
B.2.2.1: Average 3 years (2009-2011)	4%	53%	41%	2%
B.2.2.2: Average 5 years (2007-2011)	7%	47%	44%	2%
B.2.2.3: Average 7 years (2005-2011)	7%	43%	49%	2%
B.2.2.4: Highest 3 years (2005-2011)	9%	45%	44%	2%

These time frames are reflective of the most recent improvements to the bait fishery landing reporting systems. Since 2005, only one reduction fishery plant was in operation in Virginia.

Suboptions B.2.2.1, B.2.2.2., and B.2.2.3. are based on the average historical landings for the time frame specified.

Suboption B.2.2.4 is based on an average of the highest 3 years of landings, by fishery, since 2005.

SUBOPTIONS C: Menhaden commercial TAC to be managed on a state-by-state basis.

SUBOPTION C.1: Menhaden coastal commercial TAC not to be allocated by fishery, only state-by-state.
(if chosen, go to suboptions C.1)

SUBOPTION C.2: Menhaden coastal commercial TAC to be allocated by fishery, and state-by-state.
(if chosen, go to suboptions C.2)

SUBOPTIONS C.1: Menhaden coastal commercial TAC not to be allocated by fishery, only state-by-state.

State-by-State Suboptions	C.1.1 Average 3 years (2009-2011)	C.1.2 Average 5 years (2007-2011)	C.1.3 Average 7 years (2005-2011)	C.1.4 Highest 3 years (2005-2011)
Maine	0.04	0.21	0.16	0.31
New Hampshire	0	0	0	0
Massachusetts	0.84	1.33	1.14	1.69
Rhode Island	0.02	0.02	0.02	0.03
Connecticut	0.02	0.02	0.04	0.08
New York	0.06	0.04	0.04	0.05
New Jersey	11.19	10.12	8.72	10.76
Delaware	0.01	0.01	0.02	0.02
Maryland	1.37	1.48	1.56	1.74
PRFC	0.62	0.81	0.86	0.88

Virginia	85.32	85.55	87.06	83.94
North Carolina	0.49	0.38	0.36	0.47
South Carolina	0	0	0	0
Georgia	0	0	0	0
Florida	0.02	0.02	0.02	0.02

These time frames are reflective of the most recent improvements to the bait fishery landing reporting systems. Since 2005, only one reduction fishery plant was in operation in Virginia.

Suboptions C.1.1, C.1.2., and C.1.3. are based on the average historical landings for the time frame specified.

Suboption C.1.4 is based on an average of the highest 3 years of landings, by fishery, since 2005.

SUBOPTIONS C.2: Menhaden coastal commercial TAC to be allocated by fishery, and then the bait portion of the quota by state (two parts).

Part 1: Fishery Suboptions	Bait	Reduction
C.2.1.1: Average 3 years (2009-2011)	0.2155	0.7845
C.2.1.2: Average 5 years (2007-2011)	0.2194	0.7806
C.2.1.3: Average 7 years (2005-2011)	0.1962	0.8038
C.2.1.4: Highest 3 years (2005-2011)	0.2163	0.7837

These time frames are reflective of the most recent improvements to the bait fishery landing reporting systems. Since 2005, only one reduction fishery plant was in operation in Virginia.

Suboptions C.2.1.1, C.2.1.2., and C.2.1.3. are based on the average historical landings for the time frame specified.

Suboption C.2.1.4 is based on an average of the highest 3 years of landings, by fishery, since 2005.

Part 2: State-by-State Bait Allocation Suboptions	C.2.2.1 Average 3years (2009-2011)	C.2.2.2 Average 5 years (2007-2011)	C.2.2.3 Average 7 years (2005-2011)	C.2.2.4 Highest 3 years (2005-2011)
Maine	0.182	0.965	0.761	1.302
New Hampshire	0	0	0	0
Massachusetts	3.885	6.119	5.485	7.037
Rhode Island	0.083	0.106	0.087	0.122
Connecticut	0.081	0.088	0.207	0.314
New York	0.257	0.202	0.191	0.216
New Jersey	51.851	46.407	42.097	44.754
Delaware	0.061	0.068	0.089	0.086
Maryland	6.359	6.781	7.550	7.244
PRFC	2.876	3.704	4.145	3.643
Virginia	31.998	33.751	37.569	33.219
North Carolina	2.283	1.736	1.732	1.961
South Carolina	0	0	0	0
Georgia	0	0	0	0
Florida	0.083	0.073	0.087	0.101

These time frames are reflective of the most recent improvements to the bait fishery landing reporting systems. Since 2005, only one reduction fishery plant was in operation in Virginia, so Virginia would receive the 100% of the reduction fishery allocation.

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Suboptions C.2.2.1, C.2.2.2., and C.2.2.3. are based on the average historical landings for the time frame specified.

Suboption C.2.2.4 is based on an average of the highest 3 years of landings, by fishery, since 2005.

4.2.1.4 Quota Tranfers

The following options only apply if the Board selects individual state quotas (see *Section 4.2.1.3*)

Option A: No Transfer of individual state quotas
States may not transfer quota under this option.

Option B: Allow Transfer of Quotas
Two or more states, under mutual agreement, may transfer or combine their Atlantic menhaden quota. These transfers do not permanently affect the state-specific shares of the coastwide quota, i.e., the state-specific shares remain fixed. States have the responsibility to close the Atlantic menhaden commercial fishery in their state once the quota (or a percentage thereof) has been reached. The Executive Director or designated ASMFC staff will review all transfer requests before the quota transfer is finalized. Such agreements for state-by-state transfer of quota should be forwarded to the Board through Commission staff.

Once quota has been transferred to a state, the state receiving quota becomes responsible for any overages of transferred quota. That is, the amount over the final quota (that state's quota plus any quota transferred to that state) for a state will be deducted from the corresponding state's quota the following fishing season.

4.2.1.5 Quota Rollover

Option A: Quotas May Not Be Rolled Over
Unused quota may not be rolled over from one fishing year to the next.

Option B: Rollover of Quota
A fishery/region/state may rollover any unused quota from its allocation under *(TAC Allocation, Section 4.2.1.3)* from one fishing year to the next. This option does not specify that *transferred* quota may be rolled over nor does it prohibit rollover of *transferred* quota.

Option C: Rollover of Transferred Quota (if allowed)
A state may rollover any unused transferred quota from one fishing year to the next. That is, if a state receives transferred quota, and does not harvest its final quota (that state's quota plus any quota transferred to that state) amount, the remaining amount will be added to the corresponding states quota the following year but not subsequent years (i.e., no stock piling of quota).

Option D: Transferred Quota May Not Be Rolled Over
A state may not rollover any unused transferred quota.

Option E: Maximum 5% Quota Rollover
A fishery/region/state may roll any unused quota from its final allocation (including transferred quota) from one fishing year to the next. The maximum total rollover may not exceed 5% of a

state or regional allocation for the fishing year in which the under-harvest occurred. For example if a state's final allocation is 1.5 million pounds and that state only lands 1 million pounds during the fishing season, the state may only roll 75,000 pounds (5%) into the subsequent fishing season.

4.2.1.6 Quota Payback

Option A: No Payback of Overharvest of Quota

Option B: Payback of Quota Overages (including transferred quota if applicable)
When the quota in any fishery, region or state is projected to be reached, the commercial landing, harvest and possession of Atlantic menhaden will be prohibited in state waters of that fishery, region or state until the end of the current fishing season. When the quota allocated to a fishery, region or state is exceeded in a fishing season, the amount over the allocation will be deducted from the corresponding fishery, region or state in the subsequent fishing season.

4.2.1.7 Bycatch Allowance

Option A. No bycatch allowance when the fishing season is closed.

Option B. Pound based bycatch allowance
No directed fisheries for Atlantic menhaden shall be allowed when the fishing season is closed. An incidental bycatch allowance of up to OPTION pounds of Atlantic menhaden per trip for non-directed fisheries shall be in place during a season closure. The amount of Atlantic menhaden landed by one vessel in a day, as a bycatch allowance, shall not exceed OPTION pounds (this prohibits a vessel from making multiple trips in one day to land more than the bycatch allowance). A trip shall be based on a calendar day basis.

Option 1. 1,000 pound bycatch allowance
Option 2. 2,000 pound bycatch allowance
Option 3. 5,000 pound bycatch allowance

Option C. Percent based bycatch allowance
No directed fisheries for Atlantic menhaden shall be allowed when the fishing season is closed. An incidental bycatch allowance of up to OPTION% of Atlantic menhaden relative to the total catch per trip for non-directed fisheries shall be in place during a season closure. The amount of Atlantic menhaden landed by one vessel in a day, as a bycatch allowance, shall not exceed OPTION% of the total landings for one trip (this prohibits a vessel from making multiple trips in one day to land more than the bycatch allowance). A trip shall be based on a calendar day basis.

Option 1. 2 percent bycatch allowance
Option 2. 5 percent bycatch allowance
Option 3. 10 percent bycatch allowance

4.2.2 Atlantic Menhaden Chesapeake Bay Reduction Fishery Harvest Cap

The Board may consider changes to the Atlantic menhaden harvest cap, a current management measure that will expire in 2013. The current management language is below the list of options.

Option A: Status quo. 2013 is the final year for the Chesapeake Bay (CB) cap.

Option B: Extend the CB cap to any specified time frame (e.g., 5 years).
Option C: Adjust the CB cap as it relates to any quota management approach selected.

The annual total allowable harvest from the Chesapeake Bay by the reduction fishery is limited to no more than 109,020 metric tons (the average landings from 2001-2005). Harvest for reduction purposes shall be prohibited within the Chesapeake Bay when 100% of the cap is harvested from Chesapeake Bay. This cap is in place for the fishing seasons starting in 2011 and going through 2013. Over-harvest in any given year will be deducted from the next year's allowable harvest.

Annual Credit for Harvest Underages

The annual Chesapeake Bay harvest cap under Addendum IV is not based on a scientifically quantified harvest threshold, fishery health index, or fishery population level study. Due to data limitations, it is unknown if exceeding the 109,020 metric-ton limit will negatively affect the health of the menhaden population. The cap is designed to prevent the Chesapeake Bay reduction fishery harvest of Atlantic menhaden from expanding while the necessary scientific studies are being conducted to explore the potential for localized depletion in the Chesapeake Bay.

Assuming a cap of 109,020 metric tons had been in place over the 2001-2005 reference period, the maximum underage that would have occurred during that time period is 13,720 metric tons. The maximum rollover of unlanded fish is 13,720 metric tons. Adding that underage to the 109,020 metric ton cap results in a cap of 122,740 metric tons.

In years when annual menhaden harvest in the Chesapeake Bay for reduction purposes is below the 109,020 metric-ton cap, the underage amount shall be credited to the following year's allowable harvest. Under no circumstances can allowable harvest in any given year from 2011 through 2013 exceed 122,740 metric tons. Such credit can only be applied to the following calendar year's harvest cap and cannot be reserved for future years or spread over multiple years.

Further, if no more than the underage amount in one year is credited to the next year's allowable harvest, the annual average harvest for 2011 through 2013 cannot exceed 109,020 metric tons.

4.5.3 *De minimis* Fishery Guidelines

Option A. Status Quo, *de minimis* criteria is not established through Amendment 2.

Option B. Define *de minimis* for States without a Reduction Fishery. If Option B is selected, the Board must select both the Criteria for *De Minimis* Consideration (*Section 4.5.3.1*) and the plan requirements if *de minimis* is granted (*Section 4.5.3.2*).

4.5.3.1 Criteria for De Minimis Consideration

A state can apply annually for *de minimis* status if a state does not have a reduction fishery.

Option 1. To be eligible for *de minimis* consideration in the bait fishery, a state must prove that its commercial bait landings in the most recent two years for which data are available did not exceed 1% of the coastwide bait landings.

Option 2. To be eligible for *de minimis* consideration in the bait fishery, a state must prove that its commercial bait landings in the most recent two years for which data are available did not exceed 2% of the coastwide bait landings.

4.5.3.2 Plan Requirements if De Minimis Status is Granted

If *de minimis* status is granted, the *de minimis* state is require to implement, at a minimum, the coastwide requirements contained in *Section 3.6* of Amendment 2. Any additional components of the FMP, which the Board determines necessary for a *de minimis* state to implement, can be defined at the time *de minimis* status is granted. For all other required components of the plan, the Board will specify by motion which measures a *de minimis* state must adopt.

Option 3: *De minimis* criteria exempts a state from biological monitoring (e.g., age data), but the state must adhere to timely quota monitoring requirements (as specified in Section 3.1) and may not exceed quota allocated. If the fishery is closed for any reason, *de minimis* states must close their fisheries as well.

Option 4: *De minimis* criteria exempts a state from both biological monitoring (e.g., age data), and timely quota monitoring requirements (as specified in Section 3.1), but must still submit annual landings, and may not exceed quota allocated. If the fishery is closed for any reason, *de minimis* states must close their fisheries as well.

4.6.2 Measures Subject to Change

The following measures are subject to change under adaptive management upon approval by the Atlantic Menhaden Management Board:

(1) Fishing seasons including season closures
(2) Trip limits
(3) Limited entry
(4) Area closures
(5) Annual specifications, including maximum sustainable yield (MSY), allowable biological catch (ABC), optimum yield (OY), internal waters processing (IWP) allocations, etc.;
(6) Overfishing definition
(7) Rebuilding targets and schedules
(8) Catch controls
(9) Effort controls
(10) Reporting requirements
(11) Gear restrictions including mesh sizes
(12) Measures to reduce or monitor bycatch
(13) Observer requirements
(14) Management areas
(15) Recommendations to the Secretaries for complementary actions in federal jurisdictions;
(16) Research or monitoring requirements
(17) Any other management measures currently included in Amendment 2.

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4.9 RECOMMENDATIONS TO THE SECRETARY FOR COMPLEMENTARY ACTIONS IN FEDERAL WATERS

The Atlantic States Marine Fisheries Commission believes that the measures contained in Amendment 2 are necessary to prevent the overfishing of the Atlantic menhaden resource. If any of the above options are adopted through the addendum process, the Board should consider recommending the adopted measures to the National Marine Fisheries Service for implementation in the EEZ.

ACKNOWLEDGEMENTS

Completed in final version

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1.0 INTRODUCTION

The Atlantic States Marine Fisheries Commission (ASMFC) is developing an amendment to its Interstate Fishery Management Plan (FMP) for Atlantic Menhaden (*Brevoortia tyrannus)* under the authority of the Atlantic Coastal Fisheries Cooperative Management Act (ACFCMA). The Commission, through the coastal states of Maine through Florida, is responsible for managing Atlantic menhaden. ASMFC has coordinated interstate management of Atlantic menhaden in state waters (0-3 miles) since 1981. Atlantic menhaden is currently managed under Amendment 1 and Addenda I-V to the Fishery Management Plan (FMP). Amendment 2 to the Interstate Fishery Management Plan for Atlantic menhaden replaces Amendment 1 to the 1981 FMP. This document contains all applicable management options still in implementation from Amendment 1 and all five addenda. Management authority in the exclusive economic zone (EEZ, 3-200 miles from shore) lies with NOAA Fisheries.

1.1 BACKGROUND INFORMATION

1.1.1 Statement of the Problem

The 2010 Atlantic menhaden benchmark stock assessment Peer Review Panel noted that menhaden population abundance had declined steadily and recruitment had been low since the last peak observed in the early 1980s. Fishing at the fishing mortality (F) threshold reference point in the terminal year (2008) has resulted in approximately 8% of the maximum spawning potential (MSP). Therefore, the Panel recommended alternative reference points be considered that provide greater protection for spawning stock biomass (SSB) or population fecundity relative to the unfished level. In November 2011, the Atlantic Menhaden Management Board responded to that recommendation and adopted new F reference points via Addendum V. The new reference points are more conservative than the previous to account for the following: (1) while menhaden are not overfished the number of fish in the population has been declining, (2) while menhaden are important for many fisheries they also provide important ecological services, (3) strong recruitment classes may be dependent on favorable environmental conditions, and (4) recent science suggest conserving a larger percentage of the spawning stock is an important consideration for forage species such as menhaden. The new F threshold is $F_{15\%MSP}$ and the new F target is $F_{30\%MSP}$. Full $F/F_{15\%MSP}$ for the terminal year (2011) was greater than 1, therefore, overfishing is occurring. Addendum V states that when overfishing is occurring the Board will take steps to reduce F to the target level. In order to reduce overfishing to the target, the Board needs to consider changes in the management tools used to regulate the fishery.

The new F reference points adopted by the Board are intended to be interim reference points while the Commission's Multispecies Technical Committee develops ecological-based reference points (ERP). The ERPs will take some time to develop due to the complexity of modeling predator-prey relationship in marine species that rely on menhaden for forage (e.g., striped bass, bluefish, weakfish). In either case (biological or ecological reference points) the intent is to manage Atlantic menhaden at sustainable levels to support fisheries and meet predator demands through sufficient SSB to prevent stock depletion and protect against recruitment failure.

1.1.2 Benefits of Implementation

Amendment 2 when fully implemented, is designed to minimize the chance of a population decline due to overfishing, reduce the risk of recruitment failure, reduce impacts to species which are ecologically dependent on Atlantic menhaden, and minimize adverse effects on participants in the fishery.

Amendment 2 contains a progressive management program designed to provide more flexibility in managing Atlantic menhaden.

Issues Addressed in Amendment 2

1. Timeline to achieve the target fishing mortality rate
   A timeline to reduce F to the target will end overfishing, and provide a program to maintain a healthy Atlantic Menhaden stock
2. A mechanism for effective and timely monitoring of the menhaden population.
   Timely and complete reporting enables managers and fishermen to monitor the landings throughout the season, and evaluate the effectiveness of any selected fishery management measures.
3. Commercial Fishery Management Tools
   A quota management program has been used in several fisheries to maintain a healthy stock size, while maximizing benefits of the fisheries.

The Committee of Economic and Social Sciences (CESS) is developing an benefits and impacts sections for this amendment. Their findings will be included in supplemental materials.

1.1.3 Ecological Benefits

Ecologically, Atlantic Menhaden occupy a very important link in the coastal marine food chain, transferring planktonic material into animal biomass. Atlantic menhaden are ubiquitous in nearshore coastal waters because of their ability to directly utilize phytoplankton and zooplankton, which is the basic food resource in aquatic systems. Other species of marine fish are not equipped to filter such small organisms from the water. Consequently, large populations of other species cannot be supported without this contribution from menhaden, therefore maintaining a healthy Atlantic menhaden population will contribute to a balanced marine ecosystem. Because menhaden are so abundant in nearshore coastal and estuarine waters, they are an important forage fish for a variety of larger piscivorous fishes, birds, and marine mammals. As a result of this, menhaden influence the conversion and exchange of energy and organic matter within the coastal ecosystem throughout their range (Peters and Schaaf 1981; Lewis and Peters 1984; Peters and Lewis 1984).

1.2 DESCRIPTION OF THE RESOURCE

1.2.1 Species Life History

1.2.1.1 Stock Structure and Migration

Atlantic menhaden are euryhaline species that inhabit nearshore and inland tidal waters from Florida to Nova Scotia, Canada. Size-frequency information and tagging studies indicate that the Atlantic menhaden resource is a single unit stock (Dryfoos et al. 1973; Nicholson 1972 and 1978). Recent genetic studies also support the treatment of Atlantic menhaden as a single stock (Anderson 2007; Lynch 2008).

Spawning occurs principally at sea with some activity in bays and sounds in the northern portion of its range (Judy and Lewis 1983). Eggs hatch at sea and the larvae are transported by ocean currents (Checkley et al. 1988; Nelson et al. 1977; Quinlan et al. 1999) to estuaries where they metamorphose and grow rapidly as juveniles (Edwards 2009). Adults stratify by size during the summer, with older, larger individuals migrating north to southern New England by May and the Gulf of Maine by June. During November and December, most of the adult population that migrated north of Chesapeake Bay moves south of the Virginia and North Carolina capes. Adults that remain in the south Atlantic region during spring and summer migrate south later in the year, reaching northern Florida by fall. Schools of adult menhaden reassemble in late March or early April and migrate northward. By June the population is redistributed from Florida to Maine.

1.2.1.2 Age and Growth

Atlantic menhaden as old as age-8 were present in the spawning population during the 1950s and early 1960s, but fish older than age-6 have been uncommon since 1965. A few rare specimens of age 10 were landed in the 1950s and early 60s. In recent years, the majority of the landings are comprised of fish ages 1-3 (citation, maybe latest stock assessment report).

Growth of Atlantic menhaden varies from year-to-year and occurs primarily during the warmer months (AMTC 2006). Growth of juveniles is density dependent (Ahrenholz et al. 1987); in other words, growth rates are accelerated during the first year when juvenile abundance is low and are reduced when juvenile abundance is high. Young-of-the-year menhaden range widely in size with lengths varying as a function of density, timing of larval ingress, temperature and *chl-a* availability (Ahrenholtz 1991; Houde 2011). Older (age-6) fish reach an average length of 330 mm FL and a weight of 630 g, although growth varies from year to year and is inversely density-dependent. Due to their greater migratory range (see *Section 1.2.1.7*), larger fish of a given age are captured farther north than smaller fish of the same age (Nicholson 1978; Reish et al. 1985). This fact complicates any attempt to estimate overall growth for the entire stock from size-at-age data compiled from any individual area along the coast.

1.2.1.3 Spawning and Reproduction

Although some Atlantic menhaden become sexually mature during their second year (late age-1), most do not mature until their third year (late age-2; Higham and Nicholson 1964; Lewis et al.

1987). First-spawning age-3 fish have accounted for most of the stock's egg production since 1965 (Vaughan and Smith 1988). Atlantic menhaden mature at smaller sizes at the southern end of their range (180 mm FL in the south Atlantic versus 210 mm FL in the Chesapeake Bay and 230 mm farther north) because of latitudinal differences in size-at-age and the fact that larger fish of a given age are distributed farther north than smaller fish of the same cohort (Lewis et al. 1987).

A majority of eggs are spawned over the continental shelf in winter in the coastal ocean off the Carolinas, inshore of the Gulf Stream (Ahrenholz 1991; Judy and Lewis 1983; Kendall and Reintjes 1975). However, evidence is accumulating that indicates a substantial fraction of spawning occurs in fall months in the Mid-Atlantic Bight from New Jersey to Virginia (SABRE 1999; Warlen et al. 2002; Light and Able 2005). Additionally, spring and summer spawning occurs within estuaries, in coastal embayments, and in near-shore coastal areas (i.e. Chesapeake Bay; *Houde, UMCES, pers. comm.*). There is evidence that spawning events may also occur in the South Atlantic Bight after strong winds and storms create conditions that promote upwelling and potentially high food production for larval menhaden (Checkley et al. 1999).

Recently, there has been progress in relating measures of primary productivity to recruitment and growth of YOY menhaden. During the past two decades, there has been a positive correlation between recruitment and euphotic-zone *chl-a* and integrated annual primary production in the Chesapeake Bay (Houde and Harding 2009), suggesting that menhaden populations are controlled in part by bottom-up processes (i.e., quantity of food available). Furthermore, bioenergetics modeling indicates that much of the variability in YOY growth observed in the field can be explained by variability in *chl-a* levels and temperature (Annis et al. 2011). Spatially-explicit bioenergetics models have been used to estimate carrying capacity of menhaden in the Bay as well as the reduction of habitat volume and productivity from eutrophication and hypoxia (Brandt and Mason 2003; Luo et al. 2001). The recent validation of bioenergetics model estimates of growth potential using field data (Annis et al. 2011) indicates that these models have excellent potential to evaluate trophic interactions by menhaden with respect to water quality and plankton productivity on an ecosystem scale. Despite these findings, however, additional work has found no significant correlation between YOY menhaden abundance and *chl-a* for the entire four-decade period that included periods of both low and high menhaden recruitment events in Chesapeake Bay. The strong correlation between YOY menhaden abundance and *chl-a* in recent years (1989-2004) as noted above did not persist throughout the longer time series (1966-2006). On average, years with low freshwater flow and low turbidity supported higher abundances and recruitment of YOY menhaden (Love et al 2006; Lynch et al 2010). Other simple correlations between YOY menhaden abundance and environmental or hydrographic variables were not significant or were only marginally significant (e.g., negative correlations with total dissolved phosphorus and with abundances of zooplankton taxa favored by low salinities). These conflicting bodies of work further highlight the complexity that exists between nutrient cycling, climatic drivers, and understanding the life history traits of Atlantic menhaden.

1.2.1.4 Mortality

The Atlantic menhaden population is subject to a high natural mortality rate. Natural mortality is also higher during the first two years of life than during subsequent years. Ahrenholz et al. (1987a) reported an annual instantaneous natural mortality rate (M) of 0.45 in the absence of fishing; this rate is equivalent to an annual reduction in population numbers of 36%. This rate is quite high compared to other pelagic marine species. Atlantic herring, for example, is characterized by an 18% annual natural mortality rate (Fogarty et al. 1989).

Menhaden natural mortality is probably due primarily to predation given the fish are so abundant in coastal waters during the warmer months of the year. All large piscivorous sea mammals, birds, and fish are potential predators on Atlantic menhaden. Menhaden are preyed upon by species such as bluefish, striped bass, king mackerel, Spanish mackerel, pollock, cod, weakfish, silver hake, tunas, swordfish, bonito, tarpon, and a variety of sharks. See additional details in *Ecolgoical Roles* section below.

Coastal pollution, habitat degradation, and disease also threaten marine fish species like Atlantic menhaden which spend their first year of life in estuarine waters and the rest of their life in both ocean and estuarine waters. Fish kills, due principally to low dissolved oxygen conditions, disease, and parasites are additional and poorly understood sources of natural mortality (Burkholder et al. 1992; Kane et al. 1998; Blazer et al. 1999; 2000; Noga 2000; Law 2001; Glasgow et al. 2001; Vogelbein et al. 2001; Kiryu et al. 2002; Reimschussel et al. 2003; Burkholder et al. 2005). A variety of diseases are thought to affect menhaden survival (Stephens et al. 1980; Noga and Dykstra 1986; Noga et al. 1988; Levine et al. 1990a; Levine et al. 1990b; Dykstra and Kane 2000; Goshorn et al. 2004; Stine et al. 2005; Blazer et al. 2007). Atlantic menhaden found in estuaries may also be affected by large fluctuations in dissolved oxygen (Burnett 1997; Paerl et al. 1998). Menhaden are also known to induce fatal hypoxic events and reports of such school-induced hypoxia and resulting fish kills go back to the 1800's (Oviatt et al. 1972; Smith 1999).

1.2.1.5 Ecological Roles

In ecological terms, menhaden occupy a very important link in the coastal marine food chain, transferring planktonic material into animal biomass. As a result, menhaden influence the conversion and exchange of energy and organic matter within the coastal ecosystem throughout their range (Peters and Schaaf 1981; Lewis and Peters 1984; Peters and Lewis 1984).

1.2.1.6 As Forage

Because menhaden are abundant in nearshore coastal and estuarine waters, they are an important forage fish for a variety of larger piscivorous fishes, birds, and marine mammals. Menhaden provides a critical link between primary production and larger piscivorous predators such as striped bass (*Morone saxatilis*), bluefish (*Pomatomus saltatrix*), weakfish (*Cynoscion regalis*), and piscivorous birds (Viverette et al. 2007). The important trophic role of menhaden is highlighted in the development of multispecies models (ASMFC's coastwide MSVPA-X and the Chesapeake Bay EwE model).

1.2.1.7 *Nutrient Dynamics*

Atlantic menhaden occupy two distinct types of feeding niches during their lifetime. Phytoplankton is the major food of juvenile and young adult menhaden. The role of zooplankton in the diet becomes more important in older menhaden as gill raker spacings on their filtering apparatus increase in size (Friedland et al. 1984, 2006). The relative importance of each food type varies with ontogeny, region, and in relation to local availability.

The role of Atlantic menhaden in systems function and community dynamics has received much attention in recent years. Simulation models also indicated that Atlantic menhaden in Narragansett Bay and Chesapeake Bay potentially has substantial effects on zooplankton and phytoplankton populations, and on nutrient dynamics (Durbin and Durbin 1975, 1998; Gottlieb 1998), although more research is needed to confirm these possibilities. Spatially-explicit bioenergetics models have also been used to estimate carrying capacity of menhaden in the Bay as well as the reduction of habitat volume and productivity from eutrophication and hypoxia (Brandt and Mason 2003; Luo et al. 2001). The recent validation of bioenergetics model estimates of growth potential using field data (Annis et al. 2011) indicates that these models have excellent potential to evaluate trophic interactions by menhaden with respect to water quality and plankton productivity on an ecosystem scale. However, a recent study by Lynch et al. (2010) for Chesapeake Bay suggests that the menhaden population probably plays little role in removing nitrogen from Chesapeake Bay waters, and may actually provide additional nitrogen to Bay phytoplankton. The study evaluated the influence of YOY and age-1+ menhaden in Chesapeake Bay on rates of phytoplankton (chl *a*) ingestion and total dissolved nitrogen (TDN) excretion, as measured experimentally across varying phytoplankton concentrations. Results suggest that YOY menhaden focus their grazing on patches of elevated phytoplankton abundance and/or supplement their diet with other sources (e.g. zooplankton and detritus) to maintain a positive nitrogen balance. Population-level estimates of net nitrogen removal imply that menhaden play a minimal role regarding water quality in Chesapeake Bay.

1.2.2 Stock Assessment Summary

Based on tagging studies (Dryfoos et al. 1973; Nicholson 1978), and genetic studies (Anderson 2007; Lynch 2008), the Atlantic menhaden fishery is believed to be a single stock or population of fish. Therefore it is assessed as a single coastwide stock. The Atlantic Menhaden Stock Assessment Subcommittee used commercial and recreational landings at age from Florida to Maine, a fishery dependent adult index developed from Potomac River Fisheries Commission (PRFC) pound net survey, and a juvenile index (JAI) developed from coastwide beach seine information. In addition, growth, weight, and maturity at age were developed using fishery dependent and independent information, while age and time variant natural mortality was estimated using a multi-species virtual population analysis (MSVPA-X) (NEFSC 2006a, 2006b).

The Beaufort Assessment Model (BAM) was the model used to produce final assessment results. This is a statistical forward-projection model with separable selectivities using the Baranov catch equation (ASMFC, 2011).

1.2.2.1 *Abundance and Structure*

Annual Atlantic menhaden population size (age 0 and older at the start of the fishing season) has ranged from approximately 8 to 85 billion fish since 1955 (Figure 4). Population size averaged 40.8 billion menhaden during 1955-1961 when landings were high (averaging 604,400 mt), while the average was 14.5 billion menhaden between 1962 and 1974 when landings were low (288,600 mt). From 1975 to 1992 population size averaged 36.6 billion menhaden, comparing favorably to population sizes between 1955 and 1961, but landings improved by only 15% to an average of 355,800 mt. The inability of the modern fishery to regain former high levels of landings (in weight) is due primarily to reduced mean weight-at-age which occurred during the 1970s, and was caused in part by changes in fishing patterns, both geographically and seasonally. As has been noted, the migratory behavior of Atlantic menhaden results in older and larger menhaden moving farther north during spring and summer. Part of the decline in landings is due to the shift of the center of the fishing activity southward and subsequent fishing on smaller fish at age. Part can also be explained by the inverse relationship noted between first year growth of Atlantic menhaden and year class strength (Reish et al. 1985; Ahrenholz et al. 1987a). These factors, however, do not account for the entire decline in mean weight-at-age. The remainder is attributable to unknown biological or environmental factors.

1.2.2.2 *Fishing Mortality*

Total full fishing mortality rates (full F) were estimated within BAM (Figure 5). Highly variable fishing mortalities were noted throughout the entire time series, with a slight decline in fishing mortality from the mid-1960s to the early 1980s. Since the mid-1980s the fishing mortality rate has been quite variable, ranging between some of the highest and lowest values in the entire time series. The estimates suggest a high degree of variability, but in general the reduction fishery has experienced declining fishing mortality rates since the mid-1960s, while the bait fishery has experienced increasing fishing mortality rates since the 1980s. However, reduction fishery fishing mortality rate has risen in the last two years of the assessment (2010-2011). Finally, F rates can vary substantially among age groups. Selectivity on age-1 is small, greater on age-2, almost fully selected at age-3, and generally fully selected at older ages.

1.2.2.3 *Recruitment*

Age-0 recruits of Atlantic menhaden (Figure 6) were high during the late 1950s, especially the 1958 year-class. Recruitment was generally poor during the 1960s and high during the late 1970s and early 1980s. The late 1970 and early 1980s values are comparable to the late 1950s (with the exception of the extraordinary 1958 year-class). Generally low recruitment has occurred since the early 1990s. There is a hint of a potential long-term cycle from this historical pattern of recruitment, but not enough data are present to draw any conclusions regarding the underlying cause at this point. The most recent estimate for 2011 is quite low and likely to be modified in the future as more data from the cohort (age-1 in 2012, age-2 in 2013, etc.) are added to the analysis. The current estimate of recruits to age-0 in 2011 (4.03 billion) is the second lowest recruitment value for the entire time series.

1.2.2.4 *Spawning Stock Biomass (Fecundity)*

Section 1.2.2.1 describes the current understanding of the stock abundance and age structure of Atlantic menhaden. Often reproductive capacity of a stock is modeled using female weight-at-age, primarily because of a lack of fecundity data. To the extent that egg production is not linearly related to female weight, indices of egg production (fecundity) are better measures of reproductive output of a stock of a given size and age structure. Additionally, fecundity better emphasizes the important contribution of older and larger individuals to population egg production. Thus in the most recent stock assessment update (ASMFC 2012), modeling increases in egg production with size is preferable to female biomass as a measure of reproductive ability of the stock.

Population fecundity (SSB, number of maturing ova) is variable, but in general declined from high levels in the late 1960s, increased through the 1990s, then declined through 2011 (Figure 7). The largest values of population fecundity were present in 1955 and 1961, resulting from two very strong recruitment events in 1951 and 1958 as noted in earlier stock assessments (Ahrenholz et al. 1987b; Vaughan and Smith 1988; Vaughan et al. 2002b; ASMFC 2004). Throughout the time series, the age-3 fish produced most of the total estimated number of eggs spawned annually.

1.2.2.5 Maximum Spawning Potential

During the 2010 Atlantic menhaden benchmark stock assessment, the Peer Review Panel noted that menhaden population abundance had declined steadily and recruitment had been low since the last peak observed in the early 1980s (ASMFC 2010). Therefore, the Panel recommended alternative reference points be considered that provide greater protection for spawning stock biomass (SSB) or population fecundity relative to the unfished level.

In November of 2011, the Atlantic menhaden management board approved Addendum V to Amendment 1 of the Atlantic menhaden fishery management plan (ASMFC 2011). This addendum set forth new biological reference points to be used in the menhaden fishery. In part based on the recommendation from the peer review panel, the board approved using maximum spawning potential (MSP) as an interim reference point for menhaden.

The MSP approach identifies the fishing mortality rate necessary to maintain a given level of stock fecundity (number of mature eggs) relative to the potential maximum stock fecundity under unfished conditions. The management board chose two MSP values to use as the two interim biological reference points; an MSP of 15% as the threshold and an MSP of 30% for the target. As an example, a 15% MSP would equate to a fishing mortality rate threshold required to maintain approximately 15% of the spawning potential of an unfished stock. An unfished stock is equal to 100% MSP.

1.2.3 Present condition of the stock

Current stock status determination is based on the 2012 Atlantic Menhaden Stock Assessment Update report (ASMFC 2012). See http://www.asmfc.org/atlanticMenhaden.htm for the most recent stock assessment reports and stock status determination.

1.2.3.1 2012 Assessment Update Report Summary (ASMFC, 2012)

The purpose of the 2012 assessment was to update the 2010 Atlantic menhaden benchmark with recent data from 2009-2011. No changes in structure or parameterization were made to the base model run. Additional sensitivity analyses and landings projections were conducted.

Updated data included reduction, bait, and recreational landings, samples of annual size and age compositions from the landings, the coastwide juvenile abundance index (JAI), and the Potomac River Fisheries Commission (PRFC) pound net index. Also, a new matrix of age- and time-varying natural mortality estimates was obtained from the 2012 update of the MSVPA-X model.

Abundance of menhaden has remained at similar levels as reported in the 2010 benchmark assessment. Total abundance in 2011 was estimated to be 7.84 billion fish. Generally low recruitment has occurred since the early 1990s. The most recent estimate for 2011 (4.03 billion) is the second lowest recruitment value for the entire time series, but is likely to be modified in the future as more data from the cohort are added to the analysis. Population fecundity (SSB, number of maturing ova) was variable across the time series, but has declined since the 1990s to a 2011 terminal year estimate of 13 trillion eggs.

Fishing mortality estimates suggest a high degree of variability, but in general the reduction fishery has experienced declining fishing mortality rates since the mid-1960s, while the bait fishery has experienced increasing fishing mortality rates since the 1980s. Reduction fishing mortality rates have risen, though, in the last two years of the assessment (2010-2011). The estimate of full fishing mortality in 2011 was 4.5.

The current overfishing definition is a fecundity-per-recruit threshold of $F_{15\%MSP}$. The current fecundity-based overfished definition is a threshold of $SSB_{MED.T}$ (half of SSB_{MED}). Benchmarks were calculated using all years, 1955-2011. The ratio of Full F in the terminal year to the overfishing benchmark ($F_{2011}/F_{15\%MSP}$) was greater than 1. The ratio of SSB in the terminal year to the SSB benchmark ($SSB_{2011}/SSB_{threshold}$ was greater than 1. **Therefore overfishing is occurring, but the stock is not overfished. However, the TC warns that there is a technical mismatch between the current overfishing and overfished reference points.** The TC recommends that, given the Board has adopted a $F_{15\%MSP}$ overfishing definition, a matching overfished definition of $SSB_{15\%MSP}$ should be adopted as well.

Retrospective pattern analysis suggested that this model is not robust to addition of new data. An underestimation of F and overestimation of SSB was evident during the 2010 benchmark stock assessment; however, these patterns became more worrisome during this update when a switch in direction of the pattern was observed such that F was overestimated and SSB was underestimated in recent years. It is unclear exactly what is causing this retrospective pattern, but it appears that some data sources have developed discordance since 2003.

Overall, the retrospective pattern and a number of other issues cast considerable doubt on the accuracy of the estimates from this stock assessment update. The TC warns that additional data analysis and modeling work are necessary to resolve these model structure and performance issues. An expedited benchmark assessment during which the TC can more fully examine many of the issues raised above is warranted. Although the Technical Committee could not come to consensus on the utility of the terminal year point estimates of F and SSB for management advice, there was consensus that the status determinations were likely robust. In other words, the ratio of $F_{2011}/F_{15\%MSP}$ is likely greater than 1.0 (overfishing is occurring), and $SSB_{2011}/ SSB_{MED.T}$ is likely greater than 1.0 (the stock is not overfished), but the exact magnitude of these ratios could not be determined.

1.2.4 Peer Review Panel Results

A Review Workshop of the 2010 Atlantic Menhaden Benchmark Assessment Report was held March 8 – 12, 2010 in Charleston, South Carolina. The Review Workshop provided a comprehensive and in-depth evaluation of this assessment. The following are the Panel's summary findings:

The Panel was comfortable with the results from the menhaden base run. They stated that the model results and the status determination were robust.

The Panel was concerned that the 2008 F estimate was very close to the threshold. Following the Peer review, a coding error was found in the model, which was subsequently corrected, and the determination upon that correction was that overfishing was occurring.

The Panel also voiced concern about the use of Fmed and the fecundity associated with it as reference points. As stated previously in this document, their concern was that there was no information on the relationship of the target and threshold fecundity in relation to virgin fecundity levels. Projections were run to examine this, and they found that estimated annual fecundity since 1998 was only 5 to 10% of the virgin fecundity.

The Panel recommended that model specifications similar to the Panel's reference run be considered for future assessments, including capped effective sample size at 200, allowing the gaps in the pound net index and bait fishery age composition where data were not available, modification of the reduction and bait fleets to northern and southern fleets, and time-varying domed selectivity for the southern region.

Many of these recommendations were considered during the development of both Addendum V to the Atlantic Menhaden Fishery Management Plan as well as during the development of the 2012 update stock assessment.

1.3 DESCRIPTION OF THE FISHERY

1.3.1 Commercial Fishery

Atlantic menhaden have supported one of the United States' largest fisheries since colonial times. Menhaden have repeatedly been listed as one the nation's most important commercial fisheries species in terms of quantity. Preliminary Atlantic menhaden landings in 2011 totaled 228,800 mt

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(504 million lb). Landings records indicate that 24 million mt (52.9 billion lb.) of Atlantic menhaden have been caught by fishing fleets operating from Maine to Florida since 1940.

Native Americans were the first to use menhaden, primarily for fertilizer. Colonists soon recognized the value of whole menhaden for fertilizer, and local seine fisheries gradually developed from New York to Maine. The menhaden oil industry began in Rhode Island in 1811 (Frye 1999). Numerous small factories were located along the coasts of the northeastern states. However, their supply was limited to fish that could be captured by the traditional shore-based seines. In 1845, the purse seine was introduced, and an adequate supply of raw material was no longer a problem. By 1870, the industry had expanded southward, with several plants in the Chesapeake Bay and North Carolina areas (Whitehurst 1973). The industry gradually developed during the late 1800s and early 1900s and was described in considerable detail prior to World War I by Greer (1915). The primary use of menhaden changed from fertilizer to animal feed during the period following World War I, through a process known as fish reduction. Menhaden meal was mixed into poultry, swine, and cattle feeds as the amount used for fertilizer was decreasing (Harrison 1931). The current commercial fishery is divided into the reduction fishery and the bait fishery (menhaden harvested to supply bait to other commercial and recreational fisheries).

1.3.1.1 *Reduction Fishery*

Vessels and Domestic Harvesting Capacity

The early menhaden purse seine reduction fishery utilized sailing vessels, while coal-fired steamers were introduced after the Civil War. In the 1930s, diesel-powered vessels began to replace the steamers, although a few sailing vessels were still in use. The refrigeration of vessel holds in the 1960s and 1970s was crucial for the industry to maintain its viability. Despite restricted access to a number of traditional grounds, a reduced fleet size and fewer processing plants to land fish, refrigerated holds enabled the fleet to maximize the harvest during peak resource availability. Refrigeration also allowed the fleet to range over a larger area and stay out longer, greatly improving the ability to catch fish when and where they are available. All ten vessels in the menhaden fleet in 2011 utilized refrigerated fish holds, compared to only 60% of the fleet in 1980. A more detailed description of historical fishing vessels and methods is available in Amendment 1 (ASMFC 2001).

Currently, commercial reduction menhaden purse seine fishing operations use spotter aircraft to locate schools of menhaden and direct vessels to the fish. When a school is located, two purse boats approximately 39 ft (13 m) in length with a net stretched between them are deployed. The purse boats encircle the school and close the net to form a purse or bag. The typical purse-seine net used for reduction has a bar mesh of 7/8 in (2.2 cm) and net lengths up to 1,800 ft and the depth from about 65 ft (20 m) to 90 ft (27 m). Catch from individual sets can vary from 10 to more than 100 mt, and large vessels can carry 400-600 mt of refrigerated fish.

Historically, the total number of vessels fishing for menhaden was generally related to the availability of the resource. Greer (1915) reported 147 vessels in 1912. During 1955-1959, about 115-130 vessels fished during the summer season, while 30-60 participated in the North Carolina fall fishery. As the resource declined during the 1960s, fleet size decreased more than

50%. Through the 1970s, approximately 40 vessels fished during the summer season, while nearly 20 were active in the fall fishery. During 1980-1990, 16-33 vessels fished the summer season, and the level of effort in the fall fishery ranged from 3 to 25 vessels.

The reduction fleet during the 1990 season was composed of 22 vessels each using two purse boats. An additional 3-4 large vessels from Virginia and/or the Gulf of Mexico fished in the south Atlantic during the fall fishery. A major change in the reduction industry took place following the 1997 fishing season, when the two reduction plants operating in Reedville, VA, consolidated into a single company and a single factory; this significantly reduced effort and overall production capacity. Seven of the 20 vessels operating out of Reedville, VA, were removed from the fleet prior to the 1998 fishing year and 3 more vessels were removed prior to the 2000 fishing year, reducing the Virginia fleet to generally 10 vessels from 2000 through 2011. Another major event within the industry occurred in spring of 2005 when the fish factory at Beaufort, NC, closed and the owners sold the property to coastal developers.

Over the years, vessels participating in the Atlantic menhaden purse seine reduction fishery have varied considerably in size, fishing methods, gear type, and intensity of effort. During peak landing years (1953-1962), mean vessel capacity was about 678,000 standard fish, representing a total fleet capacity of approximately 76,000,000 standard fish (Nicholson 1971). The fleet landed daily catches at 20 menhaden reduction plants from New York to Florida. In comparison, the 1990 fleet of 33 vessels, which operated within a more restrictive and regulated environment, landed their catch at five plants, including a foreign processing vessel. In 2011, 10 reduction purse seine vessels ranging from about 166 ft (51 m) to 200 ft (61 m) in length (the majority were less than 170 ft long) landed at a single plant in Reedville,Virginia.

Reduction landings averaged 322.7 mt from 1940-2011, but only averaged 164.4 mt from 2002 – 2011 (Table 12; Figure 1). Reduction landings since 1940 peaked in 1956 at 712.1 mt, with the lowest value since 1940 (141.1 mt) occurring in 2008. Reduction landings in recent years have been the lowest of the time series. This decline is most likely influenced by several factors including population size, reduced fleet size and reduced reduction plant capacity.

Since preparation of the 1981 Atlantic Menhaden FMP (AMMB 1981), there have been numerous regulatory changes affecting the menhaden fishery, such as season limits, area closures, a Chesapeake Bay annual landings cap and changes in license fees. In some state waters, a prohibition on commercial menhaden fishing operations using purse seines has been implemented.

Processing Activities and Products

Menhaden reduction plants, through a process of heating, separating, and drying, produce fish meal, fish oil, and fish solubles from fresh menhaden. Meal is a valuable ingredient in poultry and livestock feeds because of its high protein content (at least 60%). Menhaden oil is (or has been) used in cooking oils, margarine, dietary supplements, soap, linoleum, waterproof fabrics, and certain types of paint. Solubles are the aqueous liquid component remaining after oil removal. In general, most meal producers add the soluble component to the meal to create a product termed "full meal." The use of solubles as an export product is limited because most companies in the feed industry are not equipped with the necessary storage tanks, pumps, and meters to handle a liquid product.

Section 306 of the Magnuson-Stevens Fishery Conservation and Management Act (PL 94-265) allows foreign fish processing vessels to operate within the internal waters of a state with the permission of the Governor of that state. Up to three IWP ventures operated within Maine's coastal waters during 1988-93. Under state jurisdiction, a foreign vessel was permitted to process menhaden caught by US vessels into fish meal and oil during the 1988-93 fishing seasons. In 1987, two New England-based menhaden vessels began to fish the Gulf of Maine area, landing the catch at a Canadian processing plant. Another Canadian factory in Nova Scotia processed menhaden in 1992 and 1993. No menhaden have been processed in the North Atlantic since the summer of 1993.

1.3.1.2 *Bait Fishery*

Harvest comes from directed fisheries, primarily purse seines, pound nets, cast nets and gill nets, and bycatch in various food-fish fisheries, such as pound nets, haul seines, and trawls. Menhaden are taken for bait in almost all Atlantic coast states and are used for bait in crab pots, lobster pots, and hook and line fisheries (both sport and commercial). Information on the harvest and use of menhaden for bait is difficult to obtain because of the nature of the bait fisheries and data collection systems. (Table 13; Figure 1). The New England region accounted for a high proportion of bait landings in the late 1980s and early 1990s (Figure 2). The Chesapeake Bay region has generally been the largest harvester of menhaden bait since the 1993, with the Mid-Atlantic only exceeding the Chesapeake Bay harvest in 1994, 1997, 2010 and 2011. Reported bait landings averaged 11% of the total Atlantic menhaden landings from 1985-99 and 19% of total landings from 2000 to 2011. The increase in percent of coastal landings are attributed to better data collection in the bait fishery and a decline in coastal reduction landings due to reductions in the number of processing plants and fleet size. Closure of reduction plants in New England and the mid-Atlantic may have influenced growth in the bait fishery, making more product available for the lobster and crab pot fisheries, as well as bait and chum for sport fishermen. Additionally, the passage of a net ban in Florida in November 1994 reduced the availability of bait and chum in that state, which opened up new markets for menhaden bait caught in Virginia and the mid-Atlantic states. The appearance of growth in the Atlantic coast bait fishery (Figure 1) must be tempered by the knowledge that reporting systems for bait landings, particularly for Atlantic menhaden, have historically been incomplete at best. Despite problems associated with estimating menhaden bait landings, data collection has improved in many areas. Some states license directed bait fisheries and require detailed landings records. In most cases, recent landings estimates are more accurate, but for some states, bait landings may continue to be underestimated (Table 14). There are some well-documented, large-scale, directed bait fisheries for menhaden using gears such as purse seines, pound nets, and gill nets. There are also many smaller-scale directed bait fisheries and bycatch fisheries supplying large quantities of bait which historically had few, if any reporting requirements. Most states implemented reporting requirements for the smaller scale fisheries by the late 2000's. Menhaden taken as bycatch in other commercial fisheries is often reported as "bait" together with other fish species. The "over-the-side" sale of menhaden for bait among commercial fishermen is likely under-reported (and may go unreported (Table 15).

The principal use for menhaden as bait in North Carolina is in the blue crab pot fishery. Very small operators use cast nets in the late afternoon or early morning during the summer months. In addition to harvesting bait for crab fishing, one type of operation keeps the fish alive in holding tanks for "slow trolling" for king mackerel, or bottom fishing for cobia. Nearshore head and charter boats also purchase menhaden. South Carolina and Georgia have no directed menhaden fisheries, shrimp trawl bycatch and cast netting supply menhaden to crab potters and sport fishermen in those states. Florida's east coast had substantial menhaden landings for bait from gill nets and purse seines prior to the implementation of a net ban in 1994.

Bait landings of menhaden in Virginia are dominated by purse seine vessels referred to as 'snapper rigs'; most have only one purse boat. From 2009 to 2011 four 'snapper rig' vessels have operated from Northern Neck, VA, near Reedville. These vessels range from about 80 to 135 ft long. On average vessels in the reduction fleet make about 5 sets per fishing day (Smith 1999), whereas snapper rig vessels make three to four purse-seine sets per day (Smith and O'Bier 2011). 'Snapper rig' nets traditionally were somewhat smaller than the nets employed by reduction vessels, but have been approaching the size of reduction nets in recent years. The catches of the snapper rigs are mostly sold for bait (sport fishery, crab pots, etc.) with minor quantities being used for reduction.

Bait landings of menhaden in Maryland and the Potomac River are dominated by pound net catches. Pound nets are a large fixed gear, with most fishermen having one to five nets set at any given time. The pound net fishery in the Chesapeake Bay region is prosecuted by numerous small non-refrigerated vessels. Maximum hold capacity of pound net vessels is 9 mt or less, but daily catches are usually well below vessel capacity and are limited by the number of fish encountering the fixed gear. The majority of these fish supply the local blue crab pot fishery.

In recent years there has been an expansion of the purse seine bait fishery in New Jersey. The New Jersey fishery utilizes about 20 carry vessels and about 15 catch vessels per year. Most operations have a catch vessel paired with a specific carry vessel, but some vessels are both catch and carry. Carry vessel length ranges from 59 to 90 feet, though most are in the 70-85 foot range, and catch vessel length ranges from 40 to 88 feet, but most are 40-50 feet. Net length is restricted to 150 fathoms (900 feet) by regulation. Pound nets and gill nets contribute to bait landings in New York and New Jersey. Delaware closely regulates its directed gill net fishery, obtaining detailed catch/effort data each year.

In the New England region, purse seine landings in Maine, Massachusetts and Rhode Island account for the majority of the recorded bait landings. The New England operators are fairly small, typically with one harvest vessel, with the size ranging from the mid-30s to 90 feet in length. Smaller operators also have a "carry" boat to take the catch to shore. In past years, an ocean trap net fishery operated in Rhode Island and Massachusetts. In New Hampshire and Connecticut, smaller directed gill net fisheries are well-regulated and monitored. The bulk of menhaden landings for bait in New England are used in the lobster fishery. Schools of large menhaden have been scarce in the New England region since the early 1990s.

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1.3.2 Recreational Fishery

Menhaden are important bait in many recreational fisheries; some recreational fishermen employ cast nets to capture menhaden or snag them with hook and line for use as bait, both dead and live. Recreational harvest is not well captured by the Marine Recreational Information Program (MRIP) because there is not a known identified direct harvest for menhaden, other than for bait. MRIP intercepts typically capture the landed fish from recreational trips as fishermen come to the dock or on the beach. Since menhaden caught by recreational fishermen are used as bait during their trip, they will not be a part of the catch that is typically seen by the surveyor completing the intercept.

The recreational catch has varied over time with a high of 672.3 mt in 1992 and a low of 12.2 metric tons in 2000. The average harvest since 1981 is 176.5 mt. Landings have averaged 300 mt over the last 5 years (Figure 3).

1.3.3 Subsistence Fishing

No subsistence fisheries for Atlantic menhaden have been identified at this time.

1.3.4 Non-Consumptive Factors

Outside of providing a forage base for various predators and the ecological role which menhaden serve (see *Sections 1.2.1.10; 1.2.1.11; 2.7*), other non-consumptive factors have not been identified at this time.

1.3.5 Interactions with Other Fisheries, Species, or Users

Incidental bycatch of other finfish species in menhaden purse seines has been a topic of interest and concern for many years to the commercial and recreational fishing industry, as well as the scientific community (Smith 1896; Christmas et al. 1960; Oviatt 1977). Numerous past studies have shown that there is little or no bycatch in the menhaden purse seine fishery. Some states restrict bycatch to 1% or less of the total catch on a vessel by regulation.

The Virginia Institute of Marine Science studied bycatch levels of finfish, turtles, and marine mammals in the Atlantic menhaden fishery. Results from that study indicated that bycatch in the 1992 Atlantic menhaden reduction fishery was minimal, comprising about 0.04% by number (Austin et al. 1994). The maximum percentage bycatch occurred in August (0.14%) and was lowest in September (0.002%). Among important recreational species, bluefish accounted for the largest bycatch, 1,206 fish (0.0075% of the total menhaden catch). No marine mammals, sea turtles, or other protected species were killed, captured, entangled or observed during sampling.

Additional data are available from the Gulf of Maine IWP fishery in 1991. Every catch unloaded onto the processing vessel was inspected by a state observer. A total of 93 fish were taken as bycatch along with about 60,000,000 individual menhaden (D. Stevenson, Maine DMR, pers. comm.; as cited in ASMFC 1992).

1.4 HABITAT CONSIDERATIONS

1.4.1 Physical Description of Habitat

Atlantic menhaden occupy a wide variety of habitats during their life history. Adult Atlantic menhaden spawn primarily offshore in continental shelf waters. Larvae enter estuaries and transform into juveniles, utilizing coastal estuaries as nursery areas before migrating to ocean waters in the fall. They make extensive north-south migrations in the near-shore ocean.

1.4.1.1 Gulf of Maine

The Gulf of Maine is a semi-enclosed sea of 36,300 mi^2 (90,700 km^2) bordered on the east, north and west by the coasts of Nova Scotia, New Brunswick, and the New England states. To the south, the Gulf is open to the North Atlantic Ocean. Below about 165 ft (50 m) depth, however, Georges Bank forms a southern boundary for the Gulf. The interior of the Gulf of Maine is characterized by five major deep basins (>600 ft, 200 m) which are separated by irregular topography that includes shallow ridges, banks, and ledges. Water flows in and out of the Bay of Fundy around Grand Manan Island. Major tributary rivers are the St. John in New Brunswick; St. Croix, Penobscot, Kennebec, Androscoggin, and Saco in Maine; and Merrimack in Massachusetts.

The predominantly rocky coast north of Portland, Maine is characterized by steep terrain and bathymetry, with numerous islands, embayments, pocket beaches, and relatively small estuaries. Tidal marshes and mud flats occur along the margins of these estuaries. Farther south, the coastline is more uniform with few sizable bays, inlets, or islands, but with many small coves. Extensive tidal marshes, mud flats, and sandy beaches along this portion of the coast are gently sloped. Marshes exist along the open coast and within the coves and estuaries.

The surface circulation of the Gulf of Maine is generally counterclockwise, with an offshore flow at Cape Cod which joins the clockwise gyre on the northern edge of Georges Bank. The counterclockwise gyre in the Gulf is more pronounced in the spring when river runoff adds to the southwesterly flowing coastal current. Surface currents reach velocities of 1.5 knots (80 cm sec) in eastern Maine and the Bay of Fundy region under the influence of extreme tides, up to 30 ft (9 m) and gradually diminish to 0.2 knots (10-20 cm/sec) in Massachusetts Bay where tidal amplitude is about 10 ft (3 m).

There is great seasonal variation in sea surface temperature in the Gulf, ranging from 4°C in March throughout the Gulf to 18°C in the western Gulf and 14°C in the eastern Gulf in August. The salinity of the surface layer also varies seasonally, with minimum values in the west occurring during summer, from the accumulated spring river runoff, and during winter in the east under the influence of runoff from the St. Lawrence River (from the previous spring). With the seasonal temperature and salinity changes, the density stratification in the upper water column also exhibits a seasonal cycle. From well mixed, vertically uniform conditions in winter, stratification develops through the spring and reaches a maximum in the summer. Stratification is more pronounced in the southwestern portion of the Gulf where tidal mixing is diminished.

1.4.1.2 Middle Atlantic Region (Cape Cod, MA to Cape Hatteras, NC)

The coastal zone of the middle Atlantic states varies from a glaciated coastline in southern New England to the flat and swampy coastal plain of North Carolina. Along the coastal plain, the beaches of the barrier islands are wide, gently sloped, and sandy, with gradually deepening offshore waters. The area is characterized by a series of sounds, broad estuaries, large river basins (e.g., Connecticut, Hudson, Delaware, and Susquehanna), and barrier islands. Conspicuous estuarine features are Narragansett Bay (Rhode Island), Long Island Sound and Hudson River (New York), Delaware Bay (New Jersey and Delaware), Chesapeake Bay (Maryland and Virginia), and the nearly continuous band of estuaries behind barrier islands along southern Long Island, New Jersey, Delaware, Maryland, Virginia, and North Carolina. The complex estuary of Currituck, Albemarle, and Pamlico Sounds behind the Outer Banks of North Carolina (covering an area of 2,500 square miles) is an important feature of the region. Coastal marshes border small estuaries in Narragansett Bay and much of the glaciated coast from Cape Cod to Long Island Sound. Nearly continuous marshes occur along the shores of the estuaries behind the barrier islands and around Delaware Bay.

At Cape Hatteras, the Continental Shelf extends seaward approximately 20 mi (33 km), and widens gradually northward to about 68 mi (113 km) off New Jersey and Rhode Island where it is intersected by numerous underwater canyons. Surface circulation north of Cape Hatteras is generally southwesterly during all seasons, although this may be interrupted by coastal indrafting and some reversal of flow at the northern and southern extremities of the area. Speeds of the drift north of Cape Hatteras are on the order of six miles (9.7 km) per day. There may be a shoreward component to this drift during the warm half of the year and an offshore component during the cold half. The western edge of the Gulf Stream meanders in and out off Cape Hatteras, sometimes coming within 12 mi (20 km) of the shore, but it becomes less discrete and veers to the northeast north of the Cape. Surface currents as high as 4 knots (200 cm/sec) have been measured in the Gulf Stream off Cape Hatteras.

Hydrographic conditions in the mid-Atlantic region vary seasonally due to river runoff and warming in spring and cooling in winter. The water column becomes increasingly stratified in the summer and homogeneous in the winter due to fall-winter cooling of surface waters. In winter, the mean range of sea surface temperatures is 0-7°C off Cape Cod and 1-14°C off Cape Charles (at the southern end of the Delmarva Peninsula); in summer, the mean range is 15-21°C off Cape Cod and 20-27°C off Cape Charles. The tidal range averages slightly over 3 ft (1 m) on Cape Cod, decreasing to the west. Within Long Island Sound and along the south shore of Long Island, tide ranges gradually increase, reaching 6 ft (2 m) at the head of the Sound and in the New York Bight. South of the Bight, tide ranges decrease gradually to slightly over 3 ft (1 m) at Cape Hatteras. Prevailing southwest winds during the summer along the Outer Banks often lead to nearshore upwelling of colder bottom water from offshore, so that surface water temperatures can vary widely during that period (15-27°C over a period of a few days).

The waters of the coastal middle Atlantic region have a complex and seasonally dependent circulation pattern. Seasonally varying winds and irregularities in the coastline result in the formation of a complex system of local eddies and gyres. Surface currents tend to be strongest during the peak river discharge period in late spring and during periods of highest winds in the winter. In late summer, when winds are light and estuarine discharge is minimal, currents tend to be sluggish, and the water column is generally stratified.

1.4.1.3 South Atlantic Region

The south Atlantic coastal zone extends in a large oceanic bight from Cape Hatteras south to Biscayne Bay and the Florida Keys. North of Florida it is bordered by a coastal plain that stretches inland for a hundred miles and a broad continental shelf that reaches into the ocean for nearly an equal distance. This broad shelf tapers down to a very narrow and precipitous shelf off the southeastern coast of Florida. The irregular coastline of North Carolina, South Carolina, Georgia, and eastern Florida is generally endowed with extensive bays and estuarine waters, bordered by nutrient-rich marshlands. Barrier beaches and dunes protect much of the shoreline. Along much of the southern coast from central South Carolina to northern Florida estuarine salt-marsh is prominent. Most of the east coast of Florida varies little in general form. Sand beaches with dunes are sporadically interrupted by mangrove swamps and low banks of earth and rock.

The movements of oceanic waters along the South Atlantic coast have not been well defined. The surface currents, countercurrents, and eddies are all affected by environmental factors, particularly by winds. The Gulf Stream flows along the coast at 6-7 miles per hour (10-11 km/hr). It is nearest the coast off southern Florida and gradually moves away from the coast as it flows northward. A gyral current that flows southward inshore of the Gulf Stream exists for most of the year north of Cape Canaveral.

Sea surface temperatures during the winter increase southward from Cape Hatteras to Fort Lauderdale, Florida, with mean minimums ranging from 2-20°C and maximums ranging from 17-26°C. In the summer, the increases are more gradual, ranging north to south from minimums of 21-27°C to maximums of 28-30°C. Mean sea-surface salinity is generally in the range of 34 to 36 ppt year round. Mean tidal range is just over 3 ft (1 m) at Cape Hatteras and increases gradually to about 6-7 ft (2 m) along the Georgia coast. Tides decrease south of Cape Canaveral to 3 ft (1 m) at Fort Lauderdale.

1.4.2 Habitat Quality

Of primary importance is the fact that Atlantic menhaden are estuarine-dependent. Following oceanic spawning, menhaden larvae are transported into the coastal estuaries where they transform into juveniles. They utilize the estuary from low salinity headwaters to high salinity areas near inlets as nursery areas for most of their first year.

1.4.3 Environmental Requirements of Atlantic Menhaden

1.4.3.1 Temperature, Salinity and Dissolved Oxygen (see Amendment 1)

1.4.3.2 Primary Production

Abundance of YOY juvenile menhaden is strongly and positively correlated with *chl-a* and primary production in Chesapeake Bay, at least during the most recent two decades (Houde & Harding). Furthermore, the relationship between *chl-a* and abundance of YOY recruits is principally generated in spring months during the period larvae are transitioning to the filter-feeding juvenile stage when menhaden become dependent on phytoplankton for food. Although recent research indicates that age-1 and older menhaden may derive most energy from zooplankton food (Lynch et al. 2010; Friedland et al. 2011), it is apparent that YOY menhaden can efficiently filter small phytoplankton (Friedland et al. 2006) and that it is their primary food. The timing, intensity, quality, and spatial variability of the spring phytoplankton bloom in Chesapeake Bay show high interannual variability and are strongly affected by climate (Adolf et al. 2006; Miller and Harding 2007; Miller et al. 2006). This variability in primary production is probably a key factor controlling production potential of young menhaden in Chesapeake Bay.

1.4.3.3 Environmental Factors and Recruitment Success

Relationships between recruitment success of YOY menhaden and factors other than variables associated with primary productivity were less clear. Numerous fish and avian predators are major consumers of young menhaden in Chesapeake Bay but there are no estimates of predation rates or of variability in natural mortality rates of YOY menhaden. Bioenergetics and predation models indicate potential for predators to control abundances of YOY menhaden in Chesapeake Bay (Zhang et al. 2011).

There is evidence that temperature experienced by YOY menhaden positively affects seasonal and inter-annual variability in growth within the Bay (Houde and Harding 2009; Houde et al. 2009) and is an important parameter in bioenergetics models that predict growth potential (Annis et al. 2011). Recent observations suggested that flow-related variables were important, but acted indirectly and in complex ways to exercise control over recruitment levels. Regional analyses of synoptic climatology supported the observation that menhaden recruitment, in general, is elevated in years of low late-winter precipitation and freshwater flow, when relatively warm and dry weather conditions, often described as “Bermuda High” patterns, prevail (Wood et al. 2004; Kimmel et al. 2009; Wood and Austin 2009).

1.4.3.4 Sediments and Turbidity

Historically, forest clearing has led to changes in sediment loading (Brush 1986). Regionally in Chesapeake Bay, before 1700, the mean rate of deposition was 0.05cm/yr, but increased to 0.60 cm/yr after 1750 (Hilgartner and Brush, 2006). Without the buffer provided by trees, shrubs, plants, and wetlands that previously bordered tributaries and the Bay, storm water was unchecked. This resulted in erosion that brought increased sediment into the estuary. Moreover, the dramatic increase in impermeable surfaces has also increased runoff. Impervious surfaces amplify storm water discharges into streams that feed the Bay (Goetz and Jantz 2006). One consequence of these changes is that sediment grain size has changed over time so that very fine sediment predominates now that reduces light penetration. Secchi disk readings have steadily declined since 1985 from just over 2 meters to about 1 meter in 2008 (Greer 2008). Because juvenile menhaden while filter feeding can retain particles as small as 5-7 μm, and to a minor extent particles <5 μm, there is a possibility that menhaden feeding could be compromised (Friedland et al. 1984).

Increased turbidity acts to shade submerged aquatic vegetation (SAV), thus decreasing the extent and composition of SAV beds. Loss of SAV may indirectly affect menhaden by increasing turbidity as a result of increased sediment resuspension (Orth et al., 2006) which in turn can lower phytoplankton productivity. SAV has also been shown to exercise control over ecosystem function through nutrient recycling and linkage to fish productivity (Orth et al., 2006; Hughes et al., 2009), which may impact menhaden abundance, although specific impacts in Chesapeake Bay are not known at present.

1.4.3.5 Water Movement

Currents and circulation features play an important role in cueing reproduction and in controlling dispersal of larval stages, assuring that some larvae are transported to the coastal estuaries and embayments that serve as juvenile nurseries. Most larval menhaden are found shoreward of the Gulf Stream Front (GSF); those sampled in the GSF or seaward of it presumably are rapidly advected northeast and lost to the population, although it is possible that warm-core rings and onshore streamers could return some larvae to the shelf (Hare and Govoni 2005). There is ample evidence, based on observations and models, that coastward transport of larvae is supported by favorable winds and currents on the shelf (e.g., Checkley et al. 1988; Werner et al., 1999). Models and observations of advective mechanisms at estuary mouths present a less-clear picture of how menhaden larvae move into estuaries, although it is apparent that winds, tides, and larval behavior control the ingress.

Interannual variability in recruitments is believed to be at least partly controlled by variability in oceanographic conditions that affect hydrography, circulation, and possibly biological productivity. Weather and climate patterns are probable drivers of such variability. Wood et al. (2004) demonstrated that prevalence of a late-winter climate pattern designated a “Bermuda-Azores High” that brings dry and warm late-winter weather to the Mid-Atlantic region is associated with high recruitment of Atlantic menhaden. This weather pattern may promote favorable shoreward transport or feeding conditions for early-stage menhaden larvae while on the continental shelf.

The remarkable temperature tolerance of larval menhaden is notable in distribution statistics. Larvae have been collected at temperatures from 0 to 25 °C. The low-temperature observations are for late-stage menhaden larvae (usually >20 mm length), in winter that have been advected to the mouths of mid-Atlantic estuaries (e.g., Kendall and Reintjes 1975).

The mechanics and details of larval ingress to estuaries are poorly known, despite numerous studies to describe and explain it. Larval ingress may occur in pulses, supported by windgenerated high-inflow events (Forward et al. 1999b). Wind forcing may play an important role, in combination with entrainment in up-estuary residual flow (Hare et al 2005).

1.4.3.6 Environmental Contaminants

In a study of chlorinated hydrocarbon residues in menhaden fishery products from the Atlantic and Gulf of Mexico, Stout et al. (1981) showed that overall levels have decreased since the late 1960s, although significant differences between years for levels of polychlorinated biphenyls (PCB’s) in the South Atlantic region and for dieldrin in the Mid-Atlantic region could not be demonstrated. There was also a general lack of significant differences between areas within years, although this may have been due to the sampling regime. They speculated that PCB levels have remained somewhat high because of leakage from sources established prior to regulation and continued allowance of limited specialty uses. Menhaden oil products carry the highest concentrations of such non-polar compounds and some samples contained levels in excess of USFDA temporary tolerances as of 1977. Warlen et al. (1977) demonstrated that C^{14} - DDT uptake by Atlantic menhaden is dose-dependent, with an assimilation value between 17 and 27%. Application of their model to field data suggested that uptake was by way of plankton and detritus. Little information exists about the toxicity of contaminants to Atlantic menhaden (Rogers and Van Den Avyle 1989).

1.4.3.7 *Substrate and System Features*

The association of Atlantic menhaden with estuarine and nearshore systems during all phases of its life cycle is well documented. It is evident that young menhaden require these food rich waters to survive and grow, and the fishery is concentrated near major estuarine systems. Filling of estuarine wetlands, in addition to exacerbating extremes in environmental conditions, has physically limited the nursery habitat available to Atlantic menhaden and other estuarine-dependent species. The relative importance, however, of different habitat types (i.e. sounds, channels, marshes) and salinity regimes has received little detailed attention (Rogers and Van Den Avyle 1989).

1.4.4 Identification and Distribution of Essential Habitat

Almost all of the estuarine and nearshore waters along the Atlantic coast from Florida to Nova Scotia, serve as important habitat for juvenile and/or adult Atlantic menhaden. Spawning occurs in oceanic waters along the Continental Shelf, as well as in sounds and bays in the northern extent of their range (Judy and Lewis 1983). Larvae are carried by inshore currents into estuaries from May to October in the New England area, from October to June in the mid-Atlantic area, and from December to May in the south Atlantic area (Reintjes and Pacheco 1966). After entering the estuary, larvae congregate in large concentrations near the upstream limits of the tidal zone, where they undergo metamorphosis into juveniles (June and Chamberlin 1959, Houde 2011). The relative densities of juvenile menhaden have been shown to be positively correlated with higher chlorophyll *a* levels in the lower salinity zones of estuaries (Friedland et al. 1996, Houde & Harding 2007). As juvenile menhaden grow and develop, they form dense schools and range throughout the lower salinity portions of the estuary, most eventually migrating to the ocean in late fall-winter.

Many factors in the estuarine environment affect the behavior and well-being of menhaden. The combined influence of weather, tides, and river flow can expose estuarine fish to rapid changes in temperature and salinity. It has been reported that salinity affects menhaden temperature tolerance, activity and metabolic levels, and growth (Lewis 1966; Hettler 1976). Factors such as waves, currents, turbidity, and dissolved oxygen levels can impact the suitability of the habitat, as well as the distribution of fish and their feeding behavior (Reintjes and Pacheco 1966). However, the most important factors affecting natural mortality in Atlantic menhaden are considered to be predators, parasites and fluctuating environmental conditions (Reish et al. 1985).

It is clearly evident that estuarine and coastal areas along the Atlantic coast provide essential habitat for most life stages of Atlantic menhaden. However, an increasing number of people live near the coast, which precipitates associated industrial and municipal expansion, thus, accelerating competition for use of the same habitats. Consequently, estuarine and coastal habitats have been significantly reduced and continue to be stressed adversely by dredging, filling, coastal construction, energy plant development, pollution, waste disposal, and other human-related activities.

Estuaries of the mid-Atlantic and south Atlantic states provide almost all of the nursery areas utilized by Atlantic menhaden. Areas such as Chesapeake Bay and the Albemarle-Pamlico system are especially susceptible to pollution because they are generally shallow, have a high total volume relative to freshwater inflow, low tidal exchange, and a long retention time. Most tributaries of these systems originate in the Coastal Plain and have relatively little freshwater flow to remove pollutants. Shorelines of most estuarine areas are becoming increasingly developed, even with existing habitat protection programs. Thus, the specific habitats of greatest long-term importance to the menhaden stock and fishery are increasingly at risk.

1.4.5 Anthropogenic Impacts on Atlantic Menhaden and their Habitat

Pollution and habitat degradation threaten the Atlantic menhaden population, particularly during the estuarine residency of larvae and juveniles. Concern has been expressed (Ahrenholz et al. 1987b) that the outbreaks of ulcerative mycosis in the 1980s may have been symptomatic of deteriorating water quality in estuarine waters along the east coast. The growth of the human population and increasing development in the coastal zone are expected to further reduce water quality unless steps are taken to ameliorate their effect on the environment (Cross et al. 1985). Changing habitats and water quality potentially can affect habitat use and productivity of menhaden in the coastal ocean, estuaries, and particularly the estuarine systems. Menhaden's various life stages occur in waters ranging from the coastal estuaries and inlets along the continental shelf to the western margin of the Gulf Stream from southern Florida to Nova Scotia (Manooch 1991) Estuarine habitats have been altered dramatically over the past decade.

Perhaps the most significant physical alteration of the Chesapeake Bay watershed in recent decades has been the increase in impervious surfaces, with at least 400,000 hectares projected by 2010 (Brush 2009). These surfaces increase the rate of flow of nutrients, sediment, and contaminants to the Chesapeake Bay (Clagett 2007) and exacerbate eutrophication and expansion of anoxic zones. Although not studied at present, reduced water quality associated with increases in impervious surfaces could diminish habitat for menhaden or their predators.

Effects on menhaden habitat use and productivity are possible as well due to climate change. Menhaden ingress is sensitive to changes in wind patterns and temperatures which are known to be variable and may be influenced by climate change (Quinlan et al. 1999; Austin 2002). Moreover, nursery habitats within bays and estuaries are likely to be transformed by the effects of climate change, in some cases potentially enhancing menhaden productivity and other cases resulting in lower production and recruitment.

The effects of climate change are projected to include: increased water temperatures; sea-level rise; change in precipitation patterns, changes in climate variability that include increased storm and drought events, among other related phenomena (Jones & Friedland, 2009). These changes can influence salinity, temperature, and nutrients throughout nursery grounds.

In addition to long-term climate change, the Atlantic coast has also experienced shorter-term, decadal fluctuations in weather, shifting between cold-wet and warm-dry periods. Austin (2002) showed that the 1960s were warmer and wetter than the 1970s and 1990s in the mid-Atlantic. Menhaden recruitment success tends to be relatively high in years when late winter-spring conditions are warm and dry (Wood 2000). The generally low recruitments of YOY menhaden in recent years appear to be constrained by frequent cool and wet, winter-spring conditions that favor recruitment of anadromous spawners, but not offshore-spawning fishes such as menhaden (Kimmel et al. 2009). It is not certain how climate change will affect longterm abundance and productivity of menhaden, as noted in the next section.

1.4.6 Description of Programs to Protect, Restore, Preserve and Enhance Atlantic Menhaden Habitat

The federal Coastal Zone Management Act provides a framework under which individual coastal states have developed their own coastal habitat protection programs. In general, wholesale dredging and filling are not allowed. Individual development projects are subject to state and federal review and permit limitations. Every Atlantic coast state has a coastal habitat protection program in place (Table 11.27 in ASMFC 1992). These protection programs have greatly reduced the loss of vital coastal habitat to dredging and filling since the mid-1970s. Virtually all proposals affecting coastal habitat are now reviewed by a variety of local, state, and federal agencies, and wholesale destruction of coastal wetlands is rare. Many important estuarine habitats are now protected as part of various wildlife refuges, national and state parks, and public and private nature preserves. In addition, a federal permit program is conducted by the U.S. Army Corps of Engineers, generally in cooperation with the state programs. Every state also conducts water quality protection programs under the federal Clean Water Act. National Pollution Discharge Elimination System permits are required for point-source discharges. Unfortunately, these programs provide much less control over non-point pollution, especially that originating from agricultural and silvicultural activities.

1.5 IMPACTS OF THE FISHERY MANAGEMENT PROGRAM

1.5.1 Biological and Environmental Impacts

1.5.1.1 Timeline to Achieve Target F

The new F reference points adopted by the Board are intended to be interim reference points while the Commission’s Multispecies Technical Committee develops ecological-based reference points (ERP). The ERPs will take some time to develop because of the complexity of modeling predator-prey relationship in marine species that rely on menhaden for forage (e.g., striped bass, bluefish, weakfish). A multi-species model will take into account the effect of changes in the menhaden population on species that utilize them as prey, as well as how changes in predator populations affect menhaden abundance. In either case (biological or ecological reference points) the intent is to manage Atlantic menhaden at sustainable levels to support fisheries and meet predator demands through sufficient SSB to prevent stock depletion and recruitment failure.

The current status of the Atlantic menhaden stock is not overfished, but overfishing is occurring. Through Amendment 2, the Board will take immediately actions to end overfishing. However, because the reductions in F are more substantial to achieve the F target, the Board is considering a three, five and ten year schedule to reduce F to the target level. If the target F is to be achieved on a shorter time frame, annual reductions in landings may be more substantial than if the F was achieved over a longer time period.

1.5.1.2 *Data Collection and Reporting Requirements*

Implementing improved reporting criteria for menhaden bait fishermen and continuation of the current reduction fishery reporting will increase the precision of estimates of stock status and calculation of reference points. If one or more quotas are used to manage the fishery accurate and timely landings reporting would be vital to their success. Reporting systems for most bait fisheries currently include delays up to three months, or more, from the time of landing until becoming available to fisheries managers. These lengthy delays could lead to quota overages or fisheries being closed prematurely because of uncertainty in levels of harvest. Updating current reporting systems will require increased staff time and resources for agencies gathering the information and/or the individual fishermen. This cost may reduce fishermen profits, increase financial demands on states/jurisdictions or both. Utilizing electronic reporting systems (e.g., SAFIS) on existing systems could minimize costs of implementation and the associate impacts on fishermen and states/jurisdictions.

1.5.1.3 *Quotas*

Limiting the catch by imposing quotas by fishery, region or state is an efficient reliable way to reduce harvest. The fishing season would close after the annual total allowable catch has been harvested. In theory this would protect a larger proportion of the spawning stock, rather than allowing fishing to continue under current regulations. If properly set and enforced a quota would likely end overfishing and allow the stock to increase. In the long term this would lead to increased quotas that potentially would equal or exceed current harvest levels. An increase in stock size would also increase the forage base of commercially and recreationally important predator species. A quota would reduce income, and likely employment levels, of one or more of the following groups in the short term: menhaden bait fishermen, commercial fisheries reliant on menhaden for bait, the reduction industry, businesses reliant on menhaden products (from reduction) or business that use species caught using menhaden for bait. Harvest of other bait species may increase if the number of menhaden landed for bait is not adequate to meet the demand of the blue crab and American lobster fisheries, which both currently rely heavily on menhaden. Another potential consequence of a quota system is dead discards of menhaden in multi-species fisheries, particular in fixed gear such as pound nets, after the quota has been met but the gear is still being fished for other species.

1.5.1.4 *De minimis*

De minimis status could exempt qualifying states from mandatory monitoring measures, such as updated commercial monitoring systems or biological monitoring. In jurisdictions with relatively small Atlantic menhaden commercial landings, the cost of implementing monitoring measures may be greater than the value of the jurisdictions fishery. Jurisdiction granted *de minimis* status would still have to abide by any management measures that are in place to safeguard against developing nontraditional fisheries or a market for out of jurisdiction fish.

1.5.1.5 No Action

The menhaden fishery would be managed under the existing rules and regulations enforced throughout the Atlantic coast fishery by the individual states/jurisdictions (Table 16). Management would be piecemeal and subject to regional perceptions and influences. This option would allow existing fisheries to operate so that the participants can maximize their benefits, with minimal additional costs to administer and enforce management or monitoring measures. However, taking no action will allow overfishing to continue and would likely lead to over-exploitation of the resource in the long term. If the stock became overfished or depleted there would be a significant economic impact in the menhaden fisheries, fisheries for species that feed on menhaden and fisheries that use menhaden for bait. Impacts to non-game species of fish, birds and marine mammals that feed on menhaden, or feed on species that feed on menhaden, would also be negatively impacted. No action may lead to increased social and political conflicts and could also result in additional area closures based on socio-economic concerns rather than a biological basis.

1.5.2 Social Impacts

Menhaden, also known as pogies, bugmouth, fat-back, mossbunker and bunker, were highly prized for human consumption due to their "superior flavor" from the mid-18th to late 19th century. With the exception of roe (Smith 2000), menhaden are no longer commonly sought for the fresh fish market in the United States (Frey 1978). Rather, menhaden are processed to obtain omega-3 fish oil that is used as a dietary health supplement for humans (Lands 1986). In addition to human consumption, menhaden is used in fertilizer, fishmeal, and livestock feed (Smith 1991). Menhaden oil has long been used for marine lubricants and additives, as well as formulated for use in paints, plastics, resins and cosmetics.

Menhaden are used as bait in several valuable commercial fisheries, particularly the blue crab fishery of the Chesapeake Bay and the Atlantic lobster fishery, as well as in several recreational fisheries. In addition, menhaden are thought to provide important ecosystem services, not only serving as forage for a variety of fish, birds and marine mammals, but also as filter feeders, and their widespread abundance is considered beneficial to water quality.

Consequently, analysis of the potential social impacts of changes in the regulation of menhaden should consider effects on businesses directly dependent on menhaden; the commercial fisheries that land menhaden and the processors that transform the menhaden into products such as fish oil, fishmeal, fertilizer and livestock feed. Other stakeholders, indirectly dependent on menhaden, include both the commercial and recreational fisheries that rely on menhaden for bait (e.g., lobster and crab fisheries; striped bass, tuna, and bluefish fisheries); those that rely on the presence of menhaden as forage for their business activity (e.g., charter boats, bird-watching companies, and whale watch boats); as well as those who rely on or value clear water.

Others who may also be affected by regulatory change include the businesses that support the commercial and recreational fisheries (e.g., gear manufacturers, fuel providers, other infrastructure providers), companies and individuals who rely on or need the products of menhaden processing, and individuals who value the way of life associated with fishing.

A lack of data detailing the full range of stakeholders and their dependency on menhaden, either directly or indirectly, prohibits full analysis of the social impacts of menhaden regulation. We know little about the demographics of the various stakeholders and even less about the social variables (e.g., families, behavioral norms, cultural values) associated with the menhaden industry. What follows is a description of the major characteristics of the businesses or others that use menhaden (e.g., gear and vessels used, processing plant) and the most prominent businesses likely to be impacted by regulatory change.

1.5.2.1 Fisheries Gear

As has been described previously in *Section 1.3.1* focused on the commercial fishery, there are multiple gears used to fish for menhaden along the Atlantic coast. The gear associated with the greatest landings, however, is the purse seine that is used by the reduction fishery and by some in the bait fishery. Other gear used includes gill nets, cast nets and pound nets. Pound nets and smaller purse seines tend to be more commonly used in the Chesapeake Bay to obtain menhaden for sale as bait for the blue crab fishery.

1.5.2.2 Recreational Fishery

There is a recreational fishery for menhaden, but it is currently neither monitored external to MRIP nor thought to be extensive enough to have significant effects upon populations of the fish. Typically the fish are caught by cast net and used soon after as bait in recreational fishing targeting such species such as striped bass, bluefish, tuna, cobia, and crab. In addition, some menhaden caught commercially are purchased and used as chum, cut fish for bait, and as processed oils and attractants for various fish from crustaceans to game fish.[1]Stanley O'Bier(2012) noted that the menhaden from the Chesapeake supplies approximately half the bait for Florida recreational fishing in the form of whole fish and chum.

1.5.2.3 The Reduction Fishery[2]

Menhaden was used as fertilizer by Native Americans long before the Europeans arrived. By the 19th century, farmers in New England had formed small companies to catch and transport menhaden to their fields. In the 1850's the scarcity of whale oil led to the production of menhaden oil for use as lubricants and liquid fuel in the burgeoning industrial economy. Twenty years later, with the invention of the purse seine and increasing demand, almost 100 factories reduced the menhaden to extract oil and sell the scrap as fertilizer. Following World War II, spotter planes were used to locate huge menhaden schools along the Atlantic coast and the catch

[1] (http://www.catchnbait.com/fishing-chum.htm, http://www.tarbayseafood.com/Menhaden-Bait-Fish-6-Pack-p/bfm-m01.htm).

[2] *Information for this section comes from Kirkley et al.2011*

soared to 1.6 billion pounds in 1956. The product became a key ingredient in agricultural feed. By 1969, however, the annual catch had plummeted. Eventually, most of the factories went out of business.

The reduction fishery for Atlantic menhaden is now associated with a single processing plant, Omega Protein, located in Reedville, Northumberland County, Virginia. The plant corporate office is located in Houston, Texas. It is incorporated in the state of Nevada. The company maintains operations in both the northwest Atlantic and the Gulf of Mexico with processing facilities in Louisiana, Mississippi, and Reedville, Virginia. The Louisiana and Mississippi plants process Gulf menhaden.

In 2008, the company employed 159 individuals, of which 157 were full time seasonal workers, to harvest menhaden. The company also employed 140 individuals of which 126 were full time year round employees, to process and distribute menhaden-based products. Omega provides health care, paid holidays, and retirement programs for all employees. Plant employees also receive paid life insurance and vacation days.

In 2008, the Reedville facility had total sales of meal, oil, and soluble of approximately $60.0 million. The total payroll for vessel and plant employees was nearly $11.4 million, which was fairly evenly divided between plant and vessel employees. In addition, Omega Protein paid approximately $1.2 million in union dues on behalf of its employees. The plant's total operational expenditures, excluding payroll, equaled $18.9 million. In 2008, Omega Protein of Reedville donated approximately $70,000 to charity.

Kirkley et al (2011) found that reductions in the bay fishery could largely be replaced by the ocean fishery for Atlantic menhaden with little effect on the reduction fishery in terms of overall product output. Costs would increase for the plant and there would be loss of approximately 20 jobs (roughly 7 percent). However, when a survey was undertaken as to the preferences of the people of Virginia for the employment of fishermen and/or plant employees as opposed to retaining menhaden in the Chesapeake, it was determined that the people of Virginia preferred the higher employment level as opposed to increased numbers of menhaden in the Chesapeake.

The people who worked in the plant at the time of the study thought that if they became unemployed they could find other employment, but they did not think they could find employment in the same type of work or at the same level of income. This part of the study was conducted in 2008, and since then, the unemployment rate in the region and nation has increased, making alternative employment more difficult to find.

1.5.2.4 The Bait Fishery

Menhaden are caught for bait in all regions of the Atlantic. In recent years there has been increasing demand for menhaden as bait for lobster in response to the limitations on herring availability due to regulatory changes. Since menhaden are more plentiful in the Mid-Atlantic and Chesapeake areas and due to a preference for larger menhaden as noted by Smith and O'Bier (2011), it is assumed that much of the lobster bait originates from the Mid-Atlantic area.

New England

As described in Draft Addendum V to the menhaden management plan, New England operators tend to be small, generally with one harvest vessel, of a size range from the mid-30s to 90 feet in length.[3] Smaller operators also have a "carry" boat to take the catch to shore. Each vessel carries from seven to ten crewmembers, and has associated support employees onshore to accommodate the business end of the operation, including unloading, packing, salting, and any other shipping preparations. The geographic range of a portion of the New England fleet is substantial, from Maine to New Jersey, while the seasonal basis is from late spring to fall. As the boats travel from location to location, they purchase dock space, food, and fuel from the local communities.

In Maine there are also two to three herring seiners who switch to harvesting menhaden for bait on an opportunistic basis including outside of the Gulf of Maine.[4] Other vessels that land herring also land menhaden as ancillary catch, though whether targeted or incidental is not specified. By herring vessel category, Category A and Category C had a 2% dependency on menhaden for years 2007-2010. Smaller inshore bait vessels are at a disadvantage compared to vessels prepared to go beyond the EEZ limit to fish for menhaden or that move to the Mid-Atlantic to access additional bait sources.

For New England, the main use of menhaden is for lobster bait. Although herring is the preferred bait for lobster, herring supply has been reduced due to changes in regulations designed to limit potential bycatch of river herring and move the larger herring vessels offshore. These limits have encouraged the lobstermen to look for additional sources of bait. The lobster fishery is important to New England and the United States because lobster is a high value fishery that from 2007 to 2010 provided 380,133,575 pounds of landings valued at $1,378,276,659 in New England.[5] Herring is the preferred bait for lobster in Maine, but due in part to the herring restrictions, the percentage use of menhaden has increased from roughly 6% in 2006 to as high as 32% in 2012 according to the Maine Lobstermen's Association.[6] A provider of menhaden for bait in New England notes that she is now providing double the amount of menhaden for the lobster fishery as she did four years ago.

Mid-Atlantic

Mid-Atlantic operators for menhaden use pound nets, haul seines, fyke nets, gill nets, handlines, eel pots, turtle traps and purse seines (McCay and Cieri 2000). The highest landings come from purse seines and with the possible exception of pound nets, the other landings may be considered incidental because the landings for all species were equal to or less than 0.1% of all landings. The landings from fyke nets, gill nets, handlines, eel pots and turtle traps are unlikely to have contributed greatly to the significantly increased landings in the Mid-Atlantic area. McCay and

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[3] Based on information from Kaelin, personal communication, 2011

[4]From Draft Amendment 5to the Fishery Management Plan for Atlantic Herring(http://www.nefmc.org/herring/planamen/draft_a5/FORMAL%20DEIS%20RESUBMISSION%20MARCH%2014%202012/FINAL.VERSION.Draft.AM.5.DEIS.Resubmission.WITH.INDEX.March.14.2012.pdf)

[5]http://www.st.nmfs.noaa.gov/pls/webpls/MF_MONTHLY_LANDINGS.RESULTS.

[6]http://www.ncfish.org/A_Great_Bait_-_2-29-12.pdf.

Cieri note that pound nets are used in limited areas, so without expansion of these specific areas, it is also unlikely that they have contributed to the increase in landings.

According to Smith and O'Bier (2011), older and larger menhaden are caught in New Jersey compared to the Chesapeake and these menhaden are preferred for the lobster fishery. This probably explains the recent increase in catches and landings of menhaden in the Mid-Atlantic because Atlantic herring are the preferred lobster bait for Maine and much of New England is currently under restriction under ASMFC Addendum II to Amendment 2 to the Atlantic Herring Plan and New England Fishery Management Council's Amendment 4 to the Fishery Management Plan. Further restrictions are anticipated when Amendment 5 is completed and implemented.

Chesapeake Bay[7]

Chesapeake Bay menhaden are predominantly caught by two methods, purse seines – locally known as snapper rigs—and pound nets. Chesapeake Bay menhaden are primarily used for the crab pot fishery of the Chesapeake, North Carolina, and other pot crab fisheries. If there is a bait glut, menhaden may be sold to the reduction fishery. Five vessels are currently being used for menhaden bait landings in the Chesapeake Bay. Snapper rigs tend to be smaller vessels than the reduction fishery purse seine vessels although three of the five vessels active in the last five years were originally purse seine vessels from Beaufort, NC. Typically, vessels employ six crew members (Stanley O'Bier, personal communication). Spotter planes were used to assist in 90% of the purse seine sets. The season generally runs from mid-May through mid-November. Data is collected via log books known as Captain's Daily Fishing Reports. Most sets occur in the central bay, between the Rappahannock River and the Maryland state line, with some sets occurring between the York River and the Rappahannock River. No sets of the purse seines appeared to have occurred south of the York River area near the mouth of the Chesapeake for the time period under study. Pound nets are found in Virginia, although there is a cap on pound nets set at a total of 161 nets.[8] More pound nets are concentrated in Maryland waters as purse seines are prohibited in Maryland state waters.

Currently, Virginia pound nets are placed in locations to select for higher value species than menhaden, such as striped bass and other food fishes, so they tend to contribute less to the menhaden fishery (Stanley O'Bier, personal communication). In Maryland the geographic distribution of pound nets are concentrated in the area along the Eastern Shore between Cambridge and Crisfield, and on the western side of the Chesapeake between Deale and Annapolis and around the southernmost peninsulas and rivers.[9] This is not to say that pound nets are not found above the Bay Bridge or on the Atlantic, but that they are less common.

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[7]Much of the Chesapeake Bay data comes from Smith and O'Bier (2011)

[8]http://www.mrc.virginia.gov/regulations/fr600.shtm.

[9]http://dnr.maryland.gov/fisheries/commercial/poundnets/index.asp, http://www.arcgis.com/home/webmap/viewer.html?webmap=eae2515e27f84c2dbcc4d3864f35501d&extent=-77.2886,37.7866,-74.8551,39.6444)

Menhaden are the predominant bait for the blue crab pot fishery in the central area of the Chesapeake Bay. Blue crab is the highest value fishery from the Chesapeake Bay, with a dockside value in Maryland alone of $52,020,000 in 2009.[10] In Maryland the crabbers prefer to use fresh menhaden collected from pound nets in 65 pound bushels each morning due to their higher oil content, lower price and to support local business. Watermen of the area consider it "the mainstay of the bait business." When not able to access their local pound nets, crabbers purchase frozen menhaden in 50 pound flats from a Virginia distributer for $10-$12. A bushel of fresh menhaden, costing about $8 in 2012, is used to bait approximately 100 pots.

Cuts in the menhaden fishery could result in more severe reductions for the pound net fishery than for the more mobile purse seine fishery of the Chesapeake which could, if pushed, physically move to offshore waters to take bait. Economically however, this response may not be feasible. According to Stanley O'Bier (2012), the fuel costs would double, product quality would diminish due to the longer distance to offloading facilities, and more importantly, safety concerns would inhibit the use of snapper rigs in the EEZ. Resulting increases in the cost of bait to the blue crab fishery could be quite difficult for both Maryland and Virginia. Both states saw an early spring return of crabs in 2012 but this did not lead to economic benefits in the summer. The blue crab fishery has already faced difficult decisions and is struggling to maintain a way of life in isolated communities.[11]

Stanley O'Bier (2012) noted that the menhaden supplied from the Chesapeake provides approximately half the bait for Florida recreational fishing in the form of menhaden fish and chum. Further, nearly 55% of the company's production is distributed to states in the southern region for bait used in both commercial and recreational fishing. Therefore one could expect increasing pressures on more distant users of menhaden bait from the Chesapeake. Specifically, the increases in the price of bait plus delivery costs will probably lead to a search for substitute baits or other changes, possibly including a reduction in fishing.

Finally, Mr. O'Bier (2012) discussed what he considered the important linkage between the bait fishery and the reduction fishery. When the market for menhaden bait is oversupplied, the market for menhaden reduction generally takes the excess, thus maintaining a better price for harvesters, and making the bait fishery a viable fishery year round. Considering the need for the bait fishery for the larger area from Maryland to Texas, this linkage may be worth additional consideration.

South Atlantic

In the South Atlantic area menhaden fishing occurred most frequently around Beaufort, NC where a reduction plant was located until 2004. Its demise has eased fishing pressure in the area, but ancillary fishing for bait still occurs in the state. Gears used included gill net, fly net, pound net and other, with gill net, and fly net providing 37.8% of landings, and 32.2% of landings

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[10] http://www.msa.md.gov/msa/mdmanual/01glance/html/seafoodp.html
[11] http://www.smithsonianmag.com/people-places/Tangier-Island-and-the-Way-of-the-Watermen.htmlandhttp://www.nytimes.com/2008/03/31/us/31cake.html

respectively between 2006 and 2010 yet making up only 0.3% of Atlantic coast-wide landings.[12] North Carolina also noted that in 2010, 258 commercial fishermen reported landing 1.3 million pounds of menhaden in 1,629 trips. Thus menhaden supported the crab fishery that used 11.2 million pounds of menhaden as bait, costing about $3 million.[13] Note that an additional 9.9 million pounds of menhaden for bait necessarily came from elsewhere.

Large scale fishing for menhaden, referred to as industrial fishing, has recently been prohibited in North Carolina waters, though smaller purse seines are allowed.[14] Other states within the region have had some landings, but they are not the dominant locations for landings when compared to the northern portion of this region.

As noted in the Chesapeake region discussion, menhaden bait from the Chesapeake is distributed into the southern region and there are links between the two regions. One processor noted that nearly 55% of their distribution is to the southern region, and another substantial percentage is sent to the Gulf Coast.

1.5.2.5 *Non Consumptive Uses*

Kirkley et al (2011) and Chesapeake Bay Foundation describe menhaden as being of interest to conservation since they are filter feeders, interpreted to mean that they "clean the bay." In addition, they are prey for several species of fish, for various bird species (particularly osprey), and for marine mammals.[15] Further north, in the Mid-Atlantic and New England, conservation efforts are mostly concerned with menhaden as forage species for recreationally fished species. The greatest interest is found among fishing organizations focused on striped bass and similar species. These groups maintain that the more menhaden available, the larger and healthier individual striped bass will be and the larger and healthier the striped bass population will be.

As noted earlier, whale-watching and bird-watching (both commercial businesses and individual recreational activities) may also benefit from menhaden left in the water as forage. Because of their schooling behavior, menhaden are a favorite target for the common loon, herons, egrets, gulls, gannets, ospreys, and eagles. Some mammals, such as whales and dolphins, also feed on menhaden.[16]

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[12]NC Marine Fisheries, (http://mobile.ncleg.net/DocumentSites/Committees/MFC-LRC/Meetings/2-02-2012/Handouts%20and%20Presentations/2012-0202%20L.Daniel-DMF_Menhaden%20Presentation.pdf, slide 5

[13]http://mobile.ncleg.net/DocumentSites/Committees/MFC-LRC/Meetings/2-02-2012/Handouts%20and%20Presentations/2012-0202%20L.Daniel-DMF_Menhaden%20Presentation.pdf, slide 11

[14]http://portal.ncdenr.org/web/mf/nr-18-12-menhaden-purse-seine.

[15]http://www.cbf.org/Page.aspx?pid=1624

[16] Atlantic Menhaden, Chesapeake Bay Ecological Foundation. Available online at http://www.chesbay.org/forageFish/menhaden.asp

1.5.3 Economic Impacts

1.5.3.1 Economic impacts of status quo and harvest restrictions on the reduction fishery

The menhaden reduction fishery creates direct, indirect and induced economic impacts which are concentrated in Virginia, particularly in Northumberland County, the location of OMEGA Protein. Because OMEGA is the only firm engaged in the harvesting and processing of menhaden for reduction, economic impacts from reduction quota that take place outside the Northumberland County area can be assumed to be negligible. Kirkley et al (2011) developed an input/output (IO) model for economic activities of the reduction fishery to estimate economic impacts from sales, income, and employment generated by operations of OMEGA Protein. The authors estimate baseline (status quo) economic impacts of OMEGA Protein Operations in 2008 that include 519 full and part-time jobs (299 direct, 114 indirect and 106 induced), approximately $22.75 million in incomes ($12.56 million direct, $6.2 million indirect and $4 million induced), and output valued at $88.15 million ($59.92 million direct, $15.75 million indirect and $12.49 million induced).

Closure of the reduction industry would result in the loss of these economic impacts, which is equivalent to a 14.3% decline in total outputin Northumberland County, a 14.1% decline in county income and a 8.1% decline in county employment. Closure of the Chesapeake Bay reduction fishery would result in profit losses between $7.3 million and $10 million, depending on assumptions about changes in costs.

Reducing Bay quota from 109,020 metric tons to 25,000 metric tons (a 77% decrease) would reduce employment by 221 jobs (60%), output by $37.54 million (42.6%) and income by $9.69 million (42.6%). Reducing Bay quota from 109,020 metric tons to 50,000 metric tons(a 54% decrease) would reduce employment by 128 jobs (25%), output by $21.8 million (25%) and income by $5.63 million (25%). Reducing the commercial Bay quota from 109,020 metric tons to 75,000 metric tons (a 31% decrease) would reduce Virginia employment by 37 jobs (7.1%), output by $6.2 million (7.1%), and income by $1.6 million (7.1%). The relatively small impacts from this latter reduction stem from the fact that contemporary Bay harvests have been below quota, not exceeding 85,000 metric tons in recent years. Assuming that coastal ocean harvests remain unchanged, restricting Bay quota to 50,000 metric tons and 25,000 metric tons reduces OMEGA gross profits to $11.3 million and $0.6 million respectively. Restricting coastal ocean quotas from 141,100 metric tons to 50,000 metric tons is expected to reduce the value of OMEGA sales proportionately from $59.5 to $21.2 million, and decrease profits from $14.2 to $2.3 million. The disproportionate impact on profits is due to an assumed increase in operating costs that would result if harvest operations were limited to offshore.

While the Kirkley analysis does not explicitly examine reductions in quota outside of the Bay, and does not permit estimation of the effects of quota changes outside of Virginia, decreases in harvest quota in other states can be assumed to have economic impacts that are proportionately higher due to fuel, maintenance and repair expenses that are expected to increase with distance from OMEGA and additional time required for harvest. In short, harvest quota restrictions in states further from Virginia are expected to have proportionately higher economic impacts.

In addition to the input/output analysis, Kirkley et al (2011) used contingent valuation analysis to estimate the economic value to regional stakeholders of retaining or reducing the current commercial quota in the Bay. This analysis produced estimates of the annual dollar amounts that individuals would be willing to pay for different levels of commercial harvest of menhaden for reduction purposes, and suggests that a decrease in the menhaden industrial catch is valued at $28 in net benefits per household, while its maintenance is valued at $50 per household. Aggregation of this result suggests that there is a gain in net benefits of $110.0 million for maintaining the status quo relative to reducing the Bay quota. In other words, regional stakeholders prefer maintenance of the status quo over reducing allowable Bay quota, suggesting that economic value is associated with the existence of the reduction fishery.

1.5.3.2 Economic impacts of status quo and harvest restrictions on the bait fishery

Landings of menhaden for bait have averaged approximately 40,000 metric tons per year since 2002, the majority of which is harvested in the Mid-Atlantic and Chesapeake Bay. Comprising roughly 20% of total menhaden landings in recent years, the bait fishery plays an important economic role in commercial and recreational fisheries throughout the range of the species. The use of menhaden as bait appears to be especially critical for the commercial crab and lobster fisheries, which are among the most economically significant fisheries on the east coast. Menhaden harvested for bait in the Mid-Atlantic region appear to be primarily directed toward lobster fisheries, while those harvested in the Chesapeake Bay appear to largely support blue crab fisheries (Smith and O'Bier 2011).

According to the National Marine Fisheries Service (2010) in New England (Connecticut, Maine, Massachusetts, New Hampshire, and Rhode Island) American lobster had higher landings revenues than any other species or species group, averaging $323 million in landings revenue from 2000 to 2009. In the Mid-Atlantic Region (Delaware, Maryland, New Jersey, New York, and Virginia), blue crab generated landing revenues of $70 million, while American lobster generated landings revenues of roughly $8 million. In the South Atlantic Region (East Florida, Georgia, North Carolina, and South Carolina) blue crab averaged approximately $38.3 million in landings revenues from 2000-2009, and was responsible for the highest landings revenue across all species in the South Atlantic Region in 2009, with $35 million.

Menhaden appear to comprise an increasingly large percentage of bait used by lobster and crab fishers. For example, in New Jersey, where menhaden are the preferred bait for lobster, between 70 and 100 percent of bait used by lobstermen is menhaden (Toni Kerns, ASMFC, personal communication). In Connecticut, menhaden comprise between 40 and 70 percent of bait used by lobster fishers depending on the season (Toni Kerns, ASMFC, personal communication). In Maine, the preferred lobster bait is herring, but menhaden may comprise up to 30 percent of bait. It is unknown what percentage of crab bait is comprised of menhaden.

While it is clear that menhaden play an important supporting role in these fisheries, it is beyond the scope of this report to attempt to assign a specific portion of lobster and crab fishery value to the maintenance of menhaden harvests, or to attempt to determine the economic impact on these fisheries from menhaden quota reductions. Such valuations would require a more detailed understanding of the prices and availability of substitute baits and how lobster and crab catch rates vary with bait type. We can however put forth a back-of-the-envelope estimate of the gross value of menhaden bait landings. Assuming an ex-vessel price of roughly $0.0738 per pound for menhaden (personal communication, ASMFC AP member) and sales prices ranging from $0.1125 (direct wholesale to fishers) to $0.22 per pound (retail), the average annual bait harvest of 88.2 million pounds generates approximately $6.5 million in gross revenues to fishers, with an additional $3.41 – $12.87 million in gross value added realized by wholesalers and retailers. These sales also create indirect and induced economic impacts, which we do not attempt to estimate here.

1.5.3.3 Benefits of commercial harvest restrictions to recreational fishing

Reductions in menhaden quota may have positive economic impacts on the recreational fishing sector. The economic value and economic impact of recreational angling are unquestionably significant. For example, in a review of 26 empirical studies estimating the economic values of recreational fishing, Sturtevant et al (1995) find that river fishing experiences in the eastern region of the United States generate net economic gains of up to $59.00 per person per trip, with an average of approximately $20.00 per trip. Schuhmann and Schwabe (2004) find that the value of a 25% increase in the expected catch of striped bass is between $2.67 and $36.98 per trip, depending on the characterization of congestion and whether or not anglers practice catch-and-release. Freeman (1995) finds that most per trip values for recreational fishing access to singlespecies are between $10 and $100 and that most annual values are between $100 and $1,000 per person. Importantly, the literature provides a clear link between the behavior of recreational anglers and the quality of catch (Freeman, 1995).

However, despite the obvious and measurable benefits from recreational fishing, and the obvious connection between fishing success and economic value, the empirical link between the quality of fishing and menhaden harvest remains tenuous. An examination of the relationships between numbers of striped bass, bluefish, weakfish, and spotted sea trout caught, abundance of those species and the abundance of menhaden, Kirkley et al (2011) find no empirical evidence that a restriction or elimination of menhaden harvest for reduction in the Bay or in coastal waters would result in an increase in the economic impacts derived from the recreational fishing for game fish species that prey on menhaden. The authors find no statistically significant causality between game fish abundance and menhaden abundance and game fish catch (numbers) and menhaden abundance. No causality is found between menhaden abundance and recreational angler trips.

It is important to note that based on data from 2000-2008, Kirkley et al (2011) do find a relationship between menhaden abundance and the weight of striped bass. Specifically, a 1.0 billion fish increase in menhaden abundance is expected to increase the mean weight of recreationally harvested striped bass by 0.05 pounds per fish. Hence, to the extent that recreational anglers derive value from marginal increases in the weight of striped bass, increased abundance of menhaden due to harvest restrictions may produce additional economic value. To conclude, while it seems intuitive that reductions in menhaden harvest will improve the quality of economically valuable recreational fishing experiences, more evidence is needed to ascertain the nature and extent of the associated economic gains.

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1.5.4 Other Resource Management Efforts

Single species management of various predators of Atlantic menhaden will have a direct effect on the status of the menhaden population and should be considered in a multispecies management approach. Such an approach is not available at this time but the Commission has sponsored a workshop to investigate the feasibility of various modeling approaches in relation to Atlantic menhaden and has awarded a grant to develop a multispecies model incorporating menhaden, striped bass, bluefish and weakfish abundance and interactions. This grant led to the production of a multi-species virtual population analysis (MSVPA-X) (NEFSC 2006a, 2006b). The MSVPAX has been used in the menhaden model to produce the predation component of the natural mortality information being used in the model. As well, the ASMFC has awarded an additional grant to the University of Rhode Island to produce a second multi-species model using the same species complex, but will be developed in a statistical catch-at-age framework. Along with the modeling exercises, a formal ecological reference point (ERP) evaluation process implemented through a series of facilitated workshops is being proposed through a Multiple Management Objective Decision Analysis (MODA). MODA would involve representative Board members, key stakeholders, and technical committee members as well as use a facilitated "Structured Decision-Making" process to come to consensus on an explicit set of ecosystem management goals and objectives and ERP performance measures. The MODA process would allow for the collaborative development of models to evaluate ERP performance under a suite of uncertain environmental conditions. The MODA would also transparently evaluate and review potential consequences of ERPs and produce a recommended set of ERPs for Atlantic menhaden that are most likely to adequately meet the consensus ecosystem goals and objectives. MODA would help the Board to evaluate the unanticipated consequences of managing a forage fish like menhaden through collaborative model development and performance evaluation. The results of these efforts should ultimately lead to a better understanding of the dynamics involving these species and could lead to alternative management approaches in the future.

In addition to the fishery analysis and management efforts noted above, habitat and water quality management efforts can also impact the status of the menhaden population.

1.6 LOCATION OF TECHNICAL DOCUMENTATION FOR FMP

1.6.1 Review of Resource Life History and Biological Relationships

Atlantic menhaden life history information was summarized by Arhenholz (1991) and Rogers and Van Den Avyle (1989).

1.6.2 Stock Assessment Documentation

Detailed information pertaining to the menhaden stock assessment and methodology can be found in the report of the Menhaden Peer Review Panel (ASMFC 2010), and in the following research publications: Vaughan (1993); Cadrin and Vaughan (1997); and Vaughan et al. (2002). Assessment updates occur every three years and the results are found in the most recent report of the technical committee (ASMFC 2012).

1.6.3 Social Assessment Documentation

Kirkley et al. (2011) evaluated the social components of the reduction fishery as it relates to OMEGA Protein, and the Chesapeake Bay region. The results of the Kirkley et al. (2011) study are summarized in *Section 1.5*.

1.6.4 Economic Assessment Documentation

Kirkley et al. (2011) developed an input/output (IO) model for economic activities of the reduction fishery to estimate economic impacts from sales, income, and employment generated by operations of OMEGA Protein. The results of the Kirkley et al. (2011) study are summarized in *Section 1.5*.

1.6.5 Law Enforcement Assessment Documentation

The Commission's Law Enforcement Committee has prepared a document entitled Guidelines for Resource Managers on the Enforceability of Fishery Management Measures (November 2002) which can be used to evaluate the effectiveness of future measures.

2.0 GOALS AND OBJECTIVES

2.1 HISTORY AND PURPOSE OF THE PLAN

2.1.1 History of Prior Management Actions

The first coastwide management plan (FMP) for Atlantic menhaden was passed in 1981 (ASMFC 1981). The 1981 FMP did not recommend or require specific management actions, but provided a suite of options should they be needed. After the FMP was approved, a combination of additional state restrictions, imposition of local land use rules, and changing economic conditions resulted in the closure of most reduction plants north of Virginia by the late 1980s (ASMFC 1992). In 1988, the ASMFC concluded that the 1981 FMP had become obsolete and initiated a revision to the plan.

The 1992 Plan Revision included a suite of objectives to improve data collection and promote awareness of the fishery and its research needs (ASMFC 1992). Under this revision, the menhaden program was directed by the ASMFC Atlantic Menhaden Management Board, which at the time was composed of up to five state directors, up to five industry representatives, and one representative each from the National Marine Fisheries Service and the National Fish Meal and Oil Association.

Representation on the Management Board was revised in 2001 to include three representatives from each state Maine through Florida, including the state fisheries director, a legislator, and a governor's appointee. The reformatted board has passed one amendment and five addenda to the 1992 FMP revision.

Amendment 1, passed in 2001, provides specific biological, social/economic, ecological, and management objectives. Addendum I (2004) addressed biological reference points for menhaden, the frequency of stock assessments (every three years), and updated the habitat section of the FMP.

Addendum II (2005) instituted a harvest cap on Atlantic menhaden by the reduction fishery in Chesapeake Bay. This cap was established for the fishing seasons in 2006 through 2010. The Atlantic Menhaden Technical Committee determined the following research priorities to examine the possibility of localized depletion of Atlantic menhaden in the Chesapeake Bay: determine menhaden abundance in Chesapeake Bay; determine estimates of removal of menhaden by predators; exchange of menhaden between bay and coastal systems; and larval Studies (determining recruitment to the Bay).

Addendum III (2006) was initiated in response to a proposal submitted by the Commonwealth of Virginia that essentially mirrors the intent and provisions of Addendum II. It placed a five-year annual cap on reduction fishery landings in Chesapeake Bay. The cap, based on the mean landings from 2001 – 2005, was in place from 2006 through 2010. Addendum III also allowed a harvest underage in one year to be added to the next year's quota. The maximum cap in a given year is 122,740 metric tons. Though not required by the plan, other states have implemented more conservation management measures in their waters. Addendum IV (2009) extends the Chesapeake Bay harvest cap three additional years (2011-2013) at the same cap levels as established in Addendum III.

Addendum V (2011) establishes a new F threshold and target rate (based on MSP) with the goal of increasing abundance, spawning stock biomass, and menhaden availability as a forage species.

Amendment 2 to the Interstate Fishery Management Plan for Atlantic menhaden replaces Amendment 1 to the 1981 FMP for Atlantic menhaden. This document contains all applicable management options still in implementation from Amendment 1 and all five addenda.

2.1.2 Regulatory Trend

Throughout much of its history, the Atlantic menhaden fishery has been managed by unilateral regulatory actions imposed by individual states. Current state specific regulations are detailed in (Table 16).

2.1.3 Purpose and Need for Action

The 2010 Atlantic menhaden benchmark stock assessment Peer Review Panel noted that menhaden population abundance had declined steadily and recruitment had been low since the last peak observed in the early 1980s. Fishing at the fishing mortality (F) threshold reference point in the terminal year (2008) has resulted in approximately 8% of the maximum spawning potential (MSP). Therefore, the Panel recommended alternative reference points be considered that provide greater protection for spawning stock biomass (SSB) or population fecundity relative to the unfished level. In November 2011, the Atlantic Menhaden Management Board responded to that recommendation and adopted new F reference points. The new reference points are more conservative than the previous to account for the following: (1) while menhaden are not overfished the number of fish in the population has been declining, (2) while menhaden are important for many fisheries they also provide important ecological services, (3) strong recruitment classes may be dependent on favorable environmental conditions, and (4) recent science suggest conserving a larger percentage of the spawning stock. The new F threshold is $F_{15\%MSP}$ and the new F target is $F_{30\%MSP}$. Full $F/F_{15\%MSP}$ for the terminal year (2011) was greater than 1, therefore, overfishing is occurring. Addendum V states that when overfishing is occurring the Board will take steps to reduce F to the target level. In order to reduce overfishing to the target, the Board needs to consider changes in the management tools used to regulate the fishery.

2.2 GOAL

Amendment 2 to the Interstate Fishery Management Plan for Atlantic Menhaden replaces Amendment 1 to the 1981 FMP for Atlantic Menhaden.

The goal of Amendment 2 is to manage the Atlantic menhaden fishery in a manner that is biologically, economically, socially and ecologically sound, while protecting the resource and those who benefit from it.

2.3 OBJECTIVES

The following objectives are selected to support the goal of Amendment 2:

Biological Objectives

- Protect and maintain the Atlantic menhaden stock at levels to maintain viable fisheries and the forage base with sufficient spawning stock biomass to prevent stock depletion and guard against recruitment failure.

- Maintain a uniform data collection system for the reduction fishery and develop new protocols for other harvesting sectors, including biological, economic, and sociological data (ACCSP protocols as a minimum; NMFS reduction fishery monitoring system should be continued).

- Evaluate, develop, and improve approaches or methodologies for stock assessment including fishery-independent surveys and variable natural mortality at age or by area.

- Optimize utilization of the resource within the constraints imposed by distribution of the resource, available fishing areas, and harvest capacity.

Social/Economic Objectives

- Maintain existing social and cultural features of the fishery to the extent possible.

- Develop a public information program for Atlantic menhaden, including the fishery, biology, estuarine ecology and role of menhaden in the ecosystem.

Ecological Objectives

- Protect fishery habitats and water quality in the nursery grounds to insure recruitment levels are adequate to support and maintain a healthy menhaden population.

- Improve understanding of menhaden biology, food web ecology and multispecies interactions that may bear upon predator-prey and recruitment dynamics.

- Protect and maintain the important ecological role Atlantic menhaden play along the coast.

- Improve understanding of climatic drivers of recruitment.

Management Objectives

- Insure adequate accessibility to fishing grounds.

- Develop options or programs to control or limit effort, and regulate fishing mortality by time or area.

- Base regulatory measures upon the best available scientific information and coordinate management efforts among the various political entities having jurisdiction over the fisheries.

2.4 SPECIFICATION OF MANAGEMENT UNIT

The management unit for Amendment 2 is defined as the Atlantic menhaden resource throughout the range of the species within U.S. waters of the northwest Atlantic Ocean from the estuaries eastward to the offshore boundary of the EEZ. This definition is consistent with recent stock assessments which treat the entire resource in U.S. waters of the northwest Atlantic as a single stock. It is also recognized that the menhaden resource, as defined here, is interstate and state-federal in nature, and that effective assessment and management can be enhanced through cooperative efforts with all Atlantic coast state and federal scientists and fisheries managers.

2.4.1 Management Area

The management area for Amendment 2 shall be the entire coastwide distribution of the resource.

2.5 BIOLOGICAL REFERENCE POINTS

Threshold reference points are the basis for determining stock status (i.e., whether overfishing is occurring or a stock is overfished). When the fishing mortality rate (F) exceeds the F-threshold, then overfishing is occurring; the rate of removal of fish by the fishery exceeds the ability of the stock to replenish itself. When the reproductive output (measured as spawning stock biomass or population fecundity) falls below the biomass-threshold, then the stock is overfished, meaning there is insufficient mature female biomass (SSB) or egg production (population fecundity) to replenish the stock.

Current Overfishing, Overfished/Depleted Definitions

The current overfishing definition is a fecundity-per-recruit threshold of $F_{15\%MSP}$ and a target of $F_{30\%MSP}$. The current fecundity-based overfished definition is a target of SSB_{MED} and a threshold of $SSB_{MED.T}$ (half of SSB_{MED}). Benchmarks are calculated using all years, 1955-2011. Reference points are recalculated during an update and benchmark stock assessment, see the latest stock assessment for point estimates of reference points and stock status determination (ASMFC, 2012).

SSB Reference Points

As noted, the current overfished definition is SSB_{MED} as a target and 50% of SSB_{MED} as a threshold. Since the 2010 benchmark assessment, the Atlantic Menhaden Management Board adopted $F_{30\%MSP}$ and $F_{15\%MSP}$ as the menhaden management *F*-based overfishing target and threshold, respectively. **The TC warns that there is a technical mismatch between the current overfishing and overfished reference points. The TC recommends that if the Board wishes to manage the stock with an $F_{15\%MSP}$ overfishing definition, then a matching overfished definition ($SSB_{15\%MSP}$) should be adopted as well.**

The Board may consider a change to the SSB biological reference points through Amendment 2.

Option A: Status Quo. The current fecundity-based overfished definition is a target of SSB_{MED} and a threshold of $SSB_{MED.T}$ (half of SSB_{MED}).

Option B: The fecundity-based overfished definition is a target of $SSB_{30\%MSP}$ and a threshold of $SSB_{15\%MSP}$.

History of Atlantic Menhaden Biological Reference Points
Amendment 1 Benchmarks

The reference points in Amendment 1, adopted in 2001, were developed from the historic spawning stock per recruit (SSB/R) relationship. As such, F_{MED} was selected as $F_{threshold}$ (representing replacement level of stock, also known as F_{REP}) and was calculated by inverting the median value of R/SSB and comparing to the SSB/R curve following the method of Sissenwine and Shepherd (1987). The spawning stock biomass corresponding to $F_{threshold}$, was calculated as a product of median recruitment and SSB/R at F_{MED}, from equilibrium YPR analysis, which became the SSB_{target}. The threshold for SSB ($SSB_{threshold}$) was calculated to account for natural mortality [(1-*M*)*SSB-target, where *M*=0.45]. In Amendment 1, the F_{target} was based on F_{MAX} (maximum fishing mortality before the process of recruitment overfishing begins).

Addendum 1 Benchmarks

Based on the 2003 benchmark stock assessment for Atlantic menhaden, the benchmarks were modified by the ASMFC in Addendum 1 as recommended by the Technical Committee (ASMFC 2004). The TC recommended using population fecundity (number of maturing or ripe eggs; SSB) as a more direct measure of reproductive output of the population compared to spawning stock biomass (the weight of mature females; SSB). For Atlantic menhaden, older menhaden release more eggs than younger menhaden per unit of female biomass. By using the number of eggs released, more reproductive importance is given to older fish in the population than accounted for simply by female biomass. They also recommended modifications to the fishing mortality (F) target and threshold. The TC recommended continued use of F_{MED} to represent F_{REP} as the $F_{threshold}$, but estimated it using fecundity per recruit rather the SSB per recruit. Because the analysis calculated an F_{MAX} (target) that was greater than FMED (and may be infinite), they recommended instead that F_{target} be based on the 75th percentile. This approach was consistent with the approach used for the $F_{threshold}$. For biomass (or egg) benchmarks, the TC recommended following the approach of Amendment 1.

Addendum V Benchmarks

In November 2011, Addendum V was approved, which established an interim fishing mortality threshold and target. The interim $F_{threshold}$ and F_{target} are based on maximum spawning potential (MSP). The new threshold and target equate to MSP of 15% and 30%, respectively. Addendum V did not establish any new interim SSB based reference points.

2.6 STOCK REBUILDING PROGRAM

2.6.1 Stock Rebuilding Targets

The Management Board will evaluate the current estimates of F with respect to its reference points (*Section 2.5*) before proposing any additional management measures. If the current F exceeds the threshold level, the Board will take steps to reduce F to the target level; if current F exceeds the target, but is below the threshold, the Board should consider steps to reduce F to the target level. If current F is below the target F, then no action would be necessary to reduce F.

The Management Board will evaluate the current estimates of SSB with respect to its reference points (*Section 2.5*) before proposing any additional management measures. If the current SSB is below the threshold level, the Board will take steps to increase SSB to the target level; if current SSB is below the target, but above the threshold, the Board should consider steps to increase SSB to the target level. If current SSB is above the target SSB, then no action would be necessary to increase SSB.

2.6.2 Stock Rebuilding Schedules

SSB Rebuilding Schedule

The Board shall take action to rebuild the Atlantic menhaden stock to at least the target SSB level in a time frame that shall be no longer than 10 years.

F Rebuilding Schedule

Through Amendment 2, the Board will take immediate actions to end overfishing. However, because the reductions in F are more substantial to achieve the F target, the Board is considering a three, five and ten year schedule to reduce F to the target level. Depending on the schedule for

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reducing F, a time stepped approach may be used in which F would be reduced in smaller increments until the target is reached. If the target F is to be achieved on a shorter time frame, annual reductions in landings may be more substantial than if the F was achieved over a longer time period.

Option A: The Board is not required to specify a time frame to rebuild the Atlantic menhaden stock to the target F level.

Option B: The Board shall take action to rebuild the Atlantic menhaden stock to at least the target F level in a time frame that shall be no longer than 3 years.

Option C: The Board shall take action to rebuild the Atlantic menhaden stock to at least the target F level in a time frame that shall be no longer than 5 years.

Option D: The Board shall take action to rebuild the Atlantic menhaden stock to at least the target F level in a time frame that shall be no longer than 10 years.

2.7 RESOURCE COMMUNITY ASPECTS

See Section 1.4 for the role Atlantic Menhaden play in ecosystem dynamics.

2.8 IMPLEMENTATION SCHEDULE

As part of the final approval of Amendment 2, the Management Board will establish an implementation schedule.

3.0 MONITORING PROGRAM SPECIFICATIONS/ELEMENTS

An Atlantic menhaden stock assessment will be performed on a schedule of every three years by the stock assessment subcommittee. The technical committee and advisory panel will meet to review the stock assessment and all other relevant data sources. In interim years, a series of population metrics, or “triggers” will be monitored. An annual report will be presented to the Management Board in a timely fashion (usually May or June depending on Commission meeting week scheduling) in order to make annual adjustments to the management program as necessary. The stock assessment report shall follow the general outline as approved by the ISFMP Policy Board for all Commission-managed species. In addition to the general content of the report as specified in the outline, the stock assessment report will also address the specific topics detailed in the following sections.

3.1 ASSESSMENT OF ANNUAL AGE/SIZE STRUCTURE

Annual estimates of Atlantic menhaden age and size structure will be monitored based on results of the stock assessment. These estimates are available from the BAM model and are mainly based on the reduction fishery, though efforts are being made to acquire age and size samples from the bait fisheries, particularly in the northern range of the stock. Efforts to include data from the bait fishery and other sources as available should be continued in order to provide an overall picture of the status of the menhaden population.

The Technical Committee will monitor the age structure through the current BAM model methodology and report to the Board the results. The old trigger estimates, from the 1992 FMP, will be retained as part of a long-term monitoring program and renamed as Biological and Fishery Status Reference Points. These data will be used only for the evaluation of current stock status with the caveats identified by the Menhaden Peer Review Panel (i.e. landings based reference points reflect conditions of the fishery and not the actual population, subject to sampling coverage; ASMFC 1999b). In particular, the percent age-0 and percent age-3+ fish in the reduction landings may serve to indicate the status of the population age structure and incoming year-class strength. Another indicator could be the number and relative size of age-classes in the population as estimated through the BAM model.

3.2 ASSESSMENT OF ANNUAL RECRUITMENT

Annual recruitment of Atlantic menhaden will be estimated by examination of a variety of data sources. The first is the estimate of recruitment to age-1 from the BAM model as currently conducted. Secondly will be the examination of various fishery-independent data sources, including the juvenile abundance indices that are integrated in to the statistical modeling process. Although many of these surveys are not designed to specifically target menhaden, continued examination of these surveys in the future may prove worthwhile. In addition, surveys designed to specifically monitor menhaden abundance along the coast are needed. Efforts to examine power plant impingement data for their utility in estimating young-of-year menhaden abundance should be continued.

3.3 ASSESSMENT OF SPAWNING STOCK BIOMASS

Spawning stock biomass (SSB, measured as mature ova) will be estimated from the BAM model every three years. The terminal year estimates will be used for evaluating stock status versus the chosen reference points. Because of the retrospective problems observed in the latest menhaden stock assessment update, a three-year running average of SSB will also be developed (Table 11). Terminal year estimates generated by the BAM model tend to be subject to some fluctuation as additional data are added each year. Therefore, terminal year estimates may not accurately depict current conditions. A three-year running average may be more reflective of overall trends in the population and might reduce the risk of implementing management measures based on a false reading of the population status. However, three-year running averages may lessen the chance of detecting a decline in SSB or an increase in F over the short term. The running average approach may be fine so long as the menhaden population does not undergo wide variations or fluctuations from year to year.

3.4 ASSESSMENT OF FISHING MORTALITY

Fishing mortality (F) rates will be estimated by the BAM model every three years. Fishing mortality will be estimated for each age-class for examination, but the metric used for comparison to the reference point values will be full F, or the comprehensive fishing mortality rate for all ages of the entire coastwide stock. Currently, fishing mortality rates are estimated for the reduction fishery, the bait fishery, and the recreational fishery.

3.5 PROJECTION METHODOLOGY

The Stock Assessment Subcommittee provided estimates of fishing mortality and spawning stock biomass for the terminal year of 2011 and through a 20 year projection during the development of Amendment 2. Projections using constant landings scenarios were run in order to explore options to achieve 1) the fishing mortality threshold immediately and 2) the fishing mortality target over a range of 3, 5, and 10 years. Decisions regarding the structure and inputs for the projection analysis were discussed by the technical committee during a meeting on January 9, 2012; for documentation see the projection analysis white paper (ASMFC 2012).

The results of these projections are presented here. As might be expected, the higher the landings, the lower the probability of F being less than the threshold and target (Table P1, Table P2). However, the range in F was fairly broad for a given level of constant landings. At the low end of fixed landings considered (75,000 and 100,000 mt) the fishing mortality rapidly declines and the probability of 100% for F being below overfishing threshold is achieved by the year 2016 or 2017. The rate of decline in F slows down and the range of possible F values for a given year increases as the amount of constant landings goes up. In some cases, the F value could not be estimated or was estimated at an extremely high value, sometimes even hitting the bound of F=25. In the scenarios with landings equaling 225,000 mt, the F value often reached a bound, but still could not produce 225,000 mt in landings indicating that the stock is unable to sustain this level of landings under the assumed stock productivity parameters (selected variability in recruitment, growth and natural mortality).

There is an overall general trend of rise in SSB (mature ova) through time, which varies from a ten fold increase of the median SSB estimate at 75,000 mt constant landings to less than a two fold increase at 225,000 mt constant annual landings.

Table P1. Constant landing projections based on the 2012 stock assessment update. The probability of the fishing mortality rate (F) being less than the THRESHOLD over time for given constant landing scenarios. Total landings are partitioned with 75% to the commercial reduction fishery and 25% to the commercial bait fishery.

Landings (1000s mt)	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
75	0	0.09	0.86	0.99	1	1	1	1	1	1
100	0	0.01	0.5	0.89	0.97	1	1	1	1	1
125	0	0	0.19	0.58	0.81	0.92	0.97	0.99	0.99	1
150	0	0	0.04	0.25	0.47	0.62	0.74	0.83	0.9	0.93
175	0	0	0.01	0.06	0.16	0.27	0.36	0.44	0.51	0.57
200	0	0	0	0.01	0.02	0.06	0.1	0.12	0.14	0.17
225	0	0	0	0	0.01	0.01	0.01	0.01	0.02	0.02

Table P2. Constant landing projections based on the 2012 stock assessment update. The

probability of the fishing mortality rate (F) being less than the TARGET over time for given constant landing scenarios. Total landings are partitioned with 75% to the commercial reduction fishery and 25% to the commercial bait fishery.

Landings (1000s mt)	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
75	0	0	0.24	0.83	0.98	1	1	1	1	1
100	0	0	0.02	0.37	0.72	0.9	0.97	0.99	1	1
125	0	0	0	0.06	0.28	0.49	0.65	0.78	0.87	0.91
150	0	0	0	0.01	0.04	0.11	0.21	0.31	0.38	0.46
175	0	0	0	0	0	0.01	0.02	0.04	0.06	0.08
200	0	0	0	0	0	0	0	0.01	0.01	0.01
225	0	0	0	0	0	0	0	0	0	0

Variability in recruitment was a major driving factor for these projections and was one of the most uncertain components of the projections. The recruitment uncertainty carried through all of the results.

The technical committee had many caveats and reservations relating to the projections. This section of the update stock assessment document (ASMFC 2012) should be reviewed carefully when considering the use of the projection information.

3.6 SUMMARY OF MONITORING PROGRAMS

In order to achieve the goals and objectives of Amendment 2, the collection and maintenance of quality data is necessary.

3.6.1 Catch and Landings Information

The reporting requirements for the Atlantic menhaden fishery are based in part on Captains Daily Fishing Reports (CDFRs). The ASMFC, NMFS, US Fish & Wildlife Service, the New England, Mid-Atlantic, and South Atlantic Fishery Management Councils, and all the Atlantic coastal states have developed a coastwide fisheries statistics program (Atlantic Coastal Cooperative Statistics Program). A minimum set of reporting requirements based on a trip-level for fishermen and dealers has been developed as the minimum standard for data collection on the Atlantic coast. Nothing in the proposed program would prohibit a state/agency from requiring more detailed information on a trip basis if so desired.

3.6.1.1 Commercial Catch and Effort Data Collection Program(s)

The ACCSP commercial data collection program is a mandatory, trip-based system with all fishermen and dealers required to report a minimum set of standard data elements (refer to the Atlantic Coast Fisheries Data Collection Standards for details).

All menhaden purse seine and bait seine vessels (or snapper rigs) shall be required to submit the Captain's Daily Fishing Reports (CDFRs) through the Standard Atlantic Fisheries Information System (eTrips), an ACCSP standards compliant electronic reporting system.

Reduction Fishery
Daily vessel unloads (in thousands of standard fish) are emailed daily to the NMFS. Captains Daily Fishing Reports (CDFRs) from the Reedville menhaden fleet are used to estimate in-season removals from Chesapeake Bay (Chesapeake Bay Cap). CDRFs are deck logbooks maintained by the Virginia reduction purse-seine vessels. Total removals by area are calculated at the end of the fishing season. At-sea catches from the CDFRs are summed by vessel, and compared to total vessel unloads from company catch records. Individual at-sea sets are then multiplied by an adjustment factor (company records/ at-sea estimates). Adjusted catches by set are converted to metric tons, and accumulated by fishing area. Catch totals are reported by ocean fishing areas (New Jersey, Delaware, and Maryland in the EEZ, Virginia and North Carolina), while catches inside and outside Chesapeake Bay are delineated by the Chesapeake Bay Bridge Tunnel.

NMFS port agent samples purse-seine catches at dockside in Reedville, VA, throughout the fishing season (May through December), providing data for age composition determination.

Bait Fishery
The current catch reporting requirements for the Atlantic menhaden fisheries do not provide timely or complete data for use by managers and scientists, particularly the bait fishery. The summary of current reporting requirements, by state, are provided in Table 15.

3.6.1.2 *Quota Monitoring*

Quota monitoring, whether coastal, or state-by-state, is dependent upon the strength of state specific monitoring programs, as described in Section 3.6.1.

Option A. Status Quo
- Utilize current monitoring systems, as described in *Section 3.6.1.1.,* in existence, no additional requirements.
- Does not improve timeliness or completeness of data collection.

Option B. Approved State Methodology for Monitoring
- Must be approved by the Board as a valid method for monitoring (high probability of success)
- ability to monitor fisheries landings to within 7 days of actual landing dates.

Option C. Require SAFIS dealer weekly reporting system
- Due Tuesday by midnight, available by 6am Wednesday consolidated (lag 1-10 days)
- Consistent with NE dealers reporting requirements
- Difficult to implement in states with established harvester-dependent reporting, not dealer-dependent reporting.
- Not difficult to implement in states that use ACCSP eTrips.

Option D. Require SAFIS ETrips fisherman daily reporting system

- Due by 10pm, available by 6am next day for consolidation
- Limiting factor, computer access and familiarity of fisherman

Option E. SAFIS weekly with trigger to SAFIS eTrips when approaching quota maximum (85% trigger)

- Utilize weekly system until it is projected that 85% of the quota will be attained, then require daily reporting system until close of fishery (or end of season), whichever comes first.

3.6.1.3 Recreational Catch and Effort Data Collection Program(s)

The Marine Recreational Fisheries Statistics Survey (MRFSS) contains estimated Atlantic menhaden catches from 1981-2003 and the Marine Recreational Information Program (MRIP) contains estimated Atlantic menhaden catches from 2004-2011. These catches were downloaded from http://www.st.nmfs.noaa.gov/st1/recreational/queries/index.html using the query option.

See MRFSS/MRIP online for discussion of survey methods:
http://www.st.nmfs.noaa.gov/st1/recreational/overview/overview.html#meth

3.6.1.4 For-Hire Catch/Effort Data Collection Programs

ACCSP standards allow for the use of MRIP for-hire sampling or a census system such as ACCSP's eTrips. For-hire sampling provide data by period, but eTrips can provide data within a 24-hour period.

3.6.2 Fishery-Dependent Data

3.6.2.1 Biological Data

The Beaufort Laboratory of the Southeast Fisheries Science Center (NMFS) conducts biostatistical sampling of the Atlantic menhaden reduction fishery (Smith 1991). The program began preliminary sampling in the Mid-Atlantic and Chesapeake Bay areas during 1952-1954 and has continued uninterrupted since 1955, sampling the entire range of the Atlantic menhaden purse-seine reduction fishery. Detailed descriptions of the sampling procedures and estimates gathered through the program are cited in Smith (1991).

The biostatistical data, or port samples, for length- and weight-at-age are available from 1955 through 2011, and represent one of the longest and most complete time series of fishery data sets in the nation (Table 1). The NMFS employs a full-time port agent at Reedville, VA to sample catches at dockside throughout the fishing season for age and size composition of the reduction catch.

Table 1. Number of ten fish samples from the reduction fishery landings at Reedville, VA from 2007-2011.

Year	2007	2008	2009	2010	2011

Number of ten-fish samples acquired in VA Reduction Fishery	379	277	283	327	323

Biological sampling of the Atlantic menhaden bait harvest for size was initially scrutinized by the Atlantic Menhaden Advisory Committee (AMAC; predecessor of the Atlantic Menhaden Technical Committee) in the early 1990s. Target sample sizes from the menhaden bait fisheries by state and gear were established by the AMAC in 1994 (Table 2). Table 3 presents recent bait harvest sampled by year, state and gear during 2007-2011. All age samples are processed by the NMFS Beaufort Laboratory.

Table 2. Target number of ten fish samples as established in 1994 for the bait harvest.

State	Target # of 10-fish samples
Massachusetts & Maine Combined (RI*)	37
New Jersey	50
Virginia	41
North Carolina	14
Total	142

*Bait purse-seine crews at the time were fishing in Naragansett Bay (RI), but landing catch in Swansea, MA.

Table 3. Number of ten fish samples by year, state, and gear, sampled from the bait harvest from 2007-2011.

	VA		PRFC		NJ		RI/MA		ME		Total	
Year	purse seine	pound net	purse seine	pound net	purse seine	pound net	purse seine	pound net	purse seine	pound net	Purse seine	pound net
2007	47	8	0	0	61	1	17	19	0	0	125	28
2008	37	8	0	0	73	5	12	14	16	0	138	27
2009	57	11	0	0	44	1	3	4	0	0	104	16
2010	36	12	0	3	55	0	0	7	0	0	91	22
2011	37	17	0	9	51	0	0	0	0	0	88	26

The Board may consider mandatory biological sampling requirements to meet the data needs of Atlantic menhaden stock assessments.

Option A. Status quo. Biological sampling requirements are not a mandatory element of the FMP.

Option B. The TC will review and recommend the targeted number of ten fish samples to be collected by state, and based on the TC's recommendation the Board may select specific biological monitoring requirements for Amendment 2.

3.6.2.2 Adult Survey Index

PRFC Pound Net Index

Pound net landings collected by the Potomac River Fisheries Commission (PRFC) are used to develop a fishery-dependent index of relative abundance for adult menhaden. Pound nets are a

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stationary, and presumably nonselective, fishing gear. PRFC pound nets are set in the Potomac River adjacent Chesapeake Bay; among other fishes, they catch menhaden primarily ages-1 through -3. Other than the reduction landings, these data represent the only other available information that can be used to infer changes in relative abundance of adult menhaden along the east coast of the U.S.
The index (1976-2011) is based on annual ratios of pounds of fish landed to total pound net days fished. Raw catch and effort data are available for 1976-1980 and 1988-2011. Recently, the PRFC was able to obtain and computerize more detailed data on pound net landings and effort, which allowed index values to be calculated for 1964-1975 and 1981-1987.

The Board may consider mandatory fishery-dependent sampling requirements to meet the data needs of Atlantic menhaden stock assessments.

Option A. Status quo. Fishery-dependent sampling requirements for an adult survey index are not a mandatory element of the FMP.

Option B. Require all states that have a pound net fishery, to keep catch/effort data (i.e., pounds landed, number of nets fished, number of days fished per net) for potential development of a CPUE index of adults across the range of Atlantic menhaden. Additional biological data would be required including age and length samples to determine the selectivity of those fisheries.

3.6.3 Fishery-Independent Survey Data

3.6.3.1 *Juvenile Abundance Indices (JAI)*

Data collected from seine surveys conducted within several states along the east coast of the U.S. were used to develop indices of relative abundance for juvenile menhaden. The primary objective of these seine surveys is to measure the recruitment strength of species other than menhaden, that is, the underlying sampling protocols were designed to target juvenile striped bass, alosines, or other fishes and species complexes. Although menhaden are a bycatch species in these surveys, the seine catch-per-haul data represent the best available information for the construction of a menhaden juvenile abundance index (JAI).

The calculation of the menhaden JAI was based on data from the following state seine surveys:
The North Carolina Alosine seine survey (Program 100S) has operated continuously from 1972-present in the Albemarle Sound and surrounding estuarine areas. The survey targets juvenile alosine fishes and sampling is conducted monthly from June through October.

The Virginia striped bass seine survey was conducted from 1967-1973 and 1980-present. The survey targets juvenile striped bass following a fixed station design, with most sampling occurring monthly from July through September and occasional collections in October and November. Rivers sampled in the southern Chesapeake Bay system include the James, Mattaponi, Pamunkey, Rappahannock, and York rivers.

The Maryland striped bass seine survey targets juvenile striped bass and has operated continuously from 1959-present. Survey stations are fixed and sampled repeatedly in three rounds in July, August, and SeptemberPermanent stations within the northern Chesapeake Bay system are sampled in five regions: Choptank River, Head of Bay, Nanticoke River, Patuxent and Potomac River.

The New Jersey seine survey targets a variety of fishes and has operated continuously in the Delaware River from 1980-present. The sampling scheme has been modified over the years but the core survey area, sampling locations, and field time frame (June-November) have remained consistent. The current sampling protocol, which was established in 1998, consists of 32 fixed stations sampled twice a month from June through November within three distinct habitats: Area 1 – brackish tidal water; Area 2 – brackish to fresh tidal water; Area 3 – tidal freshwater. the juvenile index calculation, data from Area 3 were omitted due to the rare occurrences of menhaden in tidal freshwater.

The Connecticut seine survey targets juvenile alosines in the Connecticut River and has continuously operated from 1987-present. Sampling occurs monthly from July through October.

The Rhode Island seine survey targets a variety of fishes in Narragansett Bay and has operated continuously from 1988-present. A total of 18 fixed stations are sampled from June through October.

The New York seine survey targets a variety of fishes in western Long Island Sound and has operated continuously from 1984-present. Sampling occurs with a 61 m beach seine primarily from May through October within three areas: Jamaica Bay, Little Neck Bay, and Manhasset Bay.

3.6.4 Social Information

Currently there are no programs designed specifically to collect social data pertaining to the Atlantic menhaden fishery. The Atlantic Coastal Cooperative Statistics Program (ACCSP) is currently developing a comprehensive coastwide data collection program that will include social data.

3.6.5 Economic Information

Currently there are no programs designed specifically to collect economic data pertaining to the Atlantic menhaden fishery. The Atlantic Coastal Cooperative Statistics Program (ACCSP) is currently developing a comprehensive coastwide data collection program that will include economic data.

3.6.6 Observer Programs

As a condition of state and/or federal permitting, vessels are required to carry at-sea observers when requested. A minimum set of standard data elements are to be collected through the ACCSP at-sea observer program (refer to the ACCSP Program Design document for details). Specific fisheries priorities will be determined by the Discard/Release Prioritization Committee of the ACCSP.

3.7 STOCKING PROGRAM

Given the current technology, stocking of menhaden is not cost-effective and should not be considered as a management tool.

3.8 BYCATCH MONITORING PROGRAM

When the ACCSP is implemented, quantifiable data should be available to evaluate the extent of bycatch in menhaden fisheries, as well as the bycatch of menhaden in other fisheries. Independent studies of these two aspects of the bycatch question are encouraged and identified as a research need (see *Section 6.2.1*). Bycatch of menhaden in other fisheries is probably an important component of the overall bait market.

3.8.1 Measures to Reduce/Monitor Bycatch

No bycatch management or monitoring measures are implemented through this amendment. It may be possible to limit menhaden fishing in areas or by season where a significant bycatch may occur, but observer data are necessary to document areas of concern before any measures could be developed.

3.9 HABITAT MONITORING PROGRAM

Periodic review of various programs to monitor habitat and water quality would play an important role in understanding menhaden population dynamics. The following topics should be examined: nutrient loading; long-term water quality monitoring; hypoxia events; incidence of red tides *and Mycobacteriosus*; habitat modification permits; and wetlands protection.

4.0 MANAGEMENT PROGRAM IMPLEMENTATION

4.1 RECREATIONAL FISHERY MANAGEMENT MEASURES

No recreational fisheries management measures are included in this amendment. Recreational landings of Atlantic menhaden (for bait) are currently believed to be insignificant in terms of total harvest; therefore, regulation of this fishery is unnecessary at this time. The Board has the option of considering management changes to the recreational fishery through a future addendum, as detailed in Adaptive Management (*Section 4.6*).

4.2 COMMERCIAL FISHERY MANAGEMENT MEASURES

4.2.1 Total Allowable Catch (TAC)

Option A. Status quo. Harvest will not be restricted through the use of a TAC.

Option B. Harvest will be restricted through the use of a TAC. (*If selected see Sections 4.2.1.1 through 4.2.1.7*).

4.2.1.1 TAC Specification

The Atlantic Menhaden Management Board will set an annual TAC with the option of setting a constant TAC for multiple years based on the following procedure.

The Atlantic Menhaden TC will annually review the best available data including, but not limited to, commercial and recreational catch/landing statistics, current estimates of fishing mortality, stock status, survey indices, assessment modeling results, and target mortality levels. The TC will calculate quota options based on the Board selected method of setting a quota (see *Section 4.2.1.2*). The Board will set an annual TAC with the option of setting a a constant TAC for multiple years, reviewed annually.

The directed fishery for Atlantic menhaden will be closed when the Plan Development Team Chair projects the catch will exceed OPTION% of the TAC. States have the responsibility to close the Atlantic menhaden commercial fishery in their state once the quota (or a percentage thereof) has been reached.

Acknowledging that any changes selected in reporting requirements (Section 3.6.1.2) may take time to implement completely, the Board may select a lower closing percentage to account for late reports at the time of season closure.

Option A. 85%
Option B. 90%
Option C. 95%
Option D. The Board will specify annually or multi-year, a percentage of the TAC to base closures on.

4.2.1.2 TAC Setting Method

Achieving the F threshold and target will require the implementation of management measures that lower landing levels compared to recent years.

Option A: Projections from 2012 Stock Assessment Update

The constant landings scenarios in (Table 4 and Table 5; below) are based on the current overfishing status in 2011. Intuitively, lower landing levels have a higher probability of achieving the threshold, whereas higher landing levels have a lower probability of achieving the threshold. These projections assume constant landings, meaning if a specific landing level is maintained from one year to the next the probability of achieving the threshold increases. These principles also apply to the probabilities of achieving the target over a given time frame as detailed in Table 5. The projections illustrate how the F reference points may be achieved if the board chooses to adopt a TAC based on a constant landings approach.

To give these constant landing scenarios a frame of reference, the average total landings of Atlantic Menhaden over the last 3 years was 213.5 thousand metric tons.

However, given the uncertainty in the results of the stock assessement update, the Technical Committee has concluded that, although, the projection results provide information on stock response given harvest reductions, they should not be used to establish harvest limits for the fishery.

Table 4. Constant landing projections based on the 2012 stock assessment update. The probability of the fishing mortality rate (F) being less than the THRESHOLD over time for given constant landing scenarios. Total landings are partitioned with 75% to the commercial reduction fishery and 25% to the commercial bait fishery.

Landings (1000s mt)	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
75	0	0.09	0.86	0.99	1	1	1	1	1	1
100	0	0.01	0.5	0.89	0.97	1	1	1	1	1
125	0	0	0.19	0.58	0.81	0.92	0.97	0.99	0.99	1
150	0	0	0.04	0.25	0.47	0.62	0.74	0.83	0.9	0.93
175	0	0	0.01	0.06	0.16	0.27	0.36	0.44	0.51	0.57
200	0	0	0	0.01	0.02	0.06	0.1	0.12	0.14	0.17
225	0	0	0	0	0.01	0.01	0.01	0.01	0.02	0.02

Table 5. Constant landing projections based on the 2012 stock assessment update. The probability of the fishing mortality rate (F) being less than the TARGET over time for given constant landing scenarios. Total landings are partitioned with 75% to the commercial reduction fishery and 25% to the commercial bait fishery.

Landings (1000s mt)	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
75	0	0	0.24	0.83	0.98	1	1	1	1	1
100	0	0	0.02	0.37	0.72	0.9	0.97	0.99	1	1
125	0	0	0	0.06	0.28	0.49	0.65	0.78	0.87	0.91
150	0	0	0	0.01	0.04	0.11	0.21	0.31	0.38	0.46
175	0	0	0	0	0	0.01	0.02	0.04	0.06	0.08
200	0	0	0	0	0	0	0	0.01	0.01	0.01
225	0	0	0	0	0	0	0	0	0	0

Option B: Projections from 2010 Benchmark Stock Assessment

The constant landings scenarios explored (Table 6 and Table 7; below) are based on the overfishing status in 2008. Intuitively, lower landing levels have a higher probability of achieving the threshold, whereas higher landing levels have a lower probability of achieving the threshold. These projections assume constant landings, meaning if a specific landing level is maintained from one year to the next the probability of achieving the threshold increases. These principles also apply to the probabilities of achieving the target over a given time frame as detailed in Table 7. The projections illustrate how the F reference points may be achieved if the board chooses to adopt a TAC based on a constant landings approach.

To give these constant landing scenarios a frame of reference, the average total landings of Atlantic Menhaden over the last 3 years was 213.5 thousand metric tons.

The 2010 benchmark stock assessment passed peer review and was accepted for management use by the Board. The starting points for the projections outlined below were based on the population parameters estimated in the terminal year (2008) from the benchmark assessment. However, the projection analysis was not part of the peer review process.

Table 6. Constant landing projections based on the 2010 benchmark stock assessment. The probability of the fishing mortality rate (F) being less than the THRESHOLD over time for given constant landing scenarios. Total landings are partitioned with 75% to the commercial reduction fishery and 25% to the commercial bait fishery.

Landings (1000s mt)	2009	2010	2011	2012	2013	2014	2015	2016	2017
75	0	0	0	0.01	0.56	0.89	1.00	1.00	1.00
100	0	0	0	0.01	0.40	0.74	0.93	0.99	1.00
125	0	0	0	0.01	0.28	0.55	0.78	0.91	0.96
150	0	0	0	0.01	0.17	0.37	0.56	0.73	0.84
175	0	0	0	0.01	0.10	0.22	0.35	0.47	0.56
200	0	0	0	0.01	0.05	0.11	0.17	0.22	0.28
225	0	0	0	0.01	0.02	0.05	0.07	0.08	0.09

Table 7. Constant landing projections based on the 2010 benchmark stock assessment. The probability of the fishing mortality rate (F) being less than the TARGET over time for given constant landing scenarios. Total landings are partitioned with 75% to the commercial reduction fishery and 25% to the commercial bait fishery.

Landings (1000s mt)	2009	2010	2011	2012	2013	2014	2015	2016	2017
75	0	0	0	0.0	0.21	0.62	0.91	0.99	1.00
100	0	0	0	0.0	0.09	0.35	0.66	0.88	0.96
125	0	0	0	0.0	0.02	0.15	0.38	0.59	0.76
150	0	0	0	0.0	0.01	0.05	0.14	0.27	0.40
175	0	0	0	0.0	0.00	0.01	0.04	0.07	0.11
200	0	0	0	0.0	0.00	0.00	0.00	0.01	0.02
225	0	0	0	0.0	0.00	0.00	0.00	0.00	0.00

Option C. Ad-hoc approach to setting TACs.

As an alternative to using projections to set TACs, ad hoc approaches are used by several regional Fishery Management Councils for species with poor assessment data or uncertain stock assessment results. Typically, in these situations, most Councils use their landings/catch data as the only reliable means of setting harvest limits. A document entitled "Calculating Acceptable Biological Catch for Stocks that have reliable Catch Data Only" was recently published (ORCS 2011), and serves as guidance to set interim removal levels under these conditions.

To summarize the ORCS report; generally an average of the last 3-5 years of landings are used as this reflects recent history. A precautionary multiplier is then applied to decrement the average landings and set a harvest limit. Decision of the appropriate multiplier is cautiously decided based on factors such as life history, ecological function, stock status, and an understanding of exploitation. Typically this multiplier can range from 0.85 to 0.25 (**Table 8**).

Table 8. Summary of ad-hoc approaches used by Fishery Management Councils to set harvest limits in data poor situations.

Council	Species group	Multiplier	Comments
New England	Atlantic herring	1	Not OF, OF not occurring
New England	Red crab	1	Based on stock status
Carribean		0.85	Used to set ABC and ACL
New England	Groundfish	0.75	
Pacific		0.75	Used to set ABC
Pacific	Groundfish	0.5	Used to set OY
Pacific	Coastal pelagics	0.25	Used to set ABC

In the New England approach, the multiplier was chosen at 1.0 suggesting catch be maintained at current levels. The rationale was that the stock was not overfished and overfishing was not likely to be occurring. Other evidence, such as size at age, also indicated that the overall stock status was good. Further, landings were well monitored and discards of the target stock were low.

In the case of the Pacific Fishery Management Council the multiplier was set at 0.25. This number reflected the importance of herring as forage for stellar Sea Lions and other endangered mammals, the high level of exploitation, and the fact that Pacific Herring spawn in discreet and vulnerable aggregations (when they are targeted by the fishery).

It should be noted that the multiplier is never set at a value >1.0; indicating that catch should not be allowed to increase in these uncertain situations. Table 9 provides some additional decision making framework information that goes into the choice of a multiplier.

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Table 9. The method table showing possible actions for determining ABC based on different fishery impact categories and expert opinion. Taken from the workshop report of the 2nd National SSC meeting (from ORCS, 2011).

Historical Catch	Expert Judgment	Possible Action
Nil, not targeted	Inconceivable that catch could be affecting stock	Not in fishery; Ecosystem Component; SDC not required
Small	Catch is enough to warrant including stock in the fishery and tracking, but not enough to be of concern	Set ABC and ACL above historical catch; Set ACT at historical catch level. Allow increase in ACT if accompanied by cooperative research and close monitoring.
Moderate	Possible that any increase in catch could be overfishing	ABC/ACL = f(catch, vulnerability) So caps current fishery
Moderately high	Overfishing or overfished may already be occurring, but no assessment to quantify	Set provisional OFL = f(catch, vulnerability); Set ABC/ACL below OFL to begin stock rebuilding

ABC = Acceptable Biological Catch ACL = Annual Catch Limit
ACT = Annual Catch Target OFL = Overfishing Level

For Atlantic menhaden; the stock is likely experiencing overfishing given the recent changes in reference points (ASMFC 2012). Overall, Atlantic menhaden have low vulnerability given their short life history, age at spawning, rapid growth, and fecundity. However, menhaden also serve as forage for other valuable commercial and recreationally important species. While landings history data are good, some significant uncertainties remain in recruitment due to natural variability. As such **Table 10** outlines some possible options using a 3 or 5 year average of the catch, with the addition of potential multipliers to be used on those catch values. Typically Councils and their SSC's dictate the multipliers in 0.25 increments, given the other uncertainties involved.

Table 10. Estimated harvest levels (thousand MT) for a range of uncertainty correction factors.
Probability of reducing overfishing decreases moving towards a multiplier of 1.

Average	Multiplier					
	1	0.9	0.8	0.75	0.5	0.25
3-year	213.5	192.2	170.8	160.2	106.8	53.4
5-year	209.5	188.5	167.6	157.1	104.7	52.4

Option D. Projections or Ad-hoc approach
The Board will set the TAC based on the best available science (e.g., projection analysis), but if the projections are not recommended for use by the TC, the Board may set a quota based on the ad-hoc approaches used by the Regional Councils and detailed in Option D.

4.2.1.3 TAC Allocation

If a TAC management approach is selected, it may be allocated to the bait and reduction fisheries separately, or it may be allocated based on total landings (bait and reduction fisheries combined). The following allocation options A, B, and C have sub-options to be considered to further specify how the TAC should be, or should not be, sub-allocated.

OPTION A. Menhaden commercial TAC to be managed on a coastwide basis.
(if chosen, go to suboptions A)

OPTION B. Menhaden commercial TAC to be managed on a regional basis.
(if chosen, go to suboptions B)
Regions
New England Region (ME-CT)
Mid-Atlantic Region (NY-MD Coast)
Chesapeake Bay Region (VA, PRFC, MD Bay)
South Atlantic Region (NC-FL)

OPTION C. Menhaden commercial TAC to be managed on a state-by-state basis.
(if chosen, go to suboptions C)
States
ME-FL

SUBOPTIONS A: Menhaden commercial TAC to be managed on coastwide basis.

SUBOPTION A.1: Menhaden coastal commercial TAC not to be allocated by fishery.
(if chosen, TAC allocation section complete)

SUBOPTION A.2: Menhaden coastal commercial TAC to be allocated by fishery; bait and reduction.
(if chosen, go to suboptions A.2)

SUBOPTIONS A.2: Menhaden coastal commercial TAC to be allocated by fishery; bait and reduction.

Suboptions	Bait	Reduction
A.2.1: Average 3 years (2009-2011)	0.2155	0.7845
A.2.2: Average 5 years (2007-2011)	0.2194	0.7806
A.2.3: Average 7 years (2005-2011)	0.1962	0.8038
A.2.4: Highest 3 years (2005-2011)	0.2163	0.7837

These time frames are reflective of the most recent improvements to the bait fishery landing reporting systems. Since 2005, only one reduction fishery plant was in operation.

Suboptions A.2.1, A.2.2., and A.2.3. are based on the average historical landings for the time frame specified.

Suboption A.2.4 is based on an average of the highest 3 years of landings, by fishery, since 2005.

SUBOPTIONS B: Menhaden commercial TAC to be managed on a regional basis.

SUBOPTION B.1: Menhaden coastal commercial TAC not to be allocated by fishery, only by region.
(if chosen, go to suboptions B.1)

SUBOPTION B.2: Menhaden coastal commercial TAC to be allocated by fishery, and by region.
(if chosen, go to suboptions B.2)

SUBOPTIONS B.1: Menhaden coastal commercial TAC not to be allocated by fishery, only by region

Suboptions	New England (ME-CT)	Mid-Atlantic (NY-MD Coast)	Chesapeake Bay (VA, PRFC, MD-Bay)	South Atlantic (NC-FL)
B.1.1: Average 3 years (2009-2011)	1%	11%	87%	1%
B.1.2: Average 5 years (2007-2011)	2%	10%	88%	0%
B.1.3: Average 7 years (2005-2011)	1%	9%	89%	0%
B.1.4: Highest 3 years (2005-2011)	2%	11%	87%	0%

These time frames are reflective of the most recent improvements to the bait fishery landing reporting systems. Since 2005, only one reduction fishery plant was in operation in Virginia, so the Chesapeake Bay region would receive the 100% of the reduction fishery allocation.

Suboptions B.1.1, B.1.2., and B.1.3. are based on the average historical landings for the time frame specified.

Suboption B.1.4 is based on an average of the highest 3 years of landings, by fishery, since 2005.

SUBOPTIONS B.2: Menhaden coastal commercial TAC to be allocated by fishery, and then the bait portion of the quota by region (two parts)

Part 1: Fishery Suboptions	Bait	Reduction
B.2.1.1: Average 3 years (2009-2011)	0.2155	0.7845
B.2.1.2: Average 5 years (2007-2011)	0.2194	0.7806

B.2.1.3: Average 7 years (2005-2011)	0.1962	0.8038
B.2.1.4: Highest 3 years (2005-2011)	0.2163	0.7837

These time frames are reflective of the most recent improvements to the bait fishery landing reporting systems. Since 2005, only one reduction fishery plant was in operation in Virginia.

Suboptions B.2.1.1, B.2.1.2., and B.2.1.3. are based on the average historical landings for the time frame specified.

Suboption B.2.1.4 is based on an average of the highest 3 years of landings, by fishery, since 2005.

Part 2: Regional Bait Allocation Suboptions	New England (ME-CT)	Mid-Atlantic (NY-MD Coast)	Chesapeake Bay (VA, PRFC, MD-Bay)	South Atlantic (NC-FL)
B.2.2.1: Average 3 years (2009-2011)	4%	53%	41%	2%
B.2.2.2: Average 5 years (2007-2011)	7%	47%	44%	2%
B.2.2.3: Average 7 years (2005-2011)	7%	43%	49%	2%
B.2.2.4: Highest 3 years (2005-2011)	9%	45%	44%	2%

These time frames are reflective of the most recent improvements to the bait fishery landing reporting systems. Since 2005, only one reduction fishery plant was in operation in Virginia.

Suboptions B.2.2.1, B.2.2.2., and B.2.2.3. are based on the average historical landings for the time frame specified.

Suboption B.2.2.4 is based on an average of the highest 3 years of landings, by fishery, since 2005.

SUBOPTIONS C: Menhaden commercial TAC to be managed on a state-by-state basis.

SUBOPTION C.1: Menhaden coastal commercial TAC not to be allocated by fishery, only state-by-state.
(if chosen, go to suboptions C.1)

SUBOPTION C.2: Menhaden coastal commercial TAC to be allocated by fishery, and state-by-state.
(if chosen, go to suboptions C.2)

SUBOPTIONS C.1: Menhaden coastal commercial TAC not to be allocated by fishery, only state-by-state.

State-by-State Suboptions	C.1.1 Average 3 years (2009-2011)	C.1.2 Average 5 years (2007-2011)	C.1.3 Average 7 years (2005-2011)	C.1.4 Highest 3 years (2005-2011)
Maine	0.04	0.21	0.16	0.31
New Hampshire	0	0	0	0

Massachusetts	0.84	1.33	1.14	1.69
Rhode Island	0.02	0.02	0.02	0.03
Connecticut	0.02	0.02	0.04	0.08
New York	0.06	0.04	0.04	0.05
New Jersey	11.19	10.12	8.72	10.76
Delaware	0.01	0.01	0.02	0.02
Maryland	1.37	1.48	1.56	1.74
PRFC	0.62	0.81	0.86	0.88
Virginia	85.32	85.55	87.06	83.94
North Carolina	0.49	0.38	0.36	0.47
South Carolina	0	0	0	0
Georgia	0	0	0	0
Florida	0.02	0.02	0.02	0.02

These time frames are reflective of the most recent improvements to the bait fishery landing reporting systems. Since 2005, only one reduction fishery plant was in operation in Virginia.

Suboptions C.1.1, C.1.2., and C.1.3. are based on the average historical landings for the time frame specified.

Suboption C.1.4 is based on an average of the highest 3 years of landings, by fishery, since 2005.

SUBOPTIONS C.2: Menhaden coastal commercial TAC to be allocated by fishery, and then the bait portion of the quota by state (two parts).

Part 1: Fishery Suboptions	Bait	Reduction
C.2.1.1: Average 3 years (2009-2011)	0.2155	0.7845
C.2.1.2: Average 5 years (2007-2011)	0.2194	0.7806
C.2.1.3: Average 7 years (2005-2011)	0.1962	0.8038
C.2.1.4: Highest 3 years (2005-2011)	0.2163	0.7837

These time frames are reflective of the most recent improvements to the bait fishery landing reporting systems. Since 2005, only one reduction fishery plant was in operation in Virginia.

Suboptions C.2.1.1, C.2.1.2., and C.2.1.3. are based on the average historical landings for the time frame specified.

Suboption C.2.1.4 is based on an average of the highest 3 years of landings, by fishery, since 2005.

Part 2: State-by-State Bait Allocation Suboptions	C.2.2.1 Average 3years (2009-2011)	C.2.2.2 Average 5 years (2007-2011)	C.2.2.3 Average 7 years (2005-2011)	C.2.2.4 Highest 3 years (2005-2011)
Maine	0.182	0.965	0.761	1.302
New Hampshire	0	0	0	0
Massachusetts	3.885	6.119	5.485	7.037
Rhode Island	0.083	0.106	0.087	0.122
Connecticut	0.081	0.088	0.207	0.314
New York	0.257	0.202	0.191	0.216
New Jersey	51.851	46.407	42.097	44.754
Delaware	0.061	0.068	0.089	0.086

Maryland	6.359	6.781	7.550	7.244
PRFC	2.876	3.704	4.145	3.643
Virginia	31.998	33.751	37.569	33.219
North Carolina	2.283	1.736	1.732	1.961
South Carolina	0	0	0	0
Georgia	0	0	0	0
Florida	0.083	0.073	0.087	0.101

These time frames are reflective of the most recent improvements to the bait fishery landing reporting systems. Since 2005, only one reduction fishery plant was in operation in Virginia, so Virginia would receive the 100% of the reduction fishery allocation.

Suboptions C.2.2.1, C.2.2.2., and C.2.2.3. are based on the average historical landings for the time frame specified.

Suboption C.2.2.4 is based on an average of the highest 3 years of landings, by fishery, since 2005.

4.2.1.4 Quota Tranfers

The following options only apply if the Board selects individual state quotas (see *Section 4.2.1.3*)

Option A: No Transfer of individual state quotas
States may not transfer quota under this option.

Option B: Allow Transfer of Quotas
Two or more states, under mutual agreement, may transfer or combine their Atlantic menhaden quota. These transfers do not permanently affect the state-specific shares of the coastwide quota, i.e., the state-specific shares remain fixed. States have the responsibility to close the Atlantic menhaden commercial fishery in their state once the quota (or a percentage thereof) has been reached. The Executive Director or designated ASMFC staff will review all transfer requests before the quota transfer is finalized. Such agreements for state-by-state transfer of quota should be forwarded to the Board through Commission staff.

Once quota has been transferred to a state, the state receiving quota becomes responsible for any overages of transferred quota. That is, the amount over the final quota (that state's quota plus any quota transferred to that state) for a state will be deducted from the corresponding state's quota the following fishing season.

4.2.1.5 Quota Rollover

Option A: Quotas May Not Be Rolled Over
Unused quota may not be rolled over from one fishing year to the next.

Option B: Rollover of Quota
A fishery/region/state may rollover any unused quota from its allocation under *(TAC Allocation , Section 4.2.1.3)* from one fishing year to the next. This option does not specify that *transferred* quota may be rolled over nor does it prohibit rollover of *transferred* quota.

Option C: Rollover of Transferred Quota (if allowed)

A state may rollover any unused transferred quota from one fishing year to the next. That is, if a state receives transferred quota, and does not harvest its final quota (that state's quota plus any quota transferred to that state) amount, the remaining amount will be added to the corresponding states quota the following year but not subsequent years (i.e., no stock piling of quota).

Option D: Transferred Quota May Not Be Rolled Over
A state may not rollover any unused transferred quota.

Option E: Maximum 5% Quota Rollover
A fishery/region/state may roll any unused quota from its final allocation (including transferred quota) from one fishing year to the next. The maximum total rollover may not exceed 5% of a state or regional allocation for the fishing year in which the under-harvest occurred. For example if a state's final allocation is 1.5 million pounds and that state only lands 1 million pounds during the fishing season, the state may only roll 75,000 pounds (5%) into the subsequent fishing season.

4.2.1.6 Quota Payback

Option A: No Payback of Overharvest of Quota

Option B: Payback of Quota Overages (including transferred quota if applicable)
When the quota in any fishery, region or state is projected to be reached, the commercial landing, harvest and possession of Atlantic menhaden will be prohibited in state waters of that fishery, region or state until the end of the current fishing season. When the quota allocated to a fishery, region or state is exceeded in a fishing season, the amount over the allocation will be deducted from the corresponding fishery, region or state in the subsequent fishing season.

4.2.1.7 Bycatch Allowance

Option A. No bycatch allowance when the fishing season is closed.

Option B. Pound based bycatch allowance
No directed fisheries for Atlantic menhaden shall be allowed when the fishing season is closed. An incidental bycatch allowance of up to OPTION pounds of Atlantic menhaden per trip for non-directed fisheries shall be in place during a season closure. The amount of Atlantic menhaden landed by one vessel in a day, as a bycatch allowance, shall not exceed OPTION pounds (this prohibits a vessel from making multiple trips in one day to land more than the bycatch allowance). A trip shall be based on a calendar day basis.
Option 1. 1,000 pound bycatch allowance
Option 2. 2,000 pound bycatch allowance
Option 3. 5,000 pound bycatch allowance

Option C. Percent based bycatch allowance
No directed fisheries for Atlantic menhaden shall be allowed when the fishing season is closed. An incidental bycatch allowance of up to OPTION% of Atlantic menhaden relative to the total catch per trip for non-directed fisheries shall be in place during a season closure. The amount of Atlantic menhaden landed by one vessel in a day, as a bycatch allowance, shall not exceed

OPTION% of the total landings for one trip(this prohibits a vessel from making multiple trips in one day to land more than the bycatch allowance). A trip shall be based on a calendar day basis.
Option 1. 2 percent bycatch allowance
Option 2. 5 percent bycatch allowance
Option 3. 10 percent bycatch allowance

4.2.2 Atlantic Menhaden Chesapeake Bay Reduction Fishery Harvest Cap

The Board may consider changes to the Atlantic menhaden harvest cap, a current management measure that will expire in 2013. The current management language is below the list of options.

Option A: Status quo. 2013 is the final year for the Chesapeake Bay (CB) cap.
Option B: Extend the CB cap to any specified time frame (e.g., 5 years).
Option C: Adjust the CB cap as it relates to any quota management approach selected.

The annual total allowable harvest from the Chesapeake Bay by the reduction fishery is limited to no more than 109,020 metric tons (the average landings from 2001-2005). Harvest for reduction purposes shall be prohibited within the Chesapeake Bay when 100% of the cap is harvested from Chesapeake Bay. This cap is in place for the fishing seasons starting in 2011 and going through 2013. Over-harvest in any given year will be deducted from the next year's allowable harvest.

Annual Credit for Harvest Underages
The annual Chesapeake Bay harvest cap under Addendum IV is not based on a scientifically quantified harvest threshold, fishery health index, or fishery population level study. Due to data limitations, it is unknown if exceeding the 109,020 metric-ton limit will negatively affect the health of the menhaden population. The cap is designed to prevent the Chesapeake Bay reduction fishery harvest of Atlantic menhaden from expanding while the necessary scientific studies are being conducted to explore the potential for localized depletion in the Chesapeake Bay.

Assuming a cap of 109,020 metric tons had been in place over the 2001-2005 reference period, the maximum underage that would have occurred during that time period is 13,720 metric tons. The maximum rollover of unlanded fish is 13,720 metric tons. Adding that underage to the 109,020 metric ton cap results in a cap of 122,740 metric tons.

In years when annual menhaden harvest in the Chesapeake Bay for reduction purposes is below the 109,020 metric-ton cap, the underage amount shall be credited to the following year's allowable harvest. Under no circumstances can allowable harvest in any given year from 2011 through 2013 exceed 122,740 metric tons. Such credit can only be applied to the following calendar year's harvest cap and cannot be reserved for future years or spread over multiple years.

Further, if no more than the underage amount in one year is credited to the next year's allowable harvest, the annual average harvest for 2011 through 2013 cannot exceed 109,020 metric tons.

4.3 FOR-HIRE FISHERIES MANAGEMENT MEASURES

No management measures for for-hire fisheries are proposed in this amendment.

4.4 HABITAT CONSERVATION AND RESTORATION RECOMMENDATIONS

In order to ensure the productivity of populations, each state should implement identification and protection of critical nursery areas within its boundaries for estuarine dependent, marine migratory species in general and Atlantic menhaden in particular. Such efforts should inventory historical habitats, identify habitats presently used and specify those that are targeted for recovery, and impose or encourage measures to retain or increase the quantity and quality of Atlantic menhaden essential habitats.

4.4.1 Preservation of Existing Habitat

States should provide inventories and locations of critical Atlantic menhaden habitat to other state and federal regulatory agencies. Regulatory agencies should be advised of the types of threats to Atlantic menhaden populations and recommended measures that should be employed to avoid, minimize or eliminate any threat to current habitat extent or quality.

4.4.2 Habitat Restoration, Improvement and Enhancement

While Atlantic menhaden appear to be utilizing the bulk of their historic nursery areas, water quality in these areas should be maintained or improved (if impaired), to prevent hypoxic fish kills and minimize the threat of increased mortality due to disease and parasitism. Modern trends toward the protection of wetlands will protect and improve menhaden habitat.

4.4.3 Avoidance of Incompatible Activities

Federal and state fishery management agencies should take steps to limit the introduction of compounds which are known or suspected to accumulate in any animal species' tissue and which pose a threat to human health or any animals' health.

Each state should establish windows of compatibility for activities known or suspected to adversely affect Atlantic menhaden life stages and their habitats, such as navigational dredging, inlet modifications, and dredged material disposal, and notify the appropriate construction or regulatory agencies in writing.

Projects involving water withdrawal from nursery habitats (e.g. power plants, irrigation, water supply projects) should be scrutinized to ensure that adverse impacts resulting from larval/juvenile impingement, entrainment, and/or modification of flow, temperature and salinity regimes due to water removal, will not adversely impact estuarine dependent species, including Atlantic menhaden, especially early life stages.

Each state which contains Atlantic menhaden nursery areas within its jurisdiction should develop water use and flow regime guidelines which are protective of these nursery areas and which will ensure to the extent possible, the long-term health and sustainability of the stock.

4.4.4 Fishery Practices

The use of any fishing gear or practice which is documented by management agencies to have an unacceptable impact on Atlantic menhaden (e.g. habitat damage, bycatch mortality) should be prohibited within the effected essential habitats (e.g. trawling in primary nursery areas should be prohibited).

4.5 ALTERNATIVE STATE MANAGEMENT REGIMES

Once approved by the Atlantic Menhaden Management Board, states are required to obtain prior approval from the Board of any changes to their management program for which a compliance requirement is in effect. Other measures must be reported to the Board but may be implemented without prior Board approval A state can request permission to implement an alternative to any mandatory compliance measure only if that state can show to the Board's satisfaction that its alternative proposal will have the same conservation value as the measure contained in this amendment or any addenda prepared under Adaptive Management (*Section 4.6*). States submitting alternative proposals must demonstrate that the proposed action will not contribute to overfishing of the resource. All changes in state plans must be submitted in writing to the Board and to the Commission either as part of the annual FMP Review process or the Annual Compliance Reports.

4.5.1 General Procedures

A state may submit a proposal for a change to its regulatory program or any mandatory compliance measure under this amendment to the Commission, including a proposal for *de minimis* status. Such changes shall be submitted to the Chair of the Plan Review Team, who shall distribute the proposal to the Management Board, the Plan Review Team, the Technical Committee, the Stock Assessment Committee and the Advisory Panel.

The Plan Review Team is responsible for gathering the comments of the Technical Committee, the Stock Assessment Committee and the Advisory Panel, and presenting these comments as soon as possible to the Management Board for decision.

The Atlantic Menhaden Management Board will decide whether to approve the state proposal for an alternative management program if it determines that it is consistent with the target fishing mortality rate applicable, and the goals and objectives of this amendment.

In order to maintain fishing seasons similar to those currently in place, new rules should be implemented prior to the start of the fishing season and be effective on March 1 each year. Given the time for the annual assessment to be prepared and presented to the Technical Committee, Advisory Panel and the Management Board, and the time for individual states to promulgate new regulations, it may not be possible to implement new regulations for the current fishing season. Therefore new regulations should be effective at the start of the following season after a determination to do so has been made.

4.5.2 Management Program Equivalency

The Atlantic Menhaden Technical Committee (and/or Plan Review Team) will review any alternative state proposals under this section and provide to the Atlantic Menhaden Management Board its evaluation of the adequacy of such proposals.

4.5.3 *De minimis* Fishery Guidelines

Option A. Status Quo, *de minimis* criteria is not established through Amendment 2.

Option B. Define *de minimis* for States without a Reduction Fishery. If Option B is selected, the Board must select both the Criteria for *De Minimis* Consideration (*Section 4.5.3.1*) and the plan requirements if *de minimis* is granted (*Section 4.5.3.2*).

4.5.3.1 Criteria for De Minimis Consideration

A state can apply annually for *de minimis* status if a state does not have a reduction fishery.

Option 1. To be eligible for *de minimis* consideration in the bait fishery, a state must prove that its commercial bait landings in the most recent two years for which data are available did not exceed 1% of the coastwide bait landings.

Option 2. To be eligible for *de minimis* consideration in the bait fishery, a state must prove that its commercial bait landings in the most recent two years for which data are available did not exceed 2% of the coastwide bait landings.

4.5.3.2 Plan Requirements if De Minimis Status is Granted

If *de minimis* status is granted, the *de minimis* state is require to implement, at a minimum, the coastwide requirements contained in *Section 3.6* of Amendment 2. Any additional components of the FMP, which the Board determines necessary for a *de minimis* state to implement, can be defined at the time *de minimis* status is granted. For all other required components of the plan, the Board will specify by motion which measures a *de minimis* state must adopt.

Option 3: *De minimis* criteria exempts a state from biological monitoring (e.g., age data), but the state must adhere to timely quota monitoring requirements (as specified in Section 3.1) and may not exceed quota allocated. If the fishery is closed for any reason, de minimis states must close their fisheries as well.

Option 4: *De minimis* criteria exempts a state from both biological monitoring (e.g., age data), and timely quota monitoring requirements (as specified in Section 3.1), but must still submit annual landings, and may not exceed quota allocated. If the fishery is closed for any reason, *de minimis* states must close their fisheries as well.

4.5.3.3 Procedure to apply for De Minimis Status

States must specifically request *de minimis* status each year. Requests for *de minimis* status will be reviewed by the Atlantic Menhaden Plan Review Team (PRT) as part of the annual FMP review process. Requests for *de minimis* must be submitted to the ASMFC Atlantic Menhaden

FMP Coordinator as a part of the state's yearly compliance report. The request must contain the following information: all available commercial landings data for the current and 2 previous full years of data, commercial regulations for the current year, and the proposed management measures the state plans to implement for the year *de minimis* status is requested. The FMP Coordinator will then forward the information to the PRT and, if necessary, the Atlantic Menhaden Technical Committee and Stock Assessment Subcommittee.

In determining whether or not a state meets the *de minimis* criteria, the PRT will consider the information provided with the request, the most recent available coastwide landings data, any information provided by the Technical Committee and Stock Assessment Subcommittee, and projections of future landings. The PRT will make a recommendation to the Board to either accept or deny the *de minimis* request. The Board will then review the PRT recommendation and either grant or deny the *de minimis* classification.

The Board must make a specific motion to grant a state *de minimis* status. By deeming a given state *de minimis*, the Board is recognizing that: the state has a minimal Atlantic menhaden fishery; there is little risk to the health of the menhaden stock if the state does not implement the full suite of management measures; and the overall burden of implementing the complete management and monitoring requirements of the FMP outweigh the conservation benefits of implementing those measures in the particular state.

If commercial landings in a *de minimis* state exceed the *de minimis* threshold, the state will lose its *de minimis* classification, will be ineligible for *de minimis* in the following year, and will be required to implement all the commercial fishery requirements of the FMP. If the Board denies a state's *de minimis* request, the state will be required to implement all the commercial fishery requirements of the FMP. When a state rescinds or loses its *de minimis* status the Board will set a compliance date by which the state must implement the required regulations.

4.6 ADAPTIVE MANAGEMENT

4.6.1 General Procedures

The Plan Review Team will monitor the status of the fishery and the resource and report on that status to the Atlantic Menhaden Management Board annually or when directed to do so by the Management Board. The Plan Review Team will consult with the Technical Committee, the Stock Assessment Committee and the Advisory Panel, if any, in making such review and report. The report will contain recommendations concerning proposed adaptive management revisions to the management program if necessary.

The Atlantic Menhaden Management Board will review the report of the Plan Review Team, and may consult further with Technical Committee, the Stock Assessment Committee or the Advisory Panel. The Management Board may direct the PRT to prepare an addendum to make any changes it deems necessary. The addendum shall contain a schedule for the states to implement its provisions.

The Plan Review Team will prepare a draft addendum as directed by the Management Board, and shall distribute it to all states for review and comment. A public hearing will be held in any state that requests one. The Plan Review Team will also request comment from federal agencies and the public at large. After a 30-day review period, the Plan Review Team will summarize the comments and prepare a final version of the addendum for the Management Board.
The Management Board shall review the final version of the addendum prepared by the Plan Review Team, and shall also consider the public comments received and the recommendations of the Technical Committee, the Stock Assessment Committee and the Advisory Panel; and shall then decide whether to adopt or revise and adopt the addendum.

Upon adoption of an addendum implementing adaptive management by the Management Board, states shall prepare plans to carry out the addendum, and submit them to the Management Board for approval according to the schedule contained in the addendum.

4.6.2 Measures Subject to Change

The following measures are subject to change under adaptive management upon approval by the Atlantic Menhaden Management Board:

(1) Fishing seasons including season closures
(2) Trip limits
(3) Limited entry
(4) Area closures
(5) Annual specifications, including maximum sustainable yield (MSY), allowable biological catch (ABC), optimum yield (OY), internal waters processing (IWP) allocations, etc.;
(6) Overfishing definition
(7) Rebuilding targets and schedules
(8) Catch controls
(9) Effort controls
(10) Reporting requirements
(11) Gear restrictions including mesh sizes
(12) Measures to reduce or monitor bycatch
(13) Observer requirements
(14) Management areas
(15) Recommendations to the Secretaries for complementary actions in federal jurisdictions;
(16) Research or monitoring requirements
(17) Any other management measures currently included in Amendment 2.

4.7 EMERGENCY PROCEDURES

Emergency procedures may be used by the Atlantic Menhaden Management Board to require any emergency action that is not covered by or is an exception or change to any provision in Amendment 2. Procedures for implementation are addressed in the ASMFC Interstate Fisheries Management Program Charter, Section Six (c)(10) (ASMFC 2009).

4.8 MANAGEMENT INSTITUTIONS

The management institutions for Atlantic menhaden shall be subject to the provisions of the ISFMP Charter (ASMFC 2009). The following is not intended to replace any or all of the provisions of the ISFMP Charter. All committee roles and responsibilities are included in detail in the ISFMP Charter and are only summarized here.

4.8.1 Atlantic States Marine Fisheries Commission and ISFMP Policy Board

The ASMFC (Commission) and the ISFMP Policy Board are generally responsible for the oversight and management of the Commission's fisheries management activities. The Commission must approve all fishery management plans, and amendments, including this Amendment 2; and must also make all final determinations concerning state compliance or noncompliance. The ISFMP Policy Board reviews recommendations of the various Management Boards and Sections and, if it concurs, forwards them on to the Commission for action.

4.8.2 Atlantic Menhaden Management Board

The Atlantic Menhaden Management Board is hereby established under the provisions of the Commission's ISFMP Charter (Section Four [b]) and is generally responsible for carrying out all activities under this Amendment (ASMFC 2009).

4.8.3 Atlantic Menhaden Plan Development/Review Team

The Plan Development Team (PDT) and the Plan Review Team (PRT) will be composed of a small group of scientists and/or managers whose responsibility is to provide all of the technical support necessary to carry out and document the decisions of the Atlantic Menhaden Management Board. Both are chaired by an ASMFC FMP Coordinator. The Atlantic Menhaden PDT/PRT is directly responsible to the Board for providing information and documentation concerning the implementation, review, monitoring and enforcement of Amendment 2. The Atlantic Menhaden PDT/PRT shall be comprised of personnel from state and federal agencies who have scientific and management ability and knowledge of Atlantic menhaden. The PDT will be responsible for preparing all documentation necessary for the development of Amendment 2, using the best scientific information available and the most current stock assessment information. The PDT will either disband or assume inactive status upon completion of Amendment 2. Alternatively, the Board may elect to retain PDT members as members of the PRT or appoint new members. The PRT will provide annual advice concerning the implementation, review, monitoring, and enforcement of Amendment 2 once it has been adopted by the Commission.

4.8.4 Atlantic Menhaden Technical Committee

The Atlantic Menhaden Technical Committee will consist of representatives from state or federal agencies, Regional Fishery Management Councils, Commission, university or other specialized personnel with scientific and technical expertise and knowledge of the Atlantic menhaden fishery. The Board will appoint the members of the Technical Committee and may authorize additional seats as it sees fit. Its role is to act as a liaison to the individual state and federal agencies, provide information to the management process, and review and develop options concerning the management program. The Technical Committee will provide scientific and technical advice to the Management Board, PDT, and PRT in the development and monitoring of a fishery management plan or amendment.

4.8.5 Atlantic Menhaden Stock Assessment Subcommittee

The Atlantic Menhaden Stock Assessment Subcommittee shall be appointed by the Technical Committee at the request of the Management Board, and will consist of scientists with expertise in the assessment of the Atlantic menhaden population. Its role is to assess the Atlantic menhaden population and provide scientific advice concerning the implications of proposed or potential management alternatives, or to respond to other scientific questions from the Board, Technical Committee, PDT or PRT. The Stock Assessment Subcommittee will report to the Technical Committee.

4.8.6 Atlantic Menhaden Advisory Panel

The Atlantic Menhaden Advisory Panel will be established according to the Commission's Advisory Committee Charter. Members of the Advisory Panel will be citizens who represent a cross-section of commercial and recreational fishing interests and others who are concerned about Atlantic menhaden conservation and management. The Advisory Panel provides the Board with advice directly concerning the Commission's Atlantic menhaden management program.

4.8.7 Federal Agencies

4.8.7.1 Management in the Exclusive Economic Zone (EEZ)

Management of Atlantic menhaden in the EEZ is within the jurisdiction of the three Regional Fishery Management Councils under the Magnuson-Stevens Act (16 U.S.C. 1801 et seq.). In the absence of a Council Fishery Management Plan, management is the responsibility of the NMFS as mandated by the Atlantic Coastal Fishery Conservation and Management Act (16 U.S.C. 5105 et seq.)

4.8.7.2 Federal Agency Participation in the Management Process

The Commission has accorded the United States Fish and Wildlife Service (USFWS) and the NMFS voting status on the ISFMP Policy Board and the Atlantic Menhaden Management Board in accordance with the Commission's ISFMP Charter. The NMFS also participates on the Atlantic Menhaden Plan Development Team, Plan Review Team, Technical Committee and Stock Assessment Subcommittee.

4.8.7.3 Consultation with Fishery Management Councils

At the time of adoption of Amendment 2, none of the Regional Fishery Management Councils had implemented a management plan for Atlantic menhaden nor had they indicated an intent to develop a plan.

4.9 RECOMMENDATIONS TO THE SECRETARY FOR COMPLEMENTARY ACTIONS IN FEDERAL JURISDICTIONS

The Atlantic States Marine Fisheries Commission believes that the measures contained in Amendment 2 are necessary to prevent the overfishing of the Atlantic menhaden resource. If any of the above options are adopted through the addendum process, the Board should consider recommending the adopted measures to the National Marine Fisheries Service for implementation in the EEZ.

4.10 COOPERATION WITH OTHER MANAGEMENT INSTITUTIONS

The Section will cooperate, when necessary, with other management institutions during the implementation of this amendment, including the National Marine Fisheries Service and the New England, Mid-Atlantic, and South Atlantic Fishery Management Council.

5.0 COMPLIANCE

Full implementation of the provisions of this amendment is necessary for the management program to be equitable, efficient and effective. States are expected to implement these measures faithfully under state laws. Although ASMFC does not have authority to directly compel states implementation of these measures, it will continually monitor the effectiveness of state implementation and determine whether states are in compliance with the provisions of this fishery management plan. The Section sets forth specific elements that the Commission will consider in determining state compliance with this fishery management plan, and the procedures that will govern the evaluation of compliance. Additional details of the procedures are found in the ASMFC Interstate Fishery Management Program Charter (ASMFC 2009).

5.1 MANDATORY COMPLIANCE ELEMENTS FOR STATES

A state will be determined to be out of compliance with the provision of this fishery management plan according to the terms of Section 7 of the ISFMP Charter if:

- It fails to meet any schedule required by Section 5.1.2, or any addendum prepared under adaptive management (*Section 4.6*); or
- It has failed to implement a change to its program when determined necessary by the Atlantic Menhaden Management Board; or
- it makes a change to its regulations required under *Section 4* or any addendum prepared under adaptive management (*Section 4.6*), without prior approval of the Atlantic Menhaden Management Board.

5.1.1 Mandatory Elements of State Programs

To be considered in compliance with this fishery management plan, all state programs must include a regime of restrictions on Atlantic menhaden fisheries consistent with the requirements of *Sections 4.2*; except that a state may propose an alternative management program under

Section 4.5, which, if approved by the Management Board, may be implemented as an alternative regulatory requirement for compliance.

In addition, the Atlantic Menhaden Management Board (through its Technical Committee and Advisory Panel), will monitor bycatch of Atlantic menhaden in other fisheries and report excessive bycatch problems to the management authority for the fishery causing the bycatch.

5.1.1.1 *Regulatory Requirements*

States may begin to implement Amendment 2 after final approval by the Commission. Each state must submit its required Atlantic menhaden regulatory program to the Commission through the ASMFC staff for approval by the Atlantic Menhaden Management Board. During the period from submission, until the Management Board makes a decision on a state's program, a state may not adopt a less protective management program than contained in this Amendment or contained in current state law. The following lists the specific compliance criteria that a state/jurisdiction must implement in order to be in compliance with Amendment 2:

Regulatory requirements will be specified during final action by the Management Board

5.1.1.2 *Monitoring Requirements*

Monitoring requirements will be specified during final action by the Management Board

5.1.1.3 *Research Requirements*

No mandatory research requirements have been identified at this time. However, mandatory research requirements may be added in the future under Adaptive Management, *Section 4.6*.

5.1.1.4 *Law Enforcement Requirements*

All state programs must include law enforcement capabilities adequate for successfully implementing the stat's Atlantic menhaden regulations. The adequacy of a state's enforcement activity will be measured by annual report to the ASMFC Law Enforcement Committee and the PRT.

5.1.1.5 *Habitat Requirements*

There are no mandatory habitat requirements in Amendment 2. See *Section 4.4* for Habitat Recommendations.

5.1.2 Compliance Schedule

States must implement this Amendment according to the following schedule:

XXXXXXXXXXX:	Submission of state programs to implement Amendment 2 for approval by the Atlantic Menhaden Management Board. Programs must be implemented upon approval by the Management Board.
XXXXXXXXXXX:	States with approved management programs must implement Amendment 2. States may begin implementing management programs prior to this deadline if approved by the Management Board.

Reports on compliance should be submitted to the Commission by each jurisdiction annually, no later than April 1st, each year.

5.1.3 Compliance/Technical Report Content

Each state must submit to the Commission an annual report concerning its Atlantic menhaden fisheries and management program for the previous year. A standard compliance report format has been prepared and adopted by the ISFMP Policy Board. States should follow this format in completing the annual compliance report.

The report shall cover:

- the previous calendar year's fishery and management program including activity and results of monitoring, regulations that were in effect, and harvest, including estimates of non-harvest losses; and
- the planned management program for the current calendar year summarizing regulations that will be in effect and monitoring programs that will be performed, highlighting any changes from the previous year.

5.2 PROCEDURES FOR DETERMINING COMPLIANCE

Detailed procedures regarding compliance determinations are contained in the ISFMP Charter, Section Seven (ASMFC 2009).

In brief, all states are responsible for the full and effective implementation and enforcement of fishery management plans in areas subject to their jurisdiction. Written compliance reports as specified in the Plan or Amendment must be submitted annually by each state with a declared interest. Compliance with Amendment 2 will be reviewed at least annually. The Atlantic Menhaden Management Board, ISFMP Policy Board or the Commission, may request the Plan Review Team to conduct a review of plan implementation and compliance at any time.

The Atlantic Menhaden Management Board will review the written findings of the PRT within 60 days of receipt of a State's compliance report. Should the Management Board recommend to the Policy Board that a state be determined to be out of compliance, a rationale for the recommended noncompliance finding will be addressed in a report. The report will include the required measures of Amendment 2 that the state has not implemented or enforced, a statement of how failure to implement or enforce required measures jeopardizes Atlantic menhaden conservation, and the actions a state must take in order to comply with Amendment 2 requirements.

The ISFMP Policy Board will review any recommendation of noncompliance from the Atlantic Menhaden Management Board within 30 days. If it concurs in the recommendation, it shall recommend at that time to the Commission that a state be found out of compliance.

The Commission shall consider any noncompliance recommendation from the ISFMP Policy Board within 30 days. Any state that is the subject of a recommendation for a noncompliance finding is given an opportunity to present written and/or oral testimony concerning whether it should be found out of compliance. If the Commission agrees with the recommendation of the ISFMP Policy Board, it may determine that a state is not in compliance with Amendment 2, and specify the actions the state must take to come into compliance.

Any state that has been determined to be out of compliance may request that the Commission rescind its noncompliance findings, provided the state has revised its Atlantic menhaden conservation measures.

5.3 RECOMMENDED (NON-MANDATORY) MANAGMENET MEASURES

The NMFS is encouraged to at least maintain its current Atlantic menhaden sampling program. This includes the monitoring of catch and effort data, Captains Daily Fishing Reports (CDFRs), and the biostatistical sampling program.

5.4 ANALYSIS OF THE ENFORCEABILITY OF PROPOSED MEASURES

The Law Enforcement Committee will, during the implementation of this amendment, analyze the enforceability of conservation and management measures as they are proposed.

6.0 MANAGEMENT AND RESEARCH NEEDS

6.1 STOCK ASSESSMENT AND POPULATION DYNAMICS

Many of the research and modeling recommendations from the last benchmark stock assessment remain relevant for this update stock assessment. Research recommendations are broken down into two categories: data and modeling. While all recommendations are high priority, the first recommendation is the highest priority. Each category is further broken down into recommendations that can be completed in the short term and recommendations that will require long term commitment.

<u>Annual Data Collection</u>
Long term:

1. **[Highest Priority]** Develop a coastwide fishery independent index of adult abundance at age to replace or augment the existing Potomac River pound net index in the model. Possible methodologies include an air spotter survey, or an industry-based survey with scientific observers on board collecting the data. In all cases, a sound statistical design is essential (involve statisticians in the development and review of the design; some trial surveys may be necessary). **NOTE:** An industry funded feasibility study conducted in 2011 further supported the need for this work (Sulikowski et al. 2012). A subcommittee of the Menhaden Technical Committee began discussions for development of a coastwide aerial survey in 2008. At the time of this update assessment, a contract has been awarded to develop the survey design, with results expected by the end of 2012. The Technical Committee is in consensus that an index of adult abundance is the highest priority

research recommendation but recognizes that implementation of the survey will require significant levels of funding.
2. Work with industry to collect age structure data outside the range of the fishery.
3. Validate MSVPA model parameters through the development and implementation of stomach sampling program that will cover major menhaden predators along the Atlantic coast. Validation of prey preferences, size selectivity and spatial overlap is critically important to the appropriate use of MSVPA model results.

Short term:
1. Continue current level of sampling from bait fisheries, particularly in the mid-Atlantic and New England.
2. Investigate interannual maturity variability via collection of annual samples of mature fish along the Atlantic coast.
3. Recover historical tagging data from paper data sheets.
4. Continue annual sampling of menhaden from the PRFC pound net fishery to better characterize age and size structure of catch.
5. Compare age composition of PRFC catch with the age composition of the reduction bait fishery catch in Chesapeake Bay. Upon completion of comparative analysis develop most efficient and representative method of sampling for age structure.
6. Consider developing an adult index, similar to PRFC CPUE index, using MD, VA, NJ and RI pound net information.
7. Explore additional sources of information that could be used as additional indices of abundance for juvenile and adult menhaden (ichthyoplankton surveys, NEAMAP, etc.).

<u>Assessment Methodology</u>

Long term:
1. Develop a spatially-explicit model, once sufficient age-specific data on movement rates of menhaden are available.
2. Develop multispecies statistical catch-at-age model to estimate menhaden natural mortality at age.

Short term:
1. Thoroughly explore causes of retrospective pattern in model results.
2. Explore alternative treatments of the reduction and bait fleets (e.g., spatial split, alternative selectivity configurations) in the BAM to reflect latitudinal variability in menhaden biology (larger and older fish migrating farther north during summer).
3. Review underlying data and evaluate generation of JAI and PRFC indices.
4. Perform likelihood profiling analysis to guide model selection decision-making.
5. Examine the variance assumptions and weighting factors of all the likelihood components in the model.
6. Re-evaluate menhaden natural mortality-at-age and population response to changing predator populations by updating and augmenting the MSVPA (e.g., add additional predator, prey, and diet data when available).
7. Incorporate maturity-at-age variability in the assessment model.

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<u>Future Research</u>

1. Evaluate productivity of different estuaries (e.g., replicate similar methodology to Ahrenholz et al. 1987).
2. Collect age-specific data on movement rates of menhaden to develop regional abundance trends.
3. Determine selectivity of PRFC pound nets.
4. Update information on maturity, fecundity, spatial and temporal patterns of spawning and larval survivorship.
5. Investigate the effects of global climate change on distribution, movement, and behavior of menhaden.

6.2 RESEARCH NEEDS

6.2.1 Social and Economic

- A more complete examination of the industry is needed to properly analyze the potential impacts of the plan and the current amendment. Additional research needs include:
- Broad-based and detailed socioeconomic description and analysis of the structure, operations, markets, revenues and expenditures of the Atlantic menhaden fishery itself and in relation to other commercial fisheries along the Atlantic coast.
- Ground-truthing for all of the data gathered via Federal and State databases. Contradictions and inaccuracies abound, so face-to-face interviews with a randomized sample of participants in all sectors of the fishery are needed.
- Develop a bioeconomic model to study the interactions between four variables: movements of Atlantic menhaden, catchability of menhaden, days fished, and market price.
- Develop an economic-management model to determine (1) the most profitable times to fish, (2) how harvest timing effects markets, and (3) how the market effects the timing of harvesting.
- Identify significant variables driving market prices and how their dynamic interactions result in the observed intra-annual and inter-annual fluctuations in market price for Atlantic menhaden.
- Explore networks between the various fisheries that rely on menhaden as bait.

6.2.2 Habitat

- Study specific habitat requirements for all life history stages.
- Develop habitat maps for all life history stages.
- Identify migration routes of adults.
- Study the effects of large-scale climatic events and the impacts on Atlantic menhaden.

- Evaluate effects of habitat loss/degradation on Atlantic menhaden.

7.0 PROTECTED SPECIES

The PDT will update the protected species section before the completion of Amendment 2.

In the fall of 1995, Commission member states, the National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS) began discussing ways to improve implementation of the Marine Mammal Protection Act (MMPA) and the Endangered Species Act (ESA) in state waters. Historically, these policies have been only minimally implemented and enforced in state waters (0-3 miles). In November 1995, the Commission, through its Interstate Fisheries Management Program (ISFMP) Policy Board, approved amendment of its ISFMP Charter (Section Six (b)(2)) so that protected species/fishery interactions are addressed in the Commission's fisheries management planning process. Specifically, the Commission's fishery management plans will describe impacts of state fisheries on certain marine mammals and endangered species (collectively termed "protected species"), and recommend ways to minimize these impacts. The following section outlines: (1) the federal legislation which guides protection of marine mammals and sea turtles, (2) the protected species with potential fishery interactions; (3) the specific type(s) of fishery interaction; (4) population status of the affected protected species; and (5) potential impacts to Atlantic coastal state and interstate fisheries.

7.1 MARINE MAMMAL PROTECTION ACT (MMPA) REQUIREMENTS

Since its passage in 1972, one of the underlying goals of the Marine Mammal Protection Act (MMPA) has been to reduce the incidental serious injury and mortality of marine mammals permitted in the course of commercial fishing operations to insignificant levels approaching a zero mortality and serious injury rate. Under 1994 Amendments, the Act requires the National Marine Fisheries Service (NMFS) to develop and implement a take reduction plan to assist in the recovery or prevent the depletion of each strategic stock that interacts with a Category I or II fishery. Specifically, a strategic stock is defined as a stock: (1) for which the level of direct human-caused mortality exceeds the potential biological removal (PBR)[17] level; (2) which is declining and is likely to be listed under the Endangered Species Act (ESA) in the foreseeable future; or (2) which is listed as a threatened or endangered species under the ESA or as a depleted species under the MMPA. Category I and II fisheries are those that have frequent or occasional incidental mortality and serious injury of marine mammals, respectively, whereas Category III fisheries have a remote likelihood of incidental mortality and serious injury of marine mammals.

Under 1994 mandates, the MMPA also requires fishermen in Category I and II to register under the Marine Mammal Authorization Program (MMAP), the purpose of which is to provide an exception for commercial fishers from the general taking prohibitions of the MMPA. All fishermen, regardless of the category of fishery they participate in, must report all incidental injuries and mortalities caused by commercial fishing operations.

Section 101(a)(5)(E) of the MMPA requires the authorization of the incidental taking of individuals from

[17] PBR is the number of human-caused deaths per year each stock can withstand and still reach an optimum population level. This is calculated by multiplying the minimum population estimate by stock's net productivity rate by a recovery factor ranging from 0.1 for endangered species to 1.0 for healthy stocks.

marine mammal stocks listed as threatened or endangered under the ESA in the course of commercial fishing operations if it is determined that (1) incidental mortality and serious injury will have a negligible impact on the affected species or stock; (2) a recovery plan has been developed or is being developed for such species or stock under the ESA; and (3) where required under Section 118 of the MMPA, a monitoring program has been established, vessels engaged in such fisheries are registered in accordance with Section 118 of the MMPA, and a take reduction plan has been developed or is being developed for such species or stock. Currently, there are no permits that authorize takes of threatened or endangered species by any commercial fishery in the Atlantic. Permits are not required for Category III fisheries, however, any serious injury or mortality of a marine mammal must be reported.

7.2 ENDANGERED SPECIES ACT (ESA) REQUIREMENTS

The taking of endangered sea turtles and marine mammals is prohibited under Section 9 of the ESA. In addition, NMFS may issue Section 4(d) protective regulations necessary and advisable to provide for the conservation of threatened species. There are several mechanisms established in the ESA to avoid the takings prohibition in Section 9. First, a 4(d) regulation may include less stringent requirements intended to reduce incidental take and thus allow for the exemption from the taking prohibition. Section 10(a)(1)(B) of the ESA authorizes NMFS to permit, under prescribed terms and conditions, any taking otherwise prohibited by Section 9 of the ESA, if the taking is incidental to, and not the purpose of, carrying out an otherwise lawful activity. Finally, Section 7(a) requires NMFS to consult with each federal agency to ensure that any action that is authorized, funded, or carried out by such agency is not likely to jeopardize the continued existence of any listed species. Section 7(b) authorizes incidental take of listed species after full consultation and identification of reasonable and prudent alternatives or measure to monitor and minimize such take.

7.3 PROTECTED SPECIES WITH POTENTIAL FISHERY INTERACTIONS

A number of protected species inhabit the management unit, which includes inshore and nearshore waters, as addressed in Amendment 1 to the Fishery Management Plan for Atlantic Menhaden. Nine are classified as endangered or threatened under the ESA; the remainder are protected under provisions of the MMPA. The species found in coastal Northwest Atlantic waters are listed below.

Endangered
Right whale (*Eubalaena glacialis*)
Humpback whale (*Megaptera novaeangliae*)
Fin whale (*Balaenoptera physalus*)
Leatherback turtle (*Dermochelys coriacea*)
Kemp's ridley (*Lepidochelys kempii*)
Green sea turtle (*Chelonia mydas*)
Shortnose sturgeon (*Acipenser brevirostrum*)

Threatened
Loggerhead turtle (*Caretta caretta*)

Species Proposed for ESA Listing
Harbor porpoise (*Phocoena phocoena*)

MMPA
Includes all marine mammals above in addition to:
Minke whale (*Balaenoptera acutorostrata*)
Bottlenose dolphin (*Tursiops truncatus*)

Harbor seal	(*Phoca vitulina*)
Grey seal	(*Halichoerus grypus*)
Harp seal	(*Phoca groenlandica*)

In the Northwest Atlantic waters, protected species utilize marine habitats for purposes of feeding, reproduction, as nursery areas and as migratory corridors. For several stocks of marine mammals, including humpback whales, menhaden are an important prey species. Some species occupy the area year round while others use the region only seasonally or move intermittently nearshore, inshore and offshore. Interactions may occur whenever fishing gear and marine mammals overlap spatially and temporally.

For sea turtles, the Atlantic seaboard is considered to provide important developmental habitat for post-pelagic juveniles, as well as foraging and nesting habitat for adults. The distribution and abundance of sea turtles along the Atlantic coast is related to geographic location and seasonal variations in water temperatures. Water temperatures dictate how early northward migration begins each year and is a useful factor for assessing when turtles will be found in certain areas. Moderate to high abundances of sea turtles have been observed both offshore and nearshore when water temperatures are greater than or equal to 21^{o} C. As water temperatures decline below 11^{o} C, abundance declines markedly and turtles typically move from cold inshore waters in the late fall to move offshore to the warmer waters in the Gulf Stream, generally south of Cape Hatteras, North Carolina. Conversely, in the late spring and early summer, they migrate from the Gulf Stream waters into the sounds and embayments.

7.4 PROTECTED SPECIES INTERACTIONS WITH EXISTING FISHERIES

7.4.1 Marine Mammals

There have been marine mammal interactions in the primary fisheries that target menhaden- including the purse seine, pound net and gill net- in addition to those gear types for which menhaden is a bycatch, including trawl, haul seine, cast net, as well as the pound net and gill net already mentioned. The bycatch reports included below do not represent a complete list but rather available records. It should be noted that without an observer program for many of these fisheries, actual numbers of interactions are difficult to obtain.

7.4.1.1 Purse seine

The Gulf of Maine and U.S. mid-Atlantic menhaden purse seine fisheries are currently classified as Category III fisheries (under the MMPA). In the 2000 MMPA List of Fisheries (65 FR 24448, April 26, 2000), the Gulf of Maine menhaden purse seine fishery is listed as having no incidental bycatch of marine mammals, and the U.S. mid-Atlantic menhaden purse seine fishery is listed with reported incidental bycatch of the coastal stock of bottlenose dolphin. However, in 1999, a mid-Atlantic menhaden purse seine fisherman reported through the MMAP that a humpback whale became entangled after bumping into the net; upon release from the gear, the animal was reported as showing an inability to swim or dive and equilibrium imbalance. NMFS will be updating the List of Fisheries to include the humpback whale as a marine mammal species/stocks incidentally injured/killed in the mid-Atlantic menhaden purse seine listing.

The Atlantic purse seine fishery reported the lethal incidental take of one minke whale in 1990 (NMFS 1993); however, the target species of the purse seine (i.e. tuna or menhaden) is unknown.

Historically, Atlantic menhaden purse seine fishermen have reported an annual incidental take of one to five coastal bottlenose dolphins (NMFS 1991). This information comes from reports required under a small take exemption issued under the then Section 101(a)(4) of the MMPA. Atlantic purse seine fishermen (target species unknown) also reported the lethal take of four coastal bottlenose dolphins in 1990 (NMFS 1993). Other than the humpback whale above, however, no other marine mammal interactions have been reported by the Atlantic purse seine fishery since 1990. Yet, the proposed 1999 MMPA List of Fisheries (63 FR 42803, August 11, 1998) summarizes the results of the analysis which re-categorized the Gulf of Mexico menhaden purse seine fishery based on interactions with coastal bottlenose dolphin. In brief, an observer program conducted by Louisiana State University in 1992, 1994, and 1995 recorded nine captures of coastal bottlenose dolphin, three of which were reported as mortalities. The Gulf of Mexico menhaden purse seine was subsequently re-categorized from Category III to Category II in the final 1999 MMPA List of Fisheries (64 FR 9067, February 24, 1999) as estimated mortality, based on observer data, exceeded the combined PBR level for the three Gulf coastal stocks of bottlenose dolphins. Similar observer programs of the menhaden purse seine fisheries have been conducted in the Atlantic. From September 1978 through early 1980, approximately 40 sea days were observed for fish sampling aboard menhaden purse seine vessels fishing from Maine south to North Carolina. No marine mammals were recorded as bycatch (S. Epperly, NMFS SEFSC, pers. comm.). Additionally, observations of the Atlantic menhaden fishery between June and November 1992 observed no incidental takes of marine mammals during the at-sea sampling of 43 sets (Austin et al. 1994). However, Austin et al. (1994) recommended an extended sampling scheme for a more precise assessment of bycatch as their study only occurred for one year and the sampling size was limited. Due to the reports and based on the analogy with the Gulf of Mexico menhaden purse seine fishery, additional observations are needed of the Atlantic fishery to determine interaction levels.

7.4.1.2 Atlantic Trap Nets/Stop Seines/Pound Nets

The Gulf of Maine herring and Atlantic mackerel stop seine/weir fisheries are classified in the 2000 MMPA List of Fisheries as Category III fisheries with reported species incidentally injured/killed including the North Atlantic right, humpback and minke whale, as well as harbor porpoise, harbor seal and gray seal. The U.S. mid-Atlantic mixed species stop/seine/weir is also a Category III fishery with no documented marine mammal interactions. However, the mid-Atlantic stranding network has documented interactions between coastal bottlenose dolphin and pound nets in the mouth of Chesapeake Bay during the summer. Therefore, this fishery may be elevated from its current category III status in a future MMPA List of Fisheries.

7.4.1.3 Gillnet

In the 2000 MMPA List of Fisheries, the following gillnet fisheries are classified with the marine mammal species that have been reported incidentally injured or killed.

NMFS has documented observed takes of harbor porpoise in the menhaden gillnet fishery. There were 3 observed takes in the mid-Atlantic menhaden gillnet fishery (a component of the coastal gillnet fishery complex under the MMPA List of Fisheries) in mesh sizes of 5 inches (12.7 cm) or less during 1997 (63 FR 66464, December 2, 1998). The observed bycatch rate of harbor porpoise in the menhaden drift gillnet

Category	Gillnet fishery	Marine mammal species incidentally injured/killed
I	Northeast sink	North Atlantic right whale
		Humpback whale
		Minke whale
		Killer whale
		White-sided dolphin
		Bottlenose dolphin (offshore stock)
		Harbor porpoise
		Harbor seal
		Gray seal
		Common dolphin
		Fin whale
		Spotted dolphin
		False killer whale
		Harp seal
II	U.S. mid-Atlantic coastal	Humpback whale
		Minke whale
		Bottlenose dolphin (coastal and offshore stock)
		Harbor porpoise
III	Rhode Island, southern Massachusetts and New York Bight inshore	Humpback whale
		Bottlenose dolphin (coastal stock)
		Harbor porpoise
	Long Island Sound inshore	Humpback whale
		Bottlenose dolphin (coastal stock)
		Harbor porpoise
	Delaware Bay inshore	Humpback whale
		Bottlenose dolphin (coastal stock)
		Harbor porpoise
	Chesapeake Bay inshore	None documented
	North Carolina inshore	Bottlenose dolphin (coastal stock)

fishery is lower than in other net fisheries (see Mid-Atlantic Take Reduction Team meeting handouts[18]).

[18] Mid-Atlantic Take Reduction Team. January 14-15, 2000. Alexandria, VA. Harbor porpoise bycatch data provided by NMFS Northeast Fisheries Science Center, Woods Hole, MA.

Although takes of harbor porpoise have not been documented in the mid–Atlantic sink gillnet fishery for menhaden, NMFS observer coverage has been low in comparison to the menhaden driftnet or other mid-Atlantic coastal gillnet fisheries (see Mid-Atlantic Take Reduction Team meeting handouts).

7.4.1.4 Haul Seine
The Mid-Atlantic haul seine fishery is listed as a Category II fishery in the 2000 MMPA List of Fisheries due to interactions with coastal bottlenose dolphin and possibly harbor porpoise. NMFS has recorded one observed take of a bottlenose dolphin in this fishery in 1998 (Waring and Quintal 2000).

7.4.1.5 Trawl
The Atlantic shrimp trawl fishery is currently a Category III fishery in the 2000 MMPA List of Fisheries, although some interactions have been reported to occur with coastal bottlenose dolphin. Some states have identified a menhaden trawl fishery occurring in their states, with no bycatch of marine mammals (ASMFC, Atlantic Coastal Fisheries Characterization Database, unpubl. data). This fishery falls under the umbrella of the mid-Atlantic mixed species trawl fisheries and has no reports of marine mammal species/stocks incidentally injured/killed according to the 2000 MMPA List of Fisheries.

7.4.1.6 Cast Net
Currently, cast net is not listed in the 2000 MMPA List of Fisheries. NMFS is presently evaluating this fishery to determine whether there have been any records of marine mammal interactions. Any such information obtained will be reflected in a future MMPA List of Fisheries.

7.4.2 Sea Turtles
All sea turtles that occur in U.S. waters are listed as either endangered or threatened under the Endangered Species Act of 1973 (ESA). Five species occur along the U.S. Atlantic coast, namely, loggerhead (*Caretta caretta*), Kemp's Ridley (*Lepidochelys kempi*), green (*Chelonia mydas*), leatherback (*Dermochelys coriacea*), and hawksbill (*Eretmochelys imbricata*).

The Atlantic seaboard is considered to provide important developmental habitat for post-pelagic juveniles, as well as foraging and nesting habitat for adult sea turtles. The distribution and abundance of sea turtles along the Atlantic coast is related to geographic location and seasonal variations in water temperatures. Water temperatures dictate how early northward migration begins each year and is a useful factor for assessing when turtles will be found in certain areas. Turtle abundance in estuarine and nearshore waters is generally seasonal north of Canaveral, Florida. Sea turtles do not usually appear on the summer foraging grounds in the Gulf of Maine until June, but are found in Virginia as early as April. As water temperatures decline, turtles typically move from cold inshore waters in the late fall to move offshore to the warmer waters in the Gulf stream.

The effect water temperature has on sea turtle presence is important in assessing possible interactions with the menhaden fishery. Menhaden are also affected by water temperatures and similarily migrate north in the spring and south in the fall. Thus, the menhaden purse seine fishery exhibits a 'summer' season beginning in April off North Carolina and appearing off New England in June, and a 'fall' season beginning in early November between Cape Hatteras and Cape Fear, North Carolina.

The main gear used in the directed menhaden fishery is a small mesh purse seine, however other gear is deployed, including trawls, fixed net, gillnet, haul beach seine, pound net, and cast net. From September 1978 through early 1980, approximately 40 sea days were observed for fish sampling aboard menhaden purse seiners fishing from Maine south to North Carolina. No sea turtles were recorded as bycatch (S. Epperly, NMFS SEFSC, pers. comm.). Several states have indicated that sea turtles have been incidentally captured in menhaden fixed nets and trawls, but not for seine nets (ASMFC, Atlantic Coastal Fisheries Characterization Database, unpubl. data). An observer program for protected species has not been established for this fishery.

7.4.3 Seabirds
Like marine mammals, seabirds are vulnerable to entanglement in commercial fishing gear. The interaction has not been quantified in the Atlantic menhaden fishery, but impacts are not considered to be significant. Human activities such as coastal development, habitat degradation and destruction, and the presence of organochlorine contaminants are considered to be the major threats to some seabird populations. Endangered and threatened bird species, which include the roseate tern and piping plover, are unlikely to be impacted by the gear types employed in the menhaden fishery.

7.5 POPULATION STATUS REVIEW OF RELEVANT PROTECTED SPECIES

7.5.1 Marine Mammals
Five marine mammal species known to co-occur with or become entangled in gear used by the Atlantic menhaden fishery - namely, Atlantic right whale, humpback whale, fin whale, coastal bottlenose dolphin and harbor porpoise - are classified as strategic stocks under the MMPA. Additionally, the right, humpback and fin whales are listed as endangered, and the harbor porpoise is classified as a candidate species under the ESA. Above all, the species of greatest concern is the right whale, which is one of the most endangered species in the world, numbering only around 300 animals (Waring et al. 1999).

The status of these and other marine mammal populations inhabiting the Northwest Atlantic has been discussed in great detail in the U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments. Initial assessments were presented in Blaylock et al. (1995) and were updated in Waring et al. (1999). The report presents information on stock definition, geographic range, population size, productivity rates, PBR, fishery specific mortality estimates, and compares the PBR to estimated human-caused mortality for each stock.

7.5.2 Sea Turtles
All sea turtles that occur in U.S. waters are listed as either endangered or threatened under the ESA. Five species occur along the U.S. Atlantic coast, namely, loggerhead (*Caretta caretta*), Kemp's Ridley (*Lepidochelys kempii*), green (*Chelonia mydas*), leatherback (*Dermochelys coriacea*), and hawksbill (*Eretmochelys imbricata*).

7.5.2.1 Biological Synopsis: Loggerhead Sea Turtle
The threatened loggerhead turtle is the most abundant species of sea turtle in U.S. waters, commonly occurring throughout the inner continental shelf from Florida through Cape Cod, Massachusetts. This species is found in a wide range of habitats throughout the temperate and tropical regions of the globe. These include open ocean, continental shelves, bays, lagoons, and estuaries (NMFS and USFWS 1995). The activity of the loggerhead is limited by temperature. Keinath *et al*. (1987) observed sea turtle emigration from the Chesapeake Bay when water temperatures cooled to below 18º C, generally in November. Sea turtles emigrate from the estuarine rivers, coastal bays and sounds when water temperatures cool to below 18º C (Keinath *et al*. 1987) and conversely immigrate when temperatures warm to 20º C (Burke *et al.* 1989; Musick *et al*. 1984). Work in North Carolina showed a significant movement of sea turtles into more northern waters at 11º C (Chester *et al.* 1994). Scientists studying

movements of turtles in New York waters have seen loggerheads remain in that area for extended periods at temperatures as low as 8º C. Surveys conducted offshore and sea turtle strandings during November and December off North Carolina suggest that sea turtles emigrating from northern waters in fall and winter months may concentrate in nearshore and southerly areas influenced by warmer Gulf stream waters (Epperly et al. 1995). This is supported by the collected work of Morreale and Standora (1998) who tracked 12 loggerheads and 3 Kemp's ridleys by satellite. All of the turtles tracked similar spatial and temporal corridors, migrating south from Long Island Sound, NY, in a time period of October through December. The turtles traveled within a narrow band along the continental shelf and became sedentary for one to two months south of Cape Hatteras. Some of the turtles lingered between Cape Lookout Shoals and Frying Pan Shoals offshore of Wilmington, NC prior to moving south or into the Gulf Stream.

Since they are limited by water temperatures, sea turtles do not usually appear on the summer foraging grounds in the Gulf of Maine until June, but are found in Virginia as early as April. They remain in these areas until as late as November and December in some cases, but the large majority are leaving the Gulf of Maine by mid-September. Aerial surveys of loggerhead turtles at sea north of Cape Hatteras indicate that they are most common in waters from 22 to 49 m deep, although they range from the beach to waters beyond the continental shelf (Shoop and Kenney 1992). There is no information regarding the activity of these offshore turtles.

Loggerhead sea turtles are primarily benthic feeders, opportunistically foraging on crustaceans and mollusks. Under certain conditions they also feed on finfish, particularly if they are easy to catch (*e.g.,* caught in gillnets or inside pound nets where the fish are accessible to turtles).

During 1996, a Turtle Expert Working Group (TEWG) met on several occasions and produced a report assessing the status of the loggerhead sea turtle population in the Western North Atlantic (WNA). Of significance is the conclusion that in the WNA, there are at least 4 loggerhead subpopulations separated at the nesting beach (TEWG 1998). This finding was based on analysis of mitochondrial DNA, which the turtle inherits from its mother. It is theorized that nesting assemblages represent distinct genetic entities, but further research is necessary to address the stock definition question. These nesting subpopulations include the following areas: northern North Carolina to northeast Florida, south Florida, the Florida Panhandle, and the Yucatan Peninsula. Genetic evidence has shown that loggerheads from Chesapeake Bay southward to Georgia are nearly equally divided in origin between South Florida and northern subpopulations. Work is currently ongoing in the Northwestern North Atlantic to collect samples which will provide information relative to turtles north of the Chesapeake, which is most of the action area for this consultation.

The loggerhead turtle was listed as threatened under the ESA on July 28, 1978, but is considered endangered by the World Conservation Union (IUCN) and under the Convention on International Trade in Endangered Species of Flora and Fauna (CITES). The significance of the results of the TEWG analysis is that the northern subpopulation may be experiencing a significant decline (2.5 percent - 3.2 percent for various beaches). A recovery goal of 12,800 nests has been assumed for the Northern Subpopulation, but current nests number around 6,200 (TEWG 1998). Since the number of nests declined in the 1980's, the TEWG concluded that it is unlikely that this subpopulation will reach this goal given current stresses on population performance. Considering this apparent decline and the current lack of information on the stock definition of the northern subpopulation, a conservative approach must be implemented and adverse effects from fisheries minimized as a priority for recovery.

The most recent 5-year ESA sea turtle status review (NMFS and USFWS 1995) reiterates the difficulty of obtaining detailed information on sea turtle population sizes and trends. Most long-term data is from the nesting beaches, and this is often complicated by the fact that they occupy extensive areas outside U.S.

waters. The TEWG was unable to determine acceptable levels of mortality. This status review supports the conclusion of the TEWG that the northern subpopulation may be experiencing a decline and that inadequate information is available to assess whether its status has changed since the initial listing as threatened in 1978. The current recommendation from the 5-year review is to retain the threatened designation but note that further study is needed before the next status review is conducted.

7.5.2.2 Biological Synopsis: Leatherback Sea Turtle

The leatherback is the largest living turtle and ranges farther than any other sea turtle species, exhibiting broad thermal tolerances (NMFS and USFWS 1995). Leatherback turtles are often found in association with jellyfish. The turtles feed primarily on the Cnidarians (medusae, siphonophores) and tunicates (salps, pyrosomas). These turtles are found throughout the action area of this consultation and, while predominantly pelagic, they occur annually in places such as Cape Cod Bay and Narragansett Bay during certain times of the year, particularly the Fall. Of the turtle species common to the action area, leatherback turtles seem to be the most susceptible to entanglement in pot gear and pelagic trawl gear. The susceptibility to entanglement in pot gear may be the result of attraction to gelatinous organisms and algae that collect on buoys and buoy lines at or near the surface.

Nest counts are the only reliable population information available for leatherback turtles. Recent declines have been seen in the number of leatherbacks nesting worldwide (NMFS and USFWS 1995). The status review notes that it is unclear whether this observation is due to natural fluctuations or whether the population is at serious risk. With regard to repercussions of these observations for the U.S. leatherback populations in general, it is unknown whether they are stable, increasing, or declining, but it is certain that some nesting populations (*e.g.*, St. John and St. Thomas, U.S. Virgin Islands) have been extirpated.

7.5.2.3 Biological Synopsis: Kemp's Ridley Sea Turtle

The Kemp's ridley is the most endangered of the world's sea turtle species. The only major nesting site for ridleys is a single stretch of beach near Rancho Nuevo, Tamaulipas, Mexico (Carr 1963). Estimates on the adult population reached a low of 1,050 in 1985, and increased to 3,000 individuals in 1997. First-time nesting adults increased from 6 percent to 28 percent from 1981 to 1989, and from 23 percent to 41 percent from 1990 to 1994, indicating that the ridley population may be in the early stages of exponential growth (TEWG 1998).

Juvenile Kemp's ridleys use northeastern and mid-Atlantic coastal waters of the U.S. Atlantic coastline as primary developmental habitat during summer months, with shallow coastal embayments serving as important foraging grounds. Post-pelagic ridleys feed primarily on crabs, consuming a variety of species, including *Callinectes* sp., *Ovalipes* sp., *Libinia* sp., and *Cancer* sp. Mollusks, shrimp, and fish are consumed less frequently (Bjorndal 1997). Juvenile ridleys migrate south as water temperatures cool in fall, and are predominantly found in shallow coastal embayments along the Gulf Coast during fall and winter months. Although the natural tendency of sea turtles is to migrate south to warmer waters, they may be susceptible to rapid drops in water temperatures in the enclosed, shallow bays of the mid-Atlatntic. In November and early December, 1999, 184 sea turtles, including 178 Kemp's ridleys, stranded along the Massachusetts coast as a result of cold-stunning.

Ridleys found in mid-Atlantic waters are primarily post-pelagic juveniles averaging 40 centimeters in carapace length, and weighing less than 20 kilograms (Terwilliger and Musick 1995). Next to loggerheads, they are the second most abundant sea turtle in Virginia and Maryland waters, arriving in these areas during May and June, and migrating to more southerly waters from September to November (Keinath *et al.* 1987; Musick and Limpus 1997). In the Chesapeake Bay, ridleys frequently forage in shallow embayments, particularly in areas supporting submerged aquatic vegetation (Lutcavage and Musick 1985; Bellmund *et al.* 1987; Keinath *et al.* 1987; Musick and Limpus 1997). The juvenile population in Chesapeake Bay is estimated to be 211 to 1,083 turtles (Musick and Limpus 1997).

Juvenile ridleys follow regular coastal routes during spring and fall migrations to and from developmental foraging grounds along the mid-Atlantic and northeastern coastlines. Consequently, many ridleys occurring in coastal waters off Virginia and Maryland are transients involved in seasonal migrations. However, Maryland's and Virginia's coastal embayments - which contain an abundance of crabs, shrimp, and other prey as well as preferred foraging habitat such as shallow subtidal flats and submerged aquatic vegetation beds - are likely used as a foraging ground by Kemp's ridley sea turtles (J. Musick, VIMS, 1998; pers. comm.; S. Epperly, NMFS SEFSC, 1998; pers. comm.; M. Lutcavage, New England Aquarium, 1998; pers. comm.). No known nesting occurs on Virginia or Maryland beaches.

7.5.2.4 Biological Synopsis: Green Sea Turtle:

Green turtles are distributed circumglobally, mainly in waters between the northern and southern 20EC isotherms (Hirth 1971). In the western Atlantic, several major nesting assemblages have been identified and studied. However, most green turtle nesting in the continental United States occurs on the Atlantic Coast of Florida. Nesting has been documented along the Gulf coast of Florida, at Southwest Florida beaches, as well as the beaches on the Florida Panhandle. On the west coast of Florida the Florida Department of Environmental Protection (FDEP) documented 35 nests in 1996, only 6 in 1997, and 45 in 1998. However, most documented green turtle nesting activity occurs on Florida index beaches, which are on the east coast and were established to standardize data collection methods and effort on key nesting beaches. The pattern of green turtle nesting shows biennial peaks in abundance, with a generally positive trend during the six years of regular monitoring since establishment of the index beaches in 1989, perhaps due to increased protective legislation throughout the Caribbean. The FDEP documented 3,061 nest in 1996, 731 in 1997, and 5,512 in 1998 on the east coast of Florida. There is evidence that green turtle nesting has been on the increase during the past decade.

While nesting activity is obviously important in determining population distributions, the remaining portion of the green turtle's life is spent on the foraging grounds. Juvenile green sea turtles occupy pelagic habitats after leaving the nesting beach. Pelagic juveniles are assumed to be omnivorous, but with a strong tendency toward carnivory during early life stages. At approximately 20 to 25 cm carapace length, juveniles leave pelagic habitats, and enter benthic foraging areas, shifting to a chiefly herbivorous diet (Bjorndal 1997). Post-pelagic green turtles feed primarily on sea grasses and benthic algae, but also consume jellyfish, salps, and sponges. Known feeding habitats along U.S. coasts of the western Atlantic include shallow lagoons and embayments in Florida, and similar shallow inshore areas elsewhere. Some of the principal feeding pastures in the western Atlantic Ocean include the upper west coast of Florida, the northwestern coast of the Yucatan Peninsula, the south coast of Cuba, the Mosquito Coast of Nicaragua, the Caribbean Coast of Panama, and scattered areas along Colombia and Brazil (Hirth 1971). The preferred food sources in these areas are *Cymodocea, Thalassia, Zostera, Sagittaria,* and *Vallisneria*.

Juvenile green turtles occur north to Long Island Sound, presumably foraging in coastal embayments. In North Carolina, green turtles are known from estuarine and oceanic waters. Recently, green turtle nesting occurred on Bald Head Island, just east of the mouth of the Cape Fear River, on Onslow Island, and on Cape Hatteras National Seashore. No information is available regarding the occurrence of green turtles in the Chesapeake Bay, although they are presumably present in very low numbers.

In the western Atlantic region, the summer developmental habitat encompasses estuarine and coastal waters as far north as Long Island Sound, Chesapeake Bay, and the North Carolina sounds, and south throughout the tropics (Musick and Limpus 1997). Most of the individuals reported in U.S. waters are immature (Thompson 1988). Individuals that use waters north of Florida during the summer must return to southern waters in autumn, or face the risk of cold stunning.

7.5.3 Sea Birds

DRAFT

No information is available at this time.

7.6 EXISTING AND PROPOSED FEDERAL REGULATIONS/ACTIONS PERTAINING TO THE RELEVANT PROTECTED SPECIES

7.7 POTENTIAL IMPACTS TO ATLANTIC COASTAL STATE AND INTERSTATE FISHERIES

The Northeast sink and Mid-Atlantic coastal gillnet fisheries are the two fisheries regulated by the Harbor Porpoise Take Reduction Plan (63 FR 66464, December 2, 1998; also refer to for defined fishery boundaries). Amongst other measures, the plan uses time area closures in combination with pingers in Northeast waters, and time area closures along with gear modifications for both small (mesh size greater than 5 inches (12.7 cm) to less than 7 inches (17.78 cm)), and large (mesh size greater than or equal to 7 inches (17.78 cm) to 18 inches (45.72 cm)) mesh gillnet in mid-Atlantic waters. Although the plan predominately impacts the dogfish and monkfish fisheries due to their higher porpoise bycatch rates, other gillnet fisheries are also affected. NMFS has documented observed takes of harbor porpoise in the mesh sizes of 5 inches or less and will be reevaluating observed data for these fisheries and stranding data to reconsider whether management measures are needed to reduce bycatch in these smaller mesh fisheries (63 FR 66464, December 2, 1998).

The Atlantic Large Whale Take Reduction Plan (64 FR 7529; February 16, 1999) addresses the incidental bycatch of large baleen whales, primarily the northern right whale and the humpback whale, in several fisheries including the Northeast sink gillnet and Mid-Atlantic coastal gillnet. Amongst other measures, the plan closes right whale critical habitat areas to specific types of fishing gear during certain seasons and modifies fishing practices. The Atlantic Large Whale Take Reduction Team continues to identify ways to reduce possible interactions between large whales and commercial gear. Upcoming rules will address additional gear marking and modification provisions to further reduce the risk of entanglement.

The Bottlenose Dolphin Take Reduction Team is scheduled to convene in January 2001 and will include representatives from Category I and II fisheries impacting the coastal bottlenose dolphin stock. Currently, the fisheries to be represented that also participate in the Atlantic menhaden fishery include the Mid-Atlantic coastal gillnet and haul seine fisheries. These participating fisheries may change depending on any fishery re-categorizations in future MMPA Lists of Fisheries.

7.8 IDENTIFICATION OF CURRENT DATA GAPS AND RESEARCH NEEDS

A lack of sea sampling data in regards to protected species interactions in the domestic Atlantic menhaden fisheries has been identified during the course of drafting this amendment. Additional observer coverage for these fisheries is needed to understand the level of interaction in the fisheries where there is no or limited data.

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The PDT will update and complete the list of references before the August Board Meeting.

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9.0 TABLES

Table 11. Comparison of Atlantic menhaden biological reference points and model produced output values.

	Reference Points		Model Produced Output Values	
	Target	**Threshold**	**2011 Estimate**	**2009-2011**
Fishing Mortality	0.62	1.34	4.50	3.07
SSB (in billions of mature ova)	19,092	9,546	13,333	16,879

Table 12. Atlantic menhaden reduction landings (1940-2011), bait landings (1985-2011) and total landings (1940-2011) in 1000s of metric tons.

Year	Reduction Fishery (1000 t)	Bait (1000 t)	Total Landings (1000 t)
1940	217.7		217.7
1941	277.9		277.9
1942	167.2		167.2
1943	237.2		237.2
1944	257.9		257.9
1945	295.9		295.9
1946	362.4		362.4
1947	378.3		378.3
1948	346.5		346.5
1949	363.8		363.8
1950	297.2		297.2
1951	361.4		361.4
1952	409.9		409.9
1953	593.2		593.2
1954	608.1		608.1
1955	641.4		641.4
1956	712.1		712.1
1957	602.8		602.8
1958	510.0		510.0
1959	659.1		659.1
1960	529.8		529.8
1961	575.9		575.9
1962	537.7		537.7
1963	346.9		346.9
1964	269.2		269.2
1965	273.4		273.4
1966	219.6		219.6
1967	193.5		193.5
1968	234.8		234.8
1969	161.6		161.6
1970	259.4		259.4
1971	250.3		250.3
1972	365.9		365.9
1973	346.9		346.9
1974	292.2		292.2
1975	250.2		250.2
1976	340.5		340.5
1977	341.1		341.1
1978	344.1		344.1
1979	375.7		375.7
1980	401.5		401.5
1981	381.3		381.3
1982	382.4		382.4
1983	418.6		418.6
1984	326.3		326.3
1985	306.7	28.3	335.0
1986	238.0	31.1	269.1
1987	327.0	34.1	361.1
1988	309.3	36.2	345.5
1989	322.0	34.8	356.8
1990	401.2	33.6	434.8
1991	381.4	39.7	421.1
1992	297.6	42.4	340.0
1993	320.6	34.9	355.5
1994	260.0	27.2	287.2
1995	339.9	30.5	370.4
1996	292.9	23.3	316.2
1997	259.1	26.9	286.0
1998	245.9	40.4	286.3
1999	171.2	37.1	208.3
2000	167.2	35.0	202.2
2001	233.7	37.4	271.1
2002	174.0	37.2	211.2
2003	166.1	35.0	201.1
2004	183.4	35.3	218.7
2005	146.9	38.2	185.1
2006	157.4	26.2	183.6
2007	174.5	44.6	219.1
2008	141.1	47.3	188.5
2009	143.8	39.0	182.8
2010	183.1	43.9	227.0
2011	174.0	54.8	228.8

Table 13. Menhaden total bait landings and bait landings by region in 1000s of metric tons, 1985-2011.

Year	New England	Mid Atlantic	Chesapeake Bay	South Atlantic	Total (ME-FL)
1985	6.2	1.8	16.4	2.3	26.7
1986	13.8	1.3	10.5	2.4	28.0
1987	13.3	1.3	13.5	2.6	30.6
1988	19.7	1.2	12.4	2.9	36.3
1989	9.5	1.6	16.5	3.4	31.0
1990	11.2	4.5	11.1	4.1	30.8
1991	14.5	8.0	10.4	3.4	36.2
1992	12.4	13.0	10.5	3.1	39.0
1993	11.6	13.4	15.7	2.1	42.8
1994	0.4	17.8	17.7	3.2	39.1
1995	4.1	17.2	19.6	1.6	42.4
1996	0.0	16.2	18.5	0.6	35.3
1997	0.1	17.6	17.1	1.7	36.5
1998	0.2	15.3	22.5	1.3	39.4
1999	0.2	12.8	21.9	1.3	36.2
2000	0.2	14.5	19.7	1.0	35.3
2001	0.1	12.2	22.7	1.4	36.3
2002	0.7	11.5	23.7	1.1	37.1
2003	0.1	8.0	24.9	0.8	33.9
2004	0.0	9.6	25.3	0.5	35.5
2005	1.0	8.2	29.0	0.7	38.8
2006	1.6	9.9	14.5	0.5	26.5
2007	2.6	17.1	22.5	0.6	42.8
2008	7.8	17.6	21.2	0.3	46.8
2009	3.7	15.0	19.3	1.0	39.0
2010	2.3	23.1	17.9	0.6	43.9
2011	0.1	33.8	18.4	1.7	54.0

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Table 14. Atlantic menhaden bait landings by state in pounds, 2005-2011.

Year	ME	NH	MA	RI	CT	NY	NJ	DE	MD	PRFC	VA	NC	SC	GA	FL
2005	30,311	273	2,177,724	14,086	30,636	216,832	17,574,826	121,351	10,441,961	4,759,545	48,797,352	1,502,455	0		36,298
2006	37,047	[redacted]	2,524,255	15,524	866,235	0	21,290,309	111,308	4,269,562	3,413,517	24,369,322	962,648	0		157,117
2007	134,687	484	5,543,805	8,948	90,254	0	37,202,485	81,546	9,060,731	5,036,906	35,587,999	1,134,167	0		71,247
2008	4,156,005	384	13,370,200	268,788	104,881	234,700	38,210,688	72,970	5,659,101	4,820,645	36,627,423	645,231	0		44,327
2009	452,355	33	6,719,048	[redacted]	173,252	226,980	32,787,777	69,476	5,667,415	3,191,905	33,614,601	2,124,733	0		52,800
2010	46,162	390	4,973,944	77,089	44,967	321,043	50,497,293	51,933	6,885,330	2,790,728	32,729,719	1,299,130	0	0	60,307
2011*	[redacted]	0	116,151	81,300	27,459	232,807	74,324,485	64,566	6,777,209	2,759,597	30,917,419	3,515,553	0		139,980

*2011 harvest is preliminary

[redacted] cells can not be reported because data are confidential

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Table 15. Summary of Reporting Requirements, compiled in 2011.

State	Summary of Reporting Requirements
ME	Mandatory dealer reporting began in 2008: trip level reporting collecting pounds and gear type. Mandatory trip level harvester reporting began in 2011: trip level reporting collecting area fished, pounds, gear, and disposition. Both are reported monthly on the 10th day of the following month. Prior to 2008 menhaden reported on voluntary basis by dealers. Some harvester reporting in 2001 and 2002 that used bait gill nets. Amount of unreported landings is marginal. Harvesters collecting bait for own lobster traps are reported as of 2011.
NH	Mandatory harvester reporting on a trip level through state logbook since the early 1980s. Coastal harvest permit requires reporting of any species captured with any gear other than hook and line. Includes area fished, pounds, gear, and disposition. State dealers are not required to report menhaden but Federally permitted dealers are. There are few state dealers dealing menhaden.
MA	Mandatory comprehensive trip-level reporting for all fishermen started in 2010. MA fishermen with federal permits report their landings to NMFS via their VTRs (weekly reporting schedule, due following the Tuesday by midnight). MA fishermen without federal permits report their landings to MA DMF (monthly reporting schedule, due 15th of the following month). Potential for live bait transfers that aren't reported, but are most likely insignificant. Mandatory comprehensive transaction-level reporting for all dealers began in 2005. All dealers purchasing directly from fishermen, whether federally permitted or not, are required to report a week's transactions by the following Tuesday at midnight.
RI	Mandatory dealer reporting through SAFIS back to 2005. There is a reporting gap between 1990 and 2005, but RI was not landing a lot of menhaden at that time. Mandatory logbook requirement for harvesters including area fished, gear, weight. Call in requirement for commercial fishing in Narragansett Bay which is in addition to the SAFIS reporting that captures any harvest landed in a different state. Commercial harvest of menhaden that is sold directly to bait shops may go unreported if the harvester does not report them in their harvester logbook.
CT	Mandatory monthly harvester logbooks of daily activity, and weekly and monthly dealer reports since 1995. These reports contain daily records of fishing and the disposition and dealer purchase activity including gear type and area fished. Logbooks are due on the 10th of the following month
NY	Mandatory VTR reporting for all commercial harvesters, reports are due monthly. Lobster bait permit holders can harvest menhaden and report pounds landed annually when they renew their lobster license. Mandatory weekly electronic dealer reporting including weight, price, area, dealer and harvester ID. Menhaden are taken for personal use in the recreational sector, but the significance of those landings is unknown.

NJ	Mandatory trip level harvester reporting: area and pounds landed reported on a monthly basis since 1989. Reported monthly by the 10th of the following month. Require "no harvest" reports - if fishermen didn't harvest anything for a month, they must still submit a monthly report. Reporting requirements are just for purse seines, and the only way that landings are reported for other gears is if they sell to a federal dealer. State dealers do not report menhaden, but the number of state dealers is small and therefore, the landings are most likely small as well. No dealer reporting requirements.
DE	Mandatory harvester reporting: trip level reporting collects pounds of fish, area fished, gear used, fishing time, trip length reported monthly since 1984.
MD	Mandatory harvester reporting daily: trip level reporting collects pounds of fish, area fished, gear used, trip date, port landed; reported monthly implemented in 2006. Prior to that it was mandatory, but on a monthly basis.
PRFC	Mandatory harvester trip level for commercial fishing reported weekly. Monthly harvester reporting began in 1964.
VA	Implemented CDFR reporting requirement for bait seine/snapper rigs in 2002. The reduction fishery landings in VA are reported via daily catch records and CDFRs to the NMFS from Amendment 1. Mandatory electronic federal dealer reported started in May 2004, this created a possible duplication of data records in Virginia. In 2007 ACCSP partnered with VA and NMFS to eliminate/reduce the possibility of duplication. All data from VA trips records are sent to ACCSP and they are merged with NMFS SAFIS records and any possible duplication is removed. ACCSP delivers a cleaned text file for offshore menhaden data sold to a federally permitted dealer that has not been reported by VA trips. This report is generated once a year in mid-May of the following year. All harvest reports are daily trip reports due monthly on the 5th of the following month since 1994. Live market is reported, but only fish that survive to be sold, so this represents an insignificant amount of unreported harvest.
NC	Mandatory commercial fishery reporting (trip ticket) dealer program since 1994. There is the potential for unreported harvest if for personal use, but it is estimated to be insignificant. Trip tickets for a given month are submitted to the NCDMF by the 10th of the following month. Recently implemented cast net survey of recreational anglers, but the data are unavailable at this time. NC requires all individuals or businesses that buy seafood in the state must have a seafood dealer's license and must buy only from licensed fishermen. These dealers are mandated to report all fish and shellfish landings per trip to the NCDMF. Each trip ticket includes the amount in units/pounds of each species landed, type of gear(s) fished, water body from which the majority of the catch was harvested, start date of the trip, date of landing, number of crew, and license numbers.

SC	Mandatory trip level dealer reporting. Separate license for bait dealers, but bait dealers are not required to report, no reason to believe they are dealing menhaden. Prior to implementation of the ACCSP trip level data reporting (September 2003), licensed wholesale dealers were required to submit monthly summaries of their seafood harvest business transactions. The only data elements we collected were species, quantity, unit price, area caught and gear used. Commercial crabbers buy menhaden from out of state.
GA	Mandatory commercial fishery dealer reporting trip ticket since 2001. The only menhaden harvested are for recreational purposes.
FL	Mandatory commercial fishery reporting (trip-ticket) began in 1984. Dealer based trip level reporting that collects both harvester and dealer ID, gear type, soak time, pounds, area fished, value. Reports are submitted monthly on the 10^{th} day of the following month.

Table 16. Summary of State Regulations for 2011

State	Met Reporting Requirement of Section 4.2.5.1	Summary of Regulations
ME	Yes	Commercial license and endorsement if gillnetting. Unlawful to fish more than 2000 feet of bait gillnet in territorial waters. Bait gillnet shall have less than 3.5 inches diamond or square stretch mesh throughout the entire net. Area pilot program with daily catch limits and vessel restrictions.
NH	Yes	State law prohibits the use of mobile gear in state waters.
MA	Yes	No specific menhaden regulations. Purse seining prohibited in some areas (mostly nearshore), and no purse seines larger than 100 fathoms may be used.

RI	Yes	Menhaden harvest by purse seine for reduction (fish meal) purposes is outlawed. No purse seines larger than 100 fathoms in length or 15 fathoms in depth may be used. Commercial gear and vessels need to be inspected and may not have a useable fish storage capacity greater than that that can hold 120,000 pounds of menhaden. Daily catch limit of 120,000 pounds per vessel when standing stock estimate reaches 3,000,000 pounds. When 50% of estimated weekly standing stock is harvested, or estimated weekly standing stock drops below a 1,500,000 pound threshold, the fishery closes until further notice. Permanent closures in specific areas.
CT	Yes	Purse seines prohibited in state waters. Menhaden can be caught by other gear and sold as bait. Personal gillnet restricted to mesh greater than 3 inches and net shall not exceed 60 feet in length.
NY	Yes	Purse seines limited to certain times/areas. Purse seine season commences on the Monday following the fourth day of July and ending on the third Friday in October.
NJ	Yes	Prohibited purse seining for reduction purposes in state waters. Mandatory reporting for purse seine (bait) fishery. Bait fishery subject to gear restrictions and closed seasons. In 2011, implemented a limited entry program for purse seine fishery. To purchase a license applicant must have purchased a license at least one year during 2002-2009 and a license in 2010. Length of vessel under permit is allowed to increase by 10% (not to exceed 90 feet) and up to 20% greater horsepower.
DE	Yes	Purse-seine fishery prohibited since 1992. No specific regulation of gillnetting for menhaden.
MD	Yes	Purse-seine fishing prohibited; menhaden harvested by pound net primarily.
PRFC	Yes	All trawling and purse nets are prohibited. In 2011, Pound net fishery which is limited entry must use at least six PRFC approved fish cull panels properly installed in each pound net to help release undersized fish.
VA	Yes	Unlawful to use any net with stretch mesh size of less than 1 3/4 inches.
NC	Yes	Combination of gear restrictions and seasonal and area closures (e.g., no purse seine fishing within 3 miles of coast of Brunswick Co. from May – October).
SC	Yes	Purse seines prohibited in state waters; requests de minimis status.
GA	Yes	State waters closed to purse seine fishing; requests de minimis status.
FL	Yes	Purse seines prohibited in state waters; primarily a cast net fishery; requests de minimis.

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10.0 FIGURES

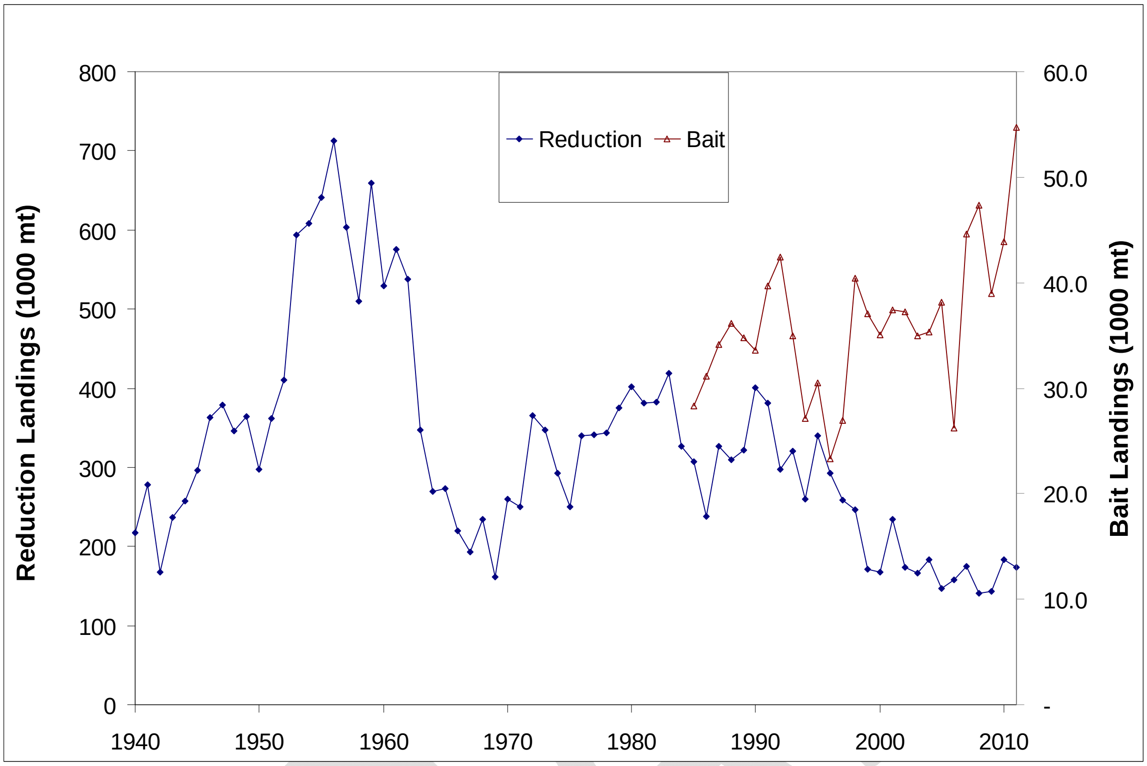

Figure 1. Atlantic menhaden reduction (1940-2011) and bait (1985-2011) landings in 1000s of metric tons. Note scale for bait landings is on right axis.

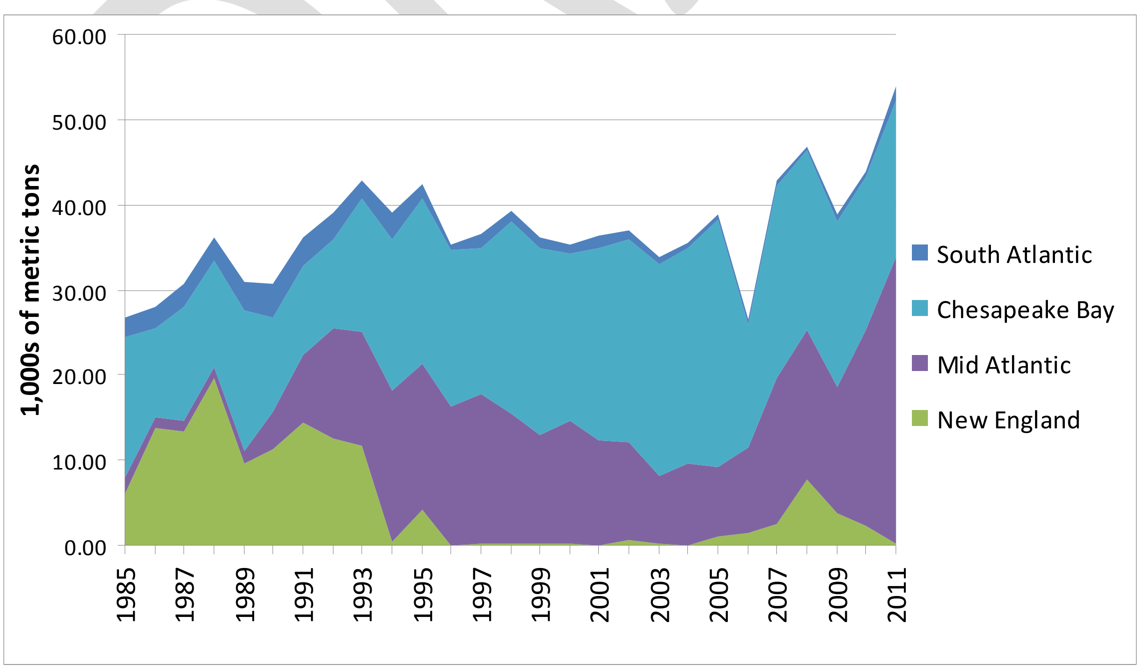

Figure 2. Atlantic menhaden bait landings by region in 100s of metric tons, 1985-2011.

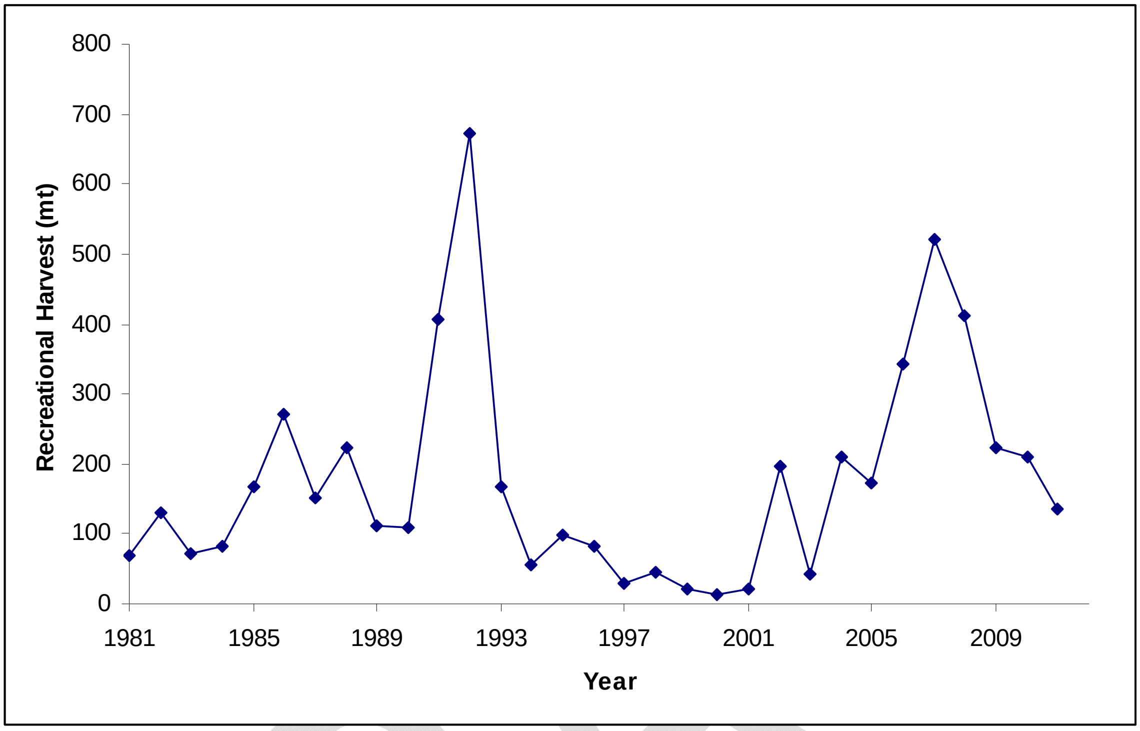

Figure 3. Atlantic Menhaden Recreational Harvest (A1+B1) from 1981-2011. Source: "Personal communication from the National Marine Fisheries Service, Fisheries Statistics Division. [July 05, 2011]

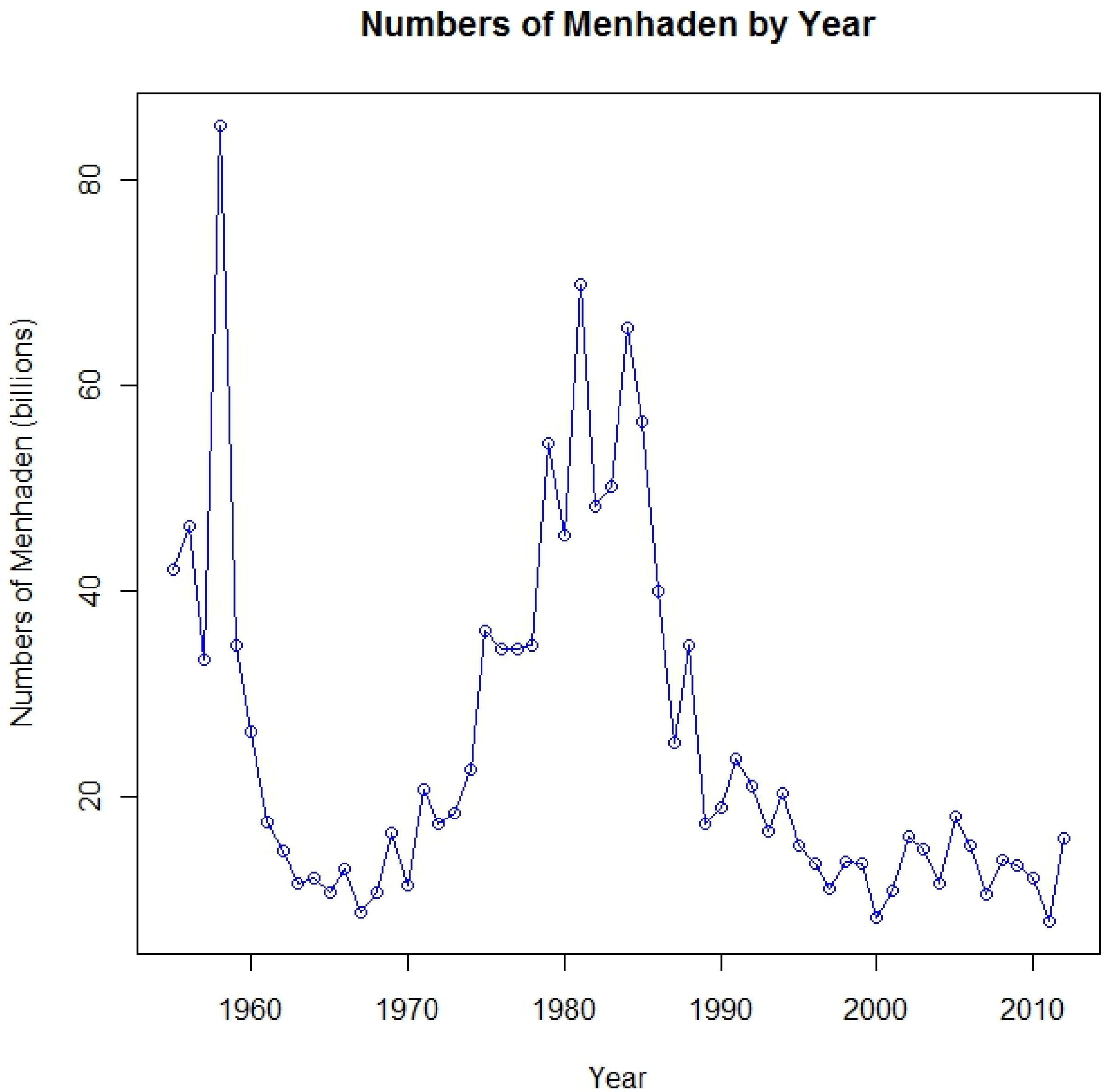

Figure 4. Estimated numbers at age of Atlantic menhaden (billions) at the start of the fishing year from the base BAM model.

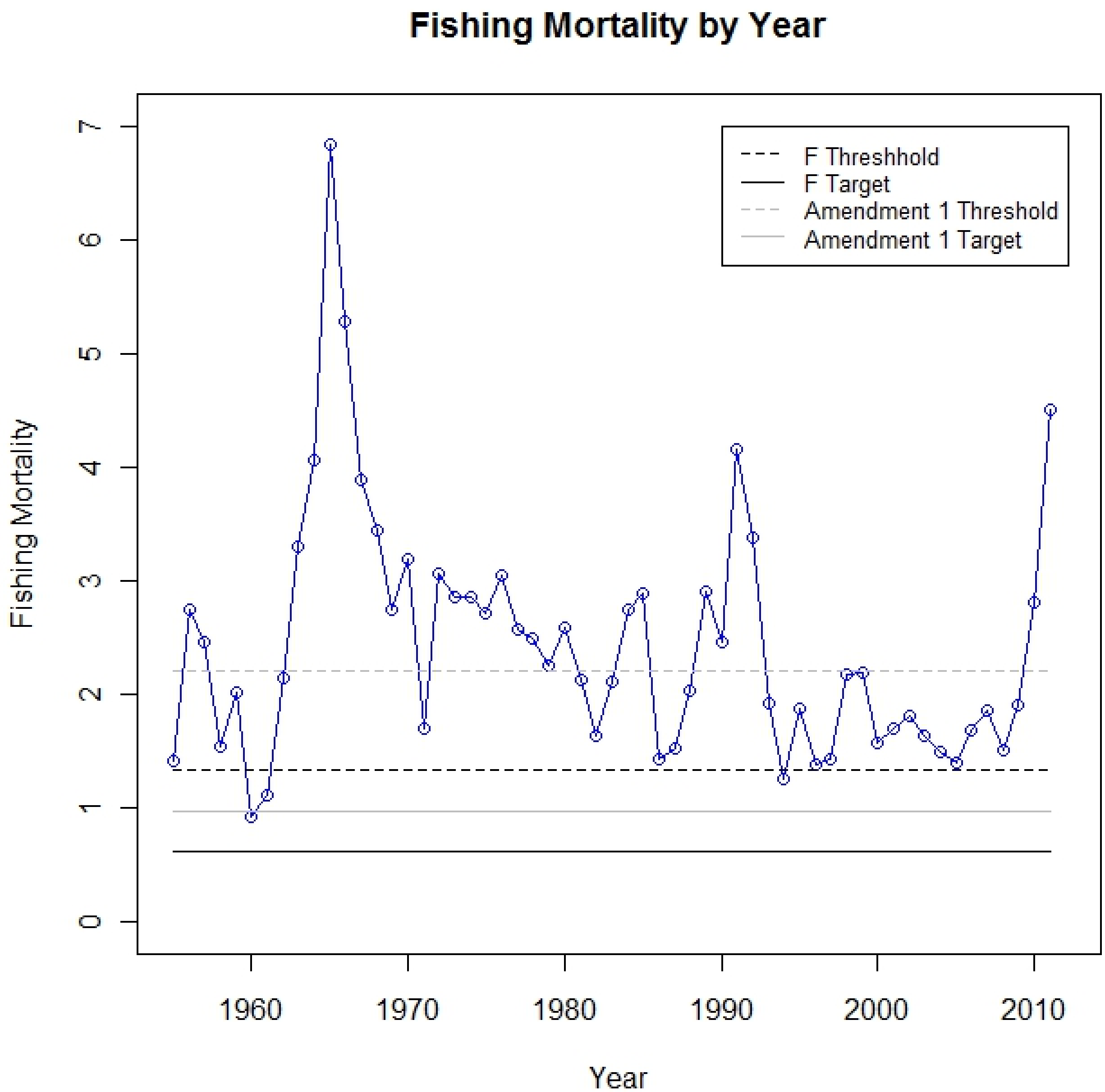

Figure 5. Estimated annual full fishing mortality rate from the base BAM model. Included are the $F_{15\%MSP}$ threshold and $F_{30\%MSP}$ target lines.

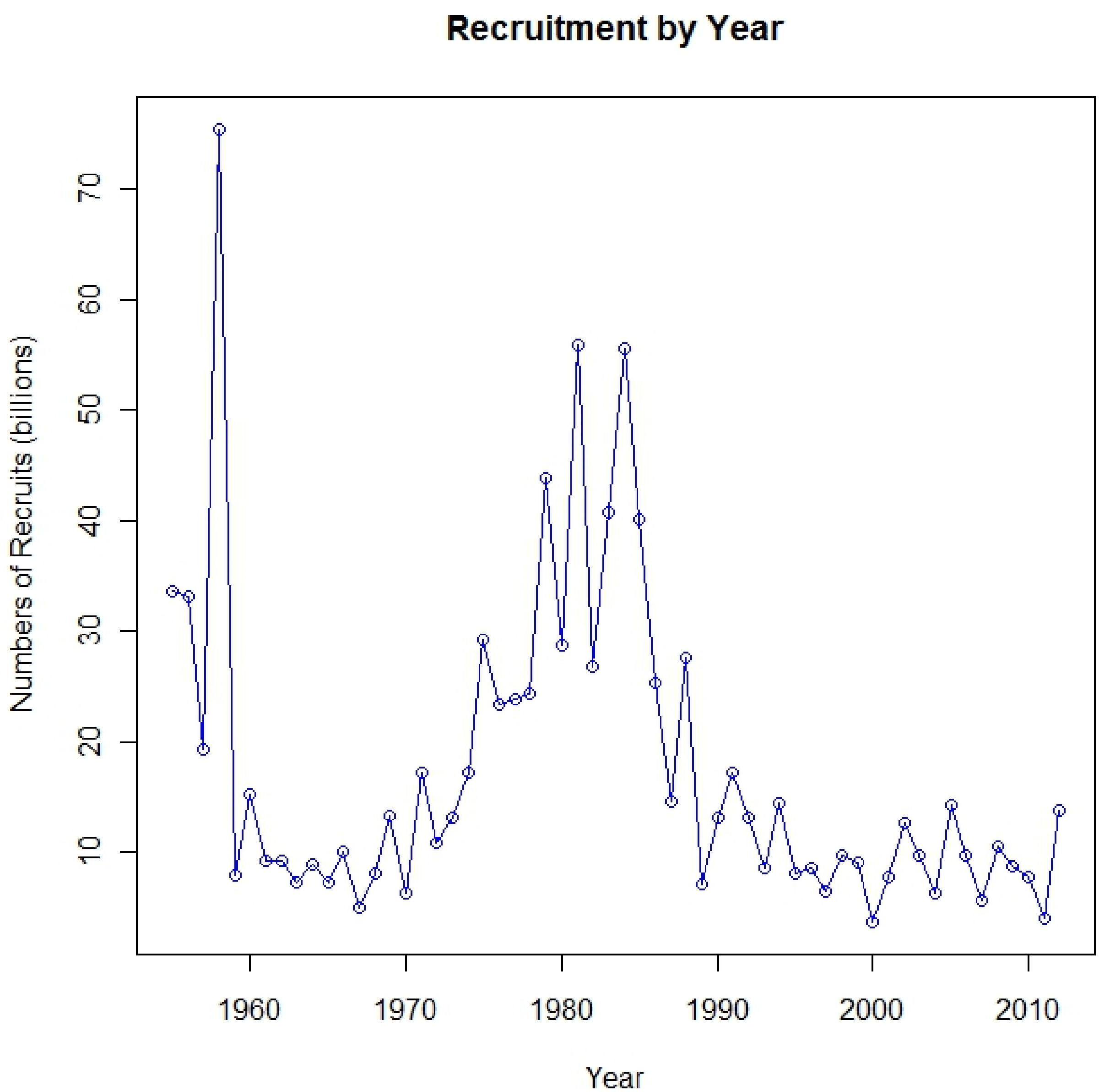

Figure 6. Estimated annual recruitment to age-0 (billions) from the base BAM model.

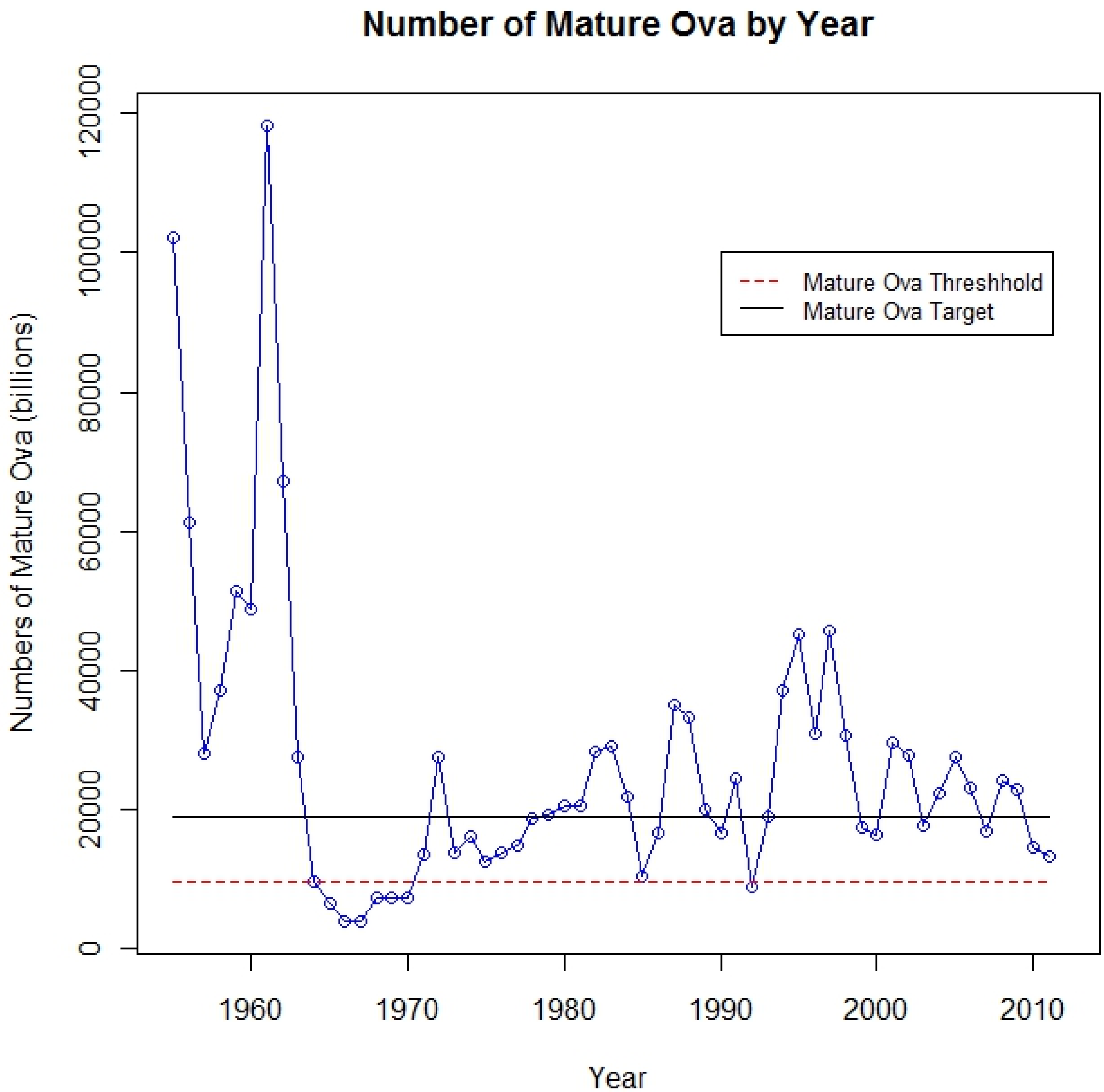

Figure 7. Estimated annual SSB (fecundity or number of mature ova) from the base BAM model. Included are the SSB_{med} threshold and SSB_{med} target lines.