Atlantic States Marine Fisheries Commission

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Douglas E. Grout (NH), Chair *James J. Gilmore, Jr., (NY), Vice-Chair* *Robert E. Beal, Executive Director*

Vision: Sustainably Managing Atlantic Coastal Fisheries

MEMORANDUM

July 20, 2016

TO: Commissioners; Proxies; American Eel Management Board; American Lobster Management Board; Atlantic Coastal Cooperative Statistics Program (ACCSP) Coordinating Council; ACCSP Executive Committee; Atlantic Menhaden Management Board; Atlantic Striped Bass Management Board: Atlantic Sturgeon Management Board; Coastal Sharks Management Board; Executive Committee; Horseshoe Crab Management Board; ISFMP Policy Board; South Atlantic State/Federal Fisheries Management Board; Tautog Management Board

FROM: Robert E. Beal
Executive Director

RE: Summer Meeting: August 2-4, 2016 (TA # 16-059)

The Atlantic States Marine Fisheries Commission's Summer Meeting will be August 2-4, 2016 at **The Westin Alexandria** (Telephone: 703.253.8600) located at 400 Courthouse Square, Alexandria, Virginia. Meeting materials are available on the Commission website at http://www.asmfc.org/home/2016-summer-meeting. Supplemental materials will be posted to the website on Wednesday, July 27, 2016. CDs containing all meeting materials will also be available at the meeting in limited quantities.

Board/Section meeting proceedings will be broadcast daily via webinar beginning at 10:15 a.m. on August 2nd and continuing daily until the conclusion of the meeting (expected to be 4:00 p.m.) on Thursday August 4th. The webinar will allow registrants to listen to board/section deliberations and view presentations and motions as they occur. No comments or questions will be accepted via the webinar. Should technical difficulties arise while streaming the broadcast, the boards/sections will continue their deliberations without interruption. We will attempt to resume the broadcast as soon as possible. Please go to https://attendee.gotowebinar.com/register/1739748828569474306 to register.

We look forward to seeing you at the Summer Meeting. If the staff or I can provide any further assistance to you, please call us at 703.842.0740.

Attachments: Final Agenda, Hotel Directions, TA#16-059, and Travel Reimbursement Guidelines

Atlantic States Marine Fisheries Commission

Summer Meeting

August 2-4, 2016

The Westin Alexandria

Alexandria, Virginia

Public Comment Guidelines

With the intent of developing policies in the Commission's procedures for public participation that result in a fair opportunity for public input, the ISFMP Policy Board has approved the following guidelines for use at management board meetings:

For issues that are not on the agenda, management boards will continue to provide opportunity to the public to bring matters of concern to the board's attention at the start of each board meeting. Board chairs will use a speaker sign-up list in deciding how to allocate the available time on the agenda (typically 10 minutes) to the number of people who want to speak.

For topics that are on the agenda, but have not gone out for public comment, board chairs will provide limited opportunity for comment, taking into account the time allotted on the agenda for the topic. Chairs will have flexibility in deciding how to allocate comment opportunities; this could include hearing one comment in favor and one in opposition until the chair is satisfied further comment will not provide additional insight to the board.

For agenda action items that have already gone out for public comment, it is the Policy Board's intent to end the occasional practice of allowing extensive and lengthy public comments. Currently, board chairs have the discretion to decide what public comment to allow in these circumstances.

In addition, the following timeline has been established for the **submission of written comment for issues for which the Commission has *NOT* established a specific public comment period** (i.e., in response to proposed management action).

1. Comments received 3 weeks prior to the start of a meeting week will be included in the briefing materials.
2. Comments received by 5:00 PM on the Tuesday immediately preceding the scheduled ASMFC Meeting (in this case, the Tuesday deadline will be ***July 26, 2016***) will be distributed electronically to Commissioners/Board members prior to the meeting and a limited number of copies will be provided at the meeting.
3. Following the Tuesday, ***July 26, 2016 5:00 PM deadline***, the commenter will be responsible for distributing the information to the management board prior to the board meeting or providing enough copies for the management board consideration at the meeting (a minimum of 50 copies).

The submitted comments must clearly indicate the commenter's expectation from the ASMFC staff regarding distribution. As with other public comment, it will be accepted via mail, fax, and email.

Final Agenda

The agenda is subject to change. The agenda reflects the current estimate of time required for scheduled Board meetings. The Commission may adjust this agenda in accordance with the actual duration of Board meetings. Interested parties should anticipate Boards starting earlier or later than indicated herein.

<u>Tuesday, August 2, 2016</u>

8:00 – 10:00 a.m. — **Executive Committee**

Breakfast to be served

(A portion of this meeting may be a closed session for Committee members and Commissioners only)

Members: Abbott, Blazer, Boyles, Bull, Chanda, Clark, Davis, Estes, Gilmore, Grout, Keliher, McNamee, Miller, Pierce, Shiels, Simpson, Woodward
Chair: Grout
Staff: Leach

1. Welcome/Call to Order *(D. Grout*)
2. Committee Consent
   - Approval of Agenda
   - Approval of Meeting Summary from May 2016
3. Public Comment
4. Discuss ASMFC Staff Lead on Assessments
5. Discuss Conservation Equivalency
6. Discuss Plan Development Team Membership White Paper
7. Discuss Commission-specific Meeting Procedures
8. Discuss Renaming the Hart Award
9. Discuss Health Benefits for Retired ASMFC Employees
10. 75th Annual Meeting Update *(L. Leach)*
11. Discuss ACCSP Governance (Closed Session)
12. Other Business/Adjourn

10:15 – 11:45 a.m. — **South Atlantic State/Federal Fisheries Management Board**

Member States: New Jersey, Delaware, Maryland, Virginia, North Carolina, South Carolina, Georgia, Florida
Other Members: PRFC, DC, NMFS, USFWS, SAFMC
Other Participants: Lynn, McDonough, Rickabaugh, Murphy, Daniel
Chair: Estes
Staff: Kerns

1. Welcome/Call to Order *(J. Estes)*
2. Board Consent
   - Approval of Agenda
   - Approval of Proceedings from May 2016
3. Public Comment

4. Discuss Commission Involvement in Cobia Management (*L. Daniel)*
   - Discuss Possible Management Scenarios
   - Recommend to the ISFMP Policy Board How the Commission Should be Involved in Cobia Management
5. Red Drum Working Group Report (*J. Kipp)*
   - Presentation of Progress on Follow Up Tasks to the Red Drum Assessment
6. Consider 2015 Fishery Management Plan Review and State Compliance for Red Drum and Atlantic Croaker (*T. Kerns*) **Action**
7. Other Business/Adjourn

12:15 – 1:45 p.m. **Tautog Management Board**

Member States: Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Delaware, Maryland, Virginia
Other Members: NMFS, USFWS
Chair: Nowalsky
Other Participants: McNamee, Snellbaker, Kasper
Staff: Harp

1. Welcome/Call to Order *(A. Nowalsky)*
2. Board Consent
   - Approval of Agenda
   - Approval of Proceedings from February 2016
3. Public Comment
4. 2016 Regional Stock Assessments for Long Island Sound (LIS) and New Jersey-New York Bight (NJ-NYB) **Action**
   - Presentation of the LIS Stock Assessment Report *(J. Kasper)*
   - Presentation of the NJ-NYB Stock Assessment Report *(J. McNamee)*
   - Presentation of the Peer Review Panel Report *(P. Campfield)*
   - Consider Acceptance of Regional Stock Assessments and Peer Review Report for Management Use
5. Consider a Specific Regional Management Approach for Draft Amendment 1 (*A. Nowalsky)* **Possible Action**
6. Update on Commercial Harvest Tagging Program *(A. Harp)*
7. Other Business/Adjourn

2:00 – 3:30 p.m. **Horseshoe Crab Management Board**

Member States: Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Delaware, Maryland, Virginia, North Carolina, South Carolina, Georgia, Florida
Other Members: PRFC, NMFS, USFWS
Chair: Gilmore
Other Participants: Doctor, Cooper, Messeck, Lyons
Staff: Rootes-Murdy

1. Welcome/Call to Order *(J. Gilmore)*
2. Board Consent
   - Approval of Agenda
   - Approval of Proceedings from May 2016
3. Public Comment
4. Review and Consider Recommendations from the Adaptive Resource Management (ARM) Subcommittee on Revisions to the ARM Framework *(J. Lyons)* **Action**
   - Technical Committee Report *(S. Doctor)*
   - Advisory Panel Report *(J. Cooper)*
5. Discuss Additional Bait Trials *(R. Ballou)* **Possible Action**
6. Other Business/Adjourn

3:45 – 4:30 p.m. **Coastal Sharks Management Board**

Member States: Maine, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Delaware, Maryland, Virginia, North Carolina, South Carolina, Georgia, Florida
Other Members: NMFS, USFWS
Chair: Nowalsky
Other Participants: Belcher, Frampton, Gillingham
Staff: Harp

1. Welcome/Call to Order *(A. Nowalsky)*
2. Board Consent
   - Approval of Agenda
   - Approval of Proceedings from May 2016
3. Public Comment
4. Draft Addendum IV for Final Approval **Final Action**
   - Review Options (*A. Harp*)
   - Summary of Public Comment (*A. Harp*)
   - Advisory Panel Report (*L. Gillingham*)
   - Law Enforcement Committee Report (*M. Robson*)
   - Consider Final Approval of Addendum IV
5. Consider 2015 Fishery Management Plan Review and State Compliance *(A. Harp)* **Action**
6. Review and Populate Advisory Panel Membership *(A. Harp)* **Action**
7. Elect Vice-chair **Action**
8. Other Business/Adjourn

4:45 – 5:30 p.m. **Atlantic Sturgeon Management Board**

Member States: Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Delaware, Pennsylvania, Maryland, Virginia, North Carolina, South Carolina, Georgia, Florida
Other Members: DC, PRFC, USFWS, NMFS
Chair: Vacant
Other Participants: Park, Huss, Damon-Randall
Staff: Appelman

1. Welcome/Call to Order *(R. Beal)*
2. Board Consent
    - Approval of Agenda
    - Approval of Proceedings from February 2016
3. Public Comment
4. Update on 2017 Benchmark Stock Assessment *(K. Drew)*
5. Review and Discuss Comment on NOAA Proposed Rules Designating Critical Habitat for Atlantic Sturgeon *(K. Damon-Randall)* **Action**
6. Elect Chair and Vice-chair **Action**
7. Other Business/Adjourn

<u>Wednesday, August 3, 2016</u>

8:00 – 11:00 a.m. **Atlantic Menhaden Management Board**

Member States: Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Delaware, Maryland, Virginia, North Carolina, South Carolina, Georgia, Florida
Other Members: NMFS, PRFC, USFWS
Chair: Ballou
Other Participants: Kersey, McNamee, Kaelin
Staff: Ware

1. Welcome/Call to Order *(R. Ballou)*
2. Board Consent
    - Approval of Agenda
    - Approval of Proceedings from May 2016
3. Public Comment
4. Draft Addendum I for Final Approval **Final Action**
    - Review Options *(M. Ware)*
    - Public Comment Summary *(M. Ware)*
    - Advisory Panel Report *(J. Kaelin)*
    - Law Enforcement Committee Report *(M. Robson)*
    - Consider Final Approval of Addendum I
5. Set 2017 Atlantic Menhaden Fishery Specifications **Final Action**
    - Overview of Specification Process *(M. Ware)*
    - Technical Committee Report *(J. McNamee)*
    - Advisory Panel Report *(J. Kaelin)*

6. Provide Guidance to Plan Development Team on Draft Amendment 3 Public Information Document *(M. Ware)*
7. Update on the Commercial Fishery Socioeconomic Study *(J. Harrison)*
8. Discuss Advisory Panel Membership *(M. Ware)*
9. Other Business/Adjourn

11:15 a.m. – 12:15 p.m. **Atlantic Coastal Cooperative Statistics Program (ACCSP) Executive Committee**
(A portion of this meeting may be a closed session for Committee members only)
Members: Beal, Boyles, Carmichael, Colvin, Cyr, Detlor, Fegley, Laney, Patterson
Chair: Boyles, Jr.
Staff: Cahall

1. Welcome/Introductions (*R. Boyles, Jr.)*
2. Public Comment* *(R. Boyles, Jr.)*
3. Committee Consent *(R. Boyles, Jr.)* **Action**
    - Approval of Agenda
    - Approval of Proceedings from April 2016
    - Approval of Proceedings from May 2016
4. ACCSP Status Report *(M. Cahall)*
    - For-Hire Workshop
    - Bluefin Tuna Dealer Reporting
    - GARFO VTR Transition
5. Governance Transition Update *(R. Boyles, Jr.)*
6. Other Business
7. Closed Session
8. Adjourn

*See Public Comment Guidelines:
http://www.accsp.org/sites/all/themes/aqua/File/ACCSP_PublicCommentPolicyOct2013.pdf

11:15 a.m. – 12:15 p.m. **Atlantic Striped Bass Management Board**
Member States: Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, Pennsylvania, New Jersey, Delaware, Maryland, Virginia, North Carolina
Other Members: NMFS, DC, PRFC, USFWS
Chair: Gilmore
Other Participants: Blanchard, Lengyel
Staff: Appelman

1. Welcome/Call to Order *(J. Gilmore)*
2. Board Consent
    - Approval of Agenda
    - Approval of Proceedings from February 2016

3. Public Comment
4. Review Striped Bass Advisory Panel Meeting Summary *(M. Appelman)*
5. Consider Approval of 2016 Atlantic Striped Bass Fishery Management Plan Review and State Compliance *(M. Appelman)* **Action**
   - Review Performance of Addendum IV Regulatory Measures in 2015
6. Other Business/Adjourn

12:30 – 1:30 p.m. **Legislative and Governors' Appointee Commissioner Luncheon**

1:30 – 3:30 p.m. **Interstate Fisheries Management Program (ISFMP) Policy Board**
Member States: Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Delaware, Pennsylvania, Maryland, Virginia, North Carolina, South Carolina, Georgia, Florida
Other Members: DC, NMFS, PRFC, USFWS
Chair: Grout
Staff: Kerns

1. Welcome/Call to Order *(D. Grout)*
2. Board Consent
   - Approval of Agenda
   - Approval of Proceedings from May 2016
3. Public Comment
4. State Directors Meeting Report *(D. Grout)*
5. Executive Committee Report *(D. Grout)*
6. Review of Stock Rebuilding Performance *(T. Kerns)*
7. Discuss Recommendation from South Atlantic State/Federal Fisheries Management Board Regarding Commission Involvement in Cobia Management (*J. Estes)* **Action**
8. Discuss Revisions to Conservation Equivalency Guidance Document (*T. Kerns*)
9. Risk and Uncertainty Policy Workgroup Progress Report (*S. Madsen)* **Action**
10. Habitat Committee Report (*L. Havel*) **Action**
11. Artificial Reef Committee Report (*L. Havel*)
12. Atlantic Coastal Fish Habitat Partnership Report (*L. Havel*)
13. Review Non-compliance Findings (if necessary) **Possible Action**
14. Other Business/Adjourn

3:45 – 5:15 p.m. **ACCSP Coordinating Council**
Members: Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Delaware, Maryland, District of Columbia, PRFC, Virginia, North Carolina, South Carolina, Georgia, Florida, ASMFC, NOAA Fisheries, NEFSC, GARFO, SEFSC, SERO, USFWS, NEFMC, MAFMC, SAFMC
Chair: R. Boyles, Jr.
Staff: Cahall

1. Welcome/Introductions *(R. Boyles, Jr.)*
2. Public Comment*

3. Council Consent **Action**
    - Approval of Agenda
    - Approval of Proceedings from May 2016
4. ACCSP Status Report
    - Program Updates *(M. Cahall*)
    - Committee Updates
5. Governance Transition Update *(R. Boyles, Jr.)*
6. Other Business/Adjourn

*See Public Comment Guidelines:
http://www.accsp.org/sites/all/themes/aqua/File/ACCSP_PublicCommentPolicyOct2013.pdf

Thursday, August 4, 2016

8:00 – 9:30 a.m. **American Eel Management Board**
Member States: Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, Pennsylvania, New Jersey, Delaware, Maryland, Virginia, North Carolina, South Carolina, Georgia, Florida
Other Members: NMFS, DC, PRFC, USFWS
Other Participants: Cornish, Wildman
Chair: Clark
Staff: Rootes-Murdy

1. Welcome/Call to Order *(J. Clark)*
2. Board Consent
    - Approval of Agenda
    - Approval of Proceedings from May 2016
3. Public Comment
4. Discussion to Consider Changes to Addendum IV Yellow Eel Allocations (*K. Rootes-Murdy*) **Possible Action**
    - Technical Committee Report (*T. Wildman*)
5. Consider North Carolina Glass Eel Aquaculture Plan for 2017 (*K. Rootes-Murdy*) **Action**
    - Technical Committee Report *(T. Wildman)*
    - Law Enforcement Committee Report *(M. Robson)*
6. Other Business/Adjourn

9:45 – 10:30 a.m. **Business Session**
Member States: Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Delaware, Pennsylvania, Maryland, Virginia, North Carolina, South Carolina, Georgia, Florida
Chair: Grout
Staff: Beal

1. Welcome/Introductions *(D. Grout)*
2. Board Consent
    - Approval of Agenda
    - Approval of Proceedings from May 2016

3. Public Comment
4. Review Non-compliance Findings (if necessary) **Possible Action**
5. Review ACCSP Transition Plan and Associated Documents **Action**
6. Other Business/Adjourn

10:45 a.m. – 4:00 p.m. **American Lobster Management Board**
Member States: Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Delaware, Maryland, Virginia
Other Members: NMFS, NEFMC
Chair: Borden
Other Participants: Cornish, Glenn
Staff: Ware

1. Welcome/Call to Order *(D. Borden)*
2. Board Consent
   - Approval of Agenda
   - Approval of Proceedings from May 2016
3. Public Comment
4. Update on Status of Federal Rulemaking for American Lobster *(P. Burns)*
5. American Lobster Technical Committee Report on Southern New England
   - Management Options to Achieve a 20-60% Increase in Egg Production In the Southern New England American Lobster Stock *(B. Glenn)*
6. Discuss Management Options to be Included in American Lobster Draft Addendum XXV *(D. Borden)* **Possible Action**
7. Discuss Technical Committee Recommendation for, and NOAA Letter on, Increased Reporting in the American Lobster Fishery *(D. Borden; P. Burns)* **Possible Action**
8. Consider Jonah Crab Draft Addendum II for Public Comment *(M. Ware)* **Action**
9. Consider Maine Conservation Equivalency Proposal for Exchange Trap Tags **Action**
   - Review of Maine Proposal (*P. Keliher)*
   - American Lobster Plan Review Team Report *(M. Ware)*
   - American Lobster Advisory Panel Report *(M. Ware)*
   - Law Enforcement Committee Report (*M. Robson)*
   - Consider Approval of Maine's Conservation Equivalency Proposal
10. Update from the Offshore Lobster Law Enforcement Subcommittee *(M. Robson)* **Possible Action**
11. Update on New England Fishery Management Council Omnibus Deep-Sea Coral Amendment *(M. Ware)*
12. Update on State Implementation of the Jonah Crab FMP *(M. Ware)*
13. Other Business/Adjourn

NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION

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Memorandum

To: ASMFC American Eel Management Board

From: James Gilmore

Subject: American Eel Commercial Yellow Eel Allocation

Date: July 21, 2016

Background: At the 2016 ASMFC Spring Board meeting, a motion was made to reconsider the coastal cap and state-by-state yellow eel allocations of Addendum IV, to help address the issue of New York's more accurate recent landings data. A subsequent motion passed to postpone the cap/allocations discussion until the August meeting. The Board felt that the simplest thing to do might be to try to increase the coast-wide cap by the amount New York would need, to reflect its more recent data. The Board requested further information from New York, regarding:

1. Good documentation to show why NY felt its recent years landings were a result of more accurate data collection, and not just increased landings.

2. And documentation to show the amount of increased quota NY would need to have a potentially viable fishery.

A. Improved Landings Data:

Prior to 2011, NY used data queried from the NOAA/NMFS Commercial Fisheries Statistics Database to report eel landings to the ASMFC via yearly state compliance reports. It was later called to our attention that the NOAA/NMFS data did not include confidential landings, or (after 2007), data from fishermen and dealers who had state, but not federal, licenses or permits. The NOAA database also did not include landings from inland waters (Hudson and Delaware Rivers), and it did not always include landings that were sold by fishermen for cash or bait. NY then made a concerted effort to get more accurate data by getting access to ACCSP Data Warehouse Confidential Discoverer Reports, as well as data from our inland fisheries. In addition, improvements were made to NY's commercial trip reporting systems, as outlined below.

Table 1. NMFS vs. NY Reported American Eel Landings, 1998 - 2014.

Year	Species	NY Pounds (NMFS)	NY Pounds (NY)
1998	EEL, AMERICAN	382	16,896
1999	EEL, AMERICAN	44	7,945
2000	EEL, AMERICAN	1,108	5,852
2001	EEL, AMERICAN	15	19,187
2002	EEL, AMERICAN	161	26,824
2003	EEL, AMERICAN	393	3,881
2004	EEL, AMERICAN	2,994	5,386
2005	EEL, AMERICAN	8,964	25,515
2006	EEL, AMERICAN	3,927	7,673
2007	EEL, AMERICAN	4,480	15,077
2008	EEL, AMERICAN	2,287	15,159
2009	EEL, AMERICAN	5,687	13,115
2010	EEL, AMERICAN	7,808	13,220
2011	EEL, AMERICAN	35,557	56,963
2012	EEL, AMERICAN	32,451	48,637
2013	EEL, AMERICAN	34,697	32,573
2014	EEL, AMERICAN	26,877	34,142
GRAND TOTALS:	-	167,832	348,045

NY landings are derived from a combination of Dealer Reports and Harvester Trip Reports (VTRs).

<u>Timeline of Improvements to New York's Vessel Trip Reporting Systems</u>

1. **Prior to 2008:** All marine/coastal vessel trip reports (VTRs) were sent to NOAA and entered into databases (via contract to Cornell Cooperative Extension (CCE)). Many eel fishermen sell their product as bait and mistakenly assume they are not commercial fishermen, and do not have to file reports. Landings sold by fishermen for cash or bait are also not part of the federal dealer report database.

   NY Delaware River weir licenses are issued by Albany Special Licenses Unit, and, although fishermen are required to file yearly landings logbook reports to the DEC, several do not do so. Additionally, Albany retains logbooks for two years, then destroys all records.

2. **2008:** NOAA no longer accepts VTRs from fishermen who have NY licenses/permits, but lack federal permits. NY develops a NY VTR form, and data is entered into ACCSP databases (via CCE contracts). Contract ends in August 2008.

3. **2009 – 2011:** NY DEC is unable to procure contracts for data entry due to fiscal limitations brought on by the National recession. DEC staff date stamp and file VTR reports, and only enter data from quota-managed species into databases. Therefore, other VTRs go largely unprocessed.

   In 2011, regulatory changes were made to 6NYCRR, in order to clarify fishermen's and dealers reporting requirements. Dealers are now required to enter information electronically into the SAFIS eDr database.

4. **2012:** DEC develops an upgraded searchable database, NYFISH.

5. **2013:** NY develops enhanced reporting compliance protocols, including those for Hudson and Delaware River eel fisheries.

6. **2014:** NY DEC creates its own Fisheries Data Management Unit, with funding from ACCSP grants.

   NYS DEC limits Delaware River eel weir licenses to nine individuals.

7. **2015:** Delaware River weir licenses are now issued by the Bureau of Marine Resources (now Division of Marine Resources), and reports must be sent to the Bureau.

   All backlogged VTRs have now been entered into the database, except 2009. VTRS were entered into the database in reverse chronological order (i.e. newest data entered first). 2010 VTRs are currently undergoing QA/QC. VTRs from 2009 are expected to be entered by the end of 2016.

   Regardless of the reasons (better reporting, increased compliance, an actual increase in harvest, or a combination of the above), NY's commercial eel harvest has increased significantly since 2010, the terminal year of the last stock assessment, as indicated by both NOAA and NY data.

B. Increase Coast Wide Harvest Cap :

Table 2. Commercial yellow eel landings by state from 1998 through 2015. Source: Table 2 from Addendum IV, plus preliminary 2014 and 2015 state data. Note that all data need to be confirmed as final by the states/jurisdictions.

Year	ME	NH	MA	RI	CT	NY[1]	NJ	DE	MD	PRFC	VA	NC	SC	GA	FL	Total
1998	20,671	459	5,606	967	5,606	16,896	94,327	131,478	301,833	209,008	123,819	91,084		*	13,819	1,015,64
1999	36,087	245	10,281	140	10,281	7,945	90,252	128,978	305,812	163,351	183,255	99,939	*		17,533	1,054,12
2000	14,349	310	5,158	25	5,158	5,852	45,393	119,180	259,552	208,549	114,972	127,099	*		6,054	911,824
2001	9,007	185	3,867	329	1,724	19,187	57,700	120,634	271,178	213,440	96,998	107,070	*	*	14,218	915,585
2002	11,616	67	3,842	234	3,710	26,824	64,600	90,353	208,659	128,595	75,549	59,940	*	*	7,587	681,609
2003	15,312	36	4,047	246	1,868	3,881	100,701	155,515	346,412	123,450	121,043	172,065		*	8,486	1,053,11
2004	29,651	65	5,328	971	1,374	5,386	120,607	141,725	273,142	116,163	123,314	128,875			7,330	953,931
2005	17,189	120	3,073	0	341	25,515	148,127	110,456	378,659	103,628	66,701	49,278			3,913	907,000
2006	17,259	93	3,676	1,034	3,443	7,673	158,917	120,462	362,966	83,622	82,738	33,581			1,248	876,712
2007	9,309	70	2,853	1,230	885	15,077	164,331	131,109	309,215	97,361	56,463	34,486			7,379	829,767
2008	7,992	25	6,046	8,866	6,012	15,159	140,418	80,003	381,993	71,655	84,789	24,658	*		15,624	843,762
2009	2,525	83	1,217	4,855	630	13,115	121,471	59,619	324,773	58,863	119,187	65,481			6,824	778,643
2010	2,624	80	277	4,642	164	13,220	107,803	68,666	511,201	57,755	78,076	122,104	*	*	11,287	978,004
2011	2,700	129	368	1,521	20	56,963	129,065	90,631	715,162	29,010	103,856	61,960			25,601	1,216,98
2012	10,785	167	532	1,484	3,560	48,637	111,810	54,304	583,057	90,037	122,058	64,110		*	11,845	1,104,42
2013	1,826	106	2,499	2,244	2,638	32,573	89,300	80,811	539,775	32,290	84,385	33,980		*	17,246	919,953
2014	7,368	0	3,903	2,378	4,386	34,142	102,960	62,388	610,585	49,293	108,494	58,886	*	*	15,057	1,059,97
2015	4,130	0	2,502	1,538	3,052	53,389	88,828	44,708	470,532	31,588	78,869	57,791	*	*	5,632	842,683

1 NY includes DE River Weir. Add. IV requires all NY eel landings be included in the quota and catch cap.
*confidential landings

Appendix A of ASMFC Addendum IV to the Interstate Fishery Management Plan for American Eel outlines the steps made for the determination of the coastwide quota and state-by-state allocations for yellow eels.

1. The quota was initially set at the 2010 harvest level (978,004 lbs.), the terminal year of the benchmark stock assessment.

2. A 16% reduction was then applied, bringing the quota down to 821,523 lbs.

3. The average 2011 - 2013 percent landings for the States and Jurisdictions was calculated next. At this step, New York would have been given 4.26% of the 821,523 lb. quota (34,997 lbs.).

4. A complex filtering mechanism was next applied, in an attempt to increase equity in quota distribution:
   - All States or Jurisdictions were given a minimum quota of 2,000 lbs., in order to decrease their administrative burdens.

   - No State or Jurisdiction would be allocated a quota that was more than 2,000 lbs. above its 2010 commercial harvest.

- No State or Jurisdiction would be allocated a quota more than 15% below its 2010 commercial harvest.

5 After this filtering method was applied, the coastwide quota would have been 893,909 lbs. At this step, NY would have received a quota of 15,220 lbs. (A 56.5% reduction of what was calculated in Step 3).

6 At its October 2014 meeting, the TC recommended the quota be set to the 1998 – 2010 average coastal harvest (907,669 lbs.). The difference between 907,669 lbs. and 893,909 lbs. (13,760 lbs.) was then split evenly among the States and Jurisdictions (RI, NJ, DE, PRFC, NC) that would have received a reduction from their 2010 harvests (except for MD, and not to exceed each State's 2010 landings), for a resultant quota of 907,669 lbs. NY's final quota remained at 15,220 lbs.

Results are summarized in the Table below:

Table 1 from Addendum IV Appendix A: Quota and Allocation Calculation Process.

	2010 Landings	2011-2013 Harvest Average	Initial Allocation Based on Harvest Average	Initial Quota	After Filtering Method is Applied	Final Quota
Maine	2,624	5,104	0.48%	3,943	3,907	3,907
New Hampshire	80	134	0.01%	82	2,000	2,000
Massachusetts	277	450	0.04%	329	2,000	2,000
Rhode Island	4,642	1,750	0.16%	1,314	3,946	4,642
Connecticut	164	2,073	0.19%	1,561	2,000	2,000
New York	13,220	46,058	4.26%	34,997	15,220	15,220
New Jersey	107,803	110,058	10.19%	83,713	91,633	94,899
Delaware	68,666	75,249	6.97%	57,260	58,366	61,632
Maryland	511,201	612,665	56.72%	465,968	465,968	465,968
PRFC	57,755	50,446	4.67%	38,365	49,092	52,358
Virginia	78,076	103,433	9.58%	78,702	78,702	78,702
North Carolina	122,104	53,350	4.94%	40,583	103,788	107,054
South Carolina	2			0	2,000	2,000
Georgia	103	1,162	0.11%	904	2,000	2,000
Florida	11,287	18,231	1.68%	13,802	13,287	13,287
Total	978,004	1,080,160	100%	821,523	893,909	907,669

NY's 2011 - 2015 harvests ranged from a low of 32,573 lbs. to a high of 56,963 lbs. Average harvests for 2013 - 2015 were 40,035 lbs. Average harvests for 2011 - 2015 were 45,141 lbs. If NY's quota were increased by 24,815 lbs., it would achieve its 2013 - 15 average harvest. If the quota were increased by 29,921 lbs., it would achieve its 2011 - 15 average harvest.

Table 3. NY Quota Example 2011 – 2015

Year	NY Harvest			
2011	56,963			
2012	48,637			
2013	32,573			
2014	34,142			
2015	53,389			
	Total NY Quota	**Current Quota**	**Additional Quota Needed**	**Total Coastwide Quota**
2011 - 13 Average	46,058	15,220	30,838	938,507
2013 - 15 Average	40,035	15,220	24,815	932,484
2011 - 15 Average	45,141	15,220	29,921	937,590

The "no more than 2,000 lbs. above 2010 harvest "filtering mechanism gave NY a final quota that was only 34% of the amount of eels NY has been harvesting annually for the past five years. Increasing the catch cap to one of the above amounts, without changing the other States or Jurisdictions quotas, would give NY the amount of quota it needs to sustain a viable fishery. This would require a new addendum to change Addendum IV.

C. Quota Transfer Example – Using 2014 Harvest Numbers

It has been suggested that NY can always obtain quota through transfers, so a permanent increase to their annual quota is unnecessary. Below is an example of State's quota surpluses and deficits, based on 2014 harvest data, the year before the coast-wide harvest cap would have gone into effect. There was a coast-wide overharvest of 211,668 lbs., but only 59,365 lbs. would have been available for transfers. As an example, MD would have had to have a transfer of 144,617 pounds of quota from other states, with only 59,365 lbs. available. NY would have had to have a transfer of 18,922 lbs. of quota, and, if it was unable to do so, the fishery would have been shut down the following year.

Table 4.
Scenario - If States had to Enact Yellow Eel State by State Quota, Based on 2014 Harvest

State	Quota	Harvest	Difference	Available Surplus	Deficit	Total Deficit
ME	3,907	7,368	-3,461		-3,461	
NH	2,000	0	2,000	2,000		
MA	2,000	3,903	-1,903		-1,903	
RI	4,642	2,378	2,264	2,264		
CT	2,000	4,386	-2,386		-2,386	
NY	15,220	34,142	-18,922		-18,922	
NJ	94,899	102,960	-8,061		-8,061	
DE	61,632	62,388	-756		-756	
MD	465,968	610,585	-144,617		-144,617	
PRFC	52,358	49,293	3,065	3,065		
VA	78,702	108,494	-29,792		-29,792	
NC	107,054	58,886	48,168	48,168		
SC	2,000	66*	1,934	1,934		
GA	2,000	66*	1,934	1,934		
FL	13,287	15,057	-1,770		-1,770	
Total	907,669	1,059,972	-152,303	59,365	-211,668	-152,303

* SC and GA harvest numbers are confidential; therefore, SC and GA numbers are examples only.

All numbers need to be confirmed by States/Jurisdictions.

D. Quota Re-allocation Example:

It is an ASMFC operating principle that we use the most accurate data for management of our fisheries. Member states are currently not operating under a quota for yellow phase American eels. But once management triggers are tripped, a State by State quota system will be put into effect in perpetuity. No mechanism was included in Addendum IV to revisit allocation over a set period of time or when new data become available. This issue also exists with management of several other ASMFC quota managed fisheries (e.g., menhaden, summer flounder, bluefish). Provisions exist currently to re-evaluate allocations through the addendum process but this is voluntary and tends not to occur if the disadvantaged states are in the minority.

Suggested Options from the Spring 2016 ASSMFC Board Meeting Memo For Reallocation of Quota:

1) Reconsidering Current Commercial Yellow Eel Quota:
See Table 5 for examples of state-by-state allocation for options A - C.

Option A: Status quo from Addendum IV. A combination of landings from 2010; the State's average harvests from 2011 - 2013; and a set of rules that prohibited any state be allocated a quota that was more than 2,000 pounds above its 2010 commercial yellow eel harvest.

Option B: Allocation based on the most recent three years of data (i.e., 2013 - 2015).

Option C: Allocation based on the most recent five years of data (i.e., 2011 - 2015).

Option D: Allocation based on the most recent five years as a partial percentage and some historical landings timeframe as a partial percentage. An example is not included in Table 5, because the exact percentages of recent vs historical landings, as well as the years used to determine the historical timeframes would need to be determined by the Board.

Table 5. State-by-state allocation examples showing quotas for options A - C. Note landings data used to create Table 5 as for example only and need to be confirmed by the states/jurisdictions as final.

State	A: Addendum IV Status Quo	B: Recent 3 Yrs. (2013 - 2015)	C: Recent 5 Yrs. (2011 - 2015)
ME	3,907	4,285	4,731
NH	2,000	34	71
MA	2,000	2,863	1,730
RI	4,642	1,981	1,617
CT	2,000	3,240	2,410
NY	15,220	38,624	39,827
NJ	94,899	90,394	92,103
DE	61,632	60,428	58,732
MD	465,968	521,255	515,093
PRFC	52,358	36,394	40,976
VA	78,702	87,390	87,815
NC	107,054	48,449	48,830
SC	2,000	*	*
GA	2,000	*	*
FL	13,287	12,199	13,301
Total	907,669	907,669	907,669

(2) Consideration of a revisiting timeframe for allocation moving forward

Option A: Status quo, no revisiting timeframe specified.

Option B: Revisit allocation every three years.

Option C: Revisit allocation every five years.

Atlantic States Marine Fisheries Commission

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MEMORANDUM

TO: American Lobster Management Board

FROM: American Lobster Technical Committee

DATE: July 25, 2016

SUBJECT: Effect of Gauge Changes on Exploitation, SSB, Reference Abundance, and Catch

The following analysis looks at the effect of gauge size changes on egg production, exploitation, spawning stock biomass (SSB), reference abundance, and catch. This work is intended to provide a holistic view of stock and fishery changes that may result from alterations to the minimum and maximum gauge size. Table 1 summarizes scenarios in which a 20% or 60% increase in egg production is achieved, per the motion of the Board at the May 2016 meeting. Tables 2-6 look at all combinations of gauge changes in regards to egg production, exploitation, SSB, reference abundance, and catch.

Table 1. Minimum and maximum size window necessary to achieve a 20% and 60% increase in egg production respectively. Includes % change in exploitation, spawning stock biomass, reference abundance, and catch associated with the size windows presented. *Assumes changes in gauge size from the current 86 mm minimum and 133 mm maximum size inshore, and an 89 mm minimum size and a 171 mm maximum size offshore. English unit conversions are approximate.

	Min	Max	Egg Production	Exploitation	Spawning Stock Biomass	Reference Abundance	Catch
Inshore	88 mm (3 15/32")	105 mm (4 1/8")	20%	-18%	20%	9%	-11%
	91 mm (3 9/16")	115 mm (4 1/2")	18%	-22%	22%	11%	-14%
	92 mm (3 5/8")	165 mm (6 1/2")	20%	-27%	25%	13%	-17%
Offshore	91 mm (3 9/16")	105 mm (4 1/8")	22%	-21%	22%	9%	-13%
	94 mm (3 11/16")	115 mm (4 1/2")	20%	-26%	24%	12%	-17%
	95 mm (3 3/4")	165 mm (6 1/2")	21%	-28%	26%	13%	-19%
Inshore	99 mm (3 7/8")	115 mm (4 1/2")	60%	-56%	71%	32%	-42%
	101 mm (3 29/32")	165 mm (6 1/2")	59%	-59%	76%	35%	-45%
Offshore	102 mm (4")	115 mm (4 1/2")	62%	-60%	71%	31%	-47%
	103 mm (4 1/16")	165 mm (6 1/2")	63%	-63%	75%	34%	-50%

Table 2. Inshore and offshore minimum/maximum gauge change scenarios and corresponding egg production changes from the current gauge sizes. Egg production is expressed as percent increases from the current conditions.

Inshore; Min=86, Max=133

Min Size \ Max size	105	115	125	135	145	155	165
82	2%	-7%	-8%	-8%	-8%	-8%	-8%
83	3%	-6%	-7%	-7%	-7%	-7%	-7%
84	5%	-4%	-5%	-5%	-5%	-5%	-5%
85	8%	-1%	-3%	-3%	-3%	-3%	-3%
86	12%	1%	0%	0%	0%	0%	0%
87	15%	5%	3%	3%	3%	3%	3%
88	20%	8%	6%	6%	6%	6%	6%
89	23%	11%	9%	9%	9%	9%	9%
90	27%	14%	12%	12%	12%	12%	12%
91	33%	18%	16%	16%	16%	16%	16%
92	39%	22%	20%	20%	20%	20%	20%
93	46%	28%	26%	25%	25%	25%	25%
94	51%	31%	29%	28%	28%	28%	28%
95	NA	35%	32%	32%	32%	32%	32%
96	NA	40%	37%	37%	37%	37%	37%
97	NA	47%	43%	43%	43%	43%	43%
98	NA	56%	51%	51%	51%	51%	51%
99	NA	59%	54%	54%	54%	54%	54%
100	NA	63%	58%	57%	57%	57%	57%
101	NA	69%	63%	62%	62%	62%	62%
102	NA	76%	70%	69%	69%	69%	69%
103	NA	87%	79%	78%	78%	78%	78%
104	NA	91%	82%	81%	81%	81%	81%
105	NA	NA	85%	84%	84%	84%	84%
106	NA	NA	90%	89%	89%	89%	89%
107	NA	NA	97%	96%	95%	95%	95%
108	NA	NA	107%	105%	105%	105%	105%
109	NA	NA	110%	108%	107%	107%	107%
110	NA	NA	113%	111%	110%	110%	110%

Offshore; Min=89, Max=171

Min Size \ Max size	105	115	125	135	145	155	165
82	-7%	-14%	-15%	-16%	-16%	-16%	-16%
83	-6%	-14%	-15%	-15%	-15%	-15%	-15%
84	-3%	-12%	-13%	-13%	-13%	-13%	-13%
85	0%	-9%	-10%	-11%	-11%	-11%	-11%
86	3%	-7%	-8%	-8%	-8%	-8%	-8%
87	6%	-4%	-5%	-5%	-5%	-5%	-5%
88	10%	-1%	-2%	-2%	-2%	-2%	-2%
89	13%	2%	0%	0%	0%	0%	0%
90	17%	5%	3%	3%	3%	3%	3%
91	22%	8%	6%	6%	6%	6%	6%
92	27%	12%	11%	10%	10%	10%	10%
93	34%	18%	15%	15%	15%	15%	15%
94	39%	20%	18%	18%	18%	18%	18%
95	NA	24%	22%	21%	21%	21%	21%
96	NA	29%	26%	26%	25%	25%	25%
97	NA	35%	32%	31%	31%	31%	31%
98	NA	43%	39%	39%	39%	39%	39%
99	NA	46%	42%	41%	41%	41%	41%
100	NA	50%	45%	45%	45%	45%	45%
101	NA	55%	50%	49%	49%	49%	49%
102	NA	62%	56%	55%	55%	55%	55%
103	NA	72%	64%	64%	63%	63%	63%
104	NA	75%	67%	66%	66%	66%	66%
105	NA	NA	70%	69%	69%	69%	69%
106	NA	NA	75%	74%	73%	73%	73%
107	NA	NA	81%	80%	79%	79%	79%
108	NA	NA	90%	89%	88%	88%	88%
109	NA	NA	92%	91%	90%	90%	90%
110	NA	NA	95%	93%	93%	93%	93%

Table 3. Inshore and offshore minimum/maximum gauge change scenarios and corresponding exploitation changes from the current gauge sizes. Exploitation is expressed as percent increases from the current conditions.

Inshore; Min=86, Max=133

Max size →

Min Size ↓	105	115	125	135	145	155	165
82	7%	14%	14%	14%	14%	14%	14%
83	5%	12%	13%	13%	13%	13%	13%
84	1%	8%	9%	9%	9%	9%	9%
85	-4%	4%	4%	4%	5%	5%	5%
86	-8%	-1%	0%	0%	0%	0%	0%
87	-13%	-6%	-5%	-5%	-5%	-5%	-5%
88	-18%	-11%	-10%	-10%	-10%	-10%	-10%
89	-22%	-14%	-13%	-13%	-13%	-13%	-13%
90	-26%	-18%	-17%	-17%	-17%	-17%	-17%
91	-31%	-22%	-22%	-21%	-21%	-21%	-21%
92	-37%	-28%	-27%	-27%	-27%	-27%	-27%
93	-43%	-33%	-32%	-32%	-32%	-32%	-32%
94	-46%	-36%	-35%	-35%	-35%	-35%	-35%
95	NA	-39%	-38%	-38%	-38%	-38%	-38%
96	NA	-43%	-42%	-42%	-42%	-42%	-42%
97	NA	-48%	-46%	-46%	-46%	-46%	-46%
98	NA	-54%	-53%	-53%	-52%	-52%	-52%
99	NA	-56%	-54%	-54%	-54%	-54%	-54%
100	NA	-58%	-56%	-56%	-56%	-56%	-56%
101	NA	-61%	-59%	-59%	-59%	-59%	-59%
102	NA	-65%	-63%	-63%	-63%	-63%	-63%
103	NA	-71%	-68%	-68%	-68%	-68%	-68%
104	NA	-72%	-69%	-69%	-69%	-69%	-69%
105	NA	NA	-71%	-70%	-70%	-70%	-70%
106	NA	NA	-73%	-72%	-72%	-72%	-72%
107	NA	NA	-75%	-75%	-75%	-75%	-75%
108	NA	NA	-80%	-79%	-79%	-79%	-79%
109	NA	NA	-81%	-80%	-80%	-80%	-80%
110	NA	NA	-81%	-81%	-81%	-81%	-81%

Offshore; Min=89, Max=171

Max size →

Min Size ↓	105	115	125	135	145	155	165
82	23%	31%	32%	32%	32%	32%	32%
83	21%	29%	30%	30%	30%	30%	30%
84	16%	24%	25%	25%	25%	25%	25%
85	11%	20%	20%	21%	21%	21%	21%
86	6%	14%	15%	15%	15%	15%	15%
87	0%	9%	10%	10%	10%	10%	10%
88	-6%	3%	4%	4%	4%	4%	4%
89	-10%	-1%	0%	0%	0%	0%	0%
90	-15%	-5%	-4%	-4%	-4%	-4%	-4%
91	-21%	-11%	-10%	-9%	-9%	-9%	-9%
92	-27%	-16%	-15%	-15%	-15%	-15%	-15%
93	-34%	-23%	-22%	-22%	-22%	-22%	-22%
94	-38%	-26%	-25%	-25%	-25%	-25%	-25%
95	NA	-30%	-28%	-28%	-28%	-28%	-28%
96	NA	-34%	-33%	-33%	-33%	-33%	-33%
97	NA	-40%	-38%	-38%	-38%	-38%	-38%
98	NA	-47%	-45%	-45%	-45%	-45%	-45%
99	NA	-49%	-47%	-47%	-47%	-47%	-47%
100	NA	-52%	-50%	-50%	-49%	-49%	-49%
101	NA	-55%	-53%	-53%	-53%	-53%	-53%
102	NA	-60%	-57%	-57%	-57%	-57%	-57%
103	NA	-66%	-63%	-63%	-63%	-63%	-63%
104	NA	-68%	-64%	-64%	-64%	-64%	-64%
105	NA	NA	-66%	-66%	-66%	-66%	-66%
106	NA	NA	-68%	-68%	-68%	-68%	-68%
107	NA	NA	-72%	-71%	-71%	-71%	-71%
108	NA	NA	-77%	-76%	-76%	-76%	-76%
109	NA	NA	-78%	-77%	-77%	-77%	-77%
110	NA	NA	-79%	-78%	-78%	-78%	-78%

Table 4. Inshore and offshore minimum/maximum gauge change scenarios and corresponding spawning stock biomass (SSB) changes from the current gauge sizes. SSB is expressed as percent increases from the current conditions.

Inshore; Min=86, Max=133

Min Size \ Max size	105	115	125	135	145	155	165
82	-1%	-9%	-10%	-10%	-10%	-10%	-10%
83	0%	-8%	-9%	-9%	-9%	-9%	-9%
84	4%	-5%	-6%	-6%	-6%	-6%	-6%
85	7%	-2%	-3%	-3%	-3%	-3%	-3%
86	11%	1%	0%	0%	0%	0%	0%
87	16%	5%	4%	4%	4%	4%	4%
88	20%	9%	8%	8%	8%	8%	8%
89	25%	13%	11%	11%	11%	11%	11%
90	30%	17%	15%	15%	15%	15%	15%
91	36%	22%	20%	20%	20%	20%	20%
92	43%	27%	26%	25%	25%	25%	25%
93	51%	34%	32%	32%	32%	32%	32%
94	57%	38%	36%	36%	36%	35%	35%
95	NA	43%	40%	40%	40%	40%	40%
96	NA	49%	46%	46%	46%	46%	46%
97	NA	57%	54%	53%	53%	53%	53%
98	NA	67%	63%	63%	63%	63%	63%
99	NA	71%	67%	66%	66%	66%	66%
100	NA	76%	71%	71%	71%	71%	71%
101	NA	82%	77%	76%	76%	76%	76%
102	NA	90%	84%	84%	84%	84%	84%
103	NA	102%	95%	94%	94%	94%	94%
104	NA	106%	98%	97%	97%	97%	97%
105	NA	NA	102%	101%	101%	101%	101%
106	NA	NA	107%	106%	106%	106%	106%
107	NA	NA	115%	113%	113%	113%	113%
108	NA	NA	125%	124%	124%	124%	124%
109	NA	NA	128%	126%	126%	126%	126%
110	NA	NA	131%	129%	129%	129%	129%

Offshore; Min=89, Max=171

Min Size \ Max size	105	115	125	135	145	155	165
82	-11%	-18%	-19%	-19%	-19%	-19%	-19%
83	-10%	-17%	-18%	-18%	-18%	-18%	-18%
84	-7%	-15%	-16%	-16%	-16%	-16%	-16%
85	-4%	-12%	-13%	-13%	-13%	-13%	-13%
86	0%	-9%	-10%	-10%	-10%	-10%	-10%
87	4%	-6%	-7%	-7%	-7%	-7%	-7%
88	8%	-2%	-3%	-3%	-3%	-3%	-3%
89	12%	1%	0%	0%	0%	0%	0%
90	17%	5%	4%	4%	4%	4%	4%
91	22%	9%	8%	8%	8%	8%	8%
92	29%	15%	13%	13%	13%	13%	13%
93	36%	21%	19%	19%	19%	19%	19%
94	41%	24%	22%	22%	22%	22%	22%
95	NA	28%	26%	26%	26%	26%	26%
96	NA	34%	31%	31%	31%	31%	31%
97	NA	41%	38%	38%	38%	38%	38%
98	NA	50%	47%	46%	46%	46%	46%
99	NA	54%	50%	50%	49%	49%	49%
100	NA	58%	54%	53%	53%	53%	53%
101	NA	64%	59%	59%	59%	59%	59%
102	NA	71%	66%	65%	65%	65%	65%
103	NA	82%	75%	75%	75%	75%	75%
104	NA	85%	78%	77%	77%	77%	77%
105	NA	NA	82%	81%	81%	81%	81%
106	NA	NA	87%	86%	85%	85%	85%
107	NA	NA	93%	92%	92%	92%	92%
108	NA	NA	103%	101%	101%	101%	101%
109	NA	NA	105%	103%	103%	103%	103%
110	NA	NA	108%	106%	106%	106%	106%

Table 5. Inshore and offshore minimum/maximum gauge change scenarios and corresponding reference abundance changes from the current gauge sizes. Reference abundance is expressed as percent increases from the current conditions.

Inshore; Min=86, Max=133

Max size →

Min Size ↓

	105	115	125	135	145	155	165
82	-3%	-6%	-6%	-6%	-6%	-6%	-6%
83	-2%	-5%	-5%	-5%	-5%	-5%	-5%
84	0%	-3%	-4%	-4%	-4%	-4%	-4%
85	2%	-2%	-2%	-2%	-2%	-2%	-2%
86	4%	0%	0%	0%	0%	0%	0%
87	6%	3%	2%	2%	2%	2%	2%
88	9%	5%	5%	5%	5%	5%	5%
89	11%	7%	6%	6%	6%	6%	6%
90	13%	9%	8%	8%	8%	8%	8%
91	16%	11%	10%	10%	10%	10%	10%
92	19%	14%	13%	13%	13%	13%	13%
93	23%	17%	16%	16%	16%	16%	16%
94	25%	19%	18%	18%	18%	18%	18%
95	NA	21%	20%	20%	20%	20%	20%
96	NA	23%	22%	22%	22%	22%	22%
97	NA	26%	25%	25%	25%	25%	25%
98	NA	31%	30%	30%	30%	30%	30%
99	NA	32%	31%	31%	31%	31%	31%
100	NA	34%	33%	33%	33%	33%	33%
101	NA	36%	35%	35%	35%	35%	35%
102	NA	40%	38%	38%	38%	38%	38%
103	NA	45%	42%	42%	42%	42%	42%
104	NA	46%	43%	43%	43%	43%	43%
105	NA	NA	45%	44%	44%	44%	44%
106	NA	NA	46%	46%	46%	46%	46%
107	NA	NA	49%	49%	49%	49%	49%
108	NA	NA	53%	53%	53%	53%	53%
109	NA	NA	54%	54%	54%	54%	54%
110	NA	NA	55%	55%	55%	55%	55%

Offshore; Min=89, Max=171

Max size →

Min Size ↓

	105	115	125	135	145	155	165
82	-8%	-11%	-11%	-11%	-11%	-11%	-11%
83	-8%	-10%	-11%	-11%	-11%	-11%	-11%
84	-6%	-9%	-9%	-9%	-9%	-9%	-9%
85	-4%	-7%	-8%	-8%	-8%	-8%	-8%
86	-2%	-5%	-6%	-6%	-6%	-6%	-6%
87	0%	-3%	-4%	-4%	-4%	-4%	-4%
88	2%	-1%	-1%	-2%	-2%	-2%	-2%
89	4%	0%	0%	0%	0%	0%	0%
90	6%	2%	2%	2%	2%	2%	2%
91	9%	4%	4%	4%	4%	4%	4%
92	12%	7%	7%	7%	6%	6%	6%
93	16%	10%	10%	10%	10%	10%	10%
94	18%	12%	11%	11%	11%	11%	11%
95	NA	14%	13%	13%	13%	13%	13%
96	NA	16%	15%	15%	15%	15%	15%
97	NA	19%	18%	18%	18%	18%	18%
98	NA	23%	22%	22%	22%	22%	22%
99	NA	25%	23%	23%	23%	23%	23%
100	NA	26%	25%	25%	25%	25%	25%
101	NA	28%	27%	27%	27%	27%	27%
102	NA	31%	30%	30%	30%	30%	30%
103	NA	36%	34%	34%	34%	34%	34%
104	NA	37%	35%	35%	35%	35%	35%
105	NA	NA	36%	36%	36%	36%	36%
106	NA	NA	38%	38%	38%	38%	38%
107	NA	NA	40%	40%	40%	40%	40%
108	NA	NA	44%	44%	44%	44%	44%
109	NA	NA	45%	45%	45%	45%	45%
110	NA	NA	46%	46%	46%	46%	46%

Table 6. Inshore and offshore minimum/maximum gauge change scenarios and corresponding catch changes from the current gauge sizes. Catch is expressed as percent increases from the current conditions.

Inshore; Min=86, Max=133

Min Size ↓ / Max size →	105	115	125	135	145	155	165
82	4%	7%	8%	8%	8%	8%	8%
83	3%	6%	7%	7%	7%	7%	7%
84	0%	4%	5%	5%	5%	5%	5%
85	-2%	2%	2%	2%	2%	2%	2%
86	-5%	0%	0%	0%	0%	0%	0%
87	-8%	-3%	-3%	-3%	-3%	-3%	-3%
88	-11%	-6%	-6%	-6%	-6%	-6%	-6%
89	-14%	-9%	-8%	-8%	-8%	-8%	-8%
90	-17%	-11%	-10%	-10%	-10%	-10%	-10%
91	-20%	-14%	-13%	-13%	-13%	-13%	-13%
92	-25%	-18%	-17%	-17%	-17%	-17%	-17%
93	-30%	-22%	-21%	-21%	-21%	-21%	-21%
94	-33%	-24%	-23%	-23%	-23%	-23%	-23%
95	NA	-27%	-26%	-26%	-26%	-26%	-26%
96	NA	-30%	-29%	-29%	-29%	-29%	-29%
97	NA	-34%	-33%	-33%	-33%	-33%	-33%
98	NA	-40%	-39%	-38%	-38%	-38%	-38%
99	NA	-42%	-40%	-40%	-40%	-40%	-40%
100	NA	-44%	-42%	-42%	-42%	-42%	-42%
101	NA	-47%	-45%	-45%	-45%	-45%	-45%
102	NA	-51%	-49%	-49%	-49%	-49%	-49%
103	NA	-58%	-55%	-54%	-54%	-54%	-54%
104	NA	-59%	-56%	-56%	-56%	-56%	-56%
105	NA	NA	-58%	-57%	-57%	-57%	-57%
106	NA	NA	-60%	-60%	-60%	-59%	-59%
107	NA	NA	-63%	-63%	-63%	-63%	-63%
108	NA	NA	-69%	-68%	-68%	-68%	-68%
109	NA	NA	-70%	-69%	-69%	-69%	-69%
110	NA	NA	-71%	-71%	-71%	-71%	-71%

Offshore; Min=89, Max=171

Min Size ↓ / Max size →	105	115	125	135	145	155	165
82	13%	17%	17%	17%	17%	17%	17%
83	12%	16%	16%	16%	16%	16%	16%
84	9%	13%	14%	14%	14%	14%	14%
85	6%	11%	11%	11%	11%	11%	11%
86	3%	8%	9%	9%	9%	9%	9%
87	0%	5%	6%	6%	6%	6%	6%
88	-4%	2%	2%	2%	2%	2%	2%
89	-6%	-1%	0%	0%	0%	0%	0%
90	-10%	-3%	-3%	-3%	-3%	-3%	-3%
91	-13%	-7%	-6%	-6%	-6%	-6%	-6%
92	-18%	-11%	-10%	-10%	-10%	-10%	-10%
93	-24%	-15%	-14%	-14%	-14%	-14%	-14%
94	-27%	-17%	-17%	-16%	-16%	-16%	-16%
95	NA	-20%	-19%	-19%	-19%	-19%	-19%
96	NA	-24%	-23%	-22%	-22%	-22%	-22%
97	NA	-28%	-27%	-27%	-27%	-27%	-27%
98	NA	-35%	-33%	-33%	-33%	-33%	-33%
99	NA	-37%	-35%	-35%	-35%	-35%	-35%
100	NA	-39%	-37%	-37%	-37%	-37%	-37%
101	NA	-42%	-40%	-40%	-40%	-40%	-40%
102	NA	-47%	-44%	-44%	-44%	-44%	-44%
103	NA	-54%	-51%	-50%	-50%	-50%	-50%
104	NA	-56%	-52%	-52%	-52%	-52%	-52%
105	NA	NA	-54%	-54%	-53%	-53%	-53%
106	NA	NA	-56%	-56%	-56%	-56%	-56%
107	NA	NA	-60%	-60%	-60%	-60%	-60%
108	NA	NA	-66%	-66%	-66%	-66%	-66%
109	NA	NA	-67%	-67%	-67%	-67%	-67%
110	NA	NA	-69%	-68%	-68%	-68%	-68%

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
GREATER ATLANTIC REGIONAL FISHERIES OFFICE
55 Great Republic Drive
Gloucester, MA 01930-2276

JUL 2 1 2016

Mr. David Borden, Chair
American Lobster Management Board
c/o Atlantic States Marine Fisheries Commission
1050 N. Highland Street, Suite 200 A-N
Arlington, VA 22201

Dear David:

Last year was a watershed year in lobster management. The Commission, states, and NOAA Fisheries created the novel Lobster Trap Transfer Database and successfully rolled out the Commission's groundbreaking Trap Transfer Program. In addition, the SNE stock gained new protections as state and federal managers implemented measures to reduce exploitation (Addendum XVII) and reduce traps (Addendum XVIII), with additional protective measures (trap banking and aggregate trap limits in Addenda XXI and XXII) on deck for future implementation.

To date, our SNE management efforts have been recommended and enacted based upon our understanding of the science that existed at the time. That understanding changed with the new stock assessment in 2015. This latest assessment unequivocally shows that the SNE stock is in a continued state of recruitment failure and in far worse condition than previously thought. The assessment and subsequent analyses by the Lobster Technical Committee (TC) indicated that significant reductions in exploitation are needed to stabilize the stock at current levels. Scientists are still trying to better understand the situation, but it appears that our recent SNE management efforts – so promising just a short time ago – may need to be augmented, amended, or altogether redone.

With so much uncertainty, it appears imprudent for us to publish a proposed rule for Federal trap cap and banking measures recommended within the context of the previous stock assessment from 2009. In light of this, we have suspended our Addenda XXI and XXII rulemaking efforts until we have a better understanding of our collective response to the SNE stock assessment. Nevertheless, we will continue to offer trap transferability to the industry as a tool to optimize their businesses and adjust to the annual trap reductions in Areas 2 and 3.

As we enter the next stage of our SNE management program, the TC is presently analyzing potential measures that would result in a 20- to 60-percent increase in SNE egg production. Recall that that Board chose this egg production approach at the May 2016 meeting with the hope that doing so would provide a meaningful response to the recent stock assessment. Although we have not seen the TC's final analysis, we are concerned that an egg production approach may not be measurable and, alone, will not provide sufficient reductions in exploitation to help stabilize the SNE stock. If the TC's report confirms this, we urge the Board to consider further action to adopt additional measures to sufficiently reduce exploitation and foster recruitment, with a focus on metrics that align more directly with the Lobster Plan's biological reference points, such as effective exploitation and reference abundance.

Finally, lobster harvester reporting is another issue that the Board will discuss at the August meeting. As I stated in my response to the Commission's letter to me on the topic dated May 26, 2016, we agree that improvements in reporting are achievable, however; we believe that such changes should be done through the Commission process and in a manner consistent with the states and the Lobster Plan. I encourage the Board to formally consider the data collection parameters of the Lobster Plan to more effectively address this issue.

Thank you for your interest in and commitment to the conservation of this important fishery and resource.

Sincerely,

John K. Bullard
Regional Administrator

cc: ASMFC American Lobster Management Board

Atlantic States Marine Fisheries Commission

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MEMORANDUM

TO: American Lobster Management Board

FROM: American Lobster Plan Review Team

DATE: July 19, 2016

SUBJECT: Comments on Maine's Conservation Equivalency Proposal

The Plan Review Team (PRT) met via conference call on July 18, 2016 to review Maine's conservation equivalency proposal regarding exchange tags. Below is a summary of the meeting:

PRT Attendees
Kathleen Reardon (ME)
Dan McKiernan (MA)
Allison Murphy (NMFS)
Pete Burns (NMFS)

ASMFC Staff
Megan Ware

The PRT supports Maine's proposal to attach lobster trap tags via hog rings because it improves compliance and enforcement in the lobster fishery. Since this program removes the need for exchange tags, the PRT believes Maine's conservation equivalency proposal will reduce the number of potential counterfeit tags in the water and alleviate the burden on Maine's marine patrol to trace extra tags in the system. Furthermore, given there have been reports of malfunctioning tags in Maine this year, the hog rings provide a useful alternative for fishermen to effectively attach tags to their traps. The PRT notes that this proposal is more conservative than other states which automatically issue Area 1 fishermen 80 extra tags to account for traps being taken in and out of the water.

Atlantic States Marine Fisheries Commission

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MEMORANDUM

TO: American Lobster Management Board

FROM: American Lobster Advisory Panel

DATE: July 19, 2016

SUBJECT: Comments on Maine's Conservation Equivalency Proposal

Comments from the Advisory Panel (AP) regarding Maine's Conservation Equivalency Proposal were submitted via email and telephone on July 18, 2016. Below is a summary of the comments:

AP Members Who Participated
Robert Baines (ME)
Arthur Sawyer (MA)

ASMFC Staff
Megan Ware

Both AP members supported Maine's proposal to attached lobster trap tags with hog rings. One AP member commented that "*the ability to transfer tags from one trap to another has been a time and money saver for those fishermen who need to re-tag traps. It had been an unnecessary burden on marine patrol to issue the new tags and to enforce the proper use of the exchange tags. This new program simply allows a fisherman to use the tags that were originally purchased for the duration of the year.*"

ACCSP Transition Document

July 26, 2016

Introduction

In May 2016, the ACCSP Coordinating Council and the Atlantic States Marine Fisheries Commission agreed to alter the governance structure of ACCSP. Under the new governance structure, ACCSP will be fully integrated into ASMFC and will be comparable to other ASMFC programs (e.g., ISFMP, Science). Prior to this governance change, ACCSP was an independent program with ASMFC serving as its administrative home.

This governance change will allow:

- Full integration of ACCSP with ASMFC management and science programs;
- Improved visibility among partners and stakeholders;
- Full incorporation of ACCSP activities into state and federal legislative outreach efforts;
- Consistent application of ASMFC policies for all staff;
- More consistent supervision of ACCSP Director.

This document details the plans for fully integrating ACCSP into ASMFC. An Addendum to the ACCSP Memorandum of Understanding (MOU) will also be developed to formalize all structural changes.

General

ACCSP will be fully integrated into ASMFC, while maintaining its identity for stakeholders and partners as the central fisheries dependent data entity for the Atlantic coast. ACCSP will maintain its current website to provide consistency and transparency for stakeholders seeking data or other information about the program. ASMFC will modify its website homepage to provide a link to the ACCSP site on the primary menu bar. This approach will allow stakeholders easy access through either website.

Outreach efforts will be continued to inform stakeholders of ACCSP's capabilities and resources. The primary function of ACCSP's outreach is to inform users and potential users of new developments and promote program capacities. ACCSP and ASMFC outreach experts will work closely together to develop content, network, and promote ACCSP.

Under this governance change, the ACCSP committee structure and membership will not change significantly. For example, the Coordinating Council and Operations Committee will maintain their current makeup and functions. However, there will be some changes to reduce redundancy between the ASMFC and ACCSP committees. For example, there is no need to have two separate Executive Committees.

The needed modifications to the ACCSP have been divided into short, medium and long-term changes. These are detailed below.

Short-Term Changes (0-6 months)

- ACCSP Director participates in ASMFC processes consistent with other ASMFC directors
- ACCSP staff will be guided by the ASMFC Employee Handbook
- ACCSP Coordinating Council composition remains the same, with continued focus on budgetary and data policy issues
  - Responsible for spending decisions of funding allocated to the Program
    - ASMFC Executive Committee will continue to determine (with NMFS concurrence) the allocation of ACFCMA funds between ASMFC, States, and ACCSP.
    - FIN funding for ACCSP will come directly from NMFS
- ACCSP (Management Committee, Leadership Committee, Policy Committee, Oversight Committee, Interim Action Committee etc.) responsibilities shift and committee composition changes:
  - **3 – State Reps -** One Coordinating Council member or proxy from each Region (see below). These seats may be filled by the Chair, Vice Chair and past Chair of the Coordinating Council.
    - Add additional state representative(s) beyond the Chair, Vice Chair, and the former Chair, if necessary (e.g., a federal partner is chair), to maintain three state regional representatives.
    - CC immediate past Chair, Ex Officio
    - The Coordinating Council Chair and Vice Chair shall serve as the Chair and Vice Chair of the Executive Committee, respectively. It is expected that these positions will usually be rotated among the three regions defined below: New England; Mid-Atlantic; South Atlantic.
  - 1 – NMFS or USFWS Representative
  - 1 – Council Representative for the three Councils (NEFMC, MAFMC, SAFMC)
  - ASFMC Executive Director
    - The ACCSP Director will provide staff support to the Executive Committee meetings.
  - Serves as a 'quick response' team when Coordinating Council is not meeting or is impractical.
  - Responsibilities consistent with Coordinating Council as a whole
- ACCSP Director provides at least semi-annual updates with budget highlights to ASMFC Executive Committee
  - Promotes buy-in from state directors
- Approve Addendum to MOU

Mid-Term Changes (6-12 months)

- Continue Integration
  - Look for staff efficiencies in technical and administrative support

- Consider integration of separate ASMFC and ACCSP outreach efforts
- Consider Information Systems changes (Phase out @accsp.org email addresses and provide ACCSP staff with @asmfc.org emails, etc.)

- Work towards ACCSP as primary data source for ASMFC needs. Find ACCSP-based solutions to ASMFC management and science data needs.
- Update all ACCSP SOPPs to be consistent with ASMFC and reflect the new governance structure.

Long Term Changes (~24 months)

- Integrate planning
  - Incorporate ACCSP Strategic planning into next ASMFC Strategic Plan
    - Both Strategic Plans end in 2018. The ACCSP activities will be included as a new goal in the ASFMC Strategic Plan and no new ACCSP Strategic Plan will be developed.
    - Incorporate provisions to add recommendations from external reviews of ACCSP.
  - ACCSP will fully participate in the ASFMC's annual Action Planning and budgeting process, including a new ACCSP goal in the Action Plan.
  - Consider the need to continue the ACCSP administrative grant. Possibly fold ACCSP administrative funding into ASFMC programmatic budget.
  - Evaluate the impacts of governance changes and see if additional adjustments are warranted.
  - Evaluate and report to CC if ACCSP has been invigorated, renewed engagement from State Directors, and program is advancing in its mission.

July 8, 2016

ADDENDUM

To the
MEMORANDUM OF UNDERSTANDING

For establishment of an

ATLANTIC COASTAL COOPERATIVE
STATISTICS PROGRAM

(ACCSP)

ACCSP Coordinating Council
APPROVED: XXXXXXX

INTRODUCTION

When first established in May 1995, Section 8 of the Memorandum of Understanding (MOU) for the Atlantic Coastal Cooperative Statistics Program (ACCSP) provided that:

> The Atlantic States Marine Fisheries Commission (ASMFC), the National Marine Fisheries Service (NMFS), and the U.S. Fish and Wildlife Service (USFWS) shall agree on the appropriate method of providing support staff and executive secretarial services to the Council and the Committee established under this Section, subject to the approval of the Council. Responsibility for the day-to-day coordination, planning and implementation of tasks associated with the program shall be the responsibility of all of the partners, under the guidance of the Council and the Committee.

During the first few years of existence, the ACCSP was in a planning stage. Planning was conducted by a variety of committees, with adequate staff support provided first by the ASMFC and then a coordinator from the USFWS who was detailed to the program for a year. As the program completed planning of various modules, it began evolving into an operational stage. Additional staff were required to support planning, building of the central data warehouse, and implementation activities. The need for a permanent home for the ACCSP staff was becoming apparent.

In June 1998, the ACCSP Coordinating Council approved a motion that:
- The ASMFC should serve as the administrative body for the ACCSP and its Coordinating Council,
- The ASMFC should hire new staff under the existing Commission structure to support ACCSP Partners with planning, prototype development, research, and implementation, and
- The services provided by the ASMFC to the ACCSP should be formalized through an addendum to the ACCSP MOU.

An Administrative Assistant, Information Technology Manager, Program Manager, and finally two additional information technology staff were hired from 1999 to 2001. As the program continued to grow, and the public became more aware of the existence and purpose of the ACCSP, discussion continued concerning the structure and support of the program. Options that were considered ranged from continuation of the status quo to complete separation of ACCSP into a stand-alone operational unit. A number of concerns influenced the choice:
- Perception – the public has concerns when data are collected by the same entity that is using the data for management. Separation of ACCSP from regulatory bodies, to the extent practical, was seen to help address this perception issue.
- The structure would be cost effective and meet the administrative obligations of ACCSP efficiently.
- Any structure would be within Current Legal Authority.
- The structure would reflect that the ACCSP is a partnership that includes the ASMFC, and is not just another ASMFC program.

- The structure would accommodate the continuing growth and maturity of ACCSP.
- There would be clear lines of authority within the program.

In July 2001, the Coordinating Council approved a motion that:
- The ASMFC will provide administrative support to the ACCSP.
- A new ACCSP Director position will be created to provide executive leadership for the program. The ACCSP Director will serve as overall program leader and will have executive authority to manage the continuing development and operation of ACCSP.
- The ASMFC Executive Director and ACCSP Coordinating Council Chair will conduct the performance review for the new ACCSP Director, with oversight by the ACCSP Executive Committee.

The Coordinating Council felt that this decision was the best solution for all concerns. ACCSP would be separated from other ASMFC programs, which addresses perception issues. The structure is within current authorities and would meet the ACCSP's administrative obligations in an efficient, cost-effective manner. The Director would provide leadership and management of the program and be the public view of ACCSP. The continued growth and maturity of the program would be well served with a single, strong program leader. Clear lines of authority were provided for policy/program guidance and staff performance review. This resulted in an amendment to the MOU implementing these recommendations.

In 2012, the Program conducted an Independent Program Review (IPR) that resulted in a series of recommendations. To address one of the ACCSP's 2012 IPR recommendations to "undergo a governance review" the Executive Committee formed a Governance Ad-Hoc Workgroup (Workgroup). The IPR Panel Report indicated they "realize that the situation today is very different than 1995[1], when the ACCSP was created. ACCSP needs a better relationship and interface with Atlantic States Marine Fisheries Commission (ASMFC), and linkages established and strengthened. Consideration should be given to placing ACCSP as a program under ASMFC, which could possibly re-engage the state directors. There are issues of economy of scale and potential improvements to efficiency that could be gained, working relationships strengthened, resources leveraged, etc."

It was the recommendation of the workgroup, approved by the ACCSP Coordinating Council and the ASMFC Executive Committee and Commission as a whole in May 2016, that ACCSP be folded into ASMFC as a Program. Under this alternative the ACCSP would be incorporated into the ASMFC, and ACCSP would be congruent with existing ASMFC programs such as the Interstate Fishery Management Program (ISFMP). The ASMFC Executive Director would directly supervise the ACCSP Director, and all staff would be governed by existing ASMFC governance structures. This alternative should not have any affect under the current budget of ACCSP or ASMFC.

[1] Original Memorandum of Understanding between partners framed the ACCSP in 1995.

AMENDMENT

This Addendum incorporates the June 1998, July 2001 and May 2016 program changes into the MOU, as follows:

All references in Section Eight to *Atlantic Fisheries Statistics* are be amended to read *ACCSP*.

Section 8 is amended to read:

A. *Atlantic Fisheries Statistics Coordinating Council.* There shall be an Atlantic Fisheries Statistics Coordinating Council (hereafter: Council). The Council shall oversee the design and implementation of the ACCSP, set policy to guide the Program and the partners participation therein, allocate funding dedicated to the Program, establish Committees as necessary, and recommend solutions for any issue related to the program raised by any of the partners to the ASMFC Executive Committee. The Council members, who shall represent the policy levels within their agencies with the ability to make policy commitments therefore, shall be: one voting representative of each signatory partner, plus three (3) additional nonvoting representatives from NMFS. The Council shall make its decisions by consensus where possible, or by majority vote. The Council shall elect its Chair and Vice Chair.

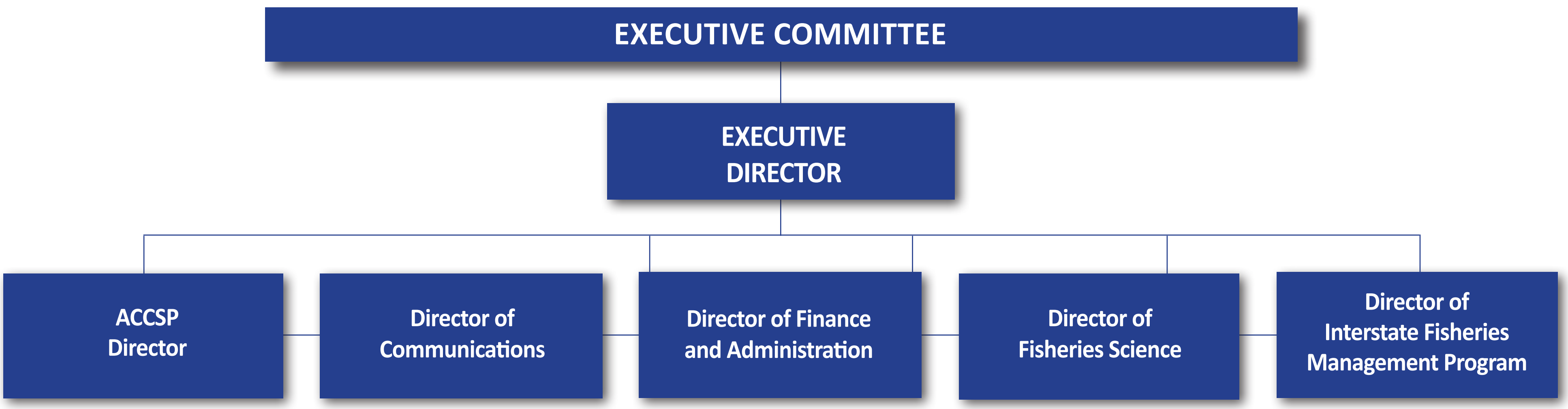
B. *ACCSP Operations Committee.* The ACCSP Operations Committee will recommend program priorities, funding criteria, and other items as requested by the Coordinating Council, and/or ACCSP Director. It shall also be responsible for maintaining the *Program Design*, making changes to fisheries standards as needs evolve. The Operations Committee is comprised of an experienced staff person from each partner and one representative each from the National Marine Fisheries Service Headquarter Office of Science and Technology, Southeast Fisheries Science Center, Southeast Regional Office, the Greater Atlantic Fisheries Regional Office, and the Northeast Fisheries Science Center. The Operations Committee shall make its decisions by consensus.

C. *ACCSP Director.* The ACCSP Director serves as overall program leader and has authority to manage the continuing development and operation of ACCSP consistent with guidance from the Coordinating Council. The ACCSP Director reports to and receives guidance from the Executive Director of ASMFC who in turn shall abide by the data management, collection and standards policy decisions made by the Coordinating Council with respect to the ACCSP mission. The ACCSP Director will be responsible for supervision of ACCSP staff. Specific responsibilities include providing overall guidance to all ACCSP staff, ensuring the policies of both the ASFMC and ACCSP are met by ACCSP staff, coordinating long-range planning and budget requirements, , and conducting annual performance evaluations of ACCSP staff. Hiring and firing of ACCSP staff shall be consistent with ASMFC policy. The ACCSP Director will provide staff support to all ACCSP Committees and Subcommittees and administer any grant or cooperative agreement associated with the ACCSP.

D. *ASMFC Program Support*.

The ASMFC Executive Director shall ensure that the ACCSP Director is accountable for implementation of the ACCSP program elements and for carrying out policies of the Coordinating Council. The ASMFC Executive Director, in consultation with the ACCSP Coordinating Council Chair will conduct the annual performance review for the ACCSP Director consistent with ASMFC policy.

The ASMFC shall provide appropriate administrative and logistical services/support for ACCSP operations, as with all other ASMFC programs. The ACCSP long term and annual planning processes shall be integrated with those already in existence for ASMFC, conform to policy as set by the Council and informed by periodic independent reviews of the ACCSP.


EXECUTIVE COMMITTEE
EXECUTIVE DIRECTOR
ACCSP Director
Director of Communications
Director of Finance and Administration
Director of Fisheries Science
Director of Interstate Fisheries Management Program

Atlantic States Marine Fisheries Commission

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MEMORANDUM

TO: Atlantic Menhaden Management Board

FROM: Atlantic Menhaden Advisory Panel

DATE: July 14, 2016

SUBJECT: AP Recommendations on Draft Addendum I and 2017 Fishery Specifications

The Advisory Panel (AP) met via conference call on July 14, 2016 to formulate comments on Draft Addendum I and provide recommendations for the 2017 fishery specification process. Panel members in attendance represented commercial harvesters, recreational anglers, and conservation coalition members. The following is a summary of the conference call.

Attendees

Advisory Panel Members
Donald Swanson (NH)
Jeff Kaelin (NJ, Chair)
John Dean (MD)
David Sikorski (MD)
Ken Hinman (Non-trad)

ASMFC Staff
Megan Ware

TC Members
Jeff Brust (NJ)

Commissioners
Bob Ballou
Michelle Duval
Nichola Meserve
Rob O'Reilly

Public
Peter Himchak
Kate Wilke
John Rosano
Shaun Gehan
Aaron Kornbluth

2017 Fishery Specifications

AP members reviewed the TC's June 22, 2016 memo on projection runs for the 2017 fishery specifications. The AP was split in its recommendations to the Board with two members recommending the coastwide TAC remain the same until final action on Amendment 3 (**187,880 mt**) and two members supporting a TAC which has a 50% probability of being below the F target (**267,500 mt**).

- Two AP members advised the Board maintain the current TAC (187,880 mt) until Amendment 3 is completed and implemented in 2018. They stated that the purpose of the Amendment is to re-allocate menhaden between states and the ecosystem. To change the TAC before this time would be premature given ecological reference points are being developed and there is an on-going socio-economic study on the commercial fishery. Furthermore, they expressed concern that the projections are based on the current single-species reference points and therefore do not consider the impact of an increased TAC on predators. Overall, these AP members recommended the Board maintain the 187,880 mt TAC until the ecological and socio-economic implications of an increase can be fully understood.

- Two AP members recommended the Board increase the TAC to a level that has a 50% probability of being below the F target in 2017 (267,500 mt). They felt that the resource is under-fished since there is a high abundance of juvenile fish in the bays and estuaries and many state's directed fisheries are already closed. As a result, they felt the risk associated with a 50% probability of exceeding the F target is well within the sustainable limits of the menhaden fishery. These AP members also stated the recent stock assessment was robust in considering predator needs and they were not concerned that the projections are based on single-species reference points. Furthermore, they stated that Amendment 3 will primarily focus on allocation and, as a result, there is no need to hold off on a decision regarding an increase to the coastwide TAC.
- One AP member felt that a 40% increase in the coastwide TAC was too large, but did not provide specific detail on what level of TAC he preferred.

Draft Addendum I

AP members also reviewed Draft Addendum I and supported **Option C**, which allows two authorized individuals working from the same vessel fishing stationary multi-species gear in a limited entry fishery to land up to 12,000 pounds per day, and **Option D**, which allows two permitted fishermen working from the same vessel fishing pound nets to land up to 12,000 pounds per day.

- Two AP members supported Option C, highlighting that this option is a robust way to provide flexibility to multiple gear types which harvest under the bycatch provision. They felt it was important these gears be part of a limited entry fishery since this would ease enforcement.
- One AP member supported Option D, noting that for some states Options B, C, and D are the same.
- Another AP member supported an option which ensures bycatch allowances can be accurately monitored and easily enforced.
- One AP member did not have a preference for an option.

Atlantic States Marine Fisheries Commission

PUBLIC INFORMATION DOCUMENT

For Amendment 3 to the Interstate Fishery Management Plan For

ATLANTIC MENHADEN

July 2016

Vision: Sustainably Managing Atlantic Coastal Fisheries

This initial draft document was developed for Management Board feedback and discussion. This document is not intended to solicit public comment as part of the Commission/State formal public input process. The Board will consider approval of an updated draft document for public comment in October 2016.

The Atlantic States Marine Fisheries Commission seeks your input on the initiation of Amendment 3 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 Month Day, 201X.** 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 when developing the first draft of Amendment 3.

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:

Megan Ware
Fishery Management Plan Coordinator
Atlantic States Marine Fisheries Commission
1050 North Highland Street, Suite 200A-N
Arlington, Virginia 22201
Fax: (703) 842-0741
mware@asmfc.org (subject line: Menhaden PID)

If you have any questions please call Megan Ware at (703) 842-0740.

YOUR COMMENTS ARE INVITED

The Atlantic States Marine Fisheries Commission (Commission) is developing an amendment to revise the interstate fishery management plan (FMP) for Atlantic menhaden. The Commission, through the coastal states of Maine through Florida, is responsible for managing Atlantic menhaden.

This is your opportunity to inform the Commission about changes observed in the fishery, actions you feel should or should not be taken in terms of management, regulation, enforcement, and research, and any other concerns you have about the resource or the fishery, as well as the reasons for your concerns.

WHY IS THE ASMFC PROPOSING THIS ACTION?

At the May 2015 meeting, the Menhaden Board initiated the development of Amendment 3 to the Atlantic Menhaden FMP to pursue the development of Ecological Reference Points (ERPs) and revisit allocation methods.

The 2015 Atlantic Menhaden Benchmark Stock Assessment and Peer Review Report categorized the development of ERPs as a high priority for Atlantic menhaden management. Currently, the stock is assessed with single-species biological reference points based on maximum spawning potential. However, this method does not consider the ecological role that menhaden serve as forage fish or how changes in the population of predator species may impact the abundance of menhaden. ERPs will consider the broad role that menhaden play in the ecosystem by incorporating data on the status of several predator and prey species, and is a tool that could improve the management of menhaden. Additionally, Amendment 2 (2012) requires that state quota allocations be revisited every 3 years. Atlantic menhaden quota is currently allocated to states based on a three average catch between 2009 and 2011. In revisiting the allocations, the Board decided to investigate different allocation methods and timeframes given concerns that the current allocation scheme does not strike an equitable balance between gear types and regions.

In order to pursue the implementation of ERPs as well as changes to the current quota allocations, the Board needs to consider changes in the management tools used to regulate the fishery. This document proposes a suite of management tools which consider different types of current reference points and allocation methods.

WHAT IS THE PROCESS FOR DEVELOPING AN AMENDMENT?

The publication of this document and announcement of the Commission's intent to amend the existing FMP for Atlantic menhaden is the first step of the formal amendment process. Following the initial phase of information gathering and public comment, the Commission will evaluate potential management alternatives and the impacts of those alternatives. The Commission will then develop Draft Amendment 3, incorporating the identified management options, for public review. Following that review and public comment, the Commission will specify the management measures to be included in Amendment 3, as well as a timeline for implementation. In addition to issues identified in this Public Information Document (PID), the Draft Amendment may include issues identified during the public comment period of the PID.

The timeline for completion of Amendment 3 is as follows:

	Oct 2016	Nov 2016 – Jan 2017	Feb 2017	Mar – July 2017	Aug 2017	Sept – Oct 2017	Nov 2017
Approval of Draft PID by Board Current Step	**X**						
Public review and comment on PID		**X**					
Board review of public comment; Board direction on what to include in Draft Amendment 3			**X**				
Preparation of Draft Amendment 3				**X**			
Review and approval of Draft Amendment 3 by Board for public comment					**X**		
Public review and comment on Draft Amendment 3						**X**	
Board review of public comment on Draft Amendment 3							**X**
Review and approval of the final Amendment 3 by the Board, Policy Board and Commission							**X**

WHAT IS THE PURPOSE OF THIS DOCUMENT?

The purpose of this document is to inform the public of the Commission's intent to gather information concerning Atlantic menhaden and to provide an opportunity for the public to identify major issues and alternatives relative to the management of this species. Input received at the start of the amendment development process can have a major influence in the final outcome of the amendment. This document is intended to solicit observations and suggestions from fishermen, the public, and other interested parties, as well as any supporting documentation and additional data sources.

To facilitate public input, this document provides a broad overview of the issues already identified for consideration in the amendment; background information on the Atlantic menhaden population, fisheries, and management; and a series of questions for the public to consider about the management of the species. In general, the primary question on which the Commission is seeking public comment is: **"How would you like the Atlantic menhaden fisheries to look in the future?"**

WHAT ISSUES WILL BE ADDRESSED?

The primary issues considered in the PID are:

- Reference Points
- Commercial Fishery Management Tools

ISSUE 1: Reference Points

Background: The 2015 Atlantic Menhaden Benchmark Stock Assessment established single-species biological reference points based on the maximum spawning potential of the population. The reference points include a measure of fishing mortality (F) to determine an overfishing designation and a measure of fecundity to determine an overfished status. The F target and threshold are 0.38 and 1.26, respectively, while the fecundity target and threshold are 189,270 billion eggs and 86,821 billion eggs, respectively. As of 2013, the stock is not overfished (170,536 billion eggs) and overfishing is not occurring (F=0.22). These reference points were recommended for use by the Technical Committee and Stock Assessment Peer Review Panel.

Given the crucial biological role which menhaden play as a forage fish, the Board has expressed interest in developing ecological reference points by which to manage the menhaden stock. Forage fish serve an important role in the ecosystem as they provide a food source to a variety of species including larger fish (ie: weakfish, striped bass), birds, and marine mammals. As a result, changes in the abundance of menhaden may have implications for the larger ecosystem. Ecological reference points (ERPs) provide a method to assess the status of menhaden while considering the interactions with predators and other prey species. This method accounts for changes in the abundance of several species when setting an overfished and overfishing threshold for menhaden. The benefit of this approach is that is allows fishery managers to consider the harvest of menhaden within the context of the predators that the species supports.

In May 2015, the Board tasked the Biological Ecological Reference Point Workgroup (BERP) with developing ERPs for Atlantic menhaden. As a first step in this process, the BERP identified four modeling approaches which could be used to successfully calculate ERPs for menhaden. Given the complexity of these models and the large amounts of data required, it is expected that these ERPs will be finished after Amendment 3 is finalized. The BERP will be having several data, assessment, and modeling workshops over the next few years in order to finish the ERPs by 2019.

The Lenfest Ocean Program, a grantmaking program which is managed by Pew Charitable Trusts, has also developed guidelines for the development of ERPs for forage fish. In their 2012 report by Pikitch et al, Lenfest describes how they applied a suite of 10 published models to evaluate a variety of harvest control rules which specify fishing intensity. From these models they developed a general equation to predict predator responses to specific levels of forage fish abundance. This equation by Pikitch et al. (2012) proposes that fishing mortality for menhaden not exceed half of the species natural mortality rate and that, when biomass falls below 40% of the biomass expected under an unfished stock, fishing be prohibited.

The BERP was asked to review the ERPs proposed by Pikitch et al (2012) and noted several concerns with the analysis. The primary concern of the BERP was that the Lenfest equation was developed for forage species that are a main component (> 50%) of a predator's overall diet. Although menhaden are important forage for a number of marine species, and may be a main food source for some species during certain seasons, they do not account for more than 20% of the overall diet for any of the finfish predators currently included in the BERP multispecies model. The BERP also raised concerns that the Pikitch et al (2012) equation assumes a stock-recruit relationship can be defined for the forage species. Available data indicate, however, that recruitment of menhaden is driven primarily by environmental effects rather than stock size. For these reasons, the BERP recommended that the Lenfest equation was not an appropriate method for developing ERPs for menhaden (See Appendix 1 for BERP Memo dated April 20, 2015).

Moving forward, there are several options for the Board (Table 1) with respect to reference points. The Board could continue use of the single-species reference points approved in the 2015 stock assessment. The Board could also adopt the ERPs proposed by Pikitch et al (2012) or, upon completion, adopt the ERPs created by the BERP. Given that the BERP ERPs will not be completed before 2019, the Board would have to choose interim reference points by which to manage the menhaden stock.

Table 1. Current reference points and those proposed by Pikitch et al (2012). FEC is a fecundity reference point to determine an overfished status while F is a fishing mortality reference point to determine whether overfishing is occurring.

Reference Points	Benchmark
F (current single species threshold)	1.26
F (current single species target)	0.38
F (Pikitch et al 2012)	0.29
F (in 2013)	0.22
FEC (current singles species threshold)	86,821 billion eggs
FEC (current single species target)	189,270 billion eggs
FEC (in 2013)	170,536 billion eggs

Statement of the Problem: Given the ecological importance of menhaden as a forage fish, the Board is interested in developing ERPs for the stock. Options for ERPs include those proposed by Pikitch et al (2012) and those which are currently being developed by the BERP. If the Board wants to pursue the ERPs developed by the BERP, interim reference points must be selected given this modeling work will not be completed until 2019.

Option A: Single Species Reference Points (Status Quo)
The Atlantic menhaden stock is managed with single-species biological reference points developed in the 2015 benchmark stock assessment. These set an F target and threshold of 0.38 and 1.26, respectively, and a fecundity target and threshold of 189,270 billion eggs and 86,821 billion eggs, respectively.

Option B: Pikitch et al (2012) Ecological Reference Points
The Atlantic menhaden stock is managed with the ecosystem based reference points proposed by Pikitch et al (2012). Under these reference points, fishing is prohibited when biomass levels fall below 40% of the unfished biomass. Above this level, fishing mortality does not exceed half the species' natural mortality rate. The calculated F reference point under this scenario is 0.29.

Option C: Interim Reference Points Until New Ecological Reference Points Are Developed
The Atlantic menhaden stock is managed under interim reference points until the ecological reference points developed by the BERP are completed in 2019. Potential interim reference points could include the current single species biological reference points, the Pikitch et al (2012) ecological reference points, or another control rule.

Public Comment Questions: Should the Board manage the Atlantic menhaden stock with ecological reference points? Do you support the use of interim reference points until analysis is complete by the BERP?

ISSUE 2: Quota Allocation

Background: Amendment 2 established a commercial total allowable catch (TAC) for Atlantic menhaden and divided this catch into commercial quotas for participating jurisdictions (ME through FL). A TAC and quota system were adopted in order to respond to the overfishing stock status from the 2010 stock assessment and cap landings in the commercial fishery. Since it was implemented in 2013, the quota system has been able to successfully limit the harvest of menhaden. The 2015 benchmark stock assessment found that the Atlantic menhaden stock is not overfished and overfishing is not occurring. As a result, the 2015 and 2016 TACs were raised 10%, from the 2013–2014 level of 170,800 mt to 187,880 mt. (See Table 1 in Appendix 1 for the state allocations and yearly quotas).

Amendment 2 requires that allocation be revisited every three years. Currently, the TAC is divided among jurisdictions based on average landings between 2009 and 2011. In beginning the discussion on quotas, the Board decided to re-visit the allocation methods given concern that this approach does not strike an equitable balance between gear types and regions, as well as the present needs of the fishery versus future growth opportunities. More specifically, because 85% of the quota is allocated to Virginia, where the last remaining menhaden reduction fishery takes place, increases in the TAC provide limited benefit to the small-scale bait fisheries along the coast. Additionally, given improvements in the condition of the Atlantic menhaden stock, the process of determining allocation on historical catch could limit states who currently have minimal quota from participating in the growing fishery. Some states have also found evidence of un-reported landings during the reference period, meaning the quota system may have reduced their fisheries to a greater extent than originally intended.

Given these concerns, the Board is interested in exploring other allocation strategies. Many fisheries use quotas to limit effort in the fishery and provide examples of how catch can be allocated. Atlantic herring quota is currently allocated by season in the inshore management area. None of the quota is allocated between January and May due to spring spawning and interactions with other fisheries; 72.8% of the quota is available from June through September and 27.2% from October through December. Northern shrimp allocates its quota by gear-type with 87% of catch allocated to the trawl fishery and 13% allocated to the trap fishery. This was done to ensure participation by trap fishermen who harvest northern shrimp later in the season. Spiny dogfish uses both a regional and state allocation system with the northern region (ME–CT) receiving 58% of the quota and the states of NY through NC receiving individual state shares. This allocation system was used to allow Southern states the ability to participate in the fishery before the total allowable catch is caught by the northern most states.

In May 2015, the Menhaden Board established an Allocation Working Group to initiate the process of revisiting quota allocation. During their discussion the

Allocation Working Group considered landings history, the performance of state fisheries, and the challenges associated with the current management plan. As a result, they created a broad range of allocation options which are presented below. Information on menhaden landings by jurisdiction, gear type, and disposition can be found in Tables 2 and 3 and Figure 1 of Appendix 1. Graphical representations of each of the quota options, including how they relate to quota transfers, overage pay-back, and rollovers are included in Appendix 3.

Statement of the Problem: Amendment 2 requires that menhaden allocation be revisited every three years. The Board is exploring different allocation strategies due to several concerns with the current state by state quotas, including inequitable access to quota among gear types and the inability for some states to participate in the growing fishery.

Option A. Jurisdictional Quotas (Status Quo)
Quotas are allocated to each state/jurisdiction in the management unit based on its landings during a selected reference period.

Option B. State-specific Quotas with Fixed Minimum
Quotas are allocated to each state/jurisdiction in the management unit based on its landings during a selected reference period; however, no state/jurisdiction receives less than a minimum fixed percent quota (e.g., 1% of the coastwide TAC). A minimum fixed quota allocation provides growth opportunity for states that have small quotas and has been used in other ASMFC management plans (e.g., American eel).

Option C. Coastwide Quota
There is one coastwide quota which applies to the entire Atlantic menhaden fishery.

Option D. Seasonal Quotas
The TAC is divided into designated seasons. Under this option, it may be possible to consider further allocation (e.g., regional, state by state) of the season-specific quotas to provide equitable access to the fishery.

Option E. Regional Quotas
Quotas are allocated to designated regions. The intent of these geographic delineations would be to capture the spatial dynamics of the fishery. Specific regional options include:

1. Two region split: (1) North, defined as waters north of Machipongo Inlet, VA, on the Delmarva Peninsula; and (2) South, defined as waters south of Machipongo Inlet, including the Chesapeake Bay. These regions match those used for stock assessment purposes in the 2015 Benchmark Stock Assessment.
2. Two region split: (1) Chesapeake Bay; and (2) Coast.

3. Three region split: (1) New England, defined as ME–CT; (2) Mid-Atlantic, defined as NY–DE; and (3) Chesapeake Bay South, defined as MD–FL.
4. Four region split: (1) New England, defined as ME–CT; (2) Mid-Atlantic, defined as NY–DE; (3) Chesapeake Bay, defined as MD–VA; and (4) South Atlantic, defined as NC–FL.

Option F. Disposition Quotas

Quotas are allocated to the bait and reduction fisheries separately. The intent of this option is to capture the different dynamics that exist between the bait and reduction fisheries. Under this option, it may be possible to consider further allocation (e.g., regional, state by state) of the disposition-specific quotas to provide equitable access to the quota.

Option G. Fleet Capacity Quotas

Quotas are allocated to various fleets based on their harvest capacity, as determined by gear type. The intent of this option is to capture the different scales of operation that exist in the fishery and their dynamics. It may be possible to consider further allocation (e.g., regional, state by state, disposition) of the capacity-specific quotas to provide equitable access to the quota. Some of the specific fleet capacity options below include a "soft quota" concept, which sets a target quota but does not subject the fleet to a fishery closure. The intent of a soft quota is to restrict the retention of menhaden but add flexibility for additional catch in years when fish are abundant.

Specific fleet options include:

1. Two Fleet Capacity Allocation

Small Capacity Fleets:

Types of gears in the small-capacity fleet include, but are not limited to, cast net, trawl, trap/pot, haul seine, fyke net, hook and line, pound nets and gill nets. Total coastwide landings for these small capacity gears are approximately 22 million pounds annually or 5% of coastwide landings from 2009–2012. The small capacity fleet could be defined by a trip limit such that a vessel must land less than X pounds of menhaden to fish in the small capacity fleet; otherwise they would move to the large capacity fleet. Alternatively (or additionally), a trip limit could be established if small capacity fleet harvest grows to an unacceptable level. Given the small capacity of these gear types, this fleet would be managed with a soft quota (e.g., 5% of the coastwide TAC), but this harvest would be allowed to fluctuate above the quota in years when fish are available (Figure 1). The majority of non-purse seine menhaden harvest is taken by fixed, multi-species gears, which include pound nets, anchored/staked gill nets, and fyke nets. Harvest from these gears fluctuates with the availability of fish in the area. Flexibility in the quota would minimize menhaden discards from this fleet.

Large-Capacity Fleet:

Types of gears in the large-capacity fleet include, but are not limited to, purse seines and pair trawls. Total coastwide landings are approximately 436.2 million pounds annually or approximately 95% of the coastwide TAC from 2009–2012, and include both bait and reduction fishery harvest. Given the large capacity of these gear types, this fleet would be managed with a hard quota (e.g., 93–96% of the coastwide TAC).

2. Three Fleet Capacity Allocation

Small-Capacity Fleet:

Types of gears in the small-capacity fleet include, but are not limited to, cast net, trawl, trap/pot, haul seine, fyke net, and hook and line. Total coastwide landings for these small-capacity gears are approximately 3.14 million pounds annually or roughly 1% of the coastwide TAC from 2009–2012. Given the small capacity of these gear types, this fleet would be managed with a soft quota (e.g., 1% of the coastwide TAC).

Medium-Capacity Fleet:

Types of gears in the medium-capacity fleet include, but are not limited to, pound nets and gill nets. Total coastwide landings for these gear types are approximately 18.92 million pounds annually or 4% of the coastwide TAC from 2009–2012. Given the medium capacity of these gear types, this fleet would be managed with a soft or hard quota (e.g., 6–8% of the coastwide TAC).

Large-Capacity Fleet:

Types of gears in the large-capacity fleet include, but are not limited to, purse seines and pair trawls. Total coastwide landings for these gears are approximately 436.2 million pounds annually or 95% of the coastwide TAC from 2009–2012, and include both bait and reduction fishery harvest. Given the large capacity of these gear types, this fleet would be managed with a hard quota (e.g., 93–96% of the coastwide TAC).

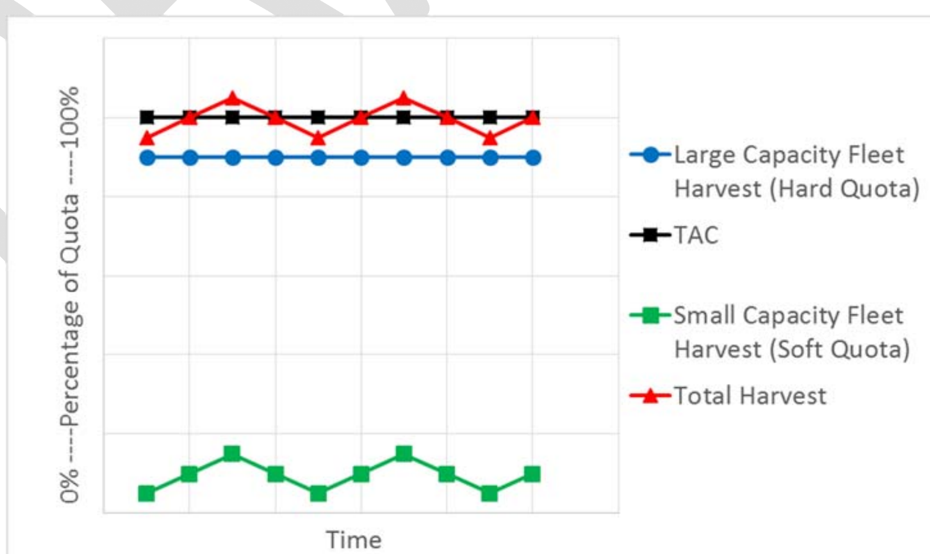

Figure 1. A graphical representation of the two fleet capacity allocation showing the fluctuating small capacity bait harvest and its impact on total harvest relative to the quota.

Public Comment Questions: What allocation mechanisms provide for the fair and equitable distribution of coastwide total allowable catch? Which allocation scheme strikes a balance between current needs and future growth opportunities? Do you support the use of soft quotas for some user groups?

ISSUE 3: Allocation Timeframe

Background: As part of its required review of menhaden allocation, the Board is also considering changes to the reference period on which quota is based. Amendment 2 divides the total allowable catch into jurisdictional quotas based on average landings between 2009 and 2011. The primary question facing the Board is whether this timeframe represents a fair and equitable picture of coastwide menhaden catch.

Statement of the Problem: Amendment 2's reference period does not consider recent changes in the fishery. In addition, some states have expressed concerns about underreported harvest during 2009–2011. In revisiting state-by-state quotas, the Board must decide if these three years are an appropriate timeframe on which to base allocation.

Option A: 2009–2011 Average (Status Quo)
Quota allocation is based on a three-year average catch between 2009 and 2011.

Option B: 2009–2012 Average
Quota allocation is based on a four-year average catch between 2009 and 2012. 2012 was the last year prior to the implementation of Amendment 2 in 2013.

Option C: Weighted Allocation
Allocation is weighted over two time periods: a more distant period and a more recent period. For example, 50% of the allocation could be based on average landings between 2009 and 2012 while the other 50% of allocation could be based on average landings between 2013 and 2015. Weighting is intended to balance prior trends in the fishery with recent changes in catch.

Public Comment Questions: Should the Board consider changes to the reference period on which menhaden allocation is based? Should allocation consider prior trends as well as recent changes in the fishery?

ISSUE 4: Quota Transfers and Overage Payback

Background: Amendment 2 allows for two or more states to transfer (or combine) their Atlantic menhaden quota. Transfers often occur when a jurisdiction has exceeded its allocation for the year; rather than reduce its subsequent year quota by the amount of the overage, as required by Amendment 2, a state can receive quota from another state which did not harvest its entire allocation. These transfers do not permanently affect a state's quota allocation. All states participating in a transfer (i.e., the donor states and the receiving states) must individually submit signed letters to the Commission, requesting approval for the transfer of a specified poundage of menhaden. Transfers are not final until written approval in granted by the Executive Director.

As a practical matter, fisheries routinely yet inadvertently exceed or under perform their quota due to the challenges of quota monitoring, including delays in reporting and unanticipated changes in catch rates. Transfers are a highly useful technique to address these occurrences. However, some regions may be disadvantaged by the quota transfer system due to the timing of their fishery relative to other fisheries along the coast, meaning they may not know that they've had an overage until late in the year when available quota has already been donated. Furthermore, there is no ASMFC guidance on how to apportion unused quota if there are multiple transfer requests at the same time.

Other fisheries allow for quota transfers and provide examples of potential management tools. The black sea bass fishery allows for quota reconciliation such that, in a year where the coastwide quota is not exceeded, any state-specific overage is automatically forgiven in its entirety. This streamlines the transfer process and avoids the need for written approval from the individual states and the ASMFC Executive Director. In years when the coastwide quota is exceeded, states which did not meet their allocation may transfer their un-used quota to a common pool. This common pool quota is then re-distributed to states that exceeded their quota based on the existing allocation proportions and the magnitude of the overage. Any overages that remain after the re-distribution of unused quota are deducted the subsequent year.

Statement of the Problem: Amendment 2's procedure for quota transfers may not benefit states evenly, lacks specific guidance, and can be an administrative burden on donor and receiving states. Consequently, the Board is considering a quota reconciliation process to address quota overages, as a replacement of quota transfers for this purpose. Quota transfers could still occur for other reasons (e.g., a state grants a vessel safe harbor with catch destined for another state that is then unloaded there). In the case of the fleet capacity quota allocation options, reconciliation would not be necessary for any fleet assigned a soft quota.

Option A: Quota Transfers (Status Quo)
Two or more jurisdictions, under mutual agreement, may transfer or combine their Atlantic menhaden quota to address an overage, per the Amendment 2 process. Any remaining overage, after all quota transfers are conducted, is deducted from the jurisdictions subsequent year's quota.

Option B: Voluntary Quota Transfers to Shared Pool
Any jurisdiction with a quota underage can determine whether to make all or part of its unused quota accessible to states with quota overages via a shared pool. Quota in the shared pool is distributed to states with overages through an established process (e.g., state negotiations or based on existing allocation proportions). Any remaining overage, after all shared pool transfers are conducted, is deducted from the jurisdictions subsequent year's quota. The intent of this option is to add equity and guidance to the transfer process, without sacrificing a state's option to rollover unused quota.

Option C: Overage Reconciliation
In a year where the coastwide TAC is not exceeded, any quota overage would be automatically forgiven in its entirety. In a year where the coastwide TAC is exceeded, but at least one entity has an underage, the unused quota is automatically pooled and distributed to those with overages, thereby lessening the amount of their payback the following year. A process is followed for how the pooled unused quota is distributed (e.g., negotiations or based on existing allocation proportions). The reconciliation process replaces the quota transfer process to address quota overages. Additionally, because states must forfeit their unused quota for the shared pool, this option is incompatible with quota rollovers.

Public Comment Questions: Should the process for quota transfers be further defined or replaced by an automatic reconciliation process? Should state-specific quota overages be automatically forgiven in years when the coastwide total allowable catch is not exceeded? When the coastwide TAC is exceeded, would a transfer or reconciliation process following established protocols treat all states more fairly than the current quota transfer system?

ISSUE 5: Quota Rollovers

Background: Amendment 2 allows for unused quota to be rolled over for use in the subsequent fishing year only when the stock is not overfished and overfishing is not occurring. At the time of implementation (2013), the Atlantic menhaden stock was considered not overfished but overfishing was occurring. As a result, the amendment deferred defining the specifics of the rollover program until overfishing was no longer occurring.

In 2015, a new benchmark stock assessment was approved for management use which found the stock is not overfished and overfishing is not occurring. As a result, the stock met the qualifications for quota rollovers; however, how much quota can be carried into the next year has not been established. In August 2015, the Board agreed to consider the details of quota rollovers in Amendment 3. Other species, including spiny dogfish and Atlantic herring, allow for a percentage (5% and 10%, respectively) of unused quota to be rolled over from one year to the next. For example, in the spiny dogfish fishery, if a state's annual quota is 1 million pounds, a maximum of 50,000 pounds (5%) of unused quota can be rolled over into the subsequent year.

Statement of the Problem: The Atlantic menhaden stock is not overfished and overfishing is not occurring, thereby qualifying the stock for quota rollovers per Amendment 2. However, the details of a quota rollover program were not specified in Amendment 2, preventing any rollovers from occurring.

Option A: Quota Rollover Permitted
Any unused quota may be rolled over from one year to the next. The issues of quota reconciliation and quota rollover are mutually exclusive, such that it is not possible to have quota overages automatically forgiven via reconciliation and unused quota rollover over into the subsequent fishing year. Any soft quota would also not be eligible for any unused quota rollover over into the subsequent fishing year.

Option B: Limited Quota Rollover Permitted
A jurisdiction's unused quota may be rolled over into the subsequent year as long as the amount does not exceed a percentage of the jurisdiction's allocation. For example, a jurisdiction may be allowed to rollover up to 10% of its quota. This means that if a state is allocated 1 million pounds of quota and lands 500,000 pounds, the state may only roll over 100,000 pounds (10% of 1 million pounds) into the subsequent fishing year. The issues of quota reconciliation and quota rollover are mutually exclusive, such that it is not possible to have quota overages automatically forgiven via reconciliation and unused quota rollover over into the subsequent year. Any soft quota would also not be eligible for any unused quota rollover over into the subsequent fishing year.

Option C: No Quota Rollover Permitted
Quota underages may not be rolled over from one year to the next.

Public Comment Questions Should unused quota be rolled over into the subsequent year? Should the amount rolled over be limited to a percent of quota? Should all sectors of the fishery be allowed to roll over quota?

ISSUE 6: Bycatch Allowance

Background: Upon a state reaching its individual quota and closing its directed fishery, Amendment 2 provides an incidental bycatch allowance of up to 6,000 pounds of Atlantic menhaden per trip for non-directed fisheries. The bycatch allowance is tied to a vessel such that a single vessel cannot land more than 6,000 pounds per trip. As specified in Amendment 2, bycatch landings which occur during a state designated open season count towards a state's quota; however, bycatch landings following the closure of a state's directed fishery do not count towards the quota.

Coastwide, the vast majority of menhaden harvested under the bycatch allowance is with stationary multi-species gears. Table 4 in Appendix 1 shows the average bycatch landings between 2013 and 2015 by gear and jurisdiction. On average, 5.7 million pounds of menhaden bycatch are landed each year, representing 1-2% of total landings in the fishery. Over 80% of the bycatch harvest comes from stationary gears with the biggest contributors being the Maryland pound net fishery and the Virginia anchored gill net fishery. Cast nets contribute 6% of bycatch landings and represent the largest contributor from the mobile gear sector. This is followed by drift gill nets (5%) and beach seines (3.7%). Jurisdictions in the Chesapeake Bay contribute the most to bycatch landings of menhaden, with Maryland harvesting 40.7%, Virginia harvesting 24.9%, and the Potomac River Fisheries Commission harvesting 15.4% of annual coastwide bycatch landings. Between 2013 and 2015, 59.6% of bycatch trips using stationary gears landed less than 1,000 pounds of menhaden and 80.7% trips landed less than 3,000 pounds of menhaden (Table 5 in Appendix 1).

Several concerns have been raised regarding the current bycatch provision. The first is that landings under the bycatch allowance do not count toward a state's quota. As a result, bycatch landings could undermine the efficacy of the coastwide TAC since there is no yearly bycatch limit. Another concern is that neither bycatch nor non-directed fisheries are defined in Amendment 2. This leads to questions of whether Atlantic menhaden bycatch must remain under a specific percent composition of catch and whether small-capacity gears which direct on menhaden, such as cast nets, should be included in the bycatch provision. Currently, Massachusetts is the only state to require menhaden bycatch be less than 5% of the weight of the entire catch landed on that trip. Finally, the current bycatch provision dissuades cooperative fishing since the bycatch allowance is per vessel rather than permitted individual. This is particularly problematic in the Chesapeake Bay where it is traditional for multiple permitted individuals to work together from the same vessel to harvest menhaden. Addendum I…[*Paragraph to be updated following final action on Addendum I*]

Statement of the Problem: Under Amendment 2, there is 6,000 pound incidental bycatch limit per vessel per trip for non-directed fisheries. Several issues have been identified with this bycatch allowance, namely that bycatch is not included in the

TAC, the allowances does not support cooperative fishing, and there is no definition of what constitutes bycatch or a directed fishery.

Option A: 6,000 lbs Bycatch Limit per Vessel (Status Quo)
Currently, there is a 6,000 pound incidental bycatch limit per vessel per trip. This bycatch limit is permitted for non-directed fisheries following the closure of the directed fishery. [*Option to be updated following final action on Addendum I*].

Option B: Bycatch Included in Quota
All bycatch of menhaden would count toward the directed fishery quota. Once the quota is reached, the menhaden fishery would be closed and no landings would be allowed.

Option C: Bycatch Cap and Trigger
Rather than a trip limit, bycatch in the Atlantic menhaden fishery would be limited by a harvest cap. If the collective bycatch landings exceed this cap by a certain percentage in a single year or by any percentage in two consecutive years, management action would be triggered by the Board to reduce bycatch landings in the fishery.

Option D: Bycatch Allowance per Permitted Individual
An incidental bycatch limit would be established per person/trip, rather than per vessel/trip. As a result, multiple permitted individuals on the same vessel could each land the bycatch limit.

Option E: Bycatch Trips Defined by Percent Composition
Trips landing greater than 1,000 pounds of menhaden would be required to maintain their menhaden landings under a specific percent composition of catch. This option can be combined with either a bycatch allowance per trip or a bycatch cap in order to limit menhaden bycatch landings in the non-directed fisheries.

<u>Public Comment Questions?</u> Should there by a cap on bycatch landings in the Atlantic menhaden fishery? Should bycatch be defined as a percent composition? Should the bycatch allowance be allocated to vessels or permit holders?

ISSUE 7: Episodic Events Set Aside

<u>Background</u>: Amendment 2 sets aside 1% of the overall TAC for episodic events, which are times and areas where Atlantic menhaden are available in more abundance than they normally occur. The purpose of the set aside is to enable increased harvest of menhaden during episodic events so as to minimize discards in the fishery. The details of the program were approved by the Board in May 2013 and are outlined in Technical Addendum I.

Eligibility in the episodic events set aside program is reserved for the New England states (Maine through Connecticut). To participate in the program, these states must implement daily trip level harvest reporting, restrict the harvest and landing of menhaden under the episodic events program to state waters, and implement a maximum daily trip limit no greater than 120,000 pounds/vessel. In order for a state to declare participation in the episodic events program, a state must demonstrate that it has reached its quota prior to September 1 and provide information indicating the presence of unusually large amounts of menhaden in its state waters. Any set aside quota that is not used by October 31 can be added to the coastwide quota and redistributed to the states. If the set aside quota is exceeded, overages are deducted from the next year's episodic event set aside amount.

In 2014 and 2015, Rhode Island was the only state to declare participation in the episodic set aside program, harvesting 8% of the set aside in 2014 and 45% of the set aside in 2015 (Table 2). In 2016, Rhode Island again declared participation in the program and New York requested inclusion in the episodic events set aside. While New York is not considered a New England state under Technical Addendum I, New York highlighted the unusually large amounts of menhaden in the Peconic Bay estuary and the potential for fish kills. The Board approved New York's request to harvest under the episodic events set aside, capping New York's harvest under the program to 1 million pounds.

Table 2: Episodic events set aside for 2013-2015 and the percent used by participating states.

Year	Set Aside (lbs)	Landed (lbs)	% Used	State	Unused Set Aside Reallocated (lbs)
2013	3,765,491				
2014	3,765,491	295,000	8%	RI	3,470,491
2015	4,142,040	1,883,292	45%	RI	2,258,748

Given the increasing amounts of menhaden landed under the episodic events program and New York's request to harvest under the set aside, the Board is considering changes to the program. Specific questions include whether the percent of TAC allocated to the set aside should be increased, which states should be allowed to participate in the program, and whether the current definition of an episodic event is appropriate. Furthermore, the Board is considering whether changes to the allocation of quota may negate the need for such a set aside.

<u>Statement of the Problem:</u> Since 2013, participation in and landings under the Episodic Events Set Aside Program have increased. As a result, the Board is considering changes to the scope of the program, including the amount of quota allocated to the set aside and which states are qualified to participate.

Option A: 1% of TAC (Status Quo)
The states of Connecticut through Maine are allowed to participate in the episodic events set aside program. 1% of the TAC each year is set aside for episodic events, which are defined as a state meeting its quota before September 1st and experiencing large amounts of menhaden in its state waters.

[Additional options will be included following August Board discussion]

Public Comment Questions? Should a percentage of the TAC be set aside for episodic events? If yes, how much quota should be set aside and which states should be allowed to participate in this program?

ISSUE 8: Chesapeake Bay Reduction Fishery Cap

Background: The Chesapeake Bay reduction fishery is currently limited by a harvest cap of 87,216 metric tons. The goal of this restriction is to prevent all of the reduction fishery harvest from occurring in the Chesapeake Bay, a critical nursery area for Atlantic menhaden. Harvest by the reduction fishery is prohibited within the Chesapeake Bay when 100% of the cap has been reached. A maximum of 10,976 metric tons of un-landed fish can be rolled over into the subsequent year's harvest cap. The Chesapeake Bay reduction fishery has consistently underperformed the 87,216 metric ton harvest cap, landing less than 50,000 metric tons in 2015, less than 45,000 metric tons in 2014, and less than 40,000 metric tons in 2013.

The Chesapeake Bay Reduction Fishery Cap, which was originally implemented in 2005, was intended to prevent the localized depletion of menhaden. There was an assumption that the potential for localized depletion exists in the Chesapeake Bay given the concentrated harvest of the species in the area, particularly from the reduction fishery. Possible outcomes of localized depletion include compromised predator-prey relationships and chronic low recruitment of larval menhaden. The Board committed to assessing the potential for localized depletion at its February 2005 meeting and established the Atlantic Menhaden Research Program (AMRP) to evaluate the possibility of such depletion occurring. In 2009, work completed under the AMRP was peer reviewed by the NOAA Center for Independent Experts (CIE). The peer review concluded localized depletion was not occurring in the Chesapeake Bay. It also noted that given the high mobility of menhaden, the potential for localized depletion could only occur on a "relatively small scale for a relatively short time".

Given that harvest by the reduction fishery has consistently been below the cap and recent evidence suggestions that localized depletion is not occurring in the Chesapeake Bay, the Board would like feedback on whether this is an important management tool in the Atlantic menhaden fishery.

Statement of the Problem:
The Chesapeake Bay Reduction Fishery Cap was intended to protect menhaden nursery areas and prevent against localized depletion; however the reduction fishery has consistently under-performed its harvest cap and a peer review report concluded localized depletion is not occurring in the Chesapeake Bay. The Board would like feedback on whether this is an essential management tool.

Public Comment Questions: Should the Chesapeake Bay Reduction Fishery Cap be maintained? Is it an important tool for the management of Atlantic menhaden?

BACKGROUND INFORMATION ON THE MANAGEMENT AND STOCK STATUS OF ATLANTIC MENHADEN

Summary of Fishery Management

The Commission has coordinated interstate management of Atlantic menhaden (*Brevoortia tyrannus)* in state waters (0-3 miles) since 1981. Management authority in the exclusive economic zone (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. Subsequent addenda (I-V) to Amendment 1 sought to improve the biological reference points for menhaden and cap the reduction fishery. Addenda II and III instituted a harvest cap on the Chesapeake Bay Atlantic menhaden reduction fishery for the 2006 through 2010 fishing seasons. Addendum IV extended this harvest cap through 2013. Addendum V, which was approved in November 2011, established 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.

The Atlantic menhaden fishery is currently managed through Amendment 2 to the Atlantic Menhaden FMP, which was passed in 2012 and implemented in 2013. It sets a coastwide total allowable catch for the stock and allocates this harvest into state quotas. Amendment 2 also establishes a bycatch provision which allows for the harvest of up to 6,000 pounds of Atlantic menhaden per trip for non-directed fisheries and sets aside 1% of the overall TAC for episodic events. In order to effectively implement the management measures established in Amendment 2, states are required to implement timely reporting systems to monitor catch.

Technical Addendum I outlines the provisions of the episodic events set aside program. It restricts participation in the program to the New England states and requires these states to implement daily harvester reporting, restrict harvest to states waters, and set a 120,000 pound daily trip limit in order to harvest under the set aside. Technical Addendum I also outlines a process for declaring participation in the program.

Addendum I to Amendment 2 revisits the bycatch provision and considers allowing two licensed individuals to harvest up to 12,000 pounds of menhaden bycatch when working from the same vessel fishing stationary, multi-species gear. *[Additional information will be added following final action on Addendum I]*

Summary of Stock Status

The latest peer reviewed stock assessment is the 2015 benchmark assessment. The assessment used the Beaufort Assessment Model, a statistical catch-at-age model which estimates population size at age and recruitment in 1955 and then projects the population forward in time to the terminal year of the assessment (2013). The model estimates trends in population dynamics, including abundance at age, recruitment, spawning stock biomass, egg production, and fishing mortality rates.

Model results indicate the population has undergone several periods of both high and low abundance over the time series. Biomass has fluctuated over time from an estimated high of over 2,284,000 metric tons in 1958 to a low of 667,000 metric tons in the mid-1990s. Population fecundity (measured as number of maturing ova, or eggs) has also varied throughout the time series with a large number of eggs seen in the early 1960s, the 1970s, the early 1990s, and the 2000's. Fishing mortality has steadily decreased throughout the model time series. This is primarily due to a decrease in harvest in the reduction fishery which peaked in the late 1950's at over 700,000 metric tons and decreased to roughly 130,000 metric tons in 2013. In contrast, bait landings have slowly increased from roughly 30,000 metric tons in the late 1980s to over 60,000 metric tons in 2012.

Population fecundity in 2013 was estimated to be 170,536 billion eggs, well above the fecundity threshold of 86,821 eggs (Figure 2). As a result, the population is deemed not overfished. Overfishing is also not occurring as the fishing mortality in 2013 (0.22) is below the fishing mortality target of 0.38 (Figure 3).

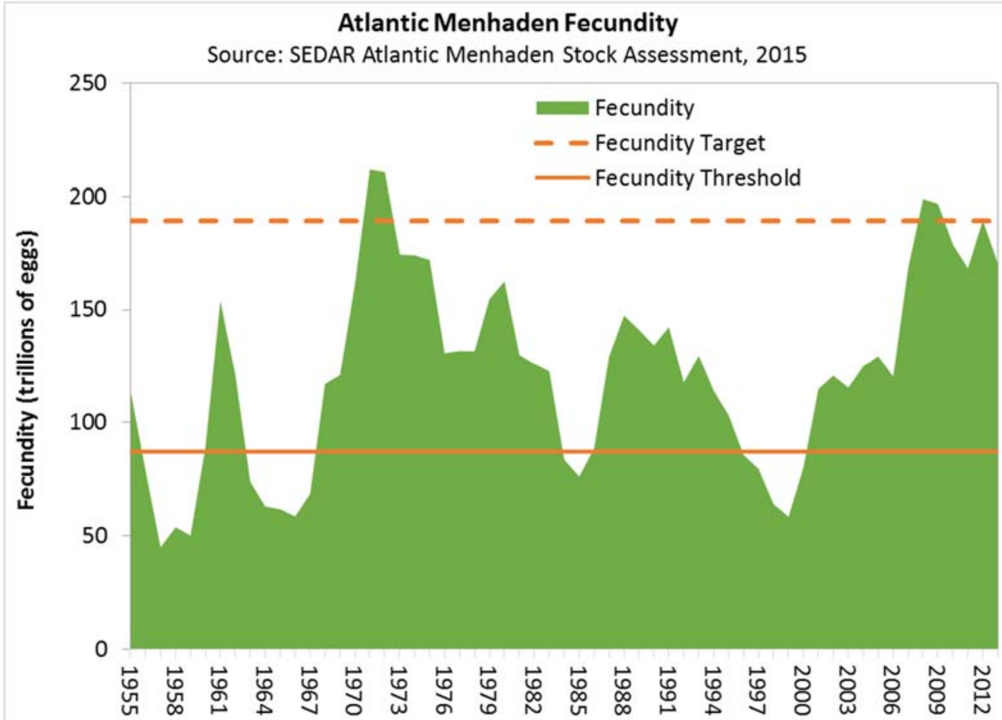

Figure 2: Atlantic menhaden fecundity target and threshold from the 2015 stock assessment. Population fecundity in 2013 was estimated to be 170,536 billion eggs, well above the fecundity threshold of 86,821 eggs.

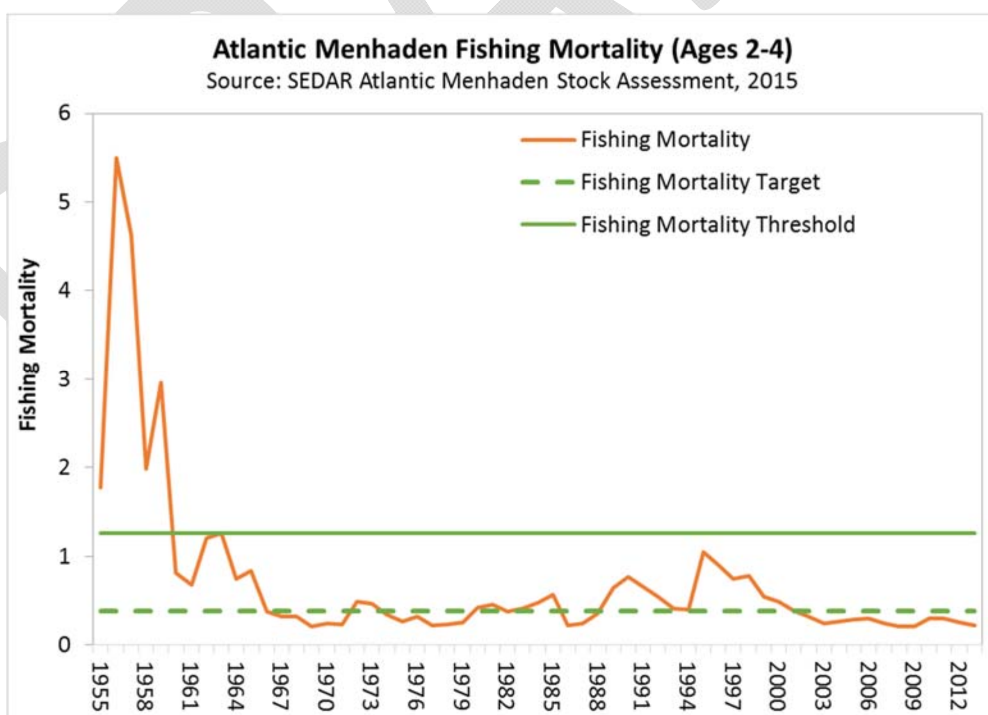

Figure 3: Atlantic menhaden fishing mortality target and threshold from the 2015 stock assessment. Overfishing is also not occurring as the fishing mortality in 2013 (0.22) is below the fishing mortality target of 0.38.

Social and Economic Impacts

Changes in the allocation of total allowable catch are expected to have socioeconomic impacts on affected states/jurisdictions, regions, and fishery interests. Overall, improvements in the menhaden stock which lead to increased TAC should benefit fishery participants; however, reductions in allocation to a particular area or interest could lead to reduced employment and associated reductions in the economic benefits derived from menhaden. In general, the reduction sector is expected to take fish in response to the allowable catch in relation to prices of competing oils (for example flax or other vegetable oils), and demand for oil and fishmeal products. The bait sector is expected to take fish in response to allowable catch in relation to the following factors: available fish, competing products (for example herring as bait for lobster), demand for menhaden as a primary desired bait, and prices for competing products in addition to the cost of fishing, fuel and vessel maintenance.

Currently, there is little socioeconomic data available with which to assess the specific effects of changes in allocation and other management actions. The Commission's Committee on Economics and Social Sciences (CESS) issued a request for proposals to fund research in order to characterize the coastwide commercial fisheries, including the bait and reduction sectors and the fishery communities they support. The study will gather both primary and secondary information from stakeholders to understand spatial trends in landings, the distribution of revenue, operational costs, and participation in the fishery. A project was selected early in 2016 and the research is presently being conducted. It is anticipated that this data and other project deliverables will be available to the Commission and CESS early in 2017. Information from this survey will be incorporated into Draft Amendment 3.

References

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Appendix 1

Table 1. Atlantic Menhaden Allocation and Quotas for 2013-2016. Current state-by-state allocation is based off of average landings between 2009 and 2011. Quota totals do not include the 1% of the TAC which is reserved for the Episodic Events Set Aside Program. Florida exceeded their quota in 2015 and this overage is deducted from their 2016 quota.

State	Allocation	2013-2014 Quota (lbs)	2015-2016 Quota (lbs)
ME	0.00039	146,787	161,466
NH	0.0000003	112	123
MA	0.00839	3,126,024	3,438,630
RI	0.00018	66,779	73,457
CT	0.00017	65,034	71,537
NY	0.00055	206,695	227,365
NJ	0.11192	41,721,164	45,893,335
DE	0.00013	49,230	54,153
MD	0.01373	5,116,874	5,628,568
PFRC	0.00621	2,314,174	2,545,595
VA	0.85322	318,066,790	349,873,884
NC	0.00493	1,836,948	2,020,645
SC	0.00000	-	-
GA	0.00000	-	-
FL	0.00018	66,995	73,695 (72,030 in 2016)
TOTAL	**-**	**372,783,605**	**410,062,453**

Table 2: Atlantic menhaden total landings (1985-2015) by jurisdiction. Total landings include directed harvest, bycatch, and landings from the Episodic Events Set Aside Program.

	ME	NH	MA	RI	CT	NY	NJ	DE	MD	PFRC	VA	NC	SC	GA	FL
1985	33,192,713		3,039,625	8,388,046	234,800	901,800	2,879,766	176,135	5,372,193	16,768,889	17,320,505	97,738,403	C		7,579,674
1986	C		3,411,000	10,389,187	254,400	399,650	2,453,593	20,081	5,449,350	10,971,973	9,885,311	66,377,931	9,952		7,997,973
1987	18,668,660		1,215,175	13,609,224	94,900	206,795	2,563,163	22,034	5,793,683	13,120,698	14,318,627	55,498,571	C		2,776,777
1988	19,687,805	C	8,047,320	15,583,437	175,200	504,100	1,984,045	127,713	6,430,164	13,231,368	44,976,740	73,715,713	500		1,026,228
1989	380,619	C	1,459,402	19,033,173	148,500	449,100	2,854,361	104,382	6,166,236	8,334,174	24,310,430	66,756,288			1,372,959
1990	5,744,597	264,500	1,709,605	17,102,650	96,706	649,710	9,041,459	167,116	1,662,275	4,523,776	18,224,186	72,231,989			2,636,497
1991	16,107,463	204,000	12,798,310	5,090,375	96,300	650,150	16,597,402	278,774	3,540,179	5,376,264	14,487,238	110,528,754			2,062,983
1992	14,857,195	C	13,499,450	2,849,359	91,200	1,131,701	27,470,906	130,833	1,777,088	5,061,565	16,233,980	57,515,712	C		2,788,592
1993	19,520,455	C	1,211,569	5,146,280	195,827	1,048,993	28,296,741	164,046	2,326,613	7,884,001	296,453,210	64,711,384			2,584,766
1994			351,251	533,800	60,128	961,474	38,176,201	78,672	2,369,071	6,680,937	270,775,349	73,853,901			1,387,012
1995			2,910,613	5,873,315	255,264	1,087,978	36,572,507	101,388	4,264,754	7,002,818	360,140,489	58,374,081			687,944
1996			8,500	802	82,851	11,135	35,516,726	100,063	3,906,808	5,111,423	294,195,660	53,850,943			294,936
1997			238,500	5,750	72,329	553,953	38,118,579	55,733	3,457,237	5,757,370	267,021,139	97,727,057	C		408,492
1998	C	C	121,200	400	338,817	430,084	33,287,641	58,048	2,933,818	3,980,738	513,879,901	57,976,455			301,566
1999	C		292,800	2,330	30,298	242,886	27,753,567	78,551	4,460,534	4,860,883	374,942,360	42,799,080			288,144
2000	C		72,600	320,000	14,423	565,800	31,266,780	47,980	3,935,307	5,023,374	358,236,761	56,280,112			260,710
2001	C		144,600	-	38,865	576,426	26,375,573	53,257	3,970,243	3,329,035	484,528,580	56,012,396			179,951
2002	70,062		301,500	5,750	1,138,788	444,739	24,716,412	80,261	4,023,389	3,122,050	362,640,618	69,190,596			55,304
2003			218,255	62	46,515	384,875	17,080,463	42,593	3,163,252	2,438,790	372,486,794	48,936,502			35,810
2004		C	-	39,232	33,210	543,481	20,678,813	75,635	5,369,952	5,411,043	394,100,339	50,577,983			21,220
2005	30,302		2,177,724	14,453	30,636	871,081	17,574,826	120,658	10,635,776	4,759,905	368,988,147	13,386,245			39,404
2006	37,297		2,524,255	15,524	866,235	811,934	21,290,309	111,405	6,841,296	3,413,517	365,305,722	962,648			157,117
2007	C	C	5,543,805	8,948	90,254	483,557	37,202,485	81,850	11,370,064	5,036,906	405,836,300	1,134,167			71,373
2008	4,310,055	C	14,131,256	269,288	104,881	410,121	38,210,688	72,970	8,153,008	4,820,645	339,001,968	645,231			60,098
2009	166,942	33	6,719,048	107,548	170,907	330,496	33,329,177	69,476	7,756,192	3,191,905	335,238,841	2,124,733			52,800
2010	C	C	4,973,857	78,149	42,489	394,556	50,497,253	51,933	6,903,300	2,790,728	404,384,758	1,299,130			76,593
2011	C		116,151	83,899	26,929	279,117	74,324,485	70,326	6,506,430	2,759,597	389,652,459	3,529,967			146,534
2012	39,383	C	1,648,395	106,606	37,454	258,271	85,457,890	130,725	13,737,314	5,892,228	386,552,474	538,783			126,141
2013	C		2,314,888	99,821	26,463	1,187,525	39,819,342	125,909	7,074,727	3,295,295	316,537,921	454,172			224,872
2014	C		2,226,294	500,903	36,552	825,549	41,449,670	161,509	7,005,271	3,175,893	322,492,690	917,375			220,587
2015	C		2,932,128	1,802,089	77,003	1,468,165	47,811,837	150,542	7,551,430	2,739,035	350,524,668	839,637	C		377,729
% of total landings 1985-2015	**1.4%**	**0.0%**	**0.8%**	**0.9%**	**0.0%**	**0.2%**	**7.9%**	**0.0%**	**1.5%**	**1.6%**	**73.6%**	**11.8%**	**0.0%**	**0.0%**	**0.3%**

Table 3: Atlantic menhaden coastwide landings averages by gear type for 2009-2012 and 2013-2014. Bycatch allowance landings are included in the 2013-2014 average. Data are preliminary and subject to change.

Landings in Pounds	2009-2012 Average	Percent by Gear	2013-2014 Average	Percent by Gear
Purse Seine	436,211,312	95.188%	353,766,645	94.207%
Pound Net	16,129,566	3.520%	13,990,507	3.726%
Trawl	2,639,414	0.576%	1,444,210	0.385%
Gill Net	2,784,530	0.608%	5,052,734	1.346%
Cast Net	213,494	0.047%	750,823	0.200%
Trap/Pots	104,775	0.023%	156,790	0.042%
Fyke Net	51,994	0.011%	3,865	0.001%
Haul Seine	64,215	0.014%	118,651	0.032%
Other	65,608	0.014%	237,735	0.063%
Total	**458,264,908**	**100%**	**375,521,959**	**100%**

Table 4: Average landings under the bycatch allowance from 2013-2015 by gear type and jurisdiction. The highlighted cells indicate the high bycatch landings in the Maryland pound net fishery and the Virginia anchored gill net fishery. (C)= confidential landings and (-)=no landings. Total confidential landings were 209,277 pounds (i.e., the sum of all C's in the table below). Note that the sum of pounds and percent of total columns do not include confidential data.

State/Jurisdiction	RI*	NY	NJ**	DE	MD	PRFC	VA	FL	Sum lbs (NonConf)	% of Total
Stationary Gears While Fishing										
Pound net	57,231	128,854	C	-	2,306,552	884,843	122,913	-	3,500,393	60.9%
Anchored/stake gill net	C	-	100,202	28,998	5,131	-	1,242,512	C	1,376,843	24.0%
Pots	-	C	-	C	10,001	-	-	C	10,001	0.2%
Fyke nets	-	-	C	-	C	-	C	-	<1000	0.0%
Mobile Gears While Fishing										
Cast Net	C	183,137	C	-	C	-	-	163,776	346,913	6.0%
Drift Gill net	-	18,175	129,620	66,117	16,082	-	57,794	-	287,788	5.0%
Seines Haul/Beach	-	206,587	-	-	C	-	5,119	-	211,706	3.7%
Trawl	C	9,733	C	-	-	-	-	-	9,733	0.2%
Hook & Line	C	-	-	-	C	-	-	C	<300	0.0%
Sum lbs (NonConf)	**57,231**	**546,485**	**229,822**	**95,116**	**2,337,766**	**884,843**	**1,428,339**	**163,776**	**5,744,572**	
% of Total	1.0%	9.5%	4.0%	1.7%	40.7%	15.4%	24.9%	2.9%		

NJ** an ad hoc method was used to split gill net data between stationary and mobile gears
RI* trips do not include those landed under the episodic events set aside because those landings are counted as part of the directed fishery.

Table 5: Total number of bycatch allowance trips landing menhaden by stationary gears from 2013-2015 by jurisdiction and percent of total trips by 1,000 pound landings bins. (C)= confidential landings.

Bins (LBS)	VA	MD	PRFC	NJ	NY	DE	RI*	FL	Total Trips	Total Bin%
1-1000	71%	35%	31%	85%	88%	91%	53%	100%	5,350	59.6%
1001-2000	13%	12%	21%	10%	9%	4%	14%	0%	1,176	13.1%
2001-3000	7%	8%	15%	3%	C	4%	18%	0%	716	8.0%
3001-4000	3%	7%	10%	1%	3%	1%	4%	0%	426	4.7%
4001-5000	3%	7%	13%	C	C	1%	3%	0%	441	4.9%
5001-6000	2%	14%	10%	C	C	0%	6%	0%	519	5.8%
6000+	0%	16%	0%	C	C	0%	3%	0%	351	3.9%
Total Trips	**4672**	**2057**	**1138**	**477**	**345**	**165**	**102**	**23**	**8,979**	
Total Trips %	52.0%	22.9%	12.7%	5.3%	3.8%	1.8%	1.1%	0.3%		

RI* trips do not include those landed under the episodic event set aside because those landings are counted as part of the directed fishery.

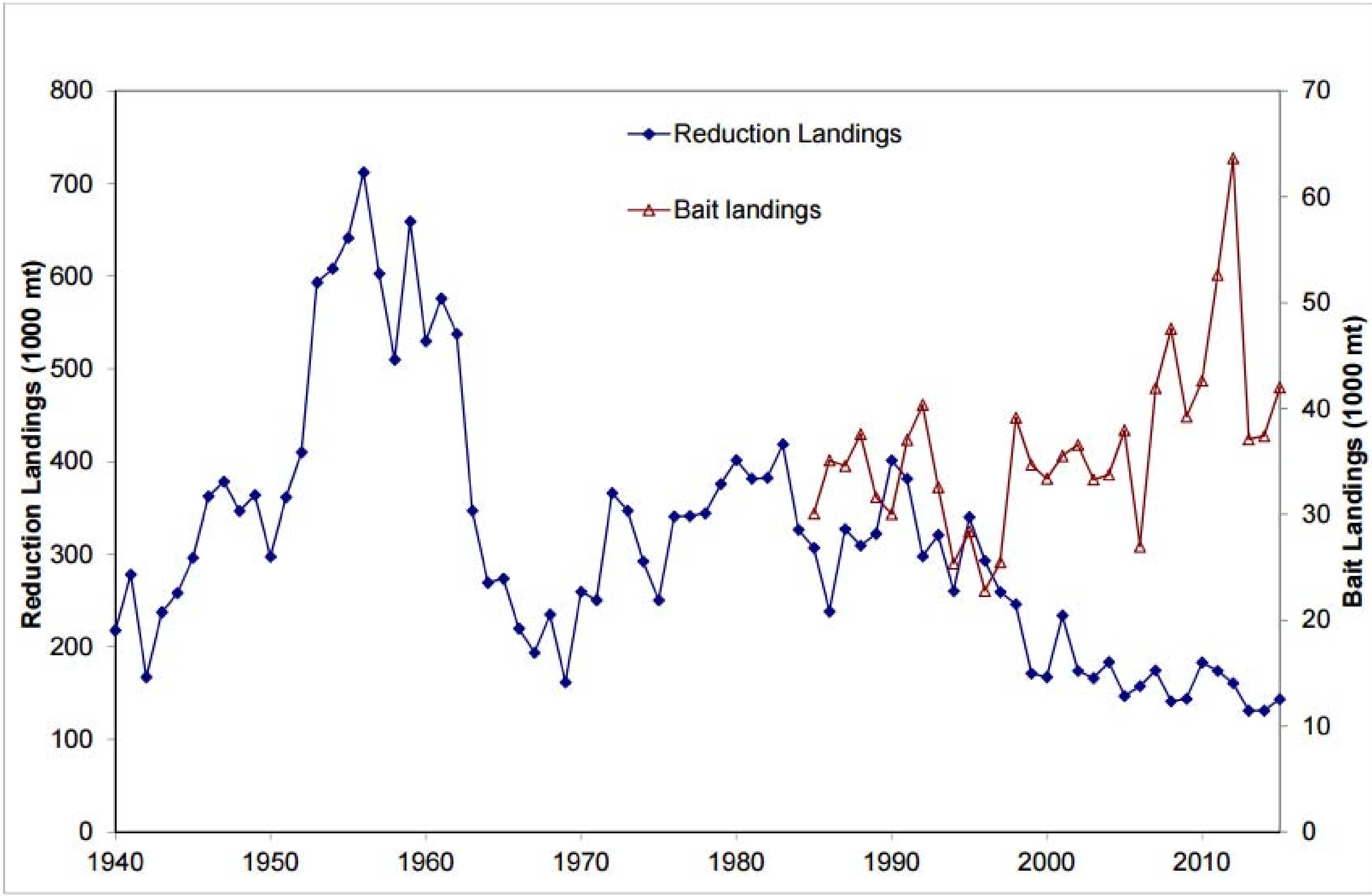

Figure 1: Landings from the reduction purse seine fishery (1940-2015) and the bait fishery (1985-2015) for Atlantic menhaden.

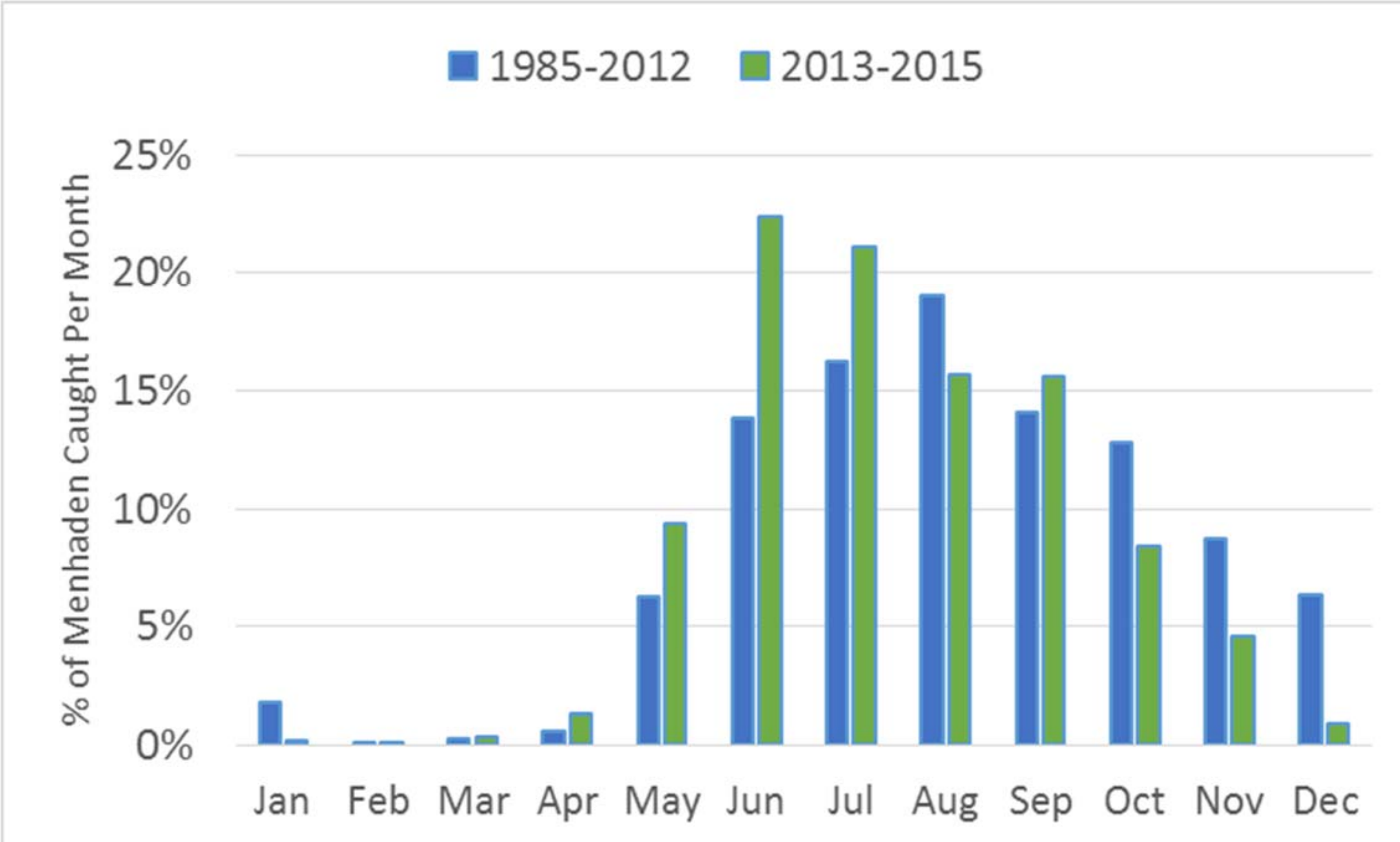

Figure 2: Percent of landings from the menhaden commercial fishery by month. Blue bars show landings from 1985 to 2012 and the green bars show landings from 2013-2015 (following the implementation of Amendment 2).

Appendix 2

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

April 20, 2015

To: **Atlantic Menhaden Management Board**

From: **Biological Ecological Reference Points Workgroup**

RE: **Ecological Reference Points using Pikitch et al. (2012)**

At its February meeting, the Atlantic Menhaden Management Board (Board) tasked the BERP WG with developing ecological reference points for Atlantic menhaden using Pikitch et al. (2012) as described in the ERP Report. As the Workgroup noted in the ERP Report, models or ERPs presented in the ERP report required further review by the BERP WG. To complete this task, the Workgroup reviewed the methodology by Pikitch et al. (2012) to determine which "information tier" Atlantic menhaden fit into. Subsequently, the WG evaluated the applicability of the recommended management action associated with that information tier. After detailed discussions, the WG concluded:

1. The WG recognizes that the recommendations in Pikitch et al. (2012) are based on the idea that the variable stock dynamics of forage species, like Atlantic menhaden, may require additional managment precautions than other non-forage species.
2. The WG acknowledges that while the ERPs referenced in Pikitch et al. (2012) may be a bet-hedging strategy, it assumes that there must be some stock-recruitment relationship that has not yet been identified for Atlantic menhaden.
3. The WG decided that menhaden fall under the "intermediate information tier" as defined by Pikitch et al. (2012), with strong caveats (please see the attached table).
4. The intermediate information tier recommends management actions in the form of applying a hockey stick harvest control rule with $B_{LIM} \geq 0.4B_0$ and F=0.5M. In this scenario, fishing would be prohibited when biomass levels fall below 40 percent of unfished biomass. When biomass is greater than 40 percent of unfished biomass, the fishing mortality would not exceed half the species' natural mortality rate. The recommended fishing mortality rate from Pikitch et al. (2012) and a comparison to the

2015 Benchmark Stock Assessment single species reference points are displayed below including the terminal year F_{2013}.

Reference Points/Terminal Year F	**Benchmark**
$F_{26\%MSP}$ (threshold)	1.26
$F_{57\%\ MSP}$ (target)	0.38
$F_{64\%\ MSP}$ (Pikitch et al. 2012)	0.29
$F_{70\%\ MSP}$ (F in terminal year 2013)	0.22

5. The WG notes that many of the case studies examined in Pikitch et al. (2012) involved predators that were "highly dependent" (i.e., ≥50% of diet) on a single forage species, with strong trophic effects caused by changes in forage abundance. However, in the case of the coast-wide stock of Atlantic menhaden, the primary predator species are more opportunistic, consuming a diverse prey base.
6. While the WG was able to identify that striped bass may meet the Pikitch et al. (2012) predator dependency definition (with menhaden as forage) at certain times of the year and in certain areas (e.g., Chesapeake Bay in winter), the WG determined that none of our predator species of interest could fit the criteria of "highly dependent" predator (with menhaden as forage) on a coast-wide scale. Therefore, the WG does not believe the reference point recommendations in Pikitch et al. (2012) are applicable to this system.
7. Ultimately, the BERP WG does not feel that the management actions recommended in Pikitch et al. (2012) are appropriate for Atlantic menhaden specific management. Furthermore, the WG cannot evaluate if the Pikitch et al. (2012) buffers will actually provide enough forage to sustain predators of interest at desired population levels. Overall, although the ERPs in Pikitch et al. (2012) are less than ideal, predator removals are a large source of mortality for this stock. As such, through the framework of the ERP Report, the WG is working to have better ERP advice that is specific to Atlantic menhaden management.

The WG recommends that the Board form a subcommittee to collaborate with the BERP WG and industry to define more concrete ecosystem management goals and objectives. This would help the WG identify which models might be the most appropriate to achieve proposed objectives. Moving forward, the WG would like to combine the recommendations of a Board subcommittee with those of the Atlantic menhaden peer reviewers to define an objective approach to developing ERPs.

References

Pikitch, E., Boersma, P.D., Boyd, I.L., Conover, D.O., Cury, P., Essington, T., Heppell, S.S., Houde, E.D., Mangel, M., Pauly, D., Plagányi, É., Sainsbury, K., and Steneck, R.S. (2012). Little Fish, Big Impact: Managing a Crucial Link in Ocean Food Webs. Lenfest Ocean Program. Washington, DC. 108 pp.

Chesapeake Bay Ecological Foundation, Inc.
Easton, MD 21601
410-822-4400

7/25/16

Predator/Prey Monitoring Program Study Findings and Additional Recommendations for Menhaden Management

(In addition to the paper "**STRIPED BASS & ATLANTIC MENHADEN MANAGEMENT QUESTIONED"** that was submitted with meeting materials at May 2016 ASMFC Spring meeting)

The Chesapeake Bay is the largest production area in North America for young striped bass and young Atlantic menhaden. A shortage of menhaden in the Chesapeake Bay has existed for 2 decades. This imbalance between striped bass prey supply and demand is a threat to the health of the Bay's striped bass population. Atlantic menhaden have the most influence on the Bay's ecosystem. They utilize the Chesapeake Bay and most of its tributaries and are the most important and abundant large prey species in the Bay. As prey and filter feeders, Atlantic menhaden are an ecologically critical fish species. They consume and redistribute a significant amount of energy (by turning plankton into menhaden flesh) within and between the Chesapeake Bay and other estuaries, and the coastal ocean. This is due, in part, to their tremendous numbers, individual growth rate, filter feeding capacity, and seasonal movements. Menhaden are an extremely important prey species for many predatory fish. Because of their schooling behavior, they are also 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. Analysis of Chesapeake Bay Ecological Foundation's study determined that protecting menhaden less than 9" (purse seine fishery only) can be crucial for multiple prey species and maintenance of healthy Chesapeake Bay non-migratory adult male striped bass.

The Nature Conservancy
Protecting nature. Preserving life.®

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nature.org

July 26, 2016

Robert E. Beal, Executive Director
Atlantic States Marine Fisheries Commission
1050 N. Highland Street
Arlington, VA 22201
[*sent via email*]

Dear Mr. Beal,

On behalf of The Nature Conservancy, I am writing to express our support for the development of Amendment 3 to the Atlantic Menhaden Fishery Management Plan and to comment on 2017 fishery specifications. The Nature Conservancy and many other organizations and agencies are committed to helping create and maintain the conditions necessary for healthy and resilient marine and estuarine food webs. Collectively, we have made deep investments towards this goal. On the Atlantic coast, long-term success requires ensuring that forage fishes, including Atlantic menhaden, remain abundant and available as forage, at all life stages, throughout their historic ranges. Therefore, the importance of the Atlantic States Fisheries Commission's commitment to move away from single species management and instead manage Atlantic menhaden for its role as forage cannot be overstated. The Nature Conservancy continues to support the development and implementation of Ecological Reference Points (ERPs) that maintain enough Atlantic menhaden at all ages and geographies to fulfill the forage needs for all of the managed and unmanaged fish and wildlife that depend upon them.

With regard to the 2017 quota specification process, we urge the Management Board to sustain its commitment to managing Atlantic menhaden for their role as forage by maintaining status quo harvest levels until the Commission establishes ERPs. The Management Board already increased the Total Allowable Catch (TAC) by 10% in 2015 and 2016 based on the updated assessment from 2015. Although this assessment indicated that Atlantic menhaden were not being overfished and that overfishing was not occurring, these findings were based on single species reference points that do not account for the role of Atlantic menhaden in the ecosystem. Similarly, recent stock projections suggest that the TAC could be further increased without causing overfishing, but again, these analyses are based on single species reference points that the Commission has already determined are inappropriate for this species.

The 2017 stock assessment update and completion of Amendment 3 will provide an improved context for making any change to the TAC for Atlantic menhaden. The Commission should refrain from setting a new TAC until the updated information is available. Stability and resilience for fisheries and the ecosystem has been identified as a fundamental objective for Atlantic Menhaden management, and with an assessment update scheduled and a transition to ecological reference points in process, a change in TAC at this time is premature.

Thank you for considering our comments and we look forward to supporting the development of Amendment 3 through its completion. Please contact Kate Wilke at kate.wilke@tnc.org or (804) 249-3412 with any questions or ideas for how we might assist.

Sincerely,

Jay Odell
Mid-Atlantic Marine Program Director
The Nature Conservancy

TOWN OF WELLFLEET

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To: ASMFC Menhaden Management Board July 23, 2016

Re: Amendment 3 for Atlantic Menhaden / development and implementation

Dear ASMFC Menhaden Management Board members:

We are writing to express our concern about an increase to the coast wide TAC of Atlantic Menhaden for the 2017 fishing season that is up for discussion at this August's meeting. This, despite having no new data since the 2015 benchmark stock assessment on which to base any quota change. The ASMFC has indicated a desire to manage menhaden based on the needs of predators, many of which are managed by the Commission, through the development of Amendment 3, and should keep this in mind by resisting any pressure for a quota change while waiting for the Amendment 3 development process to be completed.

Specifically, we'd like to request leaving a significantly larger portion of the menhaden stock in the water for the predators that depend on them for their lives. We believe this should be the top priority under amendment 3, and also believe that new ecological reference points (ERP's) once established, will justify a much smaller coast wide TAC than is currently on the books. We'd also suggest including a suite of options be sent out for public comment that would more equitably allocate menhaden to the bait fishery – especially in those states in the northern and southern range of menhaden abundance, where the rebuilding trend will hopefully continue, and where the bulk of those affected by the currently diminished supply of menhaden could use some help. Finally, please make every effort not to further delay the timeline for implementation of amendment 3.

In our area of Massachusetts we've yet to see any significant increase in menhaden abundance despite 3 years of modest belt tightening. In an effort to restore menhaden throughout their historic range, it's worth pointing out that they're still a long way from recovered here on the Outer Cape. It's great to see the whales, osprey, and bluefish returning in droves to feed on menhaden in areas to our south where they had long been absent. We need to ensure that this trend continues. Until such a time that we have enough menhaden to feed all of our predators, and until such a time that our fishermen will no longer need to steam so far south to satisfy our own bait needs, let's err on the side of caution, and resist the pressure to increase the Coast wide TAC to satisfy the needs of a small minority of ASMFC's member states.

Thanks for considering our comments, and for the productive time you've spent in the development of amendment 3.

Sincerely,

The Wellfleet Natural Resources Advisory Board
John Riehl (Chair), John Duane, Laura Hewitt, Thomas Slack, Sylvia Smith

Cc: David Pierce
Sarah Peake
William Adler

Virginia Saltwater Sportfishing Association, Inc (VSSA)
PO Box 28898
Henrico, VA 23228
www.ifishva.org

Mr. John Bull
Commissioner VMRC
2600 Washington Ave.
Newport News, VA 23607

Dear John, July 26, 2016

I am writing to express our views on matters likely to be discussed in the upcoming ASMFC Menhaden Meetings. Harvest specifications for the 2017 season will be set and, important guidance will be provided to the plan development team on the content of the Amendment 3 public information document. **VSSA is opposed to any increase in the total allowable catch (TAC) for menhaden for the following reasons:**

1. There is no new science or data since the 2015 assessment to justify an increase in the TAC.
2. The updated assessment is coming in 2017, which should be used for Amendment 3. We should wait until we have new science to make an informed decision about quota or TAC increases.
3. The commission has committed to managing menhaden for the ecosystem. Any current increase in quota or TAC diminishes any conservation of the stock until Amendment 3. Increasing the current TAC may later be found to be excessive when the ecological reference points are in place.

Being realistic, we are cognizant there are serious issues relative to quota for the northern "bait states." Having said that, VSSA believes any and all quota increase for the northern "Bait States" should come from a quota reallocation from other states including Virginia. Or, in the worst case, an increase in the TAC of no more 5%, with the entire 5% increase being dedicated to the northern "bait states." **VSSA strongly opposes any increase in the TAC that would go to the Virginia reduction industry.**

Please feel free to contact me for additional discussion on these matters.

Respectfully,

John Bello
John Bello, Chairman

Cc: Rob O'Reilly and Menhaden Board, ASMFC

Tina Berger

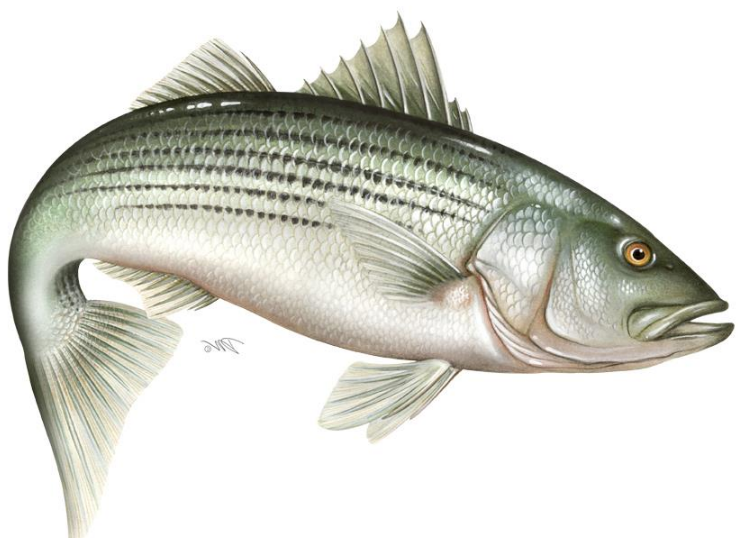
From: Brendan Ready <brendan4157@yahoo.com>
Sent: Wednesday, July 27, 2016 8:17 AM
To: Comments
Subject: Menhaden in Maine

We have watched several large seiners over the last 2 weeks load truck loads of Pogies here in Maine. I know Maine has .4% of the quota available which is about 40 truck loads of fish. I know 1 boat alone has surpassed this amount, not sure if it is getting reported or enforced but it is quite apparent that they are way over the quota allowed so far and hearing enforcement maybe be turning a blind eye as bait shortage on herring for lobstering. It would be sad if .4% of the quota couldn't be accurately enforced, as several of the smaller seiners sell direct to lobstermen without any reporting as well. Just don't want to see it get out of hand

2016 REVIEW OF THE
ATLANTIC STATES MARINE FISHERIES COMMISSION
FISHERY MANAGEMENT PLAN FOR

ATLANTIC STRIPED BASS
(Morone saxatilis)

2015 FISHING SEASON



Atlantic Striped Bass Plan Review Team
Max Appelman, Atlantic States Marine Fisheries Commission, Chair
Charlton Godwin, North Carolina Division of Marine Fisheries
Wilson Laney, US Fish and Wildlife Service
Gary Shepherd, National Marine Fisheries Service
Derek Orner, National Marine Fisheries Service

Prepared July 25, 2016

Executive Summary

Atlantic Striped Bass from Maine through North Carolina are managed under Amendment 6 and Addenda I-IV to the Interstate Fishery Management Plan.

Addendum IV to Amendment 6 was approved by the Board in October 2014, and implemented prior to the start of the 2015 fishing season. The addendum contained new fishing mortality reference points, and required coastal and Chesapeake Bay states/jurisdictions to reduce removals by 25% and 20.5%, respectively, in order to reduce F to a level at or below the target.

Total striped bass harvest in 2015 is estimated at 1.96 million fish that weighed 23.0 million pounds, which is a 23% decrease by number and by weight from 2014. The recreational fishery harvested 1.33 million fish (18.2 million pounds) in 2015, while the commercial fishery harvested 623,457 fish (4.84 million pounds). Dead discards in 2015 were estimated at 755,771 fish for the recreational sector, and 299,566 fish for the commercial sector.

Rhode Island exceeded its commercial quota by 6,903 pounds in 2015, resulting in a 174,669 pound quota for 2016. All Chesapeake Bay commercial fisheries harvested below their quota in 2015.

In 2015, Addendum IV regulatory measures achieved a 22.4% reduction in harvest compared to the reference harvest-level. All sectors achieved (or exceeded) their harvest reduction goal, except for the Chesapeake Bay recreational sector (53.4% increase compared to 2012 harvest levels).

The PRT annually reviews trends in all required JAIs. If any survey's JAI falls below their respective Q1 for three consecutive years, then appropriate action should be recommended by the PRT to the Board. No management action is triggered based on the analysis of the 2013, 2014, and 2015 JAI values.

In 2015, all states implemented management programs consistent with Amendment 6 and Addenda I-IV. Monitoring requirements vary by state, and may include monitoring commercial and/or recreational catch, effort, and catch composition, monitoring commercial tagging programs, and performing juvenile abundance surveys, spawning stock surveys, and tagging programs.

Table of Contents

I. Status of the Fishery Management Plan

Date of FMP Approval:	Original FMP – 1981
Amendments:	Amendment 1 – 1984 Amendment 2 – 1984 Amendment 3 – 1985 Amendment 4 – 1989; Addendum I – 1991, Addendum II – 1992, Addendum III – 1993, Addendum IV – 1994 Amendment 5 – 1995; Addendum I – 1997, Addendum II – 1997, Addendum III – 1998, Addendum IV – 1999, Addendum V – 2000 Amendment 6 – 2003; Addendum I – 2007, Addendum II – 2010, Addendum III – 2012, Addendum IV – 2014
Management Unit:	Migratory stocks of Atlantic striped bass from Maine through North Carolina
States With Declared Interest:	Maine - North Carolina, including Pennsylvania
Additional Jurisdictions:	District of Columbia, Potomac River Fisheries Commission, National Marine Fisheries Service, United States Fish and Wildlife Service
Active Boards/Committees:	Atlantic Striped Bass Management Board, Advisory Panel, Technical Committee, Stock Assessment Subcommittee, Tagging Subcommittee, Plan Review Team, and Plan Development Team

The Atlantic States Marine Fisheries Commission (Commission) developed a fisheries management plan (FMP) for Atlantic striped bass in 1981 in response to declining juvenile recruitment and landings. The FMP recommended increased restrictions on commercial and recreational fisheries, such as minimum size limits and harvest closures on spawning grounds. Two amendments were passed in 1984 recommending additional management measures to reduce fishing mortality. To strengthen the management response and improve compliance and enforcement, the Atlantic Striped Bass Conservation Act (P.L. 98-613) was passed in late 1984, which mandated the implementation of striped bass regulations passed by the Commission, and gave the Commission authority to recommend to the Secretaries of Commerce and Interior that states be found out of compliance when they failed to implement management measures consistent with the FMP.

The first enforceable plan under the Striped Bass Act, Amendment 3, was approved in 1985, and required size regulations to protect the 1982 year class, which was the first modest size cohort since the previous decade. The objective was to increase size limits to allow at least 95% of the females in the cohort to spawn at least once. Smaller size limits were permitted in the Albemarle Sound, Chesapeake Bay, Delaware Bay, and the Hudson River than along the coast. Several states, beginning with Maryland in 1985, opted for a more conservative approach and imposed a total moratorium on striped bass landings for several years. The amendment contained a trigger mechanism to reopen the fisheries when the 3-year moving average of the Maryland juvenile abundance index (JAI) exceeded an arithmetic mean of 8.0, which was attained with recruitment of the 1989 year class. Also in 1985, the Commission determined that the Albemarle Sound/Roanoke River (A/R) stock in North Carolina contributed minimally to the coastal migratory population, and therefore, was allowed to pursue an alternative management program.

Consequently, Amendment 4, implemented in 1989, aimed to rebuild the resource rather than maximize yield. The amendment allowed state fisheries to reopen under a target fishing mortality (F) of 0.25, which was half the estimated F needed to achieve maximum sustainable yield (MSY). Commercial measures were implemented that would reduce landings to 20% of those in the historic period of 1972-1979. For the recreational sector, dual size limit concept was maintained. The amendment only allowed an increase in the target F once spawning stock biomass (SSB) was restored to levels estimated during the late 1960s and early 1970s. Five addenda were implemented from 1990-1994 to maintain protection of the 1982 year class.

In 1990, to provide additional protection to striped bass and ensure the effectiveness of state regulations, the NOAA Fisheries passed a final rule (55 Federal Register 40181-02) prohibiting possession, fishing (i.e., catch and release fishing), harvest and retention of Atlantic striped bass in the Exclusive Economic Zone (EEZ), with the exception of a defined transit zone within Block Island Sound. Atlantic striped bass may be possessed and transported through this defined area, provided that the vessel is not used for fishing while in the EEZ and the vessel remains in continuous transit. Additionally, no bycatch of Atlantic striped bass from the EEZ may be retained and striped bass could not be targeted by catch and release fisheries.

In 1995, Chesapeake Bay and Hudson River striped bass were declared restored by the Commission (the Delaware stock was declared restored in 1995 and the A/R stock in 1997), and Amendment 5 was adopted to increase the target F to 0.33, midway between the existing F target (0.25) and $F_{MSY,}$ which was revised to 0.40 after two years of implementation. Regulations were developed to allow 70% of the historic harvest and achieve the target F, although states were allowed to submit proposals for alternative regulations that were conservationally equivalent. From 1997-2000, a series of five addenda were implemented to adjust target F in response to the latest stock status information, and adjust the regulatory regime to achieve each change in target F.

In 2003, Amendment 6 was adopted to address five limitations within the management program: 1) potential inability to prevent the Amendment 5 exploitation target from being exceeded; 2) perceived decrease in availability or abundance of large striped bass in the coastal migratory population; 3) a lack of management direction with respect to target and threshold biomass levels; 4) inequitable effects of regulations on the recreational and commercial fisheries, and coastal and producer area sectors; 5) and excessively frequent changes to the management program. Amendment 6 completely replaced the FMP (and all subsequent amendments and addenda) for Atlantic striped bass.

The goal of Amendment 6 is to perpetuate, through cooperative interstate management, migratory stocks of striped bass; to allow commercial and recreational fisheries consistent with the long-term maintenance of a broad age structure, a self-sustaining spawning stock; and also to provide for the restoration and maintenance of their essential habitat. In support of this goal, the following objectives are included:

- Manage striped bass fisheries under a control rule designed to maintain stock size at or above the target female spawning stock biomass level and a level of fishing mortality at or below the target exploitation rate.
- Manage fishing mortality to maintain an age structure that provides adequate spawning potential to sustain long-term abundance of striped bass populations.
- Provide a management plan that strives, to the extent practical, to maintain coastwide consistency of implemented measures, while allowing the States defined flexibility to implement alternative strategies that accomplish the objectives of the FMP.
- Foster quality and economically viable recreational, for-hire, and commercial fisheries.
- Maximize cost effectiveness of current information gathering and prioritize state obligations in order to minimize costs of monitoring and management.
- Adopt a long-term management regime that minimizes or eliminates the need to make annual changes or modifications to management measures.
- Establish a fishing mortality target that will result in a net increase in the abundance (pounds) of age 15 and older striped bass in the population, relative to the 2000 estimate.

Amendment 6 modified the F targets and thresholds, and introduced a new set of biological reference points (BRPs) based on female spawning stock biomass (SSB), as well as a list of management triggers based on the BRPs (the targets and thresholds were updated in 2008; see Sections II and IV for more information). The coastal commercial quotas for striped bass were restored to 100% of the states' average landings during the 1972-1979 historical period, except for Delaware's coastal commercial quota, which remained at the level allocated in 2002. In the recreational fisheries, all states were required to implement a two-fish bag limit with a minimum size limit of 28 inches, except for the Chesapeake Bay fisheries, fisheries that operate in the Albemarle Sound, and states with approved alternative regulations. The Chesapeake Bay and A/R regulatory programs were predicated on a more conservative F target than the coastal migratory stock, which allowed these jurisdictions to implement separate seasons, harvest caps, and size and bag limits as long as they remain under that F target. No minimum size limit can be less than 18 inches under Amendment 6. The same minimum size standards regulate the commercial fisheries as the recreational fisheries, except for a minimum 20 inch size limit in the Delaware Bay spring gillnet fishery.

States are permitted the flexibility to deviate from these standards by submitting proposals for review by the Striped Bass Technical Committee (TC), Advisory Panel, and Plan Review Team and contingent upon the approval of the Atlantic Striped Bass Management Board (Board). A state may request a change only if it can demonstrate that the action is "conservationally equivalent" to the management standards or will not contribute to the overfishing of the resource. This practice has resulted in a variety of regulations among states (see Tables 9 and 10).

In 2007, Addendum I was approved. The addendum established a bycatch monitoring and research program to increase the accuracy of data on Striped Bass discards and also recommended development of a web-based angler education program.

Also in 2007, President George W. Bush issued an Executive Order (E.O. 13449) prohibiting the sale of striped bass (and red drum) caught within the EEZ. The Order also requires the Secretary of Commerce to encourage management for conservation of the resources, including State designation as gamefish where the State determines appropriate under applicable law, and to periodically review the status of the populations within US jurisdictional waters.

In 2010, Addendum II was approved. The addendum established a new definition of recruitment failure to be "a value that is below 75% of all values in a fixed time series appropriate to each juvenile abundance index." The addendum was initially developed to consider options to increase the coastal commercial quota. The Board voted status quo in regards to the coastal commercial quota.

In 2012, Addendum III was approved. This addendum requires all states and jurisdictions with a commercial fishery to implement a commercial harvest tagging program. The addendum was initiated in response to significant poaching events in the Chesapeake Bay and aims to limit illegal harvest of striped bass.

In 2014, Addendum IV was approved. The addendum was initiated in response to the 2013 benchmark assessment which indicates a steady decline in spawning stock biomass since the mid-2000s. The Addendum established new fishing mortality reference points (F target and threshold), and a suite of regulatory measures to reduce F to a level at or below the new target by 2016. Prior to the start of the 2015 fishing season, all jurisdictions were required to implement regulations to achieve a 25% reduction from 2013 removals for the coastal fisheries and a 20.5% reduction from 2012 removals for Chesapeake Bay fisheries. Additionally, since tagging studies conducted on the A/R stock demonstrate that the stock contributes minimally to the coastwide complex (Callihan et al. 2014), Addendum IV defers management of the A/R stock to the State of North Carolina using stock-specific BRPs approved by the Board.

While NOAA Fisheries continues to implement a ban on the possession, fishing (i.e., catch and release fishing), harvest and retention of striped bass in the EEZ (with the exception of a defined transit zone within Block Island Sound), Amendment 6 includes a recommendation to the Secretary of Commerce to consider reopening the EEZ to commercial and recreational striped bass fisheries. In July 2003, NOAA Fisheries took steps in the rulemaking process to consider the recommendation. In September 2006, NOAA Fisheries concluded that it would be imprudent to open the EEZ to striped bass fishing and chose not to proceed further in its rulemaking. Specifically, NOAA Fisheries concluded that "(1) it could not be certain, especially after taking into account the overwhelming public perception that large trophy sized fish congregate in the EEZ, that opening the EEZ would not increase effort and lead to an increase in mortality that would exceed the threshold, and (2) both the Commission's and NOAA Fisheries' ability to immediately respond to an overfishing or overfished situation is a potential issue, particularly given the timeframe within which Amendment 6 was created, and the lag time in which a given year's data is available to management" (71 Federal Register 54261-54262).

II. Status of the Stocks

Coastal Migratory Atlantic Striped Bass Stocks

The 2013 benchmark assessment for coastal migratory Atlantic striped bass was peer-reviewed at the 57th SAW/SARC, and approved by the Board in October 2014 for management use. Among other changes, the statistical catch-at-age (SCA) model, which produces estimates of fishing mortality, abundance, recruitment and spawning stock biomass (SSB), was generalized to allow specification of multiple fleets, different stock-recruitment relationships, and year- and age-specific natural mortality rates. New fishing mortality (F) reference points were chosen to link the target and threshold F with the target and threshold female SSB. Additionally, the SARC identified high priority items for consideration in future assessments including continued improvement of the spatial modeling of the stock, and incorporating tagging data.

The assessment model was updated in 2015 with catch and index data through 2014. Based on results of the 2015 assessment update, and in comparison to the biological reference points below, coastal migratory Atlantic striped bass are not overfished and are not experiencing overfishing. Biological reference points apply to all Atlantic striped bass stocks, except for the A/R stock which has separate BRPs derived from an A/R stock specific assessment conducted by North Carolina DMF (see Section IV).

	Female Spawning Stock Biomass (SSB)	***Fully-Recruited Fishing Mortality (F)***
Threshold	SSB_{1995} = 57,626 metric tons	0.22
Target	$SSB_{threshold}$ x 1.25 = 72,032 metric tons	0.18

In 2014, female SSB was estimated at 63,918 metric tons (mt) (140.9 million pounds) which is above the SSB threshold (57,626 mt or 127.0 million pounds) but well below the target (72,032 mt or 158.8 million pounds) (Figure 1). The 2014 estimate is a slight decrease from 2013, however, female SSB estimates have continued to decline below the target and toward the threshold level since 2006.

In 2014, recruitment (age-1 abundance) was estimated at 76.1 million fish, which is below average for the most recent 15 years (92.2 million fish). Although recruitment is variable from year to year, the general trend is declining (Figure 1). The 2012 recruitment (2011 year class) estimate (125.1 million fish) is the highest value since 2006.

In 2014, the fully-recruited fishing mortality (F) rate was estimated to be 0.20, which is below the F threshold (0.22) but above the target (0.18, Figure 2). Since 2002, F has remained above the target level, oscillating back and forth across the threshold.

The next Atlantic striped bass stock assessment update will be available for Board review at its October 2016 meeting. The next benchmark stock assessment for coastal migratory Atlantic striped bass is scheduled for 2018.

III. Status of the Fishery

In 2015, total harvest of coastal migratory Atlantic striped bass (i.e., commercial landings plus recreational harvest (A + B1)) was estimated at 23.00 million pounds (1.96 million fish, Table 1 and Figure 5). This is a 23% decrease by weight and by number compared to 2014 (total harvest in 2014 was 2.56 million fish that weighed 30.0 million pounds). Per usual, harvest was dominated by the recreational sector with 79% of the total harvest by weight, and 68% by number. All coastwide harvest and discard estimates in this report exclude inshore harvest from the A/R in North Carolina (refer to Section IV for inshore harvest estimates from the A/R in 2015).

In 2015, based on annual state compliance reports, commercial landings were estimated at 4.82 million pounds (620,034 fish), a 19% decrease by weight and by number from 2014. Chesapeake Bay jurisdictions accounted for 65% of total commercial landings by weight; Maryland landed 30%, Virginia landed 23%, and the Potomac River Fisheries Commission (PRFC) landed 11%. Additional landings came from Massachusetts (18%), New York (11%), Rhode Island (4%), and Delaware (3%). Refer to Table 2, Table 3 and Figure 6 for commercial landings and dead discard estimates by state and by year. North Carolina has not recorded any coastal commercial (or recreational) harvest since 2012 due to redistribution of the over wintering component of the mixed stocks. The overwintering stock has remained well outside of three miles in recent years, affecting Virginia's harvest in the ocean as well.

Recreational harvest is estimated via the Marine Recreational Information Program (MRIP). In 2015, coastwide recreational harvest (i.e., A + B1) was estimated at 18.18 million pounds (1.34 million fish), a 24% decrease by weight from 2014 (25% by number). New Jersey landed the largest percentage of the coastwide recreational harvest by weight (28%), followed by New York (25%), Maryland (17%), Massachusetts (15%), and Connecticut (7%). Maine, New Hampshire, Rhode Island, Delaware, and Virginia accounted for the remaining 8%. By number, Maryland landed the largest percentage of the coastwide recreation harvest (30%), followed by New Jersey (21%), New York (20%), and Massachusetts (13%). Maine, New Hampshire, Rhode Island, Connecticut, Delaware, and Virginia accounted for the remaining harvest (16%). Refer to Table 4, Table 5 and Figure 7 for recreational harvest and dead discard estimates by year.

Recreational releases are also estimated via the MRIP. Coastwide recreational releases (B2) in 2015 were estimated at 8.40 million fish, which is a 15% increase compared to 2014. Applying a 9% post release mortality rate, recreational dead discards were estimated at 755,771 fish. Accordingly, in 2015, total recreational removals (i.e., A + B1 + 9% of B2) were estimated at 2.09 million fish, which is a 14% decrease from 2014.

Commercial dead discard estimates continue to be a source of uncertainty within striped bass stock assessment. Commercial dead discards are currently estimated via the ratio of tags returned from the recreational fishery to those from the commercial fishery. The tag-return ratio is adjusted by a correction factor for underreporting to get an estimate of commercial releases. Commercial releases are then apportioned among gears based on gear-specific tag-returns. Commercial dead discards are then estimated via gear-specific post-release mortality rates. In 2015, total commercial dead discards were estimated at 299,566 fish, 32% of that estimated in 2014 (931,391 fish) and the lowest estimate since 2010. Refer to Table 6 for dead discards by sector and by year.

Wave-1 Recreational Harvest Estimates

Evidence suggests that North Carolina, Virginia, and possibly other states have had sizeable wave-1 (January/February) recreational striped bass fisheries beginning in 1996 (NEFSC 2013b). MRIP has sampled for striped bass in North Carolina during wave-1 since 2004. Other states are not currently covered during wave-1. However, striped bass distribution on their overwintering grounds during

January through February has changed significantly since the mid-2000s. The migratory portion of the stocks has been well offshore in the EEZ off Virginia and North Carolina (up to 27 miles) in recent years. North Carolina has reported zero striped bass landings in the ocean for 2012-2015.

IV. Status of Albemarle Sound and Roanoke River Stocks

The most recent A/R stock assessment (data through 2012) utilized the ASAP3 statistical catch at age model. The benchmark assessment was peer reviewed by an outside panel of experts, and approved by the Board for management use in October 2014. The model incorporated all commercial and recreational harvest and discard data, as well as abundance data from fishery independent surveys conducted by North Carolina Division of Marine Fisheries (NCDMF) and NCWRC staff. The benchmark assessment produced new BRPs and associated quotas to prevent overfishing. Based on results of the 2014 benchmark, and in comparison to the biological reference points below, A/R Atlantic striped bass are not overfished and are not experiencing overfishing.

	F	***SSB***	***Total Allowable Landings pounds (TAL)***
Threshold	0.41	785,150 lb.	325,905 lb.
Target	0.33	969,496 lb.	305,762 lb.

Although the stock is not overfished, female spawning stock biomass has declined steadily since its peak in 2003 (similar to the stock status trend from the 2015 assessment update for coastal migratory stocks), and is estimated at 835,462 pounds in 2012, just above the threshold of 772,588 pounds (Figure 3). A/R striped bass experienced a period of unusually strong recruitment (number of age-1 fish entering the population) from 1994-2001 followed by a period of lower recruitment from 2002-2013. In 2012, fishing mortality was estimated at 0.34 in 2012, just above the target of 0.33 (Figure 4).

In 2015, total commercial and recreational harvest in the Albemarle Sound Management Area (ASMA) and the Roanoke River Management Area (RRMA) was 240,445 pounds (72,099 fish). Commercial harvest in the ASMA was 113,475 pounds (28,828 fish). Recreational harvest in the ASMA was 70,008 pounds (23,240 fish), while recreational harvest in the RRMA was 56,962 pounds (20,031 fish). The Interstate FMP for Atlantic Striped Bass requires North Carolina to inform the Commission of changes to striped bass management in the A/R System. North Carolina must adhere to the compliance criteria in Amendment 6. After a review, the PRT determined that North Carolina's FMP complies with the mandatory components of Amendment 6.

An update of the A/R stock assessment with data through 2014 is scheduled to be completed in the fall of 2016 and will be available for Board review at their October 2016 meeting.

V. Status of Management Measures and Issues

Addendum II: Juvenile Abundance Index Analysis

Amendment 6 requires the following states to conduct striped bass young-of-year juvenile abundance index (JAI) surveys on an annual basis: Maine for the Kennebec River; New York for the Hudson River; New Jersey for the Delaware River; Maryland for the Maryland Chesapeake Bay tributaries; Virginia for the Virginia Chesapeake Bay tributaries; and North Carolina for the A/R stock.

The PRT annually reviews trends in all required JAIs. Under the new definition per Addendum II, recruitment failure is defined as a value that is below 75% (the first quartile, or Q1) of all values in a fixed time series appropriate to each JAI. If any survey's JAI falls below their respective Q1 for three consecutive years, then appropriate action should be recommended by the PRT to the Board. The Board is the final arbiter in all management decisions.

No management action is triggered in 2016 based on review of 2013, 2014, and 2015 JAI values. Maine's JAI was below the Q1 threshold in 2015, near the long term average in 2014, and slightly above average in 2013. New York experienced a recruitment failure in 2013 but the JAI has been above average for the past two years. While New Jersey's JAI has been below average for two out of the last three years, no values were below the Q1 threshold. Maryland's 2015 JAI was well above average, with values right at the long term series average in 2013 and 2014. Virginia's JAI has been slightly above average each of the last three years. North Carolina's JAI for the A/R stock was near zero in 2013, below the Q1 threshold, but was well above average in 2014 and 2015 (Figure 8).

Addendum III: Commercial Fish Tagging Program

Addendum III to Amendment 6 includes compliance requirements for monitoring commercial fishery tagging programs. The PRT found that all states implemented commercial tagging programs consistent with the requirements of Addendum III. Table 12 describes each state's program requirements.

Addendum IV: Performance of Regulatory Measures in 2015

The Board approved Addendum IV in October 2014. The addendum established new F reference points as recommended by the 2013 benchmark assessment. A primary goal of the addendum is to reduce F to a level at or below the new target. To achieve this, prior to the start of the 2015 fishing season, all states and jurisdictions implemented measures that would reduce harvest by 25% in coastal fisheries (compared to 2013-levels) and by 20.5% in Chesapeake Bay fisheries (compared to 2012-levels) in terms of number of fish. Addendum IV regulatory measures are to remain in effect until the FMP is modified through the adaptive management process. Refer to Tables 10 and 11 for state-by-state regulations in 2015.

In 2015, states and jurisdictions achieved a 22.4% reduction in harvest, coastwide, compared to the reference harvest period in terms of number of fish (Table 7). All sectors, except for the Chesapeake Bay recreational sector, achieved the harvest reduction goal stated above. The sector-by-sector performance is as follows:

- *Coastal Commercial Fishery* – coastal commercial quotas as defined in Amendment 6 were reduced by 25%. No overages occurred in 2014, therefore no deductions were applied to 2015 quotas. In 2015, Rhode Island exceeded its quota by 6,903 pounds. Refer to Table 9 for state-by-state coastal commercial quotas and harvest in 2015, and effective quotas for 2016. Compared to 2013 harvest levels, the coastal commercial fisheries achieved a 32.6% reduction in harvest. See Table 8A for coastal commercial fishery evaluation, state-by-state.

- *Chesapeake Bay Commercial Fishery* – the Chesapeake Bay operates under a separate commercial quota. Historically, the bay-wide quota was calculated as an output from a harvest control model. The Bay-wide commercial quota was then allocated to Maryland, the PRFC, and Virginia based on historical harvest. However, Addendum IV froze the Bay-wide commercial quota at 25% of the 2012 harvest estimate, resulting in a 3,120,247 pound Bay-wide quota in 2015. In 2015, the bay-wide commercial harvest was 2,940,291 pounds and all jurisdictions harvested within their quota. Refer to Table 9 for Chesapeake Bay commercial quotas and harvest in 2015, and effective quotas for 2016. Compared to 2012 harvest levels, the Chesapeake Bay commercial fisheries achieved a 24.2% reduction in harvest. See Table 8B for the bay-wide commercial fishery evaluation.

- *Coastal Recreational Fishery* – for the recreational sector along the coast, states implemented a 28" minimum size limit, and a one fish bag limit per person per day. States may implement alternative regulations through the conservation equivalency process described in Amendment 6 (and Addendum IV), resulting in different regulations across states and sectors. Compared to 2013 harvest levels, the coastal recreational fisheries achieved a 41% reduction in harvest. See Table 8C for a state-by-state evaluation. All states, with the exception of New Jersey (18.7% reduction), achieved the target reduction of 25% or more.

- *Chesapeake Bay Recreational Fishery* – the Chesapeake Bay jurisdictions implemented regulations for the recreational sector through the conservation equivalency process in order to reduce harvest by 20.5%. Chesapeake Bay recreational fisheries did not reduce harvest in 2015 compared to 2012 harvest levels (53.4% increase in harvest). See Table 8D for bay-wide recreational fishery evaluation.

Law Enforcement Reporting

State agencies, the ASMFC, and law enforcement officers made a strong effort to educate the public of the Addendum IV regulatory changes that went in effect prior to the 2015 fishing year. Overall, there was good compliance with the regulatory changes, and most stakeholders were optimistic about the improved conservation for striped bass. Along the coast, recreational anglers were generally in favor of the size and bag limit changes, however most opposition came from the party and charter boat community regarding the change in bag limit from two fish to one. Chesapeake Bay recreational anglers were also somewhat dissatisfied with new regulations, primarily due to high numbers of fish caught that had to be released due to slot limit restrictions.

Based on compliance reports, the total number of warnings and citations issued was relatively the same compared to previous years, however it appeared that more verbal warnings were issued in 2015 which can be expected when implementing new regulations. Law enforcement officers did indicate issues with different measuring techniques between adjacent jurisdictions (e.g., fork length versus total length, and squeezing the tail fin versus laying it flat).

VI. Status of Research and Monitoring

The management plan requires certain jurisdictions to implement fishery-dependent monitoring programs for striped bass. All jurisdictions with commercial fisheries or substantial recreational fisheries are required to define the catch and effort composition of these fisheries. Additionally, all states and jurisdictions with a commercial fishery must implement a commercial tagging program pursuant to Addendum III to Amendment 6.

The management plan also requires certain states to monitor the Striped Bass population independent of the fisheries. Juvenile abundance indices (JAIs) are required from Maine (Kennebec River), New York (Hudson River), New Jersey (Delaware River), Maryland (Chesapeake Bay tributaries), Virginia (Chesapeake Bay tributaries), and North Carolina (Albemarle Sound). Spawning stock sampling is mandatory for New York (Hudson River), Pennsylvania (Delaware River), Delaware (Delaware River), Maryland (Upper Chesapeake Bay and Potomac River), Virginia (Rappahannock River and James River), and North Carolina (Roanoke River and Albemarle Sound). Amendment 6 requires NOAA Fisheries, USFWS, Massachusetts, New York, New Jersey, Maryland, Virginia, and North Carolina to continue their tagging programs, which provide data used to determine survivorship and migration patterns.

The PRT found that all states carried out the required monitoring programs in 2015. In 2015, Virginia implemented the Board approved design changes to their tagging and monitoring surveys. Specifically, the 24 hour soak in the Rappahannock and James River gill net survey was eliminated and replaced with a short set (0.5-2 hours). The short set survey was also conducted in the York River to expand the tagging program.

VII. Annual State Compliance

Amendment 6 and its Addenda I-IV set the regulatory and monitoring measures for the coastwide Striped Bass fishery in 2015. Based on the annual state compliance reports, the PRT determined that each state and jurisdiction implemented a management program for 2015 consistent with the requirements of Amendment 6 and Addenda I-IV (Table 13).

The following management program changes were documented for the 2016 season:

- RI – new fin clipping regulations were adopted for 2016 to stem illegal sale of recreationally caught striped bass.
- MD – The coastal commercial season to be extended. New season is January 1 – May 30, and October 1 – December 31, Monday – Thursday.
- MD – Recreational bag and size limit changes for the Atlantic Ocean. New regulations are 2 fish/day bag limit and a 28-38” slot limit OR ≥ 44” TL.

VIII. Plan Review Team Recommendations

- The PRT found that all states implemented regulations consistent with Amendment 6 and Addenda I-IV of the Atlantic Striped Bass FMP.
- No states requested *de minimis* status at this time.

IV. Research Recommendations

Fishery-Dependent Priorities

High

- Continue collection of paired scale and otolith samples, particularly from larger striped bass, to facilitate development of otolith-based age-length keys and scale-otolith conversion matrices.[1]

Moderate

- Develop studies to provide information on gear specific discard morality rates and to determine the magnitude of bycatch mortality.[2]
- Improve estimates of striped bass harvest removals in coastal areas during wave 1 and in inland waters of all jurisdictions year round.
- Evaluate the percentage of fishermen using circle hooks.[3]

Fishery-Independent Priorities

Moderate

- Develop a refined and cost-efficient, fisheries-independent coastal population index for striped bass stocks.
  - The PRT recommends the SBTC be tasked with exploring whether the Cooperative Winter Tagging Cruise, NEAMAP, and/or NOAA Fisheries Trawl Survey datasets would prove useful in this respect.

Modeling / Quantitative Priorities

High

- Develop a method to integrate catch-at-age and tagging models to produce a single estimate of F and stock status.[4]
- Develop a spatially and temporally explicit catch-at-age model incorporating tag based movement information.[5]
  - The PRT recommends that the SAS be tasked with reviewing recent published literature examining tag-based movement information to see if they would contribute to the development of such a model (e.g., Callihan et al. 2014)
- Review a model averaging approach to estimate annual fishing mortality with tag based models. Review validity and sensitivity to year groupings.[6]
- Develop methods for combining tag results from programs releasing fish from different areas on different dates.
- Examine potential biases associated with the number of tagged individuals, such as gear specific mortality (associated with trawls, pound nets, gill nets, and electrofishing), tag induced mortality, and tag loss.[7]
- Develop field or modeling studies to aid in estimation of natural mortality or other factors affecting the tag return rate.

Moderate

- Develop maturity ogives applicable to coastal migratory stocks.
- Examine methods to estimate annual variation in natural mortality.[8]
- Develop reliable estimates of poaching loss from striped bass fisheries.
- Improve methods for determining population sex ratio for use in estimates of SSB and biological reference points.
- Evaluate truncated matrices and covariate based tagging models.

Low

- Examine issues with time saturated tagging models for the 18 inch length group.
- Develop tag based reference points.

Life History, Biological, and Habitat Priorities

High

- Continue in-depth analysis of migrations, stock compositions, etc. using mark-recapture data.[9]
- Continue evaluation of striped bass dietary needs and relation to health condition.[10]

- Continue analysis to determine linkages between the mycobacteriosis outbreak in Chesapeake Bay and sex ratio of Chesapeake spawning stock, Chesapeake juvenile production, and recruitment success into coastal fisheries.

Moderate

- Examine causes of different tag based survival estimates among programs estimating similar segments of the population.
- Continue to conduct research to determine limiting factors affecting recruitment and possible density implications.
- Conduct study to calculate the emigration rates from producer areas now that population levels are high and conduct a multi-year study to determine inter-annual variation in emigration rates.

Low

- Determine inherent viability of eggs and larvae.
- Conduct additional research to determine the pathogenicity of the IPN virus isolated from striped bass to other warm water marine species, such as flounder, Atlantic menhaden, American and hickory shad, and largemouth Bass.

Management, Law Enforcement, and Socioeconomic Priorities

Moderate

- Examine the potential public health trade-offs between the continued reliance on the use of high minimum size limits (28 inches) on coastal recreational anglers and its long-term effects on enhanced PCB contamination among recreational stakeholders.[11, 13]
- Evaluate striped bass angler preferences for size of harvested fish and trade-offs with bag limits.

Habitat Recommendations

- Passage facilities should be designed specifically for passing striped bass with optimum efficiency.
- Conduct studies to determine whether passing migrating adults upstream earlier in the year in some rivers would increase striped bass production and larval survival, and opening downstream bypass facilities sooner would reduce mortality of early emigrants (both adult and early-hatched juveniles).
- All state and federal agencies responsible for reviewing impact statements and permit applications for projects or facilities proposed for striped bass spawning and nursery areas shall ensure that those projects will have no or only minimal impact on local stocks, especially natal rivers of stocks considered depressed or undergoing restoration.[11]
- Federal and state fishery management agencies should take steps to limit the introduction of compounds which are known to be accumulated in striped bass tissues and which pose a threat to human health or striped bass health.
- Every effort should be made to eliminate existing contaminants from striped bass habitats where a documented adverse impact occurs.
- Water quality criteria for striped bass spawning and nursery areas should be established, or existing criteria should be upgraded to levels that are sufficient to ensure successful striped bass reproduction.
- Each state should implement protection for the striped bass habitat within its jurisdiction to ensure the sustainability of that portion of the migratory stock. Such a program should include: inventory of historical habitats, identification of habitats presently used, specification of areas targeted for restoration, and imposition or encouragement of measures to retain or increase the quantity and quality of striped bass essential habitats.

- States in which striped bass spawning occurs should make every effort to declare striped bass spawning and nursery areas to be in need of special protection; such declaration should be accompanied by requirements of non-degradation of habitat quality, including minimization of non-point source runoff, prevention of significant increases in contaminant loadings, and prevention of the introduction of any new categories of contaminants into the area. For those agencies without water quality regulatory authority, protocols and schedules for providing input on water quality regulations to the responsible agency should be identified or created, to ensure that water quality needs of striped bass stocks are met.[12]
- ASMFC should designate important habitats for striped bass spawning and nursery areas as HAPC.
- Each state should survey existing literature and data to determine the historical extent of striped bass occurrence and use within its jurisdiction. An assessment should be conducted of those areas not presently used for which restoration is feasible.

Footnotes

- [1] The Fish and Wildlife Service has archived otolith samples from known-age (CWT-tagged), stocked fish, for which scale ages were derived as well. These fish were collected during past Cooperative Winter Tagging Cruises and the otoliths, once aged, will increase our sample size, and since these are known-age fish, will also allow an examination of extent that which reader error affects both otolith age, and scale age.
- [2] Literature search and some modeling work completed.
- [3] Work ongoing in New York through the Hudson River Angler Diary, Striped Bass Cooperative Angler Program, and ACCSP e-logbook.
- [4] Model developed, but the tagging data overwhelms the model. Issues remain with proper weighting.
- [5] Model developed with Chesapeake Bay and the rest of the coast as two fleets. However, no tagging data have been used in the model.
- [6] Work ongoing by the Striped Bass Tagging Subcommittee to evaluate the best years to use for the IRCR and the periods to use for the MARK models.
- [7] Gear specific survival being examined in Hudson River.
- [8] Ongoing work by the Striped Bass Tagging Subcommittee
- [9] Ongoing through Cooperative Winter Tagging Cruise and striped bass charter boat tagging trips. See Cooperative Winter Tagging Cruise 25 Year Report, in preparation.
- [10] Plans for a stomach content collection program in the Chesapeake Bay by the Chesapeake Bay Ecological Foundation.
- [11] Ongoing in New York.
- [12] Significant habitat designations completed in the Hudson River and New York Marine Districts.
- [13] Samples collected from two size groups ($\geq$ 28 inches and 20-26 inches) in Pennsylvania and processed by the Department of Environmental Protection to compare contamination of the two size groups.

X. References

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XI. Tables

Tables 1 – 6 report harvest and discard estimates from 1990-2015 due to space contraints.

Table 1. Total harvest of coastal migratory Atlantic striped bass by sector, 1990-2015. Source: MRIP and annual state compliance reports. All harvests based on the calendar year, and may differ from MRIP depending on date queried. Excludes inshore harvest from the A/R. Estimates may vary depending on MRIP query date.

Year	Commercial Landings		Recreational (A+B1)		Total	
	Pounds	Numbers	Pounds	Numbers	Pounds	Numbers
1990	689,895	115,636	2,226,545	163,242	2,916,440	278,878
1991	1,471,703	153,798	3,643,994	262,469	5,115,697	416,267
1992	1,434,495	230,714	4,026,657	300,180	5,461,152	530,894
1993	1,749,628	312,860	5,651,079	428,719	7,400,707	741,579
1994	1,776,176	307,443	6,777,886	565,167	8,554,062	872,610
1995	3,390,937	534,914	12,425,549	1,089,182	15,816,486	1,624,096
1996	3,367,185	766,518	13,123,332	1,175,112	16,490,517	1,941,630
1997	5,882,643	1,108,612	15,714,071	1,648,127	21,596,715	2,756,739
1998	6,443,874	1,233,089	12,457,222	1,457,062	18,901,096	2,690,151
1999	6,545,102	1,103,812	13,478,473	1,446,388	20,023,575	2,550,200
2000	6,698,988	1,057,712	17,498,212	2,025,113	24,197,199	3,082,825
2001	6,235,788	952,820	19,144,159	2,085,127	25,379,947	3,037,947
2002	5,999,275	658,091	18,219,143	1,973,171	24,218,418	2,631,262
2003	7,072,686	874,817	24,771,639	2,545,052	31,844,325	3,419,869
2004	7,320,357	913,160	29,184,709	2,550,747	36,505,066	3,463,907
2005	7,134,538	973,572	30,222,991	2,441,938	37,357,529	3,415,510
2006	6,783,628	1,054,664	31,044,414	2,788,125	37,828,042	3,842,789
2007	7,050,692	1,023,358	26,994,977	2,523,500	34,045,669	3,546,859
2008	7,188,715	1,010,955	30,595,742	2,466,018	37,784,457	3,476,973
2009	7,215,818	1,043,512	22,937,526	2,040,680	30,153,344	3,084,191
2010	6,979,612	1,030,938	22,994,782	1,986,415	29,974,394	3,017,353
2011	6,783,239	931,570	27,235,091	2,230,256	34,018,330	3,161,826
2012	6,514,238	839,540	19,269,083	1,545,614	25,783,321	2,385,154
2013	5,816,204	765,797	26,411,290	2,120,768	32,227,494	2,886,565
2014	5,937,662	766,610	24,062,167	1,782,868	29,999,829	2,549,478
2015	4,820,489	620,034	18,184,192	1,338,080	23,004,681	1,958,114
3 yr avg	**5,524,785**	**717,480**	**22,885,883**	**1,747,239**	**28,410,668**	**2,464,719**
10 yr avg	**6,509,030**	**908,698**	**24,972,926**	**2,082,232**	**31,481,956**	**2,990,930**

Table 2. Commercial harvest (pounds) of migratory striped bass by state, 1990-2015. Source: Annual State Compliance Reports. All harvests based on the calendar year. Excludes inshore harvest from the A/R. Commercial harvest and sale prohibited in ME, NH, CT, and NJ. Commercial quota reallocated to recreational bonus program in CT and NJ; fish harvested under the bonus program are modeled as recreational removals in stock assessment.

Year	ME	NH	MA*	RI	CT	NY	NJ	DE	MD	PRFC	VA	NC	Total
1990		37	148,000	4,000		81,870		6,509	2,887	169,060	267,735	9,797	689,895
1991			235,000	28,000		105,163		21,079	191,066	216,755	668,454	6,186	1,471,703
1992			239,200	39,000		226,611		17,795	552,451	127,398	204,338	27,702	1,434,495
1993			262,600	40,000		109,362		28,032	916,764	142,742	213,665	36,463	1,749,628
1994			199,600	39,810		171,279		33,897	884,970	149,891	204,124	92,605	1,776,176
1995			782,000	113,461		500,784		38,198	856,568	198,478	557,741	343,707	3,390,937
1996			696,815	122,562		504,350		117,560	1,523,293	346,834		55,771	3,367,185
1997			785,942	96,519		460,762		165,978	2,030,061	731,114	1,153,743	458,524	5,882,643
1998			822,000	94,663		484,900		163,169	2,368,393	726,179	1,476,502	308,068	6,443,874
1999		33	788,171	119,679		491,790		187,096	2,377,393	653,266	1,538,220	389,454	6,545,102
2000			779,736	111,812		542,659		140,634	2,411,554	666,001	1,883,856	162,736	6,698,988
2001			815,054	129,654		633,095		198,802	1,774,758	658,676	1,675,469	350,280	6,235,788
2002			924,870	129,172		518,573		160,560	1,852,634	521,048	1,592,910	299,508	5,999,275
2003			1,055,439	246,312		753,261		188,419	1,813,727	676,574	1,856,831	482,123	7,072,686
2004		203	1,206,305	245,204		741,668		181,974	1,899,539	772,333	1,668,307	604,824	7,320,357
2005			1,104,737	242,303		689,821		173,815	2,055,558	533,456	1,746,247	588,601	7,134,538
2006			1,312,168	238,797		688,446		185,987	2,207,350	673,508	1,413,914	63,458	6,783,628
2007			1,040,328	240,627		729,743		188,668	2,336,886	599,261	1,534,799	380,380	7,050,692
2008			1,160,122	245,988		653,100		188,719	2,326,023	611,789	1,714,564	288,410	7,188,715
2009			1,138,291	234,368		789,891		192,311	2,394,620	727,197	1,549,145	189,995	7,215,818
2010			1,224,356	249,520		782,402		185,410	2,150,577	680,496	1,434,219	272,632	6,979,612
2011			1,163,865	228,163		854,731		188,620	1,976,473	694,151	1,434,636	242,600	6,783,239
2012			1,219,665	239,913		681,399		194,324	1,928,982	733,789	1,509,940	6,226	6,514,238
2013			1,004,459	231,280		823,801		191,424	1,755,712	623,792	1,185,736	0	5,816,204
2014			1,138,507	217,037		531,456		167,902	1,926,612	603,068	1,353,080	0	5,937,622
2015			865,753	188,475		509,135		144,068	1,471,493	536,357	1,105,208	0	4,820,489

* includes fish taken for personal consumption

Table 3. Commercial harvest (numbers) of migratory striped bass by state, 1990-2015, and annual dead discard estimates. Source: Annual State Compliance Reports. All harvests based on the calendar year. Excludes inshore harvest from the A/R. Commercial harvest and sale prohibited ME, NH, CT, and NJ. Commercial quota reallocated to recreational bonus program in CT and NJ; fish harvested under the bonus program are modeled as recreational removals in stock assessment**.**

Year	ME	NH	MA*	RI	CT	NY	NJ	DE	MD	PRFC	VA	NC	Total	Commercial Discards
1990			5,927	784		11,784		698	534	38,884	56,222	803	115,636	510,011
1991			9,901	3,596		15,426		3,091	31,880	44,521	44,970	413	153,798	327,167
1992			11,532	9,095		20,150		2,703	119,286	23,291	42,912	1,745	230,714	186,601
1993			13,099	6,294		11,181		4,273	211,089	24,451	39,059	3,414	312,860	347,839
1994			11,066	4,512		15,212		4,886	208,914	25,196	32,382	5,275	307,443	359,518
1995			44,965	19,722		43,704		5,565	280,051	29,308	88,274	23,325	534,914	515,454
1996			38,354	18,570		39,707		20,660	415,272	46,309	184,495	3,151	766,518	394,824
1997			44,841	7,061		37,852		33,223	706,847	87,643	165,583	25,562	1,108,612	216,745
1998			43,315	8,835		45,149		31,386	790,154	93,299	204,911	16,040	1,233,089	326,032
1999			40,838	11,559		49,795		34,841	650,022	90,575	205,143	21,040	1,103,812	236,619
2000			40,256	9,418		54,894		25,188	627,777	91,471	202,227	6,480	1,057,712	666,997
2001			40,248	10,917		58,296		34,373	549,896	87,809	148,346	22,936	952,820	310,900
2002			48,926	11,653		47,142		30,440	296,635	80,300	127,211	15,784	658,091	168,201
2003			61,262	15,497		68,354		31,531	439,482	83,091	161,777	13,823	874,817	261,974
2004			66,556	15,867		70,367		28,406	461,064	91,888	147,998	31,014	913,160	465,642
2005			65,332	14,949		70,560		26,336	569,964	80,615	119,244	26,573	973,572	798,544
2006			75,062	15,429		73,528		30,212	655,951	92,288	109,396	2,799	1,054,664	194,524
2007			57,634	13,934		78,287		31,090	598,495	86,695	140,602	16,621	1,023,358	606,599
2008			65,330	16,616		73,263		31,866	594,655	81,720	134,603	12,903	1,010,955	308,715
2009			63,875	20,725		82,574		21,590	618,076	89,693	138,303	8,675	1,043,512	611,944
2010			65,277	17,256		81,896		19,830	584,554	90,258	159,197	12,670	1,030,938	254,841
2011			63,309	14,344		87,349		20,517	490,969	96,126	148,063	10,814	931,490	617,457
2012			66,394	14,953		66,897		15,738	472,517	90,616	111,891	323	839,329	792,861
2013			62,570	13,825		76,206		17,679	399,118	78,006	117,697	0	765,101	525,581
2014			60,619	10,468		52,903		14,894	370,661	81,429	175,324	0	766,298	931,391
2015			42,250	11,325		44,809		10,990	300,929	69,981	139,750	0	620,034	299,566

* includes fish taken for personal consumption

Table 4. Recreational harvest (numbers) of migratory striped bass by state, 1990- 2015

Source: MRIP queried June 26, 2016. All harvests based on the calendar year, and may differ from MRIP depending on date queried. Excludes inshore harvest from the A/R.

Year	ME	NH	MA	RI	CT^	NY	NJ^	DE	MD	VA	NC	Total
1990	2,912	617	20,515	4,677	6,082	24,799	44,878	2,009	736	56,017	0	163,242
1991	3,265	274	20,799	17,193	4,907	54,502	38,300	2,741	77,873	42,224	391	262,469
1992	6,357	2,213	57,084	14,945	9,154	45,162	41,426	2,400	99,354	21,118	967	300,180
1993	612	1,540	58,511	17,826	19,253	78,560	64,935	4,055	104,682	78,481	264	428,719
1994	3,771	3,023	74,538	5,915	16,929	87,225	34,877	4,140	199,378	127,945	7,426	565,167
1995	2,189	3,902	73,806	29,997	38,261	155,821	254,055	15,361	355,237	149,103	11,450	1,089,182
1996	1,893	6,461	68,300	60,074	62,840	225,428	127,952	22,867	337,415	244,746	17,136	1,175,112
1997	35,259	13,546	199,373	62,162	64,639	236,902	67,800	19,706	334,068	518,483	96,189	1,648,127
1998	38,094	5,929	207,952	44,890	64,215	166,868	88,973	18,758	391,824	383,786	45,773	1,457,062
1999	21,102	4,641	126,755	56,320	55,805	195,261	237,010	8,772	263,191	411,873	65,658	1,446,388
2000	62,186	4,262	181,295	95,496	53,191	270,798	402,302	39,543	506,462	389,126	20,452	2,025,113
2001	59,947	15,291	288,032	80,125	54,165	189,714	560,208	41,195	382,557	355,020	58,873	2,085,127
2002	71,907	12,857	308,749	78,190	51,060	202,075	416,455	29,149	282,429	411,248	109,052	1,973,171
2003	57,765	24,878	407,100	115,471	95,983	313,761	391,842	29,522	525,191	455,812	127,727	2,545,052
2004	48,816	8,386	445,745	83,990	102,844	263,096	424,208	25,429	368,682	548,768	230,783	2,550,747
2005	83,617	24,940	340,743	110,490	141,290	376,894	411,532	20,438	533,929	293,161	104,904	2,441,938
2006	75,347	13,521	314,987	75,811	115,214	367,835	509,606	20,159	669,140	547,482	79,023	2,788,125
2007	53,694	6,348	315,409	101,400	118,549	474,062	289,656	8,465	765,169	353,372	37,376	2,523,500
2008	59,152	5,308	377,959	51,191	108,166	685,589	309,411	26,934	415,403	401,155	25,750	2,466,018
2009	62,153	8,587	344,401	71,427	60,876	356,311	283,024	19,539	501,845	326,867	5,650	2,040,680
2010	17,396	5,948	341,045	70,108	92,806	538,374	320,413	16,244	457,898	102,405	23,778	1,986,415
2011	18,105	32,704	255,507	88,635	63,288	674,844	393,194	18,023	445,171	146,603	94,182	2,230,256
2012	11,624	14,498	377,931	61,537	64,573	424,522	168,629	25,399	262,143	134,758	0	1,545,614
2013	23,143	17,657	298,945	218,236	143,373	490,855	345,008	19,520	477,295	118,686	0	2,152,718
2014	20,750	6,415	277,138	103,516	86,763	409,342	225,910	8,774	583,028	67,486	0	1,789,122
2015	4,720	1,828	170,770	39,857	70,522	262,181	284,257	3,101	406,371	94,473	0	1,338,080

^ Commercial quota reallocated to recreational bonus program in CT and NJ; fish harvested under the bonus program are modeled as recreational removals in stock assessment.

Table 5. Recreational harvest (pounds) of migratory striped bass by state, 1990-2015 Source: MRIP queried June 26, 2016. All harvests based on the calendar year, and may differ from MRIP depending on date queried. Excludes inshore harvest from the A/R.

Year	ME	NH	MA	RI	CT^	NY	NJ^	DE	MD	VA	NC	Total
1990	60,483	11,363	319,092	73,349	193,011	505,440	588,974	18,115	12,967	443,751	0	2,226,545
1991	58,177	6,731	440,605	496,723	125,309	1,053,589	643,571	25,501	456,954	333,743	3,091	3,643,994
1992	107,693	44,612	972,116	203,109	196,278	921,201	746,343	25,677	613,174	187,852	8,602	4,026,657
1993	11,953	28,115	1,113,446	292,428	400,067	1,575,938	874,296	52,540	794,853	505,742	1,701	5,651,079
1994	66,451	66,017	1,686,049	109,817	355,829	1,974,759	438,080	63,832	1,096,409	870,140	50,503	6,777,886
1995	45,933	67,992	1,504,390	436,058	671,647	3,296,025	3,141,222	175,347	2,057,450	955,822	73,663	12,425,549
1996	44,802	102,271	1,291,706	950,973	915,418	4,809,381	1,736,508	281,481	1,560,389	1,340,414	89,989	13,123,332
1997	185,178	206,904	2,891,970	927,919	920,465	4,449,564	821,784	232,186	1,962,947	2,813,471	301,683	15,714,071
1998	178,584	114,342	2,973,456	671,841	989,923	2,318,291	1,333,329	236,926	1,908,344	1,581,560	150,626	12,457,222
1999	98,623	84,255	1,822,818	886,666	824,031	3,171,344	3,342,372	100,541	1,137,940	1,741,857	268,026	13,478,473
2000	269,325	71,370	2,618,216	1,160,304	515,962	4,050,569	4,286,040	346,905	2,100,854	2,005,721	72,946	17,498,212
2001	290,233	223,072	3,644,561	1,138,974	628,044	2,996,805	5,341,867	382,498	2,072,943	2,140,713	284,449	19,144,159
2002	383,270	152,342	4,304,883	1,192,295	600,482	2,813,596	4,133,678	299,561	1,423,515	2,648,115	267,406	18,219,143
2003	253,910	281,549	5,120,554	1,502,455	1,537,899	4,687,685	4,545,515	303,909	2,975,437	2,789,745	772,981	24,771,639
2004	226,200	98,995	6,112,746	1,386,138	1,617,561	3,727,105	5,548,167	330,623	2,347,752	2,956,310	4,833,112	29,184,709
2005	381,058	281,114	5,097,821	1,732,581	2,173,638	5,537,432	5,958,454	286,777	4,612,417	1,996,840	2,164,859	30,222,991
2006	323,355	179,181	4,832,355	999,300	2,030,878	6,028,409	7,067,533	260,134	3,868,944	3,694,529	1,759,796	31,044,414
2007	232,328	68,142	5,136,580	1,584,354	1,468,499	7,913,817	3,718,451	99,800	3,504,041	2,392,258	876,707	26,994,977
2008	271,768	73,807	5,763,763	751,507	1,868,335	10,925,408	4,696,090	333,149	2,728,048	2,657,976	525,891	30,595,742
2009	329,064	113,705	4,786,895	1,123,434	835,970	5,004,604	4,238,319	275,410	4,278,145	1,791,058	160,922	22,937,526
2010	104,117	67,409	4,270,401	1,096,369	1,259,008	6,997,089	5,382,743	251,853	2,630,802	481,147	453,844	22,994,782
2011	91,705	370,798	3,504,522	1,257,302	758,623	8,969,762	6,197,026	241,149	2,640,309	1,160,914	2,042,981	27,235,091
2012	57,509	163,804	5,489,928	851,460	815,545	6,540,024	2,376,866	360,106	1,260,490	1,353,351	0	19,269,083
2013	102,437	233,039	4,193,416	3,043,251	2,286,969	8,624,422	4,945,069	253,062	2,203,319	526,306	0	26,411,290
2014	100,213	78,310	4,397,183	2,161,265	1,783,224	7,552,788	4,133,460	107,421	3,251,151	497,152	0	24,062,167
2015	63,878	30,614	2,701,724	798,394	1,262,377	4,620,923	5,145,204	34,808	3,095,910	430,360	0	18,184,192

^ Commercial quota reallocated to recreational bonus program in CT and NJ; fish harvested under the bonus program are modeled as recreational removals in stock assessment.

Table 6. Commercial Discards, Recreational Releases and Recreational Dead Discards (numbers) of coastal migratory striped bass by state, 1990-2015. Source: MRIP queried June 26, 2016. All harvests based on the calendar year, and may differ from MRIP depending on date queried. Excludes inshore harvest from the A/R.

Year	Commercial Dead Discards	Recreational (B2)	Recreational^ Dead Discards	Total Dead Discards	%Com	%Rec
1990	510,011	1,653,594	148,823	658,834	77%	23%
1991	327,167	3,061,047	275,494	602,661	54%	46%
1992	186,601	3,367,397	303,066	489,667	38%	62%
1993	347,839	4,344,569	391,011	738,850	47%	53%
1994	359,518	7,930,839	713,776	1,073,293	33%	67%
1995	515,454	9,743,862	876,948	1,392,401	37%	63%
1996	394,824	12,288,668	1,105,980	1,500,804	26%	74%
1997	216,745	15,718,341	1,414,651	1,631,396	13%	87%
1998	326,032	14,928,367	1,343,553	1,669,585	20%	80%
1999	236,619	12,514,721	1,126,325	1,362,944	17%	83%
2000	666,997	16,808,809	1,512,793	2,179,790	31%	69%
2001	310,900	13,444,497	1,210,005	1,520,905	20%	80%
2002	168,201	13,693,056	1,232,375	1,400,577	12%	88%
2003	261,974	14,611,333	1,315,020	1,576,994	17%	83%
2004	465,642	17,053,333	1,534,800	2,000,442	23%	77%
2005	798,544	18,078,899	1,627,101	2,425,645	33%	67%
2006	194,524	23,343,299	2,100,897	2,295,421	8%	92%
2007	606,599	16,110,023	1,449,902	2,056,501	29%	71%
2008	308,715	12,510,987	1,125,989	1,434,704	22%	78%
2009	611,944	7,970,813	717,373	1,329,317	46%	54%
2010	254,841	6,258,081	563,227	818,068	31%	69%
2011	617,457	5,932,480	533,923	1,151,380	54%	46%
2012	792,861	5,191,891	467,270	1,260,131	63%	37%
2013	525,581	8,539,986	768,599	1,294,180	41%	59%
2014	931,391	7,282,547	655,429	1,586,820	59%	41%
2015	299,566	8,397,456	755,771	1,055,337	28%	72%
3 yr avg	**585,513**	**8,073,330**	**726,600**	**1,312,112**	**43%**	**57%**
10 yr avg	**514,348**	**10,153,756**	**913,838**	**1,428,186**	**38%**	**62%**

^ Dead discards are estimated by multiplying the number of released fish by a mortality rate of 9%.

Table 7. Performance of Addendum IV commercial regulatory measures in 2015. Realized change in harvest compared to predicted harvest. All analysis in numbers of fish. Commercial estimates do not account for post release mortality or poaching. Excludes inshore harvest from the A/R. Estimates may differ from MRIP depending on date queried.

Region	Sector	Reference * Harvest Estimate	2015 Harvest (predicted)	2015 Harvest (realized)	Change in Harvest (predicted)	Change in Harvest (realized)
Chesapeake Bay	Recreational	554,985	432,365	851,118	-22.1%	53.4%
	Commercial	659,963	524,699	500,349	-20.5%	-24.2%
	Subtotal	**1,214,948**	**957,064**	**1,351,467**	**-21.2%**	**11.2%**
Coastal	Recreational	2,105,069	1,480,306	1,243,033	-29.7%	-41.0%
	Commercial	182,541	162,992	123,108	-10.7%	-32.6%
	Subtotal	**2,287,610**	**1,643,298**	**1,366,141**	**-28.2%**	**-40.3%**
	Total	**3,502,558**	**2,600,362**	**2,717,608**	**-25.8%**	**-22.4%**

* Addendum IV implemented regulatory measures to achieve a 20.5% reduction in removals by number from 2012 harvest-levels for Chesapeake Bay fisheries, and a 25% reduction in removals by number from 2013 harvest-levels for the coastal fisheries.

Table 8A-8D. Performance of addendum IV regulatory measures by sector in 2015. Realized change in harvest compared to predicted estimates. All analysis in numbers of fish. Recreational harvest estimates include dead discards. Commercial estimates do not account for dead discards or poaching. Source: annual state compliance reports and MRIP. Excludes inshore harvest from the A/R. Estimates may differ from MRIP depending on date queried.

8A. Atlantic Coastal Commercial Fishery

State	2013 Harvest	2015 Harvest (predicted)	2015 Harvest (realized)	Change in Harvest (predicted)	Change in Harvest (realized)
ME	-	-	-	-	-
NH	-	-	-	-	-
MA	58,547	51,165	42,250	-12.6%	-27.8%
RI	13,825	10,660	11,325	-22.9%	-18.1%
CT*	292	292	122	0.0%	-58.2%
NY	76,206	73,617	44,809	-3.4%	-41.2%
NJ*	404	404	3,301	0.0%	717.7%
DE	17,679	13,409	10,990	-24.2%	-37.8%
MD	7,608	7,380	2,601	-3.0%	-65.8%
VA	7,980	6,065	7,710	-24.0%	-3.4%
NC	0	0	0	0.0%	0.0%
Total	**182,541**	**162,992**	**123,108**	**-10.7%**	**-32.6%**

* Commercial sale and harvest prohibited; listed harvest is under recreational bonus program

8B. Chesapeake Bay Commercial Fishery

State	2012 Harvest	2015 Harvest (predicted)	2015 Harvest (realized)	Change in Harvest (predicted)	Change in Harvest (realized)
VA	103,703	82,473	132,040	-20.5%	27.3%
MD	465,644	370,187	298,328	-20.5%	-35.9%
PRFC	90,616	72,040	69,981	-20.5%	-22.8%
Total	**659,963**	**524,699**	**500,349**	**-20.5%**	**-24.2%**

8C. Atlantic Coastal Recreational Fishery

State	2013 Harvest	2015 Harvest (predicted)	2015 Harvest (realized)	Change in Harvest (predicted)	Change in Harvest (realized)
ME	61,177	42,212	23,977	-31.0%	-60.8%
NH	25,218	17,401	6,874	-31.0%	-72.7%
MA	451,137	311,285	309,918	-31.0%	-31.3%
RI	292,601	201,895	87,285	-31.0%	-70.2%
CT	213,124	147,055	132,141	-31.0%	-38.0%
NY- coastal	579,935	400,155	311,837	-31.0%	-46.2%
NY- DE River	-	-	-	-	-
NY- Hudson	-	-	-	-	-
NJ	444,658	333,049	361,606	-25.1%	-18.7%
DE	27,034	20,227	7,043	-25.2%	-73.9%
MD- Coastal	9,142	6,308	2,262	-31.0%	-75.3%
VA- Coastal	947	654	89	-31.0%	-90.6%
NC	95	66	0	-31.0%	-100.0%
Total	**2,105,069**	**1,480,306**	**1,243,033**	**29.7%**	**-41.0%**

8D. Chesapeake Bay Recreational Fishery

State	2012 Harvest	2015 Harvest (predicted)	2015 Harvest (realized)	Change in Harvest (predicted)	Change in Harvest (realized)
MD	458,906	357,946	654,194	-22.0%	42.6%
MD- Trophy	16,769	12,560	30,496	-25.1%	81.9%
DC	-	-	-	-	-
PRFC	-	-	-	-	-
VA	79,205	61,780	166,130	-22.0%	109.7%
VA- Trophy	105	79	299	-25.0%	184.7%
Total	**554,985**	**432,365**	**851,118**	**-22.1%**	**53.4%**

Table 9. Commercial Quotas, Harvests, Overages, and Adjusted Quotas (in pounds) Source of Harvest Data: State Compliance Reports. Excludes inshore harvest from the A/R.

Atlantic Coast						
State	**Amd 6 Quota†**	**Add IV Quota⁰**	**2015 Quota**	**2015 harvest**	**overage**	**2016 Quota**
Maine*	250	188	188	N/A		188
New Hampshire*	5,750	4,313	4,313	N/A		4,313
Massachusetts	1,159,750	869,813	869,813	865,753		869,813
Rhode Island	243,625	182,719	181,572	188,475	6,903	174,669
Connecticut**	23,750	17,813	17,813	686		17,813
New York	1,061,060	795,795	795,795	509,135		795,795
New Jersey**	321,750	241,313	241,313	21,479		241,313
Delaware	193,447	145,085	145,085	144,068		145,085
Maryland	131,560	98,670	90,727	34,626		90,727
Virginia	184,853	138,640	138,640	138,141		138,640
North Carolina	480,480	360,360	360,360	0		360,360
Coastal Total	**3,806,275**	**2,854,706**	**2,845,617**	**1,902,363**		**2,838,715**
Chesapeake Bay						
Jurisdiction		**Add IV Quota**	**2015 Quota**	**2015 harvest**	**overage**	**2016 Quota**
Maryland		1,471,888	1,471,888	1,436,867		1,471,888
Virginia		1,064,997	1,064,997	967,067		1,064,997
PRFC		583,362	583,362	536,357		583,362
Chesapeake Bay Total		**3,120,247**	**3,120,247**	**2,940,291**		**3,120,247**
Total Commercial		**5,974,953**	**5,965,864**	**4,842,654**		**5,958,962**

* Commercial harvest/sale prohibited, with no re-allocation of quota.

** Commercial harvest/sale prohibited, with re-allocation of quota to the recreational fishery.

† Beginning in 2003, NY (892,293 lbs) and MD (126,396 lbs) quotas reduced due to conservation equivalency; Beginning in 2007, RI (239,963 lbs) quota reduced due to conservation equivalency.

⁰ Addendum IV quota reduced through conservation equivalency for MD (90,727 lbs) and RI (181,572 lbs)

Table 10. Summary of Atlantic Striped Bass <u>Commercial</u> Regulations in 2015. Source: Annual State Compliance Reports.

STATE	SIZE LIMITS	SEASONAL QUOTA	OPEN SEASON
ME	Commercial fishing prohibited		
NH	Commercial fishing prohibited		
MA	34" TL min size	869,813 lbs. Hook & line only	6.23 until quota reached; 15 fish/day with commercial boat permit; 2 fish/day with rod and reel permit (striped bass endorsement required for both permits)
RI	Floating fish trap: 26" min General category (mostly rod & reel): 34" min.	Total: 181,572 lbs., split 39:61 between trap and general category. Gill netting prohibited.	Trap: 4.1 – 12.31, or until quota reached; unlimited possession limit until quota reached General Category: 6.8-8.31, 9.8-12.31, or until quota reached. Closed Fridays and Saturdays during both seasons. 5 fish/vessel/day possession limit.
CT	Commercial fishing prohibited		
NY	28-38" TL min size Ocean only (Hudson River closed to commercial harvest)	795,795 lb. Pound nets, gill nets (6-8"stretched mesh), hook & line.	6.1 – 12.15, or until quota reached. Limited entry permit only.
NJ	Commercial fishing prohibited		
PA	Commercial fishing prohibited		
DE	Gillnet: 20" TL min in DE Bay/River during spring season. 28" in all other waters/seasons. Hook and Line: 28" min	Gillnet: 137,831 lbs. Hook and line: 14,509 lbs.	Gillnet: 2.15-5.31 (2.15-3.30 for Nanticoke River) & 11.15-12.31; drift nets only 2.15-28 & 5.1-31; no fixed nets in DE River Hook and Line: 4.1–12.31
MD	Bay and Rivers: 18–36" Ocean: 24" minimum	Bay and River: 1,471,888 lbs. (part of Bay-wide quota). Gear specific quotas and landing limits. Ocean: 90,727 lbs.	Bay Pound Net: 6.1-12.31, Mon-Sat Bay Haul Seine: 6.1-11.27, Mon-Fri Bay Hook & Line: 6.1-11.26, Mon-Thu Bay Drift Gill Net: 1.1-3.13, 12.1-12.31 Ocean Drift Gillnet & Trawl: 1.1-4.30, 11.1-12.31, Mon-Fri

(Table 10 continued – Summary of commercial regulations in 2015)

STATE	SIZE LIMITS	SEASONAL QUOTA	OPEN SEASON
PRFC	18" min all year 36" max 2.15–3.25	583,362 lbs (part of Bay-wide quota). Allocated by gear and season.	Hook & line: 2.15-3.25, 6.1-12.31 Pound Net & Other: 2.15-3.25, 6.1-12.15 Gill Net: 1.1-3.25, 11.9-12.31
DC	Commercial fishing prohibited		
VA	Bay and Rivers: 18" min, and 28" max size limit 3.26–6.15 Ocean: 28" min	Bay and Rivers: 1,064,997 lbs Ocean: 138,640 lbs. (ITQ- system for both areas)	Bay and Rivers: 1.16-12.31 Ocean: 1.16-12.31
NC	Ocean: 28"	360,360 lbs. (split between gear types). Number of fish allocated to each permit holder. Allocation varies by permit.	Seine fishery was open for 120 days Gill net fisher was open for 45 days Trawl fishery was open for 70 days

Table 11. Summary of Atlantic Striped Bass Recreational Regulations in 2015. Source: Annual State Compliance Reports.

STATE	SIZE LIMITS	BAG LIMIT	GEAR RESTRICTIONS	OPEN SEASONS
ME	≥ 28” TL minimum size	1 fish/day	Hook & line only	All year, except spawning areas are closed 12.1 – 4.30 and catch and release only 5.1 – 6.30
NH	≥ 28” TL minimum size	1 fish/day	No netting; no gaffing; no culling	All year
MA	≥ 28” TL minimum size	1 fish/day	Hook & line only	All year
RI	≥ 28” TL minimum size	1 fish/day*	None	All year
CT	≥ 28” TL minimum size Connecticut River Bonus Program: 22-28”	1 fish/day (CR Bonus: 1 fish/day)	CR Bonus Quota: 4,025 fish	All year CR Bonus 5.1-6.30 (limited to I-95 bridge to MA border)
NY	Ocean and Delaware River: 28” TL minimum size Hudson River: 18-28” slot limit, or ≥40” TL	1 fish/day	Angling only. Spearing permitted in ocean waters. Catch and release only during closed season.	Ocean: 4.15 – 12.15 Hudson River: 4.1 – 11.30 Delaware River: All year
NJ	1 fish at 28 to < 43”, and 1 fish ≥ 43” TL		Striped Bass Bonus program Quota: 241,313 lbs.	Closed 1.1 – 2.28 in all waters except in the Atlantic Ocean, and 4.1 – 5.31 in the lower Delaware River and tributaries (spawning ground closure)
PA	≥ 28” TL minimum size	1 fish/day		All year. From 4.1 – 5.31, a 21-25” slot limit and 2 fish/day bag limit applies
DE	28” min, no harvest 38-43” (inclusive).	2 fish/day	Hook & line, spear (for divers) only. Circle hooks required in spawning season.	All year except 4.1-5.31 in spawning grounds (catch & release allowed). In Del. River, Bay & tributaries, may only harvest 20-25”slot from 7.1-8.31

*regulation went into effect on April 6, 2015.

(Table 11 continued – Summary of recreational regulations in 2015)

STATE	SIZE LIMITS	BAG LIMIT	OTHER	OPEN SEASON
MD	Ocean: 28” min Bay Trophy: 28 to ≤36” slot, OR ≥40” Bay Summer/Fall: (2) 20-28” slot OR (1) 20-28” slot, (1) > 28” minimum size	Ocean: 1 fish/day Bay Trophy: 1 fish/day Bay Summer/Fall: 2 fish/day	See compliance report for specifics.	Ocean: All year SF: 1.1-5.3 Bay Trophy: 4.18-5.15 Bay Summer/Fall: 5.16-12.15
PRFC	Trophy: 28-36” TL slot limit or > 40” TL Summer/Fall: 20” min with 1 fish > 28” TL	Trophy: 1 fish Summer/Fall: 2 fish	No more than two hooks or sets of hooks for each rod or line	Trophy: 4.18 -5.15 Summer/Fall: 5.16-12.31
DC	≥ 20”, only one fish >28”	2 fish	Hook & line only	5.16-12.31
VA	Ocean: 28” Bay/Coastal Trophy: 36” min (28” max in tribs) CB Spring: 20-28”; only 1 fish can be >36” CB Spring: 20-28”; only 1 fish can be >28”	Ocean: 2 fish/day Bay/Coast Trophy: 1 fish/day Bay Spring/Fall: 2 fish/day	Hook & line, rod & reel, hand line only. Gaffing is illegal in Virginia marine waters.	Ocean: 1.1-3.31, 5.16-12.31 Bay/Tribs Trophy: 5.1-6.15 Coastal Trophy: 5.1-5.15 Bay Spring: 5.16-6.15 Bay Fall: 10.4-12.31
NC	Ocean: 28” min size	Ocean: 1 fish/day	No gaffing allowed.	Ocean: All year

Table 12. Status of commercial Tagging Programs by state for 2015. Quotas are presented in pounds.

State	# of Participants	# of Tags Issued	# of Tags Used	Point of Tag	[1]Biological Metric	Year, State and Unique ID on Tag	Size Limit on Tag	Number of Tag Colors	Annual Tag Color Change
MA^	115	70,980	42,250	Sale	Yes	Yes	Yes	one	Yes
RI	31	14,991	11,325	Sale	Yes	Yes	No	two by gear	Yes
NY	451	72,428	44,809	Harvest	Yes	Yes	No	one	Yes
DE	111	33,000	21,980	Both	Yes	Yes	No	Harvest: two by gear Sale: one	Yes
MD	677	473,790	342,921	Harvest	Yes	Yes	No	Three by gear/permit	Yes
PRFC	340	77,222	68,715	Harvest	Yes	Yes	No	Five by season/gear	No
VA	436	153,500	139,750	Harvest	Yes	Yes	Yes	two by area	Yes
NC*	45	34,843	34,843	Sale	Yes	Yes	Yes	Three by area	No

[1] States are required to allocate commercial tags to permit holders based on a biological metric. Most states used the average weight per fish from the previous year, or some variation thereof. Actual biological metric used is to be included in State Annual Commercial Tag Reports.

^ MA was granted an extension through Addendum III and mandated to implement a commercial tagging program prior to start of the 2014 fishing year.

* NC harvest from inshore A/R.

Table 13. Status of compliance with monitoring and reporting requirements in 2015
(JAI = juvenile abundance index survey, SSB = spawning stock biomass survey, tag = participation in coastwide tagging program, Y = compliance standards met, N = compliance standards not met, na = not applicable)

Jurisdiction	Fishery-independent monitoring		Fishery-dependent monitoring		Annual reporting
	Requirement(s)	Status	Requirement(s)	Status	Status
ME	JAI	Y	x	na	Y
NH	x	na	x	na	Y
MA	tag	Y	composition, catch & effort (C&R), tag program	Y	Y
RI	x	na	composition (C&R), catch & effort (R), tag program	Y	Y
CT	x	na	composition, catch & effort (R)	Y	Y
NY	JAI, SSB, tag	Y	composition, catch & effort (C&R), tag program	Y	Y
NJ	JAI, tag	Y	composition, catch & effort (R)	Y	Y
PA	SSB	Y	x	na	Y
DE	SSB, tag	Y	composition, catch & effort (C), tag program	Y	Y
MD	JAI, SSB, tag	Y	composition, catch & effort (C&R), tag program	Y	Y
PRFC	x	na	composition, catch & effort (C&R), tag program	Y	Y
DC	x	na	x	na	Y
VA	JAI, SSB, tag	Y	composition, catch & effort (C&R), tag program	Y	Y
NC	JAI, SSB, tag	Y	composition (C), tag program	Y	Y

XII. Figures

Figures 1 – 7 present striped bass harvest, biomass, and fishing mortality estimates from 1982-2015 when possible.

Figure 1. Coastal migratory Atlantic striped bass spawning stock biomass (SSB) and recruitment estimates, and biological reference points, 1982-2014. Source: 2015 Striped Bass Stock Assessment Update.

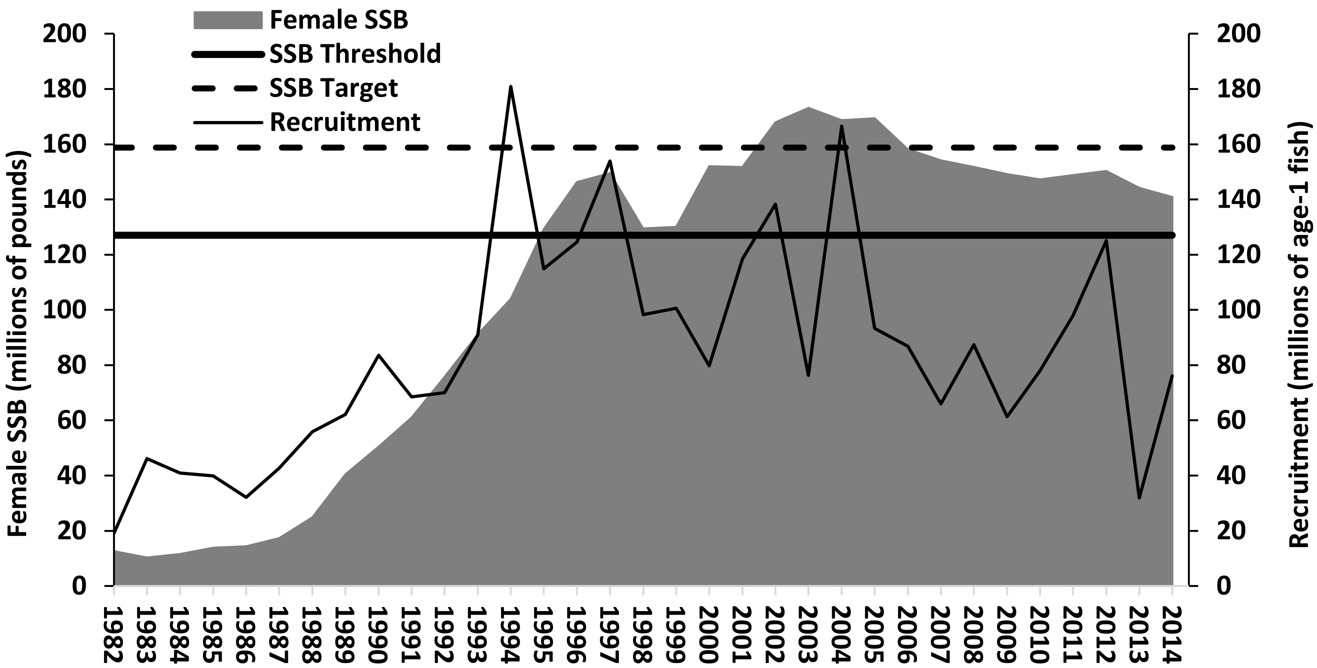


Figure 2. Coastal migratory Atlantic striped bass fishing mortality (F) estimates, and biological reference points, 1983-2014. Source: 2015 Striped Bass Stock Assessment Update

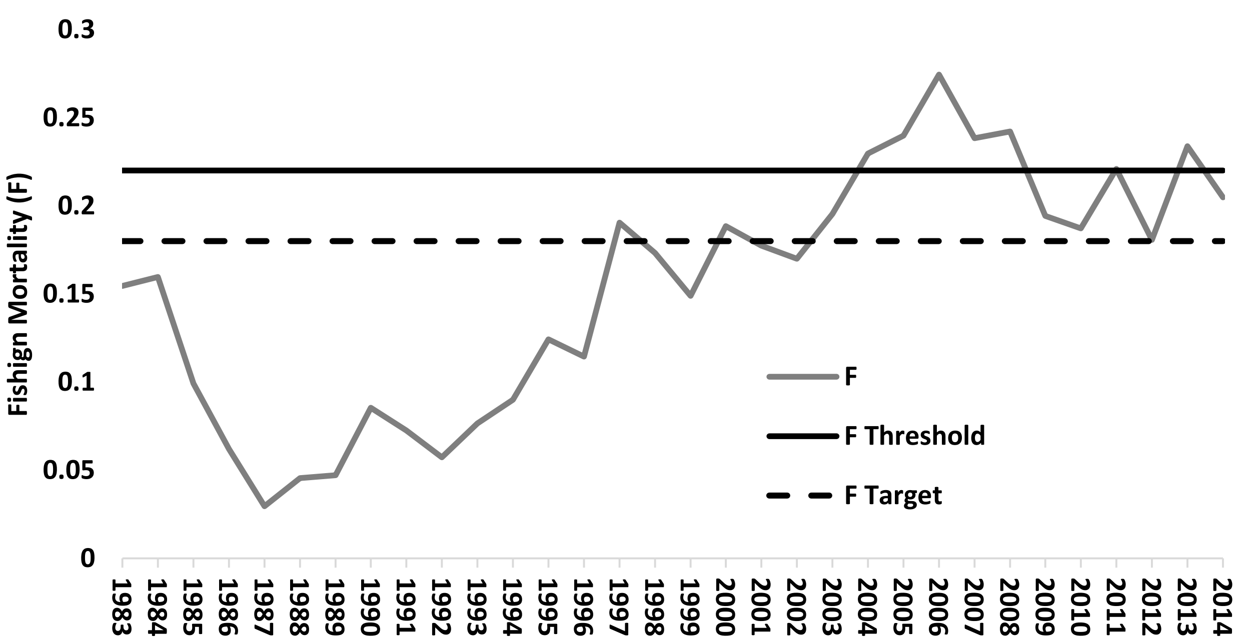


Figure 3. Albemarle/Roanoke striped bass female spawning stock biomass and recruitment (abundance of age-1), and biological reference points, 1982-2012. Source: Stock Status of Albemarle Sound-Roanoke River Striped Bass, 2014.

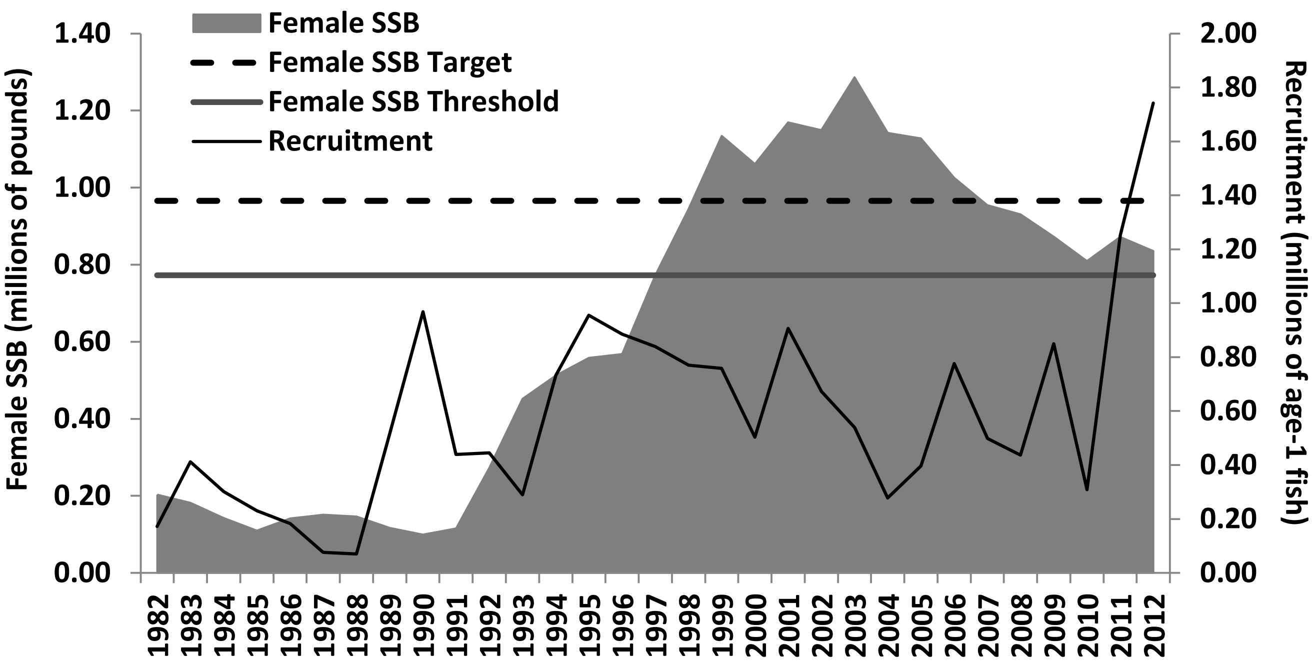


Figure 4. Albemarle/Roanoke striped bass fishing mortality (F) estimates, and biological reference points, 1982-2012. Source: Stock Status of Albemarle Sound-Roanoke River Striped Bass, 2014.

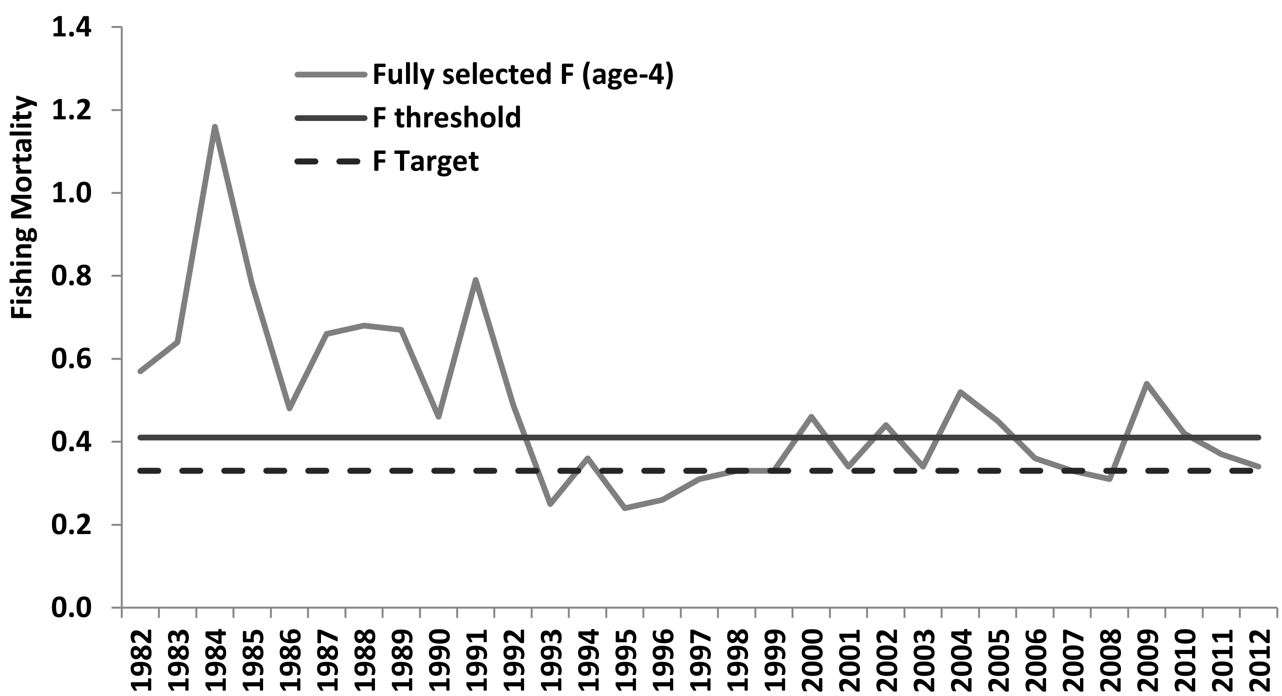


Figure 5. Total removals in millions of fish by sector, 1982-2015. Source: MRIP and annual state compliance reports. Excludes A/R inshore harvest. Estimates may differ from MRIP depending on date queried.

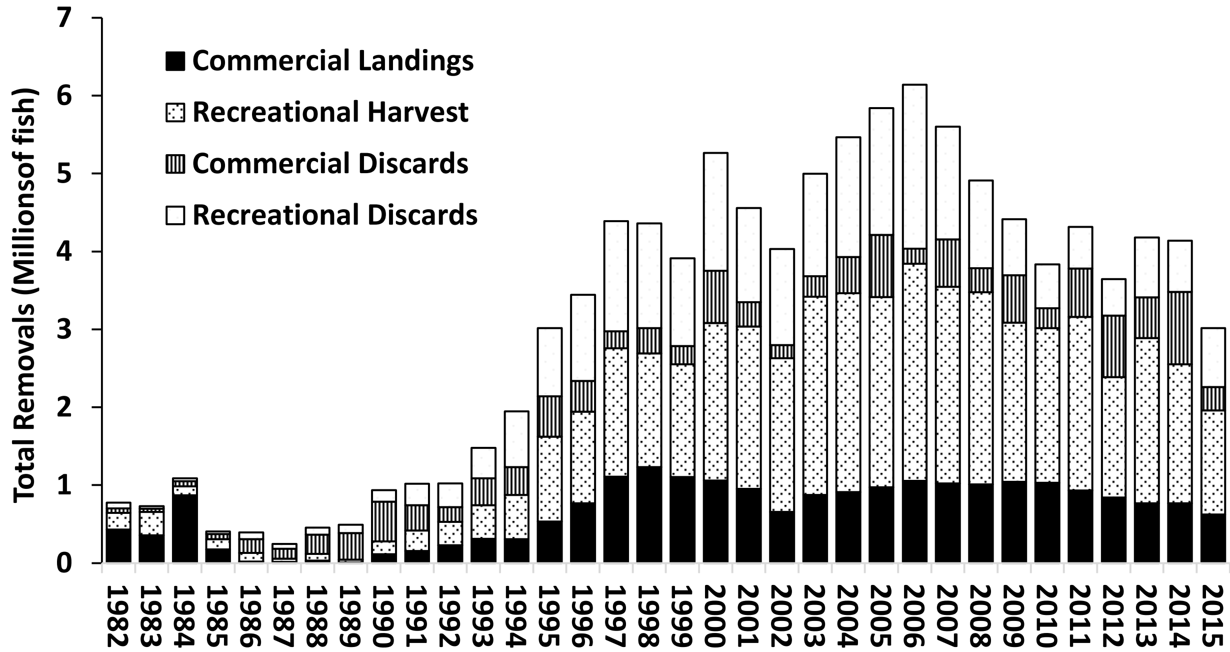


Figure 6. Commercial landings, in pounds, of migratory Striped Bass, by state, 1990-2015. Source: annual state compliance reports. All landings based on the calendar year. Excludes A/R inshore harvest. Commercial harvest and sale prohibited in ME, NH, CT, and NJ. Commercial quota reallocated to recreational bonus program in CT and NJ.

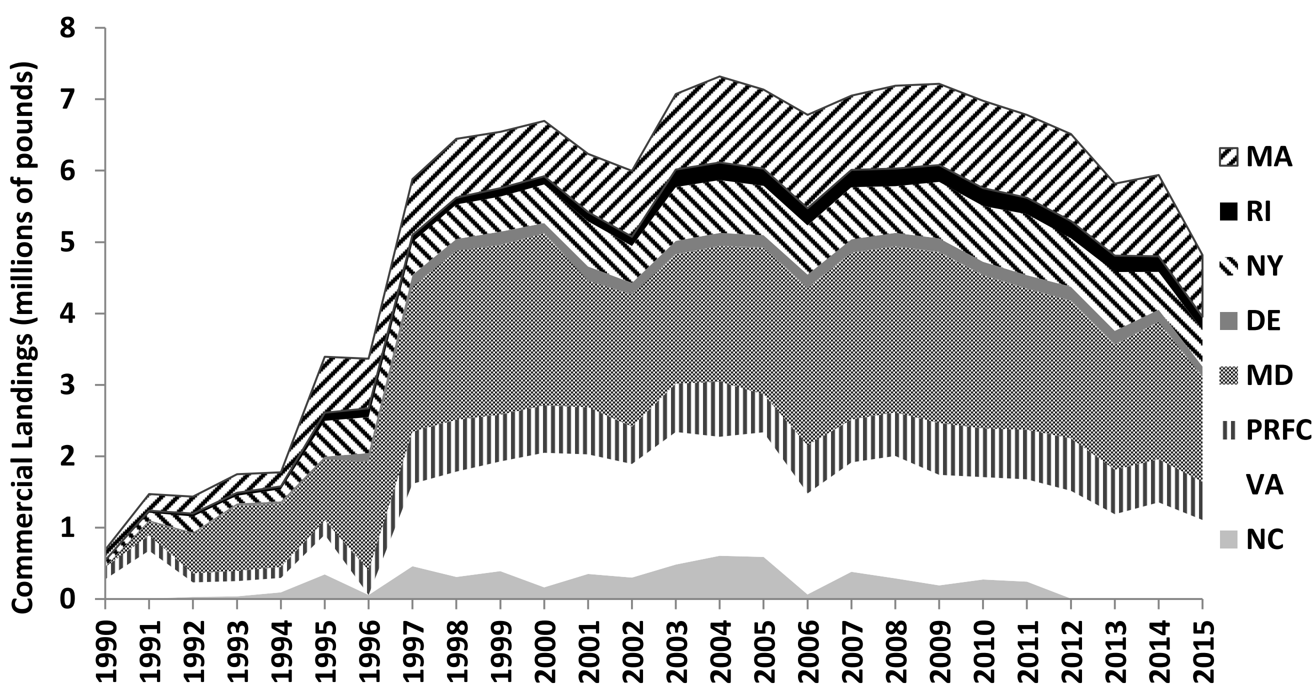


Figure 7. Recreational catch (A + B1 + B2), harvest (A + B1) and the proportion of fish released, 1982-2015. Source: Marine Recreational Information Program (MRIP) queried June 26, 2016. Estimates may differ from MRIP depending on date queried.

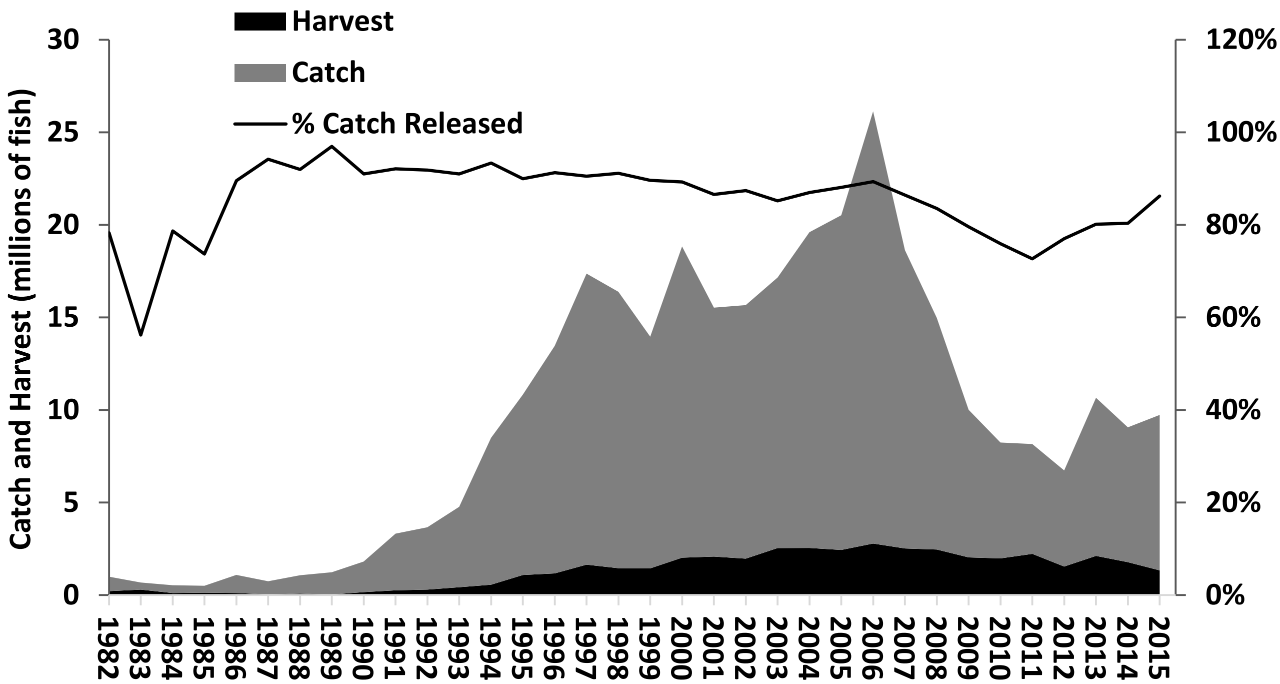
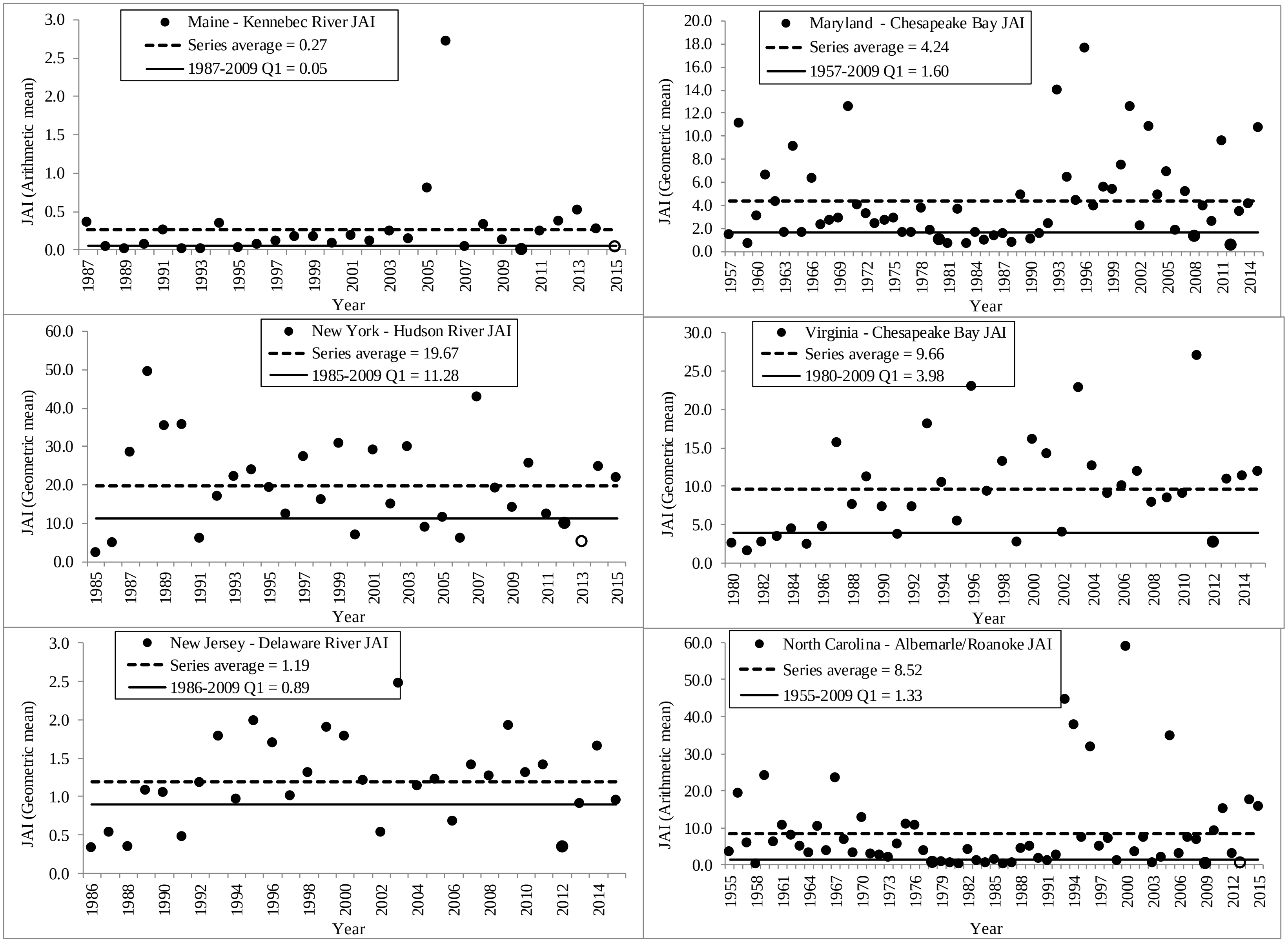


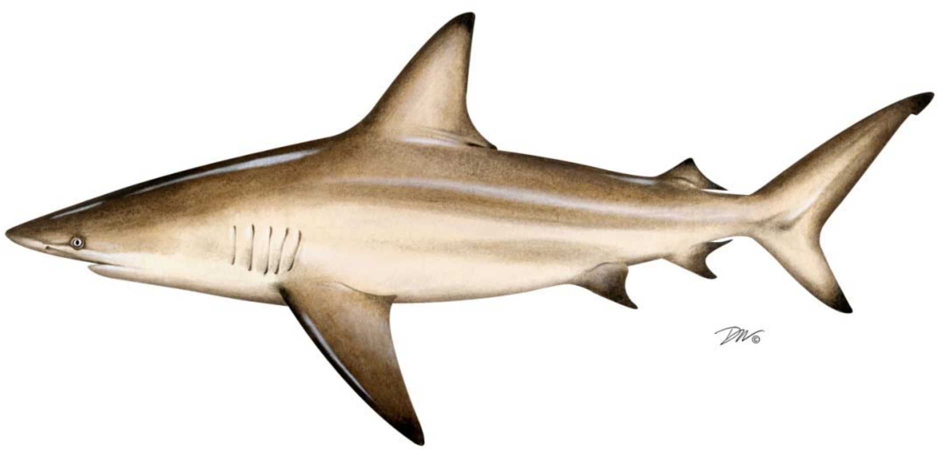
Figure 8. Juvenile abundance indices from Maine, New York, Jew Jersey, Maryland, Virginia, and North Carolina. Source: Annual State Compliance Reports. Q1 = first quartile, which is the value that is below 75% of all values in a specified time series.



2015 REVIEW OF THE
ATLANTIC STATES MARINE FISHERIES COMMISSION
FISHERY MANAGEMENT PLAN FOR

COASTAL SHARKS

2014 FISHING YEAR



Coastal Sharks Plan Review Team

Bryan Frazier, South Carolina Department of Natural Resources
Tina Moore, North Carolina Department of Environment and Natural Resources
Ashton Harp, Atlantic States Marine Fisheries Commission, Chair

Table of Contents

I. Status of the Fishery Management Plan

Date of FMP Approval:	August 2008
Amendments	None
Addenda	Addendum I (September 2009) Addendum II (May 2013) Addendum III (October 2013)
Management Unit:	Entire coastwide distribution of the resource from the estuaries eastward to the inshore boundary of the EEZ
States With Declared Interest:	Maine, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Delaware, Maryland, Virginia, North Carolina, South Carolina, Georgia, Florida
Active Boards/Committees:	Coastal Shark Management Board, Advisory Panel, Technical Committee, and Plan Review Team

a) Goals and Objectives

The Interstate Fishery Management Plan for Coastal Sharks (FMP) established the following goals and objectives.

GOALS

The goal of the Interstate Fishery Management Plan for Coastal Sharks is "to promote stock rebuilding and management of the coastal shark fishery in a manner that is biologically, economically, socially, and ecologically sound."

OBJECTIVES

In support of this goal, the following objectives proposed for the FMP include:

1. Reduce fishing mortality to rebuild stock biomass, prevent stock collapse, and support a sustainable fishery.
2. Protect essential habitat areas such as nurseries and pupping grounds to protect sharks during particularly vulnerable stages in their life cycle.
3. Coordinate management activities between state and federal waters to promote complementary regulations throughout the species' range.
4. Obtain biological and improved fishery related data to increase understanding of state water shark fisheries.
5. Minimize endangered species bycatch in shark fisheries.

b) Fisheries Management Plan Summary

Atlantic States Marine Fisheries Commission (Commission) adopted its first interstate fishery management plan for coastal sharks in 2008. Coastal sharks are currently managed as groupings or complexes (Table 1), which include: prohibited, research, non-blacknose small coastal, aggregated large coastal, blacknose, pelagic, hammerhead and smoothhound. The Commission generally approves the opening dates and quotas set forth by NMFS in the annual specifications package and will close fisheries when NMFS has determined the quota has been exceeded. Species in the prohibited category may not be possessed or taken. Sandbar sharks may only be taken with a shark fishery research permit. All species must be landed with their fin attached to the carcass by natural means, with a limited exception for smooth dogfish.

The FMP has been adapted through the following addenda:

Addendum I (2009) modified the FMP to allow limited smooth dogfish processing at sea (removal of fins from the carcass), as long as the total wet weight of the shark fins does not exceed 5 percent of the total dressed weight. In addition, smoothhound recreational possession limits and gillnet check requirements for smoothhound fishermen were removed. These restrictions were removed because they were intended for large coastal sharks. The removal allowed smoothhound fishermen to continue operations while upholding the conservation measures of the FMP.

Addendum II (2013) modified the FMP to allow year round smooth dogfish processing at sea, if fins are removed the total wet weight of the shark fins may not exceed 12 percent of the total dressed weight. State-shares of the smoothhound coastwide quota were allocated. The goal of Addendum II was to implement an accurate fin-to-carcass ratio and prevent any one state from harvesting the entire smoothhound quota, thereby excluding the others.

Addendum III (2013) modified the species groups in the FMP to ensure consistency with NOAA Fisheries (Table 1). The recreational size limit for the hammerhead species group was increased to 78” fork length.

Table 1. List of commercial shark management groups

Species Group	Species within Group
Prohibited	Sand tiger, bigeye sand tiger, whale, basking, white, dusky, bignose, Galapagos, night, reef, narrowtooth, Caribbean sharpnoes, smalltail, Atlantic angel, longfin mako, bigeye thresher, sharpnose sevengill, bluntnose sixgill and bigeye sixgill sharks
Research	Sandbar sharks
Non-Blacknose Small Coastal	Atlantic sharpnose, finetooth, and bonnethead sharks
Blacknose	Blacknose sharks

Aggregated Large Coastal	Silky, tiger, blacktip, spinner, bull, lemon, and nurse
Hammerhead	scalloped hammerhead, great hammerhead and smooth hammerhead
Pelagic	Shortfin mako, porbeagle, common thresher, oceanic whitetip and blue sharks
Smoothhound	Smooth dogfish and Florida smoothhound

II. Status of the Stocks

Stock status is assessed by species or by species complex if there is not enough data for an individual assessment. In summary, fourteen species have been assessed domestically, three species have been assessed internationally, and the rest have not been assessed. Table 2 describes stock status and the associated entity preforming the assessment.

In 2015, a benchmark stock assessment (SEDAR 39) was conducted for the smoothhound complex, including smooth dogfish, the only species of smoothhound occurring in the Atlantic. The assessment indicates Atlantic smooth dogfish (*Mustelus canis*) is not overfished and not experiencing overfishing.

The North Atlantic blue shark (*Prionace glauca*) stock was assessed by ICCAT's Standing Committee on Research and Statistics (SCRS) in 2015. The assessment indicated the stock is not overfished and not experiencing overfishing, as was also concluded in the 2008 stock assessment. However, scientists acknowledge there is a high level of uncertainty in the data inputs and model structural assumptions; therefore, the assessment results should be interpreted with caution.

SEDAR 34 (2013) assessed the Atlantic sharpnose (*Rhizoprionodon terraenovae*) and bonnethead (*Sphyrna tiburo*) sharks. The Atlantic sharpnose stock is not overfished and not experiencing overfishing. The stock status of bonnethead shark stocks (Atlantic and Gulf of Mexico) is unknown. It is recommended that a benchmark assessment for both stocks be undertaken.

The North Atlantic shortfin mako shark (*Isurus oxyrinchus*) stock was assessed by ICCAT SCRS. According to the 2012 assessment, current levels of catch may be considered sustainable as potential indicators of overfishing identified in the prior assessment have diminished. The stock is not overfished nor experiencing overfishing.

A 2011 benchmark assessment (SEDAR 21) of dusky (*Carcharhinus obscures*), sandbar (*Carcharhinus plumbeus*), and blacknose (*Carcharhinus acrontus*) sharks indicates that both dusky and blacknose sharks are overfished and experiencing overfishing. Sandbar sharks continued to be overfished. As described in the Magnuson-Stevens Act, NOAA Fisheries must establish a rebuilding plan for an overfished stock. As such, the rebuilding date for dusky sharks is 2108, sandbar sharks is 2070, and blacknose sharks is 2043. A dusky stock assessment update is scheduled for 2016.

Porbeagle sharks (*Lamna nasus*) were assessed by the ICCAT's SCRS in 2009. The assessment found the Northwest Atlantic stock is increasing in biomass, however the stock is considered to be overfished with overfishing not occurring. NOAA Fisheries established a 100-year rebuilding plan for porbeagle sharks; the expected rebuilding date is 2108.

A 2009 stock assessment for the Northwest Atlantic and Gulf of Mexico populations of scalloped hammerhead sharks (*Sphyrna lewini*) indicated the stock is overfished and experiencing overfishing. This assessment was reviewed by NOAA Fisheries and deemed appropriate to serve as the basis for U.S. management decision. In response to the assessment findings, NOAA Fisheries established a scalloped hammerhead rebuilding plan that will end in 2023.

SEDAR 11 (2006) assessed the LCS complex and blacktip sharks (*Carcharhinus limbatus*). The LCS assessment suggested that it is inappropriate to assess the LCS complex as a whole due to the variation in life history parameters, different intrinsic rates of increase, and different catch and abundance data for all species included in the LCS complex. Based on these results, NMFS changed the status of the LCS complex from overfished to unknown. As part of SEDAR 11, blacktip sharks were assessed for the first time as two separate populations: Gulf of Mexico and Atlantic. The results indicated that the Gulf of Mexico stock is not overfished and overfishing is not occurring, while the current status of blacktip sharks in the Atlantic region is unknown.

Table 2. Stock Status of Atlantic Coastal Shark Species and Species Groups

Species or Complex Name	Stock Status		References/Comments
	Overfished	Overfishing	
Pelagic			
Porbeagle	Yes	No	Porbeagle Stock Assessment, ICCAT Standing Committee on Research and Statistics Report (2009); Rebuilding ends in 2108 (HMS Am. 2)
Blue	No	No	ICCAT Standing Committee on Research and Statistics Report (2015)
Shortfin mako	No	No	ICCAT Standing Committee on Research and Statistics Report (2012)
All other pelagic sharks	Unknown	Unknown	
Aggregated Large Coastal Sharks (LCS)			
Atlantic Blacktip	Unknown	Unknown	SEDAR 11 (2006)
Aggregated Large Coastal Sharks - Atlantic Region	Unknown	Unknown	SEDAR 11 (2006); difficult to assess as a species complex due to various life history characteristics/ lack of available data
Non-Blacknose Small Coastal Sharks (SCS)			
Atlantic Sharpnose	No	No	SEDAR 34 (2013)
Bonnethead	Unknown	Unknown	SEDAR 34 (2013)
Finetooth	No	No	SEDAR 13 (2007)
Hammerhead			
Scalloped	Yes	Yes	SEFSC Scientific Review by Hayes et al. (2009); Rebuilding ends in 2023 (HMS Am. 5a)
Blacknose			
Blacknose	Yes	Yes	SEDAR 21 (2010); Rebuilding ends in 2043 (HMS Am. 5a)
Smoothhound			
Atlantic Smooth Dogfish	No	No	SEDAR 39 (2015)
Research			
Sandbar	Yes	No	SEDAR 21 (2010)
Prohibited			
Dusky	Yes	Yes	SEDAR 21 (2010); Rebuilding ends in 2108 (HMS Am. 2)
All other prohibited sharks	Unknown	Unknown	

III. Status of the Fishery

Specifications (Opening, closures, quotas)

NOAA Fisheries sets quotas for coastal sharks through the 2006 Consolidated Atlantic Highly Migratory Species Fishery Management Plan. The opening dates, closures dates and quotas are detailed in Table 3. All non-prohibited coastal shark management groups, except aggregated large coastal and hammerheads shark groupings, opened on January 1, 2014. NOAA Fisheries closes commercial shark fisheries when 80% of the available quota is reached. Commercial shark dealer reports indicate the following commercial fisheries exceeded 80% of the available quota and had an early closure: blacknose, non-blacknose small coastals, aggregated large coastal and hammerhead fishery. When the fishery closes in federal waters, the Interstate FMP dictates that the fishery also closes in state waters.

Table 3. Commercial quotas and opening dates for 2014 shark fishing season

Species Group	Region	2014 Annual Quota (mt dw)	Season Opening Dates	Closing Date (if any)
Aggregated Large Coastal Sharks (LCS)	Atlantic	168.9	June 1, 2014	Nov. 30, 2014
Hammerhead Sharks	Atlantic	27.1	June 1, 2014	Nov. 30, 2014
Non-Blacknose Small Coastal Sharks (SCS)	Atlantic	264.1	January 1, 2014	July 28, 2014
Blacknose Sharks	Atlantic	17.5	January 1, 2014	July 28, 2014
Blue Sharks	No regional quotas	273.0	January 1, 2014	
Porbeagle Sharks	No regional quotas	1.2	January 1, 2014	Dec. 17, 2014
Pelagic Sharks other than Porbeagle or Blue	No regional quotas	488.0	January 1, 2014	
Shark Research Quota (Aggregated LCS)	No regional quotas	50.0	January 1, 2014	
Sandbar Research Quota	No regional quotas	116.6	January 1, 2014	

Commercial Landings

Commercial landings of Atlantic large coastal sharks species in 2014 were 464,803 pounds (lbs) dressed weight (dw), slightly above 2012-2013 landings (Table 4). Commercial landings of small coastal shark species in 2014 were 269,252 lbs dw, roughly similar to 2013 landings which were the lowest SCS landings in five years (Table 5). Commercial landings of Atlantic pelagic sharks was 358,549 lbs dw, which represents the largest landings in the six year time series and a 40% increase from 2013 landings—the lowest landings in the time series (Table 6). The increase in pelagic shark landings can be attributed to a 138% increase in the commercial harvest of thresher sharks.

Table 4. Commercial landings of authorized Atlantic large coastal sharks by species (pounds dw), 2008-2014. Source: HMS SAFE Report, 2015.

	2008	2009	2010	2011	2012	2013	2014
Great hammerhead	0	0	0	0.0	371	7,406	13,538
Scalloped hammerhead	0	0	0	0.0	15,800	27,229	24,652
Smooth hammerhead		4,025	7,802	110	3,967	1,521	601
Unclassified	21,631	62,825	43,345	35,618	9,617	0	0
Hammerhead Total	**21,631**	**66,850**	**51,147**	**35,728**	**29,755**	**36,156**	**38,791**
Blacktip	258,035	229,267	246,617	176,136	215,403	256,277	282,009
Bull	43,200	61,396	56,901	49,927	24,504	33,980	32,372
Lemon	22,530	30,909	25,316	45,448	21,563	16,791	13,047
Nurse	10	0	71	0	81	0	0
Silky	306	1,386	1,049	992	29	186	289
Spinner	1,265	20,022	13,544	4,113	10,643	26,892	25,716
Tiger	14,119	15,172	43,145	36,425	23,245	16,561	29,062
Unclassified	187,670	70,894	2,229	50,711	53,705	0	0
Aggregated LCS Total	**527,135**	**429,046**	**388,872**	**363,766**	**349,345**	**350,687**	**382,495**
Sandbar	63,035	54,141	84,339	94,295	46,446	46,868	82,308
Hammerhead, Aggregated LCS, Sandbar Total	**611,801**	**550,037**	**524,358**	**493,775**	**425,374**	**433,710**	**464,803**

Table 5. Commercial landings of authorized Atlantic small coastal sharks by species (lbs dw), 2008-2014. Source: HMS SAFE Report, 2015.

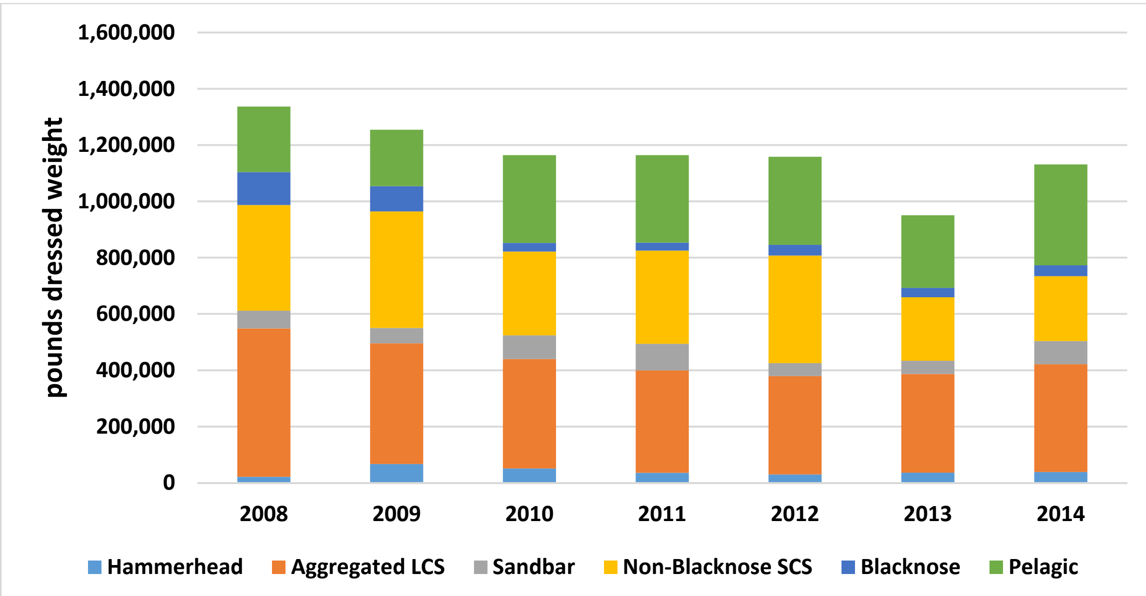
	2008	2009	2010	2011	2012	2013	2014
Blacknose	117,197	90,023	30,287	28,373	37,873	33,382	38,437
Bonnethead	61,549	53,912	9,069	28,284	19,907	22,845	13,221
Finetooth	28,872	63,359	76,438	52,318	15,922	19,452	19,026
Atl. Sharpnose	261,788	262,508	211,190	214,382	345,625	183,524	198,568
Unclassified	23,077	34,429	851	36,639	492	0	0
SCS Total	**490,483**	**504,231**	**327,835**	**359,996**	**419,819**	**259,203**	**269,252**

Table 6. Commercial landings of authorized pelagic sharks by species off the Atlantic coast of the United States (lb dw), 2008-2014. Source: HMS SAFE Report, 2015.

	2008	2009	2010	2011	2012	2013	2014
Blue	3,229	4,793	9,135	13,370	17,200	9,767	17,806
Porbeagle	5,259	3,609	4,097	5,933	4,250	54	6,414
Shortfin Mako	120,255	141,456	220,400	207,630	198,841	199,177	218,295

Unclassified Mako	39,661	9,383	0	0	0	0	0
Oceanic whitetip	1,899	933	796	2,435	258	62	22
Thresher	47,528	33,333	61,290	47,462	63,965	48,768	116,012
Unclassified pelagic	14,819	6,650	16,160	33,884	28,932	0	0
Pelagic Total	**232,650**	**200,157**	**311,878**	**310,714**	**313,446**	**257,828**	**358,549**

Figure 1: Commercial landings of coastal sharks off the east coast of the United States by species complex, 2008-2014. Source: HMS SAFE Report, 2015.



Recreational Landings

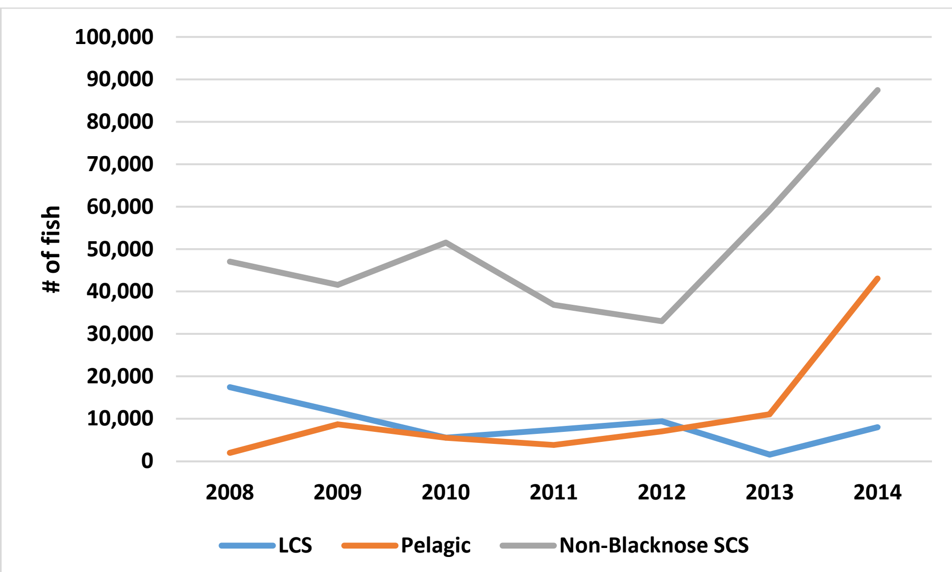
Approximately 145,000 sharks were harvested during the 2014 recreational fishing season, which represents the largest harvest in the time series (Table 7). The non-blacknose small coastal shark (SCS) group comprised 60% of the overall recreational harvest, all species within this group (Atlantic sharpnose, bonnethead, finetooth) had harvest increases. The LCS group increase is attributed to requiem shark and blacktip shark harvest increases. The estimated recreational harvest for the pelagic shark group is comprised of harvest from the Atlantic Ocean and the Gulf of Mexico. The increases in pelagic harvest is attributed to mackerel sharks, shortfin mako, and thresher sharks.

Table 7. Estimated recreational harvest of all Atlantic shark species by species group in numbers of fish, 2008-2014. Source: HMS SAFE Report, 2015.

	2008	2009	2010	2011	2012	2013	2014
Aggregated LCS	17,441	11,536	5,540	7,396	9,386	1,547	8,010
Hammerhead	4	574	13	179	41	600	900
Pelagic*	1,972	8,694	5,529	3,806	7,034	11,056	43,049
Blacknose	2	947	0	573	0	70	4146
Non-Blacknose SCS	47,059	41,577	51,529	36,850	33,005	59,207	87,481
Sandbar	4,210	6,461	2,193	1,125	857	399	1,873
Prohibited	1,502	506	4	23	15	16	2
Total	72,190	70,295	64,808	49,952	50,338	72,895	145,461

*Pelagic sharks include Gulf of Mexico landings.

Figure 2: Estimated recreational harvest for LCS, SCS and pelagic species by species group, in numbers of fish, 2008-2014. Source: HMS SAFE Report, 2015.



IV. Status of Research and Monitoring

Under the Interstate Fishery Management for Coastal Sharks, the states are not required to conduct any fishery dependent or independent studies, however they are encouraged to submit any information collected while surveying for other species. This section describes the research and monitoring efforts during the 2014 fishing year, where available.

The Cooperative Atlantic States Shark Pupping and Nursery (COASTSPAN) appears in multiple state monitoring efforts, a brief description is below. The survey monitors the presence of young-of-year and juvenile sharks along the east coast. It is managed and coordinated by NOAA's Northeast Fisheries Science Center (NEFSC) through the Apex Predators Program based at the NEFSC's Narragansett Laboratory in Rhode Island. Longline and gillnet sampling, and mark-recapture techniques are used to determine the relative abundance, distribution and migration of sharks utilizing nursing grounds from Massachusetts to Florida. In 2014, COASTSPAN program participants were the Georgia Department of Natural Resources and the South Carolina Department of Natural Resources. In addition, the survey is conducted in summer months in Narragansett and Delaware Bays, and in Massachusetts waters. Standardized indices of abundance from COASTPAN surveys are used in the stock assessments for large and small coastal sharks.

Massachusetts

Movement and Habitat Studies: With external funding from private and federal grants, *MarineFisheries* personnel continued in 2014 to collaborate with federal and academic researchers on the study of broad and fine-scale movements of numerous shark species using pop-up satellite tags, real-time satellite tags, acoustic transmitters, and conventional tags. These species include white, basking, blue, shorfin mako, tiger, and sand tiger sharks.

Basking Shark: Since 2004, 57 basking sharks have been tagged with PSAT tags and 10 with SPOT tags. A quantitative analysis of the fine-scale movements of SPOT-tagged basking sharks as they relate to oceanographic features derived from satellites was published (Curtis et al., 2014).

White Shark: From 2009 through 2014, a total of 56 individual white sharks were tagged off the eastern coast of Cape Cod, primarily in nearshore shallow waters from Orleans to the southern tip of Monomoy. Five of these sharks were tagged in partnership with the non-profit organization, OCEARCH, in 2012 and 2013. These five sharks—the first to be tagged with real time satellite transmitters in the Atlantic Ocean—can be followed live through OCEARCH's interactive tracking website. The remaining sharks were tagged with one or more of the following tags: pop-up satellite archival tags, coded acoustic transmitters, autonomous underwater vehicle transponders, active acoustic transmitters, and NOAA Fisheries conventional tags. The 56 tagged sharks ranged from roughly 7.5 to 18.5 feet in total length.

In 2014, project personnel initiated a study to quantify the regional population size of white sharks in Massachusetts waters. With funding and logistical support from the Atlantic White

Shark Conservancy, a formal survey was conducted from mid-June through October off the southern coast of Cape Cod. In total, 68 individual white sharks (43 males, 25 females) were identified. Of these, 18 were tagged with acoustic transmitters. Over the course of the summer and fall, 22 white sharks were detected by the *MarineFisheries* acoustic array off Cape Cod.

Blue, Shortfin Mako, and Tiger Sharks: In cooperation with OCEARCH and the Montauk Marine Basin, one blue, two tiger, and three shortfin mako sharks were tagged with real-time SPOT tags during the second annual Shark's Eye All-release Shark Tournament held July 12-13, 2014 in Montauk, New York. The movements of these sharks can be followed on the OCEARCH interactive tracking website.

Post-release Survivorship Studies: In 2014, work continued with University of Massachusetts researchers to study the physiological effects of longline capture in sandbar and dusky sharks. Funding for the study was obtained from the Saltonstall-Kennedy Program.

Life History: Working with NOAA Fisheries and WHOI researchers, personnel generated age and growth estimates for the white shark in the western North Atlantic. Using bomb-produced radiocarbon, which acts as a kind of bone marker, vertebral growth bands were counted and validated as annual. In 2014, part of this research was published (Hamady et al., 2014).

The following peer-reviewed publications were issued in 2014:

Hamady, L.L., L.J. Natanson, G.B. Skomal, and S.R. Thorrold. 2014. Vertebral bomb radiocarbon suggests extreme longevity in white sharks. Plos One, DOI: 10.1371/journal.pone.0084006.

Braun, C.D., G.B. Skomal, S.R. Thorrold, M.L. Berumen. 2014. Diving behaviors of the reef manta ray (Manta alfredi) link coral reefs with adjacent deep pelagic habitats. PLoS One, DOI: 10.1371/journal.pone.0088170.

Kneebone, J., J. Chisholm, and G.B. Skomal. 2014. Movement patterns of juvenile sand tigers (Carcharias taurus) along the east coast of the USA. Marine Biology 161:1149-1163.

Curtis,T.H., C.T. McCandless, J.K. Carlson, G.B. Skomal, N.E. Kohler, L.J. Natanson, G.H. Burgess, J. J. Hoey, and H.L. Pratt, Jr. 2014. Seasonal distribution and historic trends in abundance of white sharks, Carcharodon carcharias, in the western North Atlantic Ocean. PLoS ONE 9(6): e99240. doi:10.1371/journal.pone.0099240.

Thorrold, S.R., P. Afonso, J. Fontes, C.D. Braun, R.S. Santos, G.B. Skomal, and M.L. Berumen. 2014. Extreme diving behavior in devil rays links surface waters and the deep ocean. Nature Communications, DOI: 10.1038/ncomms5274.

Berumen, M.L., C.D. Braun, J. E.M. Cochran, G. B. Skomal, S. R. Thorrold. 2014. Movement patterns of juvenile whale sharks tagged at an aggregation site in the Red Sea. PLoS ONE 9(7): e103536. doi:10.1371/journal.pone.0103536.

Curtis, T.H., S.I. Zeeman, E.L. Summers, S.X. Cadrin, and G. B. Skomal. 2014. Eyes in the sky: linking satellite oceanography and biotelemetry to explore habitat selection by basking sharks. Animal Biotelemetry, www.animalbiotelemetry.com/content/2/1/12

Rhode Island

Fishery independent monitoring is limited to coastal shark species taken in the RI Division of Fish & Wildlife, Marine Fisheries Section monthly and seasonal trawl survey. During the 2014 calendar year the only coastal shark species captured in the trawl survey was smooth dogfish (*Mustelus canis*). A summary of fishery independent monitoring for coastal sharks is summarized in Table 8 below.

Table 8. Total number of coastal sharks (smooth dogfish) caught per month and during the Rhode Island seasonal trawl surveys in 2014

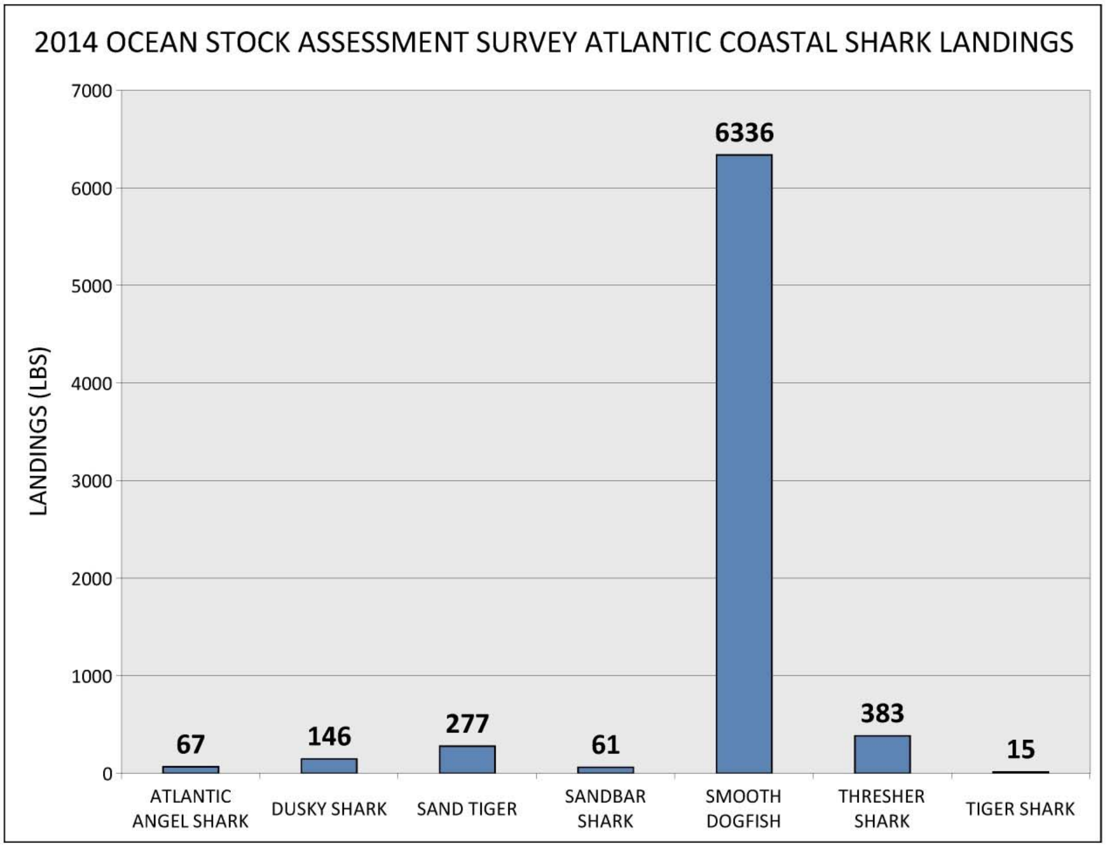
Year	Month	Tows conducted	Total weight (kg)	Total number	Number per tow	kg per tow
Monthly Coastal Trawl Survey			-	-	-	-
2014	JAN	11	0	0	0.00	0.00
2014	FEB	12	0	0	0.00	0.00
2014	MAR	10	0	0	0.00	0.00
2014	APR	13	0	0	0.00	0.00
2014	MAY	13	1.23	1	0.08	0.09
2014	JUN	13	13.94	6	0.46	1.07
2014	JUL	13	11.45	13	1.00	0.88
2014	AUG	13	11.125	13	1.00	0.86
2014	SEP	13	7.695	14	1.08	0.59
2014	OCT	13	0	0	0.00	0.00
2014	NOV	7	0	0	0.00	0.00
2014	DEC	13	0	0	0.00	0.00
Seasonal Coastal Trawl Survey			-	-	-	-
2014	Spring	44	0	0	0.00	0.00
2014	Fall	44	48.79	51	1.16	1.11

New Jersey

New Jersey does not currently conduct any fishery-independent monitoring programs for Atlantic Coastal Sharks, but does receive sharks from the State's Ocean Stock Assessment Survey. In 2014, the Survey caught approximately 67lbs of Atlantic Angel Sharks, 146lbs of Dusky Sharks, 277lbs of Sand Tiger Sharks, 61lbs of Sandbar Sharks, 6,336lbs of Smooth Dogfish, 383lbs of Thresher Sharks, and 15lbs of Tiger Sharks (Figure 3).

Sharks from the New Jersey Ocean Stock Assessment Survey are collected by a 30-meter otter trawl every January, April, June, August, and October since 1989. Tows are approximately 1 nautical mile and are performed via a stratified random sampling design. Latitudinal strata are identical to those used by the National Marine Fisheries Service groundfish survey. Longitudinal boundaries are defined by the 18-30, 30-60, and 60-90 foot isobaths. Smooth Dogfish are cumulatively weighed and measured by total length in centimeters. All other shark species are sorted by gender, weighed individually, and measured by total length in centimeters.

Figure 3. 2014 New Jersey Ocean Stock Assessment Survey, Shark Landings (lbs)



Delaware

Delaware conducts a 30' adult trawl survey and a 16' juvenile trawl survey in the Delaware Bay. In the adult trawl survey, smooth dogfish were the most common shark species caught (Figure 9), with Sand Tiger (Figure 10) and Sandbar Sharks (Figure 11) taken in low numbers. Thresher, Atlantic angel shark, Atlantic sharpnose shark (Figure 12) and dusky shark were caught in the past, but rarely. Sand tiger catch per nautical mile remained high for the time series and showed a marked increase in 2014. Sandbar shark catch per nautical mile were above average for the time series and showed a marked increase in 2014. Smoothhound catch per nautical mile continues to increase from its most recent period of low abundance in 2004 and 2005. In the juvenile trawl, the species caught were sand tiger (Figure 13), sandbar (Figure 14) and smoothhound (Figure 15). With the exception of smoothhound, the capture of coastal sharks in the juvenile trawl is a rare occurrence. Delaware will continue to conduct monitoring programs at the same level in 2015.

Figure 9. Smooth dogfish shark relative abundance (mean number per nautical mile), time series (1966 – 2014) as measured in 30-foot trawl sampling in the Delaware Bay.

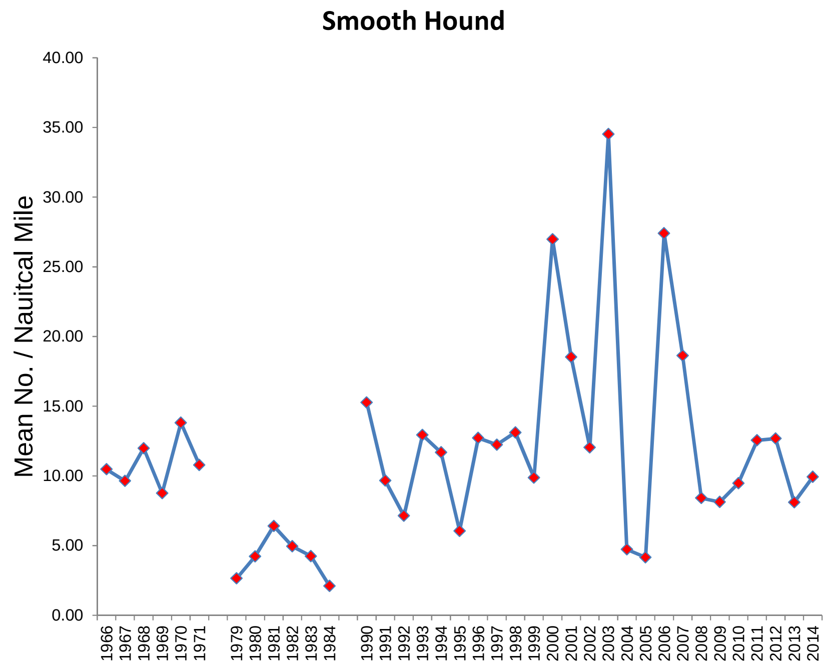


Figure 10. Sand tiger shark relative abundance (mean number per nautical mile), time series (1966 – 2014) as measured in 30-foot trawl sampling in the Delaware Bay.

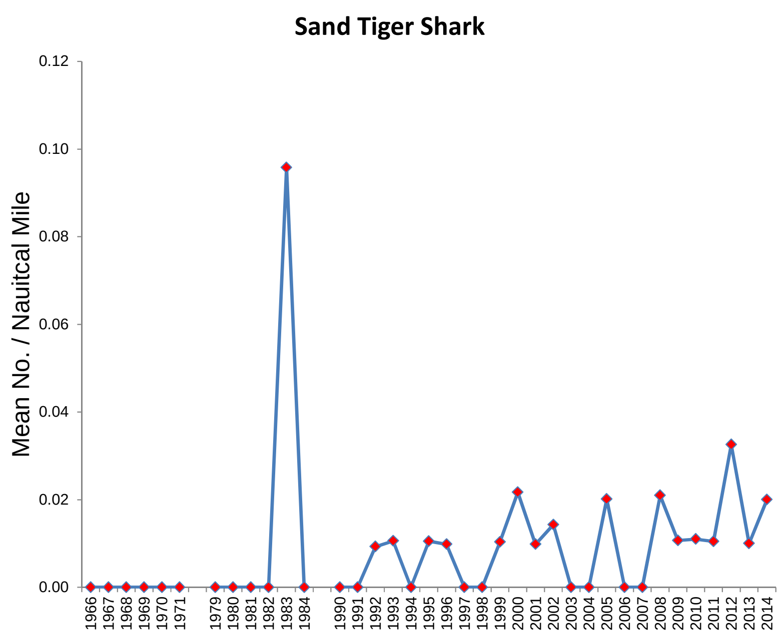


Figure 11. Sandbar shark relative abundance (mean number per nautical mile), time series (1966 – 2014) as measured in 30-foot trawl sampling in the Delaware Bay.

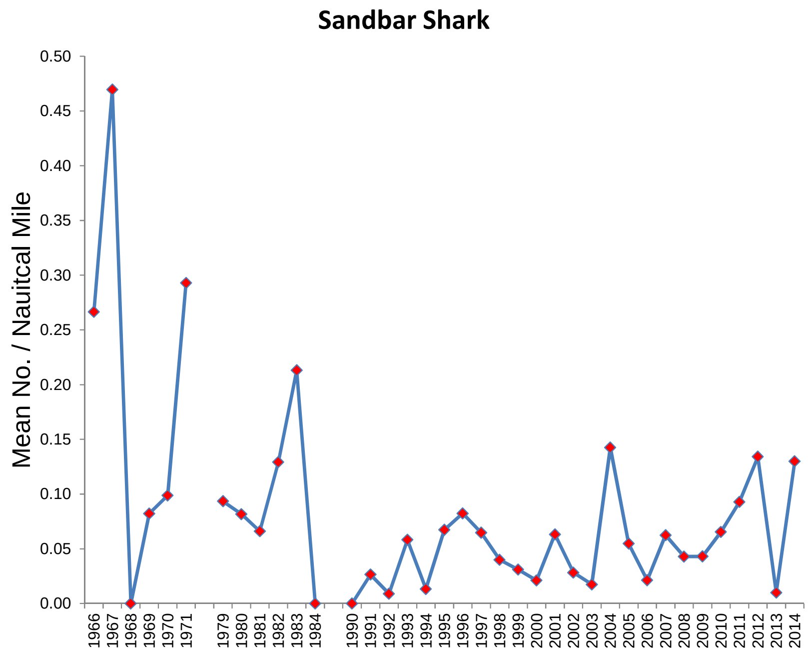


Figure 12. Atlantic sharpnose shark relative abundance (mean number per nautical mile), time series (1966 – 2014) as measured in 30-foot trawl sampling in the Delaware Bay.

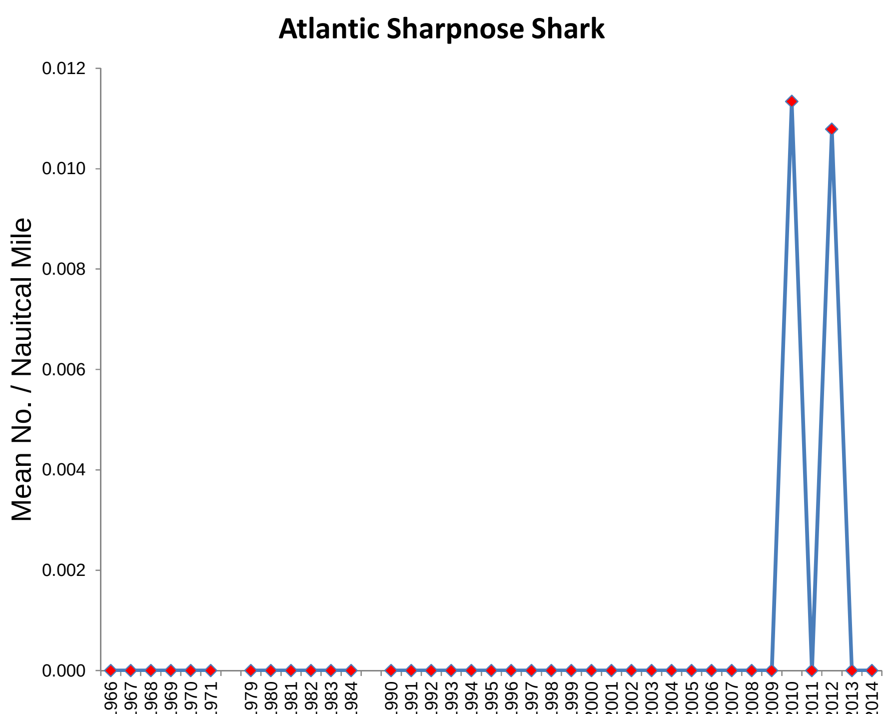


Figure 13. Index of sand tiger shark, time series (1980 – 2014) as measured by 16-foot trawl sampling in the Delaware estuary.

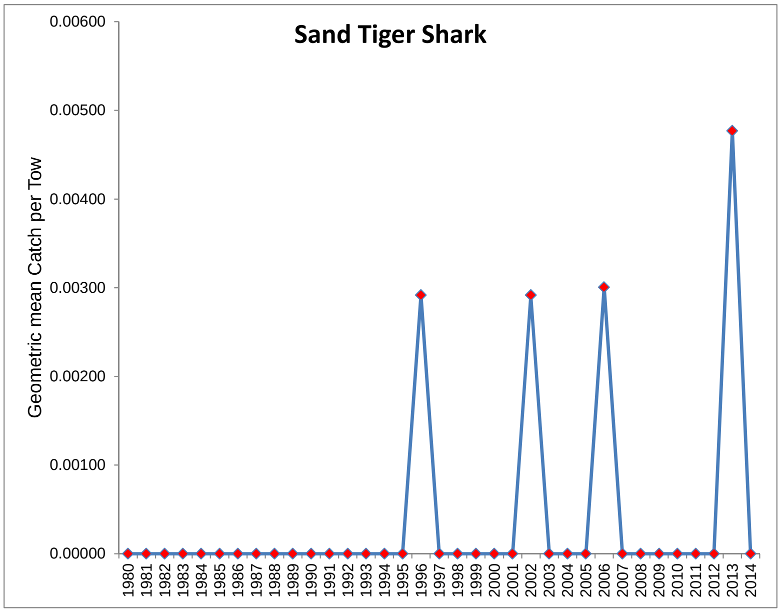


Figure 14. Index of sandbar shark, time series (1980 – 2014) as measured by 16-foot trawl sampling in the Delaware estuary.

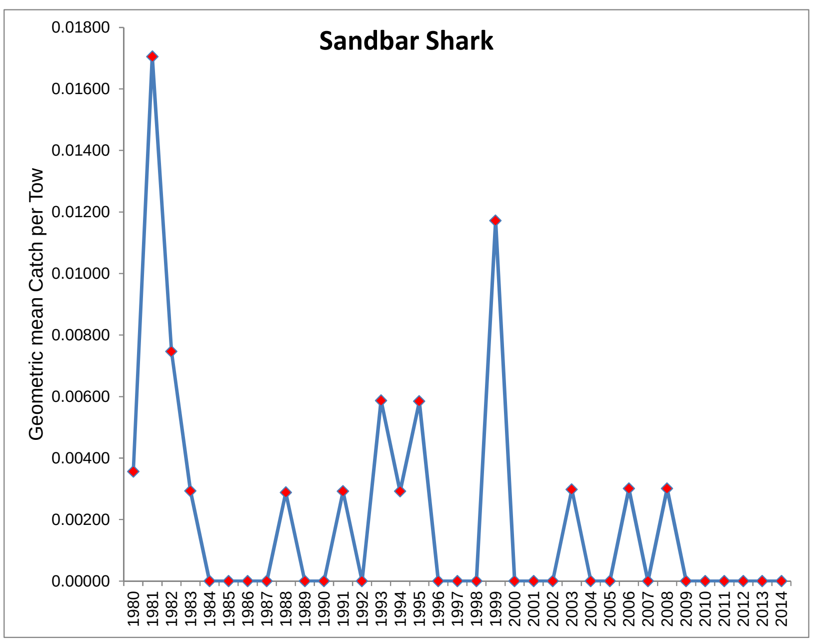
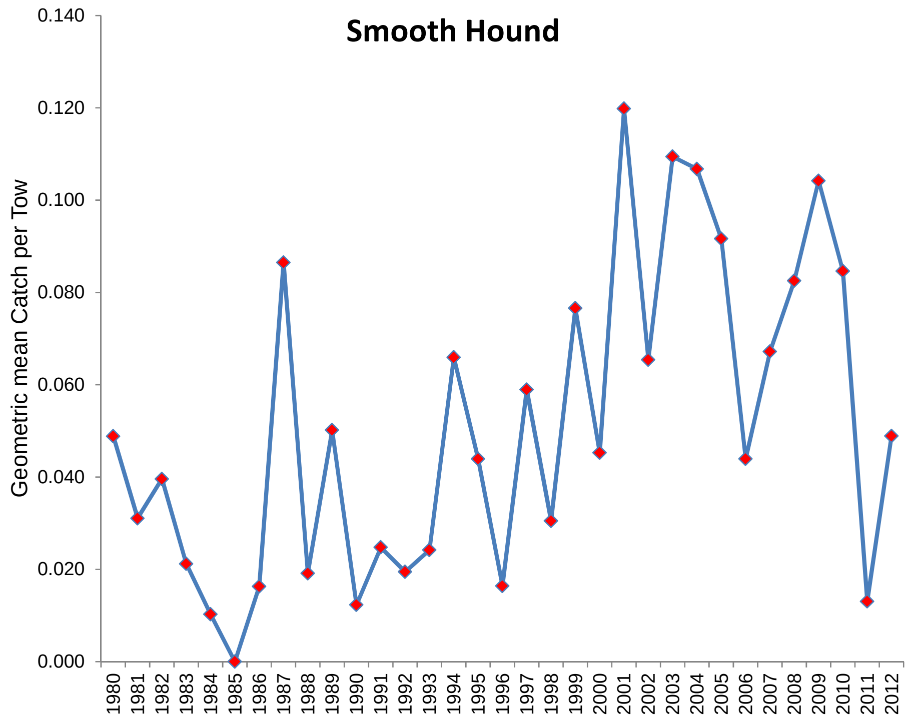


Figure 15. Index of young-of-the-year smooth dogfish abundance, time series (1980 – 2014) as measured by 16-foot trawl sampling in the Delaware estuary.



Maryland

There was no specific at sea sampling program for Atlantic coastal sharks in Maryland. Limited biological sampling of commercial catch onboard commercial offshore trawlers targeting horseshoe crabs occurred and nine sharks were encountered. Two smooth dogfish were captured on November 3, 2014 (unknown sex). Five angel sharks were caught and released on July 7, 2014 and October 8, 2014 (4 unknown sex, one female). Two sand tiger sharks were caught on July 7, 2014 (unknown sex). No fishery independent monitoring for Atlantic coastal sharks was conducted in Maryland state waters.

Virginia

The Virginia Institute of Marine Science Shark Research Program began in 1973 and is one of the longest running longline surveys in the world. The program has provided data on habitat utilization, age, growth, reproduction, trophic interactions, basic demographics, and relative abundance for dominant shark species. Cruise times have been variable over the time series, but generally sampling has occurred monthly from May through October. The survey utilizes a fixed station design with nine core sampling locations, although additional auxiliary locations have been sampled frequently over the years.

Beginning in 2012, the Virginia Institute of Marine Science Shark Research Program, with funding from NMFS, initiated a new longline survey designed specifically to target YOY sandbar sharks in the lower Chesapeake Bay and Eastern Shore. The survey follows a stratified random sampling design, rather than a fixed survey design, and falls under the broader COASTSPAN umbrella survey.

North Carolina

Fishery dependent sampling of North Carolina commercial fisheries has been ongoing since 1982 (conducted under Title III of the Interjurisdictional Fisheries Act, and funded in part by the U.S. Department of Commerce, National Marine Fisheries Service). Predominant fisheries sampled include the ocean sink net fishery, estuarine gill net fishery, winter trawl fishery, long haul seine/swipe net fishery, beach haul seine fishery, and pound net fishery.

A total of 64 fishery-dependent samples containing sharks were collected from the ocean gill net, ocean trawl and estuarine gill net fisheries in 2014. Peak sampling occurred in January, February, and April (Table 5) for sharks, including smoothhound sharks. Whole weights and lengths for sharks other than spiny dogfish are rarely obtained during sampling. Sharks are typically dressed or processed when sampling occurs therefore the number of processed individuals and aggregate weights are obtained during sampling. Smoothhound sharks and Atlantic sharpnose were the most abundant species in dependent sampling by number (Table 9).

Table 9. North Carolina fishery-dependent shark sampling summary by month in 2014

Month	# of Samples
January	10
February	10
March	3
April	9
May	7
June	3
July	2
August	1
September	6
October	2
November	5
December	6
Total	64

Table 10. North Carolina fishery-dependent shark sampling summary by species, number of individuals, sum of sample weight (lb) and sum of harvest weight (lb) in 2014

Species	# Indv.	Sum of Sample Wgt. (lb)	Sum of Harvest Wgt. (lb)
Smoothhound Shark (*M. canis*)	547	3,031	10,034
Atlantic Sharpnose Shark (*R. terraenovae*)	158	587	3,058
Sharks (*Chondrichthyes spp.)*	40	343	348
Thresher Shark (*A. vulpinus*)	31	588	670
Blacktip Shark (*C. limbatus*)	26	315	623
Spinner Shark (*C. brevipinna*)	12	234	518
Blacknose Sharks (*C. acronotus*)	9	115	115
Hammerhead Sharks (*Sphyrna spp.*)	4	535	535
Total	827	5,748	15,901

The NCDMF initiated a fishery-independent red drum longline survey in 2007 for developing an index of abundance for adult red drum;; this project also allows for capture and tagging of Atlantic coastal sharks in cooperation with the North East Fisheries Science Center's (NEFSC) Cooperative Shark Tagging Program. The red drum longline survey in the Pamlico Sound resulted in a catch of 18 sharks in 2014 (Table 11). Four species of shark were captured, ten (10) blacktip (*C. limbatus*), six (6) sandbar (*C. plumbeus*), one (1) Atlantic sharpnose, and one (1) finetoothf (*C. isodon*). A total of twelve (12) sharks were tagged with M-tags from the NEFSC Cooperative Shark Tagging Program, five (5) blacktip, six (6) sandbar, and one (1) finetooth.

Table 11. Species, number of individuals, sex and average total length [TL (mm)] of sharks caught in the 2014 estuarine red drum longline survey.

Species	# Indv.	Avg. TL (mm)
Blacktip Shark (*C. limbatus*)		
Female	9	1,437
Male	1	n/a
Atlantic Sharpnose Shark (*R. terraenovae*)		
Female	1	431
Sandbar Shark (*C. plumbeus*)		

Female	5	910
Male	1	800
Finetooth Shark (*C. isodon*)		
Male	1	1,435
Total	18	

The NCDMF initiated a fishery-independent gill net survey in 2001 and expanded its coverage in 2008 to include the Cape Fear and New Rivers and the near shore (0-3 miles) Atlantic Ocean from New River Inlet south to the South Carolina state line. The objective of this project is to provide annual, independent, relative abundance indices for key estuarine species in the near shore Atlantic Ocean, Pamlico Sound, Pamlico, Pungo, Neuse, New, and Cape Fear Rivers. The survey employs a stratified random sampling design and utilizes multiple mesh gill nets (3.0 inch to 6.5 inch stretched mesh, by ½ inch increments). Sharks from the 2014 Pamlico Sound independent gill net survey catch included: 25 smoothhound, two (2) Atlantic sharpnose, two (2) bonnethead (*S. tiburo*), and five (5) bull sharks [(*C. leucas*) Table 12]. Sharks from the 2014 Cape Fear, New and Neuse River independent gill net survey catch included: 83 Atlantic sharpnose, two (2) blacktip, 21 bonnethead, two (2) bull, and six (6) sandbar sharks (Table 13).

Table 12. Species, number of individuals, sex and average total length [TL (mm)] of sharks caught in the 2014 North Carolina Pamlico Sound gill net survey.

Species	# Indv.	Avg. TL (mm)
Atlantic Sharpnose Shark (*R. terraenovae*)		
Male	2	807
Bonnethead Shark (*S. tiburo*)		
Female	2	861
Bull Shark (*C. leucas*)		
Unknown	5	733
Smoothhound Shark (*M. canis*)		
Male	17	587
Female	8	577
Total	34	

Table 13. Species, number of individuals, sex and average total length [TL (mm)] of sharks caught in the 2014 North Carolina Cape Fear, Neuse and New River gill net survey.

Species	# Indv.	Avg. TL (mm)
Atlantic Sharpnose Shark (*R. terraenovae*)		
Male	33	807
Female	44	387
Unknown	6	368
Blacktip Shark (*C. limbatus*)		
Male	1	1,120

Species	# Indv.	Avg. TL (mm)
Female	1	1,130
Bonnethead Shark (*S. tiburo*)		
Female	21	1,027
Bull Shark (*C. leucas*)		
Male	1	950
Unknown	1	671
Sandbar Shark (*C. plumbeus*)		
Male	3	743
Female	3	1,024
Total	114	

The fisheries-independent assessment ocean gill net survey began in February, 2008, funded by the Coastal Recreational Fishing License receipts. The program utilizes the same sampling framework as the fisheries-independent gill net survey. This program is designed to gather data on fishes utilizing the nearshore ocean (<3 miles) from New River Inlet south to the SC/NC state line. The goals of the program are to provide CPUE data for coastal fishes, to supplement age, growth, and reproduction studies, to evaluate catch rates and species distribution for use in management plans, and to characterize habitat use. In 2014, 452 sharks were captured in the near shore ocean waters from New River Inlet south to the SC/NC state line (Table 14). Coastal sharks from the 2014 ocean gill net survey catch included: 281 Atlantic sharpnose, 70 bonnethead, 13 smoothhound, 34 blacktip, 42 blacknose (*C. acronotus*), two (2) sand tiger (*C. taurus*), and ten (10) scalloped hammerhead (*S. lewini*).

Table 14. Species, number of individuals, sex and average total length [TL (mm)] of sharks caught in the 2014 North Carolina ocean gill net survey.

Species	# Indv.	Avg. TL (mm)
Atlantic Sharpnose Shark (*R. terraenovae*)		
Male	164	740
Female	115	716
Blacknose Shark (*C. acronotus*)		
Male	24	1,107
Female	18	1,057
Blacktip Shark (*C. limbatus*)		
Male	12	1,243
Female	22	1,236
Bonnethead Shark (*S. tiburo*)		
Male	27	850
Female	43	988
Sand Tiger Shark (*C. taurus*)		
Unknown	2	2,279
Scalloped Hammerhead (*S. lewini*)		
Male	2	842

Species	# Indv.	Avg. TL (mm)
Female	7	811
Unknown	1	1,183
Smoothhound Shark (*M. canis*)		
Male	7	594
Female	6	597
Total	452	

South Carolina

Data related to the presence and movement of sharks in South Carolina's coastal waters will continue to be collected as encountered within the context of existing fishery dependent or fishery independent programs conducted by the SCDNR. Currently, data are collected from estuarine waters by the SCDNR Cooperative Atlantic States Shark Pupping and Nursery Habitat survey (COASTSPAN) and the SCDNR trammel net survey. The COASTSPAN survey monitors the presence and abundance of young-of-year and juvenile sharks in the estuaries and bays of South Carolina. The survey operates from April-September using gillnets, longlines and drumlines to sample index stations.

The SCDNR trammel net survey is designed to sample recreationally important species in shallow estuarine waters. Sharks are not a target species, but their abundance as well as length and sex data are recorded (Table 15). Stations selected based on suitable habitats are randomly sampled using a multi-panel gillnet to encircle a section of marsh. Species captured are measured, sexed if possible, select species (no sharks) are tagged and released and physical and water quality data are recorded.

The presence and abundance of juvenile and adult coastal sharks in the bays, sounds and coastal waters of South Carolina are documented by the Adult Red Drum and Coastal Shark Longline survey. This survey uses a stratified-random approach to sample for adult red drum and coastal sharks. The survey operates annually from August to December using longlines to sample suitable habitat for targeted species. Species captured are measured, sexed, tagged and released, and physical and water quality parameters are recorded. Species encountered and tagged for all surveys are reported in Table 15. The data gathered from these programs are shared with the NMFS apex predators program and are utilized in stock assessments and management decisions in South Carolina.

Table 15. Number of sharks captured by South Carolina Department of Natural Resources' Cooperative Atlantic States Shark Pupping and Nursery Habitat Survey (COASTSPAN), the Trammel Net Survey, and Adult Red Drum and Coastal Sharks Longline survey in 2014

	COASTSPAN		Trammel Net		Adult Red Drum and Coastal Sharks	
Shark Species	Captured	Tagged	Captured	Tagged	Captured	Tagged
Atlantic Sharpnose	198	-	187	-	913	-
Blacknose	1	-	-	-	177	151
Blacktip	84	56	5	-	66	51
Bonnethead	205	170	215	-	22	18
Bull	2	2	-	-	3	2
Finetooth	304	186	58	-	99	51
Great Hammerhead	-	-	-	-	-	-
Lemon	8	8	4	-	3	1
Nurse	-	-	-	-	3	1
Sandbar	117	113	1	-	90	80
Sandtiger	2	2	-	-	-	-
Scalloped Hammerhead	81	9	3	-	2	2
Smooth Dogfish	1	1	-	-	-	-
Spinner	1	1	-	-	4	4
Tiger	-	-	-	-	2	1
Total	1,004	548	473	-	1,384	362

Georgia

Although a directed fishery for sharks does not exist in Georgia waters, there are a several fishery dependent sampling surveys conducted by the Coastal Resources Division that could result in the incidental capture of coastal sharks. In 2014, coastal sharks were found in the following fishery independent surveys.

Sampling for the *Adult Red Drum Survey (via SEAMAP)* occurs in inshore and nearshore waters of southeast Georgia and in offshore waters of northeast Florida. Sampling occurs from mid-May through the end of December. Sampling gear consists of a bottom set 926m, 600lb test monofilament mainline configured with 60, 0.5 m gangions made of 200lb test monofilament. Each gangion consists of a longline snap and either a 12/0 or 15/0 circle hook. Thirty hooks of each size are deployed during each set. All hooks are baited with squid. Soak time for each set is 30 minutes. During 2013, CRD staff deployed 217 sets consisting of 13,014 hooks and 142 hours of soak time. During 2014, CRD staff deployed 223 sets consisting of 13,380 hooks and 111.5 hours of soak time. A total of 621 sharks, representing 10 species were captured (Table 16).

Sampling for the *Shark Nursery Survey (via COASTSPAN)* occurs in the inshore waters of St. Simons and St. Andrew sounds. Sampling occurs from mid-April through the end of September. Sampling gear consists of a 305 m braided rope mainline configured with 50, 1 m gangions made of 200lb test monofilament. Each gangion is configured with a longline snap and a 12/0 circle hook. All hooks are baited with squid. Soak time for each set is 30 minutes. During 2014, CRD staff fished 120 longline stations consisting of 6,000 hooks and a total of 60 hours of soak time. A total of 466 sharks, representing 7 species were captured (Table 3).

Each month the *Ecological Monitoring Trawl Survey (EMTS)*, a 40-foot flat otter trawl with neither a turtle excluder device nor bycatch reduction device, is deployed at up to 42 stations across six estuaries. At each station, a standard 15 minute tow is made. During this report period, 496 tows/observations were conducted, totaling 124.3 hours of tow time. A total of 321 sharks, representing 5 species, were captured during 2014 (Table 16).

Monitoring of estuarine finfish and crustaceans in the lower salinity, upriver sectors of selected estuaries is done monthly as part of the *Juvenile Trawl Survey* conducted onboard the research vessel *Navigator*. A 20-foot, semi-balloon otter trawl is towed for 5 minutes at up to 18 stations within three Georgia estuaries. In 2014, 121 tows (observations) were conducted, totaling 10.1 hours of tow time. No sharks were observed during the 2014 season.

The Marine Sportfish Population Health Survey (MSPHS) is a multi-faceted ongoing survey used to collect information on the biology and population dynamics of recreationally important finfish. Currently two Georgia estuaries are sampled on a seasonal basis using entanglement gear. During the June to August period, young-of-the-year red drum in the Altamaha/Hampton River and Wassaw estuaries are collected using gillnets to gather data on relative abundance and location of occurrence. During the September to November period, fish populations in the Altamaha/Hampton River and Wassaw estuaries are monitored using monofilament trammel nets to gather data on relative abundance and size composition. In 2014, a total of 216 gillnet and 150 trammel net sets were made, resulting in the capture of 165 individuals representing five species of coastal sharks (Table 16).

Table 16. Numbers of coastal sharks captured in Georgia fishery independent surveys in 2014 by species and by survey.

	SEAMAP (Adult Red Drum Survey)	COASTSPAN (Shark Nursery Survey)	EMTS (Ecological Monitoring Trawl Survey)	MSPHS (Trammel and Gill Net Survey)
Atlantic sharpnose shark	316	280	213	45
Blacknose	130	7	---	---

Bonnethead	124	106	104	105
Blacktip shark	23	16	2	7
Sandbar shark	13	54	---	---
Smooth dogfish	7	---	---	---
Finetooth shark	4	---	1	7
Scalloped hammerhead	2	2	1	---
Tiger shark	1	---	---	---
Spinner shark	1	---	---	---
Lemon shark	---	1	---	1
All Species Combined	621	466	321	165

V. Status of Management Measures and Issues

Fishery Management Plan

Coastal Sharks are managed under the Interstate FMP for Coastal Sharks, which was implemented in August 2008, Addendum I (2009), Addendum II (2013) and Addendum III (2013). The FMP addresses the management of 40 species and establishes a suite of management measures for recreational and commercial shark fisheries in state waters (0 – 3 miles from shore).

Prior to the FMP, shark management in state waters consisted of disjointed state-specific regulations. The FMP allows for consistency across jurisdictions. For the small coastal, pelagic, smoothhound, hammerhead and aggregated large coastal complexes, the Commission's Board does not set active quotas, but instead follows NOAA Fisheries closures.

Addendum I was added to allow commercial fishermen limited processing of smoothhounds at sea and remove recreational possession limits for smoothhounds, as well as the 2 hour net check requirement for commercial fishermen using large mesh gillnets. Addendum II modified smooth dogfish processing at sea regulation and allocated state-shares of the smoothhound federal quota. Addendum III changed the species groupings and increased the size limit for hammerhead sharks. Addendum III was initiated in response to changes in the federal plan and was implemented in March 2014 to ensure consistency between the two management plans.

ASMFC will continue to respond to changes in the Atlantic Highly Migratory Species FMP and make changes as necessary to the interstate FMP.

VI. Implementation of FMP Compliance Requirements for 2014

Addendum III to the Coastal Sharks FMP was implemented in March 2014. All states must demonstrate through the inclusion of regulatory language that the following management measures were implemented.

i. Recreational Minimum Size Limits

This modifies Section 4.2.4 Recreational Minimum Size Limits in the FMP.

Sharks caught in the recreational fishery must have a minimum fork length of 4.5 feet (54 inches) with the exception of smooth hammerhead, scalloped hammerhead, great hammerhead, smoothhound, Atlantic sharpnose, blacknose, finetooth, and bonnethead.

Smooth hammerhead, scalloped hammerhead and great hammerhead must have a minimum fork length of 6.5 feet (78 inches).

Smoothhound, Atlantic sharpnose, blacknose, finetooth and bonnethead do not have recreational minimum size limits.

Table 4.4 in the FMP is modified as follows:

Table 4.4. Recreational minimum size limits.

No Minimum Size	Minimum Fork Length of 4.5 Feet		Minimum Fork Length of 6.5 Feet
Smoothhound Atlantic sharpnose Finetooth Blacknose Bonnethead	Tiger Blacktip Spinner Bull Lemon Nurse	Shortfin mako Porbeagle Thresher Oceanic whitetip Blue	Scalloped hammerhead Smooth hammerhead Great hammerhead

ii. Commercial Species Groupings

This modifies Section 4.3.3 Commercial Species Groupings (and the appropriate sub-sections, outlined below). Two new species groups ('Blacknose' and 'Hammerhead') are created.

This FMP establishes eight commercial 'species groups' for management (Table 4.5 and 4.6): Prohibited, Research, Smoothhound, Non-Blacknose Small Coastal, Blacknose, Aggregated Large Coastal, Hammerhead and Pelagic. These groupings apply to all commercial shark fisheries in state waters.

Table 4.6 in the FMP is modified as follows:

Table 4.6. Commercial species groupings

Smoothhound	
Smooth Dogfish	Mustelus canis
Florida smoothhound	Mustelus norrisi
Non-Blacknose Small Coastal	
Atlantic sharpnose	*Rhizoprionodon terraenovae*
Finetooth	*Carcharhinus isodon*
Bonnethead	*Sphyrna tiburo*
Blacknose	
Blacknose	*Carcharhinus acronotus*
Aggregated Large Coastal	
Silky	*Carcharhinus falciformis*
Tiger	*Galeocerdo cuvier*
Blacktip	*Carcharhinus limbatus*
Spinner	*Carcharhinus brevipinna*
Bull	*Carcharhinus leucas*
Lemon	*Negaprion brevirostris*
Nurse	*Ginglymostoma cirratum*
Hammerhead	
Scalloped hammerhead	*Sphyrna lewini*
Great hammerhead	*Sphyrna mokarran*
Smooth hammerhead	*Sphyrna zygaena*
Pelagic	
Shortfin mako	*Isurus oxyrinchus*
Porbeagle	*Lamna nasus*
Common thresher	*Alopias vulpinus*
Oceanic whitetip	*Carcharhinus longimanus*
Blue	*Prionace glauca*
Prohibited	
Sand tiger	*Carcharias taurus*
Bigeye sand tiger	*Odontaspis noronhai*
Whale	*Rhincodon typus*
Basking	*Cetorhinus maximus*
White	*Carcharodon carcharias*
Dusky	*Carcharhinus obscurus*
Bignose	*Carcharhinus altimus*
Galapagos	*Carcharhinus galapagensis*

Night	*Carcharhinus signatus*
Reef	*Carcharhinus amblyrhynchos*
Narrowtooth	*Carcharhinus brachyurus*
Caribbean sharpnose	*Rhizoprionodon porosus*
Smalltail	*Carcharhinus porosus*
Atlantic angel	*Squatina squatina*
Longfin mako	*Isurus paucus*
Bigeye thresher	*Alopias superciliosus*
Sharpnose sevengill	*Heptranchias perlo*
Bluntnose sixgill	*Hexanchus griseus*
Bigeye sixgill	*Hexanchus nakamurai*
Research	
Sandbar	*Carcharhinus plumbeus*

VII. PRT Recommendations

State Compliance
All states with a declared interest in the management of sharks, except Connecticut, have submit compliance reports and have regulations in place that meet or exceed the requirements of the Interstate Fisheries Management Plan for Coastal Sharks and associated addenda.

The state of Connecticut has not provided coastal shark compliance reports for the 2014 fishing years. The PRT attempted to review regulations online and only found an accurate list of prohibited shark species. If the prohibited species list is the only shark regulation that Connecticut has implemented in state waters, then Connecticut would need to implement the full suite of ASMFC shark regulations included in Appendix 1 to be consistent with the FMP and associated addenda.

De Minimis Status
This FMP does not establish specific *de minimis* guidelines that would exempt a state from regulatory requirements contained in this plan. *De minimis* shall be determined on a case-by case basis. *De minimis* often exempts states from monitoring requirements in other fisheries but this plan does not contain any monitoring requirements.

De minimis guidelines are established in other fisheries when implementation and enforcement of a regulation is deemed unnecessary for attainment of the fishery management plan's objectives and conservation of the resource. Due to the unique characteristics of the coastal shark fishery, namely the large size of sharks compared to relatively small quotas, the taking of a single shark could contribute to overfishing of a shark species or group. Therefore, exempting a state from any of the regulatory requirements contained in this plan could threaten attainment of this plans' goals and objectives.

States that have been granted *de minimis* status are Maine and Massachusetts. New Hampshire has renounced management interest and is therefore no longer a member of the coastal shark management board. These states do not land sharks in any significant quantity and very few of the species managed by this plan are ever encountered in their state waters. These states can continue to have *de minimis* status until their landings patterns change or they request a discontinuation.

In some cases, it is unnecessary for states with *de minimus* status to implement all regulatory requirements in the FMP.

A. Massachusetts has implemented all regulations with two exceptions, it is exempt from the possession limit and closures of the aggregated large coastal and hammerhead shark fisheries.

B. Maine and New Hampshire have implemented the following regulations to comply with the goals and objectives of the FMP:
    - Require federal dealer permits for all dealers purchasing a permitted species
    - Prohibit the take or landings of prohibited species
    - Close the fishery for porbeagle sharks when the NMFS quota has been harvested
    - Prohibit the commercial harvest of porbeagle sharks in state waters
    - Require that head, fins and tails remain attached to the carcass of all shark species, except smoothhound, through landing

Research Priorities

Species-Specific Priorities

- Investigate the appropriateness of using vertebrae for ageing adult sandbar sharks. If appropriate, implement a systematic sampling program that gathers vertebral samples from entire size range for annual ageing to allow tracking the age distribution of the catch as well as updating of age-length keys.[1]
- Develop and conduct tagging studies on dusky and blacknose stock structure with increased international collaboration (e.g., Mexico) to ensure wider distribution and returns of tags. Expand research efforts directed towards tagging of individuals in south Florida and Texas/Mexico border to get better data discerning potential stock mixing.

General Priorities

- Generally update age and growth and reproductive studies for all species currently assessed
- Determine gear-specific post-release mortality estimates for all species currently assessed

[1] Recent bomb radiocarbon research has indicated that past age estimates based on tagging data for sandbar sharks may be correct and that vertebral ageing may not be the most reliable method for mature individuals. See Andrews *et al.* 2011.

- Determine life history information for data-poor species that are currently not assessed
- Examine female sharks during the pupping periods to determine the proportion of reproductive females. Efforts should be made to develop non-lethal methods of determining pregnancy status
- Expand or develop monitoring programs to collect appropriate length and age samples from the catches in the commercial sector by gear type, from catches in the recreational sector, and from catches taken in research surveys to provide reliable length and age compositions for stock assessment
- Continue investigations into stock structure of coastal sharks using genetic, conventional and electronic tags to determine appropriate management units
- Evaluate to what extent the different CPUE indices track population abundance (e.g., through power analysis)
- Explore modeling approaches that do not require an assumption that the population is at virgin level at some point in time.
- Increase funding to allow hiring of additional HMS stock assessment scientists. There are currently inadequate staff to conduct stock assessments on more than one or two stocks/species per year.

References

Andrews et al. 2011. Bomb radiocarbon and tag-recapture dating of sandbar shark (*Carcharhinus plumbeus*). Fisheries Bulletin. 109: 454-465.

Stock Assessment and Fishery Evaluation (SAFE) Report for Atlantic Highly Migratory Species. 2014. NOAA Fisheries, December 18, 2015.
< http://www.nmfs.noaa.gov/sfa/hms/hmsdocument_files/SAFEreports.htm>

APPENDIX 1. OVERVIEW OF COASTAL SHARK REGULATIONS

Coastal Sharks FMP Regulatory Requirements

1. Recreational seasonal closure (Section 4.2.1)

    a. Recreational anglers are prohibited from possessing silky, tiger, blacktip, spinner, bull, lemon, nurse, scalloped hammerhead, great hammerhead, and smooth hammerhead in the state waters of Virginia, Maryland, Delaware and New Jersey from May 15 through July 15—regardless of where the shark was caught.

    b. Recreational fishermen who catch any of these species in federal waters may not transport them through the state waters of VA, MD, DE, and NJ during the seasonal closure.

2. Recreationally permitted species (Section 4.2.2)

    a. Recreational anglers are allowed to possess aggregated large coastal sharks, hammerheads, tiger sharks, SCS, and pelagic sharks. Authorized shark species include: aggregated LCS (blacktip, bull, spinner, lemon, and nurse); hammerhead (great hammerhead, smooth hammerhead, scalloped hammerhead); tiger sharks; SCS (blacknose, finetooth, Atlantic sharpnose, and bonnethead sharks); and, pelagic sharks (blue, shortfin mako, common thresher, oceanic whitetip, and porbeagle). Sandbar sharks and silky sharks (and all prohibited species of sharks) are not authorized for harvest by recreational anglers.

3. Landings Requirements (Section 4.2.3)

    a. All sharks (with exception) caught by recreational fishermen must have heads, tails, and fins attached naturally to the carcass. Anglers may still gut and bleed the carcass by making an incision at the base of the caudal peduncle as long as the tail is not removed. Filleting sharks at sea is prohibited.

    b. All sharks (with exception) harvested by commercial fishermen within state boundaries must have the tails and fins attached naturally to the carcass through landing. Fins may be cut as long as they remain attached to the carcass (by natural means) with at least a small portion of uncut skin. Sharks may be eviscerated and have the heads removed. Sharks may not be filleted or cut into pieces at sea.

    c. Exception: Fishermen holding a valid state commercial permit may process smooth dogfish sharks at sea out to 50 miles from shore, as long as the total weight of smooth dogfish shark fins landed or found on board a vessel does not exceed 12 percent of the total weight of smooth dogfish shark carcasses landed or found on board.

4. Recreational Minimum Size Limits (Section 4.2.4)

    a. Sharks caught in the recreational fishery must have a fork length of at least 4.5 feet with the exception of Atlantic sharpnose, blacknose, finetooth, bonnethead and smoothhound which have no minimum size. Hammerhead species must have a fork length of 6.5 feet.

5. Authorized Recreational Gear (Section 4.2.5)

    a. Recreational anglers may catch sharks only using a handline or rod & reel. Handlines are defined as a mainline to which no more than two gangions or hooks are attached. A handline must be retrieved by hand, not by mechanical means.

6. Possession limits in one twenty-four hour period (Section 4.2.7 and 4.3.6)

    a. Recreational and commercial possession limits as specified in Table 9.

    b. Smooth dogfish harvest is not limited in state waters and recreational shore-anglers may harvest an unlimited amount of smooth dogfish.

7. Commercial Seasonal Closure (Section 4.3.2)

    a. All commercial fishermen are prohibited from possessing silky, tiger, blacktip, spinner, bull, lemon, nurse, scalloped hammerhead, great hammerhead, and smooth hammerhead in the state waters of Virginia, Maryland, Delaware and New Jersey from May 15 through July 15. Fishermen who catch any of the above species in a legal manner in federal waters may transit through the state waters listed above is allowed if all gear is stowed.

8. Quota Specification (Section 4.3.4)

    a. When NOAA Fisheries closes the fishery for any species, the commercial landing, harvest, and possession of that species will be prohibited in state waters until NOAA Fisheries reopens the fishery.

9. Permit requirements (Section 4.3.8)

    a. State: Commercial shark fishermen must hold a state commercial license or permit in order to commercially catch and sell sharks in state waters.

    b. Federal: A federal Commercial Shark Dealer Permit is required to buy and sell any shark caught in state waters.

    c. Display and research permit is required to be exempt from seasonal closure, quota, possession limit, size limit, gear restrictions, and prohibited species restrictions. States are required to include annual information for all sharks taken for display throughout the life of the shark.

10. Authorized commercial gear (Section 4.3.8.3)

    a. Commercial fishermen can only use one of the following gear types (and are prohibited from using any gear type not listed below) to catch sharks in state waters.

        i. **Rod & reel**
        ii. **Handlines.** Handlines are defined as a mainline to which no more than two gangions or hooks are attached. A handline is retrieved by hand, not by mechanical means, and must be attached to, or in contact with, a vessel.
        iii. **Small Mesh Gillnets.** Defined as having a stretch mesh size smaller than 5 inches.
        iv. **Large Mesh Gillnets.** Defined as having a stretch mesh size equal to or greater than 5 inches.
        v. **Trawl nets.**
        vi. **Shortlines.** Shortlines are defined as fishing lines containing 50 or fewer hooks and measuring less than 500 yards in length. A maximum of 2 shortlines are allowed per vessel.
        vii. **Pounds nets/fish traps.**
        viii. **Weirs.**

11. Bycatch Reduction Measures (Section 4.3.10)

    a. Any vessel using a shortline must use corrodible circle hooks. All shortline vessels must practice the protocols and possess the recently updated federally required release equipment for pelagic and bottom longlines for the safe handling, release, and disentanglement of sea turtles and other non-target species; all captains and vessel owners must be certified in using handling and release equipment.

12. Smooth Dogfish
    a. Each state must identify their percentage of the overall quota (Addendum II, 3.1)
    b. 12% fin-to-carcass ratio must be implemented if a state allows the fins of smooth dogfish to be removed at sea (Addendum II, 3.5)
13. This FMP establishes eight commercial 'species groups' for management which include: Prohibited, Research, Smoothhound, Non-Blacknose Small Coastal, Blacknose, Aggregated Large Coastal, Hammerhead and Pelagic. These groupings apply to all commercial shark fisheries in state waters.

Smoothhound	
Smooth Dogfish	Mustelus canis
Florida smoothhound	Mustelus norrisi
Non-Blacknose Small Coastal	
Atlantic sharpnose	*Rhizoprionodon terraenovae*
Finetooth	*Carcharhinus isodon*
Bonnethead	*Sphyrna tiburo*
Blacknose	
Blacknose	*Carcharhinus acronotus*
Aggregated Large Coastal	
Silky	*Carcharhinus falciformis*
Tiger	*Galeocerdo cuvier*
Blacktip	*Carcharhinus limbatus*
Spinner	*Carcharhinus brevipinna*
Bull	*Carcharhinus leucas*
Lemon	*Negaprion brevirostris*
Nurse	*Ginglymostoma cirratum*
Hammerhead	
Scalloped hammerhead	*Sphyrna lewini*
Great hammerhead	*Sphyrna mokarran*
Smooth hammerhead	*Sphyrna zygaena*
Pelagic	
Shortfin mako	*Isurus oxyrinchus*
Porbeagle	*Lamna nasus*
Common thresher	*Alopias vulpinus*
Oceanic whitetip	*Carcharhinus longimanus*
Blue	*Prionace glauca*

Prohibited	
Sand tiger	Carcharias taurus
Bigeye sand tiger	*Odontaspis noronhai*
Whale	*Rhincodon typus*
Basking	*Cetorhinus maximus*
White	*Carcharodon carcharias*
Dusky	*Carcharhinus obscurus*
Bignose	*Carcharhinus altimus*
Galapagos	*Carcharhinus galapagensis*
Night	*Carcharhinus signatus*
Reef	*Carcharhinus amblyrhynchos*
Narrowtooth	*Carcharhinus brachyurus*
Caribbean sharpnose	*Rhizoprionodon porosus*
Smalltail	*Carcharhinus porosus*
Atlantic angel	*Squatina squatina*
Longfin mako	*Isurus paucus*
Bigeye thresher	*Alopias superciliosus*
Sharpnose sevengill	*Heptranchias perlo*
Bluntnose sixgill	*Hexanchus griseus*
Bigeye sixgill	*Hexanchus nakamurai*
Research	
Sandbar	*Carcharhinus plumbeus*

Table 10. Possession/retention limits for shark species in state waters

Recreational	*Shore-angler*	1 shark (of any species except prohibited) per person per day; plus one Atlantic sharpnose, bonnethead and smoothhound
	Vessel-fishing	1 shark (of any species except prohibited) per vessel per trip; plus one Atlantic sharpnose, bonnethead and smoothhound per person, per vessel
Commercial	*Directed permit*	Variable possession limit for aggregated large coastal sharks and hammerhead shark management groups, the Commission will follow NMFS for in-season changes to the possession limit. The possession limit range is 0-55, the default is 45 sharks per trip. No limit for SCS or pelagic sharks.
	Incidental permit	3 aggregated LCS per vessel per trip, 16 pelagic or SCS (combined) per vessel per trip

Atlantic States Marine Fisheries Commission

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MEMORANDUM

July 26, 2016

To: **Coastal Sharks Management Board**
From: **Tina Berger, Director of Communications**

RE: **New Advisory Panel Nomination and Request for Review of Current Advisory Panel Membership**

Please find attached a new nomination to the Coastal Sharks Advisory Panel – Katie Westfall with the Environmental Defense Fund (EDF). Katie is being offered as a replacement from Tim Fitzgerald (also with EDF), who filled the non-traditional stakeholder position on the panel, but is no longer able to serve in that capacity.

I also wanted to bring to your attention that member participation has been very low on this panel. On the last conference call (7/14/16), of the 16 members only 4 participated on the conference call and one followed up following the call. The attached spreadsheet provides a detailed history of member participation since the panel's establishment in 2006. Also attached for your review is the AP membership list. Please consider appointing new members to the advisory panel. Thank you.

If you have any questions, please feel free to contact me at (703) 842-0749 or tberger@asmfc.org.

Enc.

cc: Ashton Harp

M16-67

COASTAL SHARKS ADVISORY PANEL

Bolded names await approval by the Coastal Sharks Management Board

July 26, 2016

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Phone: 252.255.5791
Email: fvtarbaby@aol.com
Appt. Confirmed 5/19/06
Appt Reconfirmed 5/10

South Carolina
Terry Annibale (comm)
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North Myrtle Beach, SC 29582
Phone: 843.224.2104
Email: Capt-terry@hotmail.com
Appt Confirmed 8/3/10

Reese (Chip) Michalove (charterboat)
PO Box 6257
Hilton Head Island, SC 29938
Phone: 843.290.0371
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Appt Confirmed 8/3/10

Georgia
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477 Midway Circle
Brunswick, GA 31523
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Appt. Confirmed 2/20/06
Appt Reconfirmed 5/10

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Appt Reconfirmed 4/22/10

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OR
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Appt. Confirmed 5/19/06

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kwestfall@edf.org

ATLANTIC STATES MARINE FISHERIES COMMISSION

Advisory Panel Nomination Form

This form is designed to help nominate Advisors to the Commission's Species Advisory Panels. The information on the returned form will be provided to the Commission's relevant species management board or section. Please answer the questions in the categories (All Nominees, Commercial Fisherman, Charter/Headboat Captain, Recreational Fisherman, Dealer/Processor, or Other Interested Parties) that pertain to the nominee's experience. If the nominee fits into more than one category, answer the questions for all categories that fit the situation. **Also, please fill in the sections which pertain to All Nominees (pages 1 and 2). In addition, nominee signatures are required to verify the provided information (page 4), and Commissioner signatures are requested to verify Commissioner consensus (page 4). Please print and use a black pen.**

Form submitted by: Tim Fitzgerald State: NY
(your name)

Name of Nominee: Katie Westfall

Address: 1875 Connecticut Ave. NW

City, State, Zip: Washington, DC 20009

Please provide the appropriate numbers where the nominee can be reached:

Phone (day): 202 572 3376 Phone (evening): 202 607 6775

FAX: ____________ Email: kwestfall@edf.org

FOR ALL NOMINEES:

1. Please list, in order of preference, the Advisory Panel for which you are nominating the above person.
   1. Coastal Sharks
   2. ____________
   3. ____________
   4. ____________

2. Has the nominee been found in violation of criminal or civil federal fishery law or regulation or convicted of any felony or crime over the last three years?

   yes______ no X

3. Is the nominee a member of any fishermen's organizations or clubs?

   yes ______ no X

   If "yes," please list them below by name.

4. What kinds (species) of fish and/or shellfish has the nominee fished for during the past year?

N/A

5. What kinds (species) of fish and/or shellfish has the nominee fished for in the past?

Rainbow, brook, brown, and cutthroat trout

Catfish, whiting, sailor's choice, and sea trout

FOR COMMERCIAL FISHERMEN:

1. How many years has the nominee been the commercial fishing business? ________ years
2. Is the nominee employed only in commercial fishing? yes______ no________
3. What is the predominant gear type used by the nominee?________________________
4. What is the predominant geographic area fished by the nominee (i.e., inshore, offshore)?________________________

FOR CHARTER/HEADBOAT CAPTAINS:

1. How long has the nominee been employed in the charter/headboat business? _______ years
2. Is the nominee employed only in the charter/headboat industry? yes _______ no_______

   If "no," please list other type(s)of business(es) and/occupation(s):________________________

3. How many years has the nominee lived in the home port community? _______ years

   If less than five years, please indicate the nominee's previous home port community.

FOR RECREATIONAL FISHERMEN:

1. How long has the nominee engaged in recreational fishing? _________ years

2. Is the nominee working, or has the nominee ever worked in any area related to the fishing industry? yes _______ no _________

   If "yes," please explain.

____

____

____

FOR SEAFOOD PROCESSORS & DEALERS:

1. How long has the nominee been employed in the business of seafood processing/dealing? ________________years

2. Is the nominee employed only in the business of seafood processing/dealing?

   yes ______ no ______ If "no," please list other type(s) of business(es) and/or occupation(s):

____

____

____

3. How many years has the nominee lived in the home port community? ________ years

   If less than five years, please indicate the nominee's previous home port community.

____

FOR OTHER INTERESTED PARTIES:

1. How long has the nominee been interested in fishing and/or fisheries management? ≈20 years

2. Is the nominee employed in the fishing business or the field of fisheries management? yes X no _____

   If "no," please list other type(s) of business(es) and/or occupation(s):

____

____

____

FOR ALL NOMINEES:

In the space provided below, please provide the Commission with any additional information which you feel would assist us in making choosing new Advisors. You may use as many pages as needed.

Nominee Signature: [signature] Date: 7/11/16

Name: Katie Westfall
(please print)

COMMISSIONERS SIGN-OFF (not required for non-traditional stakeholders)

State Director

State Legislator

Governor's Appointee

Coastal Sharks Advisory Panel Attendance

Name	State	Conf.	7/19/06	9/26/07	3/25/08	6/30/09	4/29/2013 call	7/14/2016
Francis Blount	RI	2/20/06	X			X		
Stephen Segerson	RI	2/20/06	X					
Steve Witthuhn	NY	2/20/06						
Marty Buzas	NJ	5/15/06	X	X	X			
Peter Grimbilas	NJ	8/3/10						X
Dan Dugan	DE	2/20/06		X			X	Did not attend but followed up after call
Mark Sampson	MD	8/3/10					X	
Ernest Bowden	VA	2/20/06	X	X	X		X	
Lewis Gillingham	VA	3/25/08			X	X	X	X
Dewey Hemilright	NC	5/19/06	X					
Terry Annibale	SC	8/3/10					X	
Chip Michalove	SC	8/3/10						
Greg Hildreth	GA	2/20/06						
Rusty Hudson	FL	5/19/06	X	X	X	X		X
Stephen Haigis	FL	5/19/06	X					
Sonja Fordham	NT	5/19/06	X		X		X	X
NT = non traditional stakeholder								
Past members								
Rich Ruais	NH	5/19/06						
James Donofrio	NJ	37306						
Claude Bain	VA	2/20/06	X					
Frank Blum	SC	5/19/06	X					
Tim Fitzgerald	NT	5/19/06		X			X	

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

TO: Executive Committee

FROM: Robert E. Beal

DATE: July 25, 2016

SUBJECT: Plan Development Team Membership

At the May Executive Committee meeting, a question was raised regarding board member participation on plan development teams (PDTs). Concern was expressed that if board members were on PDTs then they would have or would be perceived to have more opportunity to influence the outcome of the management process. There was not sufficient time to address the question at the May meeting, but the committee tasked staff with outlining current PDT guidance in Commission documents and providing possible options for additional guidance.

The ISFMP Charter and Technical Support Guidance Document give guidance on the composition, role, and responsibility of the PDT (see ISFMP Charter language below). PDTs are responsible for the development of a fishery management plan, amendment, or addendum. PDTs are appointed by boards/sections and comprised of personnel from state and federal agencies who have scientific and management ability, knowledge of the species and its habitat, and from a state/agency/jurisdiction with an interest in the species management program. Regional fishery management council staff, academicians, and others as appropriate may be included on a PDT. The size of the PDT shall be based on specific need for expertise but should generally be kept to a maximum of six persons. In general, most states typically appoint technical committee (TC) members to PDTs. TC members bring scientific expertise to the PDT but have less experience in writing regulatory/policy language. Often the PDT lacks members with management/regulatory expertise. When board members have been appointed to PDTs they bring this expertise, creating a more comprehensive group. In limited cases, some appointed PDT members are not board or TC members but have policy expertise.

Options for Consideration:

For the purposes of the options provided below, a board member is defined as a person or proxy on the species management board for the species in which a management document is being developed.

Option 1: Board members may participate on PDTs.

Option 2: Board members may participate on PDTs, but when the issue or management document addressed by the PDT is brought before the board, the board member must abstain

M16-66

from voting on that issue/management document. They may still participate in the discussion leading up to the vote but they may not make or second any of the motions.

Option 3: Board members may participate on PDTs, but the board member must abstain from voting on any final action on the issues/management documents brought forward by the PDT. They may still participate in the discussion leading up to the votes and they may make or second any of the votes.

Option 4: Board members may not participate on PDTs.

Section 5 (c) of the ISFMP Charter:

PDTs shall be appointed by the management boards/sections to draft FMPs, amendments and addenda.

(1) PDTs shall be comprised of personnel from state and federal agencies who have scientific and management ability, knowledge of a species and its habitat, and an interest in the management of a species under the jurisdiction of the relevant management board. Personnel from Regional Fishery Management Councils, academicians, and others as appropriate may be included on a PDT. The size of the PDT shall be based on specific need for expertise but shall generally be kept to a maximum of six persons.

(2) It shall be the responsibility of a PDT to prepare all documentation necessary for the development of an FMP, amendment, or addendum using the best scientific information available and the most current stock assessment information. Each FMP, amendment, or addendum shall be developed by the PDT in conformance with Section Six of the ISFMP Charter.

(3) PDTs shall be tasked directly by the management boards/sections. In carrying out its activities, the PDT shall seek advisement from the appropriate technical committee, stock assessment subcommittee, advisory panel, Committee on Economics and Social Sciences, and the Assessment Science, Habitat, Artificial Reef and Law Enforcement Committees, where appropriate.

(4) Following completion of its charge, the PDT will be disbanded unless otherwise determined by the board/section.

ACCSP Transition Document

July 26, 2016

Introduction

In May 2016, the ACCSP Coordinating Council and the Atlantic States Marine Fisheries Commission agreed to alter the governance structure of ACCSP. Under the new governance structure, ACCSP will be fully integrated into ASMFC and will be comparable to other ASMFC programs (e.g., ISFMP, Science). Prior to this governance change, ACCSP was an independent program with ASMFC serving as its administrative home.

This governance change will allow:

- Full integration of ACCSP with ASMFC management and science programs;
- Improved visibility among partners and stakeholders;
- Full incorporation of ACCSP activities into state and federal legislative outreach efforts;
- Consistent application of ASMFC policies for all staff;
- More consistent supervision of ACCSP Director.

This document details the plans for fully integrating ACCSP into ASMFC. An Addendum to the ACCSP Memorandum of Understanding (MOU) will also be developed to formalize all structural changes.

General

ACCSP will be fully integrated into ASMFC, while maintaining its identity for stakeholders and partners as the central fisheries dependent data entity for the Atlantic coast. ACCSP will maintain its current website to provide consistency and transparency for stakeholders seeking data or other information about the program. ASMFC will modify its website homepage to provide a link to the ACCSP site on the primary menu bar. This approach will allow stakeholders easy access through either website.

Outreach efforts will be continued to inform stakeholders of ACCSP's capabilities and resources. The primary function of ACCSP's outreach is to inform users and potential users of new developments and promote program capacities. ACCSP and ASMFC outreach experts will work closely together to develop content, network, and promote ACCSP.

Under this governance change, the ACCSP committee structure and membership will not change significantly. For example, the Coordinating Council and Operations Committee will maintain their current makeup and functions. However, there will be some changes to reduce redundancy between the ASMFC and ACCSP committees. For example, there is no need to have two separate Executive Committees.

The needed modifications to the ACCSP have been divided into short, medium and long-term changes. These are detailed below.

Short-Term Changes (0-6 months)

- ACCSP Director participates in ASMFC processes consistent with other ASMFC directors
- ACCSP staff will be guided by the ASMFC Employee Handbook
- ACCSP Coordinating Council composition remains the same, with continued focus on budgetary and data policy issues
  - Responsible for spending decisions of funding allocated to the Program
    - ASMFC Executive Committee will continue to determine (with NMFS concurrence) the allocation of ACFCMA funds between ASMFC, States, and ACCSP.
    - FIN funding for ACCSP will come directly from NMFS
- ACCSP (Management Committee, Leadership Committee, Policy Committee, Oversight Committee, Interim Action Committee etc.) responsibilities shift and committee composition changes:
  - **3 – State Reps -** One Coordinating Council member or proxy from each Region (see below). These seats may be filled by the Chair, Vice Chair and past Chair of the Coordinating Council.
    - Add additional state representative(s) beyond the Chair, Vice Chair, and the former Chair, if necessary (e.g., a federal partner is chair), to maintain three state regional representatives.
    - CC immediate past Chair, Ex Officio
    - The Coordinating Council Chair and Vice Chair shall serve as the Chair and Vice Chair of the Executive Committee, respectively. It is expected that these positions will usually be rotated among the three regions defined below: New England; Mid-Atlantic; South Atlantic.
  - 1 – NMFS or USFWS Representative
  - 1 – Council Representative for the three Councils (NEFMC, MAFMC, SAFMC)
  - ASFMC Executive Director
    - The ACCSP Director will provide staff support to the Executive Committee meetings.
  - Serves as a 'quick response' team when Coordinating Council is not meeting or is impractical.
  - Responsibilities consistent with Coordinating Council as a whole
- ACCSP Director provides at least semi-annual updates with budget highlights to ASMFC Executive Committee
  - Promotes buy-in from state directors
- Approve Addendum to MOU

Mid-Term Changes (6-12 months)

- Continue Integration
  - Look for staff efficiencies in technical and administrative support

- Consider integration of separate ASMFC and ACCSP outreach efforts
- Consider Information Systems changes (Phase out @accsp.org email addresses and provide ACCSP staff with @asmfc.org emails, etc.)

- Work towards ACCSP as primary data source for ASMFC needs. Find ACCSP-based solutions to ASMFC management and science data needs.
- Update all ACCSP SOPPs to be consistent with ASMFC and reflect the new governance structure.

Long Term Changes (~24 months)

- Integrate planning
  - Incorporate ACCSP Strategic planning into next ASMFC Strategic Plan
    - Both Strategic Plans end in 2018. The ACCSP activities will be included as a new goal in the ASFMC Strategic Plan and no new ACCSP Strategic Plan will be developed.
    - Incorporate provisions to add recommendations from external reviews of ACCSP.
  - ACCSP will fully participate in the ASFMC's annual Action Planning and budgeting process, including a new ACCSP goal in the Action Plan.
  - Consider the need to continue the ACCSP administrative grant. Possibly fold ACCSP administrative funding into ASFMC programmatic budget.
  - Evaluate the impacts of governance changes and see if additional adjustments are warranted.
  - Evaluate and report to CC if ACCSP has been invigorated, renewed engagement from State Directors, and program is advancing in its mission.

July 8, 2016

ADDENDUM

To the
MEMORANDUM OF UNDERSTANDING

For establishment of an

ATLANTIC COASTAL COOPERATIVE
STATISTICS PROGRAM

(ACCSP)

ACCSP Coordinating Council
APPROVED: XXXXXXX

INTRODUCTION

When first established in May 1995, Section 8 of the Memorandum of Understanding (MOU) for the Atlantic Coastal Cooperative Statistics Program (ACCSP) provided that:

> The Atlantic States Marine Fisheries Commission (ASMFC), the National Marine Fisheries Service (NMFS), and the U.S. Fish and Wildlife Service (USFWS) shall agree on the appropriate method of providing support staff and executive secretarial services to the Council and the Committee established under this Section, subject to the approval of the Council. Responsibility for the day-to-day coordination, planning and implementation of tasks associated with the program shall be the responsibility of all of the partners, under the guidance of the Council and the Committee.

During the first few years of existence, the ACCSP was in a planning stage. Planning was conducted by a variety of committees, with adequate staff support provided first by the ASMFC and then a coordinator from the USFWS who was detailed to the program for a year. As the program completed planning of various modules, it began evolving into an operational stage. Additional staff were required to support planning, building of the central data warehouse, and implementation activities. The need for a permanent home for the ACCSP staff was becoming apparent.

In June 1998, the ACCSP Coordinating Council approved a motion that:
- The ASMFC should serve as the administrative body for the ACCSP and its Coordinating Council,
- The ASMFC should hire new staff under the existing Commission structure to support ACCSP Partners with planning, prototype development, research, and implementation, and
- The services provided by the ASMFC to the ACCSP should be formalized through an addendum to the ACCSP MOU.

An Administrative Assistant, Information Technology Manager, Program Manager, and finally two additional information technology staff were hired from 1999 to 2001. As the program continued to grow, and the public became more aware of the existence and purpose of the ACCSP, discussion continued concerning the structure and support of the program. Options that were considered ranged from continuation of the status quo to complete separation of ACCSP into a stand-alone operational unit. A number of concerns influenced the choice:
- Perception – the public has concerns when data are collected by the same entity that is using the data for management. Separation of ACCSP from regulatory bodies, to the extent practical, was seen to help address this perception issue.
- The structure would be cost effective and meet the administrative obligations of ACCSP efficiently.
- Any structure would be within Current Legal Authority.
- The structure would reflect that the ACCSP is a partnership that includes the ASMFC, and is not just another ASMFC program.

- The structure would accommodate the continuing growth and maturity of ACCSP.
- There would be clear lines of authority within the program.

In July 2001, the Coordinating Council approved a motion that:
- The ASMFC will provide administrative support to the ACCSP.
- A new ACCSP Director position will be created to provide executive leadership for the program. The ACCSP Director will serve as overall program leader and will have executive authority to manage the continuing development and operation of ACCSP.
- The ASMFC Executive Director and ACCSP Coordinating Council Chair will conduct the performance review for the new ACCSP Director, with oversight by the ACCSP Executive Committee.

The Coordinating Council felt that this decision was the best solution for all concerns. ACCSP would be separated from other ASMFC programs, which addresses perception issues. The structure is within current authorities and would meet the ACCSP's administrative obligations in an efficient, cost-effective manner. The Director would provide leadership and management of the program and be the public view of ACCSP. The continued growth and maturity of the program would be well served with a single, strong program leader. Clear lines of authority were provided for policy/program guidance and staff performance review. This resulted in an amendment to the MOU implementing these recommendations.

In 2012, the Program conducted an Independent Program Review (IPR) that resulted in a series of recommendations. To address one of the ACCSP's 2012 IPR recommendations to "undergo a governance review" the Executive Committee formed a Governance Ad-Hoc Workgroup (Workgroup). The IPR Panel Report indicated they "realize that the situation today is very different than 1995[1], when the ACCSP was created. ACCSP needs a better relationship and interface with Atlantic States Marine Fisheries Commission (ASMFC), and linkages established and strengthened. Consideration should be given to placing ACCSP as a program under ASMFC, which could possibly re-engage the state directors. There are issues of economy of scale and potential improvements to efficiency that could be gained, working relationships strengthened, resources leveraged, etc."

It was the recommendation of the workgroup, approved by the ACCSP Coordinating Council and the ASMFC Executive Committee and Commission as a whole in May 2016, that ACCSP be folded into ASMFC as a Program. Under this alternative the ACCSP would be incorporated into the ASMFC, and ACCSP would be congruent with existing ASMFC programs such as the Interstate Fishery Management Program (ISFMP). The ASMFC Executive Director would directly supervise the ACCSP Director, and all staff would be governed by existing ASMFC governance structures. This alternative should not have any affect under the current budget of ACCSP or ASMFC.

[1] Original Memorandum of Understanding between partners framed the ACCSP in 1995.

AMENDMENT

This Addendum incorporates the June 1998, July 2001 and May 2016 program changes into the MOU, as follows:

All references in Section Eight to *Atlantic Fisheries Statistics* are be amended to read *ACCSP*.

Section 8 is amended to read:

A. *Atlantic Fisheries Statistics Coordinating Council.* There shall be an Atlantic Fisheries Statistics Coordinating Council (hereafter: Council). The Council shall oversee the design and implementation of the ACCSP, set policy to guide the Program and the partners participation therein, allocate funding dedicated to the Program, establish Committees as necessary, and recommend solutions for any issue related to the program raised by any of the partners to the ASMFC Executive Committee. The Council members, who shall represent the policy levels within their agencies with the ability to make policy commitments therefore, shall be: one voting representative of each signatory partner, plus three (3) additional nonvoting representatives from NMFS. The Council shall make its decisions by consensus where possible, or by majority vote. The Council shall elect its Chair and Vice Chair.

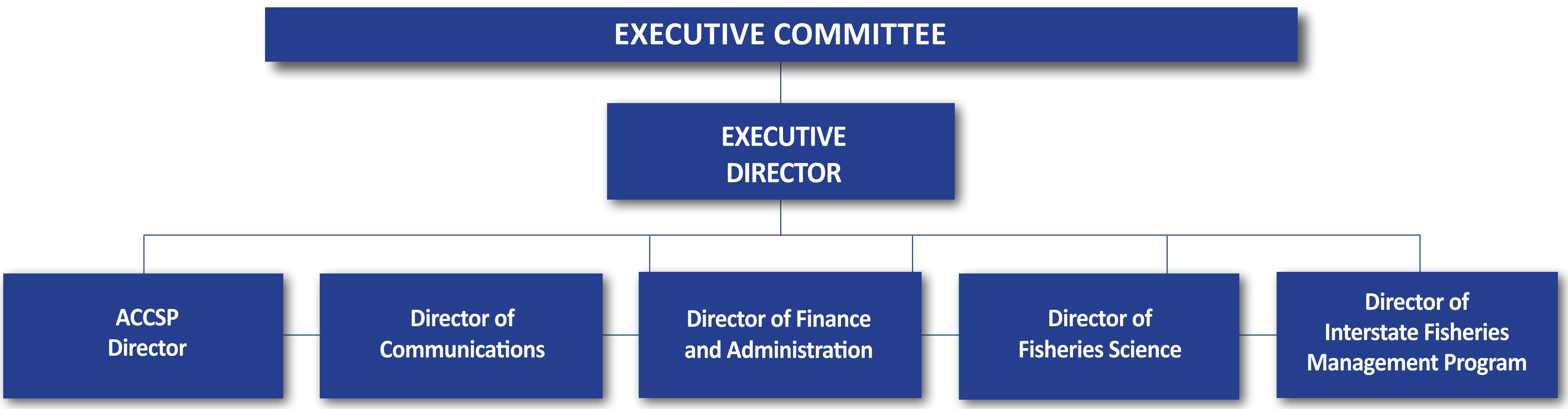
B. *ACCSP Operations Committee.* The ACCSP Operations Committee will recommend program priorities, funding criteria, and other items as requested by the Coordinating Council, and/or ACCSP Director. It shall also be responsible for maintaining the *Program Design*, making changes to fisheries standards as needs evolve. The Operations Committee is comprised of an experienced staff person from each partner and one representative each from the National Marine Fisheries Service Headquarter Office of Science and Technology, Southeast Fisheries Science Center, Southeast Regional Office, the Greater Atlantic Fisheries Regional Office, and the Northeast Fisheries Science Center. The Operations Committee shall make its decisions by consensus.

C. *ACCSP Director.* The ACCSP Director serves as overall program leader and has authority to manage the continuing development and operation of ACCSP consistent with guidance from the Coordinating Council. The ACCSP Director reports to and receives guidance from the Executive Director of ASMFC who in turn shall abide by the data management, collection and standards policy decisions made by the Coordinating Council with respect to the ACCSP mission. The ACCSP Director will be responsible for supervision of ACCSP staff. Specific responsibilities include providing overall guidance to all ACCSP staff, ensuring the policies of both the ASFMC and ACCSP are met by ACCSP staff, coordinating long-range planning and budget requirements, , and conducting annual performance evaluations of ACCSP staff. Hiring and firing of ACCSP staff shall be consistent with ASMFC policy. The ACCSP Director will provide staff support to all ACCSP Committees and Subcommittees and administer any grant or cooperative agreement associated with the ACCSP.

D. *ASMFC Program Support*.

The ASMFC Executive Director shall ensure that the ACCSP Director is accountable for implementation of the ACCSP program elements and for carrying out policies of the Coordinating Council. The ASMFC Executive Director, in consultation with the ACCSP Coordinating Council Chair will conduct the annual performance review for the ACCSP Director consistent with ASMFC policy.

The ASMFC shall provide appropriate administrative and logistical services/support for ACCSP operations, as with all other ASMFC programs. The ACCSP long term and annual planning processes shall be integrated with those already in existence for ASMFC, conform to policy as set by the Council and informed by periodic independent reviews of the ACCSP.


EXECUTIVE COMMITTEE
EXECUTIVE DIRECTOR
ACCSP Director
Director of Communications
Director of Finance and Administration
Director of Fisheries Science
Director of Interstate Fisheries Management Program

Atlantic States Marine Fisheries Commission

Horseshoe Crab Management Board

August 2, 2016
2:00 – 3:30 p.m.
Alexandria, Virginia

Draft Agenda

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

1. Welcome/Call to Order *(J. Gilmore)* — 2:00 p.m.

2. Board Consent — 2:00 p.m.
   - Approval of Agenda
   - Approval of Proceedings from May 2016

3. Public Comment — 2:05 p.m.

4. Review and Consider Recommendations from the Adaptive Resource Management (ARM) Subcommittee on Revisions to the ARM Framework (*J. Lyons*) **Action** — 2:15 p.m.
   - Technical Committee Report (*S. Doctor*)
   - Advisory Panel Report (*J. Cooper*)

5. Discuss Additional Bait Trials (*R. Ballou*) **Possible Action** — 3:00 p.m.

6. Other Business/Adjourn — 3:30 p.m.

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

MEETING OVERVIEW

Horseshoe Crab Management Board Meeting
Tuesday May 3, 2016
2:00 p.m. – 3:30 p.m.
Alexandria, Virginia

Chair: Jim Gilmore (NY) Assumed Chairmanship: 10/14	Horseshoe Crab Technical Committee Chair: Steve Doctor (MD)	Law Enforcement Committee Representative: Doug Messeck (DE)
Vice Chair: Dr. Malcolm Rhodes (SC)	Horseshoe Crab Advisory Panel Chair: Dr. Jim Cooper (SC)	Previous Board Meeting: May 3, 2016
Shorebird Advisory Panel Chair: Dr. Sarah Karpanty (VA)	Delaware Bay Ecosystem Technical Committee Chair: Greg Breese (FWS)	
Voting Members: MA, RI, CT, NY, NJ, DE, MD, DC, PRFC, VA, NC, SC, GA, FL, NMFS, USFWS (16 votes)		

2. Board Consent

- Approval of Agenda
- Approval of Proceedings from May 2016 Board Meeting

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. Review and Consider Recommendations from the Adaptive Resource Management (ARM) Framework (2:15 – 3:00 p.m.) Action
Background • At the 2016 Winter Meeting, the Board supported moving forward with a short-term, partial review of the ARM Framework to be conducted by the ARM Subcommittee in consultation with the Horseshoe Crab Technical Committee subcommittee. • The ARM Subcommittee met twice a month from February through July 2016 to consider components of the ARM Framework to be updated. Areas of possible change in the ARM Framework include valuation of female horseshoe crabs, alternative harvest packages, abundance thresholds for allowing female horseshoe crab harvest, and the possibility of

including biomedical data in the ARM Framework moving forward (**Supplemental Materials**)

Presentations

- Recommendations on Revisions to the ARM Framework by J. Lyons
- Technical Committee Report by S. Doctor
- Advisory Panel Report by J. Cooper

Board actions for consideration at this meeting

- Consider approval of recommendations from the ARM Subcommittee to the ARM Framework
- Consider initiation of an addendum to address ARM Subcommittee recommendations

6. Discuss Additional Bait Trials (3:00 -3:30 p.m.) Possible Action

Background

- In February 2016, the Board was presented the results of the 2014 alternative horseshoe crab bait trials conducted in Connecticut and Rhode Island. Based on the results of the trials, the Board tasked staff with developing a cost comparison.
- In May 2016, the Board was presented considerations by the Artificial Bait Trials Working Group and Advisory Panel in conducting a cost comparison. Based on the Board discussion, the Board expressed interest in conducting additional bait trials in the future.
- In July 2016, the Board was presented a prospectus for considering conducting additional bait trials in fall 2016. (**Briefing Materials**)

Presentations

- Prospectus for continuing alternative bait trials by R. Ballou

Board actions for consideration at this meeting

- Consider tasking the Technical Committee with conducting additional alternative bait trials

7. Other Business/Adjourn

Commonwealth of Massachusetts
Division of Marine Fisheries
251 Causeway Street, Suite 400
Boston, Massachusetts 02114
(617)626-1520
fax (617)626-1509

David E. Pierce
Director

Charles D. Baker
Governor
Karyn E. Polito
Lieutenant Governor
Matthew A. Beaton
Secretary
George N. Peterson, Jr.
Commissioner
Mary-Lee King
Deputy Commissioner

MEMORANDUM

To: Robert Ballou, RI DEM
Kirby Rootes-Murdy, ASMFC Horseshoe Crab Plan Coordinator

From: Daniel McKiernan, Deputy Director and ASMFC Horseshoe Crab Board Member

Date: July 5, 2016

Subject: Continuing horseshoe crab alternative bait trials

The Massachusetts Division of Marine Fisheries (DMF) provides the following comments on the June 6 memorandum from Robert Ballou to the ASMFC Horseshoe Crab Management Board and Technical Committee. Staff of DMF's Invertebrate Fisheries Project, led by Chief Biologist Robert Glenn and including fisheries specialists Derek Perry (horseshoe crab biologist and ASMFC technical committee member) and Steve Wilcox (whelk biologist), have been investigating fishing and baiting practices over the past few years. Although DMF has been a proponent of pursuing alternative bait types to enhance horseshoe crab conservation—and have spoken on the record in support of alternative baits—we have practical concerns about the issues raised in the June 6 memo. Specifically, we are concerned that the use of "ecobait" may not be a viable alternative to current practices and bait types. Our concerns fall into four categories: efficacy, cost, product handling challenges, and potentially exaggerated conservation benefits.

1) **Efficacy.** The ecobait uses marine species that the fishery is currently using but appears to require 2–6 times the manufacturer-recommended amount of bait to fish properly.

Based on the results of a mail survey of commercial whelk pot fishermen conducted by DMF whelk biologist Steve Wilcox, Massachusetts whelk pot fishermen use an average of a ¼ of a horseshoe crab per trap. Based on conversations with Penny Howell of CT DEP, CT harvesters use a similar amount. The standard practice used to bait traps in MA and CT is not to solely use horseshoe crab as bait, but to use a bait medley usually consisting of horseshoe crab mixed with cheaper baits such as green crabs, mussels, or fish. The June 6 memo states a goal of determining a bait alternative to fisheries that use horseshoe crabs as their sole bait. Cases of traps being baited solely with horseshoe crab appears to be very rare in MA and possibly in other neighboring states. The artificial bait trials appear to be merely testing the bait that is similar to that already being used by the fishery, but in another form that is more expensive and logistically challenging to work with.

2) **Cost.** The ecobait may be more expensive than current baiting practices.

LaMonica gave an initial price of $50 per slab which was supposed to bait approximately 50 traps ($1/trap). If 2–6 times the recommended bait is needed to fish effectively, then it is $2–$6/trap (or $400–$1200/set of 200 traps). Based on a conference call with ASMFC staff, there is also some indication that the price per slab may increase to $65–75, making it even more cost prohibitive. More recent conversations between LaMonica and ASMFC staff indicate that LaMonica may sell the product for $40 a slab for the first six months, and then reevaluate the price. MA fishermen generally buy horseshoe crabs for $3.50–$4.00/crab. At a quarter of a crab per trap, that equals about $1/trap, or less. The horseshoe crab is then mixed with a variety of cheaper baits, such as the invasive green crab. It costs an estimated $1.25 to bait a whelk trap based on current practices.

3) **Handling.** Based on feedback from RI and CT, the ecobait has a short shelf life and does not last long in the water. Also, the company has been unable to deliver the bait to New Bedford which prevented MA from being able to participate in the bait study.

The alternative ecobait appears to be replicating a similar bait medley the commercial industry is currently using, but this form may be more difficult to handle. It is our understanding that the binding agent used should not be frozen and only has a shelf life of two weeks; the manufacturer recommends refrigerating the bait, which would be problematic for many fishermen without access to walk-in refrigerators. In certain areas with strong tidal current, the bait only lasted one night. Finally, while the manufacturer suggested that New Bedford is a convenient place for them to deliver bait to our state, we were frustrated because we were unable to secure a delivery.

4) **Conservation benefit.** The alternative bait does not substantially reduce the amount of horseshoe crabs used on a per trap basis, so we conclude the conservation benefit for horseshoe crabs is overestimated.

Each “piece” of artificial bait used in the trial contained approximately ⅛ of a female horseshoe crab. When you multiply these numbers by 2 or 6 (the amount of bait needed to actually get the pot to fish), the artificial bait used ¼ to ¾ of a horseshoe crab per pot to fish effectively. The artificial bait used more horseshoe crabs per pot than what is currently used in the whelk pot fishery, thus providing no conservation benefit.

We would be open to testing the efficacy of other alternative marine species as baits, but based on the trials that have already been done by CT and RI we intend to decline to participate in further testing. We suggest testing baits that do not use any horseshoe crab but use currently available and abundant baits such as green crabs, mussels, or byproducts from crab processing (e.g., Jonah, red crab) to see how critical horseshoe crabs are to catching whelk. We would also recommend testing baits made from post-processed horseshoe crab blood which is currently discarded by the biomedical industry.

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Horseshoe Crab ARM Subcommittee Draft Recommendations of ARM Framework Review
July 2016

Executive Summary

Under the guidance of the ASMFC Horseshoe Crab Management Board (Board), the Adaptive Resource Management (ARM) Subcommittee undertook a review of the ARM Framework as outlined in Addendum VII to the Horseshoe Crab FMP. The ARM Framework allows for ecosystem considerations in annually setting horseshoe crab harvest specifications in the Delaware Bay Region. Over the last 8 months, the ARM Subcommittee considered, evaluated, and developed recommendations to the ARM Framework in three categories: 1) monitoring programs, 2) harvest rates and specifications, and 3) the ARM objective function. The ARM Subcommittee outlined the following recommendations:

- Continuation of the Virginia Tech University (VT) trawl survey to inform the population abundance estimate for Horseshoe Crabs in the ARM Framework.
    - In the absence of the VT trawl survey, continue with the composite index developed by Sweka et al. in 2015
- Redouble efforts to conduct the annual red knot shorebird mark-recapture survey
- <u>Adjust current harvest packages to account for biomedical bled mortality of female horseshoe crabs</u>
- No adjustment to the order of red knot and horseshoe crabs in the objective statement
- Removal of duplicate sex ratio constraint on the utility function
- No adjustment to the (2x) multiplier of utility of female crab harvest in the reward function as it reflects the market value of male to female crabs (2:1 male to female)
- No adjustment to the current knife-edge utility function to a sloped function.

Background

In February 2016, the Board considered several aspects of the ARM Framework that could be reviewed in the interest of maintaining and improving the ARM Framework. Aspects of the framework that were considered for review included both long-term (1-2 year) and short-term (6-8 months) items. A long-term review would include five aspects of the framework: 1) ecological models, 2) ARM optimization and software platform, <u>3)</u> monitoring programs, <u>4)</u> harvest rates and specifications, and <u>5)</u> ARM objective function; a short-term review would consider only items #3-5. The Board tasked the ARM subcommittee with a short-term review of the ARM framework- those review items have been renumbered in this report as 1) monitoring programs, 2) harvest rates and specifications, and 3) the ARM objective function).The ARM subcommittee met several times via conference call from February 2016 through July 2016 to evaluate these short-term review items and develop recommendations. Below is the summary of the ARM Subcommittee's evaluation, conclusions, and recommendations for each review item.

<u>Review Item #1</u>: *Evaluate the monitoring program; update and improve monitoring protocols as needed; use available data to assess quality and precision if possible and as needed.*

Evaluation:

A. Virginia Tech Bottom Trawl Survey

The Virginia Tech (VA Tech) bottom trawl survey was the primary horseshoe crab (HSC) monitoring effort conducted in the development and support of the Adaptive Resource Management (ARM) framework for the management of horseshoe crabs in the Delaware Bay region. Estimates of HSC abundance from this trawl survey in year *t* were used to inform harvest recommendations in year *t*+1 within the ARM framework. The VA Tech trawl survey was conducted from 2002 – 2012, but 2012 had reduced sampling effort due to funding limitations. The survey was not funded in 2013 – 2014, and was not carried out in 2015 due to timing of when grant funds were released.

Methods

From 2002 - 2010 the VA Tech trawl survey was conducted along the coastal Delaware Bay area from 39° 20' N (Atlantic City, NJ) south to 37° 40' N (slightly north of Wachapreague, VA) and was conducted in the fall of each year (October – November). The survey area was stratified according to distance from shore (0-3 nm and 3-12 nm) and by bottom topography (trough vs. non-trough). Sampling was conducted with a 16.8 m chartered commercial fishing vessel based out of Ocean City, MD. The trawl used a two-seam flounder trawl with a 18.3 m headrope and a 24.4 m footrope, rigged with a Texas Sweep of 13 mm link chain and a tickler chain. The net body consisted of 15.2 cm stretched mesh and the bag consisted of 14 cm stretched mesh. Individual tows were conducted with an approximate 15 minute bottom time. In 2011, the survey was expanded to areas inside of the lower Delaware Bay and this area was stratified by bottom topography alone (trough vs. non-trough). In 2012, funding was limited and the survey was reduced to the areas inside of the lower Delaware Bay and along the coast between 39° 10' N and 38° 10' N from shore out to 3 nm (Hallerman and Hata 2013). Captured HSC were measured for prosomal width, sexed, and maturity classified. Maturity classifications consisted of immature, newly mature (those that are capable of spawning but have not yet spawned) and mature (those that have previously spawned).

Stratum mean catch per 15 minute tow was calculated using two methods – assuming a normal distribution and a lognormal delta distribution. Stratum mean and variance estimates were then combined to estimate an overall stratified mean catch per tow. In addition to mean catch per tow, a population estimate was generated by first calculating the stratum mean density of HSC within the area sampled by the trawls and then expanding this density estimate to the total area of each stratum and summing across strata. Indices of abundance (catch per tow) and the population estimates were calculated individually for each sex. The population estimates for each sex were then used to inform ARM harvest recommendations.

Future Surveys

Funding for the VA Tech trawl survey was not available after the 2012 survey. ASMFC has secured funding for the 2016 season and is pursuing funding through NMFS to continue the survey beyond 2016. Staff at VA Tech are currently operating under the assumption that the survey will continue indefinitely (E. Hallerman, *personal communication*). The sampling plan for 2016 will be to conduct the survey as it was conducted in 2011 (the last year of full funding).

B. Index of Abundance from Other Trawl Surveys

With the lack of funding for the VA Tech trawl survey after 2012, the ARM workgroup began considering alternative methods to assess the abundance of horseshoe crabs in the Delaware Bay region. There have been several other trawl surveys in the Delaware Bay region that assess the abundance of horseshoe crabs including: the Delaware 30 foot trawl survey, the Delaware 16 food trawl survey, the New Jersey Delaware Bay trawl survey, the New Jersey Surf Clam dredge survey, and the Maryland Coastal Bays trawl survey (See ASMFC 2009a for descriptions of these trawl surveys). In 2015, the ARM workgroup developed a methodology using data from these surveys in lieu of the VA Tech trawl survey to produce estimates of abundance that could be used to make harvest recommendations for the 2016 season (ARM Workgroup 2015).

Methodology

The ARM workgroup decided that the final set of trawl surveys to be considered in this alternative abundance estimation methodology include the Delaware 30 foot trawl survey, the New Jersey Delaware bay trawl survey, and the New Jersey Ocean trawl survey. These surveys were selected because they had sex-specific abundance indices, had overlapping years of data with each other and with the VA Tech trawl survey, and they are expected to continue into the future. A linear mixed random effects model was used to generate annual composite indices of male and female abundance from 1998 – 2014. In this model, each individual survey within a year represented a random effect. The model was fit using the “lme” function from the package “nlme” in R 3.0.2 and was specified as a non-intercept model to allow for year-specific estimates of abundance rather than differences for each year from the intercept. Index values from each survey were ln + 0.01 transformed prior to model fitting and final yearly indices of abundance from the model were back-transformed.

Yearly composite indices of abundance were correlated with overlapping years of abundance estimates from the VA Tech trawl survey (2002 – 2011). Linear regression models then related the composite indices of abundance for each sex to the total abundance estimates from the VA Tech trawl survey. These regression parameters were then used to estimate the total abundance of each sex for the time period of 1998 – 2014. The resulting estimates in 2014 were 16.4 million males and 8.4 million females.

Future Surveys

It is anticipated that the three surveys used in the composite index of horseshoe crab abundance will continue into the future. The method of combining data from each of these surveys can continue into the future if the VA Tech trawl survey cannot continue indefinitely. Also, additional years in which the VA Tech trawl survey is conducted will add information to the calibration of the composite index when estimating total abundance.

Conclusions – Trawl Surveys

Future monitoring of the Delaware Bay horseshoe crab population is uncertain and ultimately depends upon funding – especially for the VA Tech trawl survey. At the time of the 2009 ASMFC stock assessment, the plan for horseshoe crab abundance estimation was to further advance a catch-survey model (Collie and Sissenwine 1983) based on data provided by the VA Tech trawl survey. This model simulates stock dynamics through time using two stages (pre-recruits and fully recruited crabs) and has minimal data requirements including: 1) annual indices of relative abundance for each stage; 2) relative selectivities of stages to the survey gear; 3) annual total harvest in number; and 4) an estimate of instantaneous natural mortality rate. Output from the model gives estimates of abundance and exploitation. This type of model is well suited for the assessment of horseshoe crabs because horseshoe crabs cannot be aged, but can be separated into pre-recruit versus fully recruited individuals. Preliminary use of the catch survey model was included as part of the 2009 stock assessment (ASMFC 2009a) and further development and use of this model was encouraged by the peer review panel, although more work is needed to identify appropriate gear selectivities for pre-recruits and fully recruited crabs.

Unfortunately, development of the catch-survey model was halted when funding for the VA Tech trawl survey ended. Other trawl surveys could not be adequate substitutes because they do not separate pre-recruits from fully recruited crabs. If the VA Tech trawl survey secures funding beyond 2016, the catch-survey model appears to be the most promising way to assess horseshoe crab abundance in the Delaware Bay region. However, it is uncertain if the catch-survey model can be run again once 2016 data is collected due to the several consecutive years of missing data when the VA Tech trawl survey was not funded, or if several additional years of data must first be been collected.

If the VA Tech trawl survey is not funded beyond 2016, a practical alternative is to continue to use the composite index of abundance based on data from other trawl surveys. The 2016 data collected from the VA Tech trawl survey can be added to the regression model which calibrates the composite index of abundance to total abundance. Although this methodology can continue into the future because the surveys on which it is based will likely continue, a major shortcoming is that this method assumes that the abundance estimates from the VA Tech trawl survey are unbiased and scaling of the composite index to total abundance would remain unchanged into the future. At this point we do not know how accurate total abundance estimates form the VA Tech trawl survey were and it is likely that they are underestimates because the efficiency of the trawl survey was not 100% as evidenced by the gear efficiency study conducted by Hallerman and Hata (2013) in 2011. This bias could compromise the ability to select optimal harvest packages in the ARM modeling framework because predictions for optimal harvest assume an accurate assessment of the state of horseshoe crabs and red knots at each time step. It is possible that estimates of total abundance from the composite index scaled to VA Tech trawl survey abundance estimates would be underestimates of horseshoe crab abundance, which we would expect to lead to recommending more conservative harvest packages than what would actually be necessary to sustain the horseshoe crab population and ensure enough resources are available to red knots. Further, if the composite index method is substituted for the VA Tech trawl survey long term, the Commission will need to coordinate with the U.S. Fish and Wildlife Service to determine if the ARM framework is still functioning as intended, and if further evaluation is needed in light of the federal listing of the red knot (*Calidris canutus rufa*) under the Endangered Species Act.

C. Mark-Recapture Approach to Horseshoe Crab Abundance Estimation

Mark-recapture efforts for horseshoe crabs have been ongoing for many years. The U.S. Fish and Wildlife Service (USFWS) has been administering a horseshoe crab tagging program since 1999 through its Maryland Fisheries Resource Office. Objectives of the program included the estimation of horseshoe crab movement and migration and to provide data necessary for estimation of survival and mortality. Horseshoe crabs are tagged along the Atlantic coast by natural resource agencies and other researchers for various purposes and the information associated with tagged crabs is maintained in a database by the USFWS. The USFWS also receives reports of tagged crabs that are recaptured in fisheries independent surveys, commercial harvests, and by sightings reported by the public including the volunteer-based spawning surveys.

Although the tagging program has relatively large spatial and temporal coverage, only two studies have used tagging data to estimate abundance of horseshoe crabs in the Delaware Bay region: Smith et al. (2006) and Merritt (2015).

Summary of Smith et al. (2006)

Smith et al. (2006) conducted an intensive tagging study in 2003 with the objective of estimating the spawning population size of horseshoe crabs in Delaware Bay. Prior to peak spawning in 2003, crabs were collected by trawling vessels and tagged throughout Delaware Bay. Recaptured tags came from the Delaware Bay spawning survey. Two estimation techniques were employed: Chapman's modification of the Petersen estimator and an extension of a likelihood estimator by Borchers et al. (2002). Smith et al. (2006) also conducted radio telemetry on horseshoe crabs to evaluate the assumption that tagging does not affect spawning behavior and used the results from the radio telemetry study to adjust population estimates.

Smith et al. (2006) tagged a total of 12,489 males and 5,054 females prior to the peak spawning period of 2003. During the spawning survey, 22,051 males and 6,675 females were counted and an additional 45 males and 3 females were tagged. Male abundance was estimated and then the ratio of males:females was used to estimate female abundance. These abundance estimates were adjusted based on radio telemetry data to account for tagging effects on crab behavior and the final estimates of abundance were 13,730,000 (8,780,000 – 19,400,000; 95% CI) males and 6,250,000 (4,000,000 – 8,840,000) females in 2003.

Summary of Merritt (2015)

Merritt (2015) explored another approach to the analysis of mark-recapture data in order to estimate abundance of horseshoe crabs in the Delaware Bay region. Merritt (2015) used a hierarchical modeling approach within a Bayesian framework which had a state-space model component to describe capture history data with a model for the unobservable or partially observable state process and a model for the observation process. The state process consisted of a model for occasion-specific spawning probabilities which allowed crabs to spawn at various times throughout the season, and when animals were not spawning, they were unavailable for detection. This modeling effort used data from 2003 and 2004 because these years coincided with large, known numbers of tagged crabs in the system from the work of Smith et al. (2006).

Results from this modeling effort gave estimates of abundance that overlapped mark-recapture estimates from Smith et al. (2006) and estimates based on expansion of the VA Tech trawl catches from Hata and Hallerman (2009). However, modeled estimates of the number of marked crabs in the population were less than the number known to be marked from Smith et al. (2006). Merritt (2015) also conducted simulations to evaluate the effects of increasing tagging and recapture effort on the precision and relative bias of population estimates. The simulations generated capture histories for known numbers of tagged individuals, with a known population size, detection probability, and probabilities of spawning. Simulated increases in effort were found to increase the precision of estimates but the relative bias of the estimates also increased. These results suggest that although this framework for estimating horseshoe crab abundance shows promise, more work is needed in the model structure and estimation techniques before a mark-recapture approach such as this can be used for management decision making in the Delaware Bay region.

Recommendations:

- The ARM subcommittee recommends continuation of the Virginia Tech Bottom Trawl Survey in future years since it supports the ARM model, provides substantial data to the assessment of horseshoe crabs, and ensures that the ARM framework will function as intended.
- Additionally, the subcommittee supports the recommendations from the 2009 Horseshoe Crab Stock Assessment to estimate the proportion of the Delaware Bay population that is available in time and space within the survey area and to continue the work to assess the selectivity of gear used in the survey.

D. Red Knot Population Monitoring

The evaluation of the Red Knot population monitoring included 1) documentation of the mark-resight study design and sampling plan used to estimate stopover population size each year, 2) discussion of the study design and sampling plan with the Delaware and New Jersey shorebird monitoring teams, and 3) a discussion of mark-resight population estimates and aerial survey population indices. Here we review how historic population indices from aerial surveys informed the development of the ARM framework, the transition to mark-resight approaches to estimate stopover population size, and assess the current mark-resight monitoring program.

Annual monitoring of the Red Knot stopover population size is an important part of the harvest decision making framework because female crab harvest recommendations depend in part on Red Knot population size. The primary approach to monitoring Red Knot stopover populations prior to, and during the development of, the ARM framework was aerial surveys; these surveys have been conducted in Delaware Bay each year since at least 1986. ARM recommendations for female crab harvest are informed by Red Knot population monitoring through a utility function that includes a utility threshold determined by Red Knot abundance (McGowan et al. 2009). When Red Knot populations are below the abundance threshold, utility of female crab harvest is set to zero, otherwise the utility of female crab harvest is set to unity, i.e., maximum utility. (There is another utility function for female crab harvest that sets utility to unity if the crab population is above a crab abundance threshold.) The Red Knot abundance threshold in the utility function was initially set at 45,000 knots in reference to historic aerial survey data from Delaware Bay (one half of historic peak counts in aerial surveys).

Mark-resight methods to monitor stopover populations were not available when ARM framework was under development and when the Red Knot abundance thresholds determined. However, during ARM development there was agreement within the Delaware Bay Ecosystem Technical Committee (DBETC) to pursue a mark-recapture/resight approach to population monitoring to replace the aerial survey. Mark-recapture/resight methods provide advantages over aerial surveys because they account for turnover in the population and probability of detection; of course, mark-resight population estimates are larger than peak counts from aerial surveys for these reasons.

Mark-resight methods for monitoring stopover populations were developed shortly after the ARM framework was complete. With the transition to mark-resight methods, the ARM Subcommittee agreed to adjust the utility threshold because the mark-resight estimates are larger than aerial survey indices for the reasons stated above. The subcommittee decide the adjustment to the Red Knot abundance threshold should be commensurate with the best available data on the ratio of mark-resight estimates and aerial survey peak counts. After discussing available data from 2011-2013, the ARM Subcommittee recommended in September 2013 to use the ratio of mark-resight and aerial survey indices from the years 2012-2013 to adjust the utility threshold. This recommendation was presented to the DBETC in October 2013 and subsequently approved by the Board.

In 2015, some members of the ARM Subcommittee and the TCs raised concerns about the higher than usual ratio of mark-resight estimate to aerial survey peak count; the mark-resight analysis suggested that more knots stopped in Delaware Bay in 2015 than in previous years, whereas the aerial survey indicated no change. In response, the ARM Subcommittee conducted additional analyses in 2015 to evaluate some possible causes for the higher-than-usual ratio in 2015, including the fact that the 2015 resighting effort was inadvertently skewed in time and space. The additional analyses evaluated some of the assumptions of the mark-resight model, and indicated that any bias in the 2015 mark-resight estimate from the resighting data being skewed in time and space would lead to under-estimating, not over-estimating, the stopover population size. There was no evaluation of the assumptions related to the aerial survey data that may have led to an underestimate.

To address any issues related to resighting data collection, details of the mark-resight study design and sampling plan were documented in 2016 (Appendix). The study design and sampling plan were reviewed by Red Knot monitoring teams from Delaware and New Jersey and discussed during a conference call in April 2016. No new protocols were implemented as a result of this review, but teams standardized their efforts to collect data in a way that is consistent with the mark-resight model of the data.

There continues to be disagreement among ARM Subcommittee members about the cause of discrepancy between aerial survey data and mark-resight estimates of stopover population size, especially in 2015. The mark-resight model estimates the number of birds that use the sampled beaches in Delaware Bay each year (i.e., the "stopover population size" or "superpopulation", N*). This estimate accounts for turnover in the population during the migration season and probability of detection of marked birds during resighting surveys. Therefore, estimated superpopulation size will always be greater than counts ("snapshots") from an aerial survey on any given day. The primary reason for the discrepancy between the superpopulation estimate (N*) and the peak count from aerial surveys (C) is population turnover.

The mark-resight model also produces time-specific population estimates (N_t) at 8-10 points during the season (depending on the amount of data available), and while not directly comparable to aerial surveys, it may be instructive to explore the discrepancy between these time-specific estimates and aerial surveys. The mark-resight data are aggregated before analysis into 3-day time periods, the length of time required to survey all beaches in the bay (Appendix). The time-specific estimates (N_t) therefore are for the number of knots in the bay during a 3-day period, whereas the aerial surveys are completed in one day and represent the number of birds present on the day of the survey. From 2011-2015 there were 1-3 aerial surveys each year. The difference (D) between peak mark-resight estimate (N_t) and peak aerial count (C) each year, expressed as a fraction of the time-specific mark-resight estimate (N_t), has ranged from 12% (2012) to 50% (2011) ($D = [\{N_t - C\}/N_t]*100$). The large discrepancy in 2011 may have been due to extenuating circumstances (observer illness during the survey); the second largest discrepancy was 36% (2015). The median discrepancy (D) during 2011-2015 was 25%.

The assumptions of the mark-resight method are described in detail in the Appendix. One set of assumptions is that the rates of arrival, stopover persistence, and resighting are the same for all marked and unmarked individuals. Heterogeneity in resighting probability can cause bias in parameter estimates (Appendix). The study design and sampling plan (Appendix) has many aspects that attempt to meet the assumption of homogeneity in resighting probability (e.g., even sampling of the study area). Effects of heterogeneity of stopover persistence on parameter estimates is not well known. Some heterogeneity of stopover persistence may occur from data aggregation into 3-day periods for analysis. The average stopover duration in Delaware Bay is much longer than three days, however, so heterogeneity in stopover persistence from data aggregation should be small. Heterogeneity in stopover persistence may also occur from population structure and stopover-age effects, where stopover age is the amount of time since arrival to the stopover. There is some evidence that age-related variation in persistence does not affect parameter estimates when the amount of variation is small to moderate. Nevertheless, effects of heterogeneity in rate parameters from stopover age and population structure require additional research. See the Appendix for a complete description of these and other assumptions of the mark-resight model.

The aerial surveys in Delaware Bay do not include corrections for bias of any sort. The surveyed area is not drawn from a sampling frame and the estimate is not extrapolated to any unsurveyed area. To the extent possible, observers attempt to be consistent in the methodology and timing to reduce errors of estimation. Nevertheless estimation errors may occur as a result of 1) imperfect detection of birds, 2) availability of birds, and 3) counting errors. Counting large flocks of birds from the air is a difficult task and imperfect detection may result from poor visibility, inclement weather, identification, bird behavior, etc. Surveys are generally conducted only in good weather conditions, but the Delaware Bay aerial survey protocol does not estimate probability of detection and it is difficult to assess the magnitude of detection errors, which result in the counts being too low by some unknown amount. Another error of estimation is related to "availability"; birds that are not in view of the aircraft are not available to be detected. The aerial survey covers most bay beaches used by knots but does not include the Atlantic coast of New Jersey (Niles et al. 2009), managed wetlands, and intertidal marshes; some birds use managed wetlands in Delaware (Niles et al. 2008) and marshes at high tide (Burger et al. 1997). Observers make efforts to cover as much suitable habitat as possible during the aerial survey and be consistent from year to year, but it is impossible to survey all habitats and it seems that some fraction of birds in the bay are not available to be counted. The aerial survey estimate may be biased low due to availability but it is difficult to determine the magnitude of this error. Counting error is another type of estimation error in the aerial survey. Counting errors may be over- or under-estimates but there is ample evidence in the literature that observers tend to under-estimate the size of large flocks of birds (Smith and Francis 2010). Smith and Francis (2010) conducted simulation experiments with experienced observers and concluded that counting errors may result in population estimates that are approximately 25% too low, and that the magnitude of under-counts increased with flock size. It is perhaps coincidence that the median discrepancy between aerial surveys and mark-resight estimates was 25%, but the implications of under-counting error should be acknowledged in an evaluation of aerial surveys and mark-resight estimates. When all sources of estimation error that are possible with aerial surveys – imperfect detection, availability bias, and counting error – are considered, almost all of which result in under-estimates, the discrepancy between aerial survey data and mark-resight estimates may not be difficult to reconcile.

Recommendations:

- At this time, mark-recapture is not a viable option for estimating horseshoe crab abundance within the ARM Framework and therefore it should not be incorporated into the model but it should continue to be developed for future consideration.
- The ARM subcommittee recommends continuation of the mark-resight methodology to estimate the Red Knot stopover population size. The continued methodology should

include the standardized resighting effort outlined in 2016 (Appendix A) in order to model abundance and turnover of birds as accurately as possible.

E. Incorporation of Biomedical Data into the ARM Framework

The ARM Subcommittee discussed the importance of capturing biomedical collection mortality data in the ARM Framework given its lack of inclusion in the initial set up of the ARM Framework through Addendum VII in 2012. In deliberating how best to incorporate this information, the ARM Subcommittee developed 5 options to took different approaches to either explicitly treating biomedical bled mortality as a model input or as a variable in adjusting the current harvest packages. Details on all of the options considered for inclusion in the ARM Framework are included in appendix B. Below is the ARM Subcommittee's recommended preferred option as well as the secondary option considered.

<u>*Preferred Option*</u>: *Adjust harvest packages to account for biomedical mortality of females.*

Mortality associated with biomedical activities due to capture, handling, or post-bleeding stress is considered to be a form of harvest, and thus is incorporated into the harvest quota. In this option, the allocation of the harvest quota among biomedical and bait sources of mortality is left to the Board to consider. The set of harvest packages will be adjusted in recognition that biomedical activities cause mortality of females in the Delaware Bay population.

Adjustment of packages will occur during the 'setup phase' and not during the 'iterative phase'. As such, the packages will be adjusted only during double loop review, which occurs about every 4 to 6 years. The allocation will use the most recent X year moving average of female mortality in Delaware Bay crabs due to biomedical activities. A moving average will be used to adhere to the confidentiality requirements. The number of years in the moving average (X) is proposed to be X=3 so that the average can be responsive to recent trends. All of the harvest packages will be adjusted by including the most recent moving average. The female quota for packages that had been previously male only (Packages 2 and 3) would be designated for biomedical activity only.

The optimization of the ARM decision model will be conducted as before except that the optimization will use the adjusted packages. After a harvest package is selected in a given year, the harvest quota will be allocated among the biomedical and bait sources of mortality. Allocation of harvest will proceed as follows: 1) the up-to-date moving average of mortality of Delaware Bay crabs due to biomedical activities will be subtracted from the quota and 2) the remainder will be allocated for bait harvest. Note that the female quota for Packages 2 and 3 are stipulated for biomedical activity only; thus, there would be no allocation of females for bait under Packages 2 and 3. Current methods would be used to allocate bait harvest among states.

In this option, harvest regardless of source will be accounted for properly in accordance with the ARM Framework. Allocation of bait industry harvest among states would use current methodology. The Management Board would not set a limit on the number of horseshoe crabs that can be killed on an annual basis by the biomedical industry as long as mortality from biomedical activities alone does not exceed the total sex-specific harvest quota. Data confidentiality will be adhered to by using a moving average.

For example, in this option (Table 1), harvest package 3 of 500,000 male crabs only would become 464,000 male crabs only for bait harvest and 36,000 males plus 18,000 females for biomedical harvest. See table below for changes in the current harvest packages under this option with a theoretical biomedical harvest.

Table 1. Comparison of Current Harvest Packages to modified Harvest Packages under the Preferred Option

Current Harvest Packages			Preferred Option Harvest Packages			
Harvest Package	Bait Harvest		Bait Harvest		Biomedical Mortality	
	Males	Females	Males	Females	Males	Females
1	0	0	0	0	36,000	18,000
2	250,000	0	214,000	0	36,000	18,000
3	500,000	0	464,000	0	36,000	18,000
4	280,000	140,000	244,000	122,000	36,000	18,000
5	420,000	210,000	384,000	192,000	36,000	18,000

Secondary Option: Account for biomedical harvest in the population dynamics equations of the ARM framework

One approach to addressing the biomedical industry's take would be to incorporate it into the population dynamics equations for adult crabs as an additional mortality factor. Currently the predicted future abundance of adults is a function of current abundance of juveniles that transition directly to breeding adults (skipping the primiparous stage), plus the number of primaparus individuals that survive the year and become adults, plus the number of current adults that survive the year with the number harvested for bait explicitly subtracted. Abundance projections are calculated for each sex separately:

$$N^{af}_{t+1} = (((N^{j}_{t} \times T^{ja}_{t}) + (N^{p}_{t} \times S^{p}_{t})) \times p) + (N^{af}_{t} - H^{f}_{t}) \times S^{af}_{t}$$

$$N^{am}_{t+1} = (((N^{j}_{t} \times T^{ja}_{t}) + (N^{p}_{t} \times S^{p}_{t})) \times (1-p)) + (N^{am}_{t} - H^{m}_{t}) \times S^{am}_{t}$$

To incorporate biomedical take (bleeding induced mortality), an additional mortality could be added to account for the bled crabs die:

$$N^{af}_{t+1} = (((N^{j}_{t} \times T^{ja}_{t}) + (N^{p}_{t} \times S^{p}_{t})) \times p) + ((N^{af}_{t} - H^{f}_{t}) - (P_{b} \times N^{af}_{t} \times M_{b})) \times S^{af}_{t}$$

$$N^{am}_{t+1} = (((N^{j}_{t} \times T^{ja}_{t}) + (N^{p}_{t} \times S^{p}_{t})) \times (1-p)) + ((N^{am}_{t} - H^{m}_{t} - (P_{b} \times N^{amf}_{t} \times M_{b}))) \times S^{am}_{t}$$

Where P_b is the proportion of the population bled and M_b is the mortality rate for bled crabs. This approach would assume that the P_b and M_b are more or less constant overtime and equivalent for both sexes. If data were available, the model could be made sex specific, relaxing the sex equivalency assumption.

Recommendations:

- The ARM subcommittee recommends the preferred option to account for biomedical bled mortality in the annual harvest specifications and modifies current harvest packages.
- As a secondary option, the ARM Subcommittee outlined an approach for incorporating biomedical bled mortality in the ARM Framework without modifications to the harvest packages

Review Item #2: *Harvest rates and specifications: evaluate the harvest of the Delaware Bay states relative to the quotas, as well as the harvest packages, e.g. 500K individual (400K males, 100K females) etc. The ARM subcommittee agreed that harvest and harvest rates should be reconsidered relative to the harvest packages outlined in Addendum VII.*

The ARM Subcommittee considered a suite of alternative harvest packages (see appendix C) to address interest from the Board in allowing female horseshoe crab harvest for the bait industry. In developing different harvest packages, the ARM Subcommittee determined that currently set thresholds for horseshoe crab abundance and the red knot stopover population dictate which harvest packages are selected. In finding that the current thresholds should not be adjusted or changed, the ARM Subcommittee recommended not to include alternative harvest packages in the ARM Framework. A detail summary of the evaluation and consideration of these alternative harvest packages is included in Appendix C.

Recommendation:

- The ARM Subcommittee does not recommend adding new harvest packages to the ARM Framework.

Review Item #3: Revisit objective function: assess the structure of the objective function, with questions such as: Are the thresholds set at the correct level? Is a threshold approach still the most appropriate?

Evaluation:

A. Discussion of Changing the Order of Red Knots and Horseshoe Crabs in the Objective Statement

The current objective statement that describes the management goals of the ARM Framework is as follows:

Manage harvest of horseshoe crabs in the Delaware Bay to maximize harvest but also to maintain ecosystem integrity and provide adequate stopover habitat for migrating shorebirds.

The group discussed switching the order of red knots and horseshoe crabs in the objective statement. A switch would imply the decision problem was one of red knot recovery and not horseshoe crab management. Given that the ASMFC management board is the decision maker and only has jurisdiction over horseshoe crab harvest, this change was not appropriate. Red knot recovery decisions are best handled with the recovery plan being developed for this sub-species by the USFWS. The original statement was carefully worded through collaborative efforts of the Horseshoe Crab and Shorebird Technical Committees and the group felt that editing this statement was beyond the scope of a short term review and unnecessary at this time.

Recommendation:

- Changing the order of red knots and horseshoe crabs in the objective statement is not recommended as it implies that the problem is one of red knot recovery rather than horseshoe crab management.

B. Discussion of Reward and Utility Functions

The group evaluated the removal of sex ratio constraint on utility of male crab harvest and the removal of the (2×) multiplier on utility of female crab harvest in the total reward function used for optimization. This was initially put in the model to reflect that the market values females twice as much as it does males.

Recommendations:

- Because the (2x) multiplier of utility of female crab harvest in the reward function reflects the market value of female crabs over males, it is recommended that this be left in the model.

C. Discussion of Utility Function for Female Horseshoe Crab Harvest (knife-edge vs sloped)

The group discussed the recommendation from the 2009 peer review of the ARM framework to evaluate how the knife-edge utility function for female crab harvest affects results compared to a sloped function. Dave Smith provided the group with summary comments on the results similar analysis he had completed on this topic, highlighting that little to no difference is seen between the two approaches. Given that there is little difference between the a more sloped function vs knife-edge, and no biological or ecological reasoning for changing the current knife-edge approach, the group was in agreement with maintaining the current knife-edge form for the utility function.

Recommendations:

- No change from current knife-edge utility function to a sloped function.

D. Discussion of Horseshoe Crab Sex Ratio Constraint on Utility of Male Horseshoe Crab Harvest

The sex ratio of horseshoe crabs was originally incorporated in two places with the ARM: 1) within the population dynamics model for horseshoe crab; and 2) within the utility function for when male harvest of horseshoe crabs would have value. If the observed sex ratio became skewed toward females due to excessive harvest of male crabs, the productivity of females would become compromised as there would not be enough males to fertilize all the eggs of the female crabs. This effect is accounted for within the horseshoe crab population dynamics model and if the sex ratio were skewed to such a degree that the population would experience a decline, the optimization would suggest more restricted harvest of male crabs or a complete moratorium on both sexes. Thus, inclusion of the sex ratio constraint in the utility function appears redundant and model system states were conducted to evaluate which supported this notion. There was little difference in recommended harvest packages with or without the sex ratio constraint in the utility function.

Recommendations:

- The ARM Subcommittee is recommending the removal of the sex ratio constraint from the utility function because it is conceptually redundant with aspects of the crab population dynamics model.

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Appendix. A

Study Design Guidelines for Mark-resight Investigations of Red Knots in Delaware Bay

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4/25/2016

Introduction

Mark-recapture/resight data from migration areas can be used to estimate passage population size and parameters related to migration ecology (Nichols 1996). The Jolly-Seber mark-recapture model for open populations (Jolly 1965, Seber 1965) is appropriate for migration studies because a stopover area can be viewed as an open, "flow-through" system. Estimation often focuses on the total number of individuals going through the system in a relatively short period of time.

When used at migration areas, the Jolly-Seber (JS) model has time-specific (i.e., specific to sampling occasion) parameters representing 1) probability of arrival to the study area, 2) probability of stopover persistence, 3) probability of being sighted during a sampling occasion, and 4) overall passage population size ("superpopulation"). Stopover persistence is the probability that a bird present in the study area at sample time t is present in the study area at time $t + 1$ (the "survival" parameter in other applications of the JS model).

At Delaware Bay, our application of the JS model relies on two types of data: repeated observations of individually marked birds ("resights"), and counts of marked and unmarked birds ("marked ratio samples"; Fig. 1). Resighting data are collected nearly every day during migration. Because it is not possible to sample the entire study area every day, the data are aggregated for analysis into 3-day periods, the time necessary to sample all parts of the study area. The 3-day periods become the "sampling occasions" in the mark-resight analysis.

The resightings of individually marked (flagged) birds are used to create encounter histories describing when individuals were observed within the season. From these encounter histories we can estimate the total number of flagged birds (detected and not detected) using the study area (M^*). The counts of marked and unmarked birds are used to estimate the proportion (π) of the population that is individually marked (flagged). Finally, the estimated number of flagged birds is adjusted upward using the estimated marked proportion, resulting in an estimate of total passage population size or superpopulation ($N^* = M^*/\pi$; Fig. 1; see Lyons et al. 2016).

At Delaware Bay, the main objective of the analysis is to estimate passage population size each year, a key parameter in the Delaware Bay adaptive management program for horseshoe crab harvest. To do this we analyze the data with a single site, single season (year) framework. In this single-season analysis, the parameters of the model – and model assumptions – are interpreted slightly differently than if the same data were used in a multi-season (year) analysis to estimate apparent annual survival or other parameters (e.g., McGowan et al. 2011).

Here we 1) review assumptions of the JS model in the context of a single-season investigation of migration, 2) review important study design considerations when estimating population size, and 3) recommend sampling plans to collect data in a way that is consistent with the model and assumptions.

Model Assumptions

To improve study designs and sampling plans for mark-resight investigations at migration areas, it is important to understand the assumptions of the JS model, and the direction of any bias that may result from violations of assumptions. In some cases, we can modify the study design and sampling plan to minimize violations of model assumptions, and in other cases we can modify the model to adequately reflect the data and relax model assumptions (i.e., accommodate sources of variation in the data).

Homogeneity of rate parameters.—One assumption of the JS model is homogeneity of rate parameters for all marked and unmarked individuals. The rate parameters of the JS model are probability of arrival to the stopover, probability of stopover persistence, and probability of resighting. The assumption of homogeneity of rates implies that the same rate parameters govern the arrival, persistence, and resighting of all marked and unmarked individuals.

As noted above, the estimation of M^* is based on the resightings of marked birds encountered at each sampling occasion. Observations of unmarked birds are not used in this part of the inference process. Heterogeneity in resighting probability, in which different marked birds present during the sampling occasions have different probabilities of being resighted, can cause bias in parameter estimates (Williams et al. 2002). "Trap response" refers to the situation in which a bird's previous detection history (usually whether it has been seen before or not) influences its subsequent probability of being resighted. If birds exhibit a "trap-happy" response, in which previously detected birds are resighted repeatedly, marked population size estimates will be negatively biased; if birds exhibit a "trap-shy" response, marked population size estimates will be positively biased (Williams et al. 2002). Trap response may seem unlikely in a mark-resight study because animals are not physically captured. However, uneven sampling of the study area may result in a form of heterogeneity and/or trap response of resighting probability. For example, if certain sites in the study area are visited more often than others, the same birds may be resighted in a pattern that mimics either heterogeneity or a trap-happy response. Finally, the legibility of the alphanumeric code may be a function of how much ink remains in the engraving. Ink is lost from the engraved leg flags over time (years). Flags that were applied many years ago may not be as legible or readable as flags applied in recent years, creating heterogeneity in resighting probability. If marks become completely illegible, those birds should be treated as unmarked. Birds with illegible flags do not appear in the resighting statistics, and they should be counted as unmarked when tallying the counts of marked and unmarked birds for estimation of π.

The above assumptions about detection probability apply to resightings of individual marked birds. The special counts used to estimate marked to unmarked ratios, π, are typically different than the surveys used to obtain detection histories of marked birds. These counts do not require individual identification information for marked birds and usually entail special counts during surveys designed to record marked bird identifications. Estimation of π requires the assumption that marked and unmarked birds have equal probabilities of being detected in these special counts. Trap response would occur if marked birds showed different detection probabilities than unmarked, but this sort of response seems unlikely in such counts. Finally, we note that detection probabilities for marked birds in the two types of surveys, those used to estimate marked to unmarked ratios, and those used to estimate M^*, need not be the same.

Effects of heterogeneity in stopover persistence on estimates of persistence and population size have not been thoroughly investigated (Williams et al. 2002). Heterogeneity in stopover persistence may result from population structure (e.g., different stopover dynamics for age classes or migratory subpopulations), and stopover-age effects, where stopover-age is measured by length of time at the stopover. In a simulation study of age-related variation in survival probability, Manly (1970) found that the JS model could be reliably used when there is small to moderate variation in survival (persistence) probability.

Some amount of heterogeneity in stopover persistence may result from aggregating data into sampling occasions for analysis, e.g., the 3-day sampling occasions used in Delaware Bay. For example, individual birds observed on day 3 of the sampling occasion may have a greater probability of remaining until the next sampling occasion than birds observed on day 1. However, because the average stopover duration of knots in Delaware Bay is much greater than 3 days, heterogeneity in stopover persistence resulting from data aggregation should be small. Hargrove and Borland (1994) found that effects aggregating data for sampling occasions did not produce bias in population parameters when survival is high within the pooled periods.

Effects of heterogeneity of rate parameters resulting from age and population structure require additional research. We plan to explore models that accommodate age-related variation in stopover persistence as part of the ongoing review of monitoring data for the Adaptive Resource Management Working Group for Delaware Bay. In addition, it may be possible to model stopover persistence as a function of boreal-wintering area of marked birds using observations away from Delaware Bay.

Marks are not lost or overlooked, and are recorded correctly.—Birds are marked with a leg flag (Clark et al. 2005), which is attached using epoxy and is not expected to fall off over time. Furthermore, loss of flags is not expected to impact population size estimates because the JS model currently implemented at Delaware Bay is a single-season model (i.e., loss of flags during the approximately 15-day stopover may be minimal).

Incorrect recording of alphanumeric combinations, however, may impact parameter estimates. Using the centralized database of capture and banding data (bandedbirds.org), alphanumeric combinations that have not been deployed in the field are removed before analysis. Some errors of recording are thus handled as part of data management. However, it is not possible to identify instances in which alphanumeric codes are incorrectly recorded as codes that actually have been deployed (i.e. "false-positives"). The rate of false positive identifications and impacts on parameter estimates requires additional research.

A form of "flag loss" may result as the ink in engraved leg flags is lost over time or the alphanumeric code otherwise becomes unreadable; this type of flag loss may be an important consideration of multi-year studies of annual survival and other parameters, but is not expected to impact passage population size estimates in single-season investigations if such flags are properly treated in analysis. Either birds with such flags should be counted as "unmarked" in the surveys for marked to unmarked ratios, or if this is too difficult (requires too much extra time), then the ratio of unreadable to readable flags in the detection history sampling can be used to adjust the marked to unmarked ratio.

Sampling is instantaneous.—This assumption is related to the assumption of homogeneous survival (persistence) probability. Strictly speaking, the assumption of instantaneous sampling is rarely met in practice. The interval between sampling occasions is typically long relative to the duration of the sampling occasion, however. In a simulation study of sampling occasions created from pooling data, Hargrove and Borland (1994) found that estimates of population sizes were acceptable because bias was small.

Permanent emigration.—Emigration from the study area is expected to be permanent. Temporary emigration will not bias estimates of passage population size if it is a completely random process (Kendall et al. 1997). That is, birds not available for detection (temporary emigrants) at one sampling occasion are no more or less likely to be available for detection at the next sampling occasion than birds that are currently available.

Independence of fates with respect to rate parameters.—This assumption may be violated if birds migrate in pairs, family groups, or other associations that remove independence of fates with respect to arrival, persistence, and resighting. We are not aware of any evidence that shorebirds migrate in groups that would result in a violation of this assumption. If this assumption is violated, variance estimates will be negatively biased resulting in confidence intervals that do not accurately reflect uncertainty in parameter estimates, but such a violation will not create bias in population estimates. Variance estimates can be adjusted with quasi-likelihood methods to accurately reflect uncertainty in parameter estimates.

Marked ratio data are representative of the population.—Scan samples of flocks of birds are used to estimate the proportion of the population with marks; in each scan sample, the observer records the number of marked birds and the number of birds checked for marks. Care should be taken to insure that the samples are representative of the flocks under study and the population as a whole. A field protocol (see appendix) has been developed to randomly select birds to be scanned and avoid bias in the data collection. Sampling throughout the season is also important to maintain a representative sample. Because birds marked with color band combinations (whether individually- or batch-marked) are not included in the data used to create encounter histories and estimate the size of the flagged population, we recommend that birds with color band combinations are not counted as "marked" during scan samples; these birds should be counted among those checked for marks but not included in the tally of marked (i.e., flagged) birds.

Study Design Considerations

When designing a mark-resight study for estimating abundance at a migration area, it is important to define the geographic boundary of the study area and the beginning and end of migration (i.e., define spatial and temporal extent of the open population).

Spatial sampling

The study area can be considered a collection of sites (beaches, shoreline segments, etc.). To reduce heterogeneity in rate parameters, it is essential that the sites are sampled at each sampling occasion. In some migration studies, each day of the migration is a sampling occasion, and resighting observations are made throughout the study area each day. When it is not possible to sample all sites in the study area in one day – when the study area is too large to sample entirely in one day, for example – it becomes necessary to change the sampling occasion from one day to a period that allows all sites to be sampled. If 3 days are required to complete a circuit of all sites, for example, then a 3-day period becomes the "sampling occasion", and all data for the 3 days are aggregated. Multiple observations of the same individual bird are lumped into one observation (detected) for the 3- day period. To facilitate even sampling of all sites, it will be helpful to define site boundaries on a map or via written description. This way observers will know the area to be sampled on each visit.

> <u>Study design recommendation: Define the geographic boundaries of all sites to be sampled.</u>

Temporal sampling

There are two temporal aspects to consider for an effective study design to estimate population size. First, resighting surveys should be conducted at all sites during each sampling occasion (e.g., 3-day period). If it is not feasible to sample all sites every 3 days, the sampling occasion could be changed to include however many days are required, given logistical constraints, to complete a circuit of the sites. Second, sampling should begin when the first birds arrive and continue until the last birds depart the study area. If resighting surveys do not begin until after birds have arrived in the study area, the stopover population size estimate will not include any birds that arrived and left before sampling began.

> <u>Study design recommendation: Begin sampling when birds arrive and continue sampling occasions until birds depart the area.</u>

> <u>Study design recommendation: Complete a circuit of sites in the study area to collect resighting data at each sampling occasion (e.g., 3-day period).</u>

Marked Ratio Data

We use a scan sampling protocol to estimate the proportion of the population with marks (see Appendix). Lyons et al. (2016) used a simulation study to investigate sample size requirements and the impact on bias and precision from factors related to data collection protocols and characteristics of the population under study. The two factors related to data collection protocols were 1) number of birds per scan sample, and 2) number of scans per day; the two factors related to the population under study were 1) stopover population size, and 2) true proportion marked. Simulation results suggested that the bias of estimates was low in all scenarios and that precision was greatest when 5-10 scan samples per day were collected and each scan sample included 50 or more birds checked for marks.

These simulation results should be interpreted with caution however (Lyons et al. 2016) because the simulation investigated only situations with constant probability of arrival to the stopover area and constant probability of stopover persistence. In Delaware Bay, we have used a model with time-dependent probability of arrival and time-dependent stopover persistence as the most biologically plausible model. In this more general model with time-dependent parameters, larger sample sizes may be required.

Therefore, we suggest that field crews attempt to collect 10 scan samples per day and attempt to count 50 birds in each scan sample. If the birds fly off before 50 birds are checked, the ratio data can still be used; simply record the number of marked birds and the number checked for marks, as usual.

Scan samples of this size usually requires less than 2 minutes to complete. This sampling thus devotes approximately 3% of every hour of field time to scan samples and 97% to collecting repeated observations of marked individual birds. Scan samples can be conducted at the beginning of each resighting session and once per hour thereafter. In the case of small flocks (small enough to check every bird relatively quickly), it is not necessary to repeat scan samples once per hour. We also recommend that observers do not count birds with color band combinations as marked birds (only leg-flagged birds) when counting marked and unmarked birds.

> Study design recommendation: A marked ratio scan sample should be collected at the beginning of each resighting session and once per hour during the session.

Field and Logistical Constraints

Much of the data for mark-resight investigations in Delaware Bay are collected by volunteers. The same field crews also conduct capture and marking operations, ground and aerial surveys, and other research and monitoring activities. All field operations are subject to constraints of weather and logistics. These operations require substantial investments of time and energy.

The mark-resight study design recommendations provided here are merely suggestions and can be modified to make the data collection more feasible while maintaining data integrity. The principal investigator of the mark-resight study should periodically visit field operations to discuss implementation of the study design and any challenges to the data collection.

Acknowledgments

J. Nichols provided comments on a draft version and helpful discussions about mark-resight methods. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

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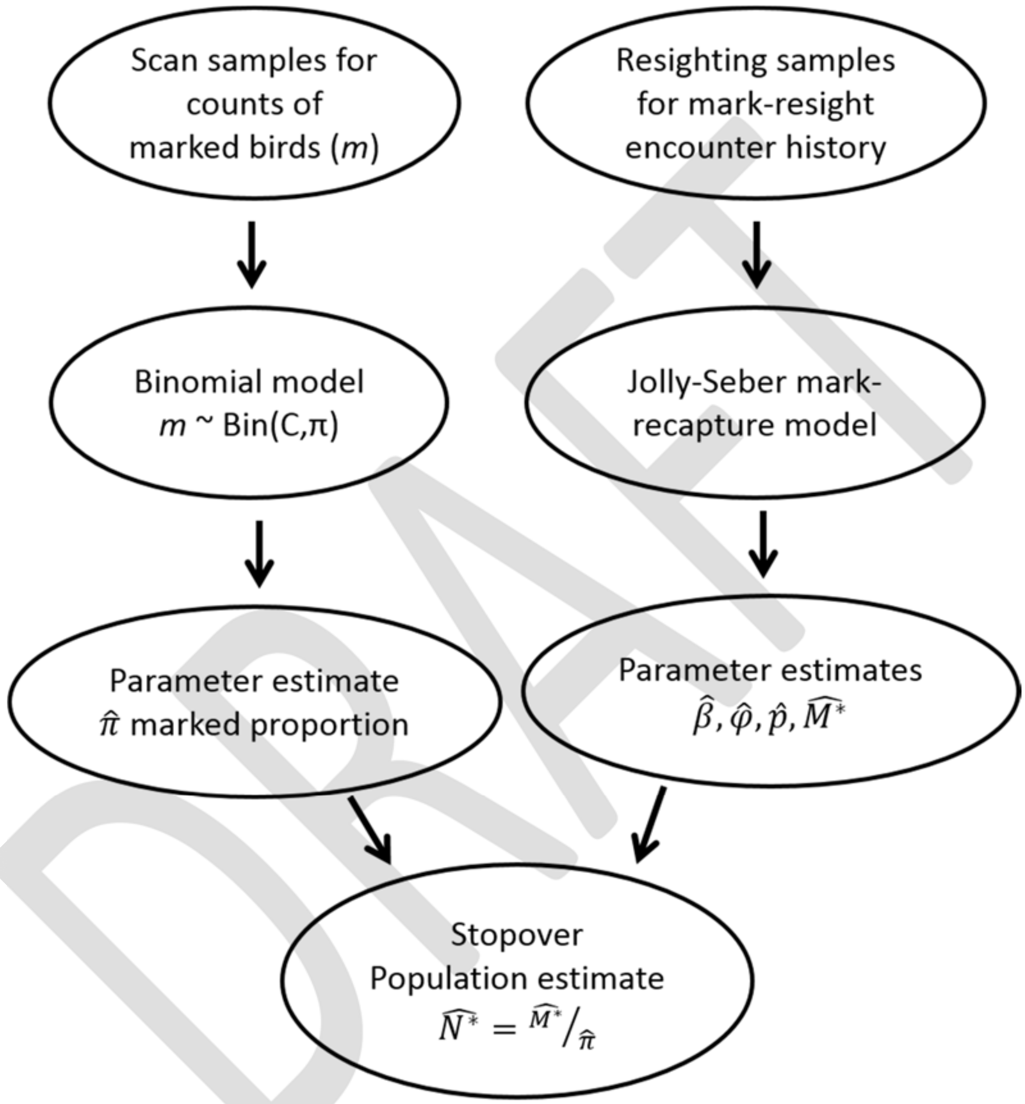

Figure 1. Flow chart for data collection and parameter estimation using mark-resight data to estimate stopover population size at migration areas. From Lyons et al. (2016).

Table 1. Dates for mark-resight sampling occasions in Delaware Bay.

Sample	Dates
1	<10 May
2	11-13 May
3	14-16 May
4	17-19 May
5	20-22 May
6	23-25 May
7	26-28 May
8	29-31 May
9	1-3 June

Appendix A.1

A Field Protocol to Estimate Marked Proportion in Mark-resight Studies

We use a scan sampling protocol (Martin and Bateson 1986) to record the ratio of marked to unmarked birds in all areas that are searched for flagged birds, with certain precautions to avoid bias in the scan samples.

For large flocks (e.g. >100 birds):

1. Determine the general area in front of the observer that is visually accessible (i.e. the area within which the birds can be viewed well enough to determine whether birds are marked or not). This is the "scan area" in front of the observer.
2. Visually divide the scan area into four equal segments and number them from one to four, e.g. left to right.
3. Using a table of random numbers between 1 and 4 (see below), randomly select a segment of the scan area.
4. Without looking through the scope, which might bias scan results if the observer begins the scan with a conspicuous (i.e. marked) bird, aim the scope at the selected segment.
5. Looking through the scope and beginning with a bird at the edge of the field of view, scan birds in the flock, and 1) tally the number of marked birds, and 2) tally the number of birds checked for marks. When a predetermined number of birds has been checked for marks, say 50 birds, record the number of birds with alphanumeric flag codes and the number of birds checked for flags. A hand-held tally counter may be helpful here.
6. If the flock flies off before the scan sample is complete (e.g., before you check 50 birds), the data are still useful. Record the number marked and the number checked, as usual.
7. Only those birds whose legs are visible are counted as checked for marks. In some cases, certain individual birds cannot be checked for marks (e.g., when roosting on one leg, with only one leg visible). If it is not possible to clearly determine whether or not a bird has an alphanumeric flag, the bird is not tallied in the total number checked for birds.
8. Only those birds with legible alphanumeric flags should be counted as marked birds.
    a. Birds that are marked with a combination of color bands only, without an alphanumeric flag, are not tallied as "marked" birds. Birds with color band combinations only are not counted as marked birds in this protocol because many color band combinations are not unique to the individual bird and therefore will not be part of the analysis using the resighting data; even birds that are marked with a unique combination of color bands are not included in the analysis with alphanumeric codes.
    b. Similarly, engraved flags that are illegible because they have lost ink (or are otherwise unreadable) should not be counted as marked; they should be counted as unmarked.

For small flocks (i.e., when it is possible to quickly check every bird present in the scan area):

1. Scan the entire flock for marks and recorded the number of birds checked for flags and the number of marked birds.
2. In the case of a small flock, it is unlikely that the observer will require more than one hour to record alphanumeric flags of individual marked birds, but in the event that the resighting session is longer than one hour, it is not necessary to conduct more than one scan-sample of the same small flock.

Random numbers table. Cut on dotted line and place in field notebook.

Random numbers table for use in the field to select birds for scan samples.

1	1	3	4	3	3	2	2	3	4
4	1	2	1	1	1	1	3	4	1
3	2	1	1	3	4	4	3	3	2
2	3	4	4	3	1	1	1	4	4
3	1	3	2	2	1	4	3	2	4
3	2	3	2	1	4	2	1	3	1
4	2	1	3	3	4	2	2	3	4
4	4	1	2	1	2	3	3	1	1
3	1	1	1	1	1	1	1	4	1
1	1	4	1	2	3	4	2	4	4
4	2	3	2	2	2	4	4	3	3
1	2	2	4	4	4	1	3	3	2
3	4	3	3	2	3	2	2	3	3
3	2	2	3	2	1	4	1	1	1
2	1	1	1	1	3	1	2	2	1
3	4	2	4	4	4	1	4	4	4
4	2	2	4	4	3	2	1	1	3
2	3	1	4	3	1	2	2	4	2
4	2	3	3	3	1	1	4	1	3

Appendix B.

Incorporation of Biomedical Data into the ARM Framework Options

Option 1: Include biomedical in the harvest allocation of horseshoe crabs within the Delaware Bay region (apportion biomedical mortality within existing harvest packages).

This option requires the Horseshoe Crab Management Board to specify a limit on the mortality of Delaware Bay origin crabs attributable to biomedical industry as a byproduct of the bleeding process. This level could be chosen based on historical numbers (e.g. average number over some number of years) bled by the biomedical industry and the estimated total mortality from the bleeding process using an assumed mortality rate (e.g. 15% of bled crabs die). Alternatively, this limit could be equivalent to some proportion of the total Delaware Bay origin harvest as recommended by the ARM. Regardless of how the limit is chosen, this limit would then be subtracted proportionately from the allowable sex-specific bait harvest of horseshoe crabs recommended by the ARM Framework.

As an example, assume the Management Board decides to allow the biomedical industry 20% of the harvest recommended by the ARM Framework. If the ARM Framework specified an allowable harvest of 500,000 males and 0 females (harvest package #3), the total mortality attributed to the biomedical industry could not exceed 100,000 male crabs (females would not be permitted). Assuming a 15% mortality rate for bled crabs, the biomedical industry should bleed and release no more than 666,667 male crabs. As another example with the same 20% biomedical allowance, if the ARM Framework specified an allowable harvest of 280,000 males and 140,000 females (harvest package #4), the total mortality attributable to the biomedical industry could not exceed 56,000 males and 28,000 females. Again, with a 15% mortality rate for bled crabs, the biomedical industry should bleed and release no more than 373,333 male crabs and 186,667 female crabs.

The bait industry would receive the remainder of the ARM recommended harvest. In the examples above, the bait industry would receive 400,000 male crabs under harvest package #3 and 224,000 males and 112,000 females under package #4. This remaining allowable harvest could then be allocated among the four Delaware Bay region states in the same manner as is currently being done under Addendum VII of the horseshoe crab fishery management plan.

Advantages of this option:

- Explicitly accounts for the mortality attributable to the biomedical industry.
- The most straight forward option for precise implementation of ARM Framework recommendations for the total allowable mortality of horseshoe crabs by the two stakeholder groups exploiting the resource.
- Allocates bait industry harvest among states according to the same methodology that is currently being used.

Disadvantages of this option:

- Requires the Management Board to set some limit on the number of horseshoe crabs that can be killed on an annual basis by the biomedical industry. This is likely to be a contentious decision, in part due to implications for human health.
- Data confidentiality may be violated. Because there is only one biomedical company in the New England Region and only one company in the Southeast Region of horseshoe crab management, either of these companies will be able to determine what the other company bled because they could subtract their number of bled crabs and the allowable number of bled crabs from the

Delaware Bay Region from the coast wide total to determine what the other company bled. However, there would still be some uncertainty in what the other company bled because it would not be known if the companies in the Delaware Bay region reached their catch limit within a year.

- There is concern that when the ARM Framework recommends 0 female harvest that the biomedical companies would end up handling and sorting more total crabs in order to fill their needs through the bleeding of only male crabs. This could result in greater overall crab mortality, exceedance of the allowable biomedical harvest set by the board, and further reductions in the allowable bait harvest in future years.

Option 2: Account for biomedical harvest in the population dynamics equations of the ARM framework

One approach to addressing the biomedical industry's take would be to incorporate it into the population dynamics equations for adult crabs as an additional mortality factor. Currently the predicted future abundance of adults is a function of current abundance of juveniles that transition directly to breeding adults (skipping the primiparous stage), plus the number of primaparus individuals that survive the year and become adults, plus the number of current adults that survive the year with the number harvested for bait explicitly subtracted. Abundance projections are calculated for each sex separately:

$$N^{af}_{t+1} = (((N^{j}_{t} \times T^{ja}_{t}) + (N^{p}_{t} \times S^{p}_{t})) \times p) + (N^{af}_{t} - H^{f}_{t}) \times S^{af}_{t}$$

$$N^{am}_{t+1} = (((N^{j}_{t} \times T^{ja}_{t}) + (N^{p}_{t} \times S^{p}_{t})) \times (1-p)) + (N^{am}_{t} - H^{m}_{t}) \times S^{am}_{t}$$

To incorporate biomedical take (bleeding induced mortality), an additional mortality could be added to account for the bled crabs die:

$$N^{af}_{t+1} = (((N^{j}_{t} \times T^{ja}_{t}) + (N^{p}_{t} \times S^{p}_{t})) \times p) + ((N^{af}_{t} - H^{f}_{t}) - (P_{b} \times N^{af}_{t} \times M_{b})) \times S^{af}_{t}$$

$$N^{am}_{t+1} = (((N^{j}_{t} \times T^{ja}_{t}) + (N^{p}_{t} \times S^{p}_{t})) \times (1-p)) + ((N^{am}_{t} - H^{m}_{t} - (P_{b} \times N^{amf}_{t} \times M_{b}))) \times S^{am}_{t}$$

Where P_b is the proportion of the population bled and M_b is the mortality rate for bled crabs. This approach would assume that the P_b and M_b are more or less constant overtime and equivalent for both sexes. If data were available, the model could be made sex specific, relaxing the sex equivalency assumption.

Option 3: Adjust harvest packages to add biomedical to the existing bait allocations

Harvest packages could be adjusted to specify allotments to bait harvest and biomedical mortality. New harvest packages would be established that explicitly detail how many male and female crabs could be collected to bait (100% mortality) and how many collected for bleeding (15% mortality). To do this, an estimation of the mean collection rates by the biomedical industry from the last 5 years could be added as allowance to the existing harvest packages. For example: if mean collection rates for the biomedical industry were 100,000 females and 200,000 males the five current harvest packages would be:

$N_{hscf,i} + 100,000 \times M_b$ and $N_{hscm,i} + 200,000 \times M_b$

Where i indicates the specific harvest package. So harvest package 3, current 500,000 male only would be come 530,000 males and 15,000 females. Presumably these levels of take were already occurring in the DE Bay population and, while neither knots nor HSC have reached threshold levels to trigger female horseshoe crab harvest, both populations are exhibiting growing or stable populations.

Option 4: *Adjust harvest packages to account for biomedical mortality of females.*

Option 4 combines elements of Options 1 and 3 (above). As in both Options 1 and 3, mortality associated with biomedical activities due to capture, handling, or post-bleeding stress is considered to be a form of harvest, and thus is incorporated into the harvest quota. In Option 4, the allocation of the harvest quota among biomedical and bait sources of mortality is left to the Board to consider; this is a difference from Option 1. In Option 4, the set of harvest packages will be adjusted in recognition that biomedical activities cause mortality of females in the Delaware Bay population. However, in contrast to Option 3, the existing packages will be modified only for female quota and male quotas will be left in place.

Adjustment of packages will occur during the 'setup phase' and not during the 'iterative phase'. In other words, the packages will be adjusted only during double loop review, which occurs about every 4 to 6 years. The allocation will use the most recent X year moving average of female mortality in Delaware Bay crabs due to biomedical activities. A moving average will be used to adhere to the confidentiality requirements. The number of years in the moving average (X) is proposed to be X=3 so that the average can be responsive to recent trends. Packages 2 and 3 will be adjusted by including the most recent moving average. The male quota for all packages, the female quota for Packages 4 and 5, and the Package 1 (moratorium) for both species will not be adjusted. The female quota for packages that had been previously male only (Packages 2 and 3) would be designated for biomedical activity only.

The optimization of the ARM decision model will be conducted as before except that the optimization will use the adjusted packages. After a harvest package is selected in a given year, the harvest quota will be allocated among the biomedical and bait sources of mortality. Allocation of harvest will proceed as follows: 1) the up-to-date moving average of mortality of Delaware Bay crabs due to biomedical activities will be subtracted from the quota and 2) the remainder will be allocated for bait harvest. Note that the female quota for Packages 2 and 3 are stipulated for biomedical activity only; thus, there would be no allocation of females for bait under Packages 2 and 3. Current methods would be used to allocate bait harvest among states.

In this option, harvest regardless of source will be accounted for properly in accordance with the ARM Framework. Allocation of bait industry harvest among states would use current methodology. The Management Board will not be required to set a limit on the number of horseshoe crabs that can be killed on an annual basis by the biomedical industry as long as mortality from biomedical activities alone does not exceed the total sex-specific harvest quota. Data confidentiality will be adhered to by using a moving average.

Option 5: Reduce bait harvests to account for biomedical mortality within existing harvest packages using the 2:1 male to female offset

Under this option, biomedical harvest would not be capped, but bait harvests would be reduced to account for biomedical mortality. Using the sample numbers from Option 3, suppose the 3-year running average of biomedical mortality in the DE Bay region is 30,000 males and 15,000 females. Here's how that would affect bait harvests under each harvest package:

Package 1: Full bait moratorium on both sexes

Package 2: 250,000 males – 30,000 biomedical males – 30,000 due to biomedical females (2:1 offset) = 190,000 males and 0 females

Package 3: 500,000 males - 30,000 biomedical males – 30,000 due to biomedical females (2:1 offset) = 440,000 males and 0 females

Package 4: 280,000 males – 30,000 biomedical males and 140,000 females – 15,000 biomedical females = 250,000 males and 125,000 females

Package 5: 420,000 males – 30,000 biomedical males and 210,000 females – 15,000 biomedical females = 390,000 males and 195,000 females

Current methods would be used to allocate bait harvest among states.

Appendix C.

Development and Evaluation of New Harvest Packages allowing Bait Female Horseshoe Crab Harvest.

Evaluation:

In recent years, the ARM harvest package #3 (500,000 males harvest, no female harvest) has been selected, while there has been a combined quota of 661,000 crabs for the Delaware Bay States available under the ASMFC Horseshoe Crab FMP. Four alternative harvest packages were developed under the following conditions: 1) stressed population, 2) recovering population, 3) recovered population, and 4) recovered population; all set to harvest levels up to 661,000 crabs.

Alternative harvest package 1: Stressed Population

Understanding that a moratorium of harvest for a stressed population would have significant impact on the industry, the harvest mortality under alternative option #1 is set at a low level for each of the Delaware Bay States on male crabs.

Alternative package 1. Stressed Population

	Delaware Bay Origin HSC Quota		Total Quota	
State	**Male**	**Female**	**Male**	**Female**
Delaware	100,000	0		0
New Jersey	100,000	0		0
Maryland	150,000	0		0
Virginia	60,000	0		0

Alternative harvest package 2: Recovering Population

For option #2 (recovering population), female harvest is allowed but limited to predominately non-DE Bay female crabs and at a small harvest level. The proposal allows harvest of 1/3 of the non-DE Bay origin horseshoe crabs in Maryland and Virginia. The reduced female harvest is allowed by not allowing the harvest of females before July 1st and after July 1st they are not allowed to be harvested on spawning beaches in the Delaware Bay region.

Alternative package 2. Recovering Population

	Delaware Bay Origin HSC Quota		Total Quota	
State	**Male**	**Female**	**Male**	**Female**
Delaware	162,136	0	162,136	0
New Jersey	162,136	0	162,136	0
Maryland	141,112	0	197,996	28,442
Virginia	34,615	0	67,775	6,778

Alternative harvest package 3: Recovered Population (10% female harvest allowed)

Under Option #3, with a recovered population, 10% of the female population can be harvested but with the same season and location restrictions as Option #2. Under this option, Delaware and New Jersey would be allowed to harvest female horseshoe crabs, while Maryland and Virginia would as well, but at a reduced level than in option 2.

Alternative package 3. Recovered Population (10% female harvest allowed)

10% Female harvest	**Present Harvest Quota**		**Proposed Harvest Quota**	
State	**Male**	**Female**	**Male**	**Female**
Delaware	162,136	0	145,923	16,213
New Jersey	162,136	0	145,923	16,213
Maryland	255,980	0	230,382	25,598
Virginia	81,331	0	73,198	8,133

Alternative harvest package 4: Recovered Population (20% female harvest allowed)

Under Option #4, with a recovered population, 20% of the female population can be harvested but with the same season and location restrictions as Options #2 and #3.

Option 4. Recovered Population. 20% female harvest allowed.

20% Female harvest	**Present Harvest Quota**		**Proposed Harvest Quota**	
State	**Male**	**Female**	**Male**	**Female**
Delaware	162,136	0	129,709	32,427
New Jersey	162,136	0	129,709	32,427
Maryland	255,980	0	204,784	51,196
Virginia	81,331	0	65,070	16,261

The group discussed whether these options would require knowing if the population is stressed or recovering, and if so, how that status is determined since those qualifiers are not currently used in the ARM Framework. There is currently an assumption in the objective function of the ARM Framework that there is value for every additional male horseshoe crab harvested when it actually drives the market price down and there is no additional value. The group was in agreement that addressing the economic value of male crabs in the ARM Framework should be done and that current harvest package options of full moratorium and male only harvest should remain and be considered with alternative harvest packages.

The group reviewed the alternative harvest packages and noted that adding additional harvest packages or switching/replacing current harvest package options with new ones would not necessarily result in different harvest packages being selected. The reason for little change in the selection of harvest packages is due to the current threshold levels for female crab abundance and red knot abundance, not the diversity of harvest packages.

Proposed addition to option selected under Subsection E ("Incorporation of Biomedical Data into the ARM Framework") of the *Horseshoe Crab ARM Subcommittee Draft Recommendations of ARM Framework Review*

BACKGROUND

The 1998 Fishery Management Plan (FMP) states, "*Because both the number of horseshoe crabs captured per year and the reported mortality are low, the horseshoe crab fishery for biomedical use is not subject to the potential limitations contained in Section 4.2.1 and 4.2.2., subject to the following restrictions. States must issue a special permit, or other specific authorization, for harvests for biomedical purposes. Horseshoe crabs taken for biomedical purposes shall be returned to the same state or federal waters from which they were collected. If horseshoe crab mortality associated with collecting, shipping, handling, or use by the biomedical industry exceeds 57,500 horseshoe crabs per year, the Commission would reevaluate potential restrictions on horseshoe crab harvest by the biomedical industry.*"

Based on data in the annual FMP reviews, the 57,500-crab threshold has been exceeded each year since 2007, and the estimated contribution of biomedical collection to coastwide total (biomedical plus bait) mortality rose from about 6 percent in 2004 to about 12 percent in 2014. According to the FMP reviews, mortality from the biomedical harvests to date hit a high of 90,440 crabs in 2012, an increase of nearly 100 percent since reporting began in 2004. Further, these data are based on a mortality rate of 15 percent of the total biomedical harvest. As cited in the 2012 FMP review, the Technical Committee (TC) recommends using a range of values (5 to 30 percent) for estimating mortality, in order to include the known variances in conditions and situations that can occur over the geographical and temporal range of collecting and bleeding the horseshoe crabs.

In 2011, the TC and industry members developed Biomedical Best Management Practices (BMPs) in a document entitled "Horseshoe Crab Biomedical Ad-Hoc Working Group Report, October 3, 2011." The industry has voluntarily adopted these BMPs.

CONCLUSIONS AND RECOMMENDATIONS

Given the consistent exceedances of the mortality threshold, steady increases in biomedical harvest levels since reporting began, and uncertainty around the actual percent of biomedical crabs that die, action should be taken consistent with the FMP. The ARM Subcommittee recommend the following actions.

1. Incorporate biomedical mortality into the Adaptive Resource Management (ARM) process and methods that are used to set harvest quotas in the Delaware Bay Region.

2. Require each company to submit confidential data on its own levels of mortality at each stage (capture, transport, holding, bleeding, and condition at release).

3. Require each company to submit an annual report regarding its specific measures, practices, and safeguards to implement the 2011 Biomedical handling BMPs, and documentation that crabs are being returned to the same waters from which they were collected.

4. Urge the industry to fund additional research regarding post-release mortality rates and sublethal effects that could affect populations.

5. Periodically revisit the Biomedical handling BMPs and update as appropriate, informed by current data and research.

Atlantic States Marine Fisheries Commission

ISFMP Policy Board

August 3, 2016
1:30-3:30 p.m.
Alexandria, Virginia

Draft Agenda

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

1.	Welcome/Call to Order *(D. Grout)*	1:30 p.m.
2.	Board Consent *(D. Grout)* • Approval of Agenda • Approval of Proceedings from May 2016	1:30 p.m.
3.	Public Comment	1:35 p.m.
4.	State Directors Meeting Report *(D. Grout)*	1:45 p.m.
5.	Executive Committee Report (*D. Grout*)	1:50 p.m.
6.	Review of Stock Rebuilding Performance (*T. Kerns*)	2:00 p.m.
7.	Discuss Recommendation from South Atlantic State Federal Management Board regarding Commission involvement in Cobia Management (*J. Estes)* **Action**	2:15 p.m.
8.	Discuss Revisions to Conservation Equivalency Guidance Documents (*T. Kerns*)	2:45 p.m.
9.	Risk and Uncertainty Policy Workgroup Progress Report (*S. Madsen)* **Action**	2:55 p.m.
10.	Habitat Committee Report (*L. Havel*) **Action**	3:05 p.m.
11.	Artificial Reef Committee Report (*L. Havel*)	3:15 p.m.
12.	Atlantic Coastal Fish Habitat Partnership Report (*L. Havel*)	3:20 p.m.
13.	Review Non-Compliance Findings, If Necessary **Possible Action**	3:25 p.m.
14.	Other Business/Adjourn	3:30 p.m.

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

Vision: Sustainably Managing Atlantic Coastal Fisheries

MEETING OVERVIEW

ISFMP Policy Board Meeting
Thursday, August 3, 2016
1:30-3:30 p.m.
Alexandria, Virginia

Chair: Doug Grout (NH) Assumed Chairmanship: 10/15	Vice Chair: Jim Gilmore (NY)	Previous Board Meeting: May 4, 2016
Voting Members: ME, NH, MA, RI, CT, NY, NJ, PA, DE, MD, DC, PRFC, VA, NC, SC, GA, FL, NMFS, USFWS (19 votes)		

2. Board Consent

- Approval of Agenda
- Approval of Proceedings from May 4, 2016

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. State Directors Meeting Report (1:45-1:50 p.m.)
Background • The State Directors met on August 1, 2016
Presentations • D. Grout will provide an update of the meeting
Board direction for consideration at this meeting • none

5. Executive Committee Report (1:50-2:00 p.m.)
Background • The Executive Committee met on August 2, 2016
Presentations • D. Grout will provide an update of the committees work
Board direction for consideration at this meeting • none

6. Review of Stock Rebuilding Performance (2:00-2:15 p.m.)
Background

- As part of the ASMFC 2014-2018 Strategic Planning process, the Commission agreed to conduct more frequent reviews of stock status and rebuilding progress.
- The ASMFC's 2016 Action Plan tasks the Policy Board with conducting a review of stock rebuilding performance.
- This will include an update on the Climate Change Work Group

Presentations

- A presentation will be given on the stock rebuilding performance for each species managed by the Commission by T. Kerns (**Supplemental Materials**)

Board actions for consideration at this meeting

- Determine if the rebuilding performance for each species is consistent with the Commission Vision and Goals.
- If the performance is not consistent with Vision and Goals, what action should be taken.

7. Discuss Recommendation from South Atlantic State Federal Management Board regarding Commission involvement in Cobia Management (2:15-2:45 p.m.) Action

Background

- The South Atlantic Council Fishery Management Council (Council) requested the Commission consider joint or complementary management of cobia with the Council (Briefing Materials).
- In 2105, 82% of the cobia harvest occurred in state waters. The ACL was exceeded by approximately 91,000 pounds. The Council is looking for a more flexible management approach to allow for timely adjustments of measures but still provide equitable access across multiple jurisdictions while meeting conservation goals.
- The Policy Board tasked the South Atlantic State/Federal Fisheries Management Board (SASFMB) to look at types of management scenarios and bring a recommendation to the Policy Board in August

Presentations

- J. Estes will present a recommendation on behalf of the SASFMB.

Board guidance for consideration at this meeting

- Does the board want to consider a cobia FMP?

8. Discuss Revisions to Conservation Equivalency Guidance Documents (2:45-2:55 p.m.)

Background

- The Executive Committee tasked staff to update the Conservation Equivalency Guidance Document to reflect the current practices of the Commission.
- The MSC and ASC reviewed proposed revisions and made recommendations to the Executive Committee (**Briefing Materials**).
- The Executive Committee will discuss the proposed revisions at the August 2 meeting.

Presentations

- T. Kerns will review the executive Committee discussion on the Conservation Equivalency Guidance Document

Board guidance for consideration at this meeting

- **None**

9. Risk and Uncertainty Policy Workgroup Update (2:55-3:05 p.m.) Action

Background

- Previously, both scientific oversight committees recommended developing a Commission Risk and Uncertainty Policy and advised the formation of a multi-disciplinary workgroup.
- The Risk and Uncertainty Policy Workgroup was formed and met to develop a timeline and create an overarching statement to guide policy development. (**Supplemental Materials)**

Presentations

- S. Madsen will review (1) the timeline for the development of the Commission's Risk and Uncertainty Policy and (2) the Risk Policy statement developed by the Workgroup (**Supplemental Materials).**

Board actions for consideration at this meeting

- Approve the Risk Policy statement

10. Habitat Committee Report (3:05-3:15 p.m.) Action

Background

- The Habitat Committee met in May in Cape May, New Jersey
- The Sciaenid Habitat Source Document is in the final writing stages.
- The Committee provided feedback on NOAA's Atlantic Sturgeon Critical Habitat designations.
- The Committee reviewed proposed seismic testing for oil and gas resources in ocean waters off the Atlantic coast. The Committee recommends the Commission adopt a position and convey that position to BOEM and other relevant entities. The recommendations are outline in a memo on **supplemental materials**.

Presentations

- L. Havel will present the Habitat Committee updates.

Board direction for consideration at this meeting

- Consider a position regarding seismic testing for energy resources in Atlantic waters.

11. Artificial Reef Committee Report (3:15-3:20 p.m.)

Background

- ACFHP's The Artificial Reef Committee met jointly with the GSMFC Artificial Reef Committee in March in San Antonio, Texas.
- ASMFC co-hosted the National Artificial Reef Workshop with NOAA Fisheries in Alexandria, VA in June.

Presentations

- L. Havel will present Artificial Reef Committee updates.

Board direction for consideration at this meeting
• None

12. Atlantic Coastal Fish Habitat Partnership Report (3:20-3:25 p.m.)
Background • ACFHP's Science and Data and Steering Committees met in May in Cape May, New Jersey to discuss several topics including: updating ACFHP's 5-year conservation strategic plan, the black sea bass habitat contract, and the eel grass conservation project in Narragansett Bay, Rhode Island. • A funding offer has been made to The Nature Conservancy to remove the Bradford Dam in Westerly, Rhode Island with funds from USFWS NFHAP funds. • Southeast fish habitat mapping project has begun thanks to funding from NOAA. The goal of the project is to prioritize habitat areas on along the Atlantic coast for restoration and protection.
Presentations • L. Havel will present ACFHP updates.
Board direction for consideration at this meeting • None

11. Review Non-Compliance Findings, if Necessary

12. Other Business

13. Adjourn

Cobia Management: How the Atlantic States Marine Fisheries Commission could take part in the management of the cobia fishery
South Atlantic State/Federal Fisheries Management Board
August 2016

Introduction

Cobia (*Rachycentron canadum*) is a member of the family Rachycentridae and is distributed worldwide in tropical, subtropical and warm-temperate waters. In the western Atlantic they occur from Nova Scotia, Canada, south to Argentina, including the Caribbean Sea. It is abundant in warm waters off the coast of the U.S. from the Chesapeake Bay south and throughout the Gulf. Cobia prefer water temperatures between 68-86°F. As a result of their wide distribution and genetic stock differences, cobia are managed as two distinct groups. The Gulf Migratory Group cobia (GMG) includes those fish off the East coast of Florida and into the Gulf of Mexico. GMG cobia are currently managed by the Gulf of Mexico Fishery Management Council, with the exception of the East coast of Florida which is managed by the South Atlantic Fishery Management Council (SAFMC). Atlantic Migratory Group cobia (AMG cobia) occur from Georgia to New York. AMG cobia are currently managed by the SAFMC through the Coastal Migratory Pelagics Fishery Management Plan; the Mid-Atlantic Fishery Management Council (MAFMC) participates through two voting seats on the SAFMC's Mackerel/Cobia Committee.

Recreational cobia landings in 2015 were 1,540,776 pounds, 145% over the annual catch limit (ACL), resulting in a June 20, 2016 closure of the fishery by NOAA Fisheries. Commercial cobia landings in 2015 were 83,148 pounds, 38% over the ACL. Late landings reports in 2015 precluded a timely closure of the commercial fishery.

Concerns were expressed by individual states whose recreational seasons were significantly reduced by the closure due to the overage of the 2015 quota. North Carolina and Virginia developed alternate management strategies to avoid the June 20, 2016 closure enacted by NOAA Fisheries for 2016. South Carolina has recently implemented more restrictive measures that are consistent with the actions of NOAA Fisheries in some areas.

As a result of the significant overage of the 2015 recreational ACL, the jurisdictional impacts and the observation that on average 82% of reported recreational landings are harvested in state waters, the SAFMC requested that the Atlantic States Marine Fisheries Commission (ASMFC) consider complementary or joint management of the cobia resource. The ASMFC considered this request at the May 2016 meeting and agreed that ASMFC management of cobia may be prudent. The ISFMP Policy Board directed the South Atlantic State/Federal Fisheries Management Board (Board) to develop options for how the ASMFC could be involved with cobia management to consider at the August 2016 meeting.

Life History

Cobia is a fast growing, moderately lived species that supports a valuable recreational fishery throughout the south Atlantic and into the mid-Atlantic region. Known for their readiness to take a bait, tough fighting abilities, and excellent table fare, the fishery is popular. The commercial fishery is primarily a by-catch in other directed fisheries such as the hook and line fishery for snapper/grouper and troll fisheries for various species (e.g., king mackerel, dolphin).

Cobia grow rapidly in their first 2 years with most mature at age 2. Females grow faster and attain larger sizes than males. Spawning occurs during a protracted spawning season from April through September. Consistent with protracted spawning, cobia spawn multiple batches of eggs throughout the season.

Recent genetic and stock structure analysis suggests the Florida portion of the stock is more appropriately managed with the Gulf of Mexico stock, while the Georgia to New York population comprise a separate, northern component. While cobia do frequent areas north of Virginia, the harvest is uncommon and sporadic. Landings have been episodically reported from Maryland, New York, New Jersey and Rhode Island and make up from 3-15% of the total mid-Atlantic landings.

The 2013 stock assessment conducted through the SouthEast Data Assessment and Review (SEDAR) process indicated overfishing is not occurring and the stock is not overfished. The current ACL is a precautionary approach to prevent the stock reaching an overfished status. The recent overage in 2015, exceeded the Council defined Overfishing Limit.

The 2013 stock assessment does provide some reasons for concern. While the terminal year of the assessment was 2011, Spawning Stock Biomass (SSB) experienced a general decline from 2002 forward (Figure 1). Further, recreational landings have increased over the latter portion of the time series that may increase potential overfishing issues in the next assessment. In June, the SAFMC proposed cobia be included in a 2017 Stock ID workshop and the 2018 SEDAR schedule for a benchmark assessment.

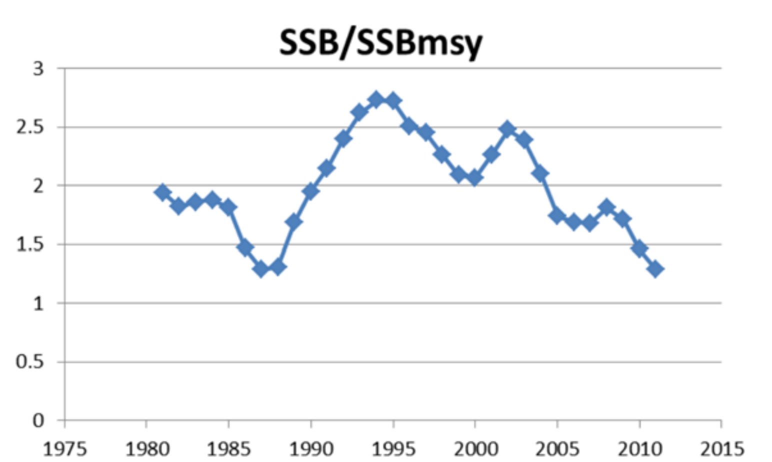

Figure 1. Spawning stock biomass relative to the MSY biomass reference for 1981-2011. SSB estimates are available farther back in time; this period was chosen to highlight the impact of landings during this time on SSB estimates

Cobia Fishery
There is both a commercial and recreational cobia fishery along the Atlantic coast. Management measures include size limits, possession limits, trip limits and quotas. State specific recreational measures vary coastwide and can be found in Table 3. Commercial restrictions, aside from the ACL, are consistent throughout most of the range with a 33"FL size limit and 2 fish trip limit. The distribution of the quota between commercial and recreational sectors is based on historical landings (50% is based on the average 2000-2008 landings and 50% is based on the average 2006-2008). Beginning in 2016, and expected to hold constant until a future assessment, the quota is split 92% recreational and 8% commercial. The 2016 Allowable Biological Catch (ABC) for AMG cobia is 670,000 pounds. The recreational ACL is 620,000 pounds and the commercial ACL is 50,000 pounds. The ABC for 2015 was slightly higher at 690,000 pounds.

Recreational cobia fisheries are prosecuted similarly along the coast. The primary methods include bottom fishing with live or dead natural bait and sight casting to single or small pods of fish, oftentimes around schools of bait (e.g., menhaden, thread fin shad). The popularity of sight casting has grown recently, resulting in increased interest in the fishery. Further, this interest has resulted in a lucrative expansion in the tackle market as baits are relatively specific for these large fish. Recreational landings for AMG cobia have varied with little trend since 2005, however, landings did hit a time series high in 2015 resulting in a significant overage in the federal ACL (Figure 2).

Commercial harvest of cobia has traditionally been a bycatch in the offshore snapper/grouper and trolling fisheries. Directed fisheries are generally precluded as a result of the low possession limits. The commercial fishery has seen an increasing trend from North Carolina through the mid-Atlantic over the time series. The AMG cobia commercial fishery closed early in 2014 (December 11, 2014). The 2015 overages would be deducted if the stock were overfished, however, given they are not overfished, the commercial quota for 20-16 will be 50,000 pounds (Figure 3).

Federal Management
The Cobia FMP is currently managed jointly in federal waters by the SAFMC and the GMFMC under the joint Coastal Migratory Pelagics Fishery Management Plan; the MAFMC participates through two voting seats on the SAFMC's Mackerel/Cobia Committee. The GMFMC sets the overall ALC for Gulf cobia and the measures to achieve that quota with the exception of the East coast of Florida. The East coast of Florida has a suballocation of the overall Gulf ACL; the percentage was determined jointly by the two councils in Amendment 20B. The suballocation is then split 92% recreational and 8% commercial. The SAFMC then sets management measures to achieve the quota. The ACL and measures to achieve the ACL for AMG cobia is set by the SAFMC.

The SAFMC is currently developing Framework Amendment 4 to the Fishery Management Plan for Coastal Migratory Pelagic Resources in the Gulf of Mexico and Atlantic Region (included in briefing materials). The framework includes actions to modify recreational and commercial harvest limits, change the recreational fishing year and modify recreational accountability measures for Atlantic migratory group cobia in the exclusive economic zone (EEZ) from the Georgia/Florida line through the Mid-Atlantic region.

State Management

Florida

Recreational cobia landing on the East coast of Florida ranged from 274,276 to 761,440 pounds (avg. = 488,788 pounds) during the 2005-2015 time series (Table 1). Current regulations are a 33" fork length and a 1 per person or 6 per vessel (whichever is less) bag limit. Legal gear is limited to spears, gigs, hook and line, seine and cast net (Table 3).

Commercial cobia landings on the East coast of Florida ranged from 57,003 to 156,069 pounds (avg. = 88,278 pounds) during the 2007-2011 time series (Table 2).

Georgia

Recreational cobia landings in Georgia ranged from 3,358 to 257,690 pounds (avg. = 58,111 pounds) during the 2005-2015 time series (Table 1). Current regulations in Georgia are a 2 fish per person bag limit with a 33"FL size limit (Table 2).

Commercial landings in Georgia and South Carolina are low and values for the two states were combined from 2010-2015 to avoid confidentiality issues and averaged 3,867 pounds (Table 4).

South Carolina

Recreational cobia landings in South Carolina ranged from 3,565 to 268,677 pounds (avg. = 76,954 pounds) during the 2005-2015 time series (Table 1). Current regulations in South Carolina consist of seasonal and areal bag limits from 1 to 2, a regional spawning season closure in May, and 33"FL size limit (Table 3). Cobia are designated as gamefish in South Carolina.

North Carolina

Recreational cobia landings in North Carolina ranged from 66,258 to 630,373 pounds (avg. = (259,883 pounds) from 2005-2015 (Table 1). Current regulations in North Carolina consist of a 1 fish bag limit with a boat limit of 2 fish for private boats and 4 fish in the for-hire sector (private vessels may only retain cobia on Monday, Wednesday, and Saturday), 37" FL size limit, and a closure in state waters effective September 30, 2016 (Table 3).

Commercial landings in North Carolina ranged from 19,950-52,315 pounds from 2010-2015, averaging 37,559 pounds over the time series. The landings of 52,315 pounds in 2015 accounted for nearly the entire AMG cobia commercial quota in 2015 and would have exceeded the 2016 quota (Table 4).

Virginia

Recreational cobia landings in Virginia ranged from 36,409 to 733,740 pounds (avg. = 368,059 pounds) during the 2005-2015 time series (Table 1). Current regulations in Virginia consist of 1 fish bag limit and 2 fish per boat. A 40”TL size limit with no more than one greater than 50”TL, no gaffing permitted, state waters close on August 30, 2016 (Table 2).

Commercial landings for the mid-Atlantic region (Virginia, Maryland, New Jersey, New York) and Rhode Island are combined in Table 4 to avoid confidentiality issues in several Mid-Atlantic States. The majority of the mid-Atlantic landings come for Virginia. The average landings from 2010-2015 were 14,732 pounds.

Table 1. Recreational landings of Atlantic cobia from 2005-2015 in pounds. Data sources: MRIP and SEFSC

Year	Virginia	North Carolina	South Carolina	Georgia	Total AMG (VA-GA)	East Coast of Florida
2005	577,284	322,272	5,793	3,358	908,707	287,267
2006	733,740	104,259	101,018	4,824	943,841	493,334
2007	322,887	90,197	268,677	64,708	746,469	580,632
2008	167,949	66,258	50,108	257,690	542,006	438,621
2009	552,995	123,061	76,229	3,997	756,282	361,120
2010	232,987	561,486	65,688	79,855	940,015	745,228
2011	136,859	121,689	3,565	90,375	352,488	761,440
2012	36,409	68,657	224,365	105,193	434,623	370,373
2013	354,463	492,969	19,130	29,224	895,786	274,276
2014	214,427	277,489	31,927	20,642	544,485	582,423
2015	718,647	630,373	123,952	67,804	1,540,776	481,956

* There are no MRIP-estimated recreational landings of AMG cobia in states north of Virginia.

Table 2. Commercial cobia landings for Florida East Coast, 2007-2011 (pounds).

	Commercial Cobia landings
2007	60,805
2008	57,003
2009	65,953
2010	101,564
2011	156,069

Table 3. Recreational measures in 2016 for Virginia, North Carolina, South Carolina and Georgia**.**

State	Bag limit	Vessel limit	Size Limit (inches)	Legal Gear
Virginia	1 fish*	2 fish	40" TL, only 1 > 50" TL	
North Carolina	1 fish**	For-hire: 4/vessel or 1 person when less than 4 people on board Private: 2 fish on vessels with more than 1 person on board	37" FL	No gaffing permitted
South Carolina – north of Jeremy Inlet, Edisto Island	2 fish	None	33" FL	
South Carolina-south of Jeremy Inlet, Edisto Island	1 fish June 1-Apr 30 Catch and release only May 1-May 31	3 fish per vessel or 1 fish per person, whichever is lower	33" FL	
Georgia	2 fish	None	33" FL	
Florida	1 per person	1 per person or 6 per vessel, whichever is less	33"FL	spears, gigs, hook and line, seine, cast net

*VA State waters close 8/30/16.
**NC State waters close 9/30/16; private recreational can only retain cobia on Mondays, Wednesdays, and Saturdays.

Table 4. Commercial cobia landings (pounds) and revenues (2014 dollars) by state/area, 2010-2015.

Year	GA/SC	NC	Mid-Atlantic*	Total
		Commercial Landing in Pounds		
2010	3,174	43,737	9,364	56,275
2011	4,610	19,950	9,233	33,793
2012	3,642	32,008	6,309	41,959
2013	4,041	35,496	13,095	52,632
2014	4,180	41,848	23,111	69,139
2015	3,555	52,315	27,277	83,148
Average	3,867	37,559	14,732	56,158
		Dockside Revenues (2014 dollars)		
2010	$11,377	$70,377	$19,976	$101,730
2011	$19,666	$37,893	$21,666	$79,224
2012	$15,554	$66,887	$14,597	$97,038
2013	$15,639	$79,397	$35,792	$130,828
2014	$13,320	$95,462	$67,972	$176,754
2015	$11,151	$147,160	$75,360	$233,672
Average	$14,451	$82,863	$39,227	$136,541

Georgia and South Carolina landings are combined to avoid confidentiality issues. Source: SEFSC Commercial ACL Dataset (December 2015) for 2010-2014 data; D. Gloeckner (pers. comm., 2016) for 2015 data.
Mid-Atlantic states include Virginia, Maryland, New York, New Jersey.

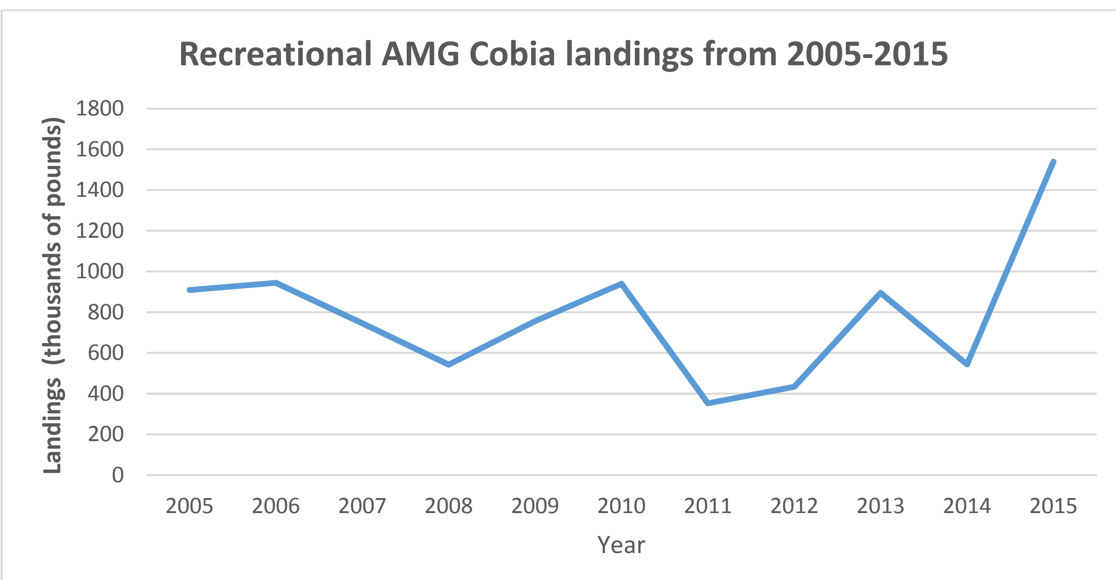

Figure 2. Recreational landings of AMG cobia (2005-2015)

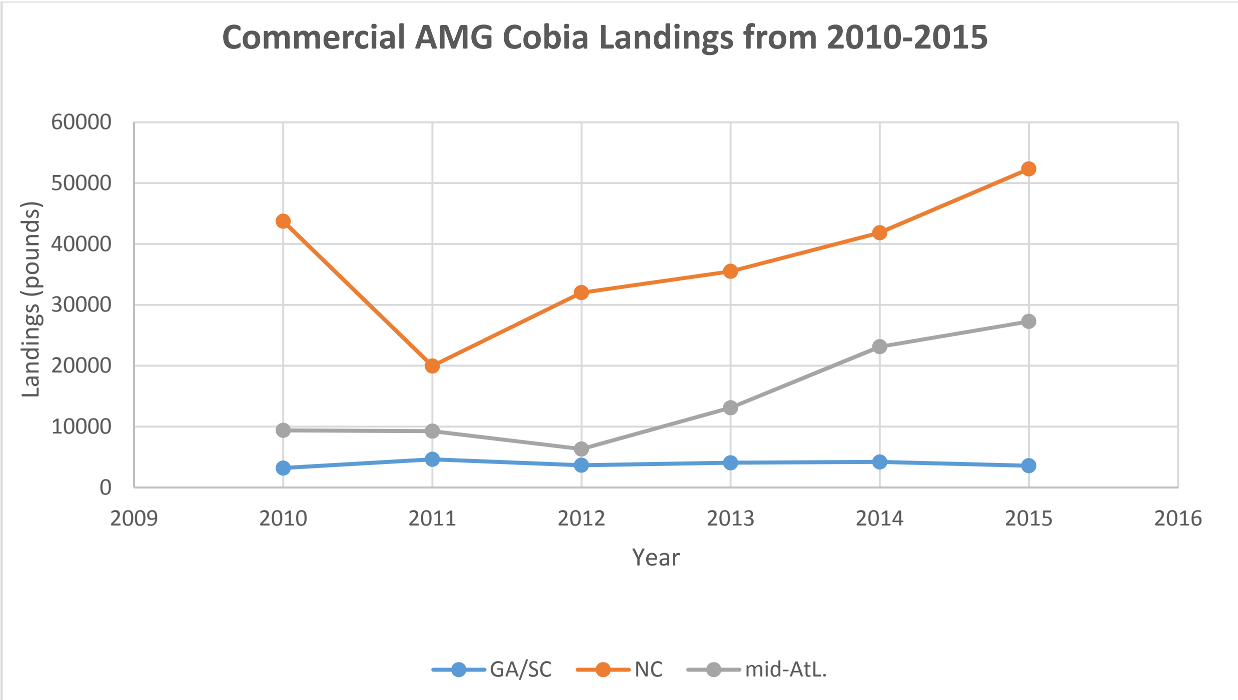

Figure 3. Commercial landings of AMG cobia (2010-2015)

Plan Development Options

The ISFMP Policy Board directed the Board to discuss whether to promulgate a cobia plan and, if so, recommend what form that plan would take at the May 2016 ASMFC meeting. Specifically, the ISFMP Policy Board requested consideration of alternatives for joint management, complementary management, and exclusive jurisdiction for the Commission.

Distinctions between various management scenarios have been developed and reviewed by the commission in the past. Essentially, the ASMFC has 3 types of Fishery Management Plans (FMP): a ASMFC FMP, a joint FMP, and a complementary FMP. A joint plan, like summer flounder in the mid-Atlantic, involves both the ASMFC Board and the Mid-Atlantic Fishery Management Council in the FMP process. A complementary plan, like spiny dogfish, separates the management processes between the two bodies (Federal/Council and ASMFC Board) and attempts to have measures that are consistent and not in direct conflict.

A. Management Plan Structure

Option 1:

ASMFC/SAFMC Complementary Fishery Management Plan

- ASMFC develops its own management documents. The ASMFC FMP can have aspects of the plan that are consistent with the Council but it is not required
- FMP development timeframe is consistent with ASMFC documents (addenda=6 to 8 months; Amendments 1.5 to 2 years)

- Not necessary to meet with SAFMC and act jointly
- Potential for lack of consistency between federal and state waters, which can result in fisherman fishing side-by-side under different regulations
- States are the responsible party for monitoring quotas in most cases
- States are the responsible party for closing state waters once quota is reached
- Stock assessments are conducted with the SEFSC/Council/Commission. The Science Center is the lead.

Option 2:

ASMFC/SAFMC Joint Fishery Management Plan

- ASMFC develops its management documents jointly with the Council. It is required to have the same management program for both state and federal waters.
- FMP development timeframe likely longer than a typical ASMFC document (addenda/framework=8 months to 1 year; Amendments 2-3 years)
- Meet with SAFMC and act jointly (must have like motions to proceeded with actions)
- Can have additional administrative procedures due to federal laws and requirements (e.g. longer rule making process; Council makes recommendations which are reviewed and approved by NOAA Fisheries (SERO))
- NOAA Fisheries is the responsible party for monitoring quotas in most cases
- NOAA Fisheries closes federal waters and states close state waters when the quota has been reached
- Some flexibility for ASMFC-only management components
- Stock assessments are conducted with the SEFSC/Council/Commission. The Science Center is the lead.

Option 3:

ASMFC exclusive management

- ASMFC would develop its own management documents.
- FMP development timeframe is consistent with ASMFC documents (addenda=6 to 8 months; Amendments 1.5 to 2 years)
- States are the responsible party for monitoring quotas in most cases
- States are the responsible party for closing state waters once quota is reached
- States are the responsible party for data collection and analysis
- Commission is responsible for conducting stock assessments (with possible assistance of the SEFSC and SEDAR)

Option 4:

Status quo: The SAFMC and GMFMC would retain all current management authority of cobia through the Coastal Migratory Pelagics Fishery Management Plan, with the MAFMC participating through 2 voting seats.

B. ASMFC Board Formation

If the Commission takes action to create a cobia fishery management plan, it will need to determine if Cobia should reside as species within the South Atlantic State/Federal Fisheries Management Board or be an independent board.

Option 1: South Atlantic State-Federal Fisheries Management Board
The Board would be charged with developing a cobia FMP under its existing framework, with states not currently on the Board having the opportunity to declare an interest in cobia management as allowed in the Commission's Rules and Regulations. Landings are sparse north of Virginia and technical expertise primarily resides in the states from Virginia and south. The Board's multi-species advisory panel may preclude the need for a stand-alone advisory panel. Final FMP approval would be subject to the Commission.

Option 2: AMG Cobia Board
A stand-alone cobia board would be charged with developing a cobia FMP. Membership of the Board would consist of those states with a declared interest in cobia as set in the Commission's Rules and Regulations. Under the provisions of the ISFMP Charter, the Commission could extend a voting seat to the SAFMC if recommended by the Cobia Board. Final FMP approval would be subject to the Commission.

Option 3: Split the South Atlantic Board
The South Atlantic Board could consider splitting the Board and having two or more species boards. One of those boards would be charged with developing a cobia FMP. Any state not currently on the Board (after the split) would have the opportunity to declare an interest in cobia management as allowed in the Commission's Rules and Regulations Under the provisions of the ISFMP Charter, the Commission could extend a voting seat to the SAFMC if recommended by the Cobia Board. Final FMP approval would be subject to the Commission.

Time Line for Development of a Cobia FMP

ASMFC Cobia FMP

Aug	• Task staff to develop a Cobia FMP
Aug-Oct	• PDT develops a Draft PID
Oct	• Board considers approval of the Draft PID for Public Comment
Nov-Jan	• Public comment and staff conducts public hearings
Feb '17	• Board reviews public comment • Board tasks PDT to develp a draft Amendment
May '17	• Board reviews draft Amendment
August '17	• Board approves draft Amendment for public comment
Aug-Oct '17	• Public Comment and staff conducts public hearings
October '17	• Board reviews public comment • Board appoves final managment options for Commission review and approval of the FMP

ASMFC Cobia Complementary FMP

Same timeline as above but would report progress to the SAFMC at their meetings. The above time line could be delayed a few months depending on the timing of Commission and Council meetings.

Joint ASMFC/SAFMC FMP

A joint FMP with the SAFMC would take at least two years to develop and finalize. All actions would have to occur at a joint meeting of both the Council and Commission. Any joint action would have to comply with federal guidelines and requirements (e.g. Magnuson-Stevens Act, NEPA, APA).

Atlantic States Marine Fisheries Commission

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MEMORANDUM

TO: **ISFMP Policy Board**

FROM: **Risk and Uncertainty Policy Workgroup**

DATE: **July 26, 2016**

SUBJECT: **Risk and Uncertainty Policy Updates and Draft Purpose Statement**

The Risk and Uncertainty Policy Workgroup met on July 18th to craft a draft purpose statement that will help to guide the creation of a Commission Risk and Uncertainty Policy. The statement below was created from common aspects from each individual Workgroup member's draft statement or policy characteristics. The intent of this statement is to describe the purpose and goals of the Commission's Policy in a concise way; the detailed objectives of the Policy will be laid out in the full document. The Workgroup asks that the ISFMP Policy Board review the statement below and provide guidance on the direction and/or language so that the Workgroup can move forward with developing a draft policy for Board review during Annual Meeting.

Draft Risk and Uncertainty Policy Purpose Statement:

"The Commission recognizes that fishery information is inherently variable, and that successful management requires full consideration of this uncertainty and the associated risks on management decisions. The purpose of the Commission's Risk and Uncertainty Policy is to provide a consistent yet flexible mechanism to account for both scientific and management uncertainty in the Commission's decision making process in order to protect all Commission-managed stocks from the risk of overfishing, while minimizing any adverse social, economic, or ecosystem effects. This Policy seeks to maximize the long term benefits across all of our marine fishery resources by providing objective criteria to characterize both scientific and management uncertainty, and to evaluate management risk. Additionally, the Policy improves transparency in the management process, allowing for better communication among managers, industry, and other stakeholders."

Atlantic States Marine Fisheries Commission

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MEMORANDUM

TO: ISFMP Policy Board

FROM: Atlantic States Marine Fisheries Commission Habitat Committee

DATE: July 26, 2016

SUBJECT: Seismic testing on the Atlantic coast

During our May 2016 meeting in Cape May, New Jersey, the Habitat Committee (HC) discussed proposed seismic testing for oil and gas resources, siting of offshore wind facilities, and characterization of sand resources in ocean waters off the Atlantic coast, and whether the issue warrants a position and comment by the Commission. Seismic testing uses loud blasts from airguns to relay information about the composition of materials up to miles below the seafloor. The blasts can reach 180 dB – louder than a jet engine – and run every few seconds for weeks at a time. HC questioned whether seismic testing is truly a habitat issue, given that the likelihood of significant impacts on the benthos and water column, the combination of which typically define 'habitat', seem to be negligible. However, seismic testing can certainly cause temporary changes in the functionality of particular areas for different species, so the impact is a habitat issue in the broader sense of determining the suitability of living space over varying temporal scales determined by the magnitude and frequency of testing. In other words, seismic testing can certainly affect the interactions between managed species and habitat.

Regardless of whether seismic testing is an issue that falls under the purview of the HC, available evidence indicates that it should clearly be of interest to the Commission. Although there are considerable uncertainties in the severity of impacts on different species (including habitat-forming species such as corals and shellfish), there is clear evidence that seismic testing can, at the very least, cause behavioral disruptions among organisms in affected areas. Fishermen have been describing changes in feeding behavior (i.e. a disruption in feeding) within a few miles of active testing. Mobile animals have been documented leaving testing sites. These movements could be short-lived[1], medium term[2], or more persistent[3], depending upon the location, species in question and the nature of the testing conducted. Fishermen observations reinforce these behavioral effects[4]. However, even short-lived movements could affect stock productivity and resilience if the timing and location of the impact coincides with feeding, breeding, or other important life history events. This suggests that impacts could be minimized to tolerable levels if testing is timed to avoid the time and location of these key life history events. However, current understanding of habitat distributions, incorporating spatial and

[1] Løkkeborg S, Soldai AV. 1993. The influence of seismic exploration with airguns on cod (*Gadus morhua)* behaviour and catch rates. *ICES Mar Sci Symp* 196: 62-67.

[2] Engås A, Løkkeborg S, Ona E, Soldal AV. 1996. Effects of seismic shooting on local abundance and catch rates of cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*). *Can J Fish Aquat Sci* 53: 2238-2249.

[3] Slotte A, Hansen K, Dalen J, Ona E. 2004 Acoustic mapping of pelagic fish distribution and abundance in relation to a seismic shooting area off the Norwegian west coast. *Fish Res* 67: 143-150.

[4] https://www.facebook.com/fishinoc/posts/771164316327991

temporal life history patterns of both managed species and important unmanaged species (e.g., prey for managed species), lacks the resolution needed to plan testing with sufficient accuracy and precision. Detailed site characterization studies with sufficient spatial and temporal scope should therefore be a prerequisite of any planned testing.

Beyond behavioral disruptions, seismic testing can also cause injuries in marine organisms[5] at the individual level depending upon the anatomy, physiology and mobility of the species in question, magnitude of the testing, and proximity to the organism. These could impact stock or population level productivity if a large number of individuals are affected, or if impacts continue over time.

The HC perspectives on this issue were influenced by comment letters from the Mid-Atlantic Fishery Management Council and the South Carolina Wildlife Federation to BOEM and the South Atlantic Fishery Management Council, respectively. These letters summarize evidence of the impacts outlined above, as well as similar impacts on protected marine mammal species. Note that impacts include sacrifices on the part of fishermen to meet management targets in light of the economic importance of fisheries in the region and management efforts by multiple agencies. The HC recommends that the Commission adopt a position similar to these partner organizations, and convey that position to BOEM and other relevant entities.

Finally, the ultimate aim of seismic testing is to identify areas for extraction of oil and gas resources. Those activities could have a much greater impact on fishery resources through alteration or outright replacement of marine habitats, loss of fishing grounds and displacement of fishing effort, pollution due to spillage and leakage, and noise and other disturbances due to ongoing operations. Therefore, evaluation of the impacts of seismic testing should take place with full consideration of the ultimate aims of that testing and impacts of the subsequent activities.

[5] McCauley RD, Fewtrell J, Popper AN. 2003. High intensity anthropogenic sound damages fish ears. *J Acoust Soc Am* 113: 638-42.

MID-ATLANTIC FISHERY MANAGEMENT COUNCIL

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Gary D. Goeke
Chief, Regional Assessment Section
Office of Environment (GM23E)
Bureau of Ocean Energy Management
Gulf of Mexico OCS Region
1201 Elmwood Park Boulevard
New Orleans, Louisiana 70123-2394

Dear Mr. Goeke,

Please accept these comments from the Mid-Atlantic Fishery Management Council (MAFMC or "Council") in response to the Draft Programmatic Environmental Impact Statement (PEIS) to evaluate potential environmental effects of multiple geologic and geophysical (G&G) activities in the Mid- and South Atlantic OCS Planning Areas. After receiving briefings on the proposed seismic activities and the potential impacts at the June Council meeting, the Council made the following motion:

> Move to submit written comments opposing the BOEM seismic testing on the US east coast due to our grave concerns of the enormous Level A and Level B marine mammal takes and the unexamined but suspected deleterious effects on other marine species that our Council manages.

The Council's primary mission is to manage fishery resources in federal waters off the coast of the Mid-Atlantic region through the implementation of management measures that prevent overfishing while achieving optimum yield (OY) from each of 13 managed fisheries. Although the Council's focus is on sustainable fisheries management, this objective is only feasible in the context of a healthy and resilient ecosystem. It is clear that G&G activities have substantial impacts on marine environments, yet the Draft PEIS provides insufficient information about how the specific proposed G&G activities may affect fish, marine mammals, benthic communities, and ecosystem structure and function. We understand that these impacts are difficult to predict or quantify, but given the existing value of marine resources to the region and the nation, it is clear that the potential benefits do not outweigh the risks of initiating the proposed G&G activities at this point.

Marine fisheries provide food, employment, recreational opportunities for millions of people in the Mid-Atlantic region, and many coastal communities depend on the utilization of fishery resources. For example, in 2009, the dockside value of commercial landings in the Mid-Atlantic region was $511.6 million. In addition, more than 2.6 million recreational anglers took 17 million fishing trips and spent more than $800 million on trip expenses. The commercial and recreational fishing industries in the Mid-Atlantic region support more than 166,000 jobs with an associated income exceeding $6 billion. In light of the insufficient data and analysis about potential impacts of G&G activities on these valuable marine resources, the Council cannot support the Draft PEIS.

MID-ATLANTIC
FISHERY MANAGEMENT COUNCIL

Over the past decades the Council has implemented management strategies to maintain sustainable levels of fishing and, in some cases, to rebuild overfished stocks. These efforts have often necessitated sacrifices from both the commercial and recreational fishing sectors in the form of economic losses and foregone fishing opportunities. After many years of working to rebuild Mid-Atlantic fisheries to sustainable levels, the potential negative impacts of G&G activities on these rebuilt resources are extremely troubling.

The Council recently hosted two scientists, Chris Clark and Aaron Rice of Cornell University, at a meeting in June. Dr. Clark reviewed the physical propagation of sound from seismic airgun surveys, and Dr. Rice addressed the potential for negative impacts of acoustic surveys on fish and fish populations. Their remarks suggest that highly mobile fish are able to easily relocate within 50 meters to avoid lethal effects of the airgun array. They may also avoid sub-lethal damage by maintaining even greater distances from areas subject to noise disturbance from the survey. However, the extensive (months long) survey timeframe makes it likely that prolonged avoidance of the arrays will be necessary and could lead to interruptions in fish spawning and access to forage. More importantly, the area under consideration in the PEIS, which includes the entire continental shelf along the mid- and South Atlantic, is enormous, and much of the shelf is at a depth (< 50 m) that would place the entire water column within the "lethal range" of the array.

The Council also has substantial concerns about the potential and unknown adverse impacts of G&G activities on marine mammals. The Council has participated in the development of Take Reduction Plans under the Marine Mammal Protection Act for Atlantic Large Whales, Harbor Porpoise and Bottlenose Dolphin. These efforts have resulted in area and gear restrictions for several fisheries within the Council's jurisdiction. In the case of north Atlantic right whales, which are among the most endangered whales in the world, protection measures have been extended to include seasonal vessel speed restrictions along the U.S. East Coast where endangered right whales travel to protect them from being injured or killed by ships. Initiating the activities described in the PEIS, many of which could harm or endanger marine mammals, would counteract many of the conservation measures that have taken years to enact.

The general lack of information included in the PEIS relative to impacts of G&G activities on fish, marine mammals, and the surrounding ecosystem is of serious concern. The Council recognizes the importance of energy exploration to U.S. economic security, but the activities described in the Draft PEIS have the potential to contravene the Council's efforts to conserve and manage living marine resources and habitat. Thank you for the opportunity to submit comments on this Draft PEIS. The Council looks forward to working with BOEM to ensure that any future G&G activities in the Mid-Atlantic region are conducted in a manner that minimizes negative impacts on the marine environment.

Sincerely,

RSeagraves for

Christopher M. Moore, PhD
Executive Director, Mid-Atlantic Fishery Management Council

SCWF

Your voice in the wild for 80 years!

March 10, 2015

South Atlantic Fisheries Management Council
South Carolina delegation: Mel Bell, Chris Conklin, Mark Brown / SAFMC staff
Via email

Dear SAFMC SC Members and Council Staff:

On behalf of the South Carolina Wildlife Federation (SCWF), thank you for your service on the South Carolina Fisheries Management Council (SAFMC) and your dedication of time and expertise in helping shape our region's fisheries policy. We write to you today to: (1) encourage your work on designating Special Management Zones to protect important fish spawning habitats; and (2) ask you to apply (and expand if necessary) your existing policies on oil and gas exploration to ensure the protection of Essential Fish Habitat (EFH), Essential Fish Habitat - Habitat Areas of Particular Concern (EFH-HAPCs), and any other important fisheries habitats and populations under your control from threats associated with energy exploration and development.

The South Carolina Wildlife Federation was formed in 1931 to help ensure that our children and grandchildren can enjoy our state's natural heritage and opportunities for outdoor enjoyment. SCWF reaches thousands of citizens, members and donors across our state, including coastal fishing enthusiasts who live from our beaches to the foothills. Our support of spawning site protections follows decades of effective leadership in habitat conservation, respect for outdoor traditions, wildlife education, advocacy and key partnerships.

1. Designation of Special Management Zones

Our organization supports the Council's actions to establish protections for important fish spawning sites off our coast. We understand the next step is to select key areas to be designated as Special Management Zones, where bottom fishing would be prohibited. We support these efforts, guided by good fishery research and your knowledge of spawning's key role in improving fish stock assessments. The benefits will impact many fish and especially grouper and snapper species. Establishing protections for areas with scientifically documented fish spawning will include difficult choices. We appreciate that the process may include selecting some of the most productive fishing grounds off our coast.

It has been our experience that long-term conservation efforts also improve the outdoor economies attached to wildlife enjoyment. We expect the benefits of the actions will improve

SOUTH CAROLINA WILDLIFE FEDERATION
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commercial fishing, and promote better catch and availability of local fish for South Carolina restaurants and seafood dealers. We also believe recreational anglers will continue to purchase boats, tackle and supplies to sustain local economies as wildlife sustains our pastimes. It takes hard work to ensure wildlife's future. We know this first hand.

2. Resource and Habitat Protection from Oil Exploration and Development

As you are probably well aware, energy exploration off our coast is looming with federal permitting processes and State coastal zone certification now underway. The first step in this process is extensive and environmentally harmful seismic exploration. Seismic surveys have been shown to disrupt essential behavior in endangered whales and cause catch rates of some commercial fish to plummet—in some cases over enormous areas of ocean. Despite industry rhetoric that seismic blasts are not harmful, the literature is replete with information to the contrary.

Airguns towed behind ships shoot loud blasts of compressed air through the water and miles into the seabed. These blasts are repeated every ten seconds, 24 hours a day, for days and weeks at a time. Air gun blasts have been likened to dynamite, having range intensities between 120-260 decibels (dB). Sounds between 120-170dB can disturb animal behavior; sounds above 170dB can injure marine mammals. Impacts include temporary and permanent hearing loss, abandonment of habitat, disruption of mating and feeding, and even beach strandings and deaths.

Airgun blasts also kill fish eggs and larvae and scare away fish form important habitats. Previous seismic surveys have resulted in catch rates of cod and haddock declining by 40 to 80 percent for thousands of miles. Such disturbance will have negative economic impacts on our South Carolina recreational and commercial catch resources.

From a fisheries perspective, the area of disturbance is as much an issue as the intensity, frequency (every 10 seconds), and longevity (months) of the disturbance. At the higher decibel ranges, seismic blasts can be detected 2,500 miles away from the source. Even highly motile fish, which may be able to relocate to avoid lethal and perhaps sub-lethal effects of the airgun array, would be displaced from spawning habitats affecting future year classes.

The area under consideration for exploration includes the entire continental shelf along the mid- and South Atlantic, is enormous, and much of the shelf is at a depth that would place the entire water column within the disturbance range. Included, and of particular concern, is the Blake Plateau where methane hydrate deposits are thought to be present. This area includes the Charleston Bump, a unique and critical structural and coral formation supporting South Carolina fisheries.

SCWF opposes offshore seismic testing and oil/gas development. At the very least, we should do all we can to protect Essential Fish Habitat (EFH) and Habitat Areas of Particular Concern (HAPC) in our offshore waters. EFHs / HAPCs are high priority areas for conservation and management because they are rare, sensitive, or important to ecosystem functions. Because of the range of noise disturbance from airgun blasts, it would be almost impossible to set safe buffer zones around these important designated resources. Safety of these areas could really only be accomplished by not allowing seismic exploration using the proposed technology.

It is our understanding that the designation of proposed areas as SMZs would also then be categorized as EFHs/HAPCs. This categorization would provide a stronger argument for protecting these important places from activities associated with energy exploration. We encourage the SAFMC to address the energy development issue and all potential concerns regarding fisheries.

In their comments to the Bureau of Ocean Energy Management, our neighbors to the north, The Mid-Atlantic Fisheries Management Council have expressed concern that the proposed seismic activities "… have the potential to contravene the Council's efforts to conserve and manage living marine resources and habitat." They further expressed concern for cetaceans, including porpoises and Atlantic whales (particularly the endangered Right Whales), stating that seismic exploration "… could harm or endanger marine mammals, and would counteract many of the conservation measures that have taken years to enact."

It is important to note that the way the exploration process is set up, the current exploration proposal, currently under review by our State Ocean and Coastal Resource Management office is just the first of many to come. Multiple exploration companies will be repeating this insult to our coastal ecosystems. It is also important to note that this seismic exploration phase, imposing its own impacts on recreational and commercial fisheries, as well as on cetacean populations, is just the first step in further exploration and potential drilling activities to follow.

We greatly appreciate your dedication to ensure healthy fisheries off our state's coast and throughout the south Atlantic. The SCWF stands with you and fellow council members to protect key fish habitat and spawning sites. We strongly encourage you to send comments to the Office of Coastal Resource Management who are in the process of receiving input on their certification of the Spectrum Geo Inc. geophysical and geological survey permit (the first of many to come). Comment should be sent to Mr. Curtis Joyner, Manager, Coastal Zone Consistency, S.C. Department of Health and Environmental Control, Office of Coastal Resource Management, 1362 McMillan Ave., North Charleston, SC 29405. The comment deadline is March 13. We also encourage you to send a letter directly to the Bureau of Ocean Energy Management who are soliciting comments on the leasing licenses until March 30. We look forward to weighing in further as the spawning site/SMZ and oil exploration and development issues move forward.

Sincerely,

Ben Gregg

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Cobia Management: How the Atlantic States Marine Fisheries Commission could take part in the management of the cobia fishery
South Atlantic State/Federal Fisheries Management Board
August 2016

Introduction

Cobia (*Rachycentron canadum*) is a member of the family Rachycentridae and is distributed worldwide in tropical, subtropical and warm-temperate waters. In the western Atlantic they occur from Nova Scotia, Canada, south to Argentina, including the Caribbean Sea. It is abundant in warm waters off the coast of the U.S. from the Chesapeake Bay south and throughout the Gulf. Cobia prefer water temperatures between 68-86°F. As a result of their wide distribution and genetic stock differences, cobia are managed as two distinct groups. The Gulf Migratory Group cobia (GMG) includes those fish off the East coast of Florida and into the Gulf of Mexico. GMG cobia are currently managed by the Gulf of Mexico Fishery Management Council, with the exception of the East coast of Florida which is managed by the South Atlantic Fishery Management Council (SAFMC). Atlantic Migratory Group cobia (AMG cobia) occur from Georgia to New York. AMG cobia are currently managed by the SAFMC through the Coastal Migratory Pelagics Fishery Management Plan; the Mid-Atlantic Fishery Management Council (MAFMC) participates through two voting seats on the SAFMC's Mackerel/Cobia Committee.

Recreational cobia landings in 2015 were 1,540,776 pounds, 145% over the annual catch limit (ACL), resulting in a June 20, 2016 closure of the fishery by NOAA Fisheries. Commercial cobia landings in 2015 were 83,148 pounds, 38% over the ACL. Late landings reports in 2015 precluded a timely closure of the commercial fishery.

Concerns were expressed by individual states whose recreational seasons were significantly reduced by the closure due to the overage of the 2015 quota. North Carolina and Virginia developed alternate management strategies to avoid the June 20, 2016 closure enacted by NOAA Fisheries for 2016. South Carolina has recently implemented more restrictive measures that are consistent with the actions of NOAA Fisheries in some areas.

As a result of the significant overage of the 2015 recreational ACL, the jurisdictional impacts and the observation that on average 82% of reported recreational landings are harvested in state waters, the SAFMC requested that the Atlantic States Marine Fisheries Commission (ASMFC) consider complementary or joint management of the cobia resource. The ASMFC considered this request at the May 2016 meeting and agreed that ASMFC management of cobia may be prudent. The ISFMP Policy Board directed the South Atlantic State/Federal Fisheries Management Board (Board) to develop options for how the ASMFC could be involved with cobia management to consider at the August 2016 meeting.

Life History

Cobia is a fast growing, moderately lived species that supports a valuable recreational fishery throughout the south Atlantic and into the mid-Atlantic region. Known for their readiness to take a bait, tough fighting abilities, and excellent table fare, the fishery is popular. The commercial fishery is primarily a by-catch in other directed fisheries such as the hook and line fishery for snapper/grouper and troll fisheries for various species (e.g., king mackerel, dolphin).

Cobia grow rapidly in their first 2 years with most mature at age 2. Females grow faster and attain larger sizes than males. Spawning occurs during a protracted spawning season from April through September. Consistent with protracted spawning, cobia spawn multiple batches of eggs throughout the season.

Recent genetic and stock structure analysis suggests the Florida portion of the stock is more appropriately managed with the Gulf of Mexico stock, while the Georgia to New York population comprise a separate, northern component. While cobia do frequent areas north of Virginia, the harvest is uncommon and sporadic. Landings have been episodically reported from Maryland, New York, New Jersey and Rhode Island and make up from 3-15% of the total mid-Atlantic landings.

The 2013 stock assessment conducted through the SouthEast Data Assessment and Review (SEDAR) process indicated overfishing is not occurring and the stock is not overfished. The current ACL is a precautionary approach to prevent the stock reaching an overfished status. The recent overage in 2015, exceeded the Council defined Overfishing Limit.

The 2013 stock assessment does provide some reasons for concern. While the terminal year of the assessment was 2011, Spawning Stock Biomass (SSB) experienced a general decline from 2002 forward (Figure 1). Further, recreational landings have increased over the latter portion of the time series that may increase potential overfishing issues in the next assessment. In June, the SAFMC proposed cobia be included in a 2017 Stock ID workshop and the 2018 SEDAR schedule for a benchmark assessment.

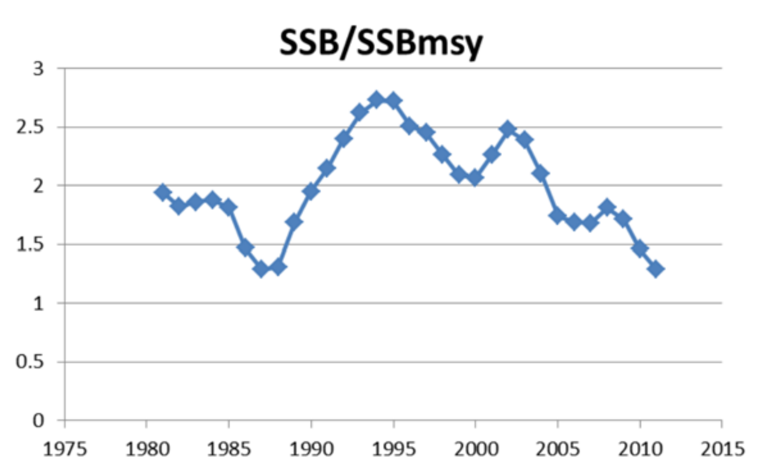


Figure 1. Spawning stock biomass relative to the MSY biomass reference for 1981-2011. SSB estimates are available farther back in time; this period was chosen to highlight the impact of landings during this time on SSB estimates

Cobia Fishery
There is both a commercial and recreational cobia fishery along the Atlantic coast. Management measures include size limits, possession limits, trip limits and quotas. State specific recreational measures vary coastwide and can be found in Table 3. Commercial restrictions, aside from the ACL, are consistent throughout most of the range with a 33"FL size limit and 2 fish trip limit. The distribution of the quota between commercial and recreational sectors is based on historical landings (50% is based on the average 2000-2008 landings and 50% is based on the average 2006-2008). Beginning in 2016, and expected to hold constant until a future assessment, the quota is split 92% recreational and 8% commercial. The 2016 Allowable Biological Catch (ABC) for AMG cobia is 670,000 pounds. The recreational ACL is 620,000 pounds and the commercial ACL is 50,000 pounds. The ABC for 2015 was slightly higher at 690,000 pounds.

Recreational cobia fisheries are prosecuted similarly along the coast. The primary methods include bottom fishing with live or dead natural bait and sight casting to single or small pods of fish, oftentimes around schools of bait (e.g., menhaden, thread fin shad). The popularity of sight casting has grown recently, resulting in increased interest in the fishery. Further, this interest has resulted in a lucrative expansion in the tackle market as baits are relatively specific for these large fish. Recreational landings for AMG cobia have varied with little trend since 2005, however, landings did hit a time series high in 2015 resulting in a significant overage in the federal ACL (Figure 2).

Commercial harvest of cobia has traditionally been a bycatch in the offshore snapper/grouper and trolling fisheries. Directed fisheries are generally precluded as a result of the low possession limits. The commercial fishery has seen an increasing trend from North Carolina through the mid-Atlantic over the time series. The AMG cobia commercial fishery closed early in 2014 (December 11, 2014). The 2015 overages would be deducted if the stock were overfished, however, given they are not overfished, the commercial quota for 20-16 will be 50,000 pounds (Figure 3).

Federal Management
The Cobia FMP is currently managed jointly in federal waters by the SAFMC and the GMFMC under the joint Coastal Migratory Pelagics Fishery Management Plan; the MAFMC participates through two voting seats on the SAFMC's Mackerel/Cobia Committee. The GMFMC sets the overall ALC for Gulf cobia and the measures to achieve that quota with the exception of the East coast of Florida. The East coast of Florida has a suballocation of the overall Gulf ACL; the percentage was determined jointly by the two councils in Amendment 20B. The suballocation is then split 92% recreational and 8% commercial. The SAFMC then sets management measures to achieve the quota. The ACL and measures to achieve the ACL for AMG cobia is set by the SAFMC.

The SAFMC is currently developing Framework Amendment 4 to the Fishery Management Plan for Coastal Migratory Pelagic Resources in the Gulf of Mexico and Atlantic Region (included in briefing materials). The framework includes actions to modify recreational and commercial harvest limits, change the recreational fishing year and modify recreational accountability measures for Atlantic migratory group cobia in the exclusive economic zone (EEZ) from the Georgia/Florida line through the Mid-Atlantic region.

State Management
Florida
Recreational cobia landing on the East coast of Florida ranged from 274,276 to 761,440 pounds (avg. = 488,788 pounds) during the 2005-2015 time series (Table 1). Current regulations are a 33" fork length and a 1 per person or 6 per vessel (whichever is less) bag limit. Legal gear is limited to spears, gigs, hook and line, seine and cast net (Table 3).

Commercial cobia landings on the East coast of Florida ranged from 57,003 to 156,069 pounds (avg. = 88,278 pounds) during the 2007-2011 time series (Table 2).

Georgia
Recreational cobia landings in Georgia ranged from 3,358 to 257,690 pounds (avg. = 58,111 pounds) during the 2005-2015 time series (Table 1). Current regulations in Georgia are a 2 fish per person bag limit with a 33"FL size limit (Table 2).

Commercial landings in Georgia and South Carolina are low and values for the two states were combined from 2010-2015 to avoid confidentiality issues and averaged 3,867 pounds (Table 4).

South Carolina
Recreational cobia landings in South Carolina ranged from 3,565 to 268,677 pounds (avg. = 76,954 pounds) during the 2005-2015 time series (Table 1). Current regulations in South Carolina consist of seasonal and areal bag limits from 1 to 2, a regional spawning season closure in May, and 33"FL size limit (Table 3). Cobia are designated as gamefish in South Carolina.

North Carolina
Recreational cobia landings in North Carolina ranged from 66,258 to 630,373 pounds (avg. = (259,883 pounds) from 2005-2015 (Table 1). Current regulations in North Carolina consist of a 1 fish bag limit with a boat limit of 2 fish for private boats and 4 fish in the for-hire sector (private vessels may only retain cobia on Monday, Wednesday, and Saturday), 37" FL size limit, and a closure in state waters effective September 30, 2016 (Table 3).

Commercial landings in North Carolina ranged from 19,950-52,315 pounds from 2010-2015, averaging 37,559 pounds over the time series. The landings of 52,315 pounds in 2015 accounted for nearly the entire AMG cobia commercial quota in 2015 and would have exceeded the 2016 quota (Table 4).

Virginia
Recreational cobia landings in Virginia ranged from 36,409 to 733,740 pounds (avg. = 368,059 pounds) during the 2005-2015 time series (Table 1). Current regulations in Virginia consist of 1

fish bag limit and 2 fish per boat. A 40"TL size limit with no more than one greater than 50"TL, no gaffing permitted, state waters close on August 30, 2016 (Table 2).

Commercial landings for the mid-Atlantic region (Virginia, Maryland, New Jersey, New York) and Rhode Island are combined in Table 4 to avoid confidentiality issues in several Mid-Atlantic States. The majority of the mid-Atlantic landings come for Virginia. The average landings from 2010-2015 were 14,732 pounds.

Table 1. Recreational landings of Atlantic cobia from 2005-2015 in pounds. Data sources: MRIP and SEFSC

Year	Virginia	North Carolina	South Carolina	Georgia	Total AMG (VA-GA)	East Coast of Florida
2005	577,284	322,272	5,793	3,358	908,707	287,267
2006	733,740	104,259	101,018	4,824	943,841	493,334
2007	322,887	90,197	268,677	64,708	746,469	580,632
2008	167,949	66,258	50,108	257,690	542,006	438,621
2009	552,995	123,061	76,229	3,997	756,282	361,120
2010	232,987	561,486	65,688	79,855	940,015	745,228
2011	136,859	121,689	3,565	90,375	352,488	761,440
2012	36,409	68,657	224,365	105,193	434,623	370,373
2013	354,463	492,969	19,130	29,224	895,786	274,276
2014	214,427	277,489	31,927	20,642	544,485	582,423
2015	718,647	630,373	123,952	67,804	1,540,776	481,956

* There are no MRIP-estimated recreational landings of AMG cobia in states north of Virginia.

Table 2. Commercial cobia landings for Florida East Coast, 2007-2011 (pounds).

	Commercial Cobia landings
2007	60,805
2008	57,003
2009	65,953
2010	101,564
2011	156,069

Table 3. Recreational measures in 2016 for Virginia, North Carolina, South Carolina and Georgia**.**

State	Bag limit	Vessel limit	Size Limit (inches)	Legal Gear
Virginia	1 fish*	2 fish	40” TL, only 1 > 50” TL	
North Carolina	1 fish**	For-hire: 4/vessel or 1 person when less than 4 people on board Private: 2 fish on vessels with more than 1 person on board	37” FL	No gaffing permitted
South Carolina – north of Jeremy Inlet, Edisto Island	2 fish	None	33” FL	
South Carolina-south of Jeremy Inlet, Edisto Island	1 fish June 1-Apr 30 Catch and release only May 1-May 31	3 fish per vessel or 1 fish per person, whichever is lower	33” FL	
Georgia	2 fish	None	33” FL	
Florida	1 per person	1 per person or 6 per vessel, whichever is less	33”FL	spears, gigs, hook and line, seine, cast net

*VA State waters close 8/30/16.
**NC State waters close 9/30/16; private recreational can only retain cobia on Mondays, Wednesdays, and Saturdays.

Table 4. Commercial cobia landings (pounds) and revenues (2014 dollars) by state/area, 2010-2015.

Year	GA/SC	NC	Mid-Atlantic*	Total
		Commercial Landing in Pounds		
2010	3,174	43,737	9,364	56,275
2011	4,610	19,950	9,233	33,793
2012	3,642	32,008	6,309	41,959
2013	4,041	35,496	13,095	52,632
2014	4,180	41,848	23,111	69,139
2015	3,555	52,315	27,277	83,148
Average	3,867	37,559	14,732	56,158
		Dockside Revenues (2014 dollars)		
2010	$11,377	$70,377	$19,976	$101,730
2011	$19,666	$37,893	$21,666	$79,224
2012	$15,554	$66,887	$14,597	$97,038
2013	$15,639	$79,397	$35,792	$130,828
2014	$13,320	$95,462	$67,972	$176,754
2015	$11,151	$147,160	$75,360	$233,672
Average	$14,451	$82,863	$39,227	$136,541

Georgia and South Carolina landings are combined to avoid confidentiality issues. Source: SEFSC Commercial ACL Dataset (December 2015) for 2010-2014 data; D. Gloeckner (pers. comm., 2016) for 2015 data.
Mid-Atlantic states include Virginia, Maryland, New York, New Jersey.

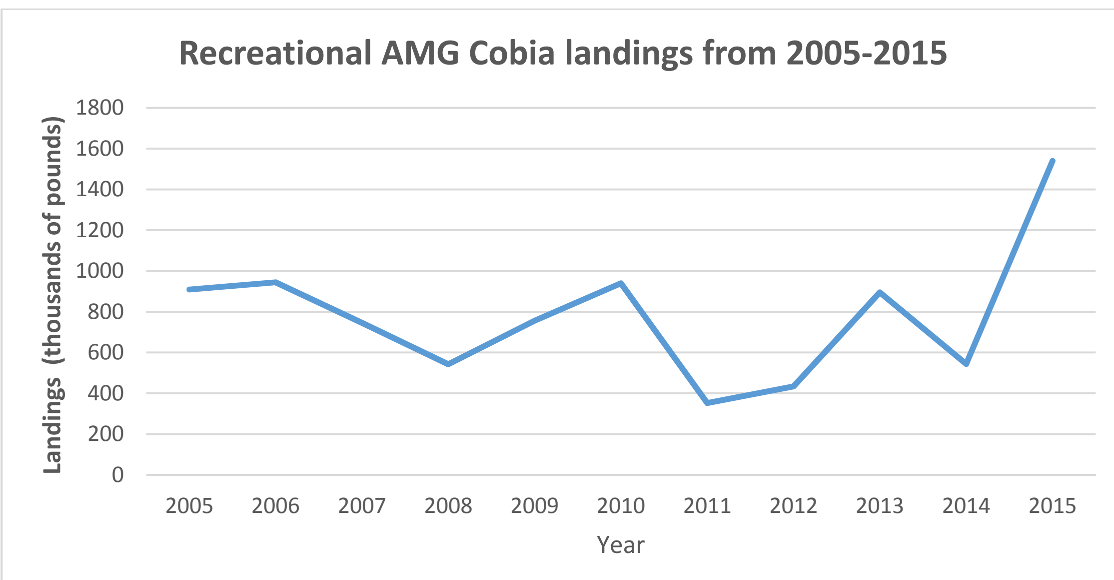


Figure 2. Recreational landings of AMG cobia (2005-2015)

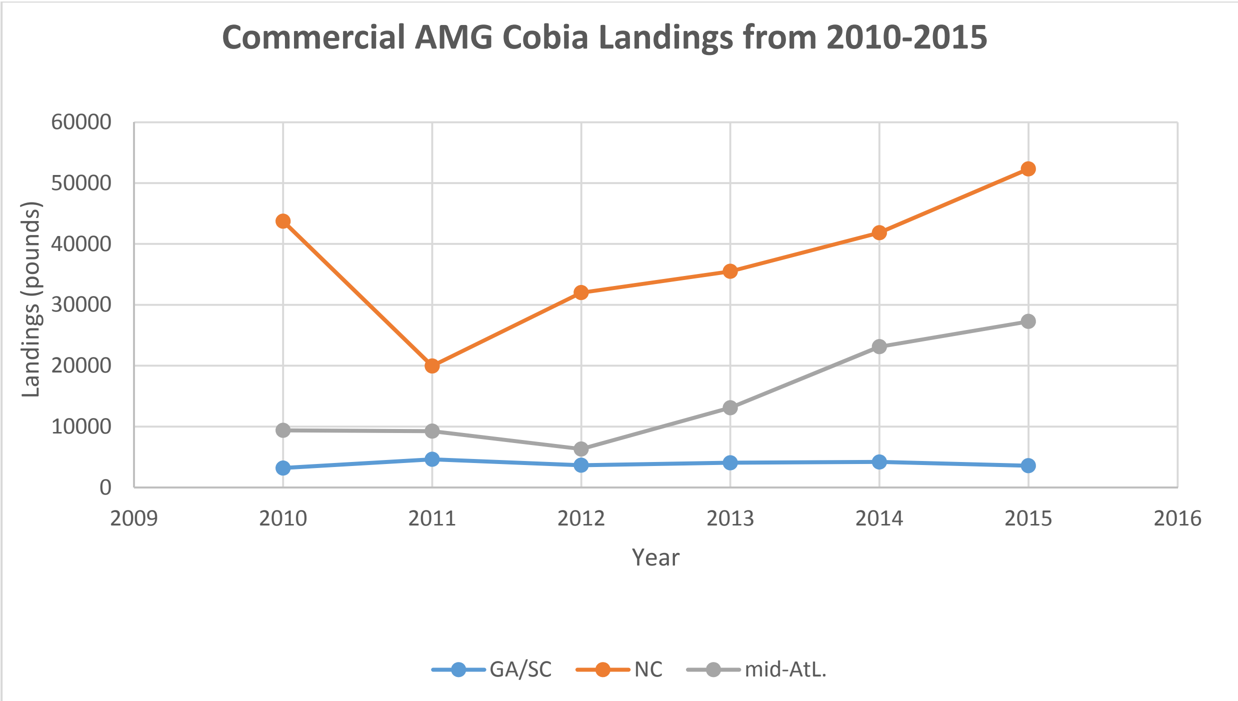


Figure 3. Commercial landings of AMG cobia (2010-2015)

Plan Development Options

The ISFMP Policy Board directed the Board to discuss whether to promulgate a cobia plan and, if so, recommend what form that plan would take at the May 2016 ASMFC meeting. Specifically, the ISFMP Policy Board requested consideration of alternatives for joint management, complementary management, and exclusive jurisdiction for the Commission.

Distinctions between various management scenarios have been developed and reviewed by the commission in the past. Essentially, the ASMFC has 3 types of Fishery Management Plans (FMP): a ASMFC FMP, a joint FMP, and a complementary FMP. A joint plan, like summer flounder in the mid-Atlantic, involves both the ASMFC Board and the Mid-Atlantic Fishery Management Council in the FMP process. A complementary plan, like spiny dogfish, separates the management processes between the two bodies (Federal/Council and ASMFC Board) and attempts to have measures that are consistent and not in direct conflict.

A. Management Plan Structure

<u>Option 1:</u>

ASMFC/SAFMC Complementary Fishery Management Plan

- ASMFC develops its own management documents. The ASMFC FMP can have aspects of the plan that are consistent with the Council but it is not required
- FMP development timeframe is consistent with ASMFC documents (addenda=6 to 8 months; Amendments 1.5 to 2 years)

- Not necessary to meet with SAFMC and act jointly
- Potential for lack of consistency between federal and state waters, which can result in fisherman fishing side-by-side under different regulations
- States are the responsible party for monitoring quotas in most cases
- States are the responsible party for closing state waters once quota is reached
- Stock assessments are conducted with the SEFSC/Council/Commission. The Science Center is the lead.

<u>Option 2:</u>
ASMFC/SAFMC Joint Fishery Management Plan

- ASMFC develops its management documents jointly with the Council. It is required to have the same management program for both state and federal waters.
- FMP development timeframe likely longer than a typical ASMFC document (addenda/framework=8 months to 1 year; Amendments 2-3 years)
- Meet with SAFMC and act jointly (must have like motions to proceeded with actions)
- Can have additional administrative procedures due to federal laws and requirements (e.g. longer rule making process; Council makes recommendations which are reviewed and approved by NOAA Fisheries (SERO))
- NOAA Fisheries is the responsible party for monitoring quotas in most cases
- NOAA Fisheries closes federal waters and states close state waters when the quota has been reached
- Some flexibility for ASMFC-only management components
- Stock assessments are conducted with the SEFSC/Council/Commission. The Science Center is the lead.

<u>Option 3:</u>
ASMFC exclusive management

- ASMFC would develop its own management documents.
- FMP development timeframe is consistent with ASMFC documents (addenda=6 to 8 months; Amendments 1.5 to 2 years)
- States are the responsible party for monitoring quotas in most cases
- States are the responsible party for closing state waters once quota is reached
- States are the responsible party for data collection and analysis
- Commission is responsible for conducting stock assessments (with possible assistance of the SEFSC and SEDAR)

<u>Option 4:</u>
Status quo: The SAFMC and GMFMC would retain all current management authority of cobia through the Coastal Migratory Pelagics Fishery Management Plan, with the MAFMC participating through 2 voting seats.

B. ASMFC Board Formation

If the Commission takes action to create a cobia fishery management plan, it will need to determine if Cobia should reside as species within the South Atlantic State/Federal Fisheries Management Board or be an independent board.

<u>Option 1:</u> South Atlantic State-Federal Fisheries Management Board
The Board would be charged with developing a cobia FMP under its existing framework, with states not currently on the Board having the opportunity to declare an interest in cobia management as allowed in the Commission's Rules and Regulations. Landings are sparse north of Virginia and technical expertise primarily resides in the states from Virginia and south. The Board's multi-species advisory panel may preclude the need for a stand-alone advisory panel. Final FMP approval would be subject to the Commission.

<u>Option 2:</u> AMG Cobia Board
A stand-alone cobia board would be charged with developing a cobia FMP. Membership of the Board would consist of those states with a declared interest in cobia as set in the Commission's Rules and Regulations. Under the provisions of the ISFMP Charter, the Commission could extend a voting seat to the SAFMC if recommended by the Cobia Board. Final FMP approval would be subject to the Commission.

<u>Option 3:</u> Split the South Atlantic Board
The South Atlantic Board could consider splitting the Board and having two or more species boards. One of those boards would be charged with developing a cobia FMP. Any state not currently on the Board (after the split) would have the opportunity to declare an interest in cobia management as allowed in the Commission's Rules and Regulations Under the provisions of the ISFMP Charter, the Commission could extend a voting seat to the SAFMC if recommended by the Cobia Board. Final FMP approval would be subject to the Commission.

Time Line for Development of a Cobia FMP

ASMFC Cobia FMP

Aug	•Task staff to develop a Cobia FMP
Aug-Oct	•PDT develops a Draft PID
Oct	•Board considers approval of the Draft PID for Public Comment
Nov-Jan	•Public comment and staff conducts public hearings
Feb '17	•Board reviews public comment •Board tasks PDT to develp a draft Amendment
May '17	• Board reviews draft Amendment
August '17	•Board approves draft Amendment for public comment
Aug-Oct '17	•Public Comment and staff conducts public hearings
October '17	•Board reviews public comment •Board appoves final managment options for Commission review and approval of the FMP

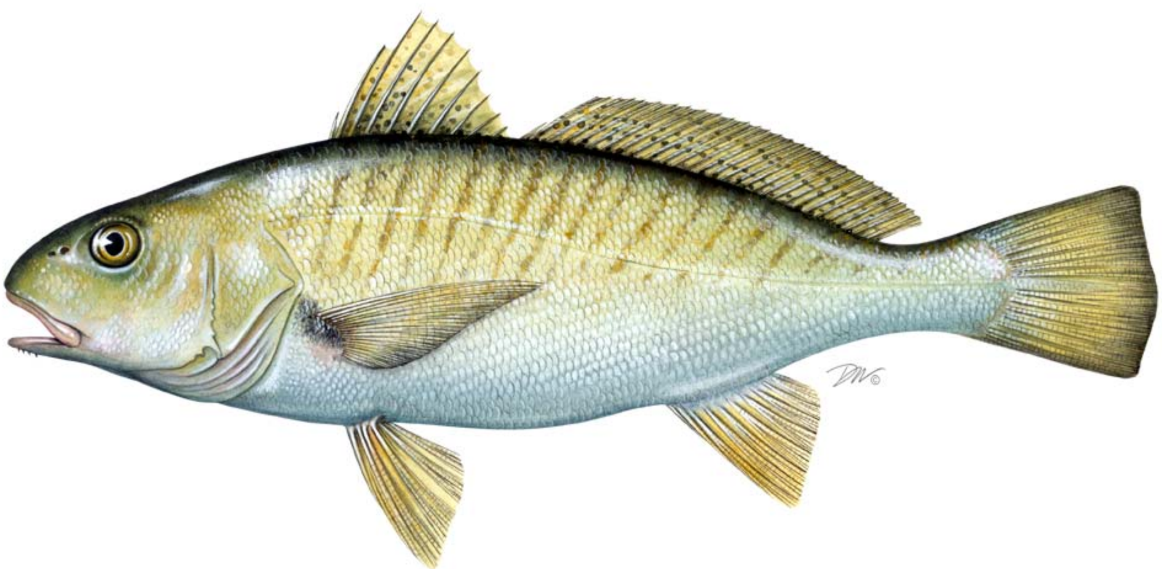
ASMFC Cobia Complementary FMP
Same timeline as above but would report progress to the SAFMC at their meetings. The above time line could be delayed a few months depending on the timing of Commission and Council meetings.

Joint ASMFC/SAFMC FMP
A joint FMP with the SAFMC would take at least two years to develop and finalize. All actions would have to occur at a joint meeting of both the Council and Commission. Any joint action would have to comply with federal guidelines and requirements (e.g. Magnuson-Stevens Act, NEPA, APA).

2016 REVIEW OF THE
ATLANTIC STATES MARINE FISHERIES COMMISSION
FISHERY MANAGEMENT PLAN FOR

ATLANTIC CROAKER
(Micropogonias undulatus)

2015 FISHING YEAR



Atlantic Croaker Plan Review Team
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Megan Ware, Atlantic States Marine Fisheries Commission, Chair

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I. Status of the Fishery Management Plan

Date of FMP Approval:	Original FMP – October 1987
Amendments:	Amendment 1 – November 2005 (implemented January 2006) Addendum I – March 2011 Addendum II – August 2014
Management Areas:	The Atlantic coast distribution of the resource from New Jersey through Florida
Active Boards/Committees:	South Atlantic State/Federal Fisheries Management Board; Atlantic Croaker Technical Committee, Stock Assessment Subcommittee, and Plan Review Team; South Atlantic Species Advisory Panel

The Fishery Management Plan (FMP) for Atlantic Croaker was adopted in 1987 and included the states from Maryland through Florida (ASMFC 1987). In 2004, the South Atlantic State/Federal Fisheries Management Board (Board) found the recommendations in the FMP to be vague, and recommended that an amendment be prepared to define management measures necessary to achieve the goals of the FMP. The Interstate Fisheries Management Program Policy Board also adopted the finding that the original FMP did not contain any management measures that states were required to implement.

In 2002, the Board directed the Atlantic Croaker Technical Committee to conduct the first coastwide stock assessment of the species to prepare for developing an amendment. The Atlantic Croaker Stock Assessment Subcommittee developed a stock assessment in 2003, which was approved by a Southeast Data Assessment Review (SEDAR) panel for use in management in June 2004 (ASMFC 2005a). The Board quickly initiated development of an amendment and, in November 2005, approved Amendment 1 to the Atlantic Croaker FMP (ASMFC 2005b). The amendment was fully implemented by January 1, 2006.

The goal of Amendment 1 is to utilize interstate management to perpetuate the self-sustainable Atlantic croaker resource throughout its range and generate the greatest economic and social benefits from its commercial and recreational harvest and utilization over time. Amendment 1 contains four objectives:

1) Manage the fishing mortality rate for Atlantic croaker to provide adequate spawning potential to sustain long-term abundance of the Atlantic croaker population.
2) Manage the Atlantic croaker stock to maintain the spawning stock biomass above the target biomass levels and restrict fishing mortality to rates below the threshold.
3) Develop a management program for restoring and maintaining essential Atlantic croaker habitat.
4) Develop research priorities that will further refine the Atlantic croaker management program to maximize the biological, social, and economic benefits derived from the Atlantic croaker population.

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

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

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

The Board initiated Addendum I to Amendment I at its August 2010 meeting, following the updated stock assessment, in order to address the proposed reference points and management unit. The stock assessment evaluated the stock as a coastwide unit, rather than the two management units established within Amendment I. In approving Addendum I, the Board endorsed consolidating the stock into one management unit, as proposed by the stock assessment. In addition, Addendum I established a procedure, similar to other species, by which the Board may approve peer-reviewed BRPs without a full administrative process, such as an amendment or addendum.

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

The TLA framework replaces the management triggers stipulated in Addendum I, which dictated that action should be taken if recreational and commercial landings dropped below 70% of the previous two year average. Those triggers were limited in their ability to illustrate long-term declines or increases in stock abundance. In contrast, the TLA approach better illustrates trends in the fishery through changes in the proportion of green, yellow, and red coloring.

Addenda I and II did not add or change any management measures or requirements. The only existing requirement is for states to submit an annual compliance report by July 1st of each year that contains commercial and recreational landings as well as results from any monitoring programs that intercept Atlantic croaker.

II. Status of the Stock

Stock status is based on data and results of the 2010 stock assessment (ASMFC 2010). Results include revised biological reference points (below), which are ratio-based and apply to the entire coastwide resource (unlike those in Amendment 1). Overfishing is occurring if F/F_{MSY} is greater than 1 and the stock is considered overfished if $SSB/(SSB_{MSY}(1-M))$ is less than 1.

	Overfishing Definition	Overfished Definition
Target	$F/(F_{MSY}*0.75) = 1$	$SSB/SSB_{MSY} = 1$
Threshold	$F/F_{MSY} = 1$	$SSB/(SSB_{MSY}(1-M)) = 1$

Atlantic croaker is not experiencing overfishing. According to the 2010 stock assessment, biomass has been increasing and fishing mortality decreasing since the late 1980s. Biomass conclusions are based on information from the data compiled for the assessment, namely increasing indices of relative abundance and expanding age structure in the catch and indices. Model estimated values of fishing mortality (F), spawning stock biomass (SSB), and biological reference points are too uncertain to be used to determine stock status. However, the ratio of F to F_{MSY} (the F needed to produce maximum sustainable yield) is reliable and can be used to determine that overfishing is not occurring. It is not possible to be confident with regard to stock status, particularly a biomass determination, until the discards of Atlantic croaker from the South Atlantic shrimp trawl fishery can be adequately estimated and incorporated into the stock assessment.

Absolute estimates of total F are unavailable because of model uncertainty; however, the general trend in total F from the model is considered reliable due to support from the data. The trend in total F decreases substantially during the first five years of the time series (1988-1992) and shows an overall decline over the remainder of the time series, except for occasional, brief spikes (Figure 1). Retrospective analysis of the model showed that estimates of F decreased as more years of data were used. A series of sensitivity runs conducted over a range of plausible values of shrimp-trawl fishing mortality found that the ratio of directed fishing mortality to F_{MSY} was less than one in all cases, indicating overfishing was not occurring.

Again, absolute estimates of SSB are unavailable because of model uncertainty; however, the general trend in SSB from the model is considered reliable due to support from the data. Spawning stock biomass shows a nearly consistent increasing trend since 1998 (Figure 2). Sensitivity runs of the model, including rough estimates of shrimp trawl discards, do not change the overall trend in SSB. Retrospective analysis of the model showed that estimates of SSB increased as more years of data were used.

Recruitment, estimated in the model as age-1 abundance, has been variable but generally increasing over the time series. Figure 2 shows the trend in recruitment; absolute values are omitted because of uncertainty in abundance estimates. The model estimated the production of strong year classes in 1997, 2001, and 2007.

III. Status of the Fishery

Total Atlantic croaker harvest from New Jersey through the east coast of Florida in 2015 is estimated at 9.47 million pounds (Tables 2 and 3, Figure 3). This represents a 77% decline in total harvest since the peak of 41.2 million pounds in 2001 (77% commercial decline, 77% recreational decline). The commercial and recreational fisheries harvested 73% and 27% of the total, respectively. The vast majority of landings are from the Mid-Atlantic region (96% in 2015), and the recent decline in total landings is a result of both commercial and recreational landings declines in that region, although some states showed increases in either or both sectors (Figure 4). Commercial and recreational landings in the South Atlantic region have been generally stable over the last decade; however, 2010 showed large decreases in the South Atlantic states' recreational harvests, followed by a slow general increase in recreational harvest in this region. Recreational and commercial harvests in the South Atlantic region rose to 4.0% of coastwide harvest in 2015 from 0.6% in 2010.

Atlantic coast commercial landings of Atlantic croaker exhibit a cyclical pattern, with low domains in the 1960s to early 1970s and the 1980s to early 1990s, and high domains in the mid-to-late 1970s and the mid-1990s to early 2000s (Figure 3). Commercial landings increased from a low of 3.7 million pounds in 1991 to 30.1 million pounds in 2001 (Table 2); however, landings have declined consistently since 2003 to 6.9 million pounds in 2015, which registers below the 1960-2015 average of 13.33 million pounds. Within the management unit, the majority of 2015 commercial landings came from Virginia (66%) and North Carolina (26%). Maryland had the next highest level, with 4% of coastwide landings.

From 1981-2015, recreational landings of Atlantic croaker from New Jersey through Florida have varied between 2.8 million fish (1.3 million pounds) and 13.2 million fish (11.1 million pounds; Tables 3 and 4, Figure 5). Landings generally increased until 2001, held stable from 2001-2006 before exhibiting a declining trend from 2007 through 2015. The 2015 landings are estimated at 5.5 million fish and 2.5 million pounds. Virginia was responsible for 61% of the 2015 recreational landings, in numbers of fish, followed by Maryland (12%), and North Carolina and Florida (8.5% and 8.1%, respectively).

The number of recreational releases increased over the time series until 2008, when numbers released began to generally decline (Figure 5). However, percentage of released recreational catch continued to increase to a peak of 65% in 2013. In 2015, anglers released approximately 7.6 million fish, a decline from the 13.8 million fish released in 2013. Anglers released an estimated 58% of the croaker catch in 2015 (Figure 5).

IV. Status of Assessment Advice

A statistical catch-at-age (SCA) model was used in the last Atlantic croaker stock assessment (ASMFC 2010). This model combines catch-at-age data from the commercial and recreational fisheries with information from fishery-independent surveys and biological information such as growth rates and natural mortality rates to estimate the size of each age class and the exploitation rate of the population. The assessment was peer reviewed by a panel of experts in conjunction with the Southeast Data, Assessment, and Review (SEDAR) process.

The Review Panel was unable to support some of the assessment results due to uncertainty regarding the estimation of Atlantic croaker discards in the shrimp trawl fishery, and the application of estimates in modeling. Specifically, model-estimated values of stock size, fishing mortality, and biological reference points are too uncertain for use; however, the trends in model-estimated parameters and ratio-based fishing F reference points are considered reliable. Adequate discard estimates cannot be developed from currently available data, and assessments of Atlantic croaker will be unreliable until adequate estimates are properly incorporated into modeling. Despite the uncertainty in assessment results caused by shrimp trawl bycatch, the Review Panel concluded that it is unlikely that the stock is in trouble. The stock is not experiencing overfishing, biomass has been trending up, commercial catches are stable, and discards from the shrimp trawl fishery have been much reduced.

In conjunction with recommending the TLA for Atlantic croaker in 2014, the Plan Review Team also recommended the species for a stock assessment. The next benchmark stock assessment was initiated in the fall of 2015 and is currently underway in 2016.

V. Status of Research and Monitoring

There are no research or monitoring programs required of the states except for the submission of an annual compliance report. The following fishery-dependent (other than catch and effort data) and fishery-independent monitoring programs were reported in the 2016 compliance reports.

Fishery-Dependent Monitoring

- New Jersey: initiated biological monitoring of commercially harvested Atlantic croaker in 2006 in conjunction with ACCSP (2015 n=170)
- Maryland: commercial pound net fishery biological sampling (942 length measurements, 127 samples aged in 2015, first year that no sampled fish were older than age seven); Maryland Charter Boat CPUE (1993-present; 2015 catch was a time-series low of 36,601 fish).
- Delaware: collects trip-based information on pounds landed, area fished, effort, and gear type data through mandatory monthly state logbook reports submitted by fishermen.
- PRFC: has a mandatory commercial harvest daily reporting system, with reports due weekly.
- Virginia: commercial fishery biological sampling (8,649 length measurements, 8,632 weight measurements, 357 otolith ages, and 490 sex determinations in 2015)
- North Carolina: commercial fishery biological sampling since 1982 for length (2015 n=9,172), weight, otolith, sex determination, and reproductive condition.
- South Carolina: recreational fishery biological sampling via SCDNR State Finfish Survey, MRIP, and a SCDNR-managed mandatory trip reporting system for licensed charter boat operators. In 2013, SCDNR took over its portion of MRIP data collection.
- Georgia: collects biological information, including length, sex, and maturity stage, through the Marine Sportfish Carcass Recovery Project (8 fish in 2015)
- Florida: commercial fishery biological sampling (6 length measurements in 2015)

<u>Fishery-Independent Monitoring</u>

- New Jersey: 3 nearshore ocean (within 12 nm) juvenile trawl surveys (New Jersey Ocean Trawl Survey1988-present; 2015 CPUE well below time-series average; nearshore Delaware Bay juvenile trawl survey (1991-present; 2015 survey index was well below time series average); Delaware River juvenile seine survey (1980-present; 2015 survey index was below time series average but above 2013 value)
- Delaware: offshore Delaware Bay adult finfish trawl survey (1990-present; 2015 #/tow = 3.18; 28% increase in relative abundance from 2014 index, below mean and median for time series); nearshore Delaware Bay juvenile finfish trawl survey (1980-present; 2015 index increased from 1.16 in 2013 to 8.48; Inland Bays index increased from 1.83 in 2013 to 3.22 in 2014, before dropping to 1.19 in 2015).
- Maryland: summer gill net survey was initiated in 2013 on lower Choptank (steady decline in catch; 476 fish in 2013, 269 in 2014, and 21 in 2015); Atlantic coast bays juvenile otter trawl survey (standardized from 1989-present; 2015 GM of 0.49 fish/hectare below time series mean of 1.62); Chesapeake Bay juvenile trawl index (standardized from 1989-present; 2015 CPUE decreased from 3.76 in 2012 to 0.21 in 2015).
- Virginia: Independent monitoring results are not yet available for the 2015 fishing year. VIMS Juvenile Finfish and Blue Crab Trawl Survey (1988-present; 2014 index representing the 2013 year class was 1.550, which is down from the 2013 value of 16.6655.)
- North Carolina: Pamlico Sound juvenile trawl survey (1987-present; 2015 juvenile abundance index (mean number of individuals/tow) was 271, below the time series average)
- South Carolina: estuarine electroshock survey for juveniles (2001-present; 2015 CPUE increased slightly since 2014, after a sharp drop in 2013); SEAMAP shallow water (15-30 ft) trawl survey from Cape Hatteras to Cape Canaveral (1989-present; 2015 CPUE increased by 174% from 2014); inshore estuarine trammel net survey for adults (May-September, 1991-present; 2015 CPUE increased 20.3% from 2014); SCECAP estuarine trawl survey (1999-present, primarily targets juveniles, CPUE is the lowest since 2009).
- Georgia: Marine Sportfish Population Health Survey (trammel and gill net surveys in the Altamaha River Delta and Wassaw estuary, 2002-present; 2015 n=168); Ecological Monitoring Survey (trawl, 2003-present; 2015 n=19,214; CPUE increased from 40.62 in 2014 to 55.53 in 2015).
- Florida: juvenile seine survey (2002-present; 2015 index continued variable trend with a decrease from 2014); juvenile trawl survey (2002-present; 2015 index continued variable trend with a decrease from 2014); adult haul seine survey (2001-present; 2015 index value is the highest since 2011)

The Northeast Fishery Science Center performs a randomly stratified groundfish survey along the U.S. east coast. Atlantic croaker are one of the main species caught throughout much of the survey area and, since the surveys started in 1972, it provides a long term data set. Regionally, mean CPUE (catch-per-unit-effort) of Atlantic croaker has increased from north to south. Since 1994, there has been an increase in annual catch variability. Catch levels in 2015 increased 49.8% from 2014 and were above the long term mean.

The Northeast Area Monitoring and Assessment Program (NEAMAP) also conducts nearshore trawl surveys from Cape Cod, MA to Cape Hatteras, NC. NEAMAP grew out of an ASMFC resolution in October 1997 to begin the development of a coordinated fishery-independent sampling program in the Northeast. The program began in 2006 with a pilot study and instituted a spring and fall survey in 2008. The surveys target both juvenile and adult fishes, including croaker. The resulting adult Atlantic croaker abundance index indicates a stable trend in croaker from 2007-2014, with one notable large peak in 2012. Due to the short length in the time series, this index was not used in the ongoing 2015 benchmark stock assessment, but will be considered in future stock assessments.

VI. Status of Management Measures and Issues

Fishery Management Plan

Amendment 1 was fully implemented by January 1, 2006, and provided the management plan for the 2009 fishing year. There are no interstate regulatory requirements for Atlantic croaker. Should regulatory requirements be implemented in the future, all state programs must include law enforcement capabilities adequate for successfully implementing the regulations. Addendum I to Amendment 1 was initiated in August 2010 and approved in March 2011, in order to 1) revise the biological reference points to be ratio-based, and 2) remove the distinction of two regions within the management unit, based on the results of the 2010 stock assessment. Addendum II was approved August 2014 and established the TLA management framework for Atlantic croaker in order to better illustrate long-term trends in the fishery.

Traffic Light Approach

Addendum II established the TLA as the new management framework for Atlantic croaker. Under this management program, if thresholds for both population characteristics (harvest and adult abundance) achieve or exceed the proportion of threshold for the specified three year period, management action will be taken. No TLA analysis has been conducted for the 2015 fishing year, as the benchmark stock assessment for Atlantic croaker is currently underway. Addendum II states that the TLA is intended as an interim management measure in years between benchmark stock assessments. Therefore, the most recent analysis is described below.

Analysis of the harvest composite index for 2014 shows that this population characteristic tripped for a second consecutive year (Figure 6). The mean proportion of red color from 2012-2014 was 44.5%, well above the 30% threshold. The harvest composite index was comprised of commercial and recreational landings. Both commercial and recreational indices would have individually tripped in 2014 at the 30% level. The TLA for commercial landings was above the 60% threshold for the second consecutive year in 2014.

The abundance composite TLA index was broken into two components based on age composition. The adult composite index was generated from the NMFS and SEAMAP surveys, since the majority of Atlantic croaker captured in those surveys were ages 1+. The juvenile composite index was generated from the NC program 195 and VIMS surveys because these two captured primarily young-of-the-year Atlantic croaker.

All four TLA composite abundance indices showed declines in 2014 with red occurring in all but one (NC 195) index. The adult composite TLA characteristic (Figure 7) did not trigger in 2014 with only a 14.2% red proportion and no red in the two previous years. The juvenile composite characteristic index (Figure 8) also did not trip in 2014; however, this is due to high index values in 2012 and 2013. In 2014, the juvenile composite index had a red proportion above the 30% threshold, due to a precipitous drop in the VIMS index. The higher annual variability for the different color proportions in the juvenile composite characteristic, in comparison to the adult composite characteristic, is likely a reflection annual recruitment variability rather than population trends.

Overall, management triggers were not tripped in 2014 since both population characteristics (harvest and abundance) were not above the 30% threshold for the 2012-2014 time period. Nonetheless, the analysis shows declining trends in the fishery independent indices as well as the commercial and recreational harvests of Atlantic croaker.

De Minimis Requests

States are permitted to request *de minimis* status if, for the preceding three years for which data are available, their average commercial landings or recreational landings (by weight) constitute less than 1% of the coastwide commercial or recreational landings for the same three year period. A state may qualify for *de minimis* in either its recreational or commercial sector, or both, but will only qualify for exemptions in the sector(s) that it qualifies for as *de minimis*. Amendment 1 does not include any compliance requirements other than annual state reporting, which is still required of *de minimis* states, thus *de minimis* status does not exempt states from any measures.

In the annual compliance reports, the following states requested *de minimis* status: Delaware (commercial fishery), South Carolina (commercial fishery), Georgia (commercial and recreational fisheries), and Florida (commercial fishery). The commercial and recreational *de minimis* criteria for 2015 are based on 1% of the average coastwide 2013-2015 landings in each fishery: 79,670 pounds for the commercial fishery and 31,999 pounds for the recreational fishery. The Delaware commercial fishery qualifies for *de minimis* status with an average of 6,774 pounds. The South Carolina commercial fishery qualifies for *de minimis* status with an average of 106 pounds. The Georgia commercial and recreational fisheries qualify for *de minimis* status with averages of zero and 29,135 pounds, respectively. The Florida commercial fishery qualifies for *de minimis* status with an average of 51,162 pounds.

Changes to State Regulations

Beginning June 1, 2015, North Carolina enacted a requirement for shrimp fishermen to use an additional bycatch reduction device (BRD), so that trawl nets are configured with two BRDs. This requirement may affect the bycatch of Atlantic croaker in North Carolina state waters.

Atlantic Croaker Habitat

The ASMFC Habitat Committee is currently preparing a Sciaenid Habitat Source Document which outlines the habitat needs of Atlantic croaker at different life stages (egg, larval, juvenile, adult). The report also highlights threats and uncertainties facing these ecological areas and identifies

Habitat Areas of Particular Concern. It is expected that the Sciaenid Habitat Source Document will be available by the end of 2016.

Bycatch Reduction

Atlantic croaker is subject to both direct and indirect fishing mortality. Historically, croaker ranked as one of the most abundant bycatch species of the south Atlantic shrimp trawl fishery, resulting in the original FMP's recommendation that bycatch reduction devices (BRDs) be developed and required in the shrimp trawl fishery. Since then, the states of North Carolina through Florida have all enacted requirements for the use of BRDs in shrimp trawl nets in state waters, reducing croaker bycatch from this fishery (ASMFC 2010). However, bycatch and discard monitoring from the shrimp trawl fishery is inadequate, resulting in a major source of uncertainty for assessing this stock, as well as other important Mid- and South Atlantic species. Most of the discarded croaker are age-0 and thus likely have not yet reached maturity (ASMFC 2010). The North Carolina Division of Marine Fisheries conducted a two-year study, published in 2015, to collect bycatch data from state shrimp trawlers. It found that Atlantic croaker represent between 34-49% of the total observed finfish bycatch by weight in estuarine waters and between 20-42% in ocean waters. The at-net mortality for Atlantic croaker was found to be 23% (Brown 2015). These data will be valuable for incorporating estimates of removals in the next stock assessment.

Atlantic croaker are also discarded from other commercial fishing gears, primarily due to market pressures and few restrictions on croaker harvest at the state level. The NMFS Pelagic Observer Program provides data to estimate these discards for use in assessments; however, the time series is limited and only discards from gill nets and otter trawls could be estimated for the last assessment based on the available data. Since 1988, estimated discards have fluctuated between 94 and 15,176 mt without trend, averaging 2,503 mt (ASMFC 2010).

Atlantic croaker is also a major component of the scrap/bait fishery. Landings from this fishery are not reported at the species level, except in North Carolina, which has a continuous program in place to sample these landings and enable estimation of croaker scrap landings for use in the stock assessment. As part of the recent stock assessment, North Carolina estimated the scrap/bait landings, which have declined in recent years, from a high of 1,569 mt in 1989 to a low of 84 mt in 2008, primarily due to restrictions placed on fisheries producing the highest scrap/bait landings (ASMFC 2010). Regulations instituted by North Carolina include a ban on flynet fishing south of Cape Hatteras, incidental finfish limits for shrimp and crab trawls in inside waters, minimum mesh size restrictions in trawls, and culling panels in long haul seines.

South Carolina has also begun a state monitoring program to account for scrap landings. The state initiated a bait harvester trip ticket program for all commercial bait harvesters licensed in South Carolina. The impetus for this program is to track bait usage of small sciaenid species (croaker, spot, and whiting) as well as other important bait species.

Several states have implemented other commercial gear requirements that further reduce bycatch and bycatch mortality, while others continue to encourage the use of the BRD devices. NOAA Fisheries published a notice on June 24, 2011 for public scoping in the Federal Register to expand the methods for reducing bycatch interactions with sea turtles, which may have additional effects on the bycatch of finfish like Atlantic croaker in trawls (76 FR 37050). Continuing to reduce the quantity of sub-adult croaker harvested should increase spawning stock biomass and yield per recruit.

Atlantic croaker are also subject to recreational discarding. The percentage of Atlantic croaker released alive by recreational anglers has generally increased over time. Discard mortality was estimated to be 10% for the last stock assessment (ASMFC 2010). The use of circle hooks and appropriate handling techniques can help reduce mortality of released fish.

VII. Implementation of FMP Compliance Requirements for 2015

The PRT finds that all states have fulfilled the requirements of Amendment 1.

VIII. Recommendations

Management and Regulatory Recommendations

- Encourage the use of circle hooks to minimize recreational discard mortality.
- Consider approval of the *de minimis* requests from Delaware, South Carolina, Georgia, and Florida.
- Consider the basic research and monitoring information needed for informed management in light of the budgetary constraints limiting all state governments.

Research and Monitoring Recommendations

High Priority

- Develop and implement compatible and coordinated sampling programs for the South Atlantic shrimp trawl fishery in order to monitor and characterize Atlantic croaker bycatch in this fishery.
- Continue fisheries-independent surveys throughout the species range, with increased focus on collecting subsamples in the southern range.
- Encourage fishery-dependent biological sampling, with increased focus in the southern range and expanding the commercial and recreational fishery samples to afford a full age-length key
- Determine migratory patterns and mixing rates through cooperative, multi-jurisdictional tagging studies; further study the relative degree of genetic separation between fish in the northern and southern range of the species; and continue research and analysis of otolith microchemistry data.
- Collect bio-profile information and conduct studies on growth rates, age structure, estimates of fecundity, and maturity schedule throughout the species range with a standardized protocol.
- Evaluate bycatch and discard estimates from commercial and recreational fisheries, and extend coverage of scrap fishery sampling to other states.
- Develop fishery-independent size, age, and sex specific relative abundance estimates to monitor long-term changes in croaker abundance.
- Maintain funding for current surveys and monitoring to provide needed information for stock monitoring and assessment.

Medium Priority

- Develop age-size data that are representative of all seasons and areas in the fisheries on an annual basis.
- Improve catch and effort statistics from the commercial and recreational fisheries and develop more rigorous methods to standardize catch-per-unit-effort.
- Collect data on fishing attributes necessary to develop gear-type-specific fishing effort estimates.
- Evaluate commercial and recreational mortality under varying environmental factors and fishery practices and include in updated assessment.
- Update studies on the effectiveness of bycatch reduction devices (BRDs) in reducing croaker bycatch.
- Validate otolith aging methods with appropriate methods, e.g., tagging, chemical marking.
- Evaluate the optimum utilization (economic and biological) of a long-term fluctuating population such as croaker.
- Identify essential habitat requirements.
- Determine species interactions and predator/prey relationships for croaker (prey) and other more highly valued fisheries (predators).
- Determine the impacts of any dredging activity (i.e. for beach re-nourishment) on all life history stages of croaker.
- Investigate environmental covariates in stock assessment models.
- Examine socio-economic aspects of the fishery.
- Re-examine historical ichthyoplankton studies of the Chesapeake Bay for an indication of the magnitude of estuarine spawning.

IX. References

Atlantic States Marine Fisheries Commission (ASMFC). 1987. Fishery Management Plan for Atlantic Croaker. Washington (DC): ASMFC. Fishery Management Report No. 10. 90 p.

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X. Figures

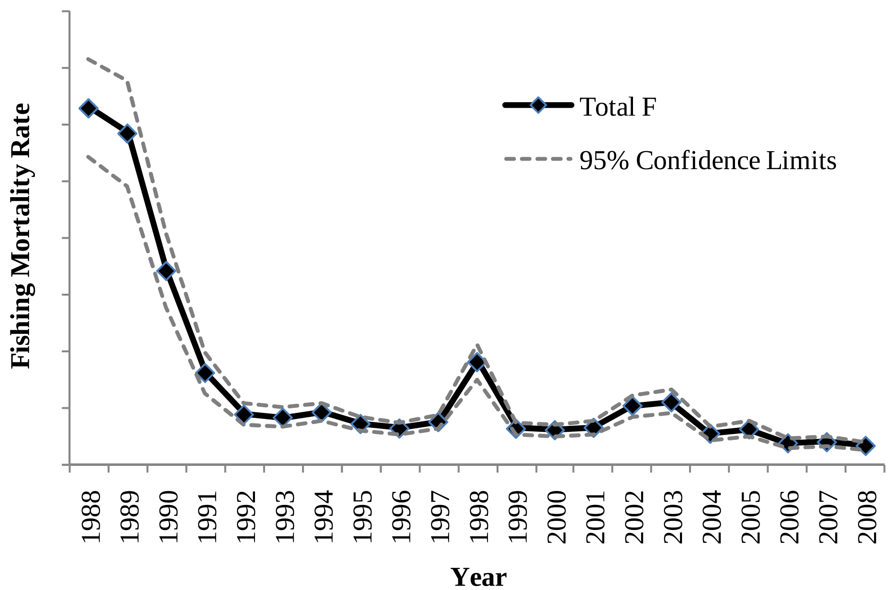


Figure 1. Trend in estimated total fishing mortality rate (F) of Atlantic croaker
(Absolute estimates of F are unreliable due to uncertainty regarding the estimation of Atlantic croaker discards in the shrimp trawl fishery, and the application of estimates in modeling. Source: ASMFC 2010.)

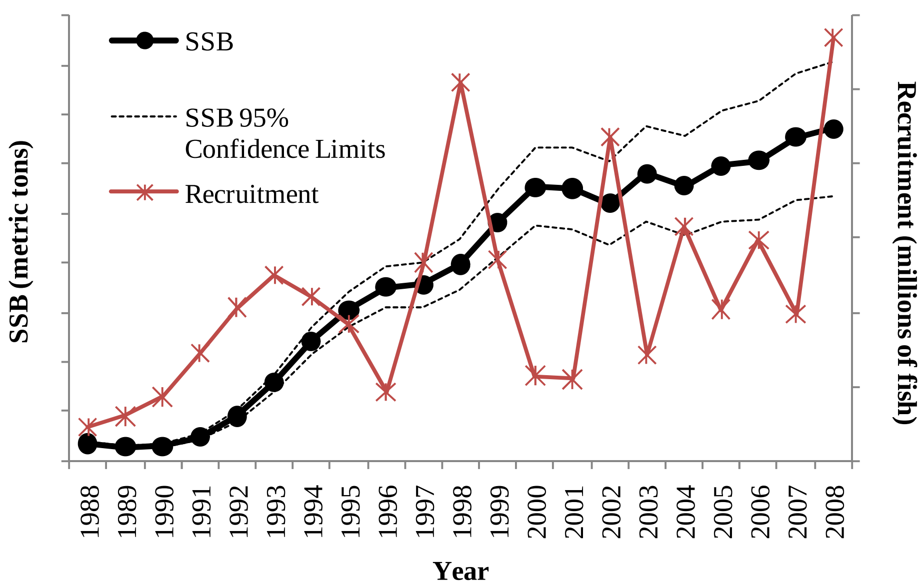


Figure 2. Trends in estimated spawning stock biomass (SSB, metric tons) and age-1 recruitment (numbers of fish) of Atlantic croaker
(Absolute estimates of stock size are unreliable due to uncertainty regarding the estimation of Atlantic croaker discards in the shrimp trawl fishery, and the application of estimates in modeling. Source: ASMFC 2010.)

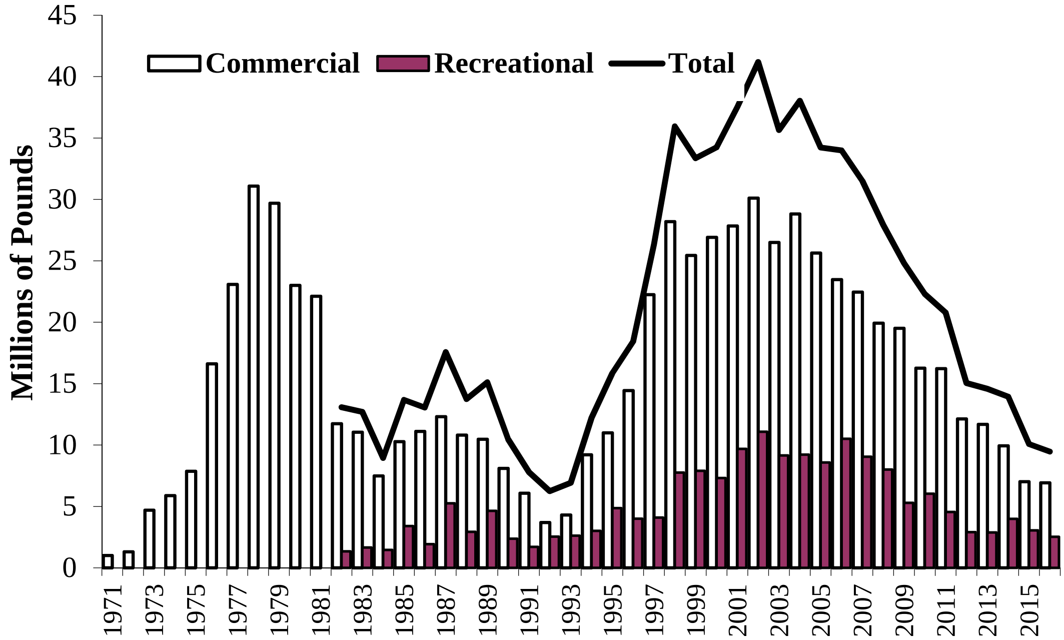


Figure 3. Atlantic croaker commercial, recreational, and total landings (pounds)
(See Tables 2 and 3 for values and source information. Commercial landings estimate for 2015 is preliminary. Reliable recreational landings estimates are not available before 1981.)

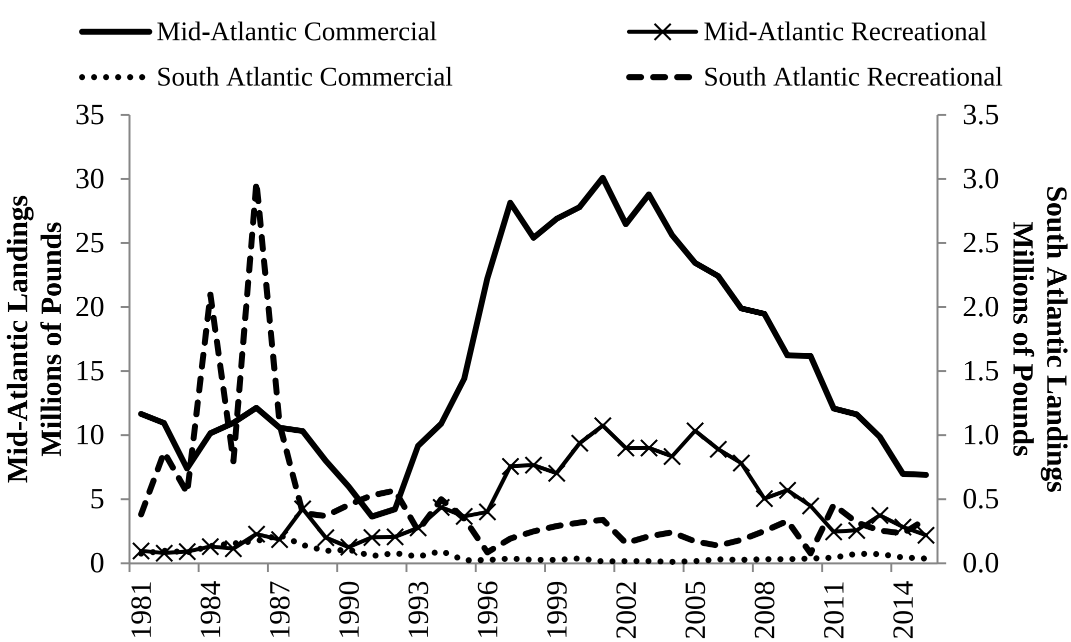


Figure 4. Mid-Atlantic (NJ-NC) and South Atlantic (SC-FL) landings (pounds)
(See Tables 2 and 3 for values and source information.)

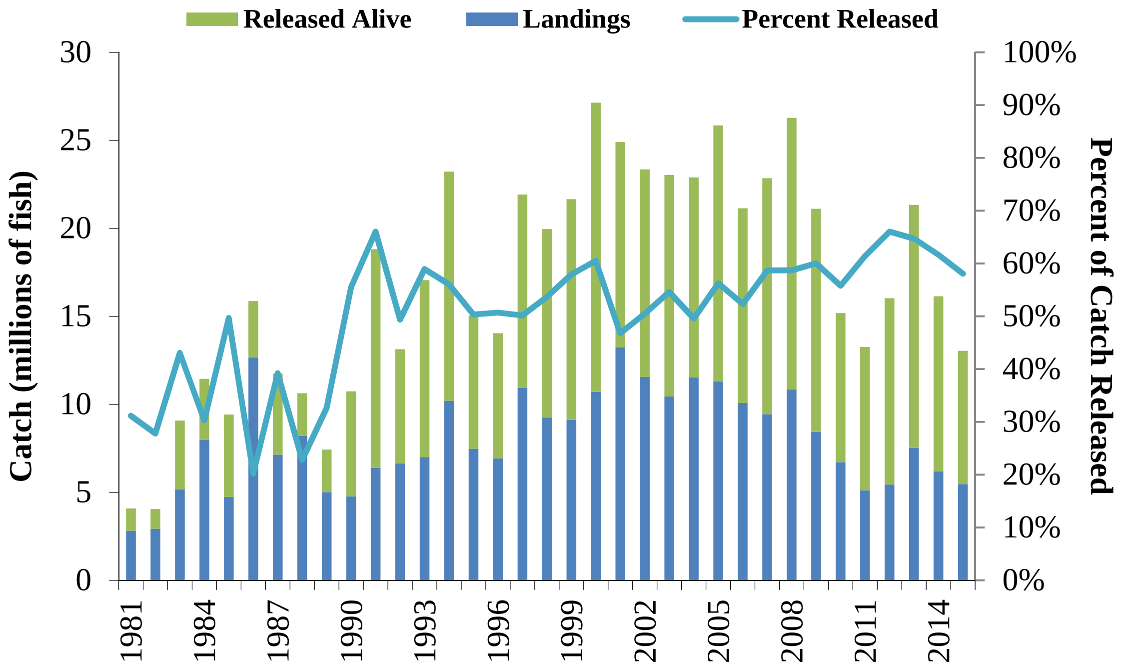


Figure 5. Recreational catch (landings and alive releases, in numbers) and the percent of catch that is released, 1981-2015
(See Tables 4 and 5 for values and source information.)

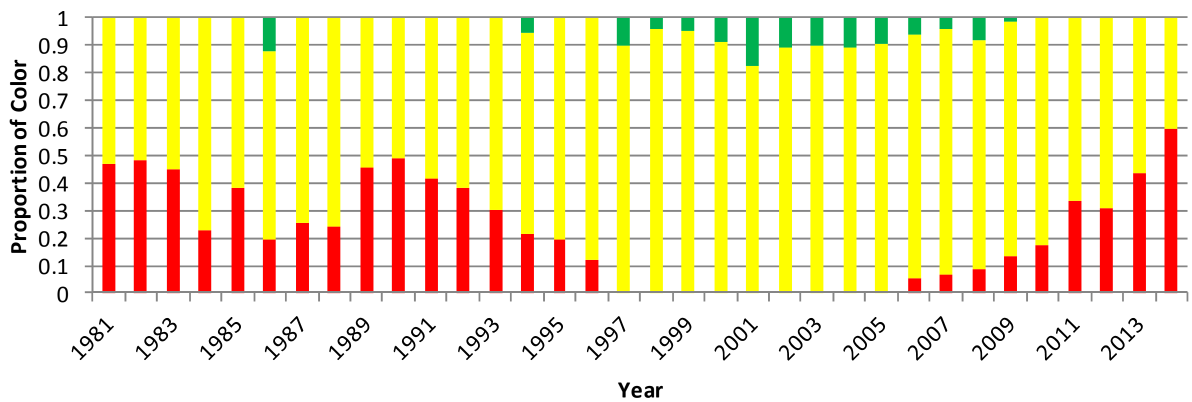


Figure 6. Annual color proportions for the harvest composite TLA of Atlantic croaker recreational and commercial landings.

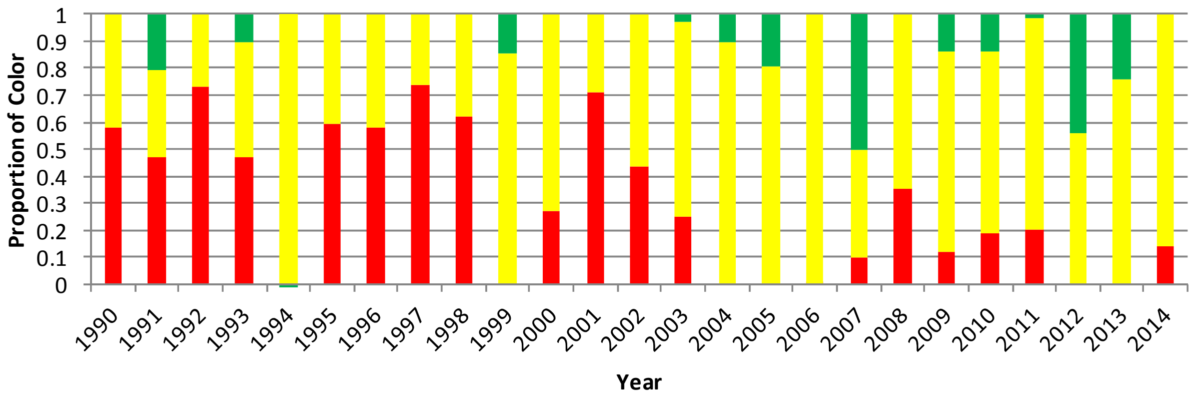


Figure 7. Adult croaker TLA composite characteristic index (NMFS and SEAMAP surveys).

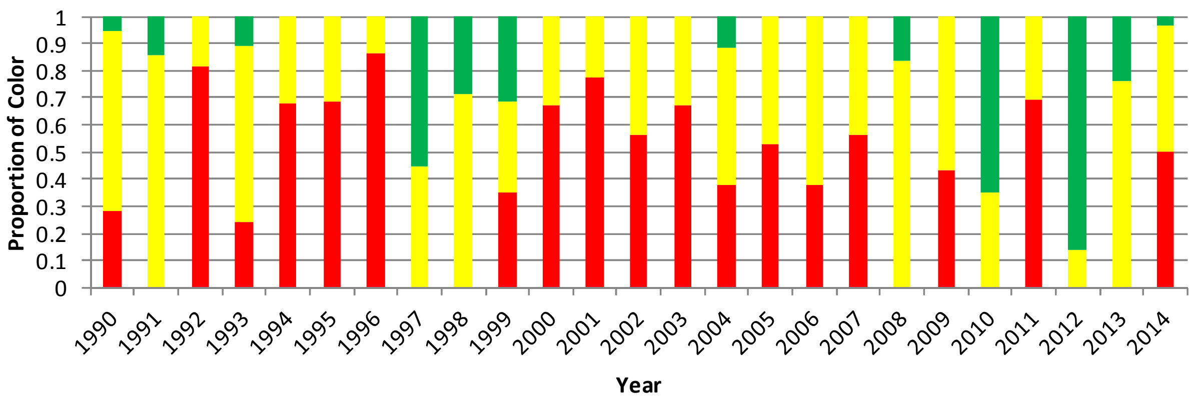


Figure 8. Juvenile croaker TLA composite characteristic index (NC 195 and VIMS surveys).

XI. Tables

Table 1. Summary of state regulations for Atlantic croaker in 2015*

State	Recreational	Commercial
NJ	none	otter/beam trawl mesh restriction for directed croaker harvest (>100 lbs in possession)
DE	8" minimum; recreational gill nets (up to 200 ft.) with license	8" minimum
MD	9" min, 25 fish/day, charter boat logbooks	9" minimum; open 3/16 to 12/31
PRFC	25 fish/day	pound net season: 2/15 to 12/15
VA	none	none
NC	recreational use of commercial gears with license and gear restrictions	
SC	mandatory for-hire logbooks, small Sciaenidae species aggregate bag limit of 50 fish/day	
GA	25 fish/day	25 fish/day limit except for trawlers harvesting shrimp for human consumption (no limit)
FL	none	none

* A commercial fishing license is required to sell croaker in all states with fisheries. For all states, general gear restrictions affect commercial croaker harvest.

Table 2. Commercial harvest (pounds) of Atlantic croaker by state, 1981-2015
(Estimates for 2015 are preliminary. Sources: state compliance reports; personal communication with ACCSP, Arlington, VA.)

Year	NJ	DE	MD	PRFC	VA	NC	SC	GA	FL	Total
1981	23,500	0	2,104	648	429,800	11,205,342	2,441	1,038	72,112	11,736,985
1982	100	0	7,091	188	119,300	10,824,953	386	2,177	95,357	11,049,552
1983	200	0	417	1,549	150,400	7,249,680	3,200	1,097	81,737	7,488,280
1984	57,700	0	27,072	73,701	817,700	9,170,775	3,793	434	131,375	10,282,550
1985	48,800	100	9,510	19,854	2,171,821	8,714,432	1,256		153,803	11,119,576
1986	106,000	500	135,922	99,373	2,367,000	9,424,828	924		173,531	12,308,078
1987	357,600	800	119,409	102,691	2,719,500	7,289,191	698	553	217,932	10,808,374
1988	30,100	200	98,855	12,796	1,749,200	8,434,415	2,614	304	140,033	10,468,517
1989	137,100	0	89,173	5,579	949,649	6,824,088	1,950		95,021	8,102,560
1990	644	42	2,473	5,115	201,353	5,769,512	1,190		104,402	6,084,731
1991	31,292	700	6,183	996	164,126	3,436,960	*		56,739	3,696,996
1992	51,600	800	17,050	17,692	1,339,353	2,796,612			79,040	4,302,147
1993	183,414	2,500	114,159	262,482	5,326,293	3,267,652	*		52,031	9,208,531
1994	117,256	3,000	158,918	240,271	5,759,975	4,615,754	*		96,018	10,991,192
1995	334,654	13,000	489,506	606,184	6,949,639	6,021,284	*		22,879	14,437,146
1996	621,889	9,681	792,326	1,427,285	9,409,904	9,961,834			26,045	22,248,964
1997	1,994,446	10,509	1,088,969	1,518,196	12,832,221	10,711,667	*		36,577	28,192,585
1998	1,029,332	10,368	1,006,529	610,885	11,898,586	10,865,897			26,418	25,448,015
1999	2,071,046	14,729	948,191	1,190,138	12,481,326	10,185,507			26,824	26,917,761
2000	2,130,465	11,121	902,379	1,812,130	12,822,400	10,122,627			37,953	27,839,075
2001	1,389,837	22,736	1,488,815	1,963,294	13,214,731	12,017,424		*	14,831	30,111,668
2002	1,828,484	10,732	894,879	1,421,094	12,133,834	10,189,153	*	*	17,191	26,495,367
2003	1,575,738	16,561	713,205	1,128,003	10,937,167	14,429,197	140	*	16,348	28,816,359
2004	2,067,992	30,369	1,354,982	1,631,596	8,550,574	11,993,003	*	*	11,413	25,639,929
2005	1,847,753	36,624	972,801	481,912	8,211,802	11,903,292	41	*	16,520	23,470,745
2006	1,617,144	19,307	466,833	670,276	9,252,110	10,396,554	160	*	30,272	22,452,656
2007	1,357,731	13,522	477,887	188,567	10,557,370	7,301,296	*		27,028	19,923,401
2008	946,062	10,465	592,211	337,062	11,796,771	5,791,766	116	*	31,560	19,506,013
2009	584,384	16,341	448,550	234,101	8,808,677	6,135,437	215	0	32,313	16,260,018
2010	342,116	6,182	490,067	162,571	7,879,847	7,312,159	3	0	36,960	16,229,905
2011	465,117	12,252	704,019	243,196	5,611,855	5,054,186	44	*	44,932	12,135,601
2012	363,381	2,811	908,619	273,849	6,963,815	3,106,615	62	*	74,023	11,693,175
2013	337,313	6,700	850,336	130,285	6,621,836	1,928,223	2	0	71,448	9,946,143
2014	271,706	9,647	479,079	177,777	3,406,958	2,629,909	247	0	45,319	7,020,642
2015	81,311	3,975	288,331	118,996	4,585,623	1,819,066	69	0	36,720	6,934,091

* confidential data

Table 3. Recreational harvest (pounds) of Atlantic croaker by state, 1981-2015
(Source: personal communication with NMFS Fisheries Statistics Division, Silver Spring, MD.)

Year	NJ	DE	MD	VA	NC	SC	GA	FL	Total
1981	582	2,317		535,297	426,240	67,284	9,665	305,547	1,346,932
1982			70,276	455,250	264,607	67,015	45,161	754,956	1,657,265
1983			32,053	486,006	395,402	14,158	25,412	510,599	1,463,630
1984			86,462	634,870	584,660	161,661	80,684	1,856,599	3,404,936
1985			17,169	843,414	278,214	72,780	40,421	684,449	1,936,447
1986		2,595	116,542	2,034,337	126,888	173,028	21,504	2,783,651	5,258,545
1987			191,628	1,306,814	352,346	64,696	14,947	1,005,053	2,935,484
1988		827	926,399	2,390,573	935,460	54,313	20,313	316,900	4,644,785
1989		284	19,189	1,329,680	658,567	80,580	21,138	268,335	2,377,773
1990		112	37,873	875,427	347,183	123,795	205,352	127,525	1,717,267
1991	4,264	10,972	117,210	1,728,021	157,660	16,173	54,116	460,453	2,548,869
1992		3,291	53,556	1,768,962	233,533	28,512	132,596	407,672	2,628,122
1993	844	9,641	476,866	1,993,915	282,910	18,005	55,604	180,517	3,018,302
1994	818	2,892	991,166	3,024,118	351,230	128,306	34,048	337,474	4,870,052
1995	9,515	82,864	567,149	2,675,381	326,135	25,386	20,862	301,918	4,009,210
1996	39,099	205,526	702,037	2,716,759	346,501	14,480	21,797	50,038	4,096,237
1997	278,758	340,198	1,117,999	5,522,195	309,457	53,863	26,272	113,096	7,761,838
1998	135,733	293,560	1,150,459	5,920,436	161,117	76,821	30,966	141,756	7,910,848
1999	301,957	522,201	1,024,398	4,969,283	212,991	26,356	32,375	231,694	7,321,255
2000	1,125,730	483,963	2,672,996	4,888,910	201,306	13,457	62,390	242,914	9,691,666
2001	1,132,214	304,127	1,278,699	7,674,759	355,009	10,750	7,844	320,487	11,083,889
2002	268,423	250,899	1,162,278	7,075,130	242,184	29,343	10,622	117,880	9,156,759
2003	682,698	262,114	2,069,176	5,674,111	317,606	59,399	71,881	79,397	9,216,382
2004	859,373	307,898	1,078,951	5,792,487	306,029	69,510	15,597	156,395	8,586,240
2005	1,193,848	755,232	987,748	7,240,971	168,797	34,922	14,995	121,320	10,517,833
2006	632,085	729,730	864,415	6,460,336	222,286	16,240	9,210	112,512	9,046,814
2007	453,854	320,458	806,024	6,111,612	131,185	11,109	12,756	159,077	8,006,075
2008	527,179	317,997	462,531	3,612,065	132,731	16,212	12,948	223,121	5,304,784
2009	114,015	239,126	1,512,280	3,708,788	131,742	71,517	36,771	222,239	6,036,478
2010	36,063	40,166	977,562	3,185,485	241,993	11,970	10,067	56,023	4,559,329
2011	21,460	52,889	443,520	1,837,183	99,298	240,665	21,548	194,848	2,911,411
2012	96,366	61,535	397,873	1,905,100	105,530	12,433	13,503	292,365	2,884,705
2013	539,125	100,320	744,642	2,217,664	141,880	32,138	17,209	205,970	3,998,948
2014	205,388	180,787	610,667	1,602,504	227,949	35,785	32,833	165,353	3,061,266
2015	99,768	67,683	360,095	1,479,567	187,590	76,531	37,363	230,968	2,539,565

Table 4. Recreational harvest (numbers) of Atlantic croaker by state, 1981-2015
(Source: personal communication with NMFS Fisheries Statistics Division, Silver Spring, MD.)

Year	NJ	DE	MD	VA	NC	SC	GA	FL	Total
1981	1,054	3,003	0	964,013	1,043,240	165,742	35,591	598,896	2,811,539
1982			10,452	273,039	596,493	193,554	169,749	1,682,619	2,925,906
1983			108,355	2,154,133	1,620,909	60,811	75,173	1,148,227	5,167,608
1984			211,035	2,047,720	2,147,871	588,114	202,364	2,781,742	7,978,846
1985			21,276	2,284,334	723,933	260,265	144,341	1,306,955	4,741,104
1986		4,694	123,578	6,384,966	356,742	599,442	69,887	5,118,552	12,657,861
1987	0	0	208,488	3,234,224	904,030	166,978	44,783	2,580,727	7,139,230
1988		1,186	1,005,452	4,048,690	2,256,128	144,057	64,093	685,778	8,205,384
1989		478	22,871	2,203,504	2,131,763	217,023	72,598	359,417	5,007,654
1990		281	100,673	2,374,679	1,063,452	346,631	585,380	304,064	4,775,160
1991	16,235	37,500	288,471	4,298,542	434,067	100,816	184,435	1,030,115	6,390,181
1992	0	9,854	117,427	4,524,040	723,823	74,051	440,185	754,595	6,643,975
1993	2,552	19,352	805,560	4,990,098	755,998	32,700	89,734	304,067	7,000,061
1994	1,567	5,718	1,633,581	6,494,691	1,179,735	188,520	102,974	599,032	10,205,818
1995	15,184	136,865	827,183	5,029,708	850,606	75,422	100,826	438,076	7,473,870
1996	35,037	235,389	775,115	4,997,021	662,240	37,464	61,957	116,575	6,920,798
1997	342,089	385,586	1,053,232	8,066,926	661,116	118,428	64,050	235,430	10,926,857
1998	143,404	391,231	1,126,058	6,730,181	387,427	170,528	64,953	234,360	9,248,142
1999	357,261	662,724	1,209,572	5,881,671	442,185	54,761	104,438	403,982	9,116,594
2000	1,023,442	517,886	2,674,880	5,486,159	391,056	32,332	128,922	455,870	10,710,547
2001	1,177,813	312,005	1,319,928	9,335,313	635,552	19,802	21,503	426,264	13,248,180
2002	253,472	261,634	1,223,385	9,129,060	408,944	66,409	36,497	177,751	11,557,152
2003	692,391	341,174	1,619,766	6,695,192	490,399	198,339	248,853	165,459	10,451,573
2004	855,927	389,218	896,855	8,259,608	511,418	171,544	38,599	415,570	11,538,739
2005	1,227,349	825,267	784,246	7,657,147	326,777	143,387	39,561	302,784	11,306,518
2006	511,220	763,216	754,969	7,221,148	556,024	58,500	34,081	172,586	10,071,744
2007	406,238	359,064	872,838	6,944,886	461,162	38,147	45,068	310,130	9,437,533
2008	600,975	368,911	619,942	8,388,497	317,940	65,853	38,246	449,054	10,849,418
2009	193,464	451,849	1,335,439	5,327,388	368,990	238,900	82,269	438,209	8,436,508
2010	63,027	75,404	1,136,589	4,743,697	478,156	46,464	35,635	132,664	6,711,636
2011	40,855	92,289	554,206	3,305,707	246,676	349,463	44,044	476,292	5,109,532
2012	266,832	84,403	701,482	3,445,232	288,813	27,873	38,402	589,642	5,442,679
2013	889,754	222401	1155538	4273744	411,882	106,938	54915	411,858	7,527,030
2014	263,734	359,010	1,085,339	3,429,768	541,657	149,890	64,138	298,322	6,191,858
2015	116,109	127,712	650,335	3,342,008	463,867	216,168	111,344	440,363	5,467,906

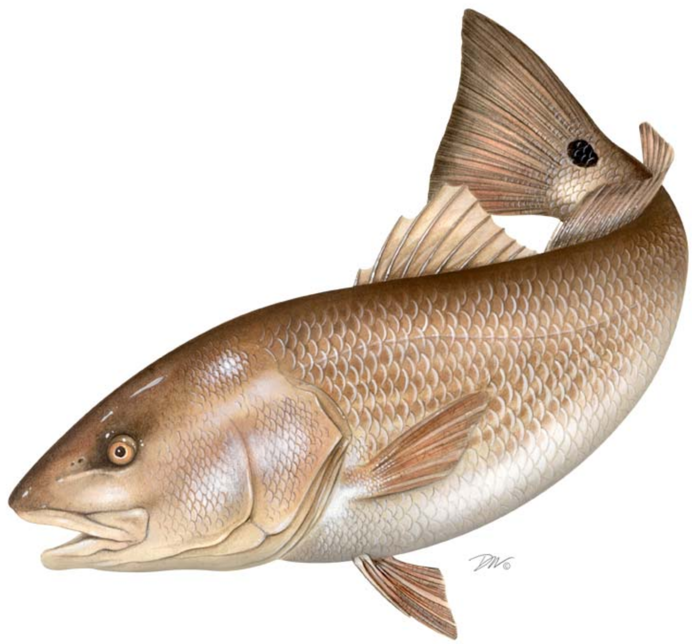
Table 5. Recreational releases (number) of Atlantic croaker by state, 1981-2015
(Source: personal communication with NMFS Fisheries Statistics Division, Silver Spring, MD.)

Year	NJ	DE	MD	VA	NC	SC	GA	FL	Total
1981			16,233	324,238	704,259	128,192	13,481	85,740	1,272,143
1982				77,756	641,327	107,340	111,630	188,277	1,126,330
1983			1,507,184	1,410,151	424,562	119,036	70,499	379,021	3,910,453
1984			70,192	673,080	1,701,418	746,905	37,573	236,432	3,465,600
1985			13,132	1,616,052	1,596,901	238,678	66,649	1,146,582	4,677,994
1986		1,757	43,399	2,578,268	137,841	84,335	40,623	318,511	3,204,734
1987	1,374	861	32,074	2,056,580	560,853	108,366	76,908	1,770,697	4,607,713
1988		582	273,231	832,284	984,219	112,271	20,021	200,630	2,423,238
1989		1,307	41,822	1,342,169	891,926	58,642	17,632	72,822	2,426,320
1990		1,268	88,688	3,922,564	1,351,152	111,085	317,497	168,144	5,960,398
1991	91,633	75,319	3,352,190	7,418,045	669,385	25,168	140,402	647,824	12,419,966
1992	4,103	43,583	856,292	4,167,137	954,494	26,729	178,267	251,343	6,481,948
1993	5,799	13,194	2,504,362	5,795,479	1,499,217	16,949	83,203	138,875	10,057,078
1994	17,253	14,069	1,628,824	7,676,780	3,110,528	141,513	99,026	331,736	13,019,729
1995	31,019	41,574	496,046	5,494,289	1,172,716	108,345	89,609	141,732	7,575,330
1996	17,585	76,851	403,776	5,151,206	1,218,799	64,494	60,282	126,300	7,119,293
1997	111,468	384,233	1,497,670	7,275,160	1,443,568	138,107	25,630	116,276	10,992,112
1998	221,324	839,932	3,021,780	4,990,541	1,060,928	266,068	159,928	152,744	10,713,245
1999	860,325	1,017,499	2,483,800	5,668,925	1,368,478	116,826	57,567	967,894	12,541,314
2000	688,746	694,813	4,967,856	7,811,048	1,569,385	96,402	169,903	428,131	16,426,284
2001	853,621	285,123	1,585,806	7,086,706	1,256,807	115,284	192,362	282,461	11,658,170
2002	369,003	361,355	2,523,276	7,107,656	925,806	92,498	194,474	217,054	11,791,122
2003	833,508	654,697	1,393,224	6,543,524	1,552,315	440,446	965,496	192,356	12,575,566
2004	1,237,164	599,207	854,132	6,276,767	1,656,049	320,788	154,259	253,951	11,352,317
2005	1,692,401	674,684	1,136,876	8,738,109	1,401,413	321,861	280,889	293,692	14,539,925
2006	503,490	937,193	1,783,557	4,193,675	2,578,819	595,075	283,851	187,562	11,063,222
2007	590,078	672,771	1,258,131	8,504,212	1,608,120	224,454	228,564	321,559	13,407,889
2008	2,373,945	601,994	2,127,219	7,806,627	1,419,019	205,373	293,926	596,450	15,424,553
2009	108,370	537,587	1,137,578	7,621,484	1,912,670	514,839	434,608	406,822	12,673,958
2010	167,191	228,936	1,011,236	4,824,151	1,598,139	187,184	263,987	188,637	8,469,461
2011	62,391	88,524	365,716	4,872,928	1,798,230	240,605	262,493	452,669	8,143,556
2012	1,134,778	444,935	1,578,524	5,091,063	1,255,216	271,321	167,488	641,570	10,584,895
2013	765,652	764,045	2,905,537	5,968,340	1,984,701	799,982	298,409	318,319	13,804,985
2014	206,098	630,964	1,148,867	3,606,078	2,713,787	780,171	470,751	393,360	9,950,076
2015	78,135	111,422	499,647	2,760,541	2,532,950	959,887	210,454	418,286	7,571,322

2016 REVIEW OF THE
ATLANTIC STATES MARINE FISHERIES COMMISSION
FISHERY MANAGEMENT PLAN FOR

RED DRUM
(*Sciaenops ocellatus*)

2015 FISHING YEAR



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I. Status of the Fishery Management Plan

Date of FMP Approval:	Original FMP – October 1984
Amendments:	Amendment 1 – October 1991 Amendment 2 – June 2002 Addendum 1 – August 2013
Management Areas:	The Atlantic coast distribution of the resource from New Jersey through Florida Northern: New Jersey through North Carolina Southern: South Carolina through the east coast of Florida
Active Boards/Committees:	South Atlantic State/Federal Fisheries Management Board; Red Drum Technical Committee, Stock Assessment Subcommittee, Plan Development Team, Plan Review Team, South Atlantic Species Advisory Panel

The Atlantic States Marine Fisheries Commission (ASMFC) adopted an interstate Fishery Management Plan (FMP) for Red Drum in 1984. The original management unit included the states from Maryland to Florida. In 1988, the Interstate Fisheries Management Program (ISFMP) Policy Board requested that all Atlantic coastal states from Maine to Florida implement the plan's recommended management regulations to prevent development of northern markets for southern fish. The states of New Jersey through Florida are now required to follow the FMP, while Maine through New York (including Pennsylvania) are encouraged to implement consistent provisions to protect the red drum spawning stock.

In 1990, the South Atlantic Fishery Management Council (Council) adopted a FMP for red drum that defined overfishing and optimum yield (OY) consistent with the Magnuson Fishery Conservation and Management Act of 1976. Adoption of this plan prohibited the harvest of red drum in the exclusive economic zone (EEZ), a moratorium that remains in effect today. Recognizing that all harvest would take place in state waters, the Council FMP recommended that states implement measures necessary to achieve the target level of at least 30% escapement.

Consequently, ASMFC initiated Amendment 1 in 1991, which included the goal to attain optimum yield from the fishery over time. Optimum yield was defined as the amount of harvest that could be taken while maintaining the level of spawning stock biomass per recruit (SSBR) at or above 30% of the level which would result if fishing mortality was zero. However, a lack of information on adult stock status resulted in the use of a 30% escapement rate of sub-adult red drum to the off-shore adult spawning stock.

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

As hoped, these management measures led to increased escapement rates of juvenile red drum. Escapement estimates for the northern region of New Jersey through North Carolina (18%) and the southern region of South Carolina through Florida (17%) were estimated to be above the 10% phase-in goal, yet still below the ultimate goal of 30% (Vaughan and Carmichael 2000). North Carolina, South Carolina, and Georgia implemented substantive changes to their regulations from 1998-2001 that further restricted harvest.

The Council adopted new definitions of OY and overfishing for red drum in 1998. Optimum yield was redefined as the harvest associated with a 40% static spawning potential ratio (sSPR), overfishing as an sSPR less than 30%, and an overfishing threshold as 10% sSPR. In 1999, the Council recommended that management authority for red drum be transferred to the states through the Commission's Interstate Fishery Management Program (ISFMP) process. This was recommended, in part, due to the inability to accurately determine an overfished status, and therefore stock rebuilding targets and schedules, as required under the revised Sustainable Fisheries Act of 1996. The transfer necessitated the development of an amendment to the interstate FMP in order to include the provisions of the Atlantic Coastal Fisheries Cooperative Management Act.

ASFMC adopted Amendment 2 to the Red Drum FMP in June 2002 (ASMFC 2002), which serves as the current management plan. The goal of Amendment 2 is to achieve and maintain the OY for the Atlantic coast red drum fishery as the amount of harvest that can be taken by U.S. fishermen while maintaining the sSPR at or above 40%. There are four plan objectives:

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

The management area extends from New Jersey through the east coast of Florida, and is separated into a northern and southern region at the North Carolina/South Carolina border. The sSPR of 40% is considered a target; an sSPR below 30% (threshold level) results in an overfishing determination for red drum. Amendment 2 required all states within the management unit to implement appropriate recreational bag and size limit combinations needed to attain the target sSPR, and to maintain current, or implement more restrictive, commercial fishery regulations. All states were in compliance by January 1, 2003. See Table 1 for state commercial and recreational regulations in 2015.

Following the approval of Amendment 2 in 2002, the process to transfer management authority to ASMFC began, including an Environmental Assessment and public comment period. The final rule became effective November 5, 2008. It repeals the federal Atlantic Coast Red Drum Fishery Management Plan and transfers management authority of Atlantic red drum in the exclusive economic zone from the South Atlantic Fishery Management Council to the Atlantic States Marine Fisheries Commission.

The Board approved Addendum I to Amendment 2 in August 2013. The Addendum revised the habitat section of Amendment 2 to include current information on red drum spawning habitat and life-stages (egg, larval, juvenile, sub-adult, and adult). It also identified and described the distribution of key habitats and habitats of concern.

II. Status of the Stocks

The red drum stock is currently being evaluated in accordance with the 2009 Benchmark Stock Assessment. At present, only an overfishing status can be determined for red drum (SAFMC 2009).

Northern Region (NJ-NC)

Recruitment (age 1 abundance) has varied since 1989 (Figure 1). Abundance of age 1 – 3 red drum increased during 1990 – 2000 and has fluctuated thereafter (Figure 2). The initial increase in abundance of these age groups can be explained by the reduction in exploitation rates early in the time series, followed by relative stability (Figure 3).

The trend in the three-year average sSPR indicates low sSPR early in the time series with increases during 1990 – 1997 and fluctuations thereafter (Figure 4). The average sSPR has been above the overfishing threshold ($F_{30\%}$) since 1994, and at or above the target ($F_{40\%}$) since 1996, except during one year (2002). Fishing pressure and mortality appear to be stabilized near the target fishing mortality. The average sSPR is also likely above the target benchmark.

Southern Region (SC-FL)

Recruitment (age 1 abundance) has fluctuated without apparent trend since 1989 (Figure 1). Abundance of age 1 – 3 red drum increased during 1989 – 1992, declined during 1992 – 1998, and has fluctuated thereafter (Figure 2). As with the northern stock, the initial increase in abundance of these age groups can be explained by the reduction in exploitation rates early in the time series. Exploitation rates appear to have slightly increased since 1990 (Figure 3).

A high level of uncertainty exists around the sSPR estimates for the southern region. More work is needed to make definitive statements about sSPR, but it is likely that the average sSPR in 2007 was above the overfishing threshold ($F_{30\%}$), although not above the target as was probable in the northern region. The stock is therefore likely not subject to overfishing at this time. Due to the uncertainties, it is not possible to determine status in relation to the target of 40% sSPR.

Ongoing 2016 Benchmark Assessment

The Technical Committee (TC) and Stock Assessment Subcommittee (SASC) is currently working on a new Benchmark Stock Assessment. Given the high level of uncertainty around the sSPR estimates in the 2009 assessment, a primary goal of the current assessment has been to accurately estimate abundance and biomass in order to determine whether or not the stock is overfished and/or overfishing is occurring. In order to achieve this, the SASC decided to switch modeling frameworks and develop a Stock Synthesis model (SS3).

During the transition to SS3, the SASC encountered several challenges in developing SS3 models that estimate plausible stock conditions and dynamics. A specific concern was the lack of stability in both the northern and southern models. These issues persisted through the SEDAR 44 workshop and, as a result, the peer review took on a collaborative approach where panelists reviewed the assessment work to date and provided constructive comments on modifications to the models. The SASC continued work on the stock assessment following the Review Workshop and was able to make significant improvements. Updated work by the SASC was desk reviewed in April 2016. The Peer Review Panel recommended the stock assessment for management and presented to the Board in May 2016. During their review of the assessment, the Board requested additional analysis to ensure the results of the new model are accurate. These analyses include an evaluation of tag return rates in the fishery and continuity models, both of which will be presented to the Board in October 2016.

III. Status of the Fishery

Total red drum landings from New Jersey through the east coast of Florida in 2015 are estimated at 1.62 million pounds (Tables 2 and 3, Figure 5). This is roughly 834,000 pounds less than was landed in 2014 and 1.482 million pounds less than in 2013. 2015 total landings also fall below the previous ten-year (2006-2015) average of 1.89 million pounds. The commercial and recreational fisheries harvested 9% and 91% of the total, respectively. The southern region includes South Carolina through Florida's east coast, while the northern region includes New Jersey through North Carolina. In 2015, 68% of the total landings came from the southern region where the fishery is exclusively recreational, and 32% from the northern region (Figure 6).

Coastwide commercial landings show no particular temporal trends. In the last 50 years, landings have ranged from approximately 55,000 pounds (in 2004) to 440,000 pounds (in 1950, Figure 5). In 2015, red drum were commercially landed only in Maryland, Virginia, and North Carolina (Table 2). Coastwide commercial harvest slightly increased from 102,949 pounds in 2014 to 141,836 pounds in 2015, with 99% harvested by North Carolina. Historically, North Carolina and Florida shared the majority of commercial harvest, but commercial harvest has been prohibited in Florida under state regulation since January 1988. South Carolina also banned commercial harvest and sale of native caught red drum beginning in 1987, and in 2013 Georgia designated Red Drum Gamefish status, eliminating commercial harvest and sale.

In North Carolina, a daily commercial trip limit and an annual cap of 250,000 pounds with payback of any overage constrain the commercial harvest. Unique to this state, the red drum fishing year extends from September 1 to August 31. In 2008, the Board approved use of the fishing year to monitor the cap. During the 2009/2010 and the 2013/2014 fishing years, North Carolina had overages of 25,858 pounds and 12,753 pounds, respectively. The commercial harvest for each following fishing year remained well below the adjusted cap allowance, providing sufficient payback.

Recreational harvest of red drum peaked in 1984 at 1.05 million fish (or 2.6 million pounds; Tables 3 and 4). Since 1988, the number has fluctuated without trend between 250,000 and 760,000 fish (800,000 to 2.6 million pounds; Figures 5 and 7). Recreational harvest decreased from 641,658 fish (2.3 million pounds) in 2014 to 426,304 fish (1.5 million pounds) in 2015. The 2015 harvest is lower than the 10 year average (2006-2015) for recreational harvest in numbers (504,346) and pounds (1.7 million). Florida anglers landed the largest share of the coastwide recreational harvest in numbers (53%), followed by South Carolina (25%), Georgia (11%), and North Carolina (9%).

Anglers release far more red drum than they keep; the percent of the catch released has been over 80% during the last decade (Figure 7). Recreational releases show an increasing trend over the time series. The proportion of releases in 2015 was 84% (versus 83% in 2014), and the overall number of fish released was 2.2 million in 2015 (Figure 3, Table 5). It is estimated that 8% of released fish die as a result of being caught, resulting in an estimated 175,608 dead discarded fish in 2015 (Table 5). Recreational removals from the fishery are thus estimated to be 601,912 fish in 2015 (Figure 8).

IV. Status of Assessment Advice

Current stock status information comes from the 2009 benchmark stock assessment (SAFMC 2009) completed by the ASMFC Red Drum Stock Assessment Subcommittee and Technical Committee; peer reviewed by an independent panel of experts at the Southeast Data, Assessment, and Review (SEDAR) 18; and approved by the South Atlantic State-Federal Fisheries Management Board for use in management decisions. Previous interstate management decisions were based on regional assessments conducted by Vaughan and Helser (1990), Vaughan (1992, 1993, 1996), and Vaughan and Carmichael (2000). Several states have also conducted state-specific assessments (e.g., Murphy and Munyandorero 2009; Takade and Paramore 2007).

The 2009 stock assessment uses a statistical catch at age (SCA) model with age-specific data for red drum ages 1 through 7+. This is a change from virtual population analyses used in past assessments, primarily due to their inherent assumption that the catch at age is known without error, whereas there is limited data to describe the catch of red drum early in the time series. Data from 1989-2007 were included from the following sources: commercial and recreational harvest and discard data, fishery-dependent and -independent biological sampling data, tagging data, and fishery-independent survey abundance data.

The SEDAR 18 Review Panel considered the use of an SCA model appropriate given the types of data available for red drum. With certain revisions made to the data and the model configurations before or at the Review Workshop, the SEDAR 18 Review Panel supported the use of the final model runs. For the northern region, the Review Panel agreed that the model was informative of age 1 – 3 abundance and exploitation rates, but not for older age groups. The model was also found to be informative of annual trends in sSPR and the 2005 – 2007 average sSPR. For the southern region, the Review Panel agreed that the model was informative of relative (not absolute) trends in age 1 – 3 abundance and exploitation, but not for older age groups. The model was also considered to be informative of relative trends in annual sSPR and the three-year average sSPR, this result being highly conditional on the estimated fishery selectivity pattern. These results for the southern region allow for only general statements on stock status.

The Review Panel accepted the existing threshold and target overfishing benchmarks of 30% sSPR and 40% sSPR for red drum. However, the Review Panel did not consider annual changes in sSPR to be informative and recommended adopting a three-year running mean of estimated annual sSPR as the indicator to compare to the management benchmarks. Because of the high uncertainty in the age 4 –7^{+} dynamics, the Review Panel did not see value in attempting to estimate indicators and benchmarks of stock biomass which would be used to measure overfished status.

A new benchmark assessment for red drum was presented to the Board in May 2016. To ensure accuracy of the new model, the Board requested additional analyses. These will be presented to the Board in October 2016.

V. Status of Research and Monitoring

No monitoring or research programs are annually required of the states except for the submission of a compliance report. The following fishery-dependent (other than catch and effort data) and fishery-independent monitoring programs were reported in the 2016 reports.

Fishery Dependent Monitoring

- Delaware DFW -- Commercial monitoring through mandatory logbook reports.
- Maryland DNR – Commercial pound nets sampled bi-weekly in the Chesapeake Bay from late spring through summer (2015 n=0). Licensed charter boat captain logbooks are monitored for red drum captures (2015: 16 caught, 2 harvested).
- PRFC -- Red drum are harvested incidentally in the commercial pound net and haul seine fisheries. The mandatory commercial harvest daily reporting system, which collects harvest and discards/releases, reported zero red drum released in 2015.
- Virginia MRC –Volunteer anglers have participated since 1995 in the Virginia Game Fish Tagging Program (2015: 283 fish tagged, 23 reported recaptures). Carcasses collected through the Marine Sportfish Collection Project since 2007 (2015 n=0).
- North Carolina DMF – Commercial cap monitored through trip ticket program; commercially-landed red drum sampled through biological monitoring program since 1982 (2015: 429 fish measured, primarily gill net). North Carolina Red Drum Tagging Program (2015: 2,115 fish tagged, 115 reported recaptures).
- South Carolina DNR –State finfish survey conducted in January and February (2015 n=129, mean catch rate: 2.9 red drum/targeted angler hour). Charter Vessel Trip Reporting (2015 release rate: 93.2%). SC Marine Game Fish Tagging Program studies movement patterns, growth rates, and release-mortality rates (in 2015, 2,089 fish tagged, 445 recaptured). Tournament and freezer fish programs (2015 n=20).
- Georgia CRD – Age, length, and sex data collected through the Marine Sportfish Carcass Recovery Project (2015: 352 red drum).
- Florida FWC –10,807 trip interviews in 2015 collected data on total-catch rates and sizes (through MRIP).
- NMFS – Length measurements and recreational catch, harvest, release, and effort data are collected via the Marine Recreational Information Program.

Fishery Independent Monitoring

- New Jersey DFW – Five annual nearshore trawl surveys conducted since 1988, in January/February, April, June, August, and October. Length and weight data, and catch per unit effort (CPUE) in number of fish per tow and biomass per tow recorded for all species. Only two red drum were caught in entire time series (single tow, 2013).
- North Carolina DMF - Seine survey since 1991 produces age-0 abundance index (2015 n=586; CPUE of 4.9, increase from 2014 CPUE of 2.3). Gill net survey in Pamlico Sound

since 2001 characterizes size and age distribution, produces abundance index, improves bycatch estimates, and studies habitat usage (2015 CPUE of 2.10, slightly below average). Longline survey since 2007 produces adult index of abundance and tags fish (2015 n=321; CPUE remained stable and near average at 4.5 fish per set).

- South Carolina DNR – Estuarine trammel net survey for subadults (2015 CPUE lowest on record). Electrofishing survey in low salinity estuarine areas for juveniles/subadults (2015 CPUE third lowest on record). Inshore bottom longline survey for biological data and adult abundance index (673 tagged, 119 sampled for age in 2015). Genetic sub-sampling and tagging conducted during these three surveys.
- Georgia CRD – Estuarine trammel net survey for subadult biological data and abundance index (2015 n = 52). Estuarine gill net survey for young-of-year (YOY) biological data and abundance index (2015 n = 296). Bottom longline survey for adult biological data and abundance index (2015 n = 37).
- Florida FWC-FWRI – Two seine surveys in northern Indian River Lagoon (IRL) and lower St. Johns River (SJR) for YOY (< 40 mm SL) abundance indices (2015 CPUE returned to low 2011-2012 levels after 2013 spike). Haul seine survey in these areas and southern IRL for subadult index (2015 CPUE was lowest on record). Age and length data collected during surveys.

VI. Status of Management Measures and Issues

Fishery Management Plan

Amendment 2 was fully implemented by January 1, 2003, providing the management requirements for 2010. Requirements include: recreational regulations designed to achieve at least 40% sSPR, a maximum size limit of 27 inches or less, and current or more stringent commercial regulations. States are also required to have in place law enforcement capabilities adequate to successfully implement their red drum regulations. In August 2013, the Board approved Addendum I to Amendment 2 of the Red Drum FMP. The Addendum revises the habitat section of Amendment 2 to include the most current information on red drum spawning habitat for each life stage (egg, larval, juvenile, sub-adult, and adult). It also identifies the distribution of key habitats and habitats of concern, including potential threats and bottlenecks.

De Minimis Requests

New Jersey and Delaware requested *de minimis* status through the annual reporting process. While Amendment 2 does not include a specific method to determine whether a state qualifies for *de minimis*, the PRT chose to evaluate an individual state's contribution to the fishery by comparing the two-year average of total landings of the state to that of the management unit. New Jersey and Delaware each harvested zero percent of the two-year average total landings. *De minimis* status does not exempt either state from any requirement; it may exempt them from future management measures implemented through addenda to Amendment 2, as determined by the Board.

Changes to State Regulations

A 12,753 pound overage occurred in North Carolina in the 2013/2014 fishing year, resulting in a cap adjustment to 237,247 pounds. Commercial harvest in the 2014/2015 fishing year remained well below the adjusted cap allowance, providing sufficient payback.

VII. Implementation of FMP Compliance Requirements for 2015

The PRT finds that all states have implemented the requirements of Amendment 2.

VIII. Recommendations of the Plan Review Team

Management and Regulatory Recommendations

< Consider approval of the *de minimis* requests by New Jersey and Delaware

< Support a continued moratorium of red drum fishing in the exclusive economic zone.

Prioritized Research and Monitoring Recommendations (H) =High, (M) =Medium, (L) =Low

Stock Assessment and Population Dynamics

< Improve catch/effort estimates and biological sampling from recreational and commercial fisheries for red drum, including increased effort to intercept night fisheries for red drum. (H)

< Allocate efforts to determine the size and age structure of regulatory discards of live red drum. (H)

< Expand biological sampling based on a statistical analysis to adequately characterize the age/size composition of removals by all statistical strata (gears, states, etc.) (H)

< Each state should develop an on-going red drum tagging program that can be used to estimate both fishing and natural mortality and movements. This should include concurrent evaluations of tag retention, tagging mortality, and angler tag reporting rates. The importance of each state's tagging data to the assessment should be evaluated. (H)

< Establish programs to provide on-going estimates of commercial discards and recreational live release mortality using appropriate statistical methods. Discard estimates should examine the impact of slot-size limit management and explore regulatory discard impacts due to high-grading. (M)

< Evaluate the broader survey needs to identify gaps in current activities and provide for potential expansion and/or standardization between/among current surveys (M).

Biological

< Explore methods to effectively sample the adult population in estuarine, nearshore, and open ocean waters, such as in the ongoing red drum long line survey. (H)

< Determine if natural environmental perturbations limit recruitment, and if spawning stock size is the cause of recruitment variability (H)

< Continue tagging studies to determine stock identity, inshore/offshore migration patterns of all life stages (i.e. basic life history info gathering). Specific effort should be given to developing a large-scale program for tagging adult red drum (M)

< Fully evaluate the effects and effectiveness of using cultured red drum to facilitate higher catch rates along the Atlantic coast. (M)

< Determine habitat preferences, environmental conditions, growth rates, and food habits of larval and juvenile red drum throughout the species range along the Atlantic coast. Assess the effects of environmental factors on stock density/yearclass strength. (M)

< Refine maturity schedules on a geographic basis. Thoroughly examine the influence of size and age on reproductive function. Investigate the possibility of senescence in female red drum. Archive histological specimens across sizes to look for shifts in maturity schedules and make regional comparisons. (M)

Social

< Examine the effectiveness of controlling fishing mortality and minimum size in managing red drum fisheries.

< Encourage the NMFS to fund socioeconomic add-on questions to the recreational fisheries survey that are specifically oriented to red drum recreational fishing.

Economic

< Encourage the NMFS to continue funding socioeconomic add-on questions to the recreational fisheries survey that include data elements germane to red drum recreational fisheries management.

< Where appropriate, encourage member states to conduct studies to evaluate the economic costs and benefits associated with current and future regulatory regimes impacting recreational anglers including anglers oriented toward catch and release fishing trips.

< Fully evaluate the efficacy of using cultured red drum to restore native stocks along the Atlantic Coast including risk adjusted cost-benefit analyses.

< Conduct a special survey and related data analysis to determine the economic and operational characteristics of the "for-hire sector" targeting red drum especially fishing guide oriented businesses in the South Atlantic states.

< Estimate the economic impacts (e.g. sales, jobs, income, etc.) of recreational red drum fisheries at the state and regional level including the "for-hire sector" (e.g. fishing guides).

< States with significant fisheries (over 5,000 pounds) should collect socioeconomic data on red drum fisheries through add-ons to the recreational fisheries survey or by other means.

Habitat

< Identify spawning areas of red drum in each state from North Carolina to Florida so these areas may be protected from degradation and/or destruction. (H)

< Identify changes in freshwater inflow on red drum nursery habitats. Quantify the relationship between freshwater inflows and red drum nursery/sub-adult habitats. (H)

< Determine the impacts of dredging and beach re-nourishment on red drum spawning and early life history stages. (M)

< Investigate the concept of estuarine reserves to increase the escapement rate of red drum along the Atlantic coast. (M)

< Identify the effects of water quality degradation (changes in salinity, DO, turbidity, etc.) on the survival of red drum eggs, larvae, post-larvae, and juveniles. (M)

< Quantify relationships between red drum production and habitat. (L)

< Determine methods for restoring red drum habitat and/or improving existing environmental conditions that adversely affect red drum production. (L)

IX. References

Atlantic States Marine Fisheries Commission (ASMFC). 2002. Amendment 2 to the Interstate Fishery Management Plan for Red Drum. ASMFC, Washington, DC, Fishery Management Report No. 38, 141 p.

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Vaughan, DS and TE Helser. 1990. Status of the red drum stock of the Atlantic coast: Stock assessment report for 1989. NOAA Tech. Mem. NMFS-SEFC-263. 117 p.

X. Figures

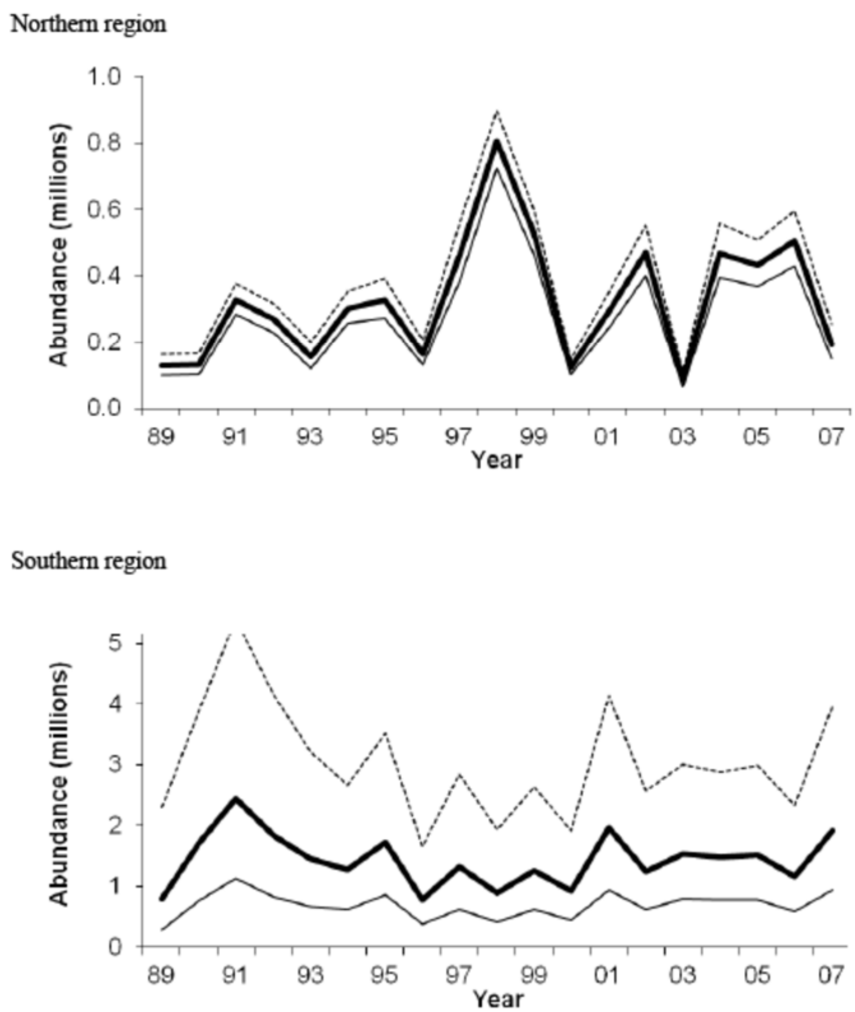
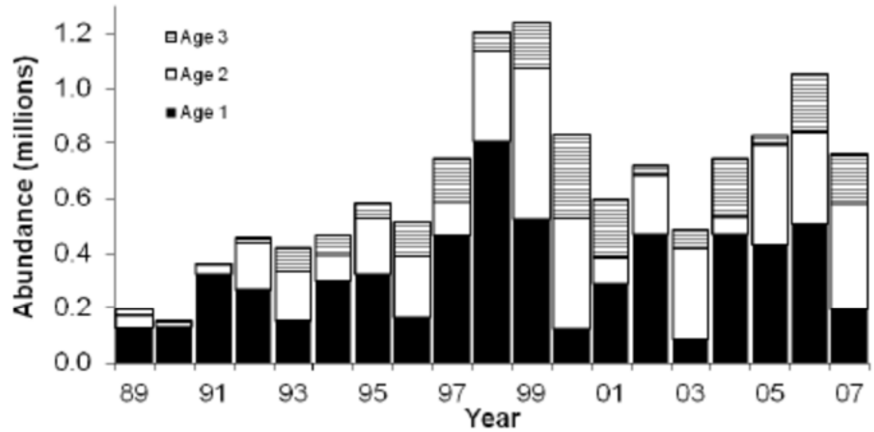


Figure 1. Estimated recruitment (age-1 abundance, heavy solid line) and ± 1.96 standard errors for the northern and southern regions during 1989-2007 (Source: SAFMC 2009). Note: assessment results for the southern region are indicative of relative trends but not absolute values.

Northern region



Southern region

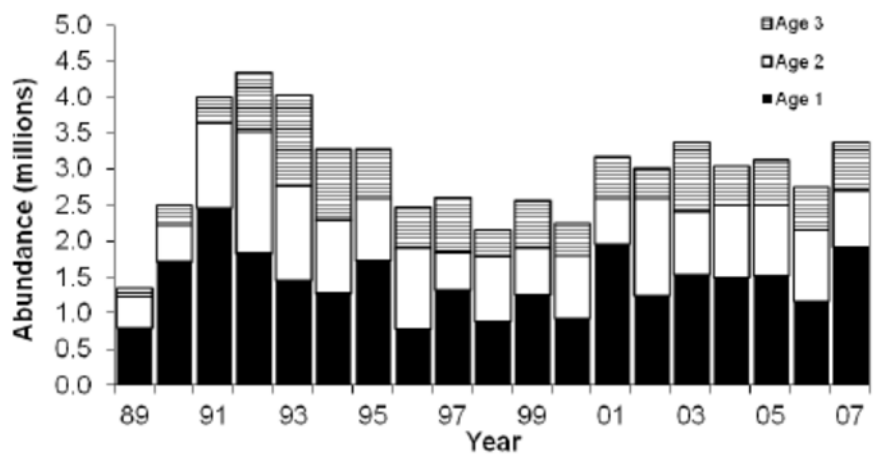
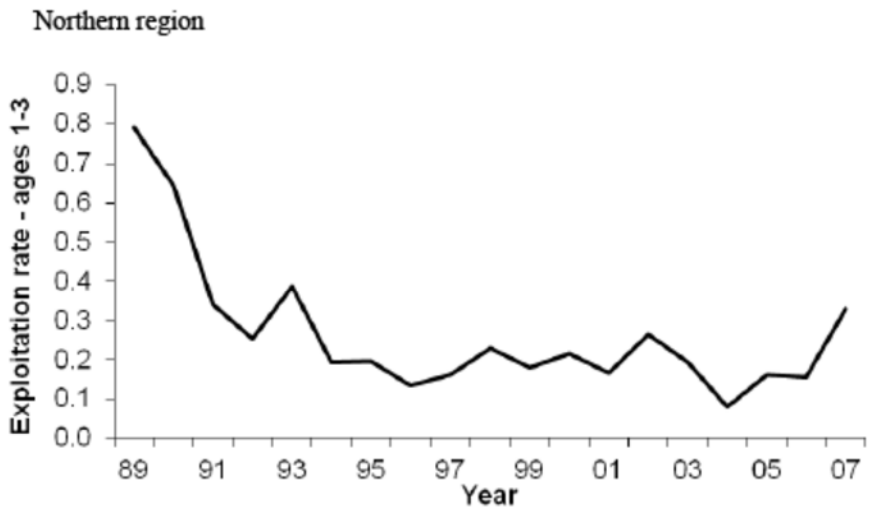


Figure 2. Estimates of abundance of red drum ages 1-3 in the northern and southern regions during 1989-2007 (Source: SAFMC 2009). Note: assessment results for the southern region are indicative of relative trends but not absolute values.



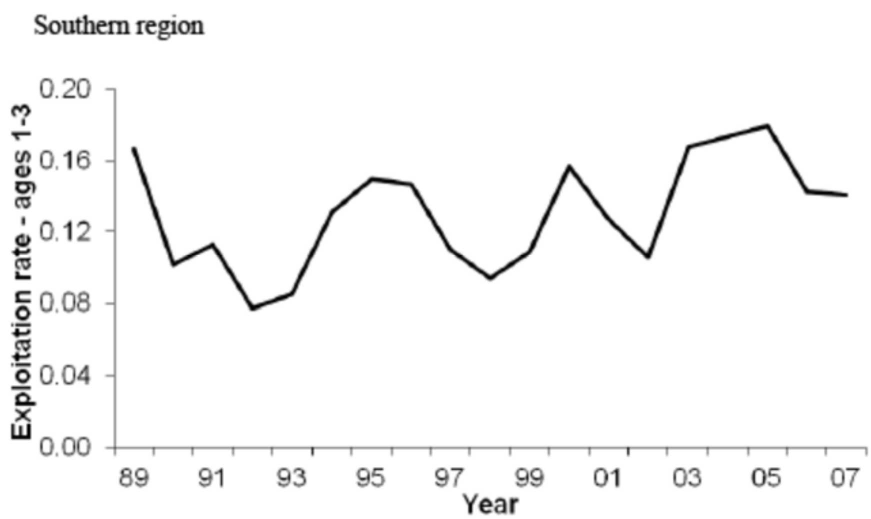
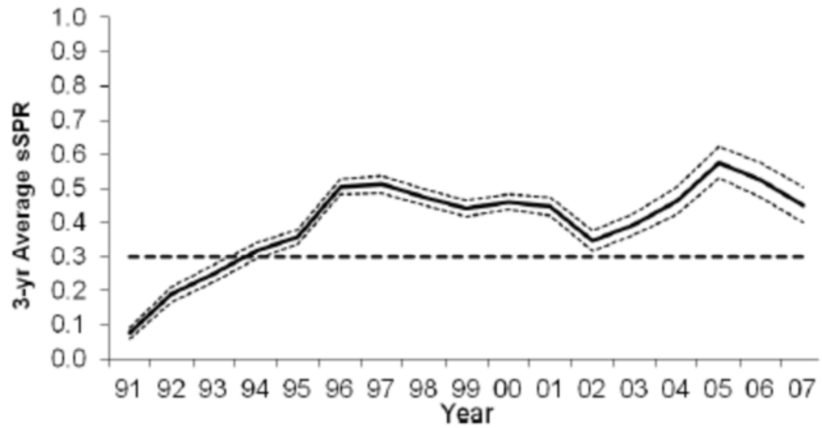


Figure 3. Estimated annual exploitation rate for red drum ages 1-3 in the northern and southern regions during 1989-2007 (Source: SAFMC 2009). Note: assessment results for the southern region are indicative of relative trends but not absolute values.

Northern region



Southern region

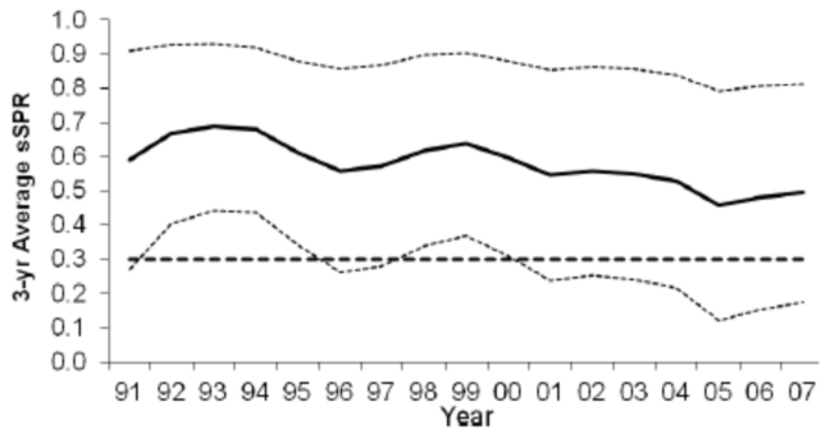


Figure 4. Northern and southern region estimates of three-year average static spawning potential ratio with ± 1.96 standard errors (dashed lines) during 1991-2007. Three-year averages include current and previous two years' sSPR estimates. The heavy dashed line shows the 30% overfishing threshold (Source: SAFMC 2009). Note: assessment results for the southern region are indicative of relative trends but not absolute values.

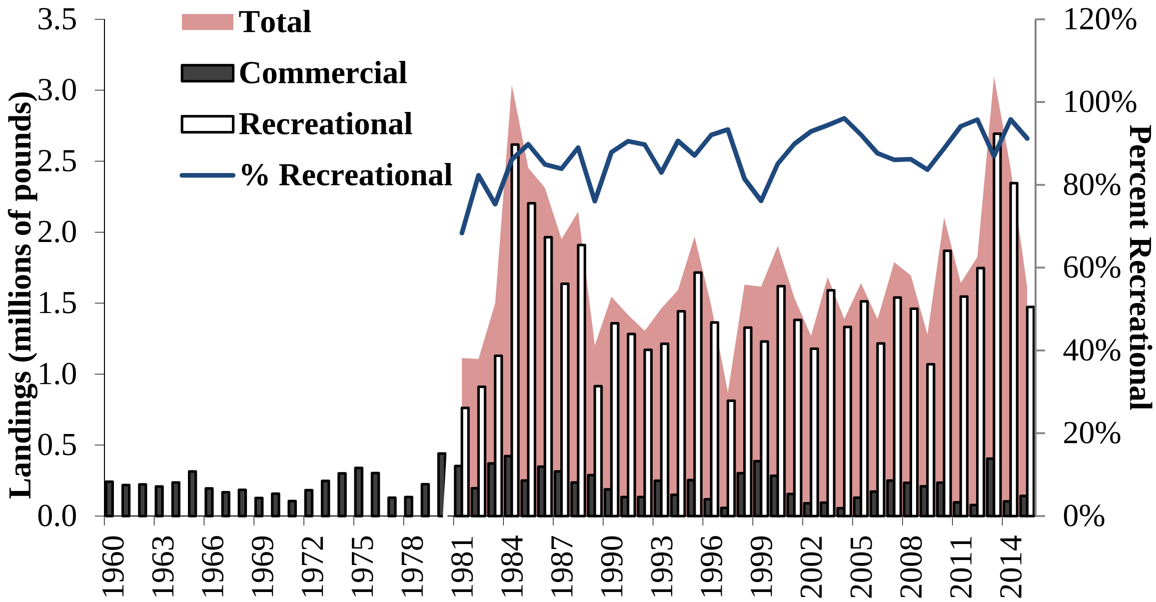


Figure 5. Commercial and recreational landings (pounds) of red drum. Recreational data not available prior to 1981. See Tables 2 and 3 for values and data sources.

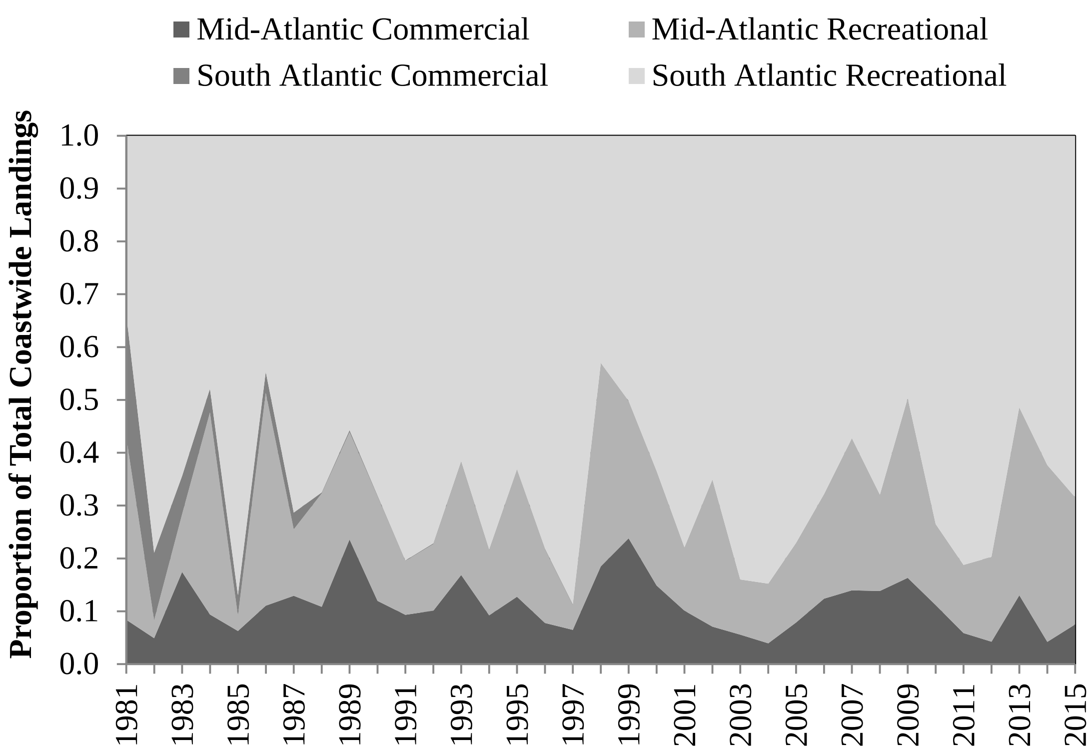


Figure 6. Proportion of regional, sector-specific landings to total coastwide landings (pounds). See Tables 2 and 3 for data sources.

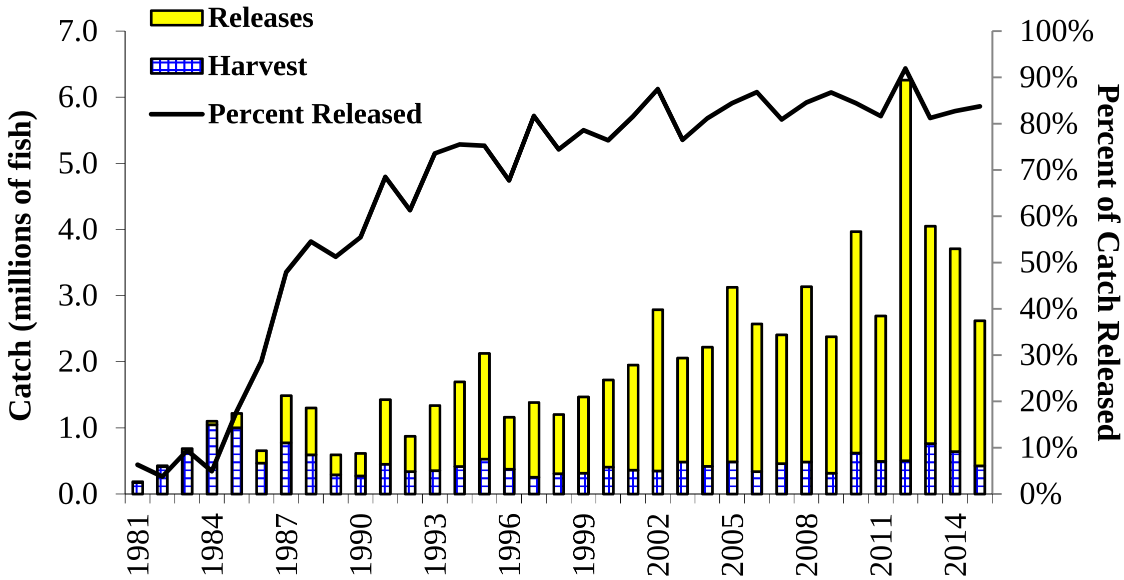


Figure 7. Recreational catch (harvest and alive releases) of red drum (numbers) and the proportion of catch that is released. See Tables 4 and 5 for values and data sources.

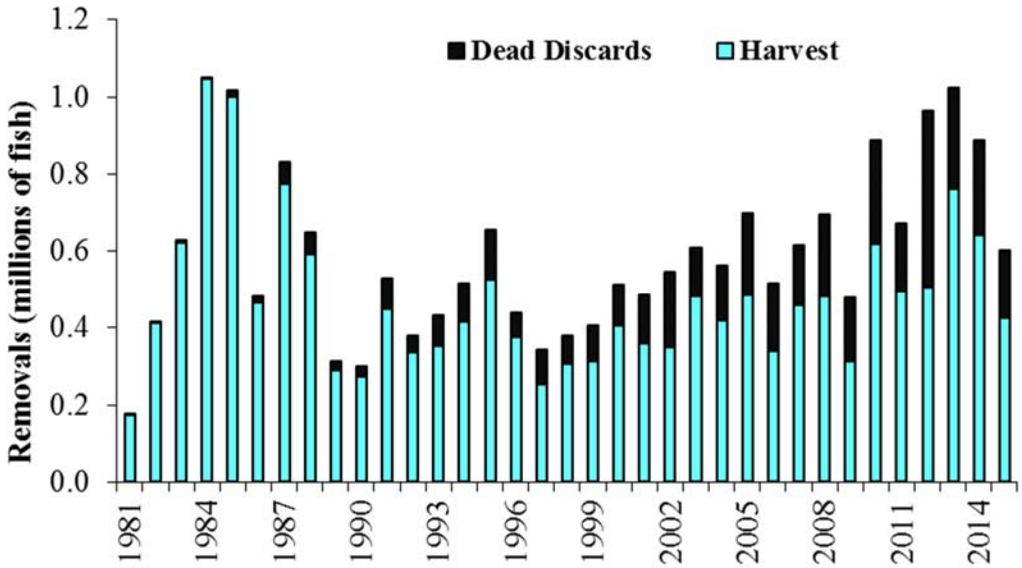


Figure 8. Recreational removals (harvest and dead discards) of red drum (numbers). Dead discards are estimated by applying an 8% discard mortality rate to alive releases. See Tables 4 & 5 for values and data sources.

XI. Tables

Table 1. Red drum regulations for 2015. The states of New Jersey through Florida are required to meet the requirements in the FMP; states north of New Jersey are encouraged to follow the regulations. All size limits are total length.

State	Recreational	Commercial
NJ	18" - 27", 1 fish	18" - 27", 1 fish
DE	20" - 27", 5 fish	20" - 27", 5 fish
MD	18" - 27", 1 fish	18" - 25", 5 fish
PRFC	18" - 25", 5 fish	18" - 25", 5 fish
VA	18" - 26", 3 fish	18" - 25", 5 fish
NC	18" - 27", 1 fish	18" - 27"; 250,000 lb harvest cap with overage payback (150,000 lbs Sept 1- April 30; 100,000 lbs May 1-Aug 31); harvest of red drum allowed with 7 fish daily trip limit; red drum must be less than 50% of catch (lbs); small mesh (<5" stretched mesh) gill nets attendance requirement May 1 - November 30. Fishing year: September 1 – August 31.
SC	15" - 23", 3 fish. Gigging allowed March-November	Gamefish Only
GA	14" - 23", 5 fish	Gamefish Only
FL	18" - 27", Northern Region- 2 fish; Southern Region- 1 fish	Sale of native fish prohibited

Table 2. Commercial landings (pounds) of red drum by state, 1981-2015. (Source: personal communication with NMFS Fisheries Statistics Division, Silver Spring, MD and ACCSP, Arlington, VA, except where noted below)

Year	NJ	DE	MD	PRFC	VA	NC	SC	GA	FL	Total
1981					200	93,420		261	258,374	352,255
1982					1,700	52,561	2,228	251	139,170	195,910
1983			100		41,700	219,871	2,274	1,126	105,164	370,235
1984					2,600	283,020	3,950	1,961	130,885	422,416
1985					1,100	152,676	3,512	3,541	88,929	249,758
1986			1,000		5,400	249,076	12,429	2,939	77,070	347,914
1987					2,600	249,657	14,689	4,565	42,993	314,504
1988			8,100	2	4,000	220,271		3,281	284	235,938
1989			1,000	86	8,200	274,356	165	3,963		287,770
1990			29	86	1,481	183,216		2,763		187,575
1991			7,533	3,808	24,771	96,045		1,637		133,794
1992			1,087	196	2,352	128,497		1,759		133,891
1993			55		8,637	238,099		2,533		249,324
1994			859		4,080	142,119		2,141		149,199
1995			6		2,992	248,122		2,578		253,698
1996			215		2,006	113,338		2,271		117,830
1997			22	4	3,820	52,502		1,395		57,743
1998	311		336		6,456	294,366		672		302,141
1999	241	6	504	186	10,856	372,942		1,115		385,850
2000			843	10	11,512	270,953		707		284,025
2001	*	*	727	191	4,905	149,616		*		155,439
2002	*	*	1,161	285	7,361	81,370		*		90,177
2003	*	*	631	47	2,716	90,525		*		93,919
2004	12	*	12	*	638	54,086		*		54,748
2005	*	*	37	51	527	128,770		*		129,385
2006	*	*	8	2	2,607	169,206		*		171,823
2007	*	*	90	58	6,372	243,658		*		249,747
2008	*	*	40	69	4,585	229,809		*		234,503
2009	129	*	*	157	8,315	200296		*		208,909
2010	*	*	19	22	3,634	231,828		*		235,503
2011				3	4,369	91,980				96,352
2012	7,971		334	81	2,609	66,519				77,514
2013	176	0	2,730	268	28,766	371,949				403,889
2014	55	0	298	3	11,999	90,594		0	0	102,949
2015	*	0	*	*	664	140,889				141,836

* Notes: NJ landings from SAFIS, 2004-present; MD landings from state reporting program, 1991-present; PRFC landings from agency reporting program, 1988-present; VA landings from state reporting program, 1996-present; NC landings from state reporting program, 1994-present; GA landings from state reporting program, 2000-present, * indicates confidential landings because less than three dealers reported.

Table 3. Recreational landings (pounds) of red drum by state, 1981-2015. (Source: personal communication with NMFS Fisheries Statistics Division, Silver Spring, MD)

Year	NJ	DE	MD	VA	NC	SC	GA	FL	Total
1981			4,370	347,939	31,519	50,230	9,442	317,963	761,463
1982					37,511	340,686	52,150	480,676	911,023
1983			3,018	51,299	109,540	222,691	67,298	675,924	1,129,770
1984				1,285	1,160,539	183,282	294,583	976,971	2,616,660
1985					70,677	1,532,316	185,887	414,176	2,203,056
1986			754,161	145,517	31,594	498,586	173,837	360,725	1,964,420
1987				44,332	200,729	913,639	250,795	227,222	1,636,717
1988				9,030	451,974	1,050,049	385,860	12,507	1,909,420
1989			2,348	27,236	214,849	396,771	127,245	146,064	914,513
1990			2,679		302,994	631,819	161,712	258,569	1,357,773
1991			5,635	30,582	108,268	284,290	337,207	516,999	1,282,981
1992				55,324	109,134	411,484	198,751	396,555	1,171,248
1993				45,505	266,459	282,614	328,245	290,930	1,213,753
1994				3,684	192,060	314,632	353,616	578,412	1,442,404
1995				66,270	405,620	417,595	300,337	525,231	1,715,053
1996				1,512	204,556	396,394	164,756	596,483	1,363,701
1997				1,810	39,077	296,155	129,836	345,390	812,268
1998				34,861	591,428	129,619	84,348	487,091	1,327,347
1999				92,794	326,303	103,777	166,630	540,310	1,229,814
2000				95,596	316,029	93,043	228,965	885,447	1,619,080
2001				51,890	132,578	188,198	155,854	853,714	1,382,234
2002		860	15,154	155,212	182,225	103,831	170,572	551,128	1,178,982
2003				57,213	118,808	449,399	234,865	729,446	1,589,731
2004				32415	124,264	312,569	296,777	566,508	1,332,533
2005				7,624	239,694	298,600	177,169	788,993	1,512,080
2006		2,064		21,039	251,735	160,760	143,699	636,742	1,216,039
2007				209,248	305,664	152,190	197,510	674,463	1,539,075
2008				72,510	236,744	254,305	244,594	652,613	1,460,766
2009				148,573	286,702	165,874	125,499	343,359	1,070,007
2010				40,323	281,587	451,144	319,427	776,346	1,868,827
2011					212,245	441,833	229,214	662,811	1,546,103
2012	0	396	26,788	27,422	238,310	368,445	107,368	978,727	1,747,456
2013	0	7,153	6,367	411,236	676,050	236,887	129,279	1,226,481	2,693,453
2014	0	0	0	221,280	598,166	242,371	154,332	1,129,663	2,345,812
2015	0	0	0	29,339	154,496	269,787	97,690	922,065	1,473,377

Table 4. Recreational landings (numbers) of red drum by state, 1981-2015. (Source: personal communication with NMFS Fisheries Statistics Division, Silver Spring, MD)

Year	NJ	DE	MD	VA	NC	SC	GA	FL	Total
1981			601	49,630	15,054	27,319	6,323	75,244	174,171
1982					16,445	160,760	30,757	204,401	412,363
1983			2,413	32,940	81,528	104,806	56,854	344,513	623,054
1984				1,457	108,787	129,547	258,188	549,381	1,047,360
1985				0	22,077	530,110	183,837	265,185	1,001,209
1986			12,804	28,139	17,501	193,188	102,279	113,440	467,351
1987				2,186	61,100	522,420	138,062	51,225	774,993
1988				4,311	142,626	287,916	147,042	9,542	591,437
1989			1,014	12,007	62,359	127,492	51,557	34,748	289,177
1990			1,279	0	33,149	118,666	76,304	44,280	273,678
1991			2,745	17,119	38,658	125,833	162,802	102,727	449,884
1992				13,275	23,593	112,534	83,861	104,265	337,528
1993				14,005	49,493	119,189	105,710	65,140	353,537
1994				1,378	28,953	129,515	134,214	120,938	414,998
1995				3,665	88,593	202,430	134,915	96,927	526,530
1996				572	36,746	130,649	60,251	146,823	375,041
1997				1,920	8,749	129,022	39,041	75,235	253,967
1998				13,070	114,638	46,509	24,929	107,982	307,128
1999				12,425	64,739	44,069	67,283	126,180	314,696
2000				22,603	61,618	37,217	94,144	191,070	406,652
2001				6,967	23,142	61,420	90,376	177,633	359,538
2002		275	5,521	49,795	42,541	41,190	90,993	119,010	349,325
2003				13,607	25,481	162,484	122,259	159,331	483,162
2004				5,005	30,017	107,803	138,893	136,728	418,446
2005				2,766	51,807	130,655	105,655	195,550	486,433
2006		468	6,362	12,665	55,714	48,703	68,813	145,860	338,585
2007				46,405	66,789	72,261	113,237	161,427	460,119
2008				20,847	50,809	119,471	133,107	159,246	483,480
2009				38,670	57,543	70,326	68,857	79,635	315,031
2010				11,076	64,024	172,708	194,826	175,828	618,462
2011	995				45,143	161,503	106,962	180,001	494,604
2012		296	17,869	28,149	52,948	121,068	45,766	238,191	504,287
2013		1,686	2,134	124,156	164,217	97,387	73,826	297,527	760,933
2014	0	0	0	53,545	116,921	103,892	91,764	275,536	641,658
2015	0	0	2	7,792	36,704	106,620	48,172	227,014	426,304

Table 5. Recreational alive releases and dead discards (numbers) of red drum by state, 1981-2015. Dead discards are estimated based on an 8% release mortality rate. (Source: personal communication with NMFS Fisheries Statistics Division, Silver Spring, MD.)

Year	NJ	DE	MD	VA	NC	SC	GA	FL	Total	Dead Discards
1981					2,230	417		9,042	11,689	935
1982						2,496	3,377	10,172	16,045	1,284
1983					1,866	6,751	1,417	54,723	64,757	5,181
1984					2,931	0	4,232	47,196	54,359	4,349
1985				1,115		16,688	6,315	193,399	217,517	17,401
1986				7,595		24,018	56,045	100,095	187,753	15,020
1987					18,499	82,595	234,676	377,959	713,729	57,098
1988				3,958	24,874	269,176	177,319	233,988	709,315	56,745
1989			2,918	7,038	7,566	42,824	71,162	172,303	303,811	24,305
1990			0	934	12,452	102,611	156,263	68,667	340,927	27,274
1991			4,432	14,461	121,178	99,968	92,803	645,773	978,615	78,289
1992	301			15,383	60,230	46,269	128,066	284,893	535,142	42,811
1993				50,434	182,301	146,324	140,386	465,656	985,101	78,808
1994				10,684	107,662	324,706	146,039	691,261	1,280,352	102,428
1995				33,560	164,520	362,844	356,618	683,706	1,601,248	128,100
1996				2,424	35,752	176,517	71,983	500,374	787,050	62,964
1997		2,571		109,754	259,570	175,772	22,736	560,559	1,130,962	90,477
1998			2,768	93,660	199,701	84,274	33,882	481,009	895,294	71,624
1999			2,148	232,893	247,146	87,776	18,586	565,981	1,154,530	92,362
2000			1,458	196,541	203,967	94,050	129,190	693,152	1,318,358	105,469
2001				30,365	238,552	221,045	249,892	850,044	1,589,898	127,192
2002		1,388	18,412	801,239	640,857	142,931	168,902	663,879	2,437,608	195,009
2003		731	2,935	43,379	75,561	430,052	272,897	748,765	1,574,320	125,946
2004				33,777	181,252	438,173	141,972	1,006,814	1,801,988	144,159
2005				28,351	378,541	493,595	334,521	1,405,967	2,640,975	211,278
2006		875	12,357	185,859	510,264	539,936	136,306	847,269	2,232,866	178,629
2007				110,566	416,352	436,797	225,985	758,684	1,948,384	155,871
2008		75	217	236,787	658,887	552,217	313,743	889,550	2,651,476	212,118
2009			14,754	178,396	429,776	751,123	167,704	521,659	2,063,412	165,073
2010			2,182	28,580	635,876	786,452	483,650	1,414,115	3,350,855	268,068
2011				61,330	207,697	664,291	213,781	1,051,143	2,198,242	175,859
2012	0	5,873	280,000	2,503,237	1,533,006	543,618	90,237	799,428	5,755,399	460,432
2013	0	407	2,207	220,305	654,030	673,377	198,722	1,541,541	3,290,589	263,247
2014	0	41	273	114,305	383,421	635,152	285,770	1,648,723	3,067,685	245,415
2015	0	0	774	25,835	334,510	571,433	168,338	1,094,215	2,195,105	175,608

Atlantic States Marine Fisheries Commission

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MEMORANDUM

July 25, 2016

To: **Tautog Management Board**

From: **Toni Kerns, ISFMP Director** TMK

RE: **Tautog LIS and NJNYB Regional Assessments & Desk Review**

The 2015 benchmark stock assessment for tautog explored multiple regional definitions for management purposes, including the three region delineation of Massachusetts-Rhode Island, Connecticut-New York-New Jersey, and Delaware-Maryland- Virginia. The Tautog Management Board accepted the stock assessment for management use and initiated Draft Amendment 1 in May 2015 to develop regional management alternatives.

Additionally, the Board requested a new assessment to support these management alternatives that would examine the population dynamics in Connecticut-New York-New Jersey in more detail. This regional assessment proposes two additional stock unit boundaries for consideration at a finer regional scale: Long Island Sound (LIS), which consists of Connecticut and New York waters north of Long Island, and New Jersey-New York Bight (NJNYB), which consists of New Jersey and New York waters south of Long Island.

The following report contains:

- **Tautog Regional Stock Assessment Desk Review** (PDF pgs 2-32)
- **Tautog Regional Stock Assessments for Long Island Sound and New Jersey-New York Bight** (PDF pgs 33-371; please note the model technical documentation and source codes begin on PDF pg 180)

M16-63

Report to the Atlantic States Marine Fisheries Commission

TAUTOG REGIONAL STOCK ASSESSMENT DESK REVIEW

July 2016

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Acknowledgements

The review panel thanks members of the Tautog Technical Committee, as well as the staff of the Atlantic States Marine Fisheries Commission for support during this review process and for quickly addressing questions during the review.

Executive Summary

Mr. Joe O'Hop and Dr. Cynthia M. Jones were contracted to provide a desk review of the most recent tautog stock assessment. The motivation for the update to the 2015 benchmark stock assessment centered on the need to provide uniform management for Long Island Sound (LIS), which was previously under Connecticut regulations for its north shore and New York regulations for its south shore. We attended a two-hour webinar held on July 1, 2016 where two presentations were made. Additional documentation was were provided at an FTP site and included: PowerPoint files of the two presentations, the ASAP3 technical manual, The ASAP input files, the AGEPRO reference manual, the Tautog 2016 Regional Assessment Report, the Coastwide Tautog 2015 Benchmark Stock Assessment, the ASMFC tautog desk assessment terms of reference and review timeline.

We commend the Tautog Technical Committee (TTC) for their hard work in developing this new four-region assessment in response to the ASMFC board's request. We conclude that the terms of reference (TORs) have been met, but that changes to the modeling framework would provide clearer results. The results of the new stock assessment provide different reference point results compared with the 2015 benchmark assessment, with the change from "not overfishing" for the NY-NJ region to "overfishing" for the new NJ-NYB. Why this change occurred is more difficult to explain because the portion of NY LIS which has been incorporated into a LIS region is also estimated as "overfishing".

The data used in the assessment were the best available. The catch time series relied on the MRFSS/MRIP data, but also the MRFSS/MRIP data as an index of CPUE. This is common practice when there are few other data sources to provide indices in predominantly recreationally-based fisheries, but it should be done with caution because both the time series and the CPUE are based on the same data collection. Other indices were also used, such as the Connecticut Volunteer Angler Survey and a variety of fishery-independent surveys, such as the New York Peconic Trawl Survey, and each was tested to evaluate its effect on model sensitivity. The age data and age-length keys (ALKs) used regionally tested ageing protocols developed from recent tautog ageing workshops. Growth curves were based on fishery-derived lengths and we recommend using bias corrections to alleviate potential length truncation as a result of size limits in the fishery.

Although genetic data support panmixia for tautog along the US east coast, we support the WG interpretation of the growth data that shows some structuring in the coastal population based on limited migration of adults, thus the value in providing regional assessments.

We conclude that the methods used in modeling met the term of reference. We add some additional insights below on improving model inputs: 1) that ASAP will fit weights to age 1 and 2 even though none are provided as input and this should be rectified, 2) some weights were not optimally matched with January 1 age dates.

Uncertainty was characterized using standard methodology and included harvest inputs, steepness and selectivity blocks. We discuss below the use of three versus four selectivity blocks, but find that the TTC working group (WG) use appropriate methods. We do suggest that the plus group weights be re-examined. We also note the severity of retrospective bias spanning selectivity block 3 is worrisome and may influence the F and SSB estimates.

ASAP uses selectivity pattern, weights at age, natural mortality rate and relative fishing intensity in the terminal year to calculate reference points. Input data appear reasonable, but also see our discussions on weights at age below. One concern that arose in the review was the selectivity estimate for the third time block in the NJ-NYB model was counterintuitive and may indicate misspecification in the model. We provide further comments below.

Evaluation of Terms of Reference (TOR)

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

The Tautog Stock Assessment Review Team (TSART) found that this TOR was met. The Tautog Technical Committee (TTC) Work Group (WG) provided a thorough review of all data sources that were considered for the assessment and provided detailed information on data sets used in the regional assessment. These data included both fishery-dependent and fishery-independent data. Fishery-dependent data included both recreational (80% component of fishery) and commercial information.

Recreational data came from MRFSS estimates from 1981-2011, which included re-estimated data for 2004-2011using MRIP methodology. Over these years, recreational harvest declined from a peak of over one million fish to around 200,000 fish recently, albeit that this data time series was quite variable inter-annually. Fishing occurs in spring and fall depending on state regulations. MRFSS on-site sampling was not based on probability-based site selection, and didn't account for night fishing. Based on recent proper sampling designs, correction factors were applied to this original MRFSS on-site data. However, the calibration has not been tested in a side-by-side comparison so there is no way to evaluate whether the calibration is accurate. Moreover, use of the catch-per-unit effort (CPUE) assumes that fishing from public access points is the same as from private access which is not sampled. This is a strong assumption for fisheries that rely largely on these data as indices and for catch (derived from CPUE). Problems arising from CPUE will depend on the proportion of public/private access to a specific species. This issue was not addressed in the review document. MRIP is also transitioning from a random-digit dialing telephone survey that was used to collect effort information to a mail-based sampling design. The re-calibration of MRFSS data is being evaluated in a three-year side-by-side comparison with the MRIP mail survey. Early evaluation appears to show that MRIP is returning higher effort estimates and because catch is calculated as CPUE x effort, this may cause a jump in catch and a discontinuity in the time series. MRFSS began identifying Long Island Sound as a specific area beginning in 1988. To obtain prior time estimates the mean harvest was used from 1988-1993. The other challenge in using these data was the low sample size of fishing trips that were directed at tautog. Tautog fishing is not widespread and to obtain estimates of fishing trips, the TTCWG used trips that were likely to catch tautog to measure catch-per-unit effort (CPUE). Such trips were defined as those that were directed at a guild of fish that used similar gear and were found in similar habitat.

The strength of using the MRFSS/MRIP time series is based on the predominance of recreational harvest in the fishery, the length of the time series available, and the fact that these data are often the only data available. The weakness of these data are in the inadequacy of the MRFSS sampling design to provide unbiased data, unknown bias even with the MRIP recalibration, and the paucity of tautog intercept interviews which contribute to great variability in the data time series. Moreover, using a guild approach, while it constitutes the best available science, doesn't provide a direct measure of tautog CPUE. Moreover, CPUE and catch are conflated even using the guild approach.

Recreational data for the Connecticut shore of the LIS was also available from the Connecticut Volunteer Angler Survey (CTVAS) since 1970. Although this survey was developed to obtain data on striped bass, trip and catch information are available from all catches that are volunteered by anglers who record their data in logbooks. As with any volunteered data, there is no way to verify that these data reflect the catches of the average angler. Typically, these volunteers are devoted anglers and may have better skill than the average. Thus, this time series could be used as a relative measure of tautog catches, but can't be used to estimate harvest of the entire recreational fishery. Care must be taken when using self-reported data unless there is a way to validate that these data represent the average angler in the fishery. CPUE will potentially be rightward shewed.

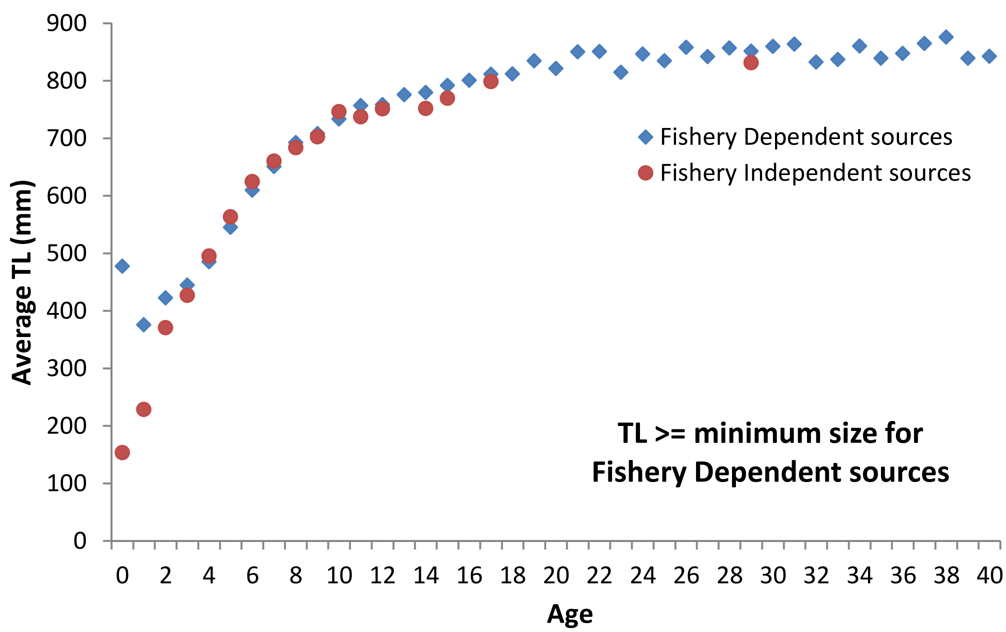
The commercial component of the fishery has declined over decades to approximately 20% of the total harvest. The predominant gear is hand harvest. Landings for the region vary seasonally but occur throughout the year. Although there are federal and state landings records since 1950, it was difficult to split the New York data into LIS and the other New York waters. Because of this, the regional assessment used data from 1988-2014. Other available data for New York was Vessel Trip Reports (VTR) and dealer reports. Prior to 1987, New York commercial landings could not be split into LIS and the south shore. To impute data to LIS, the mean of LIS data from 1986-1989 was attributed to the prior years. Although this extends the time series, it does minimize variance.

Strength of these commercial data is the reliability of mandatory reporting and the length of the time series. However, some years are imputed in the early part of the time series and there is the possibility of under-reporting because of the lack of state reporting programs in some cases. Beyond there, some error is introduced because of the difficulty in splitting the harvest between LIS and the south shore of New York.

Discard data came exclusively from the recreational collection data. This is recorded as the released numbers and dead released are calculated as released by release mortality rate. Released data are obtained from angler self-reporting and there is no way to verify these numbers from anglers using privately-owned vessels. This becomes a problem when releases are proportionally large compared to landed fish. Early in the time series the private/rental sector was 40-60% of harvest, but recently it constitutes 80-90%. Commercial discards were inconsequential and not included.

Fishery-independent data came from the Connecticut LIS Trawl Survey (CLTS), the Millstone Entrainment Sampling (MES), the New York Peconic Trawl Survey (NYPTS), the New York Western Long Island Seine Survey (NYWLISS), and the New Jersey Ocean Trawl Survey (NJOTS). These surveys provided data on relative abundance and biological metrics (sex, length, weight, maturity). However, trawls surveys are not a gear that adequately samples a structure-oriented species such as tautog and result in variable and typically low estimates. Most trawl surveys are statistically designed, employ strict sampling protocols, and provide the best data that are available for the sizes of fish that they are designed to collect.

Fig. 1. Average length of mutton snapper by source of sample.



Length and collection of opercula (in some cases also otoliths) were obtained from both fishery-dependent and fishery-independent surveys. When using length data from fisheries that have size limits, it is advisable to adjust for potential bias (e.g., Fig. 1) prior to comparing growth curves (Schueller et al. 2014 Fish Res 158: 26-39, Diaz et al. 2004). This may have an impact of the growth curve parameterization. Age-length keys were developed from these collections and were used to provide catch-at-age data for the models. Several ageing workshops and age-structure calibrations between laboratories along the US east coast have been conducted and provide consistent ageing results throughout the species range.

The stock-recruitment data are relatively flat. Apparently the growth curves did converge, as VBGF parameter values were obtained with relatively low SE. Comparisons of growth curve parameters and length-weight parameters for the LIS and NJ-NYB regions were presented in the 2016 Regional assessment. According to correspondence from the Tautog

Work Group (WG), the growth curves shown in tables in the Regional assessment were not the growth curves used for the LIS and NJ-NYB models. The growth curves used for input into the LIS and NJ-NYB models originated from analyses used in the 2015 Benchmark assessment.

Fig. 2. Observed and average weights-at-age used for the NJ-NYB model.

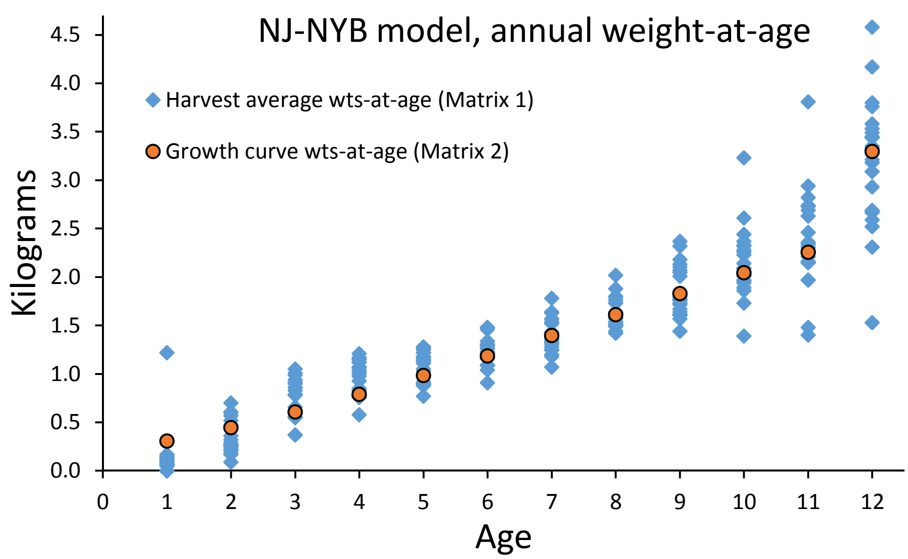
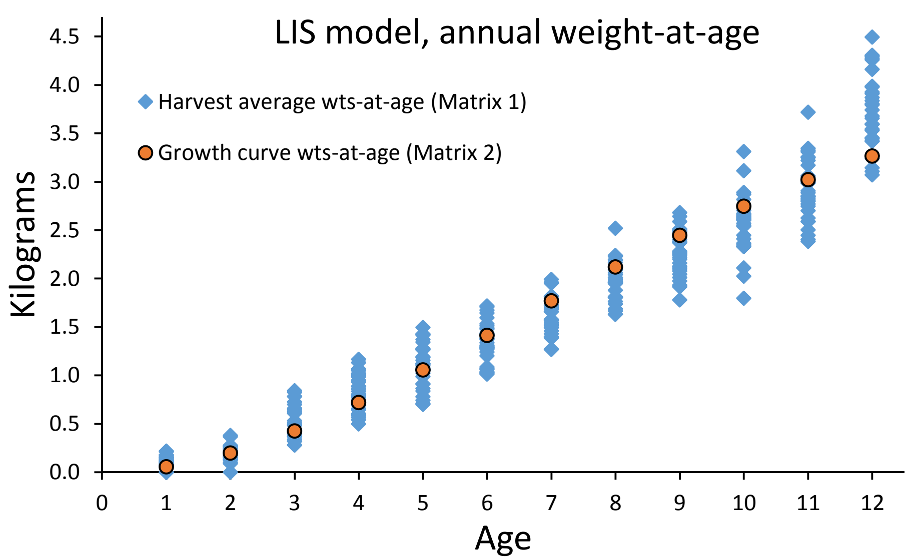


Fig. 3. Observed and average weights-at-age used for the LIS model.



Nonetheless, the growth curve presented for the NJ-NYB region and the growth curve for a somewhat similar regional treatment from the 2015 Benchmark assessment (according to correspondence from the WG) were likely adversely affected by bias (size truncation) introduced through fishery size limits. The estimated NJ-NYB weight-at-age (Fig. 2) calculated from the growth curves in the younger age classes (chiefly ages 1-2) were likely overstated compared with average weights-at-age observed in catches from the fishery which served as inputs for the harvest for this region. The LIS model was more consistent with the observed weight-at-age (Fig. 3) for the younger ages but may be understating the weight-at-age for the plus group (12+), which might understate SSB for that portion of the population and harvests that would be estimated by the model.

The criteria for data inclusion into the model for this regional assessment followed the same rules as the coast wide 2015 benchmark assessment. Data sets were rejected if the set contained fewer than 10 years of data, inadequate sample size, covered too small a geographic area so that it was not representative of the local subpopulation, or employed inconsistent methodologies. Measures of variance were provided for all input data.

2. Evaluate the assumptions of stock structure and the geographical scale at which the population was assessed.

This TOR was met. The range of tautog extends from Nova Scotia to South Carolina with greatest abundance from Cape Cod to Chesapeake Bay. Although tautog migrate seasonally, this involved largely offshore and onshore seasonal movements and a high degree of site fidelity. This type of behavior usually restricts the degree of latitudinal mixing and results in a degree of stock structure. Evidence for some structuring is seen in the difference in growth rates from north to south seen in two studies but not in another study. Growth in the Connecticut to New Jersey region showed similar growth trajectories. Similarly, length-weight relationships were similar throughout the region. However, growth parameters for the region differed from growth in the north and in the south of the species range lending credence that analyzing the Connecticut to New Jersey region separately. However, genetic studies have shown no differences between the regions. Often genetic studies will show no differences when there is a small degree of mixing, so that it is a judgment call when growth differences indicate that some structuring exists. Differences in growth will potentially result in different vulnerability to gear in different regions. However, because age-at-maturity is similar throughout the range, one doesn't expect differences in productivity. There is speculation that there could be some contributions of young of the year fish recruiting to the LIS and NJ-NYB regions through oceanographic processes, but the degree to which this may occur is unknown. Depending upon the degree of recruitment to each area, it may be appropriate to treat these two regions as separate sub-stocks as in the current configuration of the 2016 Regional assessment or as two areas with different harvest levels, age compositions, and indices of abundance from a single stock. This issue can only be resolved through future research, and cannot be further addressed at this time.

The current state of knowledge about reproductive strategies of tautog is that they are gonochoristic, but Steimle and Shaheen (1999) note that there are two types of males (one type different from females, the other similar in appearance to females) which may be an indication of protogyny in this species. Other wrasses in this family (Labridae) are known to be protogynous hermaphrodites, but it has not been demonstrated to occur in tautog. This should also be a topic for future research.

3. Evaluate the methods and models used to estimate population parameters (e.g., F, biomass, abundance) at the coastwide and regional basis, including but not limited to:
    a. Evaluate the choice and justification of the preferred model(s). Was the most appropriate model (or model averaging approach) chosen given available data and life history of the species?
    b. If multiple models were considered, evaluate the analysts' explanation of any differences in results.
    c. Evaluate model parameterization and specification.
    d. Evaluate the diagnostic analyses performed, including sensitivity analyses to determine model stability and potential consequences of major model assumptions.

The Tautog Stock Assessment Review Team (TSART) found that TOR 3a and b were met, though there were choices made by the analysts that were made for consistency with methods with the 2015 Benchmark assessment that were not well-documented despite an otherwise reasonably thorough presentation. There are always assumptions and choices made by those tasked with assessments, and it is not uncommon for analysts (including those reviewing) to prefer different methods and assumptions. The primary focus for the review is to objectively analyze the work performed and to fairly weigh the impact of the methods and assumptions on the outcomes presented.

The choice Age-Structured Assessment Program (ASAP, version 3.0.17) from the NMFS Northeast Fishery Science Center Toolbox website (http://nft.nefsc.noaa.gov/) was reasonable and can accommodate the data sets and life history parameters used as model inputs. Multiple models were not considered, though sensitivity analyses which included removing indices to examine the impact on model estimates were performed.

The configurations for the LIS and NJ-NYB models, constructed from the ASAP input data sets as provided by the WG, are shown in Appendix 1. The two models are similarly configured. The WG provided in their correspondence with the review panel justification for several of the choices made for data inputs (weights at age and SSB, constant M, and maturity) and for their configuration of selectivity parameters (basically, not including fitting criteria for the residuals to use in minimization) for fleets and indices which satisfies TOR 3c. Diagnostics and sensitivity analyses appear adequate to satisfy TOR 3d.

However, there are some conditions in the model inputs that may be improved. The harvest weights at age, in a small number of cases for ages 1 and 2 in both models had zero weight because no fish of these age classes were not observed in the harvest. But, ASAP may predict ages in the population for these age classes, and needs non-zero weights at age to calculate residuals for the harvest weights. Secondly, ASAP computes population numbers and biomass on Jan-1 for each year. The WG explained their reasoning for setting the Jan-1 and SSB weights at age to the same matrix, and that most of the weights at age were drawn from samples during the middle of the year so that the SSB weights at age were appropriate in the two models. While this use of the ASAP weight matrices may represent inconsistent treatment for the biomass at age, the WG argued that because the SSB weights at age were representative, the reference points for the stock(s) would be properly calculated. Thirdly, the growth curve parameters, derived mainly from fishery dependent sources which are affected by size restrictions on retention, that were used to calculate the SSB weights at age for the NJ-NYB model do not appear reasonable, but the estimated weight at age for spawners may be reasonable despite the misgivings about the growth curve itself (Fig. 2). The weights for age 1 and 2 fish may be overestimated compared to the observed harvest weight at age (Fig. 2), but because tautog do not mature until age 3 the potential overestimation would not impact SSB for the NJ-NYB model. The LIS model growth curve parameters incorporated data from fishery dependent and independent sources, and appears more reasonable for the harvest and SSB data (Fig. 3). However, the weight used for the age 12+ group should be re-examined to make sure that it represents a weighted average for that group. A sensitivity run using an age 15+ group estimated higher SSB, and this may be an indication that weight of 12+ age group was estimated too low. If so, that would potentially impact SSB and reference points in the base run for the LIS model. Lastly, the product of observed numbers at age in the harvest and weight at age in the harvest should equal the total observed harvest weight in the ASAP input file. This was the case for the LIS model but not for the NJ-NYB model. The WG noted that they will resolve this matter.

The WG satisfactorily explained their reasoning for not weighting the estimation of selectivity parameters for the “fleet” and indices for use in fitting the simple logistic selectivity functions by the model. The WG noted that they did not have external information on the selectivity patterns for the fishery or indices that had associated age structures. This was a choice made by the analysts, and opinions may differ on the best approaches for resolving selectivity issues in models.

The assessment document explains that recreational and commercial harvests (which includes landings, fish discarded dead, and that portion of the live releases that are expected to die after release) were grouped into a single harvest matrix by year. The harvests in both areas are primarily from recreational fishing, and the MRFSS/MRIP data was used to determine the number of dead discards and live releases. At-sea sampling and other surveys and voluntary angler programs which provide size information of released fish were used to estimate the sizes and ages (through age-length keys) in the released portion of the recreational catch. Harvests were correctly categorized as the MRFSS/MRIP Type A+B1 fish, but dead discards were incorrectly assumed to be the Type B1 fish which includes fish discarded dead but also a number of other conditions such as fish landed but not seen or not available to be measured (e.g., filleted fish) by the sampler. The Type B1 fish should be re-examined for the proper classification of these fish into dead discards and other harvest. In several species that we have examined in the southeast, very few of the B1 fish are reported as dead discards. The Type B2 fish are fish recorded as released alive, and applying an assumed release mortality rate (2.5% in both models based on tautog being a "hardy" fish) to estimate that fraction of the live releases which suffer mortality due to hook placement, barotrauma, and handling is standard in assessments where no other information on release mortality is available. However, the at-sea sampling often provides a release condition factor which may be suitable for developing estimates of immediate release mortality of the live releases. Delayed release mortality estimates may be available from tagging studies, though often there is no information of this type and potential impacts are approached through sensitivity runs.

The description of how sample sizes were determined for the fleet harvests and index age compositions for the model inputs were rather brief and not well-documented in the assessment. The WG responded that they will address this issue when the report is updated.

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

This TOR was met. And the approach used to estimate uncertainty followed commonly-used procedures. Uncertainty evaluated the sensitivities to input data, model structure, and retrospectives.

The input data that were tested included 1) individual surveys, 2) the start years for age data, and 3) underestimation of NJ recreational harvest. The Q-Q plot showed that the negative binomial fit the LIS CPUE data well through most of its range, but shows some miss-fitting at the upper range. This MRIP CPUE data also had long runs of negative or positive residuals. In contrast the NYPBTS fit surprisingly well. The CPUE index appears to use tautog catch classed as A+B1+ (0.025B2) where B1 and B2 in the PR/Rental modes are self-reported by anglers. Effort is taken as the number of trips that caught any of the guild species associated with tautog and thus to avoid over-estimating CPUE by underestimating trips from anglers that sought tautog, didn't catch any, but caught something else. While this may not add to bias or variance, it is difficult to say. Uncertainty in the start time of the indices was done to test the effect of estimated NY harvests and discards, to change the ages in the plus group, and to also start the model in 1995 when ALKs were first available. There was a suspected underestimation of recreational harvest in 2005 that was also corrected. This could have been due to poor reporting or to sampling issues in MRFSS.

Uncertainties in the model structure included 1) harvest inputs, 2) steepness and 3) selectivity blocking. To minimize some of the variability present in the MRIP harvest estimates, the TTC used a three-year moving average, thereby smoothing perturbations in the catch record, most likely due to small sample size and infrequent intercepts for anglers targeting tautog. The TTC also chose to use a steepness of one to force the LIS model to fit average recruitment, even though steepness was well estimated in the stock-recruit model. Although this was a test for sensitivity to the SR relation, using h=1 assumes infinite productivity and predetermines the reference points (Mangel et al 2013 CJFAS 70:930-940). The NJ-NYB model estimates h=0.9999 and does not fit the SR relation well. The sensitivity runs did not show any real trends.

Sensitivities comparing the use of three versus four selectivity time blocks in the model structure were evaluated. There is considerable uncertainty in SPR-based F-reference points ($F_{30\%SPR}$ and $F_{40\%SPR}$) caused by combining the third and fourth time blocks in the model structure. In both models, the F reference points in the 3-block models were lower than in the base run (4-block model). F_{MSY} in the LIS model was slightly higher in the 3-block model compared with the base run, and this comparison for the NJ-NYB model was not applicable because of the lack of fit (steepness ~ 1.0) of the stock-recruitment relationship.

Retrospective analyses for the LIS model spanned two selectivity blocks (1995-2011 and 2012-2014). Three-year (2011-2014) and seven-year (2007-2014) peels were used for the base model with ages 1-12+ and for a model configured with ages 1-15+. The LIS model showed minor retrospective bias in F or SSB for the base run and the model with 15 age groups for the three-year peels, with F for the last year of a time series tending to decline and SSB tending to increase slightly as the next year's data are added. For the seven-year peels, there is no consistent pattern apparent in F or SSB retrospective plots. The magnitudes of the F values cannot be compared between the base run and the 15 age group model, because the basis for the average F was ages 8-12+ for the base run versus ages 8-15+ for the other retrospective. SSB can be compared, and show the base run always below the age 1-15+ model. (This was noted in the assessment report as well, and we recommend [see discussion under TOR 3] that the weight at age of the 12+ group be re-examined.)

For the NJ-NYB model, the retrospective analyses for the base run used a seven-year peel (2007-2014) which spans two selectivity time blocks. The retrospective analyses gave retrospective patterns that appeared to coincide with selectivity breaks. SSB was overstated and F underestimated in the terminal year of the peel compared to the estimates when the next year's data were added for the third time block (2004-2011), and the opposite pattern seems to characterize the 2012-2014 period with SSB being slightly lower and F's higher. SSB for the 2013 peel was underestimated by 25% compared to SSB_{2013} in the base model through 2014. F is overestimated in the 2012-2013 peels. This is not surprising given that the last selectivity block spans only three years (2012-2014). The severity of the retrospective bias, particularly for years spanning selectivity time block 3, are worrisome and indicate that the F and SSB estimates are highly uncertain in this model.

5. Evaluate the best estimates of stock biomass, abundance, and exploitation from the assessment for use in management, if possible, or specify alternative methods/measures.

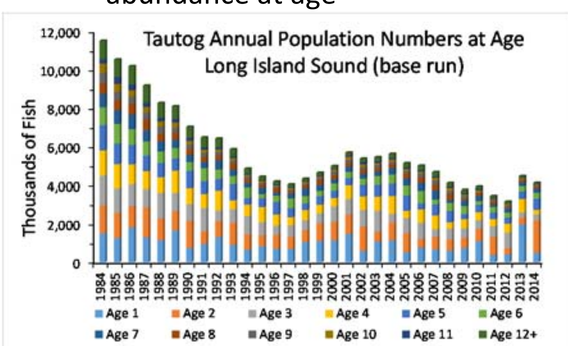
Given the preceding discussion on the previous TORs, estimates of stock biomass, abundance, and fishing mortality, the LIS model may be relatively robust. The analyses shows relatively little retrospective bias, leading to more confidence in the results from the base run. But, the sensitivity and retrospective run with ages 1-15+ indicate a potential problem with the weight at age in the age 12+ group of the base model. It should be re-examined to make sure it adequately represents this group. If it does not, the SSB may have been underestimated in the base run.

The NJ-NYB model has much greater uncertainty as shown by the inability of the model to solve for a stock-recruitment relationship and by the bias exhibited in the retrospective analysis. A re-examination of the data inputs (numbers and weights at age, growth curve, age-length keys, etc.) may be warranted.

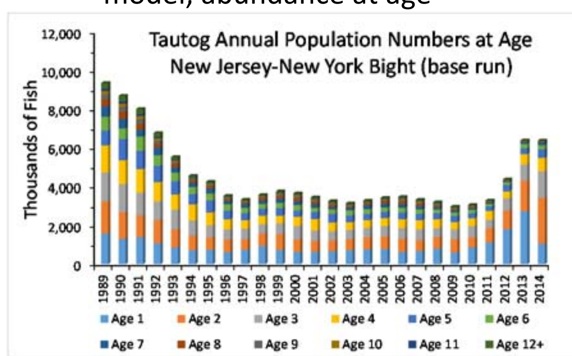
With the current base model runs, the trends (Fig. 4) in abundance and biomass at age from the LIS and NJ-NYB areas show an erosion of the older age classes which should cause concern to fisheries managers.

Fig. 4. Population trends in abundance and biomass at age from the 2016 Regional Assessment.

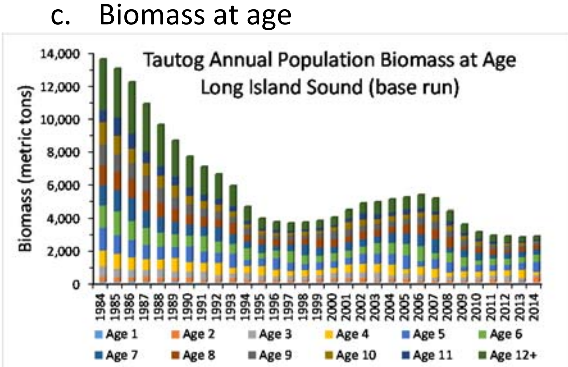
a. Long Island Sound base model, abundance at age



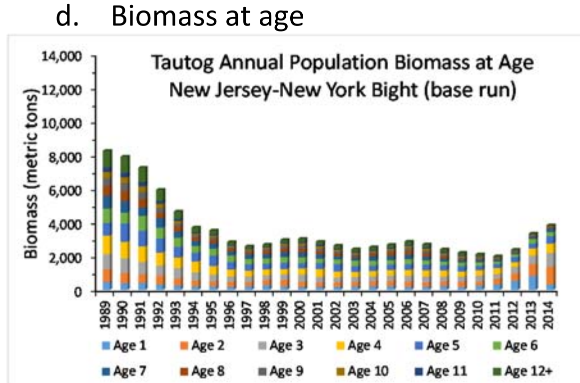
b. New Jersey-New York Bight base model, abundance at age



c. Biomass at age



d. Biomass at age



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

ASAP uses the selectivity pattern, weights at age, natural mortality rate, and relative fishing intensity in the terminal year to calculate reference points (ASAP3 reference manual, NMFS 2012a, 2012b). The input data on weights at age, natural mortality, and catch-at-age seemed reasonable. The selectivity estimated for the third time block (2004-2011) in the NJ-NYB model appears to be counterintuitive. Although size restrictions had increased at that time, the selectivity in the 2004-2011 time block is to the left of all other blocks, indicating that younger fish are caught in greater proportions. This could happen if growth suddenly showed density-dependent effects, a trend not apparent previously. However, this could result from misspecification in the models and is a worrying issue. Changes in selectivity also occur with changes in fish availability or gear, but there are no data to support these as reasons. It could also occur if there were many small fish that were included in the discards. It would be good to review the age-length keys and size-distribution information from the harvests and surveys to ensure that the data used in the analyses are correct. Changes in ageing protocols over time might be suspected, but the assessment document notes that a 2012 workshop was held in 2012 to ensure consistency in ageing methods and that in 2013 there were no consistent differences found in age estimates across states.

When the ASAP model estimates steepness close to one, as in the case for the NJ-NYB model in this assessment, then MSY reference points are inadvisable because the stock-recruit relationship is not well-estimated (Restrepo and Powers, 1999, ICES J Mar Sci 56: 847-852), and SPR reference points are more applicable as done in this assessment. Use of SPR also permits use of F-based reference points (Brooks et al 2010 ICES J Mar Sci 67:165-75). In the case of the reference points for the Long Island Sound where the base runs estimated a stock-recruitment relationship, both MSY-based and SPR-based (MSY proxy) reference points were proposed in the 2016 Regional Assessment. MSY and MSY proxies are affected by any change in fishing practices that affect selectivity (e.g., limits on vessels and gear, hook size/type, size and retention limits, etc.) and availability (e.g, area/depth/season closures) of fish to fishers. The SPR-based MSY proxies are calculated based on yield-per-recruit, so they are equilibrium-based values and are independent of annual recruitment (i.e., the values are “per recruit”). The declining trends in the older age classes seen from the LIS and NJ-NYB base runs (Fig. 4), if these model estimates are reasonable, argues for caution in the choice of reference points.

The review panel has no practical experience with the use of the AgePro software from the NMFS NFT-Toolbox. The SSB SPR-based equilibrium reference points calculated by ASAP and those derived from the use of AgePro and presented in the 2016 Regional Assessment are obviously different (Tables 1 and 2). The ASAP F-reference points are based on an age range specified on the input files. Both the LIS and the NJ-NYB models specified ages 8 to 12+ as the basis for calculating the F-reference points. The SSB estimates are calculated based on the F-reference points, so it is important to specify the basis (age range) for which the F applies. It is also important to state the criteria on which the current F is based, and is not clearly stated in section 7.3 (Stock Status Determination). The current F is defined as the 3-year average value and applies to the arithmetic average of the 2012-2014 fishing mortality rates for the 12+ age group. This is not consistent (but not too different) from the basis (ages 8-12+) for calculating the F-reference points. Other assessments have used n-weighted averages of F over a time period, and ASAP provides a time series for the average F based on ages specified in the input file. Still other assessments have chosen a geometric average F over the last years (typically 3) in the time series (see Tables 1 and 2 for examples of different criteria for use as the $F_{current}$ in assessments.

For the SPR-based SSB reference points, ASAP (see column with heading “Review Panel” and “base run”) calculates smaller SSB than the corresponding AgePro values (see column with heading “2016 Regional Assessment” and “base run”). The assessment document briefly discusses the use of AgePro for developing the SSB reference points in Section 6.3 (Reference Point Model Description). The rationale for preferring the AgePro estimates to the ASAP estimates, however, is missing and should be provided. It makes quite a difference to the stock status determination.

For the LIS model, the current fishing mortality rate (defined as the average F over 2012-2014 for age 12+) exceeds the F_{target} for both the SPR- and MSY-based F-reference points (Table 1) which means that overfishing is occurring. For the SSB reference points, the current SSB in 2014 is below the below the $SSB_{threshold}$ from the AgePro estimates and means that the population is overfished. However, the ASAP calculates that SSB_{2014} is greater than the $SSB_{threshold}$, and the population status would be “not overfished.”

Similar comments apply for the NJ-NYB reference points (Table 2), but all F and SSB estimates and reference points from the base run result in the population status of overfishing occurring (fishing mortality rate too high) and is overfished (SSB too low).

The Review Panel conducted several exploratory trials of the LIS and NJ-NYB ASAP models with slight variations on the base run configuration (Tables 1 and 2). The first variant explored the impact of assigning a weight (λ=1) and coefficient of variation (CV=0.5) to the selectivity parameters for fleets and indices with more than one associated age class. Differences of reference points, F, and SSB were slight compared with the base runs, and there was a modest decrease (better fit) in the objective function. Next, this new configuration was modified to link the MRIP index to the “fleet”. Differences in reference points, current F and SSB, and other values were slightly different and fit was slightly better in the LIS model but not the NJ-NYB model. Lastly, the input configuration was modified to add the stage-2 multipliers to the fleet and index weights on the Lambda-3 tab of ASAP. The rationale for using those weights was to attempt to more equally weight the variances of those components (see Francis 2011a, b) in the objective function. Slightly larger estimates for the SSB reference points and slightly smaller F rates were obtained for the LIS

Model, but the reverse was observed for the NJ-NYB model and the fit was degraded. These runs were not intended to add to the assessment report, only to explore some options in model configuration.

Table 1. List of reference points and other quantities from the 2015 Regional Assessment and from the Review Panel's exploratory ASAP runs using variations on the base model for the Long Island Sound.

		2016 Regional Assessment	Review Panel			
		base run	base run	exploratory	exploratory	exploratory
definition		LIS ASAP (SSB)	LIS ASAP (SSB)	selectivity λ=1, CV=0.5	selectivity λ=1, CV=0.5, MRIP linked to fleet	selectivity λ=1, CV=0.5, MRIP linked to fleet, stage-2 λ
F at 40%SPR	F_{target}	0.27	0.27	0.26	0.23	0.22
F at 30%SPR	$F_{threshold}$	0.47	0.47	0.45	0.38	0.36
Avg. F Age 12+, 2012-2014	3-year avg. F	0.53	0.53	0.51	0.40	0.42
SSB at 40%SPR	SSB_{target}	3,757	2,852	2,847	3,056	3,128
SSB at 30%SPR	$SSB_{threshold}$	2,820	1,248	1,245	1,584	1,567
SSB current	SSB 2014	1,956	1,956	1,964	2,184	2,486
Overfishing criteria based on Avg. F for Age 12+ over 2012-2014 exceeding F at 30% SPR, Overfished criteria based on current SSB below SSB at 30%SPR	Stock Status[c]	Overfishing, Overfished	Overfishing, Not Overfished	Overfishing, Not Overfished	Overfishing, Not Overfished	Overfishing[b], Not Overfished
F 2014, age 12+	F 2014 (age 12+)	0.72	0.72	0.69	0.52	0.42
F 2014, ages 8- 12+ (N-weighted)	F 2014, ages 8-12+		0.69	0.67	0.51	0.41
Avg. F Age 12+ (N-weighted)	Avg. F 12+ (N-wgt)		0.50	0.49	0.39	0.34
N-wgt $F_{geometric\ 2012\text{-}2014,\ Ages\ 8\text{-}12+}$	$F_{geo\ 2012\text{-}2014}$		0.49	0.48	0.39	0.33
steepness	*h*	0.53	0.53	0.53	0.57	0.56
objective function	objective function[d]	5214	5180	5172	5164	5164

definition		LIS ASAP (MSY)	LIS ASAP (MSY)	selectivity λ=1, CV=0.5	selectivity λ=1, CV=0.5, MRIP linked to fleet	selectivity λ=1, CV=0.5, MRIP linked to fleet, stage-2 λ
F at 75% MSY	F_{target}	0.32	----[a]	----[a]	----[a]	----[a]
F_{MSY}	$F_{threshold}$	0.16	0.16	0.16	0.16	0.15
	3-year avg. F	0.53	0.53	0.51	0.52	0.42
SSB at F_{MSY}	SSB_{target}	4,576	4,576	4,559	4,196	4,437
SSB at 75% MSY	$SSB_{threshold}$	3,432	3,432	3,419	3,147	3,128
	SSB 2014	1,956	1,956	1,964	2,184	2,184
Overfishing criteria based on Avg. F for Age 12+ over 2012-2014 exceeding F at 75% MSY, Overfished criteria based on current SSB below SSB at 75%MSY	Stock Status	Overfishing, Overfished	Overfishing, Overfished	Overfishing, Overfished	Overfishing, Overfished	Overfishing, Overfished

[a] - not calculated

[b] - F geometric criteria would change stock status to "not overfishing"

[c] - Stock Status from the 2016 Regional Assessment used AgePro for calculating SSB targets and thresholds. Calculations by the Review Panel used SSB targets and thresholds calculated by ASAP.

[d] - the contribution of discards (which were not configured in the model) to the objective function were removed for the review panel exploratory runs.

Table 2. List of reference points and other quantities from the 2015 Regional Assessment and from the Review Panel's exploratory ASAP runs using variations on the base model for the New Jersey-New York Bight.					
	2016 Regional Assessment	Review Panel			
	base run	base run	exploratory	exploratory	exploratory
	NJ_NYB ASAP	NJ_NYB ASAP	selectivity λ=1, CV=0.5	selectivity λ=1, CV=0.5, MRIP linked to fleet	selectivity λ=1, CV=0.5, MRIP linked to fleet, stage-2 λ
F_{target}	0.22	0.22	0.21	0.18	0.19
$F_{threshold}$	0.36	0.36	0.36	0.29	0.30
3-year avg. F	0.50	0.50	0.49	0.31	0.41
SSB_{target}	2,457	3,136	3,142	3,266	3,224
$SSB_{threshold}$	3,305	2,352	2,356	2,449	2,378
SSB 2014	1,972	1,972	1,986	2,270	1,885
Stock Status[c]	Overfishing, Overfished	Overfishing, Overfished	Overfishing, Overfished	Overfishing, Overfished	Overfishing, Overfished
F 2014 (age 12+)	0.66	0.66	0.65	0.39	0.52
F 2014, ages 8-12+		0.65	0.64	0.38	0.51
Avg. F 12+ (N-wgt)		0.50	0.49	0.31	0.41
$F_{geo\ 2012\text{-}2014}$		0.48	0.47	0.30	0.40
h	0.99	0.99	0.99	0.99	0.93
objective function[d]	3660	3631	3624	3685	3693

[a] - not calculated

[b] - F geometric criteria would change stock status to "not overfishing"

[c] - Stock Status from the 2016 Regional Assessment used AgePro for calculating SSB targets and thresholds. Calculations by the Review Panel used SSB targets and thresholds calculated by ASAP.

[d] - the contribution of discards (which were not configured in the model) to the objective function were removed for the review panel exploratory runs.

We did have some concerns with the configurations and data used for the LIS and NJ-NYB models. However, the stock status under this new assessment has the same conclusion. All areas covered by this assessment are overfished and overfishing is occurring as did the benchmark assessment's three region alternative model. The results of the new assessment differ however from the benchmark's preferred three region assessment in that the benchmark assessment did not find the NY-NJ region to be overfished. Because there has been a change in region-specific area inclusion, the LIS southern shore has been separated from NY-NJ, it is not possible to determine if this is the reason for the difference, whether it is sample size, or disaggregation of the MRIP interviews.

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Appendix 1. Configuration of the 2016 Tautog regional stock assessment models for the Long Island Sound and New Jersey-New York Bight arranged by ASAP interface tab, with footnotes.

Item	LIS (Long Island Sound)	NJ-NYB (New Jersey-New York Bight)
Tab: **General Data** Model specification[1]	Single fleet (commercial + recreational) 1984-2014 Ages 1-11, 12+ Surveys available: 6 Selectivity blocks: 4 Weight matrices: 2	Single fleet (commercial + recreational) 1989-2014 Ages 1-11, 12+ Surveys available: 3 Selectivity blocks: 4 Weight matrices: 2
Tab: **Weights at Age** Matrix 1: Catch weight-at-age	kg Harvest = catch-at-age x weight-at-age	kg [2]*Harvest ≠ catch-at-age x weight-at-age and Age 1 weight in 2008 anomalous*
Tab: **Weights at Age** Matrix 2: Jan-1 biomass-at-age	kg [3]*Age 12+ (plus group) weight may be low. Does it represent a weighted avg. wt. for ages 12-max. age?*	kg [3]*Ages 1-2 (many, at least) average weights in catch (Matrix 1) much less than Matrix 2.*
Tab: **Weights at Age** Matrix 3: SSB biomass-at-age (set to Matrix 2)	kg [4]*Jan-1 biomass and SSB should be different if spawning not on Jan-1.*	kg [4]*Jan-1 biomass and SSB should be different if spawning not on Jan-1.*
Tab: **Biological** Natural Mortality Maturity Fecundity[7]	 [5]Constant M (0.15) [6] - Total (both sexes) Biomass-based, SSB offset=0.42 years	 [5]Constant M (0.15) [6] - Total (both sexes) Biomass-based, SSB offset=0.42 years
Tab: **Fleets** Description Selectivity ages Release mortality[8] Fleet Directed Flag Selectivity blocks Average F basis:	 Rec + Com 1-12+ 0.025 Yes 1984-1986, 1987-1994,1995-2011, 2012-2014 N-weighted, ages 8-12+	 All removals 1-12+ 0.025 Yes 1989-1997, 1998-2003, 2004-2011, 2012-2014 N-weighted, ages 8-12+
Tab: **Selectivity**[9] Blocks 1-4 Starting values	All single logistic, ***lambda=0,cv=0*** A_{50}=5, slope=0.6, phase=2 (on)	All single logistic, ***lambda=0,cv=0*** A_{50}=5, slope=0.6, phase=2 (on)

Item	LIS (Long Island Sound)	NJ-NYB (New Jersey-New York Bight)
Tab: **Catch** Catch at Age Total Weight (Harvest)	(catch + discards combined) Numbers of fish Kilograms	(catch + discards combined) Thousands of fish Metric tons
Tab: **Discards**	Not used	Not used
Tab: **Releases**	Not used	Not used
Tab: **Index Specification** All index and age proportion units in numbers, weight calculations from matrix 2, none linked to fleets, Age 1-12+ indices single logistic Age 1 index age-specific	CT trawl, month=5, Ages 1-12+ NY trawl, month=5, Age 1 index MRIP CPUE, month=6, Ages 1-12+ NY seine, month=5, Age 1 index Millstone Eggs, Age 1 index, not used Millstone Larvae, Age 1 index, not used	NY seine, month=5, Age 1 index NJ trawl, month=6, Ages 1-12+ MRFSS, month=6, Ages 1-12+
Tab: **Index Selectivity**[10]	All: ***lambda=0,cv=0 (age 1-12+ indices)*** ***lambda=0,cv=0 (age 1 index)*** CT trawl A_{50}=5, slope=0.6, phase=2 (on) NY trawl, age-specific, phase=-1 (off) MRIP A_{50}=5, slope=0.6, phase=2 (on) NY seine, age-specific, phase=-1 (off)	***lambda=0,cv=0 (age 1-12+ indices)*** ***lambda=0,cv=1 (age 1 index)*** NY seine age-specific, phase=-1 (off) NJ trawl A_{50}=5, slope=0.6, phase=2 (on) MRFSS A_{50}=5, slope=0.6, phase=2 (on)
Tab: **Index Data** Annual values and CV for indices, age proportions and effective sample sizes if appropriate. Missing annual estimates=-999	Entered, origin of sample sizes for age 1-12+ indices?	Entered, origin of sample sizes for age 1-12+ indices?

Appendix 1. (continued) Configuration of the 2016 Tautog regional stock assessment models for the Long Island Sound and New Jersey-New York Bight arranged by ASAP interface tab.

Item	LIS (Long Island Sound)	NJ-NYB (New Jersey-New York Bight)
Tab: **Phases**		
F-mult in first year	1	1
F-mult deviations	2	2
Recruitment deviations	2	2
N in first year	2	2
Catchability in first year	3	3
Catchability deviations	-1 (off, i.e., q fixed for block)	-1 (off, i.e., q fixed for block)
Stock Recruitment Scaler	3	3
Steepness	3	3
Tab: **Lambdas-1**		
Fleet Total Catch (weight) CV and effective sample sizes for fleet age compositions	Origins of CV and ESS not in report	Origins of CV and ESS not in report
Tab: **Lambdas-2**		
Recruitment CV and lambda for recruitment deviations	CV set to 0.5, lambda set to 0.5	CV set to 0.5, lambda set to 0.5
Tab: **Lambdas-3**		
Lambda for Total Catch in weight	1	1
	1	1
Lambda for Total Discards in weight	0	0
	0.5	0.5
Lambda for F-mult in first year	0.5	0.5
	0.5	0.5
CV for F-mult in first year	All set to 1	All set to 1
Lambda for F-mult deviations	All set to 0	All set to 0
	All set to 1	All set to 1
CV for F-mult deviations	All set to 0	All set to 0
Lambda for Index	All set to 1	All set to 1
Lambda for catchability	Lambda=0, CV=0.5	Lambda=0, CV=0.5
CV for catchability	Lambda=0, CV=0.5	Lambda=0, CV=0.5
Lambda for catchability deviations	Lambda=0, CV=0.5	Lambda=0, CV=0.5
CV for catchability deviations		
N in First year deviation		
Deviation from initial steepness		
Deviation from Initial SR scaler		

Tab: **Initial Guesses**		
Numbers at Age in 1^{st} year	Entered	Entered
Stock Recruitment scaler	10000	1000
Steepness	0.7	0.7
Maximum F	5	100
Catchability for indices	All set to 0.001	All set to 0.001
F-Mult	1	1
Tab: **Projection**	Not used	Not used
Tab: **MCMC**[11]		
Iterations	1000	1000
Thinning Factor	200	200
Random seed	314156	1126
Age Pro File Option for Age 1	Use Stock Recruitment Relationship	Use Geometric mean of previous years
Start and end year for estimate	1984-2014	1989-2014
MCMC year option	Use Final Year in Stock	Use Final Year in Stock

[1] – ASAP allows the analyst to define multiple fleets, and can be configured to model landings by fleet, total harvest (landings and dead discards) by fleet, or track separately by fleet landings, discards (live and dead), and the portion of the live releases expected to die from release mortality. If the analyst includes only landings or only harvests (landings + dead discards), a single matrix can hold the harvest information. In the case where live releases are estimated to represent a significant portion of the catch (i.e., landings, dead discards, and live releases), then separate matrices are entered to keep track of the ages of the landings, total discards (live and dead), and the proportion of live releases at age in the total catch at age (landings + dead discards + live releases). In this latter case, the estimated release mortality to be applied to the expected live releases is entered as a separate input value. Also in this latter case, that portion of the observed live releases subject to the release mortality should be included in the observed dead discard numbers-at-age and discard weights so that ASAP can calculate the predicted dead discards and residuals from the "observed" dead discards (including the releases expected to die after release).

It sounds confusing, but in practice the calculations are usually straight-forward. In the case of the MRFSS/MRIP survey, for most species that we have worked on in the southeast region, there are very few records noting dead releases and in fact most anglers report releasing all their fish alive. So, the A+B1 catch is usually treated as representing landings. The Type B2 catch (live releases) is examined separately using ancillary information from at-sea studies of released fish. The proportion of released fish scored as "dead", "struggling at the surface", and sometimes other categories are assumed to represent the immediate release mortality rate, and the other portion of the released fish are subject to the delayed release mortality rate either assumed from a meta-analysis or from other observational studies (e.g., mark-recapture). Generally, age is inferred from the observed size-at-age of the releases from the at-sea studies either using observed size-at-age proportions (typically fishery independent) or through stochastic ageing techniques (e.g., growth curve, natural mortality rate, and standard deviation of length-at-age). The numbers-at-age (or proportions-at-age) of the dead releases (from immediate release mortality rates) are entered on the discard tab, and the proportions by age of the live releases surviving the encounter with the fishing gear represent the live releases by age divided by the total catch at age and entered on the releases tab. ASAP will use the assumed delayed release mortality rate entered on the Fleet tab to calculate the numbers and weights of released fish that die. To calculate residuals for the weight of total dead discards, the calculated weight of fish dying after release should be included with weight of other dead discards.

Both the LIS and NJ-NYB models were configured as single fleets to contain the landings and discards of the commercial and recreational fishing sectors. The landings were the numbers of fish (LIS) or thousands of fish (NJ-NYB) in the observed catch brought to shore (i.e., landings), and discards (Section 5.1.1.1) appeared to be fish released alive or dead and estimated based on surveys of recreational anglers or commercial fishers. Both models incorrectly defined for the MRFSS/MRIP survey that Type B1 fish as fish released dead, but both models also defined Type B1 fish appropriately as part of the harvest. [This may have been an unfortunate choice of wording in Section 5.1.1.1.] Type B1 fish includes fish discarded dead, but also defines a number of other conditions including fish landed but unavailable for measurement (filleted, etc.) or claimed by the angler and not seen by the sampler.] Harvest weights were the sum of landed weights and estimated dead discards in kilograms (LIS) or metric tons (NJ-NYB). The estimated release mortality for discards was low (2.5%). Using this configuration, both models were treating all landings and discards as harvest, and the release mortality would not operate in the models. ASAP would have no way to calculate the fraction of discards from the total harvest in this calculation, and no way to calculate live and dead releases from the discards.

Separate tables for recreational harvest (A+B1) in numbers of fish were provided for Connecticut, New York, and New Jersey (Table 4.1) and for commercial harvest in metric tons (Table 4.2) for the LIS and NJ-NYB models. However, I did not find separate tables for recreational harvests and releases for the LIS and NJ-NYB models, or for estimated releases for the commercial sector. It is difficult to ascertain the impact of the model configurations without knowing the magnitude and age structure of the live releases. If magnitudes of the estimated live releases were small relative to the harvests, then there would be a negligible impact on predicted harvests in numbers or weight even after release mortality was factored into the equation. However, it could result in residuals in the harvests and age compositions that were inappropriate.

[2] – ASAP allows the user to enter the average weights at age of the landings or harvest (landings + dead discards), and calculates the expected catch (or harvest) based upon the product of the predicted catch-at-age x catch-weight-at-age (Matrix 1). Residuals of the sums of the observed catch (or harvest) weight-at-age and the predicted catch (or harvest) at age are included in the objective function. For calculation consistency, it is advisable to ensure that the observed annual catch equals the sum of the products of the observed annual harvest-at-age (landings, dead discards, and live releases succumbing to release mortality) and annual catch weight-at-age to match the ASAP calculation method for the predicted annual catch weights. The LIS model estimated annual harvest in weight which matched the sum of the product of the catch-at-age and average weight-at-age vectors, but not the NJ-NYB model. The correspondence with the WG indicated that they will re-check these calculations.

In addition, the average weight of Age-1 fish for 2008 in the NJ-NYB model was anomalous and should be examined. However, because few (<1%) Age-1 Tautog are in the catch, the contribution of the weight of Age-1 fish in the year should have only a negligible effect on the output.

A potential situation can arise when there were no weights for specific ages in the observed catch, but for which the model may calculate a predicted catch in numbers for that age. In those cases, it would be advisable to calculate a reasonable weight-at-age for any missing age classes in the observed catch/harvest. Zero weights in a few years were observed in Matrix 1 for both the LIS and NY-NYB models, and overall probably had only a small effect since the total estimated biomass of Age 1 and 2 fish would be a small fraction of the total catch biomass. See also footnote 7.

[3] – This matrix represents the weights at age that ASAP will use to calculate weight-at-age for the population on January 1. In correspondence with the WG, they elected not to calculate weights-at-age for Jan-1 because most of their growth information probably represented mid-year values. Not calculating Jan-1 biomasses at age may cause some inconsistency with population biomass and catch by ASAP, but the impact on the assessment is probably small.

[4] – This matrix represents the weights at age that ASAP uses to calculate weight-at-age for spawners. ASAP decrements the population numbers at age by natural mortality according to the fraction of the year specified as the spawning offset by the analysts (in this case, spawning is offset by 0.42 years corresponding to June 1 in both models). Even though the weight at age for ages 1-2 in this matrix for the NJ-NYB model are higher than observed for ages 1-2 in harvests, because these young fish are not mature it will not affect the calculated spawning stock biomass (SSB). In the LIS model, the weight of the plus group (ages 12 and older are grouped into a single bin in the base models) appears a little low. The weight at age of the plus group should be calculated as a weighted average of the weight at age in the group, typically offset by natural mortality at age. The LIS model, if the plus group weight is lower than it should be, would potentially be understating SSB if this is the case. The sensitivity run using the plus group 15+ did estimate a higher SSB than the base run than other sensitivities and the base run using 12+ age group.

[5] – A constant natural mortality of 0.15 over all ages is assumed for both models. This is a choice made by the analysts based on the “rule-of-thumb” method and is within the range (0.12-0.19) for the NJ-NYB region found in the 2015 Benchmark stock assessment for Tautog (ASMFC 2015) and also used in the 2006 stock assessment for this species (ASMFC 2006). There are other natural mortality options like that of Lorenzen (1996, 2005) which observes (and there is experimental and theoretical support from size-selective predation studies) that the rate of predation on the smaller, younger fish is relatively higher than in larger, older fish. Assuming a constant rate of natural mortality in this assessment is a relatively conservative choice than using age-specific natural mortality which has been used in recent assessments in the southeastern U.S. and other areas. Correspondence with the WG noted that the model estimates using constant M and age-specific M were similar in the 2015 Benchmark assessment. However, Table 6.6.B of the 2015 Benchmark assessment generally shows higher SSB and lower or similar F for the age-specific M configurations at the target and threshold

reference points compared to the base run, but do not change the impression of current stock status.

[6] – ASAP can be configured to compute Spawning Stock Biomass and reference points based on mature biomass for both sexes ("total") or for females only. Both the LIS and NJ-NYB models based these quantities on total maturity as configured. Because the maturity values for this matrix were based on females only, and the sex ratio of females to males is assumed to be 1:1 at all ages, SSB and other reference points could be re-computed to be based upon female SSB by multiplying the maturity values in the current maturity matrix by 0.5. This is a choice to be made by the analysts/stock assessment team/management board and only impacts the magnitude of the SSB reference points. At any rate, the basis for the SSB calculations should be explicitly clear for the managers and future assessments. The correspondence with the WG indicated that this was done to maintain consistency with the 2015 Benchmark assessment.

[7] – Fecundity – based on the product of the maturity-at-age, numbers-at-age decremented by estimated total mortality corresponding to the portion of the year that elapses before spawning occurs, and weight-at-age (spawners),. In calculating the biomass of spawners from a growth curve, the weight-at-age should be adjusted for the fraction of the year elapsing before spawning occurs. ASAP will adjust the estimated numbers-at-age by the fraction of the year elapsing before spawning entered on the maturity tab, but does not adjust the spawner weight-at-age. The correspondence from the WG indicated that the weights that they estimated in weight Matrix 2 would be appropriate for mid-year weights-at age and thus appropriate to use for SSB calculations.

[8] – Release mortality and Average F basis (F_{report})– the current configuration of the model which combines landings and discards into the single catch matrix does not enable ASAP to calculate discards, so this parameter is non-functional in the models as configured. To enable discard calculations, choose the "Include discards in model" option in the General Tab. However, that would also entail estimating the total number of discards (live and dead) at age and the proportions at age of fish released alive to the total numbers of fish at age caught. ASAP enables the analyst to set the basis for fishery reference points based on a range of ages in the model. Both the LIS and NJ-NYB models specified ages 8-12+ as the basis of the reported Fishing Mortality (F) to be used to generate F and SSB reference points.

[9] – Selectivity – ASAP allows fishery selectivity (the proportions at age vulnerable to the fishing gear/fishery for the harvest and for discards if included separately in the model) to be specified as following age-specific patterns, or two function patterns (single logistic or double logistic). Selectivity may be fixed or estimated by the model. Fitting is controlled by whether the minimizer is allowed to solve for the selectivity parameters (phase >0), and whether the residuals are weighted in the objective function that is being minimized (Lambda>0). The bounds around the starting values for selectivity are controlled by specifying the CV for the parameters, and the calculated residuals are assumed to be lognormally distributed by ASAP. The WG chose to maintain consistency with the 2015 Benchmark assessment in the treatment of selectivity parameters (single logistic functions) by setting the phase to a positive value, and set lambdas and CVs to 0 (no contribution to the objective function from fitting). ASAP will replace a CV=0 with 100 to avoid calculation errors, but since the lambda is set to 0, the

contribution of the index fit will be zero in the objective function (the AD Model-Builder [ADBM] minimizer attempts to find a minimum for the objective function in the solution space for all active parameters during the fitting process).

Selectivities are arranged in a single or multiple contiguous time blocks in ASAP models, and selectivities and catchabilities (q) will be calculated (or fixed at their starting values if configured that way) for each block.

[10] – Index Selectivity – Each index may be derived from the same or different gears than operate in the fishery, and thus is adjusted for the selectivity of the gear used to sample fish populations. For each index, ASAP will also calculate a catchability (q) relating the index values to the population or harvest numbers (or biomass as appropriate). There is also an option to link indices to fleet harvests if appropriate. Sampling may be appropriate for a portion of the age composition in numbers or weight, and the fitting of the selectivity pattern can be restricted to a single age, a range of ages, or not associated with any part of the age composition. The correspondence with the WG during this review noted that they chose options for the indices consistent with the 2015 Benchmark assessment. Selectivity for age-1 indices were configured appropriately (phase set to -1, lambda set 0, and CV set to 0 or 1 [though setting the CV to 1 is the ASAP convention]. Selectivity (single logistic functions) for indices for wider age ranges (ages 1-12+ in these models) followed the 2015 Benchmark assessment by setting the phase to a positive value and turning off fitting by setting the lambdas and CVs to 0. ASAP will replace a CV=0 with 100 to avoid calculation errors, but since the lambda is set to 0, the contribution of the index fit will be zero in the objective function and will not be used in the ADMB minimization process.

[11] – MCMC – The LIS model estimated a steepness value, so using the stock-recruitment relationship was reasonable to generate recruitment values. The NJ-NYB model estimated steepness essentially at 1.0, so using the geometric mean over at time series to generate recruitment values was reasonable.

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Atlantic States Marine Fisheries Commission

Tautog Regional Stock Assessment: Long Island Sound and New Jersey-New York Bight

June 2016

Vision: Sustainably Managing Atlantic Coastal Fisheries

Atlantic States Marine Fisheries Commission

Tautog Regional Stock Assessment

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A publication of the Atlantic States Marine Fisheries Commission pursuant to National Oceanic and Atmospheric Administration Award No. NA15NMF4740069.

ACKNOWLEDGEMENTS

This regional stock assessment was founded on the preceding Benchmark Stock Assessment, which was the hard work of the Tautog Technical Committee whose current members are:

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EXECUTIVE SUMMARY

The Atlantic States Marine Fisheries Commission (ASMFC) manages Tautog (*Tautoga onitis*), under the authority of the Atlantic Coastal Fisheries Cooperative Management Act (ACFMA). The management unit consists of the coastal states from Massachusetts through Virginia. ASMFC has coordinated interstate management of Tautog in state waters (0-3 miles) since 1996.

The 2015 benchmark stock assessment for Tautog explored multiple regional definitions for management purposes, including the highly regarded three region delineation of Massachusetts-Rhode Island, Connecticut-New York-New Jersey, and Delaware-Maryland-Virginia. The ASMFC Tautog Management Board accepted the stock assessment for management use and initiated Draft Amendment 1 in May 2015 to develop regional management alternatives. The Board requested a new assessment to support these management alternatives that would examine the population dynamics in Connecticut-New York-New Jersey in more detail. This regional assessment proposes two additional stock unit boundaries for consideration at a finer regional scale: Long Island Sound (LIS), which consists of Connecticut and New York waters north of Long Island, and New Jersey-New York Bight (NJ-NYB), which consists of New Jersey and New York waters south of Long Island.

Tautog is predominantly a recreationally caught species, with anglers accounting for about 90% of landings coastwide. Tautog are not well-sampled by the MRFSS/MRIP program, resulting in higher percent standard errors (PSEs) and large annual variation in catch estimates, often driven by the small intercept sample size. In the LIS region, recreational landings in the LIS region peaked in 1988 at nearly 700,000 fish. The 2010-2015 average landings in the LIS are 200,000 fish. In the NJ-NYB region, recreational harvest peaked at 1.56 million fish in 1991. Between 2006 and 2014, annual landings in the NJ-NY Bight region have shown high interannual variability without a trend, ranging from approximately 70,000 to 400,000 fish, with an average of 268,000 fish.

The commercial value (dollars per pound) for Tautog has increased fairly steadily since 1990 and has recently surpassed $3.00 per pound. In the LIS region, commercial landings peaked in 1987 at 159 metric tons. The 2010-2014 average landings in LIS are 37.6 mt. In the NJ-NYB region, commercial harvest during the late 1980s to mid-1990s fluctuated around 70 mt annually. Landings in NJ-NYB since 2009 are 40 mt and below.

The LIS regional stock assessment was led by the University of Connecticut, while the NJ-NYB assessment was led by NJ Division of Fish and Wildlife. The Tautog Technical Committee worked closely with both groups to support these analyses by providing data and technical feedback. New York harvest data, biological samples, and some indices were separated by region (LIS or south shore) and then combined with data from Connecticut or New Jersey to develop regional estimates. The LIS region used data from 1984-2014, while the NJ-NYB region used data from 1989-2014. Population modeling was conducted using the preferred method from the benchmark stock assessment (Age Structured Assessment Program (ASAP) module of the NMFS NEFSC Tool Box).

For the LIS, fishing mortality increased from 1984 to 1995 then declined through the early 2000s, but has been steadily increasing since 2006. The LIS 2012-2014 average full F was 0.53, the highest value in the time series. In NJ-NYB, fishing mortality exhibited a somewhat cyclical trend. Sharp drops in F were observed that generally correspond with implementation of regulations, followed by increases in F in subsequent years. The NJ-NYB 2012-2014 average full F was 0.50.

Spawning stock biomass in the LIS quickly declined from a high of 11,718 mt in 1984 until the early 1990s when the decline slowed. LIS spawning stock biomass (SSB) was 1,956 mt in 2014. In NJ-NYB, SSB was at 5,984 mt in 1989 and declined rapidly during the 1990s. Regulations during the 2000s resulted in minor but temporary rebuilding. SSB declined further during the period 2006-2011, to a low of 1,045 mt in 2011, but has since increased somewhat to 1,972 mt in 2014.

Given the longer time series and the contrast in stock size observed in the LIS region, the Tautog Technical Committee (TC) recommends maximum sustainable yield (MSY)-based benchmarks for the LIS region. Consistent with the benchmark assessment, the SSB target was defined as SSB_{MSY}, equal to 4,576 mt, and the SSB threshold was defined as 75% SSB_{MSY}, equal to 3,432 mt. The F target was defined as F_{MSY}=0.16, and the $F_{threshold}$ was defined as the long-term equilibrium fishing mortality rate that would produce 75%SSB_{MSY}, equal to 0.32. Because there was considerable discussion by the TC regarding the utility of the different reference point models, spawner per recruit (SPR)-based reference points are also provided for the LIS region.

The ASAP model runs indicate the LIS stock is overfished and overfishing is occurring when both the MSY and SPR methods are applied.

In the NJ-NYB regional model, data were not sufficient to allow credible estimation of the stock-recruit relationship, so the TC considers the MSY-based reference points unreliable. Consistent with the benchmark, the TC is recommending a fishing mortality target of $F_{40\%SPR}$=0.22 and a threshold of $F_{30\%SPR}$=0.36. Recommended SSB reference points are the long term equilibrium biomass associated with the respective fishing mortality rates, with SSB_{target} = 3,305 mt and $SSB_{threshold}$ = 2,457 mt.

The ASAP model runs indicate the New Jersey and southern New York (NJ-NYB) stock are overfished and overfishing is occurring.

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TERMS OF REFERENCE

1. Characterize precision and accuracy of fishery-dependent and fishery-independent data used in the assessment.

Tautog are targeted by commercial and recreational fisheries, but approximately 90% of the total harvest comes from the recreational fishery. Commercial harvest data for Tautog are available from 1950 to present, while recreational harvest estimates are available from 1982 to present. Commercial records indicate low harvest levels from the 1950s-1970s, a similarly low harvest is assumed for the recreational sector. As the popularity of the species increased and technological advancements facilitated the identification of hard bottom habitat, directed recreational and commercial fisheries developed and landings increased rapidly during the late 1970s, peeked in the mid-to late 1980s, and have since declined substantially since.

Total catch included estimates of recreational landings and discards from Marine Recreational Fisheries Statistics Survey/Marine Recreational Information Program (MRFSS/MRIP) conducted by the National Marine Fisheries Service, and commercial landings from the Atlantic Coast Cooperative Statistics Program (ACCSP). Estimates of commercial discards developed from the Northeast Fishery Observer Program were considered too uncertain to include in the model because of the small sample size. Tautog are not well-sampled by the MRFSS/MRIP program, resulting in higher PSEs and large annual variation in catch estimates, often driven by the small intercept sample size.

As a hard structure-associated species, Tautog are also not well-captured by standard trawl-based surveys. The Technical Committee used four previously accepted fishery-independent surveys from Connecticut, New York and New Jersey, two of which are adult and two are young-of-year surveys. Two other indices, (one egg and one larvae) from the entrainment program at the Millstone, CT power plant were included in sensitivity analyses. In addition, regional fishery dependent indices of abundance (catch per unit effort) were developed from the MRFSS/MRIP intercept data. For this analysis, catch was based on total estimated recreational catch (harvest plus discards), while effort was based on trips that caught any species within a guild of species commonly associated with Tautog. Both fishery independent and fishery dependent indices were standardized using GLM to account for interannual survey variability due to environmental covariates.

2. Justify assumptions about stock structure and the geographical scale at which the population is assessed.

Tagging data suggest strong site fidelity across years with limited north-south movement, although they undergo seasonal inshore-offshore migrations in the northern end of their range. Under the previous assessment, the Technical Committee spent considerable time identifying appropriate regional structure based on life history information, fishery characteristics, data availability, and policy. The preferred regional breakdown identified three regions, but split Long Island Sound between the Southern New England (SNE) and the NY-NJ regions, so a highly regarded alternative regional scheme was presented that moved CT from the SNE region to the NY-NJ region. At that time the TC proposed that in a future assessment should split Long Island

Sound from New Jersey and the New York Bight, thus creating a four region approach. The LIS and NJ-NYB assessment is presented here.

3. Develop models to estimate population parameters (e.g., fishing mortality (F), biomass, abundance) and biological or empirical reference points at the regional basis, and analyze model performance.

This stock assessment used the Age Structured Assessment Program (ASAP) version 3.0.17, available through the Northeast Fishery Science Center (NEFSC) National Fishery Toolbox (NFT) which is a "data rich," forward projecting statistical catch at age program to assess Tautog populations. The model incorporated annual harvest estimates, adult fishery-independent and fishery-dependent biomass, available age structure, size-at-age, and juvenile abundance indices. Within each region, the ASAP model assumed a single fleet with three or four selectivity periods based on management time blocks. "Base" models were conducted for each model and region. Sensitivity runs were also conducted for each model to evaluate model sensitivity to input data, model configuration, regional structure, and other assumptions.

Given periodic changes in management for both regions with trends of increased minimum size, the technical committee determined that it was appropriate for both regional assessments to use four selectivity blocks.

Due to uncertainty in recreational harvest estimates which make up the majority of annual landings, trends in fishing mortality exhibit high interannual variability. The Technical Committee therefore determined that three-year moving averages are more appropriate to evaluate fishing mortality. For the LIS, fishing mortality spiked in the early 1990s and again exhibited a generally increasing trend since the early 2000s. In In NJ-NYB, fishing mortality exhibited a somewhat cyclical trend. Sharp drops in F were observed that generally correspond with implementation of regulations, followed by increases in F in subsequent years.

Trends in biomass are less variable than those for fishing mortality. Consistent with trends in fishing mortality, biomass in the LIS quickly declined from the mid-1980s until the early 1990s and has generally (but slowly) declined since then. In NJ-NYB, SSB declined rapidly during the 1990s. Regulations during the 2000s resulted in minor but temporary rebuilding. SSB declined further during the period 2006-2010, but has since increased back to previous levels. Spawning stock biomass estimates in each region was in the range of 2,000 MT in 2014.

The Technical Committee chose MSY-based reference points for the LIS region, due to the longer time-series of data and the good fit of the stock-recruitment curve for the base run. SSB_{target} was defined as SSB_{MSY} with an $SSB_{threshold}$ of 75% of SSB_{MSY}. This resulted in an SSB_{target} of 4,576 MT and an $SSB_{threshold}$ of 3,432 MT. The F_{target} was defined as F_{MSY} (0.16), and the $F_{threshold}$ was calculated by finding the F that would result that would result in $SSB_{threshold}$ under equilibrium conditions. This resulted in an $F_{threshold}$ of 0.32. SPR estimates are also provided below.

The S-R curve for the NJ-NYB region did not cover the earliest, least exploited period of those populations, and the TC had concerns about the reliability of the estimated parameters. The TC chose to use SPR-based reference points for that region, with F_{target} defined as F40%SPR and $F_{threshold}$ defined as F30%SPR. For NJ-NYB, this resulted in F_{target} = 0.22 and $F_{threshold}$ = 0.36. The TC chose SSB reference points associated with those levels of F by projecting the population forward under equilibrium conditions with recruitment randomly drawn from the observed time-series. SSB_{target} for NJ-NYB was 3,305 MT, and $SSB_{threshold}$ was 2,457 MT.

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

Retrospective patterns indicate F in the terminal year is overestimated in LIS and NJ-NYB. Sensitivity runs generally exhibited similar trends in F compared to the base runs, but shifted the scale of the trajectory and provided a range of terminal year estimates.

Retrospective patterns indicate SSB is slightly underestimated in LIS and overestimated relative to the base model in NJ-NYB. As with fishing mortality, sensitivity runs produced similar trends in SSB, but had varying effects on the scale and slope, resulting in a range of terminal year estimates. Sensitivity runs generally did not result in different assessments of stock status.

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

Relative to these reference points, SSB in the LIS region was estimated to be below $SSB_{threshold}$ (overfished) with the 2012-2014 average of fishing mortality above the $F_{threshold}$ (overfishing occurring). The NJ-NYB region is overfished (SSB_{2014} below $SSB_{threshold}$) and the 2012-2014 average of fishing mortality is above $F_{threshold}$ (overfishing occurring).

6. Develop detailed short and long-term prioritized lists of recommendations for future research, data collection, and assessment methodology. Identify recommendations that have been addressed since the last assessment, or that are in the process of being addressed. Highlight improvements to be made by next benchmark review.

The Technical Committee compiled a list of prioritized research needs to improve understanding of Tautog life history and stock dynamics and aid in development of future stock assessments. High priority needs included improved biological collections across sectors and size ranges, characterization of discarded length frequencies, and development of a comprehensive fishery independent survey that is more appropriate for a structure-oriented species.

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

The TC recommends conducting a Benchmark Stock Assessment in 2021. Update assessments will be conducted for all regions during the fall of 2016 with data through 2015. At that time, the TC will discuss timing of future updates.

1. INTRODUCTION

Tautog (*Tautoga onitis*) is a member of the wrasse (Labridae) family inhabiting temperate regions of the U.S. Atlantic coast. The species ranges from the Gulf of Maine through Georgia, with a primary distribution from Cape Cod, Massachusetts to Virginia Beach, Virginia. The species supports important commercial and recreational fisheries throughout the primary range, and has been managed through the Atlantic States Marine Fisheries Commission (ASMFC) since 1996 (ASMFC 1996). The 2015 benchmark stock assessment for tautog delineated the stock into multiple regions for management purposes (ASMFC 2015, Table 1.1). The ASMFC Tautog Management Board (Board) accepted the stock assessment for management use and initiated Draft Amendment 1 in May 2015 to develop regional management alternatives.

To further develop a range of regional alternatives for Draft Amendment 1, the Board requested additional spatial resolution in the Mid-Atlantic region, specifically development of a separate assessment for Long Island Sound (LIS) that includes Connecticut plus New York's north shore of Long Island. The additional region would result in four management units: Massachusetts-Rhode Island (MARI), LIS, New Jersey-New York Bight (NJ-NYB, consisting of NJ plus NY south of Long Island), and Delaware-Maryland-Virginia (DMV, Table 1.2). The purpose of this report is to address the Management Board's request, as well as update the original NYNJ regional assessment without New York's LIS data, yielding an NJ-NYB assessment.

The LIS regional stock assessment was led by the University of Connecticut, while the NJ-NYB assessment was led by NJ Division of Fish and Wildlife. Both received support and advice from the ASMFC Tautog Technical Committee (TC) and Stock Assessment Subcommittee (SAS). New York harvest data, biological samples, and some indices were separated by region (LIS or south shore) and then combined with data from CT or NJ to develop regional estimates. Population modeling was conducted using the preferred method from the benchmark stock assessment (ASAP module of the NMFS NEFSC Tool Box; ASMFC 2015). Subsequent analytical methods, estimation of biological reference points, and stock status determination also employed similar methods to the benchmark.

1.1. Management Unit Definition

Tautog stocks on the U.S. Atlantic coast are managed through the ASMFC Interstate Fishery Management Plan (FMP) for Tautog (ASMFC 1996). Under this FMP, the management unit is defined as all U.S. territorial waters of the northwest Atlantic Ocean, from the shoreline to the seaward boundary of the exclusive economic zone, and from US/Canadian border to the southern end of the species range. All states from Massachusetts through Virginia have a declared interest in the fishery management plan.

1.2. Regulatory History

The following is a brief review of the history of Tautog fishery management through the ASMFC. Additional details are provided in the various amendments and addenda to the original Tautog FMP, which are available online at *www.asmfc.org*.

Prior to the ASMFC interstate FMP, individual states managed Tautog on a unilateral basis. Some states had commercial and/or recreational regulations for Tautog, such as minimum size limits, possession limits, and effort controls, although most states did not have any Tautog regulations. An increase in fishing pressure in the mid-1980s through early 1990s, and a growing perception of the species' vulnerability to overfishing, stimulated the need for a coastwide fishery management plan. Accordingly, in 1993 the ASMFC recommended that a plan be developed as part of its Interstate Fisheries Management Program. The states of Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Delaware, Maryland, Virginia, and North Carolina declared an interest in jointly managing this species through the ASMFC. The Interstate Fishery Management Plan for Tautog was implemented in 1996 (ASMFC 1996), with the goals of conserving the resource along the Atlantic Coast and maximizing long-term ecological benefits, while maintaining the social and economic benefits of recreational and commercial utilization.

The original FMP established a 14" minimum size limit and a target fishing mortality of F = M = 0.15. The target F was a significant decrease from the 1995 stock assessment terminal year fishing mortality rate in excess of F = 0.70, so a phased in approach to implementing these regulations was established. Northern states (Massachusetts through New Jersey) were to implement the minimum size and achieve an interim target of F = 0.24 by April 1997, while southern states (Delaware through North Carolina) had until April 1998 to do the same. All states were then required to achieve the target F = 0.15 by April 1999.

In response to northern states' difficulty in achieving the interim F by their deadline, Addendum I to the FMP was in passed in 1997 delaying implementation of the interim F and target F for all states until April 1998 and April 2000, respectively.

The 1999 stock assessment included only nine months of data under the new regulations (i.e., through 1998). Given the life history of the species, the Tautog Management Board was concerned the assessment provided limited advice on the effects of the new regulations. Addendum II was therefore passed in November 1999, further extending the deadline to achieve the F=0.15 target until April 2002 to allow additional evaluation of the new regulations.

Addendum II also tasked the Tautog TC with addressing a number of questions raised by the Board, including reference point alternatives, state-wide vs. sector-specific (within a state) compliance, monitoring requirements, and guidelines on developing mode or gear specific management options within a state. The TC provided recommendations to the Board, and the Board's decisions were adopted as Addendum III to the Tautog FMP in February 2002. Most importantly, Addendum III established a new target fishing mortality rate of $F_{target} = F_{40\%SSB} = 0.29$ and mandated that states collect a minimum of 200 age samples per year.

Addendum IV, adopted in January 2007, revised the target fishing mortality rate to F = 0.20, a 28.6% reduction in overall fishing mortality, and established biomass reference points for the first time. The biomass reference points were *ad hoc*, based on the average of the 1982-1991 SSB (target; 26,800 MT) and 75% of this value (threshold; 20,100 MT). In addition, Addendum IV required states to achieve the new target F by reductions in recreational harvest only. Addendum V was subsequently passed in May 2007 to allow states flexibility in achieving the target through reductions in commercial harvest, recreational harvest, or some combination of both. A Massachusetts-Rhode Island model indicated regional F was lower than the coastwide target, therefore these two states were not required to implement management measures to reduce F.

In April 2011, Addendum VI to the FMP established a new F_{target} of F = M = 0.15 on the grounds that stock biomass had not responded to previous F levels. The new F_{target} required states to take a 39% reduction in harvest. As in Addendum IV, a regional assessment of Massachusetts and Rhode Island demonstrated a lower regional F using ADAPT VPA, and these states were not required to implement tighter regulations. To achieve the required harvest reduction, all other states adopted higher minimum size limits exceeding the FMP's minimum requirement of 14" in addition to other measures, such as possession limits, seasonal closures, and gear restrictions. Current recreational management measures for states included in this regional assessment are presented in Table 1.3; regulations for the commercial fishery are in Table 1.4.

1.3. Stock Assessment History

The first Tautog stock assessment was performed in 1995 using the ADAPT virtual population analysis (VPA) model (available through NMFS NEFSC toolbox, http://nft.nefsc.noaa.gov/). In order to incorporate perceived regional differences in biology and fishery characteristics throughout the range of the species, the Technical Committee (TC) attempted separate regional models for northern (Massachusetts to New York) and southern (New Jersey to Virginia) states. The assessment underwent peer review through the NMFS NEFSC Stock Assessment Workshop/Stock Assessment Review Committee (SAW/SARC) process. Although the assessment was not accepted by the peer review panel, the resulting fishing mortality estimate from the assessment was incorporated into the initial FMP (ASMFC 1996).

The next benchmark stock assessment, performed in 1999, was also conducted using the ADAPT VPA. The regional approach was used for data consolidation, application of age keys, and preliminary VPA runs of the model. Unfortunately, results for the southern region were unreliable. The preferred run, therefore, was based on catch at age (CAA) developed separately for north (MA-NY) and south (NJ-VA) regions and combined for a total coastwide CAA. The assessment derived coastwide estimates of F, spawning stock biomass, and recruitment. In addition, tag based survival estimates were included in the assessment as corroborative evidence. A peer review of the model through the SAW/SARC process determined that the model was suitable for management purposes. That assessment indicated that the terminal F rate had dropped to 0.29, which was attributed to increases in minimum size required in the original FMP.

This terminal F was close to the interim FMP target of 0.24, but well above the final plan target of F = 0.15.

A stock assessment update conducted in 2002 using the methods from the 1999 assessment found that recreational catch rates had returned to levels observed prior to the minimum size limit increase, and F had increased to F = 0.41. The Board responded by implementing reductions in recreational harvest in 2003, in an attempt to return F to the FMP target value. The target was revised to $F_{SSB\ 40\%}$ = 0.29 by Addendum III (ASMFC 2002), based upon updated recruitment and weight at age parameters and a desire to adopt a target with more management flexibility.

A benchmark stock assessment conducted and peer-reviewed in 2005 (ASMFC 2006) continued the use of the coastwide ADAPT VPA model based on separate regional (north/south) CAA. The assessment indicated that the coastwide population of Tautog had declined about four-fold from 1982 to 1996 and had then remained relatively stable through the terminal year. The stock was considered overfished and overfishing was occurring with a 2003 coastwide fishing mortality estimate of F=0.299. In response to concerns from the Management Board and TC regarding the utility of a coastwide model on a mostly sedentary species, the 2006 assessment also presented results of state-specific assessments (primarily catch curves) of local Tautog populations. The peer review panel generally agreed that local or regional methods were more appropriate given the life history of the species, but expressed reservations about the paucity of data available at small regional scales and the use of catch curves for management purposes. The panel approved the coastwide model for use in management, encouraging further development and refinement of more localized models for future use (ASMFC 2006).

A "turn of the crank" update assessment was completed in 2011 using the same methodology as the 2006 assessment, with data through 2009. Fishing mortality was estimated as F = 0.23 in 2009, with the three-year average F = 0.31. Both estimates were above the Addendum IV target of F_{target} = 0.20. SSB was estimated to be 10,663 MT in 2009, well below Addendum IV's target of 26,800 MT and threshold of 20,100 MT. Therefore, the 2011 stock assessment update concluded that Tautog was overfished and experiencing overfishing.

A benchmark stock assessment was completed and peer-reviewed in 2014 (ASMFC 2015). The assessment was conducted at a regional level. The TC used life history information, tagging data, fishery characteristics, and data availability considerations to split the coastwide population into three regions. Each region was assessed independently using the statistical catch-at-age model ASAP. All three regions were found to be overfished, with overfishing occurring in the northern one (preferred model) or two (alternate model) regions.

Since 2006, many of the compliance elements of the coastwide FMP have served well to increase the knowledge base regarding this species. In addition, the importance of having a coastwide plan is still high, since recreational and commercial fisheries on the stocks affect the species over broad geographic areas, even if the stock is split into discrete management units. The 2015 benchmark stock assessment proposed regional stock definitions based on localized biological and socioeconomic trends. This regional assessment proposes additional stock unit boundaries for consideration at a finer regional scale.

2. LIFE HISTORY AND STOCK STRUCTURE

Tautog is one of over 630 wrasse species comprising the family Labridae and is often known by the common name "blackfish" in the Northeastern US, in reference to its common overall coloration. Tautog are also known locally by several other common names such as “white chinner,” slippery, or tog. Most labrids inhabit tropical waters, making tautog, and its close relative Cunner (*Tautogolabrus adspersus*) exceptions to the general rule, as they range along the western Atlantic coast from Nova Scotia to South Carolina (Bigelow and Schroeder 1953). Both species are most abundant from the southern Gulf of Maine (lower Massachusetts Bay and southern Cape Cod Bay) to Chesapeake Bay (Steimle and Shaheen 1999).

In a portion of its range, adult tautog seasonally migrate. In northern regions, adult tautog move from offshore wintering grounds in the spring, to nearshore spawning and feeding areas, where they remain until late fall when the reverse migration occurs as water temperatures drop below 10°C (Briggs 1977; Cooper, 1966; Olla et al 1974, 1979; Steimle and Shaheen 1999). Populations in the southern region may undergo shorter distance seasonal migrations, and in the southernmost part of the range may not undergo seasonal migrations at all (Hostetter and Munroe 1993, Arendt et al 2001). Even further north some localized populations, such as those in the lower Chesapeake Bay, eastern Long Island Sound, and Delaware Bay, remain inshore during the winter (Olla and Samet 1977, Ecklund and Targett 1990, Hostetter and Munroe 1993, White 1996, Arendt et al 2001).

There are contradictory studies on the movement of tautog in response to changes in water temperature. Studies suggest adult Tautog may migrate to cooler waters offshore during the summer (Briggs 1969; Cooper 1966). However, other studies report adult tautog are known to remain inshore in Great South Bay, NY, when temperatures reach 19-24°C (Olla et al., 1974) and off of Virginia when water temperature reach 27°C (Arendt et al 2001).

2.1. Age and Growth

To age Tautog, most states use opercular bones following the techniques of Cooper (1967) and Hostetter and Munroe (1993). Whole opercula are obtained at random from commercial and recreational catches and fisheries independent surveys. Approximately 200 individual samples per state per year have been obtained since 1996. Opercula are most often taken in pairs from each fish, along with a total length and sometimes weight. The dissected opercular bones are boiled in water for one to two minutes and cleaned of tissue. The bones are allowed to dry for two days and then read, usually with transmitted light, without magnification. Annular marks are usually quite distinct, with the exception of the first annulus, which may be obscured by the thick bone growth in the region of the focus in older fish. Hoestetter and Monroe (1993) validated the annual nature of ring formation in opercula with marginal increment analysis. January 1 aging conventions are used and fall aged fish are treated as an age plus group. In order to address concerns about consistency in Tautog ageing methods among states, the Commission conducted a hard parts exchange and ageing workshop in May 2012. The 2012 ageing workshop concluded that there were no significant differences in age estimates arising from use of different hard parts (ASMFC 2012); however, the operculum remains the recommended standard reference for ageing Tautog. In 2013, there was a follow-up to the 2012 workshop to ensure continued consistency among state Tautog ageing methods. Ageing estimates were found to be consistent across the states.

Age and growth studies indicate a relatively slow growing, long lived fish. Individuals over 30 years are recorded in Rhode Island, Connecticut, and Virginia. Tautog also grow to large sizes, up to 11.36 kg (25 lbs). Males exhibit faster growth and larger sizes (based on total length) than females (Cooper 1967). Evidence suggests females lifespan is shorter than males, consistent with their smaller maximum size.

Growth rates from the southern part of the range are similar to those in the north, until about age 15 (Cooper 1967), after which growth rates decrease more rapidly in northern waters (Hostetter and Munroe 1993). White (1996) developed growth equations that suggested similar growth rates throughout the range, and attributed apparent geographic variability indicated by earlier work to differences in aging techniques.

2.1.1. Analysis of Regional and Temporal Variability in Life History

Age, length, and weight data were compiled to examine potential differences in growth rates and size-at-age by region and thereby inform stock structure definitions. Data for these analyses were taken from various fishery-dependent and independent surveys (Table 2.1). Analyses excluded Massachusetts samples that were taken in a targeted investigation of stunting, and two likely erroneous data points (Connecticut: a 21 kg fish with a length of 49.1 cm; Delaware: a 36-year old fish with a length of 40 cm). Length, age and weight distributions are positively skewed in all regions (Figure 2.1). Length values are distributed differently among regions in extremes (Figure 2.1A); the MARI region data has the smallest and largest length values, whereas DMV has the largest minimum length and LIS has the smallest maximum length values; mean and median values for length are similar among regions. The MARI sampling program captured the youngest fish (age 0) and also yielded the youngest maximum age, whereas the LIS samples contained the oldest maximum-age fish; mean and median values for age are similar among regions (Figure 2.1B). There is greater disparity among regions in the distribution of weight than in the distribution of length and age (Figure 2.1C), in that the weights of NJ-NYB fish are considerably less than those of other regions: the 75%ile length of NJ-NYB fish is about the same as the median weight of DMV fish, is less than the median weight of LIS fish and is less than the 25%ile of MARI fish.

Analyses of length, weight, and age relationships included nonlinear regression and general linear models. Analysis of Residual Sum of Squares (ARSS) was used to evaluate differences among regions in fitted curves from nonlinear regression (Chen et al. 1992; Haddon 2010):

$$F = \frac{\dfrac{RSS_p - \sum RSS_i}{df_p - \sum df_i}}{\dfrac{\sum RSS_i}{\sum df_i}} = \frac{\dfrac{RSS_p - \sum RSS_i}{m(c-1)}}{\dfrac{\sum RSS_i}{N - mc}}$$

where *RSS* is the residual sum of squares, *df* is the degrees of freedom, the *p* and *i* subscripts are pooled or individual curve, respectively, *c* is the number of curves being compared, *m* is the number of parameters, and *N* is the total number of observations. The significance of the result is assessed by calculating the probability of observing *F* or greater under the null hypothesis, for numerator degrees of freedom *m(c-1)* and denominator degrees of freedom *N-mc*. General linear model analysis included analysis of variance (ANOVA) and analysis of covariance (ANCOVA), in which the value of F is calculated as MS_{effect}/MS_{error}. These approaches permit assessment of how responses vary among levels of each predictor while adjusting or partialling out the effect of other predictors, using least square means (*LSMeans*) estimates. Significance of differences in mean responses among predictor levels is assessed using a multiple-means test (Tukey-Kramer) that is conducted only when the predictor is significant ($P<0.05$) to control the experimentwise error rate.

Regional differences in life history variables were tested in three sets of comparisons: differences among regions in the four-region scenario (Table 1.2), between CT and the rest of the Southern New England region (i.e. Massachusetts and Rhode Island [MARI]), and between NY data from LIS and the remainder of NYNJ (i.e., New Jersey and the New York Bight [NJ-NYB]). The purpose of the latter two tests is to discern whether LIS represents a source of heterogeneity within the SNE and NYNJ regions in the preferred three-region scenario of the 2015 Benchmark Stock Assessment (Table 1.1)

2.1.2. Regional Variability in Growth Curves Estimated via Nonlinear Regression

Von Bertalanffy growth curves were fitted to length-age data. The response for all models was length, and the predictor variable was age. The null hypothesis of no difference in growth curves among regions was tested via ARSS, as described above. Growth curves were fitted using three parameter estimates (m=3): asymptotic length (*Linf*), growth rate (*K*), and age at zero size (*t0*). In the test of difference among regions in the four-region delineation, *c*=4; in the test of difference between CT and MARI, and the test of difference between NY data from LIS and data from NJ-NYB, *c*=2. In all regression analyses, initial values of parameters were *Linf*=59, *K*=0.171 *t0*=0; to check for stability of final estimates, alternate initial values of *Linf*=70, *K*=0.7, *t0*=-7 were tested. In all cases the models converged on the same estimates. Diagnostic plots for the regression on all pooled data indicate that residuals are close to normally distributed but that the model overestimates length for the youngest fish and underestimates length for the oldest fish (Figure 2.2).

2.1.3. Regional and Temporal Variability in Length-at-Age Estimated by Analysis of Variance

Growth was also subjected to linear modeling via ANOVA, in which length was the response variable, and age, region, and year were included as categorical predictors. The null hypothesis was that there was no difference in mean length between age, year, and region. Model diagnostics indicated approximate normality of residuals that deviated appreciably only at far tails (Figure 2.4). Levene's test indicated that there was heterogeneity of variance (HOV) for each effect (P<0.0001), but no mean-variance relationship was observed in any case nor were there evidently divergent (high or low variance) levels of any effect. All interactions among main effects were significant but presentation here is limited to a reduced model including only the main effects.

2.1.4. Regional Variability in Weight-Length- Relationship Estimated via Nonlinear Regression

Parameters of the weight-length relationship for Tautog were estimated by nonlinear regression. Data on weight were fewer than data on length, in part because RI and DE rely on intercepts in fishery surveys of specimens that have been filleted. The model for fitting weight to length was the standard power equation for allometric relationships, $Weight = a*Length^b$. The null hypothesis of no difference in weight-length curves among regions was tested via ARSS, as described above (*m*=2). In the test of difference among regions in the four-region delineation, *c*=4; in the test of difference between CT and MARI, and the test of difference between LIS and NJ-NYB, *c*=2. Because there is scant data on weight of NY fish from LIS, the third hypothesis test used all observations available for weight of LIS fish (i.e., CT and LIS NY) to compare to NJ-NYB. In all regression analyses, initial values of parameters were *a*=0.00001, *b*=3; to check for stability of final estimates, alternate initial values of *a*=0.0001, *b*=2.6 were tested. In all cases the models converged on the same estimates. Diagnostic plots for the regression on all pooled data indicate that residuals are somewhat leptokurtic and that the model overestimates weight among the longest fish (Figure 2.7). An effort to correct this deviation by restricting the analysis to fish of weight < 7 kg or to fish of length $\leq$ 70 cm did not resolve the deviation so analysis proceeded with the entire dataset.

2.1.4.1. Weight Analysis of Covariance

Weight-length relationships were also subjected to linear modeling via ANCOVA, in which weight was the response variable, region, and year were included as categorical predictors and length was included as a continuous covariate. Weight and length were $\log_{10}$-transformed. The null hypothesis was that there was no difference in weight-at-length between age, year, and region. Model diagnostics indicated approximate normality of residuals that deviated appreciably only at far tails (Figure 2.5). Among-means differences were evaluated as protected Tukey-Kramer tests (conducted only when the treatment was significant at P<0.05) to control the experimentwise error rate, on means adjusted for the other effects (least-squares means [*LSMeans*]). All interactions among main effects were significant but presentation here is limited to a reduced model including only the main effects.

2.1.5. Results

1.1.1.1. Growth Curves

There is regional heterogeneity in growth curves. The von Bertalanffy assessment of growth revealed that the growth constant (*K*) generally decreased and the maximum size (*Linf*) increased from north to south (Table 2.2). The growth curves for the two northern regions are similar for young fish but the MARI curve asymptotes at a smaller size than that for LIS (Figure 2.6). The growth curve parameters for the two southern regions are similar for young fish, ascending more slowly than the curves for the northern regions, but ultimately ascending to a larger size at age. An F-test via ARSS indicates dissimilarity of growth curves among all regions (Table 2.3). Heterogeneity is also indicated between LIS and MARI, and between LIS and NJ-NYB.

2.1.5.1. Length-at-Age

Mean length varied among ages, years and regions (Table 2.4). Tukey's comparisons of *LSMeans* revealed that differences in mean length between successive ages were significant for younger ages but were not different at greater ages, especially for ages greater than 10. Most (70%) of the 435 inter-year comparisons of mean length-at-age were significant. *LSMean* length adjusted for age and region has increased over time (Figure 2.7; Pearson correlation coefficient R = 0.6, P = 0.003). Comparing *LSMean* length values that are representative of the trend over time (estimated for the years 1985 and 2014) indicates an increase of 7.3% in length at age over about three decades. In the four-region comparison, as well as in each of the comparisons of LIS and neighboring region, there was a significant difference in mean length-at-age (Table 2.4). *LSMean* length adjusted for age and year does not vary in a north-south gradient: *LSMean* lengths for NJ-NYB and LIS were smallest and the *LSMean* from DMV was largest (Figure 2.8). *LSMean* length of DMV Tautog is 10.4% longer than *LSMean* length of NJ-NYB Tautog.

2.1.5.2. Weight-Length Relationship Estimated via Nonlinear Regression

The parameters of the allometric length-weight function for LIS were estimated. The scaling parameters varied among regions, such that the elevation represented by the coefficient *a* decreased and the exponent *b* increased in a north to south gradient (Table 2.5). As a result, Tautog of intermediate length are on average heavier in northern regions, but those of greater length are on average heavier in southern regions (Figure 2.9). An F-test via ARSS indicates dissimilarity of growth curves among all regions (Table 2.6). Heterogeneity is also indicated between LIS and MARI, and between LIS and NJ-NYB.

2.1.5.3. Weight Analysis of Covariance

Mean weight-at-length varied among years and regions (Table 2.7). Tukey's comparisons of *LSMeans* revealed that 31% of the 465 inter-year comparisons of mean weight-at-length were significant. Mean weight-at-length, adjusted for region, has decreased over time (Figure 2.10;

Pearson correlation coefficient R = -0.75, P < 0.0001). After simple back transformation, the heaviest *LSMean* weight (in 1986) is 19.7% greater than the lightest *LSMean* weight (in 2013); comparing values more representative of the general trend (in 1985 and 2012) indicates a decrease of 8.6%. In the four-region comparison, as well as in each of the comparisons of LIS and neighboring region, there was a significant difference in mean weight-at-length (Table 2.7). Weight-at-length did not vary in a north-south gradient; *LSMean* weights for MARI and DMV were smallest and the *LSMean* from LIS was largest (Figure 2.11). The back-transformed *LSMean* for LIS is 5.8% greater than the back-transformed *LSMean* for MARI.

2.1.6. Discussion

Analyses indicate heterogeneity in growth parameters over space and time. Results of nonlinear regression and general linear models indicated that each region has a biologically distinctive population of Tautog. Specifically, LIS and NJ-NYB parameters are different from those of MARI and DMV, and are different from each other. While the large sample size supporting each analysis contributed to the statistical significance of these differences, the parameters vary to a biologically significant extent. Regional differences in years and collection methods for specimens used in the biological analysis may have contributed to these differences as a confounding effect. In particular, northern states have more data from the earlier years, and DMV states rely exclusively on fishery-dependent sampling thus have limited data on young small fish. Further examination of growth rate differences should be explored using data that is more representative of the full size-age structure of the population. An additional caution about the assessment of spatial and temporal variability in growth parameters is that interactions among predictors have not been considered in detail.

Regional and temporal differences in how length changes with age are reflected in von Bertalanffy curves and in estimates of age-adjusted mean length. As indicated in previous stock assessments, Tautog in southern regions achieve a larger final size than those in northern regions (mid-60 cm range vs mid-50 cm range), albeit at an initially slower rate. Predicted age- and year-adjusted length (*LSMean* length) is smallest for the two regions that are subjects of this regional assessment, LIS and NJ-NYB. There has been temporal variability in growth: predicted age- and region-adjusted *LSMean* length has increased over time by about 7%.

Regional and temporal differences in how weight varies with length are reflected in nonlinear regressions using scaling equations and in estimates of length-adjusted mean weight. Weight increases more gradually with length in northern regions but starts out at greater values. The scaling exponent for the weight-length relationship is close to the value of 3 that would be expected on general allometric principles. Analysis of regional differences in adjusted weight (*LSMean* weight adjusted for year and length) indicates that weight-at-length varies in an inverse fashion to length-at-age: mean weight is heaviest for LIS and NJ-NYB, about 6% greater than for the northernmost and southernmost regions. Weight-at-length has decreased over time by about 8% in 30 years.

2.2. Maturity

Unlike most labrids, which are protogynous hermaphrodites, Tautog are gonochoristic. Tautog reach sexual maturity at ages 3 to 4 (Chenoweth 1963, White 1996), with 50% of females maturing by 224 mm total length and 50% of males maturing by 218 mm (White et al. 2003). Female Tautog begin to mature at age 3, and males begin to mature earlier at age 2. Chenoweth (1963) found that in Narragansett Bay, Rhode Island, no females were mature at age 2, 80% of female Tautog were mature at age 3, and 100% were mature by age 4. White et al. (2003) found very similar numbers for Tautog in Virginia, with no females mature at age 2, 78% mature at age 3, and >97% mature at age 4. Mature Tautog can often be sexed from external characteristics with males having a pronounced lower mandible and more steeply sloping forehead. Females exhibit a more midline mouth position and a more ovoid body shape. Males are most often grayish in color with a white midline saddle mark common on breeding males. Juveniles and females more often exhibit a mottled and brown toned appearance.

2.3. Reproduction

The spawning season for Tautog occurs from April through September (Arendt et al 2001). The spawning peak was assumed to occur coastwide on June 1 based on observed spawning peaks throughout the range (Cooper 1967, White 1996), although White noted batch spawning with repeated spawning events extending over sixty days. Spawning occurs primarily at or near the mouth of estuaries in nearshore marine waters (Cooper 1967, Stolgitis 1970). Courtship begins between 1300 and 1600 hours (Olla and Samet, 1977). Based on observations, a pair of Tautog would rush to the surface and synchronously release gametes into the water column (Olla and Samet, 1977).

2.3.1. Female-to-Male Ratio

Studies indicate that there is a sex-ratio bias towards females (Cooper 1967; Hostetter and Munroe 1993; White et al. 2003; LaPlante and Schultz 2007). For example, White's study of Tautog in the lower Chesapeake Bay indicates a 56:44 female-to-male ratio. However, because of concerns for how representative the samples were in these studies, the TC used a 50:50 ratio.

2.3.2. Annual Fecundity

Fecundity is strongly related to female size, with larger females producing significantly more eggs than smaller females. LaPlante and Schultz (2007) estimate that females measuring 500 mm in total length produced 24-86 times more eggs than females half that size. Tautog's potential annual fecundity was estimated to range from 10 - 16 million eggs for the average female in Long Island Sound (LaPlante and Schultz, 2007) and 0.16 - 10.5 million eggs in the lower Chesapeake Bay across mature females of all ages (White et al. 2003). Based on analysis of data from a 22-year trawl survey in Long Island Sound, LaPlante and Schultz (2007) concluded that the abundance of Tautog has decreased and size structure of the population has shifted to smaller fish. However, as the overall population has shifted towards a higher female-to-male ratio, the estimated annual fecundity has not declined further than the index of abundance.

2.3.3. Spawning Site Fidelity

Tagging studies show that Tautog utilize the same spawning locales from year to year (Cooper 1967. In Narragansett Bay, mature Tautog returned to the same spawning site each year but dispersed throughout the bay after spawning. However, Olla and Samet (1977) found that Tautog did not always return to the same spawning site in the south, and that some mixing of the populations occurred on the spawning grounds.

2.4. Natural Mortality

Natural mortality was long estimated to be *M* = 0.15 based on the "rule of thumb" method of 3/*Tmax* with an assumed max age of 20 years. The TC performed an in-depth analysis during the 2015 Benchmark Stock Assessment using a number of life history- and age-based estimators of *M*. Estimates ranged from M = 0.14 to 0.22, with a coastwide average of *M* = 0.16, and regional estimates ranging from 0.15 in NY-NJ to 0.23 in SNE. The regional assessment used the NY-NJ average of 0.15 for LIS and for New Jersey-New York Bight. For more information on the analysis of the natural mortality rate, refer to the Benchmark Stock Assessment (ASMFC 2015).

2.5. Stock Definitions

Historically, the stock unit for Tautog has been consistent with the management unit, which includes all states from Massachusetts through North Carolina (ASMFC 1996). In the 2015 Benchmark Stock Assessment, the Tautog TC investigated new stock unit definitions based on life history data, fishery and habitat characteristics, and available data sources. While a three-region approach (Table 1.1) in the Benchmark Stock Assessment is still applicable, there was interest in assessing and managing the LIS as a discrete area. This regional assessment analyzes two additional regions (LIS and NJ-NYB) to potentially comprise a four-region management scenario (Table 1.2).

In the past, although regional differences in habitat and fishery characteristics were recognized (ASMFC 2006), genetic analyses showed no discernible genetic structure within the region (Orbacz and Gaffney 2000). This led to development of regional (MA-NY and NJ-NC) catch at age matrices combined into a coastwide population model for assessment and management advice (Steimle and Shaheen 1999, ASMFC 2006).

The TC has considered smaller unit stock definitions in the past, but was limited by data availability, in particular the lack of any survey data south of New Jersey to inform a southern region model. As an alternative, the 2006 assessment included state specific models (primarily catch curves; ASMFC 2006). An independent peer review panel supported the use of local/regional models, but expressed several concerns with the use of catch curves (ASMFC 2006).

In the Benchmark Stock Assessment, the Tautog SAS addressed concerns that hampered regional management during previous assessments. New work included development of fishery dependent abundance indices in areas with no fishery independent data, and the use of a more robust statistical model that better handled uncertainty in the data. These innovations allowed the TC to investigate a regional structure that was not possible in the past.

To help determine appropriate stock units, the Tautog TC considered the following in the 2015 benchmark stock assessment.

- Fishery catch and effort information from NMFS Fishing Vessel Trip Reports (VTRs) was evaluated to identify state-specific fishery characteristics. Results indicate that:
    - MA to CT fisheries remain primarily within local sounds and bays
    - NY and NJ fisheries range from LIS to Delaware Bay, with significant overlap in ocean waters of NMFS statistical areas 612 and 613 (approximately Manasquan River, NJ to Montauk, NY)
    - DE to VA fisheries remain south of Delaware Bay
- Length-weight data were analyzed to develop state specific growth curves. Results suggest that Tautog from SNE and NY waters have a significantly lower L_{inf} than fish from NJ to VA.
- Tagging data indicate that Tautog have strong site fidelity and move only short distances longitudinally, if at all, during seasonal migrations (Cooper 1966, Caruso pers. comm. (MA DMF), Arendt et al. 2001, Cimino pers. comm. (VMRC)).
- Spawning occurs over a widely distributed geographic scope among local aggregations (White et al. 2003, LaPlante and Schultz 2007).

Based on these results, the Tautog TC determined that the “coastwide” stock unit is inappropriate. The 2006 assessment proposed regions consisting of only one or two states (ASMFC 2006), but in most cases, available data in regions of this size cannot support a rigorous stock assessment. Appropriate region designations must balance Tautog’s sedentary life history with available data and political boundaries. With these considerations in mind, the Tautog TC determined that the regions of MA-CT, NY-NJ, and DE-VA would be most appropriate. During deliberations, the TC expressed concern that this regionalization splits Long Island Sound across two regions, so a highly regarded alternate regional breakdown moves CT from the southern New England to NY-NJ region.

The Peer Review Panel for the 2015 Benchmark Stock Assessment determined that either the preferred or alternate models were appropriate for management use. However, members of the Board were concerned that splitting LIS between regions (preferred model) could result in inconsistent management measures in a shared body of water, and that combining CT and NJ into a single region (alternate model) could result in regionally inappropriate management measures because of differences in life history and fishery characteristics within the region. The Board tasked the TC with developing a LIS-specific assessment model that would address both of these concerns, allowing regionally consistent and appropriate management measures.

3. HABITAT DESCRIPTION

Tautog are attracted to some type of structured habitat in all post larval stages of their life cycle. These habitats include both natural and man-made structures, such as submerged vegetation, shellfish bed, rocks, pilings, accidental shipwrecks and artificial reefs (Olla et al, 1974; Briggs 1975; Briggs and O'Connor 1971; Orth and Heck 1980; Sogard and Able 1991; Dorf and Powell 1997; Steimle and Shaheen 1999).

Juvenile Tautog require shelter from predators and for feeding and are often found in shallow nearshore vegetated areas such as eelgrass beds or algae beds. Newly settled individuals are reported to prefer areas less than one meter deep (Sogard et al 1992, Dorf and Powell 1997), moving out to deeper water as they grow. Juvenile Tautog have size-specific preference when choosing a shelter (Dixon 1994) and appear to have a strong affinity to their home site, rarely venturing more than a few meters away (Olla et al. 1974). During the winter, juveniles are believed to remain inshore in localized areas and disperse during the spring (Stolgitis 1970; Olla et al. 1979).

Adult Tautog prefer highly structured habitat, including rock piles, shipwrecks and artificial reefs which provide food and sheltering sites. Tautog exhibit diurnal activity and enter a torpid state at night during which they seek refuge in some type of structure. Soon after morning twilight, Tautog have been observed leaving their night time shelter to feed throughout the day (Olla et al. 1974; 1975).

The overwintering habitat of adult Tautog is poorly understood. When water temperatures fall between 5-8°C, Tautog enter a torpid state and hide in some type of structured habitat (Cooper 1966, Olla et al 1974, 1979).

Little is known about habitat needs critical to recruitment levels, but given the small percentage of structured habitat, relative to the overall marine habitats along the Northern Atlantic coast, Tautog range is likely bounded to some degree by available habitat. This may be especially true in the region south of Long Island NY, where relatively little natural rock habitat exists compared to the structure rich northeastern states (Flint 1971).

4. FISHERIES DESCRIPTION

4.1. Recreational Fishery

Tautog is predominantly a recreationally caught species, with anglers accounting for about 90% of landings coastwide and within the CT-NY-NJ region investigated in this assessment. Information on the coastwide recreational fishery is provided in the Benchmark Stock Assessment (ASMFC 2015). In the LIS region, recreational landings in the LIS region peaked in 1988 at nearly 700,000 fish and fell sharply to about 5% of its peak in 2000 and 2001 (Figure 4.1). Since then landings have approached peak harvest in some years but have mostly varied in the range of 100,000 to 400,000 fish. The 2010-2015 average landings are 200,000 (Table 4.1). In the NJ-NYB region, recreational harvest exceeded one million fish per year in most years between 1988 and 1993, with a peak of 1.56 million fish in 1991 (Figure 4.1, Table 4.1). Harvest dropped quickly following the peak, however, reaching a time series low of just 24,000 fish in 1998 with an average annual harvest of 415,000 fish between 1994 and 2002. Recreational landings dropped again in 2003, falling below 200,000 fish before recovering slightly by 2006. Between 2006 and 2014, annual landings have shown high interannual variability without a trend, ranging from approximately 70,000 to 400,000 fish, with an average of 268,000 fish.

The majority (nearly 70%) of Tautog recreational harvest coastwide comes from the private/rental boat mode. The remaining 30% is split relatively evenly among the shore mode and for-hire (party/charter boat) mode. Within the CT-NY-NJ region, the proportion of recreational harvest from the private/rental sector has increased from around 50% in the early 1980s to over 80% in recent years (Figure 4.2).

As reported in the Benchmark Stock Assessment (ASMFC 2015), the coastwide recreational fishery for Tautog is traditionally a late spring and fall fishery. Prior to implementation of regulations in 1998, approximately 40% of the coastwide harvest was taken during September and October, with an additional 20-25% on average coming from both May-June and November-December periods. With the advent of regulations in 1998, many states chose to limit their spring fishery in an attempt to protect spawners. This has led to a shift in harvest from May-June to November-December. Since 1998, harvest during September to December has averaged approximately 75% of annual coastwide harvest.

4.2. Commercial Fisheries

Since 1999, hand harvest has been the primary gear for commercial Tautog harvest, contributing approximately 43% of annual commercial harvest. The value (dollars per pound) for Tautog has increased fairly steadily since 1990 and has recently surpassed $3.00 per pound. The coastwide history and seasonal pattern of commercial landings and the value (dollars per pound) for Tautog are further described in the Benchmark Stock Assessment.

In the LIS region, commercial landings peaked in 1987 at 159 metric tons, declined to 15 mt in 1999 and 2000 (Figure 4.3, Table 4.2), and since then have stabilized in the range of 40 mt. The 2010-2014 average landings in LIS are 37.6 mt. In the NJ-NYB region, commercial harvest during the late 1980s to mid-1990s fluctuated around 70 mt annually, but declined rapidly to 20 mt by 1999 (Figure 4.3, Table 4.2). Landings rebounded to 60 mt by 2007 and 2008, and since then fell to 40 mt and below.

Commercial landings of Tautog occur throughout the year, but the magnitude of the fishery varies by season. In LIS and NJ-NYB, approximately 35% of the annual harvest occurs during May-July, and again during October-December (Figure 4.4). Harvest is lowest during February and March, when less than 2% of the annual catch occurs.

Since 1984, trawl, pot/trap, and hand gears have accounted for over 75% of coastwide commercial harvest (Figure 4.5). Trawls were most prevalent in the mid-1980s, contributing more than 40% of annual harvest between 1984 and 1989. Trawls continued to account for approximately 20% of harvest until 2004, but their contribution has since fallen below 10% of annual harvest. Pots and traps consistently produce approximately 20-30% of total harvest throughout the time series, with the exception of a brief peak over 40% between 1994 and 1998. Hand harvest was mainly constrained below 20% of coastwide harvest during the 1980s and early 1990s, but rose quickly during the remainder of the decade. Since 1999, hand harvest has been the primary gear for Tautog harvest, contributing approximately 43% of annual commercial harvest.

4.3. Current Fisheries Status

As reported in the Benchmark Stock Assessment (ASMFC 2015), regulatory efforts to constrain harvest have had limited effect. Tautog populations coastwide were found to be overfished, regardless of regional structure (Table 1.1). Overfishing status varied by region and regional structure, but overfishing was determined in 6 of the 9 different combinations. Trends in harvest are obscured by high interannual variability in catch and relatively high harvest measurement error. An unquantified illegal live fish market contributes to uncertainty in harvest estimates.

5. DATA SOURCES

This regional assessment uses all of the regionally appropriate data sources used in the 2015 Benchmark Stock Assessment, as well as a few additional data sources that were not available during the benchmark (Table 5.1). Following guidelines set out in the Benchmark Stock Assessment, data sets were rejected in the stock assessment based on the criteria listed below:

- If sampling was intermittent or rare (*e.g.* had fewer than 10 consecutive years of data)
- Contained a small number of samples,
- Covered a small geographic area that was not representative of the regional stock unit, or
- Employed inconsistent methodologies.

Since 2002, all states are required to collect 200 age and length samples (five fish per centimeter). There are no requirements about the source of these samples, so most states fulfill their obligations through a combination of fishery-dependent and fishery-independent sampling.

5.1. Fishery-Dependent Sampling

5.1.1. Recreational Fishery

Tautog is predominantly a recreationally caught species, with anglers accounting for about 90% of landings coastwide and within the CT-NY-NJ region investigated in this assessment. Recreational data collection began in 1981 with NOAA's MRFSS program. Data collected from 2004 to 2011 using the MRFSS methodology was re-estimated using the MRIP methodology, which is consistent with the sampling design (see Benchmark Stock Assessment Section 5.1.2.6 for more details).

The MRFSS survey was a two-part survey. Telephone intercepts were made using random digit dialing of households within coastal counties producing effort (two-month sampling periods), mode and area fished. Effort estimates are combined with intercept data from interviews with anglers at fishing sites and treated by correction factors to produce a catch per trip (angler day), within each state, wave, mode, county sampling cell.

The MRIP program implemented changes to the way recreational fishing data is collected (NOAA Fisheries 2013). A marine registry program serves as a comprehensive national directory of recreational anglers and is intended to improve efficiency of surveys. Interviewers routinely sample for biological data during angler intercepts by collecting length and weight measurements when possible. Sampling during nighttime and accounting for zero-catch trips are conducted to more accurately capture fishing behaviors and reduce potential for bias from the MRFSS data collection program. Platforms for data collection have expanded to include mail, website, and smartphone technologies to collect catch data from recreational anglers. MRIP also leverages logbook reporting and tournament sampling to improve quality of data on the distinct for-hire fleet.

The LIS and NJ-NYB stock assessments use MRFSS data from 1984 to 2003, and MRIP data from 2004 to 2014. Starting in 1988, MRFSS identified LIS as a specific fishing area, allowing the development of NY LIS specific harvest estimates. Prior to 1988, NY LIS harvest was estimated using the mean harvest from Long Island Sound 1988-1993. The sum of NY LIS harvest estimates and Connecticut harvest estimates (from all trips landed) produced the total recreational harvest for the LIS region.

The difference between NY total harvest and NY LIS harvest produced the NY south shore harvest estimates. The sum of NY south shore harvest and the NJ estimates (from all trips landed) produced the total recreational harvest in the NJ-NYB region.

Tautog are caught by a small number of dedicated anglers and are not well sampled by the MRIP program. The number of intercepted trips that caught Tautog are shown in Table 5.2. Average number of intercepts in LIS was 181 and in NJ-NYB was 296 while in the Benchmark Stock Assessment, all three regions averaged about 300 intercepts a year. Number of intercepted trips peaked in the early-1990s for both LIS and NJ-NYB.

The Benchmark Stock Assessment identifies recreational sampling design, and low sample size in particular, as a source of uncertainty for Tautog harvest estimates. Smaller regional designations (as in this regional assessment) would reduce sample size, which could lead to increased variability and uncertainty.

Another potential source of error is the separation of recreational harvest by area. Errors in the designation of harvest to the different regions would affect the recreational harvest estimates and CAA. The sensitivity of the model to these assumptions was tested with sensitivity runs.

5.1.1.1. Recreational Discards/By-catch

Recreational discards are estimated by the MRFSS/MRIP survey. Fish that are reported as released dead (Type B1) are included as part of the harvest numbers and weight, while fish released alive (Type B2) are reported only as numbers of fish. Estimates of the total number of Tautog discarded were obtained from queries of the MRFSS/MRIP data, with the NY data being divided based on area fished information. Consistent with the Benchmark Stock Assessment, recreational discard mortality was estimated at 2.5% of all fish released alive.

5.1.1.2. Recreational Catch Rates (CPUE)

As reported in the Benchmark Stock Assessment (ASMFC 2015), the Tautog TC developed fishery dependent indices of abundance from the recreational survey data. Using only trips positive for Tautog catch or harvest would likely underestimate the true effort, potentially biasing the abundance signal, so the TC investigated a range of methods to better capture trends in recreational Tautog fishing effort. The final method used "logical guilds". MRFSS raw data were analyzed to determine which species were caught on trips that were positive for Tautog (Table 5.3). A logical guild consisted of Tautog plus the four next most common species. Guilds were developed separately for each state, and all trips that caught any one of the guild species were used as a measure of potential Tautog effort for that state. Data for all states in a region were combined, and a negative binomial GLM was developed to estimate CPUE. The final model used in the benchmark was also used for this regional assessment and was specified as

Total catch ~ Year + State + Wave + Mode, offset =ln(Angler_Hours).

For this regional assessment, data for CT and NJ were unchanged from the benchmark (other than updating the data through 2014). The NY data were queried using the same logical guild as used in the benchmark, but trips were subset by region based on the area fished code. This allowed development of NJ-NYB- and LIS-specific indices of abundance from the recreational data that were used in the respective regional assessment model. Since the LIS fishing area designation was not collected until 1988, the index prior to 1988 may not be indicative of the region.

Results of the regional fishery-dependent indices based on MRFSS/MRIP data are shown in Table 5.4 and Figures 5.1 to 5.3 for the LIS region and 5.4 to 5.6 for the NJ-NYB region.

5.1.1.3. Biological Sampling from the Recreational Fishery

Recreational harvest length distributions for the LIS came from three different data sources: MRFSS/MRIP sampling, the Connecticut Volunteer Angler Survey (CTVAS), and the New York Headboat Survey (NYHBS). The NYHBS and MRFSS/MRIP also supplied harvest lengths for the NJ-NYB region, with additional samples collected by NJ DFW biological sampling program. Recreational discard lengths for both regions were obtained from MRIP Type 9 sampling, the

NYHBS sampling, and the American Littoral Society (ALSVAS) Volunteer Angler Program. Additional samples for the LIS region were obtained from the CTVAS.

The MRFSS/MRIP program routinely collects length and weight samples during intercept interviews. For 1988 to 2014, length samples from raw (unweighted) data were identified by state and region to use in the appropriate regional assessment. In 2004, MRIP implemented observers on headboats to collect lengths of fish released alive (Type 9 measurements). No data are available from the MRFSS/MRIP program on size distribution of released fish prior to 2004. MRIP PSEs from 2004-2014 were used as CVs for those years, and the mean PSE from 2004-2014 was used as the CV for 1984-2003 in the LIS region (Table 5.4). For the NJ-NYB region, PSE was calculated as a weighted average of NY and NJ PSE and the respective state proportion of total NJ-NYB harvest. PSEs calculated in this fashion during MRFSS years (1989-2003) were corrected for underestimation by increasing them 30% as in the benchmark assessment.

The Connecticut DEEP Marine Fisheries Division has conducted a Volunteer Angler Survey (CTVAS) since 1970. The survey supplements MRFSS/MRIP by providing additional length measurement data particularly concerning released fish. The survey's objective is to collect marine recreational fishing information concerning finfish species with special emphasis on striped bass. In 1997, the survey design was expanded to include length measurements and to collect information on all species. The CTVAS is designed to collect trip and catch information from marine recreational (hook and line) anglers who volunteer to record their fishing activities by logbook. The logbook format consists of recording fishing effort, target species, fishing mode (boat and shore), area fished (subdivisions of Long Island Sound and adjacent waters), catch information concerning finfish harvested and released. Instructions for volunteers were provided on the inside cover of a postage paid logbook to be returned to the Department. All individual participating angler data is kept confidential. The CTVAS lengths are reported in half-inch increments. As the half-inch measurements are underrepresented in the database, they were split 50/50 and assigned to the whole number above and below. Prior to conversion to centimeters, random a number from -0.50 to 0.49 was added to each measurement.

New York collects length and age samples for the recreational fishery predominantly from the for-hire sector in the NYHBS, and for the commercial fishery from samples obtained opportunistically from fish markets. Samples from the private recreational sector are sometimes obtained although rarely.

5.1.1.4. Recreational Harvest Length Distribution

For the LIS region, all Long Island Sound MRFSS and MRIP unscaled length measurements contributed to the development of the harvest length distribution. Tautog lengths coded as harvested from the NY headboat survey was included in this distribution. As the CTVAS is considered to not represent the whole fleet (dedicated group of conservation-minded anglers), only fish which are above the year-specific CT minimum size contributed to the harvest length distribution (Table 5.5).

For the NJ-NYB region, recreational harvest length frequency was evaluated separately for NJ and NY south shore. Unweighted MRFSS/MRIP from NJ were the sole source of information used to characterize recreational harvest length distributions in New Jersey, while the south shore harvest was characterized using combined region specific data from MRFSS/MRIP and the NYHBS sampling program (Table 5.6). The sum of the recreational harvest at length for NJ and NY south shore was used to estimate total regional harvest at length.

5.1.1.5. Recreational discard length distribution

Recreational discards are captured by the MRIP survey. Fish reported as released dead (Type B1) are included as part of the harvest weight, while fish released alive (Type B2) are reported only in numbers (not weight) by MRIP.

Numerous sources contributed to estimate the length frequency of discarded fish (Tables 5.5 and 5.6) in LIS and NJ-NYB. New York data from the ALSVAS (1982-present, discard estimated by state and year-specific regulations) and MRIP Type 9 sampling of fish released alive from headboats (2004-present) was parsed by region based on fishing area into LIS and NY south. Fishery dependent samples were also available from NYHBS sampling (1995-present) and the CTVAS volunteer angler survey (1997-present, discard estimated by state and year-specific regulations).

For LIS as there were no minimum length regulations in year 1984-1987, the discard length distribution from years 1988-1990 was used as a proxy. For the ALSVAS, all CT, NY and RI fish below the CT minimum size requirement from the years 1987-1990 were assigned to CT to fill in low sample size. These data sources provide the length frequency information used to develop the catch-at-age for released fish.

5.1.2. Commercial Fishery

Tautog commercial landings data from NMFS and state records exist for 1950 to present. The LIS and NJ-NYB assessments use data from the time series 1984-2014. Prior to 1988, the reliability of splitting the NY data (particularly recreational) into regions is uncertain. Commercial harvest estimates used in the Benchmark Stock Assessment were updated through 2014 for all three states, which resulted in minor changes to annual estimates due to standard data auditing procedures. In addition, NY commercial harvest data were updated from the benchmark based on dealer reports adjusted and prorated by Vessel Trip Report (VTR) data (S. Dumais, NYSDEC, pers. comm.). This resulted in substantial changes (increases up to 2x values used in benchmark) to harvest estimates for the years 2004-present. The VTR data were also used to split the NY harvest by region for the years 1988-2014 (LIS and south shore) based on reported statistical area (611 = LIS; 612, 613, 168, 149 = south shore). The location of the NY commercial catch prior to 1987 could not be determined based on reported data. To estimate the NY's LIS commercial harvest prior to those years, the mean from 1986-1989 (83 MT) was used.

Potential biases of commercial harvest estimates discussed in the Benchmark Stock Assessment (ASMFC 2015) include possible under reporting due to lack of state reporting programs and

Tautog not being a NMFS priority species, and the use of recreational length frequency distributions to characterize commercial length frequencies. Both of these concerns are still relevant for this regional assessment. Another source of error is the splitting of NY harvest by region using statistical areas because these areas do not exactly match regional boundaries. In addition, harvesters may fish in multiple areas on a given trip but not complete a separate VTR for each area as instructed. Similarly, all trips from CT were assumed to occur in the LIS region, although this may be inaccurate. Errors in the designation of harvest to the different regions would affect the commercial harvest estimates and CAA. The sensitivity of the model to these assumptions was tested with sensitivity runs.

5.1.2.1. Commercial Discards/By-catch

As discussed in the Benchmark Stock Assessment, commercial discards were not included in this assessment due to poor observer sample size, high uncertainty in the estimates of commercial discards, and the fact that commercial discards are a small component of total removals.

5.2. Fisheries-Independent Surveys and Biological Sampling Programs

This assessment includes fisheries-independent surveys that encounter Tautog from the state marine fisheries agencies of Connecticut through New Jersey. Individual state survey data sets were obtained directly from the states' lead species biologists as numbers per tow, stratified mean numbers per tow, or geometric mean number per tow, as in past assessments. Select data sets were standardized and used in the stock assessment models (Section 6). The program designs for surveys used in the stock assessment are described for each state below. Most states also collected limited biological information (i.e. age, length, sex, weight, and some measures of maturity) for Tautog as part of their fisheries-independent surveys. However, the total numbers captured by most states are low, meaning the data becomes supplemental to other collections and is not sufficient by itself to characterize survey catch at age, with few exceptions. The methods used by each state to collect biological samples are described below.

5.2.1. CT Long Island Sound Trawl Survey

Since 1984, the Connecticut Department of Environmental Conservation, Marine Fisheries Division has monitored Tautog abundance with a monthly trawl survey in Long Island Sound. The CT Long Island Sound Trawl Survey (LISTS) is conducted from longitude 72° 03' (New London, Connecticut) to longitude 73° 39' (Greenwich, Connecticut). The sampling area includes Connecticut and Massachusetts waters 5-46 m in depth and is conducted over mud, sand and transitional (mud/sand) sediment types.

Prior to each tow, temperature (°C) and salinity (ppt) are measured at 1 m below the surface and 0.5 m above the bottom using a YSI model 30 S-C-T meter. Water is collected at depth with a five-liter Niskin bottle, and temperature and salinity are measured within the bottle immediately upon retrieval (Connecticut DEEP, 2012).

Sampling is divided into spring (April-June) and fall (Sept-Oct) periods, with 40 sites sampled monthly, 200 sites annually. The sampling gear employed is a 14 m otter trawl with a 51 mm codend. To reduce the bias associated with day-night changes in catchability of some species, sampling is conducted during daylight hours only (Sissenwine and Bowman, 1978).

LISTS employs a stratified-random sampling design. The sampling area is divided into 1.85 x 3.7 km (1 x 2 nautical miles) sites, with each site assigned to one of 12 strata defined by depth interval (0 - 9.0 m, 9.1 - 18.2 m, 18.3 - 27.3 m or, 27.4+ m) and bottom type (mud, sand, or transitional as defined by Reid et al. 1979). For each monthly sampling cruise, sites are selected randomly from within each stratum. The number of sites sampled in each stratum was determined by dividing the total stratum area by 68 km^2 (20 square nautical miles), with a minimum of two sites sampled per stratum. Discrete stratum areas smaller than a sample site are not sampled. The survey's otter trawl is towed from the 15.2 m aluminum R/V John Dempsey for 30 minutes at approximately 3.5 knots, depending on the tide (Connecticut DEEP, 2012).

CT DEEP conducts biological sampling during the LISTS. At completion of the tow, the catch is placed onto a sorting table and sorted by species. Tautog, as well as other finfish and crustacean species, are counted and measured (cm).

The number of individuals measured from each tow varies by species, depends on the size of the catch, and range of lengths. If a species is subsampled, the length frequency of the catch is determined by multiplying the proportion of measured individuals in each centimeter interval by the total number of individuals caught. Some species are sorted and subsampled by length group so that all large individuals are measured and a subsample of small (often young-of-year) specimens is measured. All individuals not measured in a length group are counted. The length frequency of each group is estimated as described above, i.e. the proportion of individuals in each centimeter interval of the subsample is expanded to determine the total number of individuals caught in the length group. The estimated length frequencies of each size group are then appended to complete the length frequency for that species (Connecticut DEEP, 2012).

LISTS abundance index

In order to use this data to generate an index of abundance for stock assessment, statistical model-based standardization of the survey data was conducted to account for factors that affect Tautog catchability. Potential bias could result if important factors that affect catchability were not considered in the analysis.

An abundance index for Tautog was created using a negative binomial generalized linear model (glm) with a log link and asymptotic estimates of uncertainty. A full model that predicted catch as a linear function of year (categorical), month (categorical), station (categorical), stratum (categorical), depth (continuous), bottom temperature (continuous), and bottom salinity (continuous) was compared to nested submodels using AIC.

A negative binomial glm sub model of year, month, and stratum was selected because the model achieved convergence and had favorable diagnostics (Figures 5.7-5.9, Tables 5.8 and 5.9). One important note is that the continuous variables were not systematically collected until mid-way through the time series, so the final model was constructed using only the categorical variables collected over the entire time series. The index was variable over time, but nonetheless exhibited a marked decrease to low catches beginning in the late-1990s (Figure 5.10, Table 5.7). Model diagnostics indicated an adequate model, given the low and variable catch rate of Tautog in this survey, and underprediction of average annual catch per tow.

5.2.2. Millstone Entrainment Sampling

Samples have been taken since 1976. Sampling frequency varies seasonally; over the period in which Tautog eggs and larvae are collected, samples are taken day and night three times (May) or twice (June through August) a week. A conical plankton net (1.0 x 3.6 m, 335 microns mesh size) collects samples at outflow sites at the Millstone Nuclear Power Plant. Readings from four flowmeters mounted in the mouth of the net account for variations in horizontal and vertical flow. Sample volume is typically about 200 m^3. All ichthyoplankton collections are immediately fixed in 10% formalin.

Samples are split repeatedly in the laboratory using a NOAA Bourne splitter. Successive splits are sorted and counted until at least 50 larvae (and 50 eggs for samples processed for eggs) are found, or until one half of the sample volume was processed. Tautog eggs are enumerated in all samples collected from April through October. Tautog and Cunner have eggs of similar appearance and were distinguished on the basis of a weekly bimodal distribution of egg diameters (Williams 1967).

Millstone abundance index
Unlike the other survey data, variables representing factors that affect Tautog catchability were not incorporated into the analysis to standardize the Millstone survey data. The unstandardized survey data are used in sensitivity analysis only (see section 6).

The egg index indicates a high abundance in the mid-1980s, relatively low values through the 1990s, and values comparable to the 1980’s from the 2000’s to the present (Figure 5.11, Table 5.9). Larval abundance is generally quite low, variable, and has higher values since 2000.

5.2.3. NY Peconic Bay Trawl Survey

NYDEC Peconic Bay trawl survey (NYPBTS) is designed to target YOY and juvenile finfish species. Sampling station locations for the survey were selected based on a block grid design superimposed over a map of the Peconic estuary sampling area. The sampling area was divided into 77 sampling blocks, each of which measured 1’ latitude by 1’ longitude. The research vessel used throughout the survey was the David H. Wallace, a 10.7 m lobster-style workboat. At each location, a 4.9 m semi-balloon shrimp trawl with a small mesh liner was towed for 10 minutes at ~2.5 knots. From 1987-1990, nets were rigged using nylon scissors and tow ropes set by hand and retrieved using a hydraulic lobster pot hauler. Following 1990, the research vessel was re-outfitted to include an A-frame, wire cable and hydraulic trawl winches.

At the beginning and end of each tow, location and depth were recorded. At each station the time clock was started when the gear was fully deployed. If a tow was abandoned due to hangs and/or debris, a nearby site within the sampling grid was chosen and the tow redone. Temperature, salinity, and dissolved oxygen were recorded at each station. Some gaps in the environmental data exist due to equipment malfunction.

From May through October of each year, 16 stations were randomly chosen each week and sampled by otter trawl weekdays during daylight hours only.

NYS DEC collects its Tautog biological samples in the NYPBTS. Fish collected in each tow were sorted, identified, counted and measured to the nearest mm (fork or total length). Large catches were subsampled, with length measurement taken on a minimum of 30 randomly selected individual fish of each species. Some samples were stratified by length group such that all large individuals were measured and only a subsample of small (YOY or yearlings) specimens were measured. Subsampled counts could then be expanded by length group for each tow.

Other biological samples

New York also obtains length data from a juvenile finfish trawl survey in Peconic Bay, a striped bass seine survey in the western Long Island Bays and a fish trap study in Long Island Sound. The trawl and seine survey obtain primarily juvenile lengths, while the trap study obtains juvenile and adult lengths.

NYPBTS abundance index

This survey was not designed to target Tautog. In order to use this data to generate an index of abundance for stock assessment, statistical model-based standardization of the survey data was conducted to account for factors that affect Tautog catchability. Potential bias could result if all important factors that affect catchability were not considered in the analysis.

Fish between 10 and 15 cm in the catch were used for a year-one index. An abundance index for Tautog was created using a negative binomial generalized linear model (glm) with a log link and asymptotic estimates of uncertainty. The details relevant to the model for this survey are described below. Data are missing for 2005, 2006 and 2008 because the survey was not conducted or incomplete.

In each case, a full model that predicted catch as a linear function of year (categorical), month (categorical), station (categorical), depth (continuous), salinity (continuous), and temperature (continuous) was compared with nested submodels using AIC. A model with year, temperature, salinity, station and depth was selected it converged, yielded the lowest AIC value, and had favorable diagnostics (Figures 5.12-5.14, Tables 5.10 and 5.11). Year produced high variance inflation, but this parameter cannot be dropped. All other variables had favorable variance diagnostics. The index indicates a period of high abundance beginning in the 1980s, a decline to the early 1990s, then a period of variable abundance to the present (Figure 5.15). Model diagnostics indicated an adequate model, given the low and variable catch rate of Tautog, and identified underprediction of average annual catch per tow. Overall, the model exhibited adequate diagnostics given the low sample size and high variability in the number of Tautog caught in this survey.

5.2.4. NY Western Long Island Seine Survey

The NY Western Long Island Seine Survey (NYWLISS) operated from 1984-present, with a consistent standardized consistent methodology starting in 1987. The gear type used is a 200 ft long x 10 ft deep beach seine with ¼ inch square mesh in the wings, and 3/16 inch square mesh in the bunt. The seine is set by boat in a “U” shape along the beach and pulled in by hand. The survey takes place in Little Neck and Manhasset Bay on the north shore of Long Island, and Jamaica Bay on the south shore. Other bays have been sampled for short periods of time. It is a fixed site survey. Environmental information (air and water temperature, salinity, dissolved oxygen, tide stage, wind speed and direction, and wave height) were recorded at each station. Bottom type, vegetation type, and percent cover was recorded qualitatively since 1988.

The sampling season is May through October. Prior to 2000, sampling was conducted two times per month during May and June, and once a month July through October. From 2000-2002 sampling occurred two times per month from May through October. Generally, 5-10 seine sites are sampled in each Bay on each sampling trip.

Fish collected in each haul were sorted, identified, counted and measured to the nearest mm (fork or total length).

NYWLISS abundance index

This survey was not designed to target Tautog. In order to use this data to generate an index of abundance for stock assessment, statistical model-based standardization of the survey data was conducted to account for factors that affect Tautog catchability. Potential bias could result if all important factors that affect catchability were not considered in the analysis.

The NYWLI Seine Survey is conducted in three separate embayments: Little Neck and Manhasset Bay in Long Island Sound, and Jamaica Bay on the south shore of Long Island. It was possible to develop region specific indices of abundance for this survey. LIS region data are missing for 1986, 1995 and 2010; data are missing for the NJ-NYB region for 1997. A negative binomial model was used for both regions. In each case, a full model that predicted catch as a linear function of year (categorical), month (categorical), station (categorical), salinity (continuous), dissolved oxygen (continuous), and temperature (continuous) was compared with nested submodels using AIC.

For the LIS region, a model with year and temperature was selected because it converged, yielded the lowest AIC value, and had favorable diagnostics (Figures 5.16-5.18, Tables 5.12 and 5.13). The index was variable, but indicates periodic times of high abundance including the early 1990s and the early 2000s (Figure 5.19). Diagnostics identified mainly underprediction by the model of average annual catch per tow. Overall, the model exhibited adequate diagnostics given the low sample size and high variability in the number of Tautog caught in this survey.

The NJ-NYB portion (Jamaica Bay) of the seine survey encompasses 19 different stations. As not all stations were sampled continuously, only the eight stations sampled annually in at least 20 years were included in the model. Tows without environmental data were removed from the analysis (213 removed; 1,228 remaining). The full model including Year, Station, Water Temp, DO, and Salinity had a slightly higher AIC (+2) than reduced models and a relatively high collinearity factor (4.5). Dropping salinity resolved the collinearity, but DO was not significant. The model with the lowest AIC value includes Station and Water Temp, and has favorable diagnostics (Figures 5.20 to 5.22, Tables 5.14 and 5.15). The index identifies three periods of recruitment separated by 3-5 years of near zero recruitment (Figure 5.23). The three periods of recruitment show successively higher peaks, with a time series high of 2.7 fish per tow in 2012, and an average catch of 1.5 fish for the period 2012-2014.

5.2.5. NJ Ocean Trawl Survey

New Jersey has conducted a stratified random trawl survey in nearshore ocean waters since August, 1988. The survey is conducted five times per year (January, April, June, August and October) between Cape May and Sandy Hook, NJ. The sampling area is stratified into five areas north to south, that are further divided into three depth zones (<5, 5-10, 10-20 fathoms) for a total of 15 strata. During each of the April through October survey cruises, a total of 39 tows are conducted, with 30 tows taken during each January cruise, for a grand total of 186 tows per year. The sampling gear is a two-seam trawl with a 25 m head rope and 30.5 m footrope. The cod-end has a 6.4 mm liner. All Tautog taken during these surveys are counted and weighed by tow and measured to the nearest centimeter. Annual indices of Tautog abundance and biomass are determined as the stratified geometric mean number and kilogram per tow, weighted by stratum area. These indices fell from a series high in 1989 of 0.20 fish and 0.13 kg per tow to the survey low in 1997 of 0.02 fish and 0.02 kg per tow. The survey indices climbed to another peak in 2002 with 0.17 fish and 0.16 kg per tow. Since 2003, the survey indices leveled off within a range of 0.06 to 0.09 fish and 0.04 and 0.09 kg per tow. Few age-zero fish are taken in this survey.

Prior to the January 2011 trawl cruise, surface and bottom water samples were collected with a 1.2 L Kemmerer bottle for measurement of salinity and dissolved oxygen, the former with a conductance meter and the latter by the Winkler titration method. Surface and bottom temperatures were measured with a thermistor. Starting in January, 2011, water chemistry data are collected via a YSI 6820 multi-parameter water quality SONDE from the bottom, mid-point and surface of the water column. Parameters recorded include depth, temperature, dissolved oxygen and specific conductance. Water chemistry data are primarily collected prior to trawling (New Jersey DEP, 2013).

Trawl samples are collected by towing the net for 20 minutes, timed from the moment the winch brakes are set to stop the deployment of tow wire to the beginning of haulback. Enough tow wire is released to provide a wire length to depth ratio of at least 3:1, but in shallow (< 10 m) water this ratio is often much greater, in order to provide ample separation between the vessel and the net (New Jersey DEP, 2013).

Other biological samples

Since 1993, New Jersey has collected biological data on Tautog sampled from various sources and gear types. These data include total length in millimeters, sex, and age (derived from reading opercular bone samples). Collection of weight data for each fish in kilograms began in 2007. Of the 5,285 total samples collected through 2012, samples from party and charter boats accounted for 48.6%, with commercial samples accounting for 27.2%. Fishery dependent research conducted by NJ Bureau of Marine Fisheries staff from 1993-2003 supplied 20.8% of the samples. Of the rest, 110 fish came from New Jersey's ocean trawl survey, 68 fish from recreational catches confiscated by New Jersey law enforcement and one sample was received from a recreational diver. The majority of the fish were caught using hook and line (95.2%), and some with pots/traps (2.7%), and otter trawls (2.1%). All months of the year were represented in the entire time series of the sampling program with the most fish obtained in December (34.2%), followed closely by November (30.9%). The fewest fish were collected in September (0.2%) and March (0.4%). Sampled fish ranged from 73 to 864 mm in length with an average of 369 mm. Ages were obtained from 4,293 fish with an average age of 6 within a range of 1 to 29 years. From the 4,921 fish sexed, 53.2% were female and 46.7% were male. Weights were obtained from 995 samples yielding an average of 0.84 kg with a range of 0.01 to 10.85 kg (New Jersey DEP, 2013).

5.2.5.1. NJ Ocean Trawl Survey abundance index

In order to use this data to generate an index of abundance for stock assessment, statistical model-based standardization of the survey data was conducted to account for factors that affect Tautog catchability. Potential bias could result if all important factors that affect catchability were not considered in the analysis. In addition, there have been survey changes through the time series, mainly vessel changes, but it is hoped that the standardization procedure employed accounts for these modifications.

An abundance index for Tautog was created using a negative binomial generalized linear model (glm) with a log link and asymptotic estimates of uncertainty. The full model included year (categorical), month (categorical), station (categorical), depth (continuous), bottom temperature (continuous), and bottom salinity (continuous). A reduced model including year, bottom temperature, depth, and bottom salinity converged, yielded the lowest AIC value, and had favorable diagnostics (Figures 5.24 – 5.26, Tables 5.16 and 5.17). The index was variable, but indicates a period of high abundance at the beginning of the time series, declining through the late 1990s, with a recovery to moderate abundance between 2000-2010. CPUE dropped by more than 50% in 2011-2012, but recovered to previous levels around 0.5 fish per tow in recent years (Figure 5.27). Diagnostics identified mainly underprediction by the model of average annual catch per tow. Overall, the model exhibited adequate diagnostics given the low sample size and high variability in the number of Tautog caught in this survey.

5.3. Development of Age-Length Keys

The sample size and sources for age-length keys (ALK) by region are shown in Table 5.18.

5.3.1. LIS

Data sources used to create the Long Island Sound assessment ALKs include LISTS, Rhode Island Trawl Survey (RI) and New York Port Sampling (NY-N). Only fish that were collected from the North Shore of Long Island were included from New York. Rhode Island ages which were collected outside of Long Island Sound were included to ensure the full range of sizes were covered by the key. Additionally, in instances where sizes where still missing in a given year, ages were determined using a pooled key across all years. The length range of the estimated catch is 8 to 83 cm but the length range of the ALK is 15 to 60 cm. Lengths below 16 cm and above 60 cm were accordingly binned into single groups.

5.3.2. NJ-NYB

Previous assessments created ALKs for the northern region (MA-NY) and the southern region (NJ-VA). Prior to 1995, raw age data by state were not available. As a result, ALKs for the NY-NJ region could only be created for 1995 forward. This still required pooling across regional boundaries to ensure the full range of sizes were covered by each regional key. As a result, the NY-NJ key includes some data from Long Island Sound and Delaware. The distribution of the NJ-NYB harvest for the years 1989-1994 was assumed to follow the same distribution as the age distribution of the NJ Ocean Trawl survey. Sensitivity of the model to this assumption was evaluated through a sensitivity run of the population model.

6. AGE STRUCTURED ASSESSMENT PROGRAM (ASAP) MODEL, METHODS, AND RESULTS

6.1. Background

Two models from the NOAA Fisheries Toolbox were used to estimate population parameters and biological reference points. The population model used was ASAP v. 3.0.17, which produces estimates of abundance, fishing mortality, and recruitment, as well as estimates of biological reference points from input and estimated population parameters. AGEPRO v. 4.2.2 was used to estimate spawning stock biomass threshold and target levels consistent with SPR-based fishing mortality reference points. Both programs are available for download at http://nft.nefsc.noaa.gov/

6.2. Assessment Model Description

ASAP is a forward-projecting catch-at-age model programmed in ADMB. It uses a maximum likelihood framework to estimate recruitment, annual fishing mortality, and abundance-at-age in the initial year, as well as parameters like selectivity and catchability, by fitting to total catch, indices of abundance, and catch- and index-at-age data.

See *Appendix A1: ASAP Technical Documentation* for more detailed descriptions of model structure and code.

6.3. Reference Point Model Description

In addition, because of concerns about the reliability of the stock-recruitment relationship estimated by the model, and the sensitivity of MSY-based reference points to the estimated S-R parameters, the AGEPRO model was used to project the population forward in time under constant fishing mortality ($F_{30\%SPR}$ and $F_{40\%SPR}$) with recruitment drawn from the model-estimated time-series of observed recruitment to develop an estimate of the long-term equilibrium SSB associated with those fishing mortality reference points.

See *Appendix A2: AGEPRO User Guide* for a more detailed description of model structure.

6.4. Configuration

ASAP input files for each region are included in Appendix A3.

6.4.1. Spatial and Temporal Coverage

The ASAP model was run separately for LIS and NJ-NYB regions considered in this regional assessment. Base models included years 1984 to 2014 for the LIS region and 1989-2014 for the NJ-NYB region.

6.4.2. Selection and Treatment of Indices

Section 5 provides a detailed description of how indices were selected and standardized.

6.4.2.1. LIS

The model was fit to both the total standardized index (catch per tow or catch per trip) and index-at-age data, for the LISTS and MRIP CPUE indices. The New York Peconic Bay survey was used as a year one index. The WLISSS and Millstone Entrainment Survey data were treated as a young-of-year index and was lagged forward one year (e.g., the 1985 age-1 predicted index value was fit to the observed 1984 YOY index value).

6.4.2.2. NJ-NYB

The NJ-NYB regional assessment included the NJ ocean trawl index, the Jamaica Bay portion of the Western Long Island Seine Survey, and the NJ-NYB specific MRFSS recreational CPUE. The WLI seine index was treated as an age-1 index, while the NJ trawl and MRFSS indices were treated as adult indices (ages 1-12+), with age distribution estimated using survey specific length frequency data and the NYNJ ALKs.

6.4.3. Parameterization

6.4.3.1. LIS

The ASAP model used a single fleet that included total removals in weight and removals-at-age from recreational harvest, recreational release mortality, and commercial catch. Selectivity of the fleet was described by a logistic curve. Four selectivity blocks were used: 1984-1986, 1987-1994, 1995-2011, and 2012-2014. Breaks were chosen based on implementation of new regulations in Connecticut as New York regulations were implemented in a more step-wise fashion.

Adult indices were fit to index-at-age data assuming a single logistic selectivity curve and constant catchability. YOY indices had a fixed selectivity pattern of 1 for age-1 and 0 for all other ages, and also assumed constant catchability.

Recruitment was estimated as deviations from a Beverton-Holt stock recruitment curve, with parameters estimated internally.

6.4.3.2. NJ-NYB

The NJ-NYB model included year and age specific data from 1989 to 2014, assuming a plus group of ages 12+. Commercial and recreational harvest and discards were combined into a single fleet, with four single logistic selectivity blocks established based on major regulatory and data collection changes that would be expected to alter the size distribution of the catch (pre-FMP = 1995-1997, FMP implementation 1998-2003, collection of Type 9 data 2004-2012, Addendum 6 regulations 2012-2014). Selectivity patterns for the adult indices were also modeled as logistic functions, but were considered to be constant over time.

6.4.4. Weighting of Likelihoods

ASAP uses a lognormal error distribution for total catch and indices, and a multinomial distribution for catch-at-age and index-at-age data.

Likelihood components can be weighted with a lambda value, to emphasize a particular component, and with a CV, which determines how closely an observation is fit. For both regions, all components had a lambda of 1 in the base run. MRIP PSE values, inflated for missing catch, were used as the CV on total catch, and the CVs of the standardized indices were adjusted to a target mean CV of 0.3 for model convergence in the LIS region, and to bring RMSEs of the indices close to 1.0 for the NJ-NYB region.

Recruitment deviations and deviations from full F in the first year are also included in the likelihood component with an associated lambda and annual CV. These recruitment deviations were given a lambda of 0.5 and a CV of 0.5 for all years.

The effective sample size for the multinomial distributions was input as the number of sampled tows or trips. ASAP estimates the ESS internally as well, using the method of Francis (2011). When the final model configuration was determined, the input ESS were adjusted using ASAP's estimates of stage 2 multipliers for multinomials.

6.5. Estimating Precision

ASAP provides estimates of the asymptotic standard error for estimated and calculated parameters from the Hessian. In addition, MCMC calculations provide more robust characterization of uncertainty for F, SSB, biomass, and reference points. For each region, 200,000 MCMC runs were conducted for the base model, of which 1,000 were kept. Results of the MCMC analyses are presented as the median plus the 5^{th} and 95^{th} percentiles.

6.6. Sensitivity Analyses

6.6.1. Sensitivity to Input Data

6.6.1.1. LIS

A number of sensitivity runs were conducted to examine the effects of input data on model performance and results. These included:

- Removal of indices from the likelihood to examine the influence of individual data streams on model results
- Different starting values for estimated parameters
- Starting in the year 1988 to avoid estimating New York harvest and discards
- Using a 15-year old plus group
- Excluding all of the estimated New York recreational (1984-1987) and commercial (1984-1985) harvest from (discards were not excluded from this as they account for less than 0.1% of F)
- Including all of New York harvest, north and south of Long Island, recreational (1984-1987) and commercial harvest from 1984:1987-1985

6.6.1.2. NJ-NYB

Sensitivity runs conducted for the NJ-NYB region to evaluate input data include

- Removal of individual indices to evaluate the influence of each index on model output
- Starting the model in 1995 when region specific ALKs were available
- "Correcting" suspected severe underestimation of recreational harvest in NJ in 2005

6.6.2. Sensitivity to Model Configuration

6.6.2.1. LIS

In addition, a number of sensitivity runs were conducted to examine the effects of model configuration on model performance and results. These included:

- Use of 3 selectivity blocks for the catch instead of 4
- Fixing steepness at 1 (i.e., no relationship to SSB and fitting deviations to an average recruitment value)

6.6.2.2. NJ-NYB

One sensitivity analysis was conducted for the NJ-NYB region with respect to model configuration. For this run, the fourth (2012-2014) selectivity block was dropped to address a concern that three years may not be sufficient to estimate selectivity accurately.

6.7. Retrospective Analyses

6.7.1. LIS

Retrospective analyses were performed by ending the model in earlier and earlier years and comparing the results to the output of the model that terminated in 2014. For the LIS regional model, the terminal years ranged from 2011-2014 and 2007-2014. As a selectivity block ended in 2010, it is important to note that this second retrospective analysis extends into a different selectivity block the catch.

6.7.2. NJ-NYB

A retrospective analysis was conducted in the NJ-NYB region using annual peels from 2014 to 2007. It should be recognized that the last selectivity block for the base model covers years 2012-2014, so the retrospective analysis crosses into the third selectivity block, which makes interpretation of the results difficult.

6.8. ASAP Results for LIS

6.8.1. Goodness of Fit

The total likelihood and index RMSE values are shown in Table 6.1. Total catch residuals were underestimated in 20 out of 30 years in the time series (Figure 6.1). The index residuals showed some patterning (Figure 6.2). LISTS residuals were under estimated in 12 of 30 years, including all of the last three years. NY Trawl was underestimated for the last seven years the survey was conducted and NY Beach Seine survey was overestimated in each of the last 6 years the survey was conducted. MRIP CPUE is underestimated in 5 of the last 6 years and was overestimated for many of the years in the middle of the time series. The overall fit to the catch-at-age was good (Figure 6.3). Residuals for the index-at-age were good fits to the observed data (Figure 6.4).

6.8.2. Parameter Estimates

6.8.2.1. Selectivities, Catchability, and the Stock-Recruitment Relationship

Recreational minimum sizes were first implemented in CT in 1987 and in NY in 1991 and changes in the CT regulations occurred in 1995, and 2012. NY regulations proceeded in a more step-wise fashion, with minimum size increases in 1994, 1995, 1998 and 2012. Selectivity pattern changes are seen in the model after 1988, 1994, and 2012. With each change in minimum harvest size in CT the selectivity curve shifted to the right (Figure 6.5). Estimates of index catchabilities are shown in Table 6.2. ASAP estimated the steepness of the stock-recruit relationship at h=0.5294 (Figure 6.6).

6.8.2.2. Fishing Mortality

In LIS F was relatively stable for the years 1984 to 2006, with only one spike in 1993, 1994 and 1995. Since 2006 F has mostly risen and has been over 0.3 in seven of the last eight years. (Table 6.3, Figure 6.7). The median full F and the 5th and 95th percentiles from MCMC run are shown in Figure 6.8, and likelihood profiles for terminal year F are shown in Figure 6.9.

6.8.2.3. 6.8.2.3 Abundance and Spawning Stock Biomass Estimates

Total abundance and spawning stock biomass declined rapidly from 1984 until 1995. Despite a period of slightly increased abundance in the early to mid 2000s, the overall trend has been a slower but consistent decline since 1995 (Table 6.4, Figure 6.10.a). Total abundance decline from a high of 11.5 million fish to the current estimate of 4.1 million fish in 2014. Spawning stock biomass decreased from over 11,700 MT at the beginning of the time-series to the current estimate of 1,900 MT in 2014.

The median SSB and the 5th and 95th percentiles from MCMC run in shown in Figure 6.10.b, and likelihood profiles for terminal year SSB is shown in Figure 6.11.

Recruitment was generally highest in the early years of the time-series, except for 2013 which had the highest recruitment event on record. Three of the past four years have been the lowest recruitment events on record (Figure 6.10.c).

6.8.2.4. Sensitivity Analyses

Changes to the input data and model assumptions predominantly changed the initial and final estimates of SSB, but overall the trajectories remained the same. The 15-year-old plus group resulted in the highest initial SSB, while using all available indices (including the Millstone data) resulted in the lowest initial SSB. The 15-year-old plus group also resulted in the highest terminal SSB and dropping the MRIP CPUE resulted in the lowest terminal SSB (Table 6.5, Figure 6.12). Estimates of overfishing status were relatively consistent, with all runs showing overfishing in 1993, 1994, 2007, 2008, 2009, 2010, 2012, 2013 and 2014. Additionally, in 1995 and 2011 eight of nine sensitivity runs show overfishing.

6.8.3. Retrospective Analyses

Retrospective analyses were performed by ending the model in earlier and earlier years and comparing the results to the output of the model that terminated in 2014. As the most recent sensitivity block began in 2011, two retrospective analyses were performed, one with the terminal years ranging from 2011-2014 and one with terminal years ranging from 2007-2014. It is important to note that this second retrospective analysis extends into a different selectivity block.

In the retrospective analysis starting in 2012, the LIS region showed a slight retrospective pattern of overestimating F (Mohn's rho = 0.11, Figure 6.13 a) and underestimating SSB (Mohn's rho = -0.11, Figure 6.14 a). Recruitment tended to be more variable, and was also underestimated in the terminal year (Mohn's rho = -0.18, Figure 6.15 a). For the retrospective analysis ending in 2007, the LIS region showed a slight retrospective pattern of underestimating F (Mohn's rho= -0.01, Figure 6.13 b), SSB (Mohn's rho = -0.04, Figure 6.14 b) and also had variable recruitment which was underestimated in the terminal year (Mohn's rho = -0.14, Figure 6.15 b).

Retrospective analysis was also conducted for the 15 year plus group sensitivity analysis 2012-2014, F was slightly overestimated (Mohn's rho = 0.03, Figure 6.13 c) and), while SSB (Mohn's rho = -0.05, Figure 6.14 c) was slightly underestimated and recruitment in the terminal year (Mohn's rho = - 0.31, Figure 6.15 c) was underestimated. For the retrospective analysis ending in 2007, F (Mohn's rho = - 0.01, Figure 6.13 d) was near zero and SSB (Mohn's rho = 0.03, Figure 6.14 d) was slightly overestimated. Recruitment in the teriminal year was underestimated (Mohn's rho = -0.35, Figure 6.15 d).

6.8.4. Reference Point Model

6.8.4.1. Parameter Estimates

Estimates of F 30% SPR, F 40% SPR, F MSY, and SSB MSY are shown in Table 6.5. The base model estimated a steepness (h=0.529) indicating a strong fit to the S-R model. Steepness for the 15 year plus group model was higher (h = 0.662).

F MSY was estimated as 0.164 for the base model and at 0.237 for the 15-year plus group model. The associated SSB MSY values were 4,580 MT and 5,050 MT for these models, respectively.

F 30% SPR was estimated as 0.46 for the 12-year plus group and 0.43 for the 15-year plus group.

F 40% SPR was estimated as 0.29 for the 12-year plus group and 0.25 for the 15-year plus group.

6.8.4.2. Sensitivity Analyses

In general, estimates of $F_{30\%SPR}$ and $F_{40\%SPR}$ were similar across sensitivity runs, while estimates of SSB MSY and MSY-based reference points were variable (Table 6.5).

6.9. ASAP Results for NJ-NYB

6.9.1. Goodness of Fit

Diagnostics of the base model fit are shown in Table 6.1. The largest components of the overall likelihood are catch and index age comps. Fits to total catch are relatively tight, with the largest discrepancy being a period of underestimation from 1999-2002 (Figure 6.16). Annual catch at age fits show no consistent pattern in over or underestimation at age (Figure 6.17). Fits to survey indices show some patterning in residuals, particularly for the NY seine and MRFSS, but less so for the NJ trawl (Figure 6.18). Overall fit to NJ trawl proportion at age is strong, but the MRFSS index indicates slight overestimation of age 3 and underestimation of age 5.

6.9.2. Parameter Estimates

6.9.2.1. Selectivities, Catchability, and the Stock-Recruitment Relationship

The fishery selectivity shifted in the expected direction between the first and second selectivity blocks, but the model estimated an increase in selectivity at age for the third time block despite increased regulation. The reason for this is unknown but may be due to changes in data availability or sampling design. The increased size limit under Addendum 6 in 2012 shifted to the right as expected, with 50% selectivity between ages 5 and 6 (Figure 6.19). Both aged survey indices indicate 50% selectivity by age 3 (Figure 6.19); however, the NJ trawl survey shows slightly higher selectivity at ages 1 and 2, and lower selectivity ages 4 to 6 relative to the MRFSS CPUE.

Estimated catchability for the three surveys ranges from 1.5e-7 (NJ trawl) to 5.0e-7 (NY seine) (Table 6.2).

Estimated steepness for nearly all model runs was h = 0.9999, indicating the model was not able to reliably estimate steepness of the spawner-recruit curve.

6.9.2.2. Fishing Mortality

Consistent with previous assessments, including the 2015 benchmark, a three year moving average F was used to smooth the time series of F. Fully exploited fishing mortality (F-mult) shows high interannual variability, but suggests a cyclical pattern in exploitation over time, with ranges generally between (Table 6.3, Figure 6.20). The declines in F are generally consistent with changes in regulations which often included increases in minimum size. F would then increase over the next few years as the fish grew into the new size limit. Terminal year fishing mortality is estimated as F_{2014} = 0.658 or $F_{3\ year}$ = 0.50. MCMC estimate d confidence limits are relatively wide, with 90% credible intervals ranging from 0.28 to 1.33 (Figure 6.20).

6.9.2.3. Abundance and Spawning Stock Biomass Estimates

SSB shows a general decline from approximately 6,000 MT in 1989 to around 1,900 MT by 1996 (Table 6.4, Figure 6.21). Regulations in 1997 and 2003 allowed slight increases in SSB to in subsequent years, but these gains were short lived as F rebounded. From 2006 to 2011, SSB declined from around 2,050 MT to 1,050 MT, but has since recovered to around 1,950 MT in 2014. MCMC estimates of 90% credible intervals on SSB range from 1,490 to 2,860 MT (Figure 6.21).

During the early 1990s, recruitment (age 1) follows a similar pattern as SSB (Table 6.4, Figure 6.22), declining from 1.6 million in 1989 to less than 1 million by 1993. From 1993 to 2010, recruitment varied without trend between approximately 650,000 and 950,000 fish annually. Estimates of recruitment in the last four years of the model were all over one million fish, with an apparent strong year class in 2013, estimated at 2.75 million.

6.9.3. Sensitivity Analyses

The sensitivity runs investigating changes to the input data had very little influence on the trends, scale, and terminal year estimates of the model (Table 6.5, Figure 6.23). SSB estimates from all sensitivity runs were within one standard deviation of the base model run, with terminal year estimates ranging from 1,837 to 2,011 MT. Terminal year F estimates ranged from F_{2014} = 0.59 to 0.71 and F_{3yr} = 0.47 to 0.54 relative to the base model estimates of 0.66 and 0.50, respectively.

Recruitment estimates from the different sensitivity runs investigating input data showed only minor variations to the base run for most years in the time series. The largest differences occurred in 2011 for the models that dropped the NJ trawl and MRFSS CPUE indices. Both of these runs underestimated recruitment relative to the base run by approximately 20% (Figure 6.23).

The sensitivity run investigating model configuration (three selectivity blocks) resulted in nearly identical results as the base model for SSB and recruitment, but had a profound effect on fishing mortality rates in recent years (Table 6.5, Figure 6.23). From 2011-2014, the alternate configuration underestimated F relative to the base model, with a terminal year estimate of F2014 = 0.27 and a three year average F = 0.33, approximately 47% and 32% lower than base run estimate, respectively.

6.9.4. Retrospective Analyses

The NJ-NYB region retrospective analysis spanned from 2014 to 2007, which extended into the previous selectivity block, making interpretation of the results difficult. With that in mind, SSB is overestimated relative to the base model in all but the penultimate year of the model (Figure 6.24). For the 2013 peel, SSB is underestimated by nearly 25% with respect to the base model. The retrospective pattern in fishing mortality switches at the change in selectivity (Figure 6.24), from overestimated F in recent years to underestimating F during the third selectivity block. Some of the earliest estimates are underestimated by 100% or more. The pattern in recruitment is more variable, but terminal year estimates during the fourth selectivity period fall below the final base run estimates (Figure 6.24).

6.9.5. Reference Point Model

6.9.5.1. Parameter Estimates

Estimates of $F_{30\%SPR}$, $F_{40\%SPR}$, F_{MSY}, and SSB_{MSY} are shown in Table 6.5. Estimates of F_{MSY} are not considered reliable due to the model's inability to estimate stock-recruit steepness. Stochastic projections were carried out to estimate the median long-term SSB expected from fishing at $F_{30\%SPR}$ and $F_{40\%SPR}$ under observed recruitment conditions (Table 6.6).

$F_{30\%SPR}$ was estimated as 0.364, with an associated equilibrium SSB estimate of 2,457 MT (90% CI = 1,973 to 3,375 MT). $F_{40\%SPR}$ was estimated as 0.216, with an associated equilibrium SSB estimate 3,305 MT (90% CI = 2,704 to 4,339 MT).

6.9.5.2. Sensitivity Analyses

SPR based fishing mortality benchmarks were similar for all sensitivity runs investigating input data. The sensitivity run investigating model structure estimated lower benchmarks, with $F_{30\%}$ = 0.25 and $F_{40\%}$ = 0.16. This is to be expected given the higher selectivity at age under the three selectivity block configuration.

7. STOCK STATUS

7.1. Current Overfishing and Overfished Definitions

In April 2011, Addendum VI to the FMP established a new F_{target} of F = M = 0.15 for the coastwide stock. Btarg and Blim were established in Addendum 4 (2007) at 26,800 and 20,100 MT. Results from the 2011 assessment update were F=0.23 and SSB=10,663 MT, indicating the stock is overfished and overfishing is occurring. These are the current definitions for management use.

In the 2015 Benchmark Stock Assessment's 'highly regarded alternative' three-region approach, the TC proposed an SSB target of SSB_{MSY} and an SSB threshold of 75% SSB_{MSY} for MA-RI. The TC chose 75% SSB_{MSY} rather than the more commonly selected threshold of 50% SSB_{MSY}, due to concerns about Tautog's slow growth and lower steepness. For this region, the TC proposed an F target of F_{MSY} and an F threshold of the F necessary to achieve 75%SSB_{MSY}, under equilibrium conditions.

Due to concerns about the reliability of the stock-recruitment relationships fit by the model for the CT-NY-NJ and DMV regions, the TC proposed an F target of $F_{40\%SPR}$ and an F threshold of $F_{30\%SPR}$. SSB targets and thresholds were estimated based on the long-term equilibrium biomass associated with those F targets and thresholds under conditions of observed average recruitment.

The Board approved the Benchmark Stock Assessment for management use, but the proposed definitions in the Benchmark Stock Assessment have not been implemented. The Board is awaiting the results of the regional assessment to determine the regional boundaries which will then be included in Draft Amendment 1 and released for public comment.

	SSB target		SSB threshold		F target		F threshold	
	Definition	Value	Definition	Value	Definition	Value	Definition	Value
MA-RI	SSB_{MSY}	2,633 MT	$75\%SSB_{MSY}$	1,975 MT	F_{MSY}	0.16	F associated with $75\%SSB_{MSY}$	0.19
CT-NY-NJ	SSB associated with $F_{40\%SPR}$	5,160 MT	SSB associated with $F_{30\%SPR}$	3,920 MT	$F_{40\%SPR}$	0.17	$F_{30\%SPR}$	0.24
DMV	SSB associated with $F_{40\%SPR}$	2,090 MT	SSB associated with $F_{30\%SPR}$	1,580 MT	$F_{40\%SPR}$	0.16	$F_{30\%SPR}$	0.24

7.2. New Proposed Definitions

Similar to the benchmark, there was inconsistency in ASAP's ability to estimate steepness of the stock-recruit relationship, resulting in different proposed reference points by region. Estimated steepness of the LIS regional model was deemed credible by the TC, and the TC therefore recommends MSY-based benchmarks for this region. Consistent with the benchmark assessment, threshold values are recommended at 75% SSB_{MSY} and the equilibrium fishing mortality rate associated with this biomass. Because there was considerable discussion by the TC regarding the utility of the different reference point models, SPR-based reference points are also provided for the LIS region.

In the NJ-NYB regional model, data were not sufficient to allow credible estimation of the stock-recruit relationship, so the TC considers the MSY-based reference points unreliable. Consistent with the benchmark, the TC is recommending a fishing mortality target of $F_{40\%SPR}$ and a threshold of $F_{30\%SPR}$. Recommended SSB reference points are the long term equilibrium biomass associated with the respective fishing mortality rates.

	SSB target		SSB threshold		F target		F threshold	
	Definition	Value	Definition	Value	Definition	Value	Definition	Value
LIS (MSY)	SSB_{MSY}	4,576 MT	75% SSB_{MSY}	3,432 MT	F_{MSY}	0.16	$F_{75\%SSBMSY}$	0.32
LIS (SPR)	SSB associated with $F_{40\%SPR}$	3,757 MT	SSB associated with $F_{30\%SPR}$	2,820 MT	$F_{40\%SPR}$	0.27	$F_{30\%SPR}$	0.47
NJ-NYB	SSB associated with $F_{40\%SPR}$	3,305 MT	SSB associated with $F_{30\%SPR}$	2,547 MT	$F_{40\%SPR}$	0.22	$F_{30\%SPR}$	0.36

7.3. Stock Status Determination

7.3.1. Overfishing Status

7.3.1.1. LIS

The ASAP model runs indicated overfishing was occurring in Long Island Sound in 2014, by using both MSY and SPR methods. For the MSY estimates, both the point estimate of F_{2014} = 0.73 and the 3-year average value of F_{3yr} = 0.53 were above the threshold value of 0.32 (Table 7.1, Figure 7.1). For SPR estimates, both the point estimate of F_{2014} = 0.73 and the 3-year average value of F_{3yr} = 0.53 were above both F_{Target} =0.26 and $F_{threshold}$ =0.46 (Table 7.1, Figure 7.2).

7.3.1.2. NJ-NYB

The ASAP model runs indicated overfishing was occurring in New Jersey and southern New York in 2014. Both the point estimate of F_{2014} = 0.66 and the 3-year average value of F_{3yr} = 0.50 were above both F_{Target} =0.22 and $F_{threshold}$ =0.36 (Table 7.1, Figure 7.3). Approximately 20% of the MCMC iterations were below the threshold F value in 2014.

7.3.2. Overfished Status

7.3.2.1. LIS

The ASAP model runs indicated the Tautog stock was overfished in Long Island Sound by using both MSY and SPR methods. SSB_{MSY} (target, 4,576) and $SSB_{75\%MSY}$ (threshold, 3,432 MT) are above SSB_{2014} (2,083 MT, Table 7.1, Figure 7.1). SSB in 2014 was 1,956 MT, below both the SSB_{target} =3,757 MT and the $SSB_{threshold}$ = 2,2820 MT (Table 7.1, Figure 7.2).

7.3.2.2. NJ-NYB

The ASAP model run indicates that the NJ-NYB Tautog population is overfished. SSB_{2014} was estimated at 1,972 MT, approximately 20% below the $SSB_{30\% SPR}$ threshold and 40% below the SSB40%SPR target. Estimated terminal year biomass is identical to the MCMC 5th percentile estimate (Table 7.1, Figure 7.3).

8. RESEARCH RECOMMENDATIONS

The Technical Committee identified the following research recommendations to improve the stock assessment and our understanding of Tautog population and fishery dynamics. Research recommendations are organized by topic and level of priority. Research recommendations that should be completed before the next Benchmark Stock Assessment are underlined.

8.1. Fishery-Dependent Priorities

8.1.1. High

- Expand biological sampling of the commercial catch for each gear type over the entire range of the stock (including weight, lengths, age, sex, and discards).
- Continue collecting operculum from the Tautog catch as the standard for biological sampling in addition to collecting paired sub-samples of otoliths and operculum.
- Increase catch and discard length sampling from the commercial and recreational fishery for all states from Massachusetts through Virginia.
- Increase collection of effort data for determining commercial and recreational CPUE.
- Increase MRIP sampling levels to improve recreational catch estimates by state and mode. Current sampling levels are high during times of the year when more abundant and popular species are abundant in catches, but much lower in early spring and late fall when Tautog catches are more likely.

8.2. Fishery-Independent Priorities

8.2.1. High

- Conduct workshop and pilot studies to design a standardized, multi-state fishery independent survey for Tautog along the lines of MARMAP and the lobster ventless trap survey.
- Establish standardized multi-state long-term fisheries-independent surveys to monitor Tautog abundance and length-frequency distributions, and to develop YOY indices.
- Enhance collection of age information for smaller fish (<20 cm) to better fill in age-length keys.

8.3. Life History, Biological, and Habitat Priorities

8.3.1. Moderate

- Define local and regional movement patterns and site fidelity in the southern part of the species range. This information may provide insight into questions of aggregation versus recruitment to artificial reef locations, and to clarify the need for local and regional assessment.
- Assemble regional reference collections of paired operculum and otolith samples and schedule regular exchanges to maintain and improve the precision of age readings between states that will be pooled in the regional age-length keys.
- Calibrate age readings every year by re-reading a subset of samples from previous years before ageing new samples. States that do not currently assess the precision of their age readings over time should do so by re-ageing a subset of their historical samples.

8.3.2. Low

- Evaluate the potential impacts of climate change on Tautog range, life history, and productivity.
- Conduct a tag retention study to improve return rates, particularly in the northern region.
- Define the status (condition and extent) of optimum or suitable juvenile habitats and trends in specific areas important to the species. It is critical to protect these habitats or to stimulate restoration or enhancement, if required.
- Define the specific spawning and pre-spawning aggregating areas and wintering areas of juveniles and adults used by all major local populations, as well as the migration routes used by Tautog to get to and from spawning and wintering areas and the criteria or times of use. This information is required to protect these areas from damage and overuse or excessive exploitation.
- Define larval diets and prey availability requirements. This information can be used as determinants of recruitment success and habitat function status. Information can also be used to support aquaculture ventures with this species.
- Define the role of prey type and availability in local juvenile/adult population dynamics over the species range. This information can explain differences in local abundance, movements, growth, fecundity, etc. Conduct studies in areas where the availability of primary prey, such as blue mussels or crabs, is dependent on annual recruitment, the effect of prey recruitment variability as a factor in Tautog movements (to find better prey fields), mortality (greater predation exposure when leaving shelter to forage open bottom), and relationship between reef prey availability/quality on Tautog condition/fecundity.
- Define the susceptibility of juveniles to coastal/anthropogenic contamination and resulting effects. This information can explain differences in local abundance, movements, growth, fecundity, and serve to support continued or increased regulation of the inputs of these contaminants and to assess potential damage. Since oil spills seem to be a too frequent coastal impact problem where juvenile Tautog live, it may be helpful to conduct specific studies on effects of various fuel oils and typical exposure concentrations, at various seasonal temperatures and salinities. Studies should also be conducted to evaluate the effect of common piling treatment leachates and common antifouling paints on YOY Tautog The synergistic effects of leaked fuel, bilge water, treated pilings, and antifouling paints on Tautog health should also be studied.
- Define the source of offshore eggs and larvae (in situ or washed out coastal spawning).
- Confirm that Tautog, like cunner, hibernate in the winter, and in what areas and temperature thresholds, for how long, and if there are special habitat requirements during these times that should be protected or conserved from damage or disturbance. This information will aid in understanding behavior variability and harvest availability.

8.4. Management, Law Enforcement, and Socioeconomic Priorities

8.4.1. Moderate

- Collect data to assess the magnitude of illegal harvest of Tautog.

8.4.2. Low

- Collect basic sociocultural data on Tautog user groups including demographics, location, and aspects of fishing practices such as seasonality.

8.5. Research Recommendations That Have Been Met

- ✓ Sample hard parts for annual ageing from the catches of recreational and commercial fisheries and fishery-independent surveys throughout the range of the stock. *Being conducted by all participating states.*
- ✓ Conduct hard part exchange and ageing workshop to standardize techniques and assess consistency across states. *Conducted May 2012, report available at* *http://www.asmfc.org//uploads/file/2012_Tautog_Ageing_Workshop_Report.pdf*

8.6. Future Stock Assessments

The TC recommends conducting a Benchmark Stock Assessment in 2021. Update assessments will be conducted for all regions during the fall of 2016 with data through 2015. At that time, the TC will discuss timing of future updates.

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10. TABLES

Table 1.1. The four stock definitions presented in the 2015 benchmark stock assessment. Includes overfished, overfishing status for sub-regions based on the ASAP model and peer-reviewed methods. In this report, the region comprising MA, RI and CT in Option A is referred to as Southern New England (SNE); that comprising NY and NJ is abbreviated NYNJ, and the region comprising DE, MD and VA in all stock unit definitions options is abbreviated DMV. In Option B, the region comprising MA and RI is abbreviated MARI, and that comprising CT, NY and NJ is abbreviated as CTNYNJ.

<table>
<tr><th>Options for Stock Unit Definitions</th><th>MA</th><th>RI</th><th>CT</th><th>NY</th><th>NJ</th><th>DE</th><th>MD</th><th>VA</th></tr>
<tr><td>A. Three Region (Assessment Preferred)</td><td colspan="3">Overfished
Overfishing</td><td colspan="2">Overfished
Not
Overfishing</td><td colspan="3">Overfished
Not Overfishing</td></tr>
<tr><td>B. Three Region (Highly Regarded Alternative)</td><td colspan="2">Overfished
Overfishing</td><td colspan="3">Overfished
Overfishing</td><td colspan="3">Overfished
Not Overfishing</td></tr>
<tr><td>C. Two Region</td><td colspan="5">Overfished
Overfishing</td><td colspan="3">Overfished
Overfishing</td></tr>
<tr><td>D. Coastwide (status quo)</td><td colspan="8">Overfished
Overfishing</td></tr>
</table>

Table 1.2. Stock status for Long Island Sound (LIS) and New Jersey-New York Bight (NJ-NYB). Results of analysis of regional assessment presented in this document.

Option for Stock Unit Definition	MARI	LIS	NJ-NYB	DMV
A. Four Region	Overfished Overfishing	Overfished Overfishing	Overfished Overfishing	Overfished Not Overfishing

Table 1.3. Recreational regulations for Tautog by state in the two regions covered in this regional stock assessment.

STATE	SIZE LIMIT (inches)	POSSESSION LIMITS (number of fish/ person/ day)	OPEN SEASONS
Connecticut	16”	2 2 4	Apr 1-Apr 30 July 1 – Aug 31 Oct 10 – Dec 6
New York	16”	4	Oct 5 – Dec 14
New Jersey	15”	4 4 1 6	Jan 1 – Feb 28 Apr 1 – Apr 30 Jul 17 – Nov 15 Nov 16 – Dec 31

Table 1.4. Commercial regulations for Tautog by state in the two regions covered in this regional stock assessment.

STATE	SIZE LIMIT	POSSESSION LIMITS (number of fish/person/vessel)	OPEN SEASONS	GEAR RESTRICTIONS*
Connecticut	16”	10	Apr 1- Apr 30 Jul 1 - Aug 31 Oct 8 - Dec 24	Mandatory pot requirements.
New York	15”	25 (10 fish w/ lobster gear and when 6 lobsters are in possession)	Jan 1 - Feb 28/29 Apr 8 –Dec 31	Mandatory pot requirements. Pot/trap must have a 3 1/8 inch circular vent
New Jersey	15”	> 100 lbs requires directed fishery permit	Jan 1 - 15 June 11 - 30 Nov 1 - Dec 31	Mandatory pot requirements.

* FMP regulations: A pot and trap used to catch Tautog shall have hinges or fasteners on one panel or door made of one of the following degradable materials: 1) Untreated hemp or jute string of 3/16 inch in diameter or smaller; 2) Magnesium alloy fasteners; or 3) Ungalvanized or uncoated iron wire of 0.094-inch diameter or smaller.

Table 2.1. Survey data used in analyses of length, age and weight.
For each state, separate surveys are identified if known, what type of sample (Fishery Independent [FI], Commercial [C], Recreational [R], or Unknown [U]), the range of years in the survey, and sample size (length and age data [N(L-A)], weight and length data [N(W-L)]). The latter two columns are not exclusive; some fish may have provided both length-age and weight-length data.

State	Survey	Type	Years	N(L-A)	N(W-L)
CT	LISTS	FI	1984-2015	6550	6015
CT	Laplante	FI	2000-2001		111
RI		C, R	1987-2015	4303	
NY (LIS)	NYWLISS	FI	1996	1	2
NY (LIS)		C,R	1995-2015	2039	33
NY (South Shore)		C, R	1995-2015	1474	801
MA	DMF	FI	2009-2015	967	136
MA	By-catch	C	2009-2015	823	155
MA	Rec	R	2011-2015	161	
MA	Unknown		1995-2014	2995	537
NJ	Research	FI	1993-2014	1206	75
NJ	Commercial	C	2004-2014	645	1264
NJ	Recreational	R	2007-2014	206	117
NJ	Party/Charter	R	2005-2014	2830	261
DE		C, R	2003-2014	5051	
MD		C	1996-2012	3179	3270
MD		R, U	1999-2012	669	723

Table 2.2. Von Bertalanffy parameter estimates by region, arranged N to S.

	Estimate	SE
MARI		
Linf	55.1	0.3
K	0.201	0.004
t0	-0.883	0.063
LIS		
Linf	57.8	0.3
K	0.174	0.003
t0	-0.409	0.051
NJ-NYB		
Linf	65.6	1.3
K	0.094	0.005
t0	-3.05	0.16
DMV		
Linf	64.6	1.2
K	0.1	0.0
t0	-3.1	0.2

Table 2.3. ARSS of regional heterogeneity in growth curves.
The three rows of results represent test of heterogeneity among all four regions, between LIS and MARI, and between NY's data from LIS and NJ-NYB respectively. In each case the F statistic represents the probability that the residual variability as curves are fitted to data by region (four regions, LIS&MARI, LIS&NJ-NYB) is the same as variability as curves are fitted to the pooled data (coastwide, SNE, CTNYNJ). The columns represent the number of curves tested (m), the summed residual sum of squares as curves are fitted by region (ΣRSSi), the residual sum of squares as a curve is fitted to the pooled data (RSSp), the F statistic, and the p value under the null hypothesis of homogeneity among the regions.

	m	ΣRSSi	RSSp	F	p
Four regions vs. coastwide	4	4.9E+05	8.7E+05	3.2E+03	<0.0001
LIS&MARI vs. SNE	2	3.0E+05	3.3E+05	4.0E+02	<0.0001
LIS&NJ-NYB vs. NYNJ	2	1.7E+05	1.8E+05	1.2E+02	<0.0001

Table 2.4. ANOVA tests of age, year, region on length.
For each listed effect, entries are degrees of freedom (DF), type III sum of squares (SS), F value (F) estimating the difference between variability attributable to the effect and residual variability, and P value under the null hypothesis of no effect. Results are presented testing for differences among the four regions, and between LIS and MARI, finally between LIS and NJ-NYB.

	DF	SS	F	P
All four regions				
Age	29	1.3E+06	2300	<.0001
Year	31	5.0E+04	82	<.0001
Region	3	9.1E+04	1500	<.0001
LIS&MARI				
Age	29	8.0E+05	1400	<.0001
Year	31	1.3E+04	21	<.0001
Region	1	1.0E+04	520	<.0001
LIS&NJ-NYB				
Age	28	7.5E+05	1600	<.0001
Year	31	4.8E+04	94	<.0001
Region	1	1.5E+03	94	<.0001

Table 2.5. Parameter estimates for the weight-length scaling relationship.
Relationship is (Weight = a*Length^{b}) by region, arranged N to S.

	Estimate	SE
MARI		
a	5.00E-05	3.42E-06
b	2.8	0.0
LIS		
a	3.90E-05	1.74E-06
b	2.8	0.0
NJ-NYB		
a	3.60E-05	1.51E-06
b	2.9	0.0
DMV		
a	2.80E-05	1.24E-06
b	2.9	0.0

Table 2.6. ARSS of regional heterogeneity in weight-at-length curves.
The three rows of results represent test of heterogeneity among all four regions, between LIS and MARI, and between LIS and NJ-NYB respectively. In each case the F statistic represents the probability that the residual variability as curves are fitted to data by region (four regions, LIS&MARI, LIS&NJ-NYB) is the same as variability as curves are fitted to the pooled data (coastwide, SNE, CTNYNJ). The columns represent the number of curves tested (m), the summed residual sum of squares as curves are fitted by region (ΣRSSi), the residual sum of squares as a curve is fitted to the pooled data (RSSp), the F statistic, and the p value under the null hypothesis of homogeneity among the regions.

	m	ΣRSSi	RSSp	F	P
Four regions vs. coastwide	4	690	470	1030	<0.0001
LIS&MARI vs. SNE	2	410	394	139	<0.0001
LIS&NJ-NYB vs. NYNJ	2	459	453	55.0	<0.0001

Table 2.7. ANCOVA tests of year and region on weight-at-length.
For each listed effect, entries are degrees of freedom (DF), type III sum of squares (SS), F value (F) estimating the difference between variability attributable to the effect and residual variability, and P value under the null hypothesis of no effect. Results are presented testing for differences among the four regions, and between LIS and MARI, finally between LIS and NJ-NYB.

	DF	SS	F	P
All four regions				
Length	1	1370	1370	2.80E+05
Year	30	1.88	0.0628	12.9
Region	3	0.591	0.197	40.4
LIS&MARI				
Age	1	907	907	2.23E+05
Year	30	1.98	0.0661	16.2
Region	1	0.396	0.396	97.2
LIS&NJ-NYB				
Age	1	1020	1020	1.96E+05
Year	30	1.64	0.0547	10.5
Region	1	0.0234	0.0234	4.47

Table 4.1. Recreational harvest (A+B1) for Tautog in number of fish, 1981-2015 (MRIP).

Year	CT	NY	NJ
1981	100,308	721,062	132,271
1982	231,187	646,693	583,550
1983	200,676	612,163	344,580
1984	287,470	286,077	516,086
1985	182,318	1,105,234	840,627
1986	333,396	1,183,114	2,369,852
1987	312,430	929,887	1,015,123
1988	234,198	828,183	564,286
1989	303,782	562,549	710,958
1990	75,871	953,622	841,770
1991	191,137	871,221	1,067,283
1992	319,221	413,236	1,018,205
1993	180,055	505,632	773,213
1994	150,109	196,937	208,003
1995	120,259	118,006	707,963
1996	72,558	82,826	470,431
1997	32,200	92,907	196,724
1998	66,797	68,887	11,667
1999	15,701	196,564	165,505
2000	10,648	79,245	462,371
2001	16,579	45,913	467,728
2002	100,240	629,772	347,831
2003	167,875	128,729	102,593
2004	16,464	278,749	90,214
2005	35,699	84,280	43,055
2006	200,708	246,882	200,725
2007	352,819	223,798	300,179
2008	167,179	318,899	172,518
2009	85,915	346,276	127,403
2010	116,058	145,663	374,599
2011	25,823	111,406	136,674
2012	194,101	61,508	37,611
2013	104,982	76,797	111,377
2014	289,829	263,962	169,879

Table 4.2. Commercial landings for Tautog in metric tons (MT), by region, 1984-2014. Source: NOAA Fisheries and ACCSP.

Year	LIS	NJ-NYB
1984	14.8 (CT only)	59
1985	22.7 (CT only)	57
1986	129.4	55
1987	159.1	58
1988	116.9	90
1989	140.4	48
1990	77.9	70
1991	76.2	80
1992	74.4	67
1993	60.0	77
1994	35.5	98
1995	24.1	71
1996	53.0	51
1997	33.9	31
1998	30.3	23
1999	15.3	20
2000	15.5	25
2001	27.2	39
2002	29.9	26
2003	39.2	42
2004	40.8	50
2005	36.0	47
2006	39.3	52
2007	54.6	58
2008	37.3	57
2009	23.9	34
2010	32.2	52
2011	40.1	52
2012	29.8	32
2013	38.7	38
2014	47.3	32

Table 5.1. Available data sets and acceptance or rejection for use in stock assessment.

Data	Source	Years	Region(s)	Category
Recreational Landings	MRFSS, MRIP	1984 - 2014	LIS/NYB	Fishery-dependent
Recreational CPUE	VTR	1994 - 2012	LIS, NYB	Fishery-dependent
Recreational CPUE	MRFSS/MRIP	1981 - 2014	LIS, NYB	Fishery-dependent
Length distribution of recreational harvested fish	MRFSS/MRIP	1984 - 2014	LIS, NYB	Fishery-dependent
Length distribution of recreational harvested fish	Volunteer Angler Survey	1997 - 2014	LIS (CT)	Fishery-dependent
Length distribution of recreational harvested fish	NY Head Boat Sampling	1995-1999, 2006-2014	LIS/NYB (NY)	Fishery-dependent
Length distribution of recreational released fish	MRIP	2004 - 2014	LIS, NYB	Fishery-dependent
Length distribution of recreational discards	American Littoral Society	1987 - 2014	LIS, NYB	Fishery-dependent
Commercial Landings	ACCSP, NMFS	1970 - 2014	LIS/NYB	Fishery-dependent
Age	Commercial Sampling by Individual States		LIS/NYB	Biological
Abundance	Long Island Sound Trawl Survey	1984 - 2014	LIS	Fishery-independent
Abundance	Millstone Entrainment (sensitivity only)	1984 - 2014	LIS	Fishery-independent
Abundance	Peconic Bay Trawl Survey	1987 - 2012	LIS	Fishery-independent
Abundance	Western Long Island Sound Survey (NYWLI)	1984 - 2014	LIS, NYB	Fishery-independent
Abundance	NJ Ocean Trawl Survey	1988 - 2014	NYB	Fishery-independent

Table 5.2. Number of MRFSS/MRIP intercepted trips that were positive for Tautog.

	LIS			NYB		
Year	CT	NY LIS	Total	NY south	NJ	Total
1984	71		71	80	35	115
1985	55		55	109	50	159
1986	80		80	501	54	555
1987	83		83	139	122	261
1988	179	56	235	78	104	182
1989	177	155	332	442	235	677
1990	185	312	497	488	301	789
1991	124	467	591	388	333	721
1992	171	333	504	413	253	666
1993	132	262	394	350	118	468
1994	100	86	186	154	57	211
1995	50	29	79	48	147	195
1996	61	19	80	59	148	207
1997	60	41	101	53	115	168
1998	59	43	102	47	43	90
1999	38	73	111	99	91	190
2000	33	26	59	54	113	167
2001	66	18	84	73	231	304
2002	67	103	170	101	232	333
2003	191	46	237	83	140	223
2004	44	104	148	92	212	304
2005	113	76	189	43	119	162
2006	84	147	231	151	126	277
2007	92	102	194	110	182	292
2008	56	142	198	156	261	417
2009	19	126	145	103	227	330
2010	94	111	205	119	167	286
2011	28	83	111	132	119	251
2012	99	51	150	64	118	182
Grand Total	2611	3011	5622	4729	4453	9182

Table 5.3. Species included in guilds for identification of target trips and estimation of CPUE using MRFSS/MRIP data.

Common name	Scientific name	CT	NY	NJ
Black sea bass	*Centropristis striata*		5	3
Bluefish	*Pomatomus saltatrix*	6		6
Cunner	*Tautogolabrus adspersus*	3	2	2
Scup	*Stenotomus chrysops*	4	3	4
Summer flounder	*Paralichthys dentatus*	5	6	5
Tautog	*Tautoga onitis*	1	1	1
Winter flounder	*Pseudopleuronectes americanus*	2	4	

Table 5.4. MRIP CPUE, CV and PSE by region.

	LIS			NYB		
Year	Mean	CV	PSE	Mean	CV	PSE
1984	1.66	0.128	0.370	0.25	0.1	
1985	1.38	0.132	0.370	0.31	0.1	
1986	1.26	0.113	0.370	0.69	0.07	
1987	1.48	0.107	0.370	0.54	0.08	
1988	3.53	0.0726	0.370	0.52	0.08	
1989	2.54	0.0683	0.370	0.69	0.07	0.8970
1990	1.47	0.061	0.370	0.8	0.06	1.0400
1991	1.77	0.0568	0.370	0.69	0.05	0.8970
1992	2.4	0.0594	0.370	0.89	0.06	1.1570
1993	1.85	0.0686	0.370	0.49	0.07	0.6370
1994	1.37	0.0888	0.370	0.29	0.08	0.3770
1995	0.878	0.116	0.370	0.62	0.08	0.8060
1996	1.05	0.111	0.370	0.39	0.08	0.5070
1997	0.717	0.101	0.370	0.31	0.08	0.4030
1998	0.602	0.105	0.370	0.14	0.1	0.1820
1999	0.673	0.0971	0.370	0.24	0.09	0.3120
2000	0.233	0.129	0.370	0.29	0.08	0.3770
2001	0.282	0.106	0.370	0.4	0.06	0.5200
2002	1.01	0.0943	0.370	0.54	0.07	0.7020
2003	0.818	0.0782	0.370	0.18	0.07	0.2340
2004	0.67	0.0943	0.472	0.31	0.07	0.3100
2005	0.84	0.0992	0.492	0.18	0.08	0.1800
2006	1.08	0.0922	0.384	0.32	0.08	0.3200
2007	0.927	0.0922	0.275	0.34	0.08	0.3400
2008	0.902	0.09	0.221	0.33	0.08	0.3300
2009	0.817	0.107	0.267	0.57	0.08	0.5700
2010	0.869	0.0908	0.239	0.3	0.08	0.3000
2011	0.79	0.118	0.499	0.3	0.09	0.3000
2012	0.708	0.0972	0.305	0.23	0.09	0.2300
2013	0.55	0.1	0.521	0.22	0.09	0.2200
2014	1.11	0.0852	0.291	0.26	0.08	0.2600

Table 5.5. Sample size from multiple surveys used in estimating size distribution of harvested and discarded fish in LIS.

	LIS Harvest length sources			LIS Discard length sources			
Year	MRFSS/ MRIP	NYHBS	CTVAS	MRIP Type 9	NYHBS	ALSVAS	CTVAS
1984	166						
1985	58						
1986	91						
1987	204					15	
1988	260					25	
1989	428					31	
1990	370					51	
1991	535					100	
1992	515					41	
1993	455					33	
1994	195					39	
1995	37	153			184	36	
1996	55	454			340	54	
1997	51	260	142		348	11	98
1998	45	96	235		95	90	182
1999	26	176	304		134	74	110
2000	1	0	122		0	68	84
2001	64	0	134		0	72	91
2002	72	0	259		0	89	125
2003	229	0	455		0	6	213
2004	56	0	153	57	0	4	45
2005	128	0	345	143	0	41	113
2006	136	267	392	321	0	41	171
2007	99	134	349	166	0	101	123
2008	33	335	263	135	249	36	120
2009	67	150	274	122	244	4	144
2010	180	159	274	148	239	4	141
2011	65	45	375	124	52	11	246
2012	78	56	385	182	145	103	516
2013	52	42	278	40	17	86	206
2014	60	41	161	98	220	174	379

Table 5.6. Sample size from multiple surveys used in estimating size distribution of harvested and discarded fish in NJ-NYB

	New Jersey			New York south				
	Harvest	Discards		Harvest		Discards		
	MRFSS	ALS	Type 9	MRFSS	NYHBS	ALS	NYHBS	Type 9
1995	133	85		22	174	19	304	
1996	90	67		16	161	22	226	
1997	43	52		17	179	21	208	
1998	15	26		1	68	34	232	
1999	24	32		28	32	77	147	
2000	112	7		12		74		
2001	249	123		4		47		
2002	261	89		60		135		
2003	78	63		39		11		
2004	162	78	233	67		17		38
2005	40	98	57	18		4		23
2006	71	30	32	49	31	45		165
2007	109	100	87	102	22	9		158
2008	233	266	219	97	136	8	93	134
2009	218	152	147	75	124	18	521	99
2010	101	168	76	58	61	24	66	75
2011	65	219	21	39	73	8	58	32
2012	109	190	219	57	5	23	79	74
2013	54	102	58	21	57	41		19
2014	163	81	106	15	23	26	43	28

Table 5.7. Index values for the CT Long Island Sound Trawl Survey (LISTS).

Year	Mean	SE	CV	LCI	UCI	Nominal
1984	1.69741	0.49534	0.29182	0.72654	2.66828	4.62745
1985	0.95593	0.25975	0.27172	0.44683	1.46504	2.56349
1986	1.03314	0.22618	0.21893	0.58982	1.47645	2.88776
1987	0.82925	0.18088	0.21812	0.47473	1.18378	1.81500
1988	0.61670	0.13638	0.22115	0.34938	0.88401	2.27500
1989	0.77127	0.16878	0.21883	0.44046	1.10207	3.00000
1990	0.78684	0.17218	0.21882	0.44937	1.12431	2.77000
1991	1.03916	0.22479	0.21632	0.59856	1.47975	2.50500
1992	0.46545	0.11721	0.25182	0.23572	0.69518	1.65625
1993	0.25742	0.06060	0.23544	0.13863	0.37620	0.78500
1994	0.27695	0.06481	0.23403	0.14991	0.40398	1.03500
1995	0.14207	0.03586	0.25242	0.07178	0.21236	0.30500
1996	0.20613	0.04964	0.24081	0.10884	0.30342	0.68000
1997	0.27780	0.06496	0.23385	0.15047	0.40512	0.95000
1998	0.36466	0.08354	0.22908	0.20093	0.52839	0.97000
1999	0.50516	0.11294	0.22357	0.28380	0.72653	1.08500
2000	0.45355	0.10205	0.22501	0.25353	0.65357	1.43250
2001	0.54338	0.12197	0.22446	0.30433	0.78244	1.59500
2002	0.95501	0.20712	0.21688	0.54905	1.36097	2.82400
2003	0.39317	0.09665	0.24582	0.20374	0.58260	1.31000
2004	0.34850	0.08032	0.23047	0.19108	0.50593	1.16683
2005	0.29382	0.06842	0.23287	0.15972	0.42793	0.89500
2006	0.39619	0.11145	0.28131	0.17774	0.61463	1.54750
2007	0.36585	0.08376	0.22895	0.20168	0.53002	1.39800
2008	0.37876	0.09341	0.24662	0.19568	0.56185	1.11813
2009	0.26356	0.06197	0.23513	0.14210	0.38503	0.81600
2010	0.16958	0.06154	0.36289	0.04896	0.29020	0.68462
2011	0.17694	0.04637	0.26206	0.08606	0.26781	0.61395
2012	0.28546	0.06662	0.23338	0.15489	0.41604	0.67700
2013	0.28608	0.06673	0.23326	0.15529	0.41688	0.80400
2014	0.32831	0.07598	0.23141	0.17940	0.47722	0.97286

Table 5.8. Variance Inflation Factors (VIF) for the final model for the Connecticut Long Island Sound Trawl Survey.

	VIF	Df
Year	1.123055	31
Month	1.123446	6
Strata	1.001532	2

Table 5.9. Millstone entrainment abundance indices

	Millstone egg				Millstone larvae			
Year	Mean	CV	L95	U95	Mean	CV	L95	U95
1984	1910.2	19.3	1188.9	2631.4	3.1	33.4	1.1	5.1
1985	5167.9	40.8	1038.3	9297.6	13.7	39.9	3.0	24.4
1986	4476.6	37.6	1177.5	7775.8	3.3	30.7	1.3	5.3
1987	3061.9	26.5	1474.4	4649.3	6.8	26.0	3.3	10.2
1988	2630.1	30.0	1085.4	4174.9	16.0	30.2	6.5	25.5
1989	3129.0	33.5	1073.6	5184.4	13.1	27.4	6.1	20.1
1990	2039.5	29.6	854.5	3224.4	34.2	37.1	9.3	59.1
1991	2127.0	32.2	784.7	3469.3	101.5	26.2	49.4	153.6
1992	1188.9	24.4	619.5	1758.3	13.2	15.9	9.1	17.3
1993	1381.8	20.5	826.1	1937.6	6.7	25.3	3.4	9.9
1994	1370.0	24.6	710.8	2029.2	12.4	32.6	4.5	20.4
1995	1847.1	21.7	1062.9	2631.4	8.6	27.5	3.9	13.2
1996	2265.1	56.6	-246.1	4776.2	17.9	46.4	1.6	34.1
1997	627.5	20.4	377.0	877.9	2.4	23.7	1.3	3.5
1998	1015.2	36.0	299.0	1731.5	14.3	25.8	7.1	21.6
1999	1672.0	36.5	475.0	2869.0	64.3	35.8	19.2	109.3
2000	2393.0	34.4	779.5	4006.5	12.9	50.2	0.2	25.6
2001	3028.0	37.8	784.3	5271.8	120.6	61.1	-23.8	264.9
2002	2075.2	30.2	847.4	3303.0	66.7	45.5	7.2	126.1
2003	2172.6	30.7	863.6	3481.6	453.6	82.6	-280.5	1187.6
2004	3824.5	31.3	1479.1	6169.9	100.4	55.3	-8.4	209.2
2005	2307.3	34.4	753.2	3861.3	257.0	70.1	-96.2	610.1
2006	3384.2	38.7	814.3	5954.0	20.8	22.2	11.8	29.9
2007	4360.6	52.2	-102.5	8823.7	623.6	88.1	-452.8	1700.0
2008	4297.7	45.4	476.1	8119.2	13.9	30.4	5.6	22.2
2009	4345.7	45.4	476.5	8215.0	204.4	51.4	-1.5	410.2
2010	2508.5	45.0	294.4	4722.7	55.4	36.5	15.8	95.1
2011	3432.2	54.0	-200.3	7064.6	41.6	49.8	1.0	82.2
2012	3412.9	42.1	597.3	6228.6	133.7	36.5	38.0	229.5
2013	4056.7	46.6	349.2	7764.2	21.8	24.5	11.3	32.3
2014	3236.3	51.1	-3.0	6475.6	218.9	60.4	-40.1	477.8

Table 5.10. Index values for the Peconic Bay Trawl Survey.

Year	Mean	SE	CV	LCI	UCI	Nominal
1987	0.20657	0.06112	0.29589	0.08677	0.32637	0.23164
1988	0.21846	0.06185	0.28313	0.09723	0.33969	0.34272
1989	0.90036	0.24125	0.26795	0.42750	1.37321	1.11905
1990	0.35414	0.09650	0.27249	0.16500	0.54327	0.59302
1991	0.28597	0.07847	0.27441	0.13216	0.43978	0.49497
1992	0.13186	0.03792	0.28758	0.05754	0.20619	0.23358
1993	0.22749	0.06338	0.27859	0.10327	0.35171	0.50242
1994	0.07632	0.02237	0.29306	0.03248	0.12016	0.17991
1995	0.08857	0.02608	0.29445	0.03745	0.13969	0.26596
1996	0.23349	0.06497	0.27827	0.10614	0.36083	0.39609
1997	0.17690	0.05073	0.28675	0.07747	0.27632	0.31926
1998	0.24979	0.07006	0.28048	0.11247	0.38711	0.32911
1999	0.16991	0.04818	0.28353	0.07549	0.26434	0.32250
2000	0.08529	0.02528	0.29645	0.03573	0.13484	0.16667
2001	0.32618	0.08996	0.27581	0.14985	0.50250	0.61353
2002	0.13657	0.03909	0.28620	0.05996	0.21318	0.26506
2003	0.20814	0.05931	0.28495	0.09190	0.32439	0.27990
2004	0.14485	0.04160	0.28720	0.06331	0.22638	0.31204
2007	0.21885	0.06097	0.27859	0.09935	0.33836	0.35696
2009	0.92353	0.24671	0.26713	0.43999	1.40708	1.38120
2010	0.42393	0.12885	0.30395	0.17138	0.67648	0.40728
2011	0.10257	0.03106	0.30281	0.04170	0.16345	0.18750
2012	0.16114	0.04568	0.28351	0.07160	0.25068	0.42051
2013	1.13344	0.34762	0.30669	0.45211	1.81477	0.87845
2014	0.40738	0.11385	0.27946	0.18424	0.63051	0.88127

Table 5.11. Variance Inflation Factors (VIF) for the final model for the NY Peconic Bay Trawl Survey.

	GVIF	Df
Year	16.3433	27
Temp	1.42815	1
Depth	4.36575	1
Salinity	3.60431	1
Station	2.68712	76

Table 5.12. Index values for the LIS portion of the NYWLISS

Year	Mean	SE	CV	LCI	UCI	Nominal
1984	0.36852	0.21246	0.57654	-0.04791	0.78495	0.54545
1985						
1986	0.05163	0.04351	0.84276	-0.03365	0.13691	0.06522
1987	0.03251	0.02684	0.82577	-0.02011	0.08512	0.05085
1988	1.24364	0.64349	0.51743	-0.01761	2.50489	0.80357
1989	0.02614	0.02714	1.03805	-0.02704	0.07933	0.01887
1990	0.18745	0.12127	0.64696	-0.05024	0.42514	0.27451
1991	2.93227	1.49264	0.50904	0.00669	5.85785	8.35294
1992	0.45012	0.23419	0.52028	-0.00889	0.90913	0.37705
1993	0.00860	0.01128	1.31121	-0.01350	0.03070	0.01852
1994						
1995	0.06486	0.05674	0.87468	-0.04634	0.17607	0.09756
1996	0.04305	0.03598	0.83583	-0.02748	0.11357	0.03571
1997	0.28133	0.18733	0.66587	-0.08584	0.64850	0.20000
1998	0.21457	0.13072	0.60919	-0.04163	0.47078	0.19149
1999	1.00449	0.50959	0.50732	0.00568	2.00329	1.98214
2000	1.77202	0.81508	0.45997	0.17446	3.36958	1.71429
2001	0.03436	0.02700	0.78589	-0.01856	0.08728	0.04918
2002	0.54771	0.25596	0.46733	0.04602	1.04940	1.26761
2003	0.93490	0.39905	0.42683	0.15277	1.71703	0.93750
2004	0.04531	0.02958	0.65292	-0.01267	0.10328	0.06250
2005	0.33096	0.16820	0.50821	0.00129	0.66063	0.65000
2006	0.17247	0.10502	0.60889	-0.03336	0.37830	0.26087
2007	0.06386	0.03726	0.58343	-0.00916	0.13688	0.12821
2008	0.03992	0.02724	0.68247	-0.01348	0.09332	0.03947
2009						
2010	0.00975	0.01079	1.10661	-0.01139	0.03089	0.01449
2011	0.00848	0.00956	1.12647	-0.01025	0.02721	0.01282
2012	0.40178	0.19044	0.47400	0.02851	0.77504	0.89333
2013	0.02519	0.01949	0.77373	-0.01301	0.06340	0.04225
2014	0.44803	0.21138	0.47179	0.03374	0.86233	0.54054

Table 5.13. Variance Inflation Factors (VIF) for the final model for the Long Island Sound portion of NYWLISS

	VIF	Df
Year	1.11859	31
Temp	1.11859	1

Table 5.14. Index values for the NJ-NYB portion of the NYWLISS

Year	Mean	SE	CV	LCI	UCI
1987	0.083	0.059678	0.717	-0.03375	0.200182
1988	0.234	0.176132	0.751	-0.11084	0.579603
1989	1.280	0.693817	0.542	-0.08005	2.639718
1990	0.994	0.581048	0.584	-0.14452	2.133192
1991	0.407	0.209723	0.516	-0.00443	0.817686
1992	0.421	0.234922	0.558	-0.03933	0.881559
1993	0.013	0.01579	1.193	-0.01771	0.044187
1994	0.121	0.078111	0.647	-0.03235	0.273843
1995	0.090	0.073814	0.819	-0.05455	0.234806
1996	0.052	0.069127	1.336	-0.08374	0.187236
1997	0.000		1.000		
1998	0.052	0.04881	0.931	-0.04323	0.148107
1999	0.853	0.420692	0.493	0.027951	1.677063
2000	0.634	0.294142	0.464	0.05751	1.210545
2001	1.112	0.588553	0.529	-0.04145	2.265676
2002	0.135	0.086421	0.638	-0.03398	0.304792
2003	0.240	0.143782	0.599	-0.04172	0.521909
2004	1.859	0.924936	0.498	0.046195	3.671946
2005	1.477	0.711284	0.481	0.083149	2.871382
2006	0.622	0.322651	0.519	-0.01021	1.254582
2007	1.041	0.516299	0.496	0.02938	2.053271
2008	0.423	0.247174	0.584	-0.06139	0.907531
2009	0.042	0.046707	1.113	-0.04957	0.133522
2010	0.000	2.79E-09	--	-5.5E-09	5.47E-09
2011	0.066	0.06077	0.918	-0.05289	0.185335
2012	2.745	1.280495	0.467	0.234745	5.254287
2013	0.706	0.369792	0.524	-0.01888	1.430707
2014	0.922	0.43125	0.468	0.076319	1.76682
2015	1.829	0.804744	0.440	0.251654	3.406251

Table 5.15. Variance Inflation Factors (VIF) for the final model for the NJ-NYB portion of NYWLISS

	GVIF	Df	GVIF^(1/(2*Df))
Year	1.454453	27	1.006962
Station	1.361557	7	1.02229
W_temp	1.134646	1	1.065198

Table 5.16. Index values for the NJOT survey

Year	Mean	SE	CV	LCI	UCI
1988	3.9841	2.2887	0.5745	-0.5018	8.4701
1989	1.2686	0.4317	0.3403	0.4224	2.1148
1990	1.5652	0.5640	0.3603	0.4598	2.6705
1991	0.9882	0.3463	0.3504	0.3095	1.6669
1992	1.3242	0.4561	0.3444	0.4302	2.2181
1993	0.6921	0.2435	0.3518	0.2149	1.1694
1994	0.4337	0.1563	0.3603	0.1274	0.7400
1995	0.6013	0.2104	0.3500	0.1888	1.0138
1996	0.2031	0.0762	0.3751	0.0538	0.3525
1997	0.1121	0.0446	0.3982	0.0246	0.1995
1998	0.2965	0.1075	0.3624	0.0859	0.5071
1999	0.6184	0.2180	0.3525	0.1911	1.0457
2000	0.3338	0.1218	0.3649	0.0951	0.5726
2001	0.2867	0.1052	0.3669	0.0805	0.4930
2002	1.4816	0.5071	0.3423	0.4876	2.4756
2003	0.6049	0.2127	0.3516	0.1880	1.0217
2004	0.3528	0.1281	0.3631	0.1018	0.6039
2005	0.6619	0.2373	0.3585	0.1968	1.1269
2006	0.7597	0.2666	0.3509	0.2372	1.2823
2007	0.3571	0.1289	0.3610	0.1044	0.6098
2008	0.8968	0.3125	0.3484	0.2844	1.5092
2009	0.5716	0.2027	0.3546	0.1744	0.9689
2010	0.4351	0.1559	0.3583	0.1295	0.7407
2011	0.1397	0.0561	0.4014	0.0298	0.2496
2012	0.2479	0.0923	0.3723	0.0670	0.4288
2013	0.4244	0.1524	0.3590	0.1258	0.7231
2014	0.7237	0.2528	0.3494	0.2281	1.2192

Table 5.17. Variance Inflation Factors (VIF) for the final model for the NJOT survey

	GVIF	Df	GVIF^(1/(2*Df))
Year	1.276978	27	1.004538
Tempbtm	1.202562	1	1.096614
Depthm	1.018976	1	1.009443
Salinitybt	1.359375	1	1.165922

Table 5.18. Data for age-length keys by region.

	LIS		NYB	
Year	Source(s)	N	Source(s)	N
1984	CT	466		
1985	CT	472		
1986	CT	312		
1987	CT, RI	407		
1988	CT,RI	230		
1989	CT	398		
1990	CT, RI	238		
1991	CT, RI	237		
1992	CT	206		
1993	CT	129		
1994	CT	195		
1995	CT, NY-N	109	NY, NJ + CT	422
1996	CT, NY-N	288	NY, NJ + CT, DE	671
1997	CT,RI, NY-N	422	NY, NJ + CT, DE	1,461
1998	CT,NY-N	300	NY, NJ + CT, DE	1,010
1999	CT,RI, NY-N	323	NY, NJ + CT, DE	930
2000	CT, RI	284	NY, NJ + CT, DE	1,193
2001	CT, RI	249	NY, NJ + CT, DE	867
2002	CT, RI	859	NJ + CT, DE	816
2003	CT, RI	626	NJ + CT, DE	490
2004	CT,RI, NY-N	625	NY, NJ + CT, DE	993
2005	CT, RI	449	NY, NJ + CT, DE	981
2006	CT,RI, NY-N	674	NY, NJ + CT, DE	1,005
2007	CT,RI, NY-N	760	NY, NJ + CT, DE	1,263
2008	CT,RI, NY-N	742	NY, NJ + CT, DE	830
2009	CT,RI, NY-N	585	NY, NJ + CT, DE	982
2010	CT,RI, NY-N	447	NY, NJ + CT, DE	1,119
2011	CT,RI, NY-N	387	NY, NJ + CT, DE	998
2012	RI, NY-N	302	NJ, NY south	310
2013	RI, NY-N	364	NJ, NY south	433
2014	RI, NY-N	312	NJ, NY south	512

Table 6.1 Goodness of fit for each region based on the ASAP model.

	Lambda	Obj Func			Resids	RMSE
Obj Func		5214.09		Catch fleet 1	31	0.9576
				Total catch	31	0.9576
Catch fleet total	1	-18.4282		Disc fleet 1	0	0
Discard fleet total	1	34.4152		Tot disc	0	0
Index fit total	4	271.964		Index 1 - CT trawl	31	0.9215
Catch age comps	see_below	1774.42		Index 2 - NY trawl	25	2.2735
Discard age comps	see_below	0		Index 3 - MRFSS CPUE	31	1.6237
Index age comps	see_below	3155.17		Index 4 - NY seine	27	4.6044
Sel parms total	0	0		Index total	114	2.66506
Index sel parms total	0	0		Stock N year 1	0	0
q year1 total	0	0		Fmult year 1	0	0.0000
q devs total	0	0		Fmult devs fleet 1	30	0.7002
Fmult year 1 fleet total	0	0		Fmult devs total	30	0.7002
Fmult devs fleet total	0.5	3.42489		Recruitment devs	31	0.783471
N year 1	0	0		Fleet selectivity	0	0
Recruit devs	0.5	-6.86738		Index selectivity	0	0
SR steepness	0	0		q first year	0	0
SR scalar	0	0		q devs	0	0
Fmult max penalty	1000	0		SR steepness	0	0
F penalty	0	0		SR scalar	0	0
	Lambda	Obj Func			Resids	RMSE
Obj Func		3659.94		Catch fleet 1	26	0.7565
				Total catch	26	0.7565
Catch fleet total	1	-27.1004		Disc fleet 1	0	0
Discard fleet total	1	28.8644		Tot disc	0	0
Index fit total	3	4.65871		Index 1 - NY seine	24	1.0930
Catch age comps	see_below	1993.49		Index 2 - NJ trawl	26	1.0795
Discard age comps	see_below	0		Index 3 - MRFSS CPUE	26	0.9742
Index age comps	see_below	1658.83		Index total	76	1.0491
Sel parms total	0	0		Stock N year 1	0	0
Index sel parms total	0	0		Fmult year 1	0	0
q year1 total	0	0		Fmult devs fleet 1	25	1.0626
q devs total	0	0		Fmult devs total	25	1.0626

Fmult year 1 fleet total	0	0		Recruitment devs	26	0.7819
Fmult devs fleet total	0.5	6.96425		Fleet selectivity	0	0
N year 1	0	0		Index selectivity	0	0
Recruit devs	0.5	-5.77612		q first year	0	0
SR steepness	0	0		q devs	0	0
SR scalar	0	0		SR steepness	0	0
Fmult max penalty	1000	0		SR scalar	0	0
F penalty	0	0				

Table 6.2. Index catchability coefficients from the ASAP model

Region	Survey	Q
LIS	CT Trawl	2.30E-07
	NY Trawl	2.73E-07
	MRIP CPUE	6.64E-07
	NY Seine	2.86E-07
	MillEggs	na
	MillLarvae	na
NYB	NY seine	5.49E-04
	NJ trawl	2.71E-04
	MRFSS	4.61E-04

Table 6.3 Annual and 3-year average fishing mortality for base model

Region	LIS		NJ-NYB	
Year	Annual F	3-year average	Annual F	3-year average
1984	0.1208			
1985	0.1406			
1986	0.1950	0.1522		
1987	0.2243	0.1866		
1988	0.2185	0.2126		
1989	0.2520	0.2316	0.2298	
1990	0.2150	0.2285	0.3029	
1991	0.1987	0.2219	0.4895	0.3407
1992	0.2698	0.2278	0.6025	0.4650
1993	0.4743	0.3142	0.6304	0.5741
1994	0.4071	0.3837	0.3162	0.5164
1995	0.3140	0.3984	0.6107	0.5191
1996	0.2558	0.3256	0.4540	0.4603
1997	0.1897	0.2531	0.2520	0.4389
1998	0.1721	0.2058	0.0925	0.2662
1999	0.1403	0.1674	0.1991	0.1812
2000	0.0735	0.1286	0.3515	0.2144
2001	0.0846	0.0995	0.4283	0.3263
2002	0.1912	0.1164	0.4768	0.4189
2003	0.1510	0.1423	0.2246	0.3766
2004	0.1441	0.1621	0.1774	0.2930
2005	0.1124	0.1358	0.1078	0.1699
2006	0.1879	0.1481	0.3287	0.2046
2007	0.3607	0.2203	0.4977	0.3114
2008	0.4422	0.3303	0.4621	0.4295
2009	0.4027	0.4018	0.5007	0.4869
2010	0.3479	0.3976	0.7485	0.5705
2011	0.2762	0.3422	0.5005	0.5832
2012	0.4378	0.3540	0.3667	0.5386
2013	0.4362	0.3834	0.4765	0.4479
2014	0.7229	0.5323	0.6578	0.5003

Table 6.4 Estimated total abundance, SSB and recruits for base model

Region	LIS			NJ-NYB		
Year	Abundance	SSB	Recruits	Abundance	SSB	Recruits
1984	11,518,701	11,718,100	1,519,540			
1985	10,543,445	11,174,300	1,273,700			
1986	10,194,721	10,239,500	1,827,140			
1987	9,185,233	8,978,120	1,296,680			
1988	8,274,641	7,963,820	1,158,390			
1989	8,106,008	7,073,470	1,658,320	9,428.92	5,983.97	1,593.85
1990	7,034,777	6,302,510	749,857	8,742.31	5,733.54	1,322.73
1991	6,482,414	5,903,570	968,590	8,067.19	4,959.21	1,397.59
1992	6,424,968	5,365,780	1,314,580	6,799.33	3,845.61	1,088.46
1993	5,865,453	4,386,960	922,205	5,541.85	2,989.26	872.79
1994	4,854,187	3,528,280	663,198	4,549.40	2,623.25	731.64
1995	4,432,446	3,161,490	838,644	4,243.70	2,298.93	751.42
1996	4,185,540	3,027,160	705,845	3,555.80	1,887.17	630.41
1997	4,034,527	3,024,420	707,298	3,370.29	1,791.33	751.23
1998	4,328,810	3,070,470	1,069,170	3,599.79	1,891.37	952.91
1999	4,641,261	3,129,230	1,111,860	3,770.96	2,053.26	747.55
2000	4,989,587	3,355,610	1,157,240	3,683.13	2,098.62	645.11
2001	5,691,107	3,705,720	1,485,820	3,448.90	1,961.75	651.28
2002	5,380,529	3,936,390	592,421	3,255.65	1,746.51	675.14
2003	5,451,439	4,147,160	1,080,960	3,180.42	1,665.76	728.38
2004	5,624,080	4,273,530	1,148,070	3,329.57	1,752.51	764.82
2005	5,142,562	4,415,720	523,207	3,471.42	1,899.40	782.62
2006	5,010,515	4,512,660	769,280	3,507.61	1,953.09	642.72
2007	4,673,589	4,090,010	670,871	3,355.68	1,751.37	693.07
2008	4,106,654	3,367,440	612,999	3,231.98	1,502.56	808.23
2009	3,748,372	2,773,020	750,591	3,002.47	1,342.08	603.36
2010	3,923,661	2,410,670	1,096,260	3,078.12	1,178.53	870.22
2011	3,455,479	2,265,870	375,007	3,283.43	1,045.07	1,125.09
2012	3,165,989	2,275,530	413,328	4,410.59	1,181.18	1,818.49
2013	4,466,604	2,197,510	1,975,820	6,712.63	1,496.73	2,750.39
2014	4,115,365	1,956,350	495,305	6,689.31	1,971.76	1,080.65

Table 6.5 FMSY and Ftarget and Fthreshold for base and all sensitivity analyses. SSB30% and SSB40% for the base models.

	Model	FMSY	FSPR30%	FSPR40%	SSB30%	SSB40%	SSBMSY
LIS	Base Model	0.1639	0.4654	0.2686	2,820	3,757	4,576
	15 year plus	0.2372	0.4277	0.2476	3,993	5,325	5,052
	NYS, NYT, MRIP	0.0833	0.3704	0.2266			
	LISTS, MRIP	1.3026	0.4689	0.2690			
	3 selectivty blocks	0.1827	0.3492	0.2158			
	1988 forward	0.2968	0.4614	0.2666			
	LISTS, NYS, NYT	0.3760	0.5418	0.2986			
	All Indicies	0.4190	0.4544	0.2634			
	Initial values 1000x	0.2233	0.4625	0.2671			
	Steepness to 1	0.2233	0.4625	0.2671			
	CT only to 1988	0.2289	0.4612	0.2665			
	CT and ALL of NY to 1988	0.2289	0.4612	0.2665			
NYB	Base optim	2.9719	0.3645	0.2155	2,457	3,305	841
	No seine	2.9771	0.3561	0.2118			
	No trawl	0.4010	0.3624	0.2150			
	No MRFSS	2.9727	0.3660	0.2161			
	95+	2.9771	0.3543	0.2111			
	fix 05	2.9777	0.3549	0.2113			
	3 blocks	1.5502	0.2531	0.1633			

Table 7.1 Reference points, terminal year estimates, and stock status by region

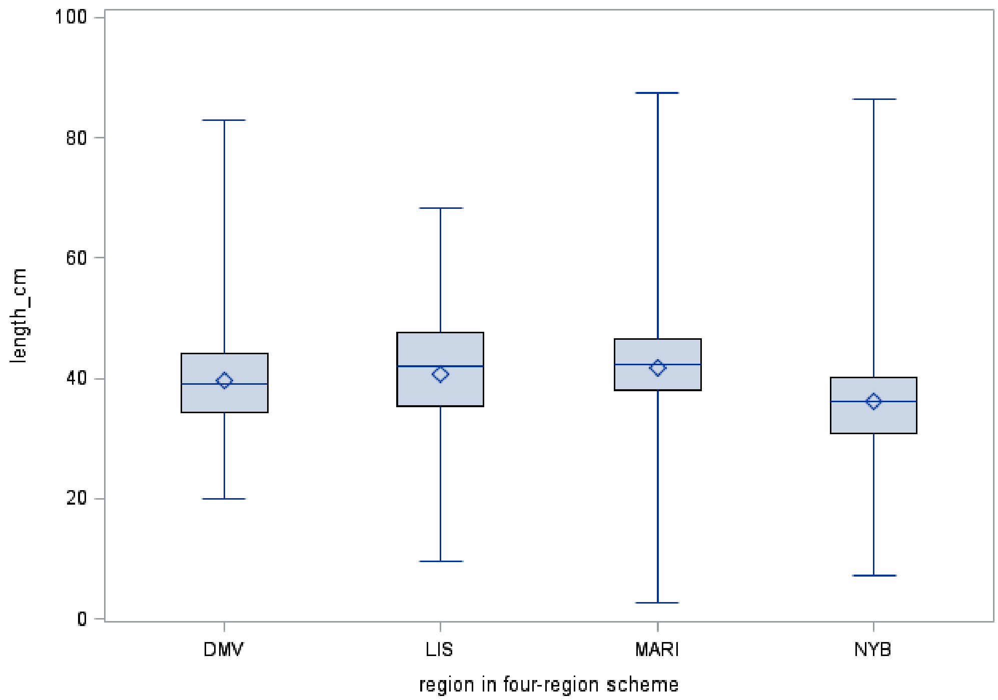
	LIS (MSY)	LIS (SPR)	NJ-NYB
F_{TARGET}	0.16	0.27	0.22
$F_{THRESHOLD}$	0.32	0.47	0.36
3-YEAR AVG.	0.53	0.53	0.5
SSB_{TARGET}	4,576 MT	3,757 MT	3,305 MT
$SSB_{THRESHOLD}$	3,432 MT	2,820 MT	2,457 MT
SSB 2014	1,956 MT	1,956 MT	1,972 MT
STOCK STATUS	Overfishing, Overfished	Overfishing, Overfished	Overfishing, Overfished

11. FIGURES

Figure 2.1. Distribution of age, length and weight by region.

The lines at the bottom and top of the whiskers represent the minimum and maximum values, the bottom and top of the boxes represent the 25th and 75th percentiles, the line in the center of each box represents the median, and the diamond symbol represents the mean.

A) Distribution of length



B) Distribution of age

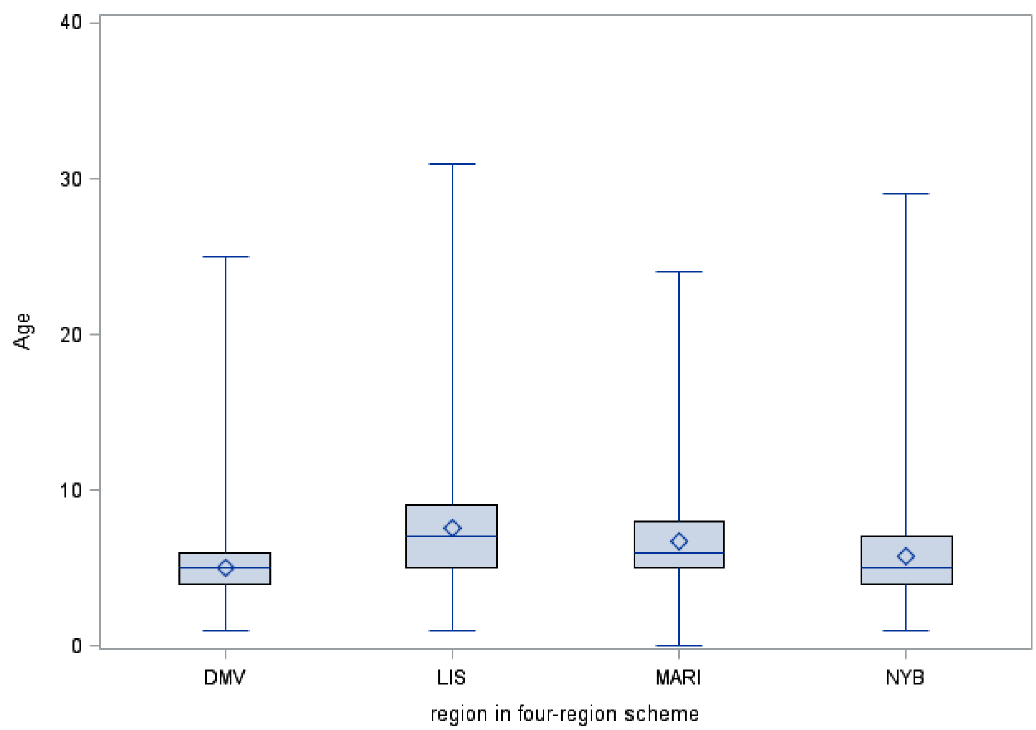


Fig 2.1 (cont'd)

C) Distribution of weight

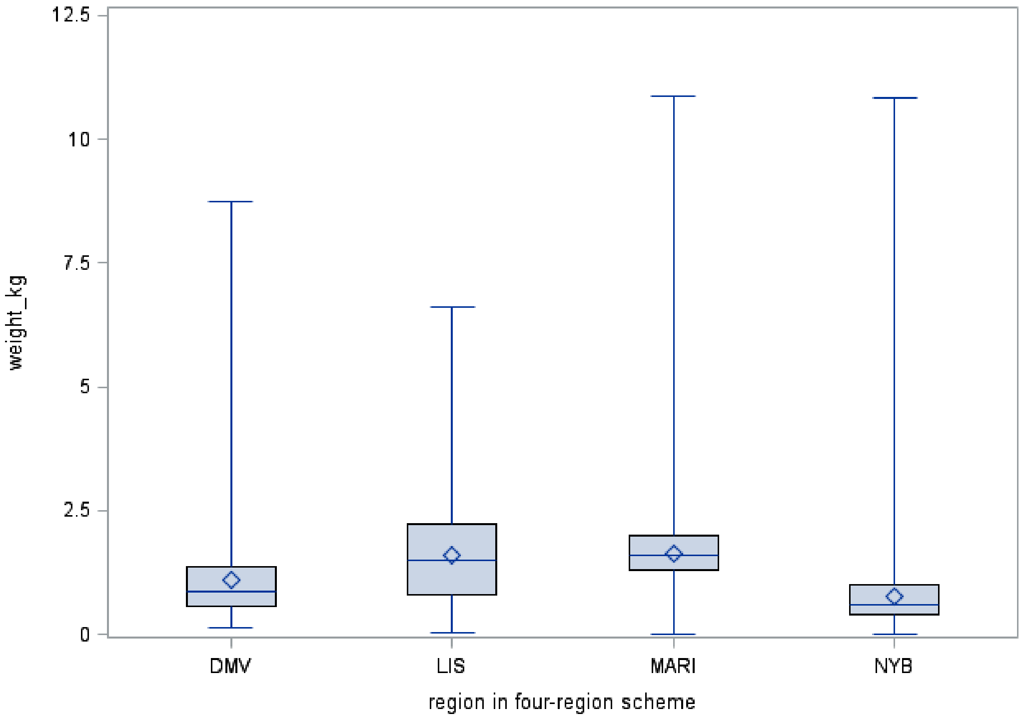


Figure 2.2. Diagnostics for nonlinear regression analysis of growth.
The upper panel represents a histogram of residuals from expected values, and the lower panel is a plot of mean residuals vs. increments of predicted value.

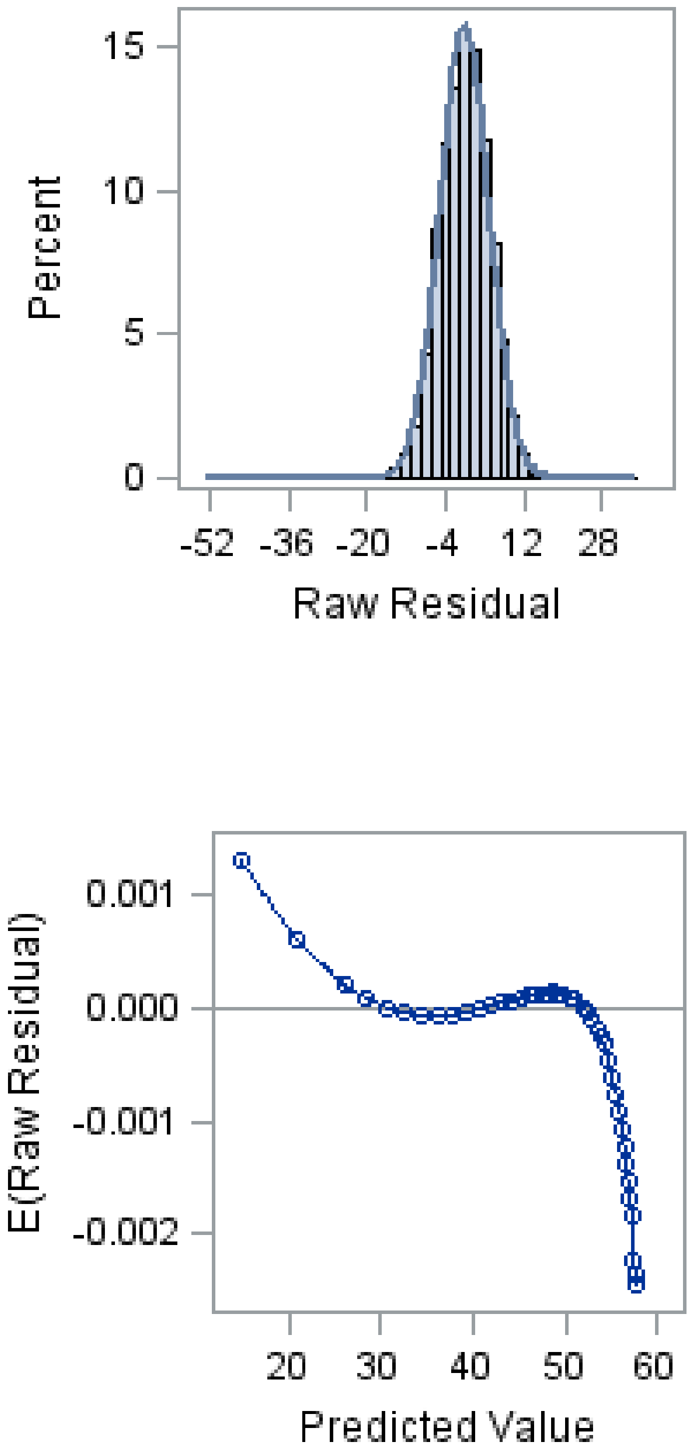


Figure 2.3. Diagnostics for length-at-age ANOVA.
The upper panel represents a histogram of residuals from expected values, and the lower panel is a quantile-quantile plot of the observed distribution of residuals vs. residuals of the standard normal curve.

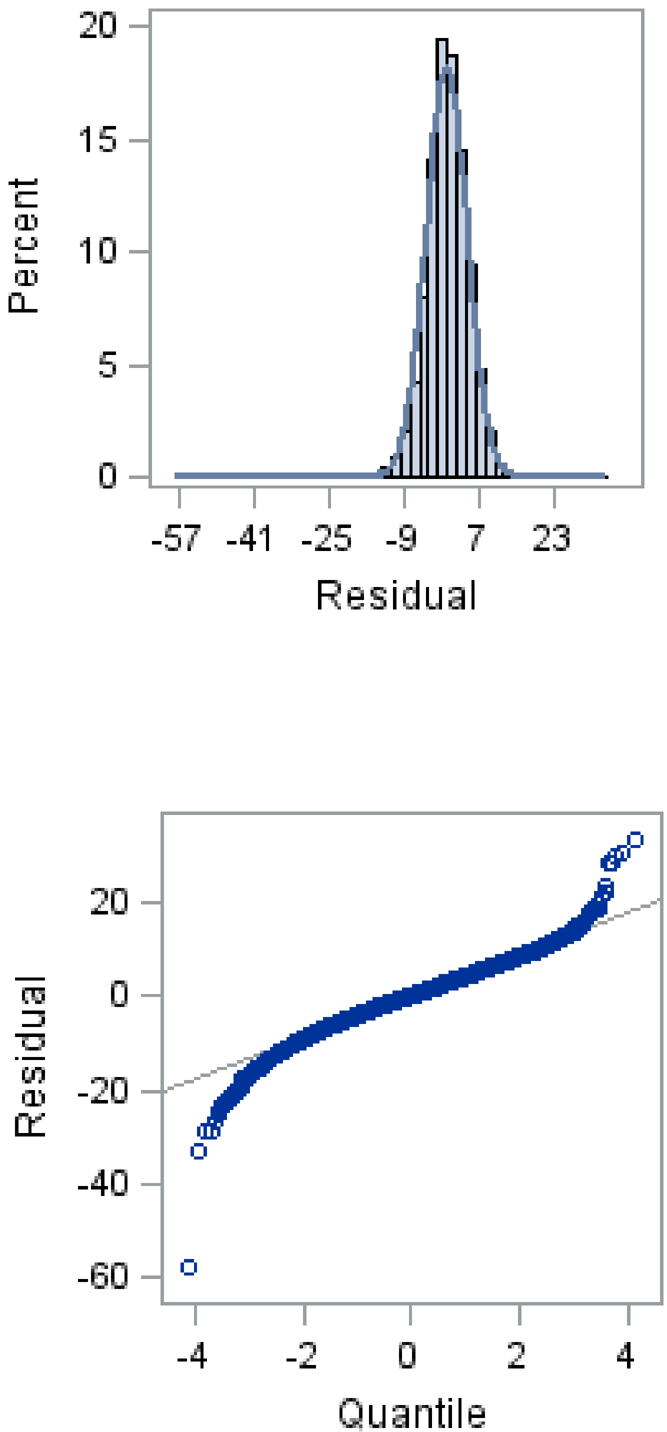


Figure 2.4. Diagnostics for weight-length nonlinear regression analysis.
The upper panel represents a histogram of residuals from expected values, and the lower panel is a plot of mean residuals vs. increments of predicted value.

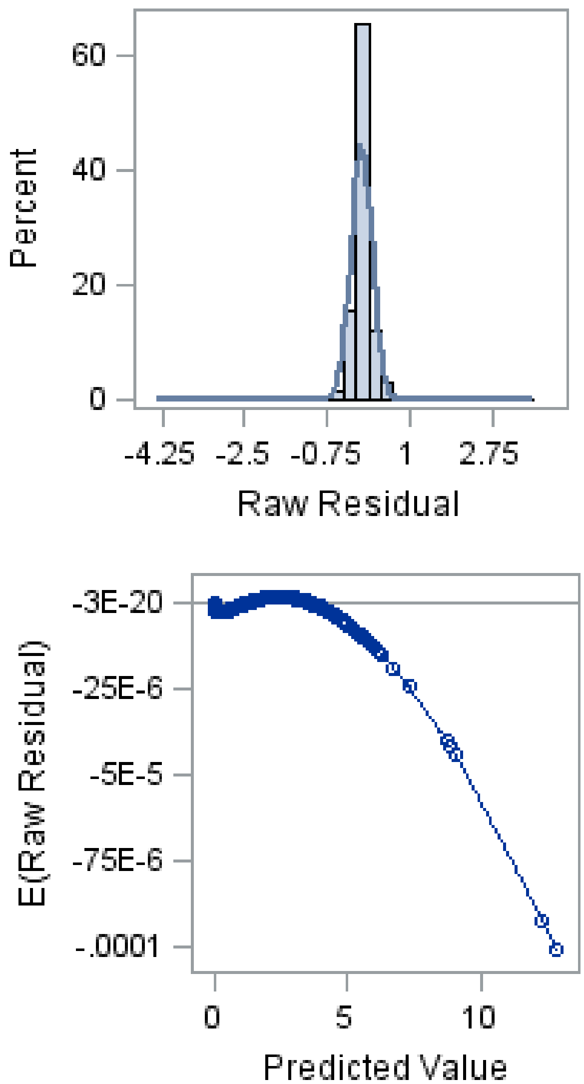


Figure 2.5. Diagnostics for weight-length ANCOVA.
The upper panel represents a histogram of residuals from expected values, and the lower panel is a quantile-quantile plot of the observed distribution of residuals vs. residuals of the standard normal curve.

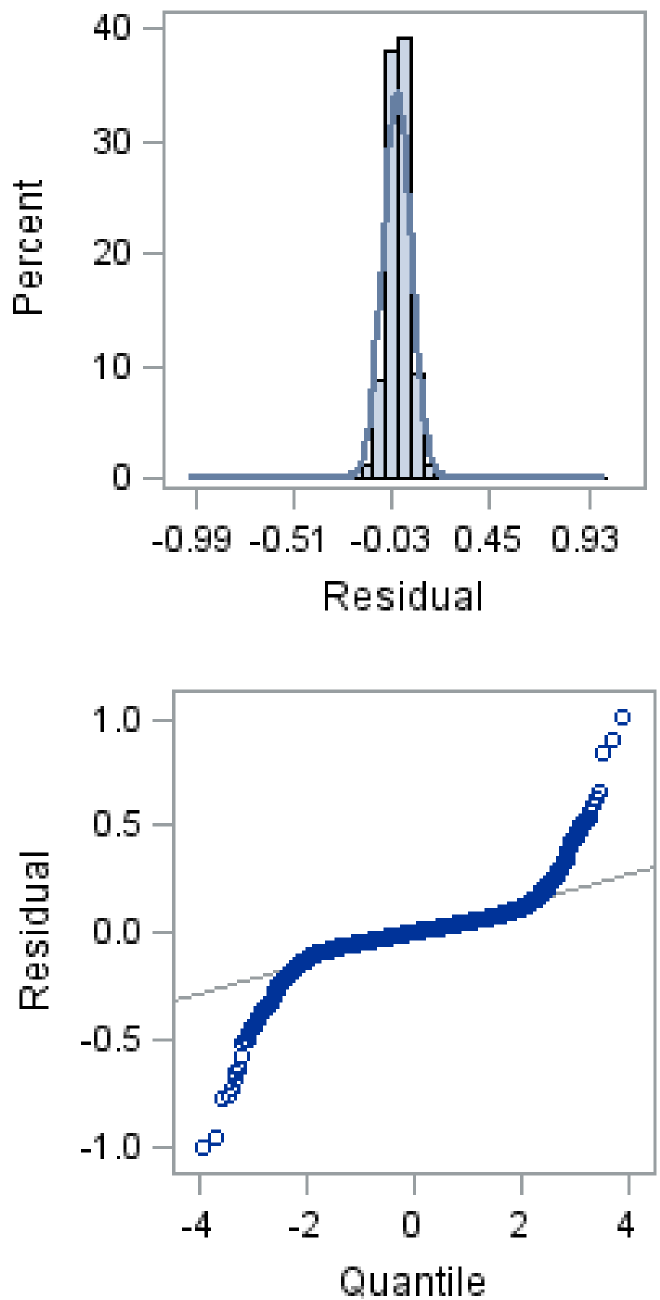


Figure 2.6. Von Bertalanffy growth curves by region.

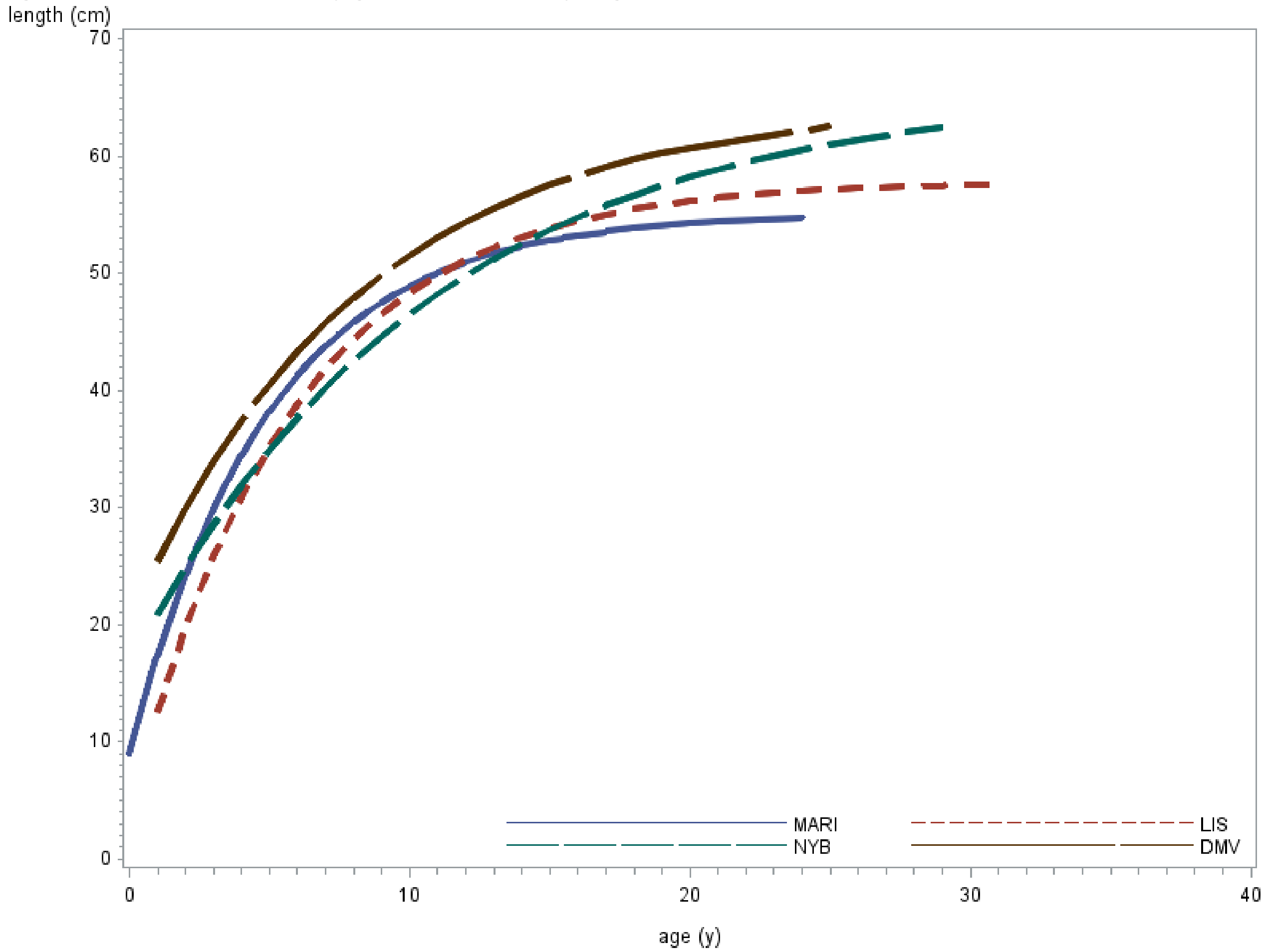


Figure 2.7. LSMean length over time.

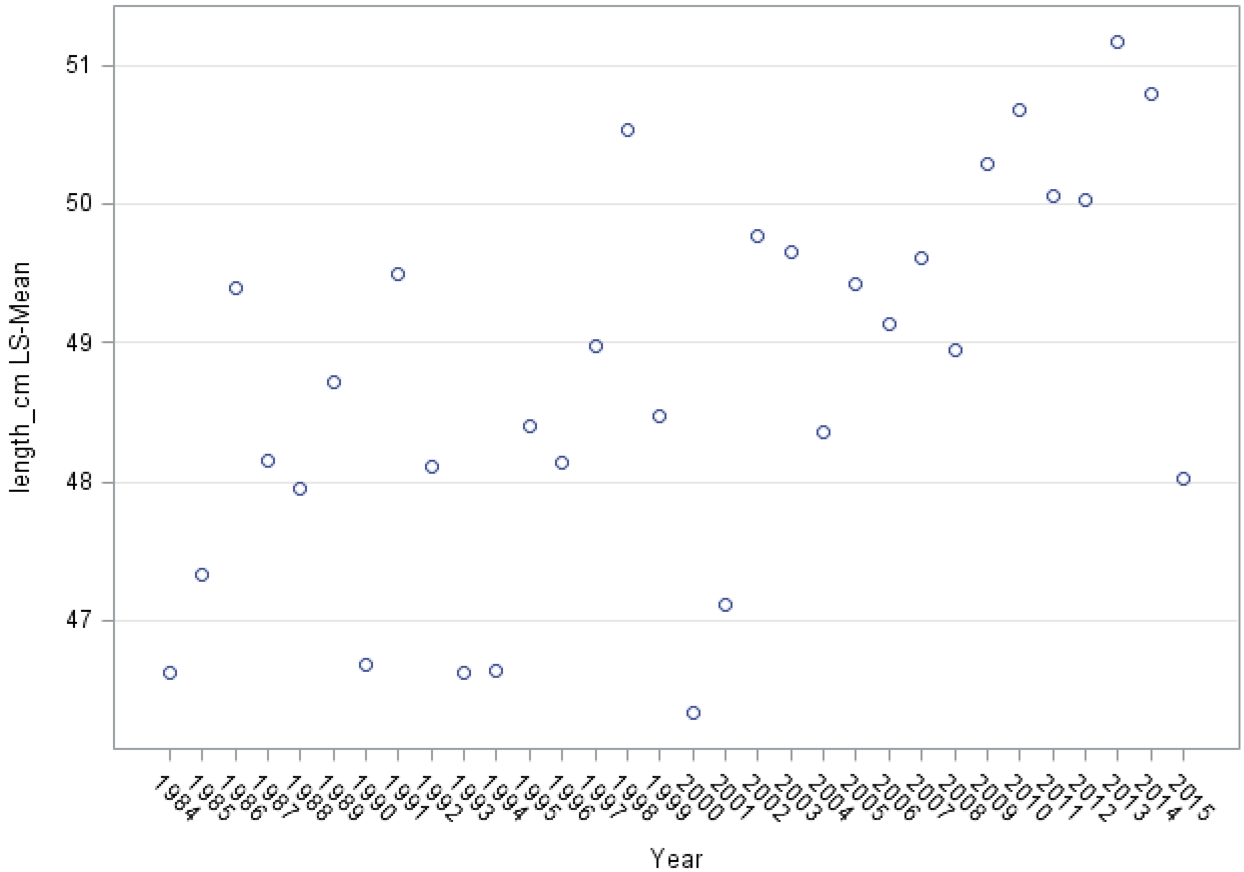


Figure 2.8. LSMean (±SD) length for each of 4 regions.
Values plotted are the difference between LSMeans of each region. Lines represent Tukey-Kramer confidence intervals.

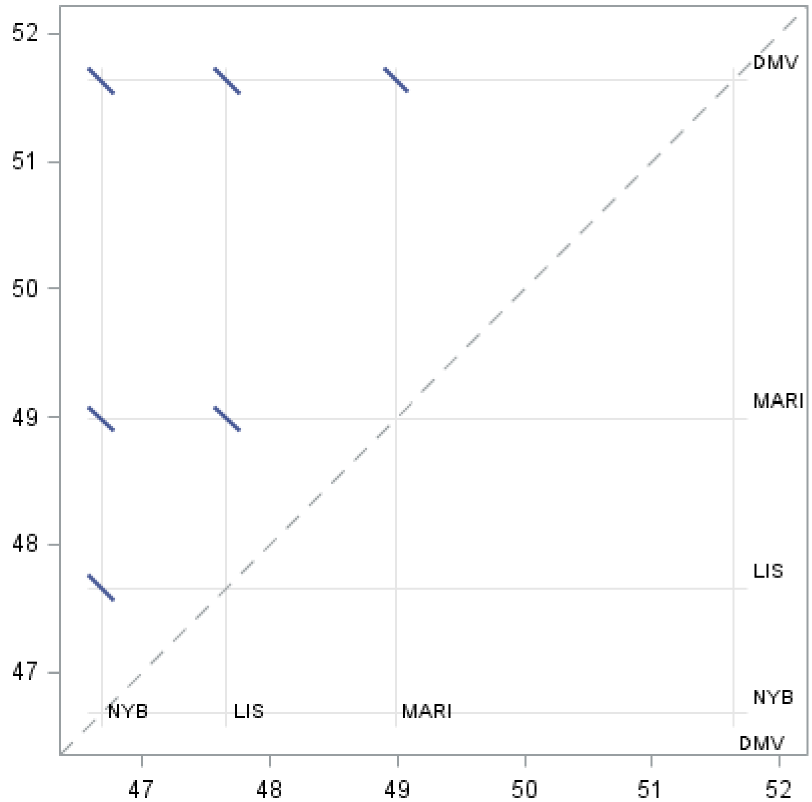


Figure 2.9. Length-weight relationships.
Plotted as regression lines fitted to allometric (power) equations weight = a*length^b.

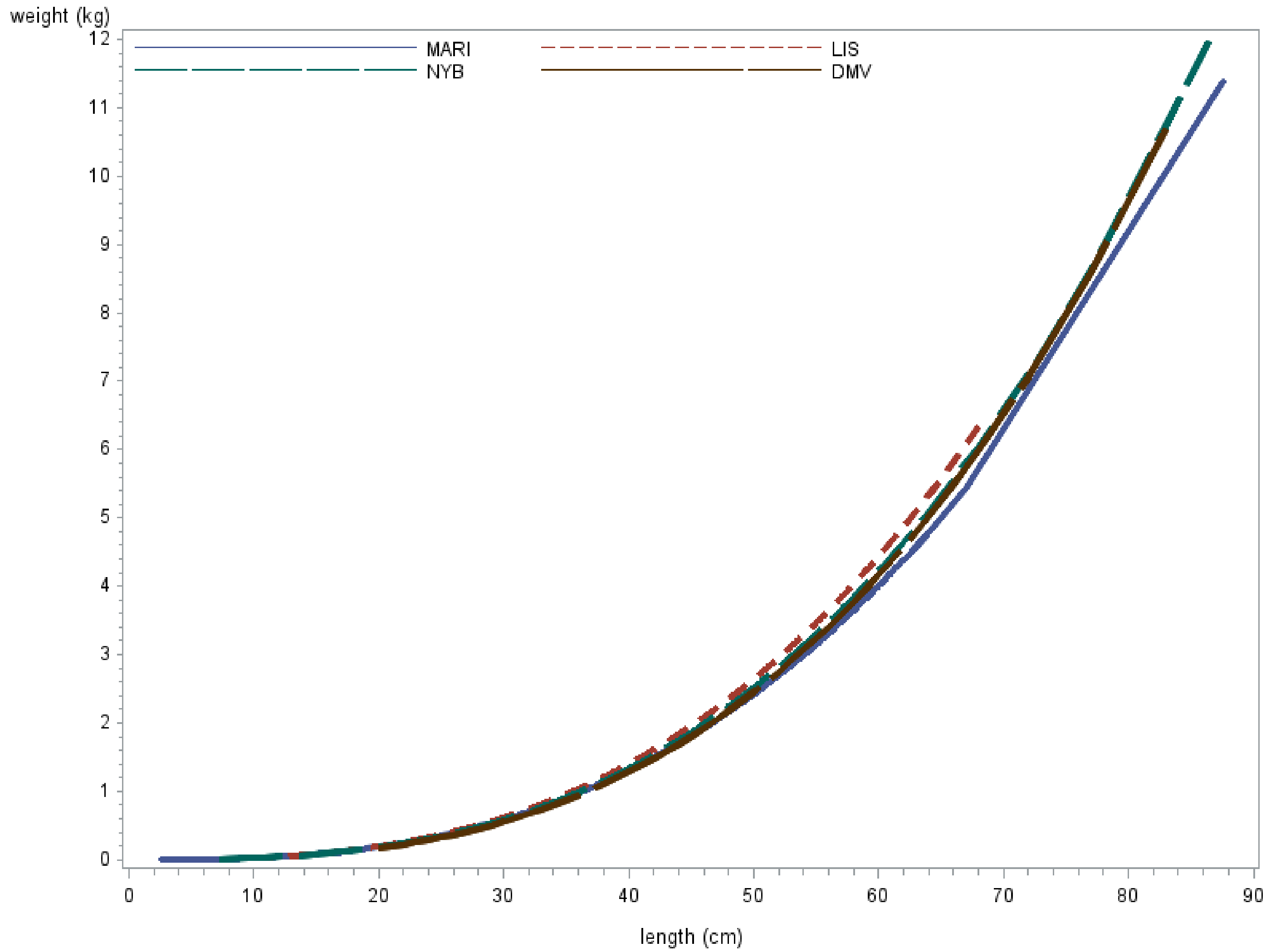


Figure 2.10. LSMean weight over time.

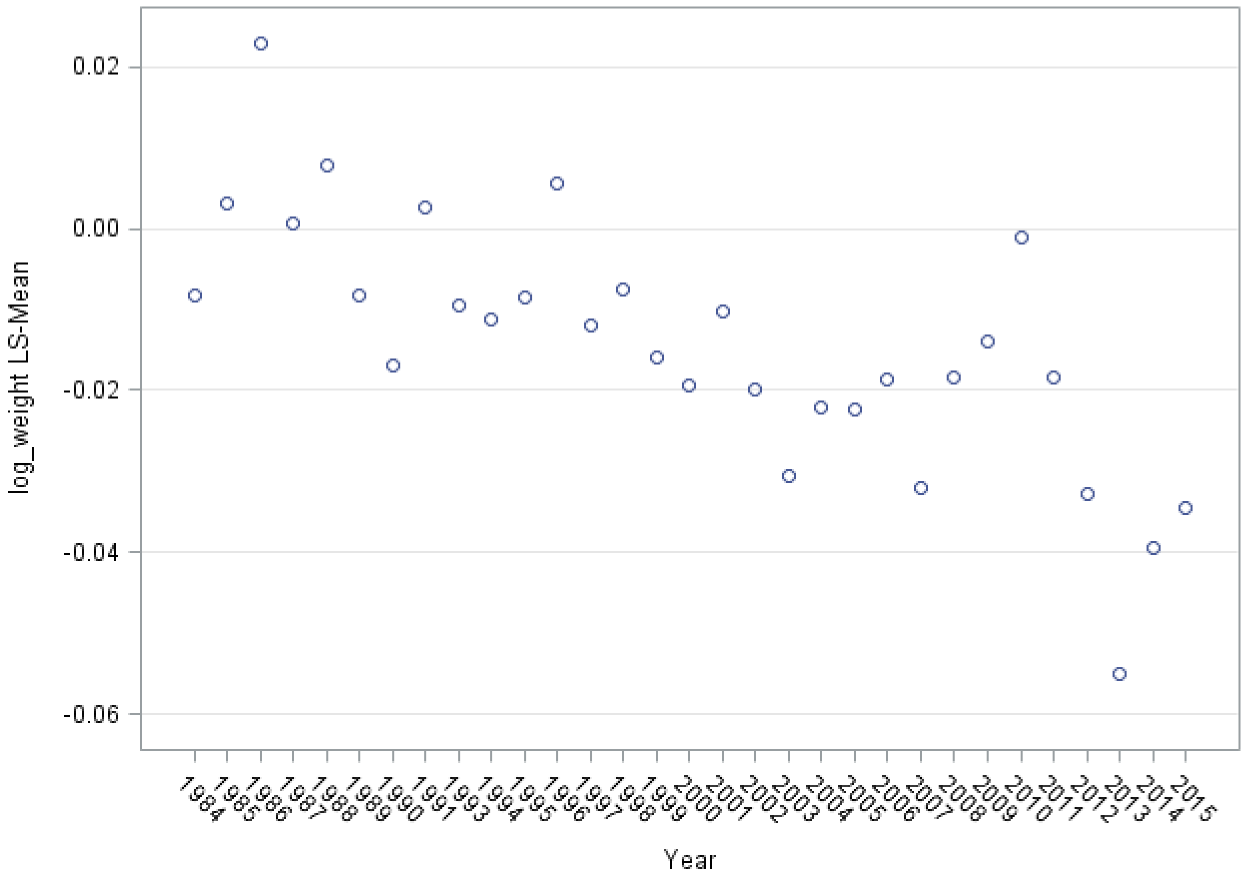


Figure 2.11. LSMean (±SD) weight-at-length for each of 4 regions.
Values plotted are the difference between LSMeans of each region. Lines represent Tukey-Kramer confidence intervals.

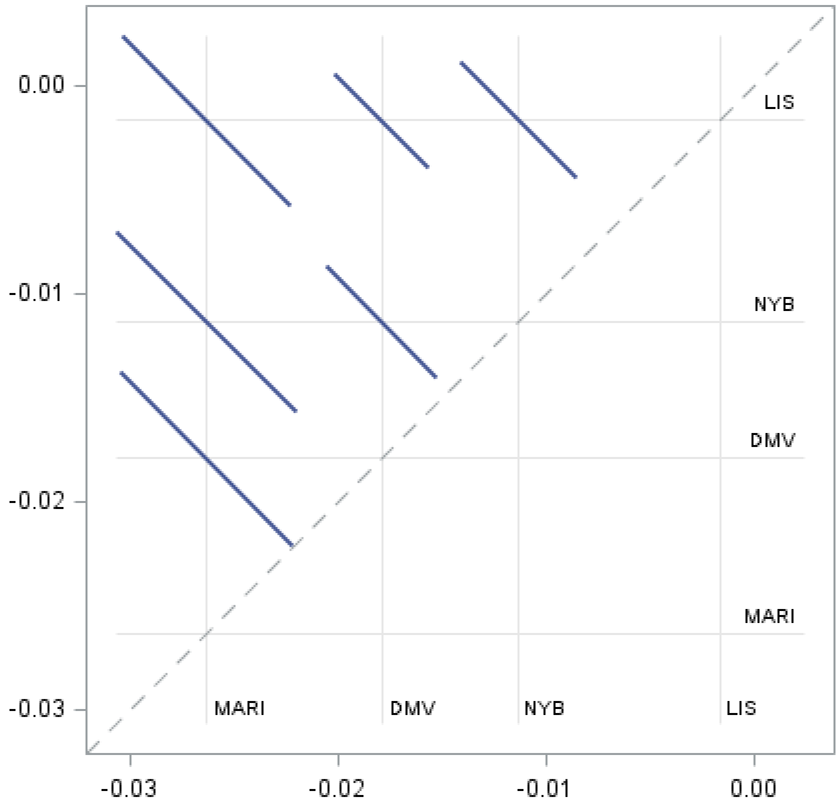


Figure 4.1. Recreational landings of Tautog in LIS and NJ-NYB, 1984-2014.
LIS data from 1984-1987 are from CT only. Source: NOAA Fisheries Commercial Fisheries Statistics Database, MRFSS, and MRIP.

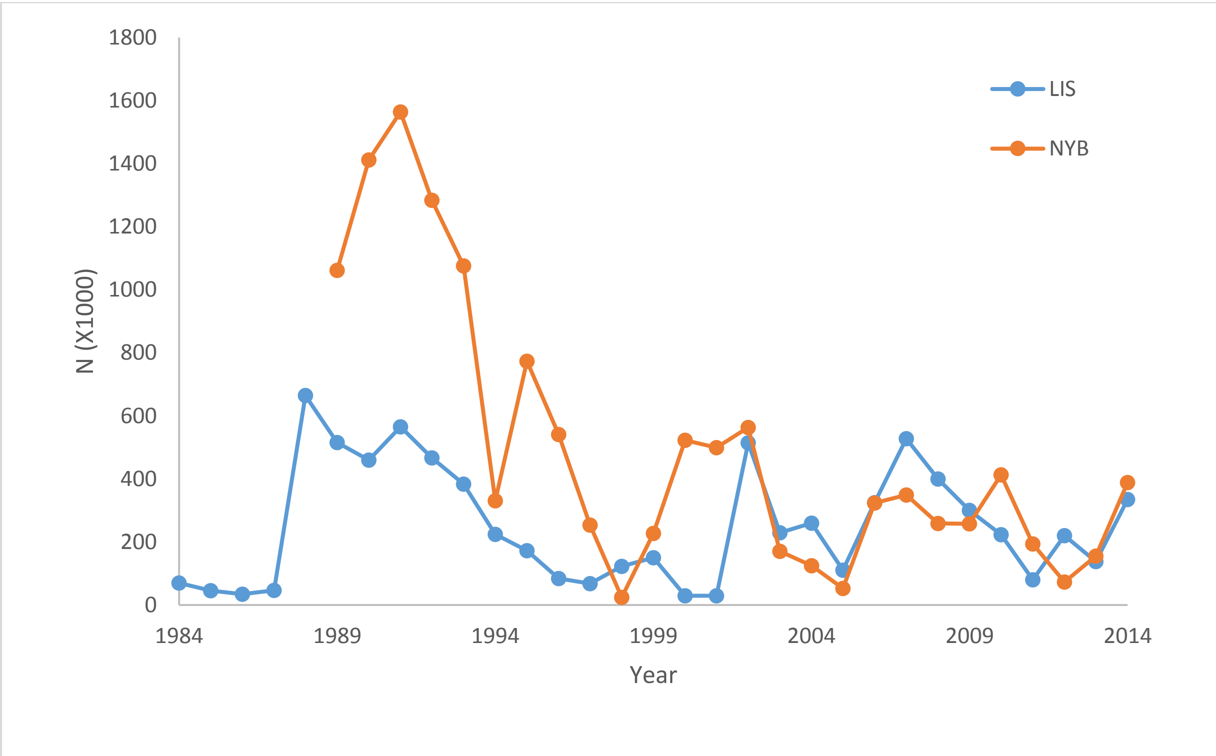


Figure 4.2. Proportion of recreational harvest (CT, NY, NJ combined) from the private/rental sector.

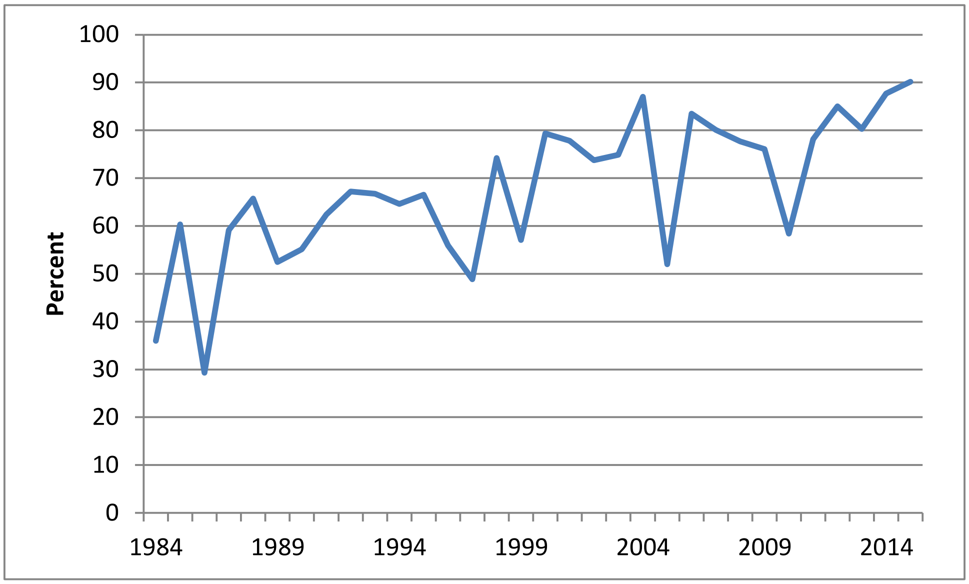


Figure 4.3. Commercial landings in LIS and NJ-NYB from 1990-2014.
LIS values for 1984 and 1985 are from CT only. Source: NOAA Commercial Fisheries Database http://www.st.nmfs.noaa.gov/commercial-fisheries/index.

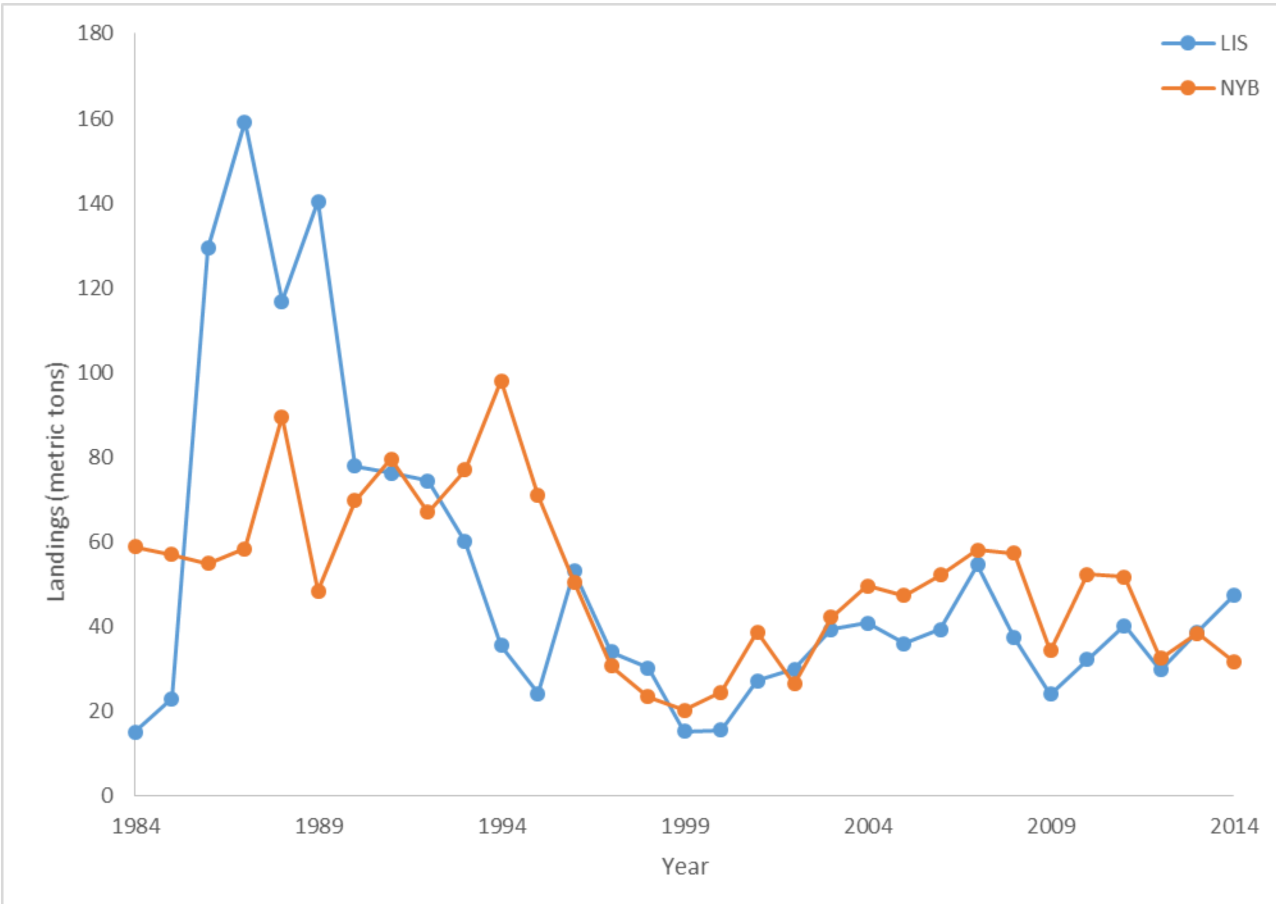


Figure 4.4. Relative activity of the commercial Tautog fishery by month, Based on CT, NY and NJ commercial landings from 1990-2014.

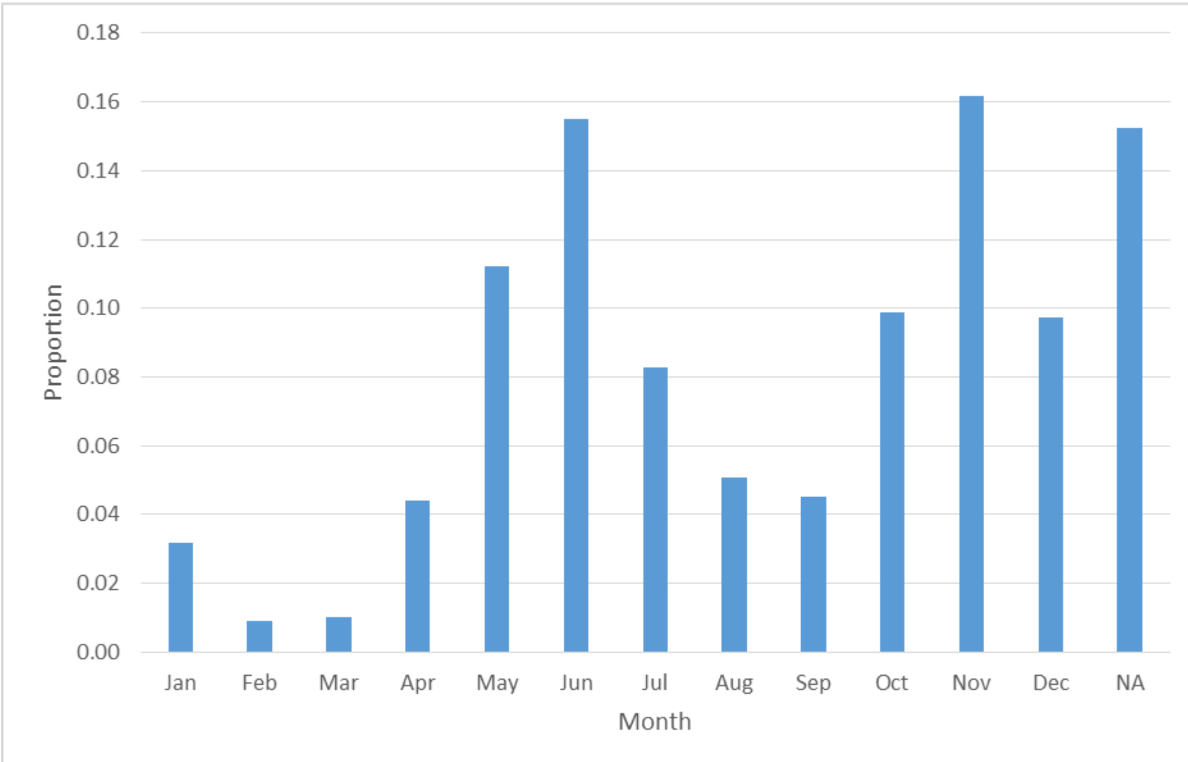


Figure 4.5. Relative commercial Tautog landings by fishing gear
Based on based on CT, NY and NJ commercial landings from 1984-2014.

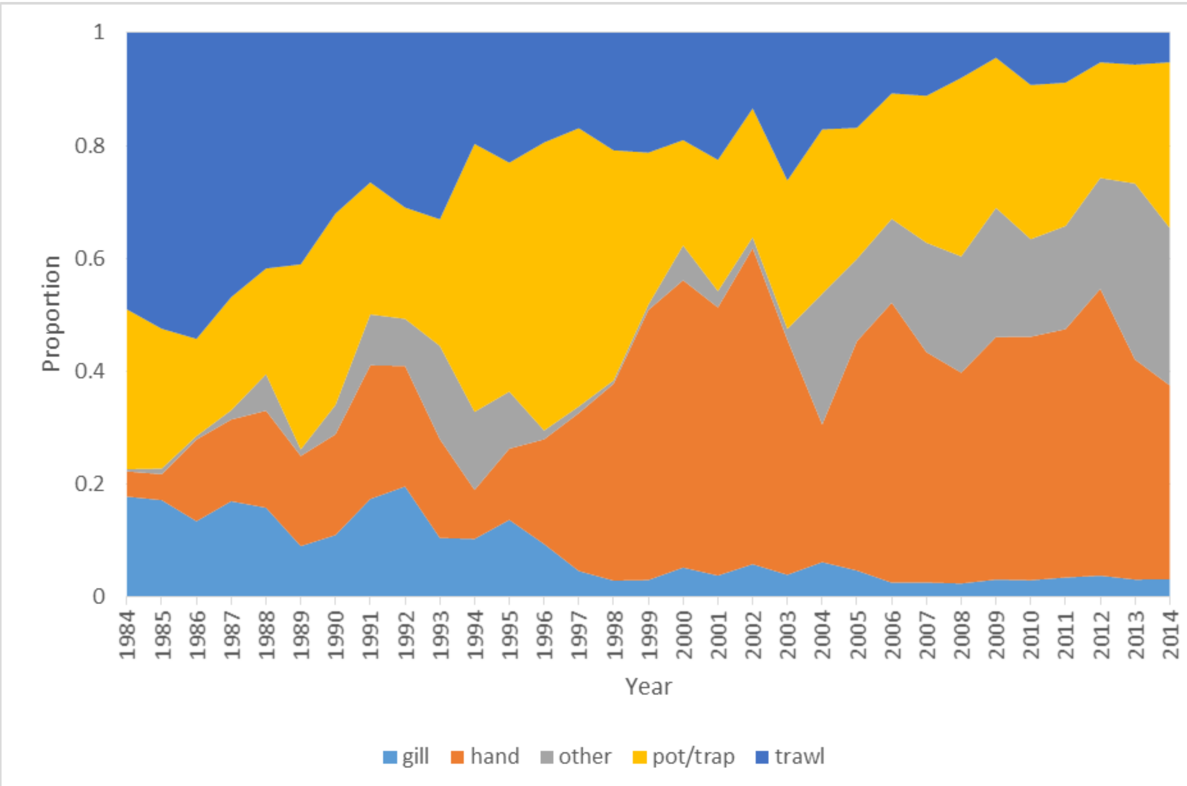


Figure 5.1. QQ plot for the negative binomial distribution of the final LIS recreational CPUE index model

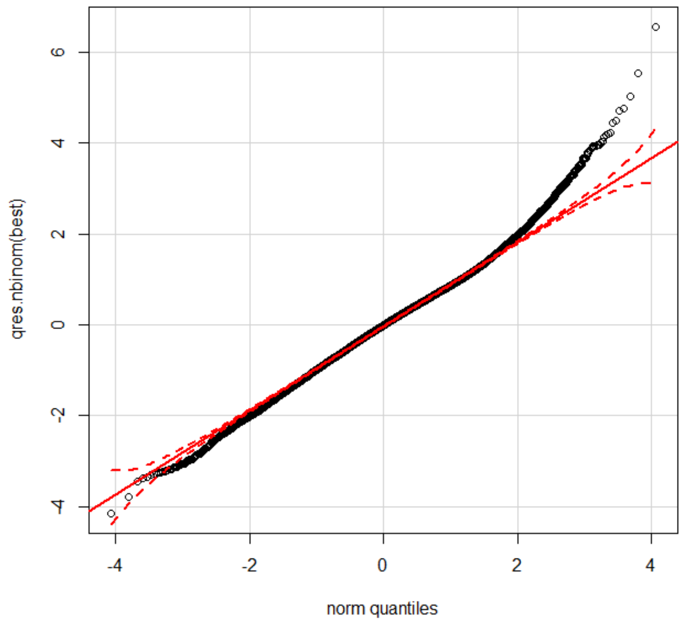


Figure 5.2. Cook's distance for the final LIS recreational CPUE index model

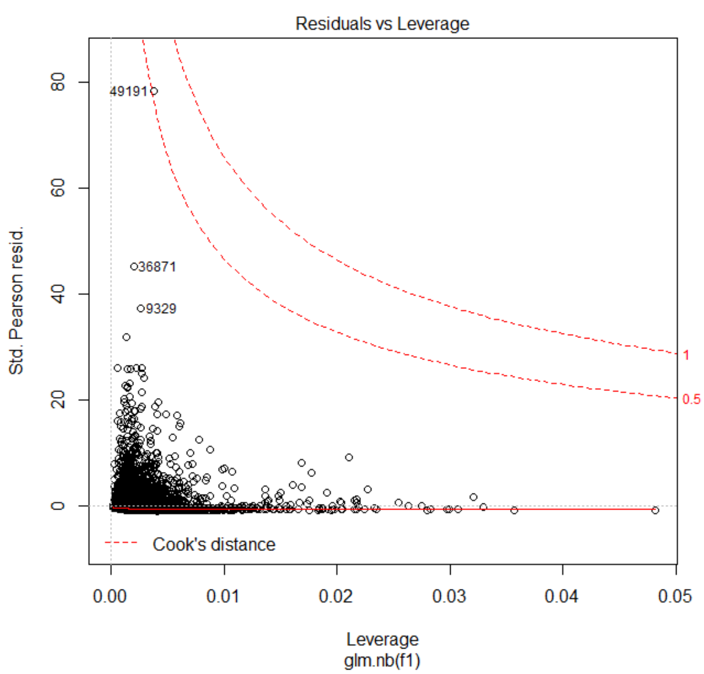


Figure 5.3. Final negative binomial distribution estimates of the LIS recreational CPUE index model

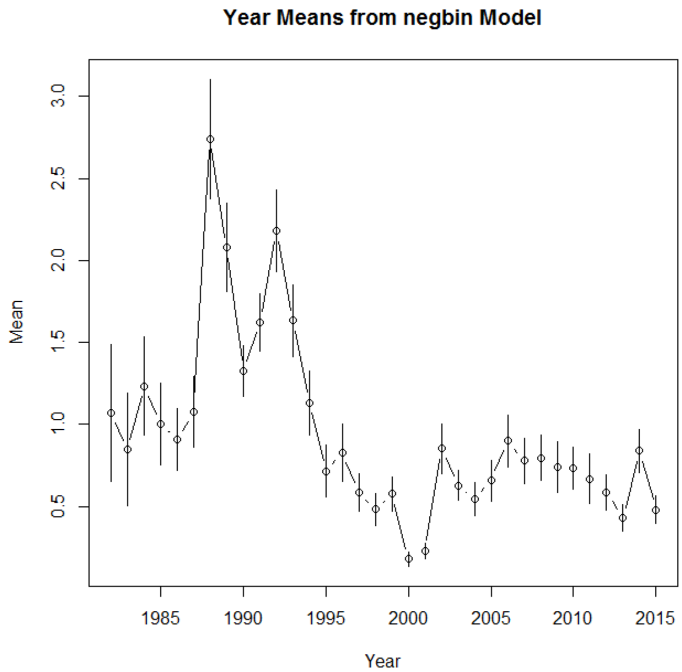


Figure 5.4. QQ plot for the negative binomial distribution of the final NJ-NYB recreational CPUE index model

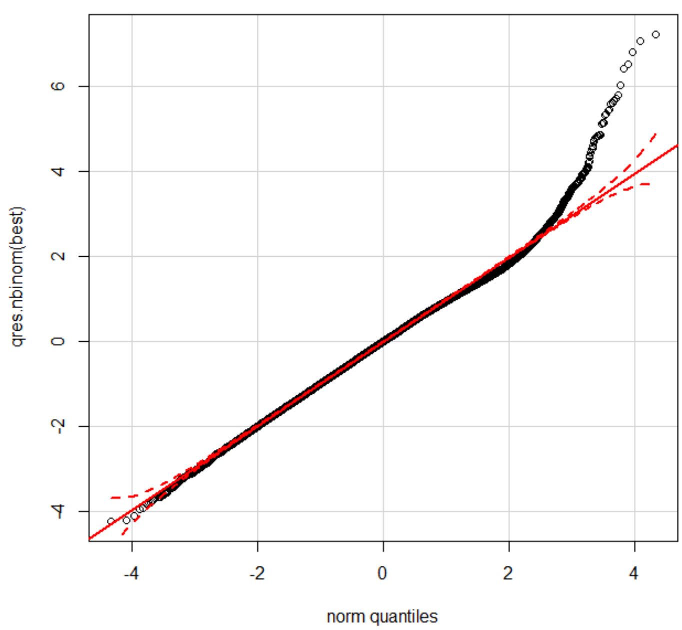


Figure 5.5. Cook's distance for the final NJ-NYB recreational CPUE index model

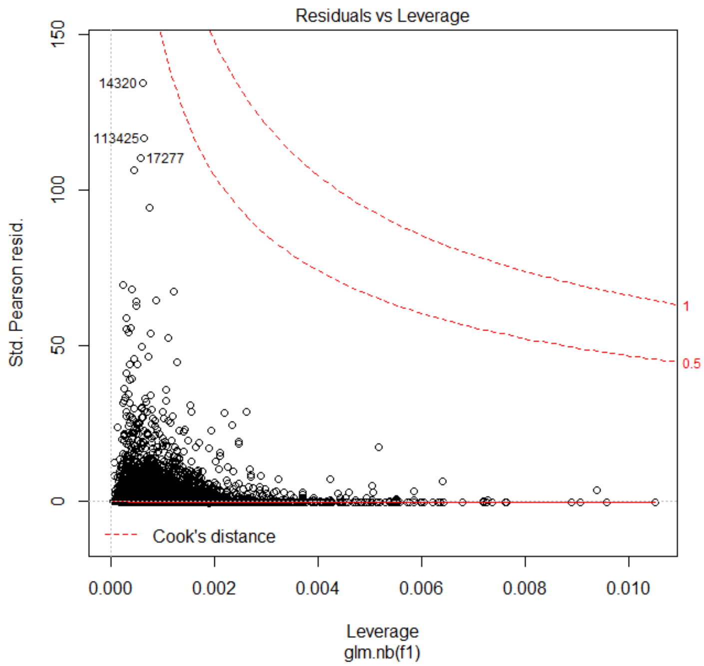


Figure 5.6. Final negative binomial distribution estimates of the NJ-NYB recreational CPUE index model

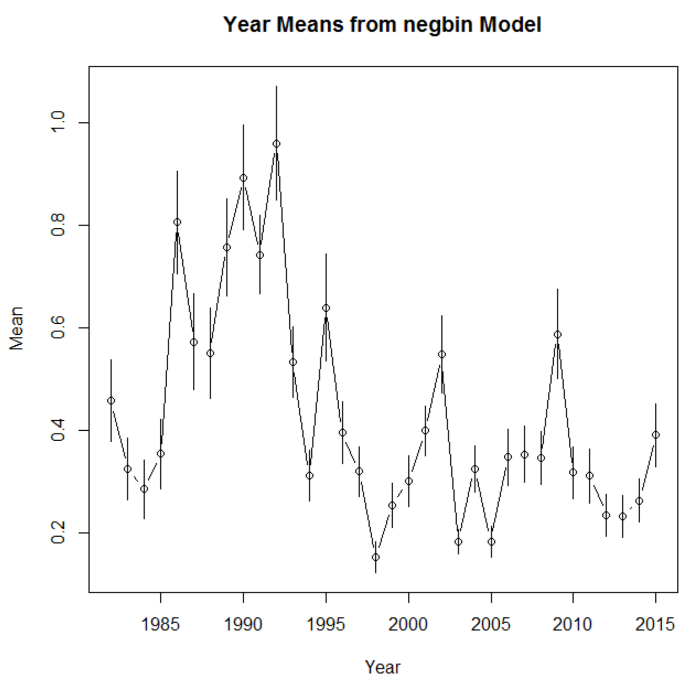


Figure 5.7. Histogram of catch data for the CT LISTS dataset.

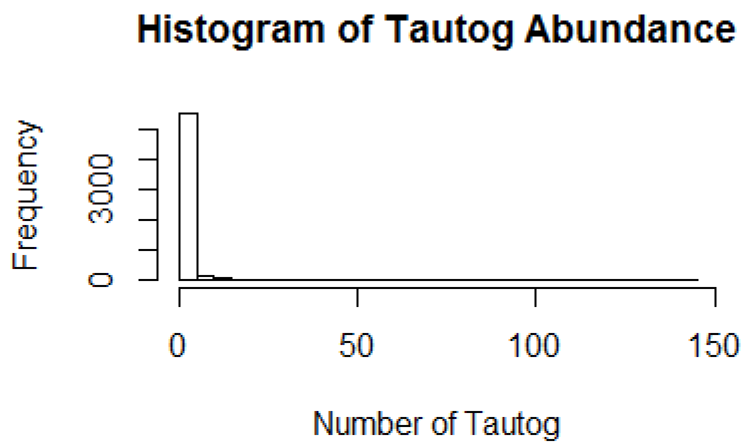


Figure 5.8. QQ Plot for negative binomial distribution for the final model used for the CT LISTS.

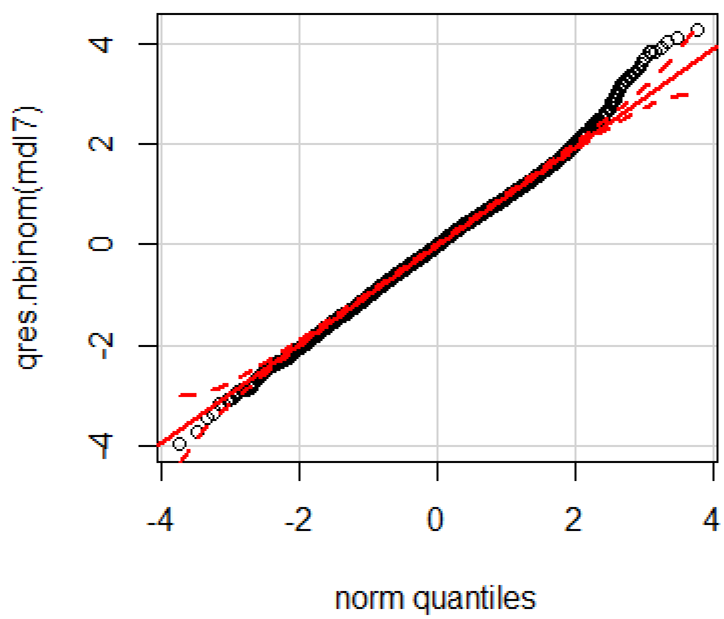


Figure 5.9. Cook's distance plot for the final model used for the CT LISTS.

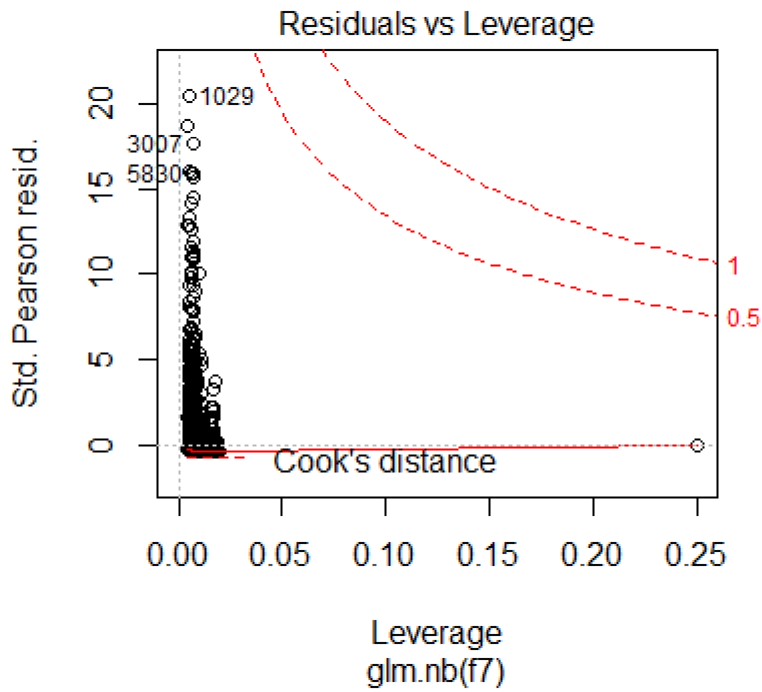


Figure 5.10. Standardized index versus the nominal index for the CT LISTS.

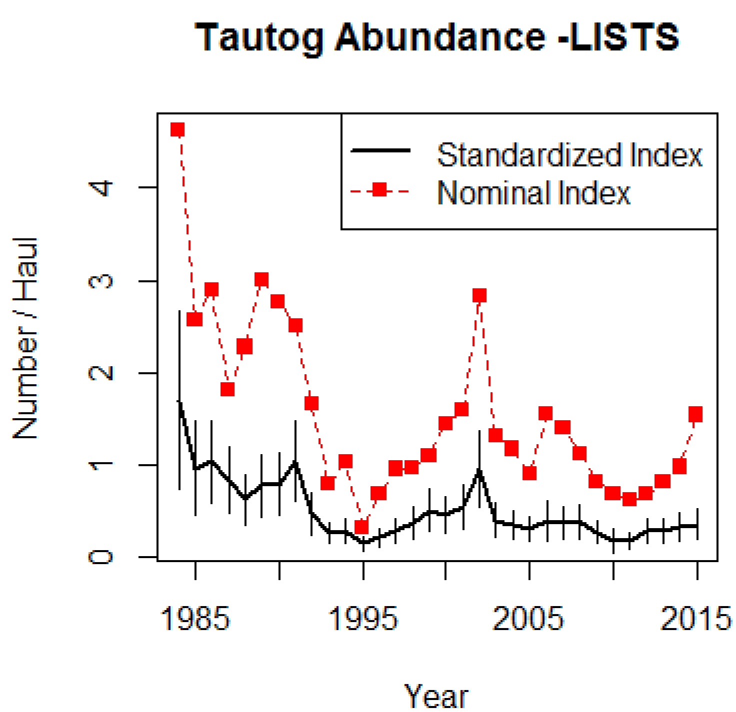


Figure 5.11. Annual abundance of Tautog eggs and larvae in the Millstone entrainment samples.
Error bars represent confidence interval. For clarity, the interval for eggs is displayed in the positive direction while the interval for larvae is displayed in the negative direction.

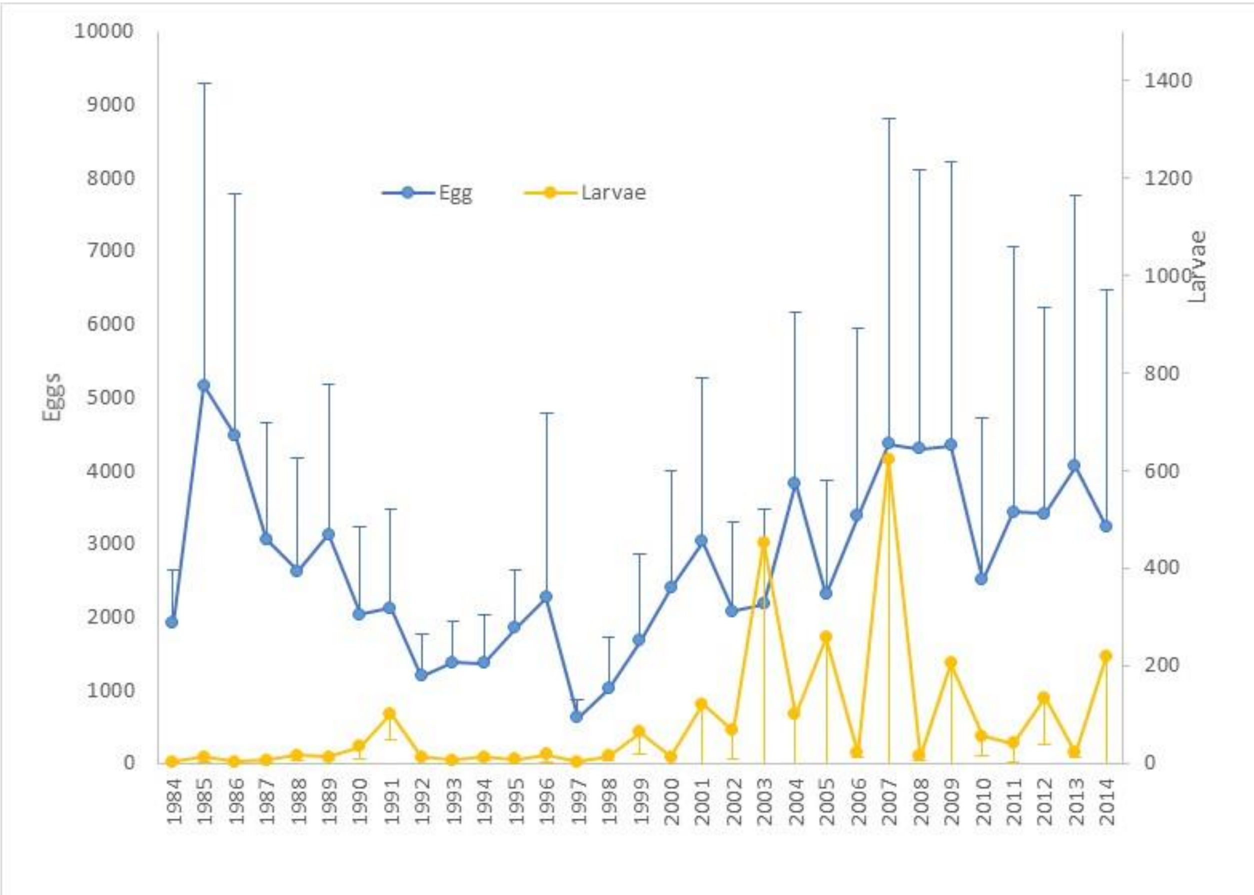


Figure 5.12. Histogram of catch data for the Peconic Bay Trawl Survey dataset.

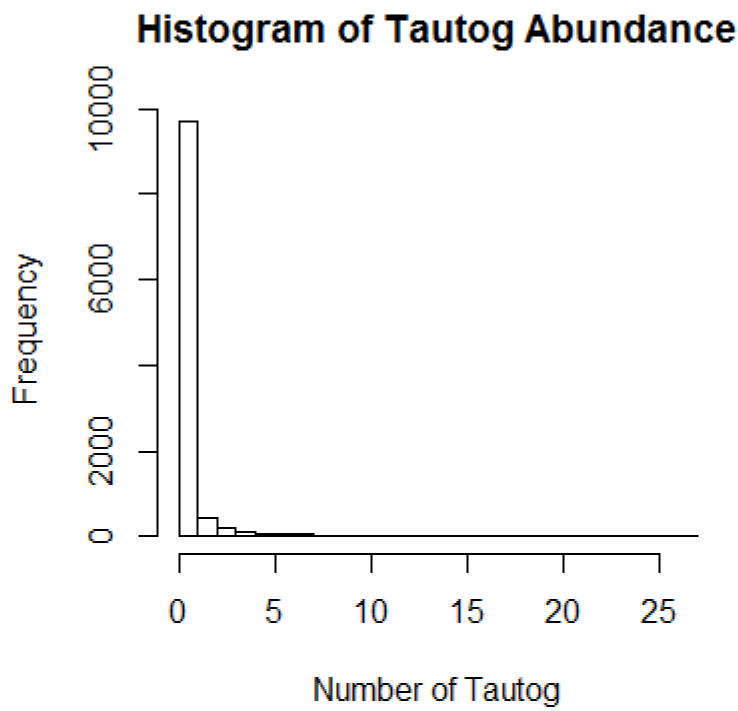


Figure 5.13. QQ Plot for negative binomial distribution for the final model used for the NYPBTS.

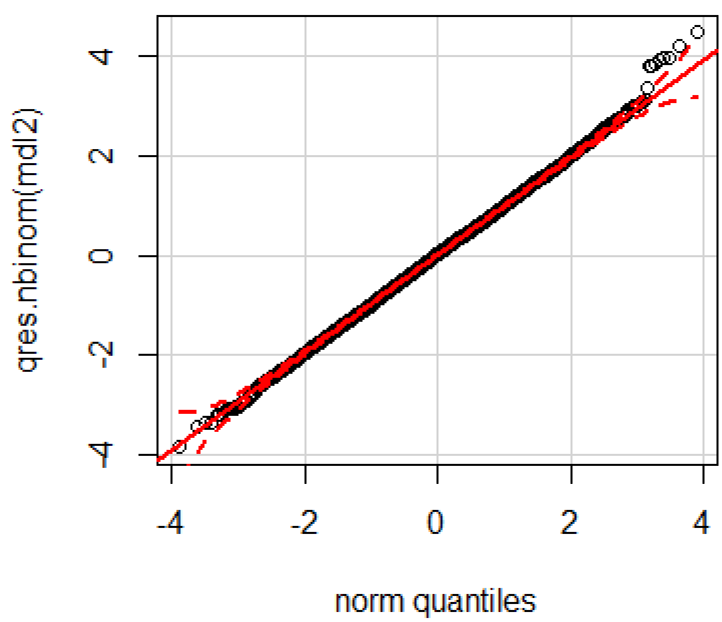


Figure 5.14. Cook's distance plot for the final model used for the NYPBTS.

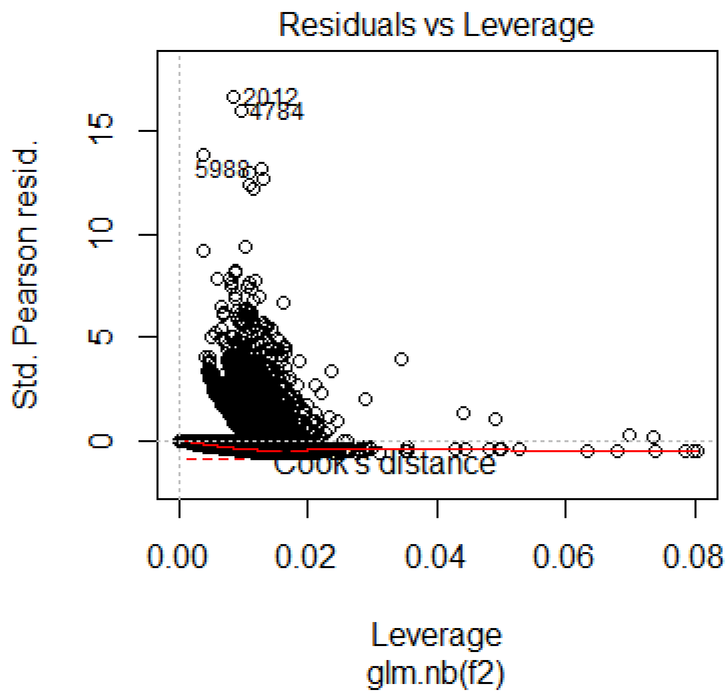


Figure 5.15. Standardized index versus the nominal index for the NYPBTS.

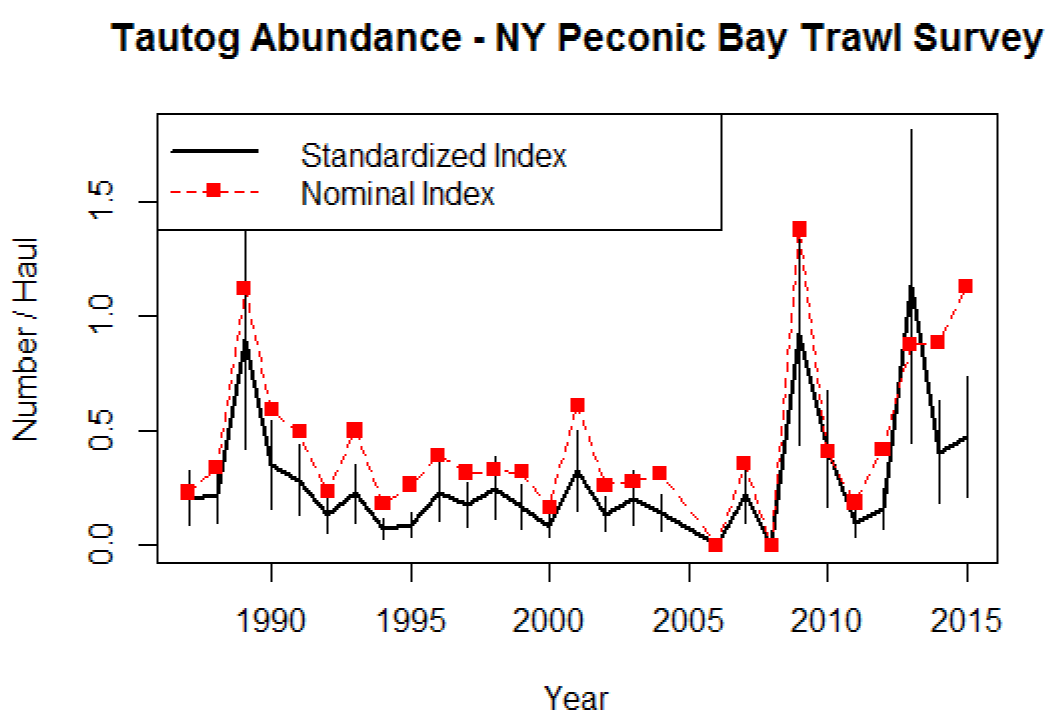


Figure 5.16. Histogram of catch data for the LIS portion of the NYWLISS dataset.

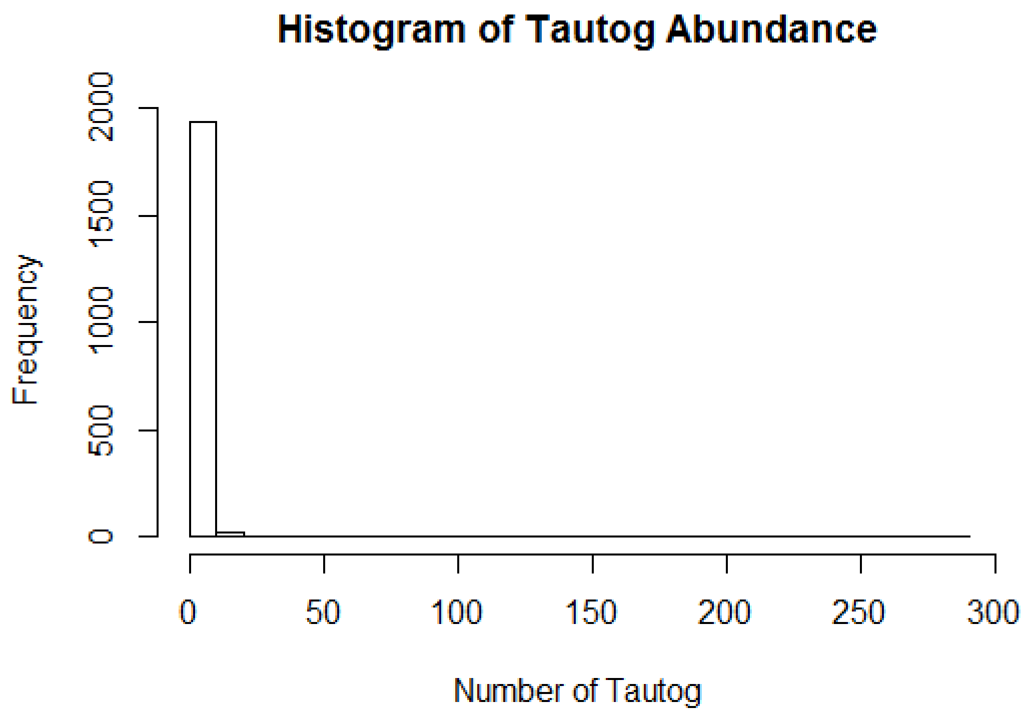


Figure 5.17. QQ Plot for negative binomial distribution for the final model used for the LIS portion of the NYWLISS.

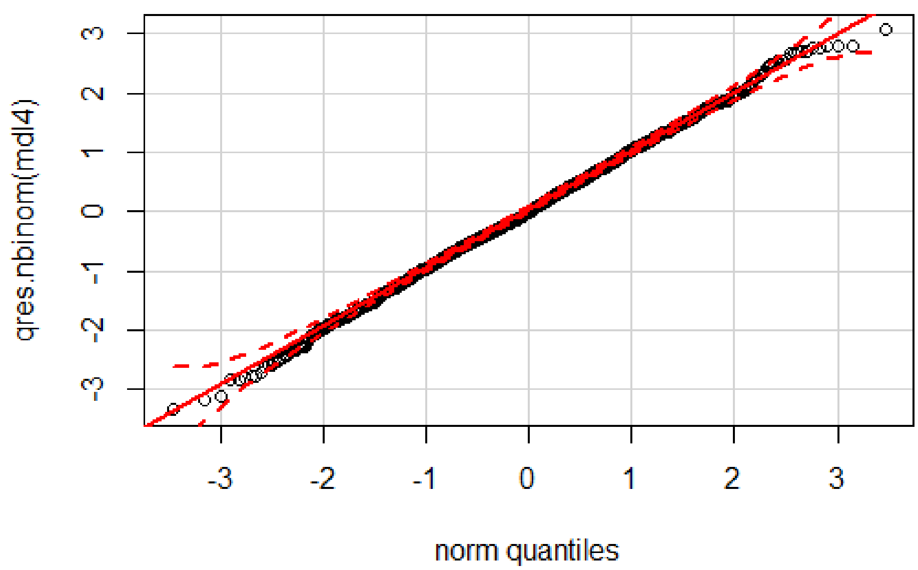


Figure 5.18. Cook's distance plot for the final model used for the LIS portion of the NYWLISS.

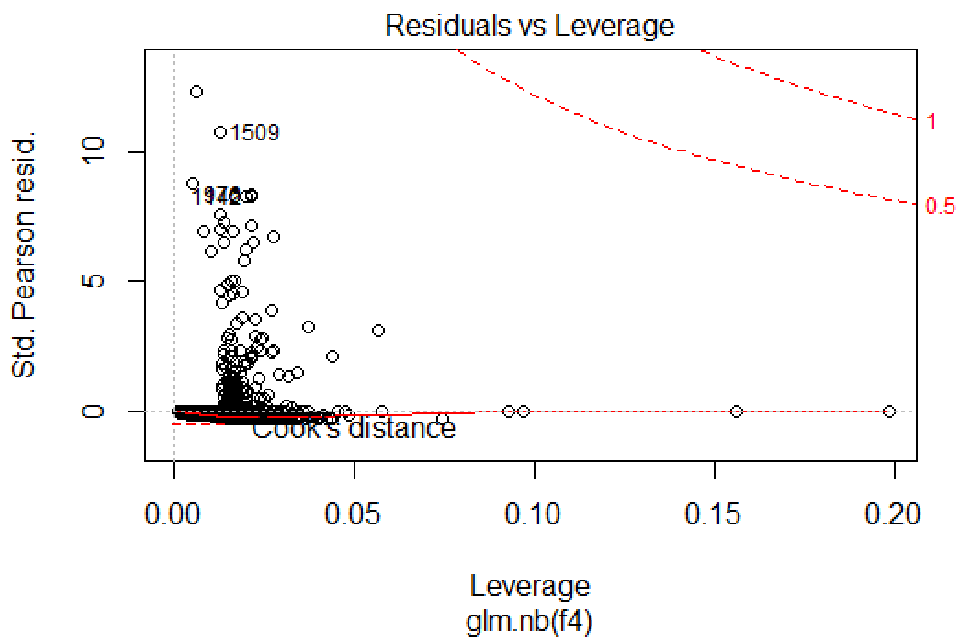


Figure 5.19. Standardized index versus the nominal index for the LIS portion of the NYWLISS.

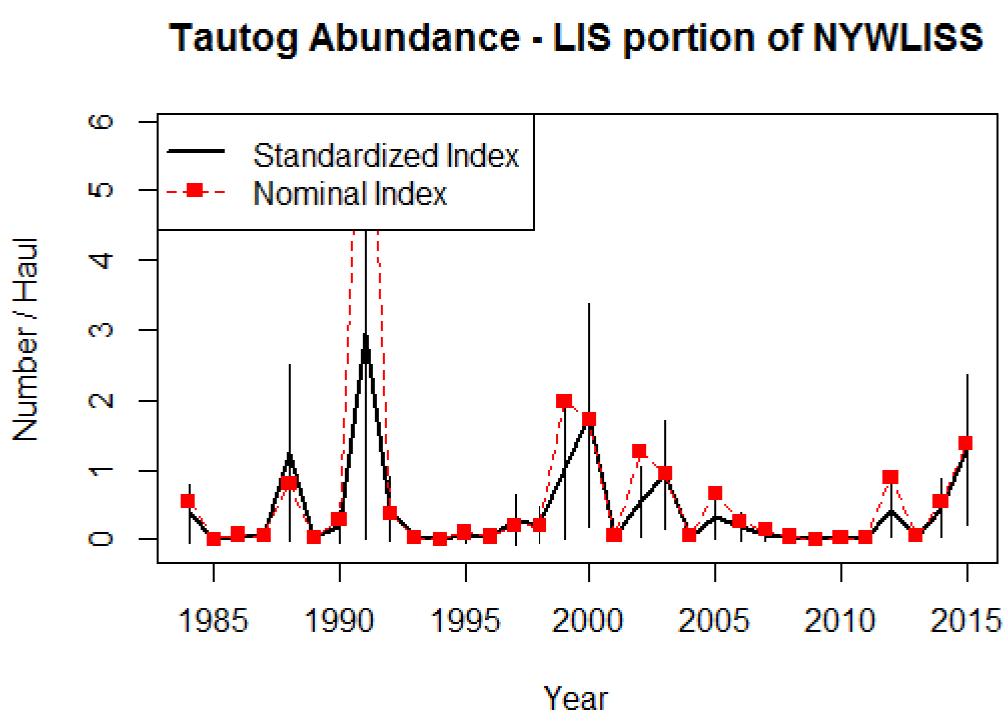


Figure 5.20. Histogram of catch data for the NJ-NYB portion of the NYWLISS dataset.

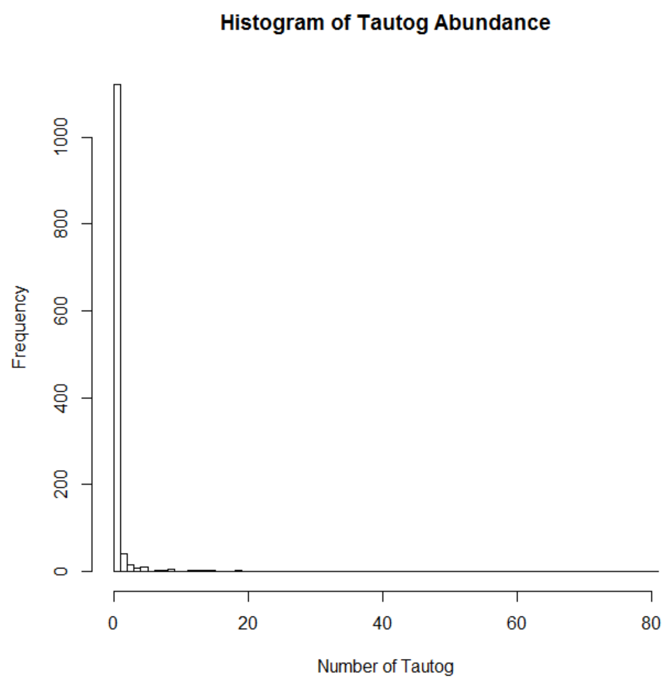


Figure 5.21. QQ plot of the negative binomial distribution for the final model of the NJ-NYB portion of the WLISS.

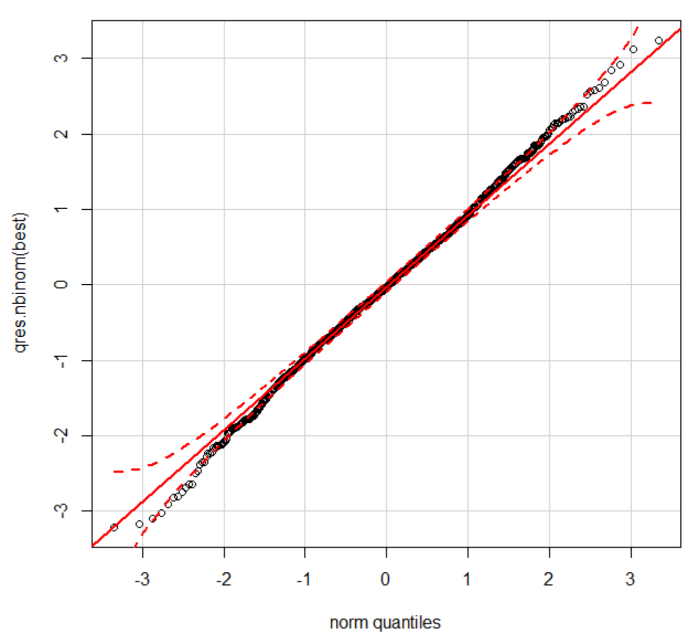


Figure. 5.22. Cook's distance for the final model of the NJ-NYB portion of the WLISS

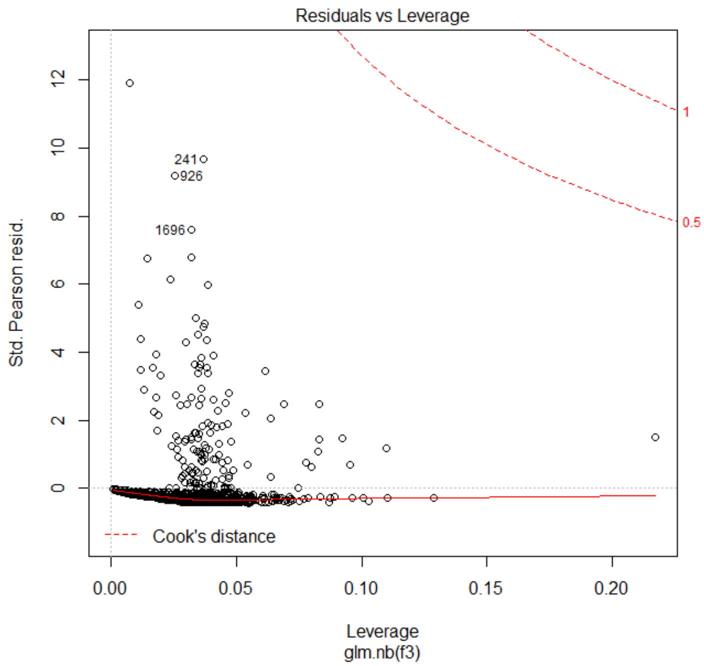


Figure 5.23. Final model estimates for the negative binomial GLM of the NJ-NYB portion of the WLISS.

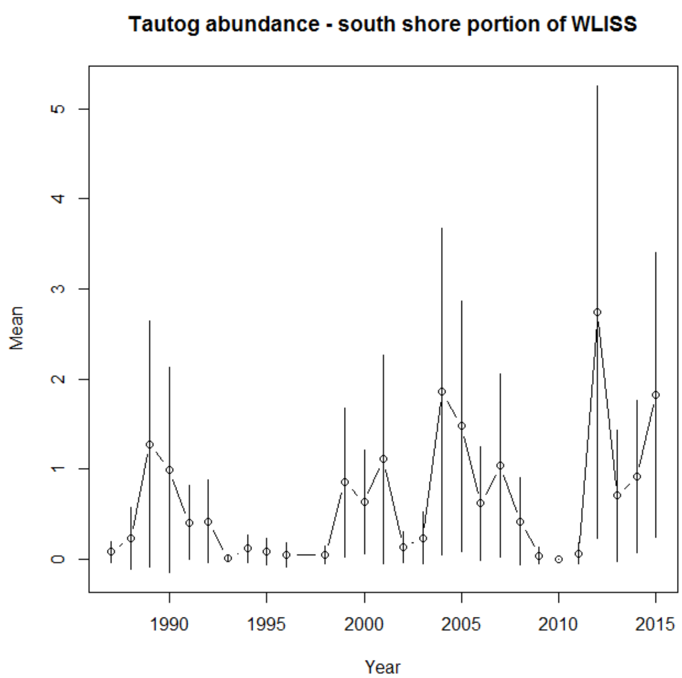


Figure 5.24. Catch histogram for the New Jersey Ocean Trawl survey

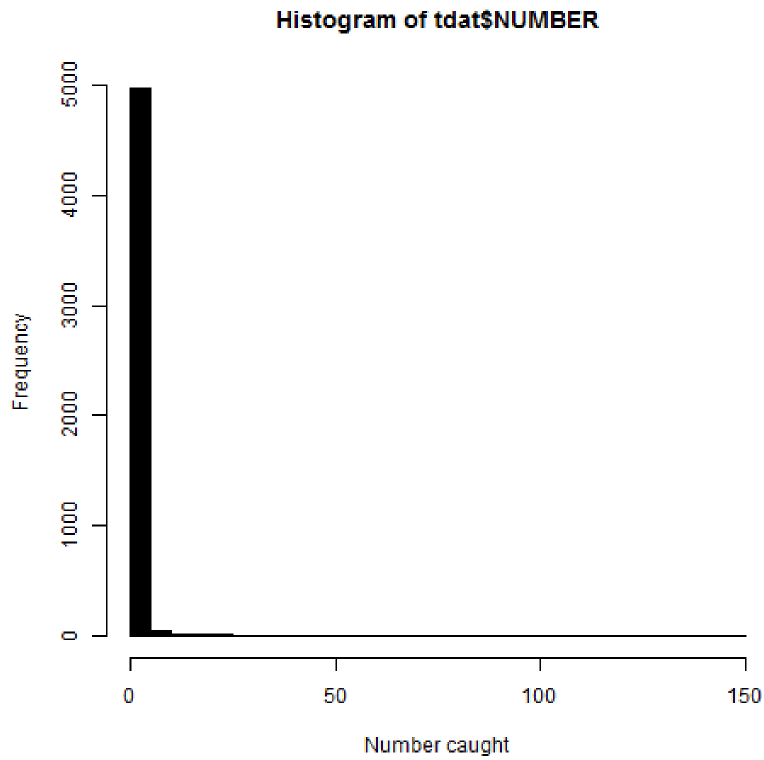


Figure 5.25. QQ plot of the negative binomial distribution for the NJ Ocean Trawl survey

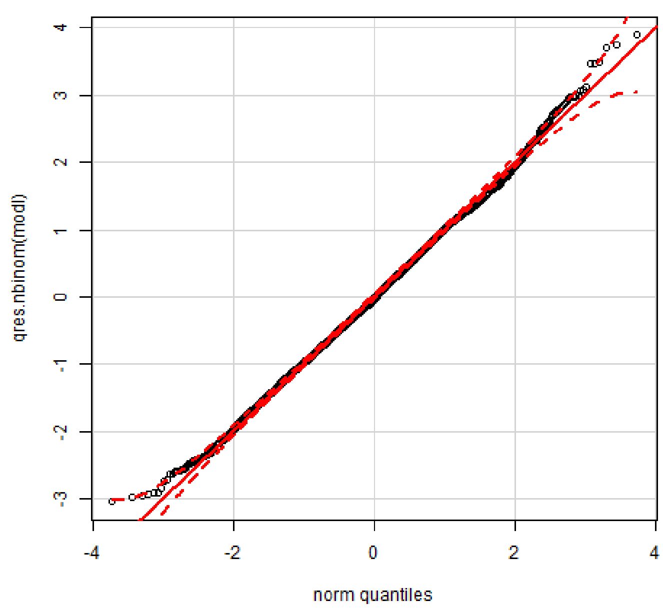


Figure 5.26. Cook's distance for the final model of the NJ Ocean Trawl survey

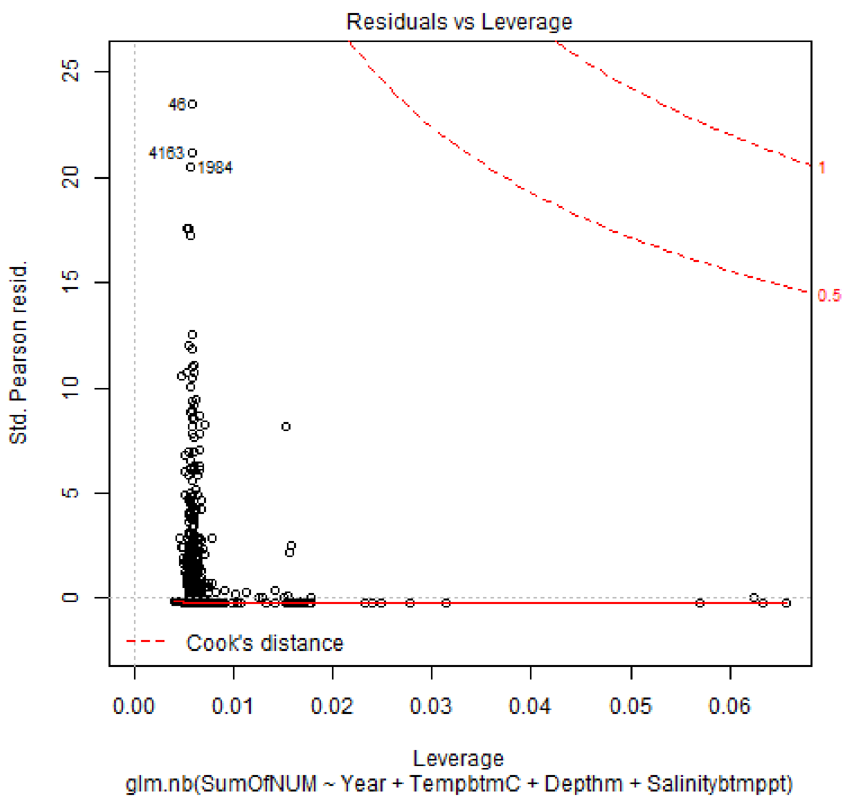


Figure 5.27. Final negative binomial model of the NJ ocean trawl survey

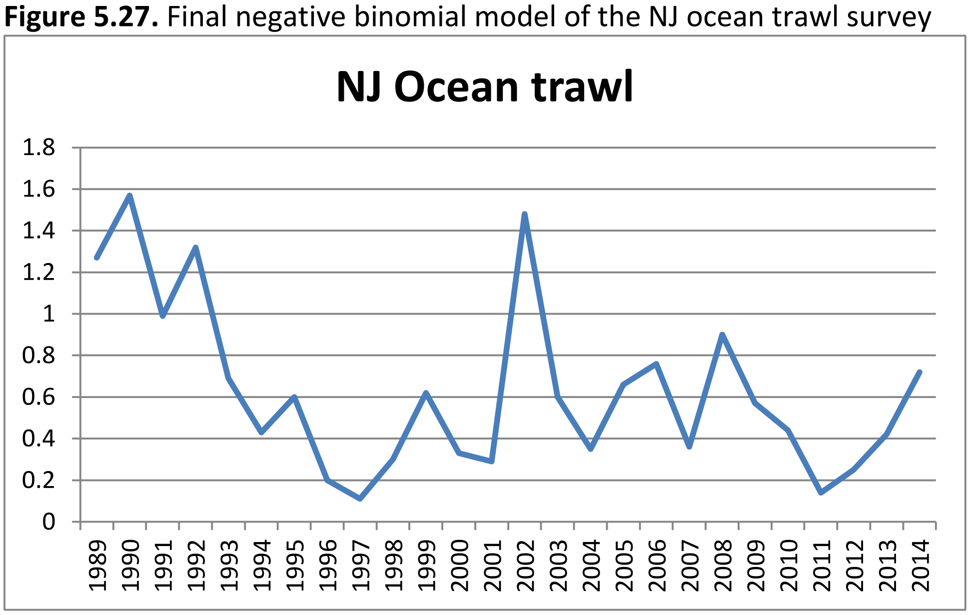


Figure 6.1. Observed and predicted total catch in weight (top) and standardized residuals (bottom) for Long Island Sound.

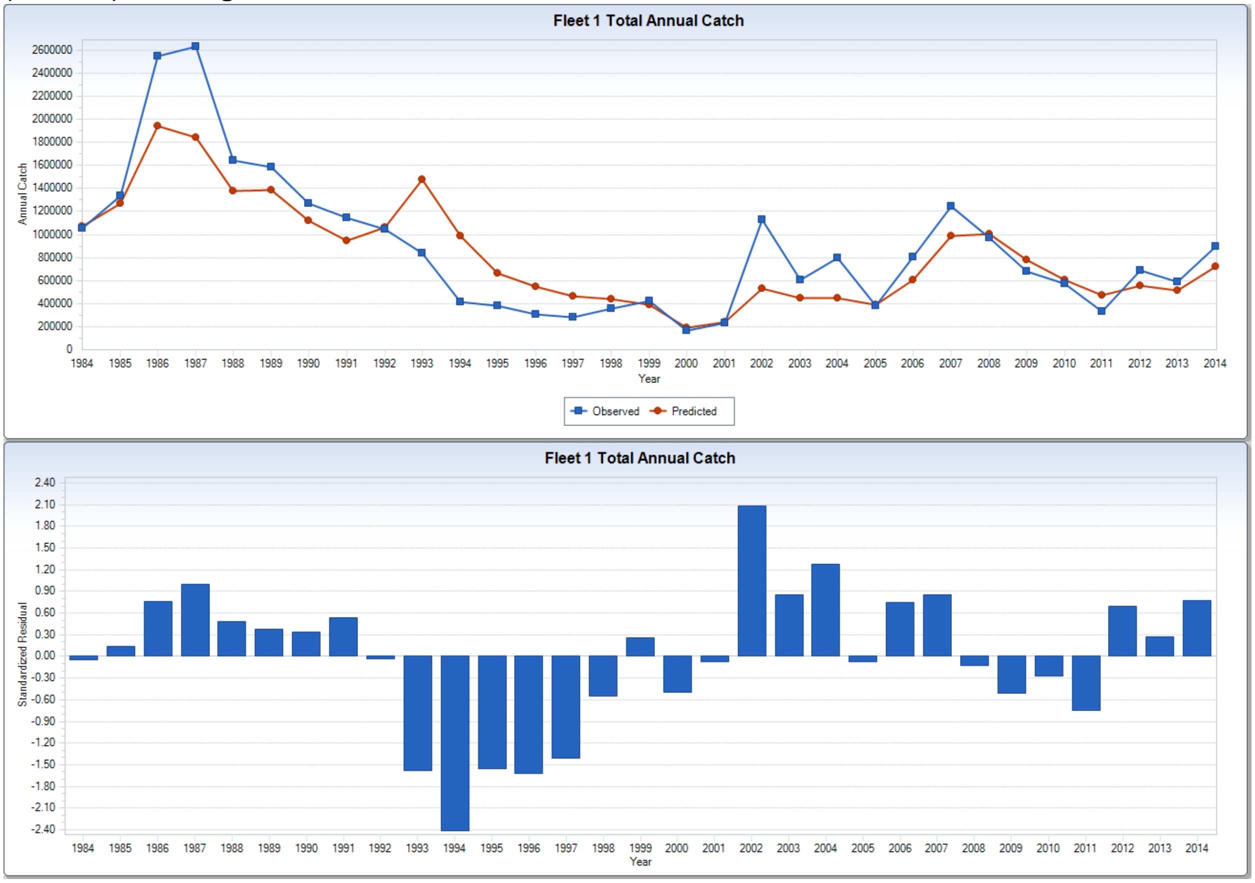
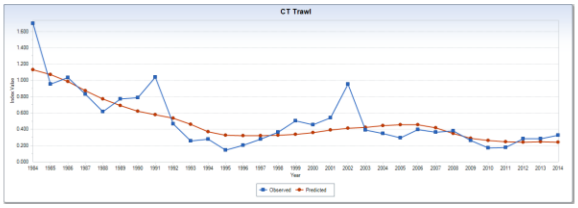
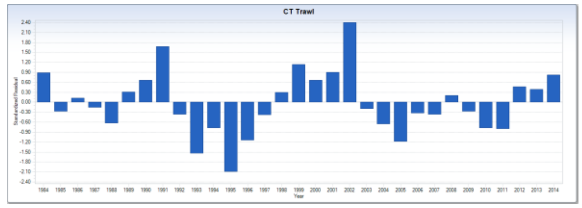


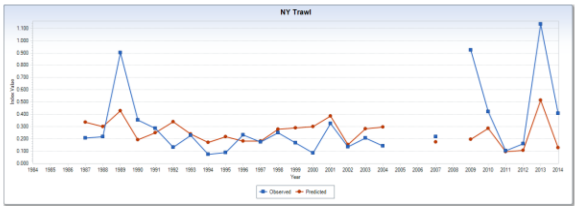
Figure 6.2. Observed and predicted fishery independent indices (left) and their standardized residuals (right) for Long Island Sound.

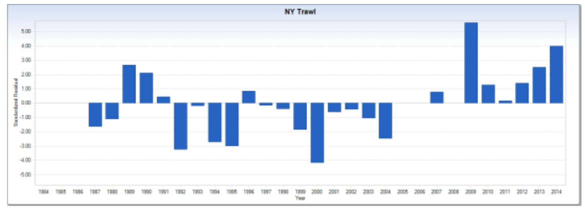
LISTS



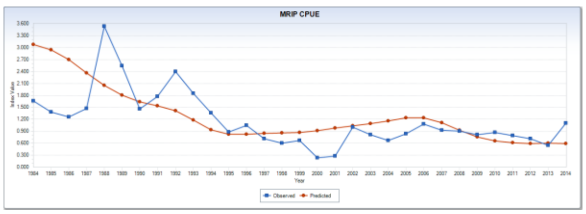


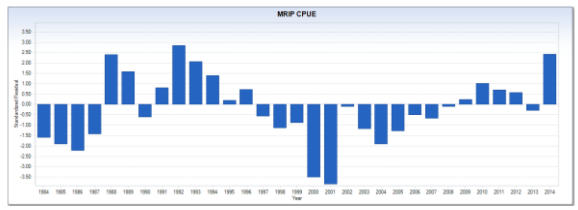
NYTrawl



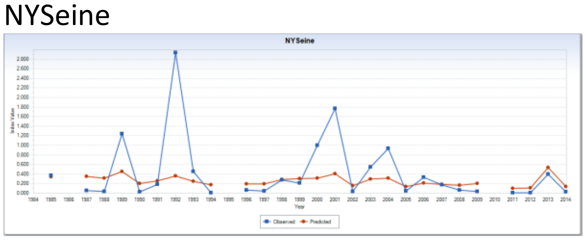


MRIP CPUE





NYSeine



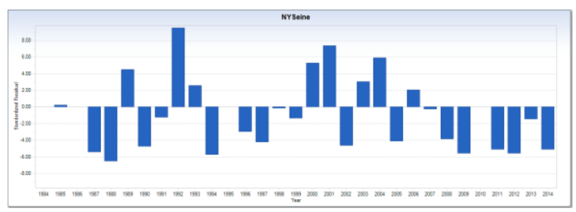


Figure 6.3. Total observed and predicted catch-at-age for Long Island Sound.

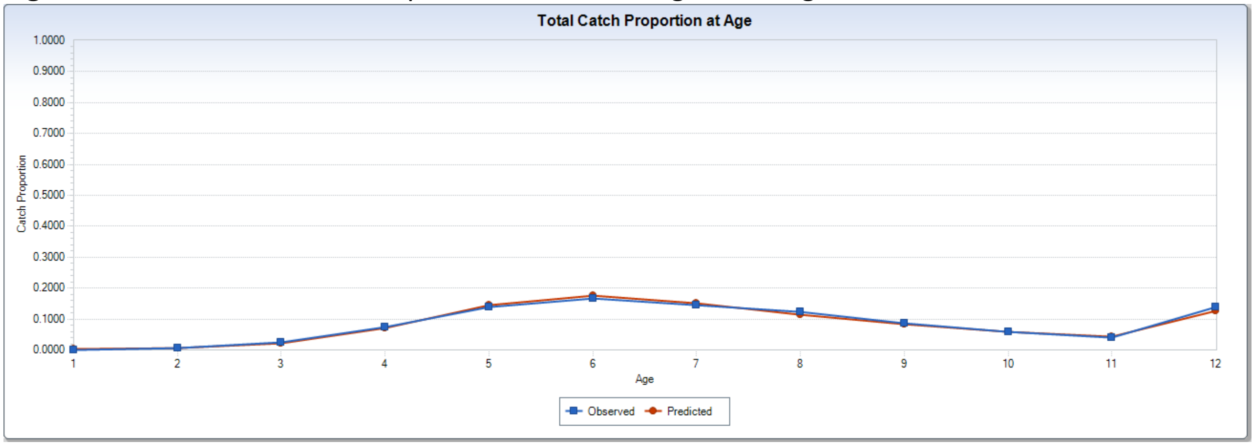


Figure 6.4. Total observed and predicted total index-at-age for Long Island Sound, LISTS (top) and MRIP (bottom).

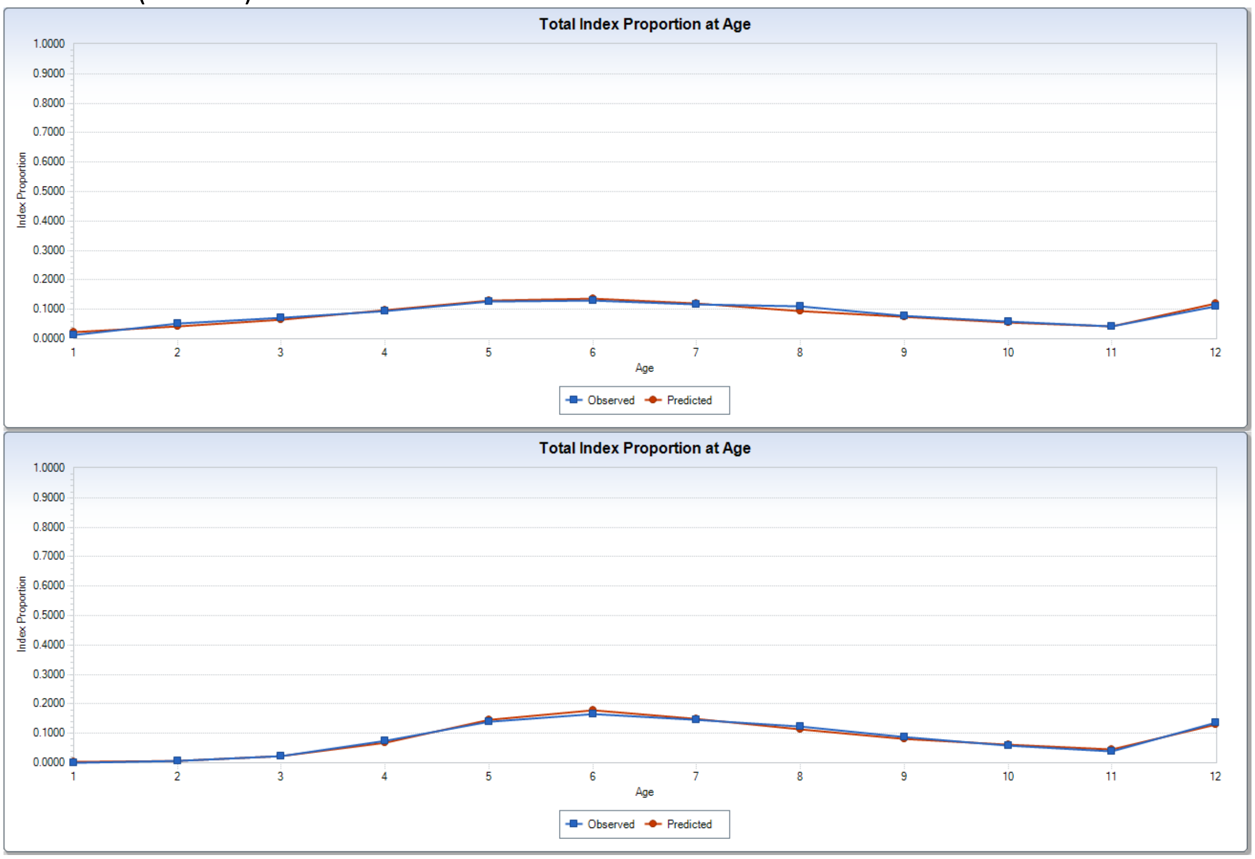


Figure 6.5. Estimated fishery selectivity patterns for the LIS regional model.

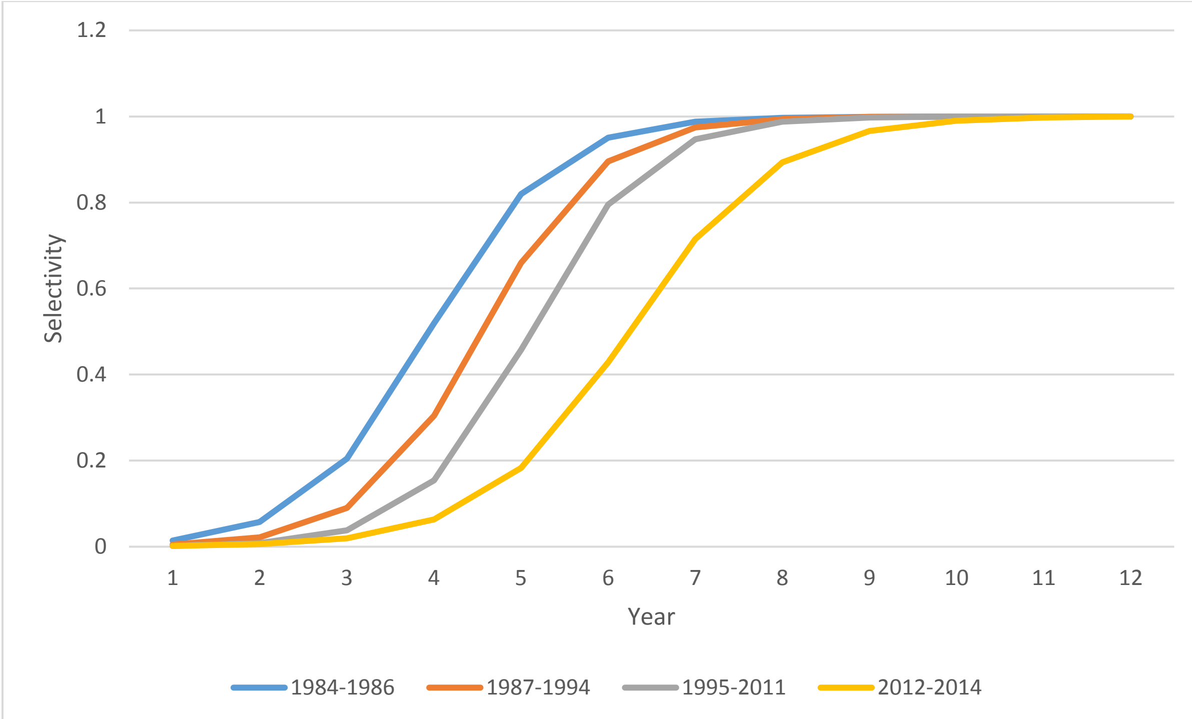


Figure 6.6. Observed and predicted stock-recruitment relationship for Long Island Sound

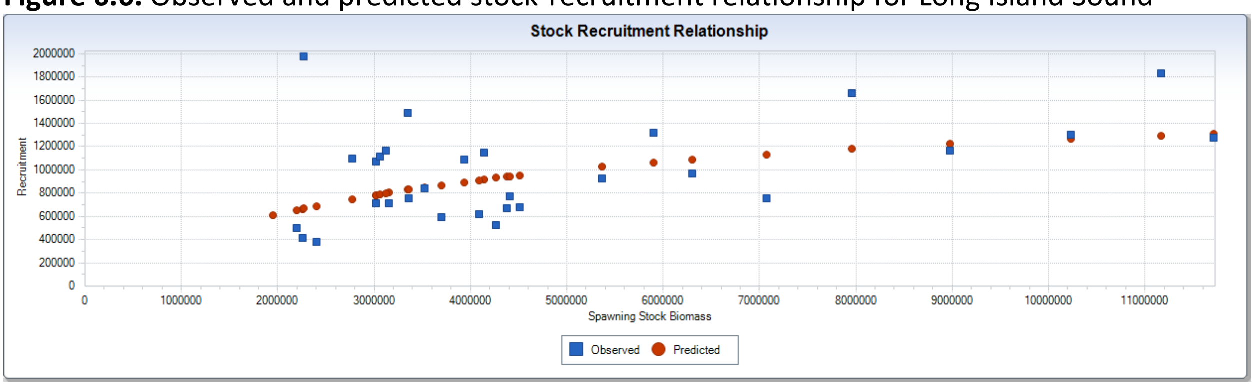


Figure 6.7. Annual and three-year average estimates of F for Long Island Sound.

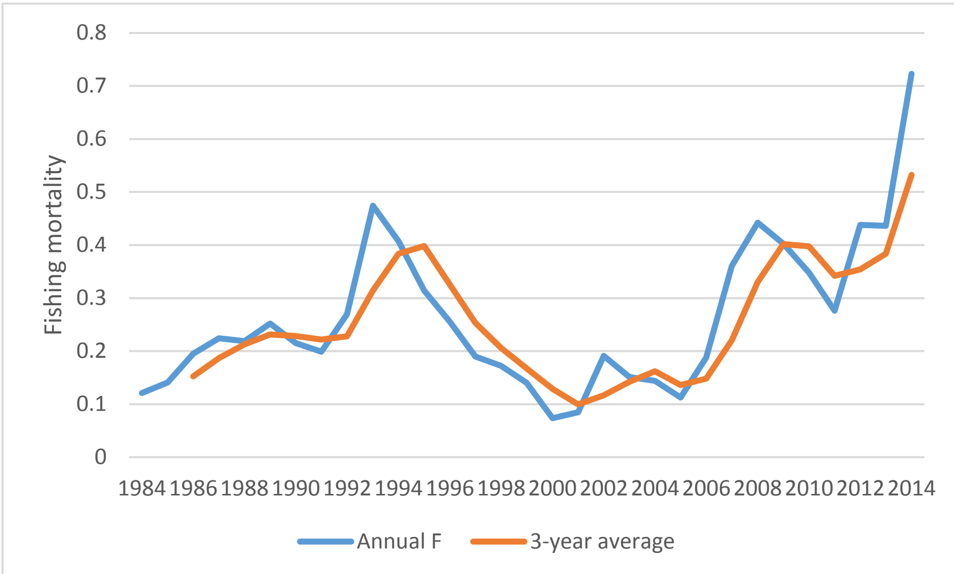


Figure 6.8. Median and 5th and 95th percentile MCMC estimates of F for Long Island Sound.

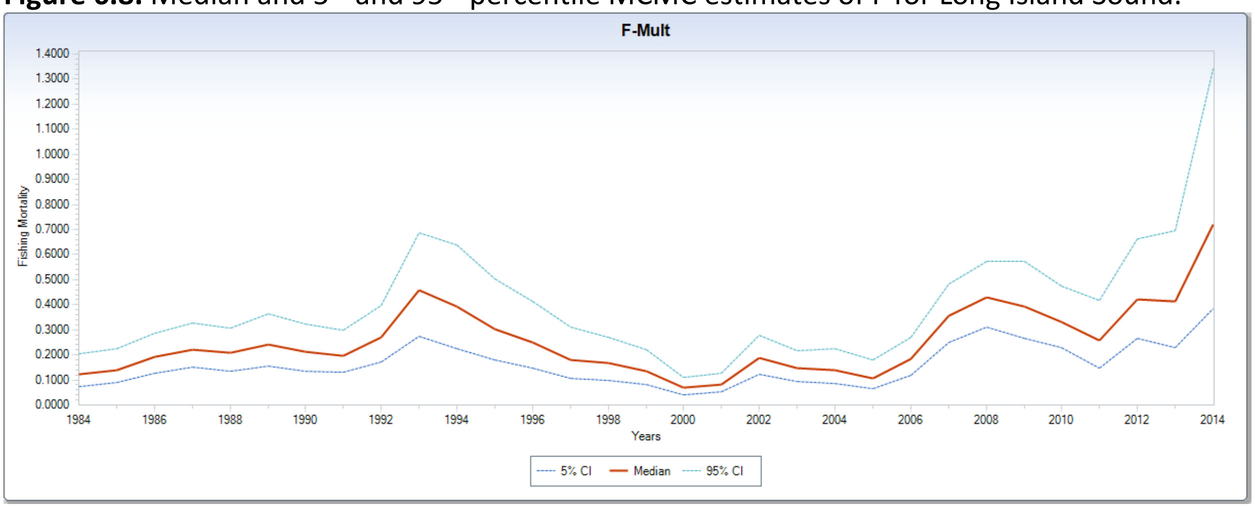


Figure 6.9. MCMC distributions on terminal F for Long Island Sound.

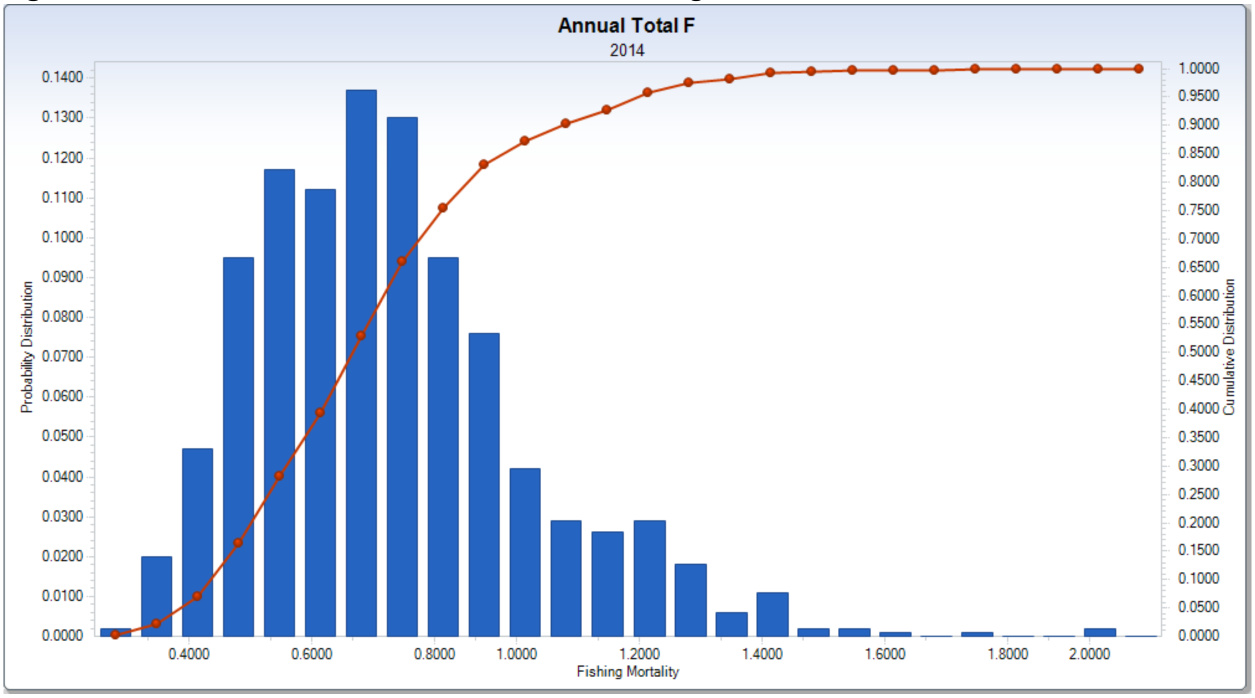
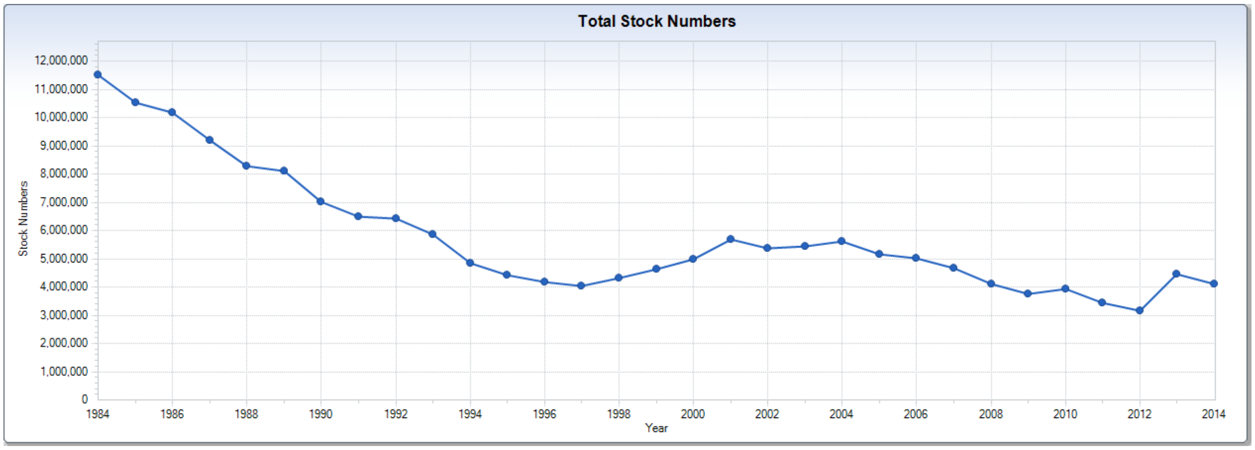
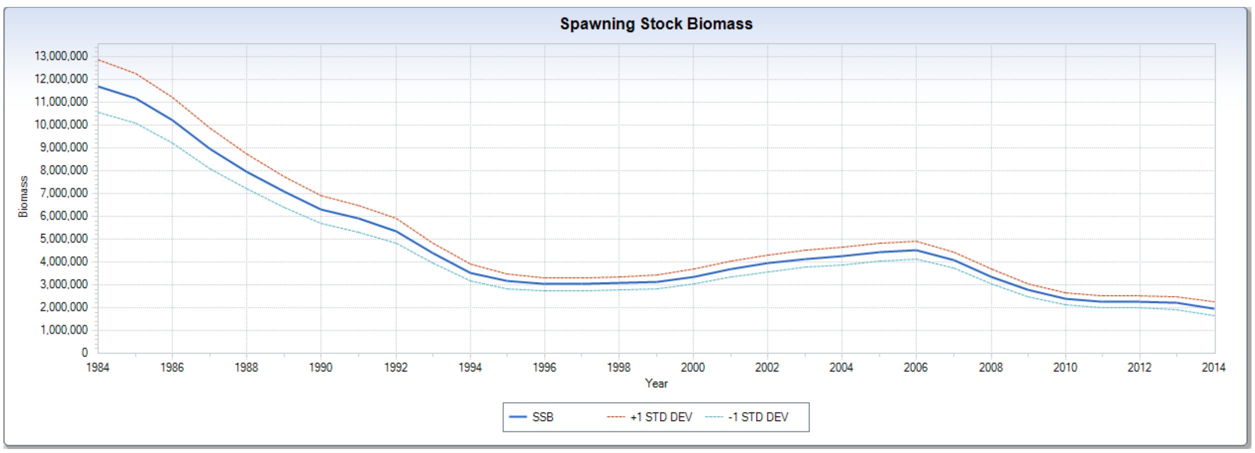


Figure 6.10. (a) Total stock numbers, (b) spawning stock biomass and (c) observed recruitment (bottom) for Long Island Sound.

a.



b.



c.

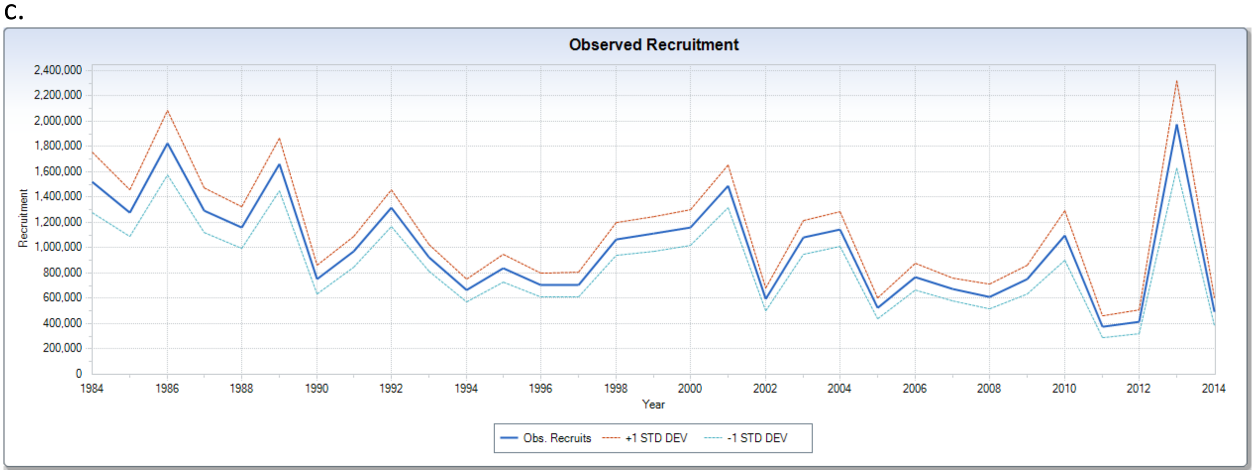


Figure 6.11. Distribution of MCMC estimates of SSB in the terminal year for Long Island Sound.

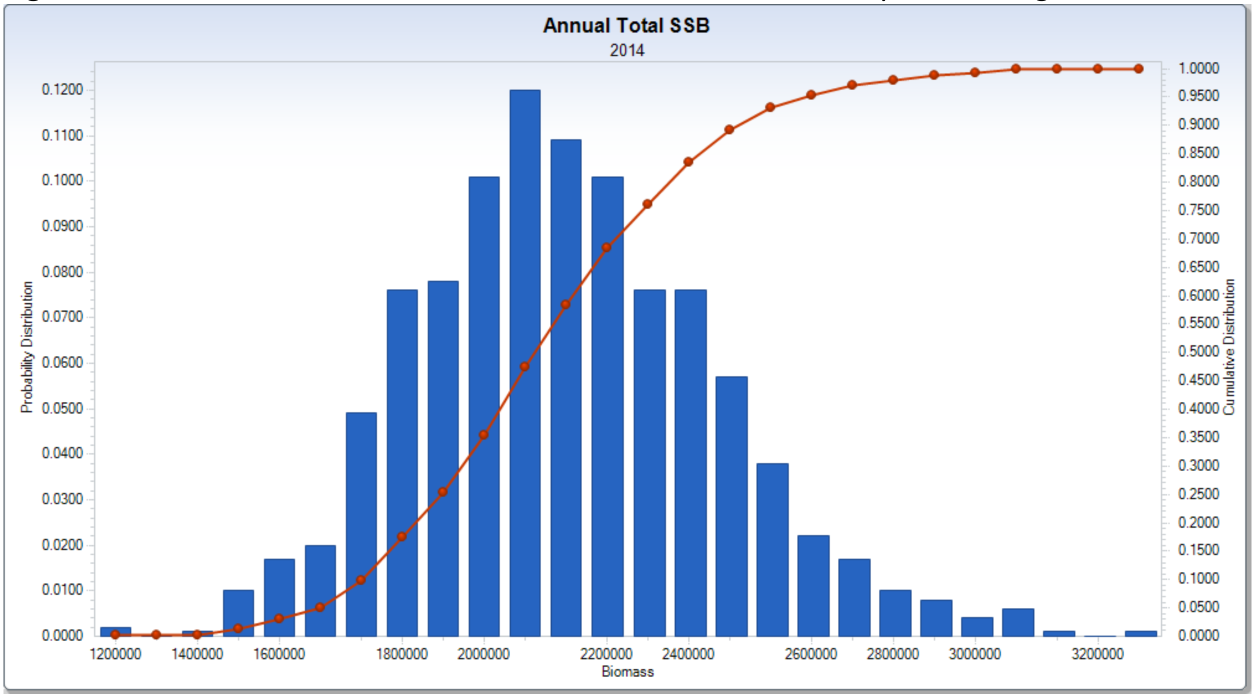
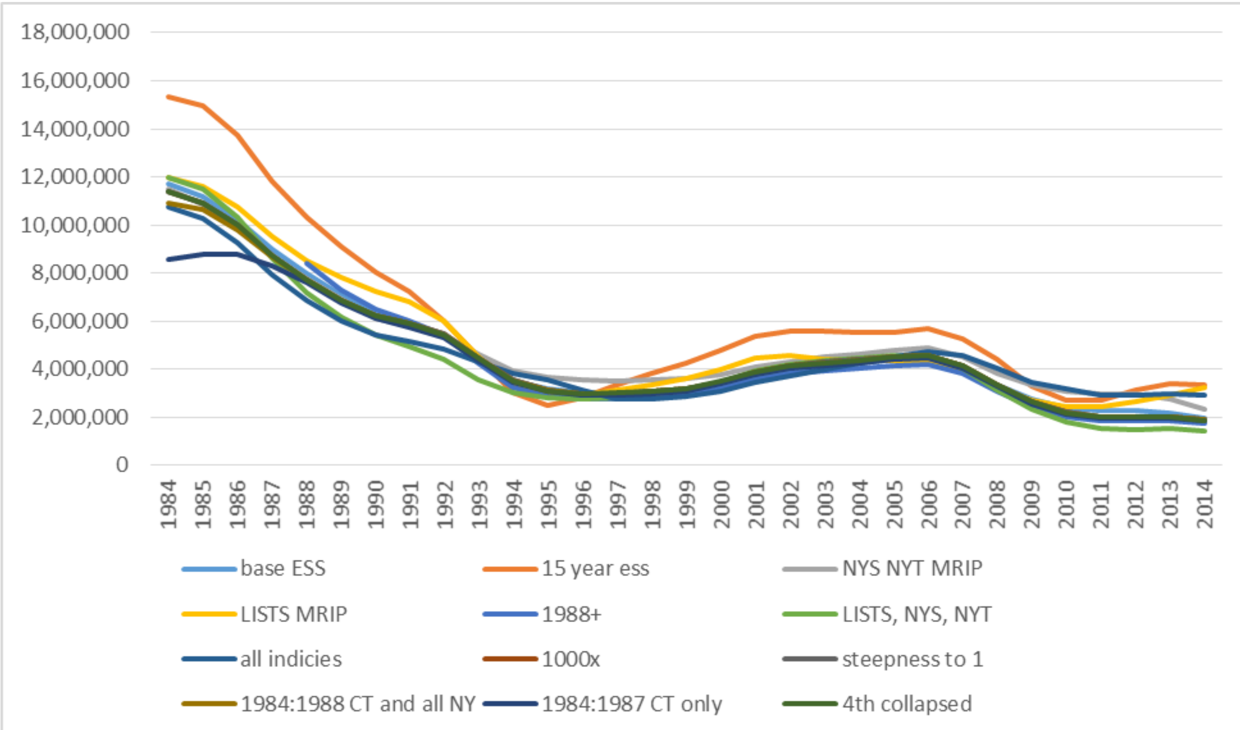


Figure 6.12. Sensitivity analyses for LIS
(a) SSB trajectories for different sensitivity runs (b) F 3 year average trajectories for different sensitivity runs, and (c) estimated number of recruits for different sensitivity runs.
(a)



(b)

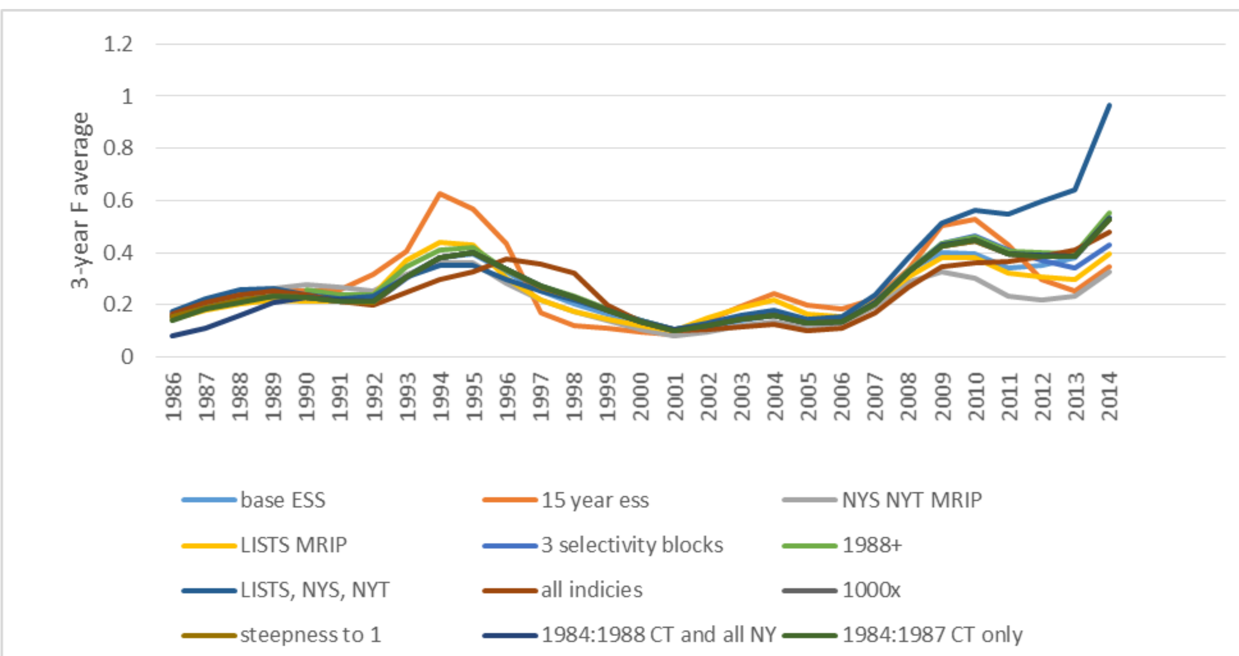


Figure 6.12. (cont'd)
(c)

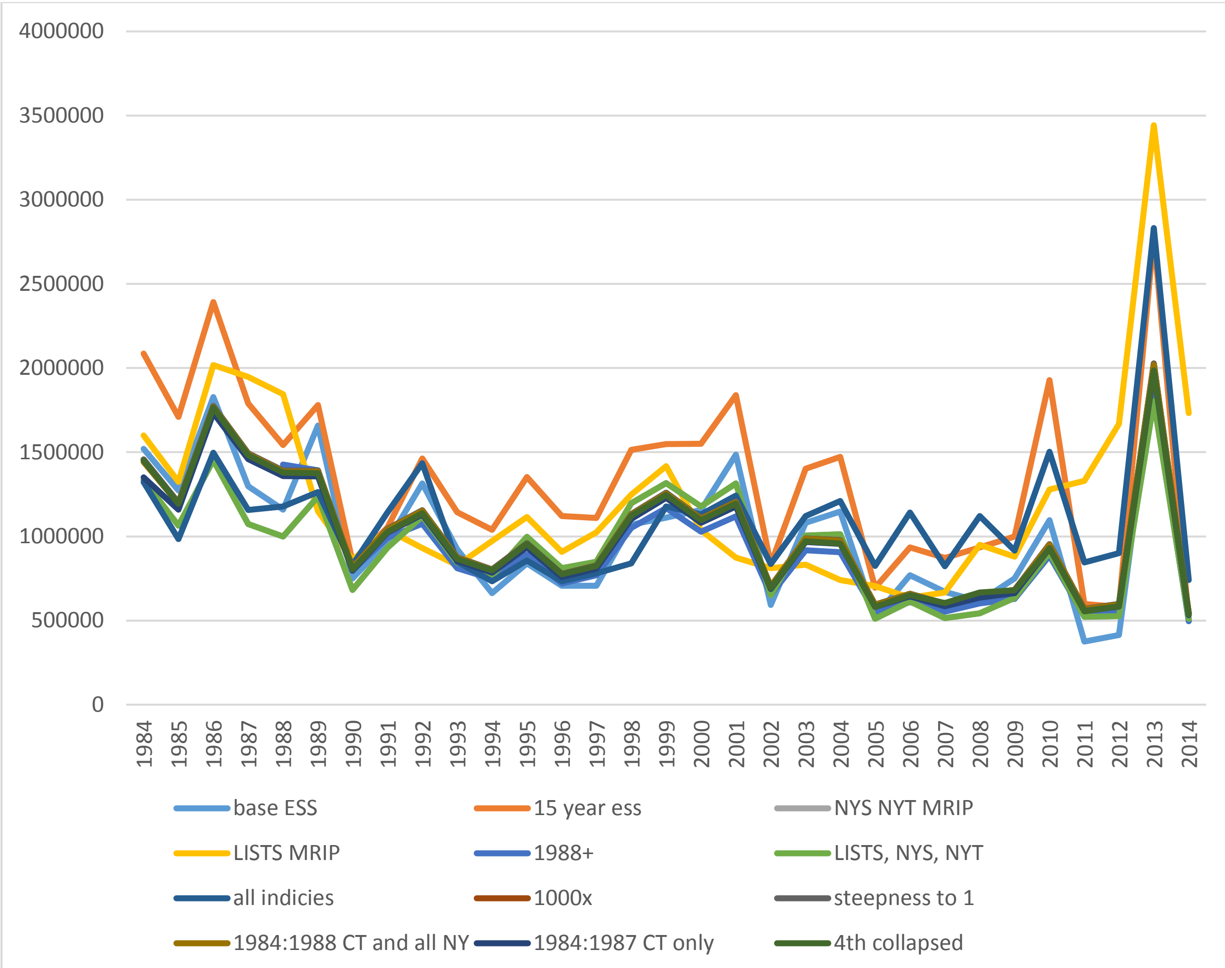
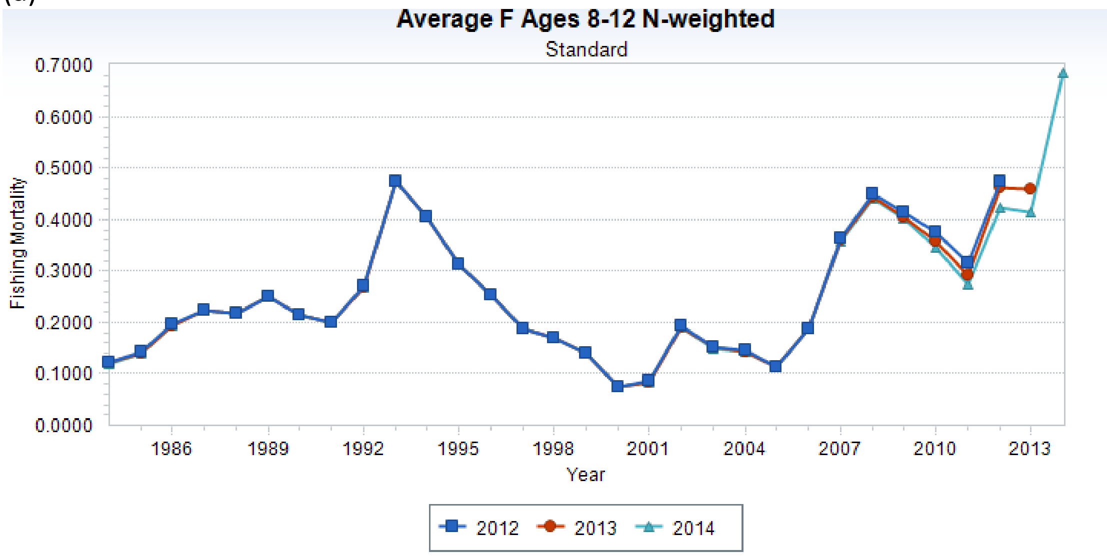
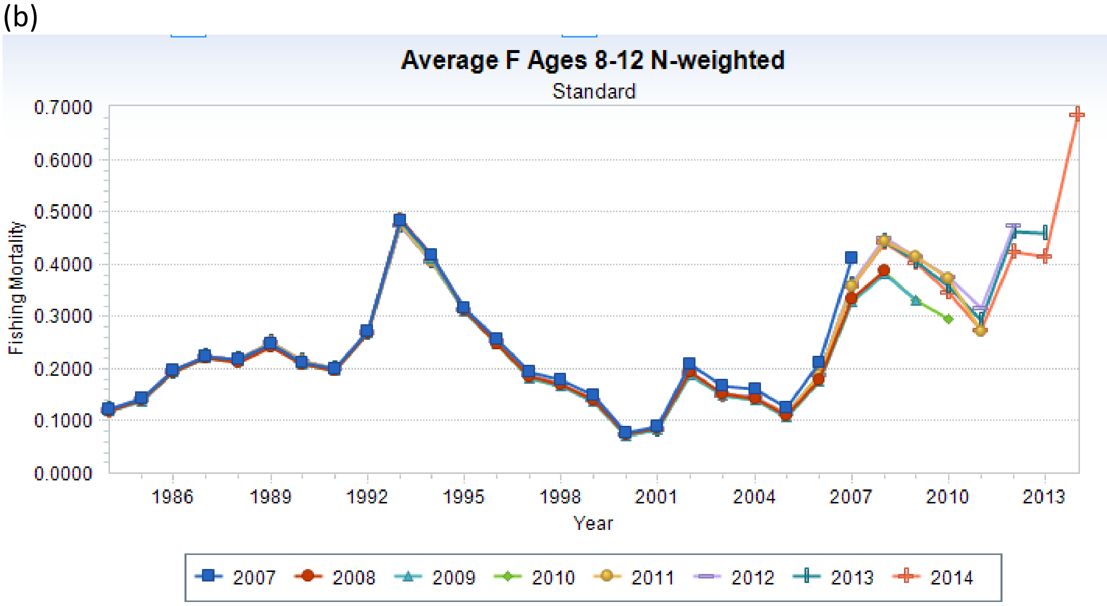


Figure 6.13. Retrospective results for F (a) 12-year plus group, start 2012, (b) 12-year plus group start 2007, (c) 15-year plus group, start 2012, (d) 15-year plus group start 2007 the LIS regional models.

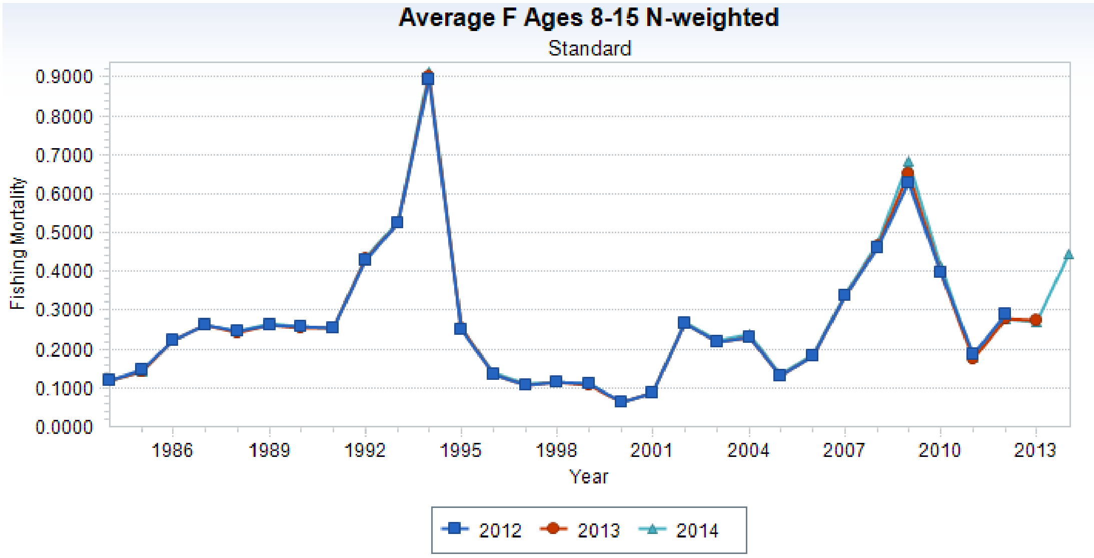
(a)



(b)

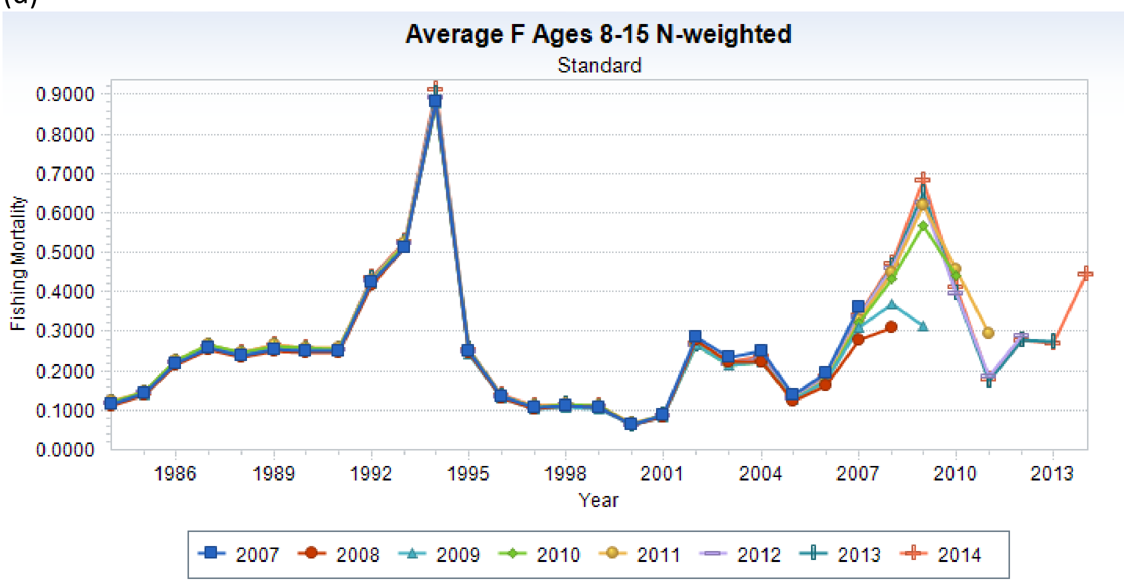


(c)



Average F Ages 8-15 N-weighted
Standard
Fishing Mortality
0.9000
0.8000
0.7000
0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0.0000
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
Year
2012
2013
2014

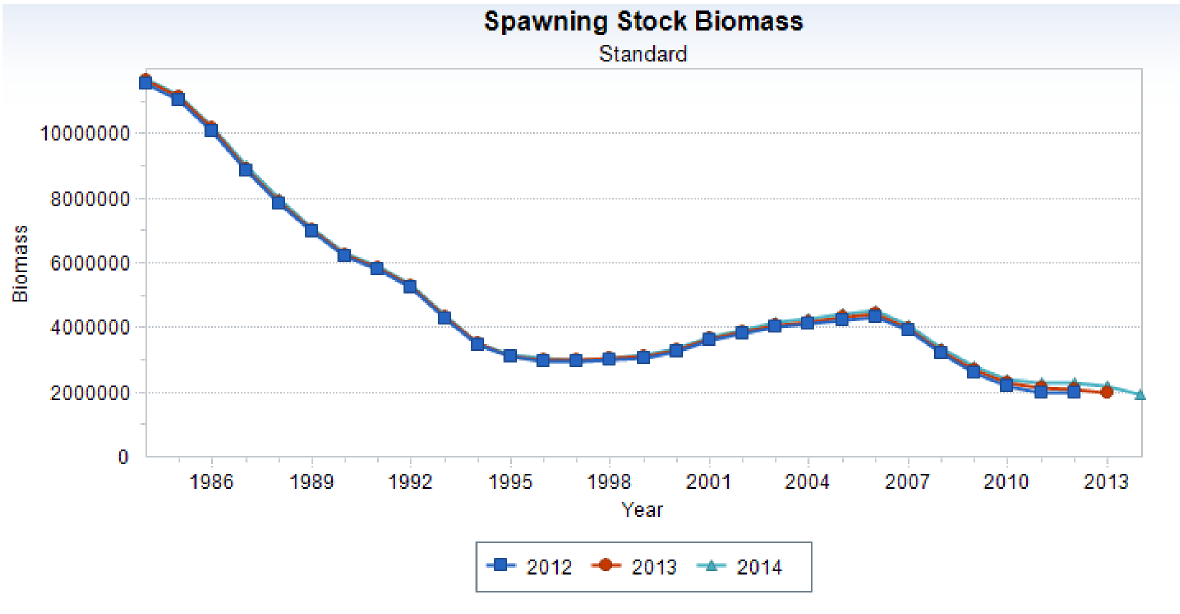
(d)



Average F Ages 8-15 N-weighted
Standard
Fishing Mortality
0.9000
0.8000
0.7000
0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0.0000
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
Year
2007
2008
2009
2010
2011
2012
2013
2014

Figure 6.14. Retrospective results for SSB (a) 12-year plus group, start 2012, (b) 12-year plus group start 2007, (c) 15-year plus group, start 2012, (d) 15-year plus group start 2007 the LIS regional models.

(a)



(b)

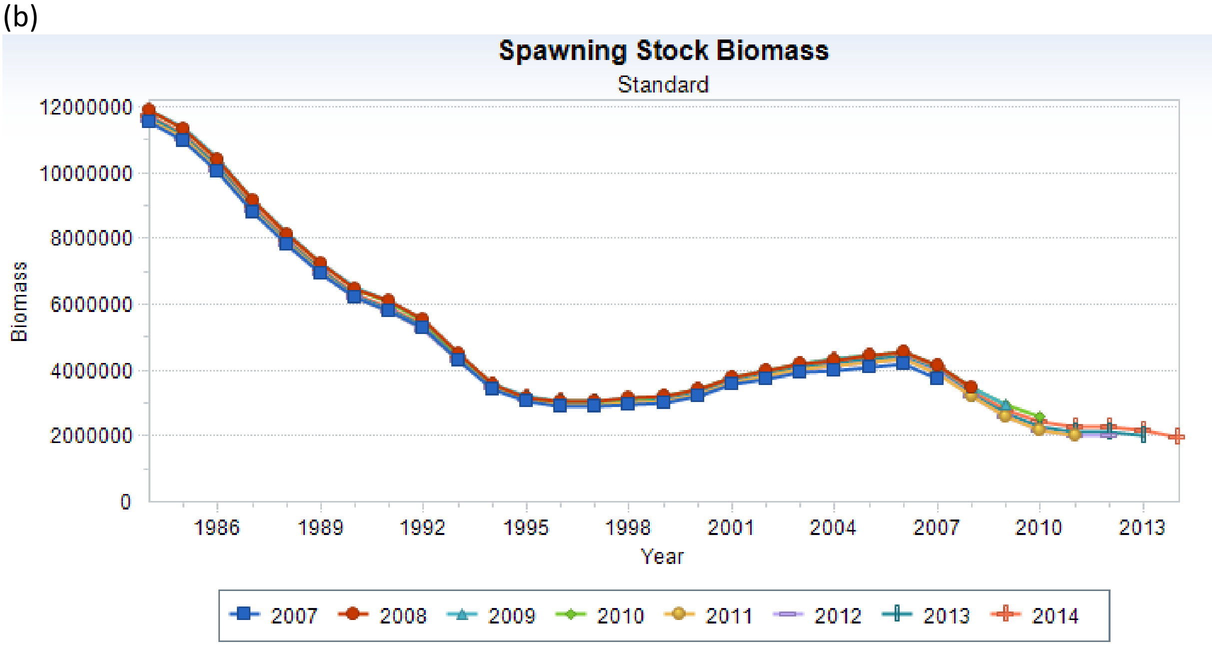
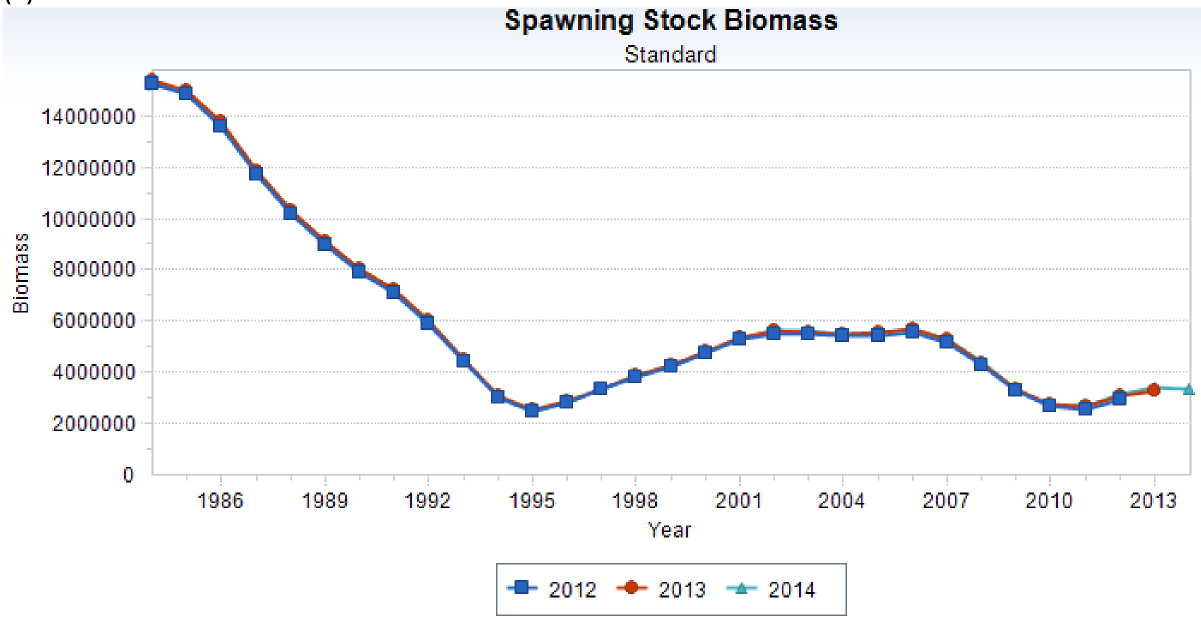


Figure 6.14 (cont.)

(c)



(d)

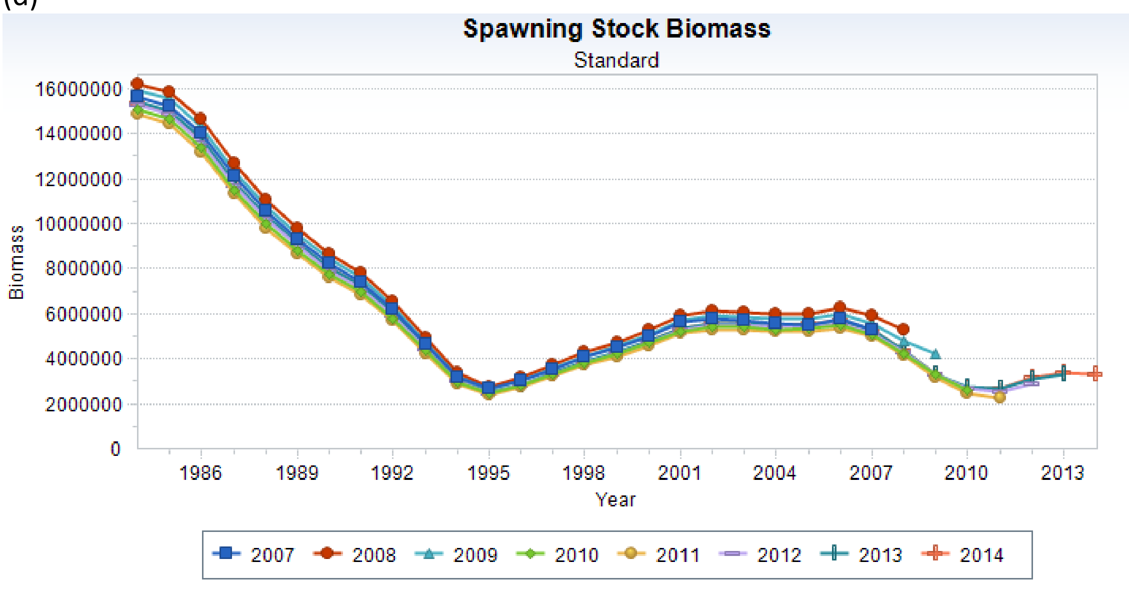
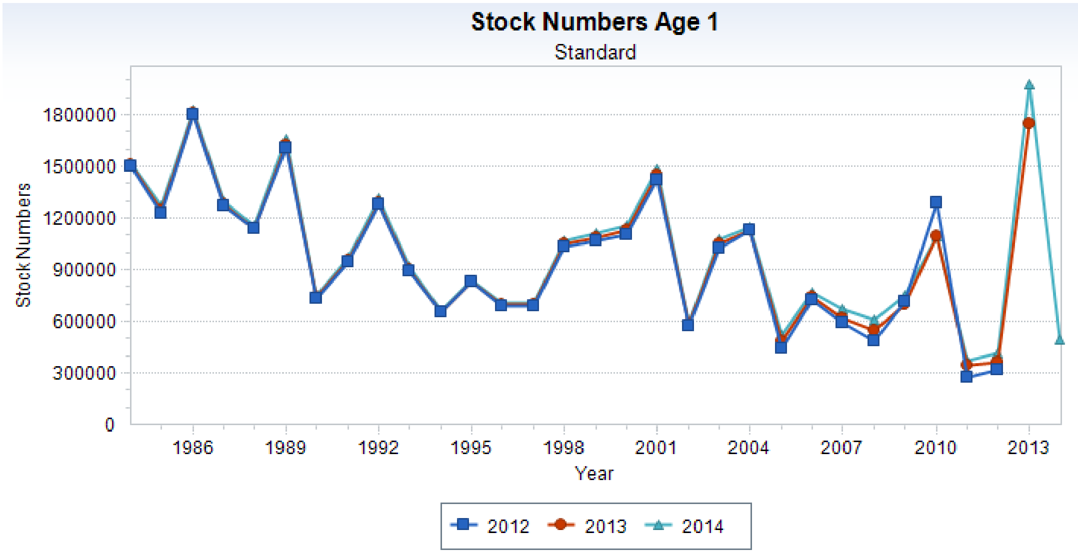


Figure 6.15. Retrospective results for recruits (a) 12-year plus group, start 2012, (b) 12-year plus group start 2007, (c) 15-year plus group, start 2012, (d) 15-year plus group start 2007 the LIS regional models.

(a)



(b)

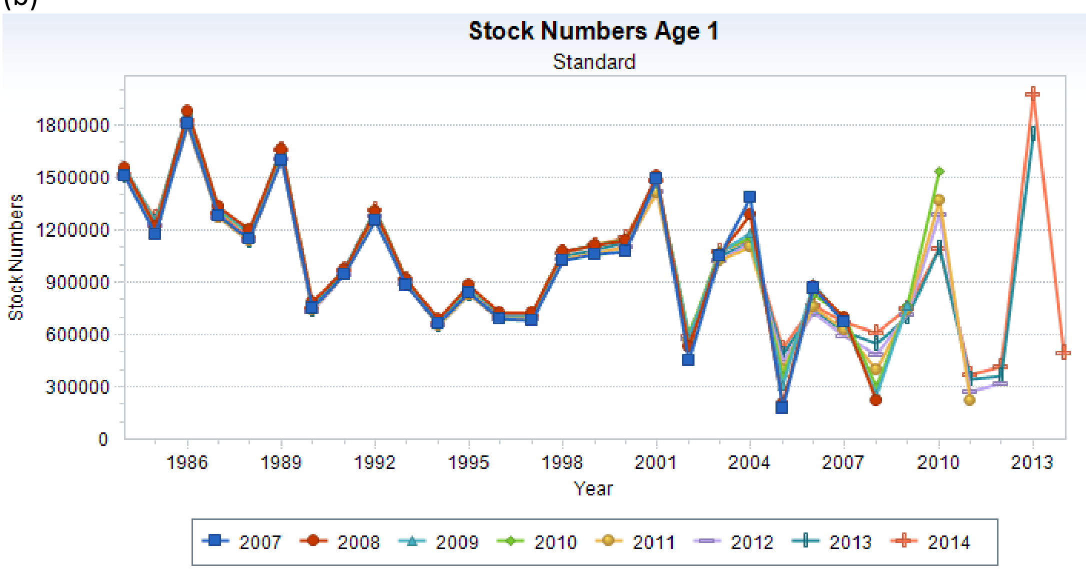
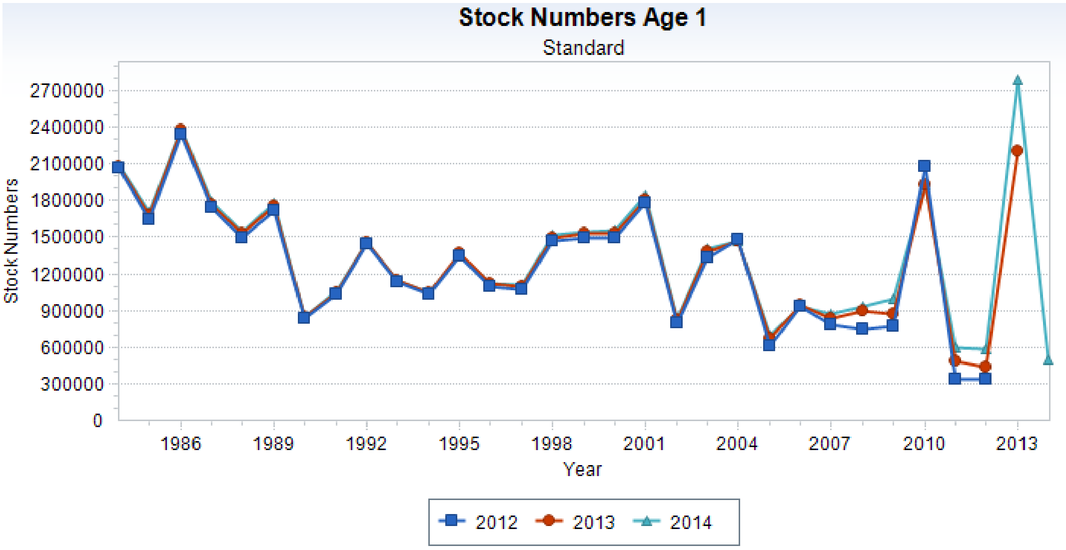


Figure 6.15 (cont.)

(c)



(d)

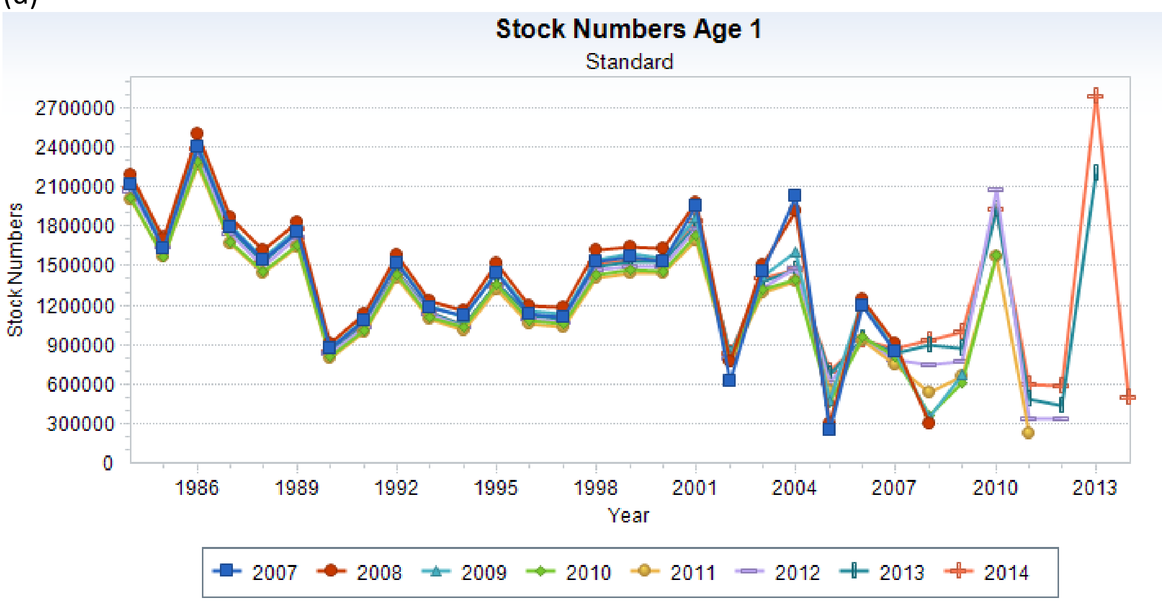
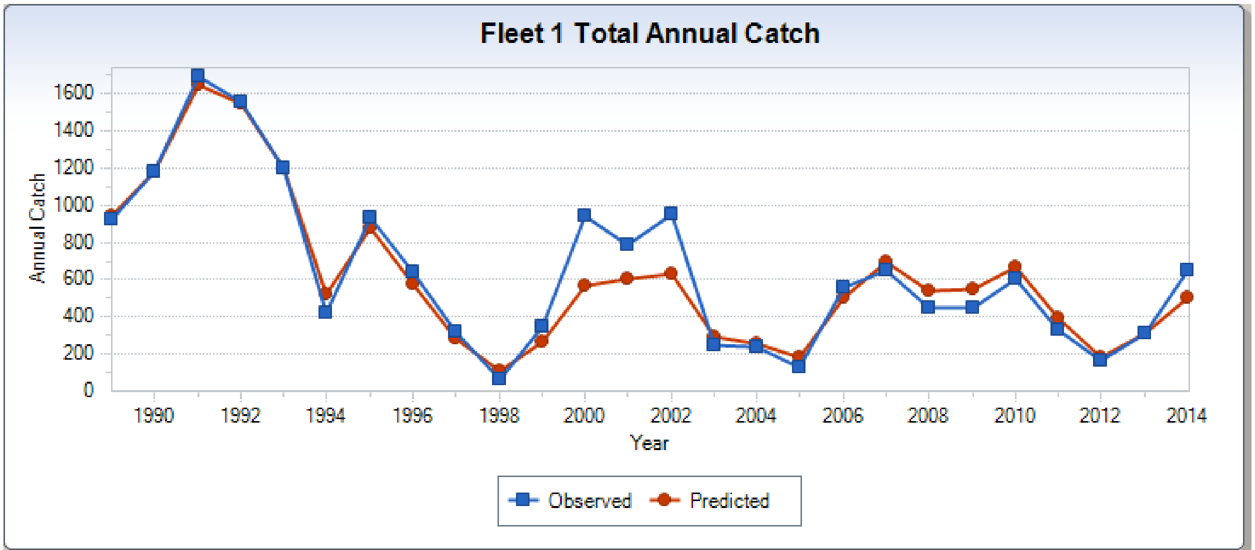


Figure 6.16. NJ-NYB regional model observed and predicted total catch (top) and standardized residuals.



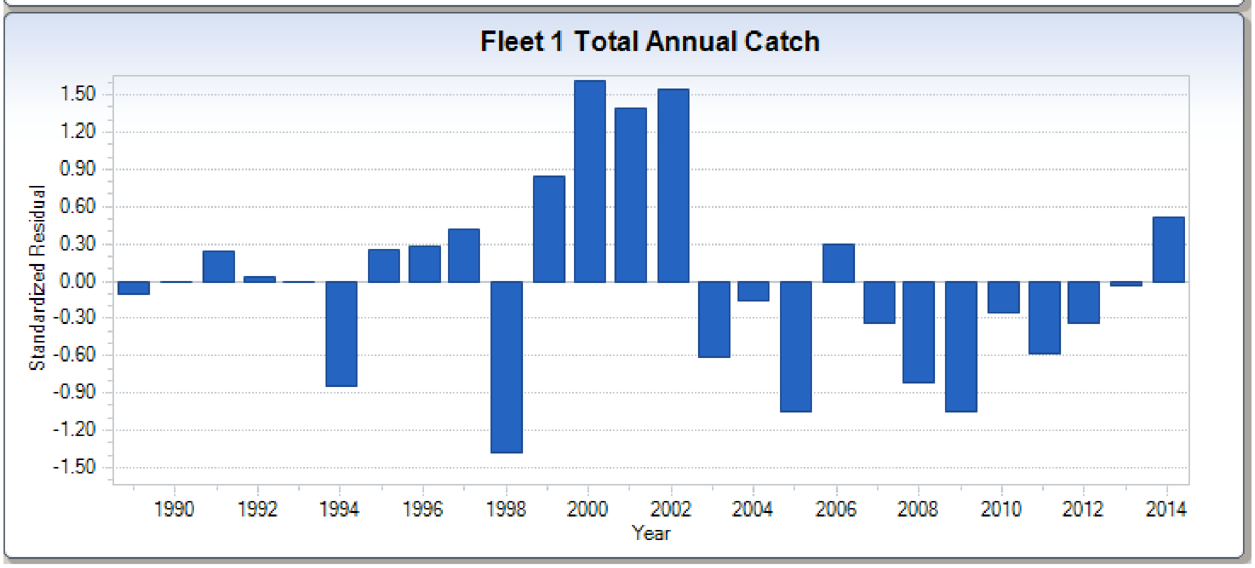


Figure 6.17. Fits to annual catch at age for the NJ-NYB regional model.

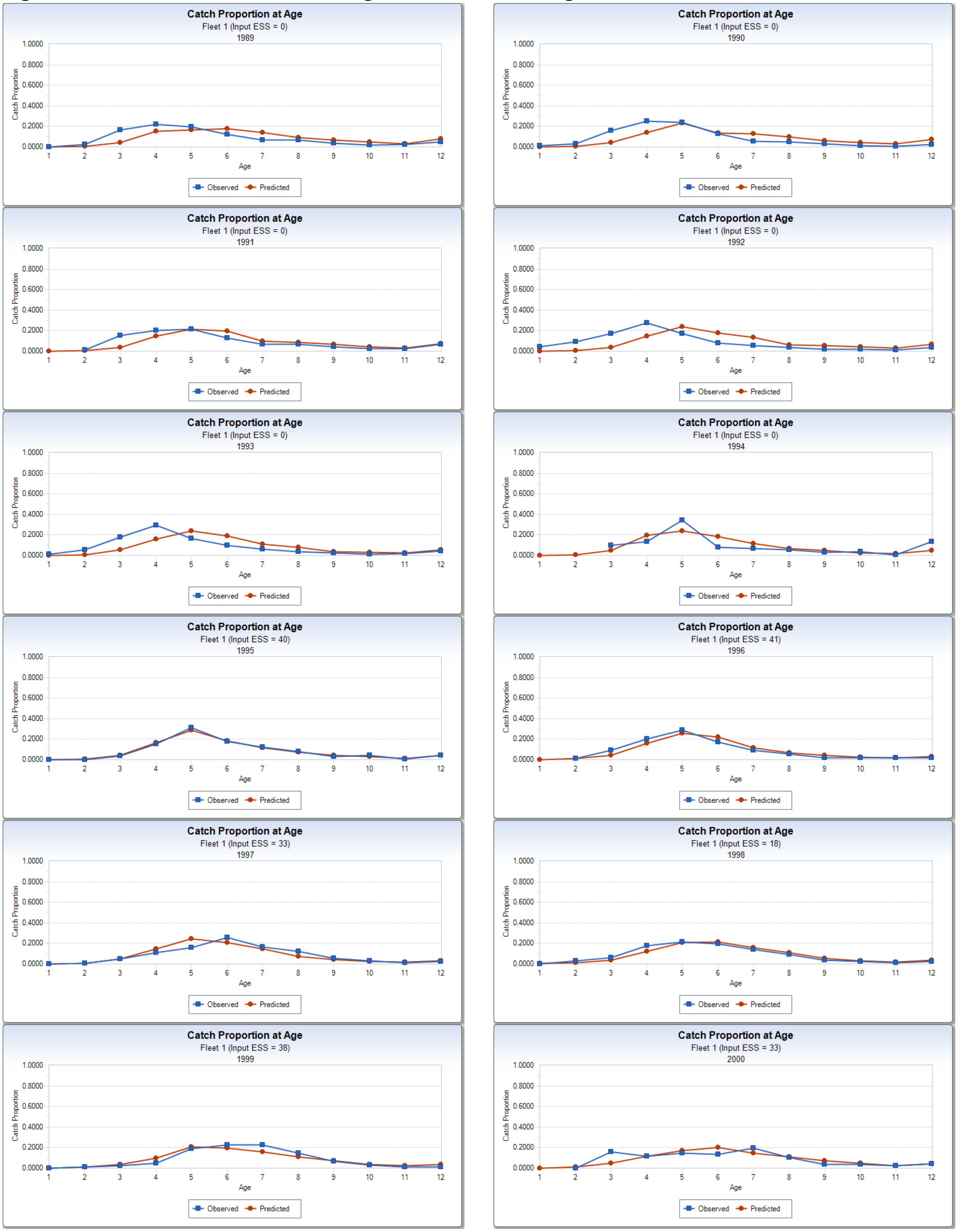


Figure 6.17 (cont.)

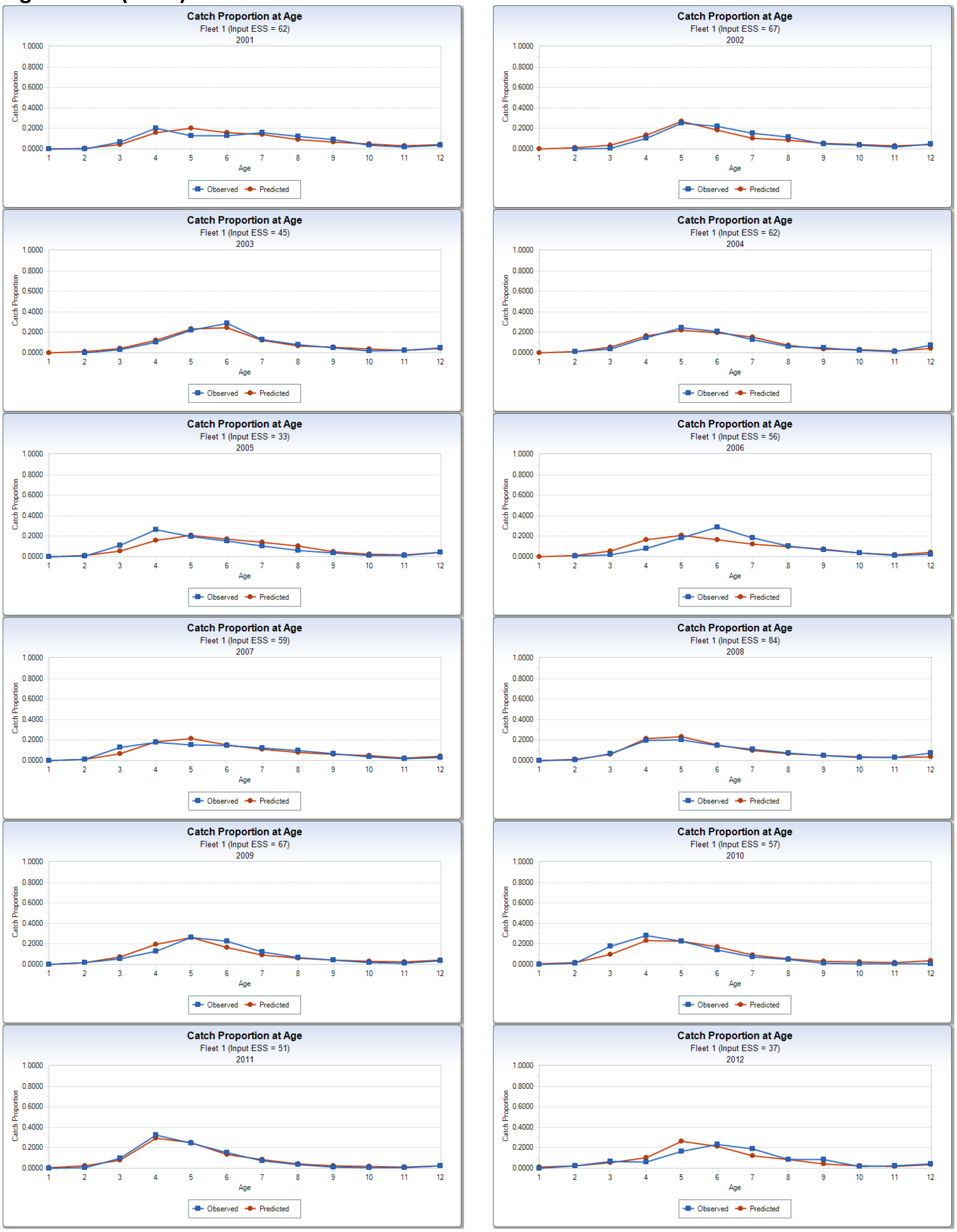


Figure 6.17 (cont.)

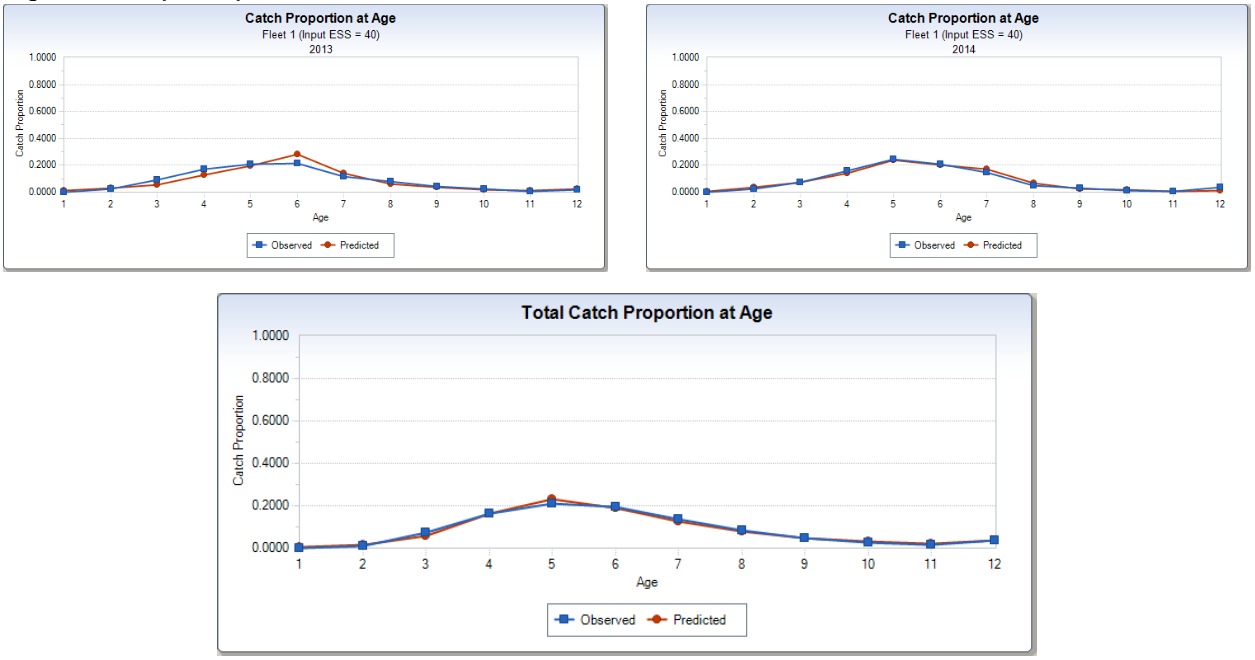


Figure 6.18. Fits to annual survey indices and overall index at age (bottom) for the NJ-NYB region.

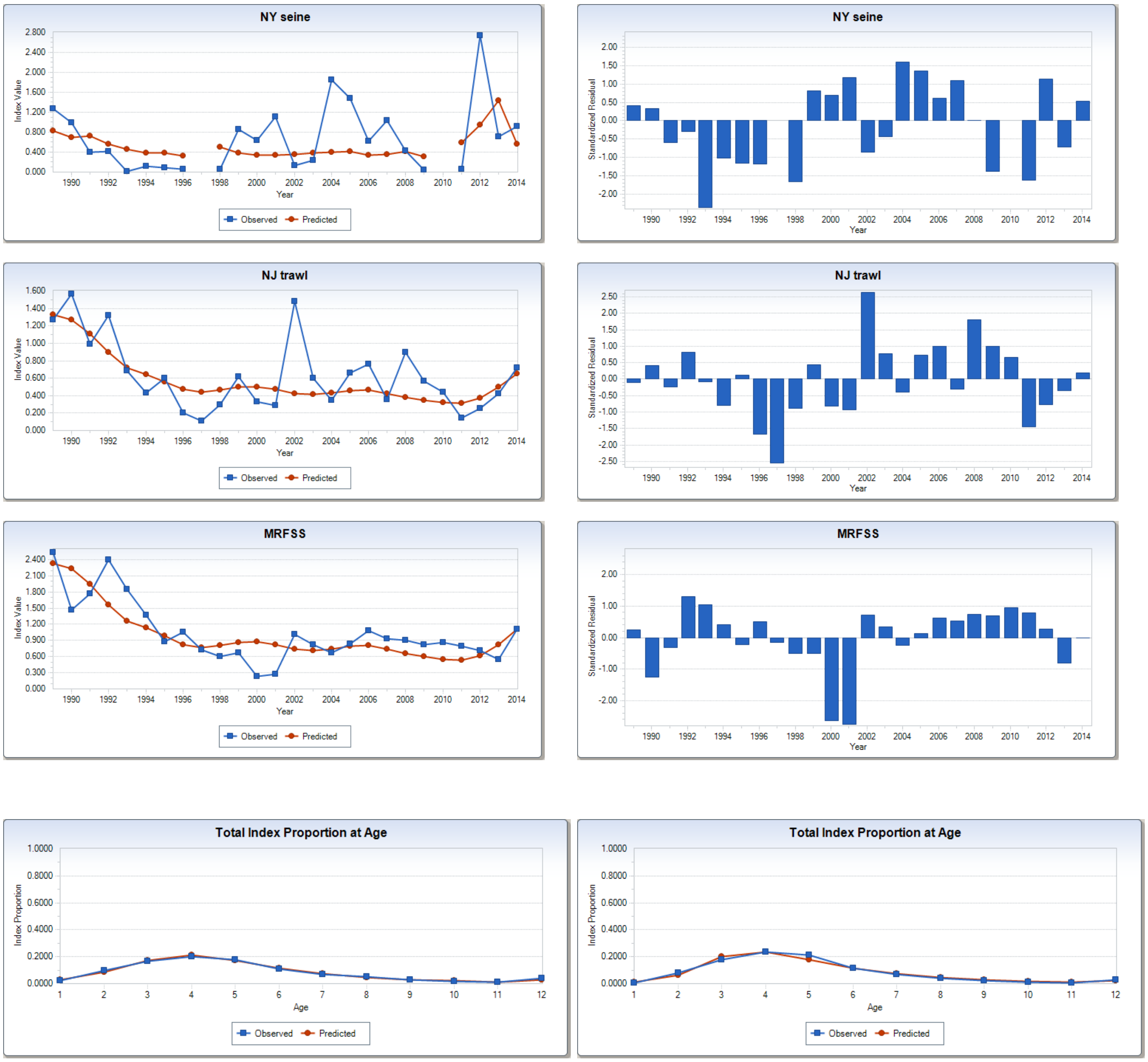
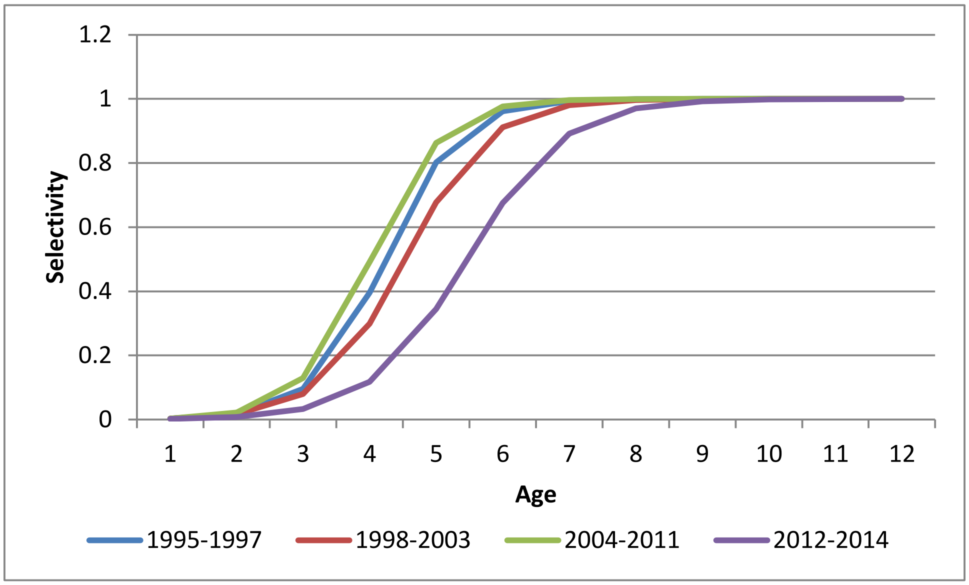


Figure 6.19. Estimated selectivity patterns for the fishery (top) and survey indices for the NJ-NYB regional model.



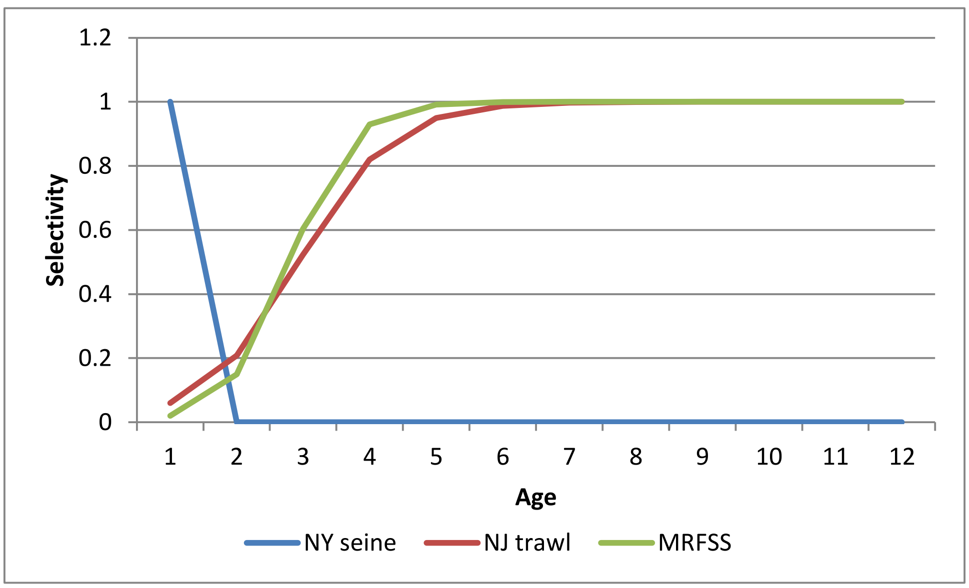
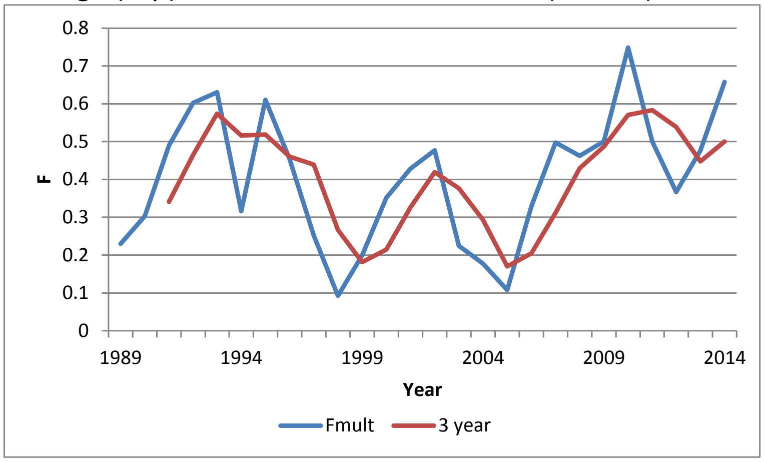
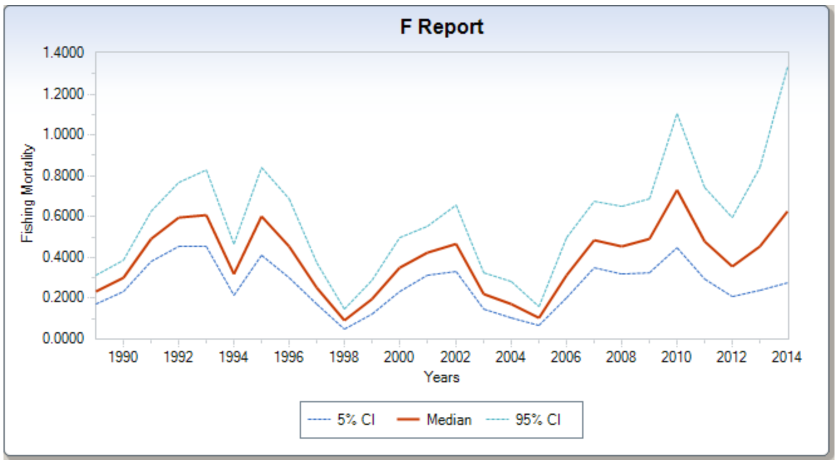


Figure 6.20. Fishing mortality estimates for the NJ-NYB regional model. Annual and three year average (top), MCMC median and 90% CI (middle) and MCMC distribution.





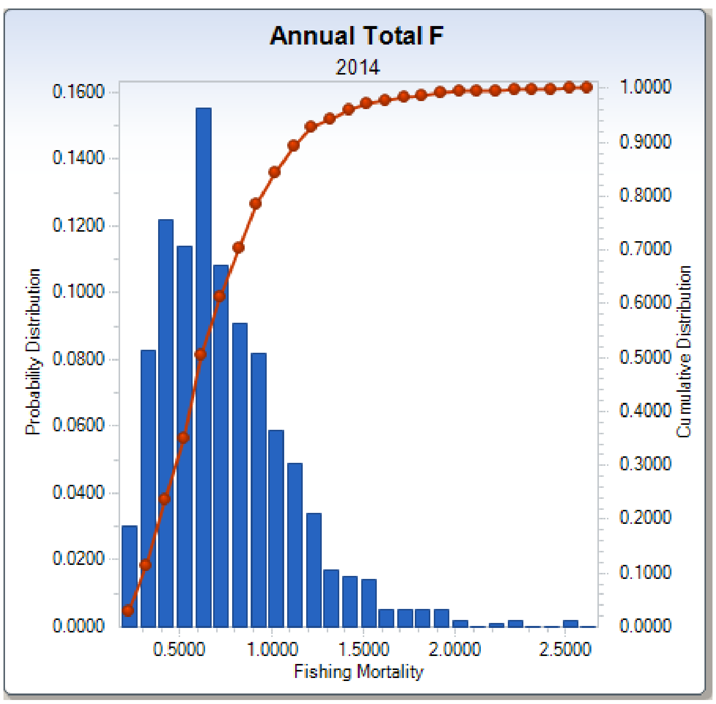


Figure 6.21. SSB estimates for the NJ-NYB regional model. Annual with +/- 1 standard deviation (top), MCMC median and 90% CI (middle) and MCMC distribution.

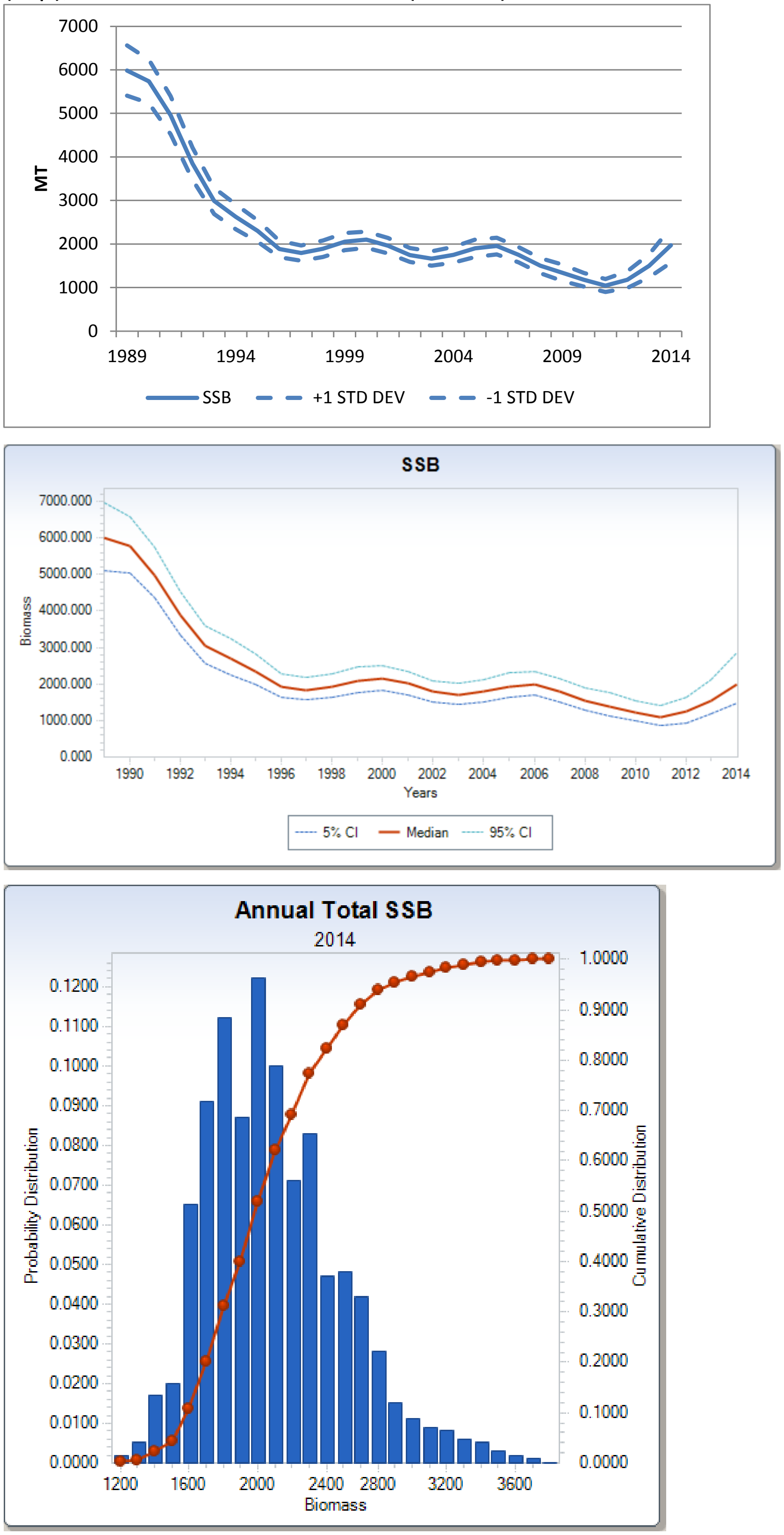


Figure 6.22. Estimated recruitment to age 1 for the NJ-NYB regional model

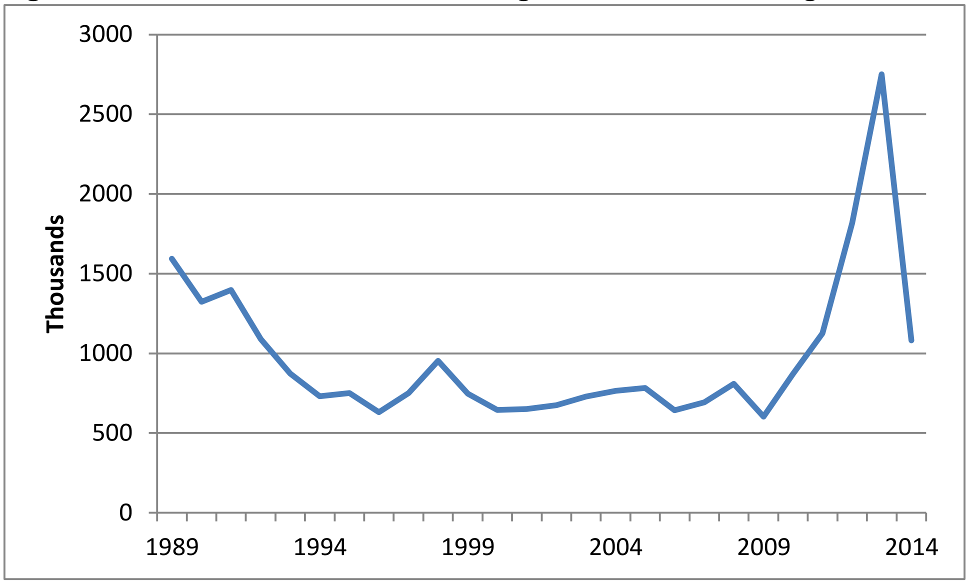
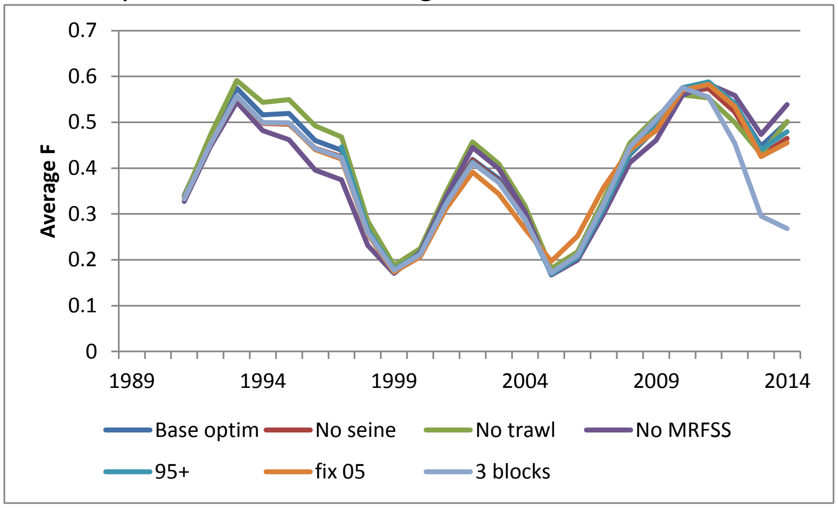
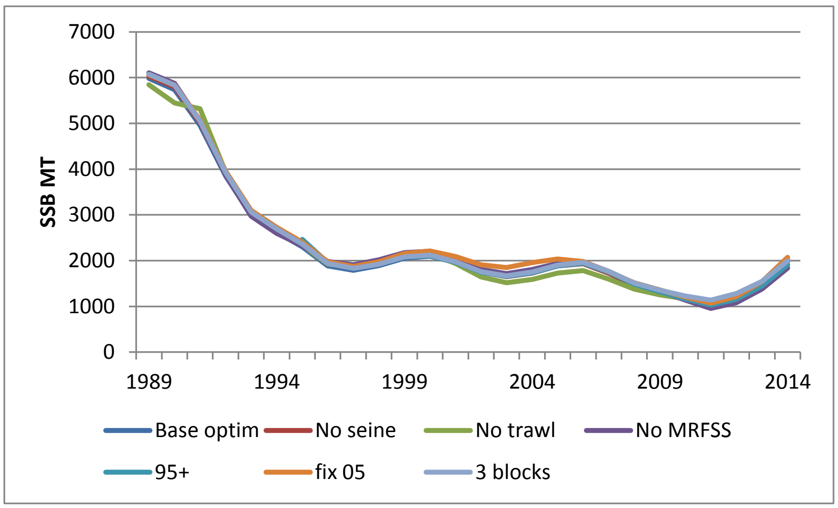


Figure 6.23 Trajectories of 3 year average F (top) and SSB (middle) and recruits (bottom) for sensitivity runs of the NJ-NYB regional model





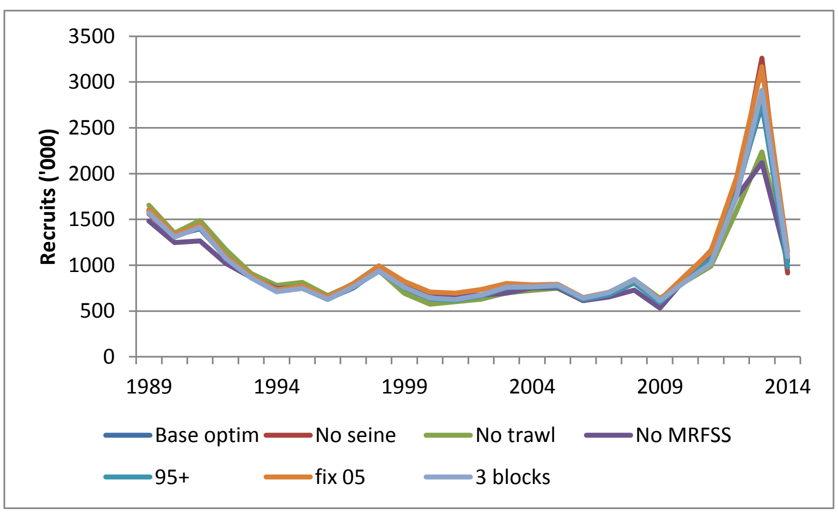
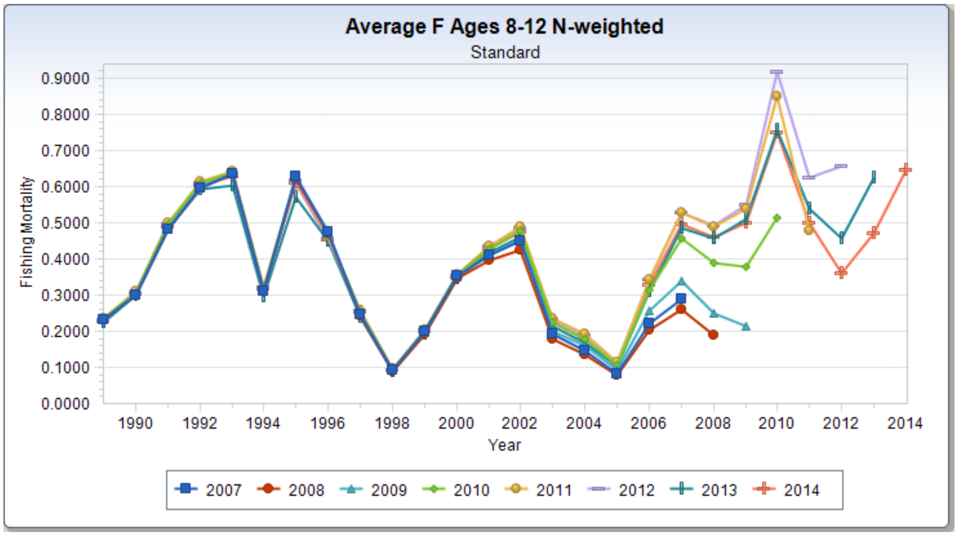
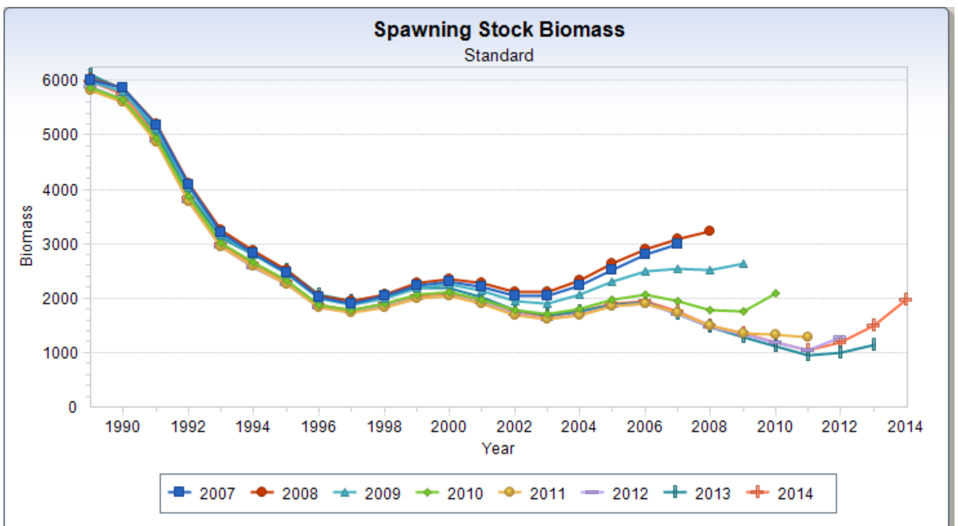


Figure 6.24. Retrospective results for F (top), SSB (middle), and recruits in the NJ-NYB regional model.





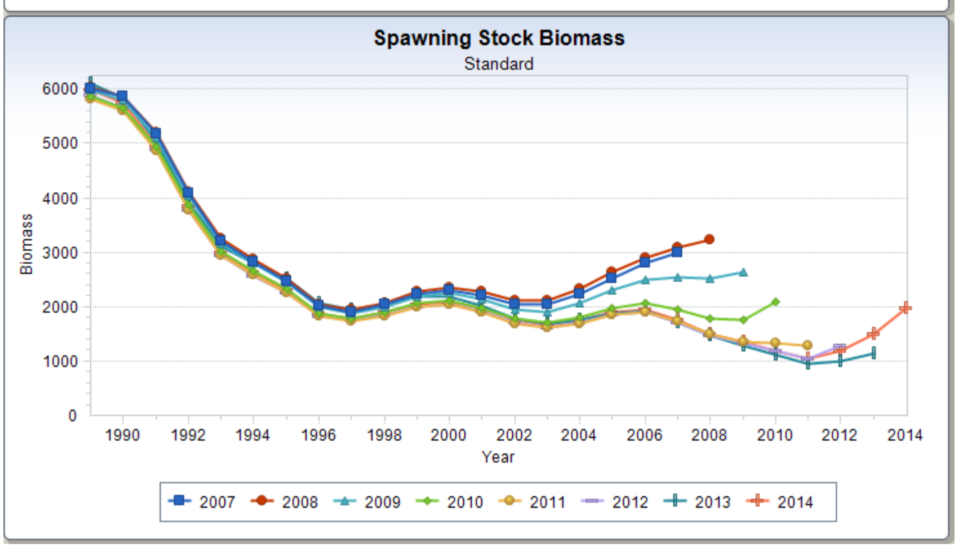
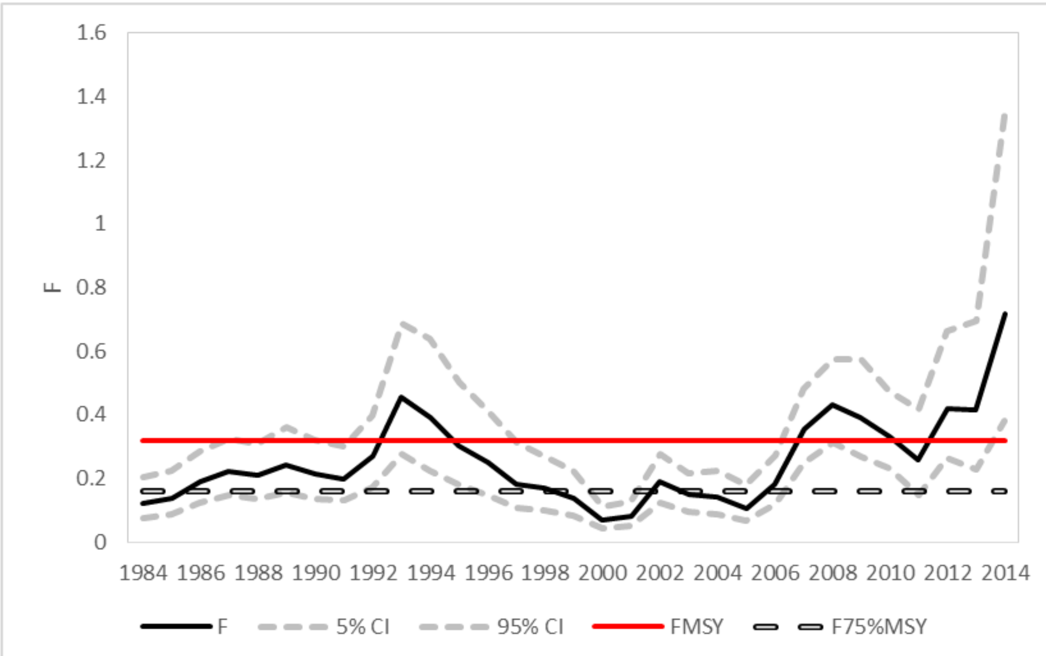


Figure 7.1 F estimates with MCMC confidence intervals and F target and threshold values (a), and SSB estimates with MCMC confidence intervals and SSB target and threshold values (b) for SPR model in LIS.

(a)



(b)

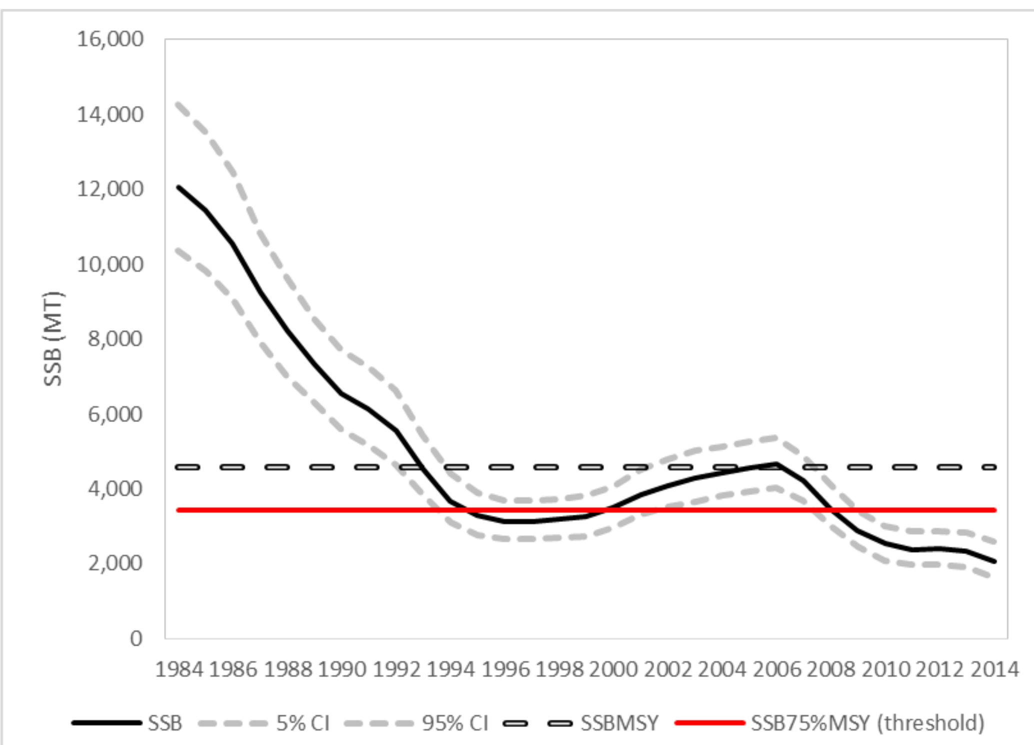
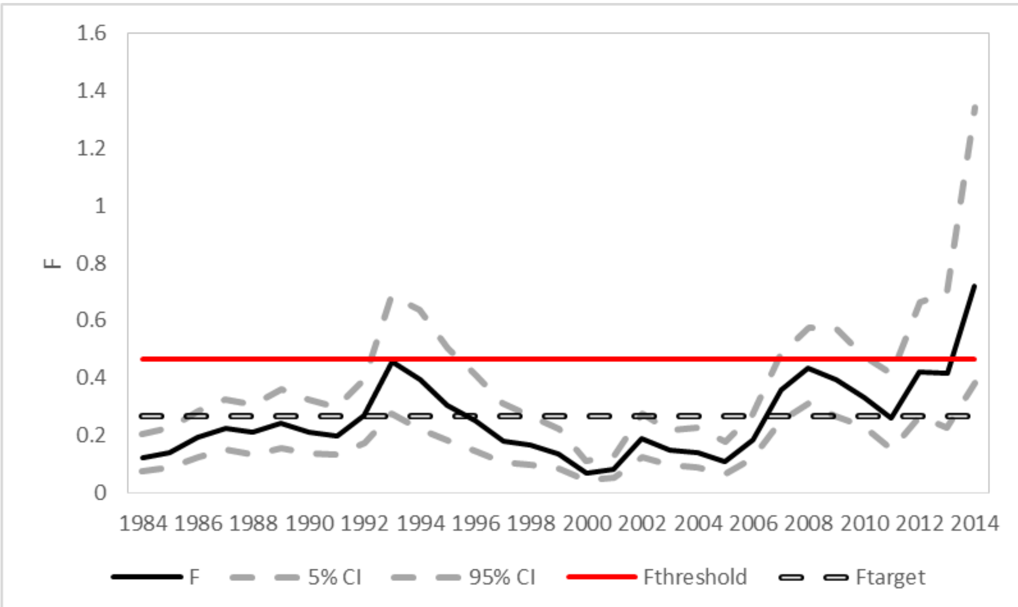


Figure 7.2 F estimates with MCMC confidence intervals and F target and threshold values (a) and SSB estimates with MCMC confidence intervals and SSB target and threshold values (b) for SPR model in LIS.

(a)



(b)

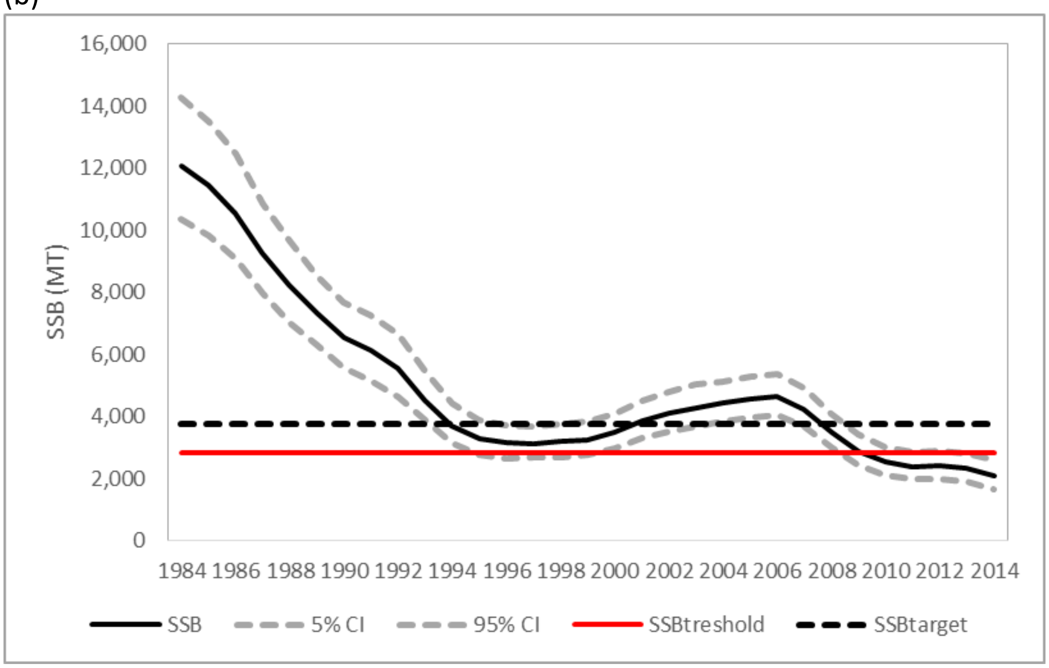
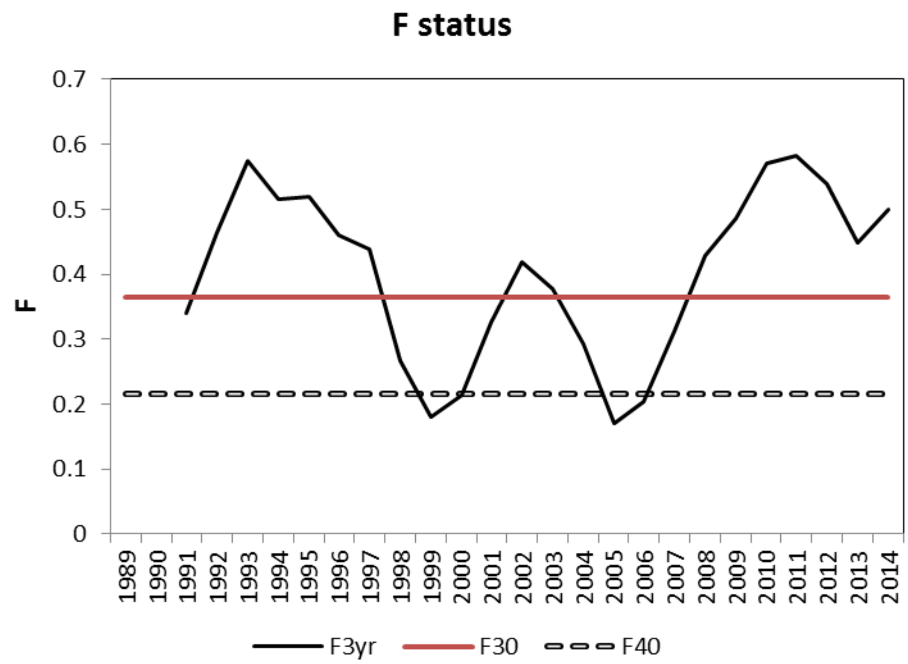
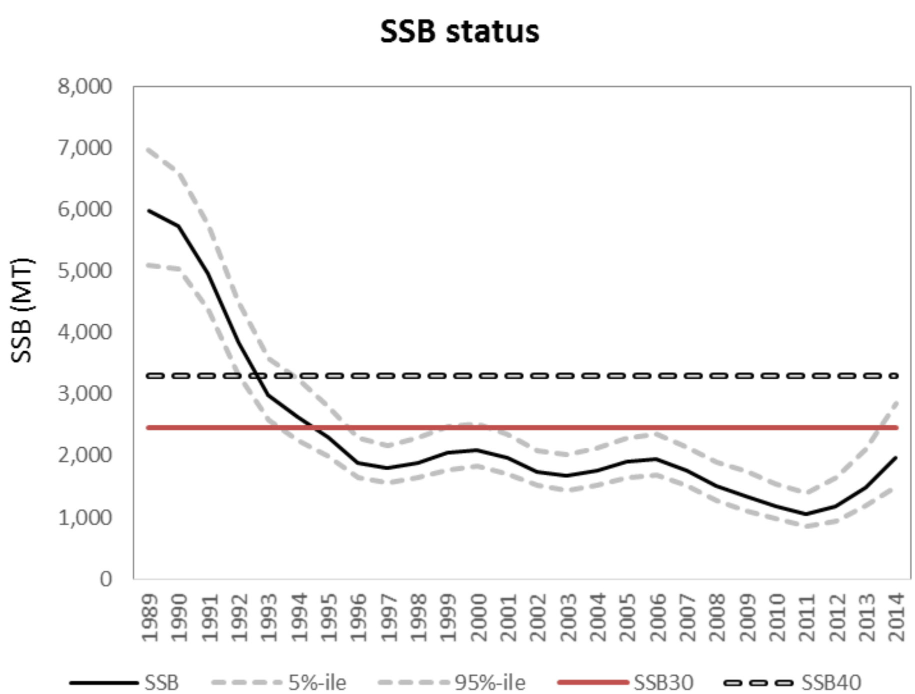


Figure 7.3. Fishing mortality (top) and spawning stock biomass relative to benchmarks for the NJ-NYB region.





Technical Documentation
for
ASAP Version 3.0

NOAA Fisheries Toolbox

September 2012

Table of Contents

Introduction

ASAP3 is an update to the program ASAP (Legault and Restrepo 1998), which was previously updated as ASAP2 in 2008. It contains a number of new features and options that are described in the ASAP3 User's Guide. This document provides the basic equations used in the program along with the approaches used to fit different components of the objective function. More importantly, it contains the actual ADMB code used to generate the executable, so that the exact calculations in the program can be followed. This document uses variable names in a number of places instead of symbols to facilitate understanding of the underlying code.

Basic Equations

The description of the model follows the steps in the code for ease of understanding. Calculation of the objective function is described in the next section.

Spawning Stock Biomass

The spawning stock biomass is calculated based on the population abundance at age (N), the fecundity (Φ), and the proportion of the total mortality (Z, see mortality section below) during the year prior to spawning (p_{SSB}) as

$$SSB_t = \sum_a N_{t,a} \Phi_{t,a} e^{-p_{SSB} Z_{t,a}} \quad (1)$$

Where the fecundity matrix is either input by the user or else derived as the element by element product of the weight at age matrix and the maturity matrix.

Stock Recruitment Relationship

The Beverton and Holt stock recruitment relationship is used to calculate the expected recruitment in year t+1 from the spawning stock biomass in year t as

$$\hat{R}_{t+1} = \frac{\alpha SSB_t}{\beta + SSB_t} \quad (2)$$

The equation is reparameterized following Mace and Doonan (ref) to use two parameters: the SR scaler and steepness (τ). The SR scaler can be either unexploited spawning stock biomass (SSB_0) or unexploited recruitment (R_0). These two values are related to each other based on the unexploited spawners per recruit (SPR_0) as $SPR_0 = SSB_0/R_0$. All three of these unexploited values are computed using the natural mortality, weights at age, and maturity (or fecundity) values in the terminal year of the assessment. The stock recruitment relationship is therefor fixed for all years using equation 2 with

$$\alpha = \frac{4\tau(SSB_0 / SPR_0)}{5\tau - 1} \quad and \quad \beta = \frac{SSB_0(1-\tau)}{5\tau - 1} \quad (3)$$

However, the program also produces the values of unexploited SSB, R, spawners per recruit, and steepness associated with the natural mortality rate, weights at age, and maturity (or fecundity) for each year in the time series. This allows the user to see the influence of these values on the stock recruitment parameters SSB_0, R_0, SPR_0, and τ over time.

Steepness for the Beverton and Holt stock recruitment relationship is only defined between 0.2 and 1.0. Fixing steepness at 1.0 makes expected recruitment constant. The actual recruitment estimated by the model is formed by multiplying the expected recruitment by a recruitment deviation. The recruitment deviations are assumed to follow a lognormal distribution, making the parameters log_Rdev_t. The parameters are estimated as a bounded vector, meaning their sum is zero, so that they are centered on the expected stock recruitment relationship. The population numbers at age 1, recruitment is always assumed to occur at age 1, are

$$N_{t,1} = R_t e^{\log\_Rdev_t} \tag{4}$$

Selectivity

The approach used to estimate fleet selectivity in ASAP3 is quite different from that in ASAP, but the same as in ASAP2. As before, there are selectivity blocks, but now they are defined independently for each fleet. Within each selectivity block, there are three options for estimating selectivity:

1. estimate parameters for each age (one parameter for each age, similar to ASAP in concept, but now each age is bounded by zero and one and at least one age should be fixed at 1.0 instead of estimated)
2. logistic function (2 parameters: α_1, β_1)

$$Sel_a = \frac{1}{1+e^{-(a-\alpha_1)/\beta_1}} \tag{5}$$

3. double logistic (4 parameters: α_1, β_1, α_2, β_2)

$$Sel_a = \left(\frac{1}{1+e^{-(a-\alpha_1)/\beta_1}}\right)\left(1-\frac{1}{1+e^{-(a-\alpha_2)/\beta_2}}\right) \tag{6}$$

The selectivity at age is then assigned to all fleet and year combinations within that block. Note that for options 2 and 3, the selectivity at age is divided by the maximum value over all ages, creating the final selectivity vector with maximum of 1.0 for that block.

Mortality

Natural mortality (*M*) is entered as a year by age matrix, as it was in ASAP2, instead of just a vector by age as it was in ASAP.

Fishing mortality (*F*) is assumed to be separable, meaning it is the product of a year effect (*Fmult*) and selectivity at age (described above). The *Fmult* for a fleet and year is determined by two sets of parameters, log_Fmult1_{ifleet}, the parameter for first year for that fleet, and $log\_Fmultdev_{ifleet,t}$, where t=2 to the number of years, the deviation of the parameter from the value in the first year for that fleet. Both sets of parameters are estimated in log space and then exponentiated as

$$Fmult_{ifleet,1} = e^{\log\_Fmult1_{ifleet}}$$

$$Fmult_{ifleet,t} = Fmult_{ifleet,1} e^{\log\_Fmultdev_{ifleet,t}} \quad \forall t \geq 2 \qquad (7)$$

Note that the *log_Fmultdev* parameters are not estimated as a dev_vector in the ADMB code, and so fishing intensity can increase continually, decrease continually, or fluctuate throughout the time series. The directed F for a fleet, year, and age, meaning that portion of the F that contributes to landings, is computed using the separable equation along with the proportion of catch released for that fleet, year, and age ($prop\_release_{ifleet,t,a}$) as

$$Fdir_{ifleet,t,a} = Fmult_{ifleet,t,a} Sel_{ifleet,t,a} (1 - prop\_release_{ifleet,t,a}) \qquad (8)$$

The bycatch F contains an additional component, the proportion of released fish that die, which is fleet specific ($release\_mort_{ifleet}$)

$$Fbycatch_{ifleet,t,a} = Fmult_{ifleet,t,a} Sel_{ifleet,t,a} prop\_release_{ifleet,t,a} release\_mort_{ifleet} \qquad (9)$$

The two parts are then added together to produce the fishing mortality for the fleet, year and age

$$F_{ifleet,t,a} = Fdir_{ifleet,t,a} + Fbycatch_{ifleet,t,a} \qquad (10)$$

The total mortality (*Z*) is the sum of natural and fishing mortality at year and age over all fleets

$$Z_{t,a} = M_{t,a} + \sum_{ifleet} F_{ifleet,t,a} \qquad (11)$$

Population Abundance

The population abundance in the first year for ages 2 through the maximum age are derived from either the initial guesses ($N1ini_a$) and the parameters $log\_Nyear1dev_a$ as

$$N_{1,a} = N1ini_a e^{\log\_Nyear1dev_a} \qquad (12)$$

or as deviations from a population in equilibrium according to the total mortality at age vector in the first year. A partial spawning stock biomass for ages 2 through the maximum age is computed and used in the stock recruitment relationship (Eq. 2) to create an expected recruitment in the first year. The recruitment deviation for the first year is applied to form the population abundance at age 1 in the first year (Eq. 4). The full spawning stock biomass is computed for year 1 using all ages (Eq. 1) now that the first year is completely filled.

The population abundance for years 2 through the end year are then filled by first computing the expected recruitment (Eq. 2) and then applying the recruitment deviation to create the abundance at age 1 (Eq. 4). Ages 2 through the maximum age are filled using the following set of equations

$$\begin{aligned} N_{t,a} &= N_{t-1,a-1} e^{-Z_{t-1,a-1}} \qquad 2 \leq a < A \\ N_{t,A} &= N_{t-1,A-1} e^{-Z_{t-1,A-1}} + N_{t-1,A} e^{-Z_{t-1,A}} \end{aligned} \qquad (13)$$

Each year the spawning stock biomass is computed (Eq. 1) and the cycle continued until the end year is reached.

F Report

The original ASAP simply output the Fmult for each fleet and year as an indicator of fishing intensity, along with the full F matrix by fleet and combined over all fleets. This approach for comparing fishing intensity is sufficient if selectivity does not change over time, but can be problematic when selectivity changes. A feature of ASAP2 that is continued in ASAP3 is the use of Freport, which averages the total fishing mortality over an input range of ages (a_{repmin} to a_{repmax}). The averaging is done unweighted ($\omega_{t,a}$=1), weighted by population abundance at age ($\omega_{t,a}$=$N_{t,a}$), and weighted by population biomass at age ($\omega_{t,a}$=$N_{t,a}W_{t,a}$ where $W_{t,a}$ denotes the January 1 weight at year and age) as

$$Freport_t = \frac{\sum_{a=a_{rep\min}}^{a_{rep\max}} \omega_{t,a} F_{t,a}}{\sum_{a=a_{rep\min}}^{a_{rep\max}} \omega_{t,a}} \qquad (14)$$

Predicted Catch

The predicted landings (*Lpred*) and discards (*Dpred*) in units of numbers of fish for each fleet, year, and age are derived from the Baranov catch equation

$$Lpred_{ifleet,t,a} = N_{ifleet,t,a} Fdir_{ifleet,t,a} (1 - e^{-Z_{t,a}}) / Z_{t,a} \qquad (15)$$

$$Dpred_{ifleet,t,a} = N_{ifleet,t,a} Fbycatch_{ifleet,t,a} (1 - e^{-Z_{t,a}}) / Z_{t,a} \qquad (16)$$

These predictions are used in two ways, one to form the predicted total weight of landings or discards for a fleet and year, and the other to form the proportions at age for a fleet and year. Both calculations are limited by the starting and ending ages for the fleet. The predicted total catch in weight calculations use the catch weight at year and age ($Wc_{t,a}$)

$$\hat{L}tot_{ifleet,t} = \sum_{a=fleetstart}^{fleetend} Lpred_{ifleet,t,a} Wc_{t,a} \qquad (17)$$

$$\hat{D}tot_{ifleet,t} = \sum_{a=fleetstart}^{fleetend} Dpred_{ifleet,t,a} Wc_{t,a} \qquad (18)$$

Note that since Fbycatch is derived using the proportion of fish that die after release, the total observed discards in weight (*Dtot*) should only include those fish that die after capture and release.

The predicted landings and discards proportions at age for each fleet and year are only computed for ages within the starting and ending range

$$\hat{L}p_{ifleet,t,a} = \frac{Lpred_{ifleet,t,a}}{\sum_{a=fleetstart}^{fleetend} Lpred_{ifleet,t,a}} \qquad (19)$$

$$\hat{D}p_{ifleet,t,a} = \frac{Dpred_{ifleet,t,a}}{\sum_{a=fleetstart}^{fleetend} Dpred_{ifleet,t,a}} \qquad (20)$$

Any predicted proportion less than 1e-15 is replaced by the value 1e-15 to avoid division by zero problems in the calculation of the likelihood function.

Catchability

Catchability for each index (*ind*) over time is computed similarly to the Fmult, with one parameter for the catchability in the first year (log_q1_{ind}) and a number of deviation parameters for each additional year of index observations ($log\_q\_dev_{ind,t}$). These parameters are combined and exponentiated to form the catchability value for the fleet and year as

$$q_{ind,t} = e^{\log\_q1_{ind} + \log\_q\_dev_{ind,t}} \quad (21)$$

where the parameter for the deviation in the first year ($log\_q\_dev_{ind,1}$) is defined as zero.

Predicted Indices

The observed indices have two characteristics that are matched when predicted values are computed, the time of year of the index and the units (numbers or biomass). The estimated population numbers at age are modified to the time of the index according to

$$N*_{ind,t,a} = N_{t,a}\frac{1-e^{-Z_{t,a}}}{Z_{t,a}} \quad (22)$$

if the index month is set to -1, corresponding to an average abundance, or

$$N*_{ind,t,a} = N_{t,a}(1-e^{-(ind\_month/12)Z_{t,a}}) \quad (23)$$

for index month between 0 and 12. Note that the index month refers to the end of the month, so *ind_month*=0 is January 1 and *ind_month*=12 is December 31. If the units for an index are biomass, then the N* values are multiplied by the user defined weights at age matrix. The selectivity associated with each index is either matched to a fleet or else input. If the selectivity for a fleet is input, it can be either fixed or estimated in the same way as the fleet selectivities (age based, logistic, or double logistic). The final predicted index (*Ipred*) is formed by summing the product of N* and selectivity values over the appropriate ages and multiplying by the catchability for the index

$$Ipred_{ind,t} = q_{ind,t}\sum_{a=indstart}^{indend} N*_{ind,t,a}\, Sel_{ind,t,a} \quad (24)$$

If the user selects to estimate the proportions at age for an index, then the proportions at age are computed in the same manner as the landings and discards at age (equations 19 and 20). Note that the units used for the aggregate index and proportions at age are set by the user separately, so all four combinations of numbers and biomass are possible.

Reference Points

The program computes a number of common reference points based on the estimated F and biological characteristics of the final year in the assessment. The reference points derive a directed and discard selectivity pattern from all the fleets that were assigned to be directed by summing the F at age and dividing by the maximum directed F. The non-directed F is summed over all fleets that were not assigned as directed, and these F values are fixed during the reference point calculations. The F reference points are computed through a bisection algorithm that is repeated 20 times (producing an accuracy of approximately 1E-05). The reference points computed are $F_{0.1}$, F_{MAX}, $F_{30\%SPR}$, $F_{40\%SPR}$, and F_{MSY}. The associated maximum sustainable yield and spawning stock biomass at F_{MSY} are also provided. The reference point values are averaged in the same manner as the Freport to allow direct comparison. Note, however, that if selectivity or biological characteristics change over time, these comparisons will not be accurate because the reference points are computed assuming the final year values. The program now computes the annual unexploited SSB, unexploited R, unexploited SSB per R, and steepness to demonstrate the potential for change in the F reference points.

Projections

The projections use the same basic calculations as the main assessment program, except that there is no fitting done. The recruitments for each projection year can either be entered by the user or else be derived from the stock recruitment curve (without deviations from the curve). The directed and discard selectivity as well as the bycatch F at age are the same as used in the reference point calculations. There are five options to define what is used to define the fishery in each projections year:

1. match an input directed catch in weight
2. fish at an input F%SPR
3. fish at F_{MSY}
4. fish at the current (terminal year) F
5. fish at an input F

Each year the bycatch F can be modified from the terminal year to examine either increases or decreases in this(these) fishery(ies).

Objective Function Calculation (Fitting the Model)

The objective function in ASAP3 is the sum of a number of model fits and two penalties. There are two types of error distributions in the calculation of the objective function: lognormal and multinomial. Both are converted to negative log likelihoods for use in the minimization conducted by ADMB. Both error distributions contain constant terms that do not change for any value of the parameters. These constants can be either included or excluded from the objective function. Note that since the weights for different components of the objective function multiply the constants, different solutions may result when the constants are included or not.

The lognormal model fits all contain a lambda value that allows emphasis of that particular part of the objective function along with an input coefficient of variation (CV) that is used to measure how strong a particular deviation is. The CV is converted to a variance (σ^2) and associated standard deviation (σ) using the equation

$$\sigma^2 = \ln(CV^2 + 1) \quad (25)$$

The lognormal distribution has a negative log likelihood, *-ln(L)*, defined by

$$-\ln(L) = 0.5\ln(2\pi) + \sum \ln(obs_i) + \ln(\sigma) + 0.5\sum \frac{(\ln(obs_i) - \ln(pred_i))^2}{\sigma^2} \quad (26)$$

The first two terms on the right side of equation (26) are the constants that are optionally kept or set to zero. The objective function is calculated as

$$obj\ fxn = \lambda * (-\ln(L)) \quad (27)$$

So that any component of the objective function can be turned off by setting λ for that component to zero. Standardized residuals for each component are calculated as

$$std\ resid_i = \frac{\ln(obs_i) - \ln(pred_i)}{\sigma} \quad (28)$$

In a perfectly fit model, the standardized residuals would have mean zero and standard deviation one.

The multinomial distribution fits employ an input effective sample size to multiply the negative log likelihood when calculating the objective function. This distribution is made up of k bins each containing p_i proportion of the total (sum of p_i=1). The input effective sample size (*ESS*) is used to create the number of fish in each bin (n_i) as $n_i=ESS*p_i$. The multinomial distribution then has a negative log likelihood defined by

$$-\ln(L) = -\ln(ESS!) + \sum_{i=1}^{k} \ln(n_i!) - ESS\sum_{i=1}^{k} p_i \ln(predp_i) \quad (29)$$

where p_i denotes an observed proportion and $predp_i$ denotes the associated predicted proportion. The first two terms on the right side of equation (29) are the constants that are optionally kept or set to zero. The objective function is simply the negative log likelihood for the multinomial distribution because the effective sample size is an integral part of the calculation of the likelihood.

The lognormal error distribution is assumed for

- Total catch in weight
- Total discards in weight
- Indices
- Stock recruitment relationship
- Selectivity parameters (relative to initial guesses)
- The two stock recruitment parameters (relative to their initial guesses)
- Fmult in year 1 by fleet (relative to initial guesses)
- Fmult deviations
- Catchability in year 1 by fleet (relative to initial guesses)
- Catchability deviations
- Numbers at age in year 1 (relative to either initial guesses or a population in equilibrium)

Multinomial distribution is assumed for

- Catch at age
- Discards at age
- Index proportions at age

The two penalties are formed from estimated total fishing mortality rates. The first is a penalty associated with any total F greater than an input maximum value, calculated as $1000*(F-Fmax)^2$ for F>Fmax. The second penalty is for F different than M in the early phases, calculated as $100*10^{-phase} (\ln(avg(F)-\ln(M))^2$. The second penalty is always set to zero in the final estimation phase, regardless of the number of phases.

Appendix 1: Source Code for ASAP3

(Note the code sometimes wraps around to the next line in the presentation here.)

```
// ASAP3 (Age Structured Assessment Program Version 3: August 2012)
//   by Christopher Legault with major contributions from Liz Brooks
//   modified from ASAP2 by Christopher Legault
//   modified from original ASAP by Christopher Legault and Victor Restrepo 1998

// Major changes from ASAP2
// user defines SR curve using steepness and either R0 or S0
// allow user to mix and match biomass and numbers for aggreagate indices and indices proportions at age
// user enters a number of weight at age matrices then defines which are used for catch, discards, SSB, Jan-1 B,
and indices
// compute annual SR curve estimates of R0, S0, steepness, and spawners per recruit to show how changes in M,
fecundity, WAA impact these estimates over time
// expected population at age in year 1 can be either an exponential decline or user initial guesses for
optional deviation calculations
// compute Francis (2011) stage 2 multiplier for multinomial to adjust input Neff

// update April 2012
// fix bug with which inconsistent year for M and WAA used in calculation of unexploited SSB per recruit
// (was first year when all other calculations were last year, now everything last year)
// also added trap for division by zero in Freport calculation to avoid crashes when pop size gets small
// incorporated Liz Brook's make-Rfile.cxx for ADMB2R to optionally create rdat file automatically
// created new output file asap2RMSE.dat for use with R script

// update April 2008
// fixed bug in get_log_factorial function - variable could be i used in two places (thanks to Tim Miller for
finding this one)
//
// Major changes from original ASAP
//
// Enter all available indices and then select which ones to use for tuning
// Change in selectivity estimation to reduce parameter correlations
//   Added option to use logistic or double logistic selectivity patterns
//   Selectivity blocks now independent with own initial starting guesses
// Added CVs and lambdas for many parameters
// Multiple matrices for weights at age at different times of the year
// M matrix instead of vector
// Freport feature to allow easier comparison among years with different selectivity patterns
// Echo input read to file for improved debugging
// MCMC capability added
//   One file for Freport, SSB, and MSY related variables
//   One file for use in AgePro software (.bsn file)
// Full likelihood calculations, including (optionally) constants
// Output of standardized residuals
// Modified year 1 recruitment deviation calculations to reduce probability of extremely large residual

TOP_OF_MAIN_SECTION
// set buffer sizes
  arrmblsize=5000000;
  gradient_structure::set_GRADSTACK_BUFFER_SIZE(10000000);
  gradient_structure::set_MAX_NVAR_OFFSET(50000);
  gradient_structure::set_NUM_DEPENDENT_VARIABLES(10000);
  time(&start); //this is to see how long it takes to run
  cout << endl << "Start time : " << ctime(&start) << endl;

GLOBALS_SECTION
  #include <admodel.h>
  #include <time.h>
  #include <C:\ADMB\admb2r-1.15\admb2r\admb2r.cpp>
  time_t start,finish;
  long hour,minute,second;
  double elapsed_time;
  ofstream ageproMCMC("asap3.bsn");
  ofstream basicMCMC("asap3MCMC.dat");
  ofstream inputlog("asap3input.log");
  //--- preprocessor macro from Larry Jacobson NMFS-Woods Hole
```

```
  #define ICHECK(object) inputlog << "#" #object "\n " << object << endl;

DATA_SECTION
  int debug
  int iyear
  int iage
  int ia
  int ifleet
  int ind
  int i
  int j
  int k
  int iloop
  int io
  number pi
 !!  pi=3.14159265358979;
  number CVfill
 !! CVfill=100.0;
// basic dimensions
  init_int nyears
 !! ICHECK(nyears);
  init_int year1
 !! ICHECK(year1);
  init_int nages
 !! ICHECK(nages);
  init_int nfleets
 !! ICHECK(nfleets);
  init_int nselblocks;
 !! ICHECK(nselblocks);
  init_int navailindices
 !! ICHECK(navailindices);

// biology
  init_matrix M(1,nyears,1,nages)
 !! ICHECK(M);
  init_number isfecund
 !! ICHECK(isfecund);
  init_number fracyearSSB
 !! ICHECK(fracyearSSB);
  init_matrix mature(1,nyears,1,nages)
 !! ICHECK(mature);
  init_int nWAAmatrices
 !! ICHECK(nWAAmatrices);
  int nrowsWAAini
 !! nrowsWAAini=nyears*nWAAmatrices;
  init_matrix WAA_ini(1,nrowsWAAini,1,nages)
 !! ICHECK(WAA_ini);
  int nWAApointbio
 !! nWAApointbio=nfleets*2+2+2;
  init_ivector WAApointbio(1,nWAApointbio) // pointers to WAA matrix for fleet catch and discards, catch all
fleets, discard all fleets, SSB, and Jan1B
 !! ICHECK(WAApointbio);
  matrix fecundity(1,nyears,1,nages)
  3darray WAAcatchfleet(1,nfleets,1,nyears,1,nages)
  3darray WAAdiscardfleet(1,nfleets,1,nyears,1,nages)
  matrix WAAcatchall(1,nyears,1,nages)
  matrix WAAdiscardall(1,nyears,1,nages)
  matrix WAAssb(1,nyears,1,nages)
  matrix WAAjan1b(1,nyears,1,nages)
 LOCAL_CALCS
  if ((max(WAApointbio) > nWAAmatrices) || (min(WAApointbio) < 1))
  {
     cout << "Problem with WAApointbio" << endl;
     ad_exit(1);
  }
  for (ifleet=1;ifleet<=nfleets;ifleet++)
  {
     int ipointcatchfleet=(WAApointbio((ifleet*2)-1)-1)*nyears;
     int ipointdiscardfleet=(WAApointbio(ifleet*2)-1)*nyears;
     for (iyear=1;iyear<=nyears;iyear++)
     {
```

```
        WAAcatchfleet(ifleet,iyear)=WAA_ini((ipointcatchfleet+iyear));
        WAAdiscardfleet(ifleet,iyear)=WAA_ini((ipointdiscardfleet+iyear));
     }
  }
  int ipointcatchall=(WAApointbio((nfleets*2)+1)-1)*nyears;
  int ipointdiscardall=(WAApointbio((nfleets*2)+2)-1)*nyears;
  int ipointssb=(WAApointbio((nfleets*2)+3)-1)*nyears;
  int ipointjan1b=(WAApointbio((nfleets*2)+4)-1)*nyears;
  for (iyear=1;iyear<=nyears;iyear++)
  {
     WAAcatchall(iyear)=WAA_ini((ipointcatchall+iyear));
     WAAdiscardall(iyear)=WAA_ini((ipointdiscardall+iyear));
     WAAssb(iyear)=WAA_ini((ipointssb+iyear));
     WAAjan1b(iyear)=WAA_ini((ipointjan1b+iyear));
  }
  if (isfecund==1)
     fecundity=mature;
  else
     fecundity=elem_prod(WAAssb,mature);
 END_CALCS

// fleet names here with $ in front of label

// Selectivity ****************************************
// need to enter values for all options even though only one will be used for each block
  init_matrix sel_blocks(1,nfleets,1,nyears) // defines blocks for each fleet in successive order
 !! ICHECK(sel_blocks);
  int nsel_ini
 !! nsel_ini=nselblocks*(nages+6);
  init_ivector sel_option(1,nselblocks) // 1=by age, 2=logisitic, 3=double logistic
 !! ICHECK(sel_option);
  init_matrix sel_ini(1,nsel_ini,1,4) // 1st value is initial guess, 2nd is phase, 3rd is lambda, 4th is CV
 !! ICHECK(sel_ini);
  int nselparm
 LOCAL_CALCS
// first count number of selectivity parameters and replace CV=0 with CVfill
  nselparm=0;
  for (i=1;i<=nselblocks;i++)
  {
     if (sel_option(i)==1) nselparm+=nages;
     if (sel_option(i)==2) nselparm+=2;
     if (sel_option(i)==3) nselparm+=4;
  }
  for (i=1;i<=nsel_ini;i++)
  {
     if (sel_ini(i,4) <= 0.0)
         sel_ini(i,4) = CVfill;
  }
 END_CALCS
  vector sel_initial(1,nselparm)
  vector sel_lo(1,nselparm)
  vector sel_hi(1,nselparm)
  ivector sel_phase(1,nselparm)
  vector sel_lambda(1,nselparm)
  vector sel_CV(1,nselparm)
  vector sel_sigma2(1,nselparm)
  vector sel_sigma(1,nselparm)
  vector sel_like_const(1,nselparm)
 LOCAL_CALCS
// now assign bounds and phases for each selectivity parameter
  k=0;
  for (i=1;i<=nselblocks;i++){
     if (sel_option(i)==1) {
        for (iage=1;iage<=nages;iage++) {
           k+=1;
           j=(i-1)*(nages+6)+iage;
           sel_initial(k)=sel_ini(j,1);
           sel_lo(k)=0.0;
           sel_hi(k)=1.0;
           sel_phase(k)=sel_ini(j,2);
           sel_lambda(k)=sel_ini(j,3);
```

```
            sel_CV(k)=sel_ini(j,4);
            sel_sigma2(k)=log(sel_CV(k)*sel_CV(k)+1.0);
            sel_sigma(k)=sqrt(sel_sigma2(k));
         }
      }
      if (sel_option(i)==2) {
         for (ia=1;ia<=2;ia++) {
            k+=1;
            j=(i-1)*(nages+6)+nages+ia;
            sel_initial(k)=sel_ini(j,1);
            sel_lo(k)=0.0;
            sel_hi(k)=nages;
            sel_phase(k)=sel_ini(j,2);
            sel_lambda(k)=sel_ini(j,3);
            sel_CV(k)=sel_ini(j,4);
            sel_sigma2(k)=log(sel_CV(k)*sel_CV(k)+1.0);
            sel_sigma(k)=sqrt(sel_sigma2(k));
         }
      }
      if (sel_option(i)==3) {
         for (ia=1;ia<=4;ia++) {
            k+=1;
            j=(i-1)*(nages+6)+nages+2+ia;
            sel_initial(k)=sel_ini(j,1);
            sel_lo(k)=0.0;
            sel_hi(k)=nages;
            sel_phase(k)=sel_ini(j,2);
            sel_lambda(k)=sel_ini(j,3);
            sel_CV(k)=sel_ini(j,4);
            sel_sigma2(k)=log(sel_CV(k)*sel_CV(k)+1.0);
            sel_sigma(k)=sqrt(sel_sigma2(k));
         }
      }
   }
  END_CALCS
   init_ivector sel_start_age(1,nfleets)
  !! ICHECK(sel_start_age);
   init_ivector sel_end_age(1,nfleets)
  !! ICHECK(sel_end_age);

   init_int Freport_agemin
  !! ICHECK(Freport_agemin);
   init_int Freport_agemax
  !! ICHECK(Freport_agemax);
   init_int Freport_wtopt
  !! ICHECK(Freport_wtopt);

   init_int use_likelihood_constants
  !! ICHECK(use_likelihood_constants);
   init_vector release_mort(1,nfleets)
  !! ICHECK(release_mort);

// Catch ******************************************
// Includes both landed and discarded components
   init_matrix CAA_ini(1,nyears*nfleets,1,nages+1)
  !! ICHECK(CAA_ini);
   init_matrix Discard_ini(1,nyears*nfleets,1,nages+1)
  !! ICHECK(Discard_ini);
   init_matrix proportion_release_ini(1,nyears*nfleets,1,nages)
  !! ICHECK(proportion_release_ini);
   3darray CAA_obs(1,nfleets,1,nyears,1,nages)
   3darray Discard_obs(1,nfleets,1,nyears,1,nages)
   3darray proportion_release(1,nfleets,1,nyears,1,nages)
   3darray CAA_prop_obs(1,nfleets,1,nyears,sel_start_age,sel_end_age)
   3darray Discard_prop_obs(1,nfleets,1,nyears,sel_start_age,sel_end_age)
   number catch_prop_like_const
   number discard_prop_like_const
   matrix Catch_tot_fleet_obs(1,nfleets,1,nyears)
   matrix Discard_tot_fleet_obs(1,nfleets,1,nyears)
   matrix CAA_prop_obs_sum(1,nfleets,1,nyears)
   matrix Discard_prop_obs_sum(1,nfleets,1,nyears)
```

```
  vector catch_tot_like_const(1,nfleets)
  vector discard_tot_like_const(1,nfleets)
 LOCAL_CALCS
  for (ifleet=1;ifleet<=nfleets;ifleet++)
  {
     catch_tot_like_const(ifleet)=0.0;
     discard_tot_like_const(ifleet)=0.0;
     for (iyear=1;iyear<=nyears;iyear++)
     {
        CAA_obs(ifleet,iyear)(1,nages)=CAA_ini((ifleet-1)*nyears+iyear)(1,nages);
        Discard_obs(ifleet,iyear)(1,nages)=Discard_ini((ifleet-1)*nyears+iyear)(1,nages);
        proportion_release(ifleet,iyear)=proportion_release_ini((ifleet-1)*nyears+iyear)(1,nages);
        Catch_tot_fleet_obs(ifleet,iyear)=CAA_ini((ifleet-1)*nyears+iyear,nages+1);
        Discard_tot_fleet_obs(ifleet,iyear)=Discard_ini((ifleet-1)*nyears+iyear,nages+1);
        if (Catch_tot_fleet_obs(ifleet,iyear)>1.0e-15)
           catch_tot_like_const(ifleet)+=0.5*log(2.0*pi)+log(Catch_tot_fleet_obs(ifleet,iyear));
        if (Discard_tot_fleet_obs(ifleet,iyear)>1.0e-15)
           discard_tot_like_const(ifleet)=0.5*log(2.0*pi)+log(Discard_tot_fleet_obs(ifleet,iyear));
     }
  }
  if (use_likelihood_constants != 1)
  {
     catch_tot_like_const=0.0;
     discard_tot_like_const=0.0;
  }
  CAA_prop_obs=0.0;
  Discard_prop_obs=0.0;
  CAA_prop_obs_sum=0.0;
  Discard_prop_obs_sum=0.0;
  for (iyear=1;iyear<=nyears;iyear++)
  {
    for (ifleet=1;ifleet<=nfleets;ifleet++)
    {
       if (Catch_tot_fleet_obs(ifleet,iyear)>0.0)
       {
          for (iage=sel_start_age(ifleet);iage<=sel_end_age(ifleet);iage++)
             CAA_prop_obs_sum(ifleet,iyear)+=CAA_obs(ifleet,iyear,iage);
          if (CAA_prop_obs_sum(ifleet,iyear)==0.0)
          {
             CAA_prop_obs(ifleet,iyear)=0.0;
          }
          else
          {

CAA_prop_obs(ifleet,iyear)=CAA_obs(ifleet,iyear)(sel_start_age(ifleet),sel_end_age(ifleet))/CAA_prop_obs_sum(ifl
eet,iyear);
          }
       }
       if (Discard_tot_fleet_obs(ifleet,iyear)>0.0)
       {
          for (iage=sel_start_age(ifleet);iage<=sel_end_age(ifleet);iage++)
             Discard_prop_obs_sum(ifleet,iyear)+=Discard_obs(ifleet,iyear,iage);
          if (Discard_prop_obs_sum(ifleet,iyear)==0.0)
          {
             Discard_prop_obs(ifleet,iyear)=0.0;
          }
          else
          {

Discard_prop_obs(ifleet,iyear)=Discard_obs(ifleet,iyear)(sel_start_age(ifleet),sel_end_age(ifleet))/Discard_prop
_obs_sum(ifleet,iyear);
          }
       }
    }
  }
 END_CALCS

// Indices ******************************
// Enter in all available indices and then pick the ones that are to be used in objective function
// navailindices is the number of indices entered
// nindices is the number of indices used (calculated by program)
```

```
  int indavail
// index names here with $ in front of label
  init_vector index_units_aggregate_ini(1,navailindices) // 1=biomass, 2=numbers
 !! ICHECK(index_units_aggregate_ini);
  init_vector index_units_proportions_ini(1,navailindices) // 1=biomass, 2=numbers
 !! ICHECK(index_units_proportions_ini);
  init_ivector index_WAApoint_ini(1,navailindices) // pointer for which WAA matrix to use for biomass
calculations for each index
 !! ICHECK(index_WAApoint_ini);
  init_vector index_month_ini(1,navailindices) // -1=average pop
 !! ICHECK(index_month_ini);
  init_ivector index_sel_choice_ini(1,navailindices) // -1=fixed
 !! ICHECK(index_sel_choice_ini);
  init_ivector index_sel_option_ini(1,navailindices) // 1=by age, 2=logisitic, 3=double logistic
 !! ICHECK(index_sel_option_ini);
  init_ivector index_start_age_ini(1,navailindices)
 !! ICHECK(index_start_age_ini);
  init_ivector index_end_age_ini(1,navailindices)
 !! ICHECK(index_end_age_ini);
  init_ivector index_estimate_proportions_ini(1,navailindices) // 1=yes
 !! ICHECK(index_estimate_proportions_ini);
  init_ivector use_index(1,navailindices) // 1=yes
 !! ICHECK(use_index);
  int nindexsel_ini
 !! nindexsel_ini=navailindices*(nages+6);
  init_matrix index_sel_ini(1,nindexsel_ini,1,4) // 1st value is initial guess, 2nd is phase, 3rd is lambda, 4th
is CV
 !! ICHECK(index_sel_ini);
  init_matrix index_ini(1,nyears*navailindices,1,3+nages+1) // year, index value, CV, proportions at age, input
effective sample size
 !! ICHECK(index_ini);
  int nindices
 !! nindices=sum(use_index);
  vector index_units_aggregate(1,nindices)
  vector index_units_proportions(1,nindices)
  ivector index_WAApoint(1,nindices)
  vector index_month(1,nindices)
  vector index_sel_option(1,nindices)
  vector index_start_age(1,nindices)
  vector index_end_age(1,nindices)
  vector index_sel_choice(1,nindices)
  ivector index_nobs(1,nindices)
  ivector index_estimate_proportions(1,nindices)
  int nindexselparms
 LOCAL_CALCS
  if ((max(index_WAApoint_ini) > nWAAmatrices) || (min(index_WAApoint_ini) < 1))
  {
     cout << "Problem with index_WAApoint_ini" << endl;
     ad_exit(1);
  }
  for (i=1;i<=nindexsel_ini;i++)
  {
     if (index_sel_ini(i,4) <= 0.0)
         index_sel_ini(i,4) = CVfill;
  }
  for (i=1;i<=nyears*navailindices;i++)
  {
     if (index_ini(i,3) <= 0.0)
         index_ini(i,3) = CVfill;
  }
  ind=0;
  nindexselparms=0;
  for (indavail=1;indavail<=navailindices;indavail++)
  {
     if (use_index(indavail)==1)
     {
       ind+=1;
       index_units_aggregate(ind)=index_units_aggregate_ini(indavail);
       index_units_proportions(ind)=index_units_proportions_ini(indavail);
       index_WAApoint(ind)=index_WAApoint_ini(indavail);
       index_month(ind)=index_month_ini(indavail);
```

```
        index_sel_option(ind)=index_sel_option_ini(indavail);
        if (index_sel_option(ind)==1) nindexselparms+=nages;
        if (index_sel_option(ind)==2) nindexselparms+=2;
        if (index_sel_option(ind)==3) nindexselparms+=4;
        index_start_age(ind)=index_start_age_ini(indavail);
        index_end_age(ind)=index_end_age_ini(indavail);
        index_sel_choice(ind)=index_sel_choice_ini(indavail);
        index_estimate_proportions(ind)=index_estimate_proportions_ini(indavail);
        j=0;
        for (iyear=1;iyear<=nyears;iyear++)
        {
          if (index_ini((indavail-1)*nyears+iyear,2)>0.0)  // zero or negative value for index means not included
              j+=1;
        }
        index_nobs(ind)=j;
      }
   }
  END_CALCS
   matrix index_time(1,nindices,1,index_nobs)
   matrix index_year(1,nindices,1,index_nobs)
   matrix index_obs(1,nindices,1,index_nobs)
   matrix index_cv(1,nindices,1,index_nobs)
   matrix index_sigma2(1,nindices,1,index_nobs)
   matrix index_sigma(1,nindices,1,index_nobs)
   matrix input_eff_samp_size_index(1,nindices,1,index_nobs)
   vector indexsel_initial(1,nindexselparms)
   vector indexsel_lo(1,nindexselparms)
   vector indexsel_hi(1,nindexselparms)
   ivector indexsel_phase(1,nindexselparms)
   vector indexsel_lambda(1,nindexselparms)
   vector indexsel_CV(1,nindexselparms)
   vector indexsel_sigma2(1,nindexselparms)
   vector indexsel_sigma(1,nindexselparms)
   vector indexsel_like_const(1,nindexselparms)
   number index_prop_like_const
   3darray index_sel_input(1,nindices,1,nyears,1,nages)
   3darray index_prop_obs(1,nindices,1,index_nobs,1,nages)
   3darray index_WAA(1,nindices,1,nyears,1,nages)
   vector index_like_const(1,nindices)
   number tempsum
  LOCAL_CALCS
   index_prop_obs=0.0;
   ind=0;
   k=0;
   for (indavail=1;indavail<=navailindices;indavail++)
   {
      if (use_index(indavail)==1)
      {
        ind+=1;
// get the index selectivity information
       if (index_sel_option(ind)==1)
       {
          for (iage=1;iage<=nages;iage++)
          {
             k+=1;
             j=(indavail-1)*(nages+6)+iage;
             indexsel_initial(k)=index_sel_ini(j,1);
             indexsel_lo(k)=0.0;
             indexsel_hi(k)=1.0;
             indexsel_phase(k)=index_sel_ini(j,2);
             indexsel_lambda(k)=index_sel_ini(j,3);
             indexsel_CV(k)=index_sel_ini(j,4);
             indexsel_sigma2(k)=log(indexsel_CV(k)*indexsel_CV(k)+1.0);
             indexsel_sigma(k)=sqrt(indexsel_sigma2(k));
          }
       }
       else if (index_sel_option(ind)==2)
       {
          for (ia=1;ia<=2;ia++)
          {
             k+=1;
```

```
            j=(indavail-1)*(nages+6)+nages+ia;
            indexsel_initial(k)=index_sel_ini(j,1);
            indexsel_lo(k)=0.0;
            indexsel_hi(k)=nages;
            indexsel_phase(k)=index_sel_ini(j,2);
            indexsel_lambda(k)=index_sel_ini(j,3);
            indexsel_CV(k)=index_sel_ini(j,4);
            indexsel_sigma2(k)=log(indexsel_CV(k)*indexsel_CV(k)+1.0);
            indexsel_sigma(k)=sqrt(indexsel_sigma2(k));
         }
      }
      else if (index_sel_option(ind)==3)
      {
         for (ia=1;ia<=4;ia++)
         {
            k+=1;
            j=(indavail-1)*(nages+6)+nages+2+ia;
            indexsel_initial(k)=index_sel_ini(j,1);
            indexsel_lo(k)=0.0;
            indexsel_hi(k)=nages;
            indexsel_phase(k)=index_sel_ini(j,2);
            indexsel_lambda(k)=index_sel_ini(j,3);
            indexsel_CV(k)=index_sel_ini(j,4);
            indexsel_sigma2(k)=log(indexsel_CV(k)*indexsel_CV(k)+1.0);
            indexsel_sigma(k)=sqrt(indexsel_sigma2(k));
         }
      }

// get the index and year specific information
       j=0;
       for (iyear=1;iyear<=nyears;iyear++)
       {
         i=(indavail-1)*nyears+iyear;
         index_sel_input(ind,iyear)=--(--(--index_ini(i)(4,3+nages)));
         if (index_ini(i,2)>0.0)
         {
             j+=1;
             index_time(ind,j)=index_ini(i,1)-year1+1;
             index_year(ind,j)=index_ini(i,1);
             index_obs(ind,j)=index_ini(i,2);
             index_cv(ind,j)=index_ini(i,3);
             index_sigma2(ind,j)=log(index_cv(ind,j)*index_cv(ind,j)+1.0);
             index_sigma(ind,j)=sqrt(index_sigma2(ind,j));
             input_eff_samp_size_index(ind,j)=index_ini(i,nages+4);
             tempsum=sum(index_sel_input(ind,iyear)(index_start_age(ind),index_end_age(ind)));
             if (tempsum > 0.0)
             {
                 for (iage=index_start_age(ind);iage<=index_end_age(ind);iage++)
                 {
                     index_prop_obs(ind,j,iage)=index_sel_input(ind,iyear,iage)/tempsum;
                 }
             }
         }
       }
     }
  }
  index_like_const=0.0;
  if (use_likelihood_constants==1)
  {
     for (ind=1;ind<=nindices;ind++)
     {
        index_like_const(ind)=0.5*double(index_nobs(ind))*log(2.0*pi)+sum(log(index_obs(ind)));
     }
  }

// set up the index_WAA matrices (indices in numbers only will have WAA set to 0)
  index_WAA=0.0;
  for (ind=1;ind<=nindices;ind++)
  {
     if (index_units_aggregate(ind)==1 || index_units_proportions(ind)==1)
     {
```

```
        int ipointindex=(index_WAApoint(ind)-1)*nyears;
        for (iyear=1;iyear<=nyears;iyear++)
        {
           index_WAA(ind,iyear)=WAA_ini((ipointindex+iyear));
        }
     }
  }
 END_CALCS

// Phase Controls (other than selectivity)
  init_int phase_Fmult_year1
 !! ICHECK(phase_Fmult_year1);
  init_int phase_Fmult_devs
 !! ICHECK(phase_Fmult_devs);
  init_int phase_recruit_devs
 !! ICHECK(phase_recruit_devs);
  init_int phase_N_year1_devs
 !! ICHECK(phase_N_year1_devs);
  init_int phase_q_year1
 !! ICHECK(phase_q_year1);
  init_int phase_q_devs
 !! ICHECK(phase_q_devs);
  init_int phase_SR_scaler
 !! ICHECK(phase_SR_scaler);
  init_int phase_steepness
 !! ICHECK(phase_steepness);
  init_vector recruit_CV(1,nyears)
 !! ICHECK(recruit_CV);
  vector recruit_sigma2(1,nyears)
  vector recruit_sigma(1,nyears)
  number SR_like_const
 LOCAL_CALCS
  for (iyear=1;iyear<=nyears;iyear++)
  {
    if (recruit_CV(iyear) <= 0.0)
        recruit_CV(iyear) = CVfill;
    recruit_sigma2(iyear)=log(recruit_CV(iyear)*recruit_CV(iyear)+1.0);
    recruit_sigma(iyear)=sqrt(recruit_sigma2(iyear));
  }
  SR_like_const=0.0;
  if (use_likelihood_constants == 1)
     SR_like_const=0.5*double(nyears)*log(2.0*pi);
 END_CALCS
  init_vector lambda_ind_ini(1,navailindices)
 !! ICHECK(lambda_ind_ini);
  init_vector lambda_catch_tot(1,nfleets)
 !! ICHECK(lambda_catch_tot);
  init_vector lambda_Discard_tot(1,nfleets)
 !! ICHECK(lambda_Discard_tot);
  init_matrix catch_tot_CV(1,nyears,1,nfleets)
 !! ICHECK(catch_tot_CV);
  init_matrix discard_tot_CV(1,nyears,1,nfleets)
 !! ICHECK(discard_tot_CV);
  matrix catch_tot_sigma2(1,nfleets,1,nyears)
  matrix catch_tot_sigma(1,nfleets,1,nyears)
  matrix discard_tot_sigma2(1,nfleets,1,nyears)
  matrix discard_tot_sigma(1,nfleets,1,nyears)
  init_matrix input_eff_samp_size_catch_ini(1,nyears,1,nfleets)
 !! ICHECK(input_eff_samp_size_catch_ini);
  init_matrix input_eff_samp_size_discard_ini(1,nyears,1,nfleets)
 !! ICHECK(input_eff_samp_size_discard_ini);
  matrix input_eff_samp_size_catch(1,nfleets,1,nyears)
  matrix input_eff_samp_size_discard(1,nfleets,1,nyears)
  number nfact_in
  number nfact_out
 LOCAL_CALCS
  for(iyear=1;iyear<=nyears;iyear++)
  {
   for(ifleet=1;ifleet<=nfleets;ifleet++)
   {
     if (catch_tot_CV(iyear,ifleet) <= 0.0)
```

```
        catch_tot_CV(iyear,ifleet) = CVfill;
    if (discard_tot_CV(iyear,ifleet) <= 0.0)
        discard_tot_CV(iyear,ifleet) = CVfill;
    catch_tot_sigma2(ifleet,iyear)=log(catch_tot_CV(iyear,ifleet)*catch_tot_CV(iyear,ifleet)+1.0);
    catch_tot_sigma(ifleet,iyear)=sqrt(catch_tot_sigma2(ifleet,iyear));
    discard_tot_sigma2(ifleet,iyear)=log(discard_tot_CV(iyear,ifleet)*discard_tot_CV(iyear,ifleet)+1.0);
    discard_tot_sigma(ifleet,iyear)=sqrt(discard_tot_sigma2(ifleet,iyear));
    input_eff_samp_size_catch(ifleet,iyear)=input_eff_samp_size_catch_ini(iyear,ifleet);
    input_eff_samp_size_discard(ifleet,iyear)=input_eff_samp_size_discard_ini(iyear,ifleet);
  }
 }
END_CALCS
 init_vector lambda_Fmult_year1(1,nfleets)
!! ICHECK(lambda_Fmult_year1);
 init_vector Fmult_year1_CV(1,nfleets)
!! ICHECK(Fmult_year1_CV);
 init_vector lambda_Fmult_devs(1,nfleets)
!! ICHECK(lambda_Fmult_devs);
 init_vector Fmult_devs_CV(1,nfleets)
!! ICHECK(Fmult_devs_CV);
 init_number lambda_N_year1_devs
!! ICHECK(lambda_N_year1_devs);
 init_number N_year1_CV
!! ICHECK(N_year1_CV);
 init_number lambda_recruit_devs
!! ICHECK(lambda_recruit_devs);
 init_vector lambda_q_year1_ini(1,navailindices)
!! ICHECK(lambda_q_year1_ini);
 init_vector q_year1_CV_ini(1,navailindices)
!! ICHECK(q_year1_CV_ini);
 init_vector lambda_q_devs_ini(1,navailindices)
!! ICHECK(lambda_q_devs_ini);
 init_vector q_devs_CV_ini(1,navailindices)
!! ICHECK(q_devs_CV_ini);
 init_number lambda_steepness
!! ICHECK(lambda_steepness);
 init_number steepness_CV
!! ICHECK(steepness_CV);
 init_number lambda_SR_scaler
!! ICHECK(lambda_SR_scaler);
 init_number SR_scaler_CV
!! ICHECK(SR_scaler_CV);
LOCAL_CALCS
 for (i=1;i<=nfleets;i++)
 {
    if (Fmult_year1_CV(i) <= 0.0)
        Fmult_year1_CV(i) = CVfill;
    if (Fmult_devs_CV(i) <= 0.0)
        Fmult_devs_CV(i) = CVfill;
 }
 if (N_year1_CV <= 0.0)
     N_year1_CV = CVfill;
 for (i=1;i<=navailindices;i++)
 {
    if (q_year1_CV_ini(i) <= 0.0)
        q_year1_CV_ini(i) = CVfill;
    if (q_devs_CV_ini(i) <= 0.0)
        q_devs_CV_ini(i) = CVfill;
 }
 if (steepness_CV <= 0.0)
     steepness_CV = CVfill;
 if (SR_scaler_CV <= 0.0)
     SR_scaler_CV = CVfill;
END_CALCS
 vector Fmult_year1_sigma2(1,nfleets)
 vector Fmult_year1_sigma(1,nfleets)
 vector Fmult_year1_like_const(1,nfleets)
 vector Fmult_devs_sigma2(1,nfleets)
 vector Fmult_devs_sigma(1,nfleets)
 vector Fmult_devs_like_const(1,nfleets)
 number N_year1_sigma2
```

```
  number N_year1_sigma
  number N_year1_like_const
  vector lambda_ind(1,nindices)
  vector lambda_q_year1(1,nindices)
  vector q_year1_CV(1,nindices)
  vector q_year1_sigma2(1,nindices)
  vector q_year1_sigma(1,nindices)
  vector q_year1_like_const(1,nindices)
  vector lambda_q_devs(1,nindices)
  vector q_devs_CV(1,nindices)
  vector q_devs_sigma2(1,nindices)
  vector q_devs_sigma(1,nindices)
  vector q_devs_like_const(1,nindices)
  number steepness_sigma2
  number steepness_sigma
  number steepness_like_const
  number SR_scaler_sigma2
  number SR_scaler_sigma
  number SR_scaler_like_const

// starting guesses
  init_int NAA_year1_flag // 1 for devs from exponential decline, 2 for devs from initial guesses
 !! ICHECK(NAA_year1_flag);
  init_vector NAA_year1_ini(1,nages)
 !! ICHECK(NAA_year1_ini);
  init_vector Fmult_year1_ini(1,nfleets)
 !! ICHECK(Fmult_year1_ini);
  init_vector q_year1_iniavail(1,navailindices)
 !! ICHECK(q_year1_iniavail);
  vector q_year1_ini(1,nindices)
  init_number is_SR_scaler_R // 1 for R0, 0 for SSB0
 !! ICHECK(is_SR_scaler_R);
  init_number SR_scaler_ini
 !! ICHECK(SR_scaler_ini);
  init_number SR_steepness_ini
 !! ICHECK(SR_steepness_ini);
  init_number Fmult_max_value
 !! ICHECK(Fmult_max_value);

  init_number ignore_guesses
 !! ICHECK(ignore_guesses);
  number delta

// Projection Info*********************
  init_int do_projections
 !! ICHECK(do_projections);
  init_ivector directed_fleet(1,nfleets)
 !! ICHECK(directed_fleet);
  init_number nfinalyear
 !! ICHECK(nfinalyear);
  int nprojyears
 !! nprojyears=nfinalyear-year1-nyears+1;
  init_matrix project_ini(1,nprojyears,1,5)
 !! ICHECK(project_ini);
  vector proj_recruit(1,nprojyears)
  ivector proj_what(1,nprojyears)
  vector proj_target(1,nprojyears)
  vector proj_F_nondir_mult(1,nprojyears)
 LOCAL_CALCS
  for (iyear=1;iyear<=nprojyears;iyear++)
  {
    proj_recruit(iyear)=project_ini(iyear,2);
    proj_what(iyear)=project_ini(iyear,3);
    proj_target(iyear)=project_ini(iyear,4);
    proj_F_nondir_mult(iyear)=project_ini(iyear,5);
  }
 END_CALCS

// MCMC Info******************************
  init_int doMCMC
 !! ICHECK(doMCMC);
```

```
 LOCAL_CALCS
  if (doMCMC == 1)
  {
     basicMCMC << " ";
     for (iyear=1;iyear<=nyears;iyear++)
     {
        basicMCMC << "F" << iyear+year1-1 << " ";
     }
     for (iyear=1;iyear<=nyears;iyear++)
     {
        basicMCMC << "SSB" << iyear+year1-1 << " ";
     }
     // Liz added Fmult_in lastyear and totBjan1
     for (iyear=1;iyear<=nyears;iyear++)
     {
        basicMCMC << "Fmult_" << iyear+year1-1 << " ";
          }
     for (iyear=1;iyear<=nyears;iyear++)
     {
        basicMCMC << "totBjan1_" << iyear+year1-1 << " ";
     }

     // end stuff Liz added
     basicMCMC << "MSY  SSBmsy  Fmsy  SSBmsy_ratio  Fmsy_ratio  ";
     basicMCMC << endl; // end of header line
  }
 END_CALCS
  init_int MCMCnyear_opt // 0=output nyear NAA, 1=output nyear+1 NAA
 !! ICHECK(MCMCnyear_opt)
  init_int MCMCnboot  // final number of values for agepro bootstrap file
 !! ICHECK(MCMCnboot);
  init_int MCMCnthin  // thinning rate (1=use every value, 2=use every other value, 3=use every third value,
etc)
 !! ICHECK(MCMCnthin);
  init_int MCMCseed   // large positive integer to seed random number generator
 !! ICHECK(MCMCseed);
// To run MCMC do the following two steps:
// 1st type "asap2 -mcmc N1 -mcsave MCMCnthin -mcseed MCMCseed"
//   where N1 = MCMCnboot * MCMCnthin
// 2nd type "asap2 -mceval"
  init_int fillR_opt // option for filling recruitment in terminal year+1 - used in agepro.bsn file only (1=SR,
2=geomean)
 !! ICHECK(fillR_opt);
  init_int Ravg_start
 !! ICHECK(Ravg_start);
  init_int Ravg_end
 !! ICHECK(Ravg_end);

  init_int make_Rfile // option to create rdat file of input and output values, set to 1 to create the file, 0
to skip this feature
 !! ICHECK(make_Rfile);

  init_int test_value
 !! ICHECK(test_value)
 !! cout << "test value = " << test_value << endl; //CHECK
 !! cout << "input complete" << endl;

  number ntemp0
  number SR_spawners_per_recruit
  vector s_per_r_vec(1,nyears)
 LOCAL_CALCS
  for (iyear=1;iyear<=nyears;iyear++)
  {
    ntemp0=1.0;
    s_per_r_vec(iyear)=0.0;
    for (iage=1;iage<nages;iage++)
    {
      s_per_r_vec(iyear)+=ntemp0*fecundity(iyear,iage)*mfexp(-1.0*fracyearSSB*M(iyear,iage));
      ntemp0*=mfexp(-M(iyear,iage));
    }
    ntemp0/=(1.0-mfexp(-M(iyear,nages)));
```

```
    s_per_r_vec(iyear)+=ntemp0*fecundity(iyear,nages)*mfexp(-1.0*fracyearSSB*M(iyear,nages));
  }
  SR_spawners_per_recruit=s_per_r_vec(nyears); // use last year calculations for SR curve
 END_CALCS

//***************************************************************************
PARAMETER_SECTION
  init_bounded_number_vector sel_params(1,nselparm,sel_lo,sel_hi,sel_phase)
  init_bounded_vector log_Fmult_year1(1,nfleets,-15.,2.,phase_Fmult_year1)
  init_bounded_matrix log_Fmult_devs(1,nfleets,2,nyears,-15.,15.,phase_Fmult_devs)
  init_bounded_dev_vector log_recruit_devs(1,nyears,-15.,15.,phase_recruit_devs)
  init_bounded_vector log_N_year1_devs(2,nages,-15.,15.,phase_N_year1_devs)
  init_bounded_vector log_q_year1(1,nindices,-30,5,phase_q_year1)
  init_bounded_matrix log_q_devs(1,nindices,2,index_nobs,-15.,15.,phase_q_devs)
  init_bounded_number_vector index_sel_params(1,nindexselparms,indexsel_lo,indexsel_hi,indexsel_phase)
  init_bounded_number log_SR_scaler(-1.0,200,phase_SR_scaler)
  init_bounded_number SR_steepness(0.20001,1.0,phase_steepness)
  vector sel_likely(1,nselparm)
  vector sel_stdresid(1,nselparm)
  number sel_rmse
  number sel_rmse_nobs
  number sum_sel_lambda
  number sum_sel_lambda_likely
  matrix indexsel(1,nindices,1,nages)
  vector indexsel_likely(1,nindexselparms)
  vector indexsel_stdresid(1,nindexselparms)
  number indexsel_rmse
  number indexsel_rmse_nobs
  number sum_indexsel_lambda
  number sum_indexsel_lambda_likely
  matrix log_Fmult(1,nfleets,1,nyears)
  matrix Fmult(1,nfleets,1,nyears)
  matrix NAA(1,nyears,1,nages)
  matrix temp_NAA(1,nyears,1,nages)
  matrix temp_BAA(1,nyears,1,nages)
  matrix temp_PAA(1,nyears,1,nages)
  matrix FAA_tot(1,nyears,1,nages)
  matrix Z(1,nyears,1,nages)
  matrix S(1,nyears,1,nages)
  matrix Catch_stdresid(1,nfleets,1,nyears)
  matrix Discard_stdresid(1,nfleets,1,nyears)
  matrix Catch_tot_fleet_pred(1,nfleets,1,nyears)
  matrix Discard_tot_fleet_pred(1,nfleets,1,nyears)
  3darray CAA_pred(1,nfleets,1,nyears,1,nages)
  3darray Discard_pred(1,nfleets,1,nyears,1,nages)
  3darray CAA_prop_pred(1,nfleets,1,nyears,sel_start_age,sel_end_age)
  3darray Discard_prop_pred(1,nfleets,1,nyears,sel_start_age,sel_end_age)
  3darray FAA_by_fleet_dir(1,nfleets,1,nyears,1,nages)
  3darray FAA_by_fleet_Discard(1,nfleets,1,nyears,1,nages)
  matrix sel_by_block(1,nselblocks,1,nages)
  3darray sel_by_fleet(1,nfleets,1,nyears,1,nages)
  vector temp_sel_over_time(1,nyears)
  number temp_sel_fix
  number temp_Fmult_max
  number Fmult_max_pen
  matrix q_by_index(1,nindices,1,index_nobs)
  matrix temp_sel(1,nyears,1,nages)
  vector temp_sel2(1,nages)
  matrix index_pred(1,nindices,1,index_nobs)
  3darray output_index_prop_obs(1,nindices,1,nyears,1,nages)
  3darray output_index_prop_pred(1,nindices,1,nyears,1,nages)
  matrix index_Neff_init(1,nindices,1,nyears)
  matrix index_Neff_est(1,nindices,1,nyears)
  3darray index_prop_pred(1,nindices,1,index_nobs,1,nages)
  number new_Neff_catch
  number new_Neff_discard
  number ntemp
  number SR_S0
  number SR_R0
  number SR_alpha
  number SR_beta
```

```
vector S0_vec(1,nyears)
vector R0_vec(1,nyears)
vector steepness_vec(1,nyears)
vector SR_pred_recruits(1,nyears+1)
number likely_SR_sigma
vector SR_stdresid(1,nyears)
number SR_rmse
number SR_rmse_nobs
vector RSS_sel_devs(1,nfleets)
vector RSS_catch_tot_fleet(1,nfleets)
vector RSS_Discard_tot_fleet(1,nfleets)
vector catch_tot_likely(1,nfleets)
vector discard_tot_likely(1,nfleets)
number likely_catch
number likely_Discard
vector RSS_ind(1,nindices)
vector RSS_ind_sigma(1,nindices)
vector likely_ind(1,nindices)
matrix index_stdresid(1,nindices,1,index_nobs)
number likely_index_age_comp
number fpenalty
number fpenalty_lambda
vector Fmult_year1_stdresid(1,nfleets)
number Fmult_year1_rmse
number Fmult_year1_rmse_nobs
vector Fmult_year1_likely(1,nfleets)
vector Fmult_devs_likely(1,nfleets)
matrix Fmult_devs_stdresid(1,nfleets,1,nyears)
vector Fmult_devs_fleet_rmse(1,nfleets)
vector Fmult_devs_fleet_rmse_nobs(1,nfleets)
number Fmult_devs_rmse
number Fmult_devs_rmse_nobs
number N_year1_likely
vector N_year1_stdresid(2,nages)
number N_year1_rmse
number N_year1_rmse_nobs
vector nyear1temp(1,nages)
vector q_year1_likely(1,nindices)
vector q_year1_stdresid(1,nindices)
number q_year1_rmse
number q_year1_rmse_nobs
vector q_devs_likely(1,nindices)
matrix q_devs_stdresid(1,nindices,1,index_nobs)
number q_devs_rmse
number q_devs_rmse_nobs
number steepness_likely
number steepness_stdresid
number steepness_rmse
number steepness_rmse_nobs
number SR_scaler_likely
number SR_scaler_stdresid
number SR_scaler_rmse
number SR_scaler_rmse_nobs
matrix effective_sample_size(1,nfleets,1,nyears)
matrix effective_Discard_sample_size(1,nfleets,1,nyears)
vector Neff_stage2_mult_catch(1,nfleets)
vector Neff_stage2_mult_discard(1,nfleets)
vector Neff_stage2_mult_index(1,nindices)
vector mean_age_obs(1,nyears)
vector mean_age_pred(1,nyears)
vector mean_age_pred2(1,nyears)
vector mean_age_resid(1,nyears)
vector mean_age_sigma(1,nyears)
number mean_age_x
number mean_age_n
number mean_age_delta
number mean_age_mean
number mean_age_m2
vector temp_Fmult(1,nfleets)
number tempU
number tempN
```

```
number tempB
number tempUd
number tempNd
number tempBd
number trefU
number trefN
number trefB
number trefUd
number trefNd
number trefBd
number Fref_report
number Fref
vector freftemp(1,nages)
vector nreftemp(1,nages)
vector Freport_U(1,nyears)
vector Freport_N(1,nyears)
vector Freport_B(1,nyears)
sdreport_vector Freport(1,nyears)
sdreport_vector TotJan1B(1,nyears)
sdreport_vector SSB(1,nyears)
sdreport_vector ExploitableB(1,nyears)
sdreport_vector recruits(1,nyears)
matrix SSBfracZ(1,nyears,1,nages)
vector final_year_total_sel(1,nages)
vector dir_F(1,nages)
vector Discard_F(1,nages)
vector proj_nondir_F(1,nages)
vector proj_dir_sel(1,nages)
vector proj_Discard_sel(1,nages)
matrix proj_NAA(1,nprojyears,1,nages)
vector proj_Fmult(1,nprojyears)
vector Ftemp(1,nages)
vector Ztemp(1,nages)
vector proj_TotJan1B(1,nprojyears)
vector proj_SSB(1,nprojyears)
number SSBtemp
number denom
matrix proj_F_dir(1,nprojyears,1,nages)
matrix proj_F_Discard(1,nprojyears,1,nages)
matrix proj_F_nondir(1,nprojyears,1,nages)
matrix proj_Z(1,nprojyears,1,nages)
matrix proj_SSBfracZ(1,nprojyears,1,nages)
matrix proj_catch(1,nprojyears,1,nages)
matrix proj_Discard(1,nprojyears,1,nages)
matrix proj_yield(1,nprojyears,1,nages)
vector proj_total_yield(1,nprojyears)
vector proj_total_Discard(1,nprojyears)
vector output_prop_obs(1,nages)
vector output_prop_pred(1,nages)
vector output_Discard_prop_obs(1,nages)
vector output_Discard_prop_pred(1,nages)
vector NAAbsn(1,nages)
number temp_sum
number temp_sum2
number A
number B
number C
number f
number z
number SPR_Fmult
number YPR_Fmult
number SPR
number SPRatio
number YPR
number S_F
number R_F
number slope_origin
number slope
number F30SPR
number F40SPR
number Fmsy
```

```
  number F01
  number Fmax
  number F30SPR_report
  number F40SPR_report
  number F01_report
  number Fmax_report
  number Fcurrent
  number F30SPR_slope
  number F40SPR_slope
  number Fmsy_slope
  number F01_slope
  number Fmax_slope
  number Fcurrent_slope
  number SSmsy
  number tempR
  vector tempFmult(1,nyears) // Liz added
  sdreport_number MSY
  sdreport_number SSBmsy_report
  sdreport_number Fmsy_report
  sdreport_number SSBmsy_ratio
  sdreport_number Fmsy_ratio
  objective_function_value obj_fun

PRELIMINARY_CALCS_SECTION
// subset only used index information
  ind=0;
  for (indavail=1;indavail<=navailindices;indavail++)
  {
     if (use_index(indavail)==1)
     {
       ind+=1;
       lambda_ind(ind)=lambda_ind_ini(indavail);
       lambda_q_year1(ind)=lambda_q_year1_ini(indavail);
       q_year1_CV(ind)=q_year1_CV_ini(indavail);
       lambda_q_devs(ind)=lambda_q_devs_ini(indavail);
       q_devs_CV(ind)=q_devs_CV_ini(indavail);
       q_year1_ini(ind)=q_year1_iniavail(indavail);
     }
  }

  if (ignore_guesses==0)
  {
     NAA(1)=NAA_year1_ini;
     log_Fmult_year1=log(Fmult_year1_ini);
     log_q_year1=log(q_year1_ini);
     log_SR_scaler=log(SR_scaler_ini);
     SR_steepness=SR_steepness_ini;
     for (k=1;k<=nselparm;k++)
     {
        sel_params(k)=sel_initial(k);
     }
     for (k=1;k<=nindexselparms;k++)
     {
        index_sel_params(k)=indexsel_initial(k);
     }
  }

  delta=0.00001;

// convert remaining CVs to variances
  Fmult_year1_sigma2=log(elem_prod(Fmult_year1_CV,Fmult_year1_CV)+1.0);
  Fmult_year1_sigma=sqrt(Fmult_year1_sigma2);
  Fmult_devs_sigma2=log(elem_prod(Fmult_devs_CV,Fmult_devs_CV)+1.0);
  Fmult_devs_sigma=sqrt(Fmult_devs_sigma2);
  N_year1_sigma2=log(N_year1_CV*N_year1_CV+1.0);
  N_year1_sigma=sqrt(N_year1_sigma2);
  q_year1_sigma2=log(elem_prod(q_year1_CV,q_year1_CV)+1.0);
  q_year1_sigma=sqrt(q_year1_sigma2);
  q_devs_sigma2=log(elem_prod(q_devs_CV,q_devs_CV)+1.0);
  q_devs_sigma=sqrt(q_devs_sigma2);
  steepness_sigma2=log(steepness_CV*steepness_CV+1.0);
```

```
  steepness_sigma=sqrt(steepness_sigma2);
  SR_scaler_sigma2=log(SR_scaler_CV*SR_scaler_CV+1.0);
  SR_scaler_sigma=sqrt(SR_scaler_sigma2);

// compute multinomial constants for catch and discards at age, if requested
  catch_prop_like_const=0.0;
  discard_prop_like_const=0.0;
  if (use_likelihood_constants == 1)
  {
     for (ifleet=1;ifleet<=nfleets;ifleet++)
     {
        for (iyear=1;iyear<=nyears;iyear++)
        {
          if (input_eff_samp_size_catch(ifleet,iyear) > 0)
          {
             nfact_in=input_eff_samp_size_catch(ifleet,iyear);
             get_log_factorial();
             catch_prop_like_const+=-1.0*nfact_out;  // negative for the total
             for (iage=sel_start_age(ifleet);iage<=sel_end_age(ifleet);iage++)
             {
                nfact_in=double(input_eff_samp_size_catch(ifleet,iyear))*CAA_prop_obs(ifleet,iyear,iage)+0.5;
// +0.5 to round instead of truncate nfact_in
                get_log_factorial();
                catch_prop_like_const+=nfact_out;   // positive for the parts
             }
          }
          if (input_eff_samp_size_discard(ifleet,iyear) > 0)
          {
             nfact_in=input_eff_samp_size_discard(ifleet,iyear);
             get_log_factorial();
             discard_prop_like_const+=-1.0*nfact_out; // negative for the total
             for (iage=sel_start_age(ifleet);iage<=sel_end_age(ifleet);iage++)
             {

nfact_in=double(input_eff_samp_size_discard(ifleet,iyear))*Discard_prop_obs(ifleet,iyear,iage)+0.5;
                get_log_factorial();
                discard_prop_like_const+=nfact_out;   // positive for the parts
             }
          }
        }
     }
  }

// compute multinomial constants for index, if requested
  index_prop_like_const=0.0;
  if (use_likelihood_constants == 1)
  {
     for (ind=1;ind<=nindices;ind++)
     {
        if (index_estimate_proportions(ind)==1)
        {
           for (i=1;i<=index_nobs(ind);i++)
           {
              if (input_eff_samp_size_index(ind,i) > 0)
              {
                 nfact_in=input_eff_samp_size_index(ind,i);
                 get_log_factorial();
                 index_prop_like_const+=-1.0*nfact_out;    // negative for total
                 for (iage=index_start_age(ind);iage<=index_end_age(ind);iage++)
                 {
                    nfact_in=double(input_eff_samp_size_index(ind,i))*index_prop_obs(ind,i,iage)+0.5;
                    get_log_factorial();
                    index_prop_like_const+=nfact_out;      // positive for the parts
                 }
              }
           }
        }
     }
  }

// selectivity likelihood constants
```

```
  sel_like_const=0.0;
  if (use_likelihood_constants == 1)
  {
     for (k=1;k<=nselparm;k++)
     {
        if (sel_phase(k) >= 1)
        {
           sel_like_const(k)=0.5*log(2.0*pi)+log(sel_initial(k));
        }
     }
  }

// index selectivity likelihood constants
  indexsel_like_const=0.0;
  if (use_likelihood_constants == 1)
  {
     for (k=1;k<=nindexselparms;k++)
     {
        if (indexsel_phase(k) >= 1)
        {
           indexsel_like_const(k)=0.5*log(2.0*pi)+log(indexsel_initial(k));
        }
     }
  }

// rest of likelihood constants
  if (use_likelihood_constants == 1)
  {
     Fmult_year1_like_const=0.5*log(2.0*pi)+log(Fmult_year1_ini);
     Fmult_devs_like_const=0.5*log(2.0*pi);
     N_year1_like_const=0.5*log(2.0*pi);
     q_year1_like_const=0.5*log(2.0*pi)+log(q_year1_ini);
     q_devs_like_const=0.5*log(2.0*pi);
     steepness_like_const=0.5*log(2.0*pi)+log(SR_steepness_ini);
     SR_scaler_like_const=0.5*log(2.0*pi)+log(SR_scaler_ini);
  }
  else
  {
     Fmult_year1_like_const=0.0;
     Fmult_devs_like_const=0.0;
     N_year1_like_const=0.0;
     q_year1_like_const=0.0;
     q_devs_like_const=0.0;
     steepness_like_const=0.0;
     SR_scaler_like_const=0.0;
  }

// set dev vectors to zero
  log_Fmult_devs.initialize();
  log_recruit_devs.initialize();
  log_N_year1_devs.initialize();
  log_q_devs.initialize();

// initialize MSY related sdreport variables
  MSY.initialize();
  SSBmsy_report.initialize();
  Fmsy_report.initialize();
  SSBmsy_ratio.initialize();
  Fmsy_ratio.initialize();

  debug=0; // debug checks commented out to speed calculations

//*********************************************************************************************
PROCEDURE_SECTION
                                       //  if (debug==1) cout << "starting procedure section" << endl;
  get_SR();                           //  if (debug==1) cout << "got SR" << endl;
  get_selectivity();                   //  if (debug==1) cout << "got selectivity" << endl;
  get_mortality_rates();               //  if (debug==1) cout << "got mortality rates" << endl;
  get_numbers_at_age();                //  if (debug==1) cout << "got numbers at age" << endl;
  get_Freport();                       //  if (debug==1) cout << "got Freport" << endl;
  get_predicted_catch();               //  if (debug==1) cout << "got predicted catch" << endl;
```

```
  get_q();                            //  if (debug==1) cout << "got q" << endl;
  get_predicted_indices();            //  if (debug==1) cout << "got predicted indices" << endl;
  compute_the_objective_function();   //  if (debug==1) cout << "computed objective function" << endl;
  if (last_phase() || mceval_phase())
  {
     get_proj_sel();                  //  if (debug==1) cout <<"got proj sel" << endl;
     get_Fref();                      //  if (debug==1) cout <<"got Fref" << endl;
     get_multinomial_multiplier();    //  if (debug==1) cout <<"got multinomial multiplier" << endl;
  }
  if (mceval_phase())
  {
     write_MCMC();
  }                                   //  if (debug==1) cout << "  . . . end of procedure section" << endl;
//***************************************************************************************************

FUNCTION get_SR
// converts stock recruitment scaler and steepness to alpha and beta for Beverton-Holt SR
// note use of is_SR_scaler_R variable to allow user to enter guess for either R0 or SSB0
  if(is_SR_scaler_R==1)
  {
    SR_R0=mfexp(log_SR_scaler);
    SR_S0=SR_spawners_per_recruit*SR_R0;
  }
  else
  {
    SR_S0=mfexp(log_SR_scaler);
    SR_R0=SR_S0/SR_spawners_per_recruit;
  }
  SR_alpha=4.0*SR_steepness*SR_R0/(5.0*SR_steepness-1.0);
  SR_beta=SR_S0*(1.0-SR_steepness)/(5.0*SR_steepness-1.0);
  // now compute year specific vectors of R0, S0, and steepness
  for (iyear=1;iyear<=nyears;iyear++)
  {
    steepness_vec(iyear)=0.2*SR_alpha*s_per_r_vec(iyear)/(0.8*SR_beta+0.2*SR_alpha*s_per_r_vec(iyear));
    R0_vec(iyear)=(SR_alpha*s_per_r_vec(iyear)-SR_beta)/s_per_r_vec(iyear);
    S0_vec(iyear)=s_per_r_vec(iyear)*R0_vec(iyear);
  }

FUNCTION get_selectivity
  dvariable sel_alpha1;
  dvariable sel_beta1;
  dvariable sel_alpha2;
  dvariable sel_beta2;
  dvariable sel_temp;
  dvariable sel1;
  dvariable sel2;
// start by computing selectivity for each block
  k=0;
  for (i=1;i<=nselblocks;i++) {
     if (sel_option(i)==1) {
        for (iage=1;iage<=nages;iage++){
           k+=1;
           sel_by_block(i,iage)=sel_params(k);
        }
     }
     if (sel_option(i)==2) {
        sel_alpha1=sel_params(k+1);
        sel_beta1=sel_params(k+2);
        k+=2;
        for (iage=1;iage<=nages;iage++) {
           sel_by_block(i,iage)=1.0/(1.0+mfexp((sel_alpha1-double(iage))/sel_beta1));
        }
        sel_temp=max(sel_by_block(i));
        sel_by_block(i)/=sel_temp;
     }
     if (sel_option(i)==3) {
        sel_alpha1=sel_params(k+1);
        sel_beta1=sel_params(k+2);
        sel_alpha2=sel_params(k+3);
        sel_beta2=sel_params(k+4);
        k+=4;
```

```
        for (iage=1;iage<=nages;iage++) {
           sel1=1.0/(1.0+mfexp((sel_alpha1-double(iage))/sel_beta1));
           sel2=1.0-1.0/(1.0+mfexp((sel_alpha2-double(iage))/sel_beta2));
           sel_by_block(i,iage)=sel1*sel2;
        }
        sel_temp=max(sel_by_block(i));
        sel_by_block(i)/=sel_temp;
     }
  }
// now fill in selectivity for each fleet and year according to block
  for (ifleet=1;ifleet<=nfleets;ifleet++) {
     for (iyear=1;iyear<=nyears;iyear++) {
        sel_by_fleet(ifleet,iyear)=sel_by_block(sel_blocks(ifleet,iyear));
     }
  }

FUNCTION get_mortality_rates
// compute directed and discard F by fleet then sum to form total F at age matrix
  for (ifleet=1;ifleet<=nfleets;ifleet++)
  {
     log_Fmult(ifleet,1)=log_Fmult_year1(ifleet);
     if (active(log_Fmult_devs))
     {
         for (iyear=2;iyear<=nyears;iyear++)
             log_Fmult(ifleet,iyear)=log_Fmult(ifleet,iyear-1)+log_Fmult_devs(ifleet,iyear);
     }
     else
     {
         for (iyear=2;iyear<=nyears;iyear++)
             log_Fmult(ifleet,iyear)=log_Fmult_year1(ifleet);
     }
  }
  FAA_tot=0.0;
  for (ifleet=1;ifleet<=nfleets;ifleet++)
  {
     for (iyear=1;iyear<=nyears;iyear++)
     {
       for (iage=1;iage<=nages;iage++)
       {

FAA_by_fleet_dir(ifleet,iyear,iage)=(mfexp(log_Fmult(ifleet,iyear))*sel_by_fleet(ifleet,iyear,iage))*(1.0-
proportion_release(ifleet,iyear,iage));

FAA_by_fleet_Discard(ifleet,iyear,iage)=(mfexp(log_Fmult(ifleet,iyear))*sel_by_fleet(ifleet,iyear,iage))*(propor
tion_release(ifleet,iyear,iage)*release_mort(ifleet));
       }
     }
     FAA_tot+=FAA_by_fleet_dir(ifleet)+FAA_by_fleet_Discard(ifleet);
  }
// add fishing and natural mortality to get total mortality
  for (iyear=1;iyear<=nyears;iyear++)
     Z(iyear)=FAA_tot(iyear)+M(iyear);
  S=mfexp(-1.0*Z);
  SSBfracZ=mfexp(-1.0*fracyearSSB*Z); // for use in SSB calcuations

FUNCTION get_numbers_at_age
// get N at age in year 1
  if (phase_N_year1_devs>0)
  {
     for (iage=2;iage<=nages;iage++)
     {
        NAA(1,iage)=NAA_year1_ini(iage)*mfexp(log_N_year1_devs(iage));
     }
  }
// compute initial SSB to derive R in first year
  SSB(1)=0.0;
  for (iage=2;iage<=nages;iage++)
  {
     SSB(1)+=NAA(1,iage)*SSBfracZ(1,iage)*fecundity(1,iage);  // note SSB in year 1 does not include age 1 to
estimate pred_R in year 1
  }
```

```
  SR_pred_recruits(1)=SR_alpha*SSB(1)/(SR_beta+SSB(1));
  NAA(1,1)=SR_pred_recruits(1)*mfexp(log_recruit_devs(1));
  SSB(1)+=NAA(1,1)*SSBfracZ(1,1)*fecundity(1,1);   // now SSB in year 1 is complete and can be used for pred_R
in year 2
// fill out rest of matrix
  for (iyear=2;iyear<=nyears;iyear++)
  {
     SR_pred_recruits(iyear)=SR_alpha*SSB(iyear-1)/(SR_beta+SSB(iyear-1));
     NAA(iyear,1)=SR_pred_recruits(iyear)*mfexp(log_recruit_devs(iyear));
     for (iage=2;iage<=nages;iage++)
         NAA(iyear,iage)=NAA(iyear-1,iage-1)*S(iyear-1,iage-1);
     NAA(iyear,nages)+=NAA(iyear-1,nages)*S(iyear-1,nages);
     SSB(iyear)=elem_prod(NAA(iyear),SSBfracZ(iyear))*fecundity(iyear);
  }
  SR_pred_recruits(nyears+1)=SR_alpha*SSB(nyears)/(SR_beta+SSB(nyears));
  for (iyear=1;iyear<=nyears;iyear++)
  {
     recruits(iyear)=NAA(iyear,1);
  }
// compute two other biomass time series
  for (iyear=1;iyear<=nyears;iyear++)
  {
     TotJan1B(iyear)=NAA(iyear)*WAAjan1b(iyear);
     ExploitableB(iyear)=elem_prod(NAA(iyear),FAA_tot(iyear))*WAAcatchall(iyear)/max(FAA_tot(iyear));
  }

FUNCTION get_Freport
// calculates an average F for a range of ages in each year under three weighting schemes
  for (iyear=1;iyear<=nyears;iyear++){
     tempU=0.0;
     tempN=0.0;
     tempB=0.0;
     tempUd=0.0;
     tempNd=0.0;
     tempBd=0.0;
     for (iage=Freport_agemin;iage<=Freport_agemax;iage++)
     {
       tempU+=FAA_tot(iyear,iage);
       tempN+=FAA_tot(iyear,iage)*NAA(iyear,iage);
       tempB+=FAA_tot(iyear,iage)*NAA(iyear,iage)*WAAjan1b(iyear,iage);
       tempUd+=1.0;
       tempNd+=NAA(iyear,iage);
       tempBd+=NAA(iyear,iage)*WAAjan1b(iyear,iage);
     }
     // April 2012 error trap addition
     if (tempUd <= 0.) Freport_U(iyear)=0.0;
     else Freport_U(iyear)=tempU/tempUd;
     if (tempNd <= 0.) Freport_N(iyear)=Freport_U(iyear);
     else Freport_N(iyear)=tempN/tempNd;
     if (tempBd <= 0.) Freport_B(iyear)=Freport_U(iyear);
     else Freport_B(iyear)=tempB/tempBd;
  }
  if (Freport_wtopt==1) Freport=Freport_U;
  if (Freport_wtopt==2) Freport=Freport_N;
  if (Freport_wtopt==3) Freport=Freport_B;

FUNCTION get_predicted_catch
// assumes continuous F using Baranov equation
  for (ifleet=1;ifleet<=nfleets;ifleet++)
  {
     CAA_pred(ifleet)=elem_prod(elem_div(FAA_by_fleet_dir(ifleet),Z),elem_prod(1.0-S,NAA));
     Discard_pred(ifleet)=elem_prod(elem_div(FAA_by_fleet_Discard(ifleet),Z),elem_prod(1.0-S,NAA));
  }
// now compute proportions at age and total weight of catch
  for (iyear=1;iyear<=nyears;iyear++)
  {
    for (ifleet=1;ifleet<=nfleets;ifleet++)
    {
       CAA_prop_pred(ifleet,iyear)=0.0;
       Discard_prop_pred(ifleet,iyear)=0.0;
```

```
Catch_tot_fleet_pred(ifleet,iyear)=sum(CAA_pred(ifleet,iyear)(sel_start_age(ifleet),sel_end_age(ifleet)));

Discard_tot_fleet_pred(ifleet,iyear)=sum(Discard_pred(ifleet,iyear)(sel_start_age(ifleet),sel_end_age(ifleet)));
       if (Catch_tot_fleet_pred(ifleet,iyear)>0.0)

CAA_prop_pred(ifleet,iyear)=CAA_pred(ifleet,iyear)(sel_start_age(ifleet),sel_end_age(ifleet))/Catch_tot_fleet_pr
ed(ifleet,iyear);
       if (Discard_tot_fleet_pred(ifleet,iyear)>0.0)

Discard_prop_pred(ifleet,iyear)=Discard_pred(ifleet,iyear)(sel_start_age(ifleet),sel_end_age(ifleet))/Discard_to
t_fleet_pred(ifleet,iyear);

Catch_tot_fleet_pred(ifleet,iyear)=CAA_pred(ifleet,iyear)(sel_start_age(ifleet),sel_end_age(ifleet))*WAAcatchfle
et(ifleet,iyear)(sel_start_age(ifleet),sel_end_age(ifleet));

Discard_tot_fleet_pred(ifleet,iyear)=Discard_pred(ifleet,iyear)(sel_start_age(ifleet),sel_end_age(ifleet))*WAAdi
scardfleet(ifleet,iyear)(sel_start_age(ifleet),sel_end_age(ifleet));
       for (iage=1;iage<=nages;iage++)
       {
          if (CAA_prop_pred(ifleet,iyear,iage)<1.e-15)
             CAA_prop_pred(ifleet,iyear,iage)=1.0e-15;
          if (Discard_prop_pred(ifleet,iyear,iage)<1.e-15)
             Discard_prop_pred(ifleet,iyear,iage)=1.0e-15;
       }
    }
  }

FUNCTION get_q
// catchability for each index, can be a random walk if q_devs turned on
  for (ind=1;ind<=nindices;ind++)
  {
     q_by_index(ind,1)=mfexp(log_q_year1(ind));
     if (active(log_q_devs))
     {
         for (i=2;i<=index_nobs(ind);i++)
             q_by_index(ind,i)=q_by_index(ind,i-1)*mfexp(log_q_devs(ind,i));
     }
     else
     {
         for (i=2;i<=index_nobs(ind);i++)
             q_by_index(ind,i)=q_by_index(ind,1);
     }
  }

FUNCTION get_predicted_indices
  dvariable sel_alpha1;
  dvariable sel_beta1;
  dvariable sel_alpha2;
  dvariable sel_beta2;
  dvariable sel_temp;
  dvariable sel1;
  dvariable sel2;
// get selectivity for each index
  k=0;
  for (ind=1;ind<=nindices;ind++)
  {
     if (index_sel_choice(ind)>0)
     {
         temp_sel=sel_by_fleet(index_sel_choice(ind));
         if (index_sel_option(ind)==1) k+=nages;
         if (index_sel_option(ind)==2) k+=2;
         if (index_sel_option(ind)==3) k+=4;

     }
     else
     {
         if (index_sel_option(ind)==1)
         {
             for (iage=1;iage<=nages;iage++)
             {
```

```
                k+=1;
                temp_sel2(iage)=index_sel_params(k);
             }
         }
         if (index_sel_option(ind)==2)
         {
             sel_alpha1=index_sel_params(k+1);
             sel_beta1=index_sel_params(k+2);
             k+=2;
             for (iage=1;iage<=nages;iage++)
             {
                temp_sel2(iage)=1.0/(1.0+mfexp((sel_alpha1-double(iage))/sel_beta1));
             }
             sel_temp=max(temp_sel2);
             temp_sel2/=sel_temp;
         }
         if (index_sel_option(ind)==3)
         {
             sel_alpha1=index_sel_params(k+1);
             sel_beta1=index_sel_params(k+2);
             sel_alpha2=index_sel_params(k+3);
             sel_beta2=index_sel_params(k+4);
             k+=4;
             for (iage=1;iage<=nages;iage++)
             {
                sel1=1.0/(1.0+mfexp((sel_alpha1-double(iage))/sel_beta1));
                sel2=1.0-1.0/(1.0+mfexp((sel_alpha2-double(iage))/sel_beta2));
                temp_sel2(iage)=sel1*sel2;
             }
             sel_temp=max(temp_sel2);
             temp_sel2/=sel_temp;
         }
         for (iyear=1;iyear<=nyears;iyear++)
         {
             temp_sel(iyear)=temp_sel2;
         }
     }
     indexsel(ind)=temp_sel(1);
// determine when the index should be applied
     if (index_month(ind)==-1)
     {
         temp_NAA=elem_prod(NAA,elem_div(1.0-S,Z));
     }
     else
     {
         temp_NAA=elem_prod(NAA,mfexp(-1.0*((index_month(ind)-1.0)/12.0)*Z));
     }
     temp_BAA=elem_prod(temp_NAA,index_WAA(ind));
// compute the predicted index for each year where observed value > 0
     if (index_units_aggregate(ind)==1)
     {
         temp_PAA=temp_BAA;
     }
     else
     {
         temp_PAA=temp_NAA;
     }
     for (i=1;i<=index_nobs(ind);i++)
     {
         j=index_time(ind,i);
         index_pred(ind,i)=q_by_index(ind,i)*sum(elem_prod(
             temp_PAA(j)(index_start_age(ind),index_end_age(ind)) ,
             temp_sel(j)(index_start_age(ind),index_end_age(ind))));
     }
// compute index proportions at age if necessary
     if (index_units_proportions(ind)==1)
     {
         temp_PAA=temp_BAA;
     }
     else
     {
```

```
            temp_PAA=temp_NAA;
        }
        index_prop_pred(ind)=0.0;
        if (index_estimate_proportions(ind)==1)
        {
            for (i=1;i<=index_nobs(ind);i++)
            {
                j=index_time(ind,i);
                if (index_pred(ind,i)>0.0)
                {
                    for (iage=index_start_age(ind);iage<=index_end_age(ind);iage++)
                    {
                        index_prop_pred(ind,i,iage)=q_by_index(ind,i)*temp_PAA(j,iage)*temp_sel(j,iage);
                    }
                    if (sum(index_prop_pred(ind,i)) > 0)
                        index_prop_pred(ind,i)/=sum(index_prop_pred(ind,i));
                    for (iage=index_start_age(ind);iage<=index_end_age(ind);iage++)
                    {
                        if (index_prop_pred(ind,i,iage)<1.e-15)
                           index_prop_pred(ind,i,iage)=1.e-15;
                    }
                }
            }
        }
    }

FUNCTION get_proj_sel
// creates overall directed and discard selectivity patterns and sets bycatch F at age
  dir_F=0.0;
  Discard_F=0.0;
  proj_nondir_F=0.0;
  for (ifleet=1;ifleet<=nfleets;ifleet++)
  {
     if (directed_fleet(ifleet)==1)
     {
        dir_F+=FAA_by_fleet_dir(ifleet,nyears);
        Discard_F+=FAA_by_fleet_Discard(ifleet,nyears);
     }
     else
     {
        proj_nondir_F+=FAA_by_fleet_dir(ifleet,nyears);
     }
  }
  proj_dir_sel=dir_F/max(dir_F);
  proj_Discard_sel=Discard_F/max(dir_F);

FUNCTION get_Fref
// calculates a number of common F reference points using bisection algorithm
  A=0.0;
  B=5.0;
  for (iloop=1;iloop<=20;iloop++)
  {
     C=(A+B)/2.0;
     SPR_Fmult=C;
     get_SPR();
     if (SPR/SR_spawners_per_recruit<0.30)
     {
        B=C;
     }
     else
     {
        A=C;
     }
  }
  F30SPR=C;
  Fref=F30SPR;
  get_Freport_ref();
  F30SPR_report=Fref_report;
  F30SPR_slope=1.0/SPR;
  A=0.0;
  B=5.0;
```

```
  for (iloop=1;iloop<=20;iloop++)
  {
     C=(A+B)/2.0;
     SPR_Fmult=C;
     get_SPR();
     if (SPR/SR_spawners_per_recruit<0.40)
     {
        B=C;
     }
     else
     {
        A=C;
     }
  }
  F40SPR=C;
  Fref=F40SPR;
  get_Freport_ref();
  F40SPR_report=Fref_report;
  F40SPR_slope=1.0/SPR;
  A=0.0;
  B=3.0;
  for (iloop=1;iloop<=20;iloop++)
  {
    C=(A+B)/2.0;
    SPR_Fmult=C+delta;
    get_SPR();
    S_F=SR_alpha*SPR-SR_beta;
    R_F=S_F/SPR;
    YPR_Fmult=C+delta;
    get_YPR();
    slope=R_F*YPR;
    SPR_Fmult=C;
    get_SPR();
    S_F=SR_alpha*SPR-SR_beta;
    R_F=S_F/SPR;
    YPR_Fmult=C;
    get_YPR();
    slope-=R_F*YPR;
//    slope/=delta; only care pos or neg
    if(slope>0.0)
    {
       A=C;
    }
    else
    {
       B=C;
    }
  }
  Fmsy=C;
  Fref=Fmsy;
  get_Freport_ref();
  Fmsy_report=Fref_report;
  SSmsy=S_F;
  SSBmsy_report=SSmsy;
  if (SSmsy>0.0)
    SSBmsy_ratio=SSB(nyears)/SSmsy;
  MSY=YPR*R_F;
  SPR_Fmult=Fmsy;
  get_SPR();
  Fmsy_slope=1.0/SPR;
  YPR_Fmult=delta;
  get_YPR();
  slope_origin=YPR/delta;
  A=0.0;
  B=5.0;
  for (iloop=1;iloop<=20;iloop++)
  {
     C=(A+B)/2.0;
     YPR_Fmult=C+delta;
     get_YPR();
     slope=YPR;
```

```
      YPR_Fmult=C;
      get_YPR();
      slope-=YPR;
      slope/=delta;
      if (slope<0.10*slope_origin)
      {
         B=C;
      }
      else
      {
         A=C;
      }
   }
   F01=C;
   Fref=F01;
   get_Freport_ref();
   F01_report=Fref_report;
   SPR_Fmult=F01;
   get_SPR();
   F01_slope=1.0/SPR;
   A=0.0;
   B=10.0;
   for (iloop=1;iloop<=20;iloop++)
   {
      C=(A+B)/2.0;
      YPR_Fmult=C+delta;
      get_YPR();
      slope=YPR;
      YPR_Fmult=C;
      get_YPR();
      slope-=YPR;
      slope/=delta;
      if (slope<0.0)
      {
         B=C;
      }
      else
      {
         A=C;
      }
   }
   Fmax=C;
   Fref=Fmax;
   get_Freport_ref();
   Fmax_report=Fref_report;
   SPR_Fmult=Fmax;
   get_SPR();
   Fmax_slope=1.0/SPR;
   Fcurrent=max(FAA_tot(nyears)-proj_nondir_F-Discard_F);
   SPR_Fmult=Fcurrent;
   get_SPR();
   Fcurrent_slope=1.0/SPR;
   if (Fmsy>0.0)
     Fmsy_ratio=Fcurrent/Fmsy;

FUNCTION get_Freport_ref
// Freport calculations for each of the reference points
  trefU=0.0;
  trefN=0.0;
  trefB=0.0;
  trefUd=0.0;
  trefNd=0.0;
  trefBd=0.0;
  nreftemp(1)=1.0;
  for (iage=1;iage<nages;iage++)
  {
     freftemp(iage)=Fref*(proj_dir_sel(iage)+proj_Discard_sel(iage))+proj_nondir_F(iage);
     nreftemp(iage+1)=mfexp(-1.0*(M(nyears,iage)+freftemp(iage)));
  }
  freftemp(nages)=Fref*(proj_dir_sel(nages)+proj_Discard_sel(nages))+proj_nondir_F(nages);
  nreftemp(nages)/=(1.0-mfexp(-1.0*(M(nyears,nages)+freftemp(nages))));
```

```
  for (iage=Freport_agemin;iage<=Freport_agemax;iage++)
  {
     trefU+=freftemp(iage);
     trefN+=freftemp(iage)*nreftemp(iage);
     trefB+=freftemp(iage)*nreftemp(iage)*WAAjan1b(nyears,iage);
     trefUd+=1.0;
     trefNd+=nreftemp(iage);
     trefBd+=nreftemp(iage)*WAAjan1b(nyears,iage);
  }
  if (Freport_wtopt==1) Fref_report=trefU/trefUd;
  if (Freport_wtopt==2) Fref_report=trefN/trefNd;
  if (Freport_wtopt==3) Fref_report=trefB/trefBd;

FUNCTION get_YPR
// simple yield per recruit calculations
  YPR=0.0;
  ntemp=1.0;
  for (iage=1;iage<nages;iage++)
  {
    f=YPR_Fmult*proj_dir_sel(iage);
    z=M(nyears,iage)+f+proj_nondir_F(iage)+YPR_Fmult*proj_Discard_sel(iage);
    YPR+=ntemp*f*WAAcatchall(nyears,iage)*(1.0-mfexp(-1.0*z))/z;
    ntemp*=mfexp(-1.0*z);
  }
  f=YPR_Fmult*proj_dir_sel(nages);
  z=M(nyears,nages)+f+proj_nondir_F(nages)+YPR_Fmult*proj_Discard_sel(nages);
  ntemp/=(1.0-mfexp(-1.0*z));
  YPR+=ntemp*f*WAAcatchall(nyears,nages)*(1.0-mfexp(-1.0*z))/z;

FUNCTION project_into_future
// project population under five possible scenarios for each year
  for (iyear=1;iyear<=nprojyears;iyear++)
  {
    proj_F_nondir(iyear)=proj_nondir_F*proj_F_nondir_mult(iyear);
    if (proj_recruit(iyear)<0.0)  // use stock-recruit relationship
    {
       if (iyear==1)
       {
          proj_NAA(iyear,1)=SR_alpha*SSB(nyears)/(SR_beta+SSB(nyears));
       }
       else
       {
          proj_NAA(iyear,1)=SR_alpha*proj_SSB(iyear-1)/(SR_beta+proj_SSB(iyear-1));
       }
    }
    else
    {
       proj_NAA(iyear,1)=proj_recruit(iyear);
    }
    if (iyear==1)
    {
       for (iage=2;iage<=nages;iage++)
          proj_NAA(1,iage)=NAA(nyears,iage-1)*S(nyears,iage-1);
       proj_NAA(1,nages)+=NAA(nyears,nages)*S(nyears,nages);
    }
    else
    {
       for (iage=2;iage<=nages;iage++)
          proj_NAA(iyear,iage)=proj_NAA(iyear-1,iage-1)*mfexp(-1.0*proj_Z(iyear-1,iage-1));
       proj_NAA(iyear,nages)+=proj_NAA(iyear-1,nages)*mfexp(-1.0*proj_Z(iyear-1,nages));
    }
    if (proj_what(iyear)==1)           // match directed yield
    {
       proj_Fmult(iyear)=3.0;  // first see if catch possible
       proj_F_dir(iyear)=proj_Fmult(iyear)*proj_dir_sel;
       proj_F_Discard(iyear)=proj_Fmult(iyear)*proj_Discard_sel;
       proj_Z(iyear)=M(nyears)+proj_F_nondir(iyear)+proj_F_dir(iyear)+proj_F_Discard(iyear);
       proj_catch(iyear)=elem_prod(elem_div(proj_F_dir(iyear),proj_Z(iyear)),elem_prod(1.0-mfexp(-
1.0*proj_Z(iyear)),proj_NAA(iyear)));
       proj_Discard(iyear)=elem_prod(elem_div(proj_F_Discard(iyear),proj_Z(iyear)),elem_prod(1.0-mfexp(-
1.0*proj_Z(iyear)),proj_NAA(iyear)));
```

```
       proj_yield(iyear)=elem_prod(proj_catch(iyear),WAAcatchall(nyears));
       proj_total_yield(iyear)=sum(proj_yield(iyear));
       proj_total_Discard(iyear)=sum(elem_prod(proj_Discard(iyear),WAAdiscardall(nyears)));
       if (proj_total_yield(iyear)>proj_target(iyear))  // if catch possible, what F needed
       {
          proj_Fmult(iyear)=0.0;
          for (iloop=1;iloop<=20;iloop++)
          {
             Ftemp=proj_Fmult(iyear)*proj_dir_sel;
             denom=0.0;
             for (iage=1;iage<=nages;iage++)
             {
Ztemp(iage)=M(nyears,iage)+proj_F_nondir(iyear,iage)+proj_Fmult(iyear)*proj_Discard_sel(iage)+Ftemp(iage);
                denom+=proj_NAA(iyear,iage)*WAAcatchall(nyears,iage)*proj_dir_sel(iage)*(1.0-mfexp(-
1.0*Ztemp(iage)))/Ztemp(iage);
             }
             proj_Fmult(iyear)=proj_target(iyear)/denom;
          }
       }
    }
    else if (proj_what(iyear)==2)      // match F%SPR
    {
       A=0.0;
       B=5.0;
       for (iloop=1;iloop<=20;iloop++)
       {
          C=(A+B)/2.0;
          SPR_Fmult=C;
          get_SPR();
          SPRatio=SPR/SR_spawners_per_recruit;
          if (SPRatio<proj_target(iyear))
          {
             B=C;
          }
          else
          {
             A=C;
          }
       }
       proj_Fmult(iyear)=C;
    }
    else if (proj_what(iyear)==3)      // project Fmsy
    {
       proj_Fmult=Fmsy;
    }
    else if (proj_what(iyear)==4)      // project Fcurrent
    {
       proj_Fmult=Fcurrent;
    }
    else if (proj_what(iyear)==5)      // project input F
    {
       proj_Fmult=proj_target(iyear);
    }
    proj_F_dir(iyear)=proj_Fmult(iyear)*proj_dir_sel;
    proj_F_Discard(iyear)=proj_Fmult(iyear)*proj_Discard_sel;
    proj_Z(iyear)=M(nyears)+proj_F_nondir(iyear)+proj_F_dir(iyear)+proj_F_Discard(iyear);
    proj_SSBfracZ(iyear)=mfexp(-1.0*fracyearSSB*proj_Z(iyear));
    proj_catch(iyear)=elem_prod(elem_div(proj_F_dir(iyear),proj_Z(iyear)),elem_prod(1.0-mfexp(-
1.0*proj_Z(iyear)),proj_NAA(iyear)));
    proj_Discard(iyear)=elem_prod(elem_div(proj_F_Discard(iyear),proj_Z(iyear)),elem_prod(1.0-mfexp(-
1.0*proj_Z(iyear)),proj_NAA(iyear)));
    proj_yield(iyear)=elem_prod(proj_catch(iyear),WAAcatchall(nyears));
    proj_total_yield(iyear)=sum(proj_yield(iyear));
    proj_total_Discard(iyear)=sum(elem_prod(proj_Discard(iyear),WAAdiscardall(nyears)));
    proj_TotJan1B(iyear)=sum(elem_prod(proj_NAA(iyear),WAAjan1b(nyears)));
    proj_SSB(iyear)=elem_prod(proj_NAA(iyear),proj_SSBfracZ(iyear))*fecundity(nyears);
  }

FUNCTION get_SPR
// simple spawners per recruit calculations
```

```
  ntemp=1.0;
  SPR=0.0;
  for (iage=1;iage<nages;iage++)
  {
    z=M(nyears,iage)+proj_nondir_F(iage)+SPR_Fmult*proj_dir_sel(iage)+SPR_Fmult*proj_Discard_sel(iage);
    SPR+=ntemp*fecundity(nyears,iage)*mfexp(-1.0*fracyearSSB*z);
    ntemp*=mfexp(-1.0*z);
  }
  z=M(nyears,nages)+proj_nondir_F(nages)+SPR_Fmult*proj_dir_sel(nages)+SPR_Fmult*proj_Discard_sel(nages);
  ntemp/=(1.0-mfexp(-1.0*z));
  SPR+=ntemp*fecundity(nyears,nages)*mfexp(-1.0*fracyearSSB*z);

FUNCTION get_multinomial_multiplier
// compute Francis (2011) stage 2 multiplier for multinomial to adjust input Neff
// Francis, R.I.C.C. 2011. Data weighting in statistical fisheries stock assessment models. CJFAS 68: 1124-1138
  Neff_stage2_mult_catch=1;
  Neff_stage2_mult_discard=1;
  Neff_stage2_mult_index=1;
  // Catch
  for (ifleet=1;ifleet<=nfleets;ifleet++){
    mean_age_obs=0.0;
    mean_age_pred=0.0;
    mean_age_pred2=0.0;
    mean_age_resid=0.0;
    for (iyear=1;iyear<=nyears;iyear++){
      for (iage=sel_start_age(ifleet);iage<=sel_end_age(ifleet);iage++){
        mean_age_obs(iyear) += CAA_prop_obs(ifleet,iyear,iage)*iage;
        mean_age_pred(iyear) += CAA_prop_pred(ifleet,iyear,iage)*iage;
        mean_age_pred2(iyear) += CAA_prop_pred(ifleet,iyear,iage)*iage*iage;
      }
    }
    mean_age_resid=mean_age_obs-mean_age_pred;
    mean_age_sigma=sqrt(mean_age_pred2-elem_prod(mean_age_pred,mean_age_pred));
    mean_age_n=0.0;
    mean_age_mean=0.0;
    mean_age_m2=0.0;
    for (iyear=1;iyear<=nyears;iyear++){
      if (input_eff_samp_size_catch(ifleet,iyear)>0){
        mean_age_x=mean_age_resid(iyear)*sqrt(input_eff_samp_size_catch(ifleet,iyear))/mean_age_sigma(iyear);
        mean_age_n += 1.0;
        mean_age_delta=mean_age_x-mean_age_mean;
        mean_age_mean += mean_age_delta/mean_age_n;
        mean_age_m2 += mean_age_delta*(mean_age_x-mean_age_mean);
      }
    }
    if ((mean_age_n > 0) && (mean_age_m2 > 0)) Neff_stage2_mult_catch(ifleet)=1.0/(mean_age_m2/(mean_age_n-
1.0));
  }

  // Discards
  for (ifleet=1;ifleet<=nfleets;ifleet++){
    mean_age_obs=0.0;
    mean_age_pred=0.0;
    mean_age_pred2=0.0;
    mean_age_resid=0.0;
    for (iyear=1;iyear<=nyears;iyear++){
      for (iage=sel_start_age(ifleet);iage<=sel_end_age(ifleet);iage++){
        mean_age_obs(iyear) += Discard_prop_obs(ifleet,iyear,iage)*iage;
        mean_age_pred(iyear) += Discard_prop_pred(ifleet,iyear,iage)*iage;
        mean_age_pred2(iyear) += Discard_prop_pred(ifleet,iyear,iage)*iage*iage;
      }
    }
    mean_age_resid=mean_age_obs-mean_age_pred;
    mean_age_sigma=sqrt(mean_age_pred2-elem_prod(mean_age_pred,mean_age_pred));
    mean_age_n=0.0;
    mean_age_mean=0.0;
    mean_age_m2=0.0;
    for (iyear=1;iyear<=nyears;iyear++){
      if (input_eff_samp_size_discard(ifleet,iyear)>0){
        mean_age_x=mean_age_resid(iyear)*sqrt(input_eff_samp_size_discard(ifleet,iyear))/mean_age_sigma(iyear);
        mean_age_n += 1.0;
```

```
        mean_age_delta=mean_age_x-mean_age_mean;
        mean_age_mean += mean_age_delta/mean_age_n;
        mean_age_m2 += mean_age_delta*(mean_age_x-mean_age_mean);
      }
    }
    if ((mean_age_n > 0) && (mean_age_m2 > 0)) Neff_stage2_mult_discard(ifleet)=1.0/(mean_age_m2/(mean_age_n-
1.0));
  }
  // Indices
  for (ind=1;ind<=nindices;ind++){
    mean_age_obs=0.0;
    mean_age_pred=0.0;
    mean_age_pred2=0.0;
    mean_age_resid=0.0;
    for (i=1;i<=index_nobs(ind);i++){
      j=index_time(ind,i);
      for (iage=index_start_age(ind);iage<=index_end_age(ind);iage++){
        mean_age_obs(j) += index_prop_obs(ind,i,iage)*iage;
        mean_age_pred(j) += index_prop_pred(ind,i,iage)*iage;
        mean_age_pred2(j) += index_prop_pred(ind,i,iage)*iage*iage;
      }
    }
    mean_age_resid=mean_age_obs-mean_age_pred;
    mean_age_sigma=sqrt(mean_age_pred2-elem_prod(mean_age_pred,mean_age_pred));
    mean_age_n=0.0;
    mean_age_mean=0.0;
    mean_age_m2=0.0;
    for (iyear=1;iyear<=nyears;iyear++){
      if (index_Neff_init(ind,iyear)>0){
        mean_age_x=mean_age_resid(iyear)*sqrt(index_Neff_init(ind,iyear))/mean_age_sigma(iyear);
        mean_age_n += 1.0;
        mean_age_delta=mean_age_x-mean_age_mean;
        mean_age_mean += mean_age_delta/mean_age_n;
        mean_age_m2 += mean_age_delta*(mean_age_x-mean_age_mean);
      }
    }
    if ((mean_age_n > 0) && (mean_age_m2 > 0)) Neff_stage2_mult_index(ind)=1.0/(mean_age_m2/(mean_age_n-1.0));
  }



FUNCTION get_log_factorial
// compute sum of log factorial, used in multinomial likelihood constant
  nfact_out=0.0;
  if (nfact_in >= 2)
  {
     for (int ilogfact=2;ilogfact<=nfact_in;ilogfact++)
     {
        nfact_out+=log(ilogfact);
     }
  }

FUNCTION compute_the_objective_function
  obj_fun=0.0;
  io=0; // io if statements commented out to speed up program

// indices (lognormal)
  for (ind=1;ind<=nindices;ind++)
  {
     likely_ind(ind)=index_like_const(ind);
     RSS_ind(ind)=norm2(log(index_obs(ind))-log(index_pred(ind)));
     for (i=1;i<=index_nobs(ind);i++)
     {
         likely_ind(ind)+=log(index_sigma(ind,i));
         likely_ind(ind)+=0.5*square(log(index_obs(ind,i))-log(index_pred(ind,i)))/index_sigma2(ind,i);
         index_stdresid(ind,i)=(log(index_obs(ind,i))-log(index_pred(ind,i)))/index_sigma(ind,i);
     }
     obj_fun+=lambda_ind(ind)*likely_ind(ind);
  }
  // if (io==1) cout << "likely_ind " << likely_ind << endl;
```

```
// indices age comp (multinomial)
  likely_index_age_comp=index_prop_like_const;
  for (ind=1;ind<=nindices;ind++)
  {
     if (index_estimate_proportions(ind)==1)
     {
       for (i=1;i<=index_nobs(ind);i++)
       {
         temp_sum=0.0;
         for (iage=index_start_age(ind);iage<=index_end_age(ind);iage++)
         {
            temp_sum+=index_prop_obs(ind,i,iage)*log(index_prop_pred(ind,i,iage));
         }
         likely_index_age_comp+=-1.0*input_eff_samp_size_index(ind,i)*temp_sum;
       }
     }
  }
  obj_fun+=likely_index_age_comp;
  // if (io==1) cout << "likely_index_age_comp " << likely_index_age_comp << endl;

// total catch (lognormal)
  for (ifleet=1;ifleet<=nfleets;ifleet++)
  {
     catch_tot_likely(ifleet)=catch_tot_like_const(ifleet);
     discard_tot_likely(ifleet)=discard_tot_like_const(ifleet);
     RSS_catch_tot_fleet(ifleet)=norm2(log(Catch_tot_fleet_obs(ifleet)+0.00001)-
log(Catch_tot_fleet_pred(ifleet)+0.00001));
     RSS_Discard_tot_fleet(ifleet)=norm2(log(Discard_tot_fleet_obs(ifleet)+0.00001)-
log(Discard_tot_fleet_pred(ifleet)+0.00001));
     for (iyear=1;iyear<=nyears;iyear++)
     {
        catch_tot_likely(ifleet)+=log(catch_tot_sigma(ifleet,iyear));
        catch_tot_likely(ifleet)+=0.5*square(log(Catch_tot_fleet_obs(ifleet,iyear)+0.00001)-
log(Catch_tot_fleet_pred(ifleet,iyear)+0.00001))/catch_tot_sigma2(ifleet,iyear);
        discard_tot_likely(ifleet)+=log(discard_tot_sigma(ifleet,iyear));
        discard_tot_likely(ifleet)+=0.5*square(log(Discard_tot_fleet_obs(ifleet,iyear)+0.00001)-
log(Discard_tot_fleet_pred(ifleet,iyear)+0.00001))/discard_tot_sigma2(ifleet,iyear);
     }
     obj_fun+=lambda_catch_tot(ifleet)*catch_tot_likely(ifleet);
     obj_fun+=lambda_Discard_tot(ifleet)*discard_tot_likely(ifleet);
  }
  // if (io==1) cout << "catch_tot_likely " << catch_tot_likely << endl;

// catch age comp (multinomial)
  likely_catch=catch_prop_like_const;
  likely_Discard=discard_prop_like_const;
  for (ifleet=1;ifleet<=nfleets;ifleet++)
  {
    for (iyear=1;iyear<=nyears;iyear++)
    {
       temp_sum=0.0;
       temp_sum2=0.0;
       for (iage=sel_start_age(ifleet);iage<=sel_end_age(ifleet);iage++)
       {
          temp_sum+=CAA_prop_obs(ifleet,iyear,iage)*log(CAA_prop_pred(ifleet,iyear,iage));
          if(proportion_release(ifleet,iyear,iage)>0.0)
             temp_sum2+=Discard_prop_obs(ifleet,iyear,iage)*log(Discard_prop_pred(ifleet,iyear,iage));
       }
       likely_catch+=-1.0*input_eff_samp_size_catch(ifleet,iyear)*temp_sum;
       likely_Discard+=-1.0*input_eff_samp_size_discard(ifleet,iyear)*temp_sum2;
    }
  }
  obj_fun+=likely_catch;
  obj_fun+=likely_Discard;
  // if (io==1) cout << "likely_catch " << likely_catch << endl;

// stock-recruitment relationship (lognormal)
  likely_SR_sigma=SR_like_const;
  if (use_likelihood_constants==1)
  {
     likely_SR_sigma+=sum(log(SR_pred_recruits));
```

```
     likely_SR_sigma-=log(SR_pred_recruits(nyears+1));  // pred R in terminal year plus one does not have a
deviation
  }
  SR_stdresid=0.0;
  if (active(log_recruit_devs))
  {
     for (iyear=1;iyear<=nyears;iyear++)
     {
        likely_SR_sigma+=log(recruit_sigma(iyear));
        likely_SR_sigma+=0.5*square(log(recruits(iyear))-log(SR_pred_recruits(iyear)))/recruit_sigma2(iyear);
        SR_stdresid(iyear)=(log(recruits(iyear))-log(SR_pred_recruits(iyear)))/recruit_sigma(iyear);
     }
     obj_fun+=lambda_recruit_devs*likely_SR_sigma;
  }
  // if (io==1) cout << "likely_SR_sigma " << likely_SR_sigma << endl;

// selectivity parameters
  sel_likely=0.0;
  sel_stdresid=0.0;
  for (k=1;k<=nselparm;k++)
  {
     if (active(sel_params(k)))
     {
        sel_likely(k)+=sel_like_const(k);
        sel_likely(k)+=log(sel_sigma(k))+0.5*square(log(sel_initial(k))-log(sel_params(k)))/sel_sigma2(k);
        sel_stdresid(k)=(log(sel_initial(k))-log(sel_params(k)))/sel_sigma(k);
        obj_fun+=sel_lambda(k)*sel_likely(k);
     }
  }
  // if (io==1) cout << "sel_likely " << sel_likely << endl;

// index selectivity parameters
  indexsel_likely=0.0;
  indexsel_stdresid=0.0;
  for (k=1;k<=nindexselparms;k++)
  {
     if (active(index_sel_params(k)))
     {
        indexsel_likely(k)+=indexsel_like_const(k);
        indexsel_likely(k)+=log(indexsel_sigma(k))+0.5*square(log(indexsel_initial(k))-
log(index_sel_params(k)))/indexsel_sigma2(k);
        indexsel_stdresid(k)=(log(indexsel_initial(k))-log(index_sel_params(k)))/indexsel_sigma(k);
        obj_fun+=indexsel_lambda(k)*indexsel_likely(k);
     }
  }
  // if (io==1) cout << "indexsel_likely " << indexsel_likely << endl;

  steepness_likely=0.0;
  steepness_stdresid=0.0;
  if (active(SR_steepness))
  {
     steepness_likely=steepness_like_const;
     steepness_likely+=log(steepness_sigma)+0.5*square(log(SR_steepness_ini)-
log(SR_steepness))/steepness_sigma2;
     steepness_stdresid=(log(SR_steepness_ini)-log(SR_steepness))/steepness_sigma;
     obj_fun+=lambda_steepness*steepness_likely;
  }
  // if (io==1) cout << "steepness_likely " << steepness_likely << endl;

  SR_scaler_likely=0.0;
  SR_scaler_stdresid=0.0;
  if (active(log_SR_scaler))
  {
     SR_scaler_likely=SR_scaler_like_const;
     SR_scaler_likely+=log(SR_scaler_sigma)+0.5*(square(log(SR_scaler_ini)-log_SR_scaler))/SR_scaler_sigma2;
     SR_scaler_stdresid=(log(SR_scaler_ini)-log_SR_scaler)/SR_scaler_sigma;
     obj_fun+=lambda_SR_scaler*SR_scaler_likely;
  }
  // if (io==1) cout << "SR_scaler_likely " << SR_scaler_likely << endl;

  Fmult_year1_stdresid=0.0;
```

```
  if (active(log_Fmult_year1))
  {
     for (ifleet=1;ifleet<=nfleets;ifleet++)
     {
        Fmult_year1_likely(ifleet)=Fmult_year1_like_const(ifleet);
        Fmult_year1_likely(ifleet)+=log(Fmult_year1_sigma(ifleet))+0.5*square(log_Fmult_year1(ifleet)-
log(Fmult_year1_ini(ifleet)))/Fmult_year1_sigma2(ifleet);
        Fmult_year1_stdresid(ifleet)=(log_Fmult_year1(ifleet)-
log(Fmult_year1_ini(ifleet)))/Fmult_year1_sigma(ifleet);
     }
     obj_fun+=lambda_Fmult_year1*Fmult_year1_likely;
  }
  // if (io==1) cout << "Fmult_year1_likely " << Fmult_year1_likely << endl;

  Fmult_devs_stdresid=0.0;
  if (active(log_Fmult_devs))
  {
     for (ifleet=1;ifleet<=nfleets;ifleet++)
     {
        Fmult_devs_likely(ifleet)=Fmult_devs_like_const(ifleet);

Fmult_devs_likely(ifleet)+=log(Fmult_devs_sigma(ifleet))+0.5*norm2(log_Fmult_devs(ifleet))/Fmult_devs_sigma2(ifl
eet);
        for (iyear=2;iyear<=nyears;iyear++)
           Fmult_devs_stdresid(ifleet,iyear)=log_Fmult_devs(ifleet,iyear)/Fmult_devs_sigma(ifleet);
     }
     obj_fun+=lambda_Fmult_devs*Fmult_devs_likely;
  }
  // if (io==1) cout << "Fmult_devs_likely " << Fmult_devs_likely << endl;

  q_year1_stdresid=0.0;
  if (active(log_q_year1))
  {
     for (ind=1;ind<=nindices;ind++)
     {
        q_year1_likely(ind)=q_year1_like_const(ind);
        q_year1_likely(ind)+=log(q_year1_sigma(ind))+0.5*square(log_q_year1(ind)-
log(q_year1_ini(ind)))/q_year1_sigma2(ind);
        q_year1_stdresid(ind)=(log_q_year1(ind)-log(q_year1_ini(ind)))/q_year1_sigma(ind);
     }
     obj_fun+=lambda_q_year1*q_year1_likely;
  }
  // if (io==1) cout << "q_year1_likely " << q_year1_likely << endl;

  q_devs_stdresid=0.0;
  if (active(log_q_devs))
  {
     for (ind=1;ind<=nindices;ind++)
     {
       q_devs_likely(ind)=q_devs_like_const(ind);
       q_devs_likely(ind)+=log(q_devs_sigma(ind))+0.5*norm2(log_q_devs(ind))/q_devs_sigma2(ind);
       for (i=2;i<=index_nobs(ind);i++)
          q_devs_stdresid(ind,i)=log_q_devs(ind,i)/q_devs_sigma(ind);
     }
     obj_fun+=lambda_q_devs*q_devs_likely;
  }
  // if (io==1) cout << "q_devs_likely " << q_devs_likely << endl;

  if (NAA_year1_flag==1)
  {
     nyear1temp(1)=SR_pred_recruits(1);
     N_year1_stdresid=0.0;
     for (iage=2;iage<=nages;iage++)
     {
        nyear1temp(iage)=nyear1temp(iage-1)*S(1,iage-1);
     }
     nyear1temp(nages)/=(1.0-S(1,nages));
  }
  else if (NAA_year1_flag==2)
  {
     nyear1temp=NAA_year1_ini;
```

```
  }
  if (active(log_N_year1_devs))
  {
     if (N_year1_sigma>0.0)
     {
        for (iage=2;iage<=nages;iage++)
           N_year1_stdresid(iage)=(log(NAA(1,iage))-log(nyear1temp(iage)))/N_year1_sigma;
     }
     N_year1_likely=N_year1_like_const+sum(log(nyear1temp));
     N_year1_likely+=log(N_year1_sigma)+0.5*norm2(log(NAA(1))-log(nyear1temp))/N_year1_sigma2;
     obj_fun+=lambda_N_year1_devs*N_year1_likely;
  }
  // if (io==1) cout << "N_year1_likely " << N_year1_likely << endl;

  Fmult_max_pen=0.0;
  for (ifleet=1;ifleet<=nfleets;ifleet++)
  {
    for (iyear=1;iyear<=nyears;iyear++)
    {
       temp_Fmult_max=mfexp(log_Fmult(ifleet,iyear))*max(sel_by_fleet(ifleet,iyear));
       if(temp_Fmult_max>Fmult_max_value)
          Fmult_max_pen+=1000.*(temp_Fmult_max-Fmult_max_value)*(temp_Fmult_max-Fmult_max_value);
    }
  }
  obj_fun+=Fmult_max_pen;
  // if (io==1) cout << "Fmult_max_pen " << Fmult_max_pen << endl;

  fpenalty_lambda=100.0*pow(10.0,(-1.0*current_phase())); // decrease emphasis on F near M as phases increase
  if (last_phase())                                       // no penalty in final solution
     fpenalty_lambda=0.0;
  fpenalty=fpenalty_lambda*square(log(mean(FAA_tot))-log(mean(M)));
  obj_fun+=fpenalty;
  // if (io==1) cout << "fpenalty " << fpenalty << endl;

FUNCTION write_MCMC
// first the output file for AgePro
  if (MCMCnyear_opt == 0)    // use final year
  {
     if (fillR_opt == 0)
     {
        NAAbsn(1)=NAA(nyears,1);
     }
     else if (fillR_opt == 1)
     {
        NAAbsn(1)=SR_pred_recruits(nyears);
     }
     else if (fillR_opt == 2)
     {
        tempR=0.0;
        for (i=Ravg_start;i<=Ravg_end;i++)
        {
           iyear=i-year1+1;
           tempR+=log(NAA(iyear,1));
        }
        NAAbsn(1)=mfexp(tempR/(Ravg_end-Ravg_start+1.0));
     }
     for (iage=2;iage<=nages;iage++)
     {
        NAAbsn(iage)=NAA(nyears,iage);
     }
  }
  else                       // use final year + 1
  {
     if (fillR_opt == 1)
     {
        NAAbsn(1)=SR_pred_recruits(nyears+1);
     }
     else if (fillR_opt == 2)
     {
        tempR=0.0;
        for (i=Ravg_start;i<=Ravg_end;i++)
```

```
        {
           iyear=i-year1+1;
           tempR+=log(NAA(iyear,1));
        }
        NAAbsn(1)=mfexp(tempR/(Ravg_end-Ravg_start+1.0));
     }
     for (iage=2;iage<=nages;iage++)
     {
        NAAbsn(iage)=NAA(nyears,iage-1)*S(nyears,iage-1);
     }
     NAAbsn(nages)+=NAA(nyears,nages)*S(nyears,nages);
  }

  // Liz added
       for (iyear=1;iyear<=nyears;iyear++)
     {
               tempFmult(iyear) = max(extract_row(FAA_tot,iyear));
               }
  // end stuff Liz added


// output the NAAbsn values
  ageproMCMC << NAAbsn << endl;

// now the standard MCMC output file
  basicMCMC << Freport << " " <<
               SSB << " " <<

                ///  Liz added

               tempFmult << " " <<

               rowsum(elem_prod(WAAjan1b, NAA)) << " " <<

               /// end stuff Liz added

               MSY << " " <<
               SSmsy << " " <<
               Fmsy << " " <<
               SSBmsy_ratio << " " <<
               Fmsy_ratio << " " <<
               endl;

REPORT_SECTION
  report << "Age Structured Assessment Program (ASAP) Version 3.0" << endl;
  report << "Start time for run: " << ctime(&start) << endl;
  report << "obj_fun        = " << obj_fun << endl << endl;
  report << "Component                Lambda          obj_fun" << endl;
  for (ifleet=1;ifleet<=nfleets;ifleet++)
     report << "__Catch_Fleet_" << ifleet << "                " << lambda_catch_tot(ifleet) << "          " <<
lambda_catch_tot(ifleet)*catch_tot_likely(ifleet) << endl;
  report << "Catch_Fleet_Total             " << sum(lambda_catch_tot) << "          " <<
lambda_catch_tot*catch_tot_likely << endl;
  if (lambda_Discard_tot*discard_tot_likely > 0.0)
  {
     for (ifleet=1;ifleet<=nfleets;ifleet++)
        report << "__Discard_Fleet_" << ifleet << "              " << lambda_Discard_tot(ifleet) << "          "
<< lambda_Discard_tot(ifleet)*discard_tot_likely(ifleet) << endl;
  }
  report << "Discard_Fleet_Total           " << sum(lambda_Discard_tot) << "          " <<
lambda_Discard_tot*discard_tot_likely << endl;
  for (ind=1;ind<=nindices;ind++)
     report << "__Index_Fit_" << ind << "                 " << lambda_ind(ind) << "          " <<
lambda_ind(ind)*likely_ind(ind) << endl;
  report << "Index_Fit_Total               " << sum(lambda_ind) << "          " << lambda_ind*likely_ind <<
endl;
  report << "Catch_Age_Comps       see_below          " << likely_catch << endl;
  report << "Discard_Age_Comps     see_below          " << likely_Discard << endl;
  report << "Index_Age_Comps       see_below          " << likely_index_age_comp << endl;
  sum_sel_lambda=0;
  sum_sel_lambda_likely=0.0;
```

```
  for (k=1;k<=nselparm;k++)
  {
     if (sel_phase(k) >= 1)
     {
        if      (k < 10  ) report << "__Sel_Param_" << k << "                 " << sel_lambda(k) << "          "
<< sel_lambda(k)*sel_likely(k) << endl;
        else if (k < 100 ) report << "__Sel_Param_" << k << "                " << sel_lambda(k) << "          "
<< sel_lambda(k)*sel_likely(k) << endl;
        else if (k < 1000) report << "__Sel_Param_" << k << "               " << sel_lambda(k) << "          "
<< sel_lambda(k)*sel_likely(k) << endl;
        sum_sel_lambda+=sel_lambda(k);
        sum_sel_lambda_likely+=sel_lambda(k)*sel_likely(k);
     }
  }
  report << "Sel_Params_Total              " << sum_sel_lambda << "          " << sum_sel_lambda_likely << endl;
  sum_indexsel_lambda=0;
  sum_indexsel_lambda_likely=0.0;
  for (k=1;k<=nindexselparms;k++)
  {
     if (indexsel_phase(k) >= 1)
     {
        if      (k <10  ) report << "__Index_Sel_Param_" << k << "           " << indexsel_lambda(k) << "
" << indexsel_lambda(k)*indexsel_likely(k) << endl;
        else if (k <100 ) report << "__Index_Sel_Param_" << k << "          " << indexsel_lambda(k) << "
" << indexsel_lambda(k)*indexsel_likely(k) << endl;
        else if (k <1000) report << "__Index_Sel_Param_" << k << "         " << indexsel_lambda(k) << "
" << indexsel_lambda(k)*indexsel_likely(k) << endl;
        sum_indexsel_lambda+=indexsel_lambda(k);
        sum_indexsel_lambda_likely+=indexsel_lambda(k)*indexsel_likely(k);
     }
  }
  report << "Index_Sel_Params_Total        " << sum_indexsel_lambda << "          " <<
sum_indexsel_lambda_likely << endl;
  if (lambda_q_year1*q_year1_likely > 0.0)
  {
     for (ind=1;ind<=nindices;ind++)
        report << "__q_year1_index_" << ind << "             "  << lambda_q_year1(ind) << "          " <<
lambda_q_year1(ind)*q_year1_likely(ind) << endl;
  }
  report << "q_year1_Total                 " << sum(lambda_q_year1) << "          " <<
lambda_q_year1*q_year1_likely << endl;

  if (lambda_q_devs*q_devs_likely > 0.0)
  {
     for (ind=1;ind<=nindices;ind++)
        report << "__q_devs_index_" << ind << "              "  << lambda_q_devs(ind) << "          " <<
lambda_q_devs(ind)*q_devs_likely(ind) << endl;
  }
  report << "q_devs_Total                  " << sum(lambda_q_devs) << "          " <<
lambda_q_devs*q_devs_likely << endl;
  if (lambda_Fmult_year1*Fmult_year1_likely > 0.0);
  {
     for (ifleet=1;ifleet<=nfleets;ifleet++)
        report << "__Fmult_year1_fleet_" << ifleet << "         " << lambda_Fmult_year1(ifleet) << "          "
<< lambda_Fmult_year1(ifleet)*Fmult_year1_likely(ifleet) << endl;
  }
  report << "Fmult_year1_fleet_Total       " << sum(lambda_Fmult_year1) << "          " <<
lambda_Fmult_year1*Fmult_year1_likely << endl;
  if (lambda_Fmult_devs*Fmult_devs_likely > 0.0)
  {
     for (ifleet=1;ifleet<=nfleets;ifleet++)
        report << "__Fmult_devs_fleet_" << ifleet << "          " << lambda_Fmult_devs(ifleet) << "          "
<< lambda_Fmult_devs(ifleet)*Fmult_devs_likely(ifleet) << endl;
  }
  report << "Fmult_devs_fleet_Total        " << sum(lambda_Fmult_devs) << "          " <<
lambda_Fmult_devs*Fmult_devs_likely << endl;
  report << "N_year_1                      " << lambda_N_year1_devs << "          " <<
lambda_N_year1_devs*N_year1_likely << endl;
  report << "Recruit_devs                  " << lambda_recruit_devs << "          " <<
lambda_recruit_devs*likely_SR_sigma << endl;
```

```
  report << "SR_steepness                  " << lambda_steepness << "          " <<
lambda_steepness*steepness_likely << endl;
  report << "SR_scaler                     " << lambda_SR_scaler << "          " <<
lambda_SR_scaler*SR_scaler_likely << endl;
  report << "Fmult_Max_penalty         1000          " << Fmult_max_pen << endl;
  report << "F_penalty                     " << fpenalty_lambda << "          " << fpenalty << endl;
  report << endl;
  for (ifleet=1;ifleet<=nfleets;ifleet++)
  {
     for (iyear=1;iyear<=nyears;iyear++)
     {
       if (input_eff_samp_size_catch(ifleet,iyear)==0)
       {
         effective_sample_size(ifleet,iyear)=0;
       }
       else
       {
         effective_sample_size(ifleet,iyear)=CAA_prop_pred(ifleet,iyear)*(1.0-
CAA_prop_pred(ifleet,iyear))/norm2(CAA_prop_obs(ifleet,iyear)-CAA_prop_pred(ifleet,iyear));
       }
       if (input_eff_samp_size_discard(ifleet,iyear)==0)
       {
         effective_Discard_sample_size(ifleet,iyear)=0;
       }
       else
       {
         effective_Discard_sample_size(ifleet,iyear)=Discard_prop_pred(ifleet,iyear)*(1.0-
Discard_prop_pred(ifleet,iyear))/norm2(Discard_prop_obs(ifleet,iyear)-Discard_prop_pred(ifleet,iyear));
       }
     }
  }
  for (ifleet=1;ifleet<=nfleets;ifleet++)
  {
     report << " Input and Estimated effective sample sizes for fleet " << ifleet << endl;
     for (iyear=1;iyear<=nyears;iyear++)
        report << iyear+year1-1 << "  " << input_eff_samp_size_catch(ifleet,iyear) << "  " <<
effective_sample_size(ifleet,iyear) << endl;
     report << " Total  " << sum(input_eff_samp_size_catch(ifleet)) << "  " <<
sum(effective_sample_size(ifleet)) << endl;
  }
  report << endl;
  for (ifleet=1;ifleet<=nfleets;ifleet++)
  {
     report << " Input and Estimated effective Discard sample sizes for fleet " << ifleet << endl;
     for (iyear=1;iyear<=nyears;iyear++)
        report << iyear+year1-1 << "  " << input_eff_samp_size_discard(ifleet,iyear) << "  " <<
effective_Discard_sample_size(ifleet,iyear) << endl;
     report << " Total  " << sum(input_eff_samp_size_discard(ifleet)) << "  " <<
sum(effective_Discard_sample_size(ifleet)) << endl;
  }
  report << endl;
  report << "Observed and predicted total fleet catch by year and standardized residual" << endl;
  for (ifleet=1;ifleet<=nfleets;ifleet++)
  {
    report << " fleet " << ifleet << " total catches" << endl;
    for (iyear=1;iyear<=nyears;iyear++)
    {
      Catch_stdresid(ifleet,iyear)=(log(Catch_tot_fleet_obs(ifleet,iyear)+0.00001)-
log(Catch_tot_fleet_pred(ifleet,iyear)+0.00001))/catch_tot_sigma(ifleet,iyear);
      report << iyear+year1-1 << "  " << Catch_tot_fleet_obs(ifleet,iyear) << "  " <<
Catch_tot_fleet_pred(ifleet,iyear) << "  " << Catch_stdresid(ifleet,iyear) << endl;
    }
  }
  report << "Observed and predicted total fleet Discards by year and standardized residual" << endl;
  for (ifleet=1;ifleet<=nfleets;ifleet++)
  {
    report << " fleet " << ifleet << " total Discards" << endl;
    for (iyear=1;iyear<=nyears;iyear++)
    {
      Discard_stdresid(ifleet,iyear)=(log(Discard_tot_fleet_obs(ifleet,iyear)+0.00001)-
log(Discard_tot_fleet_pred(ifleet,iyear)+0.00001))/discard_tot_sigma(ifleet,iyear);
```

```
      report << iyear+year1-1 << "  " << Discard_tot_fleet_obs(ifleet,iyear) << "  " <<
Discard_tot_fleet_pred(ifleet,iyear) << "  " << Discard_stdresid(ifleet,iyear) << endl;
    }
  }
  report << endl << "Index data" << endl;
  for (ind=1;ind<=nindices;ind++) {
     report << "index number " << ind << endl;
     report << "aggregate units = " << index_units_aggregate(ind) << endl;
     report << "proportions units = " << index_units_proportions(ind) << endl;
     report << "month = " << index_month(ind) << endl;
     report << "starting and ending ages for selectivity = " << index_start_age(ind) << "  " <<
index_end_age(ind) << endl;
     report << "selectivity choice = " << index_sel_choice(ind) << endl;
     report << " year, obs index, pred index, standardized residual" << endl;
     for (j=1;j<=index_nobs(ind);j++)
         report << index_year(ind,j) << "  " << index_obs(ind,j) << "  " << index_pred(ind,j) << "  " <<
index_stdresid(ind,j) << endl;
  }
  report << endl;
  index_Neff_init=0.0;
  index_Neff_est=0.0;
  for (ind=1;ind<=nindices;ind++)
  {
     for (iyear=1;iyear<=nyears;iyear++)
     {
         for (i=1;i<=index_nobs(ind);i++)
         {
             if (index_time(ind,i)==iyear)
             {
                 index_Neff_init(ind,iyear)=input_eff_samp_size_index(ind,i);
                 if (input_eff_samp_size_index(ind,i)==0)
                 {
                     index_Neff_est(ind,iyear)=0.0;
                 }
                 else
                 {
                     index_Neff_est(ind,iyear)=index_prop_pred(ind,i)*(1.0-
index_prop_pred(ind,i))/norm2(index_prop_obs(ind,i)-index_prop_pred(ind,i));
                 }
             }
         }
     }
  }
  report << "Input effective sample sizes by index (row=index, column=year)" << endl;
  report << index_Neff_init << endl;
  report << "Estimated effective sample sizes by index (row=index, column=year)" << endl;
  report << index_Neff_est << endl;
  report << endl;
  report << "Index proportions at age by index" << endl;
  for (ind=1;ind<=nindices;ind++)
  {
     output_index_prop_obs(ind)=0.0;
     output_index_prop_pred(ind)=0.0;
     if (index_estimate_proportions(ind)==1)
     {
        report << " Index number " << ind << endl;
        for (iyear=1;iyear<=nyears;iyear++)
        {
           for (i=1;i<=index_nobs(ind);i++)
           {
               if (index_time(ind,i)==iyear)
               {
                   for (iage=index_start_age(ind);iage<=index_end_age(ind);iage++)
                   {
                       output_index_prop_obs(ind,iyear,iage)=index_prop_obs(ind,i,iage);
                       output_index_prop_pred(ind,iyear,iage)=index_prop_pred(ind,i,iage);
                   }
               }
           }
           report << "Year " << iyear+year1-1 << " Obs  = " << output_index_prop_obs(ind,iyear) << endl;
           report << "Year " << iyear+year1-1 << " Pred = " << output_index_prop_pred(ind,iyear) << endl;
```

```
      }
    }
  }
  report << endl;
  report << "Index Selectivity at Age" << endl;
  report << indexsel << endl;
  report << endl;

  report << "Deviations section: only applicable if associated lambda > 0" << endl;
  report << "Nyear1 observed, expected, standardized residual" << endl;
  if (lambda_N_year1_devs > 0.0)
  {
    for (iage=2;iage<=nages;iage++)
    {
      report << iage << "  " << NAA(1,iage) << "  " << nyear1temp(iage) << "  " << N_year1_stdresid(iage) <<
endl;
    }
  }
  else
  {
    report << "N/A" << endl;
  }
  report << endl;
  report << "Fleet Obs, Initial, and Stadardized Residual for Fmult" << endl;
  if (sum(lambda_Fmult_year1) > 0.0)
  {
    for (ifleet=1;ifleet<=nfleets;ifleet++)
      report << ifleet << "  " << mfexp(log_Fmult_year1(ifleet)) << "  " << Fmult_year1_ini(ifleet) << "  " <<
Fmult_year1_stdresid(ifleet) << endl;
  }
  else
  {
    report << "N/A" << endl;
  }
  report << endl;
  report << "Standardized Residuals for Fmult_devs by fleet and year" << endl;
  if (sum(lambda_Fmult_devs) > 0.0)
  {
    for (ifleet=1;ifleet<=nfleets;ifleet++)
    {
      report << " fleet " << ifleet << " Fmult_devs standardized residuals" << endl;
      for (iyear=2;iyear<=nyears;iyear++)
        report << iyear << "  " << Fmult_devs_stdresid(ifleet,iyear) << endl;
    }
  }
  else
  {
    report << "N/A" << endl;
  }
  report << endl;
  report << "Index Obs, Initial, and Standardized Residual for q_year1" << endl;
  if (sum(lambda_q_year1) > 0.0)
  {
    for (ind=1;ind<=nindices;ind++)
      report << ind << "  " << mfexp(log_q_year1(ind)) << "  " << q_year1_ini(ind) << "  " <<
            (log_q_year1(ind)-log(q_year1_ini(ind)))/q_year1_sigma(ind) << endl;
  }
  else
  {
    report << "N/A" << endl;
  }
  report << endl;
  report << "Standardized Residuals for catchability deviations by index and year" << endl;
  if (sum(lambda_q_devs) > 0.0)
  {
    for (ind=1;ind<=nindices;ind++)
    {
      report << " index " << ind << " q_devs standardized residuals" << endl;
      for (i=2;i<=index_nobs(ind);i++)
        report << index_year(ind,i) << "  " << log_q_devs(ind,i)/q_devs_sigma(ind) << endl;
    }
```

```
  }
  else
  {
     report << "N/A" << endl;
  }
  report << endl;
  report << "Obs, Initial, and Stadardized Residual for SR steepness" << endl;
  if (lambda_steepness > 0.0)
  {
     report << SR_steepness << "  " << SR_steepness_ini << "  " << (log(SR_steepness)-
log(SR_steepness_ini))/steepness_sigma << endl;
  }
  else
  {
     report << "N/A" << endl;
  }
  report << endl;
  report << "Obs, Initial, and Stadardized Residual for SR scaler" << endl;
  if (lambda_SR_scaler > 0.0)
  {
     report << mfexp(log_SR_scaler) << "  " << SR_scaler_ini << "  " << (log_SR_scaler-
log(SR_scaler_ini))/SR_scaler_sigma << endl;
  }
  else
  {
     report << "N/A" << endl;
  }
  report << endl;
  report << "End of Deviations Section" << endl << endl;

  report << "Selectivity by age and year for each fleet" << endl;
  for (ifleet=1;ifleet<=nfleets;ifleet++) {
     report << " fleet " << ifleet << " selectivity at age" << endl;
     for (iyear=1;iyear<=nyears;iyear++)
       report << sel_by_fleet(ifleet,iyear) << endl;
  }
  report << endl;
  report << "Fmult by year for each fleet" << endl;
  Fmult=mfexp(log_Fmult);
  for (iyear=1;iyear<=nyears;iyear++) {
     for (ifleet=1;ifleet<=nfleets;ifleet++){
         temp_Fmult(ifleet)=Fmult(ifleet,iyear);
     }
     report << iyear+year1-1 << "  " << temp_Fmult << endl;
  }
  report << endl;
  report << "Directed F by age and year for each fleet" << endl;
  for (ifleet=1;ifleet<=nfleets;ifleet++)
  {
     report << " fleet " << ifleet << " directed F at age" << endl;
     for (iyear=1;iyear<=nyears;iyear++)
         report << FAA_by_fleet_dir(ifleet,iyear) << endl;
  }
  report << "Discard F by age and year for each fleet" << endl;
  for (ifleet=1;ifleet<=nfleets;ifleet++)
  {
     report << " fleet " << ifleet << " Discard F at age" << endl;
     for (iyear=1;iyear<=nyears;iyear++)
         report << FAA_by_fleet_Discard(ifleet,iyear) << endl;
  }
  report << "Total F" << endl;
  for (iyear=1;iyear<=nyears;iyear++)
     report << FAA_tot(iyear) << endl;
  report << endl;
  report << "Average F for ages " << Freport_agemin << " to " << Freport_agemax << endl;
  if (Freport_wtopt==1) report << "Freport unweighted in .std and MCMC files" << endl;
  if (Freport_wtopt==2) report << "Freport N weighted in .std and MCMC files" << endl;
  if (Freport_wtopt==3) report << "Freport B weighted in .std and MCMC files" << endl;
  report << "year    unweighted   Nweighted    Bweighted" << endl;
  for (iyear=1;iyear<=nyears;iyear++){
```

```
     report << iyear+year1-1 << "  " << Freport_U(iyear) << "  " << Freport_N(iyear) << "  " << Freport_B(iyear)
<< endl;
  }
  report << endl;
  report << "Population Numbers at the Start of the Year" << endl;
  for (iyear=1;iyear<=nyears;iyear++)
     report << NAA(iyear) << endl;
  report << endl;
  report << "Biomass Time Series" << endl;
  report << "Year, TotJan1B, SSB, ExploitableB" << endl;
  for (iyear=1;iyear<=nyears;iyear++)
  {
     report << iyear+year1-1 << "  " << TotJan1B(iyear) << "  " << SSB(iyear) << "  " << ExploitableB(iyear) <<
endl;
  }
  report << endl;
  report << "q by index" << endl;
  for (ind=1;ind<=nindices;ind++)
  {
     report << " index " << ind << " q over time" << endl;
     for (i=1;i<=index_nobs(ind);i++)
     {
         report << index_year(ind,i) << "  " << q_by_index(ind,i) << endl;
     }
  }
  report << endl;
  report << "Proportions of catch at age by fleet" << endl;
  for (ifleet=1;ifleet<=nfleets;ifleet++)
  {
    report << " fleet " << ifleet << endl;
    for (iyear=1;iyear<=nyears;iyear++)
    {
       output_prop_obs=0.0;
       output_prop_pred=0.0;
       output_prop_obs(sel_start_age(ifleet),sel_end_age(ifleet))=CAA_prop_obs(ifleet,iyear);
       output_prop_pred(sel_start_age(ifleet),sel_end_age(ifleet))=CAA_prop_pred(ifleet,iyear);
       report << "Year " << iyear << " Obs  = " << output_prop_obs << endl;
       report << "Year " << iyear << " Pred = " << output_prop_pred << endl;
    }
  }
  report << endl;
  report << "Proportions of Discards at age by fleet" << endl;
  for (ifleet=1;ifleet<=nfleets;ifleet++)
  {
    report << " fleet " << ifleet << endl;
    for (iyear=1;iyear<=nyears;iyear++)
    {
       output_Discard_prop_obs=0.0;
       output_Discard_prop_pred=0.0;
       output_Discard_prop_obs(sel_start_age(ifleet),sel_end_age(ifleet))=Discard_prop_obs(ifleet,iyear);
       output_Discard_prop_pred(sel_start_age(ifleet),sel_end_age(ifleet))=Discard_prop_pred(ifleet,iyear);
       report << "Year " << iyear << " Obs  = " << output_Discard_prop_obs << endl;
       report << "Year " << iyear << " Pred = " << output_Discard_prop_pred << endl;
    }
  }
  report << endl;
  report << "F Reference Points Using Final Year Selectivity and Freport options" << endl;
  report << " refpt           F       slope to plot on SR" << endl;
  report << "  F0.1     " << F01_report << "     " << F01_slope << endl;
  report << "  Fmax     " << Fmax_report << "     " << Fmax_slope << endl;
  report << "  F30%SPR  " << F30SPR_report << "     " << F30SPR_slope << endl;
  report << "  F40%SPR  " << F40SPR_report << "     " << F40SPR_slope << endl;
  report << "  Fmsy     " << Fmsy_report << "     " << Fmsy_slope << "    SSBmsy    " << SSBmsy_report << "
MSY   " << MSY << endl;
  report << "  Fcurrent " << Freport(nyears) << "     " << Fcurrent_slope << endl;
  report << endl;
  report << "Stock-Recruitment Relationship Parameters" << endl;
  report << " alpha     = " << SR_alpha << endl;
  report << " beta      = " << SR_beta << endl;
  report << " R0        = " << SR_R0 << endl;
  report << " S0        = " << SR_S0 << endl;
```

```
  report << " steepness = " << SR_steepness << endl;
  report << "Spawning Stock, Obs Recruits(year+1), Pred Recruits(year+1), standardized residual" << endl;
  report << "init  xxxx  " << recruits(1) << "  " << SR_pred_recruits(1) << "  " <<
            (log(recruits(1))-log(SR_pred_recruits(1)))/recruit_sigma(1) << endl;
  for (iyear=1;iyear<nyears;iyear++)
    report << iyear+year1-1 << "  " << SSB(iyear) << "  " << recruits(iyear+1) << "  "  <<
SR_pred_recruits(iyear+1) << "  " <<
             (log(recruits(iyear+1))-log(SR_pred_recruits(iyear+1)))/recruit_sigma(iyear+1) << endl;
  report << nyears+year1-1 << "  " << SSB(nyears) << "      xxxx   " << SR_pred_recruits(nyears+1) << endl;
  report << endl;

  report << "Annual stock recruitment parameters" << endl;
  report << "Year, S0_vec, R0_vec, steepness_vec, s_per_r_vec" << endl;
  for (iyear=1;iyear<=nyears;iyear++)
    report << iyear+year1-1 << "  " << S0_vec(iyear) << "  " << R0_vec(iyear) << "  " << steepness_vec(iyear) <<
"  " << s_per_r_vec(iyear) << endl;
  report << endl;

  report << "Root Mean Square Error computed from Standardized Residuals" << endl;
  report << "Component                 #resids         RMSE" << endl;
  for (ifleet=1;ifleet<=nfleets;ifleet++)
  {
     report << "_Catch_Fleet_" << ifleet << "               " << nyears << "           " <<
sqrt(mean(square(Catch_stdresid(ifleet)))) << endl;
  }
  report << "Catch_Fleet_Total            " << nyears*nfleets << "           " <<
sqrt(mean(square(Catch_stdresid))) << endl;
  for (ifleet=1;ifleet<=nfleets;ifleet++)
  {
     if (norm2(Discard_stdresid(ifleet)) > 0.0 )
     {
        report << "_Discard_Fleet_" << ifleet << "             " << nyears << "           " <<
sqrt(mean(square(Discard_stdresid(ifleet)))) << endl;
     }
     else
     {
        report << "_Discard_Fleet_" << ifleet << "             " << "0" << "            " << "0" << endl;
     }
  }
  if (norm2(Discard_stdresid) > 0.0)
  {
     report << "Discard_Fleet_Total          " << nyears*nfleets << "           " <<
sqrt(mean(square(Discard_stdresid))) << endl;
  }
  else
  {
     report << "Discard_Fleet_Total          " << "0" << "            " << "0" << endl;
  }
  for (ind=1;ind<=nindices;ind++)
  {
     report << "_Index_" << ind << "                     " << index_nobs(ind) << "           " <<
sqrt(mean(square(index_stdresid(ind)))) << endl;
  }
  report << "Index_Total                 " << sum(index_nobs) << "           " <<
sqrt(mean(square(index_stdresid))) << endl;
  N_year1_rmse=0.0;
  N_year1_rmse_nobs=0;
  if (lambda_N_year1_devs > 0.0 && norm2(N_year1_stdresid) > 0.0)
  {
     N_year1_rmse=sqrt(mean(square(N_year1_stdresid)));
     N_year1_rmse_nobs=nages-1;
  }
  report << "Nyear1                      " << N_year1_rmse_nobs << "           " << N_year1_rmse << endl;
  Fmult_year1_rmse=0.0;
  Fmult_year1_rmse_nobs=0;
  if (sum(lambda_Fmult_year1) > 0.0 && norm2(Fmult_year1_stdresid) > 0.0)
  {
     Fmult_year1_rmse=sqrt(mean(square(Fmult_year1_stdresid)));
     Fmult_year1_rmse_nobs=nfleets;
  }
```

```
  report << "Fmult_Year1                  " << Fmult_year1_rmse_nobs << "           " << Fmult_year1_rmse <<
endl;
  Fmult_devs_fleet_rmse=0.0;
  Fmult_devs_fleet_rmse_nobs=0;
  Fmult_devs_rmse=0.0;
  Fmult_devs_rmse_nobs=0;
  for (ifleet=1;ifleet<=nfleets;ifleet++)
  {
     if (sum(lambda_Fmult_devs) > 0.0 && norm2(Fmult_devs_stdresid(ifleet)) > 0.0)
     {
        Fmult_devs_fleet_rmse(ifleet)=sqrt(mean(square(Fmult_devs_stdresid(ifleet))));
        Fmult_devs_fleet_rmse_nobs(ifleet)=nyears-1;
     }
     report << "_Fmult_devs_Fleet_" << ifleet << "          " << Fmult_devs_fleet_rmse_nobs(ifleet) << "
" << Fmult_devs_fleet_rmse(ifleet) << endl;
  }
  if (sum(lambda_Fmult_devs) > 0.0 && norm2(Fmult_devs_stdresid) > 0.0)
  {
     Fmult_devs_rmse=sqrt(mean(square(Fmult_devs_stdresid)));
     Fmult_devs_rmse_nobs=nfleets*(nyears-1);
  }
  report << "Fmult_devs_Total             " << Fmult_devs_rmse_nobs << "           " << Fmult_devs_rmse << endl;
  SR_rmse=0.0;
  SR_rmse_nobs=0;
  if (lambda_recruit_devs > 0.0 && norm2(SR_stdresid) > 0.0)
  {
     SR_rmse=sqrt(mean(square(SR_stdresid)));
     SR_rmse_nobs=nyears;
  }
  report << "Recruit_devs                 " << SR_rmse_nobs << "           " << SR_rmse << endl;
  sel_rmse=0.0;
  sel_rmse_nobs=0;
  if (sum(sel_lambda) > 0.0 && norm2(sel_stdresid) > 0.0)
  {
     sel_rmse=sqrt(mean(square(sel_stdresid)));
     for (k=1;k<=nselparm;k++)
     {
        if (sel_lambda(k) > 0.0)
           sel_rmse_nobs+=1;
     }
  }
  report << "Fleet_Sel_params             " << sel_rmse_nobs << "           " << sel_rmse << endl;
  indexsel_rmse=0.0;
  indexsel_rmse_nobs=0;
  if (sum(indexsel_lambda) > 0.0 && norm2(indexsel_stdresid) > 0.0)
  {
     indexsel_rmse=sqrt(mean(square(indexsel_stdresid)));
     for (k=1;k<=nindexselparms;k++)
     {
        if (indexsel_lambda(k) > 0.0)
           indexsel_rmse_nobs+=1;
     }
  }
  report << "Index_Sel_params             " << indexsel_rmse_nobs << "           " << indexsel_rmse << endl;
  q_year1_rmse=0.0;
  q_year1_rmse_nobs=0;
  if (sum(lambda_q_year1) > 0.0 && norm2(q_year1_stdresid) > 0.0)
  {
     q_year1_rmse=sqrt(mean(square(q_year1_stdresid)));
     for (ind=1;ind<=nindices;ind++)
     {
        if (lambda_q_year1(ind) > 0.0)
           q_year1_rmse_nobs+=1;
     }
  }
  report << "q_year1                      " << q_year1_rmse_nobs << "           " << q_year1_rmse << endl;
  q_devs_rmse=0.0;
  q_devs_rmse_nobs=0;
  if (sum(lambda_q_devs) > 0.0 && norm2(q_devs_stdresid) > 0.0)
  {
     q_devs_rmse=sqrt(mean(square(q_devs_stdresid)));
```

```
      for (ind=1;ind<=nindices;ind++)
      {
         if (lambda_q_year1(ind) > 0.0)
            q_devs_rmse_nobs+=index_nobs(ind)-1;
      }
   }
   report << "q_devs                       " << q_devs_rmse_nobs << "           " << q_devs_rmse << endl;
   steepness_rmse=0.0;
   steepness_rmse_nobs=0;
   if (lambda_steepness > 0.0)
   {
      steepness_rmse=sfabs(steepness_stdresid);
      steepness_rmse_nobs=1;
   }
   report << "SR_steepness                 " << steepness_rmse_nobs << "           " << steepness_rmse << endl;
   SR_scaler_rmse=0.0;
   SR_scaler_rmse_nobs=0;
   if (lambda_SR_scaler > 0.0)
   {
      SR_scaler_rmse=sfabs(SR_scaler_stdresid);
      SR_scaler_rmse_nobs=1;
   }
   report << "SR_scaler                    " << SR_scaler_rmse_nobs << "           " << SR_scaler_rmse << endl;
   report << endl;

   report << "Stage2 Multipliers for Multinomials (Francis 2011)" << endl;
   report << "Catch by Fleet" << endl;
   report << Neff_stage2_mult_catch << endl;
   report << "Discards by Fleet" << endl;
   report << Neff_stage2_mult_discard << endl;
   report << "Indices" << endl;
   report << Neff_stage2_mult_index << endl;
   report << endl;
   report << "New Input ESS based on applying stage2 multipliers" << endl;
   report << "Catch (rows are fleets, columns are years)" << endl;
   for (ifleet=1;ifleet<=nfleets;ifleet++){
     report << input_eff_samp_size_catch(ifleet) * Neff_stage2_mult_catch(ifleet) << endl;
   }
   report << "Discards (rows are fleets, columns are years)" << endl;
   for (ifleet=1;ifleet<=nfleets;ifleet++){
     report << input_eff_samp_size_discard(ifleet) * Neff_stage2_mult_discard(ifleet) << endl;
   }
   report << "Indices (rows are indices, columns are years)" << endl;
   for (ind=1;ind<=nindices;ind++){
     report << index_Neff_init(ind) * Neff_stage2_mult_index(ind) << endl;
   }
   report << endl;

   if (do_projections==1 && last_phase())
   {
      project_into_future();
      report << "Projection into Future" << endl;
      report << "Projected NAA" << endl;
      report << proj_NAA << endl;
      report << "Projected Directed FAA" << endl;
      report << proj_F_dir << endl;
      report << "Projected Discard FAA" << endl;
      report << proj_F_Discard << endl;
      report << "Projected Nondirected FAA" << endl;
      report << proj_F_nondir << endl;
      report << "Projected Catch at Age" << endl;
      report << proj_catch << endl;
      report << "Projected Discards at Age (in numbers)" << endl;
      report << proj_Discard << endl;
      report << "Projected Yield at Age" << endl;
      report << proj_yield << endl;
      report << "Year, Total Yield (in weight), Total Discards (in weight), TotJan1B, SSB, proj_what, SS/SSmsy"
<< endl;
      for (iyear=1;iyear<=nprojyears;iyear++)
```

```
       report << year1+nyears-1+iyear << "  " << proj_total_yield(iyear) << "  " << proj_total_Discard(iyear) <<
"  " << proj_TotJan1B(iyear) << "  " << proj_SSB(iyear) << "  " << proj_what(iyear) << "  " <<
proj_SSB(iyear)/SSmsy << endl;
     report << endl;
  }
  else
  {
     report << "Projections not requested" << endl;
     report << endl;
  }
  report << "that's all" << endl;

  if (make_Rfile==1 && last_phase())
  {
    #include "make-Rfile_asap3.cxx"  // ADMB2R code in this file
  }

RUNTIME_SECTION
  convergence_criteria 1.0e-4
  maximum_function_evaluations 1000,1600,10000

FINAL_SECTION
  //Calculates how long is taking to run
  // this code is based on the Widow Rockfish model (from Erik H. Williams, NMFS-Santa Cruz, now Beaufort)
  time(&finish);
  elapsed_time = difftime(finish,start);
  hour = long(elapsed_time)/3600;
  minute = long(elapsed_time)%3600/60;
  second = (long(elapsed_time)%3600)%60;
  cout<<endl<<endl<<"starting time: "<<ctime(&start);
  cout<<"finishing time: "<<ctime(&finish);
  cout<<"This run took: ";
  cout<<hour<<" hours, "<<minute<<" minutes, "<<second<<" seconds."<<endl<<endl<<endl;
```

Appendix 2: make-Rfile_asap3.cxx (to make rdat file)

```
// this is the file that creates the R data object

//=========================================================================
// Open the output file using the AD Model Builder template name, and
// specify 6 digits of precision
// use periods in R variable names instead of underscore

// variables used for naming fleets and indices
adstring ifleetchar;
adstring indchar;
adstring onenum(4);
adstring onednm(4);
adstring twodnm(4);

open_r_file(adprogram_name + ".rdat", 6, -99999);

  // metadata
  open_r_info_list("info", true);
      wrt_r_item("program", "ASAP3");
  close_r_info_list();


  // basic parameter values
  open_r_info_list("parms", false);
      wrt_r_item("styr", year1);
      wrt_r_item("endyr", (year1+nyears-1));
      wrt_r_item("nyears", nyears);
      wrt_r_item("nages", nages);
      wrt_r_item("nfleets", nfleets);
      wrt_r_item("nselblocks", nselblocks);
      wrt_r_item("navailindices", navailindices);
```

```
    wrt_r_item("nindices", nindices);
close_r_info_list();

// run options
open_r_info_list("options", false);
    wrt_r_item("isfecund", isfecund);
    wrt_r_item("frac.yr.spawn", fracyearSSB);
    wrt_r_item("do.projections", do_projections);
    wrt_r_item("ignore.guesses", ignore_guesses);
    wrt_r_item("Freport.agemin", Freport_agemin);
    wrt_r_item("Freport.agemax", Freport_agemax);
    wrt_r_item("Freport.wtopt", Freport_wtopt);
    wrt_r_item("use.likelihood.constants", use_likelihood_constants);
    wrt_r_item("Fmult.max.value", Fmult_max_value);
    wrt_r_item("N.year1.flag",NAA_year1_flag);
    wrt_r_item("do.mcmc",doMCMC);
close_r_info_list();

// Likelihood contributions
open_r_info_list("like", false);
    wrt_r_item("lk.total", obj_fun);
    wrt_r_item("lk.catch.total", (lambda_catch_tot*catch_tot_likely));
    wrt_r_item("lk.discard.total", (lambda_Discard_tot*discard_tot_likely));
    wrt_r_item("lk.index.fit.total", (lambda_ind*likely_ind));
    wrt_r_item("lk.catch.age.comp", likely_catch);
    wrt_r_item("lk.discards.age.comp", likely_Discard);
    wrt_r_item("lk.index.age.comp", likely_index_age_comp);
    wrt_r_item("lk.sel.param.total", sum_sel_lambda_likely);
    wrt_r_item("lk.index.sel.param.total", sum_indexsel_lambda_likely);
    wrt_r_item("lk.q.year1", (lambda_q_year1*q_year1_likely));
    wrt_r_item("lk.q.devs", (lambda_q_devs*q_devs_likely));
    wrt_r_item("lk.Fmult.year1.total", (lambda_Fmult_year1*Fmult_year1_likely));
    wrt_r_item("lk.Fmult.devs.total", (lambda_Fmult_devs*Fmult_devs_likely));
    wrt_r_item("lk.N.year1", (lambda_N_year1_devs*N_year1_likely));
    wrt_r_item("lk.Recruit.devs", (lambda_recruit_devs*likely_SR_sigma));
    wrt_r_item("lk.SR.steepness", (lambda_steepness*steepness_likely));
    wrt_r_item("lk.SR.scaler", (lambda_SR_scaler*SR_scaler_likely));
    wrt_r_item("lk.Fmult.Max.penalty", Fmult_max_pen);
    wrt_r_item("lk.F.penalty", fpenalty);
close_r_info_list();

// fleet, block, and index specific likelihood contributions
open_r_info_list("like.additional", false);
    wrt_r_item("nfleets",nfleets);
    wrt_r_item("nindices",nindices);
    wrt_r_item("nselparms",nselparm);
    wrt_r_item("nindexselparms",nindexselparms);
    if (nfleets>1)
    {
        for (ifleet=1;ifleet<=nfleets;ifleet++)
        {
            if (nfleets < 10) itoa(ifleet, onenum, 10);
            else onenum="0";
            ifleetchar = "fleet" + onenum;
            adstring lk_catch_fleet = adstring("lk.catch.") + ifleetchar;
            wrt_r_item(lk_catch_fleet,(lambda_catch_tot(ifleet)*catch_tot_likely(ifleet)));
        }

        for (ifleet=1;ifleet<=nfleets;ifleet++)
        {
            if (nfleets < 10) itoa(ifleet, onenum, 10);
            else onenum="0";
            ifleetchar = "fleet" + onenum;
            adstring lk_discard_fleet = adstring("lk.discard.") + ifleetchar;
            wrt_r_item(lk_discard_fleet,(lambda_Discard_tot(ifleet)*discard_tot_likely(ifleet)));
        }

        for (ifleet=1;ifleet<=nfleets;ifleet++)
        {
            if (nfleets < 10) itoa(ifleet, onenum, 10);
            else onenum="0";
```

```
        ifleetchar = "fleet" + onenum;
        adstring lk_Fmult_year1_fleet = adstring("lk.Fmult.year1.") + ifleetchar;
        wrt_r_item(lk_Fmult_year1_fleet,(lambda_Fmult_year1(ifleet)*Fmult_year1_likely(ifleet)));
    }

    for (ifleet=1;ifleet<=nfleets;ifleet++)
    {
        if (nfleets < 10) itoa(ifleet, onenum, 10);
        else onenum="0";
        ifleetchar = "fleet" + onenum;
        adstring lk_Fmult_devs_fleet = adstring("lk.Fmult.devs.") + ifleetchar;
        wrt_r_item(lk_Fmult_devs_fleet,(lambda_Fmult_devs(ifleet)*Fmult_devs_likely(ifleet)));
    }
}

if (nindices>1)
{
    for (ind=1;ind<=nindices;ind++)
    {
        if (ind <= 9)  // note have to deal with one digit and two digit numbers separately
        {
            itoa(ind, onednm, 10);
            twodnm = "0" + onednm;
        }
        else if (ind <=99)
        {
            itoa(ind,twodnm, 10);
        }
        else
        {
            twodnm = "00";
        }
        indchar = "ind" + twodnm;
        adstring lk_index_fit_ind = adstring("lk.index.fit.") + indchar;
        wrt_r_item(lk_index_fit_ind,(lambda_ind(ind)*likely_ind(ind)));
    }

    for (ind=1;ind<=nindices;ind++)
    {
        if (ind <= 9)  // note have to deal with one digit and two digit numbers separately
        {
            itoa(ind, onednm, 10);
            twodnm = "0" + onednm;
        }
        else if (ind <=99)
        {
            itoa(ind,twodnm, 10);
        }
        else
        {
            twodnm = "00";
        }
        indchar = "ind" + twodnm;
        adstring lk_q_year1_ind = adstring("lk.q.year1.") + indchar;
        wrt_r_item(lk_q_year1_ind,(lambda_q_year1(ind)*q_year1_likely(ind)));
    }

    for (ind=1;ind<=nindices;ind++)
    {
        if (ind <= 9)  // note have to deal with one digit and two digit numbers separately
        {
            itoa(ind, onednm, 10);
            twodnm = "0" + onednm;
        }
        else if (ind <=99)
        {
            itoa(ind,twodnm, 10);
        }
        else
        {
            twodnm = "00";
```

```
            }
            indchar = "ind" + twodnm;
            adstring lk_q_devs_ind = adstring("lk.q.devs.") + indchar;
            wrt_r_item(lk_q_devs_ind,(lambda_q_devs(ind)*q_devs_likely(ind)));
        }
    }

    for (k=1;k<=nselparm;k++)
    {
        if (sel_phase(k) >=1)
        {
            if (k <= 9)  // note have to deal with one digit and two digit numbers separately
            {
                itoa(k, onednm, 10);
                twodnm = "0" + onednm;
            }
            else if (k <=99)
            {
                itoa(k, twodnm, 10);
            }
            else
            {
                twodnm = "00";
            }
            adstring lk_sel_param = adstring("lk.sel.param.") + twodnm;
            wrt_r_item(lk_sel_param,(sel_lambda(k)*sel_likely(k)));

        }
    }

    for (k=1;k<=nindexselparms;k++)
    {
        if (indexsel_phase(k) >=1)
        {
            if (k <= 9)  // note have to deal with one digit and two digit numbers separately
            {
                itoa(k, onednm, 10);
                twodnm = "0" + onednm;
            }
            else if (k <=99)
            {
                itoa(k, twodnm, 10);
            }
            else
            {
                twodnm = "00";
            }
            adstring lk_indexsel_param = adstring("lk.indexsel.param.") + twodnm;
            wrt_r_item(lk_indexsel_param,(indexsel_lambda(k)*indexsel_likely(k)));

        }
    }

close_r_info_list();

// initial guesses
open_r_list("initial.guesses");
    open_r_info_list("SR.inits", false);
        wrt_r_item("is.SR.scaler.R",is_SR_scaler_R);
        wrt_r_item("SR.scaler.init",SR_scaler_ini);
        wrt_r_item("SR_steepness.init",SR_steepness_ini);
    close_r_info_list();
    wrt_r_complete_vector("NAA.year1.init",NAA_year1_ini);
    wrt_r_complete_vector("Fmult.year1.init",Fmult_year1_ini);
    wrt_r_complete_vector("q.year1.init",q_year1_ini);
    wrt_r_complete_vector("release.mort", release_mort);
    wrt_r_complete_vector("index.use.flag",use_index);
close_r_list();

// control parameters
open_r_list("control.parms");
```

```
      open_r_info_list("phases", false);
          wrt_r_item("phase.Fmult.year1", phase_Fmult_year1);
          wrt_r_item("phase.Fmult.devs", phase_Fmult_devs);
          wrt_r_item("phase.recruit.devs", phase_recruit_devs);
          wrt_r_item("phase.N.year1.devs", phase_N_year1_devs);
          wrt_r_item("phase.q.year1", phase_q_year1);
          wrt_r_item("phase.q.devs", phase_q_devs);
          wrt_r_item("phase.SR.scaler", phase_SR_scaler);
          wrt_r_item("phase.steepness", phase_steepness);
      close_r_info_list();
      open_r_info_list("singles", false);
          wrt_r_item("lambda.N.year1.devs",lambda_N_year1_devs);
          wrt_r_item("N.year1.cv",N_year1_CV);
          wrt_r_item("lambda.recruit.devs",lambda_recruit_devs);
          wrt_r_item("lambda.steepness",lambda_steepness);
          wrt_r_item("steepness.cv",steepness_CV);
          wrt_r_item("lambda.SR.scaler",lambda_SR_scaler);
          wrt_r_item("SR.scaler.cv", SR_scaler_CV);
      close_r_info_list();
      open_r_info_list("mcmc", false);
          wrt_r_item("mcmc.nyear.opt",MCMCnyear_opt);
          wrt_r_item("mcmc.n.boot",MCMCnboot);
          wrt_r_item("mcmc.n.thin",MCMCnthin);
          wrt_r_item("mcmc.seed",MCMCseed);
          wrt_r_item("fillR.opt",fillR_opt);
          wrt_r_item("Ravg.start",Ravg_start);
          wrt_r_item("Ravg.end",Ravg_end);
      close_r_info_list();
      wrt_r_complete_vector("recruit.cv",recruit_CV);
      wrt_r_complete_vector("lambda.ind",lambda_ind);
      wrt_r_complete_vector("lambda.catch.tot",lambda_catch_tot);
      open_r_matrix("catch.tot.cv");
          wrt_r_matrix(catch_tot_CV, 2, 2);
          wrt_r_namevector(year1, (year1+nyears-1));
          wrt_r_namevector(1, nfleets);
      close_r_matrix();
      wrt_r_complete_vector("lambda.Discard.tot",lambda_Discard_tot);
      open_r_matrix("discard.tot.cv");
          wrt_r_matrix(discard_tot_CV, 2, 2);
          wrt_r_namevector(year1, (year1+nyears-1));
          wrt_r_namevector(1, nfleets);
      close_r_matrix();
      wrt_r_complete_vector("lambda.Fmult.year1",lambda_Fmult_year1);
      wrt_r_complete_vector("Fmult.year1.cv",Fmult_year1_CV);
      wrt_r_complete_vector("lambda.Fmult.devs",lambda_Fmult_devs);
      wrt_r_complete_vector("Fmult.devs.cv",Fmult_devs_CV);
      wrt_r_complete_vector("lambda.q.year1",lambda_q_year1);
      wrt_r_complete_vector("q.year1.cv",q_year1_CV);
      wrt_r_complete_vector("lambda.q.devs",lambda_q_devs);
      wrt_r_complete_vector("q.devs.cv",q_devs_CV);
      wrt_r_complete_vector("directed.fleet",directed_fleet);
      wrt_r_complete_vector("WAA.point.bio",WAApointbio);
      wrt_r_complete_vector("index.units.aggregate", index_units_aggregate);
      wrt_r_complete_vector("index.units.proportions", index_units_proportions);
      wrt_r_complete_vector("index.WAA.point", index_WAApoint);
      wrt_r_complete_vector("index.month", index_month);
      wrt_r_complete_vector("index.sel.start.age",index_start_age);
      wrt_r_complete_vector("index.sel.end.age",index_end_age);
      wrt_r_complete_vector("index.sel.choice",index_sel_choice);
      wrt_r_complete_vector("index.age.comp.flag",index_estimate_proportions);
  close_r_list();

  // selectivity input matrices for fleets and indices
  open_r_list("sel.input.mats");
      // input selectivity matrix, contains combinations of values not used, see fleet_sel_option to determine
which choice was made for each block
      open_r_matrix("fleet.sel.ini");
          wrt_r_matrix(sel_ini, 2, 2);
          wrt_r_namevector(1, (nselblocks*(nages+6)));
          wrt_r_namevector(1, 4);
      close_r_matrix();
```

```
    open_r_matrix("index.sel.ini");
        wrt_r_matrix(index_sel_ini, 2, 2);
        wrt_r_namevector(1, (navailindices*(nages+6)));
        wrt_r_namevector(1, 4);
    close_r_matrix();
close_r_list();

// Weight at Age matrices
open_r_list("WAA.mats");
    for (ifleet=1;ifleet<=nfleets;ifleet++)
    {
        if (nfleets < 10) itoa(ifleet, onenum, 10);
        else onenum="0";
        ifleetchar = "fleet" + onenum;
        adstring WAA_c_fleet = adstring("WAA.catch.") + ifleetchar;
        open_r_matrix(WAA_c_fleet);
            wrt_r_matrix(WAAcatchfleet(ifleet), 2, 2);
            wrt_r_namevector(year1, (year1+nyears-1));
            wrt_r_namevector(1,nages);
        close_r_matrix();
        adstring WAA_d_fleet = adstring("WAA.discard.") + ifleetchar;
        open_r_matrix(WAA_d_fleet);
            wrt_r_matrix(WAAdiscardfleet(ifleet), 2, 2);
            wrt_r_namevector(year1, (year1+nyears-1));
            wrt_r_namevector(1,nages);
        close_r_matrix();
    }
    open_r_matrix("WAA.catch.all");
        wrt_r_matrix(WAAcatchall, 2, 2);
        wrt_r_namevector(year1, (year1+nyears-1));
        wrt_r_namevector(1, nages);
    close_r_matrix();

    open_r_matrix("WAA.discard.all");
        wrt_r_matrix(WAAdiscardall, 2, 2);
        wrt_r_namevector(year1, (year1+nyears-1));
        wrt_r_namevector(1, nages);
    close_r_matrix();

    open_r_matrix("WAA.ssb");
        wrt_r_matrix(WAAssb, 2, 2);
        wrt_r_namevector(year1, (year1+nyears-1));
        wrt_r_namevector(1, nages);
    close_r_matrix();

    open_r_matrix("WAA.jan1");
        wrt_r_matrix(WAAjan1b, 2, 2);
        wrt_r_namevector(year1, (year1+nyears-1));
        wrt_r_namevector(1, nages);
    close_r_matrix();

    for (ind=1;ind<=nindices;ind++)
    {
        if (index_units_aggregate(ind)==1 || index_units_proportions(ind)==1)
        {
            if (ind <= 9)  // note have to deal with one digit and two digit numbers separately
            {
                itoa(ind, onednm, 10);
                twodnm = "0" + onednm;
            }
            else if (ind <=99)
            {
                itoa(ind,twodnm, 10);
            }
            else
            {
                twodnm = "00";
            }
            indchar = "ind" + twodnm;
            adstring index_WAA_name = adstring("index.WAA.") + indchar;
```

```
            open_r_matrix(index_WAA_name);
                wrt_r_matrix(index_WAA(ind), 2, 2);
                wrt_r_namevector(year1, (year1+nyears-1));
                wrt_r_namevector(1,nages);
            close_r_matrix();
        }
    }

  close_r_list();

  // Year by Age Matrices (not fleet specific): M, maturity, fecundity, N, Z, F,
  open_r_matrix("M.age");
      wrt_r_matrix(M, 2, 2);
      wrt_r_namevector(year1, (year1+nyears-1));
      wrt_r_namevector(1, nages);
  close_r_matrix();

  open_r_matrix("maturity");
      wrt_r_matrix(mature, 2, 2);
      wrt_r_namevector(year1, (year1+nyears-1));
      wrt_r_namevector(1, nages);
  close_r_matrix();

  open_r_matrix("fecundity");
      wrt_r_matrix(fecundity, 2, 2);
      wrt_r_namevector(year1, (year1+nyears-1));
      wrt_r_namevector(1, nages);
  close_r_matrix();

  open_r_matrix("N.age");
      wrt_r_matrix(NAA, 2, 2);
      wrt_r_namevector(year1, (year1+nyears-1));
      wrt_r_namevector(1, nages);
  close_r_matrix();

  open_r_matrix("Z.age");
      wrt_r_matrix(Z, 2, 2);
      wrt_r_namevector(year1, (year1+nyears-1));
      wrt_r_namevector(1, nages);
  close_r_matrix();

  open_r_matrix("F.age");
      wrt_r_matrix(FAA_tot, 2, 2);
      wrt_r_namevector(year1, (year1+nyears-1));
      wrt_r_namevector(1, nages);
  close_r_matrix();

  // Fleet by Year Matrices: Catch.tot.obs, Catch.tot.pred, Catch.tot.resid), Discard.tot.obs, Discard.tot.pred,
Discard.tot.resid
  open_r_matrix("catch.obs");
      wrt_r_matrix(Catch_tot_fleet_obs, 2, 2);
      wrt_r_namevector(1, nfleets);
      wrt_r_namevector(year1, (year1+nyears-1));
  close_r_matrix();

  open_r_matrix("catch.pred");
      wrt_r_matrix(Catch_tot_fleet_pred, 2, 2);
      wrt_r_namevector(1, nfleets);
      wrt_r_namevector(year1, (year1+nyears-1));
  close_r_matrix();

  open_r_matrix("catch.std.resid");
      wrt_r_matrix(Catch_stdresid, 2, 2);
      wrt_r_namevector(1, nfleets);
      wrt_r_namevector(year1, (year1+nyears-1));
  close_r_matrix();

  open_r_matrix("discard.obs");
      wrt_r_matrix(Discard_tot_fleet_obs, 2, 2);
      wrt_r_namevector(1, nfleets);
      wrt_r_namevector(year1, (year1+nyears-1));
```

```
close_r_matrix();

open_r_matrix("discard.pred");
    wrt_r_matrix(Discard_tot_fleet_pred, 2, 2);
    wrt_r_namevector(1, nfleets);
    wrt_r_namevector(year1, (year1+nyears-1));
close_r_matrix();

open_r_matrix("discard.std.resid");
    wrt_r_matrix(Discard_stdresid, 2, 2);
    wrt_r_namevector(1, nfleets);
    wrt_r_namevector(year1, (year1+nyears-1));
close_r_matrix();


// Age Compositions: Catch and Discards observed and predicted by fleet
open_r_list("catch.comp.mats");
    for (ifleet=1;ifleet<=nfleets;ifleet++)
    {
        if (nfleets < 10) itoa(ifleet, onenum, 10);
        else onenum="0";
        ifleetchar = "fleet" + onenum;
        adstring ccomp_ob = adstring("catch.") + ifleetchar + adstring(".ob");
        open_r_matrix(ccomp_ob);
            wrt_r_matrix(CAA_prop_obs(ifleet), 2, 2);
            wrt_r_namevector(year1, (year1+nyears-1));
            wrt_r_namevector(sel_start_age(ifleet), sel_end_age(ifleet));
        close_r_matrix();

        adstring ccomp_pr = adstring("catch.") + ifleetchar + adstring(".pr");
        open_r_matrix(ccomp_pr);
            wrt_r_matrix(CAA_prop_pred(ifleet), 2, 2);
            wrt_r_namevector(year1, (year1+nyears-1));
            wrt_r_namevector(sel_start_age(ifleet), sel_end_age(ifleet));
        close_r_matrix();

        adstring dcomp_ob = adstring("discard.") + ifleetchar + adstring(".ob");
        open_r_matrix(dcomp_ob);
            wrt_r_matrix(Discard_prop_obs(ifleet), 2, 2);
            wrt_r_namevector(year1, (year1+nyears-1));
            wrt_r_namevector(sel_start_age(ifleet), sel_end_age(ifleet));
        close_r_matrix();

        adstring dcomp_pr = adstring("discard.") + ifleetchar + adstring(".pr");
        open_r_matrix(dcomp_pr);
            wrt_r_matrix(Discard_prop_pred(ifleet), 2, 2);
            wrt_r_namevector(year1, (year1+nyears-1));
            wrt_r_namevector(sel_start_age(ifleet), sel_end_age(ifleet));
        close_r_matrix();
    }
close_r_list();


// fleet selectivity blocks
open_r_matrix("fleet.sel.blocks");
    wrt_r_matrix(sel_blocks, 2, 2);
    wrt_r_namevector(1, nfleets);
    wrt_r_namevector(year1, (year1+nyears-1));
close_r_matrix();

// vectors of fleet selectivity options
wrt_r_complete_vector("fleet.sel.start.age",sel_start_age);
wrt_r_complete_vector("fleet.sel.end.age",sel_end_age);
wrt_r_complete_vector("fleet.sel.option",sel_option);

// selecivity matrices for each fleet
open_r_list("fleet.sel.mats");
    for (ifleet=1;ifleet<=nfleets;ifleet++)
    {
        if (nfleets < 10) itoa(ifleet, onenum, 10);
        else onenum="0";
```

```
        ifleetchar = "fleet" + onenum;
        adstring sel_fleet_char = adstring("sel.m.") + ifleetchar;
        open_r_matrix(sel_fleet_char);
            wrt_r_matrix(sel_by_fleet(ifleet), 2, 2);
            wrt_r_namevector(year1, (year1+nyears-1));
            wrt_r_namevector(1, nages);
        close_r_matrix();
    }
close_r_list();

// Fmults by fleet
open_r_matrix("fleet.Fmult");
    wrt_r_matrix(Fmult, 2, 2);
    wrt_r_namevector(1, nfleets);
    wrt_r_namevector(year1, (year1+nyears-1));
close_r_matrix();

// FAA by fleet directed and discarded
open_r_list("fleet.FAA");
    for (ifleet=1;ifleet<=nfleets;ifleet++)
    {
        if (nfleets < 10) itoa(ifleet, onenum, 10);
        else onenum="0";
        ifleetchar = "fleet" + onenum;

        adstring fleet_FAA_dir = adstring("FAA.directed.") + ifleetchar;
        open_r_matrix(fleet_FAA_dir);
            wrt_r_matrix(FAA_by_fleet_dir(ifleet), 2, 2);
            wrt_r_namevector(year1, (year1+nyears-1));
            wrt_r_namevector(1,nages);
        close_r_matrix();

        adstring fleet_FAA_discard = adstring("FAA.discarded.") + ifleetchar;
        open_r_matrix(fleet_FAA_discard);
            wrt_r_matrix(FAA_by_fleet_Discard(ifleet), 2, 2);
            wrt_r_namevector(year1, (year1+nyears-1));
            wrt_r_namevector(1,nages);
        close_r_matrix();
    }
close_r_list();

// proportion release year by age matrices by fleet
open_r_list("fleet.prop.release");
    for (ifleet=1;ifleet<=nfleets;ifleet++)
    {
        if (nfleets < 10) itoa(ifleet, onenum, 10);
        else onenum="0";
        ifleetchar = "fleet" + onenum;
        adstring fleet_prop_release = adstring("prop.release.") + ifleetchar;
        open_r_matrix(fleet_prop_release);
            wrt_r_matrix(proportion_release(ifleet), 2, 2);
            wrt_r_namevector(year1, (year1+nyears-1));
            wrt_r_namevector(1,nages);
        close_r_matrix();
    }
close_r_list();

// fleet specific annual effective sample sizes input and estimated for catch and discards
open_r_matrix("fleet.catch.Neff.init");
    wrt_r_matrix(input_eff_samp_size_catch, 2, 2);
    wrt_r_namevector(1, nfleets);
    wrt_r_namevector(year1, (year1+nyears-1));
close_r_matrix();

open_r_matrix("fleet.catch.Neff.est");
    wrt_r_matrix(effective_sample_size, 2, 2);
    wrt_r_namevector(1, nfleets);
    wrt_r_namevector(year1, (year1+nyears-1));
close_r_matrix();

open_r_matrix("fleet.discard.Neff.init");
```

```
    wrt_r_matrix(input_eff_samp_size_discard, 2, 2);
    wrt_r_namevector(1, nfleets);
    wrt_r_namevector(year1, (year1+nyears-1));
close_r_matrix();

open_r_matrix("fleet.discard.Neff.est");
    wrt_r_matrix(effective_Discard_sample_size, 2, 2);
    wrt_r_namevector(1, nfleets);
    wrt_r_namevector(year1, (year1+nyears-1));
close_r_matrix();

// vector of q for each index if qdevs turned off, otherwise a list with vectors for each index
if (phase_q_devs <= 0)
{
    wrt_r_complete_vector("q.indices",  column(q_by_index,1));
}
else
{
    open_r_list("q.random.walk");
        for (ind=1;ind<=nindices;ind++)
        {
            if (ind <= 9)  // note have to deal with one digit and two digit numbers separately
            {
                itoa(ind, onednm, 10);
                twodnm = "0" + onednm;
            }
            else if (ind <=99)
            {
                itoa(ind,twodnm, 10);
            }
            else
            {
                twodnm = "00";
            }
            indchar = "ind" + twodnm;
            adstring q_ind = adstring("q.") + indchar;
            wrt_r_complete_vector(q_ind,q_by_index(ind));
        }
    close_r_list();
}

// vectors for Freport and Biomasses (TotJan1B, SSB, ExploitableB)
wrt_r_complete_vector("F.report",Freport);
wrt_r_complete_vector("tot.jan1.B",TotJan1B);
wrt_r_complete_vector("SSB",SSB);
wrt_r_complete_vector("exploitable.B",ExploitableB);


// F reference values
open_r_info_list("Fref", false);
    wrt_r_item("Fmax", Fmax_report);
    wrt_r_item("F01", F01_report);
    wrt_r_item("F30", F30SPR_report);
    wrt_r_item("F40", F40SPR_report);
    wrt_r_item("Fcurrent", Freport(nyears));
close_r_info_list();

// SR curve parameters
open_r_info_list("SR.parms", false);
    wrt_r_item("SR.alpha", SR_alpha);
    wrt_r_item("SR.beta", SR_beta);
    wrt_r_item("SR.SPR0", SR_spawners_per_recruit);
    wrt_r_item("SR.S0", SR_S0);
    wrt_r_item("SR.R0", SR_R0);
    wrt_r_item("SR.steepness", SR_steepness);
close_r_info_list();

// SR obs, pred, devs, and standardized resids
// note year coresponds to age-1 recruitment, when plot SR curve have to offset SSB and R by one year
open_r_df("SR.resids", year1, (year1+nyears-1), 2);
    wrt_r_namevector(year1, (year1+nyears-1));
```

```
      wrt_r_df_col("year", year1, (year1+nyears-1));
      wrt_r_df_col("recruits", recruits, year1);
      wrt_r_df_col("R.no.devs", SR_pred_recruits, year1);
      wrt_r_df_col("logR.dev", log_recruit_devs, year1);
      wrt_r_df_col("SR.std.resid", SR_stdresid, year1);
  close_r_df();

  // annual values for S0_vec, R0_vec, steepness_vec, s_per_r_vec (last year values should match SR.parms
values)
  open_r_df("SR.annual.parms", year1, (year1+nyears-1), 2);
      wrt_r_namevector(year1, (year1+nyears-1));
      wrt_r_df_col("year", year1, (year1+nyears-1));
      wrt_r_df_col("S0.vec", S0_vec, year1);
      wrt_r_df_col("R0.vec", R0_vec, year1);
      wrt_r_df_col("steepness.vec", steepness_vec, year1);
      wrt_r_df_col("s.per.r.vec",s_per_r_vec, year1);
  close_r_df();



  // index stuff starts here

  // selectivity by index
  open_r_matrix("index.sel");
      wrt_r_matrix(indexsel, 2, 2);
      wrt_r_namevector(1, nindices);
      wrt_r_namevector(1, nages);
  close_r_matrix();

  wrt_r_complete_vector("index.nobs",index_nobs);

  // index year counter (sequential numbers starting at 1 for first year)
  open_r_list("index.year.counter");
      for (ind=1;ind<=nindices;ind++)
      {
          if (ind <= 9)  // note have to deal with one digit and two digit numbers separately
          {
              itoa(ind, onednm, 10);
              twodnm = "0" + onednm;
          }
          else if (ind <=99)
          {
              itoa(ind,twodnm, 10);
          }
          else
          {
              twodnm = "00";
          }
          indchar = "ind" + twodnm;
          wrt_r_complete_vector(indchar,index_time(ind));
      }
  close_r_list();

  // index years
  open_r_list("index.year");
      for (ind=1;ind<=nindices;ind++)
      {
          if (ind <= 9)  // note have to deal with one digit and two digit numbers separately
          {
              itoa(ind, onednm, 10);
              twodnm = "0" + onednm;
          }
          else if (ind <=99)
          {
              itoa(ind,twodnm, 10);
          }
          else
          {
              twodnm = "00";
          }
          indchar = "ind" + twodnm;
```

```
        wrt_r_complete_vector(indchar,index_year(ind));
    }
close_r_list();

// index CV
open_r_list("index.cv");
    for (ind=1;ind<=nindices;ind++)
    {
        if (ind <= 9)  // note have to deal with one digit and two digit numbers separately
        {
            itoa(ind, onednm, 10);
            twodnm = "0" + onednm;
        }
        else if (ind <=99)
        {
            itoa(ind,twodnm, 10);
        }
        else
        {
            twodnm = "00";
        }
        indchar = "ind" + twodnm;
        wrt_r_complete_vector(indchar,index_cv(ind));
    }
close_r_list();

// index sigmas (derived from input CV)
open_r_list("index.sigma");
    for (ind=1;ind<=nindices;ind++)
    {
        if (ind <= 9)  // note have to deal with one digit and two digit numbers separately
        {
            itoa(ind, onednm, 10);
            twodnm = "0" + onednm;
        }
        else if (ind <=99)
        {
            itoa(ind,twodnm, 10);
        }
        else
        {
            twodnm = "00";
        }
        indchar = "ind" + twodnm;
        wrt_r_complete_vector(indchar,index_sigma(ind));
    }
close_r_list();

// index observations
open_r_list("index.obs");
    for (ind=1;ind<=nindices;ind++)
    {
        if (ind <= 9)  // note have to deal with one digit and two digit numbers separately
        {
            itoa(ind, onednm, 10);
            twodnm = "0" + onednm;
        }
        else if (ind <=99)
        {
            itoa(ind,twodnm, 10);
        }
        else
        {
            twodnm = "00";
        }
        indchar = "ind" + twodnm;
        wrt_r_complete_vector(indchar,index_obs(ind));
    }
close_r_list();

// predicted indices
```

```
  open_r_list("index.pred");
      for (ind=1;ind<=nindices;ind++)
      {
          if (ind <= 9)  // note have to deal with one digit and two digit numbers separately
          {
              itoa(ind, onednm, 10);
              twodnm = "0" + onednm;
          }
          else if (ind <=99)
          {
              itoa(ind,twodnm, 10);
          }
          else
          {
              twodnm = "00";
          }
          indchar = "ind" + twodnm;
          wrt_r_complete_vector(indchar,index_pred(ind));
      }
  close_r_list();

  // index standardized residuals
  open_r_list("index.std.resid");
      for (ind=1;ind<=nindices;ind++)
      {
          if (ind <= 9)  // note have to deal with one digit and two digit numbers separately
          {
              itoa(ind, onednm, 10);
              twodnm = "0" + onednm;
          }
          else if (ind <=99)
          {
              itoa(ind,twodnm, 10);
          }
          else
          {
              twodnm = "00";
          }
          indchar = "ind" + twodnm;
          wrt_r_complete_vector(indchar,index_stdresid(ind));
      }
  close_r_list();

  // index proportions at age related output
  if (max(index_estimate_proportions)>0)  // check to see if any West Coast style indices, skip this section if
all are East Coast style
  {
      // Index Age Comp
      open_r_list("index.comp.mats");
          for (ind=1;ind<=nindices;ind++)
          {
              if (ind <= 9)  // note have to deal with one digit and two digit numbers separately
              {
                  itoa(ind, onednm, 10);
                  twodnm = "0" + onednm;
              }
              else if (ind <=99)
              {
                  itoa(ind,twodnm, 10);
              }
              else
              {
                  twodnm = "00";
              }
              indchar = "ind" + twodnm;

              adstring acomp_ob = indchar + adstring(".ob");
              open_r_matrix(acomp_ob);
                  wrt_r_matrix(output_index_prop_obs(ind), 2, 2);
                  wrt_r_namevector(year1, (year1+nyears-1));
                  wrt_r_namevector(1,nages);
```

```
            close_r_matrix();

            adstring acomp_pr = indchar + adstring(".pr");
            open_r_matrix(acomp_pr);
                wrt_r_matrix(output_index_prop_pred(ind), 2, 2);
                wrt_r_namevector(year1, (year1+nyears-1));
                wrt_r_namevector(1, nages);
            close_r_matrix();
        }
    close_r_list();

  // Neff for indices initial guess
  open_r_matrix("index.Neff.init");
      wrt_r_matrix(index_Neff_init, 2, 2);
      wrt_r_namevector(1, nindices);
      wrt_r_namevector(year1, (year1+nyears-1));
  close_r_matrix();

  // Neff for indices estimated
  open_r_matrix("index.Neff.est");
      wrt_r_matrix(index_Neff_est, 2, 2);
      wrt_r_namevector(1, nindices);
      wrt_r_namevector(year1, (year1+nyears-1));
  close_r_matrix();

}  // end if-statement to test for any index age comp


// deviations section: only reported if associated with lambda > 0
if (lambda_N_year1_devs > 0)
{
    // note: obs and pred include age 1 while std.resid does not - do not use age 1 when plotting
    open_r_list("deviations.N.year1");
        wrt_r_complete_vector("N.year1.obs",NAA(1));
        wrt_r_complete_vector("N.year1.pred",nyear1temp);
        wrt_r_complete_vector("N.year1.std.resid",N_year1_stdresid);
    close_r_list();
}


// RMSE number of observations section
open_r_info_list("RMSE.n", false);
    if (nfleets>1)
    {
        for (ifleet=1;ifleet<=nfleets;ifleet++)
        {
            if (nfleets < 10) itoa(ifleet, onenum, 10);
            else onenum="0";
            ifleetchar = "fleet" + onenum;
            adstring rmse_n_catch_fleet = adstring("rmse.n.catch.") + ifleetchar;
            wrt_r_item(rmse_n_catch_fleet,nyears);
        }
    }
    wrt_r_item("rmse.n.catch.tot",(nyears*nfleets));

    if (nfleets>1)
    {
        for (ifleet=1;ifleet<=nfleets;ifleet++)
        {
            if (nfleets < 10) itoa(ifleet, onenum, 10);
            else onenum="0";
            ifleetchar = "fleet" + onenum;
            adstring rmse_n_discard_fleet = adstring("rmse.n.discard.") + ifleetchar;
            if (sum(Discard_tot_fleet_obs(ifleet)) > 0)
            {
                wrt_r_item(rmse_n_discard_fleet,nyears);
            }
            else
            {
                wrt_r_item(rmse_n_discard_fleet,0);
            }
```

```
        }
    }
    if (sum(Discard_tot_fleet_obs) > 0)
    {
        wrt_r_item("rmse.n.discard.tot",(nyears*nfleets));
    }
    else
    {
        wrt_r_item("rmse.n.discard.tot",0);
    }

    if (nindices>1)
    {
        for (ind=1;ind<=nindices;ind++)
        {
            if (ind <= 9)  // note have to deal with one digit and two digit numbers separately
            {
                itoa(ind, onednm, 10);
                twodnm = "0" + onednm;
            }
            else if (ind <=99)
            {
                itoa(ind,twodnm, 10);
            }
            else
            {
                twodnm = "00";
            }
            indchar = "ind" + twodnm;
            adstring rmse_n_ind = adstring("rmse.n.") + indchar;
            wrt_r_item(rmse_n_ind,index_nobs(ind));
        }
    }
    wrt_r_item("rmse.n.ind.total",sum(index_nobs));

    wrt_r_item("rmse.n.N.year1",N_year1_rmse_nobs);

    wrt_r_item("rmse.n.Fmult.year1",Fmult_year1_rmse_nobs);

    if (nfleets>1)
    {
        for (ifleet=1;ifleet<=nfleets;ifleet++)
        {
            if (nfleets < 10) itoa(ifleet, onenum, 10);
            else onenum="0";
            ifleetchar = "fleet" + onenum;
            adstring rmse_n_Fmult_devs_fleet = adstring("rmse.n.Fmult.devs.") + ifleetchar;
            wrt_r_item(rmse_n_Fmult_devs_fleet,Fmult_devs_fleet_rmse_nobs(ifleet));
        }
    }
    wrt_r_item("rmse.n.Fmult.devs.total",Fmult_devs_rmse_nobs);

    wrt_r_item("rmse.n.recruit.devs",SR_rmse_nobs);

    wrt_r_item("rmse.n.fleet.sel.params",sel_rmse_nobs);

    wrt_r_item("rmse.n.index.sel.params",indexsel_rmse_nobs);

    wrt_r_item("rmse.n.q.year1",q_year1_rmse_nobs);

    wrt_r_item("rmse.n.q.devs",q_devs_rmse_nobs);

    wrt_r_item("rmse.n.SR.steepness",steepness_rmse_nobs);

    wrt_r_item("rmse.n.SR.scaler",SR_scaler_rmse_nobs);

close_r_info_list();

// RMSE section
open_r_info_list("RMSE", false);
    if (nfleets>1)
```

```
{
    for (ifleet=1;ifleet<=nfleets;ifleet++)
    {
        if (nfleets < 10) itoa(ifleet, onenum, 10);
        else onenum="0";
        ifleetchar = "fleet" + onenum;
        adstring rmse_catch_fleet = adstring("rmse.catch.") + ifleetchar;
        wrt_r_item(rmse_catch_fleet,sqrt(mean(square(Catch_stdresid(ifleet)))));
    }
}
wrt_r_item("rmse.catch.tot",sqrt(mean(square(Catch_stdresid))));

if (nfleets>1)
{
    for (ifleet=1;ifleet<=nfleets;ifleet++)
    {
        if (nfleets < 10) itoa(ifleet, onenum, 10);
        else onenum="0";
        ifleetchar = "fleet" + onenum;
        adstring rmse_discard_fleet = adstring("rmse.discard.") + ifleetchar;
        if (sum(Discard_tot_fleet_obs(ifleet)) > 0)
        {
            wrt_r_item(rmse_discard_fleet,sqrt(mean(square(Discard_stdresid(ifleet)))));
        }
        else
        {
            wrt_r_item(rmse_discard_fleet,0);
        }
    }
}
if (sum(Discard_tot_fleet_obs) > 0)
{
    wrt_r_item("rmse.discard.tot",sqrt(mean(square(Discard_stdresid))));
}
else
{
    wrt_r_item("rmse.discard.tot",0);
}

if (nindices>1)
{
    for (ind=1;ind<=nindices;ind++)
    {
        if (ind <= 9)  // note have to deal with one digit and two digit numbers separately
        {
            itoa(ind, onednm, 10);
            twodnm = "0" + onednm;
        }
        else if (ind <=99)
        {
            itoa(ind,twodnm, 10);
        }
        else
        {
            twodnm = "00";
        }
        indchar = "ind" + twodnm;
        adstring rmse_ind = adstring("rmse.") + indchar;
        wrt_r_item(rmse_ind,sqrt(mean(square(index_stdresid(ind)))));
    }
}
wrt_r_item("rmse.ind.total",sqrt(mean(square(index_stdresid))));

wrt_r_item("rmse.N.year1",N_year1_rmse);

wrt_r_item("rmse.Fmult.year1",Fmult_year1_rmse);

if (nfleets>1)
{
    for (ifleet=1;ifleet<=nfleets;ifleet++)
    {
```

```
            if (nfleets < 10) itoa(ifleet, onenum, 10);
            else onenum="0";
            ifleetchar = "fleet" + onenum;
            adstring rmse_Fmult_devs_fleet = adstring("rmse.Fmult.devs.") + ifleetchar;
            wrt_r_item(rmse_Fmult_devs_fleet,Fmult_devs_fleet_rmse(ifleet));
        }
    }
    wrt_r_item("rmse.Fmult.devs.total",Fmult_devs_rmse);

    wrt_r_item("rmse.recruit.devs",SR_rmse);

    wrt_r_item("rmse.fleet.sel.params",sel_rmse);

    wrt_r_item("rmse.index.sel.params",indexsel_rmse);

    wrt_r_item("rmse.q.year1",q_year1_rmse);

    wrt_r_item("rmse.q.devs",q_devs_rmse);

    wrt_r_item("rmse.SR.steepness",steepness_rmse);

    wrt_r_item("rmse.SR.scaler",SR_scaler_rmse);

 close_r_info_list();

 open_r_list("Neff.stage2.mult");
    wrt_r_complete_vector("Neff.stage2.mult.catch", Neff_stage2_mult_catch);
    wrt_r_complete_vector("Neff.stage2.mult.discard", Neff_stage2_mult_discard);
    wrt_r_complete_vector("Neff.stage2.mult.index", Neff_stage2_mult_index);
 close_r_list();

// close file
close_r_file();
```

AGEPRO User Guide

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Version 3.4
1 April 2011

Abstract

This User Guide describes the AGEPRO version 3.4 model and software to perform stochastic projections for an exploited age-structured fish stock. This new version allows for multiple recruitment models to account for alternative hypotheses about recruitment dynamics and applies model-averaging to predict the distribution of realized recruitment given estimates of recruitment model probabilities. The AGEPRO model can be used to quantify the probable effects of a harvest scenario on an age-structured population over a given time horizon. Primary outputs include the projected distribution of spawning biomass, fishing mortality, recruitment, and landings by time period. This guide describes the numerical algorithms as well as the theoretical basis of the projection model. Program inputs, outputs, structure and general usage are also described in detail. The AGEPRO model is distributed in the hope that it will be useful, but includes no warranty. If you have problems with the software, please consult the User Guide and if the problem persists, please contact Alan.Seaver@NOAA.GOV or Jon.Brodziak@NOAA.GOV.

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Introduction

The AGEPRO program can be used to perform stochastic projections of the abundance of an exploited age-structured population over a given time horizon. The primary purpose of the AGEPRO model is to produce management strategy projections that characterize the sampling distribution of key fishery system outputs such as landings, spawning stock biomass, population age structure, and fishing mortality accounting for uncertainty in initial population estimates, future recruitment, and natural mortality. The acronym "AGEPRO" derives from **age**-structured **pro**jections, in contrast to size- or biomass-based projection models. The user can evaluate alternative harvest scenarios by setting quotas or fishing mortality rates in each year of the time horizon.

Three elements of uncertainty can be included in an AGEPRO projection: **recruitment**, **initial population size**, and **natural mortality**. Recruitment is the primary stochastic element in the population model, where recruitment is defined as the number of fish entering the modeled population at the beginning of each year in the time horizon. There are a total of fifteen stochastic recruitment models that can be used for population projection. It is also possible to simulate a deterministic recruitment trajectory (see recruitment model 9 below).

Initial population size is the second potential element of uncertainty for population projection. To include this element, a distribution of initial population sizes at age must be calculated a priori. This is typically done using bootstrapping, Markov chain Monte carlo simulation, or other techniques in most age-structured assessments. If recruitment occurs at an age greater than age-1, then additional distributions of population size at age and fishing mortality at age prior to the projection time horizon are needed. Alternatively, projections can be based on the best point estimate of initial population size.

The third potential element of uncertainty is natural mortality. The user can choose to simulate natural mortality as a constant or a stochastic process at age. In the stochastic case, the instantaneous natural mortality rate is simulated as an autocorrelated lognormal process. Annual natural mortality rates at age are random samples from age-specific uniform distributions with means equal to the age-specific vulnerabilities of each age class to the full natural mortality rate and with age-specific coefficients of variation.

The AGEPRO model was initially developed in 1994 to determine optimal strategies to rebuild a depleted fish stock. The model was reviewed at the May 1994 meeting of the Northeast Fisheries Science Center Methods Working Group (Brodziak and Rago, 1994; Brodziak et al. 1998). Subsequently, the model was applied to groundfish stocks at the 18th SARC (NEFSC 1994) to evaluate Amendment 5 harvest scenarios (NEFMC 1994) and was applied again in 1995 to assist with Amendment 7 (NEFMC 1996). The User Guide was prepared in 1997 to provide documentation and has been updated since then to describe modifications to the model and software. The current program is written in Fortran 95 to allow for dynamic array allocation and to achieve rapid processing speeds.

Age-Structured Population Model

A simple age-structured population model is the basis for the AGEPRO model and software. This model represents an iteroparous fish population whose abundance changes due to fluctuations in recruitment, natural mortality, and fishing mortality. Population size at age changes continuously throughout the year due to the concurrent forces of natural and fishing mortality. Recruitment (R) to the population occurs at the beginning of each year (January 1st) and is the first element in the population size at age vector (Table 1).

Population Abundance, Survival, and Spawning Biomass

The AGEPRO model calculates the number of fish alive within each age class of the population through time. Let Y denote the number of years in a projection where t indexes time for t=1,2, ..., Y. The maximum number of years (Y) in the projection is a dynamic variable specified by the user and constrained by the amount of computer memory. The youngest age class comprises the recruits and the age of recruitment (r) is specified by the user. The oldest age class is a plus-group which consists of all fish that are at least as old as a cutoff age (A). The maximum number of age classes is 100. For each age class, the number of fish alive at the beginning of a each calendar year (January 1st) is $N_j(t)$ where "j" indexes age class and "t" indexes year. Note that $N_A(t)$ is the number of fish that are age-A or older at the beginning of year t. Given this, the population abundance at the beginning of year t is the vector $\underline{N}(t)$ with R(t) used as an alternate notation to emphasize that a recruitment submodel is needed to stochastically generate recruitment through time horizon

(1)
$$\underline{N}(t) = \begin{bmatrix} N_r(t) \\ N_{r+1}(t) \\ N_{r+2}(t) \\ \vdots \\ N_A(t) \end{bmatrix} = \begin{bmatrix} R(t) \\ N_{r+1}(t) \\ N_{r+2}(t) \\ \vdots \\ N_A(t) \end{bmatrix}$$

When the age of recruitment is greater than age-1, the modeled age classes are age-r through the plus-group. In this case, the dynamics of age classes younger than age-r are not explicitly modeled.

Population survival at age from year t-1 to year t is calculated using instantaneous fishing and mortality rates at age. To describe annual survival through mortality, let $M_a(t)$ denote the instantaneous natural mortality rate on age group a and let $F_j(t)$ denote the instantaneous fishing mortality rate for age-j fish in year t. Population size at age in year t for the age classes indexed by a= r +1 to A-1 is given by

(2)
$$N_a(t) = N_{a-1}(t-1) \cdot e^{-M_{a\text{-}1}(t-1) - F_{a\text{-}1}(t-1)}$$

Similarly, population size at age in year t for the plus group of fish age-A and older is given by

(3) $$N_A(t) = N_A(t-1)\cdot e^{-M_A(t-1)-F_A(t-1)} + N_{A-1}(t-1)\cdot e^{-M_{A-1}(t-1)-F_{A-1}(t-1)}$$

where survival for the plus-group involves an age-A and an age-(A-1) component. Incoming recruitment is determined through a stochastic process that is either dependent or independent of spawning biomass in year t-r (see **Stock-Recruitment Relationship** below).

Annual spawning biomass ($B_S(t)$) is calculated from the population size vector $\underline{N}(t)$ and total mortality rates as well as information on sexual maturity and weight at age. To describe natural mortality at age in year t, let M(t) denote the instantaneous natural mortality rate and let $P_{M,a}(t)$ be the fraction of the natural mortality rate experienced by age group a . The age-specific natural mortality rate ($M_a(t)$) is then the product of M and the vulnerability at age-a, i.e., $M_a(t) = M(t)PM_a(t)$. To describe annual survival, let $F_j(t)$ be the instantaneous fishing mortality rate for age-j fish in year t. Further, let $P_{S,j}(t)$ denote the average fraction of age-j fish that are sexually mature in year t and let $W_{S,j}(t)$ denote the average spawning weight of an age-j fish in year t. Last, let $P_Z(t)$ denote the proportion of total mortality that occurs from January 1st to the mid-point of the spawning season. Given this, population size at the midpoint of the spawning season in year t ($\underline{N}_s(t)$) is obtained by applying instantaneous natural and fishing mortality rates that occur prior to the spawning season to the population vector at the beginning of the year, $\underline{N}(t)$.

(4) $$\underline{N}_S(t) = \begin{bmatrix} N_r(t)\cdot e^{-P_Z(t)[M_R(t)+F_R(t)]} \\ N_{r+1}(t)\cdot e^{-P_Z(t)[M_{R+1}(t)+F_{R+1}(t)]} \\ N_{r+2}(t)\cdot e^{-P_Z(t)[M_{R+2}(t)+F_{R+2}(t)]} \\ \vdots \\ N_A(t)\cdot e^{-P_Z(t)[M_A(t)+F_A(t)]} \end{bmatrix}$$

The amount of spawning biomass in year t, $B_S(t)$, is the sum of the weight of mature fish at the midpoint of the spawning season

(5) $$B_S(t) = \sum_{a=r}^{A} W_{S,a}(t)\cdot P_{S,a}(t)\cdot N_a(t)\cdot e^{-P_Z(t)[M_a(t)+F_a(t)]}$$

Catch, Landings, and Discards

The fishery catch depends on the fraction of the population that is vulnerable to harvest or the exploitable stock size. Catch by age class is determined by the Baranov catch equation (see, for example, Quinn and Deriso 1999), and the catch of age-a fish in year t ($C_a(t)$) is

(6) $$C_a(t) = \frac{F_a(t)}{M_a(t) + F_a(t)}\left[1 - e^{-M_a(t) - F_a(t)}\right]\cdot N_a(t)$$

To account for age-specific discarding of fish, let $P_{D,a}(t)$ be the proportion of age-a fish that are discarded and die in year t, and let $W_{L,a}(t)$ and $W_{D,a}(t)$ be the average weight at age-a in year t for landed and discarded fish, respectively. Then, if discarding is included in the projections (discflag=true), the total landed weight in year t, denoted by L(t), is

(7) $$L(t) = \sum_{a=r}^{A} C_a(t)\cdot\left[1 - P_{D,a}(t)\right]\cdot W_{L,a}(t)$$

Similarly, the total weight of discarded fish in year t, denoted by D(t), is

(8) $$D(t) = \sum_{a=r}^{A} C_a(t)\cdot P_{D,a}(t)\cdot W_{D,a}(t)$$

Population Harvest

There are two options for determining the level of population harvest in each year of the time horizon. The first option is a user-input fishing mortality rate (effort-based management, quotaflag=false & mixflag=false). The second option is a user-input landings quota (quota-based management, quotaflag=true & mixflag=false). These two harvest options can be mixed in any order within a given projection run where effort-based management is applied in some years and quota-based management in the other years (mixflag=true). In this case, the user sets a binary index I(t) to determine the harvest option for each year in the projection time horizon. If I(t) =1, a quota-based management is applied in year t; else if I(t)=0, effort-based management is applied in year t. A mixture of quotas and effort-based harvest can be useful when projecting forward from a previous assessment when only catch is available for intervening years.

When effort-based management is applied, catch at age is determined by setting $F_a(t)$ for each age class. In this case, the fishing mortality rate on age-a fish in year t is the product of the fully-selected fishing mortality rate, denoted by F(t), and the age-specific fishery selectivity (or partial recruitment) of age-a fish, denoted by $P_{F,a}(t)$

(9) $$F_a(t) = F(t)\cdot P_{F,a}(t)$$

Landings and discards, if applicable, are then determined from $F_a(t)$. When quota-based management is applied, however, the F(t) that would yield the landings quota must be determined numerically.

Under quota-based management, the landings quota in year t, denoted by Q(t), will translate into a variety of effective fishing mortality rates depending on population size, fishery selectivity, and discarding, if applicable. Ignoring the time dimension for a moment, a landings quota Q can be expressed as a function of F, Q= L(F), where F is the fully-recruited F and L is the landings as a function of F. To see this result, observe that the catch of age-a fish can be expressed as a function of F

(10) $$C_a(F) = \frac{F \cdot P_{F,a}(t)}{M_a(t) + F \cdot P_{F,a}(t)} \left[1 - e^{-M_a(t) - F \cdot P_{F,a}(t)}\right] \cdot N_a(t)$$

As a result, landings can also be expressed as a function of F

(11) $$L(F) = \sum_{a=r}^{A} C_a(F) \cdot \left[1 - P_{D,a}(t)\right] \cdot W_{L,a}(t)$$

The fully-recruited fishing mortality which satisfies the equation Q=L(F) can be found using Newton's method. Details of this numerical approach are provided below (see Appendix). Quotas which exceed the exploitable biomass of the population are infeasible; conditions defining infeasible quotas are also specified below (Appendix).

Stock-Recruitment Relationship

In general, the relationship between spawning stock B_S and recruitment R is highly variable owing to intrinsic variability in factors governing early life history survival and to measurement error in the estimates of recruitment and the spawning biomass that generated it. The stock-recruitment relationship ultimately defines the sustainable yield curve and its expected variability assuming that the stochastic processes of growth, maturation, and natural mortality are density-independent and stationary throughout the time horizon. Quinn and Deriso (1999) provide a useful general discussion of stock-recruitment models, renewal processes, and sustainable yield. Note that the assumed stock-recruitment relationship does not affect the initial population abundance at the beginning of the time horizon (see **Initial Population Abundance**).

A total of nineteen stochastic recruitment models are available for population projection in the AGEPRO software. Twelve of the recruitment models are functionally dependent on B_S while seven do not depend on B_S. Five of the recruitment models have time-dependent parameters, ten are time-invariant, and four may include time as a predictor, or not. The user is responsible for the choice and parameterization of the recruitment models. In what follows, the age of recruitment to the population is denoted as "r"; the recruitment age is either age-1 or age-r for r>1. A description of each of the recruitment models follows. Also note that the absolute units for recruitment are numbers of age-r fish, while for B_S, the absolute units are kilograms of spawning biomass in each of the recruitment models below.

Model 1. Markov Matrix

A Markov matrix approach to modeling recruitment may be useful when there is uncertainty about the functional form of the stock-recruitment relationship. A Markov matrix contains transition probabilities that define the probability of obtaining a given level of recruitment given that B_S was within a defined interval range. In particular, the distribution of recruitment is assumed to follow a multinomial distribution conditioned on the spawning biomass interval (state). The Markov matrix model depends on spawning biomass and is time-invariant.

An empirical approach to estimate a Markov matrix uses stock-recruitment data to determine the parameters of a multinomial distribution for each spawning biomass state. In this case, matrix elements can be empirically determined by counting the number of times that a recruitment observation interval lies within a given spawning biomass state, defined by an interval of spawning biomass, and normalizing over all spawning states. To do this, assume that there are m recruitment states and n spawning biomass states defined by disjoint intervals on the recruitment and spawning biomass axes

(12) $$I_j = \left[B_{S,j}, B_{S,j+1}\right] \ and \ O_k = \left[R_k, R_{k+1}\right]$$

where $B_{S,j}$ and R_k are endpoints of the disjoint intervals of spawning biomass and recruitment. Note that $B_{S,1}=0$ and that the spawning biomass intervals are defined by the cut points $B_{S,2}$, $B_{S,3}$, ..., $B_{S,J}$.

The conditional probability of realizing the kth recruitment state given that spawning biomass ($P_{j,k}$) is in the jth state is the element in the jth row and kth column of the Markov matrix where

(13) $$P_{j,k} = \Pr\left(N_r \in O_k \mid B_S \in I_j\right)$$

This conditional probability can be approximated by the computing the number of points in the stock recruitment data set that fall within the I_j x O_k cell and normalizing within each spawning biomass interval I_j. If x_{jk} represents the number of stock-recruitment observations in cell I_j x O_k and there is at least one observation in spawning state j, then an empirical estimate of $P_{j,k}$ is

(14) $$\Pr\left(R \in O_k \mid B_S \in I_j\right) = \frac{x_{j,k}}{\sum_k x_{j,k}}$$

Note that the $P_{j,k}$ are nonnegative and the sum of $P_{j,k}$ over k is unity.

If there are few stock-recruitment observations, then an empirical approach will produce imprecise estimates of the $P_{j,k}$. In this case, elements of the Markov matrix might be estimated using either a frequentist bootstrapping or a Bayesian parametric approach.

Up to 25 recruitment states and up to 10 B_S states can be used in the Markov matrix model. The simulated recruitments ($N_{r,k}$) are defined to be the midpoints of the recruitment intervals O_k. That is, $R = N_{r,k} = (R_k + R_{k+1})/2$. For each spawning biomass interval, the user also needs to specify the conditional probabilities of realizing the expected recruitment level, e.g., the $P_{j,k}$.

Model 2. Empirical Recruits Per Spawning Biomass Distribution

For some stocks, the distribution of recruits per spawner may be independent of the number of spawners over the range of observed data. The recruitment per spawning biomass (R/B_S) model randomly generates recruitment under the assumption that the distribution of the R/B_S ratio is stationary and independent of stock size. The empirical recruits per spawning biomass distribution model depends on spawning biomass and is time-invariant.

To describe this nonparametric approach, let S_t be the R/B_S ratio for the t^{th} stock recruitment data point

(15) $$S_t = \frac{N_r(t)}{B_S(t-r)}$$

and let R_S represent the s_{th} element in the ordered set of S_t. The empirical probability density function for R_S, denoted as $g(R_S)$, is 1/T for all values of R/B_S where T = the number of stock-recruitment data points. Let $G(R_S)$ denote the cumulative distribution function (cdf). Let $G(R_{MIN}) = 0$ and $G(R_{MAX}) = 1$ so that the cdf of R_s can be written as

(16) $$G(R_S) = \frac{s-1}{T-1}$$

Random values of $S=R/B_S$ can be generated by applying the probability integral transform to the empirically derived cdf. To do this, let U be a uniformly distributed random variable on the interval [0,1]. The value of R/B_S corresponding to U is determined by applying the inverse function of the cdf $G(R_s)$. In particular, when U is an integer multiple of 1/(T-1) so that U=s/(T-1) then $R/B_S = G^{-1}(U) = R_S$. Otherwise R/B_S can be obtained by linear interpolation when U is not a multiple of 1/(T-1).

In particular, if (s-1)/(T-1) < U < s/(T-1), then

(17) $$U = \left(\frac{\frac{s}{T-1} - \frac{s-1}{T-1}}{R_{S+1} - R_S} \right) \left(\frac{R}{B_S} - R_S \right) + \frac{s-1}{T-1}$$

Solving for R/B_S as a function of U yields

(18) $$\frac{R}{B_S} = (T-1)(R_{S+1} - R_S)\left(U - \frac{s-1}{T-1}\right) + R_S$$

where the interpolation index s is determined as the greatest integer in 1+U(T-1). Given a random value of R/B_S, recruitment is generated as

(19) $$R(t) = N_r(t) = B_S(t-r)\cdot\frac{R}{B_S}$$

The AGEPRO program can generate stochastic recruitments using model 2 with up to 100 stock-recruitment data points.

Model 3. Empirical Recruitment Distribution

Another simple model for generating recruitment is to draw randomly from the observed set of recruitments { $N_r(1)$, $N_r(2)$, ..., $N_r(T)$}. This may be a useful approach when the recruitment has randomly fluctuated about its mean and appears to be independent of spawning biomass for the observed range of data. In this case, the recruitment distribution may be modeled as a multinomial random variable where the probability of randomly choosing a particular recruitment is 1/T given T observed recruitments. The empirical recruitment distribution model does not depend on spawning biomass and is time-invariant.

In this model, realized recruitment N_r is simulated using

(20) $$\Pr\left(R = N_r(t)\right) = \frac{1}{T}\ ,\quad for\ t \in \{1,2,...,T\}$$

The empirical recruitment distribution approach is nonparametric and assumes that future recruitment is totally independent of spawning stock biomass. When current levels of B_S are near the midrange of historical values this assumption is acceptable. However, if contemporary B_S values are near the bottom of the range, then this approach could be overly optimistic, for it assumes that all historically observed recruitment levels are possible, regardless of B_S. The AGEPRO program allows up to 100 observed recruitments for random sampling. Note that the empirical recruitment distribution model can be used to make deterministic projections by specifying a single observed recruitment.

Model 4. Two-Stage Empirical Recruits Per Spawning Biomass Distribution

The two-stage recruits per spawning biomass model is a direct generalization of the R/B_S model where the spawning stock of the population is categorized into “low” and “high” states. The two-stage empirical recruits per spawning biomass distribution model depends on spawning biomass and is time-invariant.

In this model, there is an R/B_S distribution for the low spawning biomass state and an R/B_S distribution for the high spawning biomass state. Let G_{LOW} be the cdf and let T_{LOW} be the number of R/B_S values for the low B_S state. Similarly, let G_{HIGH} be the cdf and let T_{HIGH} be the number of R/B_S values for the high B_S state. Further, let B_S* denote the cutoff level of B_S such that, if $B_S>B_S*$, then B_S falls in the high state. Conversely if $B_S<B_S*$ then B_S falls in the low state. Recruitment is stochastically generated from G_{LOW} or G_{HIGH} using equations (18) and (19) dependent on the B_S state. The AGEPRO program can generate stochastic recruitments using the two-stage model with up to 100 stock-recruitment data points per B_S state.

Model 5. Beverton-Holt Curve with Lognormal Error

The Beverton-Holt curve (Beverton and Holt 1957) with lognormal errors is a parametric model of recruitment generation where survival to recruitment age is density dependent and subject to stochastic variation. The Beverton-Holt curve with lognormal error model depends on spawning biomass and is time-invariant.

The Beverton-Holt curve with lognormal error generates recruitment as

(21)

$$n_r(t) = \frac{\alpha \cdot b_S(t-r)}{\beta + b_S(t-r)} \cdot e^w$$

$$where \;\; w \sim N\left(0, \sigma_w^2\right),\; R(t) = c_R \cdot n_r(t),\; and \;\; B_S(t) = c_B \cdot b_S(t)$$

The stock-recruitment parameters "α", "β", and the error variance"σ_w^2" and the conversion coefficients for recruitment c_R and spawning stock biomass c_B are specified by the user. Here it is assumed that the parameter estimates for the Beverton-Holt curve have been estimated in relative units determined (e.g., $n_r(t)$ and $b_S(t\text{-}r)$) which can be converted to absolute values with the conversion coefficients. Note that the absolute value for recruitment is numbers of fish, while for B_S, the absolute value is kilograms of B_S. For example, if the stock-recruitment curve was estimated with stock-recruitment data that were measured in millions of fish and thousands of metric tons of B_S, then $c_R = 10^6$ and $c_B = 10^6$. It may be important to estimate the parameters of the stock-recruitment curve in relative units to reduce the potential effects of roundoff error on parameter estimates. It is important to note that the expected value of the lognormal error term is not unity but is $\exp\left(\frac{1}{2}\sigma_w^2\right)$. To generate a recruitment model that has a lognormal error term that is equal to 1, premultiply the parameter α by $\exp\left(-\frac{1}{2}\sigma_w^2\right)$; this mean correction applies when the lognormal error used to fit the Beverton-Holt curve has a log-scale error term w with zero mean.

The Beverton-Holt curve is often reparameterized in a modified form with steepness (h), virgin recruitment (R_0), and virgin spawning biomass ($B_{S,0}$) parameters. The modified Beverton-Holt curve produces $h \cdot R_0$ recruits when $B_S = 0.2 \cdot B_{S,0}$ and has the form

(22)

$$R = \frac{4hR_0B_S}{B_{S,0}(1-h) + B_S(5h-1)}$$

The parameters α and β can be expressed as functions of the parameters of the modified Beverton-Holt curve as

(23) $$\alpha = \frac{4hR_0}{5h-1} = 4B_{S,0}\frac{h}{\left(\frac{B_{S,0}}{R_0}\right)(5h-1)}$$

and

(24) $$\beta = \frac{B_{S,0}(1-h)}{(5h-1)} = \frac{\alpha\left(\frac{B_{S,0}}{R_0}\right)\left(h^{-1}-1\right)}{4}$$

Thus, parameter estimates for the modified curve can be used to determine the Beverton-Holt parameters for the AGEPRO program.

Model 6. Ricker Curve with Lognormal Error

The Ricker curve (Ricker 1954) with lognormal error is a parametric model of recruitment generation where survival to recruitment age is density dependent and subject to stochastic variation. The Ricker curve with lognormal error model depends on spawning biomass and is time invariant.

The Ricker curve with lognormal error generates recruitment as

(25) $$n_r(t) = \alpha \cdot b_S(t-r) \cdot e^{-\beta \cdot b_S(t-r)} \cdot e^{w}$$
$$\text{where } w \sim N\left(0,\sigma_w^2\right),\ R(t) = c_R \cdot n_r(t),\ \text{and } B_S(t) = c_B \cdot b_S(t)$$

The stock-recruitment parameters "α", "β", and the error variance "σ_w^2" and the conversion coefficients for recruitment c_R and spawning stock biomass c_B are specified by the user. Here it is assumed that the parameter estimates for the Ricker curve have been estimated in relative units determined by the user (e.g., $n_r(t)$ and $b_S(t-r)$) and then converted to absolute values with the conversion coefficients. It is important to note that the expected value of the lognormal error term is not unity but is $\exp\left(\frac{1}{2}\sigma_w^2\right)$. To generate a recruitment model that has a lognormal error term that is equal to 1, premultiply the parameter α by $\exp\left(-\frac{1}{2}\sigma_w^2\right)$; this mean correction applies when the lognormal error used to fit the Ricker curve has a log-scale error term w with zero mean.

Model 7. Shepherd Curve with Lognormal Error

The Shepherd curve (Shepherd 1982) with lognormal error is a parametric model of recruitment generation where survival to recruitment age is density dependent and subject to stochastic variation. The Shepherd curve with lognormal error model depends on spawning biomass and is time-invariant.

The Shepherd curve with lognormal error generates recruitment as

$$n_r(t) = \frac{\alpha \cdot b_S(t-r)}{1 + \left(\frac{b_S(t-r)}{k}\right)^{\beta}} \cdot e^{w}$$

(26)

$$\text{where } w \sim N\left(0, \sigma_w^2\right),\ R(t) = c_R \cdot n_r(t),\ \text{and } B_S(t) = c_B \cdot b_S(t)$$

The stock-recruitment parameters "α", "β", "k" and the error variance "σ_w^2" and the conversion coefficients for recruitment c_R and spawning stock biomass c_B are specified by the user. Here it is assumed that the parameter estimates for the Shepherd curve have been estimated in relative units determined by the user (e.g., $n_r(t)$ and $b_S(t-r)$) and then converted to absolute values with the conversion coefficients. It is important to note that the expected value of the lognormal error term is not unity but is $\exp\left(\frac{1}{2}\sigma_w^2\right)$. To generate a recruitment model that has a lognormal error term that is equal to 1, premultiply the parameter α by $\exp\left(-\frac{1}{2}\sigma_w^2\right)$; this mean correction applies when the lognormal error used to fit the Shepherd curve has a log-scale error term w with zero mean.

Model 8. Lognormal Distribution

The lognormal distribution provides a parametric model for stochastic recruitment generation. The lognormal distribution model does not depend on spawning biomass and is time-invariant.

The lognormal distribution generates recruitment as

$$n_r(t) = e^{w}$$

(27)

$$\text{where } w \sim N\left(\mu_{\log(r)}, \sigma_{\log(r)}^2\right) \text{ and } R(t) = c_R \cdot n_r(t)$$

The lognormal distribution parameters "$\mu_{\log(r)}$" and the log-scale variance "$\sigma_{\log(r)}^2$" as well as the conversion coefficient for recruitment c_R are specified by the user. It is assumed that the parameters of the lognormal distribution have been estimated in relative units (e.g., $n_r(t)$) and then converted to absolute values with the conversion coefficients.

Model 9. Time-Varying Empirical Recruitment Distribution

The time-varying empirical recruitment distribution model is a time-dependent extension of model 3. The time-varying empirical recruitment distribution model does not depend on spawning biomass and is time-dependent.

In this approach, the empirical model for the estimation of recruitment draws randomly from a set of T recruitments levels for year t of the time horizon { $N_r(t,1)$, $N_r(t,2)$, ..., $N_r(t,T)$ }. Here the recruitment distribution for each year of the time horizon is a time-dependent multinomial random variable where the probability of randomly choosing a particular recruitment level is 1/T given T levels of recruitment. In particular, realized recruitment in year t is simulated using

(28) $$\Pr\left(R(t) = N_r\left(t,k\right)\right) = \frac{1}{T} \ , \quad for\ k \in \left\{1,2,...,T\right\}$$

This approach is nonparametric and assumes that future recruitment is totally independent of spawning stock biomass. Further, it is the responsibility of the USER to determine an appropriate set of recruitment levels for each year of the time horizon. The AGEPRO software permits up to 100 observed recruitments for the recruitment distribution in each year of the time horizon. The user must input T potential recruitment levels in each year for a total of TY recruitment inputs. As in recruitment model 3, the time-varying empirical recruitment distribution model can be used to make deterministic projections by specifying a single recruitment level for each year of the time horizon. In this case, recruitment will be constant time series over the time horizon.

Model 10. Beverton-Holt Curve with Autocorrelated Lognormal Error

The Beverton-Holt curve with autocorrelated lognormal errors is a parametric model of recruitment generation where survival to recruitment age is density dependent and subject to serially-correlated stochastic variation. The Beverton-Holt curve with autocorrelated lognormal error model depends on spawning biomass and is time-dependent.

The Beverton-Holt curve with autocorrelated lognormal error generates recruitment as

(29) $$n_r\left(t\right) = \frac{\alpha \cdot b_S\left(t-r\right)}{\beta + b_S(t-r)} \cdot e^{\varepsilon_t}$$

$$where\ \ \varepsilon_t = \phi\varepsilon_{t-1} + w_t\ \ where\ Var\left(\varepsilon\right) = \sigma^2,$$
$$\sigma_w^2 = \left(1-\phi^2\right)\sigma^2,\ \ w_t \sim N\left(0,\sigma_w^2\right),$$
$$R\left(t\right) = c_R \cdot n_r\left(t\right),\ and\ \ B_S\left(t\right) = c_B \cdot b_S\left(t\right)$$

The stock-recruitment parameters "α", "β", "ε_0", "φ" and error variance "σ^2" and the conversion coefficients for recruitment c_R and spawning stock biomass c_B are specified by the user. The parameter ε_0 is the log-scale residual for the stock-recruitment fit in the first time period prior to the projection. If this value is not known, set ε_0=0.

Model 11. Ricker Curve with Autocorrelated Lognormal Error

The Ricker curve with autocorrelated lognormal error is a parametric model of recruitment generation where survival to recruitment age is density dependent and subject to serially correlated stochastic variation. The Ricker curve with autocorrelated lognormal error model depends on spawning biomass and is time-dependent.

The Ricker curve with autocorrelated lognormal error generates recruitment as

$$n_r(t) = \alpha \cdot b_S(t-r) \cdot e^{-\beta \cdot b_S(t-r)} \cdot e^{\varepsilon_t}$$

(30)
$$\begin{aligned} &\text{where } \varepsilon_t = \phi\varepsilon_{t-1} + w_t \text{ where } Var(\varepsilon) = \sigma^2, \\ &\sigma_w^2 = (1-\phi^2)\sigma^2, \; w_t \sim N(0, \sigma_w^2), \\ &R(t) = c_R \cdot n_r(t), \text{ and } B_S(t) = c_B \cdot b_S(t) \end{aligned}$$

The stock-recruitment parameters "α", "β", "ε_0", "φ" and error variance "σ^2" and the conversion coefficients for recruitment c_R and spawning stock biomass c_B are specified by the user. The parameter ε_0 is the log-scale residual for the stock-recruitment fit in the first time period prior to the projection. If the log-scale residual value is not known, set $\varepsilon_0=0$.

Model 12. Shepherd Curve with Autocorrelated Lognormal Error

The Shepherd curve with autocorrelated lognormal error is a parametric model of recruitment generation where survival to recruitment age is density dependent and subject to serially-correlated stochastic variation. The Shepherd curve with autocorrelated lognormal error model depends on spawning biomass and is time-dependent.

The Shepherd curve with autocorrelated lognormal error generates recruitment as

$$n_r(t) = \frac{\alpha \cdot b_S(t-r)}{1 + \left(\frac{b_S(t-r)}{k}\right)^{\beta}} \cdot e^{\varepsilon_t}$$

(31)
$$\begin{aligned} &\text{where } \varepsilon_t = \phi\varepsilon_{t-1} + w_t \text{ where } Var(\varepsilon) = \sigma^2, \\ &\sigma_w^2 = (1-\phi^2)\sigma^2, \; w_t \sim N(0, \sigma_w^2), \\ &R(t) = c_R \cdot n_r(t), \text{ and } B_S(t) = c_B \cdot b_S(t) \end{aligned}$$

The stock-recruitment parameters ""α", "β", "k", "ε_0", "φ" and error variance "σ^2" and the conversion coefficients for recruitment c_R and spawning stock biomass c_B are specified by the user. The parameter ε_0 is the log-scale residual for the stock-recruitment fit in the first time period prior to the projection. If this value is not known, set ε_0=0.

Model 13. Autocorrelated Lognormal Distribution

The autocorrelated lognormal distribution provides a parametric model for stochastic recruitment generation with serial correlation. The autocorrelated lognormal distribution model does not depend on spawning biomass and is time-dependent.

The autocorrelated lognormal distribution is

$$n_r(t) = e^{\mu_{\log(r)}} \cdot e^{\varepsilon_t}$$

(32)

$$\begin{aligned} &where\ \ \varepsilon_t = \phi\varepsilon_{t-1} + w_t \ \ where\ Var(\varepsilon) = \sigma^2_{\log(r)}, \\ &\sigma^2_w = \left(1-\phi^2\right)\sigma^2_{\log(r)},\ \ w_t \sim N\left(0,\sigma^2_w\right), \\ &and\ \ R(t) = c_R \cdot n_r(t) \end{aligned}$$

The lognormal distribution parameters "$\mu_{\log(r)}$", "$\sigma^2_{\log(r)}$", "ε_0", "φ" and the conversion coefficient for recruitment c_R are specified by the user. The parameter ε_0 is the log-scale residual for the stock-recruitment fit in the first time period prior to the projection. If this value is not known, set ε_0=0.

Model 14. Empirical Cumulative Distribution Function of Recruitment

The empirical cumulative distribution function of recruitment can be used to randomly generates recruitment under the assumption that the distribution of the R is stationary and independent of stock size. The empirical cumulative distribution function of recruitment model does not depend on spawning biomass and is time-invariant.

To describe this nonparametric approach, let R_S represent the S^{th} element in the ordered set of observed recruitment values. The empirical probability density function for R_S, denoted as $g(R_S)$, is 1/T for all observed values of R where T is the number of stock-recruitment data points. Let $G(R_S)$ denote the cumulative distribution function of observed recruitment.

Random values of R can be generated by applying the probability integral transform to the empirically derived cdf. Let U be a uniformly distributed random variable on the interval [0,1]. The value of R corresponding to U is determined by applying the inverse of the cdf $G(R_S)$. In particular, when U is an integer multiple of 1/(T-1) so that U=s/(T-1) then $R = G^{-1}(U) = R_S$. Otherwise R can be obtained by linear interpolation when U is not a multiple of 1/(t-1). In particular, if (s-1)/(T-1) < U < s/(T-1), then

(33) $$U = \left(\frac{\frac{s}{T-1} - \frac{s-1}{T-1}}{R_{S+1} - R_S} \right) \left(R - R_S \right) + \frac{s-1}{T-1}$$

Solving for R as a function of U yields

(34) $$R = \left(T-1\right)\left(R_{S+1} - R_S\right)\left(U - \frac{s-1}{T-1}\right) + R_S$$

where the interpolation index s is determined as the greatest integer in 1+U(T-1). The AGEPRO program can generate stochastic recruitments using model 14 with up to 100 recruitment data points.

Model 15. Two-Stage Empirical Cumulative Distribution Function of Recruitment

The two-stage empirical cumulative distribution function of recruitment model is an extension of Model 14 where the spawning stock of the population is categorized into "low" and "high" states. The two-stage empirical cumulative distribution function of recruitment model depends on spawning biomass and is time-invariant.

In particular, there is a cdf for R when the population is in the low B_S state and a cdf for R when the population is in the high B_S state. Let G_{LOW} be the cdf and let T_{LOW} be the number of R values for the low B_S state. Similarly, let G_{HIGH} be the cdf and let T_{HIGH} be the number of R values for the high B_S state. Further, let B_S* denote the cutoff level of B_S such that, if $B_S > B_S^*$, then B_S falls in the high state, while if $B_S < B_S^*$ then B_S falls in the low state. Recruitment is stochastically generated from G_{LOW} or G_{HIGH} using equations (33) and (34) dependent on the B_S state. The AGEPRO program can generate stochastic recruitments using model 15 with up to 100 stock-recruitment data points.

Model 16. Linear Recruits Per Spawning Biomass Predictor with Normal Error

The linear recruits per spawning biomass predictor with normal error is a parametric model to simulate random values of recruits per spawning biomass R/B_S and associated random recruitments. The predictors in the linear model ($X_p(t)$) can be any continuous variable and may typically be survey indices of cohort abundance or environmental covariates that are correlated with recruitment strength. Input values of each predictor are required for each time period. If a value of a predictor is missing or not known for one or more periods, the missing values can be imputed using appropriate measures of central tendency, e.g., mean or median values. Similarly, if this model has zero probability in a given time period (e.g., is not a member of the set of probable models), then dummy values can be input for each predictor. For each time period and simulation, a random value of R/B_S is generated using the linear model

$$(35) \qquad \frac{R}{B_S} = \beta_0 + \sum_{p=1}^{N_p} \beta_p \cdot X_p(t) + \varepsilon$$

where N_p is the number of predictors, β_0 is the intercept, β_p is the linear coefficient of the p^{th} predictor and ε is a normal distribution with zero mean and constant variance σ^2. It is possible negative values of R/B_S to be generated using this formulation; such values are excluded from the set of simulated values of R/B_S from equation (35) by testing if R/B_S repeating the random sampling until an acceptable positive value of R/B_S is obtained. This model randomly generates R/B_S values under the assumption that the linear predictor of the R/B_S ratio is stationary and independent of stock size. Random values of R/B_S are multiplied by realized spawning biomass to generate recruitment in each time period. The linear recruits per spawning biomass predictor with normal error depends on spawning biomass and is time-invariant unless time is used as a predictor.

Model 17. Loglinear Recruits Per Spawning Biomass Predictor with Lognormal Error

The loglinear recruits per spawning biomass predictor with lognormal error is a parametric model to simulate random values of recruits per spawning biomass R/B_S and associated random recruitments. Predictors for the loglinear model ($X_p(t)$) can be any continuous variable and could include survey indices of cohort abundance or environmental covariates that are correlated with recruitment strength. Input values of each predictor are required for each time period. If a value of a predictor is missing or not known for one or more periods, the missing values can be imputed using appropriate measures of central tendency, e.g., mean or median values. If this model has zero probability in a given time period (e.g., is not a member of the set of probable models), then dummy values can be input for each predictor. For each time period and simulation, a random value of the natural logarithm of R/B_S is generated using the loglinear model

$$(36) \qquad \log\left(\frac{R}{B_S}\right) = \beta_0 + \sum_{p=1}^{N_p} \beta_p \cdot X_p(t) + \varepsilon$$

where N_p is the number of predictors, β_0 is the intercept, β_p is the linear coefficient for the pth predictor and ε is a normal distribution with constant variance σ^2 and mean equal to -$\frac{1}{2}\sigma^2$. In this case, the mean of ε implies that the expected value of the lognormal error term is unity. This model generates positive random values of R/B_S under the assumption that the linear predictor of the R/B_S ratio is stationary and independent of stock size. Random values of R/B_S are multiplied by realized spawning biomass to generate recruitment in each time period. The loglinear recruits per spawning biomass predictor with lognormal error depends on spawning biomass and is time-invariant unless time is used as a predictor.

Model 18. Linear Recruitment Predictor with Normal Error

The linear recruitment predictor with normal error is a parametric model to simulate random values of recruitment R. The predictors in the linear model ($X_p(t)$) can be any continuous variable and could represent survey indices of cohort abundance or environmental covariates correlated with recruitment strength. Input values of each predictor are required for each time period. If a value of a predictor is missing or not known for one or more periods, the missing values can be imputed using appropriate measures of central tendency, e.g., mean or median values. Similarly, if this model has zero probability in a given time period (e.g., is not a member of the set of probable models), then dummy values can be input for each predictor. For each time period and simulation, a random value of R is generated using the linear model

(37)
$$n_r(t) = \beta_0 + \sum_{p=1}^{N_p} \beta_p \cdot X_p(t) + \varepsilon$$
$$with\ R(t) = c_R \cdot n_r(t)$$

where N_p is the number of predictors, β_0 is the intercept, β_p is the linear coefficient for the pth predictor, ε is a normal distribution with zero mean and constant variance σ^2, and the conversion coefficients for recruitment is c_R. It is possible that negative values of R can be generated using this formulation; such values are excluded from the set of simulated values of R from equation (37) by testing if R repeating the random sampling until an acceptable positive value of R is obtained. This model randomly generates R values under the assumption that the linear predictor of R is stationary and independent of stock size. The linear recruitment predictor with normal error does not depend on spawning biomass and is time-invariant unless time is used as a predictor.

Model 19. Loglinear Recruitment Predictor with Lognormal Error
The loglinear recruitment predictor with lognormal error is a parametric model to simulate random values of recruitment R. Predictors for the loglinear model ($X_p(t)$) can be any continuous variable such as survey indices of cohort abundance or environmental covariates that are correlated with recruitment strength. Input values of each predictor are required for each time period. If a value of a predictor is missing or not known for one or more periods, the missing values can be imputed using appropriate measures of central tendency, e.g., mean or median values. If this model has zero probability in a given time period (e.g., is not a member of the set of probable models), then dummy values can be input for each predictor. For each time period and simulation, a random value of the natural logarithm of R is generated using the loglinear model

(38)
$$\log(n_r(t)) = \beta_0 + \sum_{p=1}^{N_p} \beta_p \cdot X_p(t) + \varepsilon$$
$$with\ R(t) = c_R \cdot n_r(t)$$

where N_p is the number of predictors, β_0 is the intercept, β_p is the linear coefficient for the pth predictor, ε is a normal distribution with constant variance σ^2 and mean equal to $-\frac{1}{2}\sigma^2$, and the conversion coefficients for recruitment is c_R. In this case, the mean of ε implies that the expected value of the lognormal error term is unity. This model generates positive random values of R under the assumption that the linear predictor of the R is stationary and independent of stock size. The loglinear recruitment predictor with lognormal error does not depend on spawning biomass and is time-invariant unless time is used as a predictor.

Constrained Recruits Per Spawning Biomass For Lognormal Error Models

The lognormal error terms for the six parametric recruitment models and the two lognormal distribution models can produce outliers of R/B_S in a projection analysis because lognormal distributions are highly skewed and generally have a wide tail. The impact of recruitment outliers on a projection analysis can be substantial. To address this issue, realized R/B_S values can be constrained for the eight stock-recruitment models that use the lognormal distribution by setting the bounded recruitment flag to be true (bdrecflag=true). Two constraints can be applied based on the level of B_S within the stock. Let $B_{S,CUT}$ denote a cutoff of B_S, where one R/B_S constraint operates below $B_{S,CUT}$ and another constraint operates above $B_{S,CUT}$. Let [L_{Low}, U_{Low}] and [L_{High}, U_{High}] denote the lower and upper R/B_S constraint intervals. If $B_S(t) < B_{S,CUT}$ in year t, then the realized R/B_S value generated from a lognormal recruitment model must lie within the interval [L_{Low}, U_{Low}]

(39) $$B_S(t) < B_{S,CUT} \;\Rightarrow\; \Pr\left(\frac{N_r(t)}{B_S(t)} \in \left[L_{Low}, U_{Low}\right]\right) = 1$$

If the realized R/B_S falls outside the interval [L_{Low}, U_{Low}], additional recruitments are simulated until one falls within the constraining interval. Similarly, if $B_S(t) > B_{S,CUT}$ in year t then the realized R/B_S value generated from the recruitment model must lie within the interval [L_{High}, U_{High}]

(40) $$B_S(t) > B_{S,CUT} \;\Rightarrow\; \Pr\left(\frac{N_r(t)}{B_S(t)} \in \left[L_{High}, U_{High}\right]\right) = 1$$

If R/B_S values are expected to be more variable when B_S is above $B_{S,CUT}$ then it is natural to choose to have the interval [L_{Low}, U_{Low}] to be within the interval [L_{High}, U_{High}]. In this case, the endpoints of the intervals are ordered as $L_{High} < L_{Low} < U_{Low} < U_{High}$.

The use of R/B_S constraints may be appropriate when the stock is near an historic low value of B_S. In this case, it would be natural to set $B_{S,CUT}$ to be the historic minimum value of B_S. Extrapolating R/B_S values that would result if $B_S(t)$ falls below $B_{S,CUT}$ could have substantial influence on estimating a rebuilding strategy for the stock. For example, one might constrain the realized R/B_S values when $B_S(t)$ falls below $B_{S,CUT}$ to be between the 10_{th} and 90_{th} percentiles of the empirical R/B_S distribution taken from the assessment. When $B_S(t)$ is above $B_{S,CUT}$, one might consider other bounds on the R/B_S values such as 1/100 of the minimum observed R/SB value or 100 times the maximum observed R/B_S value. Similar comments apply for a population that is near its historic maximum value of B_S. While the AGEPRO program requires the user to set two bounding intervals for R/B_S

values when the R/B_S constraint option is selected, one can create a single interval by either (i) setting the intervals to be equal or (ii) setting $B_{S,CUT}$ to be 0.

Recruitment Model Probabilities

Model uncertainty about the appropriate stock-recruitment model can be directly incorporated into AGEPRO projections. Multiple recruitment models may be appropriate when each model provides a similar statistical fit to a set of stock-recruitment data, where similarity can be measured using Akaike's, Bayesian, or deviance information criterion. Given a measure of a model's relative likelihood compared to a set of alternative models, one can use information criteria to calculate an individual model's probability of best representing the true state of nature. Alternatively, one can assign model probabilities based on judgment of other measures of goodness of fit or use this principle of indifference to assign equal probabilities in the absence of compelling information.

Regardless of the approach used to develop model probabilities, such probabilities can be used in AGEPRO to drive the stochastic recruitment dynamics in a straightforward manner. Suppose there are a total of N_M probable recruitment models, as determined by the user. The probability that recruitment model m is realized in year t is denoted by $P_{R,m}(t)\geq 0$. The conservation of probability implies that the sum of model probabilities over the set of probable models in each year is unity

(41) $$\sum_{m=1}^{N_M} P_{R,m}(t) = 1$$

This gives a conditional probability distribution for randomly sampling recruitment models in each year of the projection time horizon. As in previous versions of AGEPRO, a single recruitment model can be chosen for the entire projection time horizon by setting $N_M=1$. One advantage of including multiple recruitment models with possibly time-varying probabilities is that one can use auxiliary information on recruitment strength, such as survey indices of relative cohort abundance or environmental covariates, to make short-term recruitment predictions (1-2 years) and then change to a different recruitment model or set of models for medium-term recruitment predictions (3-5 years). Another advantage of including multiple recruitment models is to account for model selection uncertainty, which can be a substantial source of uncertainty.

Initial Population Abundance

There are two ways to set the initial population abundance, defined as the vector of the absolute number of fish alive on January 1st of the first year of the projection time horizon ($\underline{N}(1)$). The primary option is to use a set of samples from the distribution of the estimator of $\underline{N}(1)$. This option explicitly incorporates uncertainty in the estimate of initial population abundance into the projections and occurs when the logical variable bootflag=true. In this case, either frequentist methods such as bootstrapping or Bayesian methods such as Markov Chain Monte Carlo simulation could be used to determine the sampling distribution of $\underline{N}(1)$. The secondary option is to ignore uncertainty in the estimator of initial population abundance and use a single best estimate for the value of

$\underline{N}(1)$. In this case, only a point estimate of $\underline{N}(1)$ is required for the projections (bootflag=false).

The primary option uses a set of B initial population vectors, denoted by $\{ \underline{N}_{(1)}(1), \underline{N}_{(2)}(1), ..., \underline{N}_{(B)}(1) \}$, for stochastic projections. In this case, the set of B values are random samples from the distribution of the estimator of $\underline{N}(1)$ generated by the assessment model or other means. Given this, stochastic projection can be used to characterize the sampling distribution of key fishery outputs accounting for the uncertainty in the estimate of the initial population size. The age of recruitment determines the amount of information needed to use the primary option. If the age of recruitment is age-1 (age1recflag=true), then the primary option only requires the set of initial population vectors, $\underline{\mathbf{N}} = \{ \underline{N}_{(1)}(1), \underline{N}_{(2)}(1), ..., \underline{N}_{(B)}(1) \}$ to do the projections. For each initial condition $\underline{N}_{(j)}(1)$, a set of simulations will be performed using the specified harvest strategy. Since dynamic array allocation is used to dimension the set of initial population vectors, the user may choose to input a large number of initial population vectors (B>1000) within the practical constraint of available computer memory.

If the age of recruitment is age-r for r>1 (age1recflag=false), then the primary option requires additional information to do the projections. In particular, a set of B population vectors for each of the previous (R-1) years are needed: $\underline{\mathbf{N}}(0)$, $\underline{\mathbf{N}}(-1)$, ..., $\underline{\mathbf{N}}(2-R)$, where $\underline{\mathbf{N}}(j) = \{ \underline{N}_{(1)}(j), \underline{N}_{(2)}(j), ..., \underline{N}_{(B)}(j) \}$ for year j and the ordering of the population vectors within each $\underline{\mathbf{N}}(j)$ is identical for all prior time periods j. That is, the sequence of vectors $\{ \underline{N}_{(b)}(2-R), ..., \underline{N}_{(b)}(-1), \underline{N}_{(b)}(0), \underline{N}_{(b)}(1) \}$ represents the b^{th} distinct estimate of the trajectory of population numbers at age from time=2-R to time=1 as calculated from the assessment model. Similarly, a set of B fishing mortality at age vectors for each of the previous (R-1) years are needed: $\underline{\mathbf{F}}(0)$, $\underline{\mathbf{F}}(-1)$, ..., $\underline{\mathbf{F}}(2-R)$, where $\underline{\mathbf{F}}(j) = \{ \underline{F}_{(1)}(j), \underline{F}_{(2)}(j), ..., \underline{F}_{(B)}(j) \}$. Here $\underline{F}_{(b)}(j)$ is the vector of fishing mortalities at age in time j for the b^{th} initial population trajectory $\underline{F}_{(b)}(j) = \{ F_{r,(b)}(j), F_{r+1,(b)}(j), ..., F_{A,(b)}(j)\}$. As with the $\underline{\mathbf{N}}(j)$, the ordering of the fishing mortality at age vectors within each $\underline{\mathbf{F}}(j)$ must be the same for all prior time periods. That is, each initial population and fishing mortality vector represents a single trajectory from the assessment model.

The secondary option is to use a single point estimate of $\underline{N}(1)$ for projection. In this case, one estimate of population abundance is assumed to characterize the initial state of the population. Since there is no uncertainty in the initial state of the population this option allows one to characterize the sampling distribution of key fishery outputs due to uncertainty in recruitment or natural mortality. Note that it is not possible to use an age of recruitment r>1 along with a single initial population vector which is entered directly in the input file (i.e., one cannot set both bootflag=false and age1recflag=false, see Table 1). It is possible, however, to use a single population vector with age of recruitment r>1 input from a file using the bootstrap input file option with the number of bootstraps B=1 (i.e., set bootflag=true and age1recflag=false).

Regardless of which initial population abundance option is used, the user must also specify the units of the initial population size vector taken from the assessment model. In particular, the initial population abundance vector can be input in relative units ($\underline{n}(1)$)

along with a conversion coefficient (k_N) to compute absolute numbers where absolute initial population abundance is the conversion coefficient times the relative abundance estimate, i.e., $\underline{N}(1) = k_{N^*} \underline{n}(1)$.

Retrospective Adjustment
One can adjust the initial population numbers at age vector $\underline{N}(1)$ to reflect a retrospective pattern in calculating these estimates (retroflag=true). In this case, the user must determine an appropriate vector of retrospective bias-correction coefficients, denoted by $\underline{C}$, to apply to the vector $\underline{N}(1)$. These multiplicative bias-correction coefficients may be age-specific or constant across age classes. The bias-corrected initial population vector $\underline{N}^*(1)$ is calculated from the element-wise product of $\underline{N}(1)$ and $\underline{C}$ as

(42) $$\underline{N}^*(1) = \left(C_r \cdot N_r(1),...,C_a \cdot N_a(1),...,C_A \cdot N_A(1)\right)^T$$

Note that the bias-correction coefficients are applied to all initial population vectors. If the bias-correction coefficients are determined to be constant across age classes then $\underline{C} = (C, C, ..., C)^T$ and the bias-corrected initial population vector is

(43) $$\underline{N}^*(1) = \left(C \cdot N_1(1),...,C \cdot N_a(1),...,C \cdot N_A(1)\right)^T = C \cdot \underline{N}(1)$$

The bias-correction coefficients are only applied in the first time period of the projection time horizon to reflect uncertainty in the estimated population size at age. Mohn (1999) provides a useful discussion of the retrospective problem in sequential population analysis.

Stochastic Natural Mortality
Natural mortality is often assumed to be constant over recruited age classes and equal to its long-term average for assessment purposes. The effects of constant age-specific natural mortality can be investigated using AGEPRO (set varmflag=false). The potential effects of variation in the age-specific instantaneous natural mortality rates can also be assessed when performing stochastic projections. To do this, the natural mortality rate at age can be modeled as a random variable in the AGEPRO program (set varmflag=true). In this case, the natural mortality rate can be modeled as a autocorrelated, or uncorrelated lognormal process where the natural mortality rate at age a in year t would be simulated as

(44) $$\begin{aligned} M_a(t) &= M(t) \cdot P_{M,a}(t) \;\; where \\ M(t) &= M \cdot \exp\left(\varepsilon_t - 0.5\sigma_M^2\right) \;\; and \\ \varepsilon_t &= \rho_M \cdot \varepsilon_{t-1} + \sqrt{1-\rho_M^2} \cdot \upsilon_t \;\; and \\ \upsilon_t &\sim N\left(0, \sigma_M^2\right) \end{aligned}$$

Here the simulated natural mortality rate M(t) in year t depends on a the input mean value M which is adjusted annually with an autocorrelated random error ε_t which has a lognormal distribution. Autocorrelation in the random errors ε_t can be turned off by setting ρ_M=0. The multiplicative lognormal error has a mean value of unity due to the application of the bias-adjustment factor ($-0.5\sigma_M^2$). The simulated natural mortality rate at age a in year t is M(t) times the vulnerability of age class a to the full natural mortality rate, denoted by $P_{M,a}(t)$, in year t. The vulnerabilities at age are simulated as uniform distributions with means equal to the input vulnerability values at age $P_{M,a}$ and the input coefficients of variation CV_a. In particular, the probability density function for $P_{M,a}$ is $f(P_{M,a}(t))$ which is given by

(45)
$$f\left(P_{M,a}(t)\right) = \frac{1}{U_a - L_a} \quad where \quad L_a \le P_{M,a}(t) \le U_a$$
$$and \quad L_a = P_{M,a}\left(1-\sqrt{3}\cdot CV_a\right) \quad and \quad U_a = P_{M,a}\left(1+\sqrt{3}\cdot CV_a\right)$$

Note that the input coefficient of variation cannot be greater than $\sqrt{3}$ for any age class otherwise the lower bound of the uniform distribution (L_a) is not feasible.

Total Stock Biomass

Total stock biomass (B_T) is the sum over the recruitment age (r) to the plus-group age (A) of stock biomasses at age on January 1st. The computational formula for B_T in year

(46)
$$B_T\left(t\right) = \sum_{a=r}^{A} W_{P,a}\left(t\right)\cdot N_a\left(t\right)$$

where $W_{P,a}(t)$ is the population mean weight of age-a fish on January 1st in year t.

Mean Biomass

Mean stock biomass (B_M) is the average biomass of the stock over a given year. In particular, mean stock biomass depends on the total mortality rate experienced by the stock in each year. In the AGEPRO model, the user selects the range of ages to be used for calculating mean biomass. One can choose the full range of ages in the model (age-r through age-A) or alternatively choose a smaller range if desired. The upper age (A_U) for mean biomass calculations must be less than or equal to A; similarly the lower age (A_L) must be greater than or equal to r. Let $W_{M,a}(t)$ denote the mean weight of age-a fish at the mid-point of year t. The computational formula for B_M in year t is

(47)
$$B_M\left(t\right) = \sum_{j=A_L}^{A_U} W_{M,j}\left(t\right)\cdot N_j\left(t\right)\cdot \frac{\left(1-\exp\left(-M_j\left(t\right)-F_j\left(t\right)\right)\right)}{\left(M_j\left(t\right)+F_j\left(t\right)\right)}$$

Fishing Mortality Weighted by Mean Biomass

Fishing mortality weighted by mean biomass ($F_B(t)$) in year t is the mean-biomass weighted sum of fishing mortality at age over the age range of A_L to A_U (see Mean Biomass above). This quantity may be useful for equilibrium comparisons with fishing mortality reference points developed from surplus production models. The computational formula for fishing mortality weighted by mean biomass is

(48)
$$F_B(t) = \frac{\sum_{j=A_L}^{A_U} B_{M,j}(t)\cdot F_j(t)}{B_M(t)}$$
$$\text{where } B_{M,j}(t) = W_{M,j}(t)\,N_j(t)\frac{\left(1-\exp\left(-M_j(t)-F_j(t)\right)\right)}{\left(M_j(t)+F_j(t)\right)}$$

Feasible Simulations
A feasible simulation is defined as one where the input landings quota can be harvested in each year of the projection time horizon. An infeasible simulation is one where the exploitable biomass is less than the landings quota in at least one year of the time horizon. All simulations are feasible for projections where population harvest is based solely on fishing mortality values. For projections that specify a landings quota in one or more years, the feasibility of harvesting the landings quota is evaluated using an upper bound on F that defines infeasible quotas relative to the exploitable biomass (Appendix). For purposes of summarizing projection results, the total number of simulations is denoted as K_{TOTAL} and the total number of feasible simulations is denoted as $K_{FEASIBLE}$.

Biomass Thresholds
The user can specify biomass thresholds for spawning biomass ($B_{S,THRESHOLD}$), mean biomass ($B_{M,THRESHOLD}$), and total stock biomass ($B_{T,THRESHOLD}$) for Sustainable Fisheries Act policy evaluation. This is the SFA-threshold option (sfaflag=true). If the SFA-threshold option is chosen, projected biomass values are compared to the input thresholds through time. Probabilities that biomasses meet or exceed threshold values are computed for each year. In addition, the probability that biomass thresholds were exceeded in at least one year within a single simulated population trajectory is computed. If the user specifies fishing mortality-based harvesting with no landings quotas, then the SFA-threshold probabilities are computed over the entire set of simulations. Let $K_B(t)$ be the number of times that projected biomass B(t) meets or exceeds the threshold biomass $B_{THRESHOLD}$ in year t. The counter $K_B(t)$ is evaluated for each year and biomass series (spawning, mean, or total stock). Given that K_{TOTAL} is the total number of feasible simulation runs, the estimate of the annual probability that $B_{THRESHOLD}$ would be met or exceeded in year t is

(49)
$$\Pr\left(B(t) \geq B_{THRESHOLD}\right) = \frac{K_B(t)}{K_{TOTAL}}$$

Note that this also provides an estimate of the probability of the complementary event that biomass does not exceed the threshold via

(50) $$\Pr\left(B(t) < B_{THRESHOLD}\right) = 1 - \Pr\left(B(t) \geq B_{THRESHOLD}\right) = 1 - \frac{K_B(t)}{K_{TOTAL}}$$

Next, if $K_{THRESHOLD}$ denotes the number of simulations where biomass exceeded its threshold at least once, then the probability that $B_{THRESHOLD}$ would be met or exceeded at least

(51) $$\Pr\left(\exists t \in [1,2,...,Y] \textit{ such that } B(t) \geq B_{THRESHOLD}\right) = \frac{K_{THRESHOLD}}{K_{TOTAL}}$$

If the user specifies landings quota-based harvesting in one or more years, then the SFA-threshold probabilities can be computed over the set of feasible simulations. In this case, the year-specific conditional probability that $B_{THRESHOLD}$ would be met or exceeded for feasible simulations is

(52) $$\Pr\left(B(t) \geq B_{THRESHOLD}\right) = \frac{K_B(t)}{K_{FEASIBLE}}$$

Note that the counter KB(t) can only be incremented in a feasible simulation. In contrast, the joint probability that $B_{THRESHOLD}$ would be met or exceeded for the entire set of simulations is given by Equation 42 and the probability that $B_{THRESHOLD}$ would be met or exceeded at least once during the projection time horizon is given by Equation 43.

Fishing Mortality Thresholds

The user can specify fishing mortality rate thresholds for annual fishing mortality ($F_{THRESHOLD}$) and fishing mortality weighted by mean biomass ($F_{B,THRESHOLD}$) under the SFA-threshold option. If the SFA-threshold option is chosen (sfaflag=true), projected F and F_B values are compared to the thresholds through time. Probabilities that fishing mortalities exceed threshold values are computed for each year in the same manner as for biomass thresholds (see Biomass Thresholds above). In particular, if $K_F(t)$ is the number of times that fishing mortality F(t) exceeds the threshold fishing mortality $F_{THRESHOLD}$ in year t, then the annual probability that the fishing mortality threshold is exceeded is

(53) $$\Pr\left(F(t) > F_{THRESHOLD}\right) = \frac{K_F(t)}{K_{TOTAL}}$$

and the complementary probability that the fishing mortality threshold is not exceeded is

(54) $$\Pr\left(F(t) \leq F_{THRESHOLD}\right) = 1 - \frac{K_F(t)}{K_{TOTAL}}$$

Target Fishing Mortality

In some projections, it may be necessary to change the fishing mortality rate when a spawning biomass threshold is met or exceeded. This can occur, for example, if the $B_{S,THRESHOLD}$ is the spawning biomass to produce maximum sustainable yield (B_{MSY}). In this case, the fishing mortality rate can be increased from a rebuilding value to F_{MSY}. The AGEPRO software includes an option to specify a target F (F_{TARGET}) that will be applied in the year subsequent to the year in which the $B_{S,THRESHOLD}$ is met or exceeded. This is the F-target option (ftarflag=true). Note that the F-target option requires that the SFA-threshold option is selected (sfaflag=true).

The F-target option depends on the spawning biomass realized in each year of the time horizon. In a given simulated population trajectory, F_{TARGET} is applied in the year following a year in which the $B_{S,THRESHOLD}$ is met or exceeded. In addition to specifying a target F, a calendar year within the projection time horizon when the F-target option may occur must also be specified; denote this initial year as $Y_{FTARGET}$. For example, if the projection time horizon is the interval [2002, 2007] , then $Y_{FTARGET}$ might be chosen to be 2005. Given this, the F in year 2005 would be set to F_{TARGET} if the spawning biomass threshold was achieved in 2004. In general, the F-target option sets $F(t+1) = F_{TARGET}$ in year t+1 provided that

(55) $$F\left(t+1\right) = F_{TARGET} \quad \Leftrightarrow \quad t \ge Y_{TARGET} \;\; and \;\; B_S\left(t\right) \ge B_{S,THRESHOLD}$$

Fishing Mortality Bounds

In some projections, it may be necessary to specify bounds on fishing mortality under a quota-based harvest strategy. In this case one can input an upper bound on realized fishing mortality (F_{UPPER}). If a harvest quota generates a realized F that exceeds F_{UPPER}, then the realized F is set equal to F_{UPPER} and the catch biomass generated by applying F_{UPPER} is the realized catch, not the user-specified quota. Similarly, one can set a lower bound on fishing mortality (F_{LOWER}). Fishing mortality bounds can be applied by setting the bounded F flag to be true (bdFflag=true)). When the bounded F flag is true and the harvest strategy is composed of a mixture of catch quotas and fishing mortality rates, the upper and lower bounds on F apply to both quotas and fishing mortality rates. In particular, F(t) is bounded above and below for all years t when the bounded F flag is true.

(56) $$Bounded\ F\ \ flag = true \;\Rightarrow\; F_{LOWER} \le F(t) \le F_{UPPER} \;\; for\ all\ t$$

Landings by Market Category

It may be necessary to partition projected landings into market categories for economic analyses. In particular, evaluating the expected benefits of a harvest policy can depend on whether fish price differs by fish size or market category. By setting the market category flag to be true (mcflag=1 for standard output or mcflag=2 for full distribution output), one can partition landings at age into up to three market categories. Both the number of landed fish and total weight of landed fish can be partitioned into market categories based on fish age. To apply this option, one must specify the proportion of each age class within each market category. Let $q_{a,j}$ denote the proportion of age-a fish in the j^{th} market category. These proportions must be nonnegative and less than one, $0 < q_{a,j} < 1$. Further the proportions must sum to unity across market categories for each age a.

(57) $$\sum_j q_{a,j} = 1$$

Given the proportions $q_{a,j}$ for each age class, the total number of landed fish ($L_{N,j}(t)$) in the j^{th} market category is

(58) $$L_{N,j}(t) = \sum_{a=r}^{A} q_{a,j} \cdot C_a(t) \cdot \left(1 - P_{D,a}(t)\right)$$

Similarly, the total weight of fish ($L_{W,j}(t)$) in the j_{th} market category is

(59) $$L_{W,j}(t) = \sum_{a=r}^{A} q_{a,j} \cdot C_a(t) \cdot W_{L,a}(t) \cdot \left(1 - P_{D,a}(t)\right)$$

Time-Varying Weights and Fraction Mature at Age

It may be necessary to investigate the effects of trends in mean weights and fraction mature at age through time. In particular, if average fish weights have decreased as population size has been increasing, it may be important to characterize what would happen if the trends continue in the future. The time-varying weight and fraction mature option allows one to specify a time series of average fish weights at age and fraction mature at age during the projection time horizon. If the time-varying weight option is true (varwtflag=true), the user must input a time series of Y vectors for average population ($W_a(t)$), landed ($W_{L,a}(t)$), spawning ($W_{S,a}(t)$), and mid-year ($W_{M,a}(t)$) weights at age along with a time series of Y vectors for the fraction mature at age ($P_{S,a}(t)$). In addition, if the discard option is selected, then the user must also input a time series of vectors for average discard weights at age ($W_{D,a}(t)$).

Time-Varying Fishery Selectivity at Age

It may also be necessary to assess the effects of trends in fishery selectivity at age or in the amount of total mortality occurring prior to spawning through time. If the time-varying fishery selectivity flag is set to be true (prflag=true), then the user can input a sequence of Y vectors for fishery selectivity at age ($P_{F,a}(t)$) and a set of Y values for the fraction of total mortality occurring prior to spawning ($P_Z(t)$). Of course, constant values of $P_Z(t)= P_Z$ can be input if only the effect of time-varying selectivity is of interest.

Time-Varying Discard Fraction at Age

It may also be useful to quantify the potential effects of changes in discard fraction at age through time. If the constant fishery discard flag is set to be false (constdiscflag=flag), then the user can input a sequence of Y vectors for fishery discard fraction at age ($P_{D,a}(t)$) to quantify the effects of trends in discarding practices.

Age-Specific Summaries of Spawning Biomass and Population Size
The user may select the age summary option (agesumflag=true) to produce summaries of the distribution of spawning biomass at age and population size at age by year in the standard output file. Otherwise, age-specific summaries will not be output.

Auxiliary Output Files
The user may select the outfile option (outfileflag=true) to create auxiliary output files to record simulated trajectories of spawning biomass, mean biomass, fishing mortality, and landings. This option can be useful if one wants to depict the variability of one or more simulated trajectories in a graph. One file is created for each output ($B_S(t)$, $B_M(t)$, F(t), L(t)). The four output files have the same structure. In each output file, a single row represents a single simulated time trajectory with Y entries ordered from time t=1 to time t=Y. Within the file, trajectories are ordered by initial population vector (bootstrap) and then simulation for that initial vector. For example, if $B_{S,(b),k}(t)$ denotes the spawning biomass realized from the b^{th} initial population vector and the k^{th} simulation for that vector, then the output file for spawning biomass with B initial vectors and N simulations would have B·N rows that were ordered as

$$\begin{bmatrix} B_{S,(1),1}(1) & B_{S,(1),1}(2) & \dots & B_{S,(1),1}(Y) \\ B_{S,(1),2}(1) & B_{S,(1),2}(2) & \dots & B_{S,(1),2}(Y) \\ \vdots & \vdots & \vdots & \vdots \\ B_{S,(B),N}(1) & B_{S,(B),N}(2) & \dots & B_{S,(B),N}(Y) \end{bmatrix} \tag{60}$$

The output units of spawning biomass, mean biomass, and landings are kilograms. The units of F are instantaneous fishing mortality rate per year.

Age-Structured Projection Software

Software to implement the current age-structured projection model has been revised several times since 1996 to reflect requests and technical improvements. As a result, input files for previous versions of the code will need some revision to be compatible with version 3.4. The required modifications, however, are relatively minor. Input files for more recent versions (i.e., versions 3.0x and higher) can be converted to the new format using the PC graphical user interface, with the caveat that the user must still input missing data not present in the older file format.

This part of the User Guide provides operational details for the AGEPRO software and is organized into four sections. First, input data requirements and projection options are covered and the structure of an input file is described. Second, model outputs are described in relation to logical flags in the input file and the structure of an output file is described. Third, a section on program structure describes the flow of data and calculations. Fourth, a set of examples are provided to identify some general features of the software.

Input Data

There are four categories of input data for an AGEPRO projection run: *system*, *simulation*, *biological*, and *fishery* (Figure 1). The *system* data are read from standard input (e.g., from a terminal or via input redirection) while the *simulation*, *biological* and *fishery* data are read from an input file. A description of each data category follows.

System Data

The *system* data are the file names for the input and output files for the projection run. The input and output filenames are stored in the text file that must be named "agepro34.ctl"; this is the control file for the AGEPRO application. To manually change the names of input and output files for a projection at the DOS command line prompt, first delete the existing control file "agepro34.ctl" and then move a new control file to be named "agepro34.ctl". This approach can be used to set up batch runs consisting of many projection runs with different model configurations with input and output file names. *It is recommended that the USER run the AGEPRO GUI to set up an initial set of control and input files before running the program in a batch mode.*

To run the AGEPRO program from the DOS command line, enter "agepro34.exe". You will see the following output in the command line screen:

```
>agepro34.exe
>
>Projection analysis is running ...
>
> Simulation completed for bootstrap: 1
> Simulation completed for bootstrap: 2
...
>Bootstrap loop completed. Summarizing results ...
>
>Projection analysis has been completed.
>
>Results are in the file: my_output_filename
```

The software checks whether the input file exists and prompts the user for another filename if the input file does not exist. Similarly, the software checks whether the output file already exists and prompts the user for another filename if the output file already exists. Running several large projections concurrently in batch mode can cause system crashes.

To run the AGEPRO program from the GUI, use the pull down menus to select the command "run model".

Simulation Data

The *simulation* data are the inputs needed to setup and define the simulation run. These data are required to run the AGEPRO software and are read from the input file (Tables 2 and 3, Figure 1).

Here is a description of the simulation data inputs:

1. Character tag that identified the AGEPRO version.
2. Character string that identifies the projection run (64 characters).
3. First year of the time horizon.
4. Length of time horizon.
5. Number of simulations to perform for each initial population vector.
6. Number of probable recruitment models for the projection
7. Number of replications to initialize the random number generator.
8. Age-1 recruitment flag (age1recflag). If true, recruitment occurs at age-1; else it occurs at an older age r.
9. Harvest mixture flag (mixflag). If true, the harvest scenario is a mixture of quotas and fishing mortality rates; else it is either all quotas or all fishing mortality rates.
10. Discard flag (discflag). If true, discards at age are included in the projection; else no discards are included.
11. Quota flag (quotaflag). If true, the harvest scenario is all quota-based; else it is all F-based.
12. Age summary flag (agesumflag). If true, age-specific summaries of the distribution of spawning biomass and population size at age by year are produced; else not.
13. Target F flag (ftarflag). If true, then a target value of F is applied in the year after any year when the SB threshold is achieved; otherwise no change occurs.
14. Retrospective adjustment flag (retroflag). If true, an age-specific retrospective adjustment coefficient is applied to each initial population vector; else not.
15. SFA biomass and fishing mortality threshold flag (sfaflag). If true, realized spawning biomass, mean stock biomass, total stock biomass, fully-recruited fishing mortality, and biomass-weighted fishing mortality are compared to a threshold level; otherwise no comparisons are made.
16. Market category flag (mcflag). If true, landings are summarized by market category and output to file; otherwise no market category summaries are made.
17. Time-varying weight and fraction mature at age flag (varwtflag). If true, fish weights and fraction mature at age can vary from year to year; otherwise there is no annual variation.
18. Time-varying fishery selectivity flag (prflag). If true, both the partial recruitment at age and the fraction of total mortality that occurs prior to spawning can vary from year to year; otherwise there is no annual variation.
19. Constant discard at age flag (constdiscflag). If true, the fraction discarded at age is constant; otherwise the fraction discarded at age can vary from year to year.
20. Bounded recruitment flag (bdrecflag). If true, then realized recruitments generated with the lognormal, Beverton-Holt, Ricker, and Shepherd stock-recruitment models will be bounded based on realized R/B_S ratios; otherwise no bounds are applied.
21. Bounded fishing mortality flag (bdFflag). If true realized fishing mortality is constrained within user-specified upper and lower bounds.
22. Stochastic natural mortality flag (varmflag). If true, natural mortality at age varies according to a lognormal process that may be serially correlated and the vulnerability at age to natural mortality varies according to a uniform distribution.

23. Bootstrap flag (bootflag). If true, a file of initial population vectors is used in the projection analysis; otherwise a single initial population vector is used.
24. Output file flag (outfileflag). If true, auxiliary output files for spawning biomass, mean biomass, fishing mortality, and landings are created; else not.

Biological Data

The *biological* data are the values of a set of biological inputs needed to describe the dynamics of the age-structured population. Most of these data are required to run the AGEPRO software although some data are optional and dependent upon the simulation settings (Table 3). The biological data are read from the input file. By convention, optional inputs will be enumerated sequentially along with required inputs. Note that, if recruitment age is age-R, there is no accounting of fish younger than age-R in the model.

Here is a description of the biological data inputs

25. This input is the number of age classes in the population model (A), where A < 100 along with lower and upper bound on range of ages for computing mean biomass, Lowerage and Upperage, and the age of recruitment (r) if this age is not equal to 1.
26. This input is the instantaneous natural mortality rate (M) and the vulnerability to M at age vector ($P_{M,a}$). If natural mortality at age is stochastic, then the log-variance σ_M^2 , correlation parameter ρ_M, initial error ε_0 (set to 0 if unknown), and coefficient of variation of the uniform distribution for vulnerability to M, CV_a.
27. This input is the vector of mean stock weights at age on January 1 ordered from youngest (left) to oldest (right) with Y vectors of weights if the time-varying weight option is selected.
28. This input is the vector of mean landed weights at age ordered from youngest (left) to oldest (right) with Y vectors of weights if the time-varying weight option is selected.
29. This input is the vector of mean spawning weights at age ordered from youngest (left) to oldest (right) with Y vectors of weights if the time-varying weight option is selected.
30. This input is the vector of mean mid-year weights at age ordered from youngest (left) to oldest (right) with Y vectors of weights if the time-varying weight option is selected.
31. If discards at age are included in the projection, this input is the vector of mean weights at age of discarded fish ordered from youngest (left) to oldest (right) with Y vectors of weights if the time-varying weight option is selected.
32. This input is the vector of fraction mature at age ordered from youngest (left) to oldest (right) with Y vectors of weights if the time-varying weight and fraction mature option is selected.
33. This input is the fraction of total mortality that occurs prior to spawning (P_Z). If the partial recruitment flag is true, then a set of Y values of P_Z must be input.
34. This input is the recruitment flag which is a number from 1 to 19 that identifies the choice of stochastic stock-recruitment model to be used. These models are

numbered 1 to 19 in exact correspondence with their descriptions (see **Stock-Recruitment Relationship**).

35. This input is the set of parameters needed for the probable stock-recruitment models. The set of parameters depends on the set of probable models; these parameters are specified in Table 3 for each of the nineteen stock-recruitment models.
36. This input is the set of parameters to constrain recruitment for stock-recruitment models with lognormal error terms. These parameters are input only if the bounded recruitment flag is true. If this flag is true, then the endpoints of the constraining intervals are input on one line as L_{HIGH}, L_{LOW}, U_{LOW}, U_{HIGH}, while $B_{S,CUT}$ is input on the next line.
37. This input is the set of parameters to define the initial population sizes for projection. The set of parameters depends on the value of the age-1 recruitment flag and the bootstrap flag (see Table 3).
38. This input is the set of coefficients for the retrospective bias adjustment. These parameters are input only if the retrospective adjustment flag is true.
39. This input is the set of SFA status determination parameters. These thresholds are input only if the SFA threshold flag is true.
40. This input is the set of parameters to apply the F target option. These parameters are input only if the target F flag is true and are listed in Table 3.
41. This input is the set of parameters to apply the bounded F option. These parameters are input only if the bounded F flag is true and are listed in Table 3.

Fishery Data

The *fishery* data are the values of a set of inputs needed to describe fishery impacts on the population and yields.

Here is a description of the fishery data inputs

42. This input is the set of parameters to define fishery selectivity through time. These parameters depend upon the time-varying fishery selectivity flag (Table 3).
43. This input is the set of parameters to define age-specific discarding through time. These parameters depend upon the discard and constant discard flags (Table 3).
44. This input is the set of parameters to define the harvest strategy. These parameters depend upon the harvest mixture, quota-based, and constant harvest strategy flags (Table 3).
45. This input is the set of parameters to define the market category summarization. These parameters depend upon the market category flag (Table 3).
46. This input is the set of auxiliary output file names for spawning biomass, mean biomass, fishing mortality, and landings.

Model Outputs

The AGEPRO program creates a standard output file that summarizes the projection analysis results. The program may also create an output file for market category summaries and auxiliary files storing simulated trajectories of spawning biomass, mean biomass, fishing mortality, and landings, if applicable (Figure 1).

There are twelve general categories of output in the standard output file. The first output describes the AGEPRO projection run and lists the input and output file names and the recruitment models and associated model probabilities. The second output shows the user-input harvest scenario in terms of quotas or fishing mortality rates. The third output characterizes the distribution of projected spawning biomass through time including the probability that spawning biomass exceeds a threshold if applicable. The fourth output characterizes the distribution of the projected trajectory of mean biomass. The fifth output describes the distribution of the fishing mortality weighted by mean biomass trajectory. The sixth output characterizes the distribution of the projected trajectory of total stock biomass. The seventh output characterizes the distribution of projected recruitment through time. The eighth output characterizes the distribution of the projected landings through time. The ninth output characterizes the distribution of the population numbers at age (on January 1st) through time, if applicable. The tenth output characterizes the distribution of projected landings by market category through time, if applicable. The eleventh output characterizes the distribution of projected discards and catch biomass through time, if applicable. The twelfth output characterizes the distribution of the realized fishing mortality rates through time including the probability that fishing mortality exceeds a threshold, if applicable.

There are six categories of output in the market category summary file which will be created if the market category option is selected (mcflag=1 or 2). The first output describes the AGEPRO projection run and lists the input and output file names. The second output characterizes the distribution of the projected trajectory of landed weight by market category. The third output describes the distribution of numbers of landed fish by year and market category. The fourth output shows the average total weight and numbers of fish landed weight by market category. The fifth output gives the median total weight and numbers of fish landed weight by market category. The sixth output lists the entire set of simulated trajectories of landings and weight by market category; this output occurs only if full market category output is selected (mcflag=2). In this case, each row represents market category information from a single trajectory. The output variables in a row (in order): year, total landings (kg), market category 1 landings (kg), market category 2 landings (kg), and market category 3 landings (kg). The rows are ordered by year (time), initial population vector (bootstrap), and simulation (sim). The full output option can create a large market category summary file; a 5-year projection with 1000 initial population vectors and 100 simulations per vector will produce a market category file with over 500,000 lines.

There is one category of output in the auxiliary files for spawning biomass, mean biomass, fishing mortality, and landings. These files are created if the output file option is selected (outfileflag=true). Each row in an auxiliary output file gives the trajectory of the output variable through time, ordered from the 1st to the last year in the projection time horizon.

Examples
The following two examples show some general features of the AGEPRO program. These projections are hypothetical and for the purposes of illustration only.

Example 1: This example is a projection for Acadian redfish from 2004 through 2009 using recruitment model 14. This projection illustrates the mixed harvest, SFA threshold, and stochastic natural mortality options. Fishing mortality in 2004 is assumed to be equal to the 2003 estimate. Catch biomass of redfish in 2005 is estimated from the first half-year landings in 2005. Fishing mortality in 2006-2009 is assumed to be constant with F_{2006}=0.01. This harvest scenario represents an increase in F over 2003. Mean vulnerability to natural mortality (M=0.05) is constant across age classes ($P_{M,a}$=1 for each age class a) but the coefficient of variation of vulnerability is CV_a=0.2 for ages 1-9 and CV_a=0.1 for ages 10 and older. Natural mortality has a log-variance of $\sigma_M^2 = 0.2$ with an autocorrelation parameter of ρ_M=0.5 and an initial random shock of ε_0=0. Three hypothetical questions are posed. Does this scenario reduce the spawning potential of the redfish stock ? Is there any chance that the stock would be at B_{MSY} in 2009 under this scenario? What are the potential redfish landings in 2009 under this scenario ?

These hypothetical questions can be readily answered using the output and graphing capabilities of the AGEPRO GUI. First, graphing the spawning biomass variable with 5% to 95% confidence limits shows that spawning biomass is likely to increase under this harvest scenario (Figure 3.1). Based on this graph it appears that there is a chance that the spawning biomass threshold B_{MSY} will be exceeded in 2009 and also a small chance that spawning biomass will not increase beyond 2008. In the Output Report File, one can see that the annual probabilities of exceeding BMSY are:

ANNUAL PROBABILITY THAT SSB EXCEEDS THRESHOLD: 236.700 THOUSAND MT

YEAR	Pr(SSB >= Threshold Value) FOR FEASIBLE SIMULATIONS
2004	0.000
2005	0.000
2006	0.000
2007	0.019
2008	0.154
2009	0.289

This output indicates that there is a 29% probability that BMSY would be exceeded in 2009, a moderate chance. This can also be shown by graphing of the probability of achieving this threshold (Figure 3.3). Last, graphing the landings variable with 5% to 95% confidence limits shows that landings would be very likely to increase under this harvest scenario (Figure 3.3). By 2009 the probable range of redfish landings indexed by the 5^{th} and 90^{th} percentiles would be (1.898, 2.496) thousand mt, a substantial increase over the 2005 catch estimate.

Example 2: This example is a projection for Georges Bank haddock from 2005 through 2014 using recruitment model 15. This projection illustrates the discard, age summary and market category options. Fishing mortality in 2005 is based on an expected catch of about 22.5 thousand mt. Fishing mortality in 2006-2014 is assumed to be constant with F_{2006}=0.26. Hypothetical discard fractions of age-1 to age-3 fish are 20%, 10%, and 5%

while discard fraction of fish ages 4 and older is 1%. Three hypothetical questions are posed. What is the likely trend in discard biomass through time ? What is the likely contribution of the 2003 year class to spawning biomass in 2009? What are the likely trends of landings by market category under this scenario ?

These hypothetical questions can be generally addressed using graphical output from the projection run while quantitative answers can be gathered from the Output Report File. First, plotting the time trend in discard biomass indicates it would increase to about 1500 mt in 2006 and then decline to about 600 mt in 2014 (Figure 4.1). Second, the contribution of the 2003 year class to spawning biomass in 2009 is substantial but uncertain (Figure 4.2). The median contribution of this exceptional year class would be about 300 kt but with a probable range of roughly 100-600 kt. Third, the projected landings of large haddock would increase sharply to a peak of about 50 kt during 2008-2010 and then gradually decline to about 30 kt in 2014 (Figure 4.3). In comparison, landings of scrod haddock were projected to increase to about 70 kt in 2007-2008 and then decline to about 20 kt in 2014 (Figure 4.4). The growth and eventual decline in landings from both market categories have relatively large probable ranges. This reflects uncertainty in the size of the 2003 year class which dominates the projected landings and spawning biomass in 2007-2012.

Example 3: This example is a model-averaged projection for Georges Bank haddock that compares the results of using recruitment model 15 versus using a model-averaged combination of alternative models 18 and 19 to predict recruitment during 2005-2007. The existing (status quo) recruitment prediction model for haddock was taken from the recommendations of the 2005 Groundfish Assessment Review Meeting (Mayo and Terceiro 2006). This status quo model was a two-stage cumulative distribution function for observed recruitments above and below the productivity threshold of 75,000 mt of spawning biomass (NEFSC 2002).

The first alternative model ($M_{HAD,R1}$) was a linear model with no intercept fit to log-scale R during 1985-2004 from Brodziak et al. (2006) as a function of sea surface temperature on Georges Bank during February-May. The fitted model was

(61)
$$\begin{aligned} \log\left(R\right) &= 0.3588 \cdot ST2.spr.mm + \varepsilon \\ where\ \ \varepsilon &\sim N\left(-1.209,\ 2.418\right) \end{aligned}$$

The fitted model was highly significant (P<0.001) and explained a good amount of variation in the R data relative to the model log(R) = 0 + ε (multiple $R^2 = 0.72$).

The second alternative model to predict haddock recruitment ($M_{HAD,R2}$) also used sea surface temperature during February-May and the haddock age-0 survey index but was fitted to untransformed haddock R. The estimated model was

(62)
$$\begin{aligned} R &= 1.1362 \cdot ST2.spr.mm + 1.5567 \cdot age0.had + \varepsilon \\ where\ \ \varepsilon &\sim N\left(0, 386.5\right) \end{aligned}$$

This model was also highly significant (P<0.001) and explained much of the variation in haddock R relative to the model R = 0 + ε (multiple $R^2 = 0.99$).

The model-averaged combination of the two alternative models to predict haddock recruitment ($M_{HAD,MA}$) was a weighted average of models $M_{HAD,R1}$ and $M_{HAD,R2}$. In the absence of a preference, the two model probabilities were equal to 0.5 and each model was randomly sampled with probability one-half to simulate recruitment in each year of the stochastic projections.

To compare the status quo and alternative model-averaged prediction model, estimates of recruitment for Georges Bank haddock during 2005-2007 were gathered from the recently completed 2008 stock assessment (NEFSC 2008a, NEFSC 2008b). Observed values of sea surface temperatures were not available in 2007 and SST in 2007 was imputed using the average sea surface temperature during 1985-2006. Observed catch biomasses of Georges Bank haddock during 2005 to 2007 were input to the AGEPRO model to compute annual fishing mortality during 2005-2007 for each projection. For haddock, the catch biomasses in 2005-2007 were 21814, 15989, and 16815 mt.

Because the 2008 stock assessment for Georges Bank haddock was a bench mark assessment, and not a simple assessment update, estimates of recruitment, spawning biomass, and other variables were expected to have a somewhat different scale than those from the 2005 assessments. In this case, comparing the projected recruitments during 2005-2007 with the observed values from the assessment could be misleading. To address this concern, the best-fitting linear model to predict observed from the 2008 assessment as a function of the 2005 assessment value during 1985-2004 was used to rescale predicted recruitments during 2005-2007 to be comparable to the values in the 2008 assessments of haddock. Regression analyses and associated Akaike information criteria values indicated that the best fitting linear model relating the new 2008 VPA estimates of Georges Bank haddock recruitment to the old estimates from the 2005 assessment was $R_{NEW} = 6.076 + 0.6247 \cdot R_{OLD}$. This model was used to rescale the predicted recruitment values from the projections using both the status quo models and the model-averaged alternative using the environmental covariates.

Results of the projections indicated that the model-averaged combination of two predictive models, one that used sea surface temperature and the haddock age-0 index and one that used only sea surface temperature, provided more accurate predictions of haddock recruitment during 2005-2007 (Figure 5). This model-averaged combination had a root mean-square prediction error that was roughly 5-fold lower than the status quo model. This example illustrates that the use of multiple predictive models may be able to improve predictive accuracy in some cases.

Acknowledgments

I extend a special thanks to Paul Rago for his help in developing this modeling framework and software. I also thank Alan Seaver for programming the graphical user interface, Laurel Col for assistance with the figures, and Laura Shulman for historic programming support.

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Table 1. Notation for variables used in the AGEPRO model.

Variable	Description
A	Age of plus-group (fish age-A and older) and last index value for N.
$B_S(t)$	Spawning biomass in year t.
$B_M(t)$	Mean stock biomass in year t.
$B_T(t)$	Total stock biomass on January 1st of year t.
B	Number of input initial population vectors N(1).
$C_a(t)$	Number of age-a fish that are captured and die in year t.
D(t)	Total weight of discarded fish in year t.
$F_a(t)$	Instantaneous fishing mortality rate for age-a fish in year t.
F(t)	Instantaneous fully-recruited fishing mortality rate in year t.
$F_B(t)$	Instantaneous fishing mortality weighted by mean biomass in year t.
I(t)	Harvest index for year t. If I(t) = 1, then harvest is based on a landings quota Q(t). If I(t) = 0, then harvest is based on a fishing mortality rate F(t).
L(t)	Total weight of landed fish in year t.
M(t)	Instantaneous fully-vulnerable natural mortality rate in year t.
$M_a(t)$	Instantaneous natural mortality rate for age-a fish in year t.
$N_a(t)$	Number of age-a fish alive on January 1st of year t.
N_M	Number of probable recruitment models used in the projection.
$P_{D,a}(t)$	Proportion of age-a fish discarded in year t.
$P_{F,a}(t)$	Selectivity to F(t) for age-a fish (age-specific fishery selectivity).
$P_{M,a}(t)$	Selectivity to M(t) for age-a fish (age-specific natural mortality multiplier).
$P_{R,m}(t)$	Probability that the mth recruitment model is randomly sampled in year t.
$P_{S,a}(t)$	Proportion of age-a fish that are sexually mature in year t.
$P_Z(t)$	Proportion of total mortality occurring prior to spawning in year t.
Q(t)	Landings quota in year t.
r	Age of recruitment and age of first element in population vector N.
R(t)	Recruitment (absolute number of age-r fish on January 1st) in year t.
$W_{P,a}(t)$	Average population weight of an age-a fish on January 1st in year t.
$W_{L,a}(t)$	Average landed weight of an age-a fish in year t.
$W_{S,a}(t)$	Average spawning weight of an age-a fish in year t.
$W_{M,a}(t)$	Average mid-year weight of an age-a fish in year t.
$W_{D,a}(t)$	Average weight of an age-a fish that is discarded in year t.
Y	Number of years (t) in projection time horizon where t = 1, 2, ..., Y.

Table 2. Summary of logical flags used in AGEPRO version 3.4.

Flag	Name	Description
1	Age-1 Recruitment	If true, recruitment age is age-1. Otherwise recruitment age is age-2 or older.
2	Harvest Mixture	If true, a mixture of F-based and quota-based harvest can be specified in the projection. Otherwise, harvest is either F-based or it is quota-based.
3	Discard	If true, discards at age are incorporated in the projection. Otherwise, there are no discards included in the projection.
4	Quota-Based	If true, catches are determined as quotas. Otherwise, catches are determined from fishing mortality rates.
5	Age Summary	If true, age-specific summaries of spawning biomass and population size are output. Otherwise, no summaries are output.
6	Target F	If true, a target value of F is applied if the current year is greater than or equal to the F-target year and the B_S threshold was achieved in the previous year. Otherwise, no target F is applied.
7	Retrospective	If true, retrospective adjustment coefficients are applied to each initial population vector. Otherwise no adjustments are made.
8	SFA Threshold	If true, realized B_S, B_M, B_T, F, and F_B are compared to thresholds. Otherwise, no comparisons are made.
9	Market Category	If true, landings by market category are output. Otherwise, no market category summaries are made.
10	Time-Varying Weights	If true, stock, landed, and discard weights at age and fraction mature at age can vary through time. Otherwise, they do not.
11	Time-Varying Selectivity	If true, fishery selectivity at age vector and the fraction of total mortality that occurs prior to spawning can vary through time. Otherwise, they do not.
12	Constant Discard	If true, discard proportions at age are constant. Otherwise, discard proportion at age can vary through time.
13	Bounded Recruitment	If true, realized recruitments from models with lognormal errors are constrained based on R/B_S ratios. Otherwise, no constraints are applied.
14	Bounded F	If true, realized fishing mortality is bounded below by F_{LOWER} and above by F_{UPPER}. Otherwise, no constraints are applied to F.
15	Stochastic M	If true, natural mortality at age varies stochastically through time. Otherwise, natural mortality at age is constant.
16	Bootstrap	If true, a file of initial population vectors is used for the projection analysis. Otherwise, a single initial population vector in the standard input file is used.
17	Outfile	If true, trajectories of spawning biomasses, mean biomasses, fishing mortalities, and landings are output to auxiliary files. Otherwise, no auxiliary files are created.

Table 3. Structure of an AGEPRO version 3.4 input file. Inputs can be delimited by a comma or a space.

Input #	Is input required?	Input description
1	Yes	AGEPRO version tag
2	Yes	Name of projection run, input: up to 64 character string
3	Yes	First year of projection run, input: 4-digit year (Positive integer)
4	Yes	Length of planning horizon, input: Y (Positive integer)
5	Yes	Number of simulations per initial population vector, input: Positive integer
6	Yes	Number of recruitment models (nmodel), input: Positive integer $\leq$ 19
7	Yes	Number of "warmups" for random number generator, input: Positive integer
8	Yes	Age-1 recruitment flag, input: Integer (1=true; 0=false)
9	Yes	Harvest mixture flag, input: Integer (1=true; 0=false)
10	Yes	Discard flag, input: Integer (1=true; 0=false)
11	Yes	Quota-based flag, input: Integer (1=true; 0=false)
12	Yes	Age summary flag, input: Integer (1=true; 0=false)
13	Yes	F target flag, input: Integer (1=true; 0=false)
14	Yes	Retrospective adjustment flag, input: Integer (1=true; 0=false)
15	Yes	SFA threshold flag, input: Integer (1=true; 0=false)
16	Yes	Market category flag, input: Integer (1=standard output; 2=standard and full output; 0=false)
17	Yes	Time-varying weights flag, input: Integer (1=true; 0=false)
18	Yes	Time-varying selectivity flag, input: Integer (1=true; 0=false)
19	Yes	Constant discard flag, input: Integer (1=true; 0=false)
20	Yes	Bounded recruitment flag, input: Integer (1=true; 0=false)
21	Yes	Bounded F flag, input: Integer (1=true; 0=false)
22	Yes	Stochastic natural mortality flag, input: Integer (1=true; 0=false)
23	Yes	Bootstrap flag, input: Integer (1=true; 0=false)
24	Yes	Outfile flag, input: Integer (1=true; 0=false)
25	Yes; depends on flag 1	If flag 1= true, then input number of age classes, lower and upper bound on range. If flag 1= false, then input number of age classes, lower & upper bound on range of ages for computing mean biomass, and recruitment age: A, A_L, A_U, r
26	Yes; depends on flag 15	Natural mortality rate. Input: M. Input: $P_{M,r}$, $P_{M,r+1}$, ..., $P_{M,A}$. If flag 15=true, then input: σ_M^2 and input: ρ_M, ε_0 and input: CV_r , CV_{r+1}, ..., CV_A
27	Yes; depends on flag 10	If flag 10=true, input mean population weights at age: $W_r(t)$, $W_{r+1}(t)$,... , $W_A(t)$, for t=1..Y. Else input W_r, W_{r+1} ,... , W_A

Table 3. Continued.

Input #	Is input required?	Input description
28	Yes; depends on flag 10	If flag 10=true, input mean landed weights at age: $W_{L,r}(t)$, $W_{L,r+1}(t)$,... , $W_{L,A}(t)$, for t=1..Y. Else input $W_{L,r}$, $W_{L,r+1}$,... , $W_{L,A}$
29	Yes; depends on flag 10	If flag 10=true, input mean spawning weights at age: $W_{S,r}(t)$, $W_{S,r+1}(t)$,... , $W_{S,A}(t)$, for t=1..Y. Else input $W_{S,r}$, $W_{S,r+1}$,... , $W_{S,A}$
30	Yes; depends on flag 10	If flag 10=true, input mean mid-year weights at age: $W_{M,r}(t)$, $W_{M,r+1}(t)$,... , $W_{M,A}(t)$, for t=1..Y. Else input $W_{M,r}$, $W_{M,r+1}$,... , $W_{M,A}$
31	No; required if flag 3=true	If flags 3 and 10=true, input mean discarded weights at age: $W_{D,r}(t)$, $W_{D,r+1}(t)$,... , $W_{D,A}(t)$, for t=1..Y. Else input $W_{D,r}$, $W_{D,r+1}$,... , $W_{D,A}$
32	Yes; depends on flag 10	If flag 10=true, input fraction mature at age: $P_{S,r}(t)$, $P_{S,r+1}(t)$,... , $P_{S,A}(t)$, for t=1..Y. Else input $P_{S,r}$, $P_{S,r+1}$,... , $P_{S,A}$
33	Yes; depends on flag 11	If flag 11=false, then input: P_Z If flag 11=true, input: $P_Z(1)$, $P_Z(2)$, ..., $P_Z(Y)$
34	Yes	Recruitment model vector, input: integer vector of length nmodel with elements between 1 and 19. Input only one copy of each model.
35	Yes; depends on input #34	If input #34 includes 1, input number of recruitment states: K and on the next line input: $N_{r,1}$, $N_{r,2}$, $N_{r,3}$, ..., $N_{r,K}$ and on the next line input number of spawning biomass states: J and on the next line input J-1 cut points: $B_{S,2}$, $B_{S,3}$, $B_{S,4}$, ..., $B_{S,J}$ and on the next J lines input: $p_{1,1}$, $p_{1,2}$, $p_{1,3}$, ..., $p_{1,K}$ $p_{2,1}$, $p_{2,2}$, $p_{2,3}$, ..., $p_{2,K}$ ... $p_{J,1}$, $p_{J,2}$, $p_{J,3}$, ..., $p_{J,K}$ If input #34 includes 2, input: T and on the next line input: $N_r(1)$, $N_r(2)$, $N_r(3)$, ..., $N_r(T)$ and on the next line input: $B_S(1\text{-}r)$, $B_S(2\text{-}r)$, $B_S(3\text{-}r)$, ..., $B_S(T\text{-}r)$ If input #34 includes 3, input: T and on the next line input: $N_r(1)$, $N_r(2)$, $N_r(3)$, ..., $N_r(T)$ If input #34 includes 4, input: T_{LOW} , T_{HIGH} and on the next line input: B_S* and on the next line the low-B_S state recruitment series: $N_r(1)$, $N_r(2)$, $N_r(3)$, ..., $N_r(T_{LOW})$ and on the next line the low-B_S state spawning biomass series: $B_S(1\text{-}r)$, B_S (2-r) , B_S (3-r) , ..., B_S (T_{LOW}-r) and on the next line the high-B_S state recruitment series: $N_r(1)$, $N_r(2)$, $N_r(3)$, ..., $N_r(T_{HIGH})$ and on the next line the high-B_S state spawning biomass series: $B_S(1\text{-}r)$, B_S (2-r) , B_S (3-r) , ..., B_S (T_{HIGH}-r) If input #34 includes 5, input: α, β, σ_W^2 and on the next line input: c_B , c_R

Table 3. Continued.

Input #	Is input required?	Input description
35	Yes; depends on input #34	If input #34 includes 6, input: α, β, σ_W^2 and on the next line input: c_B , c_R If input #34 includes 7, input: α, β, k, σ_W^2 and on the next line input: c_B , c_R If input #34 includes 8, input: $\mu_{\log(r)}$, $\sigma_{\log(r)}^2$ and on the next line input: c_R If input #34 includes 9, input: T and on the next line input: $N_r(1,1)$, $N_r(1,2)$, $N_r(1,3)$, ..., $N_r(1,T)$ and on the next line input: $N_r(2,1)$, $N_r(2,2)$, $N_r(2,3)$, ..., $N_r(2,T)$ ... and on the next line input: $N_r(Y,1)$, $N_r(Y,2)$, $N_r(Y,3)$, ..., $N_r(Y,T)$ If input #34 includes 10, input: α, β, σ^2 and on the next line input: φ , ε_0 and on the next line input: c_B , c_R If input #34 includes 11, input: α, β, σ^2 and on the next line input: φ , ε_0 and on the next line input: c_B , c_R If input #34 includes 12, input: α, β, k, σ^2 and on the next line input: φ , ε_0 and on the next line input: c_B , c_R If input #34 includes 13, input: $\mu_{\log(r)}$, $\sigma_{\log(r)}^2$ and on the next line input: φ , ε_0 and on the next line input: c_R If input #34 includes 14, input: T and on the next line input: $N_r(1)$, $N_r(2)$, $N_r(3)$, ..., $N_r(T)$

Table 3. Continued.

Input #	Is input required?	Input description
35	Yes; depends on input #34	If input #34 includes 15, input: T_{LOW} , T_{HIGH} and on the next line input: B_S* and on the next line the low-B_S state recruitment series: $N_r(1)$, $N_r(2)$, $N_r(3)$, ..., $N_r(T_{LOW})$ and on the next line the high-B_S state recruitment series: $N_r(1)$, $N_r(2)$, $N_r(3)$, ..., $N_r(T_{HIGH})$ If input #34 includes 16, input: N_p and on the next line input: β_0 and on the next line input: β_1 , β_2 , ..., β_{Np} and on the next line input: σ^2 and on the next N_p lines input: $X_1(1), X_1(2),..., X_1(Y)$ $X1_2(1), X_2(2),..., X_2(Y)$ ... $X_p(1), X_p(2),..., X_p(Y)$ If input #34 includes 17, input: N_p and on the next line input: β_0 and on the next line input: β_1 , β_2 , ..., β_{Np} and on the next line input: σ^2 and on the next N_p lines input: $X_1(1), X_1(2),..., X_1(Y)$ $X1_2(1), X_2(2),..., X_2(Y)$ ... $X_p(1), X_p(2),..., X_p(Y)$ If input #34 includes 18, input: N_p and on the next line input: β_0 and on the next line input: β_1 , β_2 , ..., β_{Np} and on the next line input: σ^2 and on the next N_p lines input: $X_1(1), X_1(2),..., X_1(Y)$ $X1_2(1), X_2(2),..., X_2(Y)$ ... $X_p(1), X_p(2),..., X_p(Y)$ and on the next line input: c_R If input #34 includes 19, input: N_p and on the next line input: β_0 and on the next line input: β_1 , β_2 , ..., β_{Np} and on the next line input: σ^2 and on the next N_p lines input: $X_1(1), X_1(2),..., X_1(Y)$ $X1_2(1), X_2(2),..., X_2(Y)$ ... $X_p(1), X_p(2),..., X_p(Y)$ and on the next line input: c_R

Table 3. Continued.

Input #	Is input required?	Input description
36	Yes	Input recruitment model probabilities for each year t=1,2, ..., Y Input: $P_{R,1}(1)$, $P_{R,2}(1)$, ..., $P_{R,Nm}(1)$ and on the next line input: $P_{R,1}(2)$, $P_{R,2}(2)$, ..., $P_{R,Nm}(2)$ ... and on the next line input: $P_{R,1}(Y)$, $P_{R,2}(Y)$, ..., $P_{R,Nm}(Y)$
37	No; required if flag 13=true	R/B_S constraints, input: L_{High} , L_{Low} , U_{Low} , U_{High} and on the next line input: $B_{S,CUT}$
38	Yes; depends on flags 16 and 1	Initial population abundance parameters. If flag 16=true and flag 1=true, input: B and on the next line input: name of the file (bfile1) containing B initial population vectors n(1) in relative units (one vector per row) and on the next line input the conversion coefficient: k_N If flag 16=true and flag 1=false, input: B and on the next line input: name of the file (bfile1) containing B initial population vectors n(1) in relative units (one vector per row) and B prior population vectors at time t=0 in relative units, and so on to time t=2-r. Note that in bfile1, the bootstrap data are grouped by time in blocks of B rows and where the first time block corresponds to the first year (t=1) in the time horizon, the second time block corresponds to the year prior to the first year (t=0), the third time block corresponds to the next previous year (t=-1) and so on... and on the next line input the conversion coefficient: k_N and on the next line, input: name of the file (bfile2) containing B fishing mortality at age vectors F(0) (one vector per row) and B fishing mortality at age vectors F(-1) at time t=-1, and so on to time t=2-r where the bootstrap data are grouped by time in blocks of size nboot with the first time block corresponds to the year prior to the first year (t=0), the second time block corresponds to the next prior year (t=-1) and so on... where the order of the population vectors matches the order of the fishing mortality at age vectors. If flag 16=false, input: c_N and on the next line input: $n_r(1)$, $n_{r+1}(1)$, ..., $n_A(1)$
39	No; required if flag 7=true	Retrospective adjustment coefficients, input: C_r, C_{r+1}, ..., C_A
40	No; required if flag 8=true	SFA thresholds, input: $B_{S,THRESHOLD}$,$B_{T,THRESHOLD}$, $F_{THRESHOLD}$, $B_{M,THRESHOLD}$, $F_{B,THRESHOLD}$
41	No; required if flag 6=true	F target parameters, input: F_{TARGET} and on the next line input: Y_{TARGET}
42	No; required if flag 14=true	Bounded F parameters, input: F_{LOWER} , F_{UPPER}

Table 3. Continued.

Input #	Is input required?	Input description
43	Yes; depends on flag 11	Fishery selectivity parameters. If flag 11=true, input: $P_{F,r}(1)$, $P_{F,r+1}(1)$, ... , $P_{F,A}(1)$ and on the next Y-1 lines input: $P_{F,r}(2)$, $P_{F,r+1}(2)$, ... , $P_{F,A}(2)$ $P_{F,r}(3)$, $P_{F,r+1}(3)$, ... , $P_{F,A}(3)$ ... $P_{F,r}(Y)$, $P_{F,r+1}(Y)$, ... , $P_{F,A}(Y)$ If flag 11=false, input: $P_{F,r}$, $P_{F,r+1}$, ... , $P_{F,A}$
44	No; required if flag 3=true and depends on flag 12	Discard parameters. If flag 3=true and flag 12=true, input: $P_{D,r}$, $P_{D,r+1}$, ... , $P_{D,A}$ If flag 3=true and flag 12=false, on the next Y lines input: $P_{D,r}$ (1) , $P_{D,r+1}$ (1) , ... , $P_{D,A}$ (1) $P_{D,r}$ (2) , $P_{D,r+1}$ (2) , ... , $P_{D,A}$ (2) ... $P_{D,r}$ (Y) , $P_{D,r+1}$ (Y) , ... , $P_{D,A}$ (Y)
45	Yes; depends on flags 2 and 4	Harvest strategy parameters. If flag 2=false and flag 4=true, input: Q(1) , Q(2) , Q(3) , ... , Q(Y) If flag 2=false and flag 4=false, input: F(1) , F(2) , F(3) , ... , F(Y) If flag 2=true, input: I(1) , I(2) , I(3) , ... , I(Y) where I(year)=1 indicates a quota-based harvest and I(year)=0 indicates an F-based harvest in a given year and on the next line input: Q(1) , Q(2) , Q(3) , ... , Q(Y) with placeholder values (-1) for F-based years and on the next line input: F(1) , F(2) , F(3) , ... , F(Y) with placeholder values (-1) for quota-based years
46	No; required if flag 9=true	Market category parameters, input number of market categories: MC (integer between 1 and 3) and on the next 2*MC lines input: Market category 1 label (character string) $q_{r,1}$, $q_{r+1,1}$, ..., $q_{A,1}$ Market category 2 label (character string) $q_{r,2}$, $q_{r+1,2}$, ..., $q_{A,2}$ Market category 3 label (character string) $q_{r,3}$, $q_{r+1,3}$, ..., $q_{A,3}$ and on the next line input: Market category file name (character string)
47	No; required if flag 17=true	Auxiliary output file names (4), input on four successive lines. Input: Spawning biomass output file name (character string) Input: Mean biomass output file name (character string) Input: Fishing mortality output file name (character string) Input: Landings output file name (character string)

Figure 1. AGEPRO input/output diagram

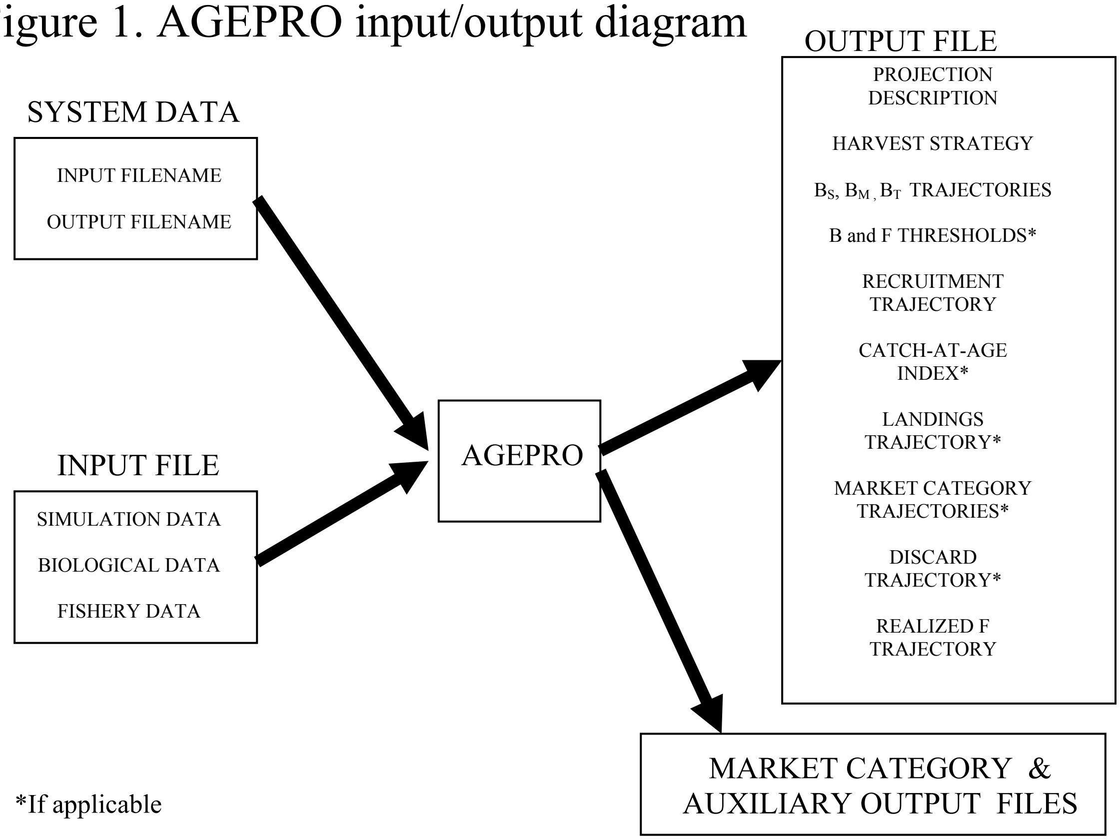
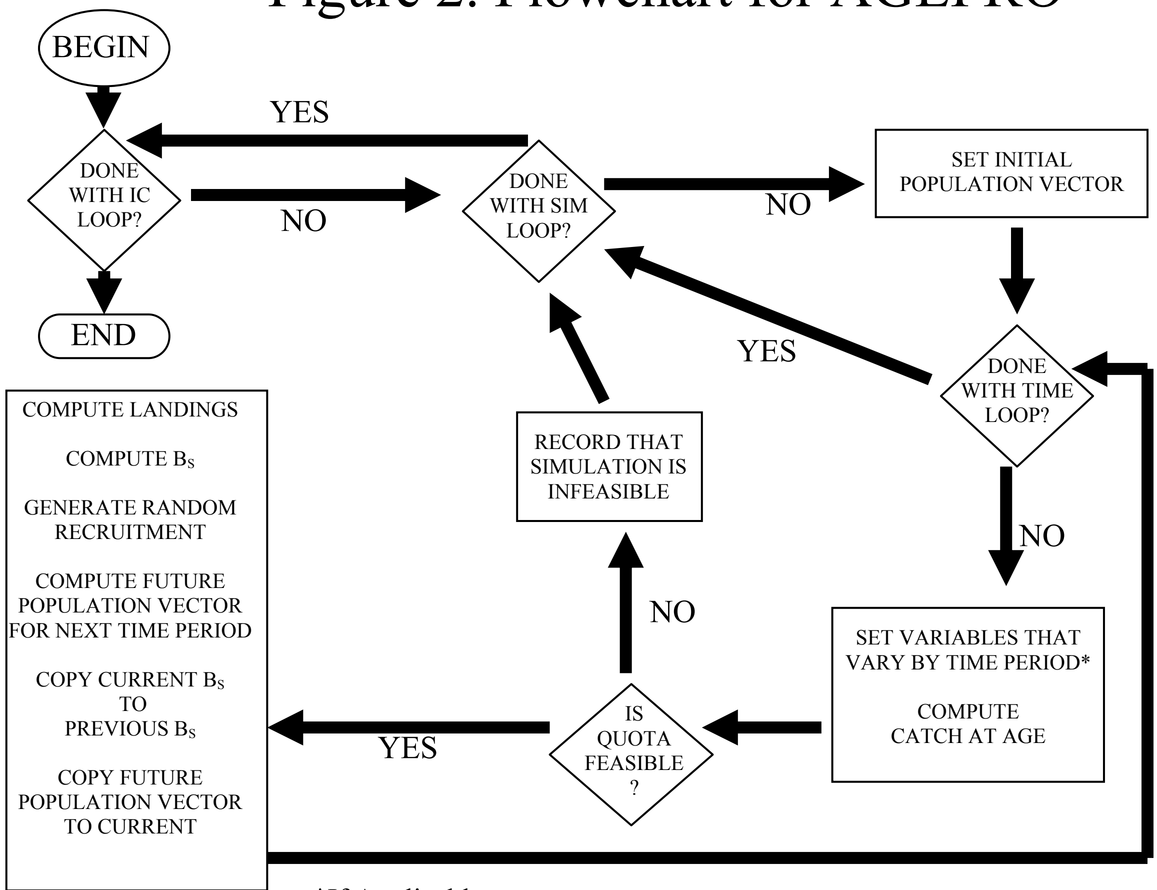


Figure 2. Flowchart for AGEPRO



*If Applicable

Figure 3.1. Projected median spawning biomass of redfish with 90% confidence intervals.

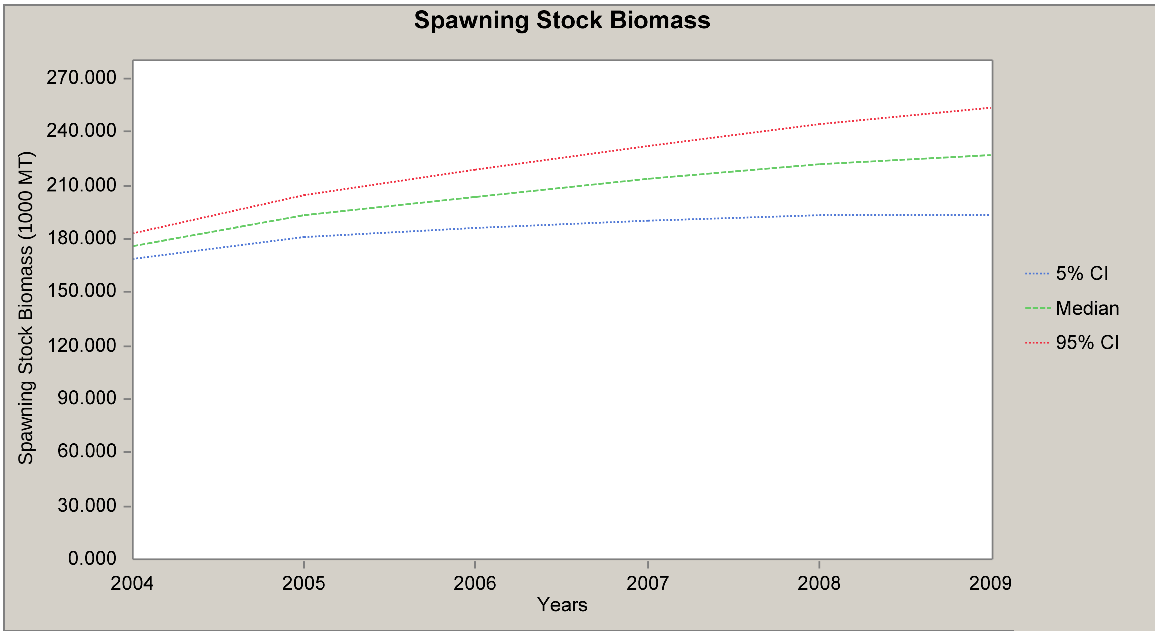


Figure 3.2. Projected annual probability of exceeding redfish spawning biomass threshold B_{MSY}.

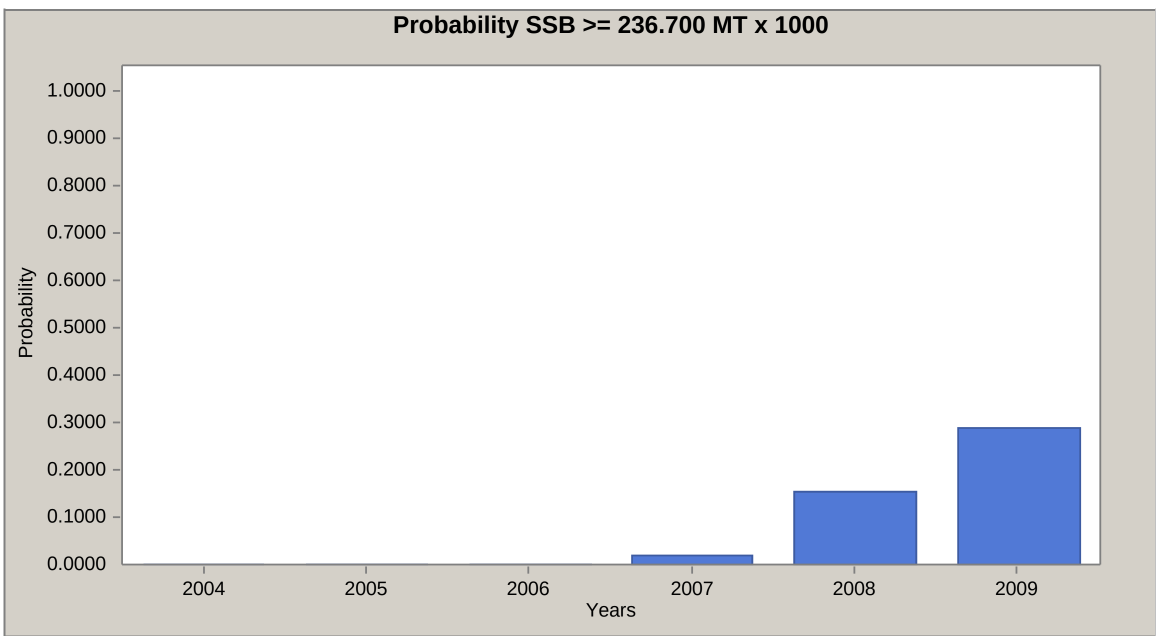


Figure 3.3. Projected median landings of redfish with 90% confidence intervals.

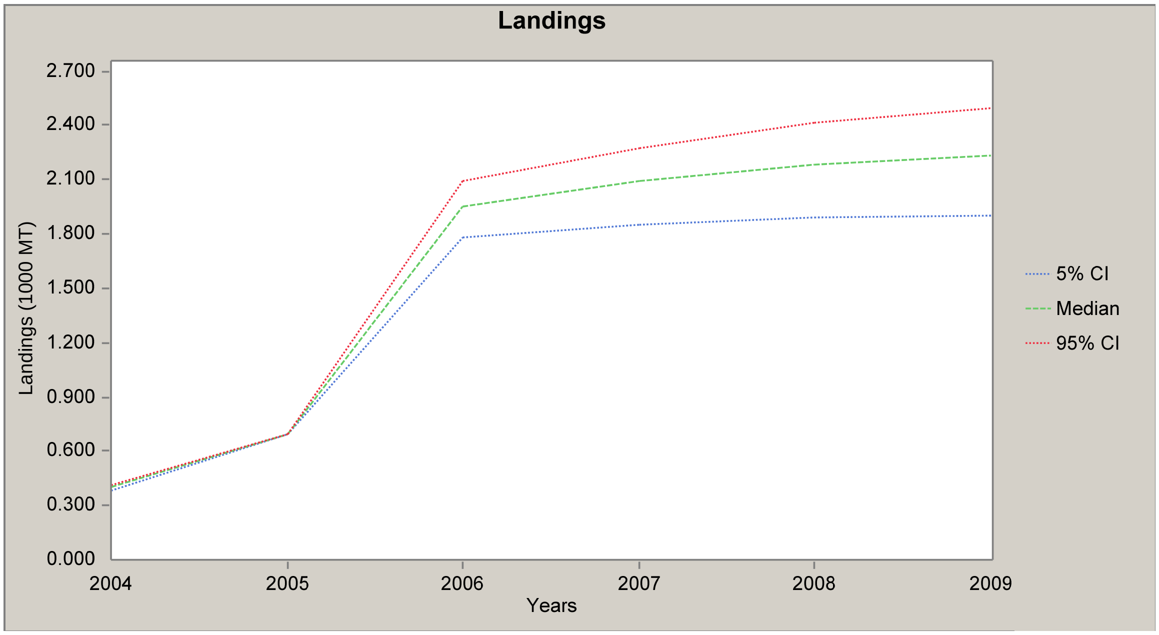


Figure 4.1. Projected median discard biomass of Georges Bank haddock with 90% confidence intervals.

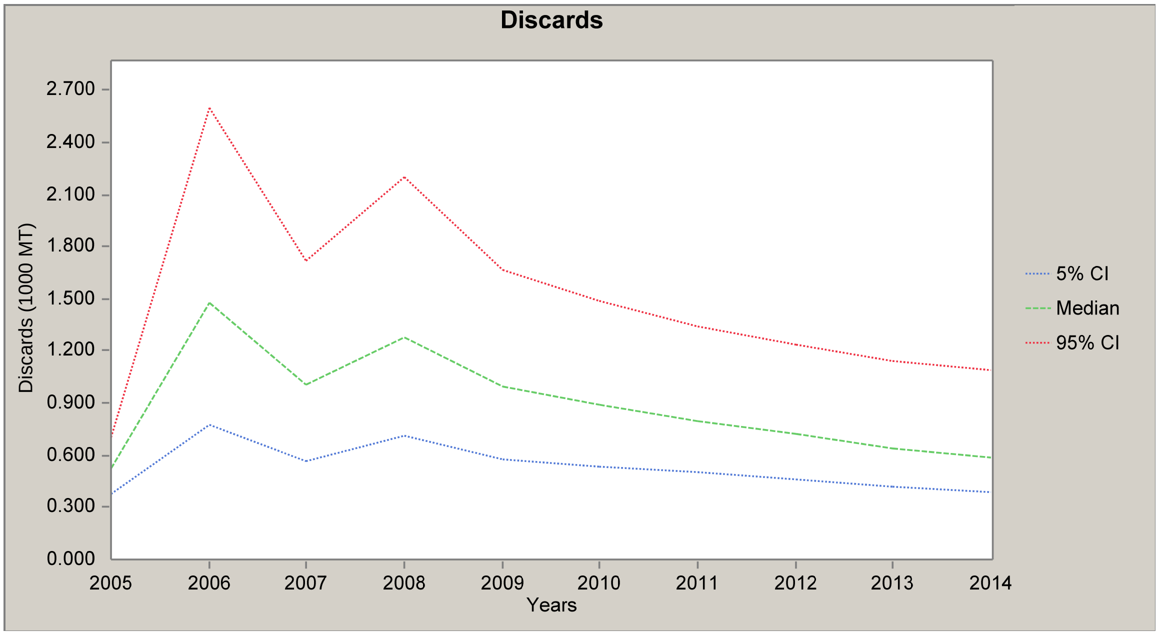


Figure 4.2. Projected median contribution of age-6 Georges Bank haddock to spawning biomass through time with 90% confidence intervals. The 2003 year class would be age 6 in 2009.

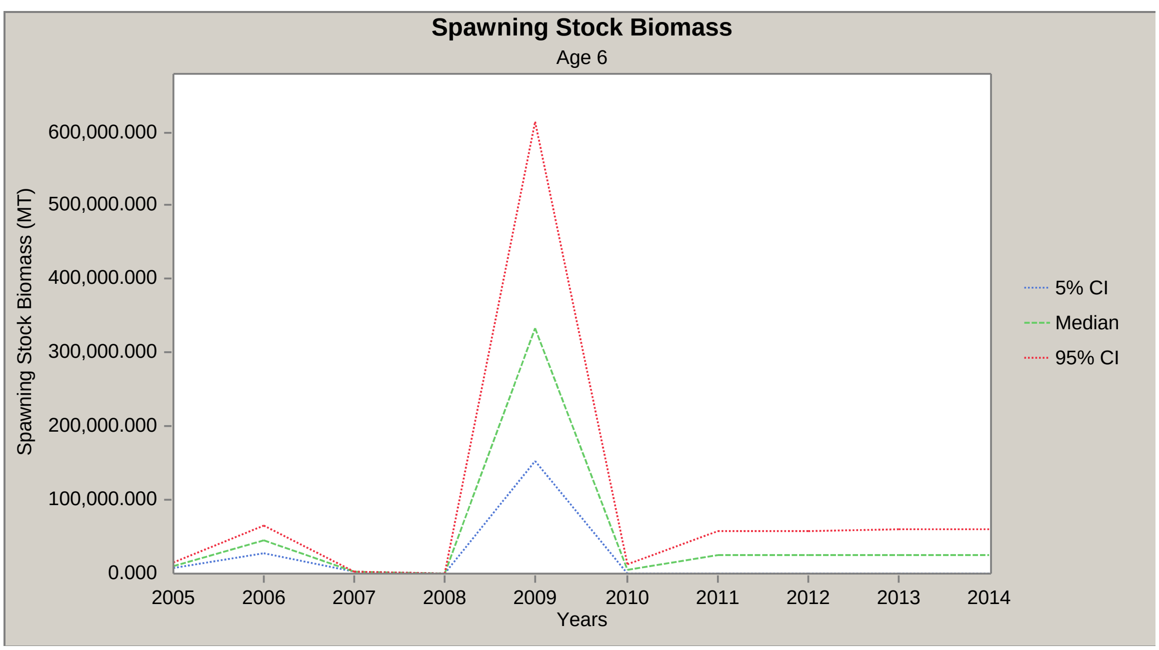


Figure 4.3. Projected median landings of large market category Georges Bank haddock with 90% confidence intervals.

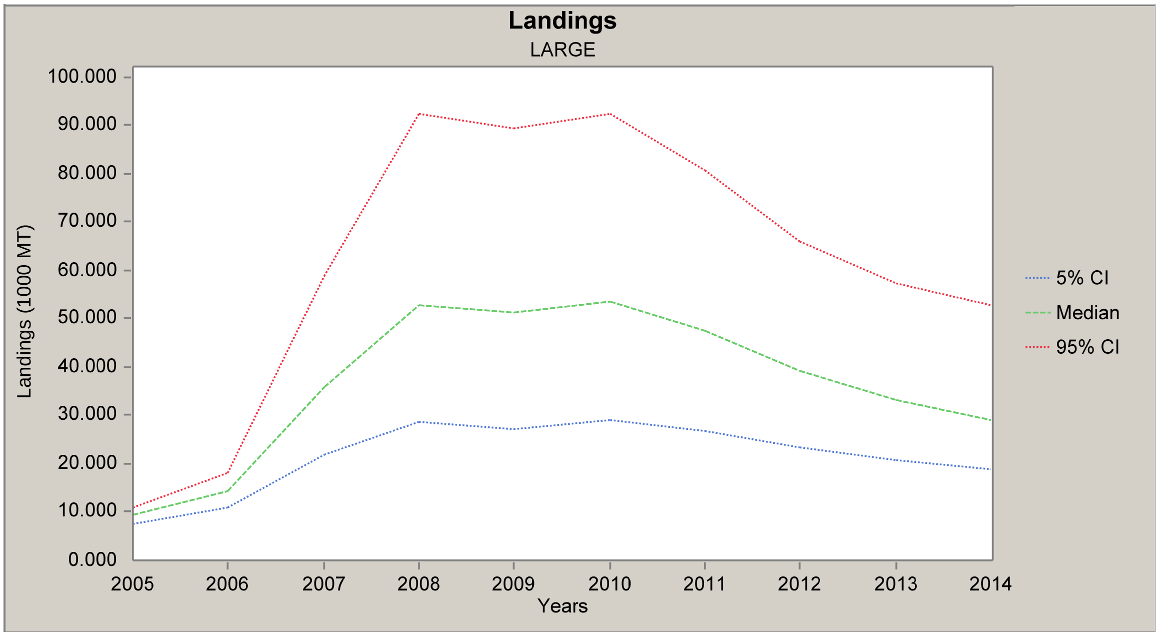


Figure 4.4. Projected median landings of scrod market category Georges Bank haddock with 90% confidence intervals.

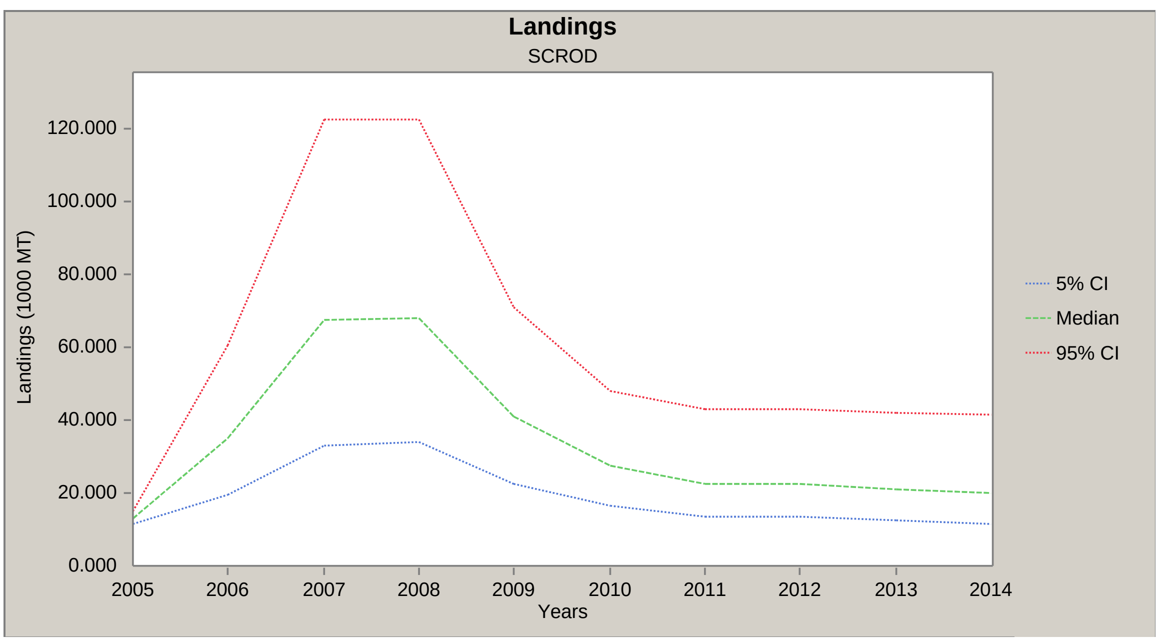
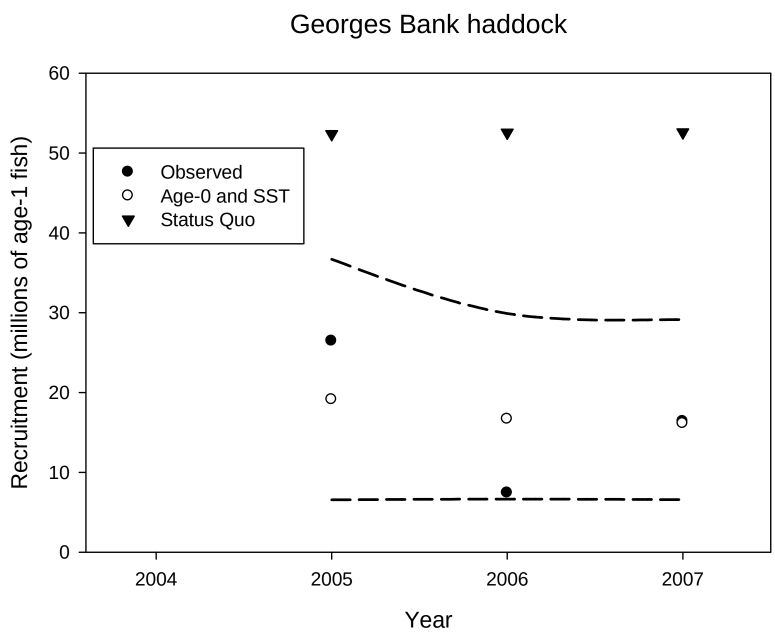


Figure 5. Comparison of Georges Bank haddock observed recruitment (solid circle) during 2005-2007 (NEFSC 2008a) and rescaled recruitment predictions from the best predictive model (open circle), a model-averaged combination of predictors using the haddock age-0 survey index and average sea surface temperature (SST) during February-May, and the status quo model (solid triangle) from Mayo and Terceiro (2006) along with 80% confidence intervals for the Age-0 index and SST-based prediction.



Appendix

Application of Newton's Method

To solve for the fishing mortality F that would yield the landings quota Q, we define a function g() and find its root. Let g(F) = L(F) - Q where L(F) is defined in Equation 11. The first order Taylor series expansion of g(F) about an arbitrary positive real number x is

(63) $$g(F) = g(x) + g'(x)\cdot(F - x)$$

Solving for the value of F that implies g(F) = 0, one obtains

(64) $$F = x - \frac{g(x)}{g'(x)}$$

One can numerically solve g(F)=0 by successively substituting iterates of $x=F^{(n)}$

(65) $$F^{(n+1)} = F^{(n)} - \frac{g\left(F^{(n)}\right)}{g'\left(F^{(n)}\right)}$$

The function g'(F) is the first derivative of L(F) - Q with respect to F. Since Q is a constant, this derivative is g'(F) = L'(F) where

(66) $$L'(F) = \sum_{a=r}^{A}\left(1-P_{D,a}\right)\cdot W_{L,a}\cdot C_a^{'}(F)$$

The derivative of catch with respect to F can be derived by taking the derivative of F with respect to C. After some algebra the derivative g'(F) reduces to

(67)
$$g'(F) = \sum_{a=r}^{A}\left(1-P_{D,a}\right)\cdot W_{L,a}\cdot\frac{P_{F,a}N_a}{\left(M_a+P_{F,a}F\right)^2}\cdot\left(M_a+\left(M_aP_{F,a}F-M_a+P_{F,a}^2F^2\right)\cdot e^{-M_a-P_{F,a}F}\right)$$

Therefore, the iterative solution for F that results in catch of the quota Q can be found from

(68) $$F^{(n+1)} = F^{(n)} - \frac{L\left(F^{(n)}\right)-Q}{g'\left(F^{(n)}\right)}$$

The iterates $F^{(n)}$ are constrained to remain within a bounded interval to ensure that the iterates $F^{(n)}$ converge to the solution of g(F)=0. In this case, the bounded interval of feasible iterates $F^{(n)}$ for g(F)=0 is set to be [0, 25] and the iteration has numerically converged when $| F^{(n+1)} - F^{(n)} | < 0.0005$.

Definition of Infeasible Quotas

An infeasible quota occurs when the landings quota cannot be removed from the exploitable biomass for some maximum feasible fishing mortality, denoted by F*. In this case, it is assumed that the maximum feasible F is F*=25.0 . Given this choice of F*and a constant M=0.2, it follows that the survival probability of average recruit would be exp(-Z) = exp(-25.2) ≈ $1.137 \cdot 10^{-11}$, or roughly 1 chance in 100 billion. This survival probability was small enough to characterize the maximum fishing mortality rate on a stock. Given F*, the maximum landings in time period t, denoted by L*, are

(69)

$$L^*\left(F^*\right) = \sum_{a=r}^{A}\left(1-P_{D,a}\left(t\right)\right)\cdot W_{L,a}\left(t\right)\cdot N_a\left(t\right)\cdot\frac{P_{F,a}\left(t\right)F^*}{M_a\left(t\right)+P_{F,a}\left(t\right)F^*}\cdot\left(1-e^{-M_a(t)-P_{F,a}(t)F^*}\right)$$

Appendix 3: ASAP Input Files for the LIS and NJ-NYB Regional Assessments

```
# ASAP VERSION 3.0
# LIS
#
# ASAP GUI 15 AUG 2012
#
# Number of Years
31
# First Year
1984
# Number of Ages
12
# Number of Fleets
1
# Number of Sensitivity Blocks
4
# Number of Available Survey Indices
6
# Natural Mortality
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
0.15    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
0.15    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
0.15    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
0.15    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
0.15    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
0.15    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
0.15    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
0.15        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
0.15        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
0.15        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
0.15        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
0.15        0.15        0.15        0.15        0.15        0.15
0.15        0.15        0.15        0.15        0.15        0.15
# Fecundity Option
0
# Fraction of year that elapses prior to SSB calculation (0=Jan-
1)
.42
# Maturity
0           0           0.8         1           1           1
1           1           1           1           1           1
0           0           0.8         1           1           1
1           1           1           1           1           1
0           0           0.8         1           1           1
1           1           1           1           1           1
0           0           0.8         1           1           1
1           1           1           1           1           1
0           0           0.8         1           1           1
1           1           1           1           1           1
0           0           0.8         1           1           1
1           1           1           1           1           1
0           0           0.8         1           1           1
1           1           1           1           1           1
0           0           0.8         1           1           1
1           1           1           1           1           1
0           0           0.8         1           1           1
1           1           1           1           1           1
0           0           0.8         1           1           1
1           1           1           1           1           1
0           0           0.8         1           1           1
1           1           1           1           1           1
```

0	0	0.8	1	1	1
1	1	1	1	1	1
0	0	0.8	1	1	1
1	1	1	1	1	1
0	0	0.8	1	1	1
1	1	1	1	1	1
0	0	0.8	1	1	1
1	1	1	1	1	1
0	0	0.8	1	1	1
1	1	1	1	1	1
0	0	0.8	1	1	1
1	1	1	1	1	1
0	0	0.8	1	1	1
1	1	1	1	1	1
0	0	0.8	1	1	1
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0	0	0.8	1	1	1
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0	0	0.8	1	1	1
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0	0	0.8	1	1	1
1	1	1	1	1	1
0	0	0.8	1	1	1
1	1	1	1	1	1
0	0	0.8	1	1	1
1	1	1	1	1	1
0	0	0.8	1	1	1
1	1	1	1	1	1
0	0	0.8	1	1	1
1	1	1	1	1	1
0	0	0.8	1	1	1
1	1	1	1	1	1
0	0	0.8	1	1	1
1	1	1	1	1	1
0	0	0.8	1	1	1
1	1	1	1	1	1
0	0	0.8	1	1	1
1	1	1	1	1	1
0	0	0.8	1	1	1
1	1	1	1	1	1

Number of Weights at Age Matrices
2
Weight Matrix - 1

0.072	0.266	0.32	0.498
0.839	1.032	1.492	1.814
2.011	2.334	2.589	3.07
0.075	0.157	0.32	0.568
0.701	1.203	1.46	1.631
2.241	2.541	2.825	3.531
0.164	0.268	0.486	0.753
0.989	1.287	1.402	1.995
1.976	2.624	2.625	5.042
0.066	0.161	0.405	0.542
0.912	1.303	1.657	1.969

2.507	2.661	3.048	4.305
0.213	0.379	0.492	0.587
0.867	1.088	1.514	1.631
1.932	2.111	2.887	3.925
0.118	0.103	0.426	0.604
0.779	1.059	1.273	1.739
2.201	2.818	3.063	3.741
0	0	0.416	0.596
1.024	1.017	1.386	1.687
1.779	2.63	2.998	4.495
0.18	0.278	0.701	0.645
1.058	1.271	1.699	2.041
2.102	2.412	2.589	3.678
0.179	0.242	0.341	0.7
0.745	1.069	1.579	1.664
2.263	2.446	2.503	3.444
0.087	0.263	0.372	0.601
0.711	1.037	1.394	1.878
2.16	2.026	2.809	3.543
0.22	0.239	0.646	0.859
0.911	1.013	1.268	1.804
2.252	1.797	3.717	3.269
0.15	0.212	0.281	0.952
1.101	1.28	1.523	2.012
2.383	2.613	2.383	3.793
0.153	0.209	0.784	0.933
1.193	1.512	1.684	1.959
2.493	2.601	2.85	3.594
0	0.193	0.843	1.166
1.278	1.479	1.993	2.197
2.487	2.646	3.255	4.276
0.095	0.163	0.727	1.015
1.372	1.644	1.814	2.165
2.374	3.314	3.251	4.16
0.11	0.27	0.782	1.134
1.345	1.595	1.951	2.52
2.643	3.115	3.346	4.297
0	0.149	0.368	1.002
1.186	1.415	1.718	2.11
2.481	2.889	2.986	3.987
0.077	0.09	0.825	0.544
1.155	1.49	1.724	2.062
2.371	2.869	2.853	3.978
0.076	0.206	0.391	0.887
1.122	1.338	1.693	1.957
2.281	2.638	2.747	3.804
0.094	0.156	0.608	0.791
1.077	1.385	1.726	1.975
2.512	2.606	2.796	3.869
0.106	0.265	0.427	0.807
1.052	1.312	1.686	2.09
2.403	2.549	2.845	3.836
0.111	0.127	0.28	0.777
1.121	1.438	1.757	2.23

2.5	2.65	3.221	3.909
0.142	0.177	0.443	0.836
1.118	1.292	1.571	1.957
2.044	2.347	2.702	3.657
0.125	0.135	0.623	0.656
1.053	1.242	1.541	1.808
2.128	2.332	2.446	3.109
0.103	0.129	0.37	0.689
1.062	1.37	1.431	1.807
2.079	2.365	2.406	3.143
0.153	0.27	0.533	1.05
1.269	1.384	1.566	1.765
1.915	2.332	2.905	3.42
0.122	0.155	0.662	1.02
1.417	1.428	1.66	1.949
2.122	2.672	2.77	3.455
0.105	0.252	0.412	1.067
1.266	1.706	1.821	2.239
2.219	2.621	3.309	3.239
0.066	0.225	0.483	0.889
1.495	1.674	1.963	2.092
2.59	2.704	3.172	3.596
0.102	0.207	0.417	0.792
1.427	1.716	1.817	2.19
2.682	2.612	2.996	4.261
0.131	0.368	0.509	0.985
1.427	1.532	1.794	2.098
2.271	2.569	3.325	3.418
# Weight Matrix - 2			
0.05815781	0.199068032	0.426010863	0.719833092
1.056389268	1.41316957	1.771964835	2.119423119
2.446614519	2.748223276	3.021683861	3.266405267
0.05815781	0.199068032	0.426010863	0.719833092
1.056389268	1.41316957	1.771964835	2.119423119
2.446614519	2.748223276	3.021683861	3.266405267
0.05815781	0.199068032	0.426010863	0.719833092
1.056389268	1.41316957	1.771964835	2.119423119
2.446614519	2.748223276	3.021683861	3.266405267
0.05815781	0.199068032	0.426010863	0.719833092
1.056389268	1.41316957	1.771964835	2.119423119
2.446614519	2.748223276	3.021683861	3.266405267
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2.446614519	2.748223276	3.021683861	3.266405267
0.05815781	0.199068032	0.426010863	0.719833092
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2.446614519	2.748223276	3.021683861	3.266405267
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2.446614519	2.748223276	3.021683861	3.266405267
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2.446614519	2.748223276	3.021683861	3.266405267
0.05815781	0.199068032	0.426010863	0.719833092

1.056389268	1.41316957	1.771964835	2.119423119
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0.05815781	0.199068032	0.426010863	0.719833092
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1.056389268	1.41316957	1.771964835	2.119423119
2.446614519	2.748223276	3.021683861	3.266405267
0.05815781	0.199068032	0.426010863	0.719833092
1.056389268	1.41316957	1.771964835	2.119423119
2.446614519	2.748223276	3.021683861	3.266405267
0.05815781	0.199068032	0.426010863	0.719833092
1.056389268	1.41316957	1.771964835	2.119423119
2.446614519	2.748223276	3.021683861	3.266405267
0.05815781	0.199068032	0.426010863	0.719833092
1.056389268	1.41316957	1.771964835	2.119423119
2.446614519	2.748223276	3.021683861	3.266405267
0.05815781	0.199068032	0.426010863	0.719833092
1.056389268	1.41316957	1.771964835	2.119423119
2.446614519	2.748223276	3.021683861	3.266405267
0.05815781	0.199068032	0.426010863	0.719833092
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2.446614519	2.748223276	3.021683861	3.266405267
0.05815781	0.199068032	0.426010863	0.719833092
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0.05815781	0.199068032	0.426010863	0.719833092
1.056389268	1.41316957	1.771964835	2.119423119
2.446614519	2.748223276	3.021683861	3.266405267
0.05815781	0.199068032	0.426010863	0.719833092
1.056389268	1.41316957	1.771964835	2.119423119
2.446614519	2.748223276	3.021683861	3.266405267
0.05815781	0.199068032	0.426010863	0.719833092
1.056389268	1.41316957	1.771964835	2.119423119
2.446614519	2.748223276	3.021683861	3.266405267
0.05815781	0.199068032	0.426010863	0.719833092
1.056389268	1.41316957	1.771964835	2.119423119
2.446614519	2.748223276	3.021683861	3.266405267
0.05815781	0.199068032	0.426010863	0.719833092
1.056389268	1.41316957	1.771964835	2.119423119
2.446614519	2.748223276	3.021683861	3.266405267
0.05815781	0.199068032	0.426010863	0.719833092
1.056389268	1.41316957	1.771964835	2.119423119
2.446614519	2.748223276	3.021683861	3.266405267
0.05815781	0.199068032	0.426010863	0.719833092
1.056389268	1.41316957	1.771964835	2.119423119
2.446614519	2.748223276	3.021683861	3.266405267
0.05815781	0.199068032	0.426010863	0.719833092
1.056389268	1.41316957	1.771964835	2.119423119
2.446614519	2.748223276	3.021683861	3.266405267
0.05815781	0.199068032	0.426010863	0.719833092
1.056389268	1.41316957	1.771964835	2.119423119
2.446614519	2.748223276	3.021683861	3.266405267
0.05815781	0.199068032	0.426010863	0.719833092

```
1.056389268     1.41316957      1.771964835     2.119423119
2.446614519     2.748223276     3.021683861     3.266405267
0.05815781      0.199068032     0.426010863     0.719833092
1.056389268     1.41316957      1.771964835     2.119423119
2.446614519     2.748223276     3.021683861     3.266405267
0.05815781      0.199068032     0.426010863     0.719833092
1.056389268     1.41316957      1.771964835     2.119423119
2.446614519     2.748223276     3.021683861     3.266405267
0.05815781      0.199068032     0.426010863     0.719833092
1.056389268     1.41316957      1.771964835     2.119423119
2.446614519     2.748223276     3.021683861     3.266405267
0.05815781      0.199068032     0.426010863     0.719833092
1.056389268     1.41316957      1.771964835     2.119423119
2.446614519     2.748223276     3.021683861     3.266405267
# Weights at Age Pointers
1
1
1
1
2
2
# Selectivity Block Assignment
# Fleet 1 Selectivity Block Assignment
1
1
1
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```
# Selectivity Options for each block 1=by age, 2=logisitic, 3
=double logistic
2  2  2  2
# Selectivity Block #1 Data
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               0               0               0
0               0               0               0
0               0               0               0
0               0               0               0
0               0               0               0
5               2               0               0
0.6             2               0               0
0               0               0               0
0               0               0               0
0               0               0               0
0               0               0               0
# Selectivity Block #2 Data
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               0               0               0
0               0               0               0
0               0               0               0
0               0               0               0
0               0               0               0
5               2               0               0
0.6             2               0               0
0               0               0               0
0               0               0               0
0               0               0               0
0               0               0               0
# Selectivity Block #3 Data
0               0               0               0
0               0               0               0
0               0               0               0
0               0               0               0
0               0               0               0
0               0               0               0
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5               2               0               0
0.6             2               0               0
0               0               0               0
0               0               0               0
0               0               0               0
0               0               0               0
# Selectivity Block #4 Data
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               0               0               0
0               0               0               0
0               0               0               0
0               0               0               0
0               0               0               0
5               2               0               0
0.6             2               0               0
0               0               0               0
0               0               0               0
0               0               0               0
0               0               0               0
# Fleet Start Age
1
# Fleet End Age
12
# Age Range for Average F
8  12
# Average F report option (1=unweighted, 2=Nweighted, 3
=Bweighted)
2
# Use Likelihood constants? (1=yes)
0
# Release Mortality by Fleet
0.025
# Catch Data
# Fleet-1 Catch Data
523             5819            34444           91952
138068          127003          93294           68923
60309           46932           18556           66249
1051773.405
2371            15209           19294           114471
88858           63136           50319           40337
54819           51866           43769           172595
1338977.954
452             13440           65538           57991
76129           154671          164525          92940
79788           28488           32274           290603
2551980.423
290             2850            11370           30544
81925           142345          148618          126702
```

94879	62538	61029	292907
2628821.385			
3033	4679	51686	77743
155259	109122	86298	94992
87427	55676	19983	174518
1641520.507			
709	3678	31235	94402
90746	102278	104165	78365
44224	46814	39734	191993
1587879.661			
0	0	21006	68348
140659	57912	47881	90651
52037	16023	31134	126804
1269734.552			
141	1545	27693	120956
146024	132402	66154	61028
45965	33689	21050	69297
1144863.545			
131	3428	16016	28715
72531	145906	109266	70415
38082	29169	18414	92357
1047820.354			
311	2482	16694	27876
34952	131976	101103	36718
25347	47292	13936	71193
837193.572			
19	521	15885	25052
46560	52519	48999	38468
27633	13144	7907	12616
415536.295			
53	284	1031	30114
56474	22251	23688	42945
12940	13928	10435	12738
382579.438			
25	651	7403	19053
36058	34352	18302	21847
13025	12533	3785	10872
307227.42			
0	342	6047	20156
28492	23425	16270	12871
7668	3369	1749	19794
278744.4			
102	849	2947	22938
43679	35489	32221	22989
7804	15316	2065	7819
360588.474			
182	1001	4718	13625
33314	35961	27261	27875
14382	9751	7663	19950
424778.391			
2	30	309	2470
6017	11264	9844	7304
5281	4997	2647	17270
162289.202			

43	111	1325	1632
5537	9871	12921	13898
17170	9513	7051	17382
231295.705			
23	460	2813	28734
84802	107853	106867	105493
49339	37431	18638	56342
1130323.03			
69	509	848	14593
61399	72797	52663	32479
26622	15772	6662	37581
606141.605			
154	1783	3827	9766
29016	67406	52122	45920
49841	33387	26603	52084
793167.251			
41	347	1967	2805
22460	40500	43585	31106
17063	7746	10817	13198
381757.689			
92	931	2665	16298
52127	72838	60266	72695
43135	32005	21310	49218
805163.778			
119	1906	5022	14999
54918	114288	103806	100490
79686	66703	41563	85721
1247958.442			
88	571	3272	12084
38803	79468	76646	58378
59494	43041	35665	91742
974503.744			
187	1843	4275	26948
56996	51418	58861	45689
31828	18022	18047	51759
679828.282			
69	399	10919	30554
37762	43815	50218	41746
21612	19621	15665	32099
571847.2			
113	995	3382	25478
23377	36629	30864	23510
11736	4642	4807	14086
329507.388			
296	1703	3974	8951
55023	49603	46853	41126
51568	15422	8405	36047
685130.31			
1042	1698	2893	5900
18965	47790	46525	36897
33954	8781	16169	34078
588397.283			
638	13393	13119	19490
84343	105595	92670	71114

26007 23455 4700 39168
897285.092
Discards
Fleet-1 Discards Data
0 0 0 0
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# Release Proportion
# Fleet-1 Release Data
0	0	0	0
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0               0               0               0
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0               0               0               0
# Survey Index Data
# Aggregate Index Units
2  2  2  2  2  2
# Age Proportion Index Units
2  2  2  2  2  2
# Weight at Age Matrix
2  2  2  2  2  2
# Index Month
5  5  6  5  5  5
# Index Selectivity Link to Fleet
-1  -1  -1  -1  -1  -1
# Index Selectivity Options 1=by age, 2=logisitic, 3=double
logistic
2  1  2  1  1  1
# Index Start Age
1  1  1  1  1  1
# Index End Age
12  1  12  1  1  1
# Estimate Proportion (Yes=1)
1  0  1  0  0  0
# Use Index (Yes=1)
1  1  1  1  0  0
# Index-1 Selectivity Data
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               0               0               0
0               0               0               0
0               0               0               0
0               0               0               0
0               0               0               0
5               2               0               0
0.6             2               0               0
0               0               0               0
0               0               0               0
0               0               0               0
0               0               0               0
# Index-2 Selectivity Data
1               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
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0               -1               0               0
0               -1               0               0
0               -1               0               0
0               -1               0               0
0               -1               0               0
0               -1               0               0
0               -1               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
# Index-3 Selectivity Data
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               0                0               0
0               0                0               0
0               0                0               0
0               0                0               0
0               0                0               0
5               2                0               0
0.6             2                0               0
0               0                0               0
0               0                0               0
0               0                0               0
0               0                0               0
# Index-4 Selectivity Data
1               -1               0               0
0               -1               0               0
0               -1               0               0
0               -1               0               0
0               -1               0               0
0               -1               0               0
0               -1               0               0
0               -1               0               0
0               -1               0               0
0               -1               0               0
0               -1               0               0
0               -1               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
# Index-5 Selectivity Data
1               -1               0               0
0               -1               0               0
```

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0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              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
# Index-6 Selectivity Data
1               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              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
# Index-1 Data
1984  1.697409106     0.485338992     0.004464286     0.03125
0.071428571     0.102678571     0.113839286     0.104910714
0.102678571     0.091517857     0.095982143     0.09375
0.033482143     0.154017857     16
1985  0.955933641     0.45190654      0
0.024221453     0.034602076     0.107266436     0.096885813
0.110726644     0.117647059     0.124567474     0.110726644
0.089965398     0.065743945     0.117647059     20
1986  1.033135691     0.36410516      0.003710575
0.018552876     0.057513915     0.027829314     0.079777365
0.14471243      0.166975881     0.141001855     0.128014842
0.070500928     0.06864564      0.092764378     31
1987  0.829253884     0.362768133     0.014450867
0.063583815     0.046242775     0.046242775     0.075144509
0.132947977     0.132947977     0.12716763      0.080924855
0.054913295     0.052023121     0.173410405     32
1988  0.616695509     0.367808108     0.013761468     0.03440367
0.052752294     0.052752294     0.068807339     0.064220183
```

0.077981651 0.112385321 0.139908257 0.094036697
0.055045872 0.233944954 32
1989 0.771265927 0.363951391 0.001821494
0.036429872 0.052823315 0.122040073 0.056466302
0.089253188 0.120218579 0.118397086 0.081967213
0.076502732 0.049180328 0.194899818 32
1990 0.786839961 0.363928907 0.005434783
0.061594203 0.14673913 0.081521739 0.108695652
0.032608696 0.043478261 0.110507246 0.088768116
0.032608696 0.088768116 0.199275362 32
1991 1.039156441 0.359774667 0.007075472
0.025943396 0.051886792 0.113207547 0.113207547
0.122641509 0.091981132 0.108490566 0.087264151
0.08490566 0.054245283 0.139150943 32
1992 0.465447409 0.418810184 0.007936508
0.047619048 0.051587302 0.027777778 0.055555556
0.111111111 0.130952381 0.087301587 0.067460317
0.067460317 0.063492063 0.281746032 25
1993 0.257415538 0.391560101 0.013333333 0.04
0.086666667 0.053333333 0.026666667 0.106666667
0.106666667 0.08 0.08 0.08
0.066666667 0.26 32
1994 0.27694918 0.389221171 0.004975124
0.049751244 0.064676617 0.109452736 0.099502488
0.099502488 0.089552239 0.139303483 0.084577114
0.059701493 0.039800995 0.15920398 32
1995 0.142073952 0.419807197 0.016666667
0.033333333 0.033333333 0.15 0.233333333
0.1 0.083333333 0.1 0.066666667
0.083333333 0.016666667 0.083333333 32
1996 0.206126913 0.40050034 0 0.08
0.056 0.072 0.168 0.136
0.088 0.104 0.096 0.08
0.024 0.096 32
1997 0.277797364 0.388918248 0 0.07486631
0.144385027 0.14973262 0.165775401 0.128342246
0.085561497 0.080213904 0.053475936 0.021390374
0.010695187 0.085561497 32
1998 0.364657178 0.380989271 0
0.032085561 0.042780749 0.117647059 0.181818182
0.13368984 0.14973262 0.128342246 0.053475936
0.069518717 0.032085561 0.058823529 32
1999 0.505163296 0.371827855 0.04784689
0.076555024 0.081339713 0.105263158 0.153110048
0.167464115 0.110047847 0.110047847 0.062200957
0.019138756 0.023923445 0.043062201 32
2000 0.453549837 0.374218884 0
0.056737589 0.070921986 0.085106383 0.106382979
0.195035461 0.166666667 0.102836879 0.067375887
0.042553191 0.024822695 0.081560284 32
2001 0.543382818 0.373306452 0.009615385
0.028846154 0.096153846 0.092948718 0.125
0.125 0.141025641 0.121794872 0.08974359
0.054487179 0.048076923 0.067307692 32

```
2002  0.955009865     0.360697332     0.001808318
0.019891501     0.045207957     0.092224231     0.150090416
0.157323689     0.157323689     0.160940325     0.072332731
0.05244123      0.028933092     0.061482821     32
2003  0.393174332     0.408823538     0               0.01025641
0.015384615     0.112820513     0.235897436     0.220512821
0.148717949     0.087179487     0.071794872     0.035897436
0.020512821     0.041025641     25
2004  0.348500718     0.383300359     0.00456621      0.02739726
0.054794521     0.059360731     0.114155251     0.251141553
0.159817352     0.095890411     0.091324201     0.059360731
0.03196347      0.050228311     31
2005  0.293824831     0.387286161     0.005813953
0.046511628     0.075581395     0.046511628     0.145348837
0.197674419     0.191860465     0.122093023     0.075581395
0.034883721     0.029069767     0.029069767     32
2006  0.396188311     0.467858285     0               0.02259887
0.033898305     0.101694915     0.146892655     0.141242938
0.124293785     0.15819209      0.096045198     0.073446328
0.04519774      0.056497175     19
2007  0.365848238     0.380773084     0
0.025830258     0.025830258     0.055350554     0.070110701
0.092250923     0.118081181     0.136531365     0.129151292
0.114391144     0.073800738     0.158671587     32
2008  0.378764766     0.410168591     0.005813953
0.034883721     0.046511628     0.075581395     0.11627907
0.13372093      0.122093023     0.087209302     0.093023256
0.058139535     0.063953488     0.162790698     25
2009  0.263561732     0.391055726     0.00625         0.0625
0.01875         0.075           0.1375          0.1125
0.14375         0.13125         0.0875          0.0625
0.05            0.1125          32
2010  0.169582153     0.603536234     0.019607843
0.039215686     0.156862745     0.117647059     0.098039216
0.098039216     0.137254902     0.098039216     0.039215686
0.039215686     0.058823529     0.098039216     12
2011  0.176935069     0.435835962     0.029126214
0.097087379     0.116504854     0.155339806     0.087378641
0.145631068     0.116504854     0.106796117     0.048543689
0.019417476     0.019417476     0.058252427     27
2012  0.285464913     0.3881398       0.06870229
0.145038168     0.160305344     0.129770992     0.175572519
0.091603053     0.061068702     0.06870229      0.061068702
0.007633588     0.007633588     0.022900763     32
2013  0.286080815     0.387949048     0.033333333
0.086666667     0.146666667     0.16            0.186666667
0.173333333     0.1             0.053333333     0.02
0.006666667     0.013333333     0.02            32
2014  0.328312393     0.38486676      0.047904192
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# Index-2 Data
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0 0 0
2011 0.102574155 0.318710294 0 0

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0.103571835     0.040950289     0.146201536     7
1985  1.3833302       0.41508728      0.004574163
0.029341392     0.037222225     0.220838876     0.171425958
0.121802756     0.09707604      0.077818642     0.105757496
0.100060532     0.084439699     0.33297242      6
1986  1.2586193       0.353808632     0.0005383
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1987  1.4753378       0.337646401     0.00040516
0.003981747     0.015885074     0.042673149     0.114457758
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0.0873721       0.08526387      0.409221588     8
1988  3.5301878       0.228222703     0.011632848     0.01794596
0.198237847     0.298177552     0.595484463     0.418529397
0.330989625     0.364334822     0.335319821     0.213541199
0.076643325     0.66935094      16
1989  2.5372833       0.214675083     0.002171726
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0.313285995     0.319066033     0.240038493     0.135461779
0.143395164     0.121708537     0.58809048      20
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1991  1.7734996       0.178552778     0.000344467
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0.112194448     0.070826856     0.355238186     27
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0.008981931     0.060412711     0.100878443     0.126485268
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0.017220213 0.00893979 0.101174503 12
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0.047441314 0.006396338 0.024219354 12
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0.063005644 0.03137237 0.094837541 14
2003 0.8180218 0.245802429 0.000175294
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0.060154162 0.047931266 0.093840997 14
2005 0.83986 0.311723428 0.000179687
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0.033947638 0.04740661 0.057841586 13
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2011  0.7903823       0.369842155     0.000497237
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2012  0.7083347       0.305316535     0.000657323     0.00378183
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1989  1.24363834      0.226976371     0               0
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1994	0.008599389	0.575180537	0	0
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0               0               0
2014  21.78           0.645465663     0               0
0               0               0               0
0               0               0               0
0               0               0
# Phase Control
# Phase for F mult in 1st Year
1
# Phase for F mult Deviations
2
# Phase for Recruitment Deviations
2
# Phase for N in 1st Year
2
# Phase for Catchability in 1st Year
3
# Phase for Catchability Deviations
-1
# Phase for Stock Recruitment Relationship
3
# Phase for Steepness
3
# Recruitment CV by Year
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
# Lambdas by Index
1  1  1  1  1  1
# Lambda for Total Catch in Weight by Fleet
1
# Lambda for Total Discards at Age by Fleet
1
# Catch Total CV by Year and Fleet
0.3699
0.3699
0.3699
0.3699
0.3699
0.3699
0.3699
0.3699
0.3699
0.3699
0.3699
0.3699
0.3699
0.3699
0.3699
0.3699
0.3699
0.3699
0.3699
0.3699
0.472
0.492
0.384
```

0.275
0.221
0.267
0.239
0.499
0.305
0.521
0.291
Discard Total CV by Year and Fleet
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
0
0
Catch Effective Sample Size by Year and Fleet
26
26
26
26
26
26
26
26
26
26
26
26
26

```
26
26
26
26
26
26
26
26
26
26
26
26
26
26
26
26
26
26
# Discard Effective Sample Size by Year and Fleet
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
0
0
# Lambda for F Mult in First year by Fleet
0
# CV for F Mult in First year by Fleet
0.5
```

```
# Lambda for F Mult Deviations by Fleet
0.5
# CV for F Mult Deviations by Fleet
0.5
# Lambda for N in 1st Year Deviations
0
# CV for N in 1st Year Deviations
0.5
# Lambda for Recruitment Deviations
.5
# Lambda for Catchability in First year by Index
0  0  0  0  0  0
# CV for Catchability in First year by Index
1  1  1  1  1  1
# Lambda for Catchability Deviations by Index
0  0  0  0  0  0
# CV for Catchability Deviations by Index
1  1  1  1  1  1
# Lambda for Deviation from Initial Steepness
0
# CV for Deviation from Initial Steepness
0.5
# Lambda for Deviation from Unexploited Stock Size
0
# CV for Deviation from Unexploited Stock Size
0.5
# NAA Deviations Flag
2
# Initial Numbers at Age in 1st Year
829  701  587  462  356  256  186  142  89  64  42  93
# Initial F Mult in 1st Year by Fleet
1
# Initial Catchabilty by Index
0.001  0.001  0.001  0.001  0.001  0.001
# Stock Recruitment Flag
0
# Initial Unexploited Stock
10000
# Initial Steepness
0.7
# Maximum F
5
# Ignore Guesses (Yes=1)
0
# Projection Control
# Do Projections (Yes=1)
0
# Fleet Directed Flag
1
# Final Year in Projection
2015
# Projection Data by Year
2015     -1         3    -99        1
# Do MCMC (Yes=1)
```

```
1
# MCMC Year Option
0
# MCMC Iterations
1000
# MCMC Thinning Factor
200
# MCMC Random Seed
314156
# Agepro R Option
1
# Agepro R Option Start Year
1984
# Agepro R Option End Year
2014
# Export R Flag
1
# Test Value
-23456
######
###### FINIS ######
# Fleet Names
#$Rec + Com
# Survey Names
#$CT Trawl
#$NY Trawl
#$MRIP CPUE
#$NYSeine
#$MillstoneEggs
#$MillstoneLarve
#
```

```
# ASAP VERSION 3.0
# NJ-NYB
#
# ASAP GUI 15 AUG 2012
#
# Number of Years
26
# First Year
1989
# Number of Ages
12
# Number of Fleets
1
# Number of Sensitivity Blocks
4
# Number of Available Survey Indices
3
# Natural Mortality
.15        .15        .15        .15        .15        .15
.15        .15        .15        .15        .15        .15
.15        .15        .15        .15        .15        .15
.15        .15        .15        .15        .15        .15
.15        .15        .15        .15        .15        .15
.15        .15        .15        .15        .15        .15
.15        .15        .15        .15        .15        .15
.15        .15        .15        .15        .15        .15
.15        .15        .15        .15        .15        .15
.15        .15        .15        .15        .15        .15
.15        .15        .15        .15        .15        .15
.15        .15        .15        .15        .15        .15
.15        .15        .15        .15        .15        .15
.15        .15        .15        .15        .15        .15
.15        .15        .15        .15        .15        .15
.15        .15        .15        .15        .15        .15
.15        .15        .15        .15        .15        .15
.15        .15        .15        .15        .15        .15
.15        .15        .15        .15        .15        .15
.15        .15        .15        .15        .15        .15
.15        .15        .15        .15        .15        .15
.15        .15        .15        .15        .15        .15
.15        .15        .15        .15        .15        .15
.15        .15        .15        .15        .15        .15
.15        .15        .15        .15        .15        .15
.15        .15        .15        .15        .15        .15
.15        .15        .15        .15        .15        .15
.15        .15        .15        .15        .15        .15
.15        .15        .15        .15        .15        .15
.15        .15        .15        .15        .15        .15
.15        .15        .15        .15        .15        .15
.15        .15        .15        .15        .15        .15
.15        .15        .15        .15        .15        .15
.15        .15        .15        .15        .15        .15
.15        .15        .15        .15        .15        .15
.15        .15        .15        .15        .15        .15
```

```
.15         .15         .15         .15         .15         .15
.15         .15         .15         .15         .15         .15
.15         .15         .15         .15         .15         .15
.15         .15         .15         .15         .15         .15
.15         .15         .15         .15         .15         .15
.15         .15         .15         .15         .15         .15
.15         .15         .15         .15         .15         .15
.15         .15         .15         .15         .15         .15
.15         .15         .15         .15         .15         .15
.15         .15         .15         .15         .15         .15
.15         .15         .15         .15         .15         .15
.15         .15         .15         .15         .15         .15
.15         .15         .15         .15         .15         .15
.15         .15         .15         .15         .15         .15
.15         .15         .15         .15         .15         .15
.15         .15         .15         .15         .15         .15
# Fecundity Option
0
# Fraction of year that elapses prior to SSB calculation (0=Jan-
1)
0.42
# Maturity
0           0           .8          1           1           1
1           1           1           1           1           1
0           0           .8          1           1           1
1           1           1           1           1           1
0           0           .8          1           1           1
1           1           1           1           1           1
0           0           .8          1           1           1
1           1           1           1           1           1
0           0           .8          1           1           1
1           1           1           1           1           1
0           0           .8          1           1           1
1           1           1           1           1           1
0           0           .8          1           1           1
1           1           1           1           1           1
0           0           .8          1           1           1
1           1           1           1           1           1
0           0           .8          1           1           1
1           1           1           1           1           1
0           0           .8          1           1           1
1           1           1           1           1           1
0           0           .8          1           1           1
1           1           1           1           1           1
0           0           .8          1           1           1
1           1           1           1           1           1
0           0           .8          1           1           1
1           1           1           1           1           1
0           0           .8          1           1           1
1           1           1           1           1           1
0           0           .8          1           1           1
1           1           1           1           1           1
0           0           .8          1           1           1
1           1           1           1           1           1
```

```
0          0          .8          1          1          1
1          1          1           1          1          1
0          0          .8          1          1          1
1          1          1           1          1          1
0          0          .8          1          1          1
1          1          1           1          1          1
0          0          .8          1          1          1
1          1          1           1          1          1
0          0          .8          1          1          1
1          1          1           1          1          1
0          0          .8          1          1          1
1          1          1           1          1          1
0          0          .8          1          1          1
1          1          1           1          1          1
0          0          .8          1          1          1
1          1          1           1          1          1
0          0          .8          1          1          1
1          1          1           1          1          1
0          0          .8          1          1          1
1          1          1           1          1          1
# Number of Weights at Age Matrices
2
# Weight Matrix - 1
0.07          0.27          0.6           0.76
0.9           1.09          1.25          1.51
1.61          2.02          2.15          2.67
0.07          0.27          0.6           0.76
0.9           1.09          1.25          1.51
1.61          2.02          2.15          2.67
0.07          0.27          0.6           0.76
0.9           1.09          1.25          1.51
1.61          2.02          2.15          2.67
0.07          0.27          0.6           0.76
0.9           1.09          1.25          1.51
1.61          2.02          2.15          2.67
0.07          0.27          0.6           0.76
0.9           1.09          1.25          1.51
1.61          2.02          2.15          2.67
0.07          0.27          0.6           0.76
0.9           1.09          1.25          1.51
1.61          2.02          2.15          2.67
0.09          0.09          0.66          0.78
0.77          0.91          1.2           1.42
1.67          2.01          2.82          3.58
0             0.57          0.83          0.82
0.88          1.09          1.07          1.54
1.57          2.61          2.73          3.33
0.05          0.27          0.59          0.84
0.92          1.04          1.18          1.49
1.76          1.73          1.48          2.31
0.07          0.17          0.37          0.58
0.89          1.16          1.37          1.58
1.44          2.33          2.31          2.59
0.12          0.25          0.55          0.78
```

1.03	1.22	1.43	1.5
1.61	1.39	1.4	1.53
0	0.23	0.99	1.01
1.17	1.3	1.64	1.73
2.05	2.09	2.34	3.45
0.14	0.26	0.91	1.21
1.22	1.27	1.28	1.57
1.8	1.97	2.36	3.18
0	0.18	0.37	1.03
1.22	1.31	1.57	1.8
2.1	2.23	2.21	3.8
0	0.21	1.01	1.03
1.11	1.16	1.52	1.88
2.13	3.23	2.74	4.17
0	0.36	0.62	1.06
1.13	1.21	1.33	1.58
1.76	1.89	2.16	3.49
0.07	0.61	0.86	1.12
1.14	1.22	1.34	1.5
2.37	2.14	2.24	4.58
0	0.47	0.6	0.93
1.05	1.16	1.31	1.53
1.72	2.37	1.97	3.44
0.05	0.7	1.05	1.07
1.22	1.29	1.36	1.6
1.78	1.94	1.97	2.52
1.22	0.26	0.79	0.98
1.14	1.26	1.31	1.44
1.73	1.96	2.27	3.21
0.12	0.32	0.9	1.15
1.18	1.23	1.36	1.79
2.01	2.26	2.69	3.35
0.13	0.6	0.94	1.12
1.26	1.3	1.31	1.6
1.77	2.28	2.46	2.69
0.11	0.26	0.86	1.07
1.15	1.34	1.53	1.73
1.64	2.09	2.3	3.53
0.15	0.29	0.56	0.85
1.25	1.48	1.54	1.64
2.18	1.86	2.63	3.09
0.17	0.46	0.78	1.17
1.28	1.48	1.78	1.76
2.07	2.44	2.94	2.93
0.1	0.52	0.91	1.15
1.28	1.46	1.63	2.02
2.32	2.32	3.81	3.76
# Weight Matrix - 2			
0.307	0.448	0.61	0.79
0.984	1.187	1.398	1.613
1.83	2.045	2.258	3.298
0.307	0.448	0.61	0.79
0.984	1.187	1.398	1.613
1.83	2.045	2.258	3.298

0.307	0.448	0.61	0.79
0.984	1.187	1.398	1.613
1.83	2.045	2.258	3.298
0.307	0.448	0.61	0.79
0.984	1.187	1.398	1.613
1.83	2.045	2.258	3.298
0.307	0.448	0.61	0.79
0.984	1.187	1.398	1.613
1.83	2.045	2.258	3.298
0.307	0.448	0.61	0.79
0.984	1.187	1.398	1.613
1.83	2.045	2.258	3.298
0.307	0.448	0.61	0.79
0.984	1.187	1.398	1.613
1.83	2.045	2.258	3.298
0.307	0.448	0.61	0.79
0.984	1.187	1.398	1.613
1.83	2.045	2.258	3.298
0.307	0.448	0.61	0.79
0.984	1.187	1.398	1.613
1.83	2.045	2.258	3.298
0.307	0.448	0.61	0.79
0.984	1.187	1.398	1.613
1.83	2.045	2.258	3.298
0.307	0.448	0.61	0.79
0.984	1.187	1.398	1.613
1.83	2.045	2.258	3.298
0.307	0.448	0.61	0.79
0.984	1.187	1.398	1.613
1.83	2.045	2.258	3.298
0.307	0.448	0.61	0.79
0.984	1.187	1.398	1.613
1.83	2.045	2.258	3.298
0.307	0.448	0.61	0.79
0.984	1.187	1.398	1.613
1.83	2.045	2.258	3.298
0.307	0.448	0.61	0.79
0.984	1.187	1.398	1.613
1.83	2.045	2.258	3.298
0.307	0.448	0.61	0.79
0.984	1.187	1.398	1.613
1.83	2.045	2.258	3.298
0.307	0.448	0.61	0.79
0.984	1.187	1.398	1.613
1.83	2.045	2.258	3.298
0.307	0.448	0.61	0.79
0.984	1.187	1.398	1.613
1.83	2.045	2.258	3.298
0.307	0.448	0.61	0.79
0.984	1.187	1.398	1.613
1.83	2.045	2.258	3.298
0.307	0.448	0.61	0.79
0.984	1.187	1.398	1.613
1.83	2.045	2.258	3.298

```
0.307           0.448           0.61            0.79
0.984           1.187           1.398           1.613
1.83            2.045           2.258           3.298
0.307           0.448           0.61            0.79
0.984           1.187           1.398           1.613
1.83            2.045           2.258           3.298
0.307           0.448           0.61            0.79
0.984           1.187           1.398           1.613
1.83            2.045           2.258           3.298
0.307           0.448           0.61            0.79
0.984           1.187           1.398           1.613
1.83            2.045           2.258           3.298
0.307           0.448           0.61            0.79
0.984           1.187           1.398           1.613
1.83            2.045           2.258           3.298
0.307           0.448           0.61            0.79
0.984           1.187           1.398           1.613
1.83            2.045           2.258           3.298
# Weights at Age Pointers
1
1
1
1
2
2
# Selectivity Block Assignment
# Fleet 1 Selectivity Block Assignment
1
1
1
1
1
1
1
1
1
2
2
2
2
2
2
3
3
3
3
3
3
3
3
4
4
4
# Selectivity Options for each block 1=by age, 2=logisitic, 3
```

```
=double logistic
2  2  2  2
# Selectivity Block #1 Data
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                0                0                0
0                0                0                0
0                0                0                0
0                0                0                0
0                0                0                0
5                2                0                0
0.6              2                0                0
0                0                0                0
0                0                0                0
0                0                0                0
0                0                0                0
# Selectivity Block #2 Data
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                0                0                0
0                0                0                0
0                0                0                0
0                0                0                0
0                0                0                0
5                2                0                0
0.6              2                0                0
0                0                0                0
0                0                0                0
0                0                0                0
0                0                0                0
# Selectivity Block #3 Data
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                0                0                0
0                0                0                0
0                0                0                0
0                0                0                0
0                0                0                0
5                2                0                0
```

```
0.6             2               0               0
0               0               0               0
0               0               0               0
0               0               0               0
0               0               0               0
# Selectivity Block #4 Data
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               0               0               0
0               0               0               0
0               0               0               0
0               0               0               0
0               0               0               0
5               2               0               0
0.6             2               0               0
0               0               0               0
0               0               0               0
0               0               0               0
0               0               0               0
# Fleet Start Age
1
# Fleet End Age
12
# Age Range for Average F
8  12
# Average F report option (1=unweighted, 2=Nweighted, 3
=Bweighted)
2
# Use Likelihood constants? (1=yes)
0
# Release Mortality by Fleet
.025
# Catch Data
# Fleet-1 Catch Data
2.29            29.65           191.751         253.225
224.377         137.603         80.707          77.158
44.761          24.04           25.414          53.576
927.2317325
14.287          47.776          247.942         386.507
363.157         196.48          87.41           71.433
51.002          22.275          13.365          34.411
1183.004296
0               23.563          254.144         342.001
364.218         212.236         113.608         109.905
71.531          45.948          36.859          108.895
1696.443787
58.48           124.39          233.369         380.876
232.956         108.704         74.166          48.985
28.483          22.566          14.861          48.16
```

1554.140048			
11.401	66.003	211.329	350.416
200.769	116.885	76.923	47.282
28.681	16.441	18.721	55.082
1194.982511			
0	0	44.988	60.561
157.504	36.883	31.783	26.091
15.163	17.85	2.869	61.699
418.9167592			
0.178	0.16	29.141	130.248
267.904	154.113	106.537	67.74
26.108	38.669	4.402	36.665
935.2385055			
0	8.678	56.641	121.276
174.235	104.334	57	34.812
12.606	10.938	10.034	11.15
640.8222493			
0.02	1.506	15.129	32.857
46.567	75.873	49.048	34.985
16.925	8.525	3.406	6.531
319.0592707			
0.044	1.676	3.235	9.667
11.581	10.449	7.474	4.857
1.986	1.248	0.556	1.163
61.70122495			
0.179	4.052	7.478	13.997
51.883	61.858	61.315	40.55
18.4	7.568	3.251	2.68
351.4289506			
0	1.204	88.873	65.112
84.413	77.897	110.887	57.512
20.013	21.165	13.646	23.654
944.1605267			
0.418	1.68	36.913	113.346
72.093	72.963	87.983	68.732
52.519	19.785	10.033	18.824
789.6749847			
0	0.43	3.057	63.504
154.4	134.493	92.422	71.675
31.473	22.162	9.943	28.161
947.9140127			
0	0.2	6.7	22.145
47.012	62.091	27.707	16.439
10.517	4.513	5.455	10.747
250.3209027			
0	2.026	6.624	25.907
42.038	35.679	22.629	10.345
8.932	4.345	2.036	12.536
237.4199129			
0.029	0.635	10.266	24.879
18.451	14.686	9.952	6.037
3.555	1.404	1.01	3.834
130.2893848			
0	2.987	6.115	31.336

```
70.263          110.758         70.822          40.998
25.529          13.027          4.316           9.721
555.5820358
0.018           5.494           54.503          76.236
65.888          60.99           51.2            40.958
29.5            16.535          7.781           13.762
646.3010123
0.246           2.399           22.75           64.409
66.923          48.373          36.679          24.735
16.464          10.552          10.673          23.294
447.0617118
0.076           6.326           17.05           39.964
80.215          69.508          38.44           21.001
12.791          5.977           3.974           11.921
450.2796357
0.149           6.202           86.787          139.419
112.169         69.371          35.1            24.269
5.914           4.491           2.954           2.371
602.3342576
0.37            1.805           25.191          83.762
63.112          40.155          19.285          9.367
3.422           2.308           1.417           6.947
328.9524909
0.177           2.801           7.105           6.28
17.928          25.103          20.439          9.327
9.134           1.675           2.58            4.353
165.307588
0.159           4.966           18.694          33.928
41.612          42.252          23.209          15.41
8.425           4.668           0.921           3.973
308
0.256           11.168          30.544          69.86
107.074         90.427          63.2            21.977
11.96           6.011           1.783           16.847
654
# Discards
# Fleet-1 Discards Data
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
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0
# Release Proportion
# Fleet-1 Release Data
0	0	0	0
0	0	0	0
0	0	0	0
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0               0               0               0
0               0               0               0
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0               0               0               0
0               0               0               0
# Survey Index Data
# Aggregate Index Units
2  2  2
# Age Proportion Index Units
2  2  2
# Weight at Age Matrix
2  2  2
# Index Month
5  6  6
# Index Selectivity Link to Fleet
-1  -1  -1
# Index Selectivity Options 1=by age, 2=logisitic, 3=double
logistic
1  2  2
# Index Start Age
1  1  1
# Index End Age
1  12  12
# Estimate Proportion (Yes=1)
0  1  1
# Use Index (Yes=1)
1  1  1
# Index-1 Selectivity Data
1               -1              0               1
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
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0               0               0               0
0               0               0               0
0               0               0               0
# Index-2 Selectivity Data
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
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0               0               0               0
0               0               0               0
0               0               0               0
0               0               0               0
0               0               0               0
5               2               0               0
0.6             2               0               0
0               0               0               0
0               0               0               0
0               0               0               0
0               0               0               0
# Index-3 Selectivity Data
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               0               0               0
0               0               0               0
0               0               0               0
0               0               0               0
0               0               0               0
5               2               0               0
0.6             2               0               0
0               0               0               0
0               0               0               0
0               0               0               0
0               0               0               0
# Index-1 Data
1989  1.28            1.36            0               0
0               0               0               0
0               0               0               0
0               0               0
1990  0.994           1.46            0               0
0               0               0               0
0               0               0               0
0               0               0
1991  0.407           1.29            0               0
0               0               0               0
0               0               0               0
0               0               0
1992  0.421           1.39            0               0
0               0               0               0
0               0               0               0
0               0               0
1993  0.013           2.98            0               0
0               0               0               0
0               0               0               0
0               0               0
1994  0.121           1.62            0               0
0               0               0               0
0               0               0               0
```

0 0 0
1995 0.09 2.05 0 0
0 0 0 0
0 0 0 0
0 0 0
1996 0.052 3.34 0 0
0 0 0 0
0 0 0 0
0 0 0
1997 0 2.5 0 0
0 0 0 0
0 0 0 0
0 0 0
1998 0.052 2.33 0 0
0 0 0 0
0 0 0 0
0 0 0
1999 0.853 1.23 0 0
0 0 0 0
0 0 0 0
0 0 0
2000 0.634 1.16 0 0
0 0 0 0
0 0 0 0
0 0 0
2001 1.112 1.32 0 0
0 0 0 0
0 0 0 0
0 0 0
2002 0.135 1.6 0 0
0 0 0 0
0 0 0 0
0 0 0
2003 0.24 1.5 0 0
0 0 0 0
0 0 0 0
0 0 0
2004 1.859 1.24 0 0
0 0 0 0
0 0 0 0
0 0 0
2005 1.477 1.2 0 0
0 0 0 0
0 0 0 0
0 0 0
2006 0.622 1.3 0 0
0 0 0 0
0 0 0 0
0 0 0
2007 1.041 1.24 0 0
0 0 0 0
0 0 0 0
0 0 0
2008 0.423 1.46 0 0

```
0              0              0              0
0              0              0              0
0              0              0
2009  0.042          2.78           0              0
0              0              0              0
0              0              0              0
0              0              0
2010  0              2.5            0              0
0              0              0              0
0              0              0              0
0              0              0
2011  0.066          2.29           0              0
0              0              0              0
0              0              0              0
0              0              0
2012  2.745          1.17           0              0
0              0              0              0
0              0              0              0
0              0              0
2013  0.706          1.31           0              0
0              0              0              0
0              0              0              0
0              0              0
2014  0.922          1.17           0              0
0              0              0              0
0              0              0              0
0              0              0
# Index-2 Data
1989  1.27           0.5            0.03           0.06
0.13           0.21           0.13           0.12
0.09           0.07           0.05           0.03
0.02           0.05           16
1990  1.57           0.53           0              0.03
0.17           0.22           0.2            0.12
0.07           0.07           0.04           0.02
0.02           0.05           16
1991  0.99           0.52           0.01           0.03
0.16           0.25           0.24           0.13
0.06           0.05           0.03           0.01
0.01           0.02           16
1992  1.32           0.51           0              0.01
0.15           0.2            0.22           0.13
0.07           0.07           0.04           0.03
0.02           0.06           16
1993  0.69           0.52           0.04           0.09
0.17           0.28           0.17           0.08
0.05           0.04           0.02           0.02
0.01           0.04           16
1994  0.43           0.54           0.01           0.06
0.18           0.29           0.17           0.1
0.06           0.04           0.02           0.01
0.02           0.05           16
1995  0.6            0.52           0              0
0.07           0.14           0.36           0.09
```

0.07 0.05 0.03 0.03
0.01 0.13 16
1996 0.2 0.55 0.01 0.13
0.11 0.28 0.18 0.07
0.04 0.03 0.04 0.04
0.02 0.06 16
1997 0.11 0.59 0 0.05
0.09 0.2 0.17 0.15
0.12 0.09 0.05 0.03
0.01 0.04 16
1998 0.3 0.53 0.01 0.02
0.07 0.21 0.17 0.15
0.12 0.08 0.04 0.04
0.03 0.05 16
1999 0.62 0.52 0.06 0.08
0.11 0.12 0.18 0.17
0.12 0.08 0.04 0.01
0.01 0 16
2000 0.33 0.54 0.08 0.13
0.14 0.17 0.15 0.09
0.09 0.07 0.02 0.01
0.02 0.02 16
2001 0.29 0.55 0.06 0.09
0.21 0.17 0.2 0.08
0.05 0.04 0.02 0.02
0.01 0.06 16
2002 1.48 0.5 0.01 0.02
0.1 0.22 0.26 0.14
0.08 0.06 0.03 0.02
0.01 0.06 16
2003 0.6 0.52 0 0
0.02 0.24 0.21 0.24
0.11 0.09 0.04 0.02
0.02 0.02 16
2004 0.35 0.54 0.01 0.14
0.26 0.17 0.18 0.13
0.04 0.02 0.01 0
0 0.04 16
2005 0.66 0.54 0.04 0.11
0.24 0.18 0.17 0.07
0.05 0.04 0.02 0.02
0.02 0.03 16
2006 0.76 0.52 0 0.06
0.03 0.19 0.17 0.15
0.12 0.07 0.07 0.05
0.03 0.06 16
2007 0.36 0.53 0 0.07
0.17 0.35 0.14 0.07
0.06 0.04 0.04 0.02
0.01 0.03 16
2008 0.9 0.51 0.01 0.03
0.1 0.2 0.19 0.12
0.09 0.07 0.05 0.03
0.03 0.07 16

```
2009  0.57          0.52          0.03          0.18
0.19          0.17          0.17          0.07
0.07          0.04          0.03          0.01
0.01          0.04          16
2010  0.44          0.53          0.02          0.1
0.35          0.17          0.12          0.08
0.04          0.03          0.01          0.01
0.02          0.05          16
2011  0.14          0.59          0.08          0.16
0.22          0.21          0.19          0.08
0.04          0.02          0             0
0             0             16
2012  0.25          0.55          0.06          0.21
0.4           0.13          0.1           0.05
0.03          0.02          0             0
0             0             16
2013  0.42          0.53          0.02          0.32
0.28          0.14          0.1           0.05
0.03          0.03          0.01          0
0             0.02          16
2014  0.72          0.53          0.02          0.35
0.2           0.12          0.11          0.07
0.05          0.03          0.02          0.01
0             0.02          16
# Index-3 Data
1989  2.54          0.38          0.002         0.0259
0.1675        0.2212        0.196         0.1202
0.0705        0.0674        0.0391        0.021
0.0222        0.0468        0
1990  1.47          0.34          0.0093        0.0311
0.1614        0.2516        0.2364        0.1279
0.0569        0.0465        0.0332        0.0145
0.0087        0.0224        0
1991  1.77          0.31          0             0.014
0.151         0.2032        0.2164        0.1261
0.0675        0.0653        0.0425        0.0273
0.0219        0.0647        0
1992  2.4           0.34          0.0425        0.0904
0.1696        0.2768        0.1693        0.079
0.0539        0.0356        0.0207        0.0164
0.0108        0.035         0
1993  1.85          0.38          0.0095        0.055
0.1761        0.292         0.1673        0.0974
0.0641        0.0394        0.0239        0.0137
0.0156        0.0459        0
1994  1.37          0.48          0             0
0.0988        0.133         0.3459        0.081
0.0698        0.0573        0.0333        0.0392
0.0063        0.1355        0
1995  0.88          0.53          0.0037        0.0037
0.0976        0.1879        0.4035        0.1227
0.0758        0.0485        0.0162        0.0196
0.0022        0.0187        19
1996  1.05          0.5           0             0.0783
```

0.1079	0.2877	0.2737	0.1178
0.056	0.0402	0.0107	0.0094
0.0084	0.0099	19	
1997 0.72	0.49	0.0011	0.0497
0.1717	0.2235	0.17	0.176
0.0989	0.0494	0.0347	0.0119
0.0049	0.0082	19	
1998 0.6	0.62	0.0042	0.1174
0.1936	0.3633	0.1803	0.0757
0.0378	0.0072	0.0176	0.0015
0.0005	0.0011	19	
1999 0.67	0.52	0.0064	0.1107
0.1071	0.1391	0.1899	0.1559
0.1374	0.0793	0.0391	0.0133
0.0172	0.0047	19	
2000 0.23	0.54	0	0.0301
0.1523	0.3187	0.1606	0.0766
0.1046	0.0556	0.0375	0.0319
0.0089	0.0231	19	
2001 0.28	0.41	0.0096	0.0361
0.1774	0.2576	0.2343	0.0976
0.0666	0.05	0.0327	0.0124
0.0059	0.02	19	
2002 1.01	0.45	0	0.007
0.0663	0.2894	0.3043	0.1486
0.0639	0.0456	0.0211	0.0147
0.0077	0.0314	19	
2003 0.82	0.43	0	0.0236
0.0174	0.1673	0.2246	0.2225
0.0822	0.06	0.0386	0.0288
0.0268	0.1083	19	
2004 0.67	0.45	0.0036	0.0923
0.1542	0.1144	0.1901	0.1054
0.0579	0.0268	0.0377	0.0172
0.0111	0.1893	19	
2005 0.84	0.52	0	0.0471
0.2071	0.1897	0.2231	0.1082
0.066	0.068	0.0227	0.0135
0.0087	0.0459	19	
2006 1.08	0.49	0	0.0082
0.0929	0.3309	0.2554	0.147
0.0717	0.0385	0.0253	0.0156
0.0056	0.0088	19	
2007 0.93	0.48	0	0.0274
0.163	0.31	0.1838	0.1042
0.079	0.053	0.0364	0.0203
0.0115	0.0114	19	
2008 0.9	0.46	0.0003	0.0347
0.1729	0.3007	0.2364	0.0993
0.059	0.0321	0.0209	0.0116
0.0109	0.0212	19	
2009 0.82	0.47	0.003	0.1738
0.1982	0.1949	0.2197	0.079
0.0885	0.0173	0.0104	0.0046

```
0.0028          0.008           19
2010  0.87            0.5             0               0.0688
0.4104          0.239           0.1253          0.0926
0.0297          0.0188          0.0043          0.0034
0.003           0.0047          19
2011  0.79            0.54            0.0134          0.0498
0.2464          0.3162          0.2306          0.0922
0.0284          0.0104          0.0044          0.0023
0.0012          0.0047          19
2012  0.71            0.53            0.015           0.1388
0.3632          0.2166          0.1115          0.0696
0.0415          0.022           0.0114          0.0023
0.003           0.0051          19
2013  0.55            0.53            0.0026          0.2396
0.2679          0.1239          0.171           0.0758
0.0415          0.0385          0.0139          0.0087
0.0056          0.0111          19
2014  1.11            0.53            0.0106          0.2975
0.2118          0.1534          0.1452          0.0824
0.0541          0.0171          0.0091          0.0046
0.0014          0.0128          19
# Phase Control
# Phase for F mult in 1st Year
1
# Phase for F mult Deviations
2
# Phase for Recruitment Deviations
2
# Phase for N in 1st Year
2
# Phase for Catchability in 1st Year
3
# Phase for Catchability Deviations
-1
# Phase for Stock Recruitment Relationship
3
# Phase for Steepness
3
# Recruitment CV by Year
.5
.5
.5
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Lambdas by Index
1 1 1
Lambda for Total Catch in Weight by Fleet
1
Lambda for Total Discards at Age by Fleet
1
Catch Total CV by Year and Fleet
0.164
0.1387
0.1324
0.1661
0.2179
0.259
0.2607
0.3902
0.2643
0.4499
0.3513
0.328
0.1993
0.2676
0.2667
0.3728
0.3162
0.374
0.2288
0.2268
0.197
0.4314
0.3332
0.2855
0.3261
0.5215
Discard Total CV by Year and Fleet
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
Catch Effective Sample Size by Year and Fleet
0
0
0
0
0
0
40
41
33
18
38
33
62
67
45
62
33
56
59
84
67
57
51
37
40
40
Discard Effective Sample Size by Year and Fleet
0
0
0
0
0
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0

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0
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0
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0
0
0
0
0
0
0
0
0
# Lambda for F Mult in First year by Fleet
0
# CV for F Mult in First year by Fleet
0.5
# Lambda for F Mult Deviations by Fleet
0.5
# CV for F Mult Deviations by Fleet
0.5
# Lambda for N in 1st Year Deviations
0
# CV for N in 1st Year Deviations
0.5
# Lambda for Recruitment Deviations
.5
# Lambda for Catchability in First year by Index
0  0  0
# CV for Catchability in First year by Index
1  1  1
# Lambda for Catchability Deviations by Index
0  0  0
# CV for Catchability Deviations by Index
1  1  1
# Lambda for Deviation from Initial Steepness
0
# CV for Deviation from Initial Steepness
0.5
# Lambda for Deviation from Unexploited Stock Size
0
# CV for Deviation from Unexploited Stock Size
0.5
# NAA Deviations Flag
2
# Initial Numbers at Age in 1st Year
2487  2103  1762  1385  1067  767  557  426  268  191  127  279
# Initial F Mult in 1st Year by Fleet
1
# Initial Catchabilty by Index
```

```
.001  .001  .001
# Stock Recruitment Flag
0
# Initial Unexploited Stock
1000
# Initial Steepness
.7
# Maximum F
100
# Ignore Guesses (Yes=1)
0
# Projection Control
# Do Projections (Yes=1)
0
# Fleet Directed Flag
1
# Final Year in Projection
2015
# Projection Data by Year
2015     -1         3     -99        1
# Do MCMC (Yes=1)
1
# MCMC Year Option
0
# MCMC Iterations
1000
# MCMC Thinning Factor
200
# MCMC Random Seed
1126
# Agepro R Option
2
# Agepro R Option Start Year
1989
# Agepro R Option End Year
2014
# Export R Flag
1
# Test Value
-23456
######
###### FINIS ######
# Fleet Names
#$All removals
# Survey Names
#$NY seine
#$NJ trawl
#$MRFSS
#
```

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Tautog Tagging Trial
Preliminary Methods
July 12, 2016

The Tautog Management Board (Board) formed a Law Enforcement Sub-Committee (Subcommittee) in 2015 to investigate the illegal harvest of tautog and provide intervention recommendations. At the suggestion of the Subcommittee, the Board is exploring tagging alternatives as part of a proposed commercial harvest tagging program. The Subcommittee has developed program objectives, procured tags and interviewed industry members to test the feasibility of a commercial harvest tagging program (see May Subcommittee meeting summary). The next step is a tank trial with research partners to test the feasibility of applying tags to live tautog.

The New York Division of Marine Resources and Stony Brook University are leading a tank trial to investigate the impacts of tagging live tautog. The following describes the materials that will be used in the study, the collection methods and the preliminary design of the tank trial. This is a working document; the methods described in this document are subject to change.

The research team is currently experimenting with tag locations on dead tautog. Two out of the three tags are traditionally used for livestock, therefore, the team is actively trying to determine if the tags will fit on a fish. In addition, the research team is taking the necessary steps to adhere to Stony Brook University's Vertebrae Handling Protocol. The trial is expected to begin in August 2016.

Research Team

- New York Division of Marine Resources
- Stony Brook University, School of Marine and Atmospheric Sciences

Materials

- The trial will take place at Flax Pond Marine Laboratory (Stony Brook, New York)
- A total of three tags will be tested: strap tag, button tag and a rototag. The tags and applicators have been transferred to the research team. *(Image A-C)*
- 10 ventless traps will be used to collect tautog in the Long Island Sound *(Image D)*
- A large holding pen was constructed for the dock *(Image E)*

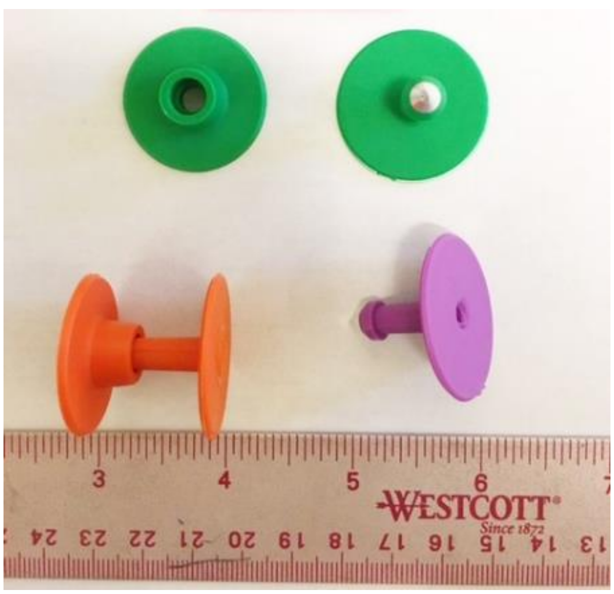
Collection Methods

- Overall, eighty tautog will be collected from the Long Island Sound. There will be two replicates of the treatment (tag application), therefore, 40 fish will be collected for the first replicate and another forty fish will be collected for the second replicate
- Fish will be collected using ventless fish traps
- Fish will be transferred from the traps to a holding pen at the dock, where they will remain for 1-2 days or until forty fish are collected
- Fish will be transferred from the holding pen to the wet lab for the tank trial

Tank Trial Methods

- Length: Each fish will be tagged and monitored for 4 weeks
- Replicate 1
  - 10 fish will be tagged with Tag A
  - 10 fish will be tagged with Tab B
  - 10 fish will be tagged with Tag C
  - 10 fish will serve as the control
- Replicate 2
  - 10 fish will be tagged with Tag A
  - 10 fish will be tagged with Tab B
  - 10 fish will be tagged with Tag C
  - 10 fish will serve as the control
- Stocking density: 10 fish per tank
- Tank: 6' x 3' cylindrical tanks *(Image F)*
- Open flow, salt water set at 55-60 degrees
- Food: fiddler crabs or mussels, 2-3x per week

Image A: Button Tag



QC Supply – button tag that is attached with an applicator; tag traditionally used for livestock, *could* be attached to the operculum or base of the caudal fin

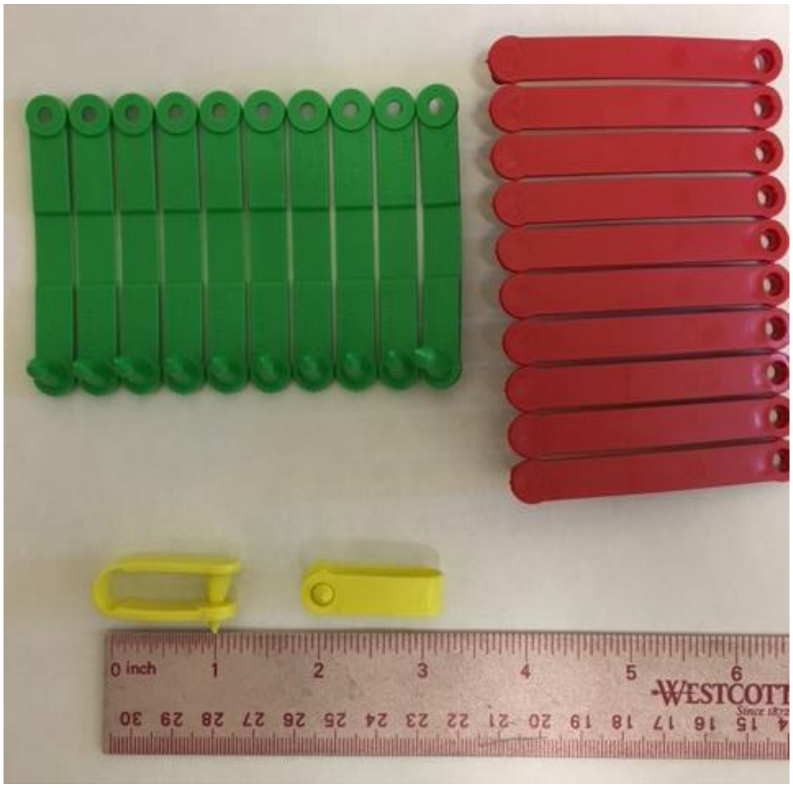
- *Subcommittee feedback:* The tag is heavy duty and cannot be easily manipulated or re-used. It comes in multiple colors and has enough room to apply state, year and unique ID. There was concern that it might be too large for a fish and since it is a generic livestock tag it might be easily obtained online (and duplicated illegally).

Image B: Strap Tag

National Band – strap tag made of monel (nickel-copper); attached to the operculum or lower jaw with an applicator, does not come in other colors

- *Subcommittee feedback:* The best option as far as size. Law enforcement attempted to open the tag using pliers and was not successful, as it was deformed in a manner that would be noticeable. The durability of the tag outweighed the lack of color options (i.e. silver only).
- The following unique IDs can be applied to each tag: (6 refers to the year, 2016)
  - Massachusetts: M#####6 (# range from 1-20,000)
  - Rhode Island: R#####6 (# range from 1-18,000)
  - Connecticut: C####6 (# range from 1-2,000)
  - New York: Y#####6 (# range from 1-40,000)
  - Etc.

Image C: Rototag



OS ID (Norway based) – rototag that is generally attached the operculum or base of the dorsal fin via an applicator

- *Subcommittee feedback:* The variety of colors is favorable, however the tag may be too large. Given these are also used in the livestock industry, staff should look for similar tags by a U.S. based company. However, if the tags are readily available then they might be easy to replicate.

Image D. 10 Ventless Traps

Image E: Holding Pen

Image F: Fish Tanks