Atlantic States Marine Fisheries Commission

Shad and River Herring Management Board

August 4, 2020
8:30 a.m. – 12:00 p.m.
Webinar

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 *(M. Armstrong)*	8:30 a.m.
2.	Board Consent • Approval of Agenda • Approval of Proceedings from October 2019	8:30 a.m.
3.	Public Comment	8:35 a.m.
4.	Consider 2020 Shad Benchmark Stock Assessment **Action** • Presentation of Stock Assessment Report *(M. Bailey)* • Presentation of Peer Review Panel Report *(K. Limburg)* • Consider Acceptance of Benchmark Stock Assessment and Peer Review Report for Management Use *(M. Armstrong)* • Consider Management Response to the Assessment and Peer Review *(M. Armstrong)*	8:45 a.m.
5.	Break	10:10 a.m.
6.	Consider State Proposals to Resolve Inconsistencies with Amendments 2 and 3 **Action** • Presentation of State Proposals and Technical Committee Recommendations *(K. Sprankle)* • Consider Approval of State Proposals	10:25 a.m.
7.	Update on River Herring Technical Expert Work Group Activities *(C. Starks)*	11:35 a.m.
8.	Update on Timeline for Shad Habitat Plan Updates *(C. Starks)*	11:45 a.m.
9.	Elect Vice-Chair *(M. Armstrong)* **Action**	11:55 a.m.
10.	Other Business/Adjourn	12:00 p.m.

This meeting will be held via webinar, click here for details.

MEETING OVERVIEW

Shad and River Herring Management Board Meeting
August 4, 2020
8:30 a.m. – 12:00 p.m.
Webinar

Chair: Mike Armstrong (MA) Assumed Chairmanship: 10/19	Technical Committee Chair: Ken Sprankle (FWS)	Law Enforcement Committee Representative: Furlong (PA)
Vice Chair: VACANT	Advisory Panel Chair: Pam Lyons Gromen	Previous Board Meeting: October 30, 2019
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 October 2019

3. Public Comment – At the beginning of the meeting public comment will be taken on items not on the agenda. Individuals that wish to speak at this time must sign-in at the beginning of the meeting. For agenda items that have already gone out for public hearing and/or have had a public comment period that has closed, the Board Chair may determine that additional public comment will not provide additional information. In this circumstance the Chair will not allow additional public comment on an issue. For agenda items that the public has not had a chance to provide input, the Board Chair may allow limited opportunity for comment. The Board Chair has the discretion to limit the number of speakers and/or the length of each comment.

4. Consider 2020 American Shad Benchmark Stock Assessment (8:45-10:10 a.m.) Action
Background • The American Shad Benchmark Stock Assessment was initiated in October 2017. After delays in the proposed timeline, the scheduled completion date was moved to August 2020. • The final Assessment Workshop was held November 18-22, 2019 in Charleston, SC. • The assessment evaluated the condition of Atlantic coast American shad stocks and habitat availability on a system-specific and coastwide metapopulation basis (**Briefing Materials)**. • The assessment was peer-reviewed virtually by a panel of independent experts June 2-5, 2020. The Peer Review Report provides the panel's evaluation of the assessment findings (**Briefing Materials**).
Presentations • Overview of Benchmark Stock Assessment by M. Bailey • Presentation of Peer Review Report by K. Limburg
Board actions for consideration at this meeting • Consider the stock assessment for management use • Consider management response to the assessment and peer review

5. Break (10:10-10:25 p.m.)

6. Consider State Proposals to Resolve Inconsistencies with Amendments 2 and 3 (10:25-11:35 a.m.) Action

Background

- In October 2017 the TC identified several inconsistencies between state SFMPs and the requirements of Amendments 2 and 3. Subsequently, the Board tasked the TC to develop proposed improvements to the Amendments with regard to several items: 1) Management and monitoring of rivers with low abundance and harvest of shad and river herring; 2) Standardization of Sustainable Fishery Management Plan (SFMP) requirements; 3) Incorporation of stock assessment information into SFMPs and discussion on the timeline for renewing plans; 4) Clarification of *de minimis* requirements as they pertain to SFMPs; and 5) Review of the number of years of data required before developing a SFMP.
- In October 2019, the TC presented a report on inconsistencies with Amendments 2 and 3, describing state inconsistencies with the FMP and case-by-case recommendations to resolve issues. The Board requested that all states with identified inconsistencies submit updated or new SFMPs or Alternative Management Plans (AMPs) following the TC recommendations. During spring 2020, the TC reviewed state proposals from ME, NH, DE, NC, SC, GA, and FL. The TC recommended approval of all proposals (**Briefing Materials**).
- In addition to SFMP and AMP proposals, NH submitted a request to keep the river herring fishery open in 2020, despite not meeting the SFMP's fishery-independent target of a 3 year average of 350 fish per acre of spawning area; NH asserts that the target was not met due to fish counter malfunctions that caused gross underestimations of run counts at the Cocheco River Fishway, rather than population concerns. The TC has reviewed NH's request and supports this approach (**Briefing Materials**).
- The TC also reviewed a proposal from GA to modify the Savannah River sustainability metric in the American shad SFMP; reductions in commercial fishing activity in the Savanah River have rendered the current fishery-dependent SFMP sustainability metric insufficient for management. GA proposes use of a fishery-independent state sampling program for the metric instead. The TC recommends approval of this proposed change (**Briefing Materials**).

Presentations

- Technical Committee Recommendations on State Proposals to Resolve Inconsistencies with Amendments 2 and 3 by K. Sprankle

Board actions for consideration at this meeting

- Approval of proposed updates to SFMPs and AMPs to resolve inconsistencies with Amendments 2 and 3.

7. Update on River Herring Technical Expert Working Group Activities (11:35-11:45 a.m.)

Background

- The River Herring Technical Expert Working Group (TEWG) was established in 2014 to address significant data deficiencies for river herring species, and compile information for use by NOAA Fisheries and ASMFC in the development of a conservation plan.
- Recently, NOAA Fisheries has secured funding for a contractor to work on revising the 2015 River Herring Conservation Plan. The goal of this work will be to update and synthesize information on river herring threats, data and research needs, and recommended conservation actions into one document that will support conservation and restoration efforts for river herring along the Atlantic coast.

- TEWG leadership has also been considering renaming the group to reflect the change in function from a work group to an information exchange forum.

Presentations

- Update on River Herring Technical Expert Working Group Activities by C. Starks

8. Update on Timeline for Shad Habitat Plan Updates (11:45-11:55 a.m.)

Background

- Amendment 3 to the Shad and River Herring FMP requires all states and jurisdictions to submit a habitat plan for American shad. A majority of the habitat plans were approved by the Board in February 2014, and it was anticipated that they would be updated every five years.
- The states have begun the process of reviewing their American shad habitat plans, however, many states have encountered delays due to COVID-19. As such, it is unlikely that states will be able to provide updated plans for consideration at the 2020 Annual Meeting. Staff recommends states provide updated plans for consideration at the Winter 2021 ASMFC meeting.

Presentations

- Update on Timeline for Shad Habitat Plan Updates by C. Starks

Board actions for consideration at this meeting

- Direct states to provide updated shad habitat plans for consideration at the Winter 2021 ASMFC meeting.

9. Elect Vice-Chair (11:55-12:00 p.m.)

10. Other Business/Adjourn

Shad and River Herring 2020 TC Tasks

Activity level: High

Committee Overlap Score: Medium (Multi-species committees for this Board)

Committee Task List

• August-October 2020: TC Task to recommend improvements to Amendments 2 and 3 related to the following items:
  ◦ Management and monitoring of rivers with low abundance and harvest of shad and river herring
  ◦ Standardization of Sustainable Fishery Management Plan (SFMP) requirements: content, metrics, and management responses to triggers
  ◦ Incorporation of stock assessment information into SFMPs and discussion on the timeline for renewing plans
  ◦ Clarification of *de minimis* requirements as they pertain to SFMPs
  ◦ Review of the number of years of data are required before developing a SFMP
• August-December 2020: Updates to state Shad Habitat Plans

TC Members: Ken Sprankle (Chair, USFWS), Mike Brown (ME), Mike Dionne (NH), Brad Chase (MA), Patrick McGee (RI), Jacque Benway Roberts (CT), Wes Eakin (NY), Brian Neilan (Vice Chair, NJ), Josh Tryninewski (PA), Johnny Moore (DE), Rob Bourdon (MD), Ellen Cosby (PRFC), Joseph Swann (DC), Eric Hilton (VA), Holly White (NC), Jeremy McCargo (NC), Bill Post (SC), Jim Page (GA), Reid Hyle (FL), Ruth Hass-Castro (NOAA)
Shad SAS: Michael Bailey (Chair, USFWS), Ken Sprankle (TC Chair, USFWS-CT), Joey Ballenger (SC), Mike Bednarski (VA), Wes Eakin (NY), Kevin Sullivan (NH), Joe Zydlewski (USGS), Jacque Benway-Roberts (CT), Kiersten Curti (NOAA-Fisheries), Angela Giuliano (MD), Jason Boucher (DE)

DRAFT PROCEEDINGS OF THE

ATLANTIC STATES MARINE FISHERIES COMMISSION

SHAD AND RIVER HERRING MANAGEMENT BOARD

Wentworth by the Sea
New Castle, New Hampshire
October 30, 2019

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

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INDEX OF MOTIONS

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

2. **Approval of Proceedings of February 2019** by consent (Page 1).

3. **Main Motion**
   Move to direct the states to follow the TC recommendations. And to present to the board in February a plan with a timeline of how they will follow the TC recommendations (Page 8). Motion by Kevin Sullivan; second by Eric Reid.

4. **Motion to Substitute**
   Move to substitute to direct states to respond to the TC recommendation with a written proposal in time for Board consideration at the spring meeting of 2020. If the state does not submit a proposal by the 2020 spring meeting, the management board can take such actions necessary to implement the TC recommendations (Page 11). Motion by Spud Woodward; second by Mel Bell. Motion carried (Page 14).

   Main Motion as Substituted
   Move to direct states to respond to the TC recommendation with a written proposal in time for Board consideration at the spring meeting of 2020. If the state does not submit a proposal by the 2020 spring meeting, the management board can take such actions necessary to implement the TC recommendations. Motion by Spud Woodward; second by Mel Bell. Motion carried (Page 14).

5. **Move to approve Maine's proposal to modify the river herring SFMP as recommended by the TC** (Page 17). Motion by Sen. Miramant; second by Eric Reed. Motion carried (Page 19).

6. **Move to approve the 2019 2019 Shad and River Herring FMP Review, state compliance reports, and *de minimis* status for Maine, New Hampshire, Massachusetts and Florida** (Page 22). Motion by Lynn Fegley; second by Justin Davis. Motion carried (Page 22).

7. **Move to appoint Mike Thalhauser, Mark Amorello, and Chuckie Green to the Shad and River Herring Advisory Panel** (Page 22). Motion by Pat Keliher; second by Ray Kane. Motion carried (Page 22).

8. **Move to adjourn** by consent (Page 22).

ATTENDANCE

Board Members

Pat Keliher, ME (AA)
Steve Train, ME (GA)
Sen. David Miramant, ME (LA)
Kevin Sullivan, NH, proxy for D. Grout (AA)
Dennis Abbott, NH, proxy for Sen. Watters (LA)
Ritchie White, NH (GA)
Mike Armstrong, MA, proxy for D. Pierce (AA)
Raymond Kane, MA (GA)
Sarah Ferrara, MA, proxy for Rep. Peake (LA)
David Borden, RI (GA)
Phil Edwards, RI, proxy for J. McNamee (AA)
Eric Reid, RI, proxy for Sen. Sosnowski (LA)
Justin Davis, CT (AA)
Bill Hyatt, CT (GA)
Sen. Craig Miner, CT (LA)
Maureen Davidson, NY, proxy for J. Gilmore (AA)
Emerson Hasbrouck, NY (GA)
John McMurray, NY, proxy for Sen. Kaminsky (LA)
Heather Corbett, NJ, proxy for L. J. Cimino (AA)
Tom Fote, NJ (GA)
Adam Nowalsky, NJ, proxy for Sen. Andrzejczak (LA)
Andy Shiels, PA, proxy for T. Schaeffer (AA)
Loren Lustig, PA (GA)
John Clark, DE, proxy for D. Saveikis (AA)
Roy Miller, DE (GA)
Lynn Fegley, MD, proxy for B. Anderson (AA)
Russell Dize, MD (GA)
Phil Langley, MD, proxy for Del. Stein (LA)
Pat Geer, VA, proxy for Steve Bowman (AA)
Bryan Plumlee, VA (GA)
Chris Batsavage, NC, proxy for S. Murphey (AA)
Jerry Mannen, NC (GA)
Mike Blanton, NC, proxy for Sen. Steinburg (LA)
Mel Bell, SC, proxy for R. Boyles, Jr. (AA)
Malcolm Rhodes, SC (GA)
Sen. Ronnie Cromer, SC (LA)
Spud Woodward, GA (AA)
Doug Haymans, GA (GA)
Jim Estes, FL, proxy for J. McCawley (AA)
Rep. Thad Altman, FL (LA)
Martin Gary, PRFC
Bryan King, DC
Derek Orner, NMFS
Mike Millard, USFWS

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

Ex-Officio Members

Ken Sprankle, Technical Committee Chair
Larry Furlong, Law Enforcement Representative

Staff

Bob Beal
Toni Kerns
Maya Drzewicki
Caitlin Starks
Dustin Colson Leaning

Guests

Robert Atwood, NH F&G
Robert T. Brown, MWA
Victoria Brown, MWA
Roy Crabtree, NMFS
Kelly Denit, NMFS
Mike Dionne, NH F&G
Zak Greenberg, PEW Trusts
Doug Grout, NH (AA)
Anne Hayden, Manomet
Rebecca Heuss, NH F&G
Kris Kuhn, PA Fish & Boat
Nicole Lengyel, RI DMF
Mike Luisi, MD DNR
Chris McDonough, SC DNR
Conor O'Donnell, NH F&G
Arnold Leo, E. Hampton, NY
Glenn Normandeau, NH F&G
Jeff Pierce, Alewife Harvesters of Maine
Nick Popoff, U FWS
Zak Robinson, Coastal Conservation Assn.
Mike Thalhauser, MCCH
Kara Villone, NH F&G

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

The Shad and River Herring Management Board of the Atlantic States Marine Fisheries Commission convened in the Wentworth Ballroom of the Wentworth by the Sea Hotel, New Castle, New Hampshire; Wednesday, October 30, 2019, and was called to order at 10:15 a.m. by Chairman Michael Armstrong.

CALL TO ORDER

CHAIRMAN MICHAEL ARMSTRONG: I'm Mike Armstrong from Massachusetts.

APPROVAL OF AGENDA

CHAIRMAN ARMSTRONG: You all have an agenda in front of you. Are there any changes that need to be done? Seeing none, we'll approve the agenda by consent.

APPROVAL OF PROCEEDINGS

CHAIRMAN ARMSTRONG: You have the proceedings from February, 2019, any comments, deletions, additions, edits? Seeing none, we approve the minutes by consent.

PUBLIC COMMENT

CHAIRMAN ARMSTRONG: At this point we accept public comment on items that are not on the agenda. We have three people signed up. It appears that the topic will be the subject of opening some Maine runs. That is an agenda item, so I would like to put those off until we address that agenda item. Is there anybody who is not on the list who would like to speak about a topic not on the agenda today?

Seeing none, we'll move on. I'm moving quickly, because we actually have a lot to accomplish in a fairly brief time. We'll move along.

REVIEW THE TECHNICAL COMMITTEE RECOMMENDATIONS ON MANAGEMENT AND MONITORING INCONSISTENCIES WITH AMENDMENT 2 AND 3

CHAIRMAN ARMSTRONG: The first item is Review the Technical Committee Recommendations on Management and Monitoring Inconsistencies with Amendment 2 and 3. This is a charge we gave them a bit ago that they've been working on. They have an extensive report that you all have, and we likely will need an action coming out of this, so Ken.

MR. KEN SPRANKLE: Good morning everyone. This presentation will be shared by Caitlin and I. I'm going to start by covering the Board charges, the TC work and approach on those, and the TC recommendations. Caitlin is part of this presentation, and will later cover how those recommendations relate to existing FMP amendments for both shad and river herring.

For background, the TC identified inconsistencies with state management programs, and FMP requirements for Amendment 2, that's for river herring, and Amendment 3, American shad. On Amendments 2 and 3, both require all states and jurisdictions to submit SFMPs for all systems that remain open to either river herring or shad harvest, that's either for commercial or recreational.

Catch and release fishing will be permitted on any system in absence of an SFMP, and SFMPs must demonstrate fisheries are sustainable with quantifiable sustainability targets and annual monitoring. The Board tasked the TC in October, 2017 with developing proposed improvements to both Amendment 2 and 3 in five areas. The TC has focused primarily on Item 1 so far, and I'll read that, that's the Management and Monitoring of Rivers with Low Abundance in Harvest of Shad and River Herring. Items 2 and 3 the TC believes can be addressed with development of the shad stock assessment that is in progress at this time. We want to make sure there is consistency, and that criteria support the stock assessment. That is going to be on hold somewhat. The TC has discussed Items 4 and 5. Item 4 has been resolved; Caitlin is going to cover that when she gets into her slides.

However, for 5, the TC indicated that they wanted to continue discussions on Item 5 before making a recommendation. The TC has been working on its first item since mid-2018 with a task group that we put together. We began by assembling all available information on harvest regulations, monitoring SFMP status, and that was all done at the river and tributary level.

The group identified and categorized inconsistencies with requirements in both Amendment 2 and 3, based on the specific issues for each water body. Just this past fall the full TC met with the Task Committee, and reviewed the group's materials and made recommendations on how to potentially resolve each issue with a rationale, and that information was included in the packet.

All cases are summarized in that case description packet that is available to you. The TC also discussed other pathways for improving the FMP with regards to these issues. We'll start with; the inconsistencies that the TC identified fall generally into three categories with a few outliers that I also will cover.

They are all cases where recreational harvest is legally allowed under state regulations, and there are no issues with commercial fisheries. The recommendations for each inconsistency type are generally similar across cases, not always but generally similar. I can start off by going through some of these.

The first one would be tributaries of river systems that do have SFMPs and monitoring, but the tributaries are not explicitly addressed in the SFMP, and so the general recommendation there was easy. It was to include tributaries of the larger systems under the SFMP for the Maine stem, and apply the management metrics and responses to those tributaries.

A second, are rivers with harvest addressed by an SFMP, but without monitoring to support sustainability. The general recommendation there was as an option to apply management metrics and responses from other appropriate monitored systems, or implement catch and release regulations, and third, rivers that were legally opened to harvest without an SFMP and/or monitoring, but where little or no harvest of shad or river herring is suspected.

That general recommendation was followed by either catch and release only regulation, or to consider development of an alternative management regime. This first table describes the inconsistencies where tributary harvest is allowed. But the Maine stem has an SFMP. It's not clear how or if the management metrics were applied to the tributaries, so this grouping was resolved by TC agreement.

There is agreement by the TC on this of inclusion of these listed tributaries in the SFMPs for the larger river systems, applying the same sustainability metrics and monitoring data, and management response. We can look to that list as an example. Delaware had two rivers, the Brandywine and Broadkill that were part of this inconsistency, and the recommendation is simply to include them in the approved Delaware River Coop SFMP. This table describes cases where the state has an SFMP for the species identified, but recreational harvest is allowed in the areas without sufficient monitoring to track harvest or population. The states in these cases indicated that harvest is expected to be nonexistent or insignificant, based on anecdotal evidence, but not direct monitoring.

The recommendation for all of these, except for the one that's bolded, which I'll talk about in a moment, is to apply a management response based on metrics from another system for which the state has an SFMP and sufficient monitoring. This provides a potential safeguard for unmonitored systems, such if the area that the state does monitor starts to show decreasing trends, or does not meet sustainability targets, the management response can be triggered, closing or reducing recreational harvest. It would also apply to the unmonitored areas.

The recommendation I noted for South Carolina that's bolded that is different for the water bodies that are shown, Wando, Ashley, ACE Basin and so on. That is flagged differently, because there was no clear system that the TC felt comfortable linking to for those systems. They left it more open in terms of potential different options that the state may be able to pursue.

I want to point out here that the recommendations here and in the following tables are recommendations. They are based on the existing FMP amendments language for the states consideration on their options and the Board's recommendations. These four issues are grouped as they occur in states that do not have an SFMP for any system specific to the species for which harvest is allowed.

You can see that in the table. Also there is limited or no monitoring to support an SFMP for the individual systems. For Maine, the issue is a statewide two-fish recreational creel limit for American shad. There is some monitoring available from the more important systems within that state. The TC recommended potentially either using that monitoring information to create an SFMP with a statewide sustainability metric.

Another option would be possibly an alternative management plan or implementing catch and release regulations. For Georgia there are no regulations in place to prohibit the harvest of river herring statewide, it is simply unregulated. There is only shad monitoring that occurs in the Savannah and Altamaha Rivers, but very limited data on river herring is gathered from those efforts.

We also sought to get data from other available sources as well that Georgia helped us with. This is a case where harvest of river herring has not been recorded, and the TC recommended that Georgia either implement catch and release only regulations for river herring statewide, or develop an alternative management regime justifying the absence of statewide harvest regulations.

Lastly for Florida, river herring may be harvested under what they term Alosa regulations, definitions that are applied for statewide regulations. For the St. Mary's, which Florida has the headwaters of, it actually flows through Georgia, any proposal should include Georgia's plan for that river. For the St. John's we are aware that there are some available fishery independent and fishery dependent data that may possibly be able to be used. This slide contains the remaining management issues. I said how we had those three general categories and this fourth, kind of catch-all group, so this reflects that fourth group. We're in New Hampshire today, for New Hampshire there was an inconsistency with the Salmon Falls River, it is a border water with the state of Maine.

The TC recommendation is to include the management of the river herring fishery in the Salmon Falls River in their existing SFMP for river herring, using the same approach in place for their other coastal rivers, and that is a system approach that's applied for monitoring and subsequent management actions they use a number for tributaries within the Great Bay system for that SFMP.

For Delaware, the noted rivers shown on this table flow from Delaware into Maryland and Chesapeake Bay, Maryland has a catch-and-release-only fishery in these rivers. The TC recommends for consistency with Maryland and a lack of an SFMP and monitoring for shad in these waters that catch and release be implemented.

Lastly for Florida, there are statewide regulations for recreational harvest of shad and river herring under the Alosa regulations, as I mentioned. The listed rivers that are shown in this table are not believed to support populations of either species, so that resulted in what you see for recommendations by the TC in this table. That is going to conclude my portion of the talking; Caitlin is going to get into some more specifics for you.

MS. CAITLIN STARKS: Thanks Ken. With this next slide, I just wanted to give some more information to help the Board better understand why the TC provided these multiple options for resolving the inconsistencies in those systems, where harvest is allowed to occur without an SFMP or monitoring.

First I want to note that implementing catch-and-release-only regulations in any of these systems that the TC identified is always an option. This is what the FMP more clearly intended for systems without sufficient monitoring to support an SFMP, so it is more clear cut, and that's why many states have already done that in their unmonitored systems.

But, recognizing that some states are more hesitant to implement a regulatory change, the TC also put forward a couple of options that are not regulatory in nature. First they suggested that if appropriate a state could use metrics from their monitored systems in their state or jurisdiction to manage their unmonitored rivers, and that would be a more broad approach where all of the rivers in the state could be regulated based on just a subset of the state's sustainability metrics.

But this approach does assume that trends in the unmonitored systems would be similar to the trends in areas that are monitored. Then lastly, the TC had a lot of discussions on the use of alternative management regimes in systems where there is not an appropriate metric to use for sustainability targets or thresholds, in particular due to the fact that either shad or river herring abundance or harvest is very low, and therefore very difficult to measure and track. The TC discussed that in those systems there is a low risk of recreational harvest having a negative impact on the stock, because there is not any or small amounts of known harvest occurring. It may be appropriate in those cases to apply an alternative management regime, where the state could use whatever limited data they have available, such as irregular creel surveys or monitoring for other species to monitor the abundance of shad or river herring, and if the population were to recover be able to then respond and put in protective measures for that stock.

I don't think this Board has discussed the alternative management regimes very much, so I wanted to go over what the FMP has in terms of language regarding that option. Section 5 of Amendment 2 is the section that refers to alternative management regimes, and then in Amendment 3 there is some similar language, but it is not as explicit.

I do think the idea applies to both shad and river herring, and what Amendment 2 says is that these plans must demonstrate that the proposed management program would not contribute to overfishing of the resource, or inhibit restoration of the resource, that they must show that the alternative proposal would have the same conservation value as the measures in Amendment 2, and that the plans would be submitted in writing to the Board and Commission for approval.

Other than that in the FMP there isn't much guidance on what information should be included in the alternative management plans, and their approval seems to be fairly open to Board discretion. However, as the TC was discussing this as an option, they did recommend that they should also have a chance to review any alternative management plan proposals that might come out of this discussion.

Really quickly as part of the TC task, the TC did look into the *de minimis* criteria and definition in the amendments, and they found it to be very clear that the *de minimis* status is based only on commercial fishery landings, and does not exempt states from the requirement to prohibit harvest and possession, including recreational harvest and possession with exceptions for those systems with an SFMP.

The TC also discussed a few changes that could be made to improve the FMP with regard to the issues we've talked about today. Those were to modify the required monitoring tables in each of the amendments to provide more clarity and consistency in monitoring requirements across the states, to require more definitive management responses to the sustainability metrics in the SFMPs, and to add language that would provide some guidance on how and when alternative management regimes are meant to be used.

However, the TC did not come to final recommendations on what changes should be made specifically, so they would require further definition and exploration. To wrap this up, this slide lays out the next steps for the Board and TC on this issue. Today the Board could provide direction, or direction is needed to inform the states on how they should move forward with the inconsistencies that the TC identified.

The Board should also establish a timeline for any changes to state regulations or plans to go into effect or be submitted to the TC for evaluation. Lastly, based on the information the TC provided, the Board should assess whether or not changes to the FMP are warranted. For the TC the next steps will be to continue working on the remaining parts of the task as Ken mentioned, and those will be further developed with information from the stock assessment. The TC would also then evaluate any changes to SFMPs or new plans being proposed by the states to resolve the inconsistencies discussed today, dependent on the Board's direction. That is the end of our presentation, and Ken and I can take any questions.

CHAIRMAN ARMSTONG: Kevin Sullivan.

MR. KEVIN SULLIVAN: Just for my recollection to Caitlin or Ken. When was the implementation of these SFMPs supposed to happen for each?

MS. STARKS: I think the original date was 2012 that the majority were implemented, and then they were recently updated in 2017 on a five-year timeline.

MR. SULLIVAN: That was for both species, okay.

MS. STARKS: River herring was first and then Amendment 3 required the shad plans.

CHAIRMAN ARMSTRONG: Pat Keliher.

MR. PATRICK C. KELIHER: Ken and Caitlin, thanks for those updates. I don't think Maine's problems are too hard to overcome. We can address both the issues in regard to river herring and shad. But my question to Caitlin is – and you may have said it and I missed it, if I did I apologize – the alternative management approaches. Are those strictly for river herring though and not shad?

MS. STARKS: I believe based on the way the amendments are written they could be applied to both. There is a specific section on it in the Amendment 2 for River Herring, but there is language similar to that in the Shad Amendment, it just doesn't have a big bold section that says Alternative Management Regimes.

CHAIRMAN ARMSTRONG: Go ahead.

MR. KELIHER: It seems to me this is the way you described it kind of conservation equivalency with different language. It seems that may be the better approach for us to be able to resolve the issues in Maine particular to shad, where our two fish shad regulation with no commercial fishery has been in place since 1998, while we've continued to grow our shad populations in the Saco, the Kennebec, Androscoggin, and Penobscot.

I want to make sure that we can continue on with that. It's a very important fishery recreationally, and a growing fishery. I want to make sure obviously that we're in compliance. Since I just got elected as the new Chairman I would kind of like to avoid noncompliance if I can.

CHAIRMAN ARMSTRONG: We'll see about that.

MS. STARKS: If I could just follow up. The TC also left it open as an option to develop an SFMP if those several rivers that you do have monitoring on, if there is enough data there to support SFMP metrics that was also an option that this TC supported.

CHAIRMAN ARMSTRONG: Further questions. John Clark.

MR. JOHN CLARK: Thanks for the presentation, Caitlin. I was just curious, a couple of the Chesapeake drainages that come into Delaware that we don't have the same regulations as Maryland. Under the SFMPs are those compliance items like with Delaware? Does Delaware have to match Maryland's regulations, theirs the more restrictive?

MS. STARKS: It's not in the FMP that Delaware has to match Maryland. But it is in the FMP that systems without monitoring, systems need to have an SFMP in place in order to have open harvest regulations.

MR. CLARK: Thanks, it just makes it easier for us then to put that into place, thanks.

CHAIRMAN ARMSTRONG: Further questions. I would like to thank the TC. This is quite a job. It's just what we asked for. Over the years we have accumulated a patchwork of inconsistencies, so we need to figure out a way to address these. We clearly can't address every state individually with a motion or something like that.

I would like some discussion about, perhaps there is an omnibus sort of motion that could be made that covers it. In each and every case the TC has provided advice, and generally a couple of options of how states could address it, so any discussion on that? John Estes.

MR. JIM ESTES: I'm not going to suggest a motion, but I don't know how we are going to do this. Either I have to go to my Commission and ask them to make these rivers that we don't believe contain shad, or certainly don't have a fishery, to make them catch and release. I probably wouldn't be back to this meeting again if I did that so I'm not going to do that.

Then some of the other rivers that are mentioned here have small shad populations, and probably herring populations. We do not monitor those, and I don't think that it's going to make the priority for monitoring those things, and so I think I'm stuck. I'm not sure what else that we can do, and I think probably there are some other states that may be in the same situation.

CHAIRMAN ARMSTRONG: Thank you, Jim. Sorry, I called you John. Pat Keliher.

MR. KELIHER: I didn't hear any mention of a timeframe here, and I'm wondering if it would be appropriate if each individual state submit back to the Board a plan on how the state wants to move forward that they would be addressed at the next meeting. As I was thinking about this last night, I mean the idea of trying to address a long omnibus type motion.

Every one of these has a different level of importance in compliance relations. I think each state is going to have to think through this. I think Jim's example is a good one. I don't want to delay too long, but I think if we could work through this over the course of a couple meetings we would be in a better situation.

CHAIRMAN ARMSTSRONG: Kevin Sullivan.

MR. SULLIVAN: Mr. Chair, I would like to provide a motion if you're ready.

CHAIRMAN ARMSTRONG: I am.

MR. SULLIVAN: I would like to move to direct the states to follow the TC recommendations. In cases where the state does not have an SFMP in place implement catch and release only regulations, until an SFMP or alternative management plan is approved, with a date of January 1, 2021.

CHAIRMAN ARMSTRONG: Okay we'll wait until we get it on the board. We have a motion, we need a second. Do we have a second, seconded by Eric Reid, discussion? Kevin Sullivan.

MR. SULLIVAN: Like I asked for clarification, I feel like New Hampshire has been compliant with that pretty quick with that said date of 2012. We've updated ours since then to keep on track, and the TCs note that not monitoring these rivers could negatively impact the fisheries. I just feel that it would benefit the states to at least work on putting that SFMP in place, to justify why they feel it can remain open if they don't monitor.

CHAIRMAN ARMSTRONG: I think this motion is close to what you said, Pat. It's moving in that direction. Mel Bell.

MR. MEL BELL: Yes from South Carolina's perspective, we were fine with the TC recommendations, and there were multiple recommendations. We felt we could certainly work with the option. We do a lot of monitoring in different systems and different rivers, so we had the ability to kind of deal with a couple of the other recommendations.

But if we went down this road with the mandatory catch and release we would have an issue, because we do not have the regulatory authority within the division to make that happen. That would be an entirely separate legislative process we would have to go through. I don't think we could necessarily achieve that very easily. But we can achieve a couple of the other alternatives.

CHAIRMAN ARMSTRONG: Further discussion. Lynn Fegley.

MS. LYNN FEGLEY: I'm trying to figure out how this does connect with what both Pat Keliher said and Jim Estes; because if I'm not mistaken what Jim just told us was that this is what they cannot do that this is not something that they could accomplish. I think Pat had the suggestion to work through this over a couple of meetings.

Certainly in Maryland, you know we have a moratorium on these fish, because we don't have the resources to monitor, and we couldn't put together a sustainable fishery management plan. I believe it's something we should go forward to, but I'm not sure this really gets to giving states a chance to kind of come back to the Board and say, "This here is what we can functionally do and here's a plan."

CHAIRMAN ARMSTRONG: Do you have a suggested amendment to this? I'll let you think about that. Pat Keliher.

MR KELIHER: I appreciate the motion but again, every individual jurisdiction is in a different place, so to force them to go to a catch and release while they're trying to work through a process. If the fishery is a limited fishery at best, it seems to be going beyond what we need at this time. I would rather have the flexibility to kind of work through this process and deal with each jurisdiction individually, to make sure that we're meeting the intent of the SFMP, and dealing with the realities of your own state.

I don't know from a timing aspect. I'll be able to deal with the issues in Maine, but from a timing aspect and priority aspect, I don't know if it will be as quick as some may want. I would not want to have to put a catch and release requirement into play for a season while we deal with it, and then come back to the Board. Just a little flexibility is all I'm looking for.

CHAIRMAN ARMSTSRONG: David Borden.

MR. DAVID V. BORDEN: Following on the earlier discussion, what would happen if we added something to the motion, and I'm not going to make this at this point? I'm just throwing it out as an idea. If people want me to make it as a motion I would be happy to. If the states cannot follow the TC advice, they will notify the Board in writing prior to the next board meeting, something like that. You either follow the recommendations or you notify the Board the reasons why you cannot follow those recommendations. Would that help?

CHAIRMAN ARMSTRONG: Any thoughts on that?

MS. STARKS: Thanks David, I just have a question about that. I'm trying to get better clarification. The TC recommended again multiple options for these states. The first part of the motion to follow the TC recommendation does give them some flexibility with how to proceed. But it's the second part I think that is not as flexible, so I don't know if they can't follow the TC recommendations resolves that part of it.

CHAIRMAN ARMSTRONG: Kevin Sullivan.

MR. SULLIVAN: I think to what Caitlin just said. Maybe adding that language to the second part, for the instance where there is not an SFMP in place they can provide justification or in writing that they're not planning to close it for catch and release. I would be okay with that.

CHAIRMAN ARMSTRONG: Toni Kerns.

MS. TONI KERNS: I have a question, Kevin. The way I'm reading this motion is that it is saying where the state does not follow advice, we're asking them to immediately implement catch and release fishing while they work on an SFMP or an alternative management program, correct? Am I reading that correctly, because I'm not sure what this letter is going to do for us, but just tell us that they are not following the plan?

CHAIRMAN ARMSTRONG: Would it work, and I'll take liberty. If we remove the immediate implementation of catch and release and just give a deadline to address the inadequacies through an SFMP or an alternative management plan or something to be named within a year. Does that work for people? I mean I think clearly the Board probably wants states to be in compliance with the FMPs with flexibility. Kevin does that?

MR. SULLIVAN: Instead of implementing the immediate catch and release we allow states to provide notification that they're not going to, possibly with some justification.

CHAIRMAN ARMSTRONG: Lynn Fegley.

MS. FEGLEY: I might try amending the motion to say something to the effect of move to direct the states to follow the TC recommendations, and to present to the Board in February a plan with timelines of how they are going to follow those recommendations. Does that do it, because what that allows them to do in that plan is to lay those issues out that we've been hearing about in Florida and Maine?

CHAIRMAN ARMSTRONG: It is close, I think. I think there are only three options though is to have a sustainable plan, an alternative plan, or catch and release, or a moratorium. Do you want to be explicit? Your language is sort of vague of what they're going to do.

MS. FEGLEY: Sure, so we could include those options with a plan and a timeline of how they will achieve a sustainable fishery management plan, catch and release regulations, or a moratorium and a timeline.

CHAIRMAN ARMSTRONG: Can we before we do that would you accept that as a friendly amendment, the first and seconder?

MR. SULLIVAN: Yes, I would.

CHAIRMAN ARMSTRONG: Seconder would you? Yes. Seeing that I believe we can do it. I see staff doesn't like friendly amendments. Mike's Rules. Are there any objections to modifying the first motion through a friendly amendment? Malcolm.

DR. MALCOLM RHODES: Well this is just a point of order. I think what we would do is the maker and seconder would withdraw the original motion, at which point Lynn's motion would become the main motion for the Board, and that would be clean and would move forward that way.

CHAIRMAN ARMSTRONG: I'm afraid Mike's Rules are falling apart here. I thought this would be easier. Toni.

MS. KERNS: Yes Malcolm is correct, but you still have to vote on the motion to withdraw, so then you might as well vote on the motion to amend, but you've already gotten rid of it, so go on with Mike's rules for this one time. I don't think anybody's objecting.

CHAIRMAN ARMSTRONG: Any objections to my offensive behavior? Thank you for that. We have a new amendment, a motion, any discussion? Ray Kane.

MR. RAYMOND W. KANE: Thank you Ms. Fegley for this motion. My concern, I read timeline but I'm not seeing a terminal date, other than they're going to come forward with a timeline. But these states will have to enact the SFMP by a particular date, so I think that should be in the motion. I mean is it going to take them two years to figure it out, three years, or five years? I would like to see a date set in there beyond just timeline, when the states have to come back with their recommendations.

CHAIRMAN ARMSTRONG: Senator Miner.

SENATOR CRAIG A. MINER: The original motion I was somewhat struggling with the fact that I thought that first sentence implied that you would almost have to do it immediately, and you would be out of compliance if you didn't somehow demonstrate that you could do whatever it was the recommendation said you had to do immediately.

In this case, it seems like there is a little more of an opportunity to come back with a plan. I do agree with Ray that the plan has to have a terminating date on it, otherwise it could be 2024. I kind of like Pat Keliher's approach, which was kind of let us take a couple of meetings to figure out where we are.

We're going to make a motion here that I don't even know if half the states here can comply with. I don't know how many of these have to get legislative approval to do what it is they're being asked to do. Are we going to end up in the same situation we are with some of the other species?

At the very least I think it should have some kind of date as to what the plan has to be able to demonstrate. The timeline must show no later than, what was the original motion 2021, January of 2021? That would allow states with some statutory requirement to at least go through the legislative process before they're found to be out of compliance.

CHAIRMAN ARMSTRONG: Spud Woodward.

MR. A.G. "SPUD" WOODWARD: I've got a substitute motion. Move to direct the states to respond to the TC recommendations with a written proposal in time for consideration by the management board at the spring 2020 meeting, and if I can get a second I will elaborate on that motion.

CHAIRMAN ARMSTRONG: Is there a second, Mel Bell second, discussion? Spud.

MR. WOODWARD: I think this addresses some of the concerns we've been hearing, and that is there are multiple options in the TC's recommendations for states, and states need a chance to digest that, decide which are most feasible, and then present their choice back to the Technical Committee for review, and then have the Technical Committee validate their recommendations and then act upon them accordingly.

Again, I think we're putting states in the position of having to comply with something, and they don't know what they're supposed to comply with. To me this moves the ball down the field, but gives the states the necessary flexibility to deal with multiple recommendations, and give us as a management board what we need to do for a decision next year.

CHAIRMAN ARMSTRONG: Further discussion on the motion to substitute. Ritchie White.

MR. G. RITCHIE WHITE: Spud's motion feels like kicking the can down the road. I guess that's my only concern. What if at the spring meeting the states come and say, you know we're not sure what we can do, and we would like to study it and come back February, 2021. Doesn't there need to be some element of urgency in this? I don't have an answer.

CHAIRMAN ARMSTRONG: Adam Nowalsky.

MR. ADAM NOWALSKY: I believe the maker of the motion wished to respond. I would be happy to defer to him, if you would like to let him speak first.

CHAIRMAN ARMSTRONG: Spud Woodward.

MR. WOODWARD: I understand what you're saying, Ritchie, and I think at that point if a state fails to comply with this motion, then they've demonstrated I guess a lack of concern, and then this Board could take the necessary action at that point to compel them to do whatever is necessary. I guess that is the way I look at it.

CHAIRMAN ARMSTRONG: Go ahead, Ritchie.

MR. WHITE: Could you put something to that effect in the motion, Spud, so it's clear that that is what is going to take place?

MR. WOODWARD: Okay it will be a little on the fly wordsmithing here. Move to substitute to direct states, and actually I think we need to modify it a little bit, because I said with a written proposal in time for consideration by the management board at the spring, 2020 meeting. The reason that I state it that way is because there has got to be adequate time for the TC to review it, before it could be brought to the management board for consideration.

To add in additional language, I guess the next sentence could be; if a state fails to submit the proposal at the spring meeting, or in time for consideration at the spring meeting, then the management board can take such action as necessary to ensure that state implements the recommendation of the Technical Committee. That is a little cumbersome.

CHAIRMAN ARMSTRONG: Mr. Bell, are you okay with what you've seen so far?

MR. BELL: Yes sir, as long as it ends up there as he just said it.

CHAIRMAN ARMSTRONG: Spud, are we getting there?

MR. WOODWARD: I guess I would ask Ritchie if he thinks it's getting there. I think so. I mean that's obviously you can read into that what take such actions necessary means, but that will be up to the Board.

CHAIRMAN ARMSTRONG: Spud Woodward, are you okay with?

MR. WOODWARD: Yes, I'm comfortable with that.

CHAIRMAN ARMSTRONG: Ritchie.

MR. WHITE: Thanks Spud and that certainly satisfies my concern, thank you I will support it.

CHAIRMAN ARMSTRONG: Pat Keliher then Justin Davis.

MR. KELIHER: Just a question to the maker of the motion. The recommendation to the Board that would be considered, I'm assuming that's just what the state's plan would be, and not a draft SFMP.

MR. WOODWARD: I think it could take whatever form is necessary, based on the options that were presented by the TC, so if you choose to expand or create a new SFMP, or you choose to implement catch and release regulations, or whatever it might be. It needs to be detailed enough that the Technical Committee could review it, and make sure it comports with their recommendations. Then the management board would then take the TCs review of that and say, okay we agree that it meets the goals and objectives, and therefore it would be approved.

CHAIRMAN ARMSTRONG: Follow up, Pat.

MR. KELIHER: I think I understood him.

CHAIRMAN ARMSTRONG: Roy Miller.

MR. ROY W. MILLER: Mr. Chairman, just to speak to the urgency or lack thereof, in some of the cases here. If a state instead of submitting a plan for bringing a particular water body under regulatory authority for shad or river herring, if the state doesn't feel that in fact there are shad that reach that part of the state. I'm referring to Maryland tributaries that have their headwaters in Delaware. If the state feels that shad can't reach there or haven't historically reached there, can they make that case instead of having to go through the regulatory process?

CHAIRMAN ARMSTRONG: I'm thinking that would be part of an alternative management regime, and I'm getting nods from the TC. Yes. The answer is yes. Adam Nowalsky.

MR. NOWALSKY: I believe while this motion doesn't explicitly state it, what I've heard multiple times is the intention is for these proposals to go to the TC first before they come to us at the Board. I believe that's what I've heard, and I see a nodding. At what point would the states be notified of what the actual timeline will be by which they need to have these ready to go?

MS. STARKS: We can send out an e-mail following this meeting with a timeline for that.

CHAIRMAN ARMSTRONG: Justin Davis.

DR. JUSTIN DAVIS: I've got two concerns here. The first is, I'll just add my voice to others around the table who said that they're uncomfortable with the fact that this motion does not have an implementation date. That there is no sort of date certain by which states will have to implement whatever it is they are going to do.

I just think that is sort of kind of gives the impression of a lack of urgency. I would prefer if there was a date such as January 1, 2021, or February of 2021 by which the action had to be implemented, but also I'm not clear on the pathway if a state did not submit a proposal by the 2020 spring meeting.

What actions could the management board take to implement the TC recommendations? For instance, if a state didn't submit a proposal, so they are not sort of signaling an intention to create an SFMP. Can the management board take action to implement catch and release in that state for those systems? I'm just not clear on what actions the management board would take to implement the TC recommendations.

CHAIRMAN ARMSTRONG: Toni Kerns.

MS. KERNS: I think all the Board can do is say that they are inconsistent with the FMP, and determine if they want to make a compliance recommendation or not.

CHAIRMAN ARMSTRONG: Further discussion. Eric Reid.

MR. ERIC REID: I'm not sure how Mike's Rules of Order or Reid's Rules of Order handle this. This got really complicated in a big hurry. I understand the issues about perhaps some noncompliance, and I've already had enough of that in this meeting, just so we're clear about that.

To me if you took out the last sentence of the motion to substitute that would be fine with me. That is what everybody is asking for. We want to figure out what we can do as individual states and then talk about it in February. That would be my suggestion to Mr. Woodward is to remove that last sentence, and we'll talk about it again in February, so we can figure it out.

CHAIRMAN ARMSTRONG: Would the motioner consider that?

MR. WOODWARD: Well, I put the last sentence in there to address concerns about there not being an urgency and accountability, so I guess I'm kind of confused as to where we ultimately want to go. I understand what Dr. Davis is saying. But I think integral to submitting a proposal will be submitting a timeline from when you would implement whatever you choose from the suite of recommendations that have come from the TC.

I mean that is integral to that and that is part of what the TCs review would be is say okay it's one thing to say, well we'll implement an SFMP, but we'll do it in five years. Well that is probably not going to be acceptable, you know to the TC. I think we're sort of at cross purposes if we want to make sure that there is accountability, but at the same time give people the time necessary to decide what is most feasible and practicable for their individual states.

As far as the last sentence, the Board taking such actions. I mean the original motion had that in there already. We were contemplating mandatory catch-and-release recommendations right now anyway. I think the Board certainly has the authority to do that. I understand where you're coming from, Eric. I think that last sentence was to build some comfort with folks that might otherwise have discomfort with the original motion.

CHAIRMAN ARMSTRONG: I've been advised that in order to strike that we would need a motion, if that is the will of the Board, but further discussion. Seeing none, we'll go to the vote. I need to caucus for 30 seconds. All right, are we done caucusing? We need a clarification before we move to the vote.

MS. STARKS: I just want to clarify. The spring 2020 meeting is the meeting that usually occurs in May, so I just wanted to make sure that was the intent. Okay.

CHAIRMAN ARMSTRONG: It seems to be the intent. **All in favor of this motion to substitute raise your hand, opposed, abstention, null. The motion passes 16 to 2 to 0 to 0.** All right next is oh sorry I'm way ahead of myself. **This is now the main motion, any discussion? Any need to caucus: All in favor raise your hand, opposed, abstentions, and null. The motion is approved 17 to 1.**

CONSIDER APPROVAL OF REVISIONS TO THE MAINE RIVER HERRING SUSTAINABLE FISHERY MANAGEMENT PLAN

CHAIRMAN ARMSTRONG: The next item is an action item. Consider Approval of Revisions to the Maine River Herring Sustainable Fishery Management Plan. Ken.

MR. SPRANKLE: This presentation was provided to me by Mike Brown, I wanted to make that clear, to present to the Board for the state of Maine. Mike first presented a proposal to the TC in September of 2019. The TC provided review comments, which Mike incorporated into a revised plan, finalized in October.

The TC had a consensus recommendation to approve the plan with the revisions that are included in this presentation that I'll be giving today, in its submission to the Board. Maine river herring fishery management includes the following items, river herring resources are strictly controlled by municipalities that own exclusive harvest rights, one fishing location and one harvester per watershed.

Season starts when fish first arrive to June 5, with an option to fish until June 15 if approved by the Commissioner. Three consecutive no fish days per week are allowed for upstream passage of fish for spawning, or a conservation equivalent. No fishing in the watershed above a municipality that has exclusive harvest rights, as outlined in the municipal harvest plan. Some other notes on this are that the runs typically start May 1, some may start a little earlier, and obviously there is some variability there.

There are approximately 20 harvest days in a season. The current status of Maine river herring fisheries include 36 municipalities maintain exclusive river herring harvest rights. Maine currently has 22 municipalities in the existing SFMP. In 2019, 17 commercial river herring fisheries were conducted by 22 municipalities.

Fourteen municipalities do not fish, because they are not covered by the SFMP, and Maine has approximately 230 waters that support river herring populations. If you look at the numbers, some municipalities share a single fishery, and that is why there are more towns harvesting than the number of fisheries.

This figure shows the state of Maine municipal river harvest data for river herring, landings data from 1950 to 2019. The first Y axis shows millions of pounds harvested, and in 2019 the commercial harvest was the best since 1981, just over two million pounds, if you can see that on the far side. The following are objectives of adding three fisheries while continuing restoration.

Capitalize on considerable community involvement, interest, participation, and fundraising to build or maintain passage and monitoring of river herring runs. Utilize the ability to harvest as a tool to continue river herring restoration interest statewide, and to develop a plan to assess the merits of a provisional process to harvest a limited number of fish while runs are under restoration, and do not currently meet the current Maine SFMP criteria.

Maine has substantial restoration projects underway in 2019 that will open 53.7 square miles of spawning habitat for river herring, and that is estimated to result in a population increase of 8.1 to 13.6 million fish within ten years. That figure shows the geographic location of the three proposed waters.

You see Sewall Pond down in the lower southern part of the state, Center Pond they're close to one another, and then Wight's Pond is in the center coastal area of the state. The proposed harvest limit for these proposed waters is 15 percent of the time series mean of the run for each of the new waters.

This slide also shows some additional data, the size of the water body, and the years that the run count data are available as well. It gives you a sense of the scale of fisheries. For the fisheries within this addendum sustainability will be defined as follows; the annual release of 235 spawning fish per surface acre to provide an alewife population capable of increasing annual river herring run size.

The run must also demonstrate the repeat spawner ratio of 20 percent, Z mortality estimates of less than 2.0, 2 or less than 2.0, and age structure that demonstrates the presence of older age fish, ages 3-7. The goal is to achieve existing Maine SFMP criteria for each of the proposed waters within a five-year period, or close the recreational and commercial river herring fisheries. This shows the definition of production terms that will be in some subsequent slides. They will be labeled, but I would like you to pay attention to the colors that are used, the red, blue, and green. The escapement threshold that will be reflected by red in the following slides is a 35 fish per acre production level.

It's used as a minimum escape number to manage original commercial river herring fisheries. The blue that you'll see is a production target. I've mentioned the 235 that is what's going to be used as a management threshold for this proposal. That is 235 fish per acre. Lastly in green is the production goal, which is 397 fish per acre.

On this slide we've got the top two panels are data for Sewall Pond. Escapement run count data are shown there in the figure. The three-year-running mean count is shown in red. If you can make that out you can see the increasing trend in the most recent years. That would be in the top left panel, and on the right upper left are the counts in reference to the production targets that we just talked about.

Remember that 235 is a requirement, and you can see relative to the data time series in recent years what is reflected there for their count data. The same shown for Center Pond in the lower two panels, again red is reflecting that three-year-running mean relative to fish count, and then you have the blue line reflecting the required 235.

The same data are shown here for Wight's Pond, the top figure you can see the three-year-running mean, maybe a little less apparent, but in the bottom you can see that red line trending upwards. Then in the bottom panel you can see that 235 production target that is shown with the blue line again.

The Technical Committee concerns included maintaining consistency with Amendment 2 of the river herring FMP. That river herring runs that are under restoration and simultaneously harvested, need to make progress toward meeting biological metrics that indicate sustainability. Increasing time series trends and total instantaneous mortality of the Z value based on repeat spawning fish should not exceed the Z collapse value that was determined in the most recent stock assessment that was for 2017.

Recognize that these are small watersheds with very small runs that are susceptible to overharvest. Two of the three runs do not meet what has typically been used; a ten-year data timeframe for requirements to make biological decisions within the existing assessment process, and harvest will impact restoration progress and may prevent achieving the long term sustainability.

The Maine plan proposes management safeguards to protect the river herring resource, and address Technical Committee concerns. If the run demonstrates a declining trend in the running three-year average that we talked about, shown by the red line of the annual run counts, the fishery will be closed the following year.

If the fishery does not achieve a Z estimate of 2.0 or less for repeat spawners for the current year, the fishery will be reduced by 5 percent of the time series mean for the remainder of the five-year period. If the average number of repeat spawners for the time series mean and sample year do not achieve the 20 percent that I mentioned earlier, the fishery will also be reduced by 5 percent for the remainder of the five-year period, or until it recovers. Lastly, river herring populations that do not demonstrate the presence of fish ranging in age from 3-7 years will be reduced by 10 percent at the end of the 2022 addendum review period.

Maine's proposed control rules and assessment criteria summarized here. Harvest will occur after May 18 in these proposed three water bodies, to allow older river herring to escape the fishery. If you recall I mentioned earlier that Maine typically the fisheries will begin, say around May 1, so this is a delayed opening for these proposed areas.

The municipalities that allow recreational fishery must enumerate and subtract the recreational harvest from the commercial catch allowance for that season. The release of a minimum spawning stock threshold of 235 fish per acre, a commercial fishery that doesn't meet that 235 escapement will close until the fishery achieves escapement goal for the following year.

There is going to be annual review of age data, mortality rates, repeat spawning data, certainly the count data to assess the need to reduce harvest numbers, or suspend any fishery short of a five-year period. That is Mike's final slide.

CHAIRMAN ARMSTRONG: Any questions? Andy Shiels.

MR. ANDREW SHIELS: Thank you for the presentation. I just wanted to follow up. You made a comment that two of the three runs did not meet the ten-year-data series. I was wondering, how far would they have to go to meet the ten-year-data series?

MR. SPRANKLE: I'm sorry, could you please repeat that. I'm sorry.

MR. SHIELS: Sure, if I can remember what I said. I think you indicated that two of the three runs did not meet a ten-year average data series, so my question was how far off were they from meeting that ten-year average?

MR. SPRANKLE: Sure thank you. I'm going to refer back to the addendum itself. I'm opening that up if you would bear with me. In the actual proposal in the data panels, the figures that are included in there. There are count data provided, sometimes it's estimated. There are breaks in the time series sometimes.

Importantly there are in two of the proposed water bodies some substantial changes, in terms of accessibility, improvements with fish passage and dam removal. To get at your question, there actually needs to be some minor corrections made in here, I talked to Mike Brown about that that for the time series mean we're using data since the modifications in that data time series, when those were in place.

What they provided, they'll say years of data and it's maybe a full set of data, but again it doesn't reflect the shorter timeframe. The concern we have was just to take into account a generation of river herring, which you know we don't have a hard figure on that but it could be five or six years of something, to at least have that sort of data. Typically it is ten years that has been used for our different stock assessment purposes. But it's not something that's been defined. We talked about trying to improve guidance with these, and this speaks to that getting better definition. They are in fact actually all less than ten years, but greater than five, so they fall between five, six, eight years of information. You saw how the data were reflected. Does that help?

MR. SHIELS: A little bit. Thank you.

CHAIRMAN ARMSTSRONG: Just to be clear and I think I missed it. The TC has approved these three runs, or recommend.

MR. SPRANKLE: Recommend for approval, yes I wanted to state that at the start, and I reaffirm that.

CHAIRMAN ARMSTRONG: Correct, more discussion, Senator Miramant.

SENATOR DAVID MIRAMANT: Seeing none, I'll make a motion, and I would like to speak to it if it is seconded. Move to approve Maine's proposal to modify the river herring SFMP as recommended by the TC.

CHAIRMAN ARMSTRONG: Is there a second? Eric Reid. We'll wait until we get it on the board. Go ahead, Senator.

SENATOR MIRAMANT: I just want to point out there was a slide there with the St. George River watershed. That is my district. The interest generated by involving the community, it's up on Facebook when the run comes. People are flocking to the river. They're making sure that the passageways are clear. This is a great tool for the kind of fisheries that you have public access to for your state's if you need it, maybe you've already done this, because I'm new, it says right here.

A lot of the fisheries we just don't have that. They only hear about the negative, and then want to protect them. This is one where they are proactively getting out and doing it. Adding these to the public access and interest will be helpful to our goal anyway, but we're doing it in spite of that but it will help too.

CHAIRMAN ARMSTRONG: Further discussion. Seeing none at the Board, we do have three people signed up from the public. We are way behind, so I would ask you to keep your comments to perhaps under a minute. Jeff Pierce.

MR. JEFFREY PIERCE: Chairman Armstrong, members of the Shad and River Herring Management Board, I hope you would take time to read the handout I gave you, in the interest of brevity. These river herring runs and the restoration are very important community building tools to help get unimpeded passage. By allowing these towns to have a small commercial harvest or education harvest, it helps promote community involvement, and also is good for other taxpayer base to see that their dollars aren't being wasted, and we are improving the watershed with unimpeded passage. Thank you.

CHAIRMAN ARMSTRONG: Thank you, Jeff, Mike Thalhauser.

MR. MIKE THALHAUSER: Thank you Mr. Chair, Committee members. Yes, I'll be brief. I am a fisheries biologist with the Maine Center for Coastal Fisheries on the Alewife Harvesters Board, and have been recently added to the Advisory Panel to this Committee. I do support the intent of this proposal, in fact I would like to really hand it to the state of Maine, Department of Marine Resources to working with stakeholders and with current harvesters, and potential future harvesters that would be part of this in developing this and putting it forward.

I would say, I know there has been some discussion around this ten years. That is really what this proposal is. It's an innovative approach to incentivizing capacity at the local level, where we can actually make fish rather than be focused on reducing harvest, and getting towns collecting data, being stewards of these fisheries, and restoring fisheries that they are socioeconomically connected to.

This is about doing that before ten years, so that they'll actually collect the data for ten years. Without incentives like this towns walk away. This is hundreds of hours of work that they need to get this data, and they're collecting it so that they can be managed appropriately. That's why this is important.

I mentioned that I supported the intent. I would like to see this have gone farther. The Technical Review Committee cut the number of runs addressed by this in half, and added I feel inappropriate, some of the inappropriate metrics that were up there that could set some of these runs up for failure, and keep them from collecting that data and restoring these fisheries.

Also one more thing, being on the Advisory Panel or at least I think maybe by the end of today. This wasn't taken up by the Advisory Panel that I think would have been more appropriate to review a nontraditional proposal like this, rather than a Technical Review of an innovative proposal. That is all I have. Thanks.

CHAIRMAN ARMSTSRONG: Thank you. Anne Hayden.

MS. ANNE HAYDEN: My name is Anne Hayden; I'm a Senior Fisheries Program Manager from Manomet, the sustainability organization based in Massachusetts, with an office in Maine where

I work. Thank you for your consideration of the proposed amendments to Maine's river herring sustainable fisheries management plan.

They are important to the communities seeking to restore their traditional fisheries, but they're also important to improving our understanding of river herring population dynamics. Manomet produced a report this year on the status and opportunities for river herring restoration in eastern Maine. We did this to support those communities working to restore fisheries. It identified a bunch of research questions that fishermen and local stakeholders had produced. I won't go through the list of what those were. But there is a lot of interest in river herring research in the research community, and there is funding increasingly available, including a five year 20 million dollar grant recently received by a consortium led by the University of Maine that is going to focus on the use of EDNA as a monitoring tool in Maine, and they've identified a significant portion of that funding to study river herring.

My point to you today is that the more of these community-based fisheries we can bring back online, the more platforms we have to study river herring, which will in turn contribute to improving the numbers and the sustainability of our commercial river herring fisheries. It will contribute to the ecological recovery of our watersheds and coastal waters, and it will improve resilience of these same ecosystems to climate impacts. Thank you.

CHAIRMAN ARMSTRONG: Back to the Board, anymore discussion? Seeing none, we need to caucus for 30 seconds. **Back to the vote please, in lieu of voting I will see if there is a consensus. Are there any objections to approving this motion? Seeing none, the motion is approved unanimously.**

PROGRESS UPDATE ON THE SHAD BENCHMARK ASSESSMENT

CHAIRMAN ARMSTRONG: The next items we would like to switch 6 and 7 in the order and do 7 first. Are there any objections to changing the agenda order? That being said, we are going to get a Progress Update on the Shad Benchmark Assessment by Jeff Kipp.

MR. JEFF J. KIPP: The Stock Assessment Subcommittee has continued to meet on roughly biweekly progress calls to get updates on analyses that are going towards the assessment. Progress has continued to be slower than hoped, I think throughout some of these calls, and hasn't changed a whole lot since the last update to this Board.

The most common reasons cited and communicated on that is just a lack of time to contribute to this assessment, given the other workloads and responsibilities among Stock Assessment Subcommittee members. We are carrying forward with our last in-person workshop as part of this assessment process, which is our assessment workshop, and that is in a little less than three weeks down in Charleston, where we will meet and review those assessment analyses that have been being worked on by the Stock Assessment Subcommittee members.

Just a reminder on the remaining timeline for this assessment, it's scheduled to go to peer review in March, and then come back to this Board at the August summer meeting for your consideration. That's all I have, and if there are any questions on the assessment I can take those now.

CHAIRMAN ARMSTRONG: Any questions, Toni Kerns.

MS. KERNS: I don't have a question, but Jeff as always is being kinder than I would be. This Committee has definitely struggled to get their work done, and I would just hope for the fact that for those states that do have folks on this Committee, if you could please help them make this a priority for this last meeting.

Continuously, there has been a lack of initiative of the Committee members to get their work done. They will come to the calls saying I worked halfway on it, but I didn't complete it. In order to finish this assessment and have a productive meeting, we need to have everybody onboard 100 percent getting things done. There have been individuals who have recently notified Jeff and Caitlin that they're not all of a sudden coming to the workshop that we had hoped they would be there. There are individuals that have been re-tasked to other species. They're still working on this, but then their work is slower, because this isn't a priority for them. We have had people leave agencies but didn't tell us that they were leaving the agency.

We thought they were working on something and obviously they were not. Then just a regular lack of engagement of committee members, and so we just plead to have your state folks engage in working on this issue, and to please communicate with that with them. If this is a priority for you, then please let them know that this is a priority.

CHAIRMAN ARMSTSRONG: Thank you Toni, we've all heard that. Any questions for Jeff, seeing none we'll move on? We are running out of time. We can go over a little, but we have a hard stop for the Hart Lunch. We can go over 45 minutes; I mean 11:45 to 11:50?

EXECUTIVE DIRECT ROBERT E. BEAL: We can recess and come back afterward.

CHAIRMAN ARMSTRONG: I've been scolded again. We can't run over, but we're running out of time, so we will in fact come back after lunch for perhaps 15, 20 minutes.

SHAD HABITAT PLAN UPDATES

CHAIRMAN ARMSTSRONG: But, we'll do one more item that's the Shad Habitat Plan Updates. Caitlin.

MS. STARKS: I have a very brief presentation on this, and it should not take much time. But I just wanted to bring to the Board's attention that under Amendment 3, all the states and jurisdictions were required to submit habitat plans for American shad, and those plans are meant to contain a summary of information on current and historical spawning and nursery habitat, threats to those habitats, and the habitat restoration programs going on within each state.

The FMP is not explicit about when or if these plans are meant to be updated, but from looking back through old meeting minutes, it does appear the Board was anticipating updates of these plans on roughly a five-year timeline. The majority of those plans were submitted and approved in 2014.

Florida's plan was a little bit later in 2017, and then for the Merrimack River, which is shared by Mass and New Hampshire, and the Hudson River in New York, no habitat plan has been submitted to date. From what I can tell looking back through meeting minutes related to this topic, there was an expectation that those two plans would be submitted at some point after the other plans had been approved in 2014.

The recommendation for the states at this time, since it has been about five years since the plans were initially approved, it's recommended that states go back and review those plans and update them as needed, and it's also recommended that New York submit a habitat plan for the Hudson River, and that New Hampshire and Massachusetts work together on a plan for the Merrimack River.

The TC can review those plans, and updated plans and new plans as needed, and then they can come back before the Board for approval. For Board action on this, I don't think there needs to be a motion as long as the Board is comfortable moving forward with this path.

CHAIRMAN ARMSTRONG: Questions for Caitlin. Seeing none, we are recessed.

MS. KERNS: Right after lunch, we're in recess, and then you just come right back here after lunch, no lollygagging.

(Whereupon a recess was taken.)

REVIEW AND CONSIDER APPROVAL OF 2019 MANAGEMENT PLAN REVIEW AND STATE COMPLIANCE

CHAIRMAN ARMSTRONG: The first item is to Review and Consider Approval of 2019 Management Plan Review and State Compliance.

MS. STARKS: I have a brief presentation on this. We'll just get through it as quickly as possible. To start off, I'll go over the landings, fish passage information for the previous year, stocking efforts in the states, sturgeon interactions, *de minimis* requests, and then get to the PRT report. I'm not going to spend too much time on these landings, but I just wanted to note that in the last several years, since the 1990s, since we've all seen a decline in the river herring landings and shad landings since the beginning of the time series in 1950.

If you just zoom into the last set of years, I wanted to show that there have been some variable trends for river herring, with some increases in the last couple of years, while American shad has been declining since the 1990s. This table shows the state landings and coastwide totals for commercial shad and river herring in 2018, excluding confidential data.

For river herring the coastwide commercial landings, including bycatch totaled 2.45 million pounds in 2018, which is a 1.8 percent increase from 2017, and for shad the total 2018 commercial landings, again directed and bycatch landings that were reported in compliance reports were 285,523 pounds, which is a 27 percent decrease from 2017.

This slide is on the required passage counts in the states listed here. In 2018, 9.4 million river herring were counted as passed among the states that monitored these runs, and for shad 642,688 shad were passed. For river herring that's a 60 percent increase from 2017, and for shad that's a 15 percent decrease from 2017.

The states listed on this slide are involved in hatchery rearing of American shad fry, and in 2018, 22.8 million shad were stocked in rivers along the coast. I just wanted to note that in 2018, Virginia ceased their stocking efforts on the James River. For sturgeon interactions, there were 343 interactions reported in 2018, 11 of which were fatalities. All of the interactions were reported by the states listed on this slide.

Rhode Island does continue to have a lag in their data, so they were not able to report their landings for 2018, but did report two interactions in 2017. For *de minimis* requests for shad; Maine, New Hampshire, Massachusetts, and Florida request *de minimis* status, and for river herring New Hampshire and Florida request *de minimis* status, and all of these states qualify for those *de minimis* status, based on their commercial landings.

The last thing here is the PRT Report. As we talked about earlier today, the PRT did note several issues, in terms of inconsistency with the FMP requirements, and those were discussed earlier, so I won't spend too much time on them, but just to note them here for due diligence. Maine has a two-fish bag limit per day with no SFMP. Georgia again does not have an SFMP for river herring, and does not have regulations in place to prohibit harvest of river herring recreationally, and Florida has similar situation of no SFMP for river herring and statewide recreational creel limits for river herring.

Other issues the PRT noted were that several states did not report on all of the monitoring requirements that are under Amendments 2 and 3, and a few states have been consistently omitting the same information from year to year. The most common issues of omissions are on the characterization of other losses, characterization of recreational harvest, length and age frequencies, and degree of repeat spawning.

The PRT recommends that the states take note of those required monitoring programs and results that were not reported, and make sure to please report those in their future compliance reports. Second, the PRT noted that most states did not submit their monitoring data in a separate Excel file along with their compliance report, which is required by Amendment 3.

If data are reported in a separate file, the compliance report should note what data are included in that file. In cases where monitoring is shared by several jurisdictions, the compliance report from those jurisdictions need to indicate which of them is responsible for the required monitoring, rather than just omitting information on the monitoring altogether, or alternatively all of the reports from the shared jurisdictions could report on that monitoring.

Lastly, the PRT found it difficult to evaluate compliance when states just included in some sections a statement that said no changes were made from the previous report. They did recommend a request that all sections of the compliance report be filled out, even if there were no changes from the previous year.

With that the action for the Board to consider today is the approval of the 2019 shad and river herring FMP review for the 2018 fishing year, and state compliance reports and *de minimis* status requests for Maine, New Hampshire, Massachusetts and Florida. Thank you.

CHAIRMAN ARMSTRONG: Are there any questions, discussion? I have one question. Were the deficiencies of the reports noted to the states?

MS. STARKS: They will be. They are noted in the FMP Review, which the states received.

CHAIRMAN ARMSTRONG: Would anyone like to make a motion similar to that? Lynn Fegley.

MS. FEGLEY: I would like to make a motion similar to that.

CHAIRMAN ARMSTRONG: That's a funny motion there.

MS. FEGLEY: Move to approve the 2019 Shad and River Herring FMP Review, state compliance reports, and *de minimis* status for Maine, New Hampshire, Massachusetts, and Florida.

CHAIRMAN ARMSTRONG: **Is there a second? Justin Davis. Discussion, is there anyone against approving this motion? Seeing none, the motion is approved unanimously**.

REVIEW AND POPULATE THE ADVISORY PANEL MEMBERSHIP

CHAIRMAN ARMSTRONG: The next item, review and populate the AP membership, and that is Tina.

MS. TINA L. BERGER**: I present for your approval the addition of Mike Thalhauser,**

Mark Amorello, and Chuckie Green to the Shad and River Herring Advisory Panel. Their nominations were included in your meeting materials.

CHAIRMAN ARMSTRONG: **Would anyone like to make that motion? Pat Keliher has moved, second Ray Kane. Discussion, seeing none, is there anyone who does not approve of this motion? Okay, we have moved to appoint Mike Thalhauser, Mark Amorello, and Chuckie Green to the Shad and River Herring Advisory Panel**.

ADJOURNMENT

CHAIRMAN ARMSTRONG: Any dissension, seeing none, the motion is approved, and is there any other business? We are adjourned.

(Whereupon the meeting adjourned at 1:15 p.m. on October 30, 2019)

Atlantic States Marine Fisheries Commission

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MEMORANDUM

TO: **Shad and River Herring Management Board**

FROM: **Shad and River Herring Technical Committee**

DATE: **July 16, 2020**

SUBJECT: **TC Recommendations on state proposals to resolve management inconsistencies with Amendment 2 and 3 requirements**

The Shad and River Herring Technical Committee (TC) met via conference call and webinar on March 30 and April 23, 2020, to achieve two objectives:

1. Review State Sustainable Fishery Management Plan (SFMP)/Alternative Management Plan (AMP) Proposals to resolve regulatory inconsistencies identified by the TC
2. Develop TC recommendations on each proposal for Board consideration

The TC recommends approval of all proposals, with the inclusion of some requested revisions. Summaries of each state's proposed changes and TC recommendations are included below. Additionally, the TC discussed how best to address the remaining TC Task items.

Maine

River Herring:

Mike Brown presented proposed changes to the state's SFMP for river herring to resolve the issue of recreational harvest occurring in unmonitored rivers. Maine proposes changes to the SFMP to apply relevant sustainability thresholds from monitored watersheds in each region (i.e. total or mean of existing fishway counts) to all rivers within the region. The 25th percentile of the mean or total fishway counts will serve as the threshold for sustainability within a regional area; if the metric falls below the threshold then a management response would apply to all systems within the region.

- The TC asked for additional description of the regional definition to be added to the SFMP, and that threshold value be stated and remain fixed until the SFMP is updated every 5 years. The TC recommends approval of the proposal with the requested revisions.

American Shad:

Mike Brown presented a proposed new SFMP for American shad to resolve the issue of recreational harvest occurring without an SFMP. In the SFMP, since the state of Maine does not conduct a recreational creel survey or survey bycatch in commercial fisheries for other species. The proposed SFMP would use a statewide sustainability metric based on fisheries independent run count data and JAI data for the Merrymeeting Bay Complex. If for three consecutive years either the JAI Survey or the trap count is below the 25th percentile the American shad creel limit will be reduced to one fish or an American shad fishing season will be instituted to reduce effort to equate to a one fish bag limit. If for three consecutive years, the JAI survey and the trap counts are below the 25th percentile the American shad fishery will close and be open only for catch and release fishing.

- The TC requested the following revisions to the proposed SFMP: explicitly state the 25th percentile value, and include a description of how management measures such as a season change would be developed. With the requested revisions, the TC recommends approval of the SFMP proposal.

New Hampshire

River Herring:

Mike Dionne presented proposed changes to the state's SFMP to address monitoring concern for the Salmon Falls River**. T**he revised SFMP for river herring clarifies the system approach for sustainability metrics, and the rivers included in the Great Bay Estuary system addressing the Salmon Falls River monitoring issue.

- The TC supported the proposed changes to the SFMP.

In addition to the SFMP changes, NH also noted that the fishery-independent target of a 3 year average of 350 fish per acre of spawning area (equates to a NH coastal return of 72,450 fish) for river herring has not been met. NH encountered fish counter malfunctions that caused gross underestimations of run counts at the Cocheco River Fishway. The NH SFMP states that the fishery must be closed if the fishery-independent target is not met. NH requests to keep the fishery open in 2020, with an explanation about the equipment failure and that they do not believe the run count is accurate.

- The TC supports this approach, and requested that NH submit a memo containing details on the situation to the Board.

New Jersey

American Shad:

Brian Neilan updated the TC on New Jersey's proposed inclusion of unidentified tributaries in a larger system plan. **The proposed changes include incorporating tidal reaches of tributaries in the Delaware Bay System under the Delaware Basin Co-op SFMP.**

- The TC supports these changes and believes it satisfies the previous recommendations

Delaware

American Shad:

Johnny Moore updated the TC on Delaware's proposed inclusion of open tributaries in a larger system plan and regulatory changes to address the TC's recommendations. The proposed changes include, incorporating Back Creek, Brandywine, and Broadkill Rivers in the Delaware System under the Delaware Basin Co-op SFMP, and implementing catch and release only regulations for all Chesapeake tributaries (Chester and Choptank Rivers). It is estimated that the regulatory changes will take effect in about 6 months.

- The TC supports these changes and believes they satisfy the previous recommendations.

North Carolina

American Shad:

Holly White and Jeremy McCargo provided a proposed update to the shad SFMP to address monitoring issues and unidentified tributaries. The revised SFMP identifies and incorporates all tributaries of the systems included in the SFMP (Albemarle Sound, Neuse, Tar-Pamlico, and Cape Fear). Additionally, the update clarifies that the Little River (portions of which flow into South Carolina) will be managed consistently with South Carolina, responding to the same sustainability metrics used for the Winyah Bay System (derived from the Great Pee Dee River).

- The TC supports the updates to the shad SFMP and believes they satisfy the previous recommendations.

South Carolina

River Herring:

Bill Post presented proposed changes to the state's SFMP for river herring to define tributaries covered under systems in the SFMP. Specifically, the Little River will be considered part of the Winyah Bay System, and will respond to sustainability metrics from the Great Pee Dee River. Other tributaries of the Winyah Bay system are the Waccamaw, Little Pee Dee, Lynches, Black, Sampit, and Bull Creek. Tributaries of the Santee-Cooper system include the Wateree, Congaree, Broad, Wando, and Ashley Rivers**.**

American Shad:

SC proposed updates to the shad SFMP to link all tributaries to a monitored system with sustainability metrics. System definitions were consistent with those in the river herring SFMP.

- The TC requested that the values for the sustainability thresholds be stated in the text of both SFMPs. With these additions, the TC recommends approval of the proposed changes to the SC shad and river herring SFMPs.

River Herring Alternative Management Plan:

For river herring, SC proposed an Alternative Management Plan (AMP) for unmonitored systems including the ACE Basin (Ashepoo, Combahee, Edisto, and Salkehatchie Rivers), the Coosawhatchie River, and the Savannah River. The AMP proposes maintaining the current regulations allowing recreational harvest in these systems because SC is unaware of any directed recreational fishing for river herring and they are considered functionally absent in these areas based on available monitoring data. Changes to the harvest regulations or development of an SFMP will be considered in the event that any surveys detect any positive recreational harvest for three consecutive years. The fishery independent monitoring will not be used for any trigger at this time.

- The TC requested that additional language be added to the AMP to more clearly define the levels of river herring harvest or abundance that would trigger a reevaluation of recreational regulations. It was also requested that monitoring results be provided in annual compliance reports. With these revisions, the TC recommended approval of the river herring AMP.

Georgia

American Shad:

Jim Page presented proposed updates to the GA American shad SFMP to address unmonitored systems, better define other systems and address a needed change in Savannah River monitoring/benchmark trigger. The proposed changes to the SFMP are to use the Altamaha system sustainability metrics for all Altamaha tributaries (Ocmulgee and Oconee Rivers), as well as the Satilla and St. Marys Rivers which do not have additional monitoring. A management response to the Altamaha metric falling below the threshold would apply to all systems. In addition, due to reductions in commercial fishing activity in the Savanah River, the current fishery-dependent SFMP sustainability metric is no longer sufficient for management. The proposed change is to use a long-term fishery-independent state sampling program for monitoring/metric that will also include South Carolina's monitoring data for coordinated oversight. See memo dated July 13, 2020 for more information on this change.

- The TC recommends approval of the proposed changes to the GA shad SFMP.

River Herring:

For river herring, GA proposed an Alternative Management Plan (AMP) for all systems statewide. The AMP proposes no regulatory change: commercial fisheries will remain closed, but recreationally river herring harvest will remain unregulated. The AMP asserts that based on available monitoring data, indications are that river herring populations in Georgia are considered functionally absent, and no fisheries for the species (commercial or recreational) have been identified. Table 15 of Amendment 2 also substantiates this assertion. GA DNR will continue to monitor any changes to river herring harvest and abundance through all currently available surveys that could capture river herring. These include MRIP, state creel surveys (e.g. Altamaha, Ogeechee, Satilla Rivers), and fishery-independent monitoring for shad in the Savannah, Altamaha, and Ogeechee (adults and juveniles), Satilla (adults only), and St. Marys (adults only). If any positive recreational harvest is detected for three consecutive years, GA will take the necessary steps to ensure sustainability for that river system (e.g. consideration of regulatory changes or development of an SFMP). The fishery independent monitoring will not be used for any trigger at this time.

- The TC requested that additional language be added to the AMP to more clearly define the levels of river herring harvest or abundance that would trigger a reevaluation of recreational regulations. It was also requested that monitoring results be provided in annual compliance reports. <u>With these revisions, the TC recommended approval of the river herring AMP.</u>

Florida

American Shad:

Reid Hyle presented proposed changes to the FL SFMP for American shad to address unmonitored systems. The proposed changes to the SFMP apply the current sustainability metrics from the St. Johns to all tributaries of the St. Johns River (Econlockhatchee, Wekiva, and Ocklawaha Rivers, and Black Creek). It also states a lack of any credible records for presence of American Shad in any systems south of the St. Johns River and that river being the southernmost extent of the species range.

- <u>The TC recommends approval of the proposed changes to the FL shad SFMP.</u>

River Herring and Shads:

For blueback herring in all systems in the state, and for American shad in all systems outside of the St. Johns, FL also proposed an Alternative Management Plan (AMP). The AMP proposes no change to the statewide recreational regulations: hook and line is the only permissible gear for all *Alosa spp.* in Florida and blueback herring and American shad are incorporated in the 10 fish daily bag limit for *Alosa* in aggregate.

The AMP states that if any surveys reveal that blueback herring harvest is occurring in the state, or if any American shad harvest is detected outside of the St. Johns system (positive detection for 3 consecutive years), then FWC will take steps to ensure that the harvest is not a threat to conservation, which may include establishing sustainability metric for the St. Johns if harvest begins to occur there, implementing monitoring in other systems if blueback herring or shad are found to be present and subject to fishing, and regulatory changes as appropriate up to the possibility of closure.

- The TC requested that additional language be added to the AMP to more clearly define the levels of river herring and shad harvest or abundance that would trigger a reevaluation of recreational regulations. The TC also asked for language to be added to explain that for the St. Marys River, FL will respond to monitoring information from GA DNR. Lastly, it was requested that monitoring results be provided in annual compliance reports. <u>With these revisions, the TC recommended</u>

approval of the river herring and shad AMP.

Next steps to address remaining TC Task items

Some TC members expressed that the while the proposed AMPs from SC, GA, and FL appear permissible under Amendments 2 and 3 based on the current language, they believe the most clear path to consistency with the FMP would be to implement catch and release only regulations for any systems without an SFMP. The group felt more clarity is needed in the FMP on what is required in cases where no known fishery is occurring, and could be attained through the adaptive management process.

The TC discussed the need to develop recommendations for improvements to the FMP to clarify the requirements for SFMPs, AMPs, and monitoring efforts, and to better integrate information from the stock assessments. The TC has formed a subgroup to develop draft recommendations to be reviewed and refined by the full TC.

MAINE DEPARTMENT OF MARINE RESOURCES

2015 Maine Herring Sustainable Fishing Plan Update (with revisions for recreational fishery)

Bureau of Marine Science
3/15/2020

The Sustainable Fisheries Management Plan Update provided below contains information that by Maine state law needs to remain confidential. This information may only be used by the ASMFC River Herring and Shad Technical Committee in the course of evaluating the updated river herring management plan. This information may not be shared with any individual or group outside of this committee. The expectation that this information will remain confidential facilitates the State of Maine's ability to collect the best quality data available from individual fishermen for use in managing Maine's commercial river herring fisheries.

§6173. Confidentiality of statistics

1. Collection and reporting of statistics. The commissioner may, with the advice and consent of the advisory council, adopt rules to collect pertinent data with respect to the fisheries, including, but not limited to, information regarding the type and quantity of fishing gear used, catch by species in numbers of fish or weight, areas in which fishing was conducted, time of fishing, number of hauls and the estimated processing capacity of, and the actual processing capacity utilized by United States fish processors. The commissioner may collect statistics from any source and may require reporting of these statistics. The information collected by or reported to the commissioner is confidential and may not be disclosed in a manner or form that permits identification of any person or vessel, except when required by court order or when specifically permitted under this section. The commissioner may share data collected under this section with the National Marine Fisheries Service or successor organization for research or fisheries management purposes, provided that federal laws and regulations protect the confidentiality of the shared data. The commissioner shall adopt rules to carry out the purposes of this section. Rules adopted under this section are routine technical rules pursuant to Title 5, chapter 375, subchapter2-A.

Maine ASMFC River Herring Sustainable Fishing Plan Update 2015

1. Introduction

The purpose of this sustainable fisheries management plan is to ensure that existing river herring resources within Maine continue to thrive and provide a source of forage for Maine's fish and wildlife and provide commercial fishing opportunities in coastal Maine's communities.

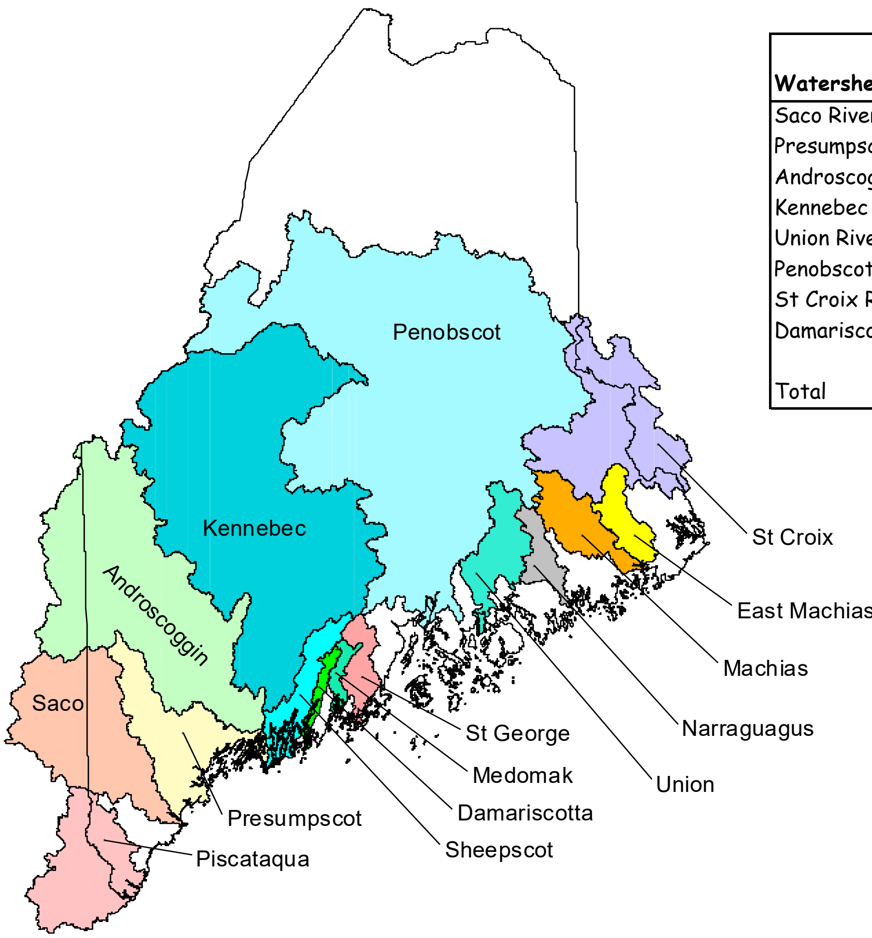
The State of Maine Department of Marine Resources (DMR) and municipalities that historically harvest river herring operate under cooperative site specific management plans that guide conservation and harvest of river herring resources within these municipalities. These plans promote and manage healthy commercial and non-commercial river herring resources where they occur within the state. Maine formalized mutual river herring management plan formats in 1950, though mutual management plans and harvest agreements existed prior to this date

Maine has forty municipalities with the exclusive right to commercially harvest river herring. The State of Maine, in conjunction with the municipalities, and in accordance with cooperative river herring management plans, reviews these plans on an annual basis. Currently, twenty-four municipalities actively harvest river herring (Table 1). Joint fisheries operate through cooperative agreements between municipalities with a shared waterway. One example is Winnegance Lake in mid-coast Maine. The three municipalities, Bath, West Bath, and Phippsburg, that boarder the spawning habitat along Winnegance Lake share management responsibilities and coordinate harvest.

Directed commercial harvest of alewife or blueback herring does not occur in the main stem of nine of Maine's largest rivers (Penobscot, Kennebec, Androscoggin, Saco, St. Croix, Presumpscot, Machias, Salmon Falls, and East Machias). Commercial fisheries do exist on the tributaries of larger rivers, for example, harvest is permitted on the Sebasticook River six miles above its confluence with the Kennebec. Maine limits directed harvest in these rivers through time/area closures and gear restrictions. These traditional conservation strategies allow alewife and blueback herring unrestricted access to spawning habitats upstream. To further conserve existing river herring populations in coastal waters this plan prohibits the use of all gear types to fish for, catch, harvest, or sell blueback herring or alewife (Alosa aestivalis, Alosa pseudoharengus), collectively known as river herring in Maine territorial waters (inside three miles) with the exception of the permitted municipal fisheries. **(Appendix B)**

There are ongoing efforts to improve commercial and non-commercial runs that occur throughout historic spawning habitats in the state. Dam construction during the last two centuries isolated river herring from many of the inland waters DMR is trying to restore through alewife reintroduction. The historical significance of anadromous fish to these waters was eventually lost, and freshwater fish communities, especially recreational game fish, began dominating these habitats. In the 1980s, DMR began restoring historic spawning habitats for anadromous fish in inland waters. Establishing a baseline for reintroduction was important to inland fisheries managers that manage fishing opportunities for salmon, trout, and bass. The interim restoration target for inland spawning habitats is six fish per surface acre for inland lake and pond locations stocked by truck. The State of Maine established this stocking rate as a result of a 10-year study conducted by MDMR, Maine Department of Environmental Protection, and Maine Inland Fisheries and Wildlife (Kircheis 2002). The goal of the study was to quantify the effects of a spawning population of alewife on the resident fish species and zooplankton community within inland waters. A stocking rate of six fish per surface acre of lake or pond habitat exhibited no negative effects on growth rates of resident fresh water fish species. The DMR observes this stocking rate for all truck-stocked locations. It is important to note that the initial stocking rate for this study was arbitrary and the stocking density could be higher and still not demonstrate significant impacts to resident fish species. The potential alewife population based on historically available habitat and estimates of current production would exceed 54.5 million fish (Figure 1).

Figure 1. Estimates of potential alewife returns from historic alewife habitat by watershed (@235/fish/acre).



Watershed	Alewife Potential
Saco River	720,630
Presumpscot River	147,700
Androscoggin River	2,300,000
Kennebec River	11,143,086
Union River	2,000,000
Penobscot River	14,561,305
St Croix River	22,660,000
Damariscotta	1,034,000
Total	54,566,721

The Maine Department of Marine Resources must receive a permit from the Maine Department of Inland fisheries and Wildlife before stocking any state waters with river herring. The numbers of spawning fish allowed into some historic spawning habitats is limited, or not permitted at all, based on perceived conflicts with rainbow smelt and recreational sport fish species such as landlocked salmon, smallmouth bass, and largemouth bass. Although there appears to be no basis for these concerns the number of river herring permitted into some historic spawning locations range from zero to six fish per surface area based on the Lake George Report. State legislation prohibits stocking river herring into several waters in the state. Most commercial runs could expand if they were not constrained by permitting or fish passage restrictions unrelated to the commercial harvest. One example is the

Androscoggin River, Maine's third largest River where only 1/3 of the historic spawning area is open to river herring restoration. A similar issue occurred on the St. Croix River when the Maine Legislature ordered modifications to these fishways to prevent river herring from ascending the river. Soon after the state closed these fishways in the 1980s, the river herring run declined from a population of 2.8 million returns to approximately 5,000. In 2013 the Maine Legislature reversed its decision and river herring were allowed to pass into a larger portion of the watershed beginning in 2014. The DMR is also working with state, federal resource agencies and NGOs to increase access to historic spawning habitats on the St. Croix River and other rivers statewide.

Commercial harvesters and supporters of river herring restoration continue to advocate for increased passage for river herring. All of the current municipalities that exercise commercial river herring fishing rights maintain and monitor up and downstream passage during the spring and fall. Since 2008 commercial fisherman collected scale samples from their respective commercial catches to meet the data collection objectives of Amendment 2. In municipalities which do not exercise their right to fish, river herring returns typically remain below expectations. In most cases, there is no local interest in providing/improving passage or monitoring these runs.

Table 1. Maine municipalities with directed commercial river herring fishing rights

Municipality	Fishery	Municipality	Fishery
Alna*	Long Pond	Lincolnville	Pitcher Pond
Arrowsic	Sewall Pond	Northport	
Bath*	Winnegance Pond	Mount Desert	Somes Pond
Phippsburg*		Newcastle*	Damariscotta Lake
West Bath*		Nobleboro*	
Benton*	Sebasticook River	Orland*	Orland River
Boothbay Harbor	West Harbor Pond	Pembroke*	Pennimaquan Lake
Breman	Webber Pond	Perry*	Boyden Lake
Bristol	Pemaquid Pond	Penobscot*	Peirce Pond
Cape Elizabeth	Alewife Pond	Phippsburg	Center Pond
Cherryfield*	Narraguagus River	South Berwick	Salmon Falls River
Columbia Falls*	Pleasant River	Steuben*	Tunk Lake
Dresden*	Mill Pond	Sullivan*	Flanders Pond
East Machias*	Gardiner Lake	Surry	Patten Pond
Ellsworth*	Union River	Tremont	Sea Cove Pond
Franklin*	Great Pond	Vassalboro*	Webber Pond
Gouldsboro*	West Bay Pond	Waldoboro	Medomak River
Hampden	Souadabscook Pond	Warren*	St. George River
Jefferson*	Dyer-Long Pond	West Bath	New Meadows Pond
Kennebunk	Alewife Pond	Woolwich*	Nequasset Lake

* Towns that currently harvest river herring

2. Current regulations

Commercial Fisheries

Local municipalities control access to most commercial quantities of river herring. These municipalities, in cooperation with the State of Maine, manage the state's river herring resources. The State of Maine requires municipalities with historic river herring harvest rights to file an annual notification that they wish to maintain exclusive fishing rights. An annual harvest plan is required for each fishery prior to approval by the Department of Marine Resources. Most commercial harvest plans follow the model plan provided below, while some plans have additional management requirements specific to an individual run. Each municipality restricts the number of harvesters to one individual who is responsible for harvesting fish under the municipality's management plan. All commercial fisheries have a 72-hour closed period or conservation equivalency to insure proper escapement into spawning habitat. Individual river/stock specific plans were provided to ASMFC for review if additional information is required. Municipal fisheries that operate under conservation equivalencies are required to pass the minimum number of spawning river herring upstream based on habitat availability at the rate of 35 fish per surface acre of spawning and nursery habitat and/or provide additional escapement periods.

Commercial Season

The annual river herring harvest begins when fish a river at the harvest site, typically the last week of April, though many runs do not commence until the first week of May. The run timing of commercial catches is progressively later as you move eastward along the coast. The river herring season ends June 5 unless the municipality submits a request for a 10-day extension until June 15. The DMR will award an extension if environmental conditions delay run timing during the season and river herring are not available to the commercial harvester. Closed periods still apply which effectively reduce the extension period to no more than seven and as few as five additional fishing days for the season. Most years the June 15 end date coincides with the start of the blueback herring run in Maine rivers. Commercial harvesters do capture blueback herring toward the end of the alewife season at some locations (Orland, Benton, Warren). Most commercial alewife harvest locations do not support blueback herring populations. In general, Maine rivers with blueback herring runs see spawning continue through the third week of July. Most commercial quantities of blueback herring are found in the main stems of our large rivers and larger tributaries and are protected by time/area closures and gear restrictions.

Model Harvest Ordinance for the Harvest of River Herring

1) A minimum unobstructed opening of two feet (2') shall be maintained at all times between the riverbank and the downstream end of the weir.

2) The maximum mesh size of wire, twine, or other material used in the weir shall not exceed one inch by one inch (1" x 1").

3) There shall be a 72-hour weekly closed season on alewives from sunrise each Thursday morning until sunrise the following Sunday morning. During the closed period, a minimum size unobstructed opening of three feet by three feet (3' x 3') shall be maintained in the upstream and downstream end of the trap to allow escapement of spawning alewives and other migratory fish.

4) Migratory fish such as salmon, shad, or other species except alewives and blueback herring that enter the trap shall be removed and allowed to pass upstream.

5) Fishing operations shall cease and all fishing gear obstructing the passage of fish shall be removed from the fishing waters not later than June 5. If late-run alewives are entering the river, the Town must seek approval from the Department of Marine Resources to extend the season up to but no later than June 15.

6) The total landings in pounds or bushels and value of the catch shall be made available to the Maine Department of Marine Resources and/or National Marine Fisheries Service on request by these agencies.

Additional Regulations for Streams with Atlantic Salmon Runs

1) The entrance to the dipping pen or trap shall be covered by bars, slats, or spacers with a maximum width of two inches (2") between said bars, slats or spacers.

2) Dipping of alewives shall be confined to the dipping pen or trap.

The U.S Fish and Wildlife Service lists Atlantic salmon as endangered in the eastern two thirds of the State of Maine. There are no known conflicts with commercial alewife fisheries in the rivers where these fisheries currently exist. River herring may provide possible benefits to the Atlantic salmon smolts during emigration by increasing the numbers of forage fish within the system during migration. The U.S. Fish and Wildlife Service is currently testing the hypothesis that alewives provide a cover for migrating Atlantic salmon smolts, lessening the morality during downstream migration to the sea.

Newly Enacted Legislation

The 124th Maine Legislature passed legislation presented as proposed legislation in the previous Sustainable Fisheries Management Plan. This legislation crates a “Commercial Pelagic and Anadromous Fishing License and Establishes the Pelagic Fisheries Fund.” This legislation requires mandatory reporting of all catch data within 60 days, tracks bycatch for river herring, and provides funding to conduct limited research **(Appendix B)**. This legislation tracks river herring bycatch statewide and helps identify fishing locations and gear types that have high incidence of river herring bycatch in coastal waters.

The 126th Maine Legislature passed legislation opening up the St. Croix River to the passage of river herring. “*By May 1, 2013, the commissioner and the Commissioner of Inland Fisheries and Wildlife shall ensure that the fishways on the Woodland Dam and the Grand Falls Dam located on the St. Croix River are configured or operated in a manner that allows the unconstrained passage of river herring.*”

Recreational Fisheries

Limited opportunities exist for recreational river herring harvest in tidal and inland waters. Current state law allows recreational anglers to take 25 fish per day for personal use. Few locations in Maine permit recreational anglers to regularly catch 25 fish per day. Gear restrictions limit anglers to hook and line and dip net only. These gear types are permitted only in areas outside of a watershed and downstream of the municipal harvest location where exclusive rights are granted by the State. The recreational fisheries do not affect escapement of spawning fish passed at commercial fishing operations.

3. Brief Description - Current Status of the Stocks

The State of Maine manages Individual river herring runs as separate stocks. These stocks have separate, well-defined spawning habitats, migration routes, and run timing that make them unique compared to similar runs throughout the state. Maine's commercial stocks were categorized as stable or increasing based on data presented in the 2008 ASMFC stock status report, though they did reflect annual variation based on a number of factors related to the environment, upstream and downstream passage efficiency, annual harvest, escapement, and bycatch in other fisheries. Data analyses compiled during the ***Atlantic States Marine Fisheries Commission 2008 River Herring Stock Status Report*** indicate increasing trends in population and stable age structure during the past two decades. The same analyses for the period 2009 through 2015 indicate similar trends in run size for commercial and non-commercial locations. These data are included below and will be included as part of Maine's section of the Atlantic States Marine Fisheries Commission 2017 River Herring Stock Status Report update.

Non-commercial runs are stable at low levels, except where active restoration efforts are improving run size. Many non-commercial runs are small by nature and experience passage issues that limit reproduction and run size. Despite commercial closure, many of these runs maintain only remnant populations. Improving upstream and downstream passage and stocking efforts to rebuild these runs could enable these habitats to produce excess fish for commercial harvest in the future.

The State of Maine is currently updating the Maine section of the ASMFC Stock Assessment Committee document ***Atlantic States Marine Fisheries Commission 2008 River Herring Stock Status Report*** with data through 2015. Highlights of the information from the 2008 report and updates through 2015 are provided below as support for the sustainable fisheries management plan update.

- Male and female river herring survival estimates using the Beverton-Holt method indicate Z-values of .69 and .54 for males and females respectively for alewives collected from the Androscoggin River for the period 2000 to 2007. The same calculation run for the period 2008 – 2016 were .54 and .33 for males and females respectively, indicating increased survival of both sexes on the Androscoggin River.

- Results are similar for the Sebasticook River where Z-estimates for both male and female river herring declined from .84 and .77 to .78 and .65 for male and females respectively. These values indicate increased survival for the period 2000 - 2015. Assessment of the period 2008 – 2015 returned survival estimates of .71 for males and .53 for females.

  Figure 2. Fisheries independent Beverton-Holt Z-Estimates.

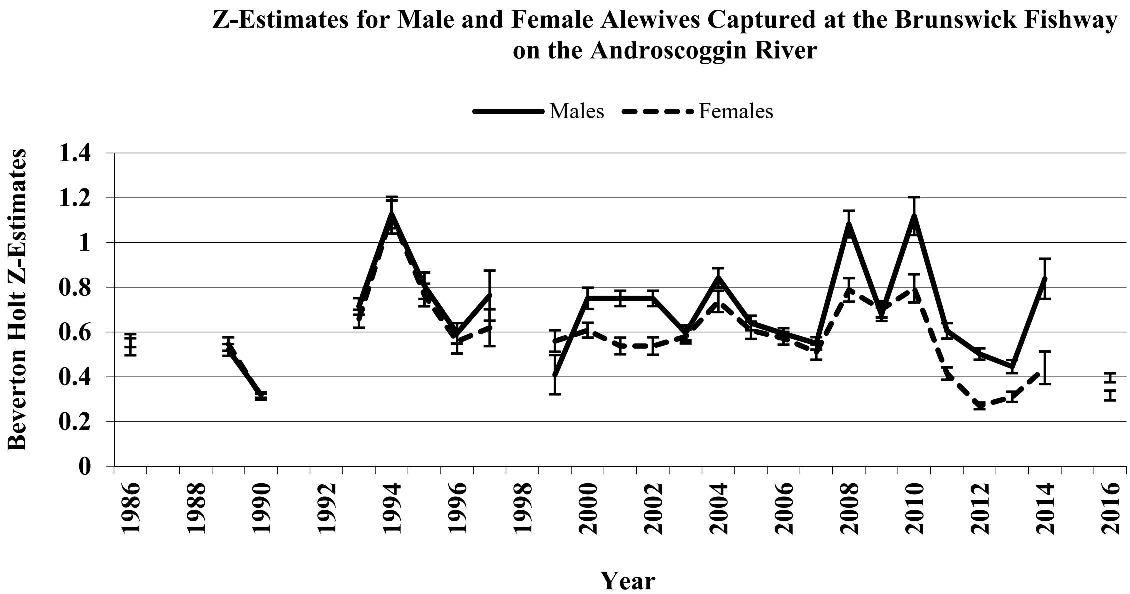


Figure 3. Fisheries independent estimates of male Z-values using Catch Curve, Heinke and Chapman-Robson.

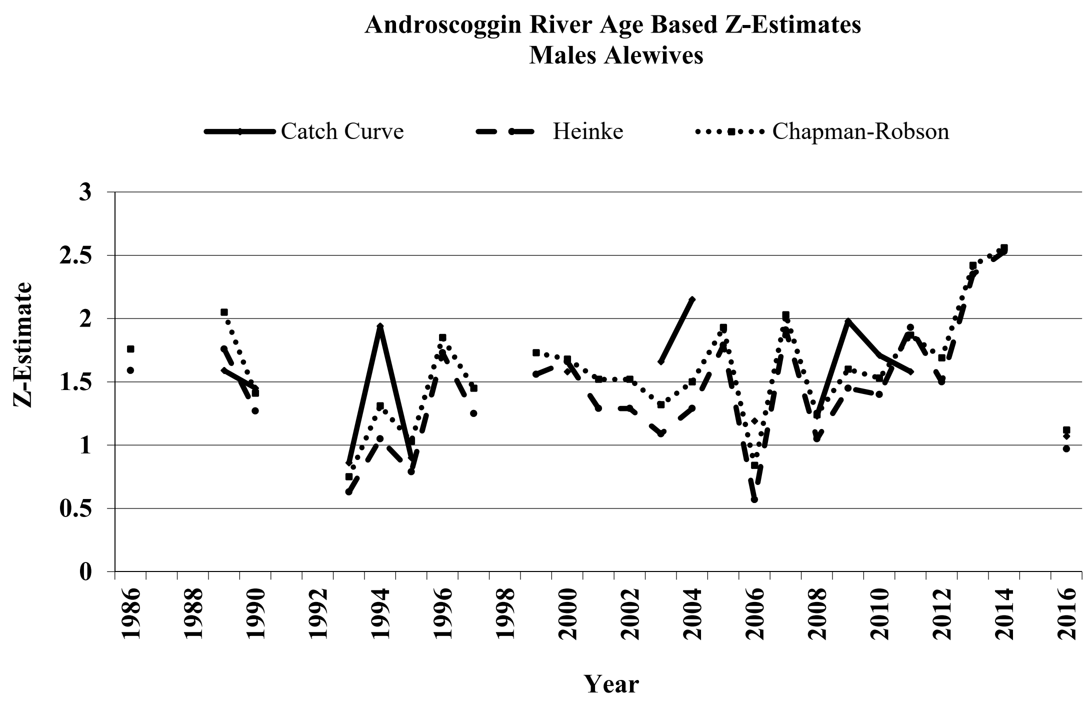
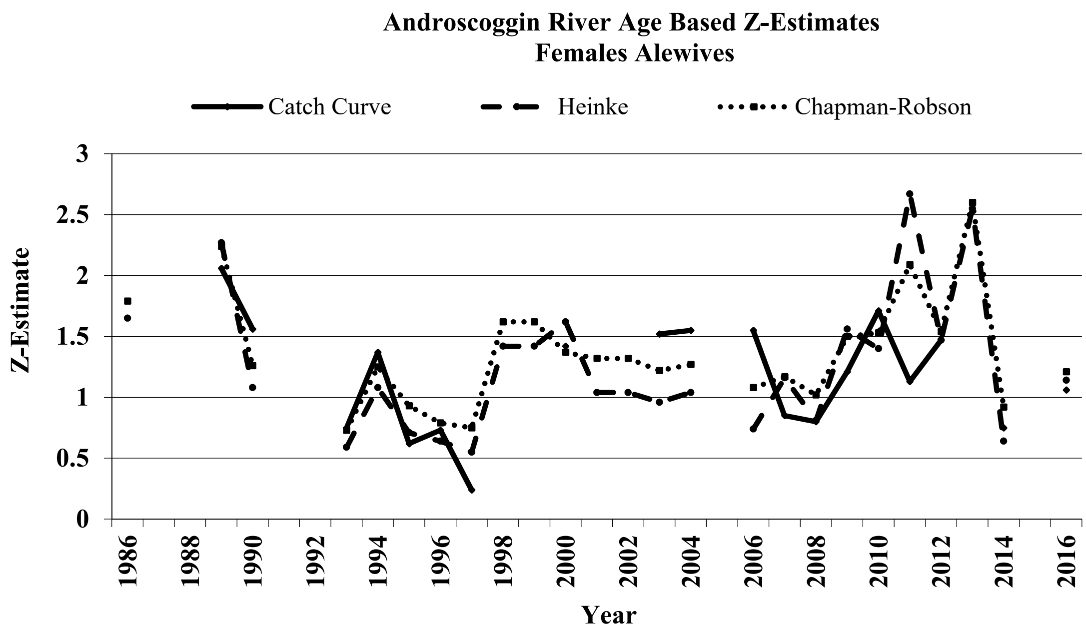


Figure 4. Fisheries independent estimates of female Z-values using catch curve, Heinke and Chapman-Robson.



- Exploitation of the Damariscotta River run was <6% for the period 1993-2000. Since 2000 the exploitation rate has ranged as high as 62%. For the years 2012 through 2016 exploitation has returned to less than 15%. The trend in exploitation for the Union River declined from 1982 – 2016 and was 50% for 2016, well below exploitation rates of greater than 90% prior to 1989.

- Increasing trends in run size in Maine for the Androscoggin, Damariscotta, and Sebasticook rivers.

- Stable maximum age for alewife and blueback herring compared to historical observations. Data from scale sample analysis show river herring as old as 8-years in our commercial fisheries. (ASMFC 2008 RHSSR page 48)

  Age data collected by Rounsefell in 1943 indicate that two commercial fisheries, Damariscotta and Orland, where dominated by single age classes of spawning fish. There were no data available for subsequent years, though Rounsefell's estimates of exploitation (90% for Maine fisheries) would indicate that there were few repeat spawning fish during the years immediately prior to or following 1943 (Rounsefell & Stringer 1943 p.6). Current age data and exploitation rates have improved the age structure and improved the repeat spawning component of these runs.

- Stable mean length at age for fisheries-independent data collected from the Androscoggin River. (ASMFC 2008 RHSSR page 48)

  Historical data collected by the U.S Fish and Wildlife Service in 1943 at Damariscotta Lake and the Orland River support the current trends discussed in the Stock Status Report for Maine alewife populations. The U.S. Fish and Wildlife Service determined that the mean lengths of male alewives were 268.9 mm and 269.7 mm respectively. Mean female lengths for the same rivers during 2008 were 275.0 mm and 278.2 mm respectively. The mean lengths observed by the U.S. Fish and Wildlife Service are shorter than those observed in biological samples collected from the 2010 and 2015 commercial fisheries at these locations. Damariscotta males averaged 274.2 (2010); 274.8 (2015) mm while females averaged 286.7 (2010); 293.1 (2015) mm, both longer than the lengths observed in 1943. Length data collected in 2010 and 2015 from the commercial fishery on the Orland River show the same trends. Mean length for males is 278 (2010); 274.9 (2016) mm and mean length for females is 294 (2010) and 286.3 (2015) mm. (Rounsefell & Stringer 1943 p.7, 23)

- Repeat spawning rates based on fisheries-independent data collected at the Brunswick Fishway have averaged 25% since 2007 and increased to 29.5% for the years 2008 through 2016. (ASMFC 2008 RHSSR page 38)

a. Landings

The State of Maine requires mandatory reporting of municipal landings by August 1st of each year. Trend analysis indicates an increasing trend in state landings for the period 1981 to 2016. The Department of Marine Resources tracks annual landings through time to observe trends by stock. Total annual landings data is becoming less dependable as a metric to assess the health of commercial runs. An increasing number of municipal harvesters are choosing to harvest for personal use or limited retail sale and not fully exploiting the available population as has occurred historically. Escapement numbers are unknown in most Maine river herring fisheries and are estimated using a ratio of closed days and reported commercial landings. Estimates of escapement and total run size using commercial landings are the best estimators of population size for most on Maine's commercial runs. A reduced commercial harvest results in a substantially lower estimate of escapement and total run size when runs are not actively harvested.

Fisheries independent estimates of annual escapement for commercial runs can range from 15 – 80 percent. To ground truth estimates of escapement to actual escapement, runs where daily counts were conducted were used as a proxy for commercial fisheries. The ratio of the number fish passed on closed days when commercial fisheries were not allowed were compared to open days when commercial fisheries were allowed. These data indicate that consecutive closed days during the week can achive an escapement rate approximating 42.8 percent of the annual run. The daily counts at the Sebasticook River Fishway indicate escapement similar to those observed at Brunswick. The escapement rate at the Sebasticook River Fishway was 45 percent based on the numbers of fish passed upstream on fishing days vs non-fishing days (Table 2). Data were also collected at the Weber Pond Fishway where an active harvest exists and the numbers of fish that pass into the lake were counted daily. These data also indicate that for the past six years escapement exceeds the target escapement of 42.8 percent. Fisheries staff bases these estimates on upstream passage at fisheries independent and fisheries dependent locations where counts provide total escapement numbers by day.

Table 2. Fisheries independent and fisheries dependent estimates of annual harvest rates associated with daily counts.

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2001-2009
Total number passed at Brunswick Fishway (FI)										
	18,196	104,520	53,732	113,686	25,846	34,239	60,577	91,859	44,725	547,380
Number passed at Brunswick Fishway (FI) during allowed fishing days										
	12,162	37,126	29,385	67,667	10,517	25,986	50,487	44,946	18,248	296,524
Estimated proportion of run harvested										
	0.67	0.36	0.55	0.60	0.41	0.76	0.83	0.49	0.41	0.54

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2010-2016
Total number passed at Brunswick Fishway (FI)										
	30,676	54,886	170,191		55,678	71,887	114,874			498,192
Number passed at Brunswick Fishway (FI) during allowed fishing days										
	21,397	25,829	77,629		31,372	37,802	46,097			240,126
Estimated proportion of run harvested										
	0.70	0.47	0.46		0.56	0.53	0.40			0.48

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2010-2016
Total number passed at Sebasticook River (FI)										
	1,628,187	2,751,473	1,702,631	2,272,025	2,378,906	2,157,983				12,891,205
Number passed at Sebasticook Fishway (FI) during allowed fishing days										
	907,123	1,227,788	1,035,058	1,252,662	1,430,235	1,266,239				7,119,105
Estimated proportion of run harvested										
	0.56	0.45	0.61	0.55	0.60	0.59				0.55

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2010-2016
Total number passed at Webber Pond Fishway (FD)										
	191,133	253,983	540,375	207,419	529,730	649,200	526,290			2,898,130
Number harvested at Webber Pond Fishway (FD) during allowed fishing days										
	47,520	110,520	265,200	71,160	150,840	282,240	173,520			1,101,000
Proportion of run harvested										
	0.25	0.44	0.49	0.34	0.28	0.43	0.33			0.38

b. Fisheries Independent and Fish Dependent Indices

Both fisheries independent and fisheries dependent data are available to provided relative measures of river herring run health and status. Most fisheries independent data come from beach seine surveys, fishway counts, or fish counts on rivers without commercial fisheries. Analysis of these data indicates that most commercial populations statewide are stable. Analysis of these data alone may not be the best way to determine the health of stock specific runs throughout the state. Stock specific data for the runs below originate from reported landings data and scale samples collected by commercial fishermen or fisheries biologists and analyzed by a Department fisheries staff (Table 3).

Table 3. Fisheries independent estimates of Z for periods 2014 & 2015.

Fisheries Independent Data — Age Based Z-Estimates

2015	**Catch Curve**				**Heinke**				**Chapman-Robson**			
	Male		**Female**		**Male**		**Female**		**Male**		**Female**	
Fishery	**Z**	**SE**	**Z**	**SE**	**Z**	**SE**	**Z**	**SE**	**Z**	**SE**	**Z**	**SE**
Alewife					0.98	0.36	1.10	0.67	1.20	0.45	1.10	0.67
Card Mill	0.76	0.34	0.59	0.40	1.03	0.16	0.87	0.14	0.99	0.15	0.84	0.13
Center			1.90	0.30	2.03	0.39	2.30	0.40	2.13	0.41	2.22	0.38
Dennys	1.35	0.65			0.77	0.11	0.74	0.11	1.09	0.15	1.11	0.18
Long	1.83	0.33	1.21	0.05	1.45	0.22	1.51	0.24	1.58	0.25	1.63	0.26
Medomak					*1.86*	*0.28*			*1.99*	*0.31*		
Pembroke			1.34	0.43	2.44	0.65	0.96	0.15	2.48	0.66	1.19	0.19
Seal Cove					2.64	0.93	1.80	0.23	2.64	0.93	1.95	0.26
Sewalls	0.72	0.42	0.81	0.28	1.54	0.45	1.39	0.34	1.15	0.33	1.13	0.27
Walker			1.89	1.09	3.47	0.97	3.14	0.68	3.47	0.97	2.77	0.55
Wights	1.10	0.95			3.20	0.68	3.74	0.98	2.83	0.55	3.74	0.98

Sexes Combined

Fisheries Independent Data — Age Based Z-Estimates

2014	**Catch Curve**				**Heinke**				**Chapman-Robson**			
	Male		**Female**		**Male**		**Female**		**Male**		**Female**	
Fishery	**Z**	**SE**	**Z**	**SE**	**Z**	**SE**	**Z**	**SE**	**Z**	**SE**	**Z**	**SE**
Brunswick			0.75	0.37	2.53	0.65	0.64	0.15	2.56	0.67	0.92	0.22
Card Mill					*2.12*	*0.51*			*2.20*	*0.53*		
Center	*1.1*	*0.18*			*0.84*	*0.09*			*0.99*	*0.10*		
Dennys					2.94	0.95	2.67	0.66	2.94	0.95	2.71	0.67
Long	1.10	0.19			1.58	0.19	1.10	0.47	1.46	0.17	1.25	0.55
Patten	1.51	0.34	1.30	0.22	1.93	0.32	1.58	0.30	1.83	0.3	1.54	0.29
Pembroke			1.86	0.67	2.87	0.55	2.69	0.54	2.91	0.56	2.46	0.47
Pierce	1.45	0.15	1.23	0.02	1.33	0.20	1.47	0.22	1.44	0.22	1.59	0.25
Seal Cove					*1.03*	*0.13*			*1.33*	*0.17*		
Sewalls	0.58	0.44	0.89	0.21	1.00	0.19	0.63	0.11	1.00	0.19	0.83	0.15
Wights	1.72	0.61	1.46	0.24	1.04	0.16	1.24	0.18	1.28	0.20	1.39	0.21
All Runs	1.14	0.23	1.22	0.21	1.42	0.09	1.30	0.08	1.42	0.09	1.24	0.08

Sexes Combined

Table 4. Fisheries dependent estimates of Z for periods 2014 and 2015.

Fisheries Dependent Data **Age Based Z-Estimates**

2015	**Catch Curve**				**Heinke**				**Chapman-Robson**			
	Male		**Female**		**Male**		**Female**		**Male**		**Female**	
Fishery	**Z**	**SE**	**Z**	**SE**	**Z**	**SE**	**Z**	**SE**	**Z**	**SE**	**Z**	**SE**
Alna	*1.34*	*0.56*			*2.81*	*0.42*			*2.69*	*0.39*		
Benton	0.80	0.16			1.56	0.28	1.61	0.28	1.63	0.30	1.77	0.32
Damariscotta	1.47	0.22	1.20	0.58	1.75	0.29	0.74	0.12	1.70	0.28	1.05	0.17
Dresden	1.88	0.45			2.46	0.46	1.47	0.23	2.32	0.42	1.66	0.27
Ellsworth					2.71	0.66	2.42	0.46	2.74	0.67	2.48	0.47
Gouldsboro	*1.58*	*0.20*			*1.09*	*0.10*			*1.28*	*0.12*		
Grist Mill	1.90	0.17	1.49	0.22	2.14	0.36	1.77	0.29	2.10	0.35	1.72	0.28
Jefferson	1.81	0.23	1.25	0.14	1.55	0.25	1.20	0.18	1.65	0.27	1.28	0.19
Orland	1.43	0.59	1.18	0.05	2.08	0.39	1.30	0.21	1.88	0.34	1.35	0.22
Perry	1.98	0.02	0.86	0.10	2.01	0.31	1.61	0.30	2.02	0.31	1.34	0.25
Sullivan	1.11	0.22	1.00	0.81	0.67	0.10	1.69	0.36	0.94	0.14	1.45	0.30
Warren	1.63	0.18	0.59	0.13	1.45	0.27	1.16	0.15	1.54	0.29	1.09	0.14
Webber	1.68	0.97	1.73	0.20	2.74	0.66	2.00	0.39	2.40	0.54	1.95	0.37
Winnegance					2.72	0.47	1.70	0.58	2.77	0.48	1.79	0.62
Woolwich	1.81	0.44			1.29	0.19	1.32	0.21	1.47	0.22	1.54	0.25

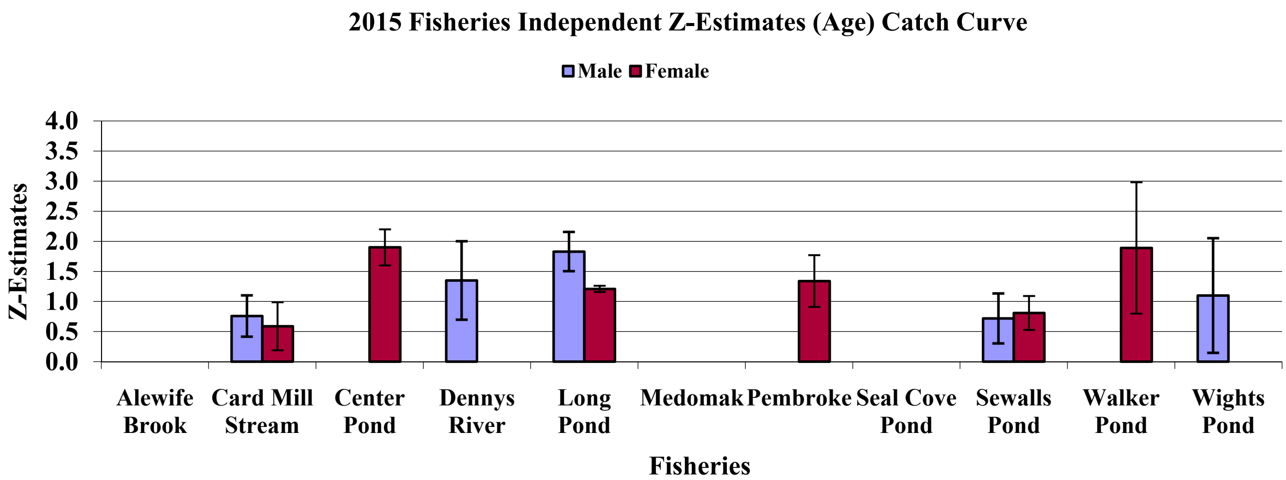
Sexes Combined

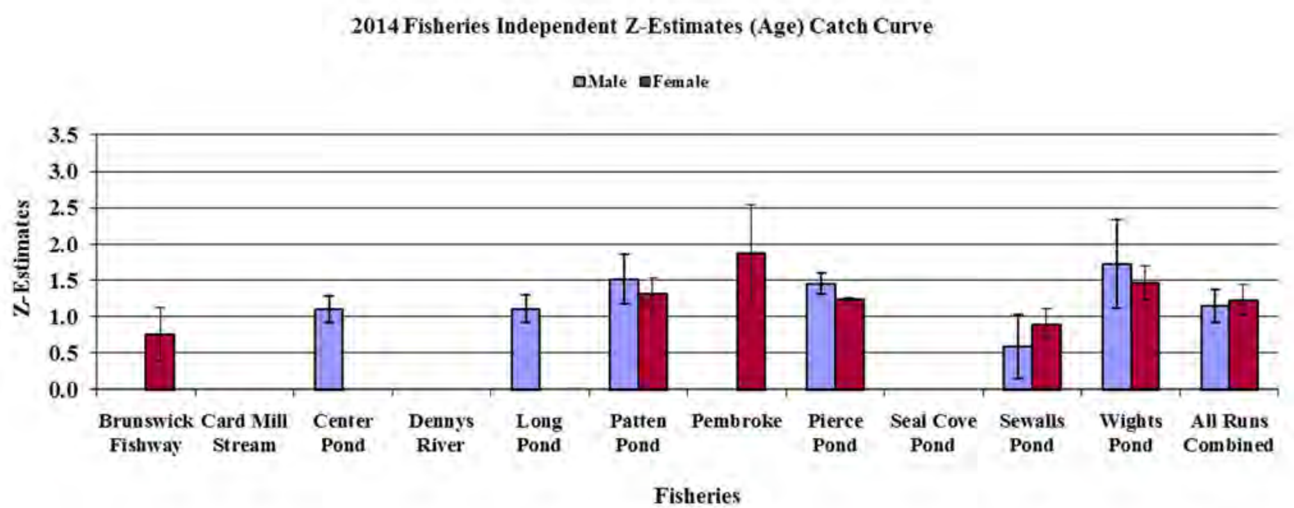
Fisheries Dependent Data **Age Based Z-Estimates**

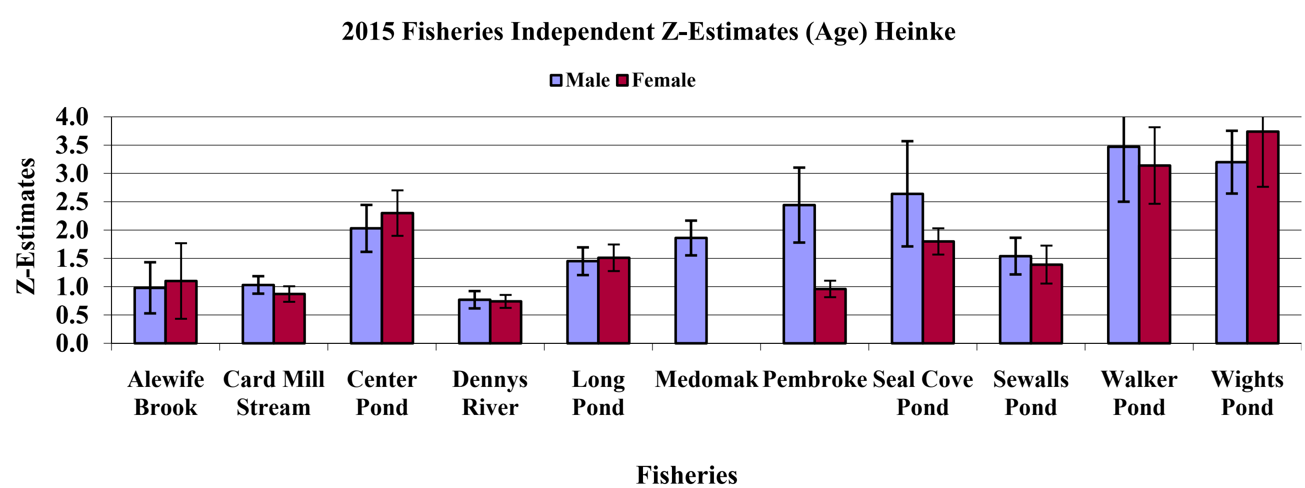
2014	**Catch Curve**				**Heinke**				**Chapman-Robson**			
	Male		**Female**		**Male**		**Female**		**Male**		**Female**	
Fishery	**Z**	**SE**	**Z**	**SE**	**Z**	**SE**	**Z**	**SE**	**Z**	**SE**	**Z**	**SE**
Alna	0.5	0.23			0.49	0.06	1.39	0.34	0.67	0.09	1.57	0.388
Benton	1.65	0.02	1.08	0.62	1.70	0.33	2.56	0.53	1.72	0.34	1.99	0.37
Damariscotta	0.71	0.18	1.04	0.28	0.98	0.16	0.94	0.14	1.05	0.17	0.96	0.14
Dresden	0.80	0.23	0.73	0.16	0.62	0.09	0.54	0.08	0.81	0.12	0.72	0.11
E. Machias			1.26	0.13	2.16	0.51	1.08	0.14	2.23	0.54	1.16	0.15
Ellsworth	1.18	0.52	1.58	0.91	1.72	0.31	2.55	0.46	1.57	0.28	2.23	0.38
Gouldsboro	2.12	0.59	0.13	0.05	2.90	0.47	1.20	0.18	2.73	0.43	1.14	0.17
Grist Mill	1.20	0.11	0.93	0.16	1.16	0.22	0.80	0.10	1.28	0.24	0.92	0.12
Jefferson	1.20	0.27	1.29	0.26	1.01	0.15	0.90	0.10	1.20	0.18	1.04	0.11
Narraguagus	*1.31*	*0.23*			*1.33*	*0.15*			*1.27*	*0.14*		
Orland	1.17	0.11	1.02	0.26	1.34	0.22	0.89	0.15	1.37	0.23	1.10	0.19
Perry	1.52	0.85			0.69	0.11	1.98	0.43	1.05	0.17	2.08	0.46
Stueben	*1.01*	*0.47*			*1.84*	*0.32*			*1.46*	*0.24*		
Sullivan	0.85	0.49	0.09	0.58	1.32	0.21	0.62	0.09	1.24	0.20	0.72	0.10
Warren	0.63	0.07	0.60	0.23	0.66	0.13	0.73	0.10	0.77	0.15	0.72	0.10
Webber	1.14	0.07	0.42	0.04	1.01	0.16	0.57	0.08	1.11	0.18	0.69	0.10
Winnegance	1.13	0.49			2.23	0.37	1.18	0.25	1.79	0.27	1.42	0.30
Woolwich	1.42	0.18	1.04	0.60	1.66	0.41	1.61	0.40	1.61	0.39	1.43	0.35
All Runs	1.6	0.25	1.33	0.174	1.59	0.25	0.98	0.04	1.34	0.06	1.04	0.039

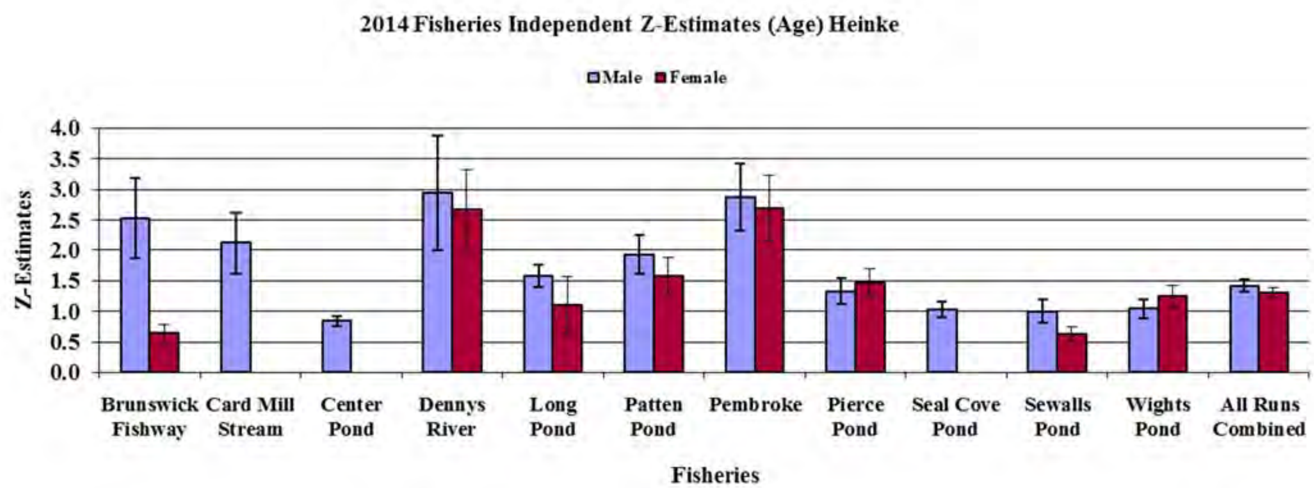
Sexes Combined

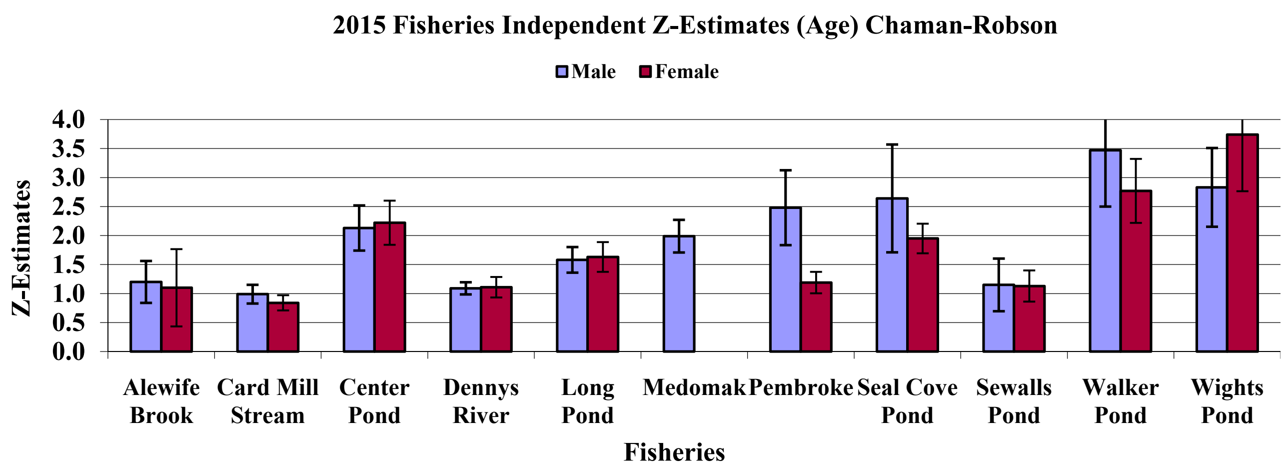
Figure 5. Fisheries independent estimates of Z for 2014 and 2015.


2015 Fisheries Independent Z-Estimates (Age) Catch Curve
Male
Female
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Z-Estimates
Alewife Brook
Card Mill Stream
Center Pond
Dennys River
Long Pond
Medomak
Pembroke
Seal Cove Pond
Sewalls Pond
Walker Pond
Wights Pond
Fisheries


2014 Fisheries Independent Z-Estimates (Age) Catch Curve
Male
Female
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Z-Estimates
Brunswick Fishway
Card Mill Stream
Center Pond
Dennys River
Long Pond
Patten Pond
Pembroke
Pierce Pond
Seal Cove Pond
Sewalls Pond
Wights Pond
All Runs Combined
Fisheries


2015 Fisheries Independent Z-Estimates (Age) Heinke
Male
Female
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Z-Estimates
Alewife Brook
Card Mill Stream
Center Pond
Dennys River
Long Pond
Medomak
Pembroke
Seal Cove Pond
Sewalls Pond
Walker Pond
Wights Pond
Fisheries





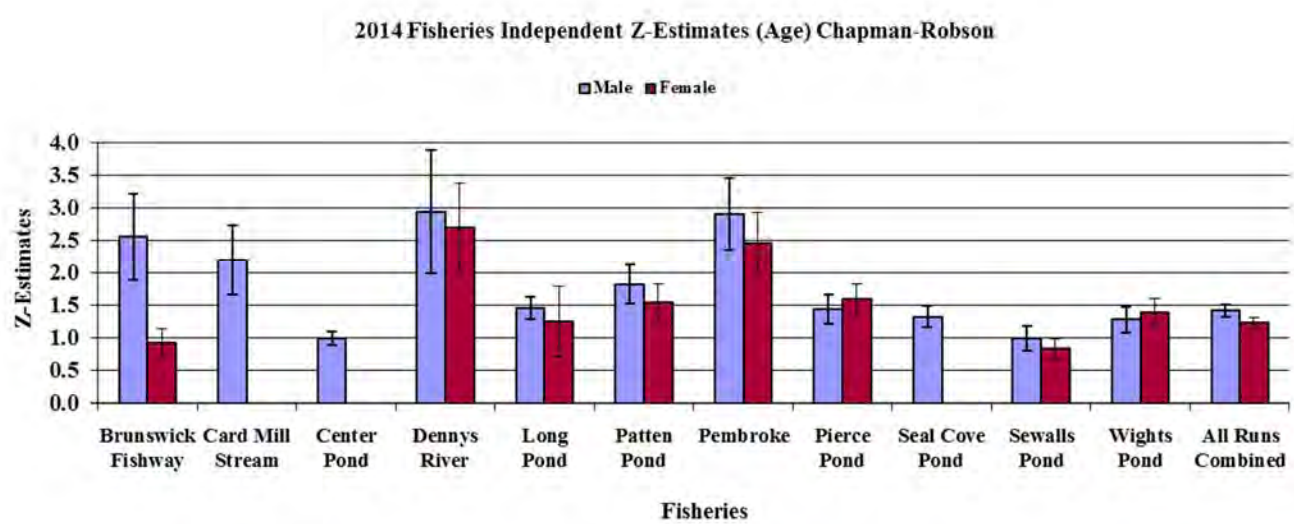
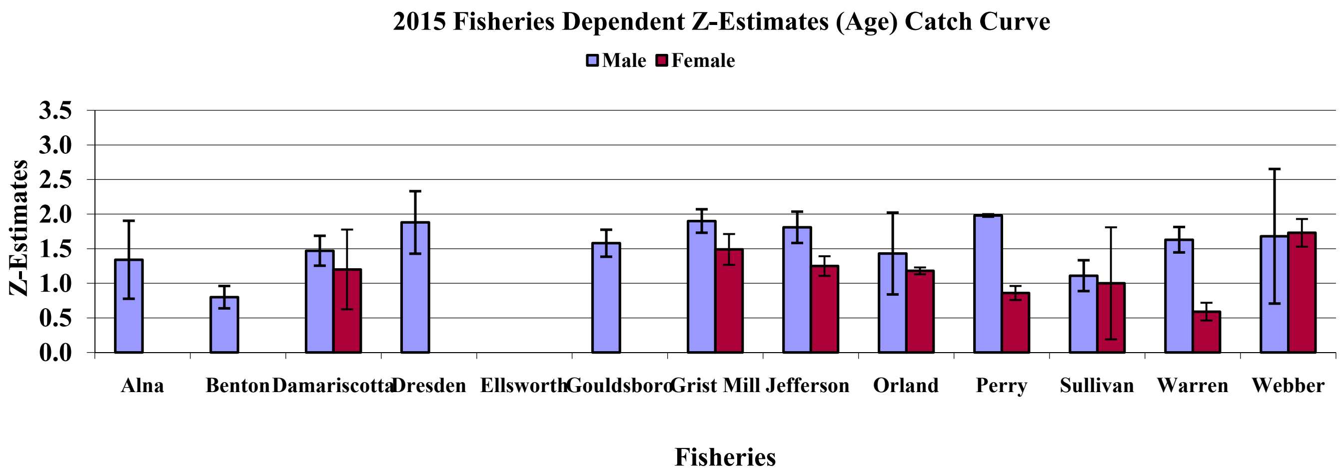
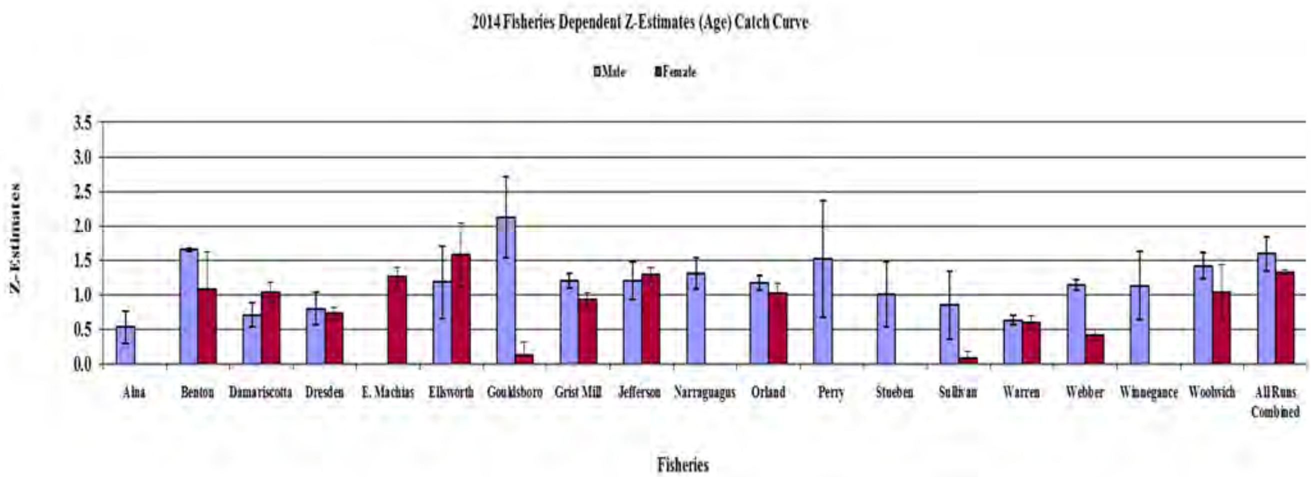
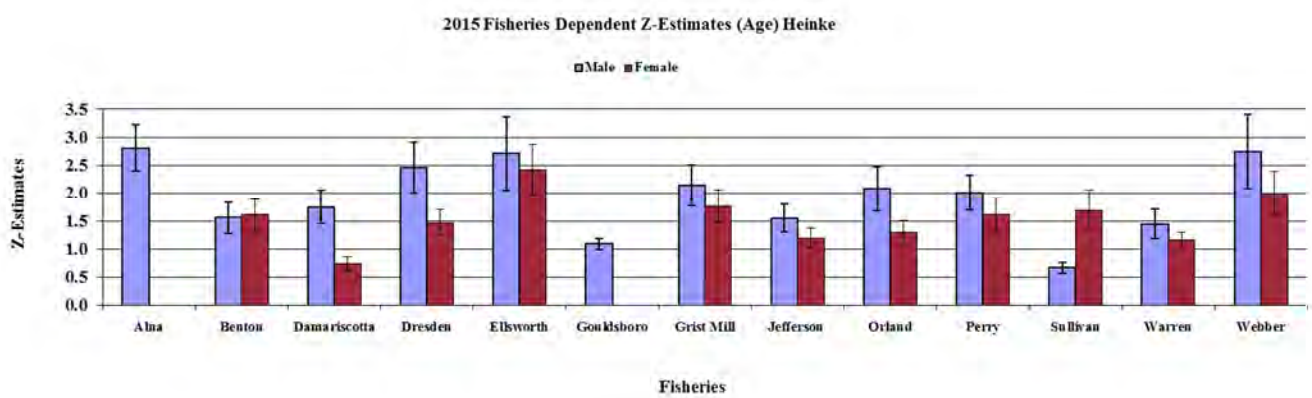
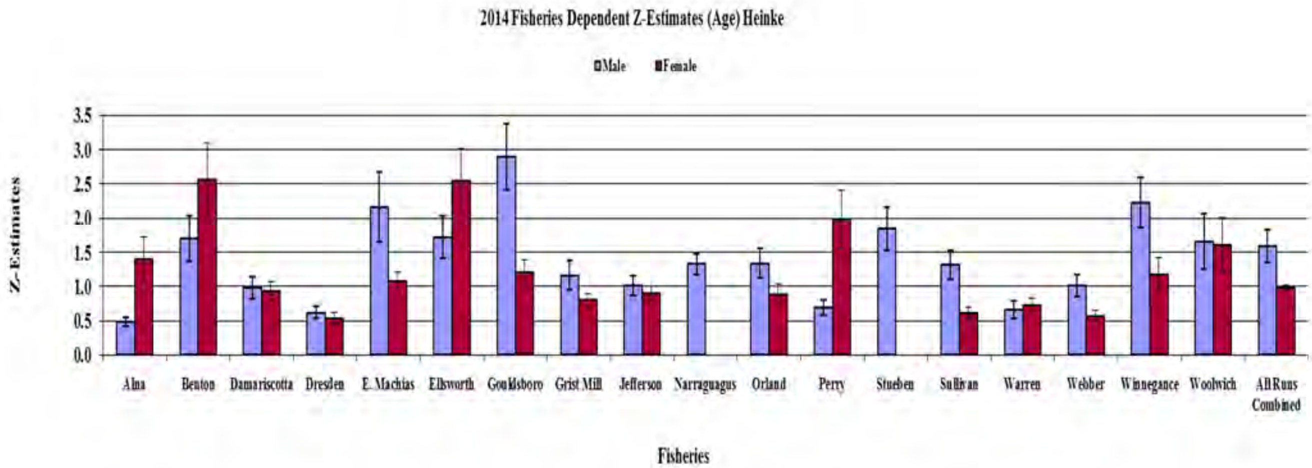


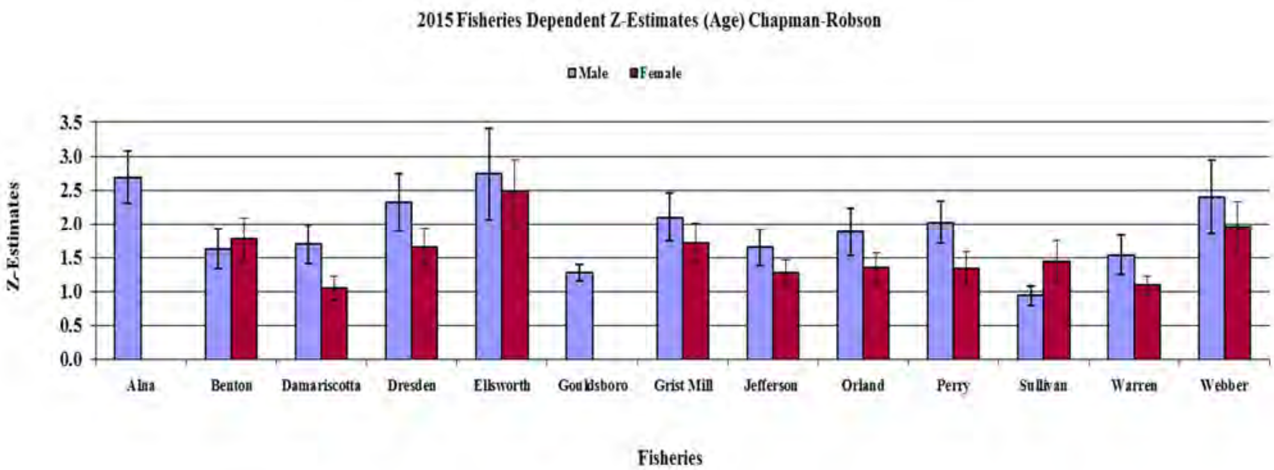
Figure 6. Fisheries dependent estimates of Z for 2014 and 2015.

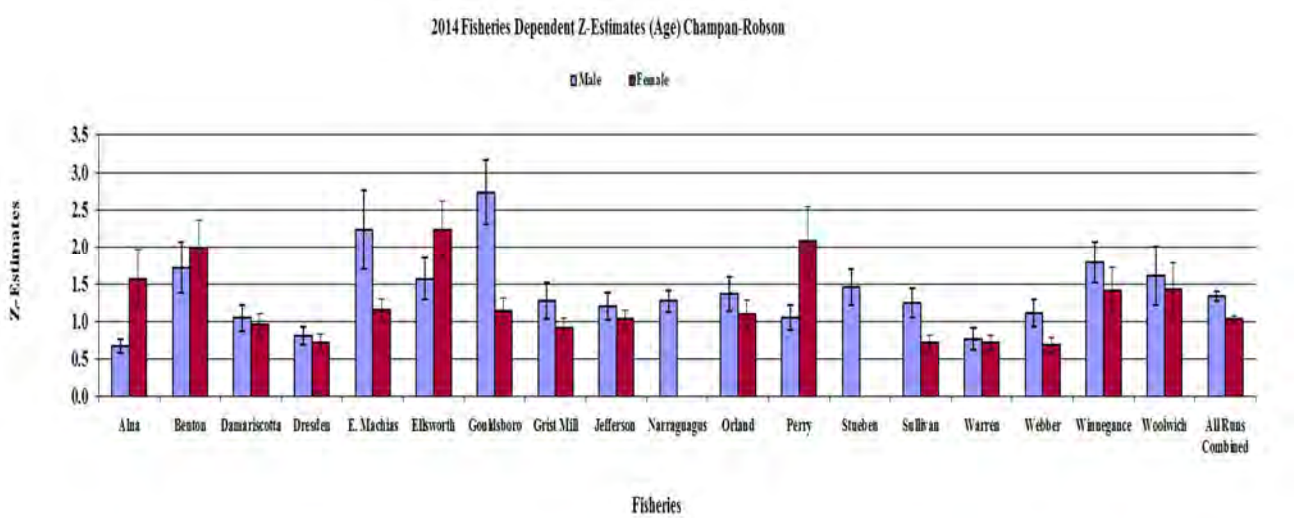

2015 Fisheries Dependent Z-Estimates (Age) Catch Curve
Male
Female
Z-Estimates
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Alna
Benton
Damariscotta
Dresden
Ellsworth
Gouldsboro
Grist Mill
Jefferson
Orland
Perry
Sullivan
Warren
Webber
Fisheries


2014 Fisheries Dependent Z-Estimates (Age) Catch Curve
Male
Female
Z-Estimates
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Alna
Benton
Damariscotta
Dresden
E. Machias
Ellsworth
Gouldsboro
Grist Mill
Jefferson
Narraguagus
Orland
Perry
Stueben
Sullivan
Warren
Webber
Winnegance
Woolwich
All Runs Combined
Fisheries


2015 Fisheries Dependent Z-Estimates (Age) Heinke
Male
Female
Z-Estimates
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Alna
Benton
Damariscotta
Dresden
Ellsworth
Gouldsboro
Grist Mill
Jefferson
Orland
Perry
Sullivan
Warren
Webber
Fisheries







Z-estimates and associated graphs presented for Maine's 2010 Sustainable Fisheries Management Plan are in Appendix A.

4. Fisheries to Remain Open

Municipality	Fishery	Municipality	Fishery
Alna	Long Pond	Jefferson	Dyer-Long Pond
Bath Phippsburg West Bath	Winnegance Pond	Newcastle Nobleboro	Damariscotta Lake
Benton	Sebasticook River	Orland	Orland River
Cherryfield	Narraguagus River	Perry	Boyden Lake
Dresden	Mill Pond	Sullivan	Flanders Pond
East Machias	Gardiner Lake	Steuben	Tunk Lake
Ellsworth	Union River	Mount Desert	Somes Pond
Franklin	Great Pond	Vassalboro	Webber Pond
Gouldsboro	West Bay Pond	Warren	St. George River
Woolwich	Nequasset Lake		

Commercial Justifications for the Municipal Fisheries Listed Above:
In the commercial landings graphs provided below, years with extremely low landings or zero landings for one or more years indicate fishing during that year did not occur or occurred at very low levels. Two main reasons for zero landings are 1) the municipality decided to close the fishery for conservation or other purposes or 2) the harvester fished for a limited number of days due to weather, gear, price, or other factors that created unfavorable market conditions. In 2005, extreme high water prevented many commercial fishermen from conducting normal fishing operations during the season. The result was a major decline in reported landings for 2005 statewide. Biological data by river for most river systems, other than commercial harvest data, are unavailable for years prior to 2008. The State of Maine and commercial harvesters began collecting data in 2008 to address concerns presented in ASMFC Amendment 2 to the Shad and River Herring Management Plan.

The sustainability threshold established in 1984 for most Maine commercial fisheries is 35 fish per surface acre of spawning habitat. Since 1984, MDMR has used 235 fish/acre to estimate commercial alewife production in Maine's lakes and ponds. The Department established this unit production value from the commercial harvest in six Maine watersheds for the years 1971-1983. Based on these data, commercial yield was assumed to be 100 pounds/surface acre of ponded habitat. This value is slightly less than the average of the lowest yield/acre for all six rivers and within the range of yields experienced in other watersheds. Assuming a weight of 0.5 pounds per adult, the commercial yield equals 200 adults/surface acre. The commercial harvest was assumed to represent an exploitation rate of 85%, because most alewife runs were harvested six days per week. Exploitation rates on the Damariscotta River, for example, ranged from 85-97% for the years 1979-1982. When commercial yield is adjusted for the 15% escapement rate, the total production is 235 adult alewives/acre. This is a conservative estimate of the numbers of returns based on an average individual weight value of .5 pounds per return, including blueback herring.

The Maine Department of Marine Resources estimates escapement for commercial runs where actual counts are not conducted. The estimate is calculated by dividing the number of fishing days allowed by the potential number of fishing days in a week then multiplying by the reported landings for the year. For most fisheries this will be 0.43 * number of fish reported landed for the season.

Fishery Specific Information

Alna Commercial Fishery:
The Maine Department of Marine Resources manages this system for a commercial escapement of 35 fish per acre. The spawning escapement needs for this system are 20,000 river herring passed upstream by the harvester throughout the season. The management plan has always achieved returns to meet the target escapement developed for this system or passed the entire run upstream. Harvesting occurs in the fishway just downstream of Long Pond, which is the only accessible spawning habitat on the east branch of the Sheepscot River. The Department of Inland Fisheries and Wildlife will not permit alewives access to historical spawning habitat in Sheepscot Pond, or the watershed above, because of concerns with disease issues that may affect sport fish raised at a state own fish hatchery downstream of Sheepscot Pond.

The west branch of the Sheepscot River leading to Branch Pond contains very few river herring. For several years the DMR stocked Branch Pond to propagate an artificial run while planning and designing a fishway to provide access to Branch Pond. An old mill sits directly on top of the outlet stream and the engineering and constructions costs of installing fish passage at this time is prohibitive. Stocking Branch Pond no longer occurs but will resume if fisheries staff can overcome fiscal challenges to acquiring fish passage in the future. There are stray river herring that do ascend the west branch each year but the numbers are low and not harvested commercially. The commercial harvester, through the town of Alna, retains the right to harvest these fish. The harvester keeps the west branch closed to promote natural recolonization of blueback herring to this branch of the river.

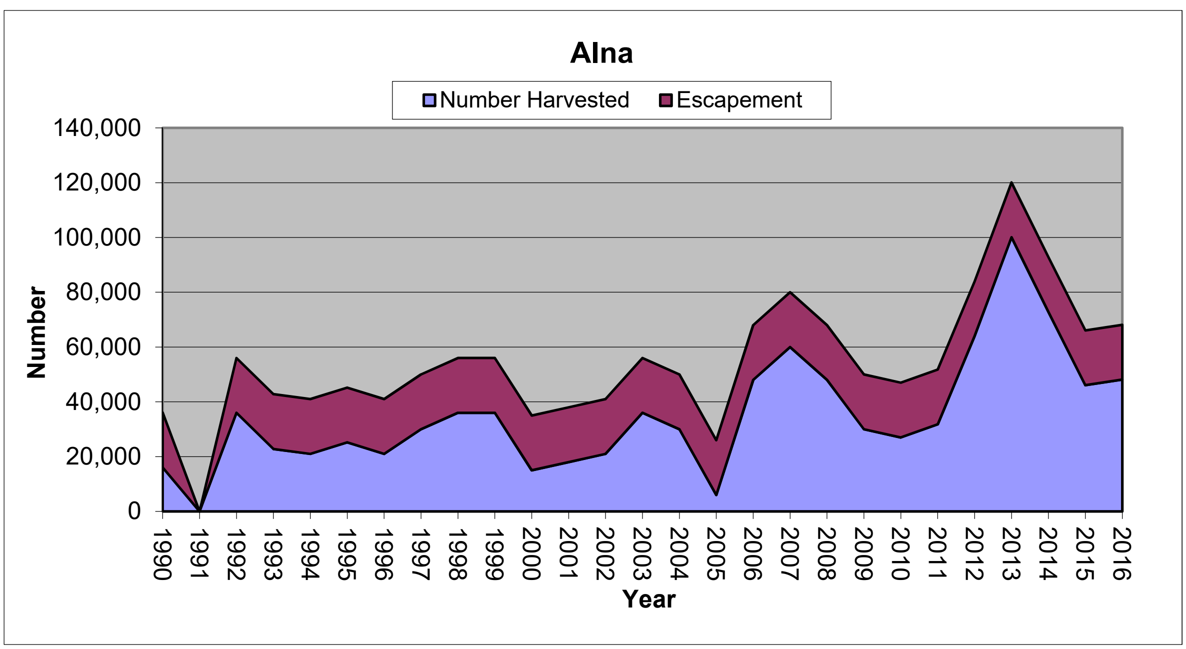
Spawning habitat is available to blueback herring in the river below the fishway. Incidences of blueback herring in the commercial catches or sampling below the fishway are rare. There is no available spawning habitat for alewives in the Sheepscot River below the commercial fishery and there are no reports of juvenile blueback herring emigrating from this system in appreciable numbers.

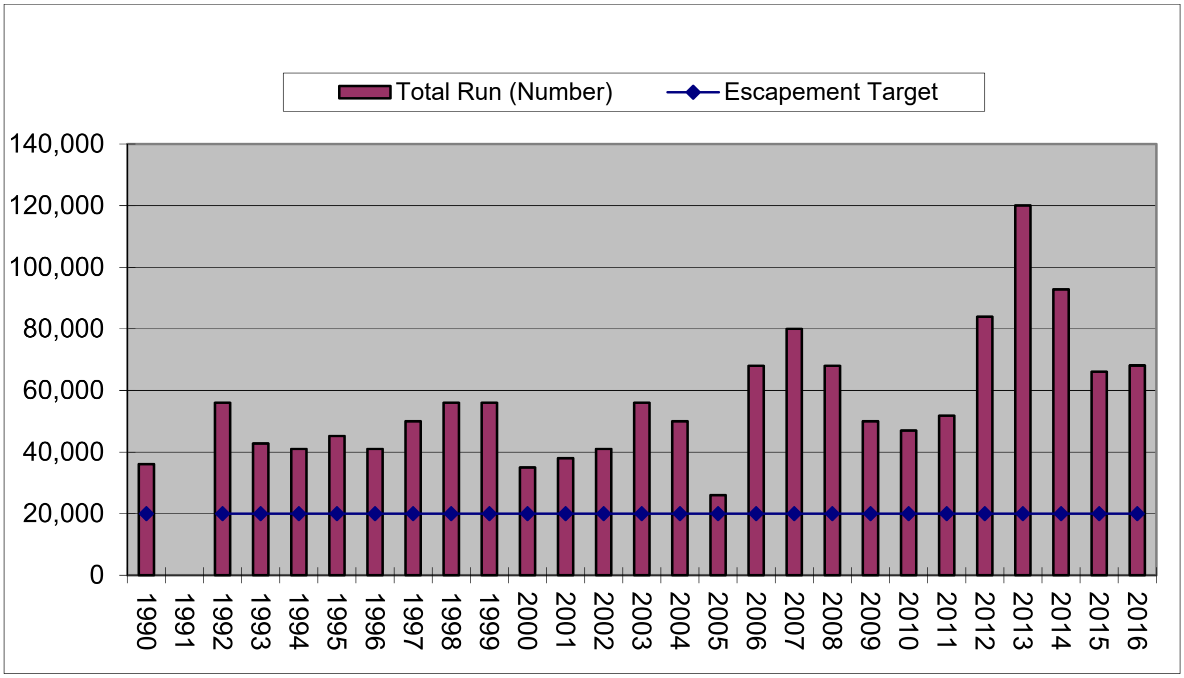
The Sheepscot River alewife run would be considerably larger if all historic river herring habitat were accessible to river herring. In 2017 the dam at Coopers Mill, the current harvest location, will be removed. Dam removal will facilitate upstream and downstream passage, but is unlikely to increase production significantly. Access restrictions placed on the harvester and the Maine Department of Marine Resources by the Maine Department of Inland Fisheries and Wildlife to Sheepscot Pond are unlikely to change in the near future. In 2016 a purchase and sale agreement was signed that will allow fish passage to be constructed at Branch Pond. This will increase production on the west branch of the Sheepscot River and is likely to increase the harvest of this commercial fishery.

Town	River	Lake size (acres)	Threshold (N/acre)
Alna	Sheepscot	571	35

Year	Municipality	River	% repeat spawners by year and frequency	R-0	R-1	R-2	R-3	Z-value
2015	Coopers Mills	Sheepscot	9.1	91.00	8.00	0.00	1.00	1.44
2014	Coopers Mills	Sheepscot	41.0	59.00	36.00	5.00		1.23
2013	Coopers Mills	Sheepscot	33.8	66.20	32.30	1.00	0.50	1.81
2012	Coopers Mills	Sheepscot	7.2	92.76	6.58	0.66		2.65
2011	Coopers Mills	Sheepscot	22.0	78.00	22.00			1.27
2010	Coopers Mills	Sheepscot	4.9	95.15	3.88	0.97		2.29
2009	Coopers Mills	Sheepscot	19.0	81.00	17.00	2.00		1.85
2008	Coopers Mills	Sheepscot	10.0	90.00	10.00			2.20

Year	Escapement Number (based on target)	Actual	Measured or estimated (.43*landings)	spawning below barrier?	Landings Number	total run size (escape+kill)	exploitation rate
1994	20,000	20,000	Measured	n/y	21,000	41,000	0.51
1995	20,000	20,000	Measured	n/y	25,200	45,200	0.56
1996	20,000	20,000	Measured	n/y	21,000	41,000	0.51
1997	20,000	20,000	Measured	n/y	30,000	50,000	0.60
1998	20,000	20,000	Measured	n/y	36,000	56,000	0.64
1999	20,000	20,000	Measured	n/y	36,000	56,000	0.64
2000	20,000	20,000	Measured	n/y	15,000	35,000	0.43
2001	20,000	20,000	Measured	n/y	18,000	38,000	0.47
2002	20,000	20,000	Measured	n/y	21,000	41,000	0.51
2003	20,000	20,000	Measured	n/y	36,000	56,000	0.64
2004	20,000	20,000	Measured	n/y	30,000	50,000	0.60
2005	20,000	20,000	Measured	n/y	6,000	26,000	0.23
2006	20,000	20,000	Measured	n/y	48,000	68,000	0.71
2007	20,000	20,000	Measured	n/y	60,000	80,000	0.75
2008	20,000	20,000	Measured	n/y	48,000	68,000	0.71
2009	20,000	20,000	Measured	n/y	30,000	50,000	0.60
2010	20,000	20,000	Measured	n/y	27,000	47,000	0.57
2011	20,000	20,000	Measured	n/y	31,800	51,800	0.61
2012	20,000	20,000	Measured	n/y	63,960	83,960	0.76
2013	20,000	20,000	Measured	n/y	100,080	120,080	0.83
2014	20,000	20,000	Measured	n/y	72,840	92,840	0.78
2015	20,000	20,000	Measured	n/y	46,080	66,080	0.70
2016	20,000	20,000	Measured	n/y	48,120	68,120	0.71



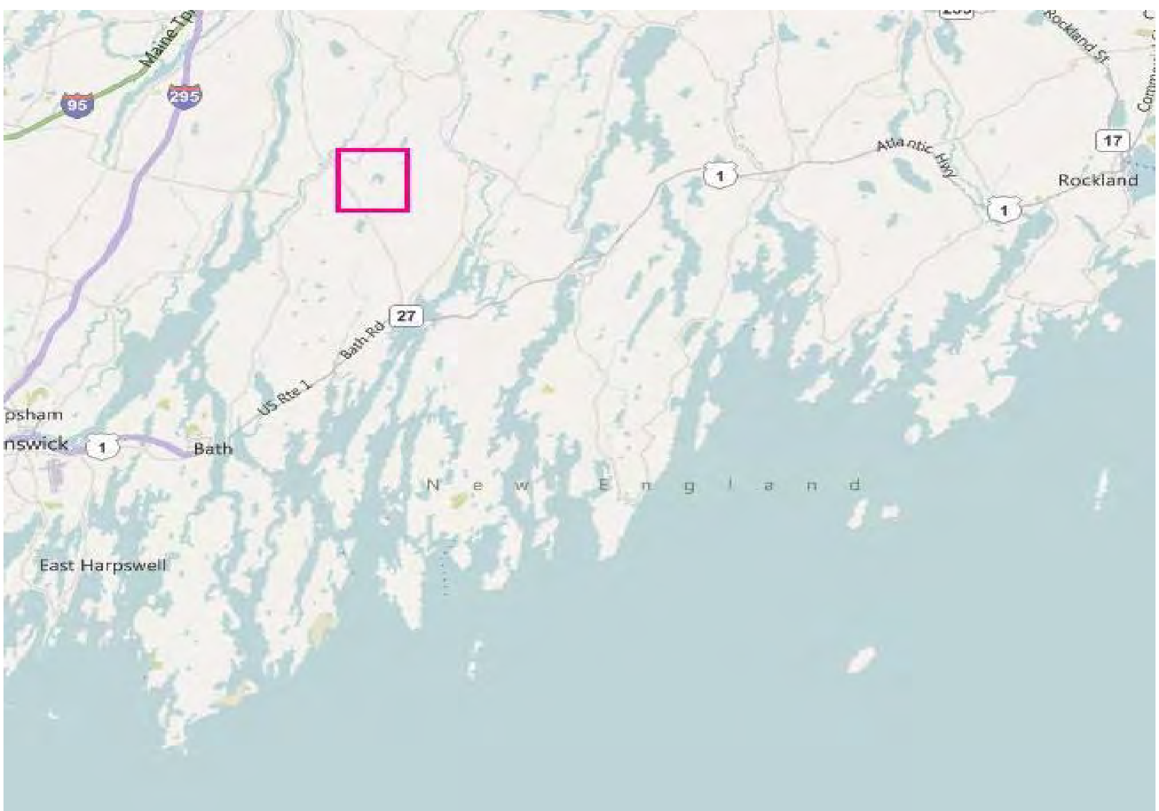


Dresden Commercial Fishery:
The Maine Department of Marine Resources manages this system for a minimum commercial escapement of 35 fish per acre. The spawning escapement need for this system is 5,950 river herring passed upstream through three consecutive closed days per week during the fishery. The management plan has always achieved returns to meet the escapement threshold developed for this system or passed the entire run for the season. The DMR does not permit the river herring fishery in the main stem of the Eastern River. The Eastern River provides available spawning and rearing habitat for blueback herring, American shad, shortnose sturgeon and striped bass. The fishery for river herring occurs upstream of the confluence of the Eastern River and Mill Stream, which leads to spawning habitat in Mill Stream and Dresden Bog.

The Eastern River is one of several rivers in Maine that protect spawning populations of anadromous fish through gear restrictions, time/area closures and seasons. The Eastern River is a free flowing tidal river without any upstream barriers to delay upstream passage. There are no estimates of numbers blueback herring spawning in the Eastern River, though numbers may be as high as several hundred thousand based on the available habitat. It is unknown if alewives spawn in the main stem of the Eastern River. Biological sample data indicate that blueback herring and alewife may interbreed in the main stem of the Eastern River. In general spawning success of alewives in Maine rivers and hydropower headponds is poor.

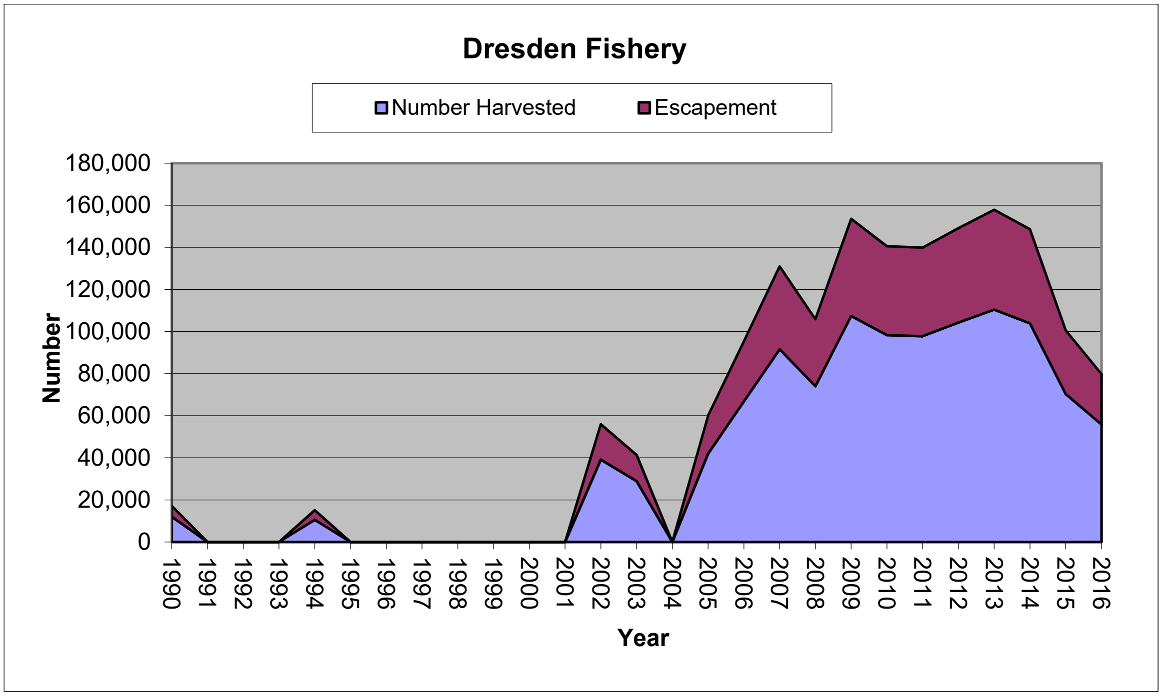
Town	River	Lake size (acres)	Threshold (N/acre)
Dresden	n/a	170	35

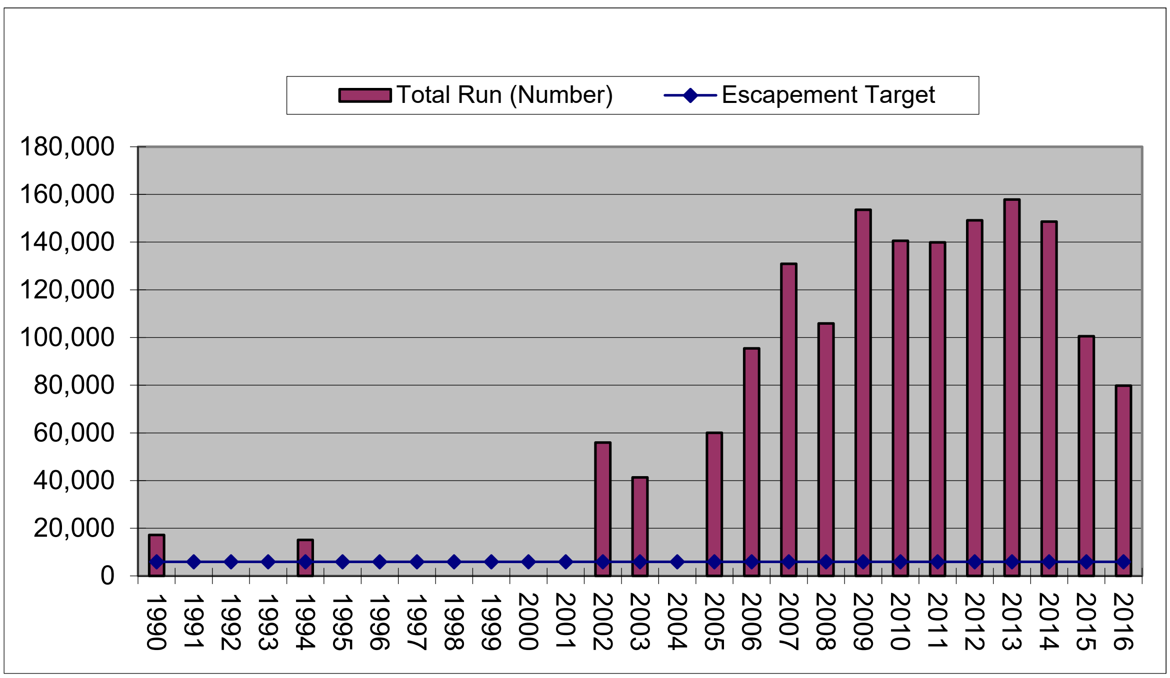

Harvest Location
Spawning Location
Dresden Mills
Dresden Bog Reservoir
Gardiner Pond
Gardiner Rd
Middle Rd


Rockland
Atlantic Hwy
Bath Rd
US Rte 1
Bath
East Harpswell
New England

Year	Municipality	River	% repeat spawners by year and frequency	R-0	R-1	R-2	R-3	Z-value
2015	Dresden	Eastern River	45.5	54.55	41.41	4.04		1.3
2014	Dresden	Eastern River	29.0	71.00	19.00	8.00	2.00	1.16
2013	Dresden	Eastern River	50.5	49.45	24.17	9.89	16.48	0.42
2012	Dresden	Eastern River	24.5	75.52	18.56	3.37	2.53	1.48
2011	Dresden	Eastern River	22.1	77.87	13.27	8.25	0.59	1.5
2010	Dresden	Eastern River	52.5	47.51	40.33	8.83	3.31	0.95
2009	Dresden	Eastern River	38.4	61.60	29.30	5.10	4.00	1.00
2008	Dresden	Eastern River	29.7	70.30	18.80	6.90	4.00	0.96

Year	Escapement Number (based on target)	Actual	Measured or estimated (.43*landings)	spawning below barrier?	Landings Number	total run size (escape+kill)	exploitation rate
1993	5,950		0	n/y	0	0	0.00
1994	5,950		0	n/y	0	0	0.00
1995	5,950		0	n/y	0	0	0.00
1996	5,950		0	n/y	0	0	0.00
1997	5,950		0	n/y	0	0	0.00
1998	5,950		0	n/y	0	0	0.00
1999	5,950		0	n/y	0	0	0.00
2000	5,950		0	n/y	0	0	0.00
2001	5,950		0	n/y	0	0	0.00
2002	5,950		16,822	n/y	39,120	55,942	0.70
2003	5,950		12,436	n/y	28,920	41,356	0.70
2004	5,950		0	n/y	0	0	0.00
2005	5,950		18,060	n/y	42,000	60,060	0.70
2006	5,950		28,690	n/y	66,720	95,410	0.70
2007	5,950		39,371	n/y	91,560	130,931	0.70
2008	5,950		31,837	n/y	74,040	105,877	0.70
2009	5,950		46,182	n/y	107,400	153,582	0.70
2010	5,950		42,260	n/y	98,280	140,540	0.70
2011	5,950		42,054	n/y	97,800	139,854	0.70
2012	5,950		44,840	n/y	104,280	149,120	0.70
2013	5,950		47,472	n/y	110,400	157,872	0.70
2014	5,950		44,686	n/y	103,920	148,606	0.70
2015	5,950		30,238	n/y	70,320	100,558	0.70
2016	5,950		23,994	n/y	55,800	79,794	0.70





Franklin Commercial Fishery:

The Maine Department of Marine Resources manages Great Pond (Grist Mill Stream) for a minimum commercial escapement of 35 fish per acre. The spawning escapement need for this system is 9,170 river herring passed upstream through three closed days per week during the fishery. The management plan has always achieved returns that meet the target escapement developed for this system or passed the total run upstream. There is no spawning below the pond. Beaver dams are a perennial problem at this location effecting upstream and downstream migration during periods of low flow. As with many small coastal runs, access to spawning habitat is influenced by spring and fall water levels necessary to permit upstream and downstream migration. Spawning does not occur in the stream below or above the commercial fishery for alewife. Blueback herring are not observed in this system and there are no historical records to indicate that blueback herring inhabited the stream.

The Franklin fishery at one time only harvested post spawn runback river herring. This practice is not permitted currently but likely had a significant effect on spawning stock, exploitation rates, and number of repeat spawning fish within the system historically.

Town	River	Lake size (acres)	Threshold (N/acre)
Franklin	n/a	262	35

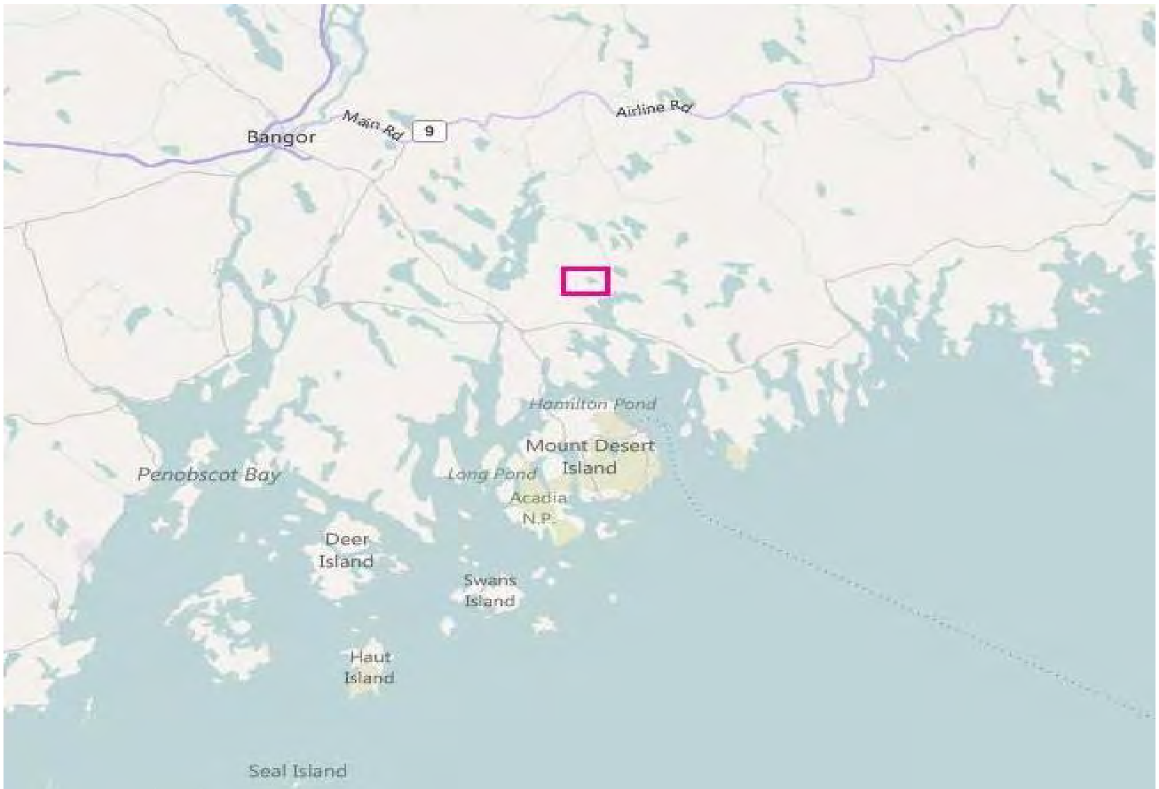
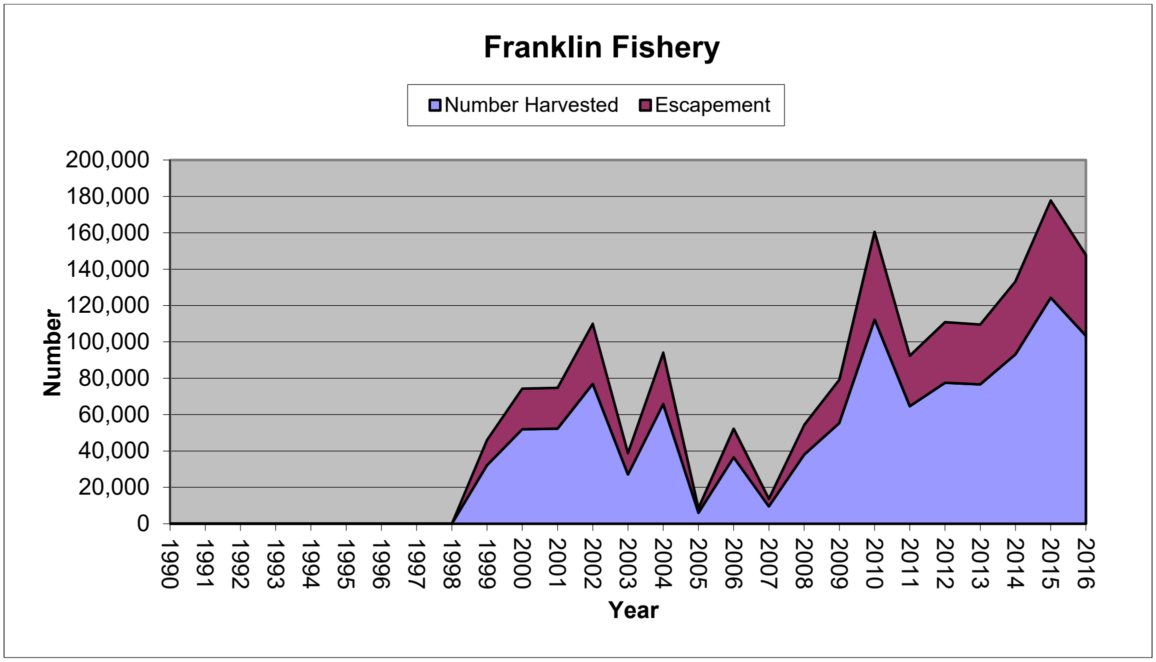
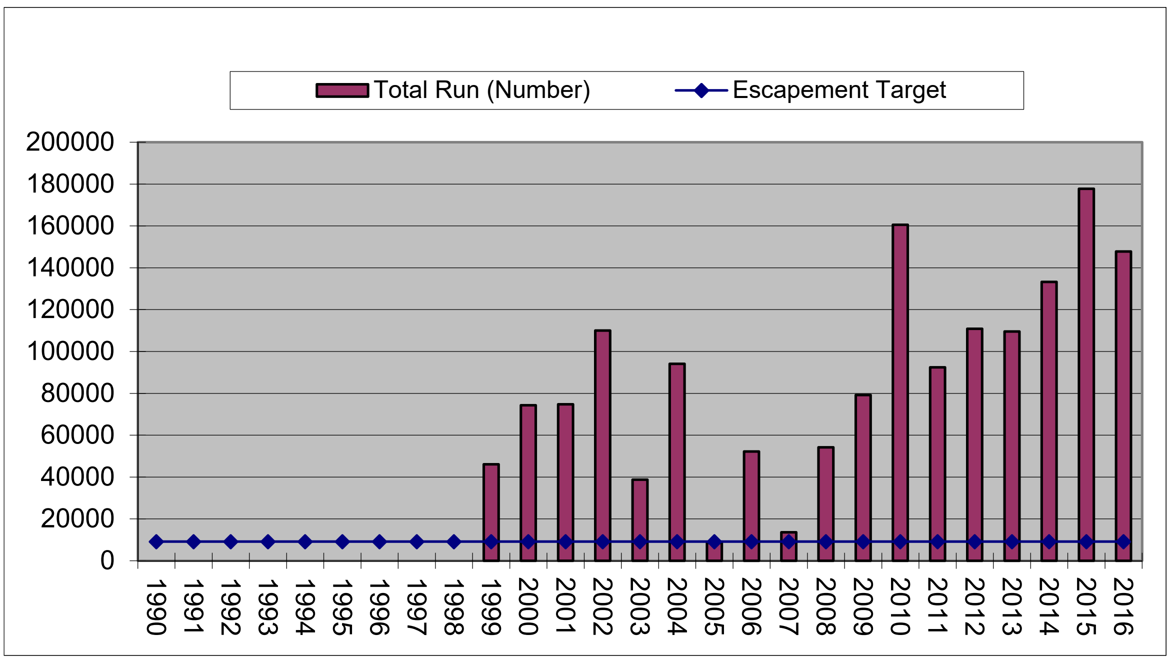


Figure 6. Harvest location for Great Pond in Franklin, Maine.

Year	Municipality	River	% repeat spawners by year and frequency	R-0	R-1	R-2	R-3	Z-value
2015	Franklin	N/A	18.2	81.19	16.83	1.98		1.86
2014	Franklin	N/A	49.5	50.50	41.58	5.94	1.98	1.17
2013	Franklin	N/A	43.8	56.17	37.65	6.17		1.1
2012	Franklin	N/A	13.8	86.17	11.47	2.35		1.8
2011	Franklin	N/A	28.4	71.63	26.54	1.45	0.36	1.95
2010	Franklin	N/A	18.8	81.17	16.31	2.50		1.77
2009	Franklin	N/A	9.7	90.30	8.90	0.80		2.38
2008	Franklin	N/A	27.6	72.40	19.40	7.10		1.39

Year	Escapement Number (based on target)	Actual	Measured or estimated (.43*landings)	spawning below barrier?	Landings Number	total run size (escape+kill)	exploitation rate
1991	9,170		0	n	0	0	0.00
1992	9,170		0	n	0	0	0.00
1993	9,170		0	n	0	0	0.00
1994	9,170		0	n	0	0	0.00
1995	9,170		0	n	0	0	0.00
1996	9,170		0	n	0	0	0.00
1997	9,170		0	n	0	0	0.00
1998	9,170		0	n	0	0	0.00
1999	9,170		13,868	n	32,250	46,118	0.70
2000	9,170		22,343	n	51,960	74,303	0.70
2001	9,170		22,472	n	52,260	74,732	0.70
2002	9,170		33,076	n	76,920	109,996	0.70
2003	9,170		11,662	n	27,120	38,782	0.70
2004	9,170		28,303	n	65,820	94,123	0.70
2005	9,170		2,580	n	6,000	8,580	0.70
2006	9,170		15,707	n	36,528	52,235	0.70
2007	9,170		4,102	n	9,540	13,642	0.70
2008	9,170		16,306	n	37,920	54,226	0.70
2009	9,170		23,813	n	55,380	79,193	0.70
2010	9,170		48,272	n	112,260	160,532	0.70
2011	9,170		21,930	n	51,000	72,930	0.70
2012	9,170		33,334	n	77,520	110,854	0.70
2013	9,170		32,947	n	76,620	109,567	0.70
2014	9,170		40,067	n	93,180	133,247	0.70
2015	9,170		53,458	n	124,320	177,778	0.70
2016	9,170		44,428	n	103,320	147,748	0.70





Nobleboro and Newcastle Commercial Fishery:

The Nobleboro and Newcastle fishery is a joint fishery conducted by two municipalities at one fishing location. The current municipal management plan for this fishery permits all river herring arriving at the fishway during the first week of the season free passage upstream (Figure 9). This fishery is one of two fisheries in Maine that currently allows continuous escapement of spawning fish throughout the season in addition to closed days, though traditionally they harvested seven days a week. Historically, Damariscotta Lake never had a river herring run. The run began in 1806 with the construction of a 42-foot high fieldstone fishway and an initial introduction of broodstock from the Sheepscot River. After local residents established the run, the fishing rights granted by the State of Massachusetts in 1810 permitted the fishery to occur seven days per week. Continuous escapement up the fishway occurred throughout the season. Estimated annual exploitation rates for this run ranged from 85-95 percent from the early 1800s through the 1984.

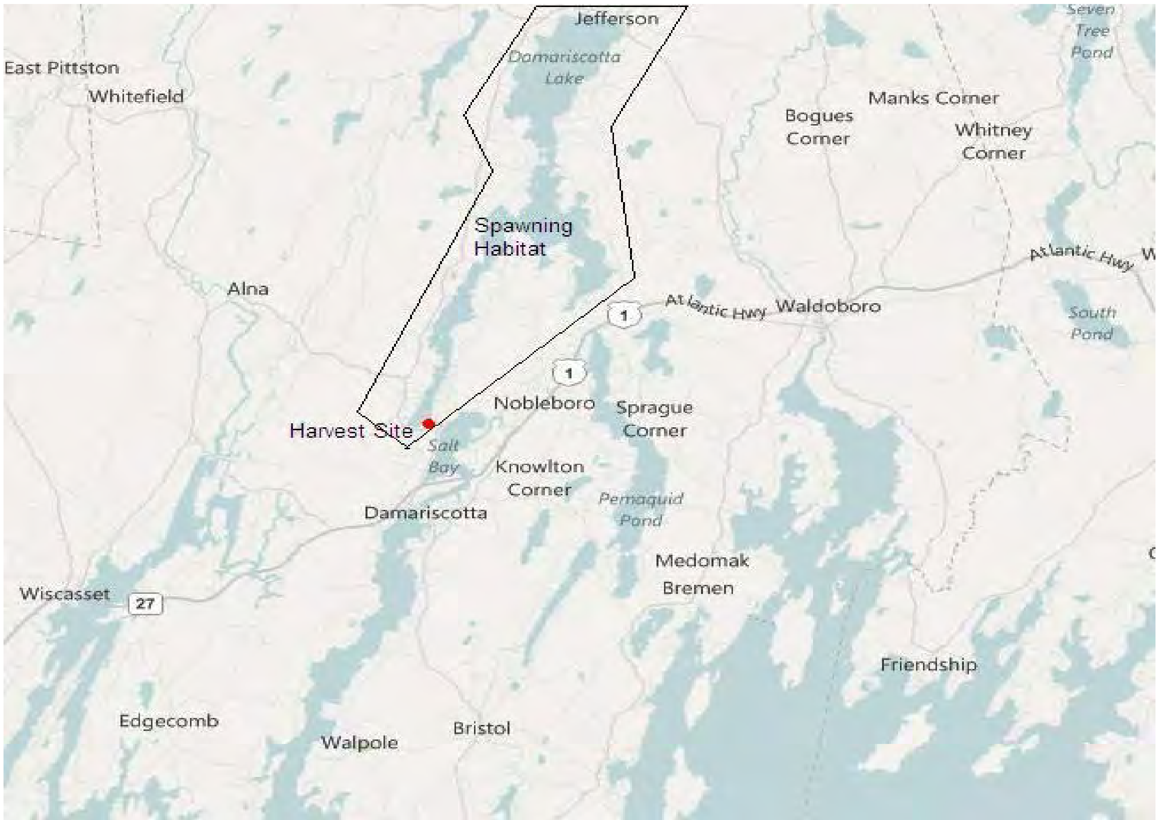
A tidal stream leads from the Damariscotta River to the base of the fishway. Alewives arrive and depart the area downstream of the fishway based on the tidal stage in the river. During the height of the run the tidal stream and fishway are full of alewives attempting to ascend into Damariscotta Lake. The run is entirely alewife with no blueback herring mixed in with the commercial catches. There is no spawning habitat for either species below the fishway due to high salinities, but an occasional American shad is observed in the area below the fishway.

The Maine Department of Marine Resources manages this pond for a minimum commercial escapement of 35 fish per acre. The spawning escapement needs for this system are 153,335 river herring counted upstream by the harvester. The age and design of the previously existing fishway limited the numbers of river herring entering spawning habitat. A 1-million dollar fishway renovation, started in 2007, significantly improved escapement into spawning habitat in Damariscotta Lake (Figures 10-12).

A hydropower turbine is located at one of the lakes two outlets and produces a limited amount of hydropower during early spring and winter. The hydropower station does not operate during the downstream migration period for alewife or American eel (July – November). Operation schedules during the 1960s and 1970s are unknown as are any associated adult or juvenile mortality events.

Damariscotta Lake is an oligotrophic lake that produces small juvenile river herring compared to other lakes in the area. These juveniles start to emigrate from the lake in early July at total lengths as small as 42 mm. Work conduced at Damariscotta indicates that increased escapement levels negatively affect the numbers of juveniles produced within the lake. Increased stocking rates appear to lead to diminished yield per adult spawner. (Walton 187. Table 1; Figure 1) (Figures 7 – 8)

Town	River	Lake size (acres)	Threshold (N/acre)
Nobleboro	n/a	4,381	35


Jefferson
Damariscotta Lake
East Pittston
Whitefield
Manks Corner
Bogues Corner
Whitney Corner
Spawning Habitat
Alna
Atlantic Hwy
Waldoboro
South Pond
Nobleboro
Sprague Corner
Harvest Site
Salt Bay
Knowlton Corner
Pemaquid Pond
Damariscotta
Medomak
Bremen
Wiscasset
Friendship
Edgecomb
Walpole
Bristol


Kennebec
Penobscot Bay
Mount Desert Island
Long Pond
Acadia N.P.
Deer Island
Swans Island
Maine Tpke
Haut Island
Seal Island
Matinicus Island

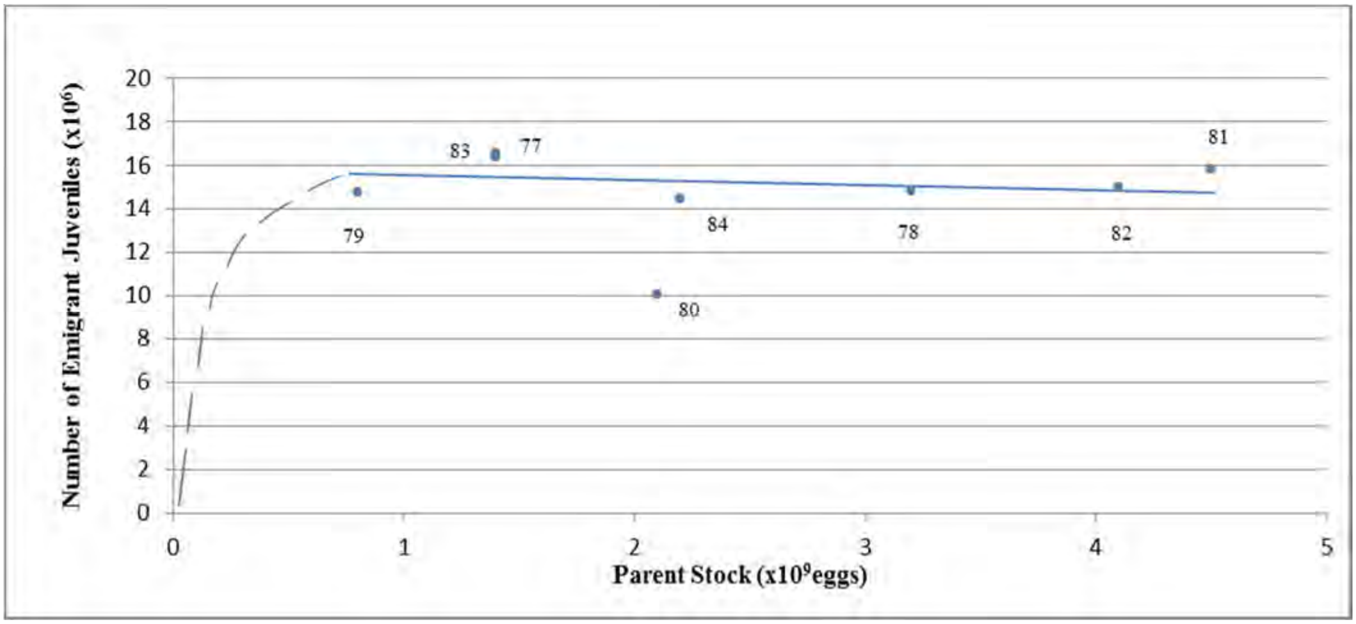


Figure 1. Relationship between an index of parental stock abundance (estimated annual egg deposition) and numbers on emigrating juvenile alewives, Damariscotta Lake, Maine, 1977-1984 (*r = +0.03; P > 0.05).*

Table 1. Statistics for adult and juvenile alewives in Damariscotta Lake, Maine 1977 -1984.

Year	Total Fish Harvested*	Fish entering the lake[b]	Male:Female ratio in lake	Females entering the lake[c]	Estimated egg deposition (10^9)	Juvenile emigrants (103)d
1977	1277640	27740	1.9:1	9,460+/-2,300	1.4	16,365+/-3,042
1978	909490	53180	1.6:1	20,580+/-3,720	3.2	14,823+/-4,505
1979	77940	20310	2.1:1	5,620+/-910	0.8	14,777+/-3,766
1980	844240	43865	2.3:1	13,470+/-1,360	2.1	10,082+/-4,100
1981	626370	69079	1.4:1	28,790+/-1,030	4.5	15,823
1982	330210	56653	1.2:1	25,930+/-1,070	4.1	14,991
1983	98730	21156	1.2:1	9,690+/-1,040	1.4	16,522
1984	231410	39561	1.7:1	14,860+/-610	2.2	14,477

[a]Estimates are rounded to the nearest 10 fish

[b]Total counts of adults were recorded after 1979

[c]Estimates +/- 95% confidence intervals

[d]Estimates +/- 95% confidence intervals, 1977-1980; total counts of juvenile emigrants were recorded after 1980.

Figure 7. Adult returns per individual spawner for the period 1977 - 2012

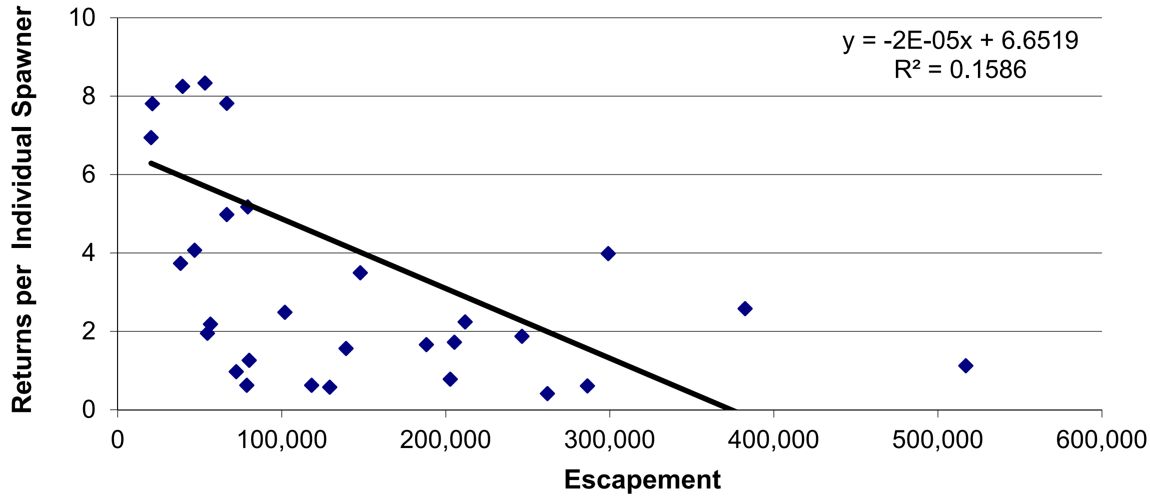
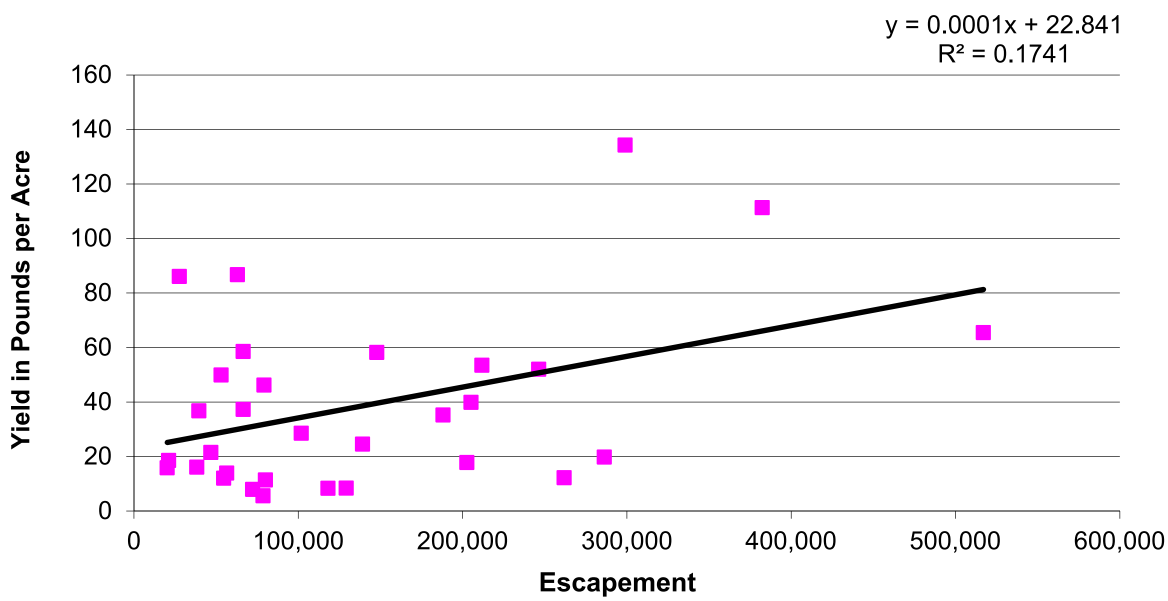


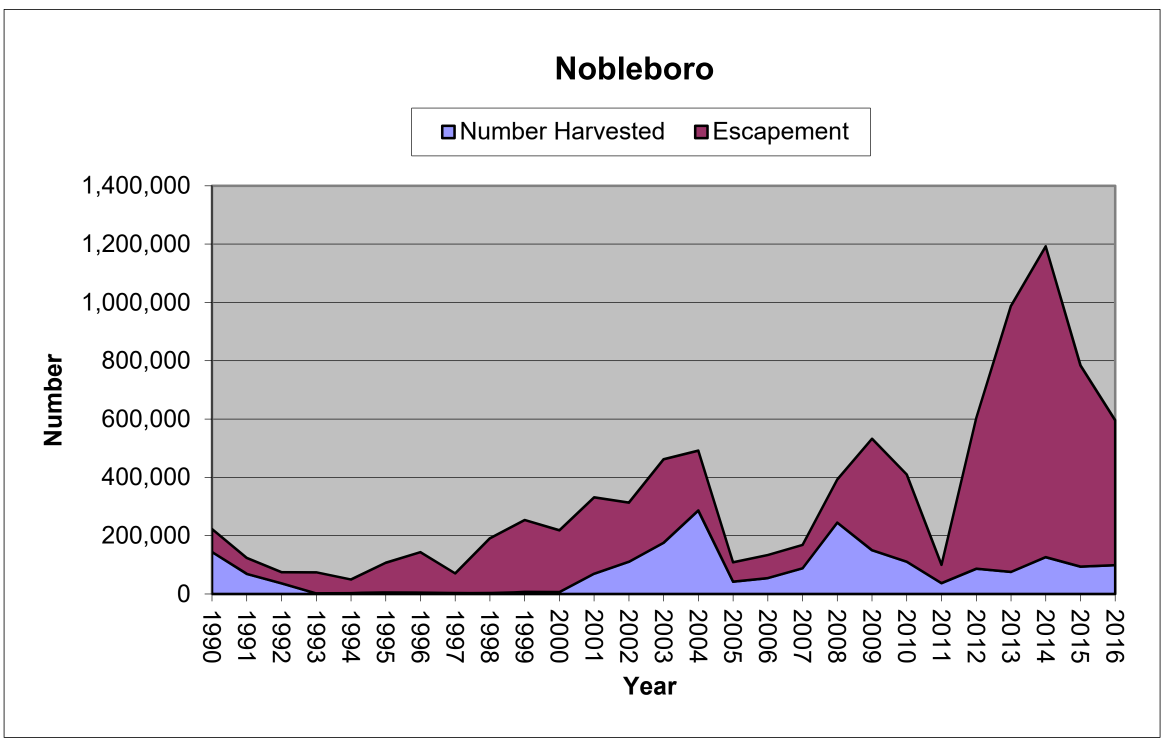
Figure 8. Yield in pounds per acre vs. escapement for the period 1977 – 2012



Year	Municipality	River	% repeat spawners by	R-0	R-1	R-2	R-3	Z-value
2015	Nobleboro	Damariscotta	25.6	70.41	23.47	5.10	1.02	1.42
2014	Nobleboro	Damariscotta	30.4	69.60	14.70	14.70	1.00	1.27
2013	Nobleboro	Damariscotta	23.8	76.20	22.80	1.00		2.17
2012	Nobleboro	Damariscotta	16.3	83.70	10.80	4.80	0.80	1.48
2011	Nobleboro	Damariscotta	33.2	66.80	27.70	5.50		1.25
2010	Nobleboro	Damariscotta	17.9	82.00	14.40	2.60	1.00	1.49
2009	Nobleboro	Damariscotta	44.7	55.30	42.60	2.10		1.64
2008	Nobleboro	Damariscotta	29.7	-	-	-	-	

Year	Escapement Number (based on target)	Actual	Measured or estimated (.43*landings)	spawning below barrier?	Landings Number	total run size (escape+kill)	exploitation rate
1977		26,813	Measured	n	1,429,540	1,456,353	0.98
1978		53,180	Measured	n	1,065,250	1,118,430	0.95
1979		20,313	Measured	n	911,670	931,983	0.98
1980		43,865	Measured	n	951,330	995,195	0.96
1981		69,079	Measured	n	1,008,450	1,077,529	0.94
1982		56,653	Measured	n	377,054	433,707	0.87
1983		21,156	Measured	n	106,696	127,852	0.83
1984		39,561	Measured	n	250,110	289,671	0.86
1985	153,335	22,233	Measured	n	112,840	135,073	0.84
1986	153,335	39,392	Measured	n	92,260	131,652	0.70
1987	153,335	56,552	Measured	n	126,770	183,322	0.69
1988	153,335	129,269	Measured	n	230,020	359,289	0.64
1989	153,335	118,221	Measured	n	219,800	338,021	0.65
1990	153,335	78,691	Measured	n	144,060	222,751	0.65
1991	153,335	54,694	Measured	n	68,940	123,634	0.56
1992	153,335	38,326	Measured	n	36,360	74,686	0.49
1993	153,335	72,297	Measured	n	1,920	74,217	0.03
1994	153,335	46,912	Measured	n	2,640	49,552	0.05
1995	153,335	101,880	Measured	n	5,040	106,920	0.05
1996	153,335	139,199	Measured	n	4,080	143,279	0.03
1997	153,335	66,527	Measured	n	3,840	70,367	0.05
1998	153,335	188,208	Measured	n	2,880	191,088	0.02
1999	153,335	246,406	Measured	n	7,200	253,606	0.03
2000	153,335	211,830	Measured	n	6,480	218,310	0.03
2001	153,335	261,909	Measured	n	69,480	331,389	0.21
2002	153,335	202,729	Measured	n	110,400	313,129	0.35
2003	153,335	286,360	Measured	n	175,680	462,040	0.38
2004	153,335	205,248	Measured	n	286,320	491,568	0.58
2005	153,335	66,534	Measured	n	42,000	108,534	0.39
2006	153,335	79,230	Measured	n	54,360	133,590	0.41
2007	153,335	80,142	Measured	n	87,960	168,102	0.52
2008	153,335	147,834	Measured	n	244,800	392,634	0.62
2009	153,335	382,422	Measured	n	150,000	532,422	0.28
2010	153,335	299,022	Measured	n	110,400	409,422	0.27
2011	153,335	63,036	Measured	n	36,900	99,936	0.37
2012	153,335	517,044	Measured	n	86,400	603,444	0.14
2013	153,335	912,930	Measured	n	75,660	988,590	0.08
2014	153,335	1,066,314	Measured	n	126,240	1,192,554	0.11
2015	153,335	690,000	Measured	n	93,840	783,840	0.12
2016	153,335	496,800	Measured	n	98,760	595,560	0.17

Figure 9. Commercial harvest of river herring at Damariscotta Lake in the 1980s



Nobleboro
Number Harvested
Escapement
1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
Number
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
Year

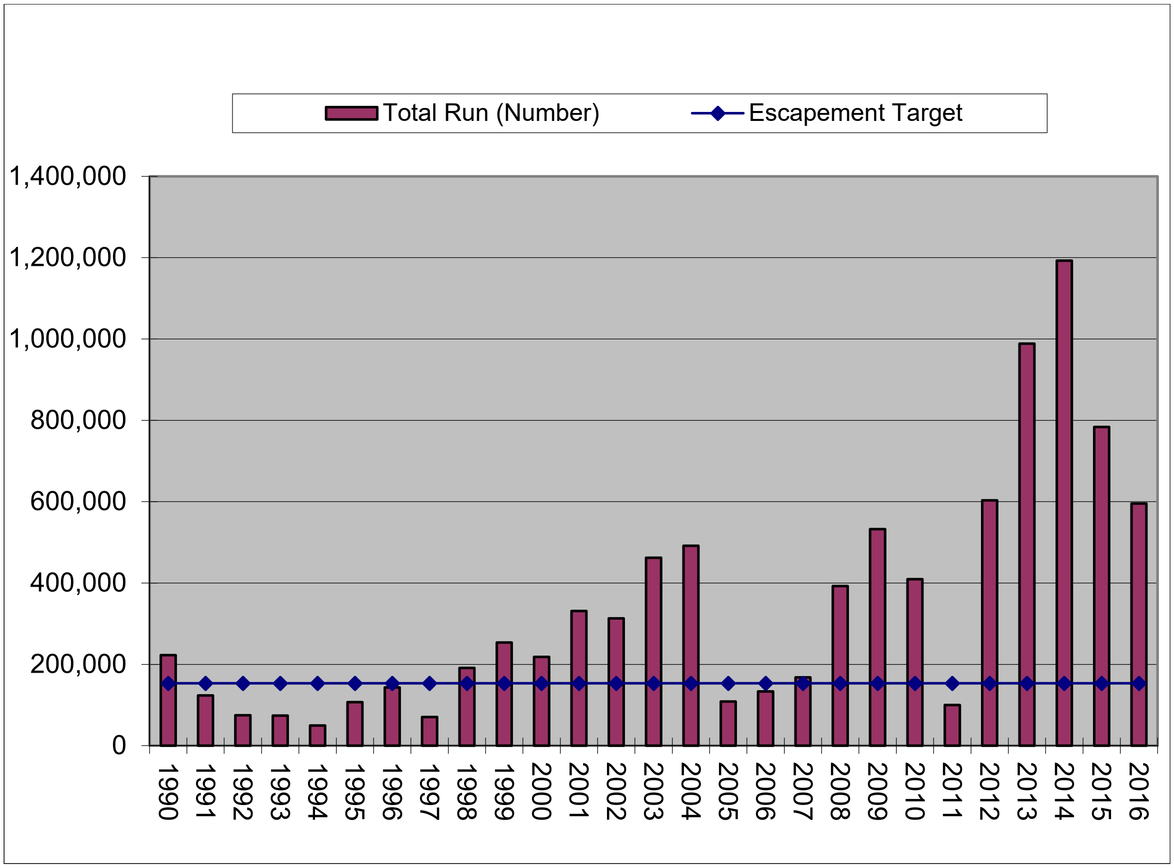


Figure 10. Entrance to the Damariscotta Fishway.

Figure 11. Upper section of the Damariscotta Fishway prior to restoration.

Figure 12. Upper section of the fishway after restoration.

Phippsburg Commercial Fishery:
The Maine Department of Marine Resources manages this pond for a minimum commercial escapement of 35 fish per acre. The spawning escapement need for this system is 4,795 river herring passed upstream through the fishway during the three day closed period per week during the fishery. The management plan has always achieved returns that meet the target escapement developed for this system or passed the total run upstream. The fishway leads from the tidal zone directly into a 137-acre lake (Figure 12A). This fishery is typically the earliest of all Maine river herring runs, with river herring arriving as early as March 15. There is no spawning below the tidal fishway.

The commercial harvester catches blueback herring at this location toward the end of the commercial fishing season. These fish enter the lake with the last of the alewife run. It is unknown how well blueback spawn or survive in the lake. Blueback herring may drop out of the lake prior to spawning to look for suitable spawning habitat which is not available in the lake. Field staff has not observed any juvenile blueback herring in biological samples collected emigrating from the lake in the fall.

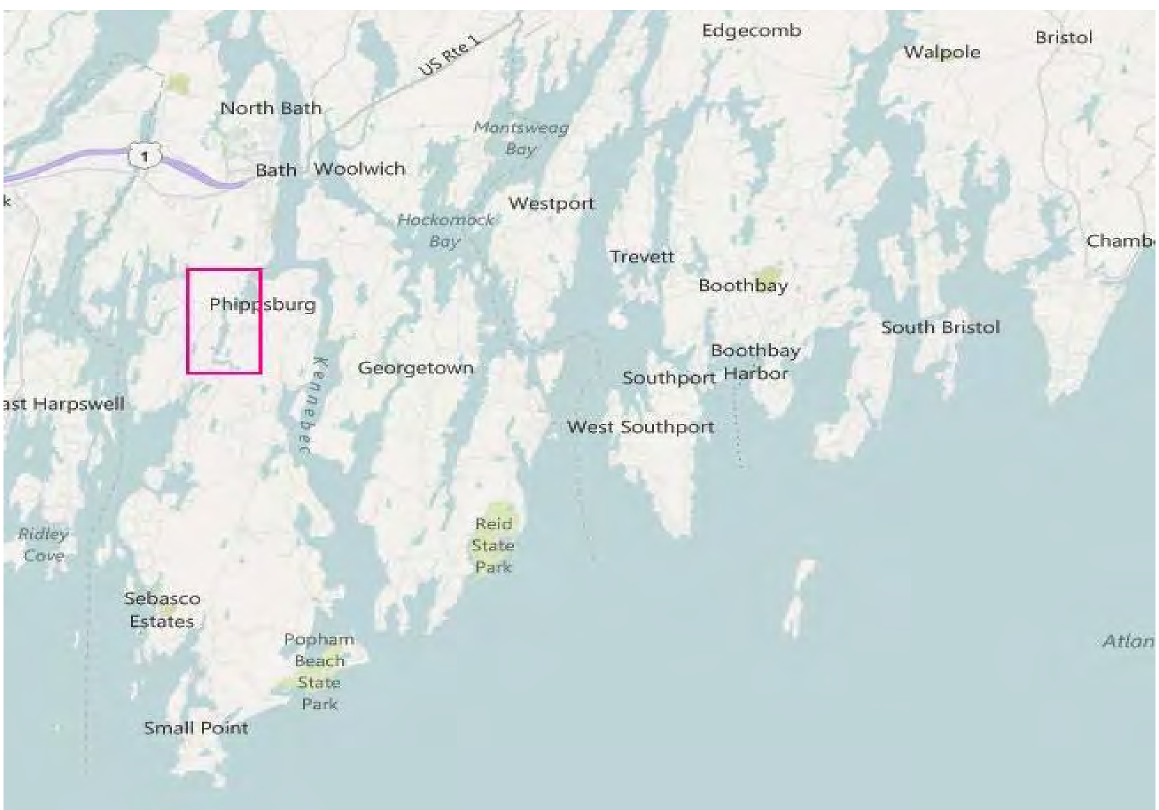
The fishery at Winnegance Lake is currently on the watch list. Though the fishery currently meets the minimum escapement levels in the plan, the annual run is below expectations. The cause for the decline in the annual run is not clear. There are several factors that may be impacting annual returns. In the early 2000's the dam at the outlet of the lake was reconstructed to repair the dam and improve the harvest area. The existing denil fishway is sufficient to pass fish into the lake but the existing configuration may make it difficult for fish to find the downstream passage. There are periods of time when downstream passage appear to be nonexistent due to low flow during the summer and fall. The size of the water combined with the numbers of fish passed into the lake may not be able to support the numbers of juvenile fish for an extended period.

In addition, the dam is low enough that the Kennebec River regularly flows back into the lake during above average high tides. The salinity of the river water flowing into the lake could be as high as 15ppm. Once this water enters the lake there is no way for the water to exit the lake. In recent years, northern pike and black crappie were illegally introduced into the lake and predation on adult and juvenile has likely increased. Both species are known to prey heavily on alewives in Maines freshwater ecosystems.

Prior to the 2017 season the Department will deploy a sonde into the lake soon after ice out to collect water quality data. In conjunction with the assessment of downstream passage the department will consider adding additional closed days to the fishery to see if there is any response in returns.

Town	River	Lake size (acres)	Threshold (N/acre)
Phippsburg	n/a	137	35

Fishing Location
Phippsburg
Spawning Location
Arrowsic
Georgetown
East Harpswell
Halls Bay
Knubble Bay
Robinhood Cove
Ridley Cove
Reid State Park
Sebasco Estates
Sagadahoc Bay
Atkins
Gurnet Rd
Harpswell Islands Rd
24

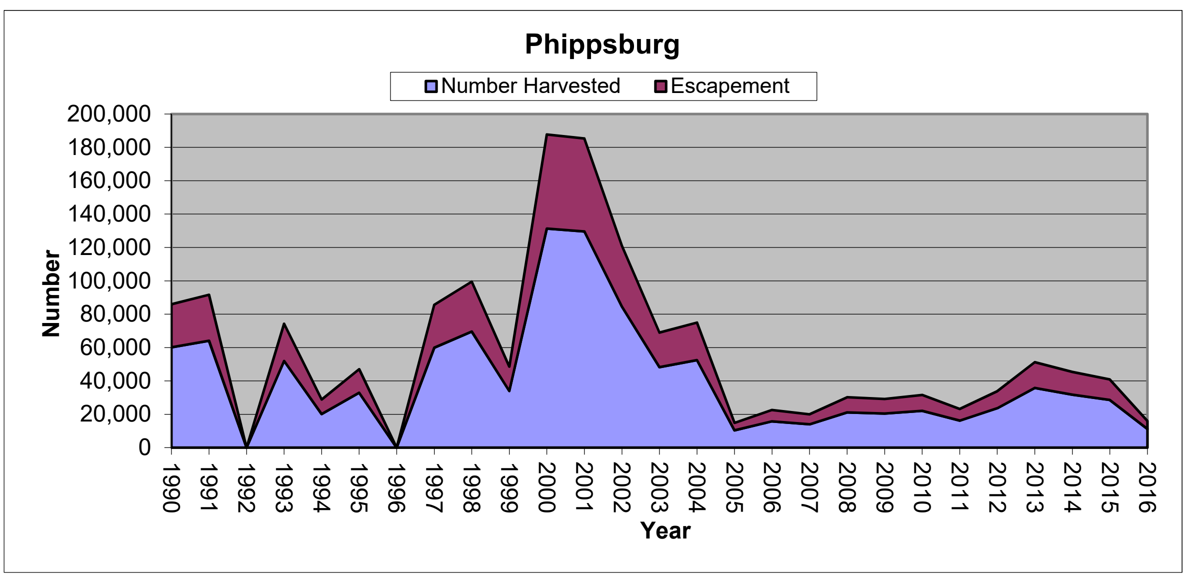


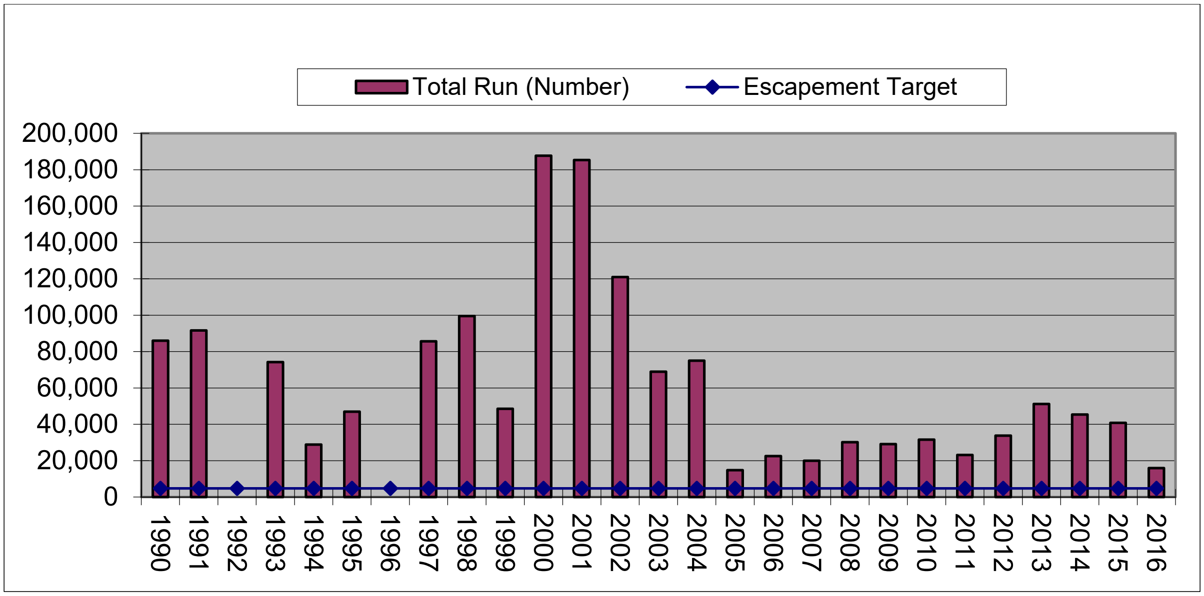
Edgecomb
Walpole
Bristol
US Rte 1
North Bath
Montsweag Bay
Bath
Woolwich
Westport
Hockomock Bay
Trevett
Boothbay
Phippsburg
South Bristol
Georgetown
Boothbay Harbor
Southport
Kennebec
West Southport
Ridley Cove
Reid State Park
Sebasco Estates
Popham Beach State Park
Small Point

Figure 12A. The Winnegance fish trap located in the lake above the fishway.

Year	Municipality	River	% repeat spawners by year and frequency	R-0	R-1	R-2	R-3	Z-value
2015	Bath	Kennebec	39.0	62.00	34.00	4.00		1.37
2014	Bath	Kennebec	16.1	83.90	12.90	2.20	1.10	1.48
2013	Bath	Kennebec	8.8	91.20	7.30	1.50		2.05
2012	Bath	Kennebec	8.0	92.00	5.00	2.00	1.00	1.45
2011	Bath	Kennebec	6.5	93.46	4.52	2.01		1.92
2010	Bath	Kennebec	25.5	74.49	17.35	8.16		1.11
2009	Bath	Kennebec	9.0	91.00	7.00	2.00		1.91
2008	Bath	Kennebec						

Year	Escapement Number (based on target)	Actual	Measured or estimated (.43*landings)	spawning below barrier?	Landings Number	total run size (escape+kill)	exploitation rate
1982	4,795		73,685	n	171,360	245,045	0.70
1983	4,795		0	n	0	0	0.00
1984	4,795		36,120	n	84,000	120,120	0.70
1985	4,795		67,080	n	156,000	223,080	0.70
1986	4,795		52,787	n	122,760	175,547	0.70
1987	4,795		0	n	0	0	0.00
1988	4,795		46,853	n	108,960	155,813	0.70
1989	4,795		0	n	0	0	0.00
1990	4,795		0	n	0	0	0.00
1991	4,795		0	n	0	0	0.00
1992	4,795		0	n	0	0	0.00
1993	4,795		0	n	0	0	0.00
1994	4,795		8,669	n	20,160	28,829	0.70
1995	4,795		14,138	n	32,880	47,018	0.70
1996	4,795		0	n	0	0	0.00
1997	4,795		25,748	n	59,880	85,628	0.70
1998	4,795		29,928	n	69,600	99,528	0.70
1999	4,795		14,603	n	33,960	48,563	0.70
2000	4,795		56,450	n	131,280	187,730	0.70
2001	4,795		55,728	n	129,600	185,328	0.70
2002	4,795		36,378	n	84,600	120,978	0.70
2003	4,795		20,743	n	48,240	68,983	0.70
2004	4,795		26,307	n	61,180	87,487	0.00
2005	4,795		5,207	n	12,110	17,317	0.00
2006	4,795		6,785	n	15,780	22,565	0.70
2007	4,795		6,011	n	13,980	19,991	0.70
2008	4,795		9,082	n	21,120	30,202	0.70
2009	4,795		8,772	n	20,400	29,172	0.70
2010	4,795		9,494	n	22,080	31,574	0.70
2011	4,795		6,966	n	16,200	23,166	0.70
2012	4,795		10,165	n	23,640	33,805	0.70
2013	4,795		15,403	n	35,820	51,223	0.70
2014	4,795		13,648	n	31,740	45,388	0.70
2015	4,795		12,281	n	28,560	40,841	0.70
2016	4,795		4,799	n	11,160	15,959	0.70





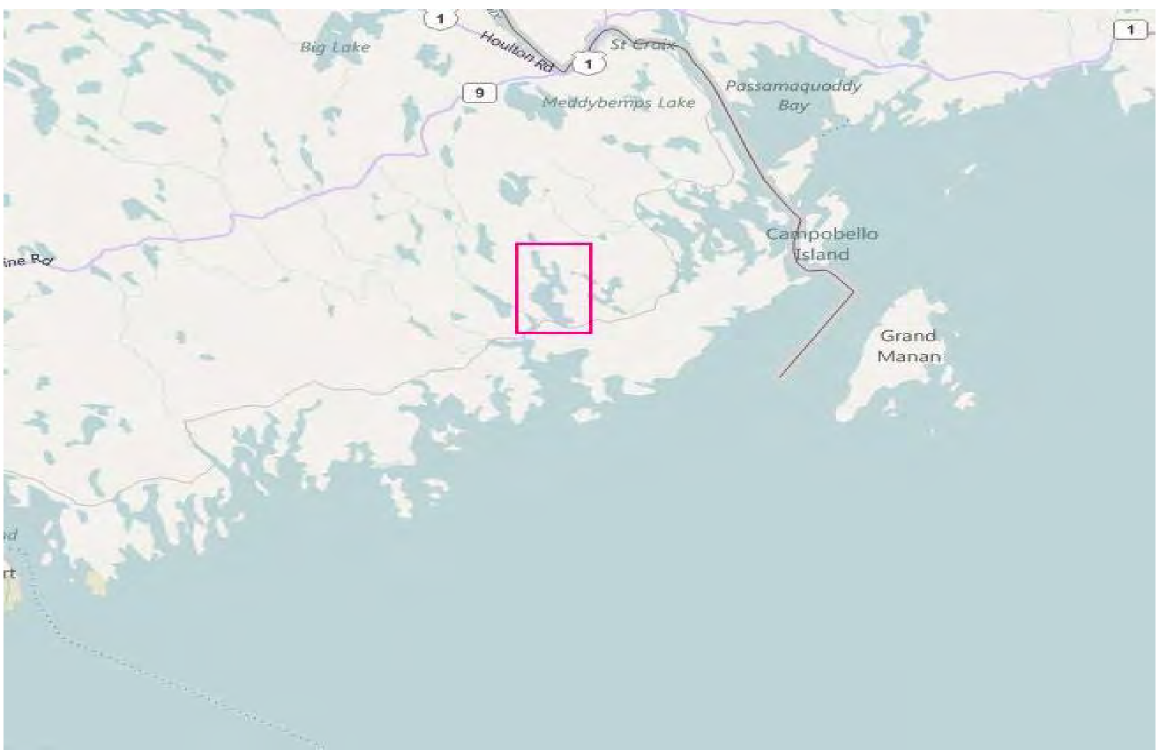
East Machias Commercial Fishery:

The Maine Department of Marine Resources manages Gardiner Lake for a commercial escapement of less than 35 fish per acre but there is no specific target for this system established at this time. The spawning escapement need for this system is 176,225 river herring passed upstream through three closed days per week in the fishery. The management plan has not achieved returns to meet the 35 fish per acre target escapement developed for other systems.

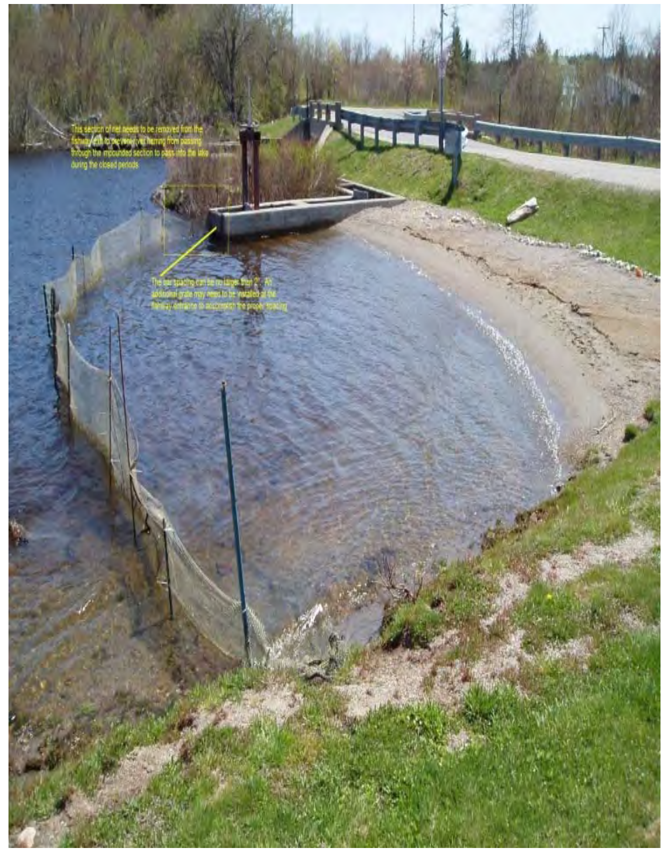
The main stem East Machias River system has a large run of river herring that is unexploited. The main stem river remains closed as a conservation measure while allowing a larger harvest at the first tributary on the river at the outlet of Gardiner Lake (Figures 13 -14). An estimated run of 2.1 – 4.5 million river herring ascend the East Machias' 9,000 acres of accessible habitat. An unknown number of blueback herring ascend the river to spawn in the main stem. These fish are not harvested and are allowed free access up and down the river. The DMR allows a higher exploitation rate for Gardiner Lake to keep the main stem of the East Machias open to free passage for all anadromous fish. The East Machias River has no dams on the main stem and provides spawning and juvenile habitat for native Atlantic salmon.

For several years prior to 2010 the harvest data from the Gardiner fishery was severely under reported. Historical landings data that are the basis for calculating escapement indicate the escapement into the lake was far below expectations compared to runs in general. Under new management and with accurate landings data the run is closer to meeting expectations. Additional data collected from this system and future analysis of the 2015 and 2016 scale samples will indicate the direction this fishery is trending. If indications are that escapement from the commercial fishery is not increasing, DMR will impose additional closed days in 2017.

Town	River	Lake size (acres)	Threshold (N/acre)
East Machias	n/a	5,035	35

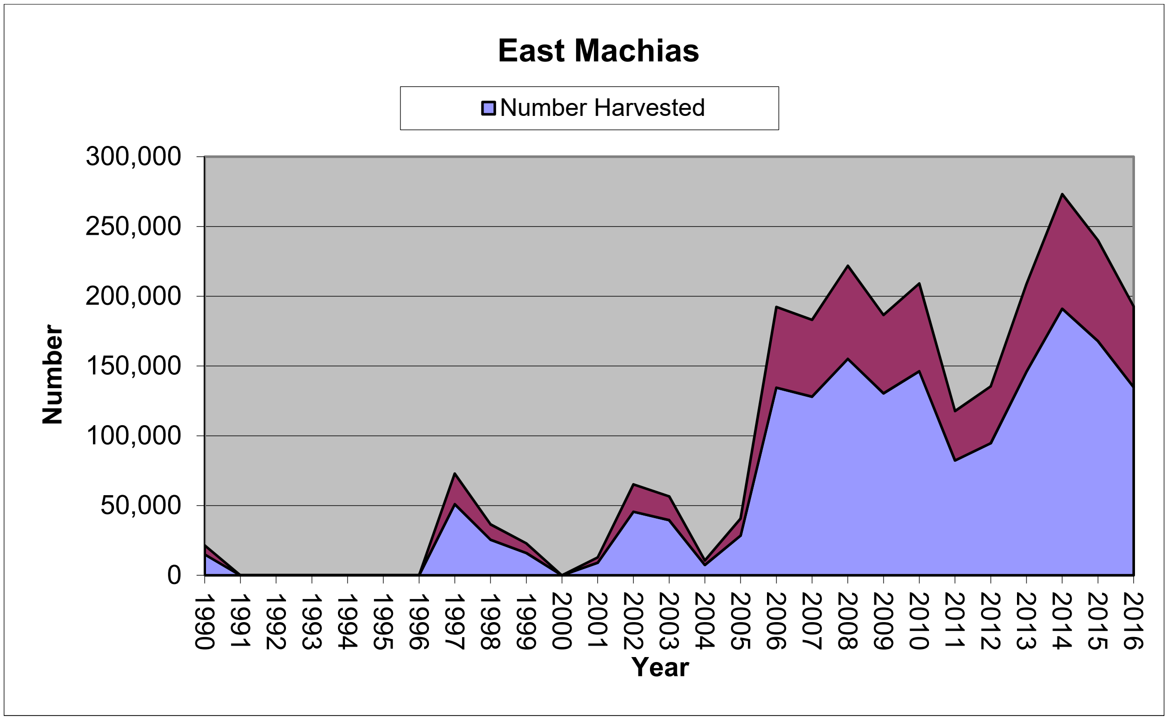


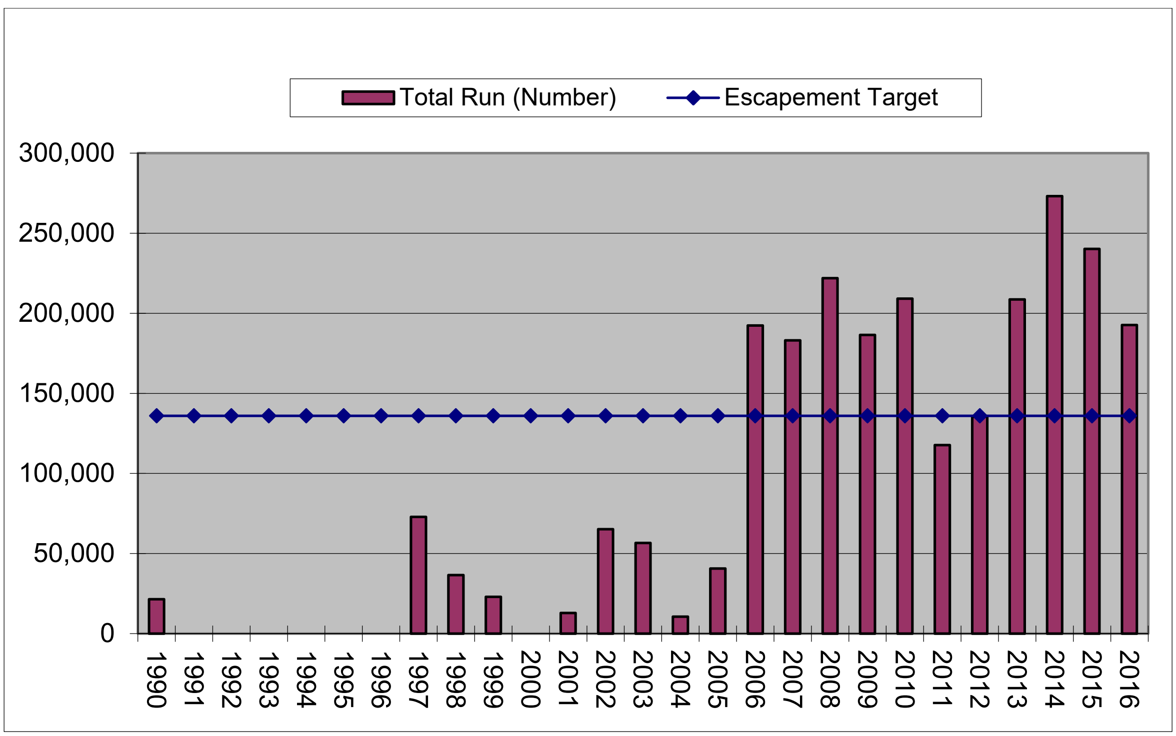
Figures 13 - 14. Chase Mill Stream is a tributary to the East Machias River. Fishing gear is deployed at the top of the fishway to capture returns to Gardiner Lake.



Year	Municipality	River	% repeat spawners by year and frequency	R-0	R-1	R-2	R-3	Z-value
2015								
2014								
2013	East Machias	N/A	31.6	68.40	28.00	2.60	1.00	1.51
2012	East Machias	N/A	20.5	79.53	14.42	4.69	1.34	1.34
2011	East Machias	N/A	50.9	49.05	41.50	9.43		0.82
2010	East Machias	N/A	23.2	76.76	22.22	0.00	1.01	1.46
2009	East Machias	N/A	17.7	82.30	17.70			1.54
2008	East Machias	N/A	6.0	94.30	5.70			2.81

Year	Escapement Number (based on target)	Actual	Measured or estimated (.43*landings)	spawning below barrier?	Landings Number	total run size (escape+kill)	exploitation rate
1990	176,225		7,525	n/y	17,500	25,025	0.70
1991	176,225		0	n/y	0	0	
1992	176,225		0	n/y	0	0	
1993	176,225		0	n/y	0	0	
1994	176,225		0	n/y	0	0	
1995	176,225		0	n/y	0	0	
1996	176,225		0	n/y	0	0	
1997	176,225		21,930	n/y	51,000	72,930	0.70
1998	176,225		10,991	n/y	25,560	36,551	0.70
1999	176,225		6,914	n/y	16,080	22,994	0.70
2000	176,225		0	n/y	0	0	
2001	176,225		3,870	n/y	9,000	12,870	0.70
2002	176,225		19,608	n/y	45,600	65,208	0.70
2003	176,225		17,028	n/y	39,600	56,628	0.70
2004	176,225		3,199	n/y	7,440	10,639	0.70
2005	176,225		12,229	n/y	28,440	40,669	0.70
2006	176,225		57,844	n/y	134,520	192,364	0.70
2007	176,225		55,057	n/y	128,040	183,097	0.70
2008	176,225		66,719	n/y	155,160	221,879	0.70
2009	176,225		56,089	n/y	130,440	186,529	0.70
2010	176,225		62,875	n/y	146,220	209,095	0.70
2011	176,225		35,398	n/y	82,320	117,718	0.70
2012	176,225		40,712	n/y	94,680	135,392	0.70
2013	176,225		62,746	n/y	145,920	208,666	0.70
2014	176,225		82,147	n/y	191,040	273,187	0.70
2015	176,225		72,214	n/y	167,940	240,154	0.70
2016	176,225		57,947	n/y	134,760	192,707	0.70



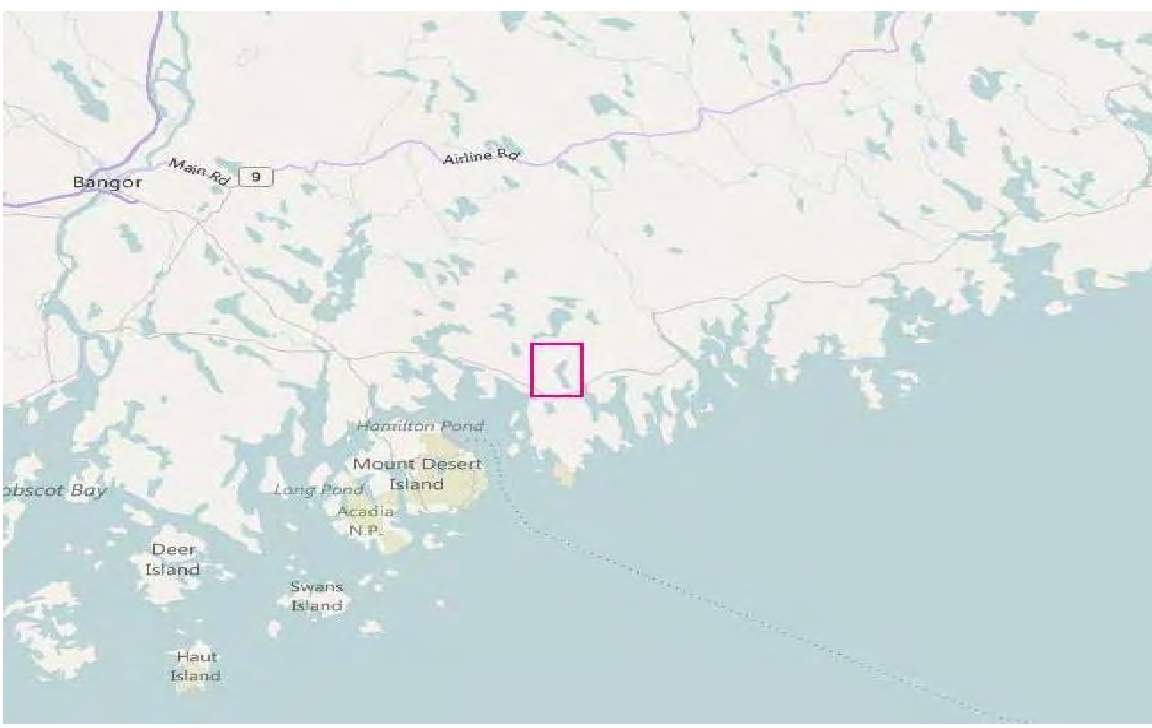


Gouldsboro Commercial Fishery:

The Maine Department of Marine Resources manages this pond for a minimum commercial escapement of 35 fish per acre. The spawning escapement need for this system is 3,500 river herring passed upstream through three closed days per week during the season (Figures 15 -17). The management plan has achieved returns to meet the target escapement developed for this system 95%

of the years during the past 20-year period or passed the entire run upstream. The run is comprised of all alewife and spawning does not occur below the fishery for either species.

Town	River	Lake size (acres)	Threshold (N/acre)
Gouldsboro	n/a	100	35

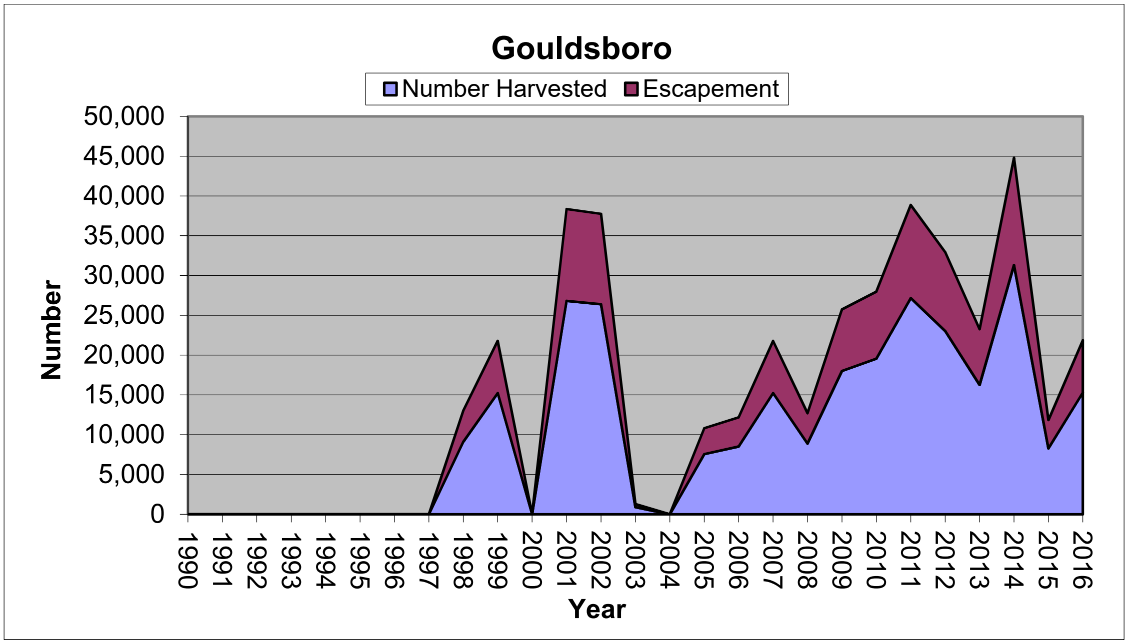


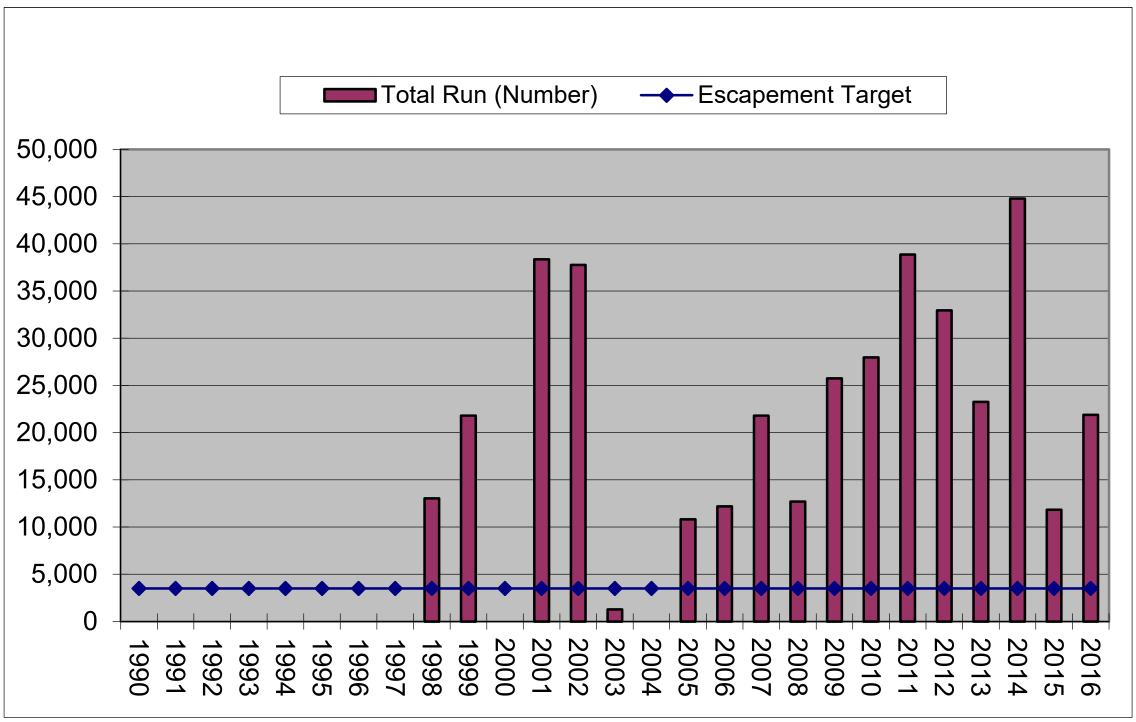
Figures 15-17. Fishway, fishing location, and trap deployed in the Gouldsboro alewife fishery.



Year	Municipality	River	% repeat spawners by year and frequency	R-0	R-1	R-2	R-3	Z-value
2015	Gouldsboro	N/A	26.6	73.42	22.15	3.17	1.27	1.14
2014	Gouldsboro	N/A	17.6	82.40	13.60	4.00		1.51
2013	Gouldsboro	N/A	33.3	66.70	30.10	2.70	0.50	1.71
2012	Gouldsboro	N/A	22.2	77.80	22.20			1.25
2011	Gouldsboro	N/A	33.8	66.15	30.76	3.07		1.54
2010	Gouldsboro	N/A	17.5	82.50	15.00	2.50		1.75
2009	Gouldsboro	N/A	17.9	82.10	3.60	14.30	4.00	0.87
2008	Gouldsboro	N/A	29.7	52.40	47.60			0.10

Year	Escapement Number (based on target)	Actual	Measured or estimated (.43*landings)	spawning below barrier?	Landings Number	total run size (escape+kill)	exploitation rate
1990	3,500		0	n	0	0	
1991	3,500		0	n	0	0	
1992	3,500		0	n	0	0	
1993	3,500		0	n	0	0	
1994	3,500		0	n	0	0	
1995	3,500		0	n	0	0	
1996	3,500		0	n	0	0	
1997	3,500		0	n	0	0	
1998	3,500		3,922	n	9,120	13,042	0.70
1999	3,500		6,553	n	15,240	21,793	0.70
2000	3,500		0	n	0	0	
2001	3,500		11,533	n	26,820	38,353	0.70
2002	3,500		11,352	n	26,400	37,752	0.70
2003	3,500		387	n	900	1,287	0.70
2004	3,500		0	n	0	0	
2005	3,500		3,251	n	7,560	10,811	0.70
2006	3,500		3,664	n	8,520	12,184	0.70
2007	3,500		6,553	n	15,240	21,793	0.70
2008	3,500		3,818	n	8,880	12,698	0.70
2009	3,500		7,740	n	18,000	25,740	0.70
2010	3,500		9,494	n	22,080	31,574	0.70
2011	3,500		6,966	n	16,200	23,166	0.70
2012	3,500		10,165	n	23,640	33,805	0.70
2013	3,500		15,403	n	35,820	51,223	0.70
2014	3,500		13,648	n	31,740	45,388	0.70
2015	3,500		12,281	n	28,560	40,841	0.70



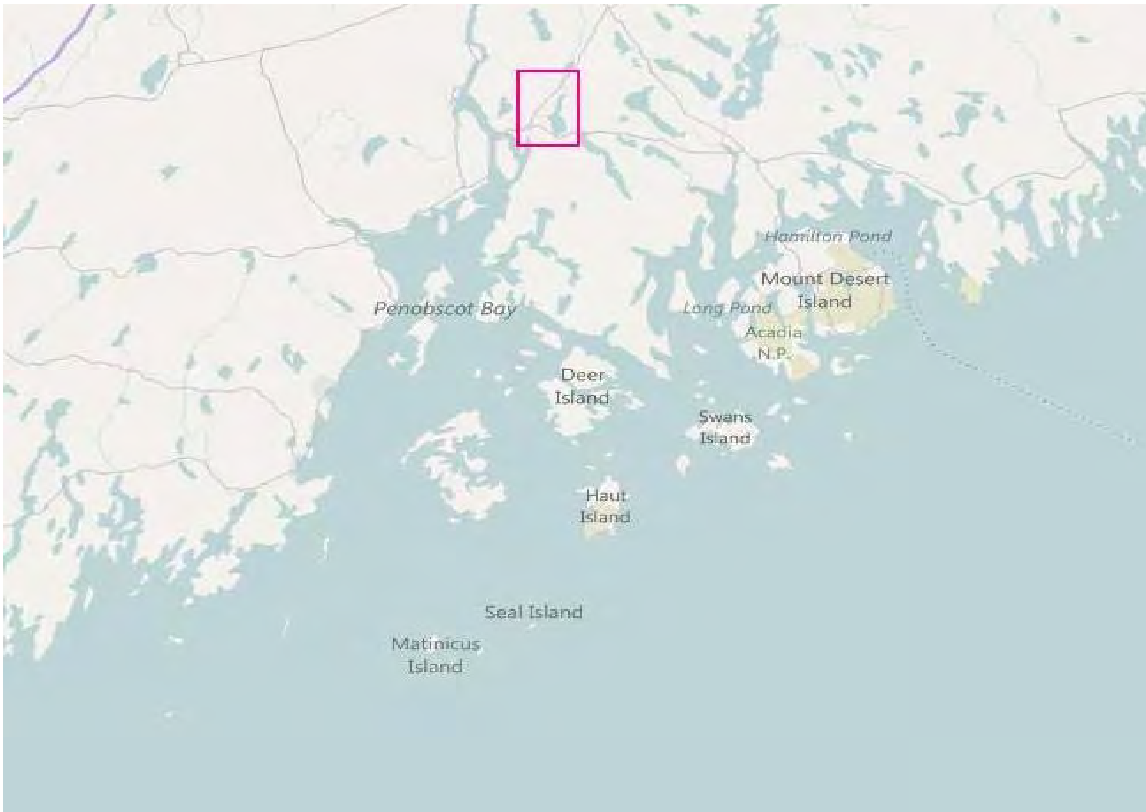


Orland Commercial Fishery:

The Maine Department of Marine Resources manages this system for a minimum commercial escapement of 35 fish per acre. The spawning escapement need for this system is 39,655 river herring passed upstream through three closed days per week during the fishery. The management plan has achieved returns to meet the target escapement developed for this system for 95% of the years during the past 20-year period or passed the entire run upstream. Only a portion of historic spawning habitat in the Orland River Watershed is accessible to river herring. Access to many of the historic spawning habitats is excluded due to conflicts with sport fish species. There is no expectation that additional habitat will reopen in the near future. The State of Massachusetts granted the municipality of Orland exclusive harvest rights in 1805. Orland is one of two fisheries that DMR permits to use tidal weirs to fish for river herring due to the size of the river at the fishing location. Like the smaller box traps, tidal weirs capture the entire run during the open fishing days (Figures 18-20). Once river herring pass the fishery they are prevented from falling back below the weir because the weir spans the entire river at low tide, preventing them from reentering the fishery. The Orland River before it was dammed likely contained runs of American shad and Atlantic salmon. There are no observations of either species at this location by field staff.

The Orland fishery captures blueback herring in the alewife fishery toward the end of the fishing season. Blueback herring account for 2-5% of the annual river herring catch. There is no spawning below the tidal fishways on the Orland River. The first dam on the Orland River has two Alaska Steep Pass fishways which provide upstream passage. Neither of these passages is available during two hours on either side of low tide.

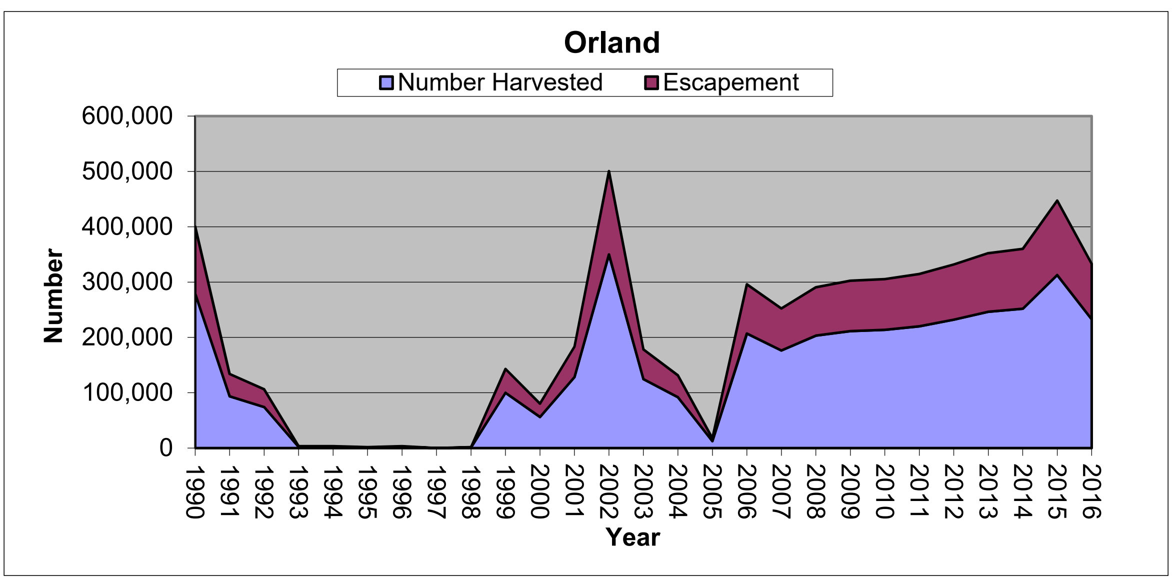
Town	River	Lake size (acres)	Threshold (N/acre)
Orland	Orland	1,133	35

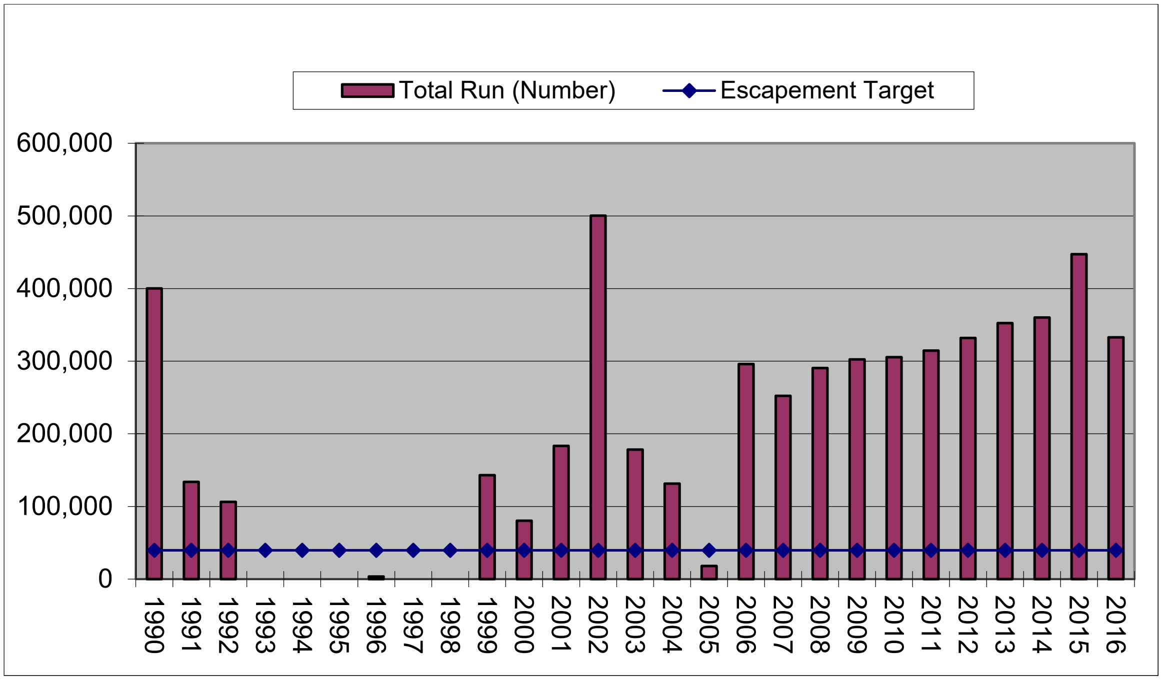


Figures 18-20. Tidal weir and commercial catches of river herring in May 2010 (bottom left) and May ~ 1970 (bottom right).

Year	Municipality	River	% repeat spawners by year and frequency	R-0	R-1	R-2	R-3	Z-value
2015	Orland	Orland River	20.4	79.61	13.59	6.80		1.23
2014	Orland	Orland River	16.7	83.33	15.33	1.33		2.07
2013	Orland	Orland River	14.1	85.90	11.20	1.50	1.50	1.42
2012	Orland	Orland River	15.0	85.00	10.00	5.00		2.14
2011	Orland	Orland River	60.0	39.89	58.08	2.02		1.49
2010	Orland	Orland River	25.0	75.00	21.00	4.00		1.75
2009	Orland	Orland River	22.2	77.80	20.20	2.00		1.83
2008	Orland	Orland River	17.2	82.80	17.20			1.57

Year	Escapement Number (based on target)	Actual	Measured or estimated (.43*landings)	spawning below barrier?	Landings Number	total run size (escape+kill)	exploitation rate
1990	39,655		140,386	n	326,480	466,866	0.70
1991	39,655		46,956	n	109,200	156,156	0.70
1992	39,655		37,264	n	86,660	123,924	0.70
1993	39,655		1,204	n	2,800	4,004	0.70
1994	39,655		1,204	n	2,800	4,004	0.70
1995	39,655		602	n	1,400	2,002	0.70
1996	39,655		1,204	n	2,800	4,004	0.70
1997	39,655		0	n	0	0	
1998	39,655		602	n	1,400	2,002	0.70
1999	39,655		50,177	n	116,690	166,867	0.70
2000	39,655		28,174	n	65,520	93,694	0.70
2001	39,655		64,294	n	149,520	213,814	0.70
2002	39,655		175,543	n	408,240	583,783	0.70
2003	39,655		62,548	n	145,460	208,008	0.70
2004	39,655		46,113	n	107,240	153,353	0.70
2005	39,655		6,321	n	14,700	21,021	0.70
2006	39,655		103,845	n	241,500	345,345	0.70
2007	39,655		88,494	n	205,800	294,294	0.70
2008	39,655		101,919	n	237,020	338,939	0.70
2009	39,655		90,919	n	211,440	302,359	0.70
2010	39,655		91,848	n	213,600	305,448	0.70
2011	39,655		97,163	n	225,960	323,123	0.70
2012	39,655		99,794	n	232,080	331,874	0.70
2013	39,655		105,935	n	246,360	352,295	0.70
2014	39,655		108,257	n	251,760	360,017	0.70
2015	39,655		134,470	n	312,720	447,190	0.70
2016	39,655		100,104	n	232,800	332,904	0.70





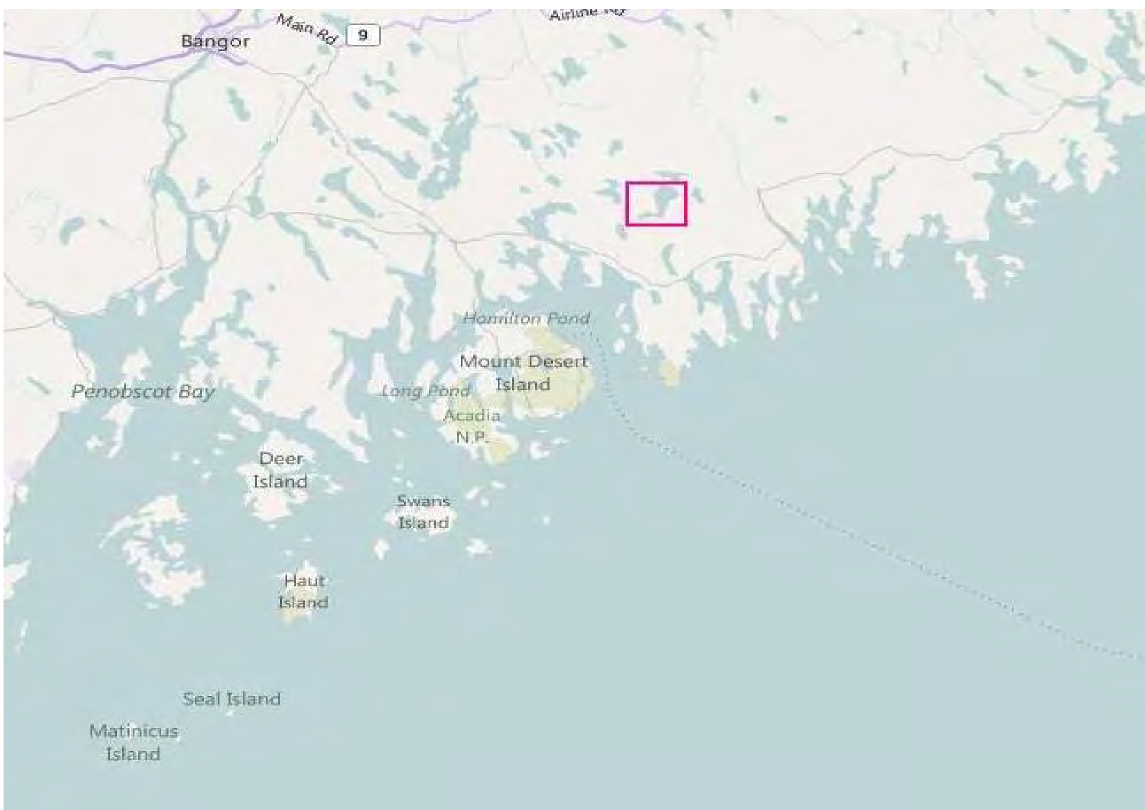
Steuben Commercial Fishery:

The Maine Department of Marine Resources manages this system for a minimum commercial escapement of three fish per acre. The spawning escapement need for this system is 6,213 river herring passed upstream by closing the harvest three days per week. The management plan has achieved returns to meet the target escapement developed for this system for 85% of the years during the past 20-year period or passed the entire run upstream. The Steuben system is located several miles inland and is severely limited by beaver activity along the 15-mile long brook leading to spawning habitat at Tunk Lake. Alewife production at this site depends on high water during both the spring and fall seasons. As a result, production from this system varies widely. This is one of several systems with landlocked salmon, lake trout, and rainbow smelt that the Maine Department of Inland Fisheries and Wildlife manages for sport fish species. There is no known spawning for either anadromous species within the stream leading to the pond.

Due to water quality issues associated with its oligotrophic characteristics, Tunk Lake produces very small juvenile alewives that emigrate to sea from July – October. The lake is nutrient poor and is not as productive as other lakes in the region. It is unlikely that increased escapement beyond the 3 fish per acre would produce consistently higher annual returns.

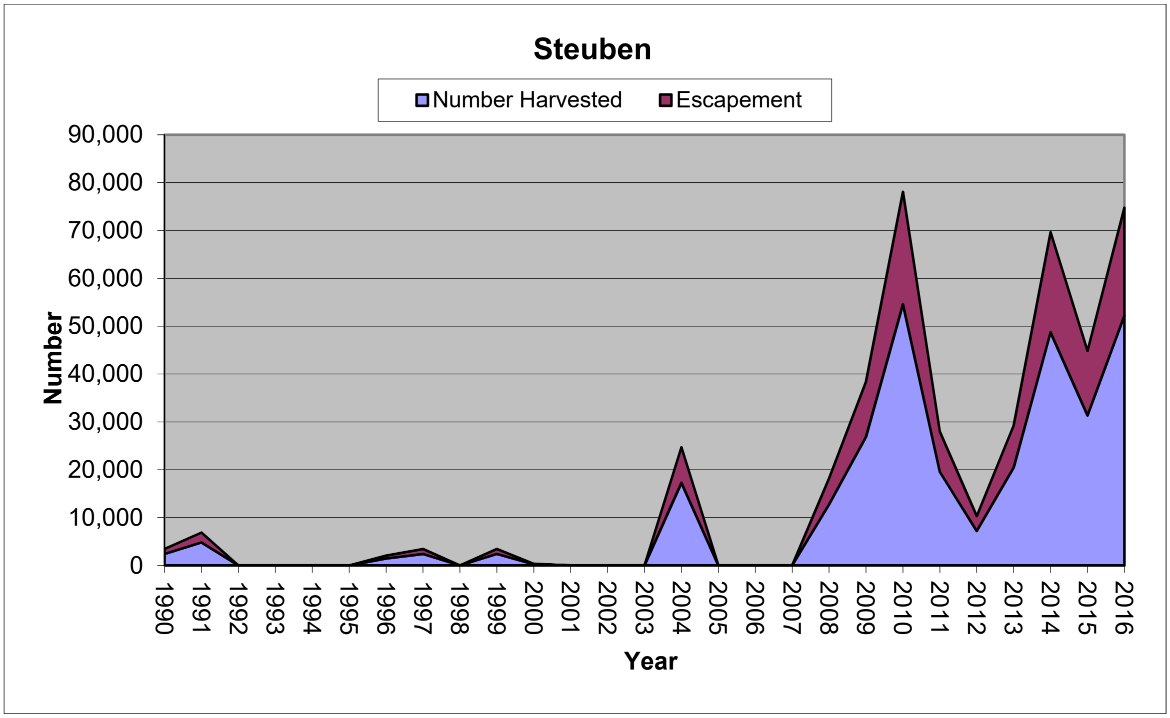
Town	River	Lake size (acres)	Threshold (N/acre)
Steuben	n/a	2,071	3

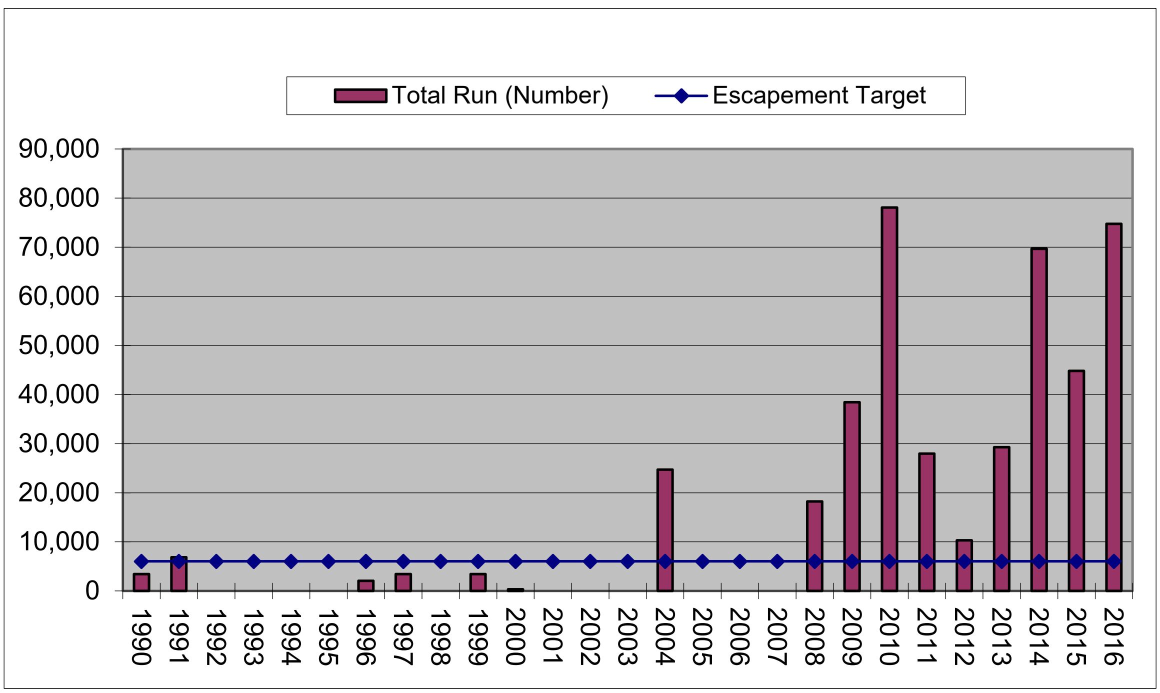

Spawning Location
Tunk Lake
Donnell Pond
Flanders Pond
Sullivan
Sorrento
Schoodic Scenic Byway
Route 1
Fishing Location
Blackswoods
Lake


Bangor
Main Rd
9
Hamilton Pond
Mount Desert Island
Long Pond
Acadia N.P.
Penobscot Bay
Deer Island
Swans Island
Haut Island
Seal Island
Matinicus Island

Year	Municipality	River	% repeat spawners by year and frequency	R-0	R-1	R-2	R-3	Z-value
2016								
2015			Unreadable					
2014	Stueben	Tunk River	16.8	83.17	7.92	8.91		1.12
2013	Stueben	Tunk River	48.0	52.00	48.00			0.08
2012								
2011	Stueben	Tunk River	20.6	79.38	14.40	6.18		1.21
2010	Stueben	Tunk River	19.6	80.40	15.70	2.00	2.00	1.3
2009								
2008								

Year	Escapement Number (based on target)	Actual	Measured or estimated (.43*landings)	spawning below barrier?	Landings Number	total run size (escape+kill)	exploitation rate
1990	6,213		1,204	n	2,800	4,004	0.70
1991	6,213		0	n	0	0	
1992	6,213		0	n	0	0	
1993	6,213		0	n	0	0	
1994	6,213		0	n	0	0	
1995	6,213		0	n	0	0	
1996	6,213		722	n	1,680	2,402	0.70
1997	6,213		1,032	n	2,400	3,432	0.70
1998	6,213		0	n	0	0	
1999	6,213		1,032	n	2,400	3,432	0.70
2000	6,213		103	n	240	343	0.70
2001	6,213		0	n	0	0	
2002	6,213		0	n	0	0	
2003	6,213		0	n	0	0	
2004	6,213		7,430	n	17,280	24,710	0.70
2005	6,213		0	n	0	0	
2006	6,213		0	n	0	0	
2007	6,213		0	n	0	0	
2008	6,213		5,483	n	12,750	18,233	0.70
2009	6,213		11,558	n	26,880	38,438	0.70
2010	6,213		23,478	n	54,600	78,078	0.70
2011	6,213		8,411	n	19,560	27,971	0.70
2012	6,213		3,096	n	7,200	10,296	0.70
2013	6,213		8,798	n	20,460	29,258	0.70
2014	6,213		20,950	n	48,720	69,670	0.70
2015	6,213		13,481	n	31,350	44,831	0.70
2016	6,213		22,478	n	52,274	74,752	0.70





Webber Pond Commercial Fishery:

The commercial fishery at Vassalboro began in 2009 as the result of a restoration project at Webber Pond started by the Maine Department of Marine Resources in 2000. Until 2009, alewives were unable to reach spawning habitat in Vassalboro unless they were hand dipped over the dam (Figure 21). Upstream passage now provides access to spawning habitat within this municipality. The Maine Department of Marine Resources manages this system for a minimum commercial escapement of 35 fish per acre. The municipality currently chooses to have the commercial harvester pass at least 18,000 alewives into spawning habitat before commercial harvest can commence. The minimum spawning escapement need for this system is 42,035 river herring passed upstream through three closed days per week during the season. The management plan has achieved the target escapement developed for this system during all years that the commercial harvest has occurred. Current returns to the commercial fishery are the result of trap and transfer operations that initially stocked the system with approximately 6 fish per acre though an agreement with the Maine Department of Inland Fisheries and Wildlife.

There is no spawning in the stream leading to Webber Pond. Like many of the small streams that lead to spawning habitat in lakes and ponds in Maine the stream is often plugged with beaver dams. The harvester must obtain a permit to remove these dams prior to downstream migration in the fall and the spawning run in the spring.

Town	River	Lake size (acres)	Threshold (N/acre)
Vassalboro	n/a	1,201	35

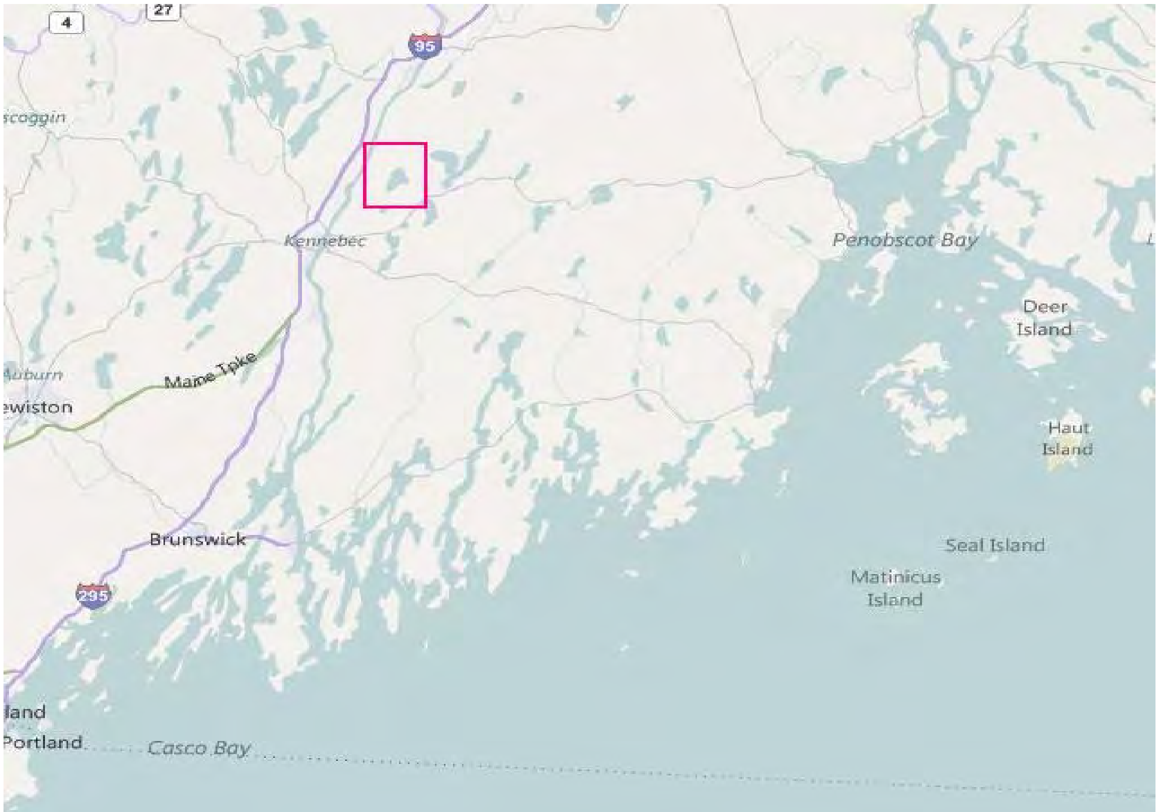
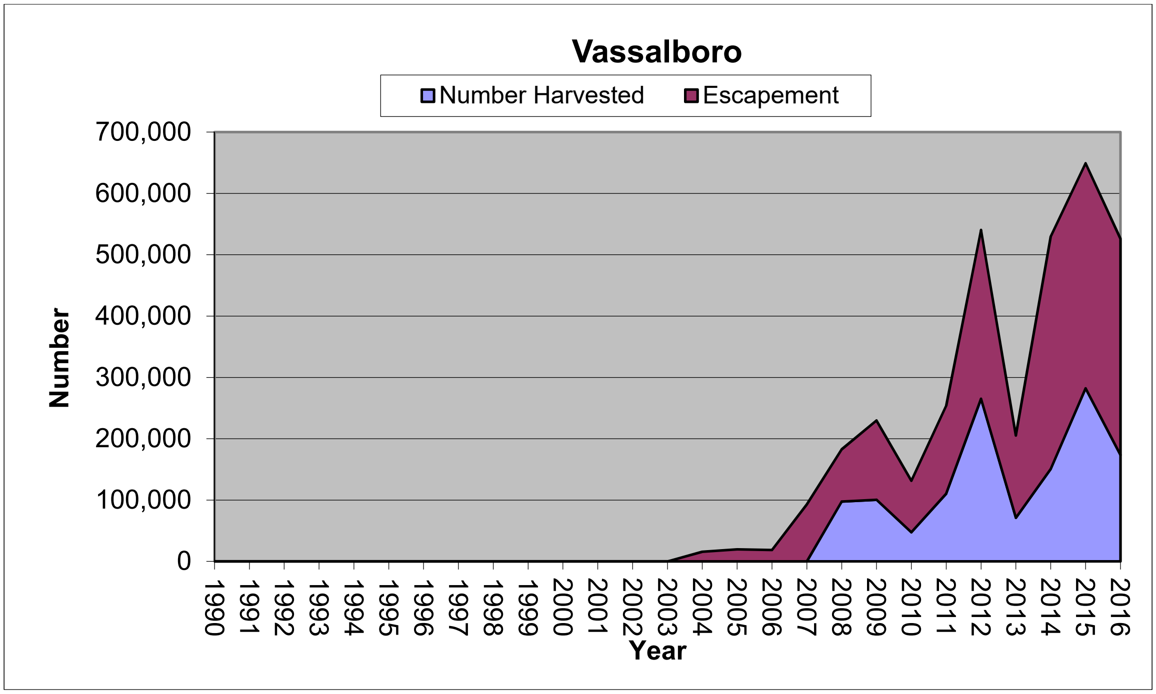
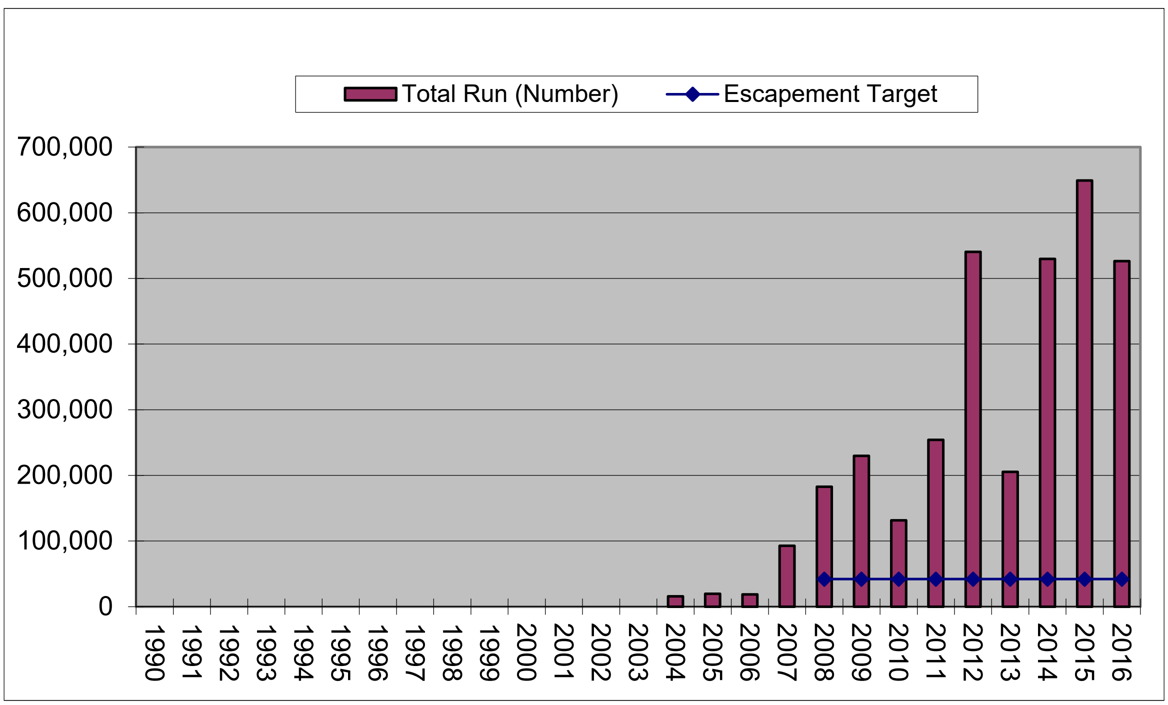


Figure 21. Outlet dam at Webber Pond. The commercial fishery occurs upstream and to the left of the dam.

Year	Municipality	River	% repeat spawners by year and frequency	R-0	R-1	R-2	R-3	Z-value
2015	Vassalboro	N/A	14.0	86.00	12.00	2.00		1.88
2014	Vassalboro	N/A	23.3	76.80	18.20	5.10		1.36
2013	Vassalboro	N/A	36.3	63.70	31.40	3.90	1.00	1.45
2012	Vassalboro	N/A	13.3	86.70	10.70	2.70		1.73
2011	Vassalboro	N/A	75.8	24.19	50.00	24.19	1.16	0.89
2010	Vassalboro	N/A	25.2	74.80	13.80	10.60	0.80	1.39
2009	Vassalboro	N/A	12.9	87.10	10.60	2.40		1.80
2008		N/A						

Year	Escapement Number (based on target)	Actual	Measured or estimated (.43*landings)	spawning below barrier?	Landings Number	total run size (escape+kill)	exploitation rate
2000	42,035	7,551	Measured	n	0	7,551	0.00
2001	42,035	7,618	Measured	n	0	7,618	0.00
2002	42,035	7,619	Measured	n	0	7,619	0.00
2003	42,035	5,343	Measured	n	0	5,343	0.00
2004	42,035	9,202	Measured	n	0	9,202	0.00
2005	42,035	19,718	Measured	n	0	19,718	0.00
2006	42,035	18,589	Measured	n	0	18,589	0.00
2007	42,035	92,852	Measured	n	0	92,852	0.00
2008	42,035	85,022	Measured	n	97,680	182,702	0.53
2009	42,035	129,247	Measured	n	100,560	229,807	0.44
2010	42,035	83,905	Measured	n	47,520	131,425	0.36
2011	42,035	143,463	Measured	n	110,520	253,983	0.44
2012	42,035	275,175	Measured	n	265,200	540,375	0.49
2013	42,035	134,259	Measured	n	71,100	205,359	0.35
2014	42,035	378,890	Measured	n	150,840	529,730	0.28
2015	42,035	366,960	Measured	n	282,240	649,200	0.43
2016	42,035	352,770	Measured	n	173,520	526,290	0.33





Ellsworth Commercial Fishery:

There are two large dams on the Union River. The largest is the Ellsworth Dam approximately 66.7 feet high and has four turbine generators and a FERC-authorized capacity of 8.9MW. Graham Lake Dam is approximately 30 feet high and used only to release water from the Graham Lake impoundment. The water storage dam expanded the size of Graham Lake to over 9,000 surface acres. Since 1996, the hydropower owner has artificially propagated the alewife run through a long term trap and truck program. For several years the numbers alewife stocked above the hydropower dam occurred as the result of the hydropower company owners trucking as many fish as possible during the closed fishing days. Prior to the 1980s the state resource agencies transported fish above the hydropower facility to initiate a river herring run. These stockings resulted in returns as high as 1.8 million returning alewives in the mid-1980s.

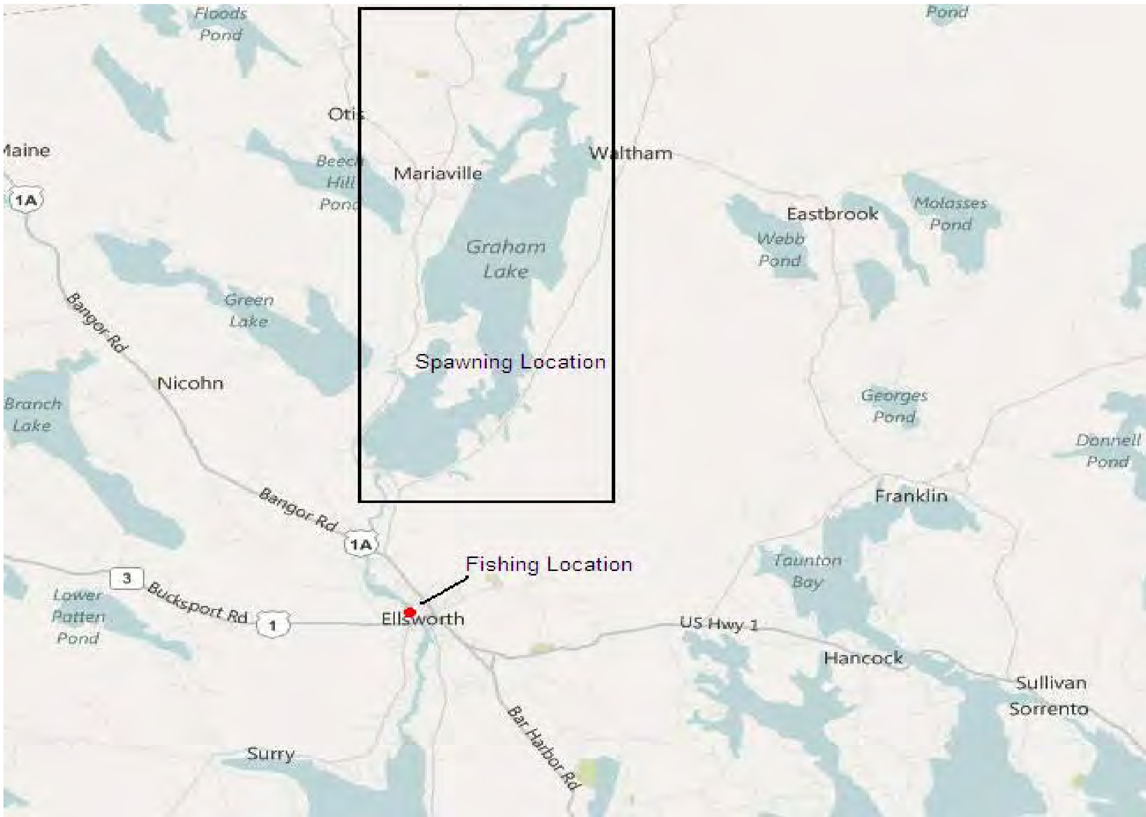
In accordance with the 2015-2017 Union River Fisheries Management Plan, the company currently stocks a minimum of 315,000 alewives annually upstream into Graham and Leonard lakes. Once the initial 150,000 alewives are captured and stocked upstream, harvesting is allowed Monday through Friday each week, with the stocking of the additional 165,000 alewives conducted on weekends through June 15 each year in order to represent the run throughout the entire spawning period. Once the harvester attains the stocking goal, the management plan permits the municipality to harvest all remaining river herring coming up the fishway which ends in the hydropower station parking lot.

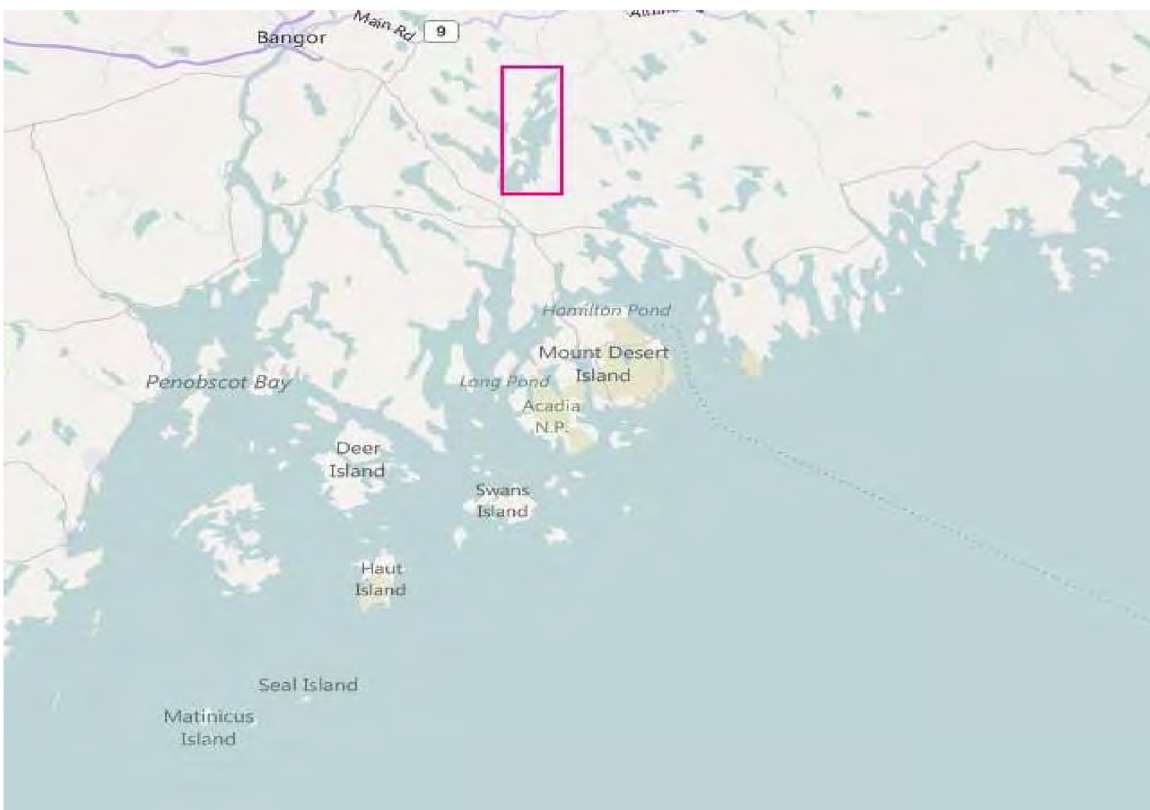
In addition to the downstream passage at the Graham Lake Dam, migrating fish are also known to pass through the turbines at Ellsworth. This can result in high mortality for both adult and juvenile river herring. The number of repeat spawning fish returning to the Union River is low compared to all other rivers in Maine. The lack of repeat spawning fish is likely the result of additional mortality from the turbines and high exploitation rate. As the numbers of fish stocked above the dam increase the number of repeat spawning fish should increase. The management plan has achieved the target escapement developed for this system each year during the past 20-year period solely through the efforts of the Black Bear Hydro Partners and the contractors the hire for the trap and truck program.

The hydropower facility is a peaking operation where water is stored during the night and passed though the turbines during the day when power demand is highest. Spill conditions exist for only three weeks during the early spring ice melt. During the remainder of the year, there is no spill over the dam except during high water resulting from an extreme rain event.

There is no spawning below the dam for either species. The Union River is tidal to the base of the dam and provides little riverine habitat for any anadromous fish species. Atlantic salmon are present during some years and when caught in the trap are trucked upstream to spawning habitat. There are several ponds in the watershed that could support river herring but alewife reintroductions are not permitted by the Department of Inland Fisheries and Wildlife because of perceived conflicts with sport fish species, rainbow smelt, or hatchery operations.

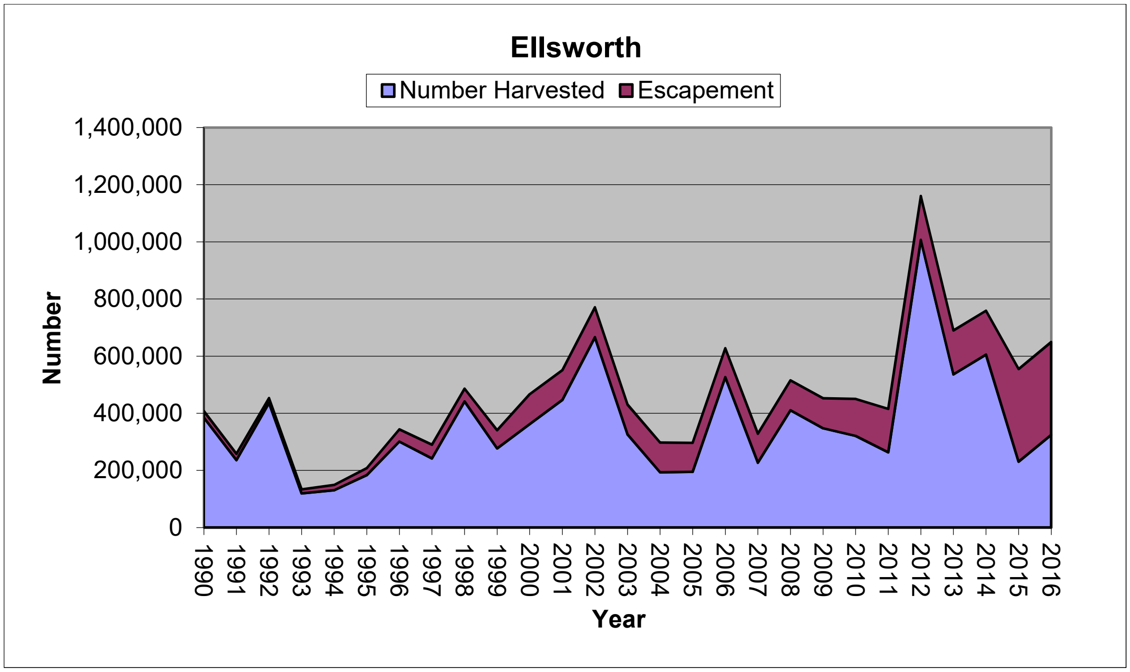
Town	River	Lake size (acres)	Threshold (N/acre)
Ellsworth	Union River	7,865	41

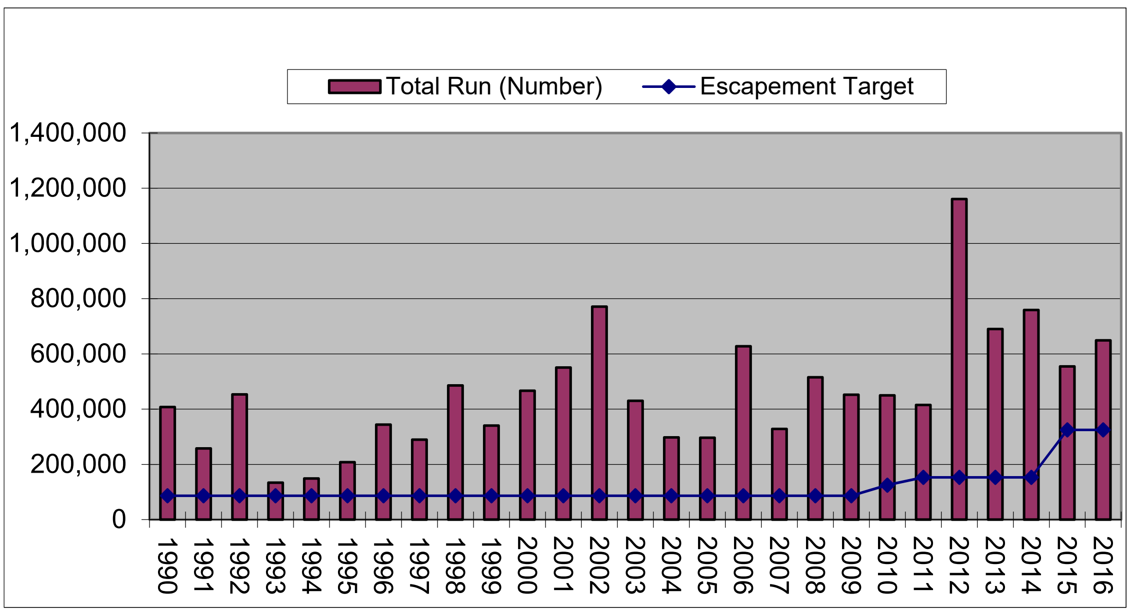

Floods Pond
Otis
Maine
Beech Hill Pond
Mariaville
Waltham
Eastbrook
Molasses Pond
Webb Pond
Graham Lake
Green Lake
Bangor Rd
Spawning Location
Nicohn
Branch Lake
Georges Pond
Donnell Pond
Franklin
Bangor Rd
1A
Fishing Location
Taunton Bay
3
Bucksport Rd
1
Lower Patten Pond
Ellsworth
US Hwy 1
Hancock
Sullivan
Sorrento
Bar Harbor Rd
Surry
Pond


Bangor
Main Rd
9
Hamilton Pond
Mount Desert Island
Penobscot Bay
Long Pond
Acadia N.P.
Deer Island
Swans Island
Haut Island
Seal Island
Matinicus Island

Year	Municipality	River	% repeat spawners by year and frequency	R-0	R-1	R-2	R-3	Z-value
2015	Ellsworth	Union	7.8	92.22	7.78			2.47
2014	Ellsworth	Union	17.0	83.00	12.00	5.00		1.4
2013	Ellsworth	Union	12.0	88.00	12.00			1.99
2012	Ellsworth	Union	10.9	89.10	7.90	3.00		2.56
2011	Ellsworth	Union	7.9	92.10	7.23	0.65		2.48
2010	Ellsworth	Union	8.0	92.00	7.00	1.00		2.26
2009	Ellsworth	Union	7.0	92.30	2.80	4.90		1.47
2008	Ellsworth	Union	2.0	98.00	2.00			3.89

Year	Escapement Number (based on target)	Actual	Measured or estimated (.43*landings)	spawning below barrier?	Landings Number	total run size (escape+kill)	exploitation rate
1972	0	1,000	Measured	n	0	1,000	0.00
1973	0	600	Measured	n	0	600	0.00
1974	0	600	Measured	n	0	600	0.00
1975	0	6,000	Measured	n	0	6,000	0.00
1976	0	2,400	Measured	n	62,857	65,257	0.96
1977	0	1,000	Measured	n	0	1,000	0.00
1978	0	1,000	Measured	n	91,571	92,571	1.00
1979	0			n			
1980	0			n			
1981	0	22,000	Measured	n	49,000	71,000	0.69
1982	0	12,720	Measured	n	119,924	132,644	0.90
1983	0	4,560	Measured	n	14,541	19,101	0.76
1984	0	6,600	Measured	n	129,448	136,048	0.95
1985	0	17,520	Measured	n	1,424,530	1,442,050	0.99
1986	0	12,720	Measured	n	1,833,409	1,846,129	0.99
1987	0	13,440	Measured	n	792,775	806,215	0.98
1988	0	11,760	Measured	n	882,339	894,099	0.99
1989	0	16,500	Measured	n	935,836	952,336	0.98
1990	0	20,280	Measured	n	385,070	590,753	0.65
1991	0	19,320	Measured	n	235,859	368,741	0.64
1992	0	15,125	Measured	n	436,395	661,637	0.66
1993	0	12,286	Measured	n	119,357	189,110	0.63
1994	0	18,360	Measured	n	130,617	211,866	0.62
1995	0	24,503	Measured	n	183,450	296,281	0.62
1996	47,190	42,795	Measured	n	300,952	343,747	0.88
1997	47,190	48,060	Measured	n	241,779	289,839	0.83
1998	47,190	44,415	Measured	n	441,481	485,896	0.91
1999	47,190	63,585	Measured	n	277,148	340,733	0.81
2000	104490	104490	Measured	n	362,247	466,737	0.78
2001	104085	104085	Measured	n	446,403	550,488	0.81
2002	104625	104625	Measured	n	666,301	770,926	0.86
2003	104220	104220	Measured	n	326,171	430,391	0.76
2004	104220	104220	Measured	n	193,329	297,549	0.65
2005	101520	101520	Measured	n	195,082	296,602	0.66
2006	101250	101250	Measured	n	526,230	627,480	0.84
2007	101385	101385	Measured	n	226,843	328,228	0.69
2008	104490	104490	Measured	n	410,670	515,160	0.80
2009	104760	104760	Measured	n	347,490	452,250	0.77
2010	129330	129330	Measured	n	320,760	450,090	0.71
2011	151875	151875	Measured	n	263,250	415,125	0.63
2012	153630	153630	Measured	n	1,006,898	1,160,528	0.87
2013	153630	153630	Measured	n	536,220	689,850	0.78
2014	153360	153360	Measured	n	605,340	758,700	0.80
2015	329160	329160	Measured	n	230,648	559,808	0.41
2016	336220	336220	Measured	n	324,270	660,490	0.49



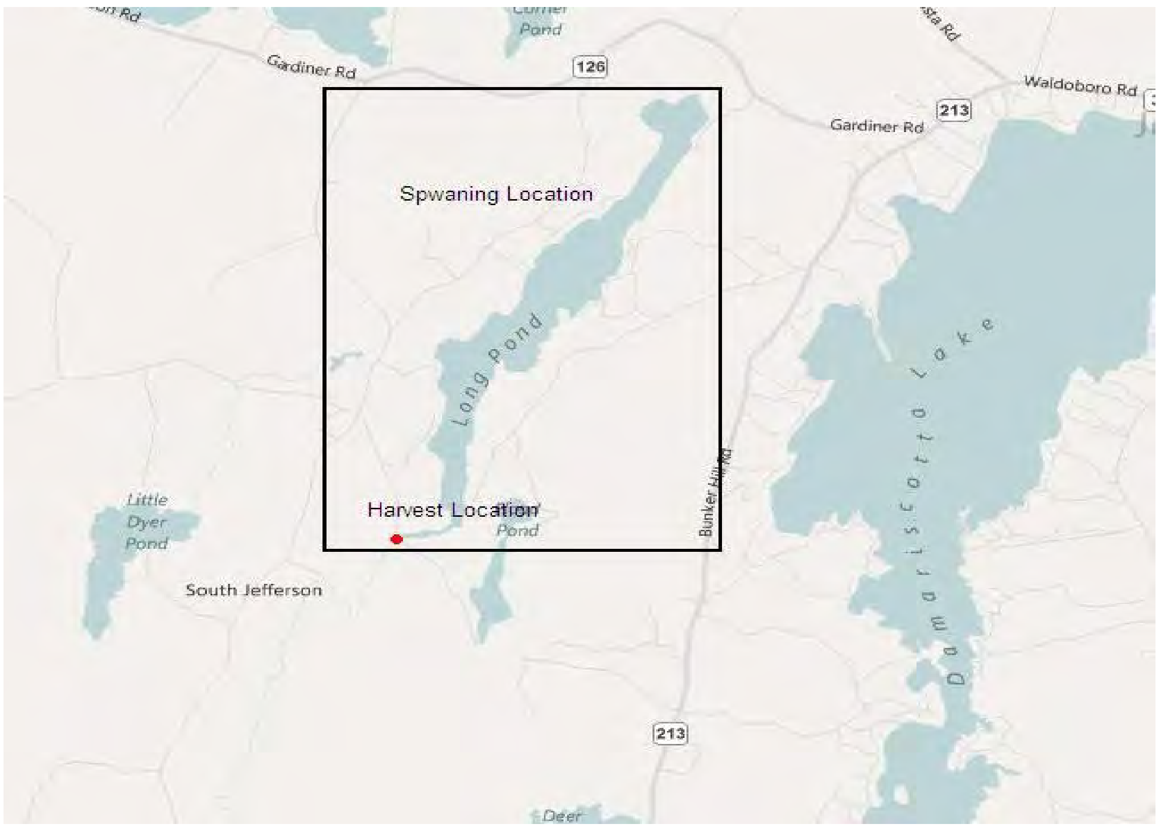


Jefferson Commercial Fishery:

The Maine Department of Marine Resources manages this system for a minimum commercial escapement of 35 fish per acre. The spawning escapement need for this system is 14,875 river herring passed upstream through a three day closed period per week throughout the season. The management plan has achieved returns to meet the target escapement developed for this system or passed the entire run during each year for the past 20-year period. This fishery is typical of the smaller commercial river herring fisheries in Maine (Figures 22-24). The outlet stream from dyer-long Pond is a small coastal tributary to the lower Sheepscot River. This stream is heavily is impacted by beaver activity in the fall that delay downstream passage and obstruct upstream passage the following spring if the dams are not breached or spring flows do not overtop the dams.

The river herring run into Dyer-Long Pond is entirely alewife. Blueback herring are not present in the commercial catches or samples collected by field staff. There is no spawning habitat below the fishway for blueback herring or alewife. Poaching along the stream is a problem at times during the spring migration. The stream is easily accessible at several points along its course to the Sheepscot River.

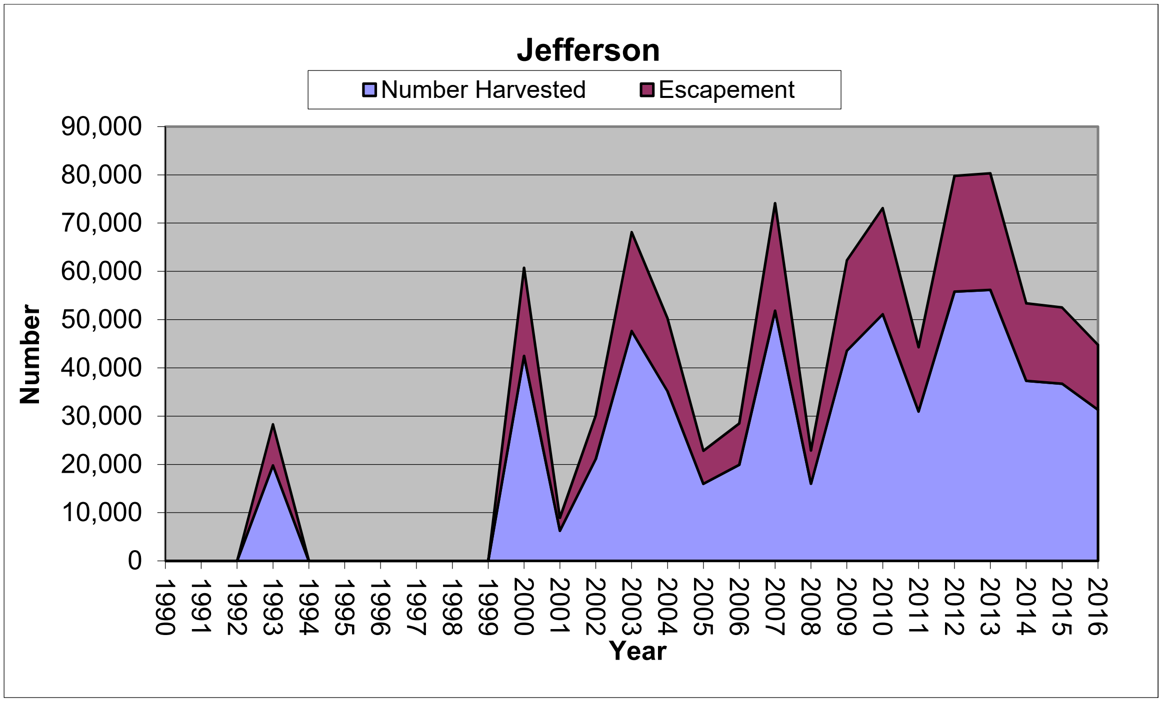
Town	River	Lake size (acres)	Threshold (N/acre)
Jefferson	Dyer River	425	35

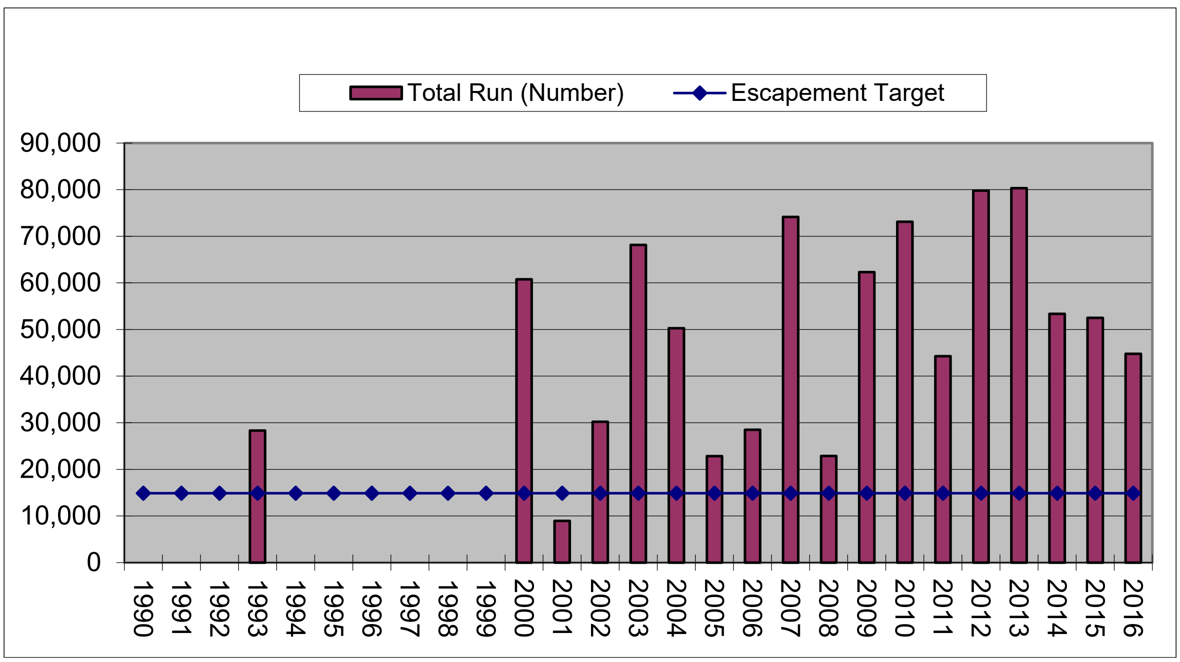


Figures 22 - 24. Outlet stream from Dyer-Long Pond, fishway leading into the pond and alewife trap at the pond outlet.

Year	Municipality	River	% repeat spawners by year and frequency	R-0	R-1	R-2	R-3	Z-value
2015	Jefferson	Dyer River	24.8	75.24	20.00	3.81	0.95	1.48
2014	Jefferson	Dyer River	26.5	73.50	20.60	5.20	0.60	1.58
2013	Jefferson	Dyer River	23.9	76.10	20.60	3.20		1.58
2012	Jefferson	Dyer River	34.3	65.70	28.30	5.10	1.00	1.28
2011	Jefferson	Dyer River	64.0	36.00	62.00	2.00		1.45
2010	Jefferson	Dyer River	15.2	84.40	14.10	1.50		2.02
2009	Jefferson	Dyer River	1.8	98.20	1.80			4.00
2008	Jefferson	Dyer River	62.7	37.25	60.78	1.96		1.47

Year	Escapement Number (based on target)	Actual	Measured or estimated (.43*landings)	spawning below barrier?	Landings Number	total run size (escape+kill)	exploitation rate
1990	14,875		0	n	0	0	
1991	14,875		0	n	0	0	
1992	14,875		0	n	0	0	
1993	14,875		9,933	n	23,100	33,033	0.70
1994	14,875		0	n	0	0	
1995	14,875		0	n	0	0	
1996	14,875		0	n	0	0	
1997	14,875		0	n	0	0	
1998	14,875		0	n	0	0	
1999	14,875		0	n	0	0	
2000	14,875		21,311	n	49,560	70,871	0.70
2001	14,875		3,130	n	7,280	10,410	0.70
2002	14,875		10,595	n	24,640	35,235	0.70
2003	14,875		23,899	n	55,580	79,479	0.70
2004	14,875		17,639	n	41,020	58,659	0.70
2005	14,875		8,007	n	18,620	26,627	0.70
2006	14,875		9,993	n	23,240	33,233	0.70
2007	14,875		26,006	n	60,480	86,486	0.70
2008	14,875		8,025	n	18,662	26,687	0.70
2009	14,875		21,853	n	50,820	72,673	0.70
2010	14,875		21,982	n	51,120	73,102	0.70
2011	14,875		13,313	n	30,960	44,273	0.70
2012	14,875		23,994	n	55,800	79,794	0.70
2013	14,875		24,149	n	56,160	80,309	0.70
2014	14,875		16,048	n	37,320	53,368	0.70
2015	14,875		15,790	n	36,720	52,510	0.70
2016	14,875		13,468	n	31,320	44,788	0.70





Sullivan Commercial Fishery:

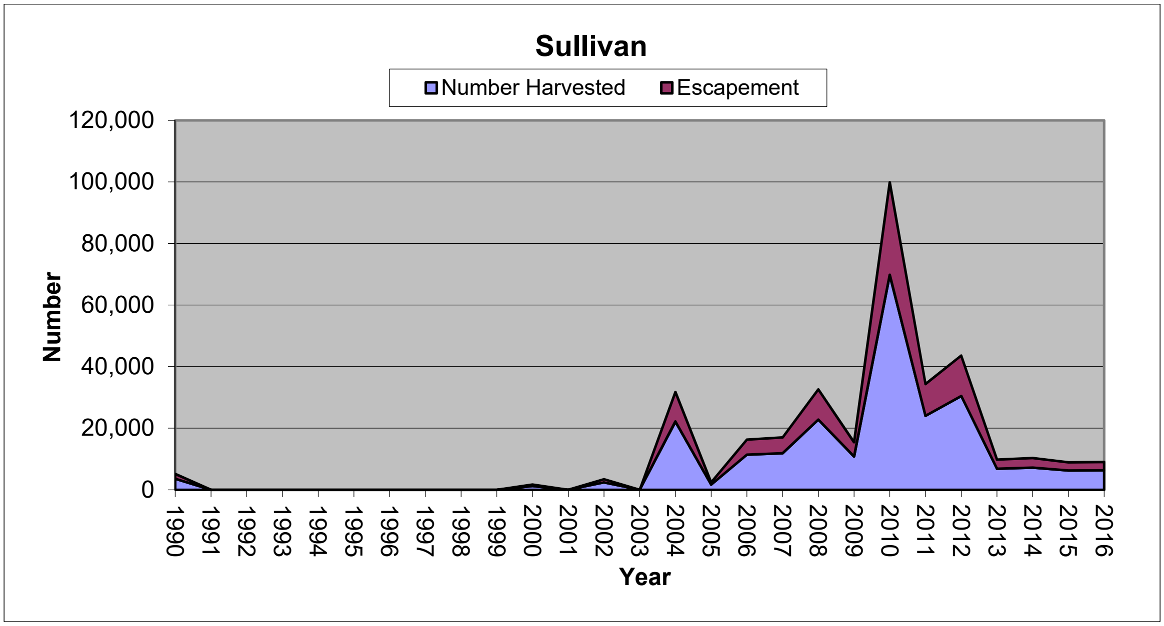
The Maine Department of Marine Resources manages this system for a minimum commercial escapement of 35 fish per acre. The spawning escapement need for this system is 3,222 river herring passed upstream during the three required closed days in the fishery each week. The management plan has achieved returns to meet the target escapement developed for this 90% of the time for the past 20-year period system or passed the entire run upstream. The harvester monitors the stream during the spring and fall migration periods to ensure upstream and downstream passage. There is no spawning habitat in the stream below or above the fishery other than the lake habitat. Blueback herring are not observed in the biological samples or commercial catches. There are no dams located on the stream, but the previous fishway and culvert did impede upstream passage at certain flows (Figure 25). In 2012 a new bottomless arched culvert was installed, eliminating fish passage issues for anadromous fish in this system.

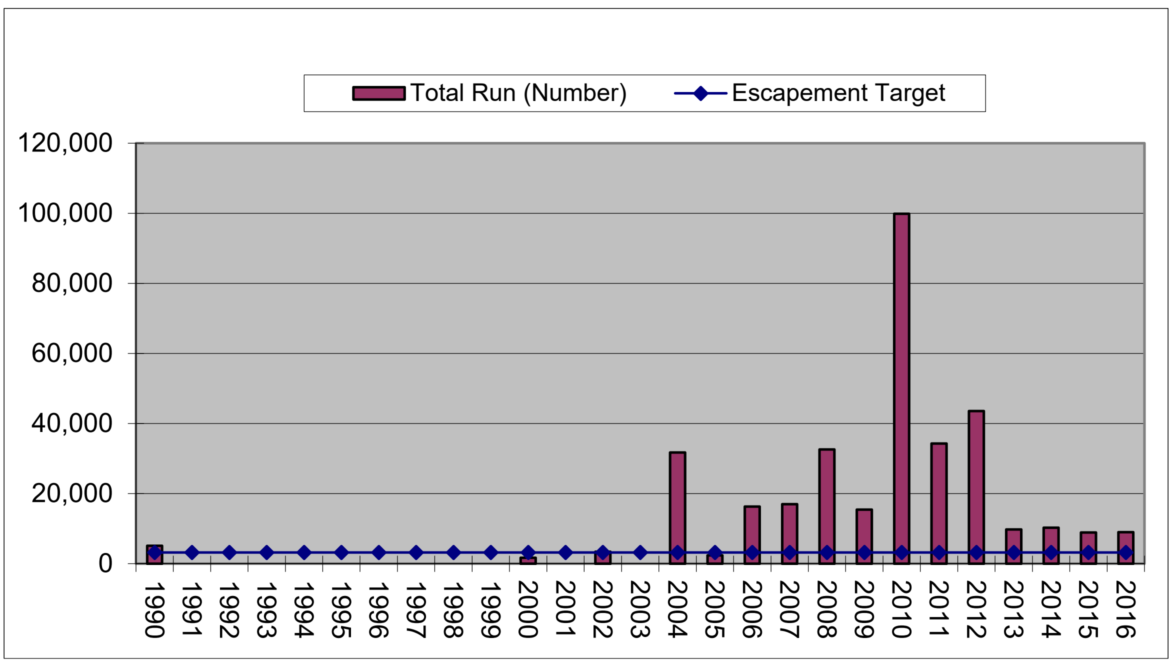
Town	River	Lake size (acres)	Threshold (N/acre)
Sullivan	n/a	92	35

Figure 25. Fishway leading to spawning habitat in Flanders Pond prior to fall of 2012 (left). Removal of the fish ladder and installation of a bottomless arch culvert ready for the 2013 alewife migration (right).

Year	Municipality	River	% repeat spawners by year and frequency	R-0	R-1	R-2	R-3	Z-value
2015	Sullivan	N/A	48.5	51.52	33.33	8.08	7.07	0.74
2014	Sullivan	N/A	43.0	57.00	21.00	22.00		0.48
2013								
2012	Sullivan	N/A	8.5	91.50	8.50			2.38
2011								
2010	Sullivan	N/A	11.8	88.20	10.50	1.30		2.11
2009	Sullivan	N/A	26.3	73.70	23.70	2.60		1.67
2008	Sullivan	N/A	33.3	66.70	22.20	11.10		0.90

Year	Escapement Number (based on target)	Actual	Measured or estimated (.43*landings)	spawning below barrier?	Landings Number	total run size (escape+kill)	exploitation rate
1990	3,222		1,806	n	4,200	6,006	0.70
1991	3,222		0	n	0	0	
1992	3,222		0	n	0	0	
1993	3,222		0	n	0	0	
1994	3,222		0	n	0	0	
1995	3,222		0	n	0	0	
1996	3,222		0	n	0	0	
1997	3,222		0	n	0	0	
1998	3,222		0	n	0	0	
1999	3,222		0	n	0	0	
2000	3,222		516	n	1,200	1,716	0.70
2001	3,222		0	n	0	0	
2002	3,222		1,032	n	2,400	3,432	0.70
2003	3,222		0	n	0	0	
2004	3,222		9,546	n	22,200	31,746	0.70
2005	3,222		722	n	1,680	2,402	0.70
2006	3,222		4,902	n	11,400	16,302	0.70
2007	3,222		5,108	n	11,880	16,988	0.70
2008	3,222		9,804	n	22,800	32,604	0.70
2009	3,222		4,644	n	10,800	15,444	0.70
2010	3,222		30,031	n	69,840	99,871	0.70
2011	3,222		10,320	n	24,000	34,320	0.70
2012	3,222		13,106	n	30,480	43,586	0.70
2013	3,222		2,941	n	6,840	9,781	0.70
2014	3,222		3,096	n	7,200	10,296	0.70
2015	3,222		2,683	n	6,240	8,923	0.70
2016	3,222		2,709	n	6,300	9,009	0.70



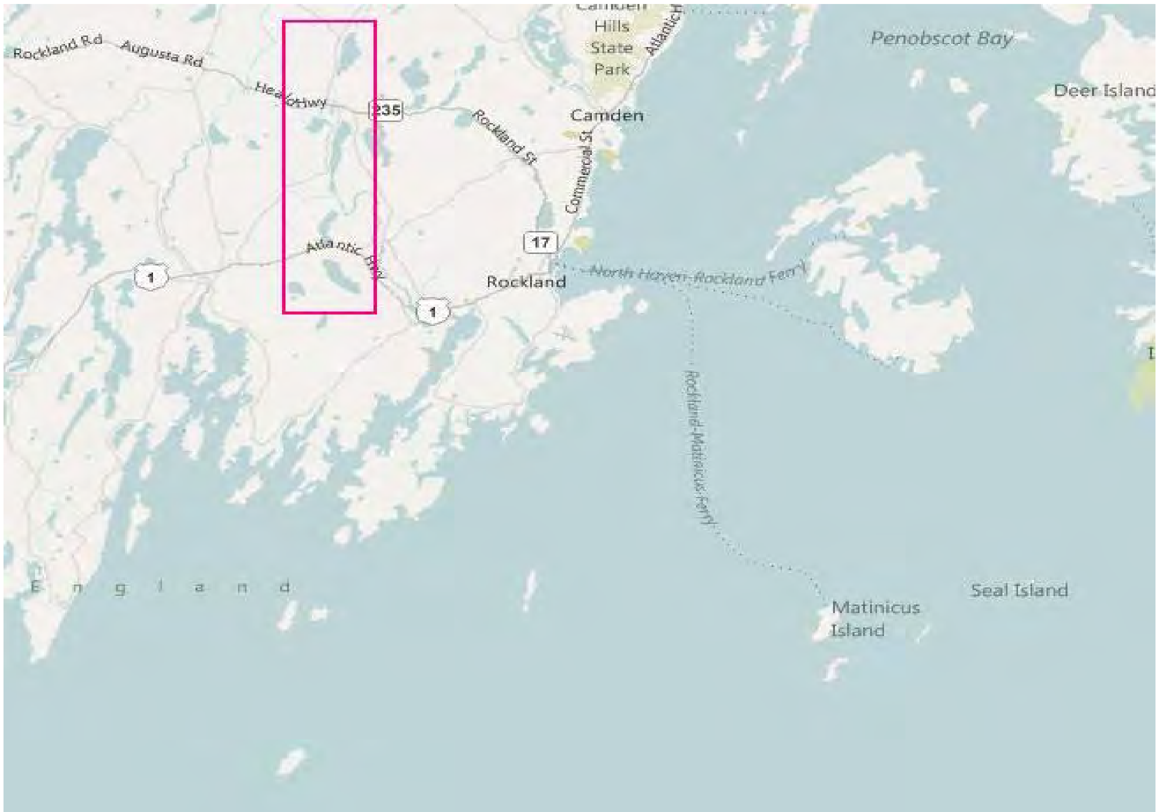


Warren Commercial Fishery:

The Maine Department of Marine Resources manages this system for a minimum commercial escapement of 35 fish per acre. The management plan has achieved returns to meet the target escapement developed for this system 95% of the time for the past 20-year period. The spawning escapement need for this system is 66,115 river herring passed upstream by a two-day closure of the fishery each week and a delay in deploying the weir until sometime after May 1 of the fishing year (Figure 26). Due to the size of the weir and spring flows in the river, deploying the weir and active fishing at this location typically does not occur until the second week of May. This permits, during some years, a larger proportion of spawning stock upstream than typical fisheries. There are several individual and varied spawning habitats within the St. George Watershed that act to support the large river herring run, both blueback herring and alewife. Unfortunately in 2016 significant drought conditions resulted in reports of several fish killing in the drainage. Fish were stranded in pools and above beaver dams as waters receded and stranded migrating fish. The impact to the 2016 year class is unknown and will first be observed when fish return in 2020 as 4-year olds.

Warren is one of the oldest and most productive commercial fisheries in Maine. The State of Massachusetts granted Warren exclusive harvest rights in 1802. By 1869 there were 16 dams on the main stem of the St George River. The main stem river is now clear of manmade obstructions and most spawning habitat is now accessible to river herring. There are portions of historic habitat that are still inaccessible in the upper watershed. Dams at lake outlets without fish passage are the biggest obstacle to full restoration of the river. There are blueback herring mixed in with the commercial alewife catches toward the end of the season. Blueback herring continue to migrate upstream after the June 5 closing date. The numbers of blueback herring in the system is estimated at 950,000 based on available spawning habitat. There is no spawning habitat located below the town fishery for either species.

Town	River	Lake size (acres)	Threshold (N/acre)
Warren	St. George	1,889	35



Year	Municipality	River	% repeat spawners by year and frequency	R-0	R-1	R-2	R-3	Z-value
2015	Warren	St .George	23.7	76.32	13.16	5.26	5.26	0.89
2014	Warren	St .George	37.6	62.38	20.79	6.93	9.90	0.66
2013	Warren	St .George	35.1	64.90	27.40	4.80	2.80	1.12
2012	Warren	St .George	44.4	55.60	30.50	8.60	5.30	0.83
2011	Warren	St .George	29.8	70.20	21.91	5.47	2.39	1.15
2010	Warren	St .George	20.0	80.00	15.00	5.00		1.39
2009	Warren	St. George	28.0	72.00	22.80	4.00	1.10	1.43
2008	Warren	St. George	37.0	63.00	24.00	13.00		0.97

Figure 26. Fishing weir located at the head of tide on the St. George River in Warren, Maine.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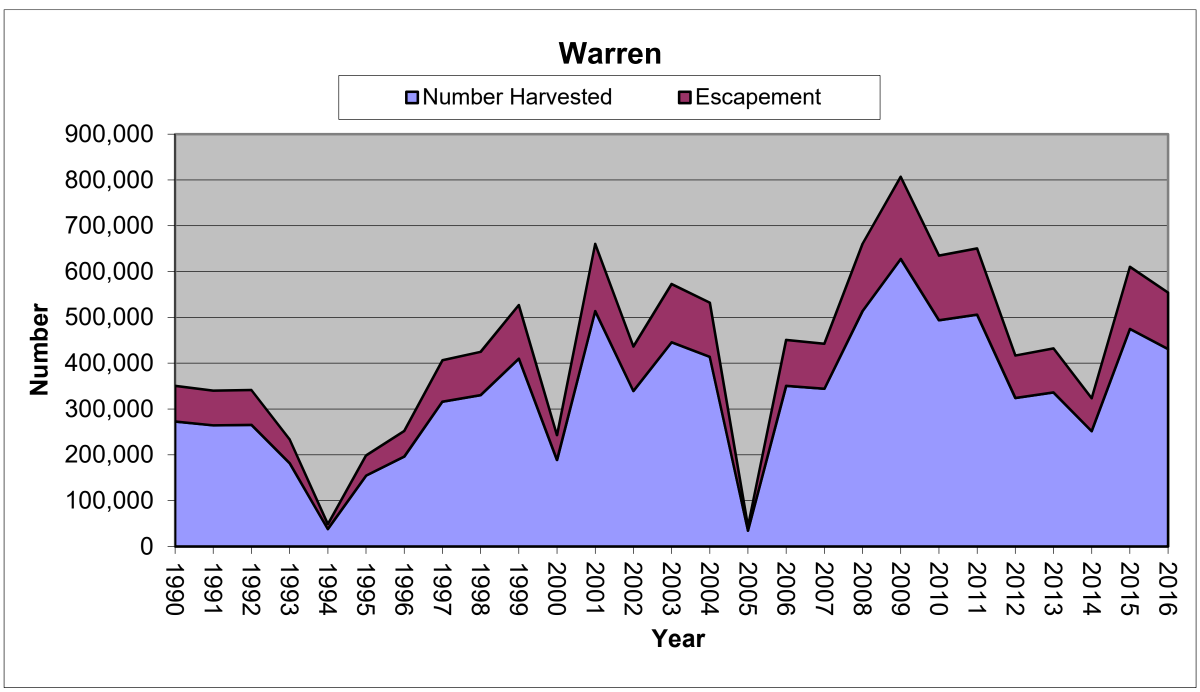
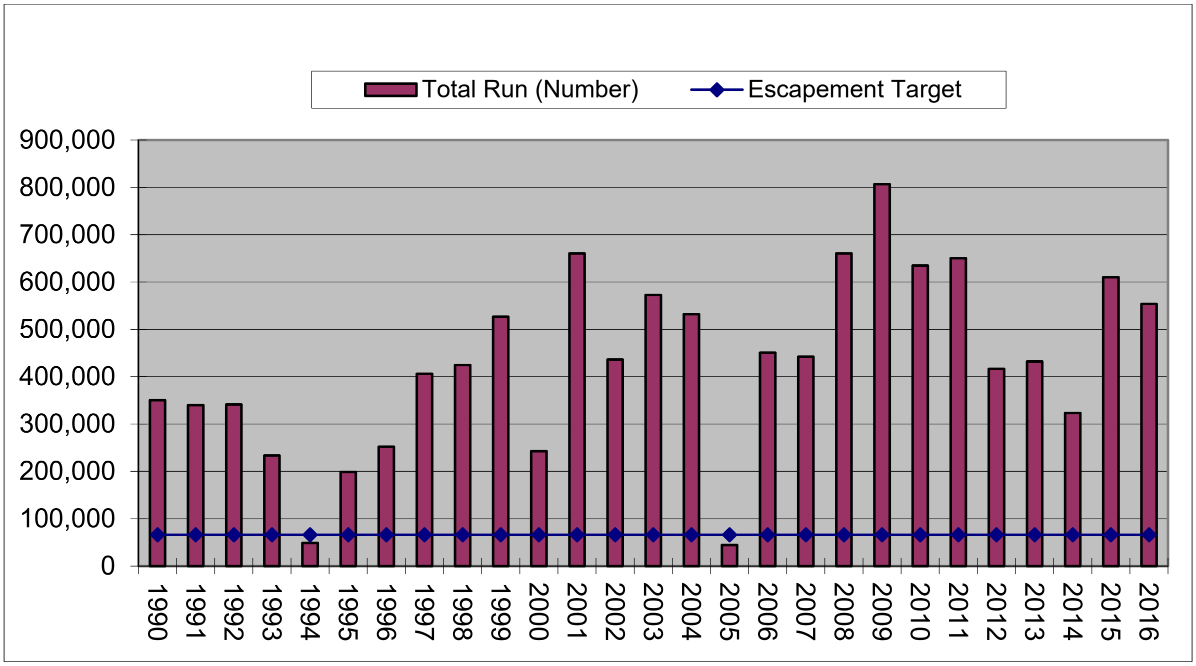
Year	Escapement Number (based on target)	Actual	Measured or estimated (.28*landings)	spawning below barrier?	Landings Number	total run size (escape+kill)	exploitation rate
1990	66,115		76,362	n	272,720	350,718	0.78
1991	66,115		86,377	n	308,490	396,718	0.78
1992	66,115		86,710	n	309,680	398,248	0.78
1993	66,115		59,349	n	474,720	272,581	0.78
1994	66,115		12,387	n	37,920	56,893	0.78
1995	66,115		50,470	n	154,500	231,802	0.78
1996	66,115		64,053	n	196,080	294,185	0.78
1997	66,115		103,253	n	316,080	474,225	0.78
1998	66,115		107,918	n	330,360	495,650	0.78
1999	66,115		133,868	n	409,800	614,837	0.78
2000	66,115		61,701	n	188,880	283,383	0.78
2001	66,115		167,815	n	513,720	770,751	0.78
2002	66,115		110,858	n	339,360	509,153	0.78
2003	66,115		145,550	n	445,560	668,489	0.78
2004	66,115		135,201	n	413,880	620,958	0.78
2005	66,115		11,250	n	34,440	51,671	0.78
2006	66,115		114,542	n	350,640	526,077	0.78
2007	66,115		112,426	n	344,160	516,355	0.78
2008	66,115		167,854	n	513,840	770,931	0.78
2009	66,115		175,728	n	627,600	807,094	0.78
2010	66,115		138,264	n	493,800	635,027	0.78
2011	66,115		144,541	n	505,920	650,461	0.78
2012	66,115		92,601	n	324,120	416,721	0.78
2013	66,115		96,029	n	336,120	432,149	0.78
2014	66,115		71,876	n	251,580	323,456	0.78
2015	66,115		135,628	n	474,720	610,348	0.78
2016	66,115		123,080	n	430,800	553,880	0.78





Cherryfield Commercial Fishery:

The Maine Department of Marine Resources manages this system for a minimum commercial escapement of 35 fish per acre. The spawning escapement need for this system is 29,050 river herring passed upstream through the three closed fishing days per week throughout the fishing season. The management plan has achieved the target escapement developed for this system 85% of the time for the past 20-year period or passed the entire run.

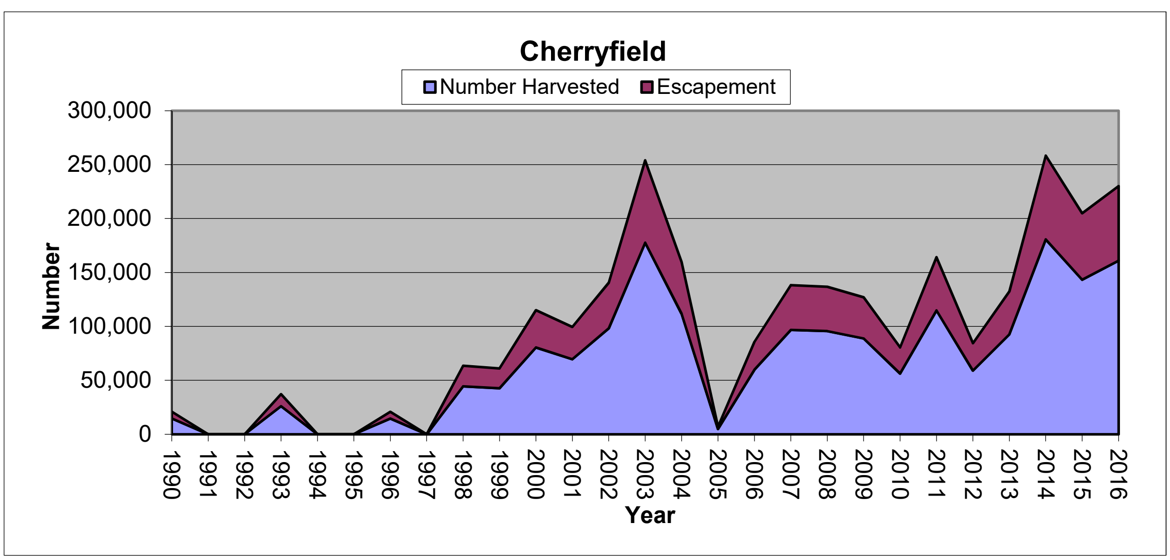
The Narraguagus River is an Atlantic salmon river with a significant number of alewives spawning in the lakes upstream of the dam located just above the head of tide (Figure 27). A small run of American shad also spawn in the river above the dam and provide sport fishing opportunities for the region. There is no indication that blueback herring utilize this river based on commercial samples collected at the fishing location. There is only a short stretch of freshwater below the dam and there is no evidence that river herring spawn in this stretch of river.

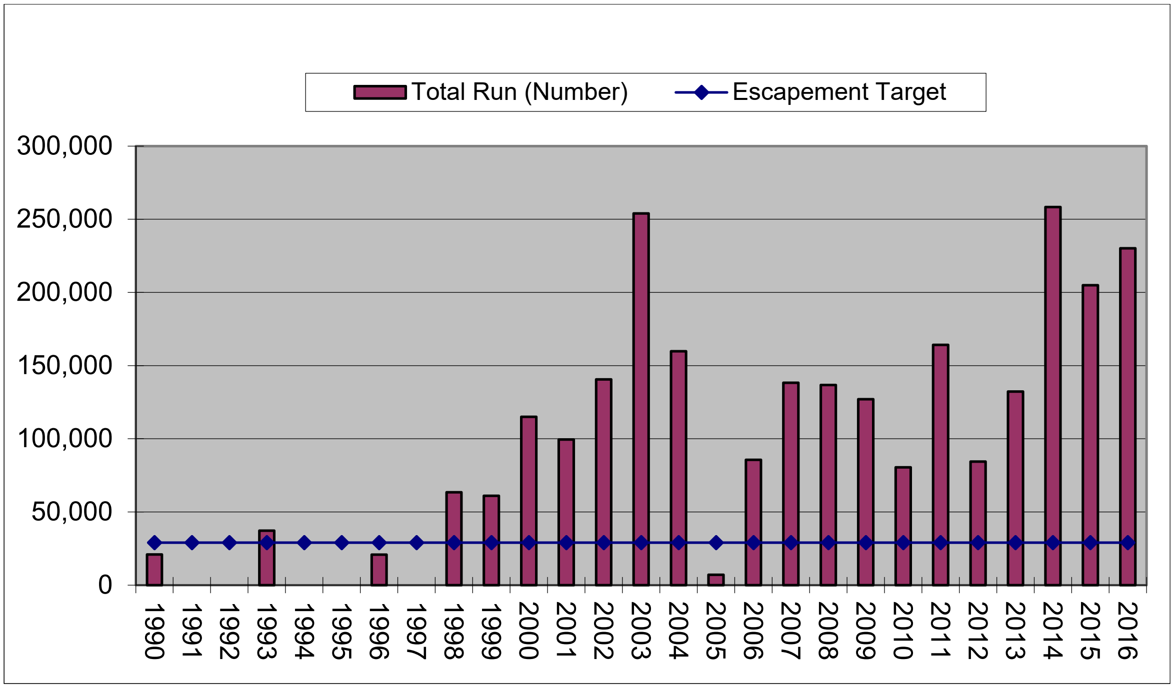
Town	River	Lake size (acres)	Threshold (N/acre)
Cherryfield	Narraguagus	830	35

Figure 27. Commercial alewife fishery above the Cherryfield dam during the 1980s.

Year	Municipality	River	% repeat spawners by year and frequency	R-0	R-1	R-2	R-3	Z-value
2015								
2014	Cherryfield	Narraguagus	23.3	76.77	12.12	11.00		0.97
2013	Cherryfield	Narraguagus	26.7	73.30	22.00	4.00	0.70	1.57
2012	Cherryfield	Narraguagus	29.0	70.94	20.94	6.10	2.00	1.19
2011	Cherryfield	Narraguagus	37.0	63.20	32.18	4.60		1.3
2010	Cherryfield	Narraguagus	20.0	80.00	18.00	1.00	1.00	1.6
2009	Cherryfield	Narraguagus						
2008	Cherryfield	Narraguagus	29.3	82.80	15.20	2.00		1.86

Year	Escapement Number (based on target)	Actual	Measured or estimated (.43*landings)	spawning below barrier?	Landings Number	total run size (escape+kill)	exploitation rate
1990	29,044		7,344	n	17,080	24,424	0.70
1991	29,044		0	n	0	0	0.00
1992	29,044		0	n	0	0	0.00
1993	29,044		13,063	n	26,040	43,443	0.70
1994	29,044		0	n	0	0	0.00
1995	29,044		0	n	0	0	0.00
1996	29,044		6,269	n	14,580	20,849	0.70
1997	29,044		0	n	0	0	0.00
1998	29,044		19,092	n	44,400	63,492	0.70
1999	29,044		18,370	n	42,720	61,090	0.70
2000	29,044		34,598	n	80,460	115,058	0.70
2001	29,044		29,928	n	69,600	99,528	0.70
2002	29,044		42,260	n	98,280	140,540	0.70
2003	29,044		76,368	n	177,600	253,968	0.70
2004	29,044		48,040	n	111,720	159,760	0.70
2005	29,044		2,116	n	4,920	7,036	0.70
2006	29,044		25,748	n	59,880	85,628	0.70
2007	29,044		41,590	n	96,720	138,310	0.70
2008	29,044		41,125	n	95,640	136,765	0.70
2009	29,044		38,184	n	88,800	126,984	0.70
2010	29,044		24,200	n	56,280	80,480	0.70
2011	29,044		49,381	n	114,840	164,221	0.70
2012	29,044		25,387	n	59,040	84,427	0.70
2013	29,044		39,784	n	92,520	132,304	0.70
2014	29,044		77,684	n	180,660	258,344	0.70
2015	29,044		61,610	n	143,280	204,890	0.70
2016	29,044		69,196	n	160,920	230,116	0.70





Woolwich Commercial Fishery:

The Maine Department of Marine Resources manages this system for a minimum commercial escapement of 35 fish per acre. The spawning escapement need for this system is 13,720 river herring passed upstream by the harvester. The management plan has achieved returns to meet the target escapement developed for this system or passed the entire run each year for the past 20-year period. This fishery is one of two commercial fisheries that allow constant spawning escapement throughout the run and closed for an additional 72-hours during the week (Figures 28 - 29). To improve passage the fishway was rebuilt in 2014 and monitoring of the new passage structure is ongoing.

The fishery is located at the entrance to the tidal fishway that leads to Nequasset Lake. The Nequasset fishery is one of a handful of locations that harvest river herring for food. River herring are salted and smoked as a seasonal delicacy. Smoked alewives sell for $90.00 per/bushel compared to $20.00 per/bushel for lobster bait. Alewives sold as bait at Nequasset are rationed between the numbers of fishermen that arrive in the morning to pick up bait. Nequasset, like most fisheries cap the number of alewives sold to any one fisherman at 2-4 bushel per day. This system allows the limited amount of bait caught on any one day to supply a larger number of individual fishermen.

Nequasset Lake is a municipal water supply for several towns in the surrounding area. Maintaining high water quality is important to the water district. Currently there are no limitations on the number of alewives permitted into the lake to spawn, though some municipal water districts prohibit alewife reintroduction. There is no evidence to this point that alewives are causing water quality concerns.

Town	River	Lake size (acres)	Threshold (N/acre)
Woolwich	n/a	392	35

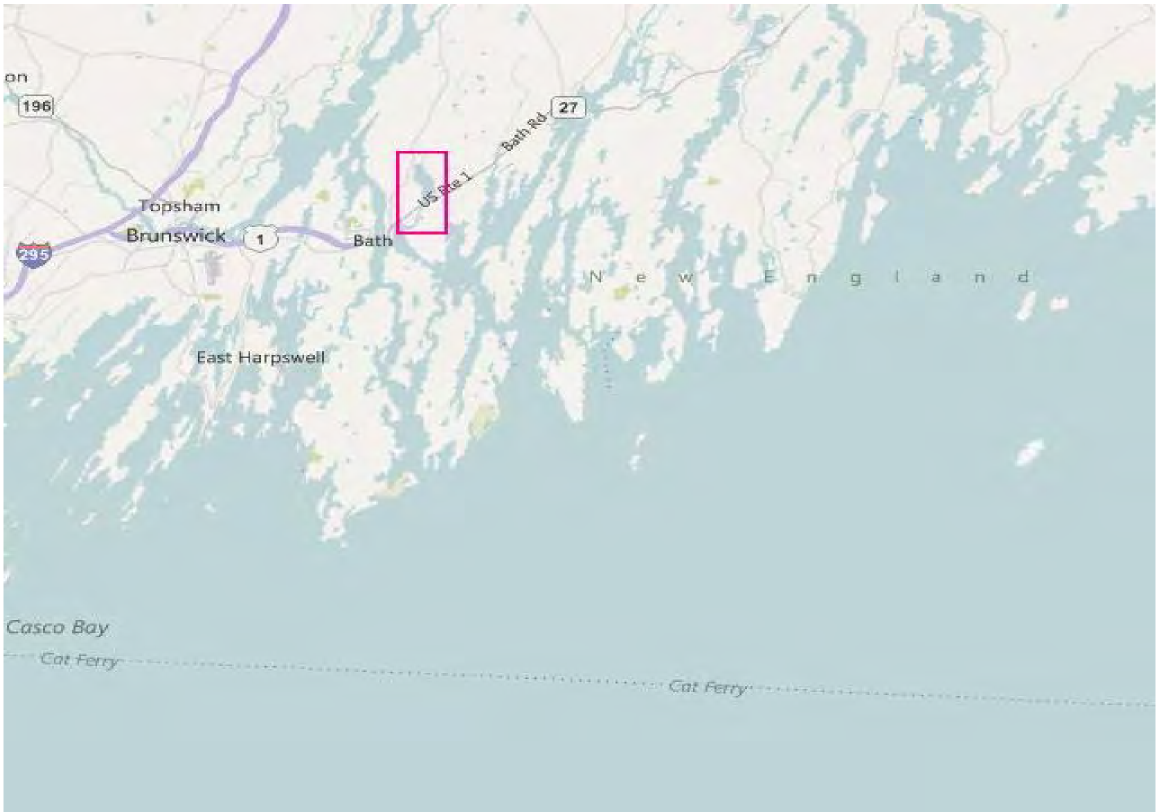
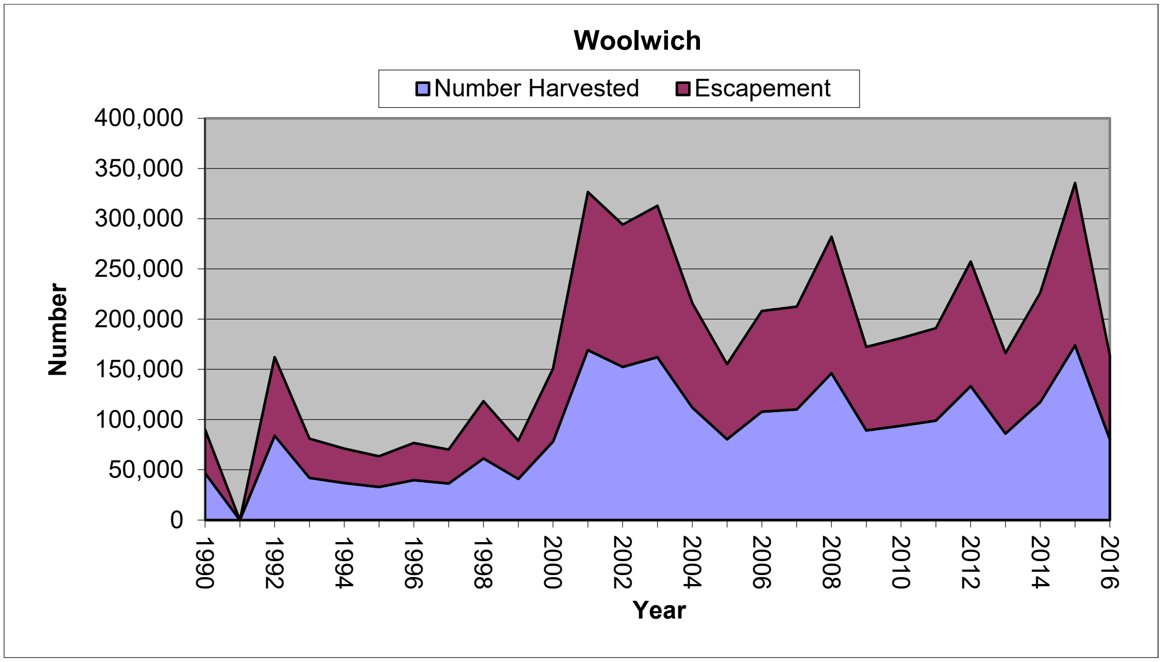


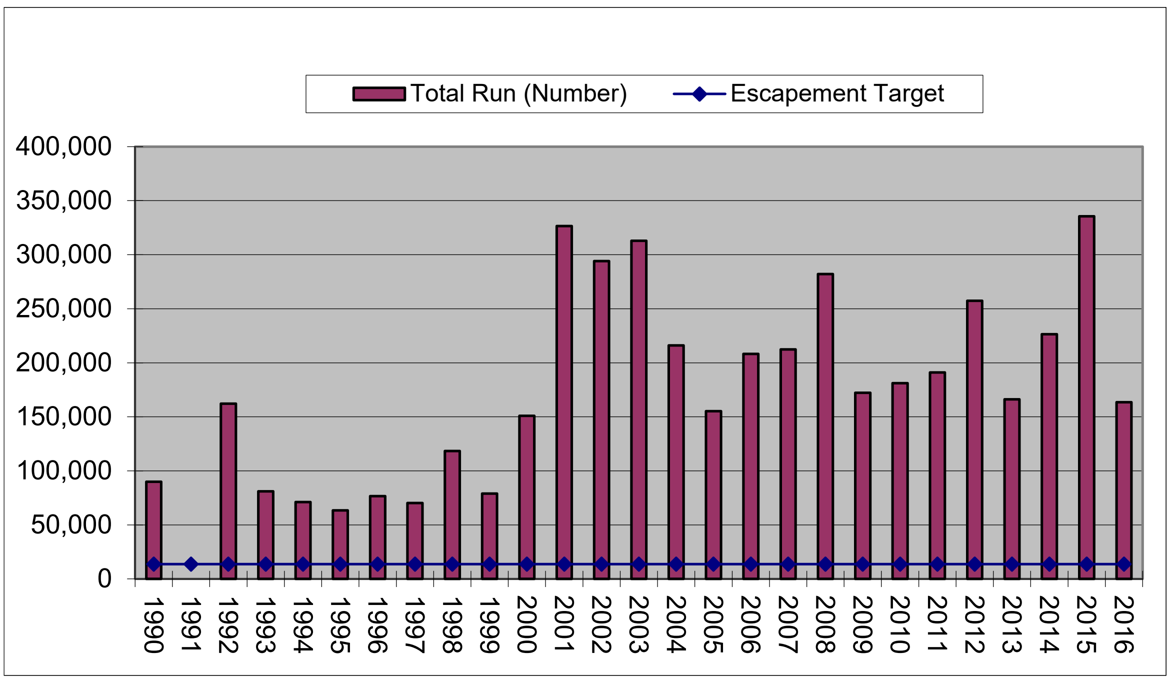
Figure 28. Historic picture of the Nequasset Mill and fish passage to spawning habitat and the trapping facility prior to 2014 rebuild.

Figure 29. The Nequasset fishway and entrance to the trapping facility after repair in 2014.

Year	Municipality	River	% repeat spawners by year and frequency	R-0	R-1	R-2	R-3	Z-value
2015	Woolwich	Kennebec	27.6	72.45	27.55			0.97
2014	Woolwich	Kennebec	11.0	89.00	10.00	1.00		2.24
2013	Woolwich	Kennebec	20.3	79.70	18.90	1.40		2.02
2012	Woolwich	Kennebec	15.2	84.80	14.30	1.00		2.22
2011	Woolwich	Kennebec	15.0	84.96	13.72	0.65	0.65	1.77
2010	Woolwich	Kennebec	9.1	90.90	7.10	2.00		1.91
2009	Woolwich	N/A	47.5	51.30	43.60	5.10		1.15
2008	Woolwich	N/A	53.8	46.20	38.50	15.40		0.55

Year	Escapement Number (based on target)	Actual	Measured or estimated (.43*landings)	spawning below barrier?	Landings Number	total run size (escape+kill)	exploitation rate
1990	13,720		20,047	n	46,620	66,667	0.70
1991	13,720		0	n	0	0	0.00
1992	13,720		36,120	n	84,000	120,120	0.70
1993	13,720		18,060	n	42,000	60,060	0.70
1994	13,720		18,481	n	42,980	61,461	0.70
1995	13,720		16,495	n	38,360	54,855	0.70
1996	13,720		19,926	n	46,340	66,266	0.70
1997	13,720		18,241	n	42,420	60,661	0.70
1998	13,720		30,762	n	71,540	102,302	0.70
1999	13,720		20,528	n	47,740	68,268	0.70
2000	13,720		39,235	n	91,245	130,480	0.70
2001	13,720		84,882	n	197,400	282,282	0.70
2002	13,720		76,454	n	177,800	254,254	0.70
2003	13,720		81,330	n	189,140	270,470	0.70
2004	13,720		56,167	n	130,620	186,787	0.70
2005	13,720		40,334	n	93,800	134,134	0.70
2006	13,720		54,120	n	125,860	179,980	0.70
2007	13,720		55,203	n	128,380	183,583	0.70
2008	13,720		73,324	n	170,520	243,844	0.70
2009	13,720		38,390	n	89,280	127,670	0.70
2010	13,720		40,351	n	93,840	134,191	0.70
2011	13,720		42,570	n	99,000	141,570	0.70
2012	13,720	29,916	Measured	n	133,320	163,236	0.82
2013	13,720	40,841	Measured	n	86,100	126,941	0.68
2014	13,720	150,950	Measured	n	117,360	268,310	0.44
2015	13,720	126,395	Measured	n	173,880	300,275	0.58
2016	13,720	43,320	Measured	n	80,160	123,480	0.65





Perry Commercial Fishery:

The Maine Department of Marine Resources manages this system for a minimum commercial escapement of 35 fish per acre. The spawning escapement need for this system is 59,570 river herring passed upstream through a three day per week closure in the fishery. The management plan has achieved the target escapement developed for this system 90% of the time during the past 20-year period or passed the entire run. This fishery is has significant issues with beaver dams that restrict upstream and downstream migration throughout the season. Fish that escape the commercial fishery may, or may not, reach spawning habitat depending on water conditions. Boyden Lake is a municipal water supply operated by the Passamaquoddy Indian Tribe. Fluctuating water levels during upstream and downstream migrations influence the number of annual returns (Figure 30). The system is responsive when spawning fish are able to access the pond. There is no spawning habitat below the dam for either species of river herring. Low water flows that fail to attract fish to the stream or fishway are the main obstacles to producing a larger run. Commercial harvest did not occur for several years prior to 2004.

The fishery in the town of Perry is operated by a commercial fisherman who chooses to harvest fish for personal use and not commercial retail sale. The harvester elects to pass fish upstream in addition to the required closed days. As a result, the harvest reported for this system is lower than expected and estimates of escapement based on harvest are low. The Maine Department of Marine Resources and Maine Sea Grant will install electronic fish counters at this location in 2017 to assess escapement.

Town	River	Lake size (acres)	Threshold (N/acre)
Perry	n/a	1,702	35

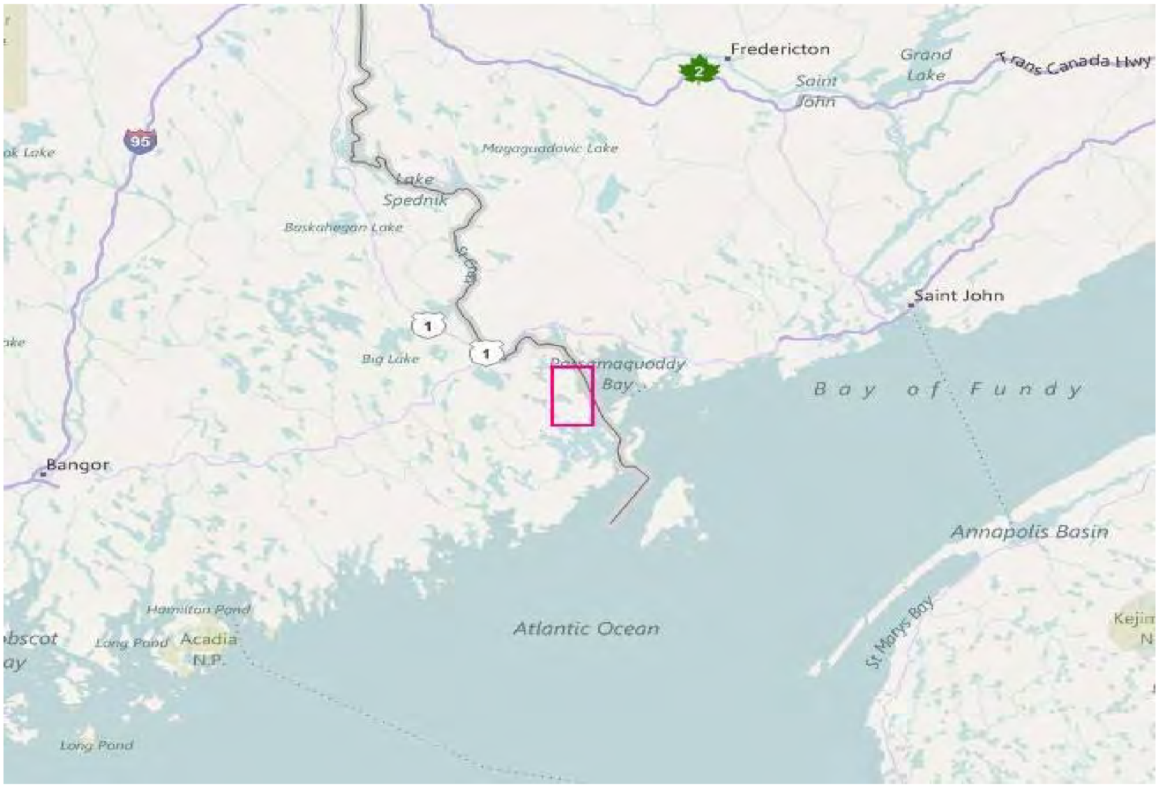
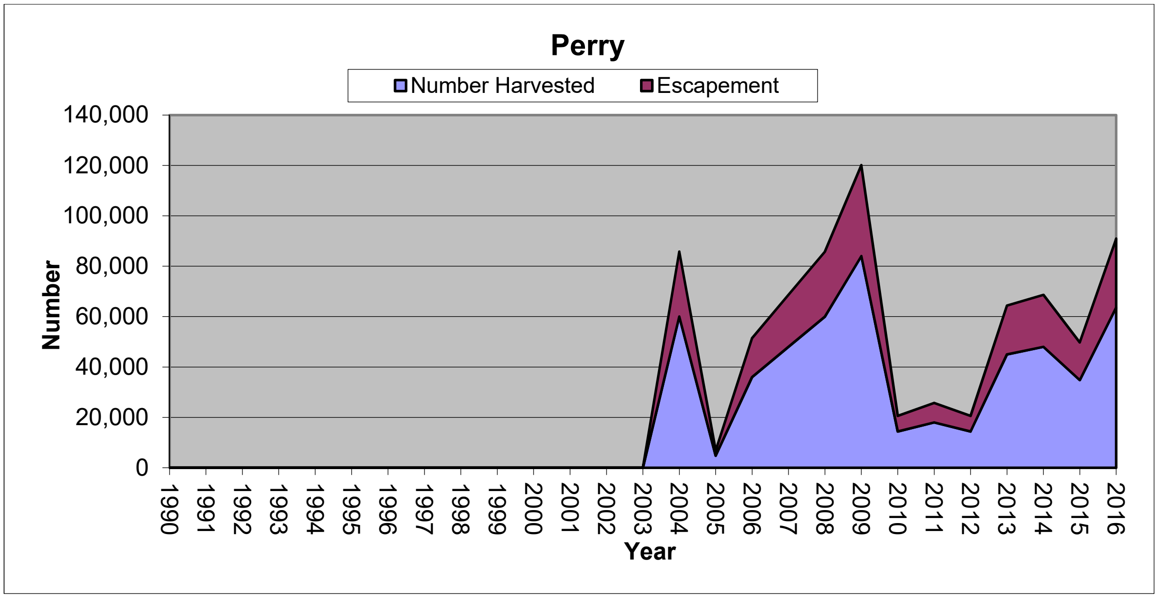
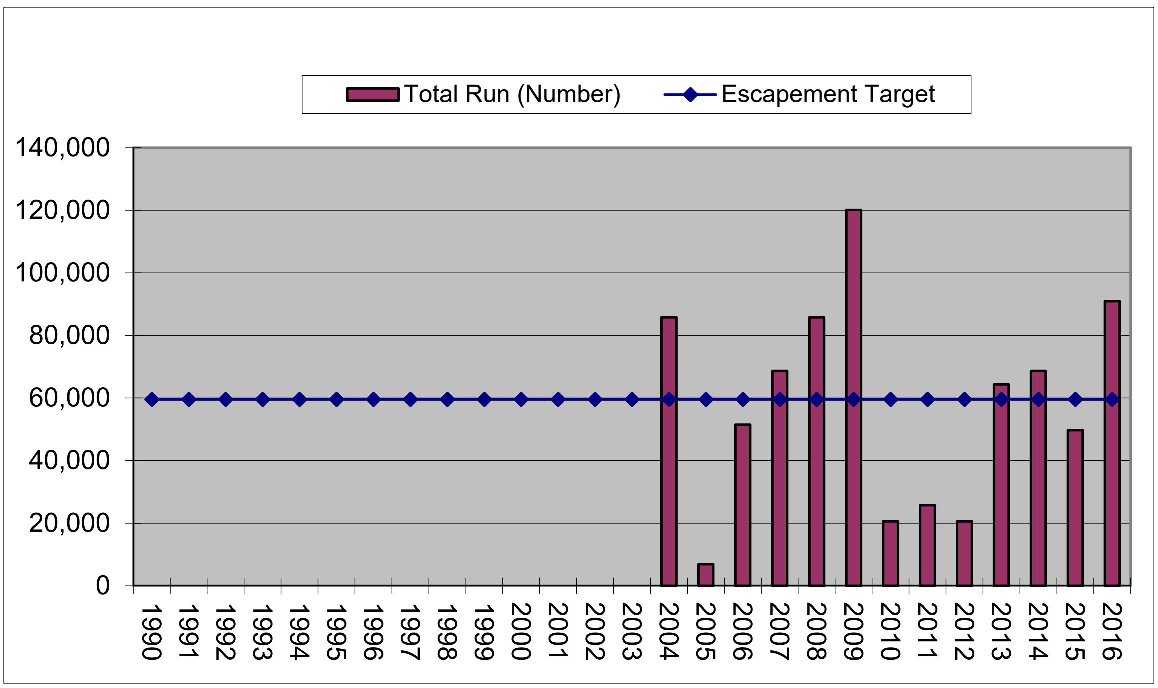


Figure 30. Dam and fishway under high flow conditions in 2006. Note harvest box and sluice pipe located at the corner pool of the fishway used to transport harvested fish into totes.

Year	Municipality	River	% repeat spawners by year and frequency	R-0	R-1	R-2	R-3	Z-value
2015	Perry	Little River	16.8	83.17	11.88	4.95		1.95
2014	Perry	Little River	8.1	91.90	7.10	1.00		2.26
2013	Perry	Little River	30.0	70.00	28.00	2.00		1.78
2012	Perry	Little River	8.1	91.90	7.10	1.00		2.26
2011	Perry	Little River	21.2	78.80	15.20	6.10		1.28
2010	Perry	Little River	38.0	62.00	34.00	4.00		1.37
2009	Perry	Little River	4.0	96.00	4.00			3.18
2008	Perry	Little River	7.0	93.00	7.00			2.59

Year	Escapement Number (based on target)	Actual	Measured or estimated (.43*landings)	spawning below barrier?	Landings Number	total run size (escape+kill)	exploitation rate
1990	59,570		0		0	0	0.00
1991	59,570		0	n	0	0	0.00
1992	59,570		0	n	0	0	0.00
1993	59,570		0	n	0	0	0.00
1994	59,570		0	n	0	0	0.00
1995	59,570		0	n	0	0	0.00
1996	59,570		0	n	0	0	0.00
1997	59,570		0	n	0	0	0.00
1998	59,570		0	n	0	0	0.00
1999	59,570		0	n	0	0	0.00
2000	59,570		0	n	0	0	0.00
2001	59,570		0	n	0	0	0.00
2002	59,570		0	n	0	0	0.00
2003	59,570		0	n	0	0	0.00
2004	59,570		30,100	n	60,000	100,100	0.70
2005	59,570		2,408	n	4,800	8,008	0.70
2006	59,570		18,060	n	36,000	60,060	0.70
2007	59,570		24,080	n	48,000	80,080	0.70
2008	59,570		30,100	n	60,000	100,100	0.70
2009	59,570		36,120	n	84,000	120,120	0.70
2010	59,570		6,192	n	14,400	20,592	0.70
2011	59,570		7,740	n	18,000	25,740	0.70
2012	59,570		6,192	n	14,400	20,592	0.70
2013	59,570		19,350	n	45,000	64,350	0.70
2014	59,570		20,640	n	48,000	68,640	0.70
2015	59,570		14,964	n	34,800	49,764	0.70
2016	59,570		27,348	n	63,600	90,948	0.70



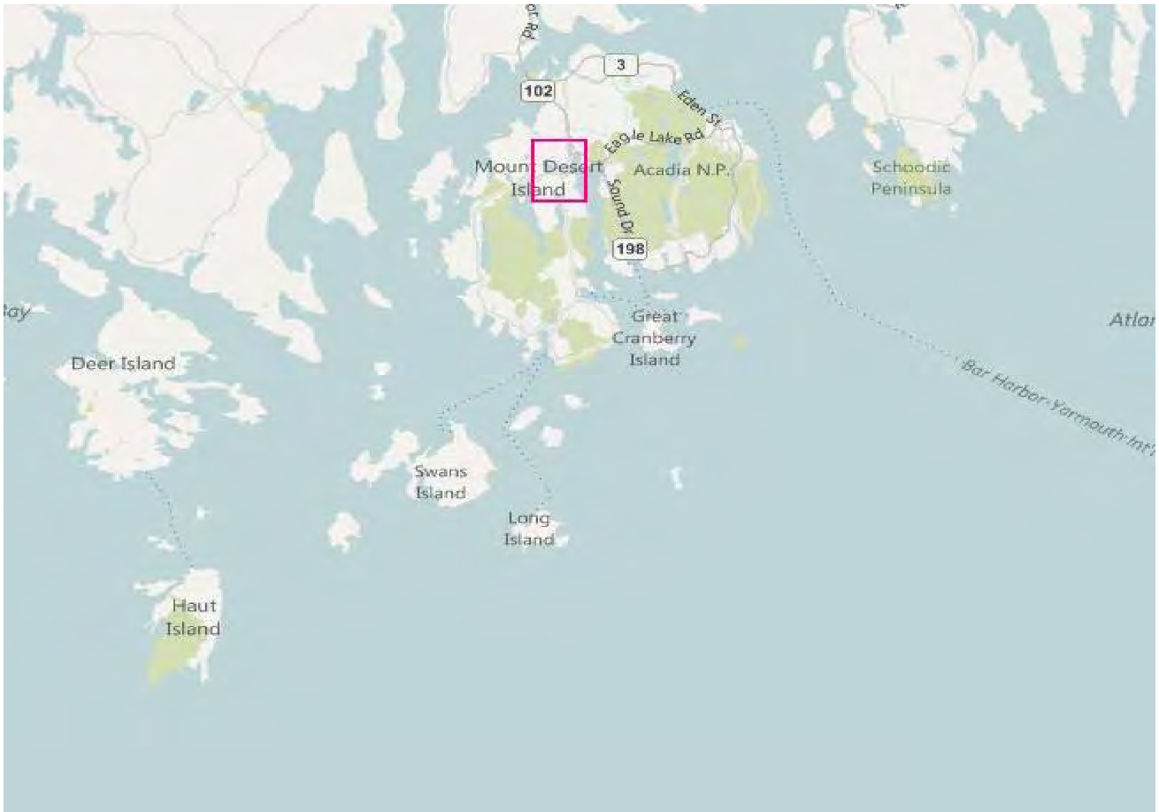


Mount Desert Commercial Fishery:

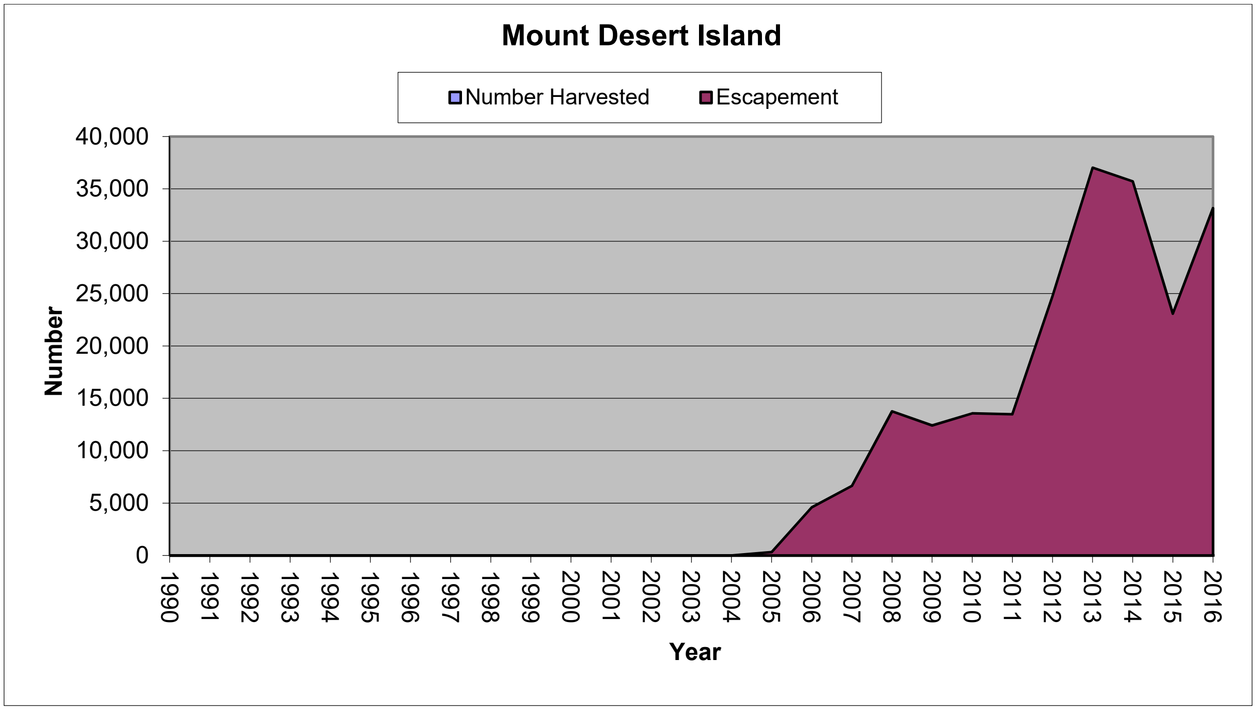
The Maine Department of Marine Resources manages this system for a minimum commercial escapement of 35 fish per acre. The spawning escapement need for this system is 3,640 river herring passed upstream. The municipality of Mount Desert selects to keep the run closed for conservation at this time, though recent counts indicate that a harvest is possible. Fisheries staff began to collect age and repeat spawning data at this location in 2010. The spawning habitat at this location is limited and historically never produced large numbers of fish migrating to Somes Pond.

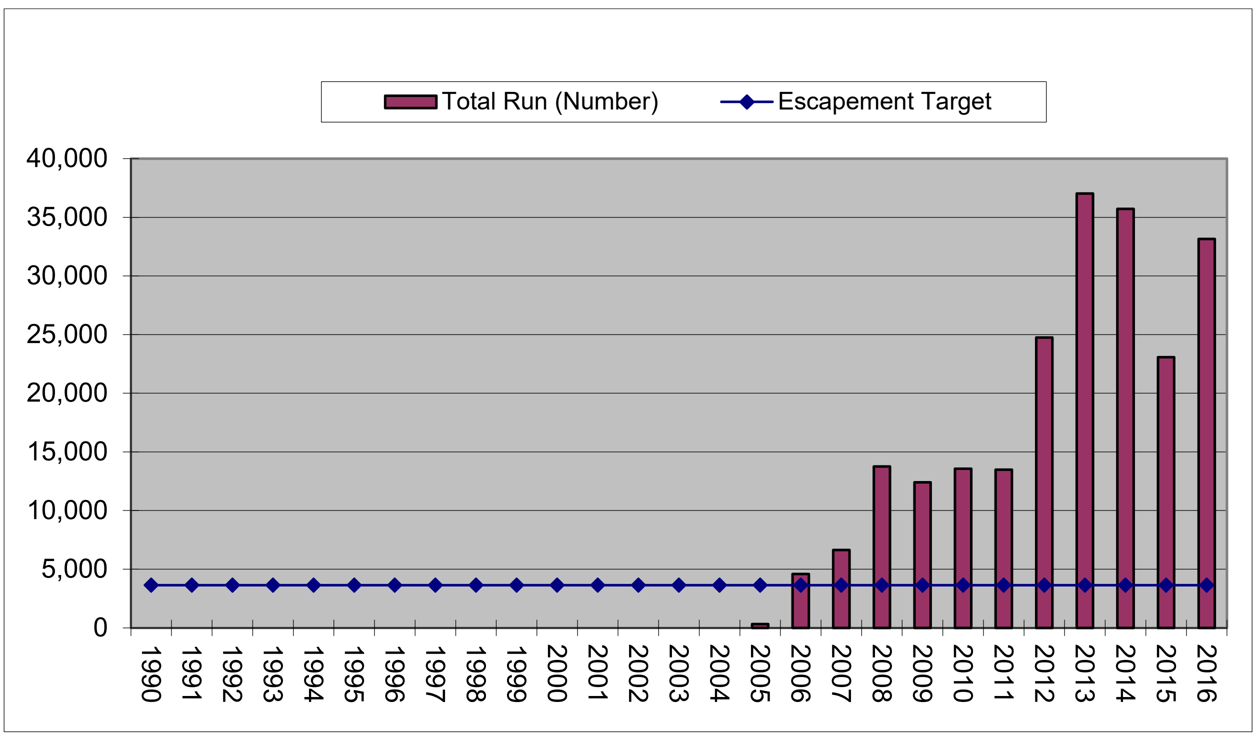
The fishway is a tidal fishway that is accessible only as the tide rises to meet the fishway entrance (Figures 31-32). This limits the opportunities for fish to access the fishway and spawning location upstream. This is common at several commercial harvest locations throughout the state. This emphasizes the need to maintain, clean, and monitor the tidal fish passages daily to ensure unobstructed upstream passage. The harvesters hired by the municipalities often fill this role, freeing state personnel to address other passage issues.

Town	River	Lake size (acres)	Threshold (N/acre)
Mount Desert	n/a	104	35



Figures 31-32. Tidal denil fishway located in Somes Harbor and Somes Brook leading to Somes Pond.


Mount Desert Island
Number Harvested
Escapement
Number
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016
Year


Total Run (Number)
Escapement Target
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016

Year	Escapement Number (based on target)	Actual	Measured or estimated (.43*landings)	spawning below barrier?	Landings Number	total run size (escape+kill)	exploitation rate
1990	3,640			n			
1991	3,640			n			
1992	3,640			n			
1993	3,640			n			
1994	3,640			n			
1995	3,640			n			
1996	3,640			n			
1997	3,640			n			
1998	3,640			n			
1999	3,640			n			
2000	3,640			n			
2001	3,640			n			
2002	3,640			n			
2003	3,640			n			
2004	3,640			n			
2005	3,640	316	Measured	n	0	316	0.00
2006	3,640	4,594	Measured	n	0	4,594	0.00
2007	3,640	6,638	Measured	n	0	6,638	0.00
2008	3,640	13,756	Measured	n	0	13,756	0.00
2009	3,640	12,412	Measured	n	0	12,412	0.00
2010	3,640	13,566	Measured	n	0	13,566	0.00
2011	3,640	13,481	Measured	n	0	13,481	0.00
2012	3,640	24,748	Measured	n	0	24,748	0.00
2013	3,640	37,021	Measured	n	0	37,021	0.00
2014	3,640	35,716	Measured	n	0	35,716	0.00
2015	3,640	23,078	Measured	n	0	23,078	0.00
2016	3,640	33,159	Measured	n	0	33,159	0.00

Benton Commercial Fishery:

In 2009 the Town of Benton resumed a commercial fishery for river herring for the first time in 198 years. The fishery is the result of the removal of the Edwards Dam in Augusta, Maine and a ten-year fisheries restoration program.

Soon after the restoration project began, the Maine Department of Inland Fisheries and Wildlife and Maine Department of Marine Resources permitted a limited dip net fishery in the river below the first dam (2000-2006). MDMR staff believes landings for this period were underreported based on the numbers of fishing permits issued and the number of landings reported at the end of the fishing season. The MDMR closed the fishery in 2007 to allow the municipality of Benton to reacquire historical rights to the harvest. The Town of Benton conducted its first commercial dip net fishery in the Sebasticook in 2009 and the Town maintains this harvest method through 2016.

The Maine Department of Marine Resources began the Sebasticook River Restoration Project by stocking 6 fish/acre into available historic spawning habitat as permitted by the Maine Department of Inland Fisheries and Wildlife. The initial stocking, which placed 57,533 pre-spawn adults within the 10,854 acres of spawning habitat, created an estimated run on the Sebasticook River ranging between 1.5 and 3.5 million fish within six years. There was no permanent upstream passage available until the State of Maine and conservation groups removed the Fort Halifax Dam in 2008. Prior to 2007, an unlimited commercial dip net harvest below the first dam on the river captured returning adults. The fish escaping the fishery remained below the dam until they dropped out of the system during early summer. Estimates of the number of river herring remaining below the dam ranged from 1.25– 3 million individuals.

The main stem river and several lakes and ponds within the Sebasticook River drainage provide excellent spawning and nursery habitat for river herring. These habitats currently support the largest monitored river herring run in Maine. Restoration efforts in the watershed will continue to open additional historic spawning areas over the next several years. There are two hydropower dams that remain on the main stem of the Sebasticook River. Both dams have dedicated upstream and downstream passage for anadromous fish. The passage efficiency for both sites is unknown at this time, though the Benton Falls Dam does pass more than 2 million fish per year on a regular basis.

Upstream passage counts during the past several seasons ranged from 1.3 to 3.5 million individuals in addition to the commercial harvest. The municipal commercial harvest plan restricts harvest gear at the base of the hydropower dam to dip nets and cast nets (Figure 33). Discussions on how to improve harvest are occurring between the harvester and the Town. These gear types severely limit the numbers of fish that the harvester can access during the fishing season.

The Maine Department of Marine Resources, in conjunction with the hydropower company, operates and monitors upstream passage on the Sebasticook River. Upstream passage is a priority at this location with 100,000 fish required to pass upstream prior to commencing harvest activities. Spawning habitat is available in the river above and below the dam for blueback herring and American shad but not alewife. There is a mix of blueback herring in the commercial alewife catch toward the end of the season. Most of the blueback herring escape the commercial alewife fishery due to the early closed date of June 5 each year. Blueback passage numbers at the Benton fish lift can exceed 400,000 for the season.

The repeat spawning rate for the Benton fishery is above average compared to most other commercial fisheries in Maine, and is among the top three in annual harvest. Maine fisheries staff started collecting scale samples in 2010 and has a collection of scales through 2016 to categorize this fishery. The Maine Department of Marine Resources currently manages this system for a minimum commercial escapement of 35 fish per acre. The minimum spawning escapement need for this system is 379,890 river herring passed upstream into several spawning habitats in the Sebasticook River drainage.

Town	River	Lake size (acres)	Threshold (N/acre)
Benton	Sebasticook	10,854	35

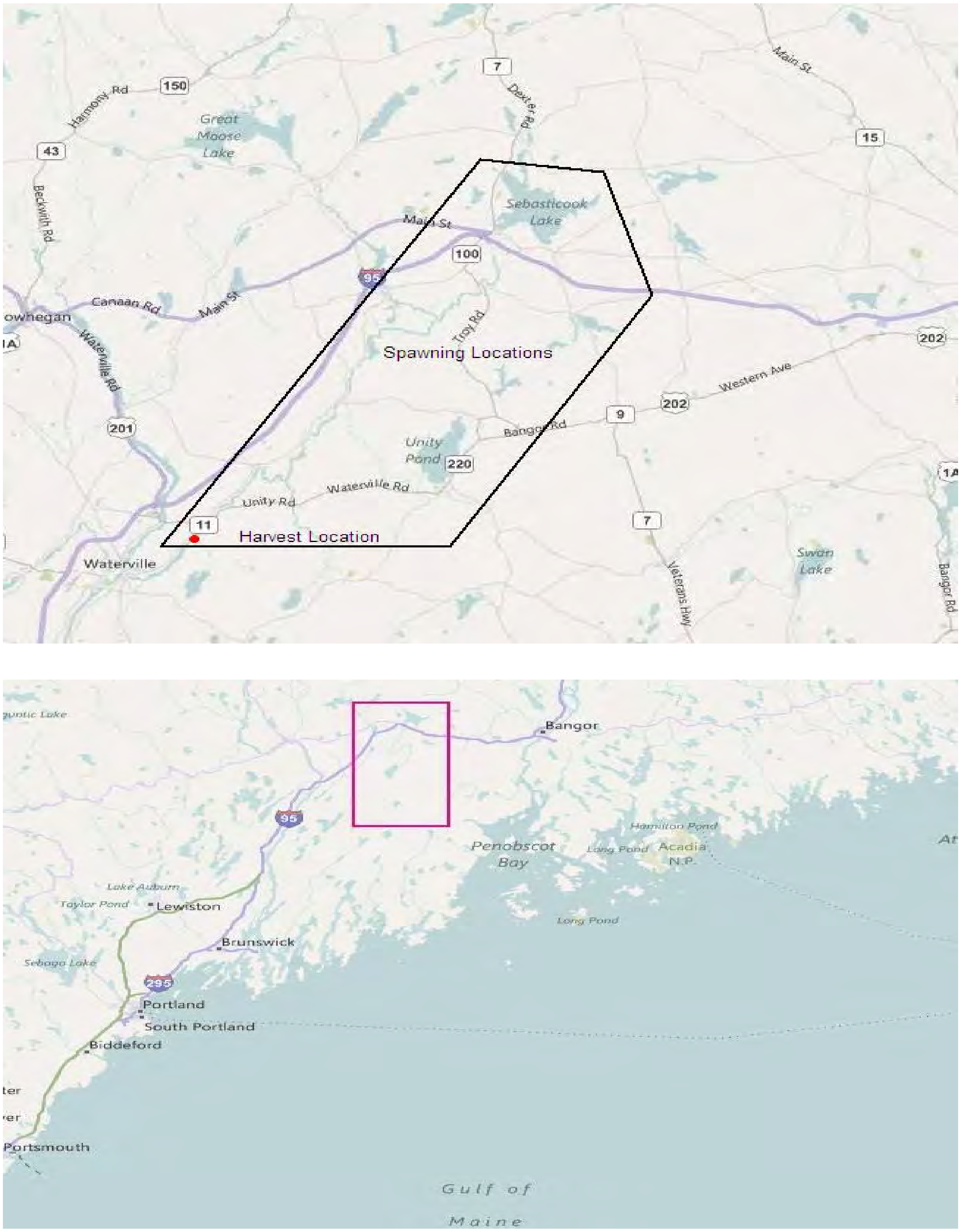
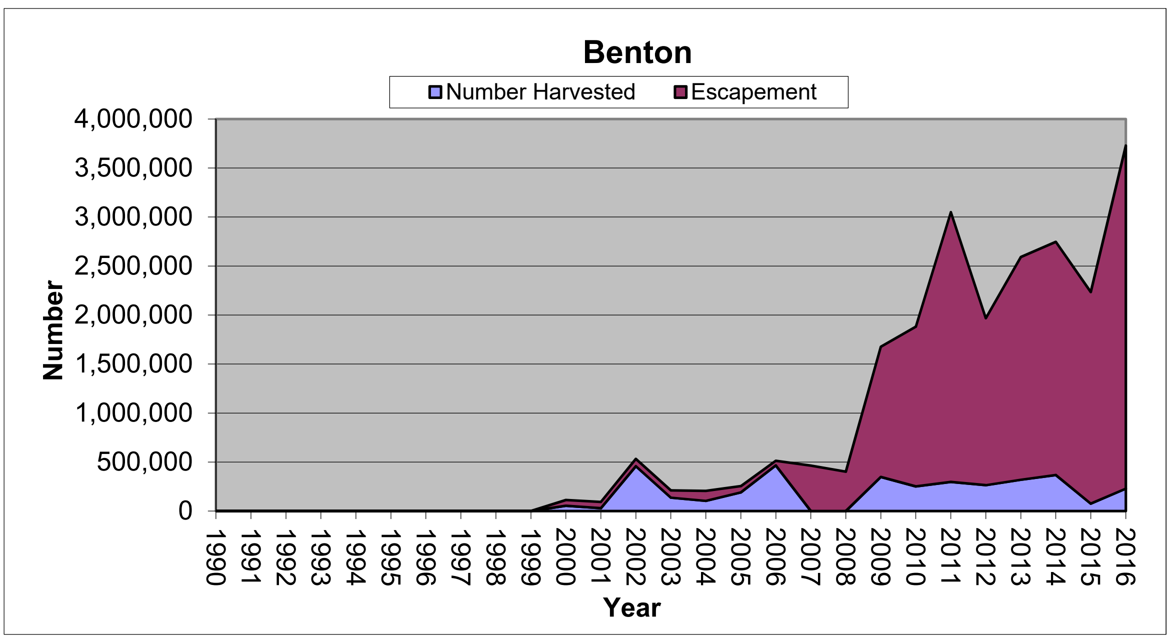
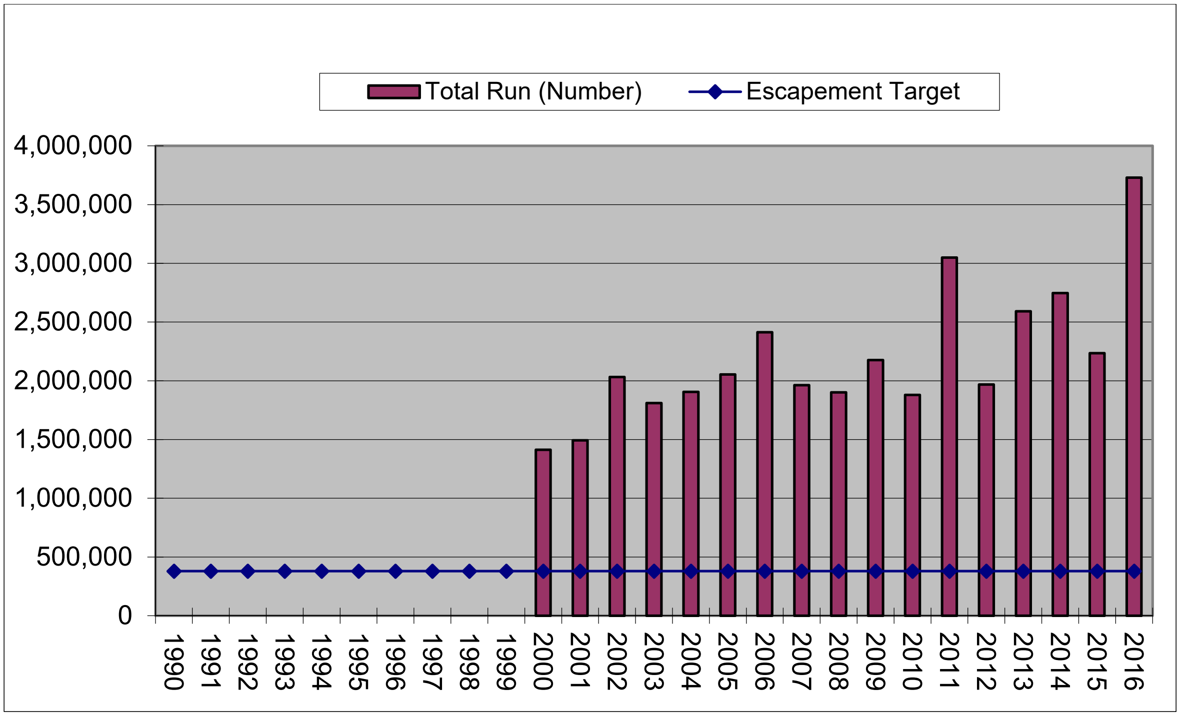


Figure 33. Benton Falls Hydropower Station. The commercial fishery occurs below the dam.

Year	Municipality	River	% repeat spawners by year and frequency	R-0	R-1	R-2	R-3	Z-value
2016								
2015	Benton	Sebasticook	21.5	78.49	19.35	1.08	1.08	1.57
2014	Benton	Sebasticook	34.3	65.71	25.71	5.70	2.85	1.22
2013	Benton	Sebasticook	26.7	75.75	22.72	15.15		1.96
2012	Benton	Sebasticook	18.9	81.10	18.90	1.59		1.46
2011	Benton	Sebasticook	16.3	83.67	14.28	1.02	1.02	1.59
2010	Benton	Sebasticook	60.0	40.00	52.00	6.00	2.00	1.11
2009								
2008								

Year	Escapement Number (based on target)	Actual	Measured or estimated (.43*landings)	spawning below barrier?	Landings Number	total run size (escape+kill)	exploitation rate
2000	65,124	58,533	Measured	n/y	54,000	112,533	0.48
2001	65,124	64,635	Measured	n/y	28,800	93,435	0.31
2002	65,124	73,835	Measured	n/y	458,040	531,875	0.86
2003	65,124	73,830	Measured	n/y	136,440	210,270	0.65
2004	65,124	102,404	Measured	n/y	103,700	206,104	0.50
2005	65,124	64,375	Measured	n/y	189,960	254,335	0.75
2006	65,124	47,106	Measured	n/y	465,720	512,826	0.91
2007	379,890	451,240	Measured	n/y	0	451,240	0.00
2008	379,890	423,333	Measured	n/y	0	423,333	0.00
2009	379,890	1,349,533	Measured	n/y	347,640	1,697,173	0.20
2010	379,890	1,628,739	Measured	n/y	216,000	1,844,739	0.12
2011	379,890	2,752,123	Measured	n/y	297,240	3,049,363	0.10
2012	379,890	1,703,820	Measured	n/y	263,880	1,967,700	0.13
2013	379,890	2,272,492	Measured	n/y	319,320	2,591,812	0.12
2014	379,890	2,378,906	Measured	n/y	367,920	2,746,826	0.13
2015	379,890	2,158,769	Measured	n/y	75,600	2,234,369	0.03





b. Recreational

Municipalities which maintain historic harvest rights control access to the majority of the river herring resources within the state. Municipalities maintain this control through exclusive harvest rights granted by the Department of Marine Resources. All locations inhabited by river herring and which are managed by a joint state/municipal management plan are open to recreational harvest if the management plan permits recreational harvest. All recreational harvest must occur below the commercial fishing location and within the municipality that owns the river herring harvest rights. The number of river herring allowed for personal use is 25 river herring per person per day with associated gear restrictions (hook and line, dip net) down from 120 fish per day allowed in 2012.

Most municipalities choose to keep recreational river herring fisheries closed. Municipalities that choose to keep the recreational fishing closed can do so through the municipal harvest plan. Closing the recreational harvest prevents recreational harvest at any location within the municipal boundaries or in the watershed above the municipality that maintains harvest rights.

Most recreational catches of river herring are used as bait to catch striped bass, halibut or smoked and used as food. Very little recreational fishing occurs for river herring in the state of Maine. The State of Maine relies on the MRIP program to collect the catch statistics for the recreational catches of blueback herring and alewife.

All locations statewide outside and below locations controlled by the states municipal fisheries will remain open to recreational fishing. A limited recreational catch/possession limit of 25 fish per person per day and gear restrictions will apply along with a statewide closed period to allow escapement of spawning fish. The statewide closed period runs from 6:00 AM Thursday to 6:00 AM Sunday each week.

5. Fisheries Requested to be Closed (if more specific than statewide)

a. Commercial

Municipality	Municipality	Municipality
*Arrowsic	Blue Hill	Boothbay Harbor
*Breman	Cape Elizabeth	Hampden
Kennebunk	*Phippsburg Center Pond)	Lincolnville
*Bristol	Northport	South Berwick
*Surry	*Waldoboro	West Bath
North Bath	*Gardiner	*Penobscot
*Surry		

The state and/or municipality will close, or keep closed, one or more waters in these towns to the harvest of river herring until these runs can produce harvestable numbers in excess of minimum escapement requirements. Commercial fisheries occurred in all the municipalities listed above prior to Amendment 2. Some of these runs are currently under restoration (*****), while others return viable numbers of fish without supplemental stocking and could support a small harvest. Most of these runs have passage problems that prevent the current population from increasing to commercially harvestable numbers. Typical returns to these rivers range from 50 to 120,000 individuals based on actual counts in Cape Elizabeth and Waldoboro.

b. Recreational

All locations statewide outside and below locations controlled by municipal fisheries will remain open to recreational fishing. A limited recreational catch/possession limit of 25 fish per person per day and gear restrictions will apply.

c. Incidental

Incidental catch of river herring may occur in small mesh trawl fisheries, weir, bait gill net, and seine fisheries for other species. There is mandatory catch/bycatch reporting for all of these fisheries. Based on Vessel Trip Reports (VTR) and Dealer Reports (DR), bycatch in state waters appears to be low. An existing law requires all commercial fishermen who fish for pelagic or anadromous species to purchase the "Pelagic and Anadromous Commercial Fishing License" will make reporting of all river herring landings mandatory. **(Appendix B)**

6. Sustainability Target/Threshold

Sustainability Definition – The number of alewife broodstock needed per surface area of spawning habitat in Maine to provide alewife populations capable of sustaining annual alewife runs at current levels while providing surplus broodstock for harvest or increasing run size in the future.

The sustainability threshold will provide an escapement number equal to 35-fish per surface acre of spawning habitat. This plan will achieve escapements numbers through passage counts above commercial fisheries, closed fishing days, season length, gear restrictions or continuous escapement.

An escapement level of six fish per surface acre is used by the Department to provide broodstock for initial introductions of anadromous alewife in Maine lakes and ponds under restoration. This number was developed as the result of a nine year study researching the effects of alewife introductions into freshwater habitats. Initial introductory or restoration stocking can produce runs that may exceed six fish per acre depending on passage and habitat. This escapement number may grow to allow for a small commercial harvest or allow managers to increase spawning stock by passing all returns upstream.

Method Used to Develop Spawning Threshold

The sustainability threshold of 35-fish per acre of spawning habitat is the result of a combination of studies, observations, and documented commercial catches over a number of years. Maine uses this sustainability threshold for continuing commercial fisheries that require escapement of broodstock from river specific populations.

Since 1984, MDMR has used 235 fish/acre to estimate commercial alewife production. The Department established this unit production value from the commercial harvest in six Maine watersheds for the years 1971-1983. Based on these data, commercial yield was assumed to be 100 pounds/surface acre of ponded habitat. This value is slightly less than the average of the lowest yield/acre for all six rivers and within the range of yields experienced in other watersheds. Assuming a weight of 0.5 pounds per adult, the commercial yield equals 200 adults/surface acre. The commercial harvest was assumed to represent an exploitation rate of 85%, because most alewife runs were harvested six days per week. Exploitation rates on the Damariscotta River, for example, ranged from 85-97% for the years 1979-1982. When commercial yield is adjusted for the 15% escapement rate, the total production is 235 adult alewives/acre.

Results from studies conducted at one of these lakes in the 1970s-1980s, Damariscotta Lake, located in mid-coast Maine, indicate that increasing the escapement of spawning alewives ranging from 40 to 60 fish per acre caused the parent progeny relationship to trend downward. (Walton, C.J. 1987. Parent-Progeny relationship for an Established Population of Anadromous Alewives in a Maine Lake. American Fisheries Society Symposium 1:451 – 454, 1987)

The relationship between increased numbers of spawning individuals and returns 4-5 years later does not support increased escapement rates for many Maine runs. Analysis of escapement numbers and commercial catches in fisheries with a sustained level of escapement over a number of years does indicate a large variation in run size unassociated with the number of spawning fish.

The State of Maine uses an alternative 6-fish per acre target or when establishing new river herring runs. The 6-fish per acre target was established through fisheries work designed to examine the effect of anadromous alewives on existing fish populations in lakes without anadromous alewives (Lake George Study). The nine year study conducted by the Maine Department of Inland Fisheries and Wildlife, Department of Environmental Protection, and the Department of Marine Resources, determined that stocking six prespawn fish per surface acre does not negatively affect growth of inland game-fish species including trout, landlocked salmon, or rainbow smelts but that there were indications that increased numbers of alewives did change the zooplankton structure in the nursery habitat. Based on the study results the Lake George Study remains the basis for the multispecies fisheries management plans in habitats that will receive new introductions of anadromous alewives.

Monitoring to be Conducted to Support Target(s)

Commercial

Fisheries staff will continue to use annual landings data, escapement counts, mortality estimates, escapement estimates, and scale sample data to track relative health of river specific stocks. Additional data comes from the JAI survey conducted in Kennebec River, Merrymeeting Bay and associated rivers to track populations of river herring possibly spawning in the main stem Kennebec River and Merrymeeting Estuary. These monitoring efforts will continue for all commercial fisheries and will occur for all directed commercial fisheries that wish to open in the future.

Recreational

For locations where commercial fisheries are permitted the monitoring of the commercial catches and existing controls will remain in place. For locations where there is no existing commercial fishery, or existing municipal harvest rights, fishway counts will be used to monitor run size. **(Appendix C)**

Fisheries staff will continue to use annual run data, escapement counts, mortality estimates, estimates, and scale data to track relative health of river specific stocks where these data are collected. Additional data may come from the JAI survey conducted in Kennebec River, Merrymeeting Bay and associated rivers to track populations of river herring possibly spawning in the mainstem Kennebec River and Merrymeeting Estuary.

7. Proposed Rule-Making to Support Target(s)

Commercial fisheries that cannot support commercial harvest levels above the spawning threshold will remain closed for conservation. In addition, this plan eliminates the directed harvest, possession, and sale of any river herring within state waters other than the approved directed fisheries contained within this plan. The State has also created a Pelagic Fisheries license which requires the harvester to report all river herring harvest activities annually. **(Appendix B)**

The Department passed a rule making proposal prohibiting the opening of new river herring fisheries as required by the Atlantic State Marine Fisheries Commission Management Board.

30.02 Limits on River Herring

Beginning January 1, 2012 it shall be unlawful for any person to take, possess, harvest or sell river herring in the State of Maine or in waters under the jurisdiction of the State of Maine.

Exceptions:

A. River Herring fishing rights. A municipality or an individual with existing river herring harvest rights granted by the Commissioner in accordance with 12 M.R.S. §6131 are not subject to Chapter 30. The Commissioner may authorize a future river herring fishery, authorized pursuant to 12 M.R.S. §6131, after submission of a sustainable fisheries management plan for that fishery by the Department, which is approved by the Atlantic States Marine Fisheries Commission (ASMFC) Management Board.

Since January of 2012 there has been no additional rule making or statute chances that affect river herring harvest.

8. Adaptive Management

a. Evaluation schedule

The Maine Department of Marine Resources reviews all municipal fisheries plans annually. Many plans carry over year to year because they provide adequate protection for the river herring resource. Plan reviews incorporate landings data, escapement counts, broodstock needs, and effort controls. There is no plan to change the review schedule for river herring management plans at this time.

b. Consequences or control rules

All Maine directed commercial river herring runs operate under a 72-hour closed period or conservation equivalent. The Maine Department of Marine Resources will extend closed periods, modify conservation equivalencies, or close fisheries that cannot sustain existing commercial fisheries.

Commercial

1) Additional management review and/or changes will occur based on decreasing trends in running three-year averages of annual landings, increasing time series trends in total mortality (z), and trends in repeat spawning rates for fishery dependent and fishery independent sites.

2) Fisheries staff will review harvest and age data collected from annual returns to assess the need to increase the number of closed days in the fishery. Due to the variability of river herring runs in Maine under stable stocking rates, run size, and age class structure are expected to exhibit wide swings in annual values.

3) The management objective is to ensure that the commercial fisheries maintain a minimum (35 fish/acre) spawning stock threshold into the future. A commercial fishery that does not meet the minimum spawning stock escapement established for that system will be required to close the following season until fishery achieves the escapement goal for that year.

Recreational

All Maine recreational river herring runs operate under a 72-hour closed period. The Maine Department of Marine Resources will extend closed periods, modify conservation equivalencies, or close fishing on populations that cannot meet the 25th percentile fisheries independent run counts.

1) Additional management review and/or changes will occur based on decreasing trends in running three-year averages of annual landings, increasing time series trends in total mortality (z), and trends in repeat spawning rates for fishery dependent and fishery independent sites where these data are collected.

2) All recreational river herring fisheries not associated with a commercial run will close if the mean statewide fishway count falls below the 25-percentile for three consecutive years.

3) Recreational fisheries not associated with a commercial fishery will close regionally if one of the fisheries independent fishway counts fails to achieve the 25-percentile for three consecutive years. The management objective is to ensure that regional recreational fisheries do not impact spawning stock on rivers without river specific monitoring. The rivers in table Fishery Independent Management Triggers for Recreational River Herring Harvest will represent regions of the state equidistance between fishway locations listed below. The 25-percentile values are fixed but will be updated once every five years when state River Herring SFMP's are reviewed and updated.

Fishery Independent Management Triggers for Recreational River Herring Harvest

Fishway	25-Percentile
Saco River	9,327
Androscoggin River	23,689
Kennebec River	45,754
Penobscot River	2,039
St. Croix River	13,365
Fishway Totals	154,711
Fishway Mean	76,636

References:

Kircheis, F.W., J.G Trial, D.P Boucher, B. Mower, Tom Squiers, Nate Gray, Matt O'Donnell, and J.S. Stahlnecker. 2002. Analysis of Impacts Related to the introduction of Anadromous Alewife into a Small Freshwater Lake in Central Maine, USA. Maine Inland Fisheries & Wildlife, Maine Department of Marine Resources, Maine Department of Environmental Protection. 53 pp.

Rounsefell,G.A.,L.D, Stringer. 1943. Restoration and Management of the New England Alewife Fisheries with Special Reference to Maine. United States Department of the Interior Fish and Wildlife Service Fishery Leaflet 42.

Walton, C. J. 1987. Parent-progeny relationship for an established population of anadromous alewife in a Maine lake. American Fisheries Society Symposium 1: 451-454.

Appendix A

Fisheries Independent Data **Age Based Z-Estimates**

2008	Catch Curve				Heinke				Chapman-Robson			
	Male		Female		Male		Female		Male		Female	
Fishery	Z	SE	Z	SE	Z	SE	Z	SE	Z	SE	Z	SE
Androscoggin River	1.23	0.24	0.80	0.17	1.05	0.12	0.81	0.11	1.24	0.14	0.81	0.11
Card Mill Stream	1.67	0.16	1.43	0.19	1.89	0.38	1.68	0.29	1.85	0.37	1.65	0.28
Flanders Stream	-	-	-	-	1.79	0.83	1.10	0.67	1.79	0.83	1.10	0.67
Patten Pond	-	-	1.39	0.40	1.79	0.28	1.85	0.34	1.93	0.31	1.73	0.32
Sewall Pond	1.25	0.59	1.49	0.24	0.76	0.08	0.88	0.08	1.08	0.12	1.13	0.11

Fisheries Independent Data **Age Based Z-Estimates**

2009	Catch Curve				Heinke				Chapman-Robson			
	Male		Female		Male		Female		Male		Female	
Fishery	Z	SE	Z	SE	Z	SE	Z	SE	Z	SE	Z	SE
Androscoggin River	1.30	0.43	0.85	0.25	0.56	0.05	0.52	0.06	0.87	0.08	0.83	0.10
Card Mill	-	-	-	-	2.30	0.90	1.79	0.59	2.30	0.90	1.87	0.62
Medomak River	-	-	-	-	*0.93*	*0.12*	-	-	*1.25*	*0.17*	-	-
Sewall Pond	1.82	0.59	0.68	0.09	1.13	0.16	0.78	0.09	1.36	0.20	0.97	0.12

Sexes Combined

Fisheries Dependent Data **Age Based Z-Estimates**

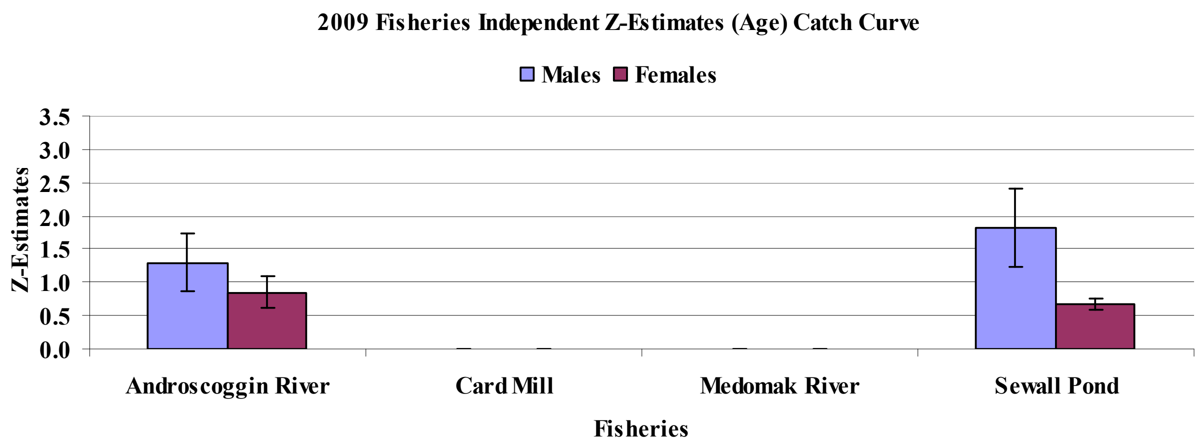
2009	Catch Curve				Heinke				Chapman-Robson			
	Male		Female		Male		Female		Male		Female	
Fishery	Z	SE	Z	SE	Z	SE	Z	SE	Z	SE	Z	SE
Damariscotta	-	-	-	-	2.56	0.92	1.87	0.60	2.56	0.92	1.95	0.63
Dresden	1.12	0.23	0.92	0.13	0.67	0.09	1.13	0.23	0.93	0.13	1.18	0.24
E. Machias	*2.00*	*0.63*	-	-	*1.22*	*0.15*	-	-	*1.44*	*0.18*	-	-
Gouldsboro	*1.00*	*0.31*	-	-	*0.73*	*0.15*	-	-	*0.96*	*0.20*	-	-
Grist Mill	*1.39*	*0.66*	-	-	*0.78*	*0.10*	-	-	*1.10*	*0.15*	-	-
Jefferson	-	-	-	-	-	-	2.69	0.47	-	-	2.74	0.48
Orland	0.87	0.01	1.59	0.28	0.99	0.20	1.30	0.24	1.10	0.22	1.44	0.27
Perry	-	-	-	-	*1.72*	*0.21*	-	-	*1.88*	*0.24*	-	-
Sheepscot	-	-	-	-	*1.54*	*0.20*	-	-	*1.73*	*0.23*	-	-
Surry	-	-	-	-	2.04	0.36	2.64	0.66	2.14	0.38	2.67	0.67
Union	-	-	1.42	0.11	1.79	0.48	1.34	0.30	1.90	0.52	1.42	0.32
Vassalboro	1.70	0.72	1.70	0.72	0.92	0.13	1.10	0.25	1.20	0.18	1.17	0.27
Warren	1.22	0.49	0.80	0.25	0.99	0.13	0.80	0.10	1.16	0.15	0.86	0.11
Winnegance	1.47	0.38	-	-	1.22	0.15	2.44	0.65	1.37	0.18	2.48	0.66
Woolwich	-	-	1.35	0.38	-	-	1.79	0.48	-	-	1.66	0.44

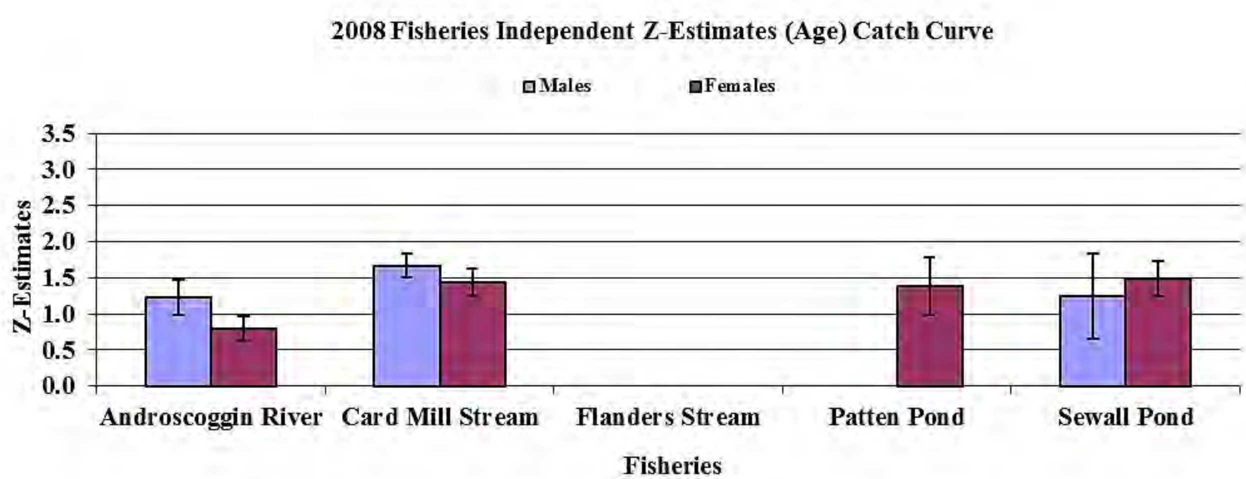
Sexes Combined

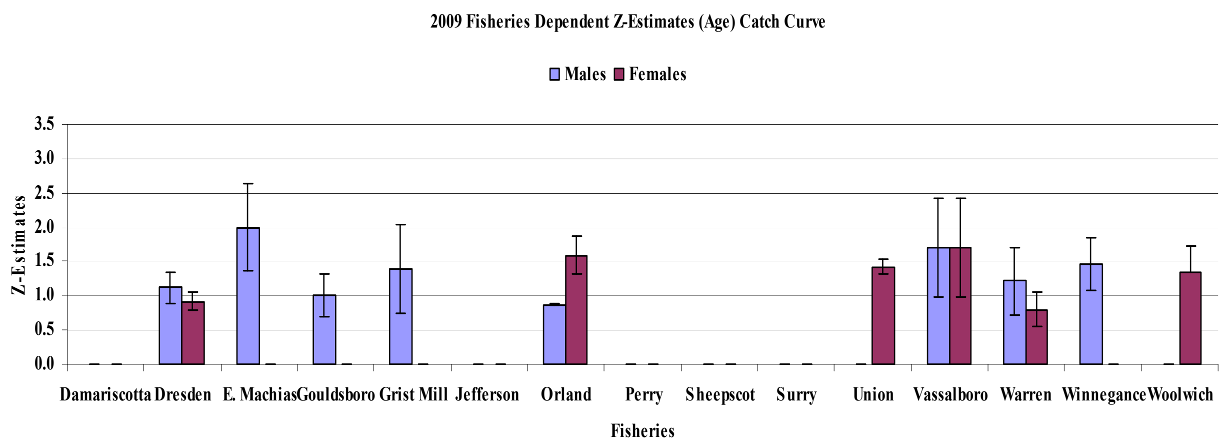
Fisheries Dependent Data **Age Based Z-Estimates**

2008	Catch Curve				Heinke				Chapman-Robson			
	Male		Female		Male		Female		Male		Female	
Fishery	Z	SE	Z	SE	Z	SE	Z	SE	Z	SE	Z	SE
Dresden	0.9	0.2	0.7	0.4	0.8	0.1	0.6	0.1	1.0	0.2	0.8	0.1
E. Machias	*1.9*	*0.1*	-	-	*1.7*	*0.2*	-	-	*1.8*	*0.2*	-	-
Flanders Pond	-	-	0.9	0.1	1.2	0.3	0.9	0.3	1.4	0.4	1.0	0.3
Gouldsboro	-	-	-	-	1.6	0.8	0.9	0.3	1.6	0.8	1.2	0.4
Grist Mill	1.1	0.1	1.1	0.2	0.9	0.2	1.3	0.2	1.1	0.2	1.2	0.2
Narraguagus	*0.8*	*0.1*	-	-	*0.6*	*0.1*	-	-	*0.8*	*0.1*	-	-
Orland	*0.9*	*0.2*	-	-	*0.9*	*0.1*	-	-	*1.1*	*0.1*	-	-
Perry	*1.6*	*0.1*	-	-	*1.4*	*0.2*	-	-	*1.5*	*0.2*	-	-
Sheepscot	*1.3*	*0.4*	-	-	*0.6*	*0.1*	-	-	*0.9*	*0.1*	-	-
Union	-	-	-	-	2.1	0.4	1.9	0.4	2.2	0.4	2.0	0.4
Warren	1.0	0.3	-	-	0.7	0.1	1.8	0.4	0.9	0.1	1.9	0.4
Woolwich	-	-	-	-	1.0	0.3	1.7	0.5	1.3	0.4	1.8	0.5

Sexes Combined



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Dresden
E. Machias
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Jefferson
Orland
Perry
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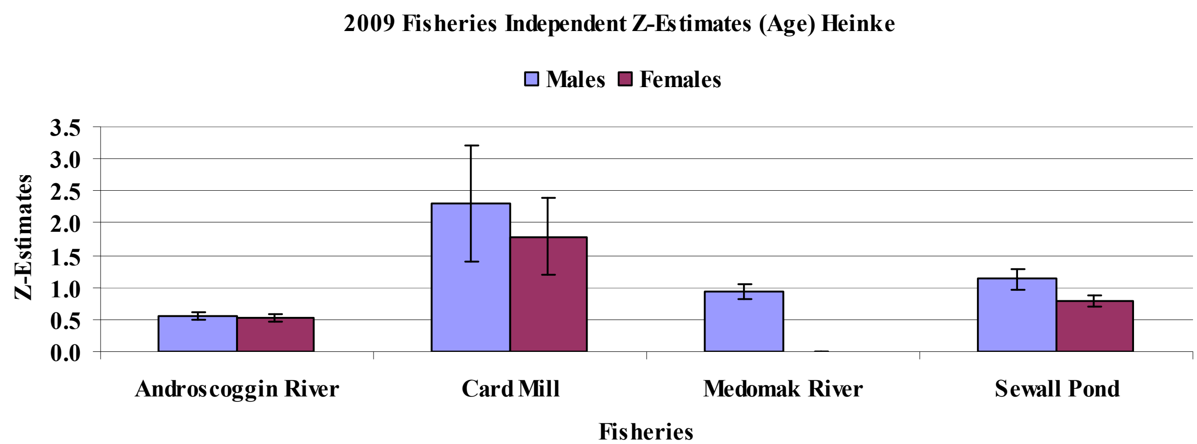
Surry
Union
Vassalboro
Warren
Winnegance
Woolwich
Fisheries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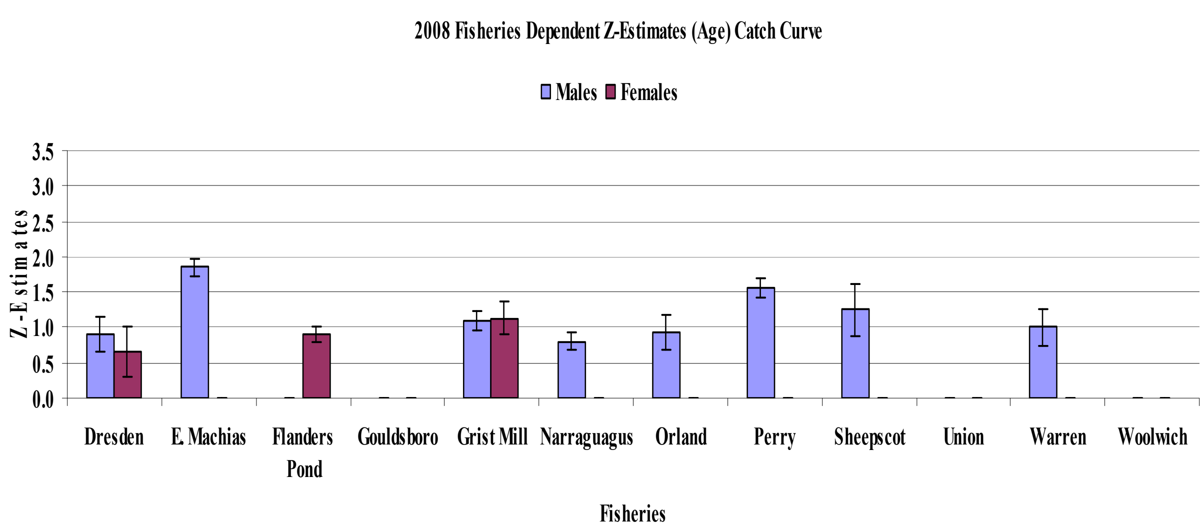
Card Mill
Medomak River
Sewall Pond
Fisheries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Warren
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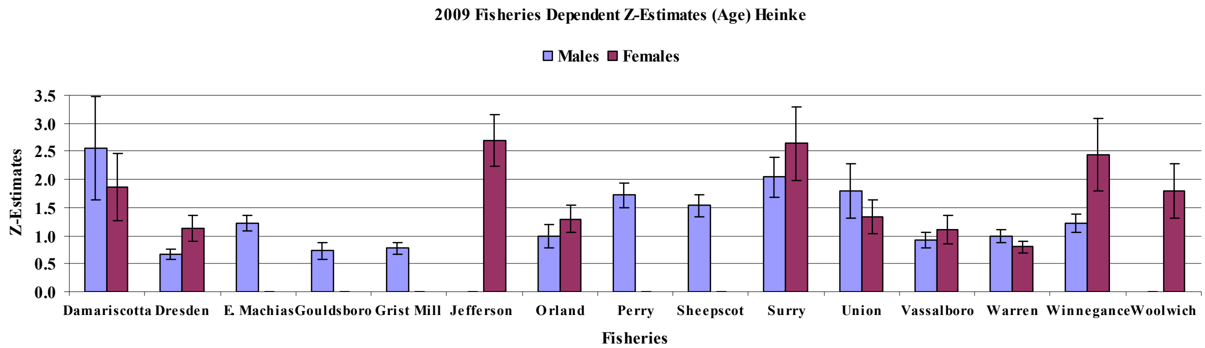
Fisheries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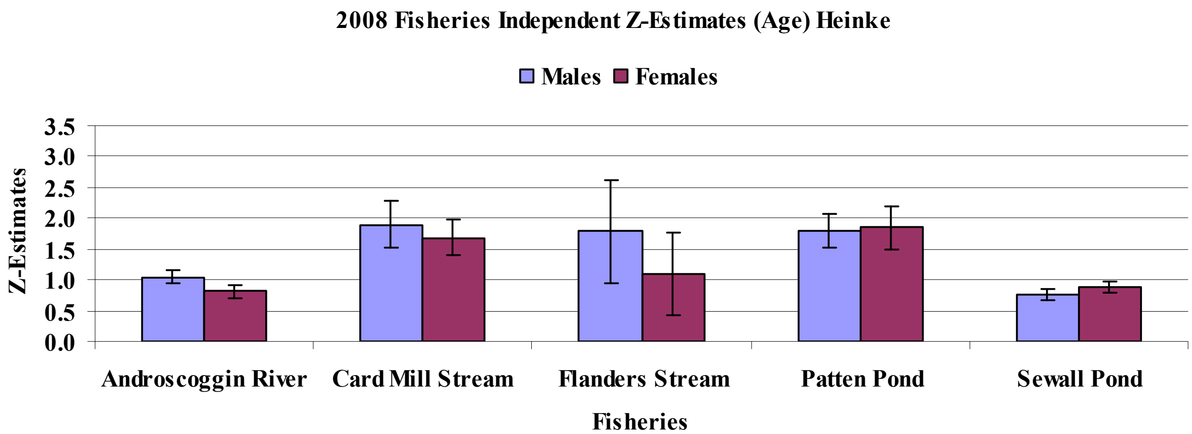
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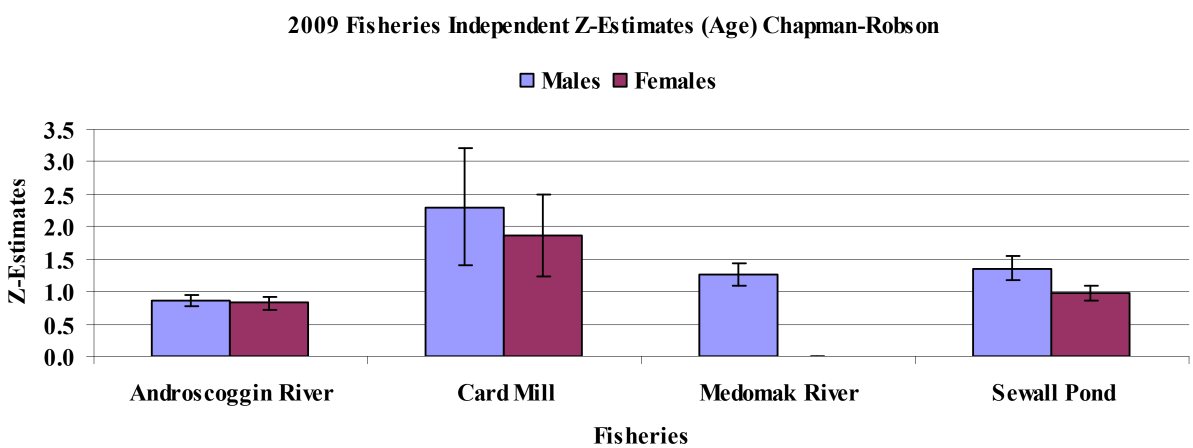
Flanders Stream
Patten Pond
Sewall Pond
Fisheries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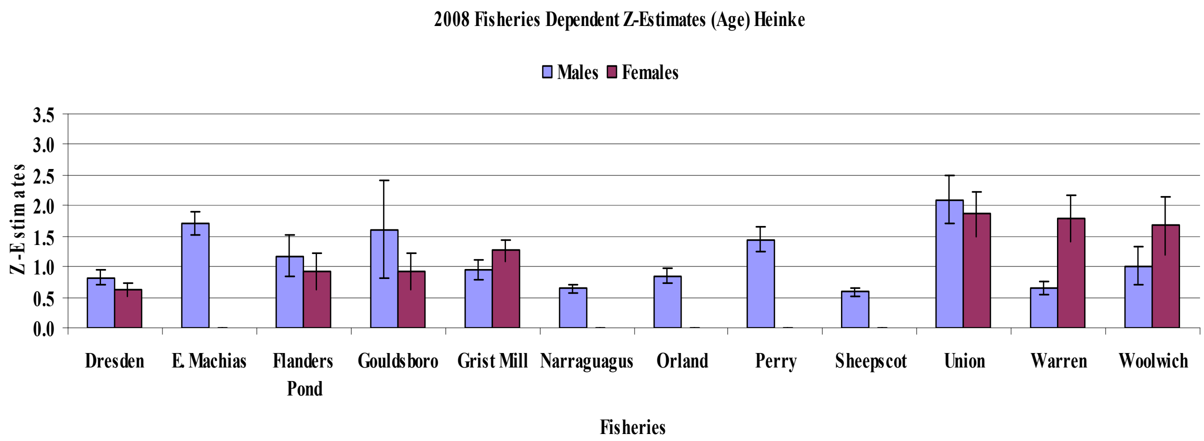
Card Mill
Medomak River
Sewall Pond
Fisheries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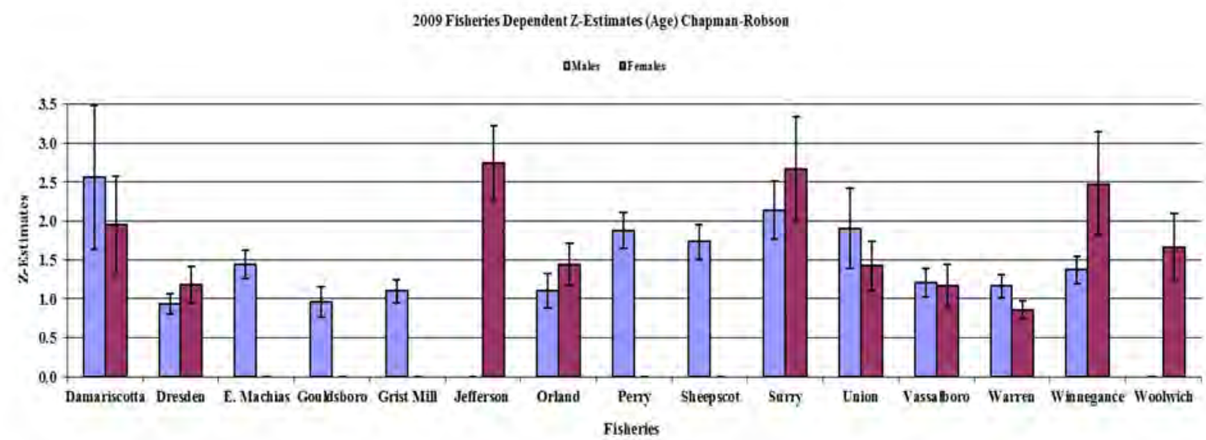
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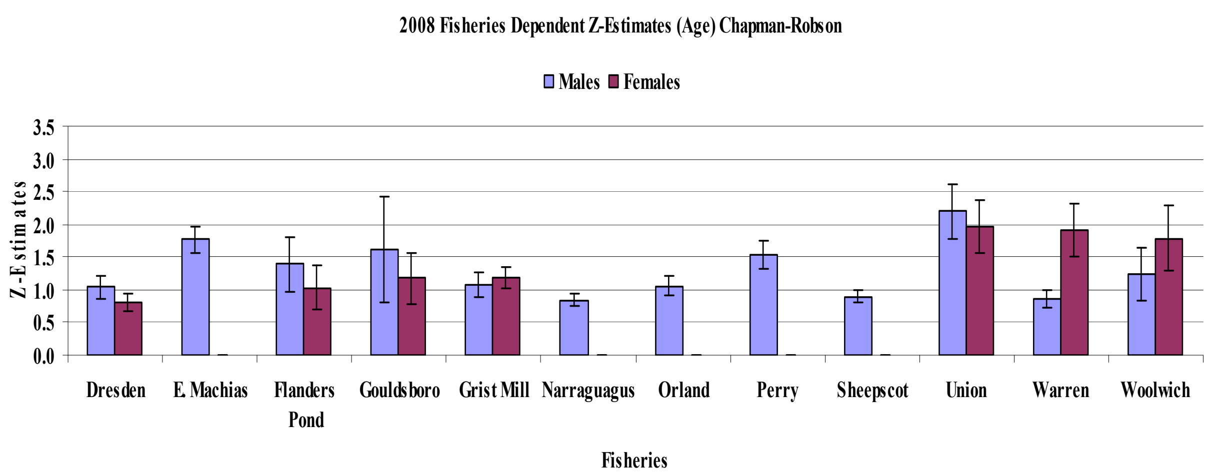
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Dresden
E. Machias
Flanders Pond
Gouldsboro
Grist Mill
Narraguagus
Orland
Perry
Sheepscot
Union
Warren
Woolwich
Fisheries

Appendix B

§6134. River herring passage; fishways on the St. Croix River

By May 1, 2013, the commissioner and the Commissioner of Inland Fisheries and Wildlife shall ensure that the fishways on the Woodland Dam and the Grand Falls Dam located on the St. Croix River are configured or operated in a manner that allows the unconstrained passage of river herring. [2013, c. 47, §1 (NEW).]

SECTION HISTORY
1995, c. 48, §1 (NEW). 2007, c. 587, §1 (RPR). 2011, c. 598, §12 (AMD). 2013, c. 47, §1 (RPR).

§6041. Pelagic and Anadromous Fisheries Fund

1. Uses of fund. The commissioner shall use the fund for research directly related to Pelagic or Anadromous fishery management and the processing of landings data information. The commissioner may authorize the expenditure of money in the fund for research and development programs that address the restoration, development, or conservation of Pelagic or Anadromous resources.

2. Sources of revenue. The fund is capitalized by surcharges assessed under **Section 2. 12 MRSA §6503**. In addition to those revenues, the commissioner may accept and deposit in the fund money from any other source, public or private.

Sec. 2. 12 MRSA §6503, is enacted to read:

§6503. Commercial Pelagic and Anadromous Fishing License

1. License required. A person may not engage in the activities authorized under this section without a current:

A. Pelagic and Anadromous fishing single license for a resident operator;

B. Pelagic and Anadromous fishing crew license for a resident operator and all crew members;

C. Nonresident Pelagic and Anadromous fishing license for a nonresident operator and all crew members.

2. Licensed activity. The holder of a Pelagic and Anadromous fishing license may fish for or take or possess, ship, transport or sell pelagic or anadromous fish that the holder has taken. The license authorizes crew members aboard the licensee's boat when it is engaged in Pelagic or Anadromous fishing to undertake these activities, if the license provides for crew members.

3. Exemptions. The licensing requirement under subsection 1 does not apply to activities described in this subsection.

A. A person may fish for, take, possess or transport any species of pelagic or anadromous fish if they have been taken by spear gun, harpoon, minnow trap, or hook and line and are only for personal use.

4. Eligibility. A Pelagic and Anadromous fishing license may be issued only to an individual.

5. Fees. Fees for Pelagic and Anadromous fishing licenses are:

A. Forty-one dollars for resident operator;

B. One hundred eleven dollars for resident operator and all crew members; and

C. Seven hundred and fifty-dollars for nonresident operator and all crew members.

6. Surcharges. The following surcharges are assessed on Commercial Pelagic and Anadromous fishing licenses issued by the department:

A. For a resident Pelagic and Anadromous fishing license, $150;

B. For a resident Pelagic and Anadromous fishing license with crew, $100; and

C. For a non-resident Pelagic and Anadromous fishing license with crew, $100.

7. Definition. For the purposes of this chapter, "pelagic fish or Anadromous fish" means Atlantic herring, Atlantic menhaden, whiting, spiny dogfish, alewife, Atlantic mackerel, blueback herring, and squid, butterfish, scup, black sea bass, smelt and shad.

8. Violation. A person who violates this section commits a civil violation for which a forfeiture of not less than $100 nor more than $500 may be adjudged.

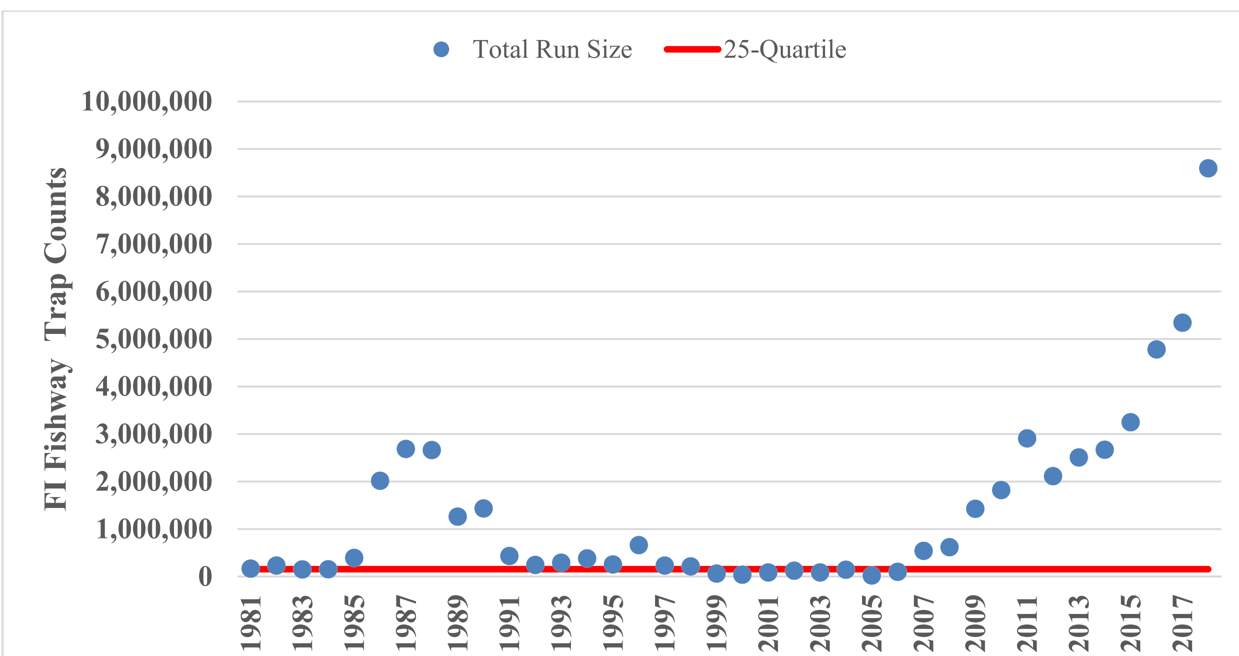
Appendix C

Table 1. Fisheries independent monitoring locations to monitor recreational river herring fisheries in Maine.

	River Herring					
Year	Androscoggin	Saco	Kennebec	Sebasticook	Penobscot	St. Croix
1981						169,620
1982						233,102
1983	601					151,952
1984	2,530					152,900
1985	26,895					368,900
1986	35,471					1,984,720
1987	63,523					2,624,700
1988	74,341					2,590,750
1989	100,895					1,164,860
1990	95,574					1,339,050
1991	77,511					358,410
1992	45,050					203,750
1993	5,202	831				289,720
1994	19,190	2,240				362,930
1995	32,002	9,820				215,133
1996	10,198	9,162				645,978
1997	5,540	2,137				225,521
1998	25,189	16,078				177,317
1999	8,909	31,070				25,327
2000	9,551	25,136				8,569
2001	18,196	66,890				5,202
2002	104,520	20,198				900
2003	53,732	26,760				7,901
2004	113,686	32,801				1,299
2005	25,846	388				22
2006	34,239	7,994	4,094	45,960		11,829
2007	60,662	16,084	3,448	461,412		1,294
2008	92,359	22,563	93,775	401,331		12,261
2009	42,759	2,012	45,754	1,327,915		10,424
2010	39,689	19,258	76,947	1,626,872	222	58,776
2011	54,886	39,597	37,846	2,751,473	2,039	25,124
2012	170,191	28,058	179,357	1,703,520	54	36,168
2013	69,267	43,414	94,456	2,272,492	12,708	16,677
2014	55,953	11,576	108,432	2,282,454	187,438	26,893
2015	71,887	53,891	91,850	2,157,983	782,521	93,503
2016	114,874	22,644	224,990	3,128,753	1,259,307	33,016
2017	49,923	44,929	289,188	3,547,091	1,256,061	157,750
2018	170,040	92,836	307,035	5,579,903	2,174,745	270,659

Figure 1. Locations of Recreational River Herring Monitoring Counts.

Figure 2. Total fishway counts for the six rivers used to monitor fish populations.



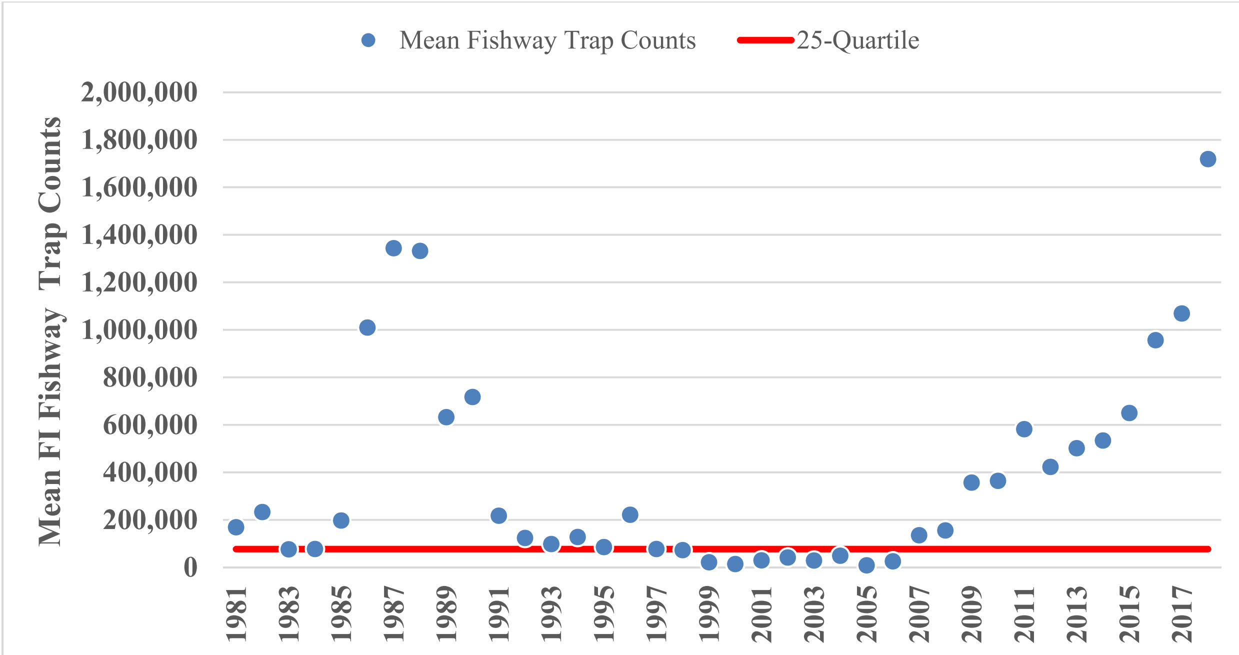


Figure 3. Mean fishway counts for the six rivers used to monitor fish populations.

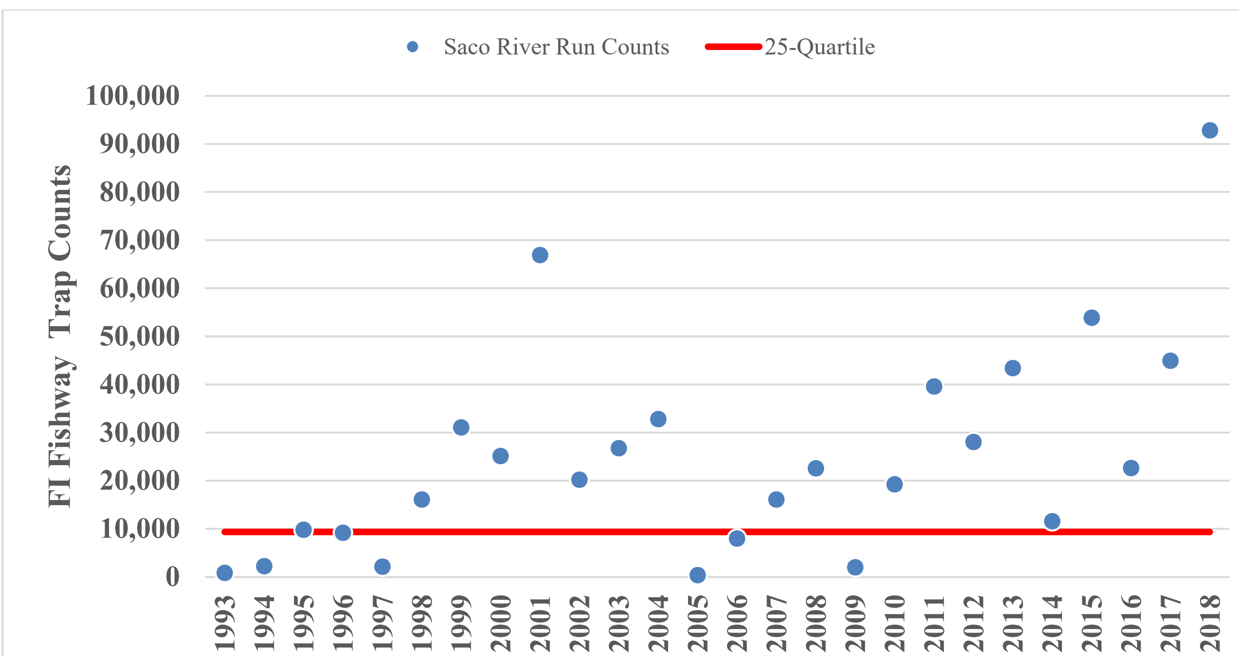


Figure 4. Fishway counts for the Saco River.

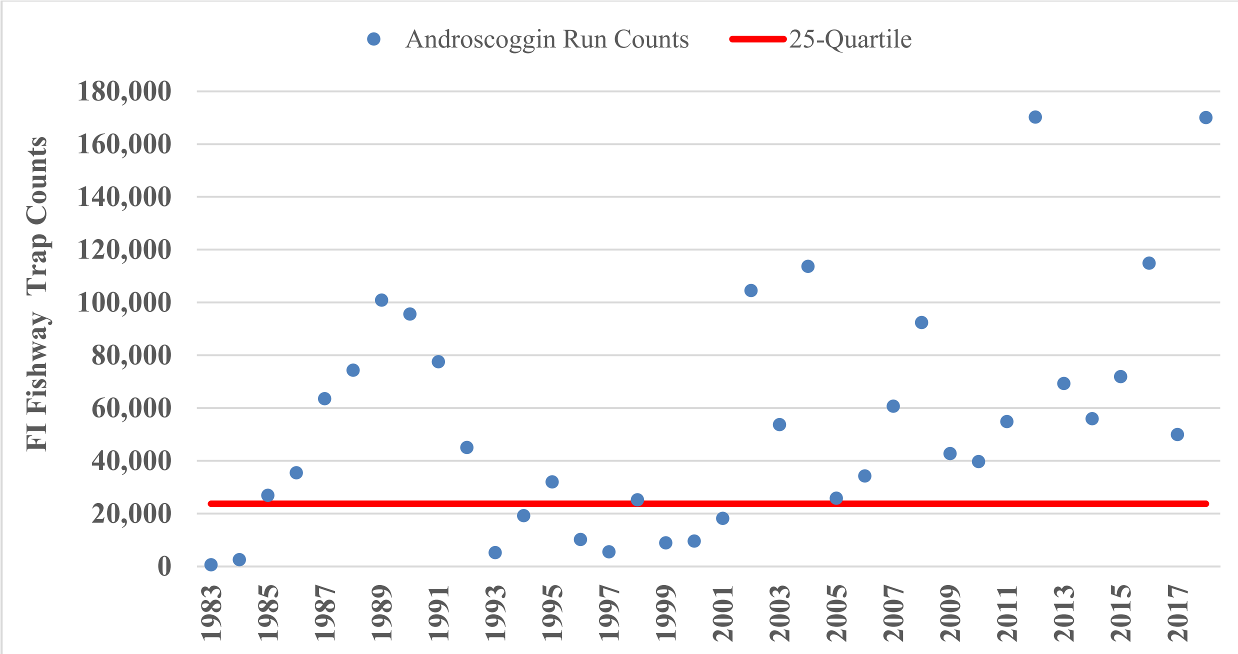


Figure 5. Fishway counts for the Androscoggin River.

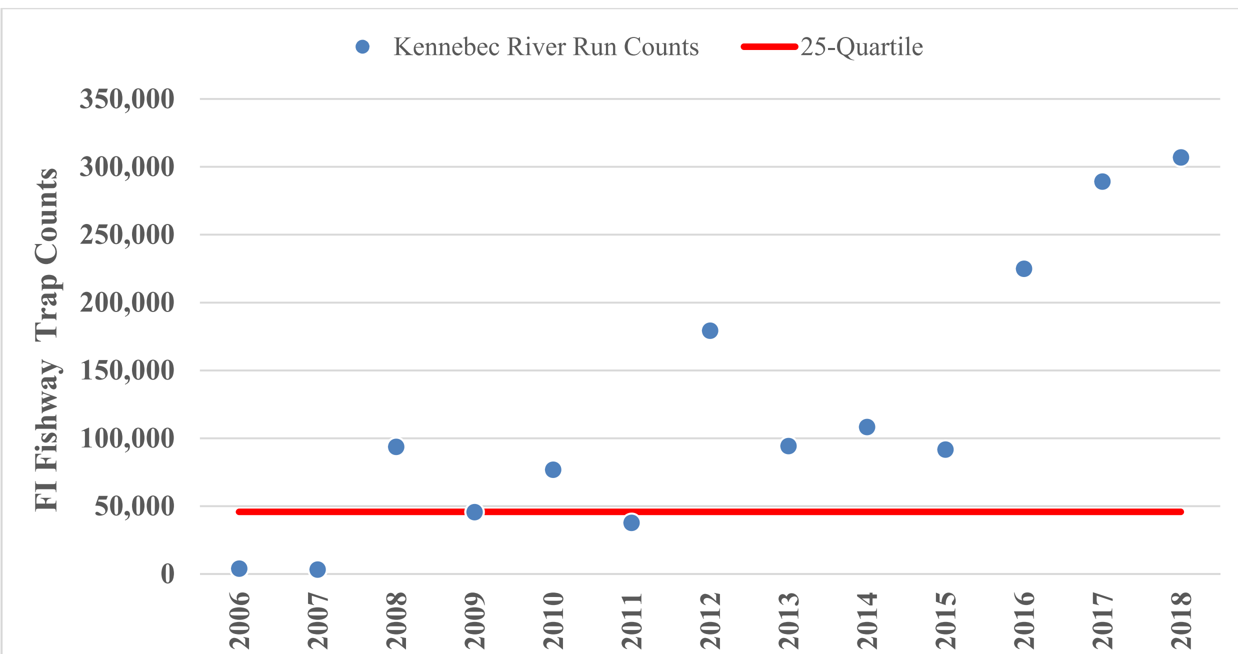


Figure 6. Fishway counts for the Kennebec River.

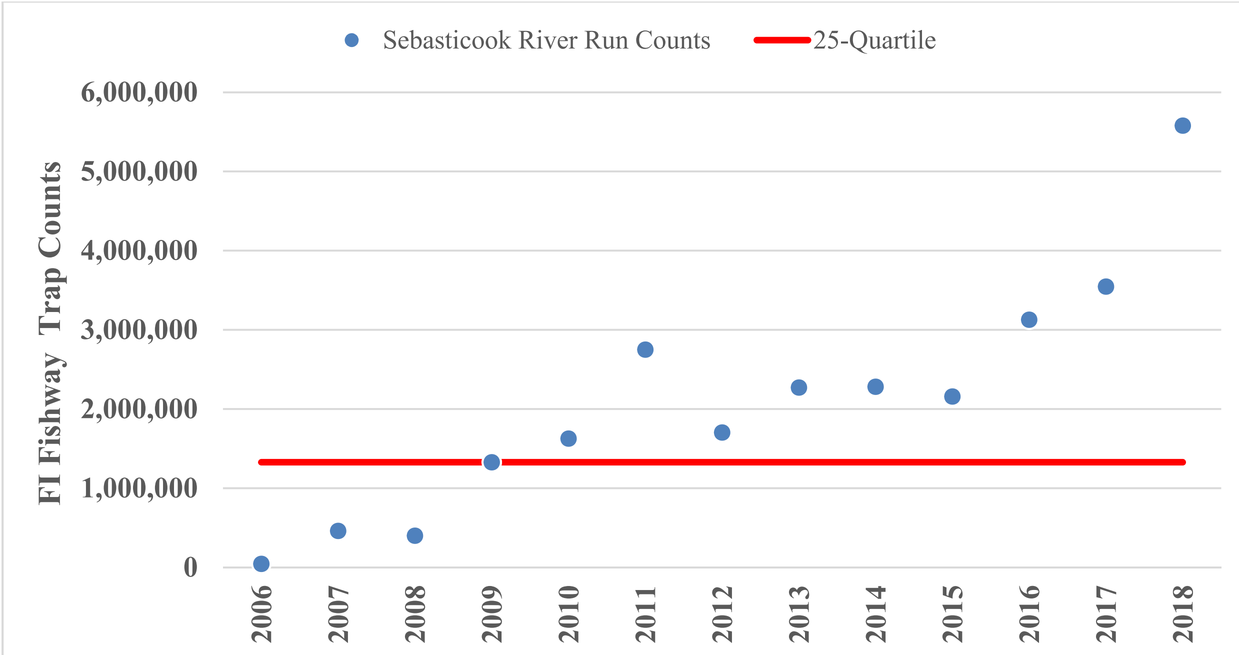


Figure 7. Fishway counts for the Sebasticook River.

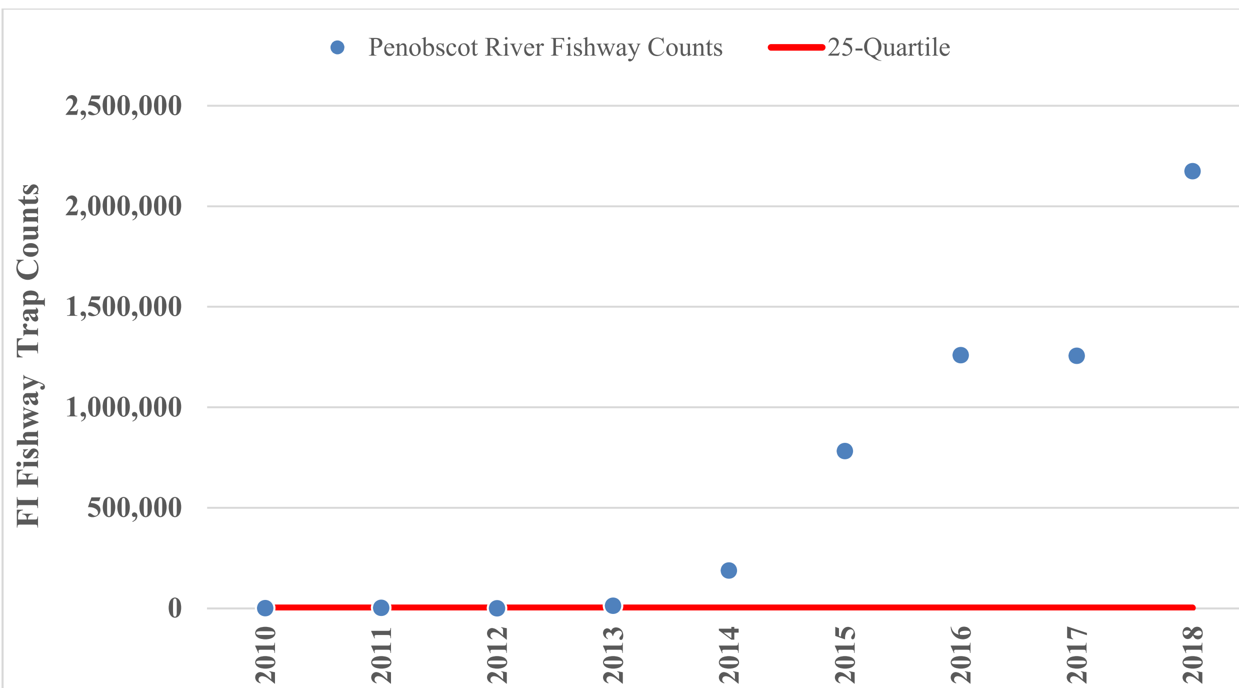


Figure 8. Fishway counts for the Penobscot River.

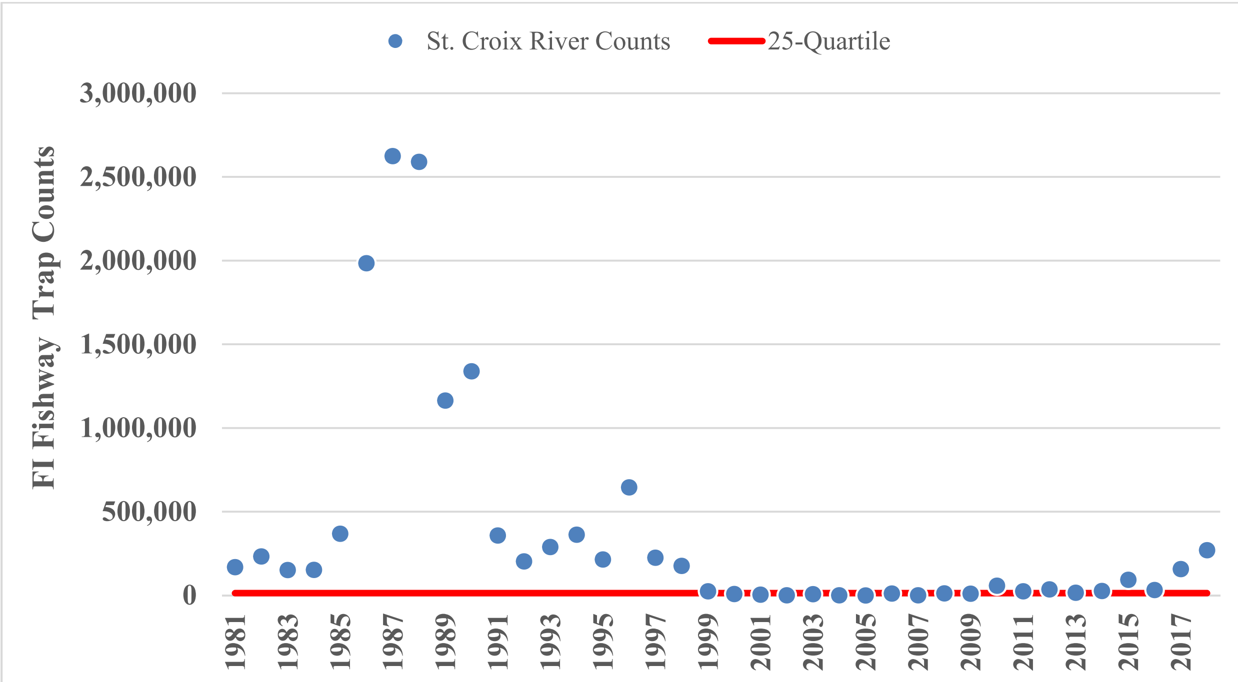


Figure 9. Fishway counts for the St. Croix River.

MAINE DEPARTMENT OF MARINE RESOURCES

Maine Sustainable Fisheries Management Plan for American Shad

Maine Department of Marine Resources
32 Blossom lane
Augusta, Maine 04333

March 15, 2020

1. Introduction

American shad (*Alosa sapidissima*) are managed in state waters by the Atlantic States Marine Fisheries Commission (ASMFC). In 2010 the Atlantic States Marine Fisheries Commission Shad and River Herring Management Board passed Amendment 3 to the American Shad and River Herring Management Plan. Amendment 3 was developed to address continued concerns over declining populations of American shad coastwide. Amendment 3 closed all commercial and recreational fishing for American shad along the East Coast starting in January 2013 unless individual states developed an ASMFC approved sustainable fisheries management plan for American shad. States without an approved sustainable fisheries management plan were limited to catch and release fishing for American shad.

2. Regulatory History

Historically, American shad were abundant in Maine's large coastal rivers and streams. American shad were an important food source for indigenous people and an important economic resource for European settlers. As shad fisheries continued to develop state fisheries managers utilized several regulatory processes to manage Maine's commercial and recreational American shad fisheries. Most of these regulations applied to the directed commercial American shad fisheries in the Kennebec, Androscoggin, and Merrymeeting Bay areas of the state from the late 1800s through the 1940s. Several of the smaller coastal rivers had additional river-specific harvest regulations. Maine regulated the directed fishing effort for American shad through mesh size and lead length restrictions for commercial shad operations that utilized gill nets and weirs. Later, closed seasons allowed additional escapement for spawning fish to migrate upstream to spawning areas. By the end of the 1940s, the effects of pollution, dam construction, and overfishing depleted many of the coastal river fisheries to the point where it became economically infeasible to continue commercial fishing operations. Commercial catches of American shad after the 1940s resulted principally from herring and groundfish fishing operations in nearshore and offshore locations in the Gulf of Maine.

3. Current Regulations

Effective May 19, 1998, the Maine Department of Marine Resources (MDMR) closed all state waters to commercial fishing for American shad. Although Hickory shad may be present in Maine's coastal waters during the spring, summer, or fall, confirmed catches of hickory shad in the commercial sector, recreational fishery, or state sponsored semi-annual trawl surveys conducted in Maine and New Hampshire have not occurred in several years. Since mandatory reporting requirements began in 1996, only one commercial trip in Maine, during the 1999 fishing season, reported catching two hickory shad.

In May 1998, the State of Maine established a two fish per day recreational limit for American shad in state waters. Gear restrictions limit anglers to a single hook and line while fishing American shad. This regulation has remained in effect since May 1998.

4. Status of the Stocks

Statewide there are 23 identified American shad rivers with over 2,545 river kilometers of potential habitat. Currently, only 1,611 river kilometers are known to be open for upstream passage for American shad, while over 810 river kilometers of historical habitat are currently inaccessible (Figure 1; Table 1). Of the habitat that is accessible, a large proportion of the habitat on many rivers is above dams with fishways that may provide only limited accessibility. It is assumed that the mapped habitat supports both adult and juvenile life stages of American shad. Adult shad numbers are increasing in Maine because of the extensive restoration on the main stems of Maine's largest rivers (Table 2). However, returns are low compared to historic numbers that once supported large commercial fisheries.

Prior to the year 1998, main stem dams without adequate upstream passage, pollution, and habitat loss virtually eliminated American shad from most Maine rivers. After the collapse of American shad populations in Maine and prior to the restoration projects started in 1984, American shad were most often caught in Maine's inland waters as incidentally catches by recreational anglers fishing for Atlantic salmon.

The occurrence of American shad in Maine rivers became more prevalent with the development of a restoration plan which utilized trap and truck of prespawn fish from other states. Development of a hatchery to propagate native and captive shad from other states for release into Maine rivers contributed to an expanding native shad population. These restoration efforts were supported through continued installation of upstream and downstream fish passage and dam removals on Maine's largest rivers.

Today recreational fishing for American shad in Maine is not widespread and is restricted to river stretches below existing main stem dams. Six rivers in Maine support most of the recreational fishing for American shad Currently, American shad are documented as catches in qualitative fishing reports from anglers fishing in the Androscoggin, Saco, Mousam, Kennebec, Penobscot and Narraguagus rivers, but there are few reports from other rivers. The population sizes in these rivers is currently unknown other than the counts provided at dams which provide upstream fish passage.

The Mousam, Saco, Androscoggin, Kennebec, Penobscot and Narraguagus rivers range in size from small coastal streams to large complex river systems. The Kennebec and Saco rivers are the most productive recreational fishing spots for American shad. These rivers, except for the Narraguagus and upper section of the Kennebec and Penobscot rivers, are covered by the NOAA MRIP survey. Data provided by NOAA for the period 1996 – 2018 confirm state fisheries biologists observations that the proportion of recreational anglers fishing for American shad is low and harvest of American shad is almost nonexistent. (Tables 3 & 4; Figure 2)

Statewide Landings

Commercial fishing for American shad is currently prohibited in the state of Maine. Historically, commercial shad fisheries were an important source of food and employment in the lower portions of the larger river systems throughout coastal Maine. Like many of Maine's coastal rivers, pollution and construction of dams without fish passage, or fishways that provided ineffective upstream fish passage, reduced shad populations to the point where commercial fishing was no longer viable.

Since Maine prohibited commercial fishing for American shad in May 1998, commercial landings of American shad occurred principally as bycatch in the groundfish gill net fishery in federal waters off the coast of Maine. With changes in the groundfish fishery, landings of American shad in Maine ports have been close to zero. (Tables 5 & 6)

Passage

Barriers to migration are the primary impediments to American shad habitat and successful spawning within Maine state waters. Of 23 rivers known to have historical or known populations of American shad, 18 rivers have a mainstem dam that limits upstream passage of American shad. Of these, five have no capacity for fish passage. Taylor 1951, documented the decline of several American shad populations in Maine's largest rivers. He identified dams as one of the major reasons for population declines and dams still remain a major threat to American shad today.

Even though fish passage may be installed at these dams, or others, the use of habitat upstream is thought to be much lower than the use of habitats below these dams. In 2011, video monitoring below the Brunswick fishway on the Androscoggin River documented over 16,000 American shad below the dam, while no shad were passed at the top of vertical slot fishway (J. Lichter, Bowdoin College, pers. comm). Similar observations have been made at several dams, including those with the newest fish passage technology.

The majority of the dams with fish passage on shad rivers in Maine utilize fish lifts or Denil fishways. Denil fishways seem to have high potential for passage (Slatick and Basham 1985, Haro *et al.* 1999), however, the ability of shad to locate the fishway entrance in a large mainstem dam can be low, especially when combined with a large spillway and spill unassociated with designed attraction flows. Most newly constructed fish passage facilities on mainstem rivers in Maine utilize fish lifts. The potential for these facilities to pass American shad is thought to be low to moderate dependent on placement and operation. As discussed above, the ability of shad to locate the fish lift entrance is likely affected by attraction flows from areas adjacent to the fishway along large spillways. At some Maine dams that utilize fish lifts there is evidence that shad may remain in holding areas below the fish lift and do not enter the headpond, as evidenced by shad found when the facilities are periodically dewatered.

Management History

Fisheries managers used a number of regulatory processes to manage American shad fisheries in Maine (gear, season, catch limits). Many of these regulations applied to the commercial American shad fisheries in the Kennebec, Androscoggin, and Merrymeeting Bay Complex from the late 1800s through the 1940s. Several of the smaller coastal rivers had additional river-specific harvest regulations. Closed seasons allowed additional escapement of spawning shad as shad populations declined. By the end of the 1940s, the effects of pollution and over fishing depleted many of the coastal river fisheries to the point where it became economically infeasible to continue commercial fishing operations. Generally, commercial shad catches after the 1940s were bycatch resulting from Atlantic herring and groundfish fishing operations in offshore fishing locations.

During the period 1940 through the mid-1980s the State of Maine passively managed American shad populations on most river systems. Management began to change on some river systems as water quality improved and fish passage became a standard in the relicensing of hydropower projects operating in Maine. With the anticipation of improved water quality and upstream passage the State initiated a more active management approach. These management actions included the trap and transfer of adult American shad from in-state and out-of-state sources and, for the first time, included the production of hatchery products for release into river systems considered for restoration.

Restoration Efforts

In addition to providing upstream and downstream passage and dam removals on several of Maine's rivers the state implemented active restoration strategies to recover American shad. The Department of Marine Resources began adult stocking and hatchery programs to restore American shad to the state of Maine prior to the anticipated removal of Edwards Dam in Augusta and in conjunction with the newly created fishway at the Brunswick hydropower dam on the Androscoggin River.

Adult stocking

Active shad restoration in Maine began in 1985 by stocking prespawn adult American shad into the Androscoggin River. For the first two years of this stocking program adult shad were captured in the Cathance River (ME) and the Merrimack River (MA) and released into the Androscoggin River. Beginning in 1988 adult shad from the Connecticut River (Holyoke fish lift), the Merrimack River (Lowell, MA) and native shad returning to the Androscoggin were released into the Androscoggin River above the Brunswick dam. Adult shad were actively stocked from out of state sources for all years except 1998, 2000, 2001, 2005, 2006. The adult shad stocking program ended in 2009 due to limited funding and the availability of American shad broodstock from other states. Due to cost and the status of American shad runs coastwide the adult transfer program is not expected to resume.

American shad restoration began on the Kennebec River in 1987 by stocking a small number of prespawn adult shad obtained from Maine rivers. Between 1988 and 1997, adult shad were taken from the Connecticut River at the Holyoke lift and released into the Kennebec River above Augusta.
Stocking adult shad directly into the rivers targeted for restoration occurred for 15 years. In 2009, the MDMR decided to discontinue the direct stocking of adult shad into the river systems and relied on the culture and release of marked hatchery larvae (Table 7)

Larval stocking

American shad larvae were raised at the Waldoboro hatchery from 1992 to 2008 using eggs collected from adults from the Kennebec, Connecticut, Androscoggin, Merrimack, Saco, and Sebasticook rivers. Beginning in 1993, shad eggs from Connecticut River adults were transported to the Waldobo Shad Hatchery in Waldoboro, ME, cultured up to 21 days, and released as larvae into the Kennebec or Sebasticook rivers (a tributary to the Kennebec River). Beginning in 1998, adult shad from the Connecticut and Merrimack rivers were transported to the Waldoboro Hatchery for use as broodstock in a tank-spawning system.

Larval American shad reared in the hatchery were 'marked' by immersion in an oxytetracycline (OTC) bath before being released. Receiving locations included multiple sites on the Androscoggin, Kennebec, and Sebasticook rivers (both below and above dams), as well as at the presumed spawning locations on the Medomak River and on the Saco River in tidal water below the dam. The hatchery closed in 2009 with no plans to reopen the hatchery due to funding, availability of broodstock and current management of American shad along the East Coast.

To assess the success of the hatchery program adult American shad otoliths were collected from mortalities at fish passage facilities, from juveniles collected during beach seine surveys, and from some anglers who voluntarily submitted samples. The Maine DMR inshore trawl survey also began collecting otoliths from a subsample of American shad during the fall of 2012. While it is difficult to directly measured the success of the stocking program statewide, juvenile abundance in the Kennebec/Androscoggin complex did increase concurrent with larval stocking.

Current Action and Progress

During the Federal Energy Regulatory Commission (FERC) relicensing process, the Maine Department of Marine Resources, in collaboration with federal agencies, advocates for fish passage infrastructure and operations that provide the best accommodation for all diadromous fish passage, including American shad. In addition to the FERC process, the Maine DMR also provides comments on all construction projects in the state where there may be an interaction with an identified shad resource. The Department provides comments and works with public and private landowners to install fish passage or upgrade existing passage to allow for maximum passage potential for all diadromous species, including American shad.

There are four ongoing annual monitoring projects that collect data on American shad in Maine waters. These projects collect data from a number of different habitats and life stages of American shad. The projects include fishway monitoring on major rivers, a juvenile beach seine survey, the Maine-New Hampshire trawl survey and the recreational fishing (MRIP) survey. Three of these projects provide fisheries independent data. Fisheries dependent data sources are limited to the MRIP survey conducted in conjunction with the federal agencies. There are few additional fisheries dependent data sources available other than historical landings records for coastal and offshore fisheries, historical tag return data and recreational fisheries data collected through the MRIP survey. The coverage and numbers of American shad sampled by the MRIP survey are highly variable and based on low numbers of American shad sampled by the survey (Tables 3&4)

1. **Fishery-Dependent Data Sources**

Statewide

Early commercial landings remained relatively stable at around 445,000 kg from 1887 to 1911 (Table 8; Figure 3). The origin of the fish captured in the commercial fishery is unknown. Research studies indicate that the American shad most likely originated from several different rivers. Catches rose to a peak of 1,495,066 kg in 1912, dropped to mean of 51,400 kg in 1928 through 1933, and remained very low through 1940. Landings then increased to a high of 502,044 kg in 1945 and remained at a relatively low level from 1948 through 1976. Since 1978, landings have ranged from a high of 41,096 kg in 1981 to a low of 8.1 kg in 2002. From 1978 to 1990, landings averaged 14,369 kg. Since the directed fishery closed in 1998, annual landings have been less than 200 kg. Ocean bycatch has decreased due to increases in the minimum gill net mesh size allowed in the groundfish gill net fishery (16.5 cm stretch mesh). Since 1950, commercial catches in gill nets generally exceeded those in other gears (Table 5). However, there is now no directed commercial fishery for shad in Maine waters and any American shad captured are bycatch resulting while conducting commercial fisheries for other species.

To estimate the number of shad native to Maine rivers and their contribution to the fishery Flagg *et al.* (1976) used a combination of harvest change following dam construction and drainage area historically available for shad spawning to estimate potential historical spawning stock size. According to Atkins (1889), the completion of the Edwards dam in Augusta in 1837 resulted in a 50 percent decline in the shad catch of the lower Kennebec. Therefore, the 8,268 square kilometers of the upper Kennebec previously accessible to shad apparently produced 50 percent of the commercial harvest. During the 12-year period from 1903 to 1914, the lower Kennebec yielded an average annual harvest of 308,370 kg. This then equaled the harvest produced from 8,268 square kilometers of accessible drainage area in the upper Kennebec. Excluding the New Hampshire portion of the Androscoggin and Saco River drainages, the total land area of Maine that drains into Maine coastal waters approximates 64,200 square kilometers. Historically, approximately 33,280 square kilometers of this drainage was accessible to American shad. Based on historical harvest from the Kennebec, this would have generated a potential yield of 1,215,000 kg of Maine-produced fish. If we assume a harvest of 30 to 80 percent of the total run that is characteristic of commercial shad fisheries in southern New England areas, the total Maine historical run size would have ranged from 1,518,750 kg to 4,050,000 kg. Assuming a mean weight of 1.8 kg, the total historical population would have been 850,000 to 2,250,000 adult fish (Flagg *et al.* 1976).

Merrymeeting Bay Complex

Fishery dependent data for the Merrymeeting Bay Complex is limited to historical data. It is likely that a combination of overfishing, pollution and habitat loss from dam construction beginning in colonial period through the early 1800s contributed to the disappearance and dramatic declines of shad stocks in the state of Maine (Flagg *et al*. 1976). The commercial fishery for American shad closed in 1998 and the recreational bag limit of 2 fish caught by hook and line was established during the same year. The state of Maine does not conduct a recreational creel survey or survey bycatch in commercial fisheries for other species. Historical commercial landings data are available from the coastal and offshore fisheries that targeted American shad or retained this species as bycatch in commercial fisheries targeting other species (Tables 5,6,8).

2. **Fishery-Independent Data Sources**

Statewide

Statewide fisheries independent data are predominantly limited to trap or lift counts and the Maine-New Hampshire Trawl Survey (Table 2). Other than the biological data collected during the trawl survey there are few instances where biological data are collected from American shad. The Department does not collect biological data due to concerns for low numbers returning to trap and lift facilities statewide. Biological data collect is limited to mortalities that result from passage and transport activities.

Merrymeeting Bay Complex

Maine DMR initiated sampling of age-0 American shad in 1979 at 14 sites in the Merrymeeting Bay Complex (Figure 4). There are four sites on the lower tidal Kennebec River, three on the lower Androscoggin River, four on Merrymeeting Bay, and one each on the Eastern, Cathance, and Abagadasett rivers. Eight sites were added to the Kennebec River above the former Edwards dam in 2000 (Figure 5). Site 8A was abandoned because a recent bridge construction project altered the river at that sampling site.

Field crews sample sites once every two weeks between July 1 and October 1 each year. Collections are made with a beach seine within three hours of low water. From 1979 through 1982, the net was 9 m long, 1.8 m deep, and constructed with 3.2 mm stretched nylon mesh. Starting in 1983, the seine was constructed of 6.4 mm stretch nylon mesh and measured 17 m long, and 1.8 m deep with a 1.8 m x 1.8 m bag at its center. Although a bag was added, and the method of seining was modified, the area sampled remained the same.

During sampling, field staff holds one end of the seine stationary at the land-water interface and the boat operator tows the other end perpendicular to shore. When the net is fully extended, the distal end is towed in an arc upriver and pulled ashore. The net samples an area of approximately 220 square meters. Field personnel sort and process all samples at the sample location. Field staff count and measure all alosines. Fifty individuals of each species, other than alosines, are measured. Dividing the number of individuals caught by the number of seine hauls gives the catch-per-unit-effort (CPUE) index. The State does not collect juvenile index data from other river systems where shad spawning exists.

Maine DMR staff believes that age-0 shad move freely among sites in the lower Kennebec, Androscoggin, Eastern, Cathance, and Abagadasett rivers, and Merrymeeting Bay. For this reason, data from these sites were combined and single arithmetic and geometric mean calculated each year (Table 9). Separate means were calculated for the sites above the site of the former Edwards dam on the upper Kennebec River (Table 10).

The annual geometric means for collections of age-0 American shad in the Merrymeeting Bay Complex were relatively high in the 1980s, low during the 1990s and increased until 2010 (Figure 6). Since 2010 the geometric mean has decreased within Merrymeeting Bay except for the years 2013, 2014 and 2017. The geometric means of the catch per haul at the upper Kennebec sites were high for the period 2004 through 2008 (Figure 10). For the period 2009 to 2018 the JAI index decreased significantly. Since 2012 the number of sampling trips had also declined to fewer than thirty-two seine hauls per season, partly due to low water levels and the ability of sample crews to access sample locations on the river.

To assess the effects of dam removal, larval stocking, and assumed increase in population size based on trap counts, comparisons were made to better understand these relationships. The relationship between the relative abundance of age zero American shad lagged by five and six years was calculated for the period 1984 to 2018. The numbers of larvae stocked were also compered to changes in the Merrymeeting Bay JAI Index for the period 1992 through 2008 as well as the contribution of larval stocking to the number of the zero aged American shad captured during the JAI survey. The number of OTC marked hatchery larvae stocked in the Kennebec River was compared to the percent of OTC marked juveniles recovered during the JAI survey. Results indicated that there was a positive relationship between the number of larvae stocked and the number of juveniles captured during the survey.

Maine-New Hampshire Trawl Survey

The Maine-New Hampshire Inshore Groundfish Trawl Survey is a fisheries independent assessment of fisheries resources inside the coastal waters of Maine and New Hampshire. Its purpose is to fill a significant information gap that effects efficient management of Maine's fisheries resources. The survey is designed to provide biological, environmental and timing data on a number of commercial and non-commercial fish species found in the coastal waters during the spring and fall of each year. When the survey originally began in the fall of 2000 the focus was to assess groundfish abundance. Over the course of the survey the focus changed to include all commercial and noncommercial species.

Survey staff sample 120 stations stratified among five sections along the Maine coast each spring and fall (Figure 8). The survey counts and weighs all shad caught at each of the 120 sample stations. The coast is divided into five areas based on geologic, oceanographic, geographic and biologic factors. Each area is divided into four depth strata; 5-20, 21-35, 36-55, and 55+ fathoms. Stations are located randomly to reflect representative conditions within each of the strata.

Gear consists of a modified shrimp net with 2-inch mesh in the wings and a 1/4 inch mesh liner in the cod end. Foot rope and head ropes are 57' and 70' respectively, with 6-inch rubber cookies. The gear was designed to be very light on the bottom to minimize habitat disruption. The survey subsamples the shad catch and measures individual fork length to the nearest centimeter.

The highest catch rates of older juvenile American shad in coastal ocean waters generally occurred in Regions 1 and 2 along the westernmost coast of Maine. These regions bracket the mouths of the Saco and Kennebec rivers. The highest arithmetic mean catches per trawl tended to occur most often during the fall rather than the spring, most likely due to the numbers of juveniles leaving the river systems (Tables 11&12). For six of the last seven years the spring survey captured higher mean numbers per trawl and were generally more consistent than the mean catches during the fall trawl survey (Figures 9). The percent occurrence of American shad captured for all tows conducted during the spring and fall survey time series indicate that an increasing number of tows capture American shad (Figure 10). Captured American shad were 7 to 48 cm FL (Table 13). Mean lengths tended to be 15 to 20 cm. Age-length curves developed for American shad of the Hudson River suggest that these fish were one and two years old (Stira 1976). The trawl survey data indicate a general increase and length and weight of American shad captured since the beginning of the survey. Numbers captured during the spring survey were generally higher during the fall survey, but the stratified means were below 20 fish for both surveys (Figures 11 & 12).

Proposed fisheries to stay open

This plan proposes to maintain a statewide 2 fish creel limit for American shad. The 2 fish recreational limit with existing gear restrictions has been in effect since May 19, 1998.

Sustainability Targets

A. Definition

A sustainable American shad fishery will not diminish future stock reproduction and recruitment of American shad in Maine.

B. Methods for Monitoring Stock

The Maine Department of Marine Resources proposes to use run count data (Figure 13) in conjunction with JAI data for the Merrymeeting Bay Complex (Figure 14). Both datasets are fisheries independent and cover the main production areas in the state and provides upstream passage counts statewide.

Fishery Independent Data

The JAI time series exists for the period 1979 through 2019 and tracks the abundance of juvenile American shad at several fixed survey stations throughout Merrymeeting Bay and the six rivers that enter the freshwater tidal estuary. The 25-percentile will be used in conjunction with run counts to make decisions to modify existing management strategies or implement rule changes to the existing creel limit.

Trap counts of American shad passed upstream will be used as an additional metric to assess the number American shad above the first main stem dam with a fishway. The 25-percentile of the aggregate number of shad counted at the first main stem dam with a fishway and counting station will be used in conjunction with the JAI survey time series. The fish passage count metric will be used as a secondary metric because of the amount of spawning habitat below some mainstem dams and the efficiency of fishways to pass American shad upstream.

Timeframe

The proposed benchmarks will be implemented as soon as they are reviewed by the American Shad and River Herring Technical Committee and approved by the Management Board.

Proposed Regulation Modifications to Support Targets

No changes are proposed to the existing recreational or commercial fish rules in effect as of May 1998, which prohibits commercial fishing for American shad and established a 2-fish recreational creel limit.

Enforcement

The Maine Marine Patrol and Maine Warden Service share enforcement authority regarding American shad within their respective jurisdictions. The Maine Department of Marine Resources coordinates with regional field offices to collaborate on enforcement issues regarding American shad.

C. Adaptive Management

Evaluation Schedule

Run count and JAI survey data will be reviewed annually and added to their respective time series to provide updated annual metric values. The 25-percentile management triggers are fixed at the values in the table American Shad Management Triggers. The management triggers will be updated every five years when the states review and update American Shad SFMPs. Annual metric values will be available for review in the annual Shad and River Herring Compliance Report submitted to the Shad and River Herring Technical Committee by July 1 of each year.

Consequence or Control Rules

If for three consecutive years either the JAI Survey or one or more of the trap counts are below the 25-percentile the American shad harvest will be reduced to one fish or an American shad fishing season will be instituted to reduce effort to equate to a one fish bag limit.

If for three consecutive years, the JAI survey and one or more of the trap counts are below the 25-percentile the American shad fishery will close and be open only for catch and release fishing.

American Shad Management Triggers

Index	25-Percentile
JAI Series (1984 - 2018)	0.23
Mean Fishway Counts (1990 - 2018)	372
Total Fishway Counts (1990 - 2018)	791.5

Potential Future Benchmarks

The American shad assessment may provide some additional direction for additional methods to monitor and assess American shad on a statewide level. As American shad populations increase biological sampling may allow the Department to collect and age scales for estimation of mortality or other indices reviewed and approved by the SARC or the Technical Committee.

Tables

Table 1. Amount of American shad habitat (river kilometers) in Maine waters (USFWS 1983). Rivers are listed in order of descending habitat kilometers.

River/Watershed	Current (though may be limited)	Current Assumed	Historical	Historical Assumed	Uncertain	Total
Penobscot Watershed	399.6		354.0	32.7		786.3
Kennebec Watershed	300.4		107.2			407.6
Salmon Falls/Piscataqua River	59.8	8.1	8.9	108.1		184.9
Sheepscot River	178.8					178.8
Narraguagus River	38.9			35.6	60.4	134.9
Royal River	106.2					106.2
Androscoggin River	48.3		17.4	34.8		100.5
Saco River	49.1			50.6		99.7
East Machias River	18.8			67.0		85.7
Pleasant River	72.1					72.1
Scarborough Marsh/Nonesuch R.	70.4					70.4
St. George River	65.5					65.5
St. Croix River	61.8					61.8
Kennebunk River	47.0					47.0
Dennys River	34.8				10.7	45.5
Presumpscot River	22.0			22.2		44.2
Tunk Stream	20.2				16.8	37.1
Ducktrap River					22.8	22.8
Webhanet River	8.9					8.9
Union River	7.9					7.9
Pennamaquan River					7.6	7.6
Mousam River	6.3					6.3
Little River	5.5					5.5
Grand Total	**1622.3**	**8.1**	**487.5**	**351.0**	**118.2**	**2587.2**

Table 2. Upstream passage of American over the lowermost dam on the Androscoggin, Saco, Kennebec, Sebasticook and Penobscot rivers 1981 – 2018.

	American Shad				
Year	**Androscoggin**	**Saco**	**Kennebec**	**Sebasticook**	**Penobscot**
1981					
1982					
1983					
1984					
1985					
1986					
1987					
1988					
1989					
1990	1				
1991	0				
1992	0				
1993	1	882			
1994	1	399			
1995	3	580			
1996	2	837			
1997	2	1,104			
1998	5	1,374			
1999	87	4,994			
2000	88	1,323			
2001	26	2,570			
2002	11	1,014			
2003	7	1,227			
2004	12	1,627			
2005	0	744			
2006	3	883	0		
2007	6	1,428	18		
2008	1	1,491	0		
2009	0	278	0	8	
2010	22	3,663	39	2	
2011	0	3,338	12	54	
2012	11	6,419	5	163	
2013	14	6,171	0	114	
2014	0	2,580	1	26	809
2015	58	6,171	26	47	1,806
2016	1,096	16,926	830	18	7,862
2017	1	3,727	213	64	3,868
2018	32	4,107	437	26	3,958
Min	**0**	**278**	**0**	**2**	**809**
Max	**1,096**	**16,926**	**830**	**163**	**7,862**
Ave	**51**	**2,918**	**122**	**52**	**3,661**
Total	**1,490**	**75,857**	**1,581**	**522**	**18,303**

Table 3. Query of MRIP data collected from Maine waters 1996 – 2018.

Year	Interviews	Anglers that Caught Shad	Total Shad Catch	Harvest
1996	1,146	2	3	0
1997	1,185	0	0	0
1998	1,528	2	2	1
1999	1,688	2	2	1
2000	1,539	2	2	1
2001	2,347	3	4	0
2002	2,002	1	1	0
2003	1,601	1	1	0
2004	1,369	2	3	0
2005	1,350	0	0	0
2006	1,292	3	6	1
2007	1,788	4	5	0
2008	1,510	5	12	1
2009	1,383	6	43	2
2010	1,440	7	11	0
2011	1,495	6	34	0
2012	1,569	6	50	0
2013	1,277	2	3	0
2014	1,770	4	6	4
2015	1,395	16	69	7
2016	1,549	28	90	10
2017	1,695	8	31	2
2018	1,444	7	17	3

Table 4. Expanded American shad catch, harvest and percent standard error (PSE) for Maine waters.

Year	Total Catch	Catch PSE	Total Harvest	Harvest PSE
1987	84,458	58.4	84,458	58.4
1992	1,149	70.7	574	100
1996	1,170	77.1	0	-
1998	461	70.5	231	99.5
1999	1,065	74.2	701	100
2000	1,137	70.7	552	100
2001	1,661	59	0	-
2002	438	100	0	-
2003	1,367	100	0	-
2004	1,545	100	0	-
2005	1,244	100	0	-
2006	8,566	74.8	1,428	100
2007	4,480	84	0	-
2008	4,812	66.9	303	98.2
2009	19,095	59.3	843	72.9
2010	9,423	66.2	0	-
2011	4,295	60.6	0	-
2012	17,620	67	0	-
2013	945	93	0	-
2014	779	97.6	779	97.6
2015	779	97.6	779	97.6
2016	8,870	52.2	1,740	88.1
2017	1,974	64.6	261	98.1
2018	45,146	83.2	4,108	90.8

Table 5. Reported commercial landings of American shad in Maine by gear.

Year	Gill Net	Trawl	Other	Total
1950	2,300		100	**2,400**
1951	47,400	100	28,700	**76,200**
1952	50,200		300	**50,500**
1953	27,000	100		**27,100**
1954	1,800	200		**2,000**
1955	6,500	100		**6,600**
1956	1,900	100		**2,000**
1957	6,800	700	100	**7,600**
1958	10,000	100		**10,100**
1959	1,600			**1,600**
1960	300			**300**
1961				
1962	100			**100**
1963				
1964				
1965				
1966		2,100		**2,100**
1967		100		**100**
1968			2,300	**2,300**
1969				
1970				
1971				
1972				
1973				
1974	400	100		**500**
1975	34,200	200	200	**34,600**
1976	14,300	400		**14,700**
1977	21,500	600		**22,100**
1978	24,300	200		**24,500**
1979	18,100	300	200	**18,600**
1980	27,500	500		**28,000**
1981	88,900	1,700		**90,600**
1982	25,100	400	300	**25,800**
1983	36,500	2,200		**38,700**

Year	Gill Net	Trawl	Other	Total
1984	31,000	2,200	100	**33,300**
1985	13,400	2,600		**16,000**
1986	21,500	1,600		**23,100**
1987	21,100	5,400		**26,500**
1988	29,000	2,600		**31,600**
1989	45,100	1,500		**46,600**
1990	11,046	758		**11,804**
1991	1,727	264		**1,991**
1992	1,085	362		**1,447**
1993	687	115		**802**
1994	972	79		**1,051**
1995	365	17		**382**
1996	976	94		**1,070**
1997	110	84		**194**
1998	96	328		**424**
1999	132	33	4	**169**
2000	214	77		**291**
2001	425	51		**476**
2002	6	12		**18**
2003		4		**4**
2004	8			**8**
2005		53		**53**
2006	663	24	24	**711**
2007	580	7	199	**786**
2008	20	18		**38**
2009	2,078	0		**2,078**
2010	55	218		**273**
2011	536			**536**
2012	3	77		**80**
2013	15			**15**
2014	0			**0**
2015	0			**0**
2016	160	0	2	**162**
2017	0	0	0	**0**
2018	0	0	0	**0**

Table 6. Harvester reported American and hickory shad catches 1998-2018. Maine passed a moratorium on directed commercial fisheries for American shad in 1998. *All data are confidential and may not be released to the public.*

Year	American Shad		Hickory Shad	
	Pounds Kept	**Pounds Discarded**	**Pounds Kept**	**Pounds Discarded**
1998	1,326	760	0	0
1999	291	301	0	2
2000	87	210	0	0
2001	461	0	0	0
2002	0	300	0	0
2003	54	0	0	0
2004	18	6	0	0
2005	159	35	0	0
2006	713	8	0	0
2007	399	4	0	0
2008	38	0	0	0
2009	2,075	185	0	0
2010	272	7,122	0	0
2011	536	8,683	0	0
2012	80	7,825	0	0
2013	17	5,082	0	0
2014	0	3,350	0	0
2015	0	2	0	0
2016	0	160	0	0
2017	0	0	0	0
2018	0	0	0	0

Table 7. Number of American shad larvae raised at the Waldoboro Hatchery and stocked in Maine Rivers, 1992-2018.

Year	Saco River	Medomak River	Androscoggin River	Main Stem Kennebec River	Sebasticook River	Kennebec River System
1992	0	230000	0	0	0	0
1993	0	61000	0	194400	0	194400
1994	0	30460	0	58800	0	58800
1995	0	318290	0	479612	0	479612
1996	0	327495	0	339319	320000	659319
1997	414201	208240	0	1615603	474313	2089916
1998	408575	269043	0	1381723	744163	2125886
1999	151774	17626	316967	1944712	839500	2784212
2000	259090	145900	522000	3374325	500004	3874329
2001	313560	213	308556	1496454	618879	2115333
2002	0	11143	295725	1571856	1013852	2585708
2003	0	0	1269842	5989358	1857184	7846542
2004	0	0	538613	4548947	382217	4931164
2005	0	0	96551	1105343	0	1105343
2006	0	0	0	262,131	0	262,131
2007	0	0	0	9,082,178	0	9,082,178
2008	0	0	712,286	1,396,689	288,507	1,685,196
2009	0	0	0	0	0	0
2010	0	0	0	0	0	0
2011	0	0	0	0	0	0
2012	0	0	0	0	0	0
2013	0	0	0	0	0	0
2014	0	0	0	0	0	0
2015	0	0	0	0	0	0
2016	0	0	0	0	0	0
2017	0	0	0	0	0	0
2018	0	0	0	0	0	0
Total	**1,547,200**	**1,619,410**	**4,060,540**	**34,841,450**	**7,038,619**	**41,880,069**

Table 8. Reported commercial landings of American shad from Maine state and federal waters.

Year	Pounds	Kg	Year	Pounds	Kg	Year	Pounds	Kg
1887	1,095,720	497,019	**1939**	9,266	4,203	**1979**	18,600	8,437
1888	839,256	380,687	**1940**	32,164	14,590	**1980**	27,958	12,682
1889			**1941**	47,800	21,682	**1981**	90,600	41,096
1890			**1942**	160,374	72,746	**1982**	25,883	11,741
1891			**1943**	360,923	163,715	**1983**	38,700	17,554
1892			**1944**	452,549	205,276	**1984**	33,414	15,157
1893			**1945**	637,620	289,224	**1985**	16,000	7,258
1894			**1946**	1,106,800	502,044	**1986**	23,012	10,438
1895			**1947**	304,395	138,074	**1987**	26,400	11,975
1896	366,738	166,352	**1948**	2,552	1,158	**1988**	31,881	14,461
1897			**1949**	4,908	2,226	**1989**	46,498	21,091
1898	1,152,000	522,547	**1950**	2,427	1,101	**1990**	11,804	5,354
1899			**1951**	76,164	34,548	**1991**	1,991	903
1900	820,400	372,133	**1952**	50,450	22,884	**1992**	1,450	658
1901	731,000	331,582	**1953**	27,294	12,381	**1993**		
1902	773,400	350,814	**1954**	1,981	899	**1994**	1,051	477
1903	1,143,600	518,737	**1955**	6,570	2,980	**1995**		
1904	1,259,400	571,264	**1956**	2,011	912	**1996**	354	161
1905	1,087,200	493,154	**1957**	7,613	3,453	**1997**	2222	1,008
1906	470,200	213,283	**1958**	10,098	4,580	**1998**	1326	601
1907	873,400	396,174	**1959**	1,635	742	**1999**	291	132
1908	1,881,800	853,584	**1960**	311	141	**2000**	87	39
1909	980,350	444,687	**1961**	154	70	**2001**	461	209
1910	847,200	384,290	**1962**	65	29	**2002**		
1911	1,386,400	628,871	**1963**			**2003**	54	24
1912	3,296,000	1,495,066	**1964**			**2004**	18	8
1913	2,088,400	947,298	**1965**			**2005**	159	72
1914	2,086,200	946,300	**1966**	2,072	940	**2006**	713	323
1915			**1967**	125	57	**2007**	399	181
1928	110,149	49,964	**1968**	2,311	1,048	**2008**	38	17
1929	36,123	16,385	**1969**			**2009**	2075	941
1930	88,635	40,205	**1970**			**2010**	272	123
1931	157,763	71,561	**1971**			**2011**	536	243
1932	107,891	48,939	**1972**			**2012**	80	36
1933	178,901	81,149	**1973**			**2013**	17	8
1934			**1974**	588	267	**2014**		
1935	13,000	5,897	**1975**	34,669	15,726	**2015**		
1936			**1976**	14,855	6,738	**2016**	162	73
1937	9,300	4,218	**1977**	22,100	10,025	**2017**		
1938	11,900	5,398	**1978**	24,500	11,113	**2018**		

Table 9. Mean catch-per-unit-effort of age-0 American shad from the Merrymeeting Bay complex in Maine. The complex includes Merrymeeting Bay and the lower Kennebec, Androscoggin, Eastern, Cathance, and Abagadasett rivers.

	Sample	Total	Arithmetic		Geometric	
Year	**Size**	**Catch**	**Mean**	**SE**	**Mean**	**SE**
1979	45	10	0.22	0.13	0.10	0.06
1980	57	9	0.16			
1981	58	29	0.50			
1982	59	9	0.15			
1983	53	42	0.79			
1984	45	32	0.71	0.33	0.29	0.09
1985	42	77	1.83	0.68	0.68	0.13
1986	62	32	0.52	0.21	0.22	0.06
1987	60	136	2.27	0.87	0.63	0.12
1988	100	1,377	13.77	8.88	0.52	0.11
1989	92	72	0.78	0.32	0.23	0.07
1990	98	211	2.15	0.69	0.51	0.09
1991	88	64	0.73	0.28	0.25	0.06
1992	79	62	0.78	0.31	0.26	0.07
1993	76	80	1.05	0.75	0.10	0.06
1994	93	24	0.26	0.13	0.09	0.04
1995	110	55	0.50	0.20	0.16	0.05
1996	89	111	1.25	0.92	0.21	0.06
1997	110	37	0.34	0.20	0.09	0.04
1998	112	40	0.36	0.28	0.06	0.04
1999	108	1,059	9.81	4.45	0.51	0.15
2000	111	398	3.59	2.25	0.29	0.08
2001	129	234	1.81	0.70	0.20	0.05
2002	127	316	2.49	1.23	0.45	0.07
2003	114	680	5.96	7.63	0.94	0.12
2004	105	1,356	12.91	7.09	1.02	0.13
2005	112	879	7.85	2.78	1.07	0.12
2006	120	2,148	17.90	6.66	1.75	0.14
2007	119	1,642	13.80	3.06	1.98	0.15
2008	104	680	6.54	1.56	1.59	0.13
2009	111	783	7.05	1.48	1.63	0.13
2010	114	1,547	13.57	4.15	1.66	0.14
2011	117	1,113	9.51	4.02	1.30	0.12
2012	118	1,135	9.62	5.05	1.21	0.12
2013	120	2,131	17.76	6.48	1.95	0.15
2014	120	1,300	10.83	2.91	1.53	0.13
2015	112	446	4.16	1.38	0.96	0.10
2016	116	297	2.56	0.60	0.83	0.09
2017	110	721	6.55	2.26	1.29	0.12
2018	120	237	2.07	0.56	0.59	0.08

Table 10. Mean catch per unit effort of age zero American shad from the Kennebec River above the former site of the Edwards Dam.

			Arithmetic		Geometric	
Year	Sample size	Total catch	Mean	SD	Mean	SD
2000	76	437	5.75	40.84	0.32	0.91
2001	63	1379	21.89	80.19	1.01	1.60
2002	64	1974	30.84	210.24	0.64	1.35
2003	46	702	15.26	55.21	0.73	1.49
2004	42	648	15.43	54.79	1.43	1.58
2005	41	3701	90.27	341.29	1.06	1.96
2006	48	4041	85.98	196.18	3.68	2.44
2007	50	9599	191.98	544.83	4.47	2.60
2008	10	668	66.8	104.92	7.51	2.14
2009	8	10	1.25	3.54	0.35	0.85
2010	21	681	32.43	126.02	1.8	1.91
2011	24	1901	79.21	159.98	4.44	2.41
2012	40	103	2.58	15.8	0.17	0.75
2013	0	0	-	-	-	-
2014	0	0	-	-	-	-
2015	32	85	2.66	9.89	0.37	0.96
2016	8	6	0.75	1.75	0.36	0.65
2017	8	0	-	-	-	-
2018	28	0	-	-	-	-

Table 11. Arithmetic mean and variation of number of American shad taken per tow in the spring survey in the near shore ocean waters of Maine

SPRING

	Number			plus/minus 2 SE		Weight			plus/minus 2 SE	
	mean	**SE**	**CV**	**Upper**	**Lower**	**mean**	**SE**	**CV**	**Upper**	**Lower**
2001	1.16	0.37	0.76	1.90	0.42	0.04	0.01	0.67	0.06	0.02
2002	3.05	0.50	0.39	4.05	2.05	0.15	0.03	0.48	0.21	0.08
2003	1.62	0.34	0.38	2.29	0.94	0.05	0.01	0.39	0.07	0.03
2004	0.45	0.11	0.46	0.67	0.24	0.02	0.00	0.53	0.02	0.01
2005	1.67	0.29	0.31	2.26	1.09	0.06	0.01	0.34	0.09	0.03
2006	8.72	1.59	0.39	11.91	5.54	0.32	0.06	0.40	0.44	0.20
2007	2.41	0.30	0.28	3.00	1.81	0.11	0.01	0.30	0.14	0.08
2008	0.98	0.35	0.78	1.68	0.29	0.03	0.01	0.51	0.05	0.02
2009	1.24	0.17	0.31	1.58	0.90	0.04	0.01	0.32	0.05	0.03
2010	1.31	0.25	0.43	1.81	0.80	0.05	0.01	0.43	0.07	0.03
2011	3.24	0.60	0.41	4.44	2.04	0.14	0.03	0.43	0.20	0.08
2012	3.06	0.34	0.26	3.75	2.38	0.21	0.02	0.29	0.26	0.16
2013	2.36	0.45	0.43	3.26	1.46	0.16	0.04	0.57	0.24	0.08
2014	1.53	0.37	0.57	2.26	0.80	0.08	0.02	0.63	0.13	0.04
2015	3.38	1.46	1.06	6.29	0.46	0.13	0.05	0.96	0.23	0.03
2016	3.26	0.66	0.49	4.58	1.95	0.13	0.03	0.59	0.20	0.07
2017	3.01	0.38	0.31	3.76	2.26	0.13	0.02	0.34	0.16	0.09
2018	3.07	0.60	0.49	4.28	1.87	0.10	0.02	0.50	0.14	0.06

Table 12. Arithmetic mean and variation of number of American shad taken per tow in the fall survey in the near shore ocean waters of Maine.

FALL	Number			plus/minus 2 SE		Weight			plus/minus 2 SE	
	Mean	**SE**	**CV**	**Upper**	**Lower**	**mean**	**SE**	**CV**	**Upper**	**Lower**
2000	0.56	0.18	0.75	0.92	0.20	0.04	0.01	0.79	0.07	0.01
2001	0.06	0.04	1.37	0.14	-0.01	0.01	0.00	1.30	0.02	0.00
2002	1.33	0.54	0.81	2.42	0.24	0.03	0.01	0.68	0.05	0.01
2003	5.45	4.52	1.43	14.49	-3.58	0.16	0.09	1.00	0.34	-0.02
2004	1.08	0.46	0.81	1.99	0.17	0.08	0.03	0.65	0.14	0.02
2005	2.81	0.37	0.21	3.56	2.06	0.25	0.03	0.18	0.31	0.20
2006	1.14	0.54	0.94	2.21	0.07	0.09	0.02	0.51	0.14	0.04
2007	13.15	7.26	1.11	27.68	-1.38	0.53	0.16	0.67	0.84	0.21
2008	1.78	0.43	0.47	2.63	0.93	0.20	0.05	0.46	0.29	0.11
2009	2.91	1.60	1.22	6.11	-0.28	0.39	0.21	1.17	0.80	-0.02
2010	1.10	0.51	0.93	2.13	0.08	0.07	0.02	0.67	0.12	0.02
2011	12.10	10.92	1.81	33.95	-9.75	0.29	0.09	0.63	0.47	0.11
2012	1.81	0.76	0.86	3.33	0.28	0.24	0.10	0.83	0.44	0.04
2013	2.33	0.69	0.71	3.70	0.96	0.37	0.09	0.57	0.54	0.19
2014	1.26	0.37	0.64	2.01	0.51	0.16	0.05	0.64	0.26	0.07
2015	16.33	10.67	1.31	37.67	-5.02	0.99	0.31	0.69	1.61	0.36
2016	2.22	0.59	0.57	3.39	1.05	0.29	0.06	0.51	0.42	0.16
2017	2.38	0.65	0.70	3.69	1.08	0.28	0.06	0.61	0.41	0.15
2018	1.67	0.40	0.52	2.48	0.86	0.20	0.04	0.47	0.28	0.11

Table 13. Fork length (cm) of American shad collected by bottom trawl in near-shore ocean waters of Maine.

Year	Season	Min	Max
2000	Fall	9	29
2001	Spring	12	26
	Fall	19	28
2002	Spring	12	28
	Fall	8	22
2003	Spring	10	19
	Fall	10	31
2004	Spring	11	24
	Fall	8	35
2005	Spring	12	24
	Fall	9	24
2006	Spring	9	25
	Fall	9	29
2007	Spring	7	30
	Fall	8	34
2008	Spring	10	28
	Fall	14	30
2009	Spring	11	25
	Fall	11	40
2010	Spring	9	22
	Fall	10	30
2011	Spring	9	28
	Fall	7	44
2012	Spring	8	39
	Fall	9	34
2013	Spring	10	30
	Fall	16	37
2014	Spring	12	47
	Fall	10	44
2015	Spring	12	42
	Fall	9	40
2016	Spring	8	48
	Fall	11	39
2017	Spring	10	43
	Fall	10	41
2018	Spring	12	26
	Fall	7	39

Figures

Figure 1. American shad habitat in Maine waters.

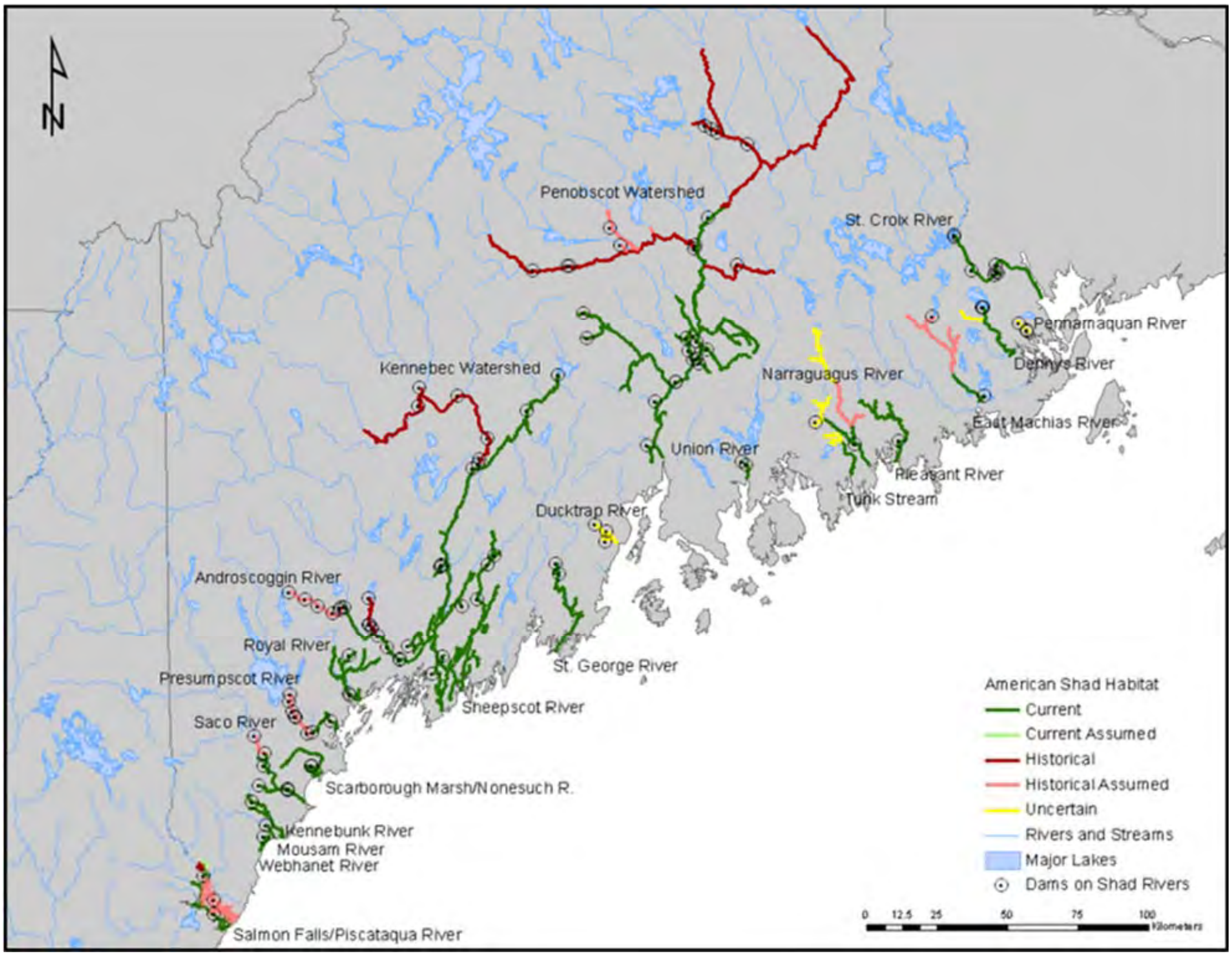


Figure 2. American shad caught and harvested based on unexpanded MRIP survey data 1996 – 2018.

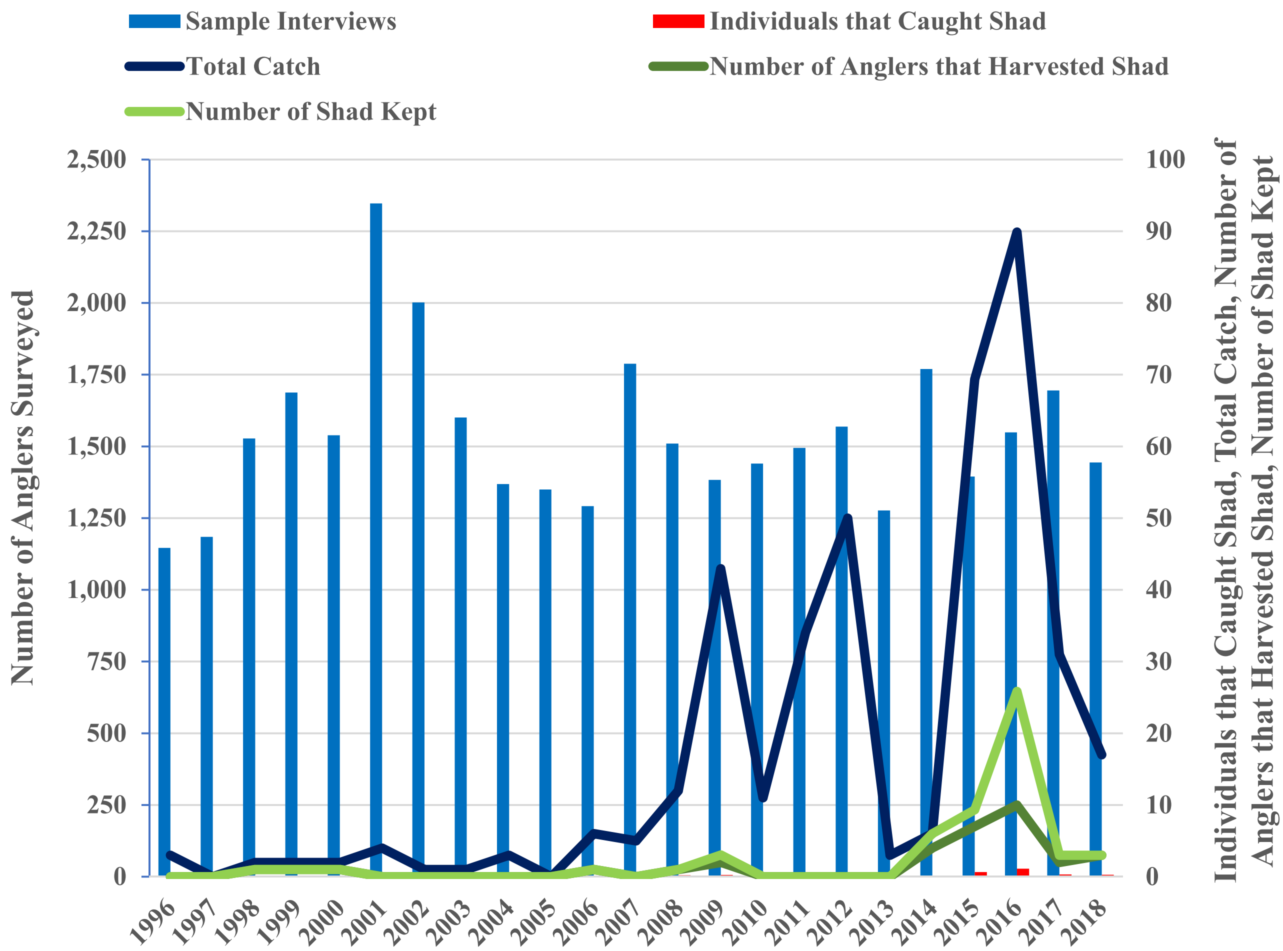


Figure 3. Commercial American shad landings for the State of Maine, 1887-2018.

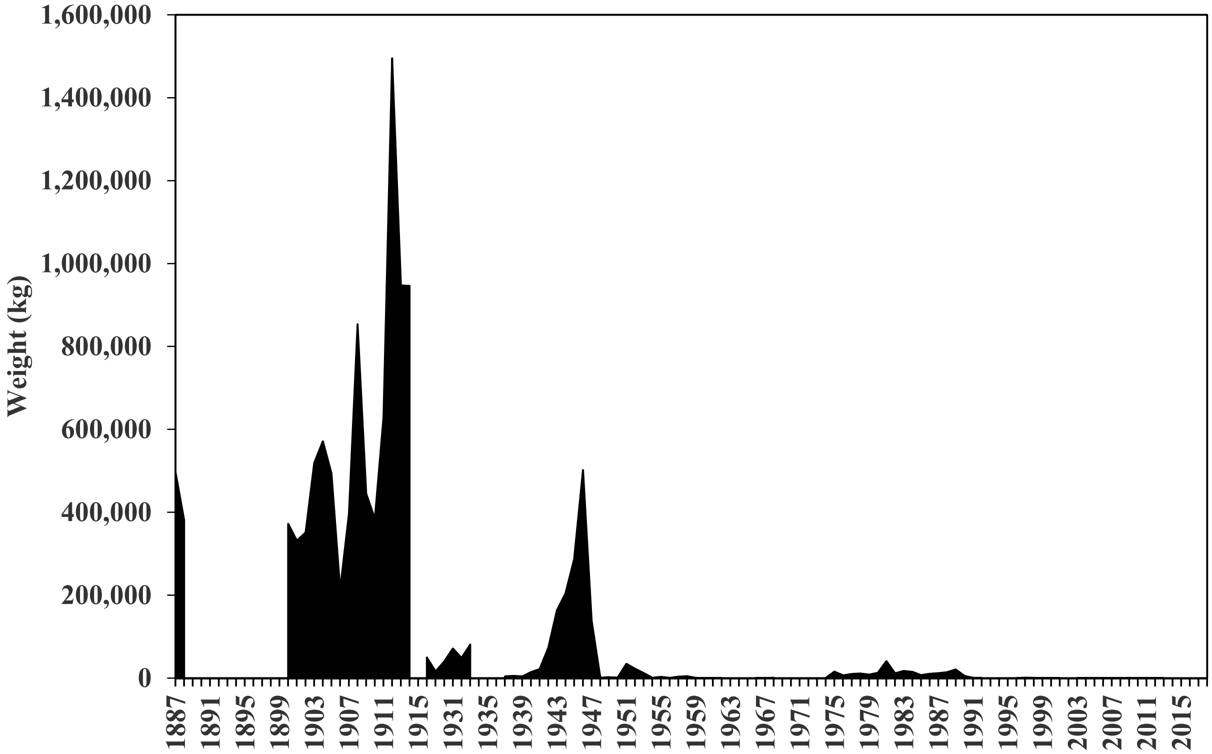


Figure 4. Juvenile alosine surveys sites in the Kennebec and Androscoggin estuary complex.

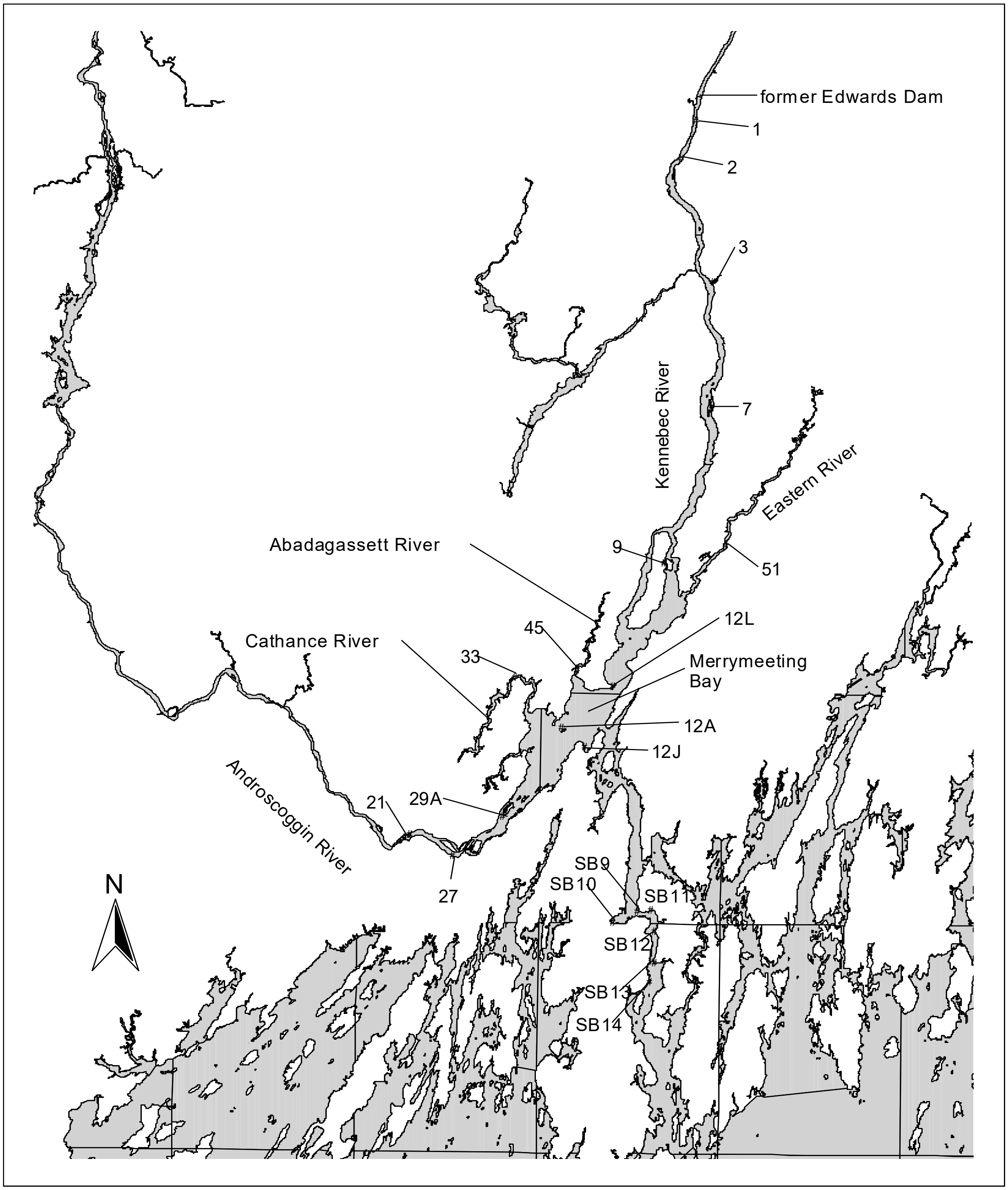


Figure 5. Beach seine sites in the non-tidal sections of the Kennebec River above the former Edwards Dam.

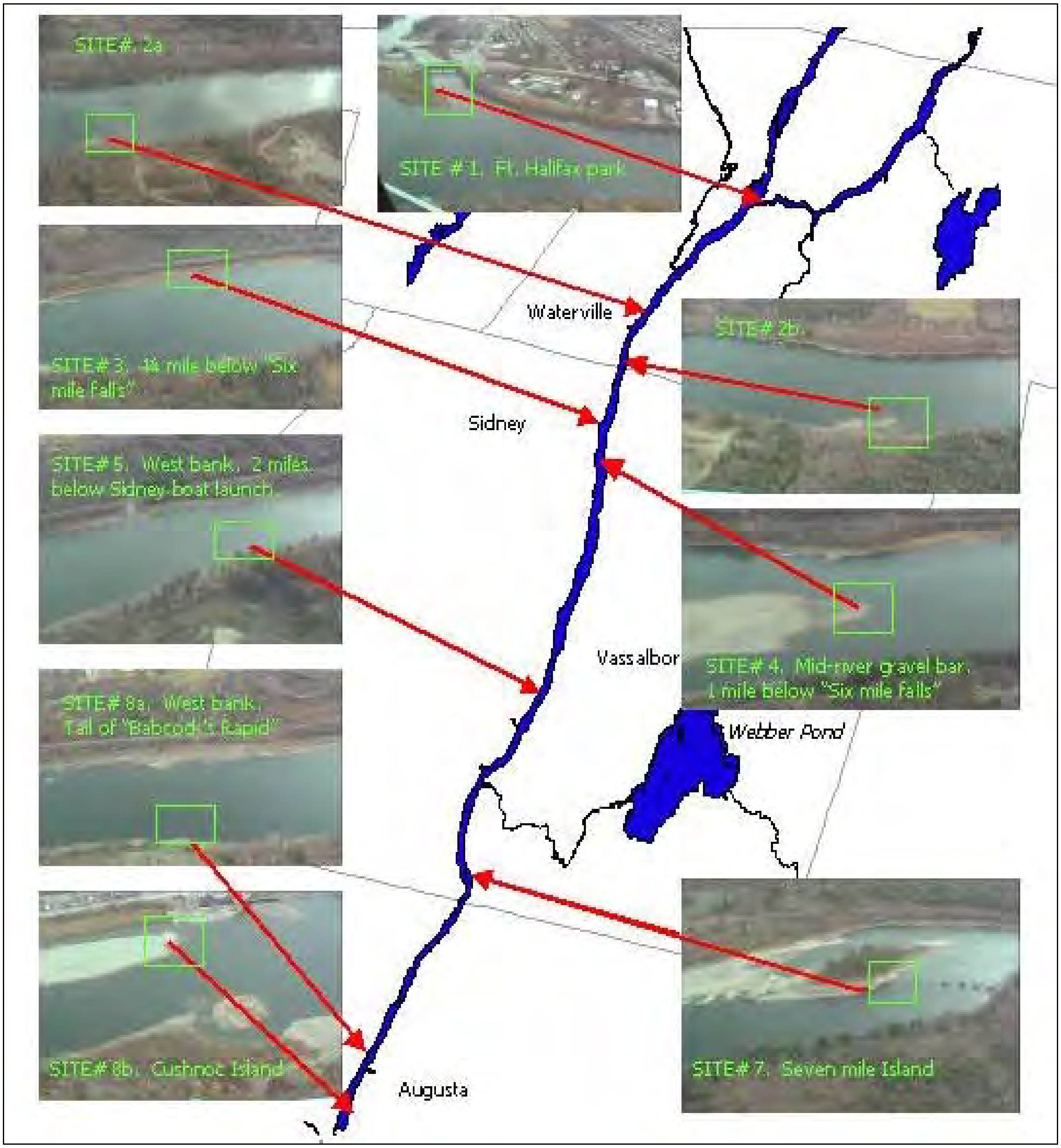


Figure 6. Geometric mean catch-per-seine-haul of age-0 American shad at sites in Merrymeeting Bay and the lower Kennebec, Androscoggin, Eastern, Cathance, and Abagadasett rivers.

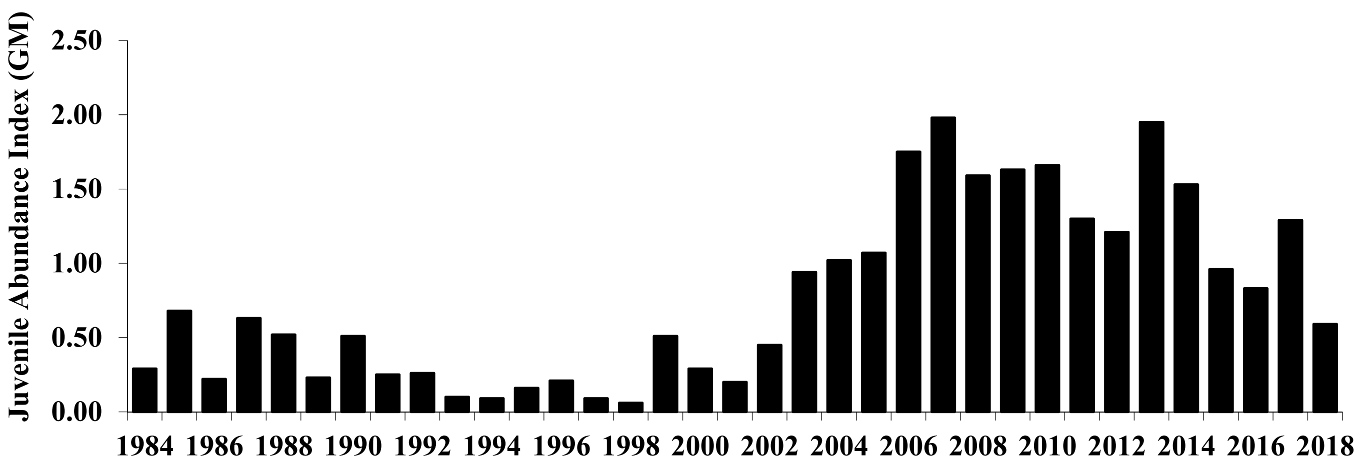


Figure 7. Geometric mean catch-per-seine-haul of age-0 American shad sites in the upper Kennebec River, Maine.

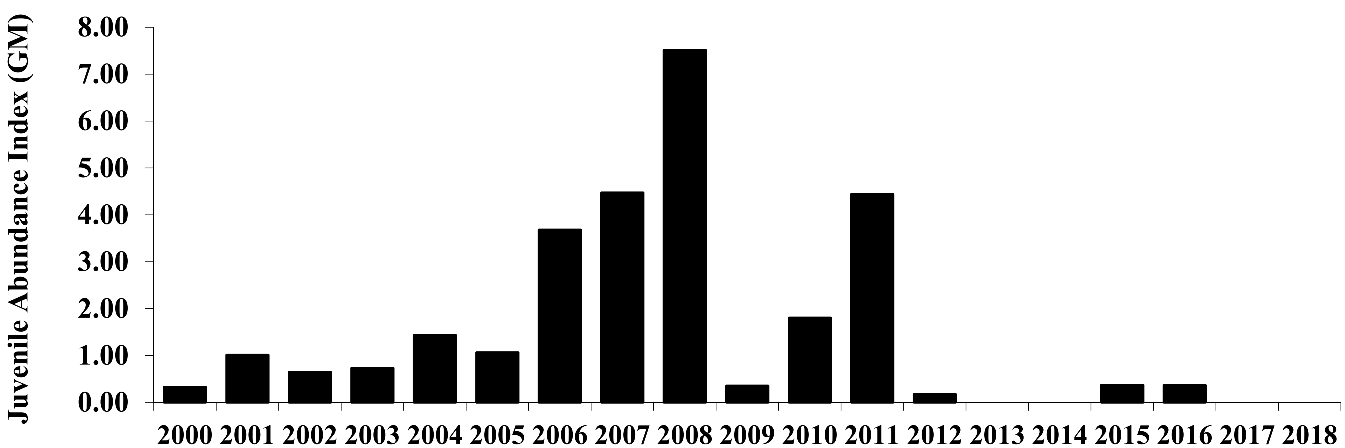


Figure 8. Ocean trawl sampling regions on the coast of Maine and New Hampshire.

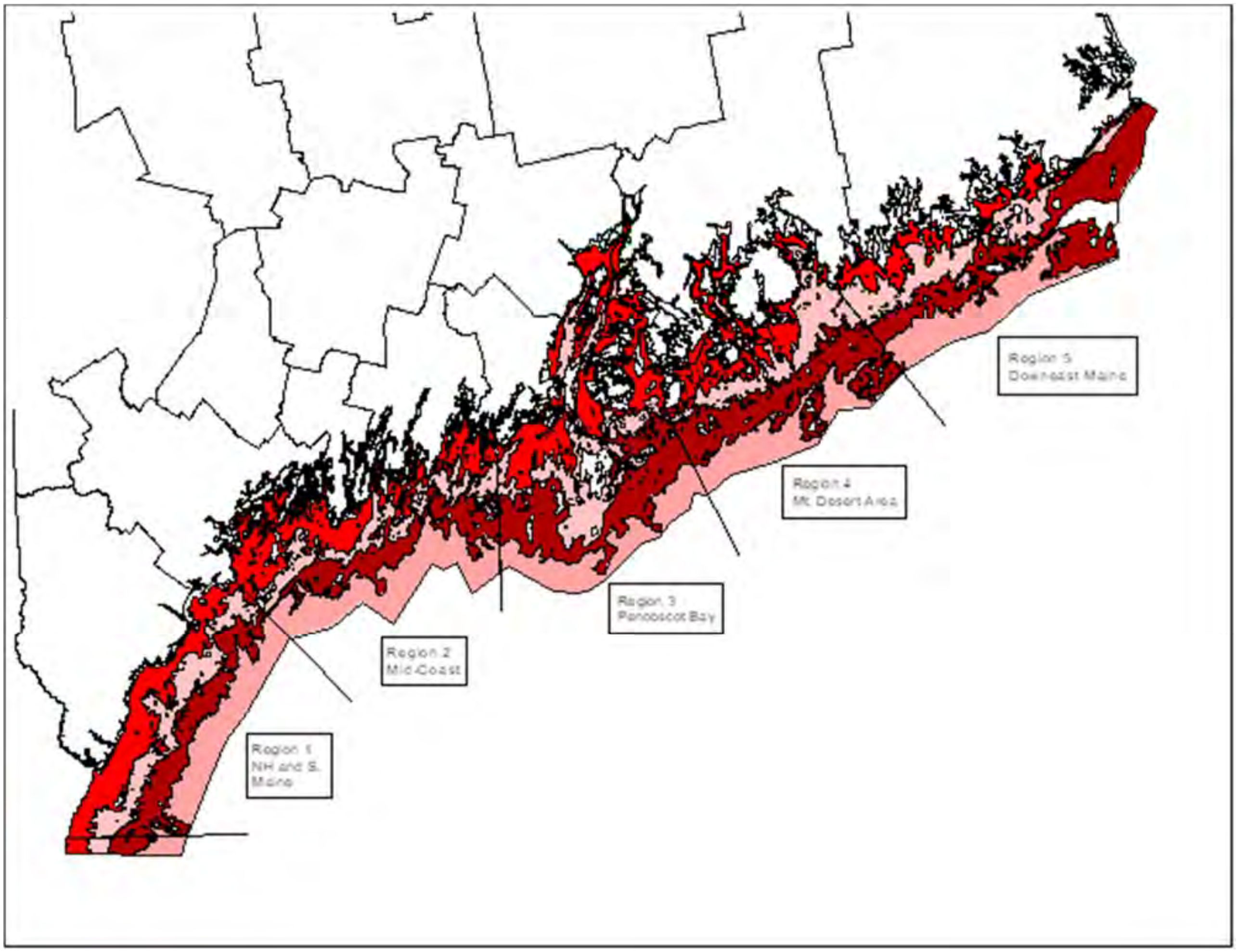


Figure 9. Catch-per-trawl of juvenile American shad taken in near shore ocean waters of Maine.

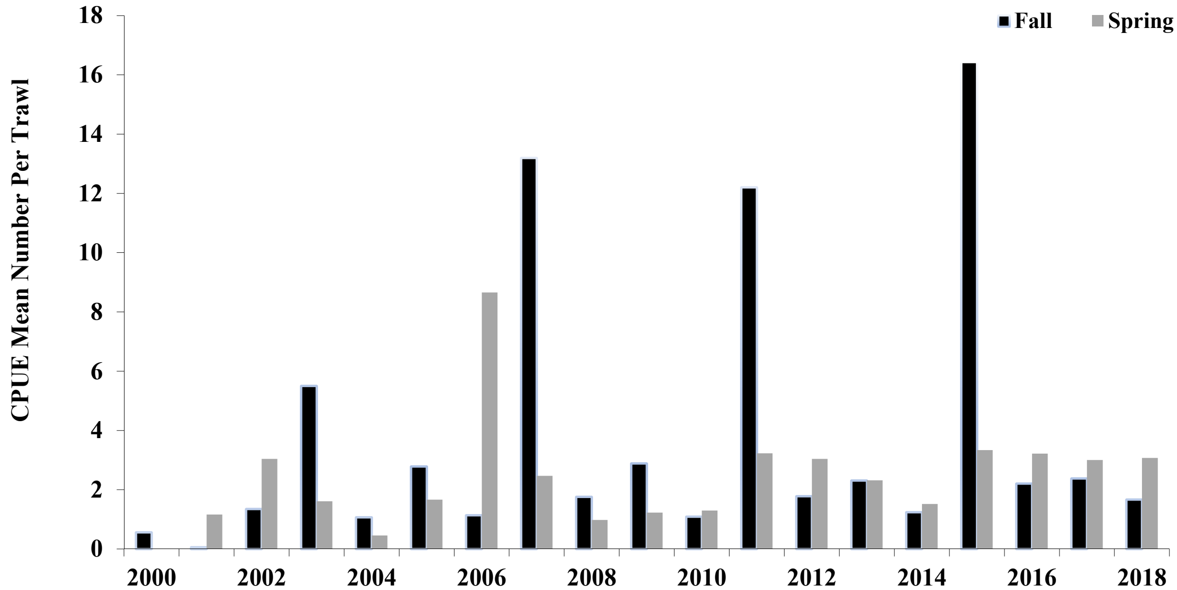


Figure 10. Percent occurrence of American shad captured for all tows conducted during the spring and fall trawl survey.

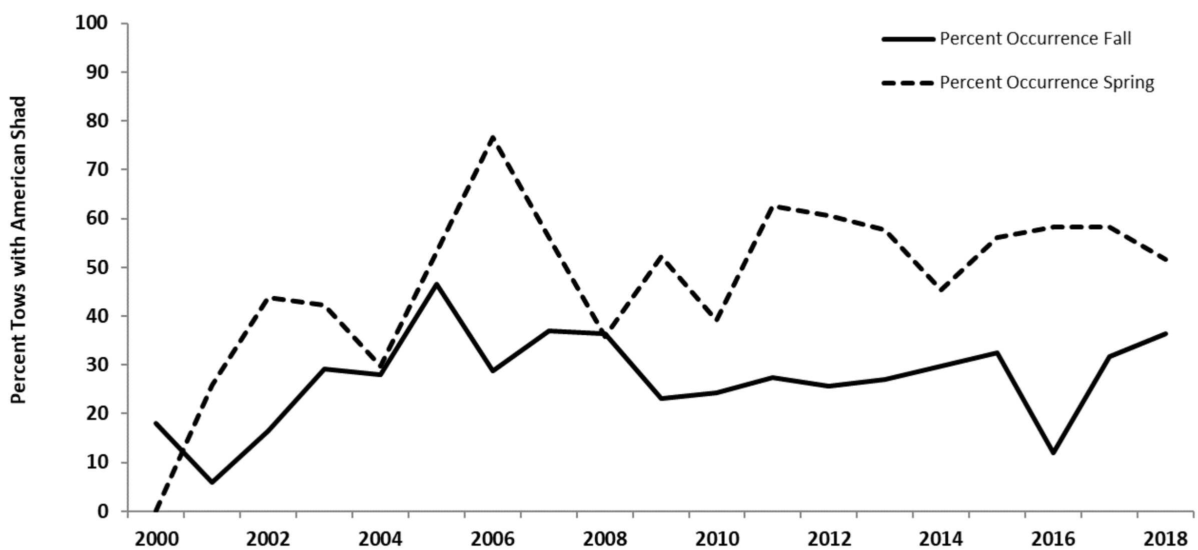


Figure 11.Stratified mean number and weight of American shad caught per tow during the spring trawl survey along the Maine coast.

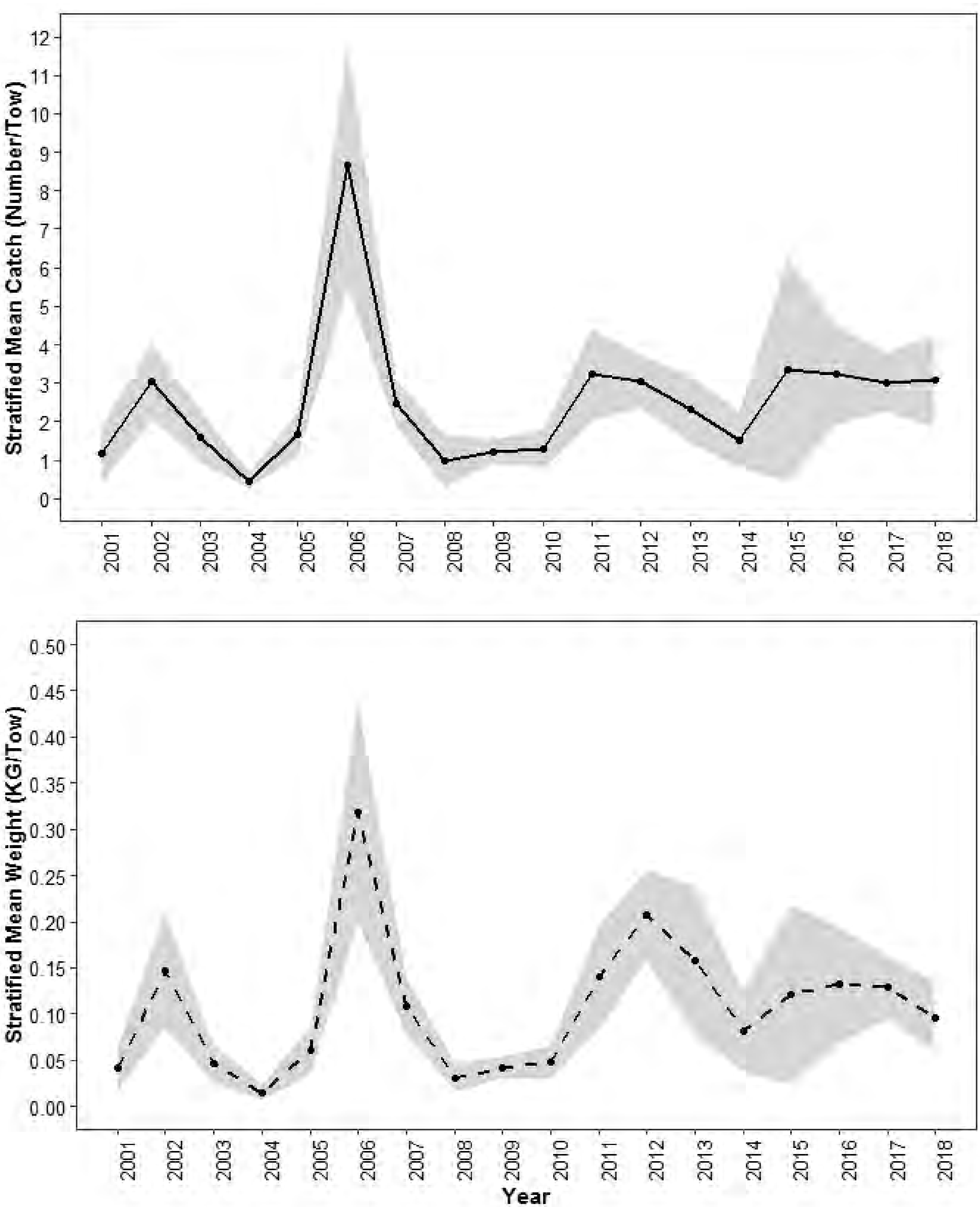


Figure 12. Stratified mean number and weight of American shad caught per tow during the fall trawl survey along the Maine coast.

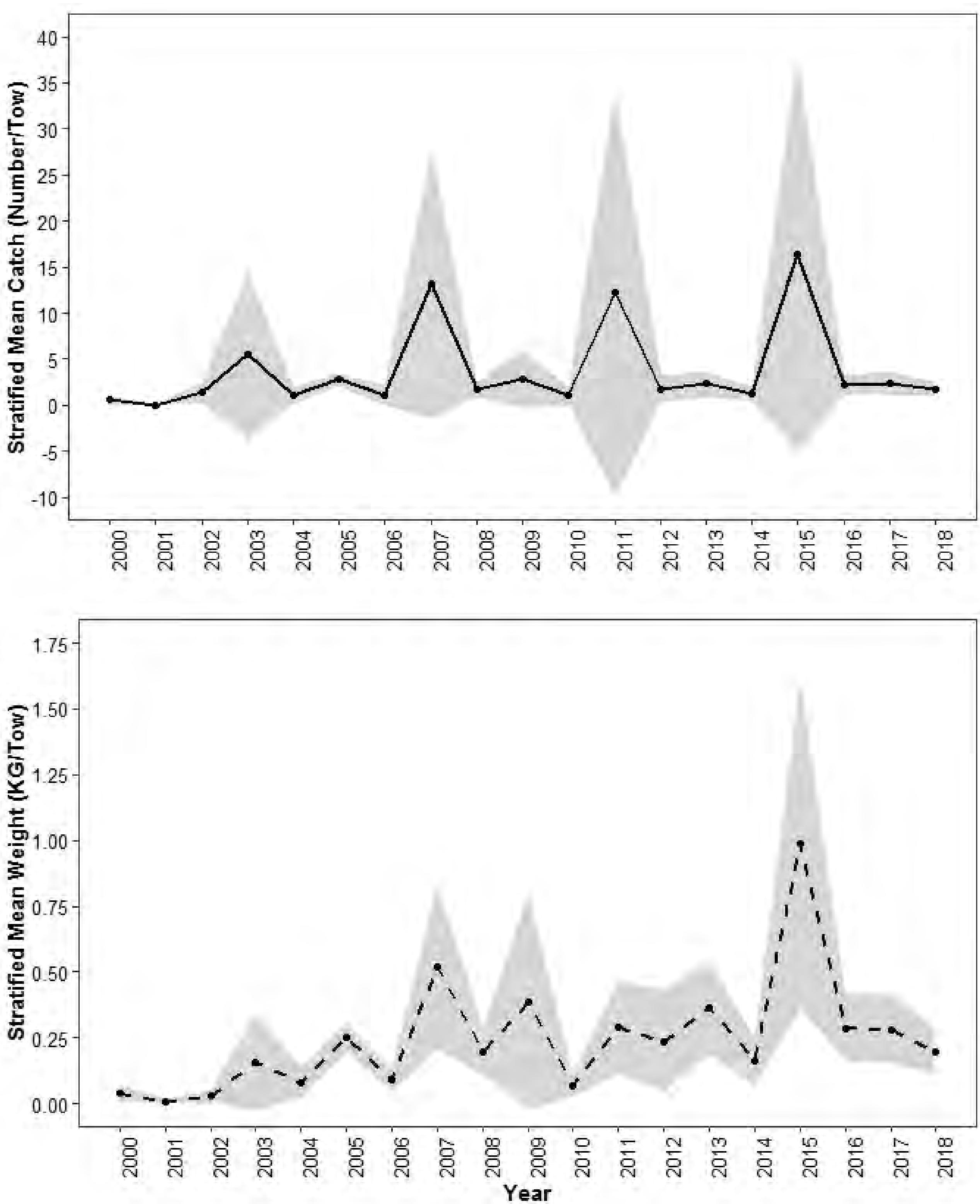


Figure 13. Cumulative upstream passage counts of American shad on all Maine rivers with counting capability.

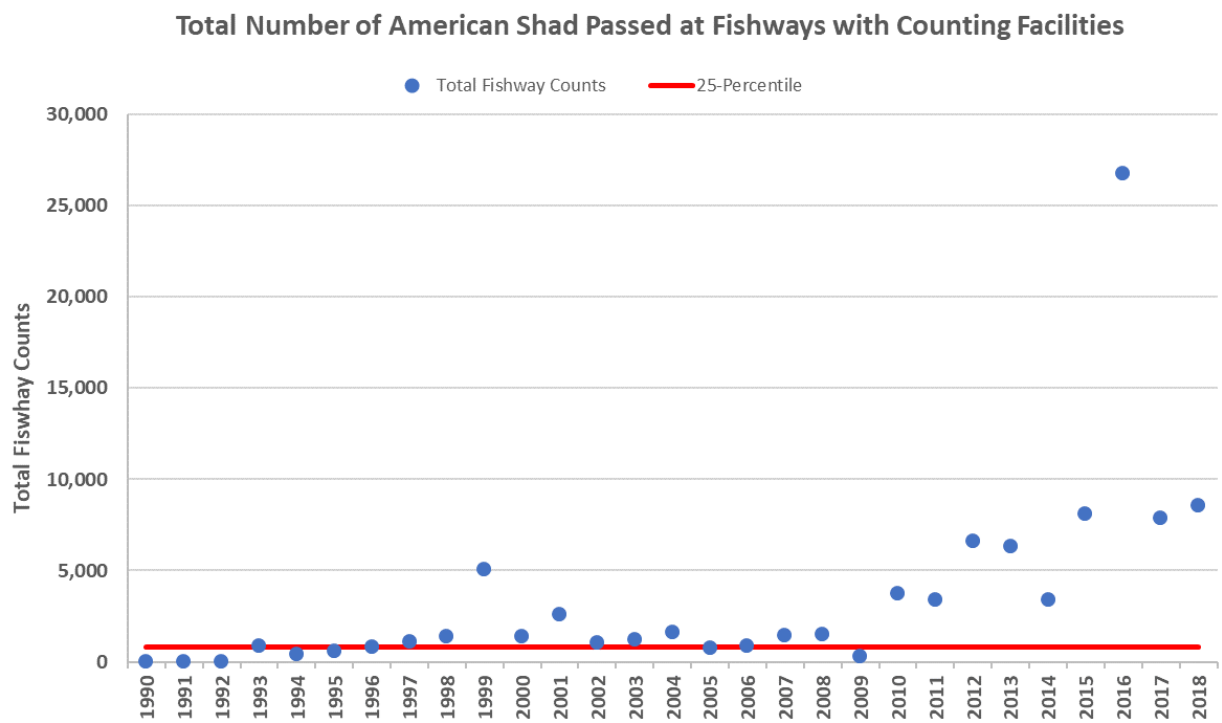
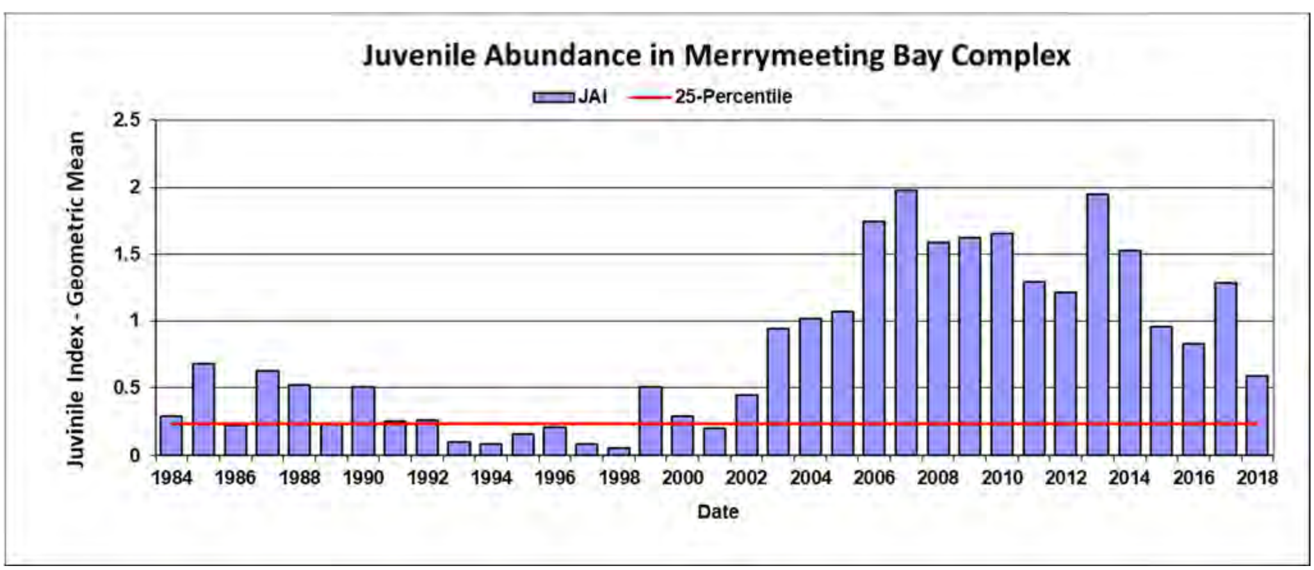


Figure 14. American shad JAI survey in Merrymeeting Bay 1984 – 2018.



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New Hampshire ASMFC River Herring Sustainable Fishing Plan

New Hampshire Fish and Game Department
March, 2020

Executive Summary

Introduction

The Atlantic States Marine Fisheries Commission's (ASMFC) Amendment 2 to the Interstate Fishery Management Plan for Shad and River Herring calls for states to close recreational and commercial river herring fisheries with an exception for systems with a sustainable fishery. The Plan defines a sustainable fishery as one "that demonstrates their alewife or blueback herring stock could support a commercial and/or recreational fishery that will not diminish potential future stock reproduction and recruitment." States and jurisdictions are required to develop sustainability targets with substantiated data, which "may include, but is not limited to, repeat spawning ratio, spawning stock biomass, juvenile abundance levels, fish passage counts, hatchery contribution to stocks and bycatch rates."

The unique ecosystem interactions found within a state or jurisdiction allow targets to be "applied state-wide or can be river and species specific." New Hampshire is proposing to use the extensive monitoring data from New Hampshire's largest estuary, the Great Bay Estuary System, to evaluate whether river herring stocks can continue to support a commercial and/or recreational fishery that will not diminish potential future stock reproduction and recruitment. River herring harvest in Great Bay Estuary accounts for 95-100% of the statewide harvest. In addition, New Hampshire Fish and Game (NHFGD) monitors river herring spawning stock returns at fish ladders on four of the seven major rivers in the Estuary and monitors juvenile abundance on an estuary-wide basis via a seine survey. Finally, Great Bay Estuary's unique geographical characteristics lend itself to monitoring the systems resource as a whole rather than on a river-specific basis. The estuary includes seven small to moderate size rivers with most flowing into a large embayment (Great Bay and Little Bay) before draining into a narrow, 15 km long opening to the sea via the Piscataqua River.

Current Regulations

The first law protecting river herring in New Hampshire state waters was enacted in 1967. This law required that any resident wishing to harvest river herring using a seine, net, or weir to obtain a license through the New Hampshire Fish and Game Department. Furthermore, in 1987 regulations prohibiting the taking of river herring on Wednesdays was established to provide a day of escapement for the fishery. In 2005, prior to adoption of Amendment 2, NHFGD took significant management action to reduce river herring harvest in the state. First, in the Exeter River, allowable harvest days were reduced from six to two days per week and a one fish tote per day possession limit was implemented. This action was taken following seven years of substantial increases in the river herring harvest in this river that accounts for the vast majority of the statewide river herring harvest. Second, a large portion of the Taylor River in the Hampton-Seabrook Estuary System was completely closed to the taking of river herring following long term and persistent declines in the river herring runs in the river. In 2012, the Oyster River was closed to the taking of river herring by any method from the head-of-tide dam at Mill Pond to the mouth of the river at Little Bay. This was in response to diminishing returns of river herring to the Oyster River fishway. These actions resulted in a significant reduction in statewide river herring harvest.

Current Status of Stocks

River herring stocks are managed on a statewide level within New Hampshire state waters. Annual return numbers have been monitored on six of the major coastal rivers, which demonstrate inter-annual variability in return numbers (Table 1). With the exception of return estimates produced in 1979, the number of river herring returning to spawn peaked in the early 1990's at nearly 300,000 fish, but has since gradually declined to levels between 100,000 and 200,000 fish. However, estimates of Z have shown a declining trend during this period (Table A4) and the percentages of repeat spawning fish in the rivers monitored in the Great Bay Estuary have ranged from 32% to 52% for all rivers combined since 2000 (Tables 6 and 7).

Changes in return numbers are most pronounced in the Oyster River where the number of returning fish increased steeply between 1985 and 1992 from less than 5,000 fish per year to more than 150,000 fish, followed by a steady, long term decline to less than 1,000 fish in recent years (Table A1). The declines in recent years may be related to low dissolved oxygen levels that have been measured during the summer months in the impoundment behind the fish ladder.

In the Exeter River, returns of spawning river herring to the fish ladder have been inhibited by the inefficiency of the ladder to pass fish. Significant spawning activity has been observed occurring below the fish ladder and reported harvest below this spawning area has consistently exceeded the ladder counts by large amounts indicating a much larger spawning stock than would be suggested by ladder counts. The Great Dam and associated fish ladder, just above the head-of-tide in the Exeter River, was removed in the fall of 2016.

In the Lamprey and Cocheco rivers, river herring returns have varied greatly without trend during the past two decades; building to a high time series level exceeding 90,000 fish in 2016 (Table A1). Spawning activity has also been observed occurring in significant numbers below the Lamprey River fish ladder. At present, the number of fish which reach and spawn below both the Lamprey and Exeter fish ladders are not quantified and therefore not included in the annual return values, making return or escapement numbers a minimum estimate.

High flows existed in all coastal rivers during April or May in the years 2005–2007, reaching "100-year flood" levels in 2006 and 2007. These high flows prevented river herring from being able to find and ascend fish ladders for significant periods during the spawning run leading to the lowest return numbers through the fish ladders in three decades. During those years, data obtained from the Great Bay Estuary juvenile abundance index seine survey exhibited increases in the geometric mean occurrence of both river herring species (Table 5). This data further suggests that return numbers determined by fish ascending fish ladders are a minimum value and that non-quantified numbers of river herring are successfully spawning below head-of-tide dams.

Sustainability Targets

River herring in New Hampshire are currently managed as a statewide management unit, but two sustainability targets, one fishery-dependent and one fishery-independent, will be established using exploitation rates and numbers of returning river herring per surface acre of available spawning habitat in the Great Bay Estuary. This method was chosen because at least 95% of the river herring harvest in New Hampshire occurs in this estuary and there are currently fish ladders on five of the seven rivers in the Great Bay Estuary, each of which are monitored by the Department annually (Table 3). Historical monitoring of river herring runs within New Hampshire have shown that the numbers of returning river herring to four rivers (Cocheco, Lamprey, Oyster, and Exeter rivers) have accounted for greater than 80% of the returning fish enumerated annually at fish passage structures on New Hampshire coastal rivers (Table 1). The Atlantic States Marine Fisheries Commission Shad and River Herring FMP states that "Definitions of sustainable fisheries and restoration goals can be index-based or model-based" and that "Member states or jurisdictions could potentially develop different sustainability target(s) for river herring based on the unique ecosystem interactions and…Targets can be applied state-wide or can be river and species specific." Therefore, New Hampshire will be using the stocks of river herring returning to the Great Bay Estuary system as an indicator of statewide river herring abundance and refer to them as the 'Great Bay Indicator Stock'. Using an estuary-wide versus river-specific approach is the best suitable method due to the physical/geographical characteristics of the Great Bay Estuary.

The sustainability plan for New Hampshire will include two separate targets, one fishery-dependent and one fishery-independent. The fishery-dependent target will be a harvest level that results in a harvest percentage (exploitation rate) that does not exceed 20% in the 'Great Bay Indicator Stock', providing an 80% escapement level. Specifically, a three-year running average of the total annual river herring harvest from throughout Great Bay Estuary will be compared to a three-year running average of minimum annual counts of spawning river herring returns documented via fish ladder counts on four rivers (Great Bay Indicator Stock) in Great Bay Estuary plus annual harvest of river herring throughout the estuary system. This is a very conservative target since the harvest from throughout Great Bay Estuary System (including seven rivers, Great Bay, Little Bay, and Portsmouth Harbor) is being compared to river herring return numbers counted at fish ladders on only four of the seven major rivers in Great Bay Estuary which represents some fraction of the total spawning river herring in the estuary each year.

For development of the fishery-independent target, New Hampshire initially used historical studies as a basis for the target used in Maine's River Herring Sustainable Fishery Plan that was previously approved by the Shad and River Herring Board. New Hampshire has never conducted studies to determine ideal densities of fish per acre of available spawning habitat, but the target was established based on studies conducted in the state of Maine during the 1970's and 1980's along with other historical information of annual river herring spawning runs in New Hampshire. Maine studies have indicated that an average return of 235 fish per surface acre and escapement rate of 35 fish per surface acre, allows for adequate harvest, escapement to maintain the run, and available broodstock to increase the run if desired. Using that analysis-based minimum annual escapement of 35 river herring per surface acre, a target value was calculated for the 207 acres of currently accessible spawning habitat in New Hampshire. This escapement level would only provide a minimum of 7,245 river herring returning to the Great Bay Estuary annually. New Hampshire believes that number would be insufficient to maintain current population levels, thus a second approach of calculating half of the mean annual return of river herring in the past 20 years was used to establish a proposed fishery-independent target escapement level of 350 fish per surface acre of available spawning habitat (72,450 fish). This target level is slightly above 50% of the mean annual river herring return to the Great Bay Estuary since 1990.

Proposed Regulation Modification to Support Target

Since recent estimates of exploitation in the Great Bay Indicator Stock have remained below 20% in recent years and total returns are above the 350 fish per acre of available spawning habitat, there are no proposed modifications to existing river herring management plans within New Hampshire state waters and no additional regulations or enforcement measures will be implemented until such a time that the sustainability targets are not met.

Adaptive Management

The Department annually monitors, evaluates, and quantifies fish passage levels along five major coastal rivers in New Hampshire (Cocheco, Oyster, Lamprey, Winnicut, and Exeter rivers). The harvest of river herring is determined through mandatory reporting of all fish taken by state permitted harvesters and through conduct of the federal Access Point Angler Intercept Survey. Fishery-independent data from the ladder monitoring and fishery-dependent data from the harvest of river herring will be reviewed annually to ensure that both sustainability targets are met within the Great Bay Indicator Stock. If the fishery-dependent target is not met, then the state will use one or more of the following management measures: 1) Add additional days of prohibited harvest of river herring; 2) Implement or lower a daily harvest limit for state-permitted harvesters; 3) Implement a daily catch limit for recreational anglers. If the fishery-independent target is not met, then the state will implement a prohibition on harvest of river herring to all fisheries operating in state waters. As a requirement of Amendment 2, this plan will be reviewed and updated as necessary or every seven years.

1. Introduction

The purpose of this river herring sustainable fishing plan is to ensure river herring populations in New Hampshire remain stable and fishing opportunities continue to exist.

New Hampshire's coastal rivers once supported abundant runs of river herring. They have been denied access to historical freshwater spawning habitat since the construction of milldams as early as the 1600s but more dramatically during the nineteenth century textile boom in many New Hampshire coastal rivers. Barriers eliminated American shad and Atlantic salmon populations, but river herring only declined in numbers because they utilized the small area of freshwater at the base of dams during spring runoffs for spawning.

Restoration of river herring populations in New Hampshire began with construction of fishways in the late 1950s and continued through the early 1970s by the New Hampshire Fish and Game Department (NHFGD) in the Cocheco, Exeter, Oyster, Lamprey, and Winnicut rivers in the Great Bay Estuary, and the Taylor River in the Hampton-Seabrook estuary. These fishways re-opened acres of freshwater spawning and nursery habitat for American shad, river herring, and other diadromous fish.

<u>'Great Bay Indicator Stock' Management Area:</u>

I. Physical Description:

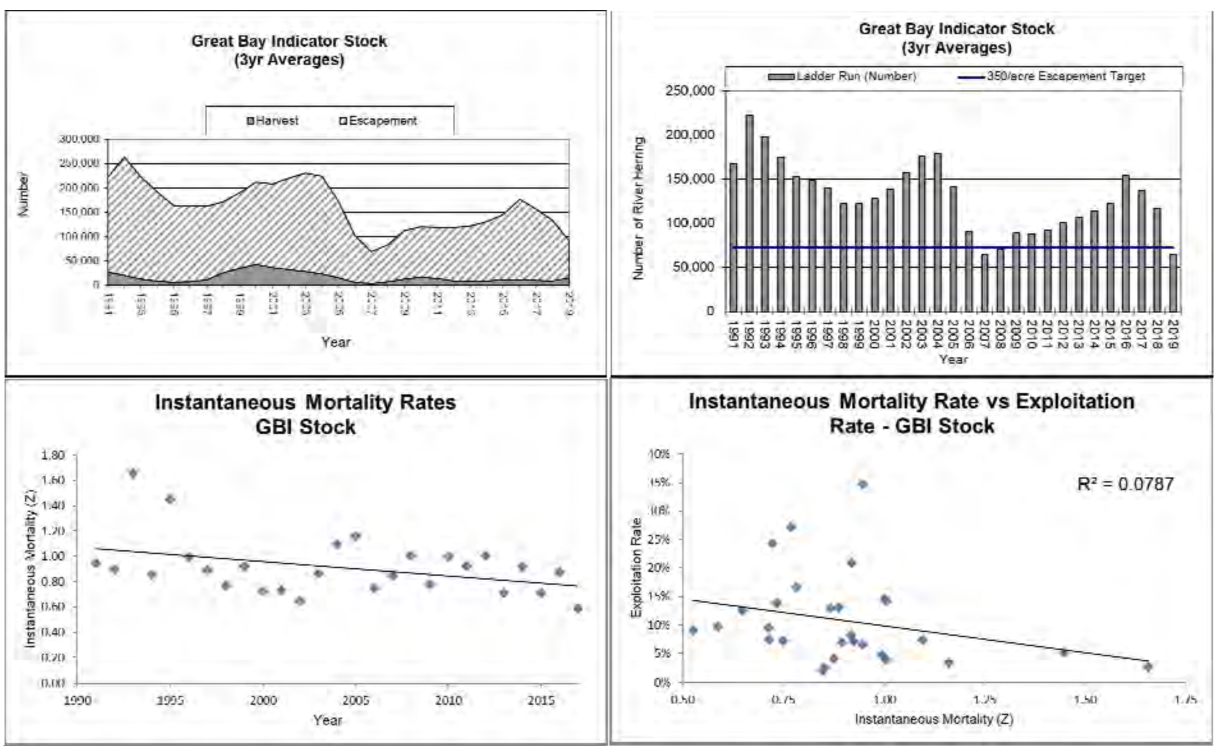
Amendment 2 states that the unique ecosystem interactions found within a state or jurisdiction allow for targets to be "applied state-wide or can be river and species specific." New Hampshire is proposing to use the extensive monitoring data from New Hampshire's largest estuary, the Great Bay Estuary System, to evaluate whether river herring stocks can continue to support a fishery that will not diminish potential future stock reproduction and recruitment.

The estuary includes seven small to moderate size rivers with most flowing into a large embayment (Great Bay and Little Bay) before draining into a narrow, 15 km long opening to the sea via the Piscataqua River. NHFGD monitors river herring spawning stock returns at fish ladders on four of the seven major rivers in the Estuary and monitors juvenile abundance on an estuary-wide basis via a seine survey. Analysis of juvenile river herring catch rates from the seine survey do not produce any significant correlations with annual ladder returns, river herring harvest levels, or exploitation rates, likely due to the estuary-wide design and the limited sampling rate in close proximity to river mouths during times of juvenile emigration in the late summer/fall. Fish passage structures on the four monitored rivers allow river herring access to approximately 207 surface acres of available spawning habitat. Great Bay Estuary's unique geographical characteristics lend itself to monitoring the river herring resource as a whole rather than on a river-specific basis.

II. Description of fishery:

River herring harvest in Great Bay Estuary accounts for 95-100% of the statewide harvest. The primary harvest of river herring in New Hampshire is for personal use as bait by anglers and lobster harvesters. The intensity of fishing effort and resulting harvest varies greatly between individual rivers, although the methods for harvest are almost primarily cast nets, dip nets, and gill nets in all locations. The annual river herring harvest numbers from the Great Bay Indicator Stock have ranged from approximately 3,200 fish to 43,600 fish (Table 3).

The exploitation rate is currently 17%, which is below the fishery-dependent target of 20% (Table 4) and the run is currently below the fishery-independent target of 350 fish per acre (Figure below and Table 1). In addition, both the three-year repeat spawning percentage of 44% (59% R-0, 19% R-1, 18% R-2, 4% R-3, 0% R-4; Tables 6 and 7) and the instantaneous mortality rates calculated from age data using the Chapman-Robson method are trending downward (Figure below and Table A4). Table A7 and the figure below shows is a significant correlation between mortality rates and exploitation rates. The trend of the data indicates that as the instantaneous mortality rate increases, the exploitation rate decreases.



New Hampshire's coastal area contains two major estuaries with the Great Bay Estuary System being the largest. The Great Bay Estuary includes seven small to moderate size rivers with most flowing into a large embayment (Great Bay and Little Bay) before draining into a narrow, 15 km long opening to the sea via the Piscataqua River (Figure 1).

The following is a description of each river in the estuary, a description of the river herring fishery, and other factors related to river herring management.

Cocheco River

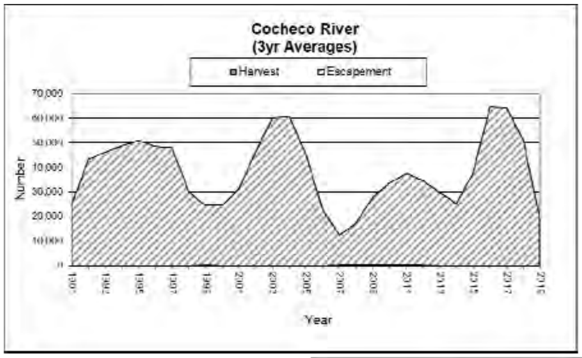
III. Physical Description of River, Watershed, and Impoundment:

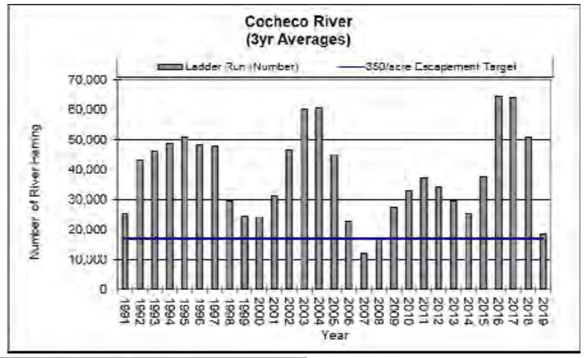
The Cocheco River flows 48 km southeast through southern New Hampshire to Dover where it joins the Salmon Falls River to form the Piscataqua River (Figure 1). The Piscataqua River flows approximately 15 km to the sea. The Cocheco River drains a watershed of 479 square km. The lowermost dam (4.6m high, built on a natural ledge for a total height of 8-10 m) on the Cocheco River is within the City of Dover, at rkm 6.1. This dam impounds an area of 20 acres. A Denil fish ladder, which provides access for anadromous fish to approximately 49 acres of potential spawning habitat, was constructed at the dam between 1969 and 1970 by NHFGD. The dam owner maintains a downstream migration structure which was replaced for increased efficiency in 2010 and modified again in 2017. The downstream passage system is a PVC tube emptying in a plunge pool below the dam, which successfully passes emigrating diadromous species when operating efficiently. The next barrier is a set of natural falls located at rkm 10.6. It has never been studied to determine if river herring can ascend this natural falls and continue migrating upriver a distance of 1.3 km to the Watson Dam in Dover, NH, during normal flow conditions. However, there is no fish ladder at this dam and no fish have been observed during occasional observations, but a downstream migration pipe is provided by the hydroelectric facility to accommodate emigration of enhancement stocking in upper river reaches.

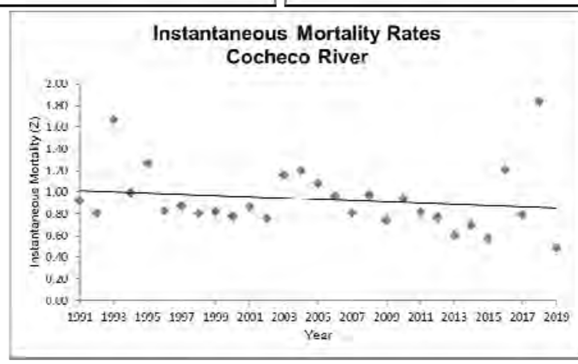
IV. Description of fishery:

The river herring fishery in the Cocheco River is very sporadic with very few fish harvested over the course of the last several years (Tables 3 and A2). Total annual in-river harvest has ranged from zero fish to approximately 600 fish (Table 4). Harvesters typically fish with cast nets, dip nets, or gill nets. The Cocheco River is closed to fishing from the fish ladder at the lowermost dam to the Washington Street Bridge, approximately 200 m downstream. Most of the river herring harvest occurs from the downstream side of the Washington Street Bridge to approximately 0.50 km downstream. In addition, there is a popular striped bass fishery that occurs along this stretch of river where recreational anglers “snag” river herring to be used as live bait.

The run is currently above the fishery-independent target of 350 fish per acre (Figure below and Table A1); has a three year repeat spawning percentage of 49% (48% R-0, 19% R-1, 28% R-2, 4% R-3, 1% R-4; Tables 6 and 7). The instantaneous mortality rates calculated from age data using the Chapman-Robson method are steady or slightly declining (Figure Below and Table A4), and there is no significant correlation between mortality rates and exploitation rates (Table A7 and Figure A1).







V. Ladder Efficiency, Spawning Area, and Water Quality:

Currently there are no concerns with the upstream passage efficiency of the existing fish ladder or the water quality throughout the spawning and emigration season in the Cocheco River. No spawning activity has been observed below the dam in recent years.

Lamprey River

I. Physical Description of River, Watershed, and Impoundment:

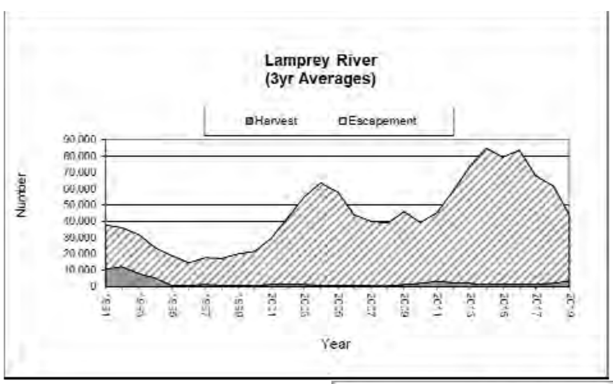
The Lamprey River flows 97 km through southern New Hampshire to the Town of Newmarket where it becomes tidal and enters the Great Bay Estuary just north of the mouth of the Exeter River (Figure 1). The mouth of the Lamprey River in Great Bay is approximately 27 km inland from the Atlantic coast. The Lamprey River watershed drains an area of 549 square km. It is the largest watershed that empties directly into The Great Bay. The Macallen Dam, located at rkm 3.8 in Newmarket, is the lowermost head-of-tide dam (8.2 m high) on the Lamprey River. A Denil fish ladder constructed between 1969 and 1970 for anadromous fish by NHFGD allows access to 120 acres of potential spawning habitat. The 3.4 m high Wiswall Dam is located 4.8 km upstream of the Macallen Dam and has a Denil fish ladder that was completed in January of 2012. The fish ladder at

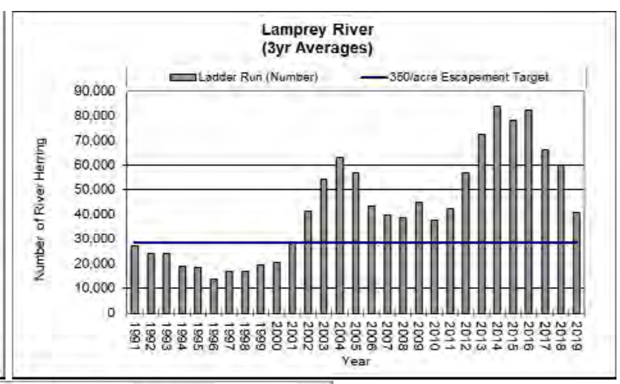
Wiswall Dam is owned and operated by the Town of Durham, NH, with technical advice and monitoring provided by NHFGD. This fishway provides access to another 5.8 km of river habitat up to the next barrier to fish passage, a partially breached dam at Wadleigh Falls in Lee, NH. There are no downstream passage facilities at the Macallen Dam and emigrating juveniles and adults must pass over the spillway. Fish kills have not been observed below the first dam suggesting that adults emigrate with limited mortality.

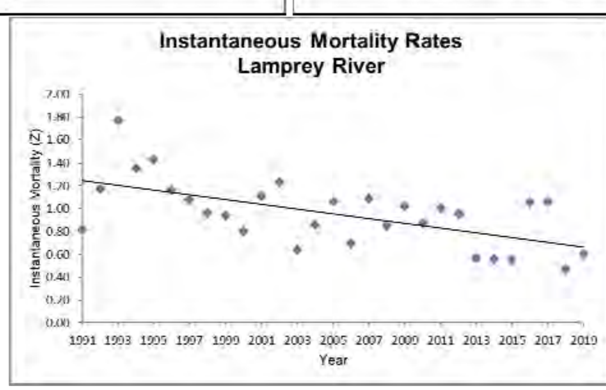
II. Description of fishery:

River herring fishing activity is very sporadic and harvest at the Lamprey River in recent years has been very low, usually less than 2,000 fish per year (Table 3). Landings are reported using a variety of methods including: cast net, gill net, dip net, and weir. Primarily the harvest occurs between approximately 70–500 m downstream of Macallen Dam. It is worth noting that each spring there is a very popular striped bass fishery that occurs within 350 m downstream of Macallen Dam and those anglers "snag" river herring to use as live bait.

The run is currently above the fishery-independent target of 350 fish per acre (Figure below and Table 1), has a three year repeat spawning percentage of 60% (39% R-0, 21% R-1, 29% R-2, 9% R-3, 0% R-4; Tables 6 and 7). The instantaneous mortality rates calculated from age data using the Chapman-Robson method are trending downward (Figure below and Table A4), and there is no significant correlation between mortality rates and exploitation rates (Table A7 and Figure A1).







III. Ladder Efficiency, Spawning Area, and Water Quality:

The run of river herring through the fishway each year tends to be mostly alewives. However, each spring towards the end of the annual migration a large number of blueback herring congregate just below the Macallen Dam. A small number of these blueback herring ascend the fishway, but the vast majority spawn below the dam. The area they spawn in is approximately 0.40 acre in size. Above the Macallen Dam, there is a variety of spawning habitat available for both alewives and blueback herring with no observed water quality issues, so it is unclear why most bluebacks spawn below the fishway/dam.

Oyster River

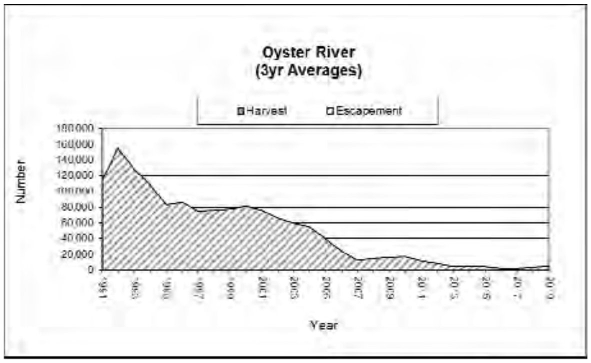
I. Physical Description of River, Watershed, and Impoundment:

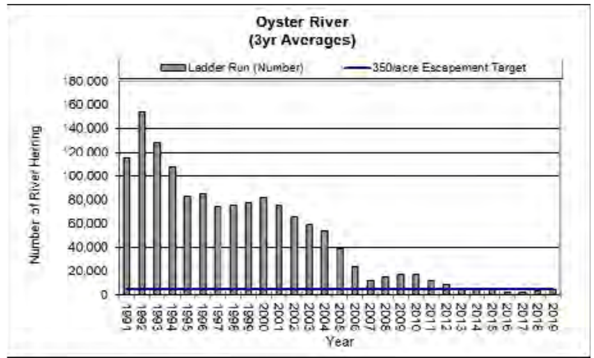
The Oyster River begins in the town of Barrington, NH. The size of the Oyster River watershed is approximately 67 square km. The Oyster flows southeasterly approximately 27.5 km through the towns of Lee and Durham and empties in Little Bay in the Great Bay Estuary (Figure 1). The mouth of the Oyster River lies approximately 19 km from the Atlantic Ocean. The head-of-tide dam occurs at rkm 4.8 in Durham, NH. There is a Denil fish ladder at this dam that was constructed in 1975. This fish ladder provides access to approximately 24 acres of potential spawning habitat. The next dam on the Oyster River occurs at rkm 8.0 and is a barrier to river herring passage.

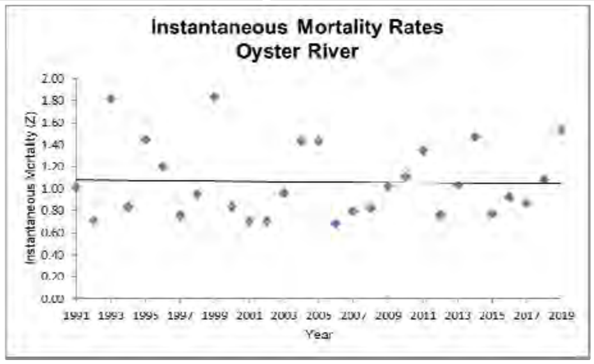
II. Description of fishery:

Prior to the harvest closure in 2012, there was typically very little river herring harvest that occurred in the Oyster River, usually less than 800 fish per year. The limited harvest that occurred was via dip net, cast net, or gill net.

The run is currently below the fishery-independent target of 350 fish per acre (Figure below and Table 1), has a three year repeat spawning percentage of 29% (74% R-0, 19% R-1, 5% R-2, 1% R-3, 0% R-4; Tables 6 and 7). The instantaneous mortality rates calculated from age data using the Chapman-Robson method appear steady (Figure below and Table A4), and there is no significant correlation between mortality rates and exploitation rates (Table A7 and Figure A1).







III. Ladder Efficiency, Spawning Area, and Water Quality:

The numbers of river herring returning to the Oyster River fishway have been decreasing since the mid 1990's. One possible explanation for the decline is diminishing water quality in the Mill Pond impoundment above the head-of-tide dam. Increasing eutrophication has been observed by NHFGD staff over the past several years. Due to this eutrophication, oxygen levels could be critically low while juvenile river herring are utilizing the impoundment as nursery habitat. In addition, the Oyster River is used as a municipal water supply. In years when river flows are lower than average very little water is observed flowing over the spillway of the head-of-tide dam. River herring can only emigrate from this impoundment over the spillway and thus become "trapped" in water with diminishing quality in years with low flows.

Squamscott/Exeter River

I. Physical Description of River, Watershed, and Impoundment:

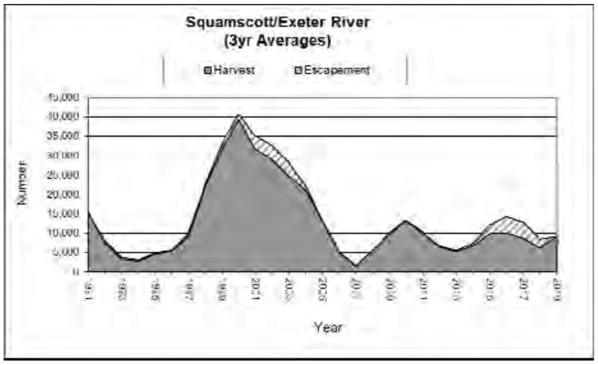
The Exeter River drains an area of 326 square km in southern New Hampshire. The river flows east and north from the Town of Chester to the Town of Exeter and empties into Great Bay northeast of Exeter (Figure 1). The head-of-tide occurs at the Town of Exeter and the saltwater portion of the river is called the Squamscott River. The two former lowermost dams on the main stem Exeter River in Exeter at river kilometer (rkm) 13.5, were removed in the fall of 2016. The next barrier is the Pickpocket Dam at rkm 26.9 (4.6 km high). Removal of the lower dams and a Denil fish ladder at the Pickpocket Dam provide access to approximately 62 acres of potential spawning habitat. The next barrier above Pickpocket Dam is a set of natural falls at rkm 38.1. The mouth of the Squamscott River in Great Bay lies approximately 27.4 km inland from the sea.

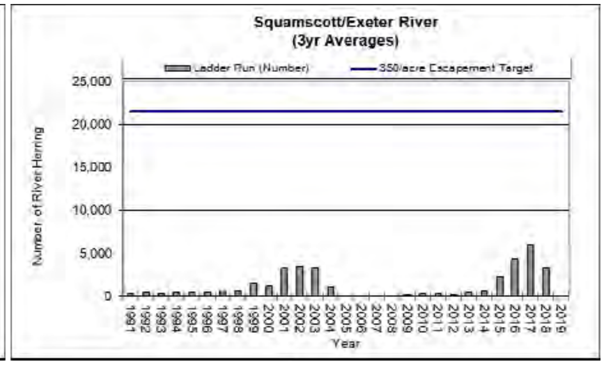
II. Description of fishery:

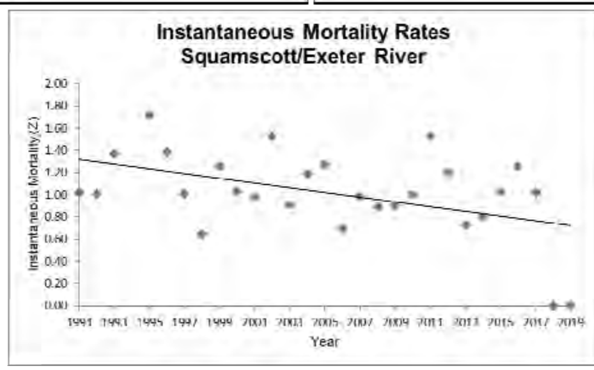
The river herring fishery that occurs in the Squamscott River is conducted to harvest river herring for personal use as bait for lobster and striped bass. The majority of the fishing occurs approximately 125 m downstream of the former Great Dam just to the northwest of the String Bridge. There is an elevated ledge under the String Bridge where migrating river herring gather in numbers waiting to ascend the falls. This is the area the harvesters focus their efforts. The gear types utilized by harvesters include; cast nets, gill nets, dip nets, and wire baskets. Despite being legally limited to just a two-day fishery and a one tote per day per angler limit, the Exeter River can still account for as much as 90% of the total New Hampshire harvest for river herring (Table 3).

In 2005, following a number of years of increased harvest in the Squamscott River, NHFGD implemented major changes to rules for river herring and shad in this river in order to reduce harvest levels. These changes included implementing a one-tote harvest limit per day and increasing the escapement days from one day per week to five days per week. Harvest levels since 2005 have been reduced by roughly 50% of the levels observed between 1998 and 2003 (Table 3) and estimates of instantaneous mortality since 2006 have been on average lower than those prior (Table A4). However, harvest in the Squamscott River has begun to increase in recent years.

The run is currently below the fishery-independent target of 350 fish per acre (Figure below and Table 1) and has a three year repeat spawning percentage of 26% (74% R-0, 18% R-1, 8% R-2, 0% R-3, 0% R-4; Tables 6 and 7). The instantaneous mortality rates calculated from age data using the Chapman-Robson method are trending downward (Figure below and Table A4), and there is no significant correlation between mortality rates and exploitation rates (Table A7 and Figure A1).







III. Ladder Efficiency, Spawning Area, and Water Quality:

The Exeter River is the only river monitored by the NHFGD that has available fresh water spawning habitat located below the fishway. NHFGD constructed upstream fish passage facilities (Denil fishways) on both dams from 1969 to 1971 for anadromous fish. Fish ladder improvements occurred in 1994 and 1999 at the Great Dam fishway and a fish trap was constructed at the upriver end of the fish ladder. In addition, improvements were made in the vicinity of the ladder entrance to enhance attraction flow during normal river flow conditions. Despite work to improve fish passage efficiency of the fish ladder at the Great Dam, the vast majority of river herring spawned below the fish ladder in an approximately 0.50-acre area of fresh water that occurs between head-of-tide and the former Great Dam caused by an elevated ledge that prevents saltwater incursion. River herring gathered in large numbers below the former Great Dam and spawning was observed. These observations combined with relatively high levels of documented harvest occurring each year below the former dam and the inefficiency of the fish ladder in passing river herring indicated that escapement to spawn in this river was much higher than measured by the number of river herring passing up river through the fish ladder. The former Great Dam and associated fish ladder were removed in the fall of 2016 and fish were observed freely passing the location in the spring of 2017. Work completed in the fall of 2017 allowed for comparably monitoring of the river herring reaching the Pickpocket Dam beginning in 2018.

There is no downstream fish passage facility at the Pickpocket Dam so emigrating adults and juveniles pass over the spillway when river flows allow. Poor water quality had been documented in the critical nursery habitat above the former Great Dam. Periodic water quality monitoring had recorded low levels of dissolved oxygen (DO) between the two dam locations in some years since 1995 (Smith et al. 2005; Langan 1995).

Other Rivers of Interest:

I. Physical Description of Rivers, Watersheds, and Impoundments:

There are four other major rivers of interest that are not monitored regularly by NHFGD staff. They are the Winnicut, Taylor, Bellamy and Salmon Falls rivers. The rivers range in length from 14.6 km for the Winnicut to 61 km for the Salmon Falls. Watershed sizes range from approximately 855 square km for the Salmon Falls to 28.6 square km for the Taylor River.

The Winnicut River flows directly into Great Bay in Greenland, NH. The NHFGD operated a Canada step-weir fish passage from approximately 1957 until 2009 on the Winnicut River. During the summer of 2009, the fish ladder and associated NHFGD owned dam were removed to restore the Winnciut River. While the dam removal drained a 34-acre impoundment, a run-of-river fishway was built just above the head-of-tide under a bridge constriction that is currently ineffective at passing most fish species.

The Bellamy River enters the Great Bay Estuary at Little Bay in Dover, NH. A partially breached timber crib dam at the head-of-tide at rkm 6.9 was removed to restore anadromous fish habitat in 2004. Since the removal, NHFGD staff has observed large numbers of river herring below the next dam complex (two consecutive dams) approximately 0.6 km upstream. These two dams were removed between 2018 and 2020. The first investigation of effective fish passage past these former dams will occur in the spring of 2020.

The Salmon Falls River joins the Cocheco River to form the Piscataqua River within the Great Bay Estuary. The head-of-tide dam is located at approximately rkm 6.7. A Denil fish ladder has been operated at this dam since 2002. The Salmon Falls River is a border river between the states of Maine and New Hampshire and the fish ladder and associated hydroelectric facility are on the Maine side, in the town of South Berwick. The hydroelectric operator is responsible for operation and maintenance of the fish ladder with technical guidance by both NHFGD and Maine Division of Marine Resources. The Denil fish ladder at the head-of-tide dam provides river herring access to a 58-acre impoundment. New Hampshire harvest estimates from the Salmon Falls River are minimal, with no reported harvest since 2014. The minimal harvest and location of the fish ladder on the Maine side of the river in South Berwick, ME, were considered justification for continuing to allow harvest in this river without direct annual monitoring by NHFGD.

The Taylor River is located in southeastern New Hampshire and is about 17.1 km long. The river begins on the border between Hampton Falls and Kensington, NH. It flows north, east, then southeast through Hampton Falls where it meets tidal water at Interstate 95. The lowermost 6.4 km of the river forms the boundary between Hampton and Hampton Falls. The first dam is located at rkm 3.2. There is a Denil fish ladder at this head-of-tide dam that was constructed in 1976. The next dam is a barrier to further fish passage and is located at rkm 5.1.

In December of 2014, the NHFGD submitted a proposal to the Atlantic States Marine Fisheries Commission (ASMFC) to withdraw its monitoring requirement of the Taylor River under Amendment 2 for the State of New Hampshire. The ASMFC Shad and River Herring Management Board approved the proposal in February 2015. Since spring 2015, the Taylor River fishway has been operated as a swim through with no regular monitoring or biological sampling performed by NHFGD. The fishway will be opened each spring in late April and closed in late June. Weekly visits by NHFGD staff to check for proper fishway operation will still occur.

River herring runs on the Taylor River have declined considerably from over 100,000 fish in 1986 (Table A1). The major cause of the decline is likely eutrophication of the Taylor River impoundment. The Taylor River fish run was estimated using a Smith-Root Model 1101 electronic fish counter. NHFGD staff made daily visits to the fishway during the migration to perform calibration counts and collect biological samples of river herring, if possible. The last time river herring were observed at the fishway was in 2008 when a total of seven fish were sampled. In addition to declining river herring returns, the Denil fishway at the Taylor River dam was constructed without a trap at the exit, which makes confirmation of fish passage difficult.

II. Description of fishery:

The Bellamy, Winnicut, and Salmon Falls Rivers have a very sporadic harvest ranging from 0 fish to as many as 2,548 fish at the Salmon Falls in 1999 (Table A2). Like many other New Hampshire coastal rivers, it is very difficult to capture river herring efficiently at these locations so harvest can occur anywhere along the tidal portion. However, in the Bellamy River some harvest does occur within the fresh water reach of the river just above the head-of-tide. Typically, gill nets, cast nets, and dip nets are used to harvest river herring at these locations.

After river herring returns diminished from around 100,000 fish in 1986 to 1,397 fish in 2003 and 1,055 fish in 2004, the Taylor River was closed to the taking of river herring by any method of netting in 2005. The closed section of river extends upriver from the railroad trestle bridge near Hampton Harbor to the first dam at the head-of-tide. No harvest of river herring was reported from the Taylor River from 1999-2004 and only 32 fish were harvested in 1998.

2. Current Regulations

The first law protecting river herring in New Hampshire state waters (inland and 0-3 miles) was enacted in 1967. This established that any resident or nonresident had to obtain a license to use a seine, net, or weir for the taking of river herring. In an effort to provide a day of escapement, the taking of river herring in state waters on Wednesdays by any method was prohibited in 1987.

The harvest of river herring by netting of any kind has been prohibited in the Taylor River from the section of the river upstream of the railroad trestle bridge to the first dam since 2005 due to declines in return numbers. Also, in response to a decline of river herring returns to the Exeter River fishway, new regulations were put in place in 2005 for the Exeter/Squamscott River in Exeter. The new regulations restricted netting to only Saturdays and Mondays. In addition, there is a one-tote limit per day. This location has consistently accounted for the vast majority of river herring harvest in New Hampshire (Tables 3 and A2). In response to diminishing returns of river herring to the Oyster River fishway, the Oyster River was closed to the taking of river herring by any method from the head-of-tide dam at Mill Pond to the mouth of the river at Little Bay in 2012 (Tables 1 and A1).

Currently there are no regulations establishing a length limit or daily bag limit for recreational anglers on either alewives or blueback herring within any tidal water body of the state. Additionally, there are no closed seasons to the taking of river herring by recreational anglers, except that they are prohibited from harvesting river herring on Wednesdays.

3. Brief Description – Current Status of Stocks

The New Hampshire Fish and Game Department manages river herring as a single statewide stock, although annual return numbers are monitored on a river-specific level through fish passage structures along five of the major coastal rivers within the state.
Each of the monitored rivers (Cocheco, Lamprey, Oyster, Exeter, and Winnicut rivers) demonstrate inter-annual variability in the number of returning fish due to various factors which are specific to each river (Table 1). Major factors affecting return values include uncontrollable variables related to environmental conditions (river flow levels, temperatures) and controllable variables such as passage efficiency and harvest levels. Data collection efforts of the Department have also indicated that numbers of returning fish are likely underestimates of actual stock size due to likely successful spawning activity occurring within rivers downstream of the monitored fish passage structures as well as non-monitored river systems that support additional small numbers of river herring returns within the state.

a. Landings

Commercial landings of river herring (fish that are sold via dealers) within the state are monitored through mandatory landings reports submitted annually to the National Marine Fisheries Service. Landings of river herring from commercial fisheries are generally incidental catch, and cannot be differentiated to a level indicating whether harvest occurs within or beyond New Hampshire state waters (Table 2).

The landings of river herring are primarily made through netting activities of state-permitted coastal netters (Tables 3 and A2). All individuals participating in netting of river herring within the state are required to annually submit trip-level reports of both fishing effort and harvest weight or numbers of river herring taken. The estimates of harvest by recreational anglers using hook and line are determined through the cooperative state/federal Marine Recreational Survey.

b. Fisheries Independent / Fisheries Dependent

The New Hampshire Fish and Game Department collects both fishery-dependent and fishery-independent data on an annual basis.

Fishery-dependent data is submitted by all state-permitted coastal harvesters as well as through reported annual harvest estimates produced by the cooperative state/federal Marine Recreational Survey. The data obtained on netting activities is area specific, but recreational angler data is only attributable to state or federal waters.

The majority of fishery-independent data is collected annually through monitoring of the six major coastal rivers in which the primary runs of river herring occur. The data collected provides river-specific enumeration of fish successfully passing the fishway as well as population structure analysis from scale and length samples taken periodically throughout the runs. The biological sample analysis allows the Department to track age structure, species and sex ratios, length distributions, and repeat spawning success of river herring within each river. A beach seine survey is also conducted at 15 fixed stations along New Hampshire coastal waters each month between June and November. Mean catch rates of juvenile river herring within the beach seine survey are used as relative indicators of occurrence of spawning activity from year to year. Although, the information was not used in formulation of the fishery-independent target due to estuary-wide design and limited sampling rate in close proximity to monitored rivers during times of peak juvenile river herring emigration in the late summer/fall months.

Analysis of fishery-independent and fishery-dependent data indicate that New Hampshire's river herring stock is relatively stable, but currently below the minimum target level of 350 fish per surface acre of available spawning habitat. Values of return numbers to the Great Bay Indicator Stock have consistently increased from 2007-2017 , but declined in 2018 and 2019 (Table 1). Estimates of Z have shown a declining trend (Table A4), the percentage of repeat spawners have remained between 32% and 52% (Table 6), spawning escapement has consistently exceeded 80% and exploitation rates since 2001 have remained below 20% until 2019 (Table 4).

c. Other

(None)

4. Fisheries to be Closed

a. Commercial

No commercial fisheries directed at harvest of river herring within New Hampshire state waters will be closed.

b. Recreational

No recreational fisheries directed at harvest of river herring within New Hampshire state waters will be closed.

5. Fisheries Requested to be Open

a. Commercial

River herring harvested in New Hampshire state waters are for personal use as bait in a variety of fisheries. Since these fish are not sold, there are no commercial fisheries occurring within New Hampshire state waters directed towards the harvest of river herring. Additionally, the National Marine Fisheries Service federal landings database that is inclusive of fishing harvest outside of New Hampshire indicates the recent annual river herring landings are negligible (Table 2). All commercial fisheries of river herring will remain open and the existing regulations will continue until such time that either the fisheries-independent or dependent targets have been met.

b. Recreational

Harvest of river herring occurring in New Hampshire is primarily through state-permitted coastal harvesters that fish for personal use, such as bait. As a result, this fishery is classified as recreational in New Hampshire. Upon all water bodies in New Hampshire (with the exception of the Exeter River) harvest of river herring is prohibited on Wednesdays and no daily limit exists. Netting in the Exeter/Squamscott River is limited to Saturdays and Mondays only between April 1 and June 30, and harvest is limited to one tote per day.

Similarly, hook and line anglers target river herring to be used as bait in a few relatively isolated locations, which are monitored through the cooperative state/federal Marine Recreational Survey with low frequency of harvest and poor associated precision values associated with those landings. There is currently no size or bag limit on river herring taken by angling in New Hampshire, but a closure to all river herring harvest on Wednesdays is in place.

All recreational fisheries will remain open in New Hampshire and the regulations stated above will continue until such time that either the fisheries-independent or dependent targets have been met.

c. Incidental

(None)

6. Sustainability Target(s)

a. Definition

The sustainability target will be established as a reference point and defined as a point below which sufficient escapement of spawning populations of river herring occurs to maintain annual runs at sustainable levels in New Hampshire.

River herring in New Hampshire are currently managed as a statewide management unit, but two sustainability targets, one fishery-dependent and one fishery-independent, will be established using exploitation rates and numbers of returning river herring per surface acre of available spawning habitat in the Great Bay Estuary. This method was chosen because 1) river herring harvest in Great Bay Estuary accounts for 95-100% of the statewide harvest, 2) New Hampshire Fish and Game monitors river herring spawning stock returns at fish ladders on 4 of the 7 major rivers in the Great Bay Estuary, and 3) monitors juvenile abundance on an estuary-wide basis via a seine survey. Historical monitoring of river herring runs within New Hampshire have shown that the numbers of returning river herring to these four rivers have accounted for greater than 80% of the returning fish enumerated annually at fish passage structures on New Hampshire coastal rivers (Tables 1 and A1). The Atlantic States Marine Fisheries Commission (ASMFC) Shad and River Herring FMP states that "Definitions of sustainable fisheries and restoration goals can be index-based or model-based" and that "Member states or jurisdictions could potentially develop different sustainability target(s) for river herring based on the unique ecosystem interactions and…Targets can be applied state-wide or can be river and species specific." Therefore, New Hampshire will be using the stocks of river herring returning to the Great Bay Estuary system as an indicator of statewide river herring abundance and refer to them as the 'Great Bay Indicator Stock'.

The fishery-dependent sustainability target will be set at a harvest level that results in a harvest percentage (exploitation) rate that does not exceed 20% in the 'Great Bay Indicator Stock', providing an 80% escapement level. Specifically, a three-year running average of the total annual river herring harvest from throughout Great Bay Estuary will be compared to a three-year running average of minimum annual counts of spawning river herring returns documented via fish ladder counts on four rivers in Great Bay Estuary plus annual harvest of river herring throughout the estuary system. This is a conservative target, since the harvest from throughout Great Bay Estuary System (including seven rivers, Great Bay, Little Bay, and Portsmouth Harbor) is being compared to river herring returns counted at fish ladders on only four of the seven major rivers in Great Bay Estuary, which represents some fraction of the total spawning river herring in the estuary each year.

Table 4 shows the calculated harvest percentages for each year in New Hampshire since 1989, based on rolling three-year averages. New Hampshire has remained below the sustainability target level of 20% harvest within the 'Great Bay Indicator Stock' for all but three years (Table 4) and in subsequent years following the high harvest percentages, the annual returns of river herring continued to increase for three consecutive years. This sustainability target allows for limited harvest of river herring within New Hampshire while still maintaining healthy populations of river herring.

For the fishery-independent target, New Hampshire is proposing to use a target similar to that used in Maine's River Herring Sustainable Fishery Plan, which was previously approved by the Shad and River Herring Board. New Hampshire has never conducted studies to determine ideal densities of fish per acre of available spawning habitat. Therefore, the target was created based on studies conducted in the state of Maine during the 1970's and 1980's, which have indicated that an average escapement rate of 35 fish per surface acre, allows for adequate harvest, escapement to maintain the run, and available broodstock to increase the run if desired. Using that analysis-based minimum annual escapement of 35 river herring per surface acre, a target value was calculated for the 207 acres of currently accessible spawning habitat in New Hampshire. This escapement level would only require a minimum of 7,245 river herring returning to the Great Bay Estuary annually. New Hampshire believes that number would be insufficient to maintain current population levels. Therefore, a second approach of calculating half of the mean annual return of river herring in the past 20 years was used to establish the proposed fishery-independent target escapement level of 350 fish per surface acre of available spawning habitat (72,450 fish). This target is slightly above 50% of the mean annual river herring return to the Great Bay Estuary since 1990 (Table A1).

b. Methods Used to Develop Target

River herring runs in New Hampshire have been monitored by the Department at fish ladders since initiation of restoration programs in the early 1970's. Seven fish ladders have been operated and maintained along six coastal rivers, although the lowermost dams and associated fish passage structures on the Winnicut River and Exeter River were removed in the fall of 2009 and 2016, respectively. At five of the locations (Cocheco, Oyster, Lamprey, Winnicut, and Exeter), river herring runs are enumerated and sampled for biological information such as age, sex, species, and repeat spawning occurrence when possible.

The period of peak abundance of returning river herring in the Great Bay Indicator Stock, occurred in the early 1990's (Table 1). Using a three-year running average, the greatest returning numbers occurred in 1992 followed by six years of successive decline in number of river herring and then six years of continued increase back to level comparative of the early 1990's. Return numbers have steadily increased in most recent years with values in 2017 that are more than double the time series low observed in 2007. The inter-annual variability of return numbers can be great, but many factors including weather, river levels, water temperature, and inefficiencies of fish passage structures play a large role in the variation.

An example of strong control by environmental conditions occurred in 2005, 2006, and 2007 when New Hampshire coastal rivers experienced flood conditions that reached "100-year flood" levels in 2006 and 2007. During years where persistent high river velocity exists in all coastal rivers in the state, many river herring are unable to reach or successfully ascend the fish ladders monitored by the Department. As a result, the passage inefficiency of fish ladders created by unusually high river flow levels, in turn reduces the annual return enumerations in those years.

Although annual river herring return values for 2005–2007 declined significantly from 2004, the previously mentioned flooding conditions were a large reason for potential underestimation during those years. Reviews of supplemental data such as young-of-the-year indices (Table 5) and percentage of repeat spawners within each river (Table 6) provide evidence of the population's health and relative stability despite reduced passage numbers. The supplemental data from the Great Bay Estuary juvenile finfish seine survey conducted by the Department showed increases in young-of-the-year indices for the two species of river herring in both 2006 and 2007 (Table 5), when the number of fish able to ascend the ladder were low. Since return numbers to the fish ladders were down those two years, large numbers of river herring may have still successfully spawned downriver from the fish ladders. Additionally, Table 6 shows that the percentage of repeat spawning fish that have been observed in the four rivers being monitored for the Great Bay Indicator Stock has been consistently high, ranging from 32% of returning fish in 2009 to 52% in 2006.

The majority of fishing effort and resulting harvest directed towards river herring in New Hampshire is conducted through state-permitted coastal harvesters using gear such as cast nets, gill nets, and dip nets. The harvest levels reported by harvesters also fluctuates between years, but is much more stable than return numbers (Table 3). All reported landings are associated with an area of fishing activity, which indicates that the large majority of river herring harvest comes from a single location, the Squamscott River (Tables 3 & 4). Collection of the harvest data by netters also has indicated that the enumeration of returning fish in the Exeter River fish passage structure is greatly underestimating the actual number of fish within that river system. This is particularly noticeable when the harvest percentages in the tidal portion is several times higher than the number of fish ascending the ladder, which would suggest that even though few ascend the fishway, many river herring in that location continue to spawn below the fish ladder.

Harvest estimates of river herring by recreational finfish anglers are also available through the cooperative state/federal Marine Recreational Survey, but infrequency of occurrence and poor levels of precision associated with the estimates make the data to unreliable for inclusion at this time (Table 2).

The Department reviewed the harvest percentages (exploitation rates) of river herring within the 'Great Bay Indicator Stock' locations between 1989 and 2019. To limit the variation between years, three-year rolling averages were used to establish both the annual return and the harvest portions of the harvest percentage. The resulting harvest percentages have ranged from as high as 26% in 2000 to 4% in 1995 (Table 4). Exploitation rate data was plotted against instantaneous mortality rates calculated from age data using the Chapman-Robson method (Figure A1). When a linear regression correlation was applied to the Great Bay Indicator Stock there was a significant correlation between the two factors, however there is no significant correlation within each river alone. Although there is a correlation between changes in the calculated instantaneous mortality rate and the exploitation rate, the plot indicates that years of high exploitation coincide with years of low mortality rate, and conversely years of low exploitation coincide with years of a high instantaneous mortality rate. This suggests that the exploitation rate is likely more dependent on the mortality rate than the mortality rate being dependent on the exploitation rate. Specifically, in years of low calculated instantaneous mortality rates, there are more fish returning and available for individuals to harvest, whereas in years of high calculated instantaneous mortality rates, there are fewer fish for state-permitted netters to harvest. Great Bay Indicator Stock exploitation rates have remained relatively low, near or below 15%, since 1991 but did increase briefly to near or above 20% from 1998 to 2002. This was driven by an increased effort and resulting harvest in the Squamscott River for unknown reasons, but prompted NHFGD to enact new regulations to limit the permitted harvesting at that location to only two days per week as opposed to the previous six days, as well as implementing a daily harvest limit of one tote per person. A brief increase in exploitation again occurred between 2009 and 2011, but never reached the 20% target (Table 4).

NHFGD does not currently have available data sufficient for analysis to determine an escapement target below which the river herring stock would be negatively affected. Therefore, the 20% fishery-dependent and 350 fish per surface acre fishery-independent sustainability targets from the 'Great Bay Indicator Stock' were set based on the downward trend of calculated instantaneous mortality rates, the correlation of exploitation rate and mortality rate that does not indicate that increased harvest corresponds to increased mortality, and the historical observations of fishing effort and exploitation rates. NHFGD feels that these two targets will provide a large enough resource of spawning river herring to maintain current population levels.

c. Monitoring to be Conducted to Support Target(s)

New Hampshire Fish and Game Department staff will monitor the return of river herring on the Cocheco, Lamprey, Oyster, and Exeter rivers, collectively referred to as the 'Great Bay Indicator Stock', on an annual basis. Monitoring of these river specific returns will include enumeration of fish successfully ascending the fish passage structure, maintenance of fishways to increase passage efficiency, and periodic biological sampling of river herring at each location throughout the run. Biological samples will be used to determine age, sex, repeat spawning percentage, and species distributions of the returning populations within each river in an effort to track relative health and stability of herring within each of the rivers. The enumeration from these four rivers of New Hampshire's primary river herring run will be used to calculate the return portion of the 3-year average harvest percentage of the 'Great Bay Indicator Stock.'

As supplemental information, a beach seine sampling study will be used to determine a mean catch per seine haul index of juvenile river herring within the Great Bay System. This relative annual index can be used to determine successful occurrence of river herring spawning activity between years, although the information was not used in formulation of the fishery-independent target due to estuary-wide design and limited sampling rate in close proximity to monitored rivers during times of peak juvenile river herring emigration in the late summer/fall months.

Mandatory reporting of harvested quantities and directed effort toward river herring is required by the ASMFC's FMP. The reported information must provide harvest data specific to a location or river system within the state. The harvest portion of the 'Great Bay Indicator Stock' will be calculated annually by totaling the number of river herring reported to be harvested from the Great Bay Estuary System. This will include the Great Bay, Little Bay, and Cocheco, Lamprey, Exeter, Bellamy, Salmon Falls, and Piscataqua rivers. The harvest and return portions of the 'Great Bay Indicator Stock' will then be used to ensure that the annual harvest percentage (exploitation rate) does not exceed the fishery-dependent sustainability target level of 20%.

The ladder counts and harvest information at each location will be used to ensure that the number of returning fish to the Great Bay Indicator Stock will remain above the fishery-independent target of 350 fish per acre of spawning habitat within the Great Bay Estuary (approximate 207 acre area), resulting in a target return of 72,450 river herring.

7. Proposed Regulation Modification to Support Target(s)

Since exploitation rates have remained well below 20% in recent years (Table 4), there are no proposed modifications to existing river herring management plans within New Hampshire state waters and no additional regulations or enforcement measures will be implemented until such a time that the sustainability targets are not met.

8. Adaptive Management

a. Evaluation Schedule

The New Hampshire Fish and Game Department annually monitors, evaluates, and quantifies fish passage levels along five major coastal rivers in New Hampshire (Cocheco, Oyster, Lamprey, Winnicut, and Exeter rivers). Returning fish are enumerated and sampled for biological information, including species, sex, age, and levels of repeat spawning. Monitoring of specified rivers will continue on an annual basis with the exception of the Winnicut River due to removal of the dam and associated fishway in the fall of 2009.

The harvest of river herring is determined through mandatory reporting of all landings by netters in New Hampshire state waters. Additional estimates of angling harvest are provided by the cooperative state/federal Marine Recreational Survey on an annual basis, but precision of those estimates is often very poor and are not reliable enough to be included in the annual harvest calculation. The harvest percentage (exploitation rate) will be determined annually and used to calculate a 3-year average value to compare to the sustainability target level of 20%.

b. Consequences or Control Rules

If the statewide harvest of river herring, determined by combining reported landings by state-permitted coastal harvesters from the 'Great Bay Indicator Stock' results in an exploitation rate that exceeds the fishery-dependent 20% sustainability target, the New Hampshire Fish and Game Department will take the following action:

i) Use landings and return data to identify the problem area(s) to determine whether over harvest of river herring is river or fishery specific.

ii) Once problem area is identified, one or more of the following measures may be used:

1) Add additional days of prohibited harvest of river herring. This could be statewide or in identified problem areas.

2) Implement or lower a daily harvest limit for state-permitted coastal netters at all areas or identified problem areas.

3) Implement a daily catch limit for recreational anglers statewide or in identified problem areas.

If the fishery-dependent target of 350 river herring per surface acre of available spawning habitat, 72,450 river herring, is not met, the New Hampshire Fish and Game Department will take the following action:

i) Implement a prohibition on harvest of river herring to all fisheries operating within state waters.

References:

Langan, R. 2004. Cooperative Institute for Coastal and Estuarine Environmental Technology. Unpublished data.

Smith, B., K. Weaver, and D. Berlinsky. 2005. The Effects of Passage Impediments and Environmental Conditions on Out-Migrating Juvenile American Shad. Final Report for NMFS Federal Aid Project no. NA03NMF4050199. 20 pp.

Table 1. Three-year running average of the number* of river herring successfully ascending fish passage structures in New Hampshire by river between 1989 and 2019. The Great Bay Indicator Stock rivers set the sustainability target.

	'Great Bay Indicator Stock'								
Year	Cocheco River	Lamprey River	Oyster River	Exeter River	Winnicut River+	Taylor River	Annual River Herring Return (# Fish)	'Great Bay Indicator Stock' Return (# Fish)	Percentage of Annual Return
1989	--	--	--	--	--	--	--	--	--
1990	--	--	--	--	--	--	--	--	--
1991	25,302	27,159	115,163	313	--	38,332	206,269	167,728	81%
1992	43,314	23,946	154,529	425	--	40,903	263,117	222,072	84%
1993	46,205	23,890	127,596	376	--	60,120	258,187	198,067	77%
1994	48,668	18,640	107,595	408	--	58,710	234,021	175,174	75%
1995	50,966	18,437	82,886	435	--	47,260	199,984	152,579	76%
1996	48,431	13,741	85,744	420	--	22,345	170,680	148,195	87%
1997	47,778	16,447	74,392	714	--	15,097	154,428	139,331	90%
1998	29,742	16,461	75,133	647	--	14,171	136,154	121,983	90%
1999	24,379	19,417	77,033	1,505	--	19,199	141,533	122,334	86%
2000	24,298	20,564	81,351	1,249	350	27,062	154,873	127,461	82%
2001	31,402	28,358	75,308	3,352	649	25,424	164,495	138,421	84%
2002	46,667	41,024	65,347	3,526	2,895	18,968	178,426	156,564	88%
2003	60,087	53,960	58,901	3,372	4,529	4,764	185,613	176,320	95%
2004	60,535	62,961	54,216	1,165	6,837	2,760	188,475	178,878	95%
2005	45,193	56,948	39,117	73	5,391	895	147,618	141,332	96%
2006	22,899	43,277	23,950	55	3,856	478	94,516	90,181	95%
2007	12,193	39,574	12,113	41	3,689	199	67,809	63,920	94%
2008	16,940	38,314	14,745	75	5,575	447	76,095	70,076	92%
2009	27,555	44,632	16,621	240	6,959	597	96,604	89,051	92%
2010	33,168	37,333	17,149	250	4,636	825	93,362	87,902	94%
2011	37,303	42,066	11,807	279	1,874	367	93,697	91,456	98%
2012	34,451	56,879	8,778	234	218	275	100,835	100,342	100%
2013	29,678	72,239	4,826	407	26	93	107,269	107,150	100%
2014	25,304	83,713	4,650	585	2	92	114,346	114,252	100%
2015	37,587	78,040	4,393	2,313	0	93	122,425	122,333	100%
2016	64,555	82,358	2,298	4,324	0	57	153,592	153,535	100%
2017	64,208	66,042	2,386	6,092	0	--	138,728	136,697	99%
2018	50,970	59,723	3,690	3,327	18	--	117,728	116,601	99%
2019	18,450	40,496	5,059	30	18	--	64,053	64,025	100%

** All numbers shown are 3-yr running average values of number of river herring returning.*

+ Winnicut River return numbers have been excluded from the return portion of the 'Great Bay Indicator Stock' because the dam and associated fish passage structure were removed in fall of 2009.

Table 2. Estimates of annual river herring harvest occurring in New Hampshire waters, derived from the cooperative state/federal Marine Recreational Fisheries Statistics Survey, with associated proportional standard error (PSE) values, and reported commercial landings+ from the federal landings database between 1989 and 2019.

	State/MRIP				Federal Landings Database	
	Blueback Herring		Alewife		Blueback Herring	Alewife
Year	Estimated Harvest (# Fish)	PSE	Estimated Harvest (# Fish)	PSE	Reported Landings (# Fish)	Reported Landings (# Fish)
1989	0	--	0	--	0	22,400
1990	0	--	0	--	0	0
1991	0	--	0	--	0	0
1992	0	--	0	--	0	19,604
1993	0	--	0	--	0	5,352
1994	0	--	0	--	0	0
1995	0	--	408	77.7	0	0
1996	0	--	0	--	0	0
1997	0	--	0	--	0	0
1998	0	--	0	--	0	51,988
1999	0	--	0	--	0	0
2000	0	--	0	--	0	0
2001	267	102.8	15,073	98.6	0	0
2002	0	--	0	--	0	0
2003	5,121	103.3	0	--	0	0
2004	0	--	0	--	0	0
2005	78	72.7	0	--	0	0
2006	0	--	0	--	0	0
2007	0	--	63,323	51.5	0	2,816
2008	0	--	154,208	71.6	0	16,264
2009	278	76.7	8,045	88.8	0	1,880
2010	0	--	14,681	89.0	0	14,932
2011	0	--	0	--	0	8,226
2012	42	102.6	34,991	84.2	0	5,362
2013	64	104.0	22,074	57.2	0	8,840
2014	5,246	98.4	61,271	54.0	0	0
2015	0	--	0	--	0	0
2016	0	--	0	--	0	0
2017	86	108.4	691	85.9	0	0
2018	0	--	13,581	85.4	0	0
2019	10,331	97.6	2,340	96.7	0	0

+ *Landings values are in numbers of fish landed by commercial harvesters within New Hampshire waters, but the location of harvest is exclusively from the EEZ*

Table 3. Number* of river herring harvested by state-permitted coastal netters in New Hampshire by location between 1989 and 2019; Areas used to calculate the harvest portion of the annual 'Great Bay Indicator Stock' used to set the sustainability target are shown.

Year	Cocheco River+	Lamprey River+	Oyster River+	Exeter River+	Winnicut River+	Bellamy River+	Salmon Falls River+	Great Bay+	Little Bay+	Portsmouth+	Piscataqua River+	All Other Locations	Statewide Total River Herring Harvested (# Fish)	Great Bay Estuary River Herring Harvested (# Fish)	% of Statewide Total
1989	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
1990	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
1991	0	10,565	385	15,224	297	1,163	61	13	0	0	326	1,467	29,502	28,035	95%
1992	19	12,058	620	7,618	74	946	68	4	0	0	20	1,023	22,451	21,428	95%
1993	34	7,952	927	3,315	80	551	112	4	3	0	20	532	13,530	12,998	96%
1994	34	4,900	855	2,767	44	47	98	13	3	0	0	468	9,229	8,761	95%
1995	16	410	621	4,606	27	164	180	13	3	0	1	98	6,139	6,041	98%
1996	2	703	522	5,274	366	238	223	14	0	0	7	44	7,393	7,349	99%
1997	105	1,053	715	9,068	375	237	594	5	0	0	17	42	12,211	12,170	100%
1998	116	917	752	21,792	368	445	1,045	1	63	0	25	634	26,158	25,524	98%
1999	140	730	384	31,432	23	543	1,807	3	63	83	43	930	36,182	35,253	97%
2000	70	897	386	39,347	24	770	1,871	3	72	83	65	1,243	44,831	43,588	97%
2001	57	1,228	504	31,631	24	820	1,762	3	62	83	76	628	36,879	36,251	98%
2002	47	1,135	574	29,097	24	1,007	997	0	62	0	52	317	33,312	32,995	99%
2003	25	1,214	444	24,808	0	844	650	15	53	0	20	3	28,077	28,074	100%
2004	82	770	475	21,051	0	518	232	15	0	0	0	127	23,270	23,143	99%
2005	85	873	363	13,215	19	369	158	15	0	0	0	127	15,224	15,097	99%
2006	114	614	305	5,084	163	435	32	2	0	0	0	127	6,875	6,748	98%
2007	171	505	103	1,552	243	610	15	2	0	0	0	0	3,202	3,202	100%
2008	334	438	86	5,488	282	569	18	3	0	0	10	0	7,228	7,228	100%
2009	482	1,279	74	9,685	137	694	31	1	0	0	10	0	12,394	12,394	100%
2010	579	1,912	96	13,152	58	569	55	1	0	0	10	0	16,432	16,432	100%
2011	399	2,940	69	10,015	0	580	59	0	0	0	0	0	14,062	14,062	100%
2012	211	2,230	39	6,459	4	505	48	10	0	0	0	0	9,506	9,506	100%
2013	7	1,730	2	5,169	4	575	20	10	0	0	0	0	7,516	7,516	100%
2014	8	1,298	0	6,645	4	604	3	16	20	0	0	0	8,599	8,599	100%
2015	8	1,473	0	9,844	0	505	0	6	20	0	0	0	11,856	11,856	100%
2016	1	1,328	0	10,020	1	394	0	6	20	0	0	0	11,771	11,771	100%
2017	0	1,482	0	8,787	1	288	0	0	0	0	0	0	10,558	10,558	100%
2018	0	1,927	0	6,116	1	402	0	0	0	0	0	0	8,447	8,447	100%
2019	0	3,380	0	9,149	0	565	0	0	0	0	0	0	13,094	13,094	100%

** All numbers shown are 3-year running average values of number of river herring reported harvested; landings reported by weight in pounds were calculated using conversion factor (1 lb = 2 river herring).*

+ These reported locations are within the Great Bay Estuary and used to calculate the 'Harvest Portion' of the 'Great Bay Indicator Stock' sustainability target.

Table 4. Number* of river herring harvested, number of river herring returning, and percentage of river herring harvested by state-permitted coastal netters in New Hampshire at 'Great Bay Indicator Stock' locations between 1989 and 2019.

	Cocheco River				Lamprey River				Oyster River				Exeter River				'Great Bay Indicator Stock' Harvest to Return Percentage			
Year	Harvest (# Fish)	Ladder Return (# Fish)	Minimum Spawning Run Estimate (# Fish)	Percent Harvest	Harvest (# Fish)	Ladder Return (# Fish)	Minimum Spawning Run Estimate (# Fish)	Percent Harvest	Harvest (# Fish)	Ladder Return (# Fish)	Minimum Spawning Run Estimate (# Fish)	Percent Harvest	Harvest (# Fish)	Ladder Return (# Fish)	Minimum Spawning Run Estimate (# Fish)	Percent Harvest	Harvest Portion+ (# Fish)	Return Portion (# Fish)	Percent Harvest	Sustainability Target Status
	H	*L*	*R=H+L*	*H/R * 100*	*H*	*L*	*R=H+L*	*H/R * 100*	*H*	*L*	*R=H+L*	*H/R * 100*	*H*	*L*	*R=H+L*	*H/R * 100*	*∑H*	*∑R*	*(∑H / ∑R)* 100*	
1989	--	--		--	--	--		--	--	--		--	--	--		--	--	--	--	--
1990	--	--		--	--	--		--	--	--		--	--	--		--	--	--	--	--
1991	0	25,302	25,302	0%	10,565	27,159	37,724	28%	385	115,163	115,548	0%	15,224	104	15,329	99%	28,035	193,902	14%	Below Target
1992	19	43,314	43,333	0%	12,058	23,946	36,005	33%	620	154,529	155,149	0%	7,618	283	7,902	96%	21,428	242,388	9%	Below Target
1993	34	46,205	46,239	0%	7,952	23,890	31,842	25%	927	127,596	128,523	1%	3,315	376	3,691	90%	12,998	210,295	6%	Below Target
1994	34	48,668	48,702	0%	4,900	18,640	23,540	21%	855	107,595	108,450	1%	2,767	272	3,039	91%	8,761	183,731	5%	Below Target
1995	16	50,966	50,982	0%	410	18,437	18,847	2%	621	82,886	83,507	1%	4,606	290	4,896	94%	6,041	158,232	4%	Below Target
1996	2	48,431	48,433	0%	703	13,741	14,444	5%	522	85,744	86,266	1%	5,274	280	5,554	95%	7,349	154,696	5%	Below Target
1997	105	47,778	47,883	0%	1,053	16,447	17,500	6%	715	74,392	75,108	1%	9,068	714	9,782	93%	12,170	150,273	8%	Below Target
1998	116	29,742	29,858	0%	917	16,461	17,378	5%	752	75,133	75,884	1%	21,792	647	22,440	97%	25,524	145,560	18%	Below Target
1999	140	24,379	24,519	1%	730	19,417	20,147	4%	384	77,033	77,417	0%	31,432	1,505	32,937	95%	35,253	155,019	**23%**	**Above Target**
2000	70	24,298	24,368	0%	897	20,564	21,461	4%	386	81,351	81,737	0%	39,347	1,249	40,596	97%	43,588	168,161	**26%**	**Above Target**
2001	57	31,402	31,460	0%	1,228	28,358	29,586	4%	504	75,308	75,813	1%	31,631	3,352	34,983	90%	36,251	171,842	**21%**	**Above Target**
2002	47	46,667	46,713	0%	1,135	41,024	42,160	3%	574	65,347	65,921	1%	29,097	3,526	32,623	89%	32,995	187,416	18%	Below Target
2003	25	60,087	60,112	0%	1,214	53,960	55,174	2%	444	58,901	59,346	1%	24,808	3,372	28,180	88%	28,074	202,812	14%	Below Target
2004	82	60,535	60,617	0%	770	62,961	63,731	1%	475	54,216	54,691	1%	21,051	1,165	22,216	95%	23,143	201,256	11%	Below Target
2005	85	45,193	45,278	0%	873	56,948	57,822	2%	363	39,117	39,481	1%	13,215	73	13,288	99%	15,097	155,869	10%	Below Target
2006	114	22,899	23,013	0%	614	43,277	43,891	1%	305	23,950	24,255	1%	5,084	55	5,139	99%	6,748	96,298	7%	Below Target
2007	171	12,193	12,364	1%	505	39,574	40,079	1%	103	12,113	12,216	1%	1,552	41	1,593	97%	3,202	66,252	5%	Below Target
2008	334	16,940	17,273	2%	438	38,314	38,753	1%	86	14,745	14,832	1%	5,488	75	5,563	99%	7,228	76,420	9%	Below Target
2009	482	27,555	28,038	2%	1,279	44,632	45,912	3%	74	16,621	16,695	0%	9,685	240	9,925	98%	12,394	100,570	12%	Below Target
2010	579	33,168	33,747	2%	1,912	37,333	39,245	5%	96	17,149	17,245	1%	13,152	250	13,402	98%	16,432	103,639	16%	Below Target
2011	399	37,303	37,702	1%	2,940	42,066	45,007	7%	69	11,807	11,876	1%	10,015	279	10,294	97%	14,062	104,879	13%	Below Target
2012	211	34,451	34,662	1%	2,230	56,879	59,108	4%	39	8,778	8,817	0%	6,459	234	6,693	96%	9,506	109,280	9%	Below Target
2013	7	29,678	29,685	0%	1,730	72,239	73,969	2%	2	4,826	4,828	0%	5,169	407	5,576	93%	7,516	114,058	7%	Below Target
2014	8	25,304	25,312	0%	1,298	83,713	85,010	2%	0	4,650	4,650	0%	6,645	585	7,230	92%	8,599	122,203	7%	Below Target
2015	8	37,587	37,595	0%	1,473	78,040	79,512	2%	0	4,393	4,393	0%	9,844	2,313	12,157	81%	11,856	133,657	9%	Below Target
2016	1	64,555	64,556	0%	1,328	82,358	83,687	2%	0	2,298	2,298	0%	10,020	4,324	14,344	70%	11,771	164,885	7%	Below Target
2017	0	64,208	64,208	0%	1,482	66,042	67,524	2%	0	2,386	2,386	0%	8,787	4,061	12,848	68%	10,558	146,966	7%	Below Target
2018	0	50,970	50,970	0%	1,927	59,723	61,649	3%	0	3,690	3,690	0%	6,116	2,218	8,334	73%	8,447	124,644	7%	Below Target
2019	0	18,450	18,450	0%	3,380	40,496	43,876	8%	0	5,059	5,059	0%	9,149	20	9,169	100%	13,094	76,555	17%	Below Target

** All numbers shown are 3-year running average values of number of river herring reported harvested or returning; landings reported by weight in pounds were calculated using conversion factor (1 lb = 2 river herring).*

+ 'Harvest Portion' of the Great Bay Indicator Stock uses reported harvest from all areas within the Great Bay Estuary (see Table 3); therefore, it will exceed the sum of the harvest from the four rivers monitored for the 'Return Portion'.

Table 5. **Geometric mean catch per seine haul of alewife, blueback herring, and both species combined from a juvenile finfish seine survey conducted in the Great Bay Estuary between 1997 and 2019.**

	Alewife		Blueback Herring		Combined	
Year	Annual Geometric Mean	3-yr Average	Annual Geometric Mean	3-yr Average	Annual Geometric Mean	3-yr Average
1997	0.07	--	0.43	--	0.51	--
1998	0.04	--	0.66	--	0.67	--
1999	0.27	0.13	0.97	0.69	1.09	0.76
2000	0.26	0.19	0.74	0.79	0.89	0.89
2001	0.14	0.22	0.89	0.87	0.98	0.99
2002	0.34	0.25	0.26	0.63	0.56	0.81
2003	0.32	0.27	0.71	0.62	1.17	0.90
2004	0.14	0.27	0.22	0.40	0.32	0.68
2005	0.11	0.19	0.35	0.43	0.47	0.65
2006	0.32	0.19	0.42	0.33	0.63	0.47
2007	0.21	0.21	0.5	0.42	0.77	0.62
2008	0.15	0.23	0.13	0.35	0.28	0.56
2009	0.10	0.15	0.20	0.28	0.26	0.44
2010	0.08	0.11	0.17	0.17	0.22	0.25
2011	0.08	0.09	0.05	0.14	0.12	0.20
2012	0.02	0.06	0.08	0.10	0.09	0.14
2013	0.22	0.11	0.04	0.06	0.27	0.16
2014	0.05	0.10	0.14	0.09	0.20	0.18
2015	0.31	0.19	0.06	0.08	0.34	0.27
2016	0.14	0.17	0.21	0.14	0.24	0.26
2017	0.21	0.22	0.30	0.19	0.50	0.36
2018	0.23	0.19	0.34	0.28	0.48	0.41
2019	0.07	0.17	0.17	0.27	0.22	0.40

Table 6. **Number* of river herring scale samples analyzed, number of repeat spawning fish, and associated repeat spawning percentage during annual river herring runs occurring in New Hampshire at 'Great Bay Indicator Stock' locations between 2000 and 2019.**

	Cocheco River			Lamprey River			Oyster River			Exeter River			'Great Bay Indicator Stock'		
Year	Scale Samples	Repeat Spawners	Repeat Spawning Percentage	Scale Samples	Repeat Spawners	Repeat Spawning Percentage	Scale Samples	Repeat Spawners	Repeat Spawning Percentage	Scale Samples	Repeat Spawners	Repeat Spawning Percentage	Scale Samples	Repeat Spawners	Repeat Spawning Percentage
2000	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
2001	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
2002	140	53	38%	160	88	55%	144	65	45%	97	31	32%	541	238	44%
2003	141	52	37%	142	83	58%	146	74	51%	83	35	42%	513	243	47%
2004	134	57	43%	148	84	57%	141	72	51%	55	19	34%	478	232	49%
2005	127	61	48%	144	77	53%	135	76	56%	59	20	34%	465	234	50%
2006	110	61	56%	138	76	55%	133	71	53%	46	15	32%	426	223	52%
2007	123	52	42%	134	75	56%	149	64	43%	40	9	23%	446	200	45%
2008	130	46	35%	139	69	49%	156	57	36%	67	9	14%	493	180	37%
2009	164	51	31%	165	78	47%	154	55	36%	167	20	12%	650	205	32%
2010	135	50	37%	145	69	48%	128	48	38%	166	21	13%	574	189	33%
2011	111	45	41%	126	67	53%	120	51	43%	139	18	13%	495	182	37%
2012	70	39	55%	85	45	53%	112	50	45%	54	12	22%	321	146	45%
2013	76	37	48%	81	40	49%	120	42	35%	64	16	24%	342	135	39%
2014	87	47	53%	87	46	53%	117	50	43%	77	26	33%	369	169	46%
2015	93	44	48%	88	50	57%	117	53	45%	92	31	33%	391	178	45%
2016	89	44	50%	86	55	64%	121	64	53%	103	37	35%	398	200	50%
2017	76	39	51%	77	53	69%	119	45	38%	84	28	34%	356	165	46%
2018	79	44	55%	78	52	66%	108	34	32%	58	18	32%	315	147	47%
2019	94	47	49%	80	48	60%	99	29	29%	31	8	26%	288	127	44%

** All numbers shown are 3-year running average values of number of river herring scale samples.*

Table 7. Distribution of repeat spawning frequency* of river herring in New Hampshire at 'Great Bay Indicator Stock' locations, from scale samples aged between 2000 and 2019.

	Cocheco River					Lamprey River					Oyster River					Exeter River					'Great Bay Indicator Stock'				
Year	% of r0	% of r1	% of r2	% of r3	% of r4	% of r0	% of r1	% of r2	% of r3	% of r4	% of r0	% of r1	% of r2	% of r3	% of r4	% of r0	% of r1	% of r2	% of r3	% of r4	% of r0	% of r1	% of r2	% of r3	% of r4
2000	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
2001	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
2002	62%	25%	12%	1%	0%	44%	33%	19%	4%	0%	55%	28%	13%	4%	0%	73%	18%	8%	1%	0%	56%	27%	14%	3%	0%
2003	64%	25%	9%	2%	0%	42%	34%	20%	5%	0%	49%	30%	16%	4%	0%	63%	24%	12%	1%	0%	53%	29%	15%	3%	0%
2004	56%	29%	13%	2%	0%	43%	28%	23%	6%	0%	48%	25%	22%	5%	0%	66%	22%	11%	1%	0%	51%	26%	18%	4%	0%
2005	51%	30%	15%	4%	0%	47%	30%	18%	5%	0%	44%	31%	21%	4%	0%	66%	22%	10%	2%	0%	50%	29%	17%	4%	0%
2006	45%	32%	16%	6%	1%	45%	32%	18%	5%	0%	47%	28%	20%	5%	0%	66%	24%	8%	2%	0%	48%	30%	17%	5%	0%
2007	56%	23%	13%	6%	1%	44%	32%	18%	4%	1%	56%	29%	11%	3%	0%	74%	21%	4%	1%	0%	55%	27%	13%	4%	0%
2008	63%	22%	9%	4%	1%	50%	27%	17%	5%	1%	64%	23%	9%	4%	0%	78%	18%	4%	0%	0%	62%	23%	11%	4%	0%
2009	71%	21%	6%	1%	0%	53%	29%	13%	3%	1%	64%	27%	7%	2%	0%	87%	11%	2%	0%	0%	69%	21%	7%	2%	0%
2010	60%	27%	12%	0%	0%	51%	33%	12%	3%	0%	61%	25%	10%	3%	0%	85%	13%	1%	1%	0%	65%	24%	9%	2%	0%
2011	57%	26%	14%	4%	0%	46%	34%	15%	6%	0%	57%	30%	10%	3%	0%	84%	14%	0%	1%	0%	61%	25%	10%	3%	0%
2012	44%	32%	19%	4%	1%	48%	31%	15%	6%	0%	55%	27%	13%	4%	0%	77%	19%	3%	1%	0%	54%	28%	14%	4%	0%
2013	51%	28%	14%	6%	1%	51%	28%	15%	6%	0%	65%	23%	10%	2%	0%	76%	19%	6%	0%	0%	60%	25%	11%	4%	0%
2014	46%	30%	17%	7%	1%	48%	34%	14%	4%	0%	56%	33%	9%	1%	0%	67%	25%	7%	0%	0%	55%	30%	12%	3%	0%
2015	53%	23%	14%	10%	0%	43%	32%	18%	7%	0%	54%	34%	10%	2%	0%	67%	25%	7%	1%	0%	55%	28%	12%	4%	0%
2016	51%	27%	13%	8%	0%	35%	34%	22%	10%	1%	46%	37%	12%	5%	0%	65%	26%	8%	1%	0%	50%	31%	13%	6%	0%
2017	49%	28%	17%	6%	1%	31%	27%	32%	9%	0%	63%	21%	11%	5%	0%	67%	21%	11%	1%	0%	54%	24%	17%	5%	0%
2018	44%	26%	26%	3%	0%	33%	21%	35%	10%	0%	73%	18%	6%	4%	0%	72%	19%	8%	0%	0%	56%	20%	19%	5%	0%
2019	48%	19%	28%	4%	1%	39%	21%	29%	9%	0%	74%	19%	5%	1%	0%	74%	18%	8%	0%	0%	59%	19%	18%	4%	0%

** All frequencies shown are 3-year running average values of number of river herring scale samples.*

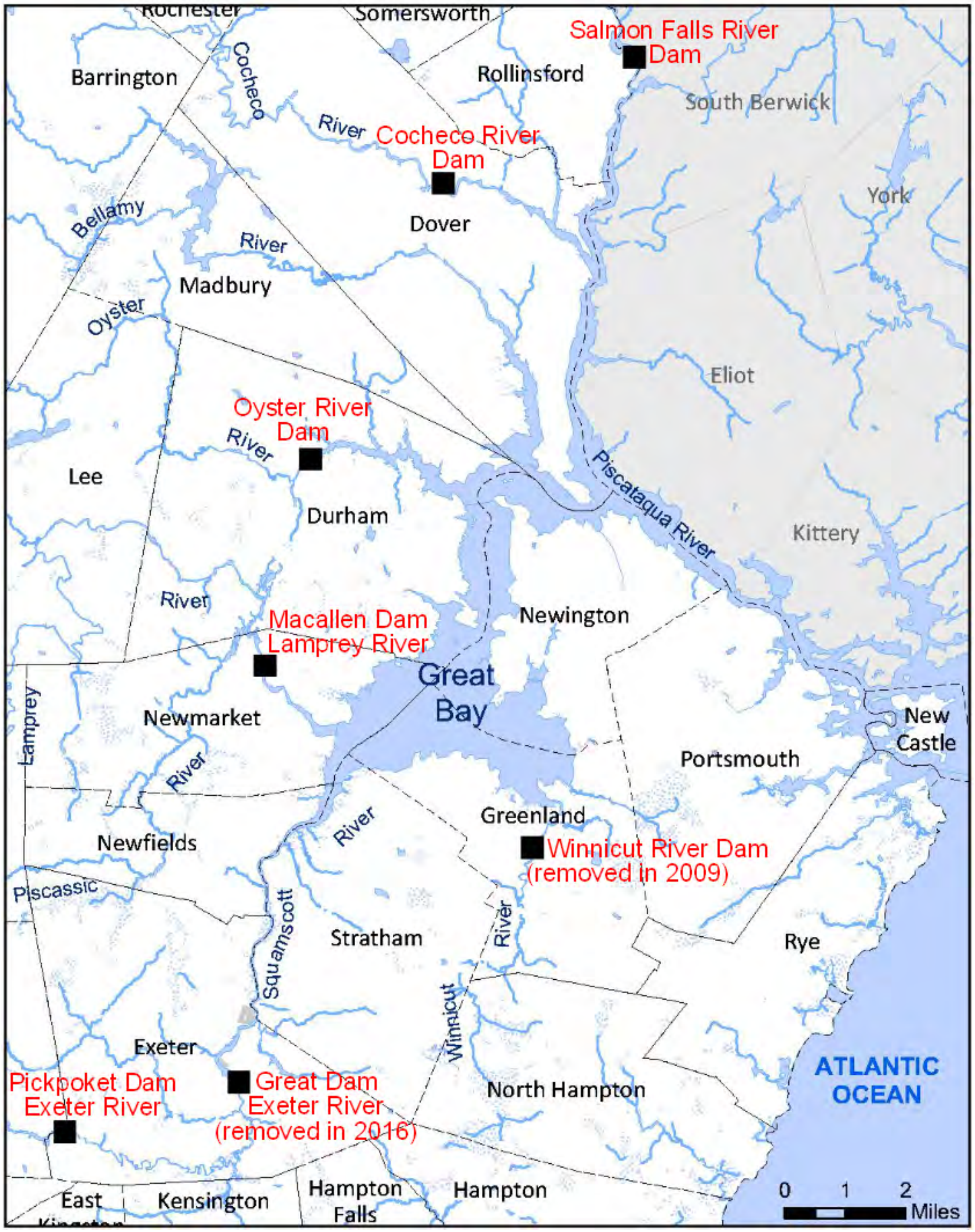


Figure 1. **Map of the Great Bay Estuary showing major coastal rivers, and dam locations.**

APPENDIX 1.

Table A1. Number of river herring successfully ascending fish passage structures in New Hampshire by river between 1978 and 2019.

Year	Cocheco River	Exeter River	Oyster River	Lamprey River	Taylor River	Winnicut River	Annual total
1978	1,925	205	419	20,461	168,256	3,229++	194,495
1979	586	186	496	23,747	375,302	3,410++	403,727
1980	7,713	2,516	2,921	26,512	205,420	4,393++	249,475
1981	6,559	15,626	5,099	50,226	94,060	2,316++	173,886
1982	4,129	542	6,563	66,189	126,182	2,500++	206,105
1983	968	1	8,866	54,546	151,100	+	215,481
1984	477		5,179	40,213	45,600	+	91,469
1985	974		4,116	54,365	108,201	+	167,656
1986	2,612	1,125	93,024	46,623	117,000	1,000++	261,384
1987	3,557	220	57,745	45,895	63,514	+	170,931
1988	3,915		73,866	31,897	30,297	+	139,975
1989	18,455		38,925	26,149	41,395	+	124,924
1990	31,697		154,588	25,457	27,210	+	238,952
1991	25,753	313	151,975	29,871	46,392	+	254,304
1992	72,491	537	157,024	16,511	49,108	+	295,671
1993	40,372	278	73,788	25,289	84,859	+	224,586
1994	33,140	*	91,974	14,119	42,164	+	181,397
1995	79,385	592	82,895	15,904	14,757	+	193,533
1996	32,767	248	82,362	11,200	10,113	+	136,690
1997	31,182	1,302	57,920	22,236	20,420	+	133,060
1998	25,277	392	85,116	15,947	11,979	219	138,930
1999	16,679	2,821	88,063	20,067	25,197	305	153,132
2000	30,938	533	70,873	25,678	44,010	528	172,560
2001	46,590	6,703	66,989	39,330	7,065	1,118	167,795
2002	62,472	3,341	58,179	58,065	5,829	7,041	194,927
2003	71,199	71	51,536	64,486	1,397	5,427	194,116
2004	47,934	83	52,934	66,333	1,055	8,044	176,383
2005	16,446	66	12,882	40,026	233	2,703	72,356
2006	4,318	16	6,035	23,471	147	822	34,809
2007	15,815	40	17,421	55,225	217**	7,543	96,261
2008	30,686	168	20,780	36,247	976	8,359	97,214
2009	36,165	513	11,661	42,425	*	4,974	95,737
2010	32,654	69	19,006	33,327	675	576+++	86,307
2011	43,090	256	4,755	50,447	59	72+++	99,338
2012	27,608	378	2,573	86,862	92	5+++	117,518
2013	18,337	588	7,149	79,408	128	0	105,610
2014	29,968	789	4,227	84,868	57	0	119,909
2015	64,456	5,562	1,803	69,843	*	0	141,664
2016	99,241	6,622	863	92,364	*	0	199,090
2017	28,926	--	4,492	35,920	*	0	69,338
2018	24,743	32	5,716	50,884	*	53	81,375
2019	1,682	28	4,969	34,684	*	0	41,363

** - Due to damage to the fish trap, fishway became a swim through operation.*
*** - Due to fish counter malfunction there was up to two weeks where passing fish were not enumerated.*
**** - Fishway operated but not monitored due to staffing constraints.*
+ - Fishway unable to pass fish until modifications in 1997.
++ - Fish netted below and hand passed over Winnicut River Dam.

Table A2. Annual number of river herring harvested by state-permitted coastal harvesters in New Hampshire by location between 1989 and 2019; Areas used to calculate the harvest portion of the annual 'Great Bay Indicator Stock' used to set the sustainability target are shown.

Year	Cocheco River+	Lamprey River+	Oyster River+	Exeter River+	Winnicut River+	Bellamy River+	Salmon Falls River+	Great Bay+	Little Bay+	Portsmouth+	Piscataqua River+	All Other Locations	Statewide Total River Herring Harvested (# Fish)	Great Bay Estuary River Herring Harvested (# Fish)	% of Statewide Total
1989	0	10,220	92	25,498	740	651	20	40	0	0	916	2,518	40,695	38,177	94%
1990	0	12,320	744	15,035	0	1,244	0	0	0	0	0	1,683	31,026	29,343	95%
1991	0	9,155	320	5,139	152	1,594	163	0	0	0	61	200	16,784	16,584	99%
1992	58	14,700	796	2,681	70	0	41	12	0	0	0	1,186	19,544	18,358	94%
1993	43	0	1,666	2,124	18	60	132	0	10	0	0	210	4,263	4,053	95%
1994	2	0	103	3,497	43	81	120	26	0	0	0	8	3,880	3,872	100%
1995	4	1,230	94	8,197	20	351	288	13	0	0	2	77	10,276	10,199	99%
1996	0	880	1,369	4,127	1,034	283	262	2	0	0	18	48	8,023	7,975	99%
1997	310	1,050	683	14,882	70	77	1,232	0	0	0	32	0	18,336	18,336	100%
1998	38	820	203	46,368	0	974	1,642	0	190	0	25	1,854	52,115	50,261	96%
1999	72	320	265	33,045	0	579	2,548	10	0	250	73	935	38,097	37,162	98%
2000	100	1,550	690	38,628	73	757	1,423	0	25	0	96	940	44,282	43,342	98%
2001	0	1,814	558	23,219	0	1,123	1,314	0	160	0	60	10	28,258	28,248	100%
2002	40	42	473	25,443	0	1,142	255	0	0	0	0	0	27,395	27,395	100%
2003	34	1,786	302	25,763	0	267	382	45	0	0	0	0	28,579	28,579	100%
2004	171	481	650	11,948	0	145	60	0	0	0	0	380	13,835	13,455	97%
2005	50	353	138	1,934	56	694	32	1	0	0	0	0	3,258	3,258	100%
2006	120	1,009	126	1,369	433	465	4	5	0	0	0	0	3,531	3,531	100%
2007	343	154	45	1,354	239	672	10	0	0	0	0	0	2,817	2,817	100%
2008	538	152	88	13,741	173	571	40	4	0	0	30	0	15,337	15,337	100%
2009	566	3,532	90	13,960	0	838	43	0	0	0	0	0	19,029	19,029	100%
2010	632	2,053	111	11,754	0	298	83	0	0	0	0	0	14,931	14,931	100%
2011	0	3,236	6	4,330	0	603	51	0	0	0	0	0	8,226	8,226	100%
2012	1	1,400	0	3,293	12	615	10	30	0	0	0	0	5,361	5,361	100%
2013	20	553	0	7,883	0	506	0	0	0	0	0	0	8,962	8,962	100%
2014	3	1,940	0	8,760	0	692	0	19	60	0	0	0	11,474	11,474	100%
2015	0	1,925	0	12,889	0	317	0	0	0	0	0	0	15,131	15,131	100%
2016	0	120	0	8,411	4	173	0	0	0	0	1	0	8,709	8,709	100%
2017	0	2,400	0	5,060	0	375	0	0	0	0	0	0	7,835	7,835	100%
2018	0	3,260	0	4,877	0	659	0	0	0	0	0	0	8,796	8,796	100%
2019	0	4,480	0	17,511	0	661	0	0	0	0	0	0	22,652	22,652	100%

+ These reported locations are within the Great Bay Estuary and are used to calculate the 'Return Portion' of the 'Great Bay Indicator Stock' sustainability target.

Table A3. Number* of river herring harvested, number of river herring returning, and percentage of river herring harvested by state-permitted coastal netters in New Hampshire at ‘Great Bay Indicator Stock’ locations between 1989 and 2019.

	Cocheco River				Lamprey River				Oyster River				Exeter River[+]				'Great Bay Indicator Stock' Harvest to Return Percentage			
Year	Harvest (Number of Fish)	Ladder Return (Number of Fish)	Return Estimate (Number of Fish)	Percent Harvest	Harvest (Number of Fish)	Ladder Return (Number of Fish)	Return Estimate (Number of Fish)	Percent Harvest	Harvest (Number of Fish)	Ladder Return (Number of Fish)	Return Estimate (Number of Fish)	Percent Harvest	Harvest (Number of Fish)	Ladder Return (Number of Fish)	Return Estimate (Number of Fish)	Percent Harvest	Harvest Portion (Number of Fish)	Return Portion (Number of Fish)	Percent Harvest	Sustainability Target Status
	H	*L*	*R=H+L*	*H/R * 100*	*H*	*L*	*R=H+L*	*H/R * 100*	*H*	*L*	*R=H+L*	*H/R * 100*	*H*	*L*	*R=H+L*	*H/R * 100*	*∑H*	*∑R*	*(∑H / ∑R)* 100*	
1989	0	18,455	18,455	0%	10,220	26,149	36,369	28%	92	38,925	39,017	0%	25,498	0	25,498	100%	35,810	119,339	**30%**	**Above Target**
1990	0	31,697	31,697	0%	12,320	25,457	37,777	33%	744	154,588	155,332	0%	15,035	0	15,035	100%	28,099	239,841	12%	Below Target
1991	0	25,753	25,753	0%	9,155	29,871	39,026	23%	320	151,975	152,295	0%	5,139	313	5,452	94%	14,614	222,526	7%	Below Target
1992	58	72,491	72,549	0%	14,700	16,511	31,211	47%	796	157,024	157,820	1%	2,681	537	3,218	83%	18,235	264,798	7%	Below Target
1993	43	40,372	40,415	0%	0	25,289	25,289	0%	1,666	73,788	75,454	2%	2,124	278	2,402	88%	3,833	143,560	3%	Below Target
1994	2	33,140	33,142	0%	0	14,119	14,119	0%	103	91,974	92,077	0%	3,497	0	3,497	100%	3,602	142,835	3%	Below Target
1995	4	79,385	79,389	0%	1,230	15,904	17,134	7%	94	82,895	82,989	0%	8,197	592	8,789	93%	9,525	188,301	5%	Below Target
1996	0	32,767	32,767	0%	880	11,200	12,080	7%	1,369	82,362	83,731	2%	4,127	248	4,375	94%	6,376	132,953	5%	Below Target
1997	310	31,182	31,492	1%	1,050	22,236	23,286	5%	683	57,920	58,603	1%	14,882	1,302	16,184	92%	16,925	129,565	13%	Below Target
1998	38	25,277	25,315	0%	820	15,947	16,767	5%	203	85,116	85,319	0%	46,368	392	46,760	99%	47,429	174,161	**27%**	**Above Target**
1999	72	16,679	16,751	0%	320	20,067	20,387	2%	265	88,063	88,328	0%	33,045	2,821	35,866	92%	33,702	161,332	**21%**	**Above Target**
2000	100	30,938	31,038	0%	1,550	25,678	27,228	6%	690	70,873	71,563	1%	38,628	533	39,161	99%	40,968	168,990	**24%**	**Above Target**
2001	0	46,590	46,590	0%	1,814	39,330	41,144	4%	558	66,989	67,547	1%	23,219	6,703	29,922	78%	25,591	185,203	14%	Below Target
2002	40	62,472	62,512	0%	42	58,065	58,107	0%	473	58,179	58,652	1%	25,443	3,341	28,784	88%	25,998	208,055	12%	Below Target
2003	34	71,199	71,233	0%	1,786	64,486	66,272	3%	302	51,536	51,838	1%	25,763	71	25,834	100%	27,885	215,177	13%	Below Target
2004	171	47,934	48,105	0%	481	66,333	66,814	1%	650	52,934	53,584	1%	11,948	83	12,031	99%	13,250	180,534	7%	Below Target
2005	50	16,446	16,496	0%	353	40,026	40,379	1%	138	12,882	13,020	1%	1,934	66	2,000	97%	2,475	71,895	3%	Below Target
2006	120	4,318	4,438	3%	1,009	23,471	24,480	4%	126	6,035	6,161	2%	1,369	16	1,385	99%	2,624	36,464	7%	Below Target
2007	343	15,815	16,158	2%	154	55,225	55,379	0%	45	17,421	17,466	0%	1,354	40	1,394	97%	1,896	90,397	2%	Below Target
2008	538	30,686	31,224	2%	152	36,247	36,399	0%	88	20,780	20,868	0%	13,741	168	13,909	99%	14,519	102,400	14%	Below Target
2009	566	36,165	36,731	2%	3,532	42,425	45,957	8%	90	11,661	11,751	1%	13,960	513	14,473	96%	18,148	108,912	17%	Below Target
2010	632	32,654	33,286	2%	2,053	33,327	35,380	6%	111	19,006	19,117	1%	11,754	69	11,823	99%	14,550	99,606	15%	Below Target
2011	0	43,090	43,090	0%	3,236	50,447	53,683	6%	6	4,755	4,761	0%	4,330	256	4,586	94%	7,572	106,120	7%	Below Target
2012	1	27,608	27,609	0%	1,400	86,862	88,262	2%	0	2,573	2,573	0%	3,293	378	3,671	90%	4,694	122,115	4%	Below Target
2013	20	18,337	18,357	0%	553	79,408	79,961	1%	0	7,149	7,149	0%	7,883	588	8,471	93%	8,456	113,938	7%	Below Target
2014	3	29,968	29,971	0%	1,940	84,868	86,808	2%	0	4,227	4,227	0%	8,760	789	9,549	92%	10,703	130,555	8%	Below Target
2015	0	64,456	64,456	0%	1,925	69,843	71,768	3%	0	1,803	1,803	0%	12,889	5,562	18,451	70%	14,814	156,478	9%	Below Target
2016	0	99,241	99,241	0%	120	92,364	92,484	0%	0	863	863	0%	8,411	6,622	15,033	56%	8,531	207,621	4%	Below Target
2017	0	28,926	28,926	0%	2,400	35,920	38,320	6%	0	4,492	4,492	0%	5,060	0	5,060	100%	7,460	76,798	10%	Below Target
2018	0	24,743	24,743	0%	3,260	50,884	54,144	6%	0	5,716	5,716	0%	4,877	32	4,909	99%	8,137	89,512	9%	Below Target
2019	0	1,682	1,682	0%	4,480	34,684	39,164	11%	0	4,969	4,969	0%	17,511	28	17,539	100%	21,991	63,354	**35%**	**Above Target**

**Landings reported by weight in pounds were calculated using conversion factor (1 lb = 2 river herring).*

Table A4. Instantaneous mortality rates (Z) calculated using Chapman-Robson method from age data obtained through scale samples from 'Great Bay Indicator Stock' locations between 1991 and 2019.

Year	Cocheco River	Exeter River	Oyster River	Lamprey River	GBI
1991	0.92	1.02	1.02	0.81	0.95
1992	0.81	1.01	0.71	1.17	0.90
1993	1.67	1.37	1.82	1.77	1.66
1994	0.99		0.84	1.35	0.85
1995	1.27	1.72	1.44	1.43	1.45
1996	0.82	1.39	1.20	1.16	0.99
1997	0.87	1.01	0.76	1.08	0.89
1998	0.81	0.64	0.95	0.96	0.77
1999	0.82	1.26	1.83	0.94	0.92
2000	0.78	1.03	0.84	0.80	0.72
2001	0.86	0.98	0.71	1.11	0.73
2002	0.76	1.53	0.70	1.23	0.65
2003	1.16	0.91	0.96	0.64	0.87
2004	1.20	1.19	1.44	0.86	1.10
2005	1.08	1.27	1.44	1.06	1.16
2006	0.96	0.69	0.68	0.70	0.75
2007	0.81	0.99	0.80	1.09	0.85
2008	0.97	0.89	0.82	0.85	1.00
2009	0.74	0.90	1.02	1.02	0.78
2010	0.94	1.00	1.11	0.87	1.00
2011	0.82	1.53	1.35	1.01	0.92
2012	0.77	1.20	0.76	0.96	1.00
2013	0.60	0.73	1.03	0.57	0.71
2014	0.70	0.80	1.47	0.56	0.92
2015	0.57	1.03	0.78	0.55	0.71
2016	1.21	1.25	0.92	1.06	0.87
2017	0.80	1.02	0.87	1.06	0.59
2018	1.84	--	1.08	0.47	0.52
2019	0.49	--	1.53	0.60	0.95

Table A5. **Correlation tests between instantaneous mortality rates (Z) and annual ladder returns of river herring from 'Great Bay Indicator Stock' locations between 1991 and 2019 (*Plots in Figure A1*).**

	Cocheco River	
Year	Z	Annual Ladder Return (single years)
1991	0.92	25,753
1992	0.81	72,491
1993	1.67	40,372
1994	0.99	33,140
1995	1.27	79,385
1996	0.82	32,767
1997	0.87	31,182
1998	0.81	25,277
1999	0.82	16,679
2000	0.78	30,938
2001	0.86	46,590
2002	0.76	62,472
2003	1.16	71,199
2004	1.20	47,934
2005	1.08	16,446
2006	0.96	4,318
2007	0.81	15,815
2008	0.97	30,686
2009	0.74	36,165
2010	0.94	32,654
2011	0.82	43,090
2012	0.77	27,608
2013	0.60	18,337
2014	0.70	29,968
2015	0.57	64,456
2016	1.21	99,241
2017	0.80	28,926
2018	1.84	24,743
2019	0.49	1,682
r^2 = 0.054		P > 0.05
Not Significant		

	Lamprey River	
Year	Z	Annual Ladder Return (single years)
1991	0.81	29,871
1992	1.17	16,511
1993	1.77	25,289
1994	1.35	14,119
1995	1.43	15,904
1996	1.16	11,200
1997	1.08	22,236
1998	0.96	15,947
1999	0.94	20,067
2000	0.80	25,678
2001	1.11	39,330
2002	1.23	58,065
2003	0.64	64,486
2004	0.86	66,333
2005	1.06	40,026
2006	0.70	23,471
2007	1.09	55,225
2008	0.85	36,247
2009	1.02	42,425
2010	0.87	33,327
2011	1.01	50,447
2012	0.96	86,862
2013	0.57	79,408
2014	0.56	84,868
2015	0.55	69,843
2016	1.06	92,364
2017	1.06	35,920
2018	0.47	50,884
2019	0.60	34,684
r^2 = 0.186		P = 0.02
Significant		

	Oyster River	
Year	Z	Annual Ladder Return (single years)
1991	1.02	151,975
1992	0.71	157,024
1993	1.82	73,788
1994	0.84	91,974
1995	1.44	82,895
1996	1.20	82,362
1997	0.76	57,920
1998	0.95	85,116
1999	1.83	88,063
2000	0.84	70,873
2001	0.71	66,989
2002	0.70	58,179
2003	0.96	51,536
2004	1.44	52,934
2005	1.44	12,882
2006	0.68	6,035
2007	0.80	17,421
2008	0.82	20,780
2009	1.02	11,661
2010	1.11	19,006
2011	1.35	4,755
2012	0.76	2,573
2013	1.03	7,149
2014	1.47	4,227
2015	0.78	1,803
2016	0.92	863
2017	0.87	4,492
2018	1.08	5,716
2019	1.53	4,969
r^2 = 0.000		P > 0.05
Not Significant		

	Squamscott/Exeter River	
Year	Z	Annual Ladder Return (single years)
1991	1.02	313
1992	1.01	537
1993	1.37	278
1994	0.00	--
1995	1.72	592
1996	1.39	248
1997	1.01	1,302
1998	0.64	392
1999	1.26	2,821
2000	1.03	533
2001	0.98	6,703
2002	1.53	3,341
2003	0.91	71
2004	1.19	83
2005	1.27	66
2006	0.69	16
2007	0.99	40
2008	0.89	168
2009	0.90	513
2010	1.00	69
2011	1.53	256
2012	1.20	378
2013	0.73	588
2014	0.80	789
2015	1.03	5,562
2016	1.25	6,622
2017	1.02	--
2018	--	32
2019	--	28
r^2 = 0.013		P > 0.05
Not Significant		

	Great Bay Indicator Stock	
Year	Z	Annual Ladder Return (single years)
1991	0.95	207,912
1992	0.90	246,563
1993	1.66	139,727
1994	0.85	139,233
1995	1.45	178,776
1996	0.99	126,577
1997	0.89	112,640
1998	0.77	126,732
1999	0.92	127,630
2000	0.72	128,022
2001	0.73	159,612
2002	0.65	182,057
2003	0.87	187,292
2004	1.10	167,284
2005	1.16	69,420
2006	0.75	33,840
2007	0.85	88,501
2008	1.00	87,887
2009	0.78	90,764
2010	1.00	85,056
2011	0.92	98,548
2012	1.00	117,421
2013	0.71	105,482
2014	0.92	119,852
2015	0.71	141,664
2016	0.87	199,090
2017	0.59	69,338
2018	0.52	81,375
2019	0.95	41,363
r^2 = 0.026		P > 0.05
Not Significant		

Table A6. Correlation tests between instantaneous mortality rates (Z) and annual harvest numbers of river herring from 'Great Bay Indicator Stock' locations between 1991 and 2019 (*Plots in Figure A2*).

	Cocheco River	
Year	Z	Annual Harvest (single years)
1991	0.92	0
1992	0.81	58
1993	1.67	43
1994	0.99	2
1995	1.27	4
1996	0.82	0
1997	0.87	310
1998	0.81	38
1999	0.82	72
2000	0.78	100
2001	0.86	0
2002	0.76	40
2003	1.16	34
2004	1.20	171
2005	1.08	50
2006	0.96	120
2007	0.81	343
2008	0.97	538
2009	0.74	566
2010	0.94	632
2011	0.82	0
2012	0.77	1
2013	0.60	20
2014	0.70	3
2015	0.57	0
2016	1.21	0
2017	0.80	0
2018	1.84	0
2019	0.49	0
$r^2 = 0.004$		$P > 0.05$
Not Significant		

	Lamprey River	
Year	Z	Annual Harvest (single years)
1991	0.81	9,155
1992	1.17	14,700
1993	1.77	0
1994	1.35	0
1995	1.43	1,230
1996	1.16	880
1997	1.08	1,050
1998	0.96	820
1999	0.94	320
2000	0.80	1,550
2001	1.11	1,814
2002	1.23	42
2003	0.64	1,786
2004	0.86	481
2005	1.06	353
2006	0.70	1,009
2007	1.09	154
2008	0.85	152
2009	1.02	3,532
2010	0.87	2,053
2011	1.01	3,236
2012	0.96	1,400
2013	0.57	553
2014	0.56	1,940
2015	0.55	1,925
2016	1.06	120
2017	1.06	2,400
2018	0.47	3,260
2019	0.60	4,480
$r^2 = 0.010$		$P > 0.05$
Not Significant		

	Oyster River	
Year	Z	Annual Harvest (single years)
1991	1.02	320
1992	0.71	796
1993	1.82	1,666
1994	0.84	103
1995	1.44	94
1996	1.20	1,369
1997	0.76	683
1998	0.95	203
1999	1.83	265
2000	0.84	690
2001	0.71	558
2002	0.70	473
2003	0.96	302
2004	1.44	650
2005	1.44	138
2006	0.68	126
2007	0.80	45
2008	0.82	88
2009	1.02	90
2010	1.11	111
2011	1.35	6
2012	0.76	0
2013	1.03	0
2014	1.47	0
2015	0.78	0
2016	0.92	0
2017	0.87	0
2018	1.08	0
2019	1.53	0
$r^2 = 0.040$		$P > 0.05$
Not Significant		

	Squamscott/Exeter River	
Year	Z	Annual Harvest (single years)
1991	1.02	5,139
1992	1.01	2,681
1993	1.37	2,124
1994		3,497
1995	1.72	8,197
1996	1.39	4,127
1997	1.01	14,882
1998	0.64	46,368
1999	1.26	33,045
2000	1.03	38,628
2001	0.98	23,219
2002	1.53	25,443
2003	0.91	25,763
2004	1.19	11,948
2005	1.27	1,934
2006	0.69	1,369
2007	0.99	1,354
2008	0.89	13,741
2009	0.90	13,960
2010	1.00	11,754
2011	1.53	4,330
2012	1.20	3,293
2013	0.73	7,883
2014	0.80	8,760
2015	1.03	12,889
2016	1.25	8,411
2017	1.02	5,060
2018	--	4,877
2019	--	17,511
$r^2 = 0.044$		$P > 0.05$
Not Significant		

	Great Bay Indicator Stock	
Year	Z	Annual Harvest (single years)
1991	0.95	14,614
1992	0.90	18,235
1993	1.66	3,833
1994	0.85	3,602
1995	1.45	9,525
1996	0.99	6,376
1997	0.89	16,925
1998	0.77	47,429
1999	0.92	33,702
2000	0.72	40,968
2001	0.73	25,591
2002	0.65	25,998
2003	0.87	27,885
2004	1.10	13,250
2005	1.16	2,475
2006	0.75	2,624
2007	0.85	1,896
2008	1.00	14,519
2009	0.78	18,148
2010	1.00	14,550
2011	0.92	7,572
2012	1.00	4,694
2013	0.71	8,456
2014	0.92	10,703
2015	0.71	14,814
2016	0.87	8,531
2017	0.59	7,460
2018	0.52	8,137
2019	0.95	21,991
$r^2 = 0.081$		$P > 0.05$
Not Significant		

Table A7. Correlation tests between instantaneous mortality rates (Z) and annual exploitation rates of river herring from 'Great Bay Indicator Stock' locations between 1991 and 2019 (*Plots in Figure A3*).

	Cocheco River	
Year	Z	Exploitation Rate (single years)
1991	0.92	0.0%
1992	0.81	0.1%
1993	1.67	0.1%
1994	0.99	0.0%
1995	1.27	0.0%
1996	0.82	0.0%
1997	0.87	1.0%
1998	0.81	0.2%
1999	0.82	0.4%
2000	0.78	0.3%
2001	0.86	0.0%
2002	0.76	0.1%
2003	1.16	0.0%
2004	1.20	0.4%
2005	1.08	0.3%
2006	0.96	2.7%
2007	0.81	2.1%
2008	0.97	1.7%
2009	0.74	1.5%
2010	0.94	1.9%
2011	0.82	0.0%
2012	0.77	0.0%
2013	0.60	0.1%
2014	0.70	0.0%
2015	0.57	0.0%
2016	1.21	0.0%
r^2 = 0.002		P > 0.05
Not Significant		

	Lamprey River	
Year	Z	Exploitation Rate (single years)
1991	0.81	23.5%
1992	1.17	47.1%
1993	1.77	0.0%
1994	1.35	0.0%
1995	1.43	7.2%
1996	1.16	7.3%
1997	1.08	4.5%
1998	0.96	4.9%
1999	0.94	1.6%
2000	0.80	5.7%
2001	1.11	4.4%
2002	1.23	0.1%
2003	0.64	2.7%
2004	0.86	0.7%
2005	1.06	0.9%
2006	0.70	4.1%
2007	1.09	0.3%
2008	0.85	0.4%
2009	1.02	8.3%
2010	0.87	6.2%
2011	1.01	6.4%
2012	0.96	1.6%
2013	0.57	0.7%
2014	0.56	2.3%
2015	0.55	2.8%
2016	1.06	0.1%
r^2 = 0.004		P > 0.05
Not Significant		

	Oyster River	
Year	Z	Exploitation Rate (single years)
1991	1.02	0.2%
1992	0.71	0.5%
1993	1.82	2.2%
1994	0.84	0.1%
1995	1.44	0.1%
1996	1.20	1.6%
1997	0.76	1.2%
1998	0.95	0.2%
1999	1.83	0.3%
2000	0.84	1.0%
2001	0.71	0.8%
2002	0.70	0.8%
2003	0.96	0.6%
2004	1.44	1.2%
2005	1.44	1.1%
2006	0.68	2.0%
2007	0.80	0.3%
2008	0.82	0.4%
2009	1.02	0.8%
2010	1.11	0.6%
2011	1.35	0.1%
2012	0.76	0.0%
2013	1.03	0.0%
2014	1.47	0.0%
2015	0.78	0.0%
2016	0.92	0.0%
r^2 = 0.022		P > 0.05
Not Significant		

	Squamscott/Exeter River	
Year	Z	Exploitation Rate (single years)
1991	1.02	94.3%
1992	1.01	83.3%
1993	1.37	88.4%
1994		
1995	1.72	93.3%
1996	1.39	94.3%
1997	1.01	90.9%
1998	0.64	99.2%
1999	1.26	92.1%
2000	1.03	98.6%
2001	0.98	77.6%
2002	1.53	88.4%
2003	0.91	99.7%
2004	1.19	99.3%
2005	1.27	96.7%
2006	0.69	98.8%
2007	0.99	97.1%
2008	0.89	98.8%
2009	0.90	96.5%
2010	1.00	99.4%
2011	1.53	82.5%
2012	1.20	89.7%
2013	0.73	93.1%
2014	0.80	91.7%
2015	1.03	69.9%
2016	1.25	56.0%
r^2 = 0.066		P > 0.05
Not Significant		

	Great Bay Indicator Stock	
Year	Z	Exploitation Rate (single years)
1991	0.95	7.0%
1992	0.90	7.4%
1993	1.66	2.7%
1994	0.85	2.6%
1995	1.45	5.3%
1996	0.99	5.0%
1997	0.89	15.0%
1998	0.77	35.1%
1999	0.92	26.4%
2000	0.72	32.0%
2001	0.73	16.0%
2002	0.65	14.2%
2003	0.87	14.9%
2004	1.10	7.9%
2005	1.16	3.6%
2006	0.75	7.8%
2007	0.85	2.1%
2008	1.00	16.5%
2009	0.78	19.8%
2010	1.00	17.1%
2011	0.92	7.6%
2012	1.00	4.0%
2013	0.71	8.0%
2014	0.92	8.9%
2015	0.71	10.5%
2016	0.87	4.3%
r^2 = 0.163		P = 0.04
Significant		

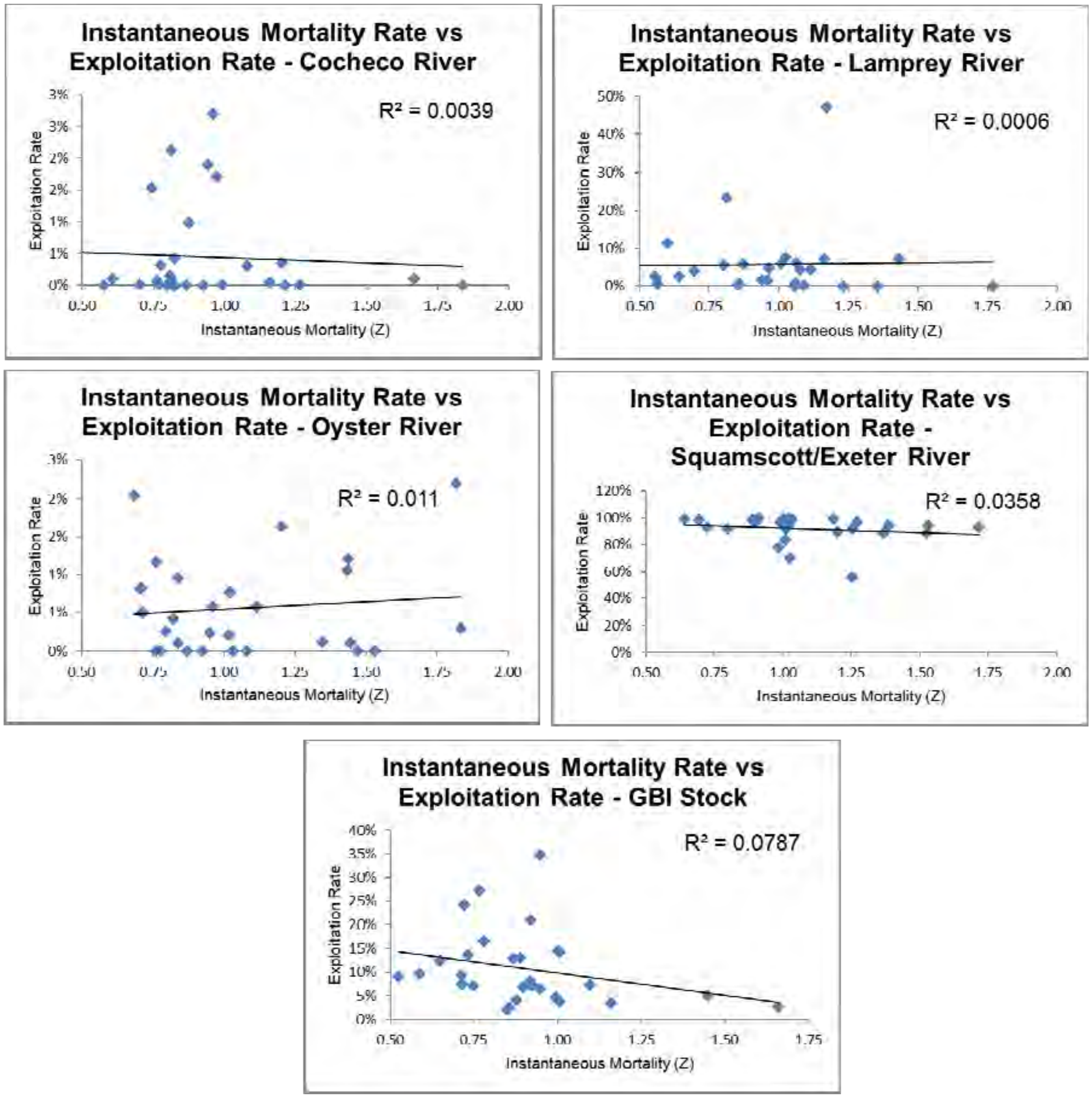


Figure A1. Plots of instantaneous mortality rate against river herring exploitation rates for individual years, 1991-2019, with associated linear regression and coefficient of determination (R^2) values, for Great Bay Indicator Stock and individual locations.

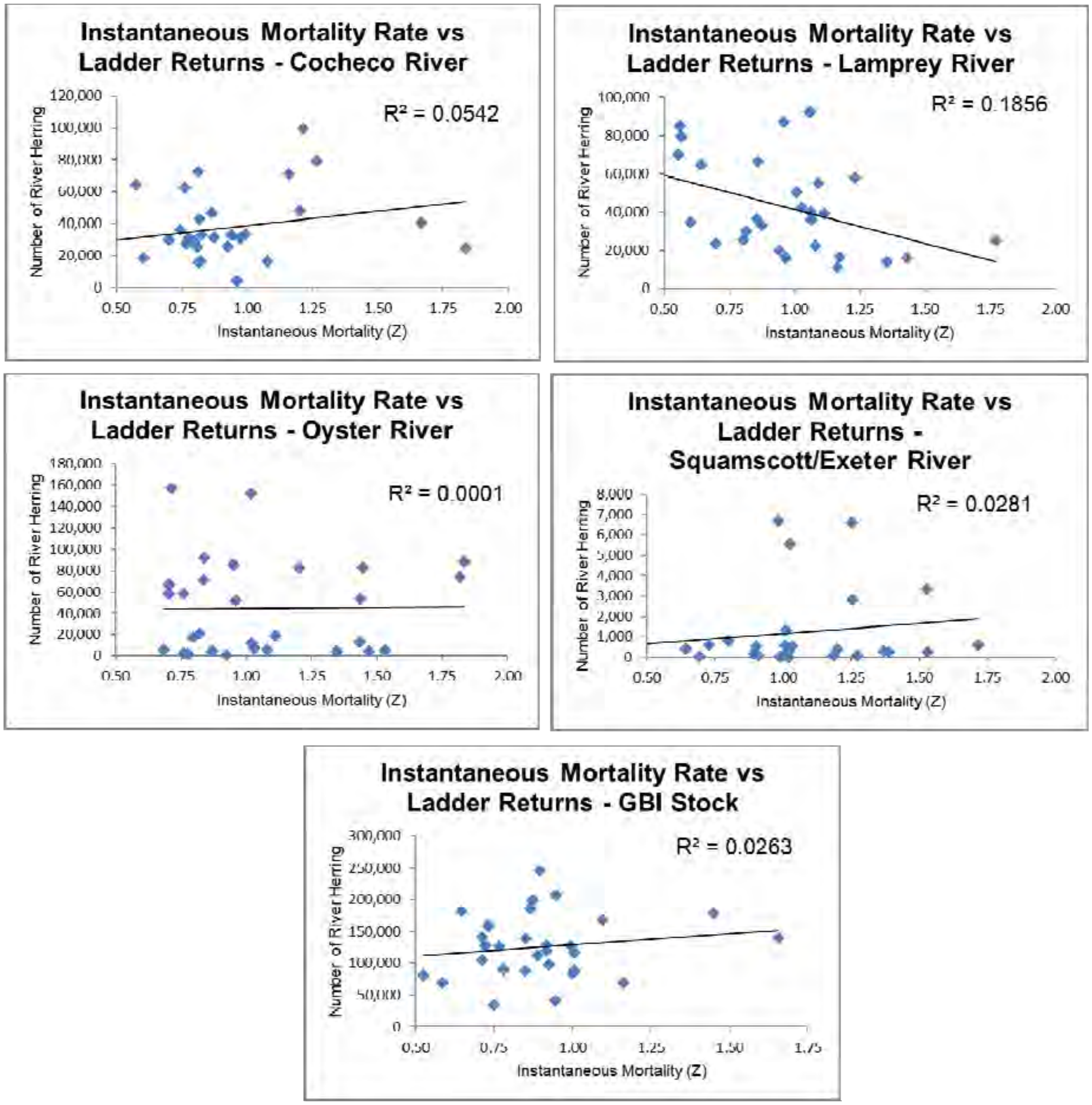


Figure A2. Plots of instantaneous mortality rate against river herring ladder returns for individual years, 1991-2019, with associated linear regression and coefficient of determination (R^2) values, for Great Bay Indicator Stock and individual locations.

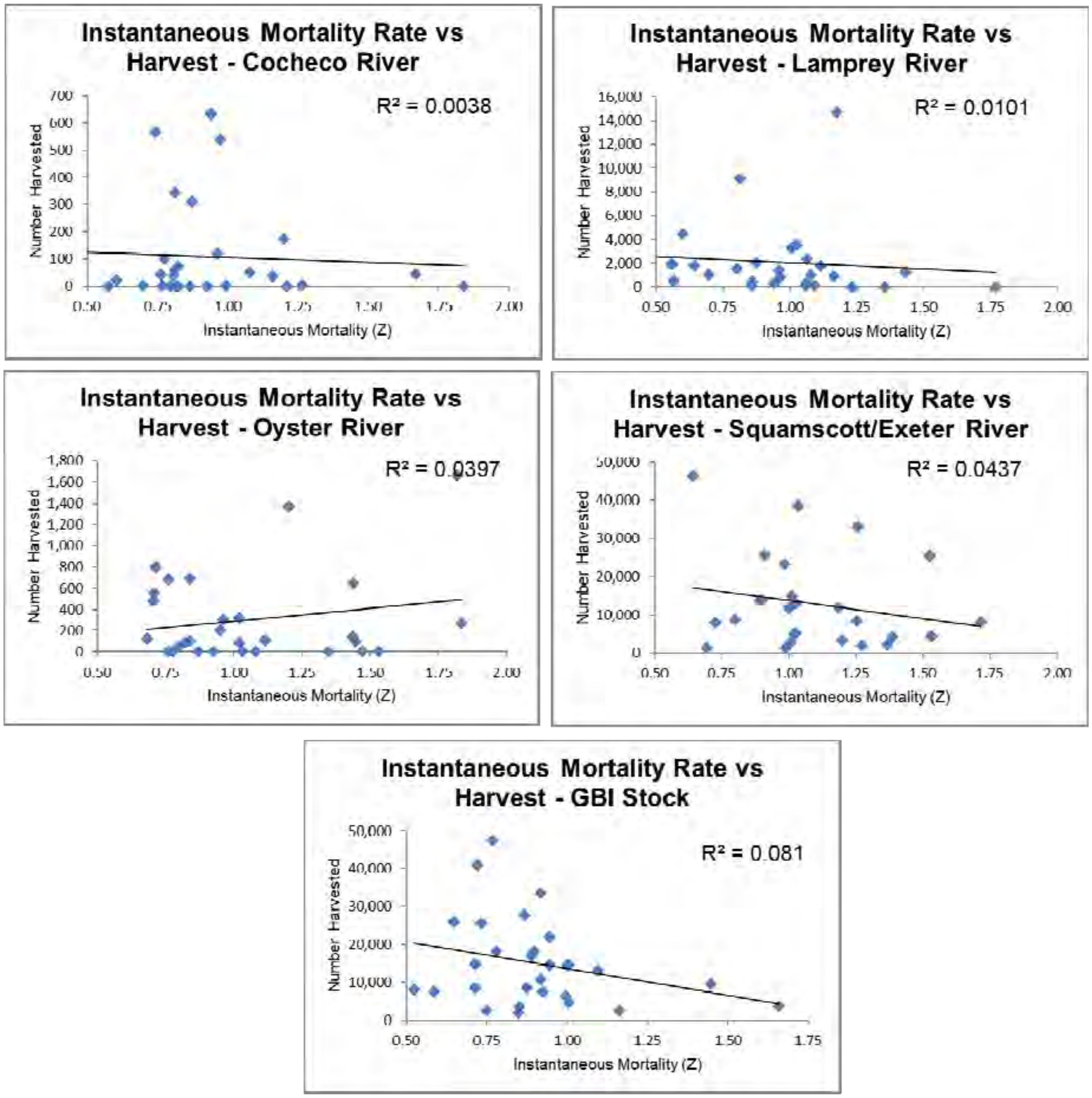


Figure A3. Plots of instantaneous mortality rate against river herring harvest for individual years, 1991-2019, with associated linear regression and coefficient of determination (R^2) values, for Great Bay Indicator Stock and individual locations.

New Hampshire
Fish and Game Department

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April 7, 2020

Shad & River Herring Management Board
Atlantic States Marine Fisheries Commission
1050 N. Highland St., Suite 200 A-N
Arlington, VA 22201

Dear Board Members,

Upon analyzing New Hampshire's (NH) 2019 anadromous fish passage data it was determined NH is currently out of compliance of the fishery-independent target in NH's River Herring Sustainable Fishery Management Plan (SFMP). The fishery-independent target is a 3-year average return to NH coastal rivers of 72,450 river herring. After low returns in 2019, the current 3-year average is 64,025 returning river herring. The SFMP states noncompliance with the fishery-independent target will result in closure of NH's river herring fishery.

There were three reasons for NH's low river herring spawning run counts in 2019 and a plan for corrective action in 2020:

1) Low water temperatures for the entire spawning season.
2) Equipment failure at the Cocheco River fishway that led to an estimated passage of 1,682 river herring. Many more river herring were observed in the fishway but could not be accurately enumerated by the electronic fish counting equipment modified for this particular river system. The 8-tube array electronic fish counter was extremely sensitive to the daily impoundment level fluctuations associated with the adjacent hydroelectric facility during 2019. The long-term average annual return, between 1976 and 2018, to the Cocheco River fishway is 28,167 river herring. If the average annual return was applied to calculate the current 3-year running average, NH would be in compliance with the fishery-independent target. In 2020, we will be returning to the single electronic counting tube that is less sensitive to varying impoundment water levels and will provide more accurate accounting of fish passage numbers.
3) Fish passage counts at the Pickpocket Dam fishway on the Exeter River continue to be low despite thousands of river herring observed in the vicinity of the former Great Dam and fishway (removed in 2016). The Pickpocket Dam fishway is located 13.4 km upstream of the former Great Dam location. With the concern that river herring are utilizing new

streambed spawning habitat between the former dam and Pickpocket Dam fishway, an alternative survey method in enumerating river herring closer to the former Great Dam location will be initiated to achieve better spawning run estimates in the Exeter River in 2020.

During a Shad and River Herring Technical Committee (SRHTC) conference call held on March 30th, 2020, NH's compliance concerns and plan moving forward were discussed. The SRHTC acknowledged the concern of equipment malfunction at the Cocheco and supported NH's plan of corrective action. It was recommended by the SRHTC to provide the Board a letter outlining all the issues that culminated in a poor accounting of NH's river herring spawning runs in 2019 as well as an update at the conclusion of the 2020 migration season ahead of the August Board meeting.

Please don't hesitate to contact me or NH's Technical Committee member, Mike Dionne (Michael.Dionne@wildlife.nh.gov), if you have any questions.

Sincerely,

Cheri Patterson

Cheri Patterson
Chief of Marine Fisheries

cc: Glenn Normandeau, Executive Director

Delaware River
Sustainable Fishing Plan for American Shad

Prepared by:

The Delaware River Basin
Fish & Wildlife Management Cooperative

Delaware Division of Fish and Wildlife • New Jersey Division of Fish and Wildlife

Pennsylvania Fish and Boat Commission • New York Division of Fish & Wildlife, Division of Marine Resources

U.S. Fish and Wildlife Service • National Marine Fisheries Service

and

Liaisons

National Park Service • The City of Philadelphia Water Department

Delaware River Basin Commission • The Nature Conservancy

For:

The Atlantic States Marine Fisheries Commission
Shad and River Herring Management Board

December 2016

Updated: March 2020

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Executive Summary

The Delaware River Basin Fish and Wildlife Management Cooperative (Co-op) is submitting this update to the 2017-2021 Sustainable Fishing Plan for American Shad (Plan) at the request of the Atlantic State's Marine Fisheries Commission's Shad and River Herring Management Board (Board) that states and/or agencies address their shad and river herring management programs to comply with Amendments 2 & 3 to the Interstate Fishery Management Plan (ISFMP) for Shad and River Herring. The Board tasked a sub-group of the Shad and River Herring Technical Committee (TC) to review all shad and river herring management programs and develop recommendations to achieve compliance with Amendments 2& 3 to the ISFMP for Shad and River Herring. Upon review of the Co-op's Plan the TC determined that the Plan was out of compliance with Amendment 3 because the states of Delaware and New Jersey allowed the harvest of American shad in unmonitored tidal tributaries of the lower Delaware River and bay. In order to come into compliance with Amendment 3 the TC recommended that the Co-op incorporate these tidal tributaries into the Plan or the states of New Jersey and Delaware implement catch and release only regulations for those locations.

Based upon the TC's recommendations, the updates to the Plan reflect the incorporation of tidal tributaries of the Delaware River and bay within the states of New Jersey and Delaware into the Plan. No fishery dependent or independent sampling occurs within these tributaries beyond commercial landings reporting. The extensive sampling that takes place in the mainstem Delaware River and bay is considered to be representative of the shad populations within these tributaries. Commercial fishery sampling conducted in the Delaware River and bay within the State of Delaware should adequately represent the American shad population utilizing Back Creek (i.e., C&D Canal). Any management actions that may take place in the mainstem Delaware River and bay will be applied to these tributaries as well. A complete update to the Plan will be submitted at the end of this current iteration's tenure, prior to the end of 2021.

The Atlantic States Marine Fisheries Commission's (ASMFC) Amendment 3 to the Interstate Fishery Management Plan for Shad and River Herring requires states to submit Sustainability Plans for continuance of American Shad fisheries in their jurisdictional waters. Within the Delaware River Basin, the Delaware River Basin Fish and Wildlife Management Cooperative (Co-op) is responsible for the management of American Shad. The Co-op is seeking renewal of their Sustainable Fishing Plan of the Delaware River American Shad stock, being managed at current levels of recreational and commercial usage. The Co-op has completed a five-year update of the Sustainable Fishing Plan that was originally approved by the ASMFC in 2012 (2012 SFP). The Co-op used four indices for monitoring the Delaware River American Shad stock with associated benchmarks in the 2012 SFP. An additional index was added to this updated plan to monitor harvest on mixed stock American Shad that occur in the Delaware Bay. The Co-op judge these fisheries as sustainable while avoiding diminishing potential stock reproduction and recruitment as long as all five indices of stock condition remain within the defined benchmarks.

Currently the Delaware River American Shad stock is considered to be stable, but at low levels. Juvenile production (JAI), assessed by seine surveys in both non-tidal and tidal reaches, has varied without trend. Below average production was observed in non-tidal reaches from 1998 to 2002, but excellent year classes were observed in both JAI indices in 1996 and 2007. The 2013 JAI was the highest of the tidal reach time series, and that index has been higher than average in three of the past five years. The non-tidal JAI, however, had the second highest value in the time series in 2012, but that was followed by lower than average values from 2013-2015, including 2013 and 2015 falling below the benchmark. Measures of relative adult abundance (Smithfield Beach and Lewis haul seine) were suggestive of declining abundance in early 1990s followed by low but stable levels from 1999 to 2009. Recent evidence (since 2009) has suggested increasing abundance of adults to levels observed in the early 1990s in the Smithfield Beach survey, and three years of higher than the time-series average index values for the Lewis Haul Seine since 2009.

Commercial exploitation of the Delaware River American Shad stock is permitted by the States of New Jersey and Delaware within the tidal and estuarine portions of the Basin. Harvest occurs generally during the spring spawning migration from late February into May principally using anchored or drift gill nets. In the 2012 SFP, the Co-op acknowledged that the commercial fishery in the Delaware Bay exploited American Shad from mixed stock fisheries, along with Delaware River stock. A demarcation line from Leipsic River, DE to Gandys Beach, NJ was established, where landings in the upper estuary are considered to be 100% Delaware River American Shad stock and landings in the Bay were of mixed stock, with an estimated 40% of Delaware origin. Upon further examination of reporting regions in the State of Delaware, it was determined that the four reporting regions (River, Upper Bay, Mid Bay and Lower Bay) do not allow for landings to be divided at the Leipsic River. A new delineation point was selected for the State of Delaware (Bowers Beach), which now assigns landings to Delaware River stock harvest for the upper three reporting regions in that state. Available tagging and genetic studies, suggest continuance of assignment of the proportion of the Delaware River stock at a similar rate as the 2012 SFP.

Fishers in New Jersey represent a small directed fishery for American Shad; whereas, landings of shad reported to the State of Delaware occur as bycatch from their concurrent Striped Bass fishery. Trends of combined landings, representative of the Delaware River stock, have been declining since 1990, with lowest levels observed in the most recent years (2008-2015), with the exception of a high harvest in 2014. The decline is most likely due to gear changes in Delaware's Striped Bass quota driven fishery and the low number of New Jersey fishers seeking American Shad.

Harvest on the mixed stock occurs in both Delaware and New Jersey in the Delaware Bay below a line from Bowers Beach, DE to Gandys Beach, NJ. A new benchmark was developed to limit expansion of the fishery on the mixed stock. Landings on the mixed stock were highest in the early 1990s and have been generally declining since that time. Landings on the mixed stock have been below the time-series mean (1985-2015) since 2006.

In addition to the Delaware Bay fisheries, a small haul seine fishery (Lewis haul seine) occurs in the Delaware River, some 15 miles above the fall line at Lambertville, NJ. This fishery exists as an eco-tourism venture with nominal harvest of shad. Trends in this fishery are highly correlated to the Smithfield Beach CPUE time-series.

Historically, a substantial recreational fishery for shad existed in the non-tidal reaches of the Delaware River; however, participation in this fishery is declining. The current recreational harvest is unknown. Most shad anglers practice catch-and-release. The mortality associated with catch-and-release of shad in the Delaware River is unknown, but considered to be minimal based on studies in the Hudson River. The recreational creel limit is currently 3 American shad in the Delaware River, bay, and tidal tributaries.

In addition to harvest and natural mortality, the Co-op investigated other factors that may also impact the Delaware River stock. As part of the American Shad restoration program for the Schuylkill and Lehigh rivers, the Pennsylvania Fish and Boat Commission (PFBC) estimates the contribution of otolith-marked hatchery shad to the returning adult spawning populations in both rivers. While evidence suggests these fry stockings substantially support the runs in the Schuylkill and Lehigh rivers, the contribution to the mainstem Delaware run above their respective confluences has been minimal. Correlations between the Atlantic Multidecadal Oscillation (AMO) and indices of adult shad relative abundance from the Lewis haul seine fishery suggest a changing relationship between shad abundance and Atlantic long-term sea surface temperatures; early in the time series (1970s-1980s) there was a positive correlation; however, more recent information (1990s-2015) indicate a negative correlation. In addition, a review of the indices of abundance of Striped Bass and American Shad has determined that Striped Bass abundance is not correlated with American Shad abundance. Possible losses from oceanic commercial fisheries principally, as bycatch, have been difficult to evaluate; but, the Co-op is concerned these offshore fisheries may be having a negative impact on the Delaware River stock. Multiple water intake structures are found in the Delaware River and upper estuary that may be causing mortality on American Shad eggs, larvae, and juveniles through impingement and entrainment. The Co-op is actively commenting on water intake projects to improve protections for shad at those facilities.

The Co-op proposes five benchmarks for sustainability. The benchmarks have been set to respond to any potential decline in stock. Thus all benchmarks are viewed as conservative measures. Failure to meet any of the defined benchmarks will independently cause immediate management action. The severity of the action will be situational and proportional to the number of benchmarks exceeded and any actions will be applied to all waters within the basin. No benchmark has tripped its target level for the last two consecutive years. All benchmarks will be reviewed annually after completion of annual ASMFC Shad and River Herring compliance reports.

- **Non-tidal JAI:** Data for this index is derived from the New Jersey Division of Fish and Wildlife (NJDFW)/Co-op annual fixed station seining (1979-2007; 2012-2015) in the non-tidal Delaware River mainstem from Phillipsburg, NJ to Milford, PA. The non-tidal JAI is standardized with respect to environmental covariates using generalized linear model methodology. The benchmark is based on data from 1988-2007 and 2012-2015. Failure is defined as the occurrence of three consecutive JAI values below a value of the 25th percentile of the historical data (1988-2015), where 75% of the values are higher.

- **Tidal JAI:** Data for this index is derived from the NJDFW annual Striped Bass seining in the upper estuary. Only those stations from New Bold Island to the Delaware Memorial Bridge are included. The JAI index represents the annual geometric mean of the catch data. A benchmark was based on data from 1987 – 2015. Failure is defined as the occurrence of three consecutive JAI values below a value of 4.0 (i.e., the 25th percentile of the historical data, where 75% of the values are higher).

- **Adult CPUE:** This index is based on the annual CPUE (shad/net-ft-hr*10,000) in the PFBC gill net, egg-collection effort at Smithfield Beach. The benchmark was based on the entire dataset (1990-2015), with failure defined as the occurrence of three consecutive CPUE values below a value of 37.5 (i.e., the 25th percentile of the historical data, where 75% of the values are higher).

- **Ratio of Harvest to Smithfield Beach CPUE:** This index is calculated as a ratio of the combined commercial harvest of the Delaware River American Shad stock, in pounds, divided by relative abundance of adult survivors captured at Smithfield Beach (CPUE) divided by 100. The benchmark is based on data from 1990-2015 and failure is defined as the occurrence of three consecutive values above a value of 36.5 (i.e., the 85th percentile of historical data, where 15% of values are higher).

- **Mixed Stock Landings:** This index is calculated as the annual landings from the mixed stock fishery. It is calculated as 60% of total shad landings below the demarcation line (Bowers Beach, DE to Gandys Beach, NJ). The benchmark is based on data from 1985 – 2015 and failure is defined as the occurrence of 2 consecutive years above a value of 47,650 (i.e., the 75th percentile of historical data, where 25% of values are higher).

It is anticipated that this sustainability plan will sustain current levels of the Delaware River American Shad stock while allowing for human use of the resource. The Co-op views this plan having a five-year term beginning with its acceptance by the ASMFC.

Sustainable Fishery Plan for the Delaware River

1. Introduction

In accordance with guidelines provided in Amendment 3 to the Interstate Fishery Management Plan for Shad and River Herring (ASMFC 2010), the Delaware River Basin Fish and Wildlife Management Cooperative (Co-op) submitted the first American Shad Sustainable Fishing Plan (SFP) in September 2011 (DRBFWMC 2011). After review, this SFP was accepted by the Atlantic States Marine Fisheries Commission (ASMFC) Policy Board in February 2012 remaining valid for a term of five years (2012 – 2016; 2012 SFP). This document (i.e., 2017 SFP) represents a revised SFP for governing management of American Shad over the next five year term, 2017 – 2021, pending final approval by ASMFC. It is submitted jointly by the States of Delaware, New Jersey, and New York, and the Commonwealth of Pennsylvania, for management of American Shad in waters of the Delaware River Basin (Figure 1).

The 2012 SFP prescribed accomplishment of several actions to further support our understanding of sustainability of American Shad. Co-op members have successfully re-initiated the non-tidal juvenile abundance beach seining. Efforts follow the same protocols as the original survey. Ageing of shad scales has been standardized among Co-op members. Over a series of workshops, Co-op members have drafted a guidance protocol to aid in consistent interpretation of scale microstructure. Ultimately, the intent of this effort is to provide annual mortality estimates. The Co-op also conducted a thorough examination of recent tagging and genetics studies and has established a new benchmark based on harvest limits on the mixed stock of American Shad that occurs in the lower Delaware Bay during the spring fishery.

The 2012 SFP also prescribed securing additional funding for tagging programs to better delineate the mixed stock fishery. Although tagging efforts were not increased during the 2012 SFP, there are plans to conduct additional genetics studies in 2017 to further describe the genetic origin of American Shad at different locations within the estuary. These results will help the Co-op refine the proportion of landings to assign to the mixed stock based on geographic regions within the estuary.

Status updates of monitoring programs supporting the 2017 SFP and associated benchmarks will be reported in annual compliance reports to ASMFC. Annual reports are jointly submitted by the Co-op.

1.1 Request for Fishery

The Co-op desires that the Shad and River Herring Management Board consider this request to approve a Sustainable Fishery Plan for American Shad of the Delaware River Basin. This plan includes a request for approval of both recreational and commercial harvest within the entirety of the mainstem Delaware River and its tidal tributaries in the states of New Jersey and Delaware. Accordingly, the Co-op justifies this request based on analysis of historical trends in juvenile and adult relative abundance, and commercial and recreational fishery data.

1.2 Definition of Sustainability

Amendment 3 to the Interstate Fishery Management Plan for Shad and River Herring defines a sustainable fishery as one that will not diminish potential future stock reproduction and recruitment. The Co-op proposes that reproduction and recruitment in the Delaware River American Shad stock be measured by two indices of age zero abundance to be augmented with an index of spawning stock abundance and a ratio of landings to that index of spawning stock abundance. Benchmarks have been proposed for all indices to define levels needed to avoid diminishing potential stock reproduction and recruitment. We will judge fisheries as sustainable as long as indices of stock condition remain within these benchmarks; otherwise exceedance will necessitate mandatory corrective management actions. Since the fishery in the lower Delaware Bay also harvests American Shad of other coastal stocks, an index with an associated benchmark has been established to limit harvest on non-Delaware River (mixed) stocks.

2. Stock Status

2.1 Previous Assessments

The Delaware River was included in the 1988 and 1998 ASMFC coast-wide stock assessments for American Shad (Gibson *et al*. 1988; ASMFC 1998). The 1988 Assessment utilized the Shepherd stock-recruitment model to estimate maximum sustainable yield (MSY) and maximum sustainable fishing rates (F_{msy}). That assessment estimated F_{msy} for the Delaware River to be equal to 0.795 with exploitation at MSY at 0.548. The historical fishing rate for the Delaware River stock was estimated to be F = 0.320. The 1998 Assessment utilized the Thompson-Bell yield-per-recruit model to derive an overfishing definition (F_{30}) for American Shad. Average fishing mortality from 1992 to 1996 for the Delaware River was estimated at F = 0.17, which includes out-of-basin estimates of harvest, and was considered well below the F_{30} value of F = 0.43.

The most recent stock assessment was completed in 2007 (ASFMC 2007). Findings identified more than twenty-five sources of fishery-independent and fishery-dependent data. Clearly, the Delaware River stock of American Shad declined through the 1990s and remained at low levels. The cause of the decline was not identified, nor was any explanation postulated for why the stock remained at low levels since the decline. The 2007 assessment concluded that juvenile production remained stable without any apparent trend, and did not appear to be correlated between adult abundance or returning adults in subsequent years (ASMFC 2007). The stock assessment sub-committee was unable to reach consensus on what could be considered the best scientific benchmark(s) from the available datasets (ASMFC 2007).

Substantial monitoring of the American Shad population has been accomplished in the Delaware River. Many of the indices analyzed for the ASMFC 2007 stock assessment have continued through 2015.

2.2 Stock Monitoring Programs

2.2.1 Fishery Independent Surveys

2.2.1.1 Juvenile Abundance Surveys

The New Jersey Division of Fish and Wildlife (NJDFW) conducted sampling for young-of-year (YOY) American Shad in the non-tidal Delaware River from 1979 – 2007. Sampling was conducted in non-tidal waters, to provide a juvenile abundance index (JAI) for management purposes. Beginning in 1979, only a single site, Byram (RM 157.0), was sampled. Other sites were added in later years with the addition of Trenton (RM 131.6) in 1980, Phillipsburg (RM 184.2) in 1981, Water Gap (RM 210.0) in 1983 and Milford Beach (RM 246.4) in 1988. Sampling was discontinued at the Byram site in 2002 due to heavy siltation without replacement as no suitable replacement beaches were identified. Since 1988, the Trenton, Phillipsburg, Water Gap, and Milford Beach sites were consistently annually monitored for YOY shad recruitment.

Sampling consisted of beach seining at fixed stations generally located adjacent to boat access points with suitable bottom substrates conducive to seining. A series of four seining hauls were accomplished once a month using a 300 ft (91.44 m) by 12 ft (3.6 m) bagless seine of 0.25 inch (6.3 mm) delta mesh, beginning at sunset, from August through October. Hauls occurred over the same swept area, but were separated by 30 minute intervals from the time of retrieval until the next deployment

Beginning in 2012, the Co-op reinitiated the NJDFW non-tidal beach seine survey for monitoring American Shad YOY production. The original four historic sites, Trenton, Phillipsburg, Water Gap, and Milford Beach are annually surveyed following the original NJDFW protocols. An additional site, located at Lackawaxen (RM 277), was also initiated in 2012. The intent was to provide better understanding of YOY production in the upper reaches of the Delaware River mainstem that were not traditionally surveyed by NJDFW. The Lackawaxen site, however, was discontinued after the 2014 season due to excessive submerged aquatic vegetation beds occurring in 2013 and 2014 that effectively prevented seining. The Lackawaxen site was not included in any analysis or estimation of JAI index.

The National Park Service (NPS) self-funded a one-year synoptic survey of YOY shad occurrence in the upper reaches of the Delaware River main stem, in 2015. The intent was exploratory sampling to identify potential long-term monitoring sites upstream of Port Jervis, New York (RM 254). Two sites were identified in the Delaware River main stem including Skinners Falls (RM 295) and Buckingham (RM 325). Fireman's Launch (E. Br. Del. R.) and Balls Eddy (W. Br. Del. R.) were also sampled. Young-of-year shad are known to occur in the East Branch of the Delaware River; whereas, they are generally acknowledged to be extirpated from the West Branch of the Delaware River (Sheppard 1983, Bovee *et al.* 2003). Outflows from New York City's Cannonsville Dam begin at the undammed reach of the West Branch and are manipulated to maintain a trout tailwater, which is generally colder than thermal tolerances of YOY shad.

Beach seining was accomplished following original NJDFW protocols. Bottom substrates in the upper Delaware River are best characterized as a mixture of large cobble, rock and boulders. Alternative sampling methodology, including fyke netting and visual surveys, were also investigated with limited success and will not be pursued further (Table 1). As expected, no shad were captured at the Balls Eddy site, which was discontinued after the September sampling. Few YOY shad (< 100 individuals) were caught by seining at the other three sites (Table 1). Rough bottom substrates and flow hindered seine efficiency at the Buckingham site. It was determined that long-term monitoring seining was impractical at the Buckingham site, due to perceived gear inefficiency and poor accessibility to the site. Over the tenure of the 2017 SFP, Co-op members will develop a time-series at the other two sites (i.e., Skinner's Falls and Fireman's Launch) for comparing to downriver catches. Catches from these exploratory sites will not be used in the estimation of the non-tidal JAI index in the 2017 SFP.

In the tidal Delaware River, NJDFW collected data pertaining to YOY shad during their annual Striped Bass recruitment survey. Since 1980, seining was accomplished using a 100 ft (30.48 m) by 6 ft (1.83 m) bagged seine of 1/4 inch (6.35 mm) delta mesh, during daylight hours. A series of fixed station sites were sampled twice a month June through November. November sampling was discontinued in 2016. Catches from sites were combined into two general regions. Region 2 represents sites (n = 16) from the Delaware Memorial Bridge, RM 70.9, to the Philadelphia Naval Shipyard, RM 94.4; whereas Region 3 represents sites (n = 8) from just north of the Betsy Ross Bridge, RM 105.8 to New Bold Island, RM 125.4. Data from lower Delaware Bay sites were eliminated where YOY American Shad are less likely to be encountered in higher salinity waters. In 2015, a QA/QC check was completed on all data sets from the Delaware River resulting in updates to the recruitment indices during the time-series.

Young-of-year shad lengths (i.e., fork length, FL) were measured to characterize trends in size over the time-series. A maximum of 25 individuals were measured for each haul at all non-tidal sites since 1979. Lengths from the four hauls at each non-tidal site were combined. Only lengths from 1983 to present were retained for analysis. Prior to 1983, non-tidal sites sampled and sampling frequency differed from the remainder of the time-series. Beginning in 2000, the first 30 individuals were measured at each site in the tidal reaches. Lengths from each tidal site were combined by region.

Median length frequencies for non-tidal and tidal sites, by year and month, are graphically illustrated (Figure 2). In general, for non-tidal sites, the smallest shad were collected in August, in all years. Median sizes ranged 42 mm (1996) to 69 mm FL (2013; Table 2). Exceptionally small (i.e., < 30 mm FL) YOY shad were frequent occurrences in August samples (n = 18 years). A total of 120 individuals less than 30 mm FL were captured over the time-series, principally at Milford (n = 50), Water Gap (n = 36), and Phillipsburg (n = 34) sites. Median lengths of shad caught in September varied 59 mm FL (1996) to 85 m FL (2015). While no shad less than 30 mm FL were captured at any September collections, two larger shad, 150 mm FL and 201 mm FL, were captured at Phillipsburg in 2015. The largest YOY shad were consistently caught in October, with median sizes varying 65 mm (1993) to 92 mm FL (2013). An exceptionally large individual, 203 mm FL, was captured at the Phillipsburg site in October, 2013. This shad possibly represents a 1+ age shad, straying further upriver. Conversely, two small sized shad, 17 mm FL and 29 mm FL were captured at the Trenton site in October, 2013.

Distribution of size among months collected from the tidal sites demonstrated increasing sized shad in later months (Figure 2; Table 3). Median sizes ranged from 49 mm (2003) to 68 mm FL (2006) in August; 52 mm (2007) to 73 mm FL (2006) in September; and 56 mm (2007) to 84 mm FL (2006) in October collections. A total of five exceptionally small (i.e., < 30 mm FL) sized shad including 27 mm FL and 29 mm FL shad in August, 2000, 28 mm FL shad in August 2003, 29 mm FL shad in August 2013, and 25 mm FL shad in September 2013, were collected during the time-series. No shad greater than 124 mm FL were captured at any tidal sites.

Examination of monthly median lengths determined from non-tidal catches demonstrated considerable variability among years (Figure 2). In some years, median sizes in September or October were more reflective of the previous months' smaller median size in other years. For example, the relatively small observed September median sizes in 1996 (59 mm FL) and 2003 (55 mm FL) were similar in size to typical August median sizes in other years. Observed small sized October medians in 1993 (65 mm FL) and 2003 (67 mm FL) were reflective of typical September median lengths in other years. Conversely, median sizes in August and September in some years were more reflective of latter months' larger median size in other years. Larger observed August median sizes in 2013 (69 mm FL) and 2015 (68 mm FL) were of similar sizes in other years September median sizes; and larger observed September median sizes in 2001 (76 mm FL), 2007 (75.5 mm FL), 2013 (80 mm FL), and 2015 (85 mm FL) were similar to October median sizes.

Monthly median sizes at tidal sites were inconsistent among years (Figure 2). Median sizes in 2002, 2006, 2008, and 2012 overall represented large YOY shad. Median sizes in August for these years, 64 mm FL, 68 mm FL, 66 mm FL, 64 mm FL, respectively, were larger than October median sizes in other years (Table 3). October median sizes in 2003 (62.5 mm FL), 2005 (62 mm FL), 2007 (56 mm FL), 2013 (61 mm FL), and 2014 (60 mm FL), conversely, were reflective of smaller sized YOY shad. These late season medians were of typical sizes observed in August for other years.

Latitudinal variation in sizes of YOY shad is unclear (Figure 3). In several years 2001, 2007, 2013, and 2014 the four upriver non-tidal sites had larger sized shad in most months, compared to tidal collections (i.e., Regions 2 and 3). Yet, median sizes of shad collected from Region 2 and 3 in 2002, 2003, 2006, and 2012 were larger than observed at some non-tidal sites. Considering only the four non-tidal sites, annual patterns among sites also remains unclear. Median sizes at Trenton, were typically smaller than observed at Phillipsburg, Water Gap and Milford in 2007, 2005, 2013, 2014, 2015; yet 1983, 1984, 1994, 2003, 2004, 2006 median sizes at Trenton tended to be larger shad.

Initial examination of the variability associated with measured fork lengths suggests considerable differences would be expected between observed length distributions (Tables 2 - 3; Figure 4). As an example, graphical comparison between Region 2 and Trenton mean distributions and standard errors, demonstrate limited overlap of observed length distributions among years and months, suggesting a significant difference among means between the two areas. This finding was consistent for all other comparisons among sites.

The out-migration of YOY shad in the Delaware River is poorly understood. As YOY shad increase in size at the non-tidal sites, they may preferentially out-migrate upon achieving some unknown suitable size. The relatively small differences of median sizes between September and October collections at upriver non-tidal sites might be reflective of this behavior. Alternatively, YOY shad may remain in non-tidal nursery waters until the onset of fall cold fronts, which finally forces out-migration. Sometimes, these fronts may occur prior to October sampling, possibly influencing out-migration of larger sized individuals. While the increased median size among months is suggestive of the overall year-class growth, the Delaware River represents an open population. Out-migration behaviors may be strongly influential on synoptic sampling characterized by the non-tidal sites.

The expectation of the tidal sites to have the larger sized shad was not realized. This assumes spawning occurs sooner in the calendar year at downriver locations; and hence experiences a longer growth period. Sites in the tidal waters occur primarily near the mouths of small tidal creeks or along estuarine shorelines. This close proximity to estuarine waters possibly allows out-migration to occur at smaller sizes. Additionally, gear catchability and avoidance behaviors of larger sized YOY shad in tidal sampling may influence the occurrences of larger shad. Collections are accomplished using a much smaller seine in daytime hours. Shad are visually-oriented and larger shad may preferentially escape from tidal collections; yet estuary waters are typically turbid. In contrast, non-tidal collections employ a much larger seine, in nighttime hours, which may allow increased catchability of larger YOY shad.

Both the non-tidal and tidal JAIs are reported as separate geometric means, with their respective sites combined among location and months. The historic non-tidal JAI (i.e., composed of Trenton, Phillipsburg, Water Gap, and Milford Beach sites) increased from 1980 to 1984, then fluctuated without trend through 2007, with good year class abundance reported in 1996 and 2007 (Table 4, Figure 5). Closer evaluation reveals an increasing trend from 1980 through the time-series peak in 1996. The JAI decreased from 1996 through 2002 but rebounded until the survey ended in 2007. Since the re-initiation of the survey, YOY abundance has been declining. Relative abundance observed in 2012 was of similar magnitude as some past years' peaks, ranking 9th highest overall. The 2015 estimate, however, was below the time-series average, ranking 20th overall. Comparatively the peak years, 1996 and 2007 ranked 1st and 2nd, respectively; whereas the poor years, 1998, 2002, and 2006 ranked, 28th, 30th, and 29th, respectively.

To further examine variation in the non-tidal index, the sampling sites were scrutinized for their contribution to the overall index. Table 4 shows the annual geometric mean catch per haul for the four historic, non-tidal index sites (i.e., Trenton, Phillipsburg, Water Gap, and Milford). Though variance is high, mean catches at Trenton are generally an order of magnitude lower than those at the other three sites. Table 5 displays a correlation matrix of log-transformed geometric CPUEs from each of the four non-tidal sites, the tidal index (i.e., Regions 2 and 3 combined), and a non-tidal index composed of only the Phillipsburg, Water Gap, and Milford sites. Though not significant (one tailed $p = 0.28$), Trenton has a higher correlation value with the tidal index than the index derived from the other three non-tidal sites (i.e., Phillipsburg, Water Gap, Milford).

The perceived agreement of the Trenton site to the tidal index is likely due to location. Historically, the Trenton site was included in the non-tidal JAI index; yet, this site is actually located in the tidal reach near head-of-tide (RM 133). Tidal influence is observed at the Trenton site. This is different from the other three sites, which are located in the non-tidal reaches where river flows are unidirectional. With a sampling regime where sites are sampled four times each night, a slowing or change in flow during sampling may have a large impact on fish presence and catchability. In addition, tidal fluctuations can impact water clarity and water chemistry at the site.

Co-op members will continue to sample the Trenton site as has been done in the past, but not include sample events at Trenton in either the non-tidal or tidal JAI indices. Comparison of the historic (i.e., Trenton, Phillipsburg, Water Gap, Milford) and new non-tidal (i.e., Phillipsburg, Water Gap, Milford, collectively informally referred to as the Big 3) geometric mean CPUE indices is shown in Figure 6. As the further upriver sites (i.e., Milford and Water Gap) had the biggest contributions to both non-tidal indices, the trends in the Big 3 non-tidal index are very similar to those explained above for the historic index. Co-op members will assess the non-tidal YOY shad recruitment using the Big 3 as the non-tidal JAI for the duration of the 2017 SFP.

To further standardize the non-tidal JAI in order to improve precision and accuracy, the Co-op conducted new analyses on the index to reduce variability in the index associated with collection and environmental variables. Previously, the Co-op had used a geometric mean to determine an annual value for the American Shad JAI. However, recent advances in fishery independent index standardization (e.g. ASMFC 2016) have led to indices being standardized by significant environmental covariates such as water temperature, depth, season, etc. using generalized linear models (GLM) to better account for variability in catch among years.

Inclusion of data was constrained based on two limitations. The non-tidal American Shad JAI data set extends back to 1981; however, the number of sampling events was not standardized until 1988. The survey samples American Shad at four fixed locations (Trenton, Phillipsburg, Delaware Water Gap, and Milford) with four hauls at each site from August through October. However, due to the lack of correlation of Trenton with the other non-tidal sites described above, the number of sites considered in this analysis was constrained to three locations (Phillipsburg, Delaware Water Gap, and Milford).

Model development considered explanatory variables (year, haul, ordinal day and site) to assess how they impacted catch. Ordinal day was the only variable considered continuous, and was treated as a proxy for temperature; all other variables were treated as categorical variables. Since catch was modeled for each tow, effort did not theoretically change and was excluded from the analysis. The generalized inflation factors were less than 1.5 after correcting for more than one degree of freedom suggesting that no collinearity was observed among any of the explanatory variables. Three models were compared in this analysis (Poisson, Negative binomial, and a Zero-inflated negative binomial). However, based on the dispersion or the relationship of the variance to the mean of all three candidate models (Poisson, Dispersion = 474.79; Zero-inflated negative binomial, Dispersion = 1.32) the negative binomial model (Dispersion = 1.05) was best fit to the data. After the full negative binomial model was considered, site was not found to be a statistically significant parameter impacting catch (df = 2, $p = 0.267$). However, all remaining covariates were highly significant ($p < 0.001$) when compared to the number of fish caught in each tow. Similarly, the final model was overall highly statistically significant (df = 2, $p < 0.001$). The final model chosen to standardize the non-tidal American Shad JAI in the Delaware River was defined as:

Number of Fish Caught ~ Year + Haul + Ordinal day

Annual estimates of mean number of fish caught or the new American Shad JAI, ranged from 53.67 – 420.81 with a 25th percentile of 145.90, median of 185.90 and a 75th percentile of 284.10.

We identified the relative power of the non-tidal JAI using the 'powertrend' function in the 'fishmethods' package in R. The power analysis for detecting trends in linear regression is implemented in 'powertrend' following procedures in Gerrodette (1987; 1991). Using the average annual proportional standard error (standard error/mean) from 1988-2015 of 0.23, we found that our survey can detect a 93% decrease and a 171% increase with a power ($1 - \beta$) of 0.80, i.e. our survey can detect changes in the annual JAI below 11.80 or above 456.99 over a five year period (Figure 7).

Comparison of the GM (i.e., Big 3) and GLM non-tidal JAI estimates is suggestive of similar trends (Figure 8). Both JAIs identified peak YOY production occurring in 1996, 2007, and 2012. Additionally, both indices also suggested JAI values observed in 1998, 2006 and 2013 as poor production years. One interesting difference between the two JAI indices is the reversal of relative abundances observed for 2003 to 2005. The Big 3 GM was suggestive of 2003 (78.7) and 2004 (80.0) JAIs being below long-term average of 123.4 and the 2005 (186.1) JAI being an above average year (Table 4). In contrast the 2003 (282.7) and 2004 (256.0) GLM JAI estimates were both well above the long-term average of 204.5 and the 2005 (204.6) JAI being an average production year (Table 4).

The ASMFC provides guidance on defining a JAI index and associated benchmarks. Amendment 3 to the ASMFC to the Interstate Fishery Management Plan for Shad and River Herring requires JAIs to be expressed as geometric means (GM) or area under the curve (AUC; ASMFC 2010). Confidence intervals should be provided for geometric means. For the 2017 SFP, the non-tidal JAI will be expressed both as a GM and a GLM; however, the benchmark for the non-tidal JAI will be based on the GLM analysis. The Co-op considers the GLM as providing a more robust JAI index than can be indexed by geometric means.

The tidal JAI increased from 1980 to 1988, and then varied without an apparent trend (Table 4, Figure 5). The tidal JAI also tended to be highly variable among years. Two good year-classes, 2005 and 2007, were immediately followed by two poor year classes in 2006 and 2008. After 2008, the tidal JAI was trending upwards, to an exceptional peak year-class abundance observed in 2013, ranking first over the time-series. Young-of-year production observed in 1996 also demonstrated very strong year-class abundance. Overall, the better than average year classes in 2005, 2007, 2013, and 2014 as well as favorable environmental conditions in recent years are encouraging (Table 4, Figure 5). The tidal JAI will continue to be calculated as a GM of annual catch for the duration of the 2017 SFP. The Co-op intends to conduct a similar GLM analysis on the tidal JAI to reduce variability and increase precision in that estimate.

The 2012 SFP found significant positive trends of both JAIs regressed on year and to each other. These relationships have since deteriorated. Previous relationships relied upon co-occurrences of peak year-classes, specifically 1996 and 2007. Over the last five years, since 2012, the JAIs tended to demonstrate opposite trends. For example, in 2012 the non-tidal estimate was suggestive of good production; whereas, the tidal JAI indicated poor production. The 2013 tidal JAI suggested exceptional year-class production, but the non-tidal was poor. Again in 2014, the tidal JAI decreased while the non-tidal JAI increased. This increased disparity between the two indices suggests divergence of year-class production success.

Multiple factors influence the success of YOY year-class production. Certainly, spawning success dictates total egg availability, but environmental conditions tend to heavily influence hatching success and subsequent survival of fry and juveniles. Differences between the two JAIs suggest variables such as the timing of the run, water temperatures, etc. may affect the two areas differently in a given year. Water quality in the upper estuary, particularly in the Philadelphia reach, continues to improve. Returning adults may simply be taking advantage of this improved spawning area.

Amendment 3 defines recruitment failure as occurring when three consecutive JAI values are lower than 75% of all other values in the data series (ASMFC 2010). The Co-op has adopted this definition for both the non-tidal and tidal JAI benchmarks. These are calculated as the 25th percentile, using the “quantile” function in the R package or “percentile.inc()” function in Microsoft Excel spreadsheets. The non-tidal benchmark is inclusive of those years in the GLM analysis (1988 – 2015). The tidal benchmark is based on JAI values from 1987 – 2015, rather than inclusive of the entire time-series (1980-2015). Prior to 1987, data collection was not standardized among tidal locations.

2.2.1.2 Adult Abundance Indices

Co-op members annually monitor the relative abundance of returning spawning adult shad in the Delaware River. Monitoring occurs after the commercial fishery, such that captured shad represent survivors from the fishery. This effort is currently being accomplished only at one location at Smithfield Beach (RM 218) as a gill net survey on actively spawning adults. Over the tenure of the 2012 SFP, an electrofishing survey at Raubsville, PA (RM 176) was also pursued. Electrofishing targeted adult shad migrating to upriver spawning grounds. Initiated in 2010, the intent was to investigate the possible substitution of the electrofishing effort in place of the gill net survey. This substitution was viewed as a cost savings in term of personnel resources; however, the Raubsville electrofishing monitoring was terminated in 2016. Study findings for both Smithfield Beach and Raubsville efforts are discussed in greater detail below.

2.2.1.2.1 Gill Net Survey

Collections at Smithfield Beach principally focus on capture of brood fish and subsequent strip-spawning to produce fertilized eggs in support of the Pennsylvania Fish and Boat Commission (PFBC) restoration efforts in the Schuylkill and Lehigh rivers, the largest tributaries to the Delaware River. Approximately 8 to 18 gill nets (200 feet in length by 6 ft deep) are set per night with mesh sizes ranging from 4.5 to 6.0 inches (stretch). The total number of net sets by mesh size per night depends on the previous nights' catch for maximizing female captures. Nets are anchored on the upstream end and allowed to fish parallel to shore in a concentrated array. Netting/spawning operations typically begin on Mother's Day when river flows are workable and river temperatures reach 16.0 ^{o}C. Sampling occurs Sunday through Thursday evenings and is typically terminated near the end of May or early June when egg viability decreases and/or river temperatures reach 21.0 ^{o}C for an extended period of days. Typically, the sampling period encompasses three weeks of nightly effort. Biological data collected include gender, length (total and fork), weight (excluding ovarian weight due to the strip spawning procedures), otolith age, scale age, repeat spawning marks, and chemical marks placed on the otolith during rearing. No biological data were recorded prior to 1996.

Overall, the total number of days spent gill netting varied from nine (1990 and 1992) to 21 (2001, Figure 9). Assigning a week number, based on the occurrence of January 1st as week one, sampling durations among years can be examined. Sampling principally occurred during weeks 20 through 22 (Figure 9). Yet, sampling in 1990 was completed early (i.e., weeks 18 and 19) compared to the time-series. In several years, however, sampling was extended into June, weeks 23 and 24.

Total catch at Smithfield Beach varied among years (Figure 10). Greatest total numbers of captured shad occurred in 1995 (n = 1,398), with several other early years (i.e., 1990 – 1994) in the time-series also having large total catches (> 1,000 individuals). Conversely, the lowest total catch occurred in 2006 (n = 356). Three other years, 2002 (n = 400), 2004 (n = 425), and 2009 (n = 372) also had very low total catches of shad. Observed sex ratios in any given year is dependent on the frequency of gill net mesh sizes deployed.

The frequency of stretch mesh sizes used varied among years (Figure 11). The use of 4.5 inch and 5.0 inch stretch mesh nets, tended to be principally deployed in any given year to support broodstock collections. The increased use of the 4.75 inch stretch mesh size in later years (i.e., post 2012) was due to a perceived need to increase the male to female ratio for improved egg viability. Use of large ($\geq$ 5.5 inch) stretch mesh sizes were not as commonly deployed as smaller stretch mesh sizes, due to the perceived lack of catch.

In any given year, most of the catch at Smithfield Beach principally originated from two stretch mesh sizes (Figure 12). The 5.0 inch stretch mesh typically captured 31% – 58% of all females.

The 4.5, 5.25, and 5.5 inch stretch mesh nets also caught female shad; but in lesser quantities, representing 4.8% - 20.0 %, 5.3 % – 13.7%, 0.3% - 18.0% of the female total catch, respectively. Female catch from the 5.75 and 6.0 stretch mesh nets were typically less than 10% in most years. The 4.5 inch stretch mesh typically captured 24% – 69% of all males. The 5.0 and 4.75 inch stretch mesh nets also captured some of the male total catch, 16% – 48% and 2.2% - 26.3%, respectively. The other larger stretch mesh sizes (> 5.25 inch stretch mesh) caught few (< 10%) males.

Size selectivity of gill nets introduces bias into catch characteristics (e.g., length and age distributions). This bias may preferentially capture a specific size range of shad dependent, in part, on stretch mesh size and fish body shapes. Figure 13 illustrates annual Smithfield Beach catch lengths by stretch mesh size (1999 – 2009). Median size, by stretch mesh size, does not appreciably increase among catches of shad from the small stretch mesh nets to comparatively larger stretch mesh nets. For example, median sizes of the female catches from the smallest stretch mesh nets (4.5 inch) was 534 mm TL compared to the median size of 573 mm TL of female shad caught in the 6.0 inch stretch mesh nets (Table 6). Similarly, median size of males caught in the smallest stretch mesh nets (4.5 inches) was 489 mm TL compared to 521 mm TL median size of males caught in the 5.5 inch stretch mesh nets (Table 6). Interestingly, the smallest median male size (466 mm TL), however, occurred from catches in the largest stretch mesh nets (6.0 inch; Table 7). The difference between the minimum and maximum median sizes for both genders, 39 mm and 55 mm, for females and males, respectively, does not suggest a broad distribution of lengths among the various gill net catches. In all years, for all stretch mesh sizes, a considerable overlap of size distributions occurs.

Median length frequencies varied among years for both female and male shad (Table 7; Figure 14). Female total lengths ranged from 437 mm TL (2008) to 644 mm TL (2003), with median sizes between 516 mm TL (2010) to 571 mm TL (2003). The overall size range (i.e., minimums and maximums) for females overlapped among years. Generally, males are smaller sized than females. Total lengths ranged from 398 mm TL (2005) to 615 mm TL (1996), with median sizes between 468 mm TL (2009) to 514 mm TL (2002). Length distributions for males among years also demonstrated considerable overlap.

Observed trends of annual length distributions appear to have limited relationships to the frequency of deployed gill net mesh size (Figure 14). Overlaying the frequency of gill net deployment on annual length distributions, suggests increased sizes of females were directly related to the proportion of the number of 5.0 inch mesh nets set per year. This relationship, however, was not significant (Spearman's Rank: $r = 0.246$, $p = 0.325$). Nor were observed female length frequencies significantly related to deployment frequency of all other mesh sizes. No significant relationships were found between observed male length frequencies to frequency of mesh sizes deployed, excepting for 5.5 stretch mesh (Spearman's Rank: $r = -0.718$, *p* = 0.00079). This finding is most likely strongly influenced by the paucity of male catch in the 5.5 stretch mesh size in addition to its infrequent deployment.

Length distributions among stretch mesh sizes are influenced by several factors. During the initial days of spawning, increased body girth due to swollen gonads, tend to allow smaller sized shad being caught in large sized mesh. Then as larger fish become spent, their slimmer body girth allows larger sized shad to be caught in smaller mesh nets. Additionally, shad tend to be fragile fishes, such that they easily perish over slight interferences. Mortalities due to entanglement (i.e., lip hooks) are a common occurrence throughout the sampling periods.

A considerable time-series of Delaware River American Shad scales and otoliths have been collected from Smithfield Beach, since 1996 to present date. While these structures have been aged, due to uncertainty associated with ageing (McBride *et al*. 2005; Duffy *et al*. 2012) this information was not presented in the 2012 SFP. In recent years, Co-op members have arrived upon an agreed protocol to provide consistency of ageing scale microstructure (Appendix A). This protocol is inclusive of a reference set to aid in identifying annuli and repeat spawning marks. Co-op members will be applying this protocol to the 2015 Smithfield Beach collections and subsequent annual collections. While this protocol has not been applied to the historical ages, Co-op members have agreed inclusion of historical age distributions as necessary to fully understand the dynamics of the Delaware River shad spawning population. Co-op members intend to review the historical records to strengthen confidence of assigned interpretations.

The Delaware River American Shad spawning population is supported by few age classes (Table 8; Figure 15). Age 5 and Age 6 typically represented the majority (> 70%) of female shad, in any given year. Only in three years were these two ages not as strongly represented, including 2006 (66%), 2012 (41%), and 2014 (69%). Ages 3 and 7, typically contributed less than 1% and 10%, respectively, in any given year; yet, in 2005 (25%), 2006 (14%), 2009 (14%), 2012 (57%), and 2014 (28%), Age 7 female shad composed a greater portion of the observed ages. Ages 8 and 9 female shad were rare (<3%) occurrences. No female shad over Age 9 were observed.

Male shad were principally (> 70%) represented by Age 4 and Age 5 shad, in any given year (Table 9; Figure 14). In three years, 2011 (77%), 2013 (60%), and 2014 (41%), Age 6 male shad also contributed to a greater proportion of the observed age distribution. Age 7 male shad were also prominent in 2012 (21%) as well; whereas, in all other years, Age 7 shad were a rare occurrence (< 5%). Young (Age 3) or old (Age 8) male shad also tended to be rare (< 10%). No male shad over Age 8 were observed.

The modal progression of age classes from peak YOY production years is apparent in observed Smithfield Beach age distributions. Strong year-class production has been related to the occurrence of subsequent returning adults to Smithfield Beach. This relationship is further discussed at the end of this section.

Application of annual age-length keys provides for the estimation of mean size-at-age (Table 9; Figure 16). Graphical representation is suggestive of a downward trend for Age 4 through Age 7 for both female and male shad. Regressing mean size-at-age on year demonstrated declining trends for Age 4 (F = 8.19, df = 18, $p = 0.010$) and Age 6 (F = 5.70, df = 18, $p = 0.028$) females; but, not for Age 5 ($p > 0.05$) or Age 7 ($p > 0.05$) females. Regressions of male mean size-at-age on year were not significant for Age 4, Age 5, or Age 6, but male Age 7 mean size-at-age were significantly declining (F = 10.44, df = 9, $p = 0.012$).

Gill net selectivity can influence observed mean size-at-age; however, we believe the impact of selectivity on mean size-at-age was minimal. The majority (i.e., 74% - 99%) of the female catch originates from the combined catch of all mesh sizes $\leq$ 5.5 inch; whereas, the majority (88% - 98%) of the male catch is from the combined catch of 4.5 inch through 5.0 inch stretch mesh net (Figure 12). The increased use of smaller mesh nets (i.e., 4.5 and 4.75 inch stretch mesh) with a concomitant decline of larger mesh nets (i.e., > 5.0 stretch mesh) use in later years may be a causative effect to the observed declining mean size-at-age (Figure 11). A significant correlation was found between female mean size-at-Age 4 shad to the frequency use of the 4.75 stretch mesh net (Spearman's Rank: r = -0.55, $p = 0.033$). All other age classes for both female and males did not significantly correlate (Spearman's Rank: $p > 0.05$) to the frequency of use of any gill nets, regardless of stretch mesh size.

There is some evidence to suggest that mean size-at-age is declining towards smaller sized shad in two age classes. These declining trends appear to be a shift in the population, given nominal influence of gill net selectivity. In later years 2011 – 2014, older (i.e., > Age 6), and presumably larger sized shad, tended to have a greater contribution to the total catch (Figure 15). Larger sized shad would be anticipated to have a greater contribution to increased mean size-at-age. The observed declining trend is contrary to that assumption. However, the declining trend is only identifiable with any certainty (i.e., significant) to females of two age classes, Age 4 and Age 6. The lack of any significant correlation for Age 5 females, who compose a large proportion of each annual spawning run, and older Age 7 female shad, is perplexing. Nevertheless, the Co-op recognizes the significance of a declining trend in size-at-age, and will continue to monitor for similar trends in multiple year classes.

Interpretation of scale microstructure potentially provides some understanding of the occurrence of shad returning for spawning in subsequent years (Figure 17). Prior to 2014, 83 % - 97 % of females and 83 % - 98 % of males captured at Smithfield Beach were principally composed of first-time (i.e., zero repeat spawning marks) spawning shad, in any given year. Shad repeat spawning in a second year (i.e., one repeat mark), varied 2 % to 17 % for either females or males; whereas, third-time (i.e., two repeat marks) spawning shad were infrequent (0 % - 3 %). A few shad (n = 10 individuals), were identified as fourth-time (i.e., three repeat marks, female: N = 8; male n = 1) or fifth-time (i.e., four repeat marks), female: n =

1; male: n = 0) spawners. In contrast, occurrences of second-time and third-time spawners occurred more frequently in 2014 and 2015, than in past years. Second-time spawners composed 53 % and 45 % of captured shad in 2014 for female and male shad, respectively. Catch of shad in 2015 also demonstrated increased occurrences of third-time spawners (female: 18 %; male: 24 %).

The incidence of repeat spawning being consistently interpreted from scale microstructure is difficult. Historical interpretations, not being subjected to the existing Co-op ageing protocol, were most likely conservative. The increased occurrences of repeat spawning in 2014 and 2015 possibly reflect influences of discussions during the development of the Co-op ageing protocol (Appendix A). Further evaluation of the historical data set needs to be refined to provide better consistency among the Co-op members' repeat spawning assignments. Until this review occurs, Co-op members will not associate any inferences to the spawning population based on repeat spawning marks.

In an attempt to get a general sense of trends in total instantaneous mortality (Z), historical age data from shad collected at Smithfield Beach were analyzed using a Chapman-Robson bias-corrected mortality estimator described in Smith *et al.* (2012). Total mortality was calculated for females and combined sexes on an annual basis beginning in 1997. To be consistent with the methods used in the 2012 Benchmark Stock Assessment for River Herring, the age of full recruitment was the age of highest abundance and there had to be at least three ages to be included in the respective analyses (ASMFC 2012). Total mortality estimates are reported in Table 10 and Figure 18. Female Z estimates ranged from 0.81 (2006) to 2.87 (2012). Total mortality estimates for combined sexes ranged from 0.83 (2015) to 2.82 (2012). Graphical representation is suggestive of an upward trend in total mortality (Z) for both female and combined sexes of American Shad collected at Smithfield Beach (Figure 18). These data are considered preliminary, given that Co-op members have not yet confirmed the historical age dataset with the updated ageing protocols (Appendix A).

The principal operations of Smithfield Beach were for broodstock collection of field fertilized eggs in support of the PFBC Lehigh and Schuylkill rivers restoration program. Standardized (i.e., Z score + 2 transformed) annual total egg collection varied among years (Figure 19). The greatest quantity of eggs were harvested in 1990 (n = 13.4 million). Total yield declined through the 1990's to a low of 3.8 million in 2000. During the 2000's total number of eggs harvested ranged between 2.0 – 6.3 million eggs. A peak in total eggs harvested was observed in 2011 (9.9 million eggs) near levels observed in the early 1990's. Subsequently, total egg harvest declined again to recent lows (3.9 million in 2015).

Evaluation of the average number of eggs per liter offers insight into the relative size of harvested eggs (Figure 19). The peak harvest of eggs observed in 1990 resulted in an average of 35,133 eggs per liter in that year. As total harvest declined through the 1990's, the average number of eggs per liter remained relatively stable (31,395 – 39,034 eggs/L). In 1998 (10.3 million eggs) and again in 2012 (8.9 million eggs) as the total egg harvest increased, concomitantly the average number of eggs per liter (1998: 55,382 eggs/L; 2012: 77,450 eggs/L) also increased. Interestingly, during the relatively low total harvest of eggs through the 2000s (2.0 – 6.3 million eggs), the average number of eggs per liter also remained relatively low (30,543 – 62,848 eggs/L). Increased catches of females were not correlated (Spearman's Rank: r = 0.236, p = 0.314) to the average number of eggs per liter, suggesting increased availability of females is not resulting in more eggs per liter. These trends are suggestive that the relative egg size was smaller in 1998 and 2012 peak periods relative to the 1990's and the 2000's.

The total number of viable eggs is declining over the time-series (Figure 19). Viability is defined as the difference of total number of eggs collected minus the total number of unsuccessfully hatched eggs. A Spearman's Rank correlation (r = -0.743) suggests this declining trend is significant (p < 0.0001). No relationship was found between annual sex ratios to total egg viability (Spearman's Rank: r = 0.159, p = 0.502). Thus, increased or decreased frequency of male to female shad does not appear to overly influence egg viabilities.

Total egg viability and total number of eggs per liter vary throughout the spawning season (Figures 20 – 21). Comparison of total egg viability among sampling week was not suggestive of any significant trend (Kruskal-Wallis: H = 10.491, p = 0.105); however, a general trend in declining mean egg viability is observed from week 18 through week 24. The total number of eggs per liter, however, were significantly different (Kruskal-Wallis: H = 44.733, p < 0.0001) among sampling weeks, suggestive of an increasing trend (Spearman's Rank: r = 0.928, p = 0.0025). American Shad are intermittent spawners, with individual shad spawning multiple times in a single season. As the season progresses, egg size appears to decrease with variability in egg viability and fecundity also being observed through the season.

Smithfield Beach catch-per-unit-effort (CPUE) values ranged from 17.1 to 190.1 shad/net-ft-hr*10,000 (Table 11; Figure 22). Abundance peaked in the early 1990's, declined through the mid 1990's, and remained relatively stable from 1999 to 2009, but below the long-term average. In 2009, CPUE was the lowest recorded (17.1 shad/ net-ft-hr*10,000); however, this was most likely impacted by climatic factors. The exceptionally wet spring resulted in higher than average freshwater flows, reducing the efficiency of the gill nets. Cold water temperatures delayed and/or marginalized spawning behavior which would also reduce gear efficiency. Catch-per-unit-effort increased with the 2011 (72.0 shad/net-ft-hr*10,000) and 2012 (73.54 shad/net-ft-hr*10,000) estimates ranking as the sixth and fifth highest, respectively, since 1990. The most recent years, 2013 – 2015, have been slightly below the long-term average.

The utility of Smithfield Beach as a monitoring program for defining sustainability of the Delaware American Shad is critical. Yet, the primary purpose as a broodstock source for the PFBC restoration program confounds conclusive statements on observed population biological trends. Should program objectives for the PFBC restoration efforts relax; monitoring objectives need to take priority. Smithfield Beach protocols need to standardize effort in the deployment of gill net mesh size frequencies to reduce uncertainty. For example, the recording of catch by stretch mesh size will be re-initiated.

2.2.1.2.2 Electrofishing Survey

The PFBC historically (1997–2001) monitored returning adult American Shad at a fixed station (RM 176) in the vicinity of Raubsville, PA using boat electrofishing gear. These historical efforts at Raubsville focused principally in aiding assessment of hatchery restoration success in the Lehigh River (Hendricks *et al*. 2002). This survey was re-initiated in 2010 under the 2012 SFP and continued through 2016 which will be its terminal year. The intent was to allow concomitant data collection for comparison of relative annual trends at Raubsville to Smithfield Beach.

Present day sampling followed historical protocol. Sampling effort at Raubsville targets American Shad as they migrate into upriver non-tidal reaches. Separate samples were collected on the PA side (west) and the NJ side (east) of the river. The river was sampled once a week from April to May (Figure 23). Weekly sampling concluded when 15 American Shad were caught or after one hour of electrofishing, whichever came first. Electrofishing effort was not recorded during 1998. Biological data collected included gender, length (total and fork), total weight, otolith age, scale age, repeat spawning, and hatchery otolith marks.

Length frequencies of captured shad are illustrated in Figure 24. Female total lengths (mm) varied from a minimum of 427 mm TL (2014) to 624 mm TL (2013). Median sizes varied among years between 503 mm TL (1997) to 553 mm TL (2013). Female median sizes appeared to increase from 503 mm TL (1997) to 546 mm TL 2001 during the historical sampling. In later years, 2010 - 2015, female median sizes appeared to increase from 528 mm TL in 2010 to a peak in size in 2013 (553 mm TL), then decrease to 530 mm TL in 2015. Male total lengths captured at Raubsville were suggestive of a consistent trend throughout the time-series. Male total lengths varied from 389 mm TL (2012) to 584 mm TL (2015). Median sizes varied by 35 mm TL among years, 466 mm TL (1997) to 501 mm TL (2011).

Graphical comparisons of median sizes captured at Raubsville to those captured at Smithfield Beach (all mesh sizes combined) are suggestive of similar trends (Figure 25). Yet these trends for female shad are not significantly correlated (Spearman's Rank: r = 0.587, p = 0.0739). The greatest difference in female median sizes, occurred in 1997, when female shad captured at Raubsville (503 mm median size) were approximately 35 mm TL smaller than captured at Smithfield Beach (538 mm median size). Male median sizes, however, were found to be significantly correlated (Spearman's Rank: r = 0.853, p = 0.0016) between Raubsville and Smithfield Beach. Electrofishing is a non-size selective sampling methodology. These close approximations of median sizes between Raubsville and Smithfield Beach shad collections lends credence to nominal selectivity being introduced by gill nets at Smithfield Beach.

The Raubsville electrofishing CPUE was highly variable among years sampled (Table 11; Figure 26). Historical catch rates demonstrated a dramatic increase of CPUE from 1999 (13.9 shad/hr.) through 2001 (48.4 shad/hr.). After the re-initiation of the survey, in 2010 and 2011, CPUE was below the long-term average (27.5 shad/hr.); but peaked in 2012 (46.5 shad/hr.); and then dropped to the time-series low in 2015 (11.3 shad/hr.). The 2011 CPUE is an under-representation of the spawning migration. No sampling occurred during traditional peak migration weeks.

The Raubsville and Smithfield Beach relative abundance trends demonstrated different trends (Figure 27). For example, the peak relative abundance observed at Raubsville in 2001 was not observed at Smithfield Beach. While both indices demonstrated a peak in 2012, the continued declining trend through 2015 at Raubsville was not evident at Smithfield Beach. Comparison of the trends (Z score + 2 transformed) between Raubsville and Smithfield Beach demonstrated no significant correlation (Spearman's Rank, $p > 0.05$) regardless of the absence/presence of the 2011 Raubsville CPUE data.

Hendricks *et al.* (2002) demonstrated returning adult shad, originally stocked as fry in the Lehigh River, tend to have increased frequency of occurrence on the Pennsylvania side of the Delaware River main stem. These returning adult hatchery shad can orient to the Lehigh River plume within the Raubsville electrofishing survey area. Thus, captures of shad on the PA side at the Raubsville (RM 176) may be more reflective of the returning Lehigh River (RM 183) spawning run, rather than shad orienting to upriver Delaware River locations (i.e., Smithfield Beach, RM 218). No significant correlation (Spearman's Rank, $p > 0.05$) using transformed (Z score + 2 transformed) data was found between separated Raubsville electrofishing catch-effort for either Pennsylvania or New Jersey CPUEs to Smithfield Beach CPUE (Table 11).

The Raubsville electrofishing efforts, while successfully capturing shad, likely underestimated the annual shad run under historical protocols. Examination of weekly effort suggests sampling was terminated prior to the end of the migration (Figure 28). For example, CPUE estimates in 2012 and 2014 appeared to be increasing when sampling ceased. Furthermore, indices in 2010 and 2013 also appear to suggest the continuance of the spawning run, although an observed peak was evident. The early cessation of sampling at Raubsville was due to reassignment of personnel to Smithfield Beach operations. The Raubsville sampling also relies on the assumption shad migrate uniformly throughout the week. This is most likely a simplistic assumption, such that the once-a-week sampling is not an adequate representation of migration. The Raubsville electrofishing is an unsuitable substitute for Smithfield Beach. The Co-op members have terminated this survey after the 2016 sampling season.

Beginning in 2002 through present date, the Philadelphia Water Department (PWD) has maintained a robust monitoring program on the Schuylkill River. Objectives include quantifying the resurgence of key migratory species such as the American Shad, assessing the relative health and abundance of both resident and migratory fish, and evaluating the success of restoration activities with fish passage counts at the Fairmount Dam fishway. Monitoring efforts are encompassed in two programs, fish passage surveillance (refer to the Adult Fish Passage subheading) and electrofishing in tidal waters immediately downriver of Fairmount Dam in the tidal Schuylkill River.

Electrofishing catch rates (i.e., CPUE) of American Shad in the tidal Schuylkill River are illustrated in Table 11 and Figure 27. Catch-per-unit-of-effort peaked at 504.9 shad/hr and 948.0 shad/hr in two years, 2006 and 2011, respectively. The 2002 CPUE (9.7 shad/hr) represents the time-series (2002 - 2014) low; however, the electrofishing CPUE observed in 2008 (177.1 shad/hr) and 2012 (314.9 shad/hr) also represent relatively low years of abundance. No significant correlation (Spearman's Rank, $p > 0.05$) was found between the Schuylkill electrofishing and Smithfield Beach time-series CPUEs. In contrast, a significant correlation (Spearman's Rank: $r = -1.0$, $p < 0.001$) was found between the Schuylkill and Raubsville electrofishing CPUEs. This comparison, however, was limited to only four years of concurrent sampling (2010; 2012-2014). A longer-time series of concurrent years sampled for the Schuylkill and Raubsville electrofishing sites is needed to provide a more robust characterization of any correlation.

2.2.1.2.3 Adult Fish Passage

Many of the Delaware River tributaries historically contained spawning runs of American Shad. Unfortunately, with the development of the lock/canal systems throughout the Delaware River Basin, including the Lehigh and Schuylkill rivers in the early 1800s, shad became extirpated in many of these tributaries. Efforts have been undertaken to restore shad in the Lehigh and Schuylkill rivers by installation of fish ladders, and the stocked fry hatchery program. A considerable time series of fish passage monitoring exists for the Lehigh and Schuylkill rivers, but passage into many other Delaware River tributaries is unknown.

The PFBC has an extended monitoring time-series, 1995 to present, characterizing shad passage into the Lehigh River from the Delaware River. The Easton Dam (RM 0.0), situated at the confluence of the Lehigh and Delaware rivers, has a vertical slot fishway equipped with observation chamber. Video surveillance (1995 – 2012) was terminated due to the loss of grant funding support from the Interjurisdictional Fisheries Act in 2013 and reduction of personnel resources. Post 2012, total passage through the Easton Dam fishway is estimated using a predictive regression relationship between total passage and a one-day electrofishing survey, developed from concurrent years monitoring 1996 – 2012. The electrofishing survey is conducted, mid-June in two pools: the Chain Dam plunge pool (RM 3.0) and Palmer Township Riverview Park (RM 2.55).

Annual passage of shad ranged from 408 to 4,740 total shad (0.11 to 2.28 average shad/hour; Table 11; Figure 29). Peak passage was observed in 2001 (n = 4,740 shad); whereas, poor passage occurred in 2003 (n = 422), 2008 (n = 408), and 2009 (n = 425). Passage of shad through the Easton Dam fishway was not significantly correlated (Spearman's Rank, $p > 0.05$) to the Smithfield Beach CPUE. Furthermore, neither was the Easton Dam fishway passage significantly (Spearman's Rank, $p > 0.05$) related to either the combined Raubsville electrofishing CPUE or the Raubsville CPUE separated into its Pennsylvania component of catch-effort.

The Philadelphia Water Department (PWD) established a video monitoring program in 2003 to assess fish passage at the Fairmount Dam fishway (Table 11; Figure 29). The 2011 fish passage season at the Fairmount Dam fishway was a record-breaking year, with 3,366 American Shad ascending the fishway. Data from 2004–2010 suggests a similar trend in upstream fish passage between the Lehigh (Easton Dam) and Schuylkill Rivers (Fairmount Dam). Discrepancies between the two trends occurred post 2010. Shad passage at Fairmount Dam fishway peaked in 2011, but the Easton Dam fishway passage was poor (n = 558). The PWD electrofishing CPUE in the tidal Schuylkill River immediately below the Fairmount Dam was significantly correlated (Spearman's Rank: r = 0.83, $p = 0.005$) to total shad passage through the Fairmount Dam fishway. No significant correlation (Spearman's Rank, $p > 0.05$), however, was found between Easton and Fairmount dam fishway passages (Figure 29). Nor was passage of shad through the Fairmount Dam fishway significantly correlated (Spearman's Rank, $p > 0.05$) to Smithfield Beach CPUE.

The lack of any relationship between the Lehigh and Schuylkill rivers shad passages suggests shad runs into these rivers are independent of the Delaware River spawning run. Co-op members agreed that Easton and Fairmount fish passage was of no utility in assessing/monitoring the shad population within the Delaware River. No attempt was made to document downriver passage from the either river back into the Delaware River.

2.2.1.2.4 Comparison of JAI to adult indices

One might expect that juvenile production (i.e., recruitment) would be a function of adult stock size. Figure 30 plots the two non-tidal (Geometric Mean and GLM) and tidal JAI indices against Smithfield Beach relative abundance (a proxy for the spawning stock size). No obvious relationship exists between adult relative abundance and year class strength (juvenile production) in any given year (Figure 30). The lack of a correlation most likely is related to sampling variability, and environmental influences, especially involving early life stages.

Hattala *et al.* (2007) provide another way to validate the adult stocks with recruitment. In the 2007 American Shad stock assessment, they successfully correlated a young-of-year index with future adult spawners coming back into the Hudson River, New York. A similar comparison is possible for the Delaware River. Since 1996, American Shad from Smithfield Beach have been aged using scales and otoliths. However, it is important to note that these fish were aged with methods differing from the 2015 Aging Protocol (Appendix A). The Smithfield Beach annual index of abundance and age structures are shown in Table 12, and age specific index values are listed in Table 13. The values in Table 13 are the observed proportion-at-age multiplied by the Smithfield Beach survey abundance index. Next, the values in Table 13 are summed along the diagonal to represent year class contributions to YOY year class production. For example, in a comparison of young-of-year to an index of four to six year olds, the 1992 young-of-year index is compared to a sum of the indices for four year olds in 1996, five year olds in 1997, and six year olds in 1997. Because most fish observed are between 4 and 7 years old, we only include groupings of those ages in the correlations.

Table 14 lists the various correlations tested between the non-tidal indices and the age specific adult indices. Note the two non-tidal indexes are evaluated, each only includes the Phillipsburg, Delaware Water Gap, and Milford Beach sites (Big 3). Based on p-values and power analyses, the best correlations are between the geometric non-tidal index and the 4-6 and 4-7 year old groupings (Table 14 and Figure 31). The non-tidal GLM index does positively correlate with the age-specific adult indices; however, the relationships are not significant and have low power. Though differing in significance levels, both JAI indices positively correlate with adult indices from Smithfield Beach (Figure 31). A review of the historical age samples as well as a more robust adult index that standardizes catch rates with environmental variables and gear use, will hopefully improve the relationship between the non-tidal GLM and the age-specific adult indices.

2.2.2 Fishery Dependent Data

2.2.2.1 Commercial Fisheries

Exploitation of the Delaware River American Shad stock occurs in several fisheries within the Basin. Commercial harvest is permitted by the States of New Jersey and Delaware. These fisheries occur in tidal waters of Delaware and New Jersey using stake and anchored or drifting gill nets. Fishers principally harvest shad during the spring spawning migration from late February into May. Fishers in New Jersey represent a small directed fishery for American Shad; whereas, landings of shad reported to the State of Delaware occur as bycatch from their concurrent Striped Bass fishery.

In addition to the Delaware Estuary/Bay fisheries, a small haul seine fishery (Lewis haul seine) occurs in the Delaware River, some 15 miles above the fall line at Lambertville, NJ.

2.2.2.1.1 Lewis Haul Seine

Lewis haul seine: The Lewis haul seine is the only in-river fishery and is located at Lambertville, NJ (RM 148.7). It dates back to the late 1880's, representing a significant time-series of recorded data with catch-per-unit-effort data documented since 1925 (Table 15). The fishery has evolved from a commercial enterprise to more of an eco-tourism enterprise. To preserve this historical data series the Co-op members support the fishery with a $6,000 grant (2008-2016) to collect CPUE (catch/haul) and biological data from the catch. Contract obligations require the Lewis haul seine to fish for shad a minimum of 33 days within the traditional fishing period (mid-March through June). Required information includes dates fished, number of hauls, and total American Shad catch per haul. Gear specifications and deployment were left to the discretion of the operator of the Lewis haul seine to maintain traditional methodology, subject to in-river flow variations.

The exceptionally long time-series of CPUE data from the Lewis haul seine is a good indication of the spawning run strength in the Delaware River. Recent CPUE shows an increasing trend from the 1960's-80's followed by an overall decrease to the mid-2000's. Since the adoption of the SFP in 2012 the CPUE peaked in 2013 (26.63) with all others years in the time period being at or below the time series mean (9.89; Figure 32). Unfortunately, the Lewis haul seine may not be an ideal abundance measure since the fishery uses varying nets depending on daily environmental conditions. In addition, natural changes to the river channel in the area of the fishery may be affecting the catchability of American Shad.

The Lewis haul seine provides a separate index of the returning adult spawning population to the Delaware River. CPUE from the Smithfield Beach gill net and Lewis haul seine for 1990-2010 exhibit similar trends (Figure 33), but have diverged in recent years. The two indices are strongly correlated (Pearson product-moment: $r = 0.822$; $p < 0.001$; Figure 34).

Data on age, size and sex composition of shad captured in the Lewis haul seine fishery have been collected intermittently since 1979. Beginning in 2008, reporting of biological data (i.e., total number shad landed, length, sex, and scale samples) was mandatory as part of contractual obligations with the Co-op (Table 16). Mean fork lengths for both genders show similar changes over time with no apparent overall trend toward an increase or decrease in mean fork length (Figure 35).

2.2.2.1.2 New Jersey Commercial Fishery

Fishery Characterization and Regulations: Prior to 1998, the National Marine Fisheries Service (NMFS) estimated American Shad landings for the State of New Jersey. In 1999, the NMFS estimates were combined with voluntary logbook data from New Jersey's commercial fishers.

These landings data reported by NMFS date from the late 1800s to 2000, while extensive, are thought to be under-reported and considered inaccurate. In 2000, the State of New Jersey instituted limited entry and mandatory reporting for the American Shad commercial fishery. American shad landings reported to the State of New Jersey are separated into two reporting regions: Upper Bay/River and Lower Bay. Historically, Gandys Beach (RM 30) was the demarcation for separating the reported landings.

These mandatory logbooks allow insight into the fishery. Records indicate that the shad fishing season started as early as February 15 and ended as late as May 22. Employed mesh sizes ranges from 5 to 6 inch stretch. American Shad are primarily landed by drifting gill nets in the Upper Bay/River fishery while staked and anchored gill nets account for the majority of shad being landed in the Lower Bay.

Regulations for American Shad harvest in New Jersey include a limited entry/limited transferability license system, limitations on the amount and type of gear allowed to be fished, and gill net season and area restrictions enforced through a limited entry permitting system in the lower Delaware Bay. Specifically, these restrictions included gill nets can be deployed from February 1 to December 15, minimum stretch mesh size increases through the season, with 2.75 inches through February 29 and 3.25 inches March 1 to December 15. Net length is also limited to 2,400 feet from Feb 1 to May 15 and 1,200 feet from May 16 to December 15 (Table 17). A haul seine can also be used to harvest American Shad from November 1 to April 30. The seine must have a 2.75 inch minimum stretch mesh and maximum length of 420 feet.

Fishery Participation: In New Jersey, as of May 3, 2016, there were 61 permits issued (37 commercial and 24 incidental) to allow harvest of American Shad. The shad permit allows the holder to fish in any state waters where the commercial harvest of shad is allowed if the permit holder meets all other net requirements for commercial fishing in a particular area. Currently, only 47 of these permits are active, due to attrition (Table 18). Since harvest reporting became mandatory in 2000 the number of fishers landing shad in New Jersey has seen a steady decrease. From 2000 through 2006 the number of fishers landing shad averaged in the mid-twenties (range of 21-29). From 2007 through 2009 this number dropped into the mid-teens (range of 14-17), and since 2010 this number has averaged around 10 fisherman landing shad in the Delaware Bay (range of 9-13). The number of fishers landing shad in New Jersey is expected to continue to decrease as the current fishers age out of the fishery and interest in the fishery itself continues to decline.

Landings: Harvest of American Shad by region in New Jersey has seen a shift from historically being a predominantly Lower Bay fishery (below Gandys Beach) to an Upper Bay /River fishery. From 1985 through 2000, landings in the Lower Bay averaged 81,013 pounds, while the Upper Bay/River fishery saw average landings of 18,759 pounds of shad. Since 2001 this trend has reversed with Lower Bay landings averaging 11,518 pounds and the Upper Bay/River fishery landing an average of 37,300 pounds of shad (Table 19, Figure 36).

Fishing Effort: Effort data for New Jersey's commercial fishery is estimated from CPUE presented in pounds per square foot of netting (Table 20). New Jersey data is partitioned to examine the Upper Bay/River CPUE as well as the Lower Bay CPUE in mixed stock areas of Delaware Bay. The overall New Jersey commercial fishery CPUE varied without trend throughout the time period with a slight decline in recent years due mainly to a lack of effort and large concentrations of Striped Bass, which NJ fishermen are not permitted to land (Figure 37). New Jersey's Upper Bay/River fishery CPUE mimics the overall trend. CPUE within the Lower Bay has actually increased in recent years with the exception of a sharp decline in 2015; however, actual effort is low. Overall effort in New Jersey has decreased more than 30 percent since 2005.

Biological Data: Length frequency data (fork length) were collected from American Shad caught during fishery independent tagging operations by gill net in lower Delaware Bay (i.e., Reed's Beach, RM 14.8; Table 21). However, data are comparable to the commercial fishery since similar gill net mesh sizes are used for this program. Fork lengths ranged from 346 mm to 615 mm and have fluctuated without trend over the course of the time series (Table 21). Sex ratios show the fishery is mostly prosecuted for females, with both the Upper Bay/River and Lower Bay fisheries averaging 80% female, but there are years when the percentage of males increased (i.e. 2010, Table 22). The State of New Jersey obtains and will continue to obtain representative samples of the commercial catch to determine gender, size, and otolith samples for age estimation as required under the ASMFC FMP.

2.2.2.1.3 Delaware Commercial Fishery

Fishery Characterization and Regulations: The Delaware commercial American Shad fishery in the Delaware River & Bay occurs during the spring spawning migration from late February through May. Landings are reported to the State of Delaware under a mandatory food fish license and are separated into four general reaches based on spatial points of reference within Delaware Bay. These areas are reported as follows: Delaware River (north of Collins Beach), Upper Bay (Collins Beach to Port Mahon), Mid Bay (Port Mahon to Bowers Beach) and Lower Bay (South of Bowers Beach; Figure 46). Almost all shad landed are in conjunction with the concurrent Striped Bass commercial season that begins February 15 and extends through May 31 in the estuary. All landings are by gill net, both anchored (fixed) and drifted. Anchor nets are used primarily in Delaware Bay; drift nets are used exclusively in the Delaware River by regulation (Table 23). There are no specific regulations that have been adopted to reduce or restrict commercial landings of American Shad in the Delaware River & Bay. Regulations governing the Striped Bass fishery have the greatest impact on the total catch of American Shad due to the presence of both species in the river and bay during the spring. Restrictions for the

Striped Bass fishery include a limited entry license system, limitations on the amount and type of gear allowed to be fished, and gill net season and area restrictions. Specifically, these restrictions included no fixed gill nets in the Delaware River north of Liston Point (RM 48) from January 1 through May 31, and not more than 200' of fixed, anchored, or staked gill net from May 10 through September in the rest of the Delaware Estuary.

Fishery Participation: Delaware has a limited entry license system for the commercial gill net fishery under their food fishing equipment permitting regulations. There is a cap of 111 gill net permits, and no new permits will be issued. Fishers may choose not to renew their permit annually, so the total number actually obtaining a permit will change annually. Fishery participation has been decreasing for multiple years and this trend is expected to continue (Table 24). Many fishers do not land any American Shad and many do not fish at all since they were allowed to transfer their individual Striped Bass quota to other licensed fishers. Furthermore, permits may be passed onto direct descendants or issued to a resident who has completed a commercial fishing apprenticeship program.

Landings: Landings are reported to the State of Delaware by geographic region; however, due to data confidentiality, landings specific to each of the four regions are not reported here. Recent review of historical landings data demonstrated the original demarcation line between Upper Bay/River fisheries and Lower Bay fisheries using Leipsic River, DE as the stated demarcation point in the 2012 SFP was unsubstantiated. Leipsic River is not a geographic reference point for landings data in the State of Delaware and the actual point used in the 2012 SFP for delineation and calculation of the Delaware River stock was Collins Beach ("Delaware River" reporting region at RM 45), about 10 miles north of Leipsic River. A new delineation point was established at Bowers Beach for the 2017 SFP, where landings in the upper three reporting regions are combined to represent Upper Bay/River landings and landings from the fourth region (south of Bowers Beach) represent Lower Bay landings. See Section 2.2.2.1.5 for further information on the adjustment of the demarcation line.

Harvest of American Shad by region in Delaware has seen a shift from historically being an Upper Bay / River fishery (above Bowers Beach) to having some landings from the Lower Bay since 2002. From 1985 through 2001 landings in the Upper Bay/River averaged 187,622 pounds while the Lower Bay had zero landings. Since 2002 landings in the Upper Bay/River have declined to an average of 30,082 pounds while the Lower Bay had an average of 10,401 pounds landed annually for the same time period (Table 25, Figure 38).

Fishing Effort: Since 1985, the data on catch, landings, and effort have been collected via logbooks. However, commercial harvesters are only required to report mesh size when landing Striped Bass. Commercial fishing effort for Delaware is measured using net yards. Net-yards were the yards of net fished on that day the landings occurred. The overall State of Delaware CPUE has declined since 1992 due to a combination of a decline in adult abundance and major changes to the way Delaware fishers prosecute the fishery (Figure 39). Shad is no longer the target species but are considered bycatch in the Striped Bass fishery. Relatively, few shad are harvested in the fishery since the larger mesh sizes used for Striped Bass allow escapement. To emphasize the decline of effort on American Shad within the Delaware Estuary, the Co-op examined effort data from the State of Delaware, expressed in yards of net fished, from 1990 to 2015 (Figure 39). Effort has decreased dramatically throughout the time series with effort peaking in the lower bay fishery in 1991 and the upper bay and river fishery in 1996.

Landings of Striped Bass in Delaware have indicated an increasing size of bass over the last decade (State of Delaware 2016). Subsequently, the mesh size of gill nets employed in the Striped Bass fishery has increased up to 7 inch stretch mesh. The majority of shad will swim through that mesh size, so catch of shad was relatively low (< 10,000 lbs) from 2009 to 2013. However, in 2014 there was an unusually large (85,794 lbs) amount of American Shad landed in Delaware. The increased catch of American Shad by Striped Bass fishers during the 2014 season is attributable to a few fishers switching to smaller gill net mesh sizes (< 7 inches) for targeting smaller Striped Bass during the 2014 season. The commercial Striped Bass fishery has a 20 inch minimum size and remains quota driven. Fishers have been known to switch to smaller mesh nets in an attempt to fill their Striped Bass quota with smaller Striped Bass. As a result, catches of American Shad increased due to their increased susceptibility to the smaller mesh nets. This shift in gear type was not representative of all fishers in 2014, nor was this pattern representative of harvest over the last ten years. Landings in 2015 were less than 2014, with a total of 21,765 pounds landed.

Biological Data: Biological data collected by the State of Delaware were gathered from New Jersey commercial fisher's landing catches from the upper Delaware Bay. The State of Delaware collects information on length (mm), weight (lbs), and sex from the commercial fisher's landings (Table 26). Scale samples have been collected from these landings, but have not yet been processed for age estimation. The Co-op members have drafted standardized ageing protocols specific to the Delaware River Basin (Appendix A). Once finalized, age and repeat spawning frequencies will be determined from commercial landing samples.

2.2.2.1.4 Determining Exploitation of the Delaware River American Shad Stock

Recent combined commercial landings (1985–2015) from the Upper Delaware Bay and River and Lower Delaware Bay are shown in Figure 40. Landings prior to 1985 are not easily partitioned between bay and river and therefore are not useful for discussions of the Delaware River stock status. State landings are considered very reliable following the implementation of mandatory reporting in 1985 in Delaware and 2000 in New Jersey. The harvest areas are delineated as river and bay based on reporting information. Upper Delaware Bay/River harvest is separated from Lower Delaware Bay harvest at a line drawn from Bowers Beach, DE to Gandys Beach, NJ.

Combined landings for Delaware and New Jersey in the upper Delaware Bay and River have declined from a peak of 425,219 pounds in 1990 to a low of 10,944 in 2010. Landings have increased slightly since 2010, with a recent peak in 2014 of 121,018 pounds (Figure 40). Combined lower Delaware Bay landings have declined from a peak of 212,749 pounds in 1990 to a low of 3,659 pounds in 2015 (Figure 40). The main causative factors of the decline in landings include regulatory action (limited entry), attrition in the fisheries, and reportedly low market value of shad, based on Delaware ex-vessel reports ($/lb = 0.40 in 2015; Figure 41), increased mesh size (7" stretch mesh) preferred by Delaware gill netters targeting larger Striped Bass, and increased abundance of Striped Bass. New Jersey gill netters who target shad complain that their nets catch Striped Bass in high numbers, yet they are not allowed to land bass; the bass damage their nets and they cut their hands on the spines and gill cover edges, so no additional effort resulting in increased landings is expected in New Jersey. Delaware gill netters report that any attempts to target shad catch large numbers of bass, and if they have already filled their Striped Bass quota, they cannot land additional Striped Bass and many will cease fishing. The overall decrease in coastal stocks of American Shad may be an additional factor to the decrease in landings of shad.

One of the main concerns of fisheries managers is potential overfishing. Determining overfishing or over-exploitation with accuracy is difficult when actual stock numbers are not measured or those estimates are considered not scientifically sound. Obtaining a ratio based on harvest and a measure of a fishery independent CPUE is one way of assessing exploitation trends. No indices of abundance, measured before harvest, exist for the Delaware River American Shad stock; therefore, we cannot estimate true relative exploitation. In the case of the Delaware River stock, the Co-op analyzed a ratio of Delaware River stock landings to the Smithfield Beach gill net CPUE since 1990.

Acceptable measures of reported commercial harvest within the Delaware Basin have only been available from Delaware since 1985 and New Jersey since 2000. Landings data have been reported since the late 1800s, but cannot be verified. Since the Smithfield Beach CPUE has been conducted since 1990, the Co-op agreed to develop a ratio of commercial harvest to CPUE for Smithfield Beach (landings/CPUE, scaled by 100) using the period from 1990-2015. The Co-op also decided to report the estimates combined and in two phases (1990-1999 and 2000-2015) to reflect the more accurate reporting from New Jersey during the 2000-2015 time period. For clarity, the 1990-1999 time period will be called the early period while data from 2000-2015 will be known as the late period.

Landings of Delaware River stock was calculated using the demarcation line from Bowers Beach, DE to Gandys Beach, NJ. Landings north of that line are assigned 100% Delaware River stock and landings south of that line are assigned 40% Delaware River stock. Delaware River stock landings ranged from a high of 510,319 pounds in 1990 to landings less than 50,000 pounds annually since 2008, with the exception of 2014 where 123,880 pounds were landed (Figure 42, Table 27). The Delaware River stock landings have varied without trend in New Jersey and have been generally declining since 1990 in Delaware.

A comparison of the commercial landings to gill net CPUE from Smithfield Beach shows a similar trend between the fishery and a measure of escapement from the upper Delaware until 2010, when lower harvest equated with higher CPUE at Smithfield Beach (Figure 43). The ratio of commercial harvest/CPUE from Smithfield Beach ranged from 14.1 to 48.4 in the early period and 2.2 to 83.0 in the late period (Figure 44, Table 28). The early time series varied without trend while the late period varied through 2004 but has declined through recent years with the exception of 2014.

It should be noted that this approach to measuring exploitation is conservative. To mimic change in actual exploitation rate, a relative exploitation rate is estimated by dividing landings by some index of stock abundance prior to the fishery. In our case, we are measuring relative abundance after the fishery occurs. That means the denominator is reduced and the relative exploitation index is biased high. The degree of bias is related to the fraction of the original population that is lost to harvest (exploitation rate or u). Bias is relatively low at low levels of exploitation, but increases as exploitation rate increases. For perspective, we created a fictitious population of fish, exploited it at different rates, and calculated actual exploitation rates based on abundance of survivors (our approach) and on abundance of the population prior to harvest (Figure 45). Results suggested low bias when actual exploitation rates were less than $u <= 0.10$, but dramatically higher bias when u exceeded 0.30. This expectation of bias was developed for the 2012 SFP and has not changed with this revision, given the Co-op's continuance of the ratio as a measure of relative exploitation.

The American Shad stock in the Delaware River is considered stable but at low levels compared to the historic population (ASMFC 2007). Juvenile production has been measured since 1980. The JAI decreased somewhat after 1996 but has increased in recent years. It is unknown why there was a decrease in numbers of returning adult American Shad within the Delaware River during the 2000s. One hypothesis is that commercial overfishing within the Delaware Estuary could be hindering stock growth. Results of the harvest to relative abundance ratio analyzed here are not consistent with that hypothesis. The harvest to relative abundance ratio has varied without trend or even decreased in recent years (Figure 44). Furthermore, the Co-op does not believe that the recreational fishery is responsible for the recent downturn in spawning stock, based on low estimated harvest in the most recent creel survey in 2002 (Volstad *et al*. 2003).

2.2.2.1.5 Commercial Landings on Mixed Stock Fisheries

Shad that inhabit the lower Delaware Bay represent multiple stocks and have been managed using a unique approach to reflect the nature of the variability of river origin. Shad harvested in the Upper Bay and Delaware River are considered to be 100% Delaware River stock while those from the lower Bay areas are mixed stock and the origin of these fish may vary annually. To help determine the proportion of mixed stock contribution to the Delaware Bay landings, the NJDFW initiated an American Shad tagging program in 1995 in Delaware Bay as part of a cooperative interstate tagging program between New York and New Jersey. Tagging was performed at Reed's Beach located in Cape May County, approximately 10 to 15 miles from ocean waters (Figure 46). This program utilizes drifting gill nets of 5.5 inch to 6 inch stretch mesh during March through May of each year.

In the program, 4,301 American Shad were tagged from 1995 to 2015 (Table 29). In recent years sampling yielded few American Shad, with fewer than 100 shad tagged annually in the past 10 years. Through May 2015, there have been 246 American Shad returns reported (5.7% of tagged fish). The tag return data indicate that shad taken in this portion of Delaware Bay are of mixed stock origin and reported recaptures ranged from the Santee River in South Carolina to the St. Lawrence River near Quebec, Canada with the majority coming from the Delaware, Hudson, and Connecticut Rivers (Table 30).

A separate study using genetic analysis was conducted in 2009 and 2010 to determine stock composition (Waldman *et al*. 2014). Stock composition was determined based on microsatellite nuclear DNA from American Shad collected in Maurice Cove, NJ (RM 21) in 2009 (n = 71) and 2010 (n = 31), and off Big Stone Beach (RM 14) in Delaware in 2010 (n = 191) (Figure 46). Stock composition estimates for 2009 and 2010 were nearly equal (50%) for Hudson River origin and Delaware River origin fish at two locations in lower Delaware Bay in a two-stock analysis. Further analysis on the 2010 samples that considered 33 baseline rivers as source rivers indicated that only 24% of the stock was of Delaware River origin.

In addition to the two recent data sources, Co-op members also evaluated two historical tagging studies (Figure 46). A study conducted by White *et al.* (1969) released tagged shad (n = 618) in 1968 off West Creek (RM 18) and Thompsons Beach (RM 19) in NJ. They reported 110 recaptures with 36% being recaptured in the Delaware Bay/River and 63% of their tags were recaptured outside of the basin. Although White *et al.* (1969) combined Delaware Bay and River into one recapture location, the proportion is similar to the 39% currently considered as Delaware River stock as determined by the more recent tagging study at Reeds Beach. A second tagging study conducted by Zarbock *et al.* (1969) tagged American Shad (n = 277) off Pickering Beach (RM 26) and Little Creek, DE (RM 27). Their study reports 26% of the 23 recapture reports were from the Delaware River/Bay. In a separate tagging effort of the same study, 81 tagged fish were released at Port Penn, DE (RM 55). Five of those fish were recaptured, with 75% of recaptures in the Delaware River/Bay. One important point to consider during these older tagging studies is that poor water quality conditions in the vicinity of Philadelphia were suggested by the authors to have impacted American Shad distribution and migration in the Delaware River and Bay during that time. Though upriver fisheries remained viable during that time period (see Lewis Haul Seine – Table 15), and one of the Delaware River recaptures in the Zarbock (1969) study was from Easton, PA, upriver of Philadelphia. Water quality conditions have improved greatly in the lower Delaware River (see Section 2.3.1) since the studies were conducted in the late 1960s.

The 2012 SFP acknowledged the occurrence of mixed shad stocks in Delaware Bay fisheries annual harvest. Delineations for assigning commercial harvest to either the mixed or Delaware River stocks was represented as a demarcation line drawn across the bay from the Leipsic River, DE (RM 34) to Gandys Beach, NJ (RM 30), as adopted from the ASMFC 2007 American Shad Stock Assessment (Figure 46). In the 2012 SFP, mark-recapture data from the NJDFW tagging program formed the basis for assigning (i.e., as a proportion) the commercial harvest to Delaware River stock. For harvest that occurred in the Bay north of the demarcation line, 100% was considered Delaware River stock. For harvest south of the demarcation line, 39% of harvest was assigned to the Delaware River stock, and the remainder was assigned as mixed stock origin shad.

For the 2017 SFP, the delineation point on the Delaware shoreline needed to be changed to better reflect how landings are reported in that state. To maintain the *status quo* with previous data reporting, the reference point would need to be changed to Collins Beach, rather than Leipsic River. Port Mahon (RM 32) is the closest Delaware reference location to Leipsic River, DE and Gandys Beach, NJ, within two River Miles from both locations. Gandys Beach has been reconfirmed by the Co-op as appropriate for the New Jersey demarcation point. In order to determine an appropriate delineation point for the Delaware River stock with respect to the four current reporting regions in Delaware, the Co-op analyzed State of Delaware landings as well as mark-recapture data and the recent genetics work of Waldman *et al.* (2014).

The majority of landings reported to the State of Delaware occur from the Delaware River and Upper Bay reporting areas in the State of Delaware (i.e., above Bowers Beach, Table 31). A reexamination of updated tag return data indicates there is limited tagging information to conclusively suggest the annual extent of the mixed stock shad into the Delaware Bay. Hudson River tagging ended in 2008, and of those tagged shad only 5 have been recaptured in Delaware Bay/River (out of 172 total recaps). Of those 5 recaptures, 4 were reported at Bowers Beach and south, while the other reported Dover as the nearest location. Based on updated (through 2015) NJDFW tagging data from the lower Bay in New Jersey, 60% of the shad in that area are from the mixed stock (Table 32). However, the tagging data from the lower Bay does not indicate how far the mixed stock travels into the Bay and River. Furthermore, tagging and subsequent recapture of shad from this program have waned over the years. Unless additional effort is committed to this tagging program, the continued poor tagging rates will remain mediocre for characterizing the extent of the mixed stocks within the Delaware River & Bay.

The recent genetics study also provided little insight into the geographic extent to which the mixed stock travels up the Delaware Bay (Waldman *et al*. 2014). The authors acknowledged the spatial and temporal constraints drawn from their conclusions, as the points of collection (Big Stone Beach, DE; Maurice Cove, NJ) were closer to the mouth of the estuary where some level of mixing would be expected and collection occurred south of the areas where the majority of commercial landings occur in Delaware. While Waldman *et al.* (2014) has provided a base line, additional annual sampling throughout the Delaware River & Bay is necessary to fully characterize the occurrences of mixed stocks.

Due to a lack of more conclusive data, the assignment of the demarcation line on the State of Delaware's shoreline among Delaware's three uppermost reporting regions was selected by the Co-op based on the limited information available. The continued use of Collins Beach (the single uppermost reporting region) as the demarcation point was unanimously agreed among Co-op members as unacceptable. Given the data deficiencies regarding the occurrence of mixed stock in the Upper Bay and Mid Bay reporting regions, the Co-op selected a new delineation point for the Delaware Shore to be located at Bowers Beach (RM 23). The justification for selecting this location was based on having genetics and tagging studies conducted in the reporting region south of Bowers Beach (Lower Bay) and that very few recaptures of Hudson River tagged American Shad were captured north of Bowers Beach in the Delaware Bay. Using the delineation proportion from the NJDFW tagging studies, all landings north of a line from Bowers Beach, DE to Gandys Beach, NJ will be considered 100% Delaware River stock. South of the demarcation line, 40% of landings will be assigned to the Delaware River stock and the remaining 60% of landings assigned to the mixed stock (Table 33).

The potential to erroneously assign commercial American Shad landings to either the Delaware or mixed stocks in the lower bay is possible. Bowers Beach represents the logbook reporting delineation just upstream (~6 miles) of the more recent tagging and genetic studies. The Co-op recognizes the potential to understate mixed stock harvest could occur. The Co-op is sensitive to the potential impacts on East Coast shad stocks should there be any increase in exploitation, especially as these stocks recover. The Co-op will continue to annually monitor landings in the lower Delaware Bay to ensure any significant increase in harvest results in increased regulatory control for keeping exploitation at current levels. The 2012 SFP did not have a mechanism to limit expansion of the Delaware Bay fisheries on the mixed stocks, but recommended that the feasibility for directly managing the mixed stock harvest be considered in the 2017 SFP. Overall, mixed stock landings have been declining since mandatory reporting was enacted by both the States of Delaware and New Jersey (Figure 47). The Co-op has proposed an additional management benchmark to explicitly manage harvest on the mixed stock under this SFP (refer to Section 3.2.3).

The Co-op recognizes the available data does not conclusively characterize the extent of the mixed stock in the Delaware Bay. In order to investigate the appropriateness of any demarcation line, the Co-op plans to conduct additional genetic analyses during the spring of 2017. Samples are anticipated to be collected from various locations within the Delaware Bay during the spring season. The 2017 sampling is envisioned as a synoptic survey to examine geographic extent of the mixed stock within the Delaware Bay. Further funding would be required to provide insight into inter-annual variation of mixed stock occurrences. As information becomes available, Co-op members anticipate petitioning ASMFC for potentially modifying the demarcation line as warranted.

2.2.2.2 Recreational Fisheries

The recreational fishery for American Shad generally occurs from late March through June of each year. The fishery is concentrated in the non-tidal reach from Trenton, New Jersey (RM 133) to Hancock, New York (RM 330). The Brandywine Creek Basin also supports a nominal recreational American Shad fishery. Typically, the lower non-tidal reach is fished earlier in the season, moving further upriver as water temperatures increase.

Participation in the recreational shad fishery fluctuates but overall, angler effort has declined from historical levels. Numerous creel surveys have been conducted since the 1960's using various sampling methodology (Marshall 1971; Lupine *et al*. 1980, 1981; Hoopes *et al.* 1983; Miller and Lupine 1987, 1996; NJDFW 1993, 2001; Volstad e*t al.* 2003; Table 34). Estimates of angler catch and harvest in 2002 (Volstad 2003) were substantially lower than reported by Miller and Lupine (1987, 1996), representing a decline of total catch by 63% and 42% since those surveys in 1986 and 1995, respectively. Similarly, the percent of harvested shad declined from 1986 (49%) to 1995 (20%) and was estimated at 19% in the 2002 survey. Angler catch rates (shad/hr), also varied among the three surveys (0.19 shad/hr, 0.25 shad/hr, 0.13 shad/hr in 1986, 1995, and 2002, respectively) with the lowest catch rate observed during the 2002 study. Inclusion of only those anglers specifically targeting American Shad during the 2002 survey however, substantially improved angler catch rate (non-tidal: 0.34 shad/hr; Volstad *et al*. 2003). No comprehensive creel survey of the Delaware River has been accomplished since 2002.

The Marine Recreational Information Program (MRIP) provides characterization of recreational American Shad harvest in the Delaware Estuary & Bay. Catch estimates are inconsistent among years and highly imprecise (Table 35). The excessively high (> 50%) percent standard error estimates (PSE) suggests total numbers of shad harvested by recreational anglers are unreliable. Co-op members agree anglers nominally fish for American Shad in the Delaware Estuary and Bay; yet, also agree the MRIP data are not representative of any shad harvest in the Delaware Estuary and Bay.

The PFBC, in collaboration with the National Park Service, jointly promoted a voluntary angler diary program (2001 – 2016) for reporting recreational angler catch (Lorantas and Myers 2003, 2005, 2007; Lorantas *et al*. 2004; Pierce and Myers 2007; Pierce and Myers 2014; NPS unpublished data). In addition, the reporting of catch was mandatory for all licensed guides operating in the Upper Delaware Scenic Recreational River (UPDE). Participation is poor (< 63 individuals) in any given year (Table 34). Most submitted logbooks originate from the licensed guides. Catch rates of shad varied among years (0.001 – 0.11 shad/hr) with the highest rate observed in 2001 thereafter declining to a relatively stable rate after 2003 (Table 34). Since 2012, however, catch rates have declined to less than 0.01 shad/hr. Harvest of shad by logbook participating anglers was typically minimal (0 – 10.9%). Prior to 2012, anglers reported 496 trips during which anglers landed shad, but anglers harvested one shad/trip from 57 trips (11%), 2 shad/trip from 19 trips (4%), 3 shad/trip from 9 trips (2%), and only 4 trips (0.8%) harvested more than 3 shad/trip. Since 2012, a total of 37 trips were reported (2012: n = 12; 2013: n = 16; 2014: n = 9) to land shad, during which anglers harvested all shad caught (Table 34).

The PFBC/NPS angler diary program is considered unrepresentative of the Delaware River recreational shad fishery. Essentially, only the licensed guides by UPDE, routinely reported trip/catch information. Anglers fishing in the river reaches within the UPDE, principally target trout occurring in the New York City water supply dam tailwater, rather than shad. Further, in most years, no information was available from participating anglers in downriver reaches (RM 133 – 303) below the UPDE, were the recreational shad fishery is principally focused. The logbook program was discontinued in 2016 due to poor participation.

The Delaware River Shad Fisherman's Association (DRSFA) represents the single largest club specifically focused on the Delaware River American Shad. Although some fish are kept to eat, the recreational fishery for shad in the Delaware River primarily practices catch-and-release (M. Topping, President, Delaware River Shad Fisherman's Association, personal communication 2016). Generally, unreported DRSFA member catch rates have been relatively consistent each year since 2012. During the peak of recent shad runs, many DRSFA members indicated 100 fish hook ups fishing in the vicinity of Easton, Pa (RM 183). Although some DRSFA members may keep as many as 6-10 fish each season (especially those that have been injured) most harvest of shad tends to be limited to a single fish. In order to protect the fish when netted, the DRSFA recommends the use of rubber nets to minimize stress to the fish when caught. The DRSFA unofficially estimates total shad caught, by club members per year since 2012, could be anywhere from a dozen to well over a 100 (M. Topping, President, Delaware River Shad Fisherman's Association, personal communication, 2016).

Recreational hooking mortality is assumed to be low in the Delaware River. A study by Millard *et al.* 2003 observed a 1.6% recreational hooking mortality of spawning American Shad caught in the Hudson River after a five day holding period. All mortality occurred for fish caught on or after May 6 when water temperatures increased to greater than 12°C. No hooking mortality studies have been conducted in the Delaware River.

There is a critical need for routine comprehensive creel surveys characterizing the recreational American Shad fishery in the Delaware River Basin. Potential future surveys need to focus principally on the non-tidal reaches. Since the MRIP program does not include non-tidal reaches, resulting data from that program poorly describes the Delaware River recreational shad fishery. Volstad e*t al.* (2003), represents the most recent comprehensive creel survey (i.e., 2002) accomplished in the non-tidal Delaware River reaches. This study was jointly supported by Co-op members, but funding was on an *ad hoc* basis. It is nearly 15 years out-of-date and likely does not represent present day shad angling behaviors. Alternative available creel data since Volstad *et al.* (2003) is of limited utility and wholly inadequate to describe recreational use and harvest of American Shad. Instead, anecdotal angler reports suggest the recreational shad fishery persists principally as catch-and-release. The lack of reliable, routinely collected data on recreational use and harvest, precludes compilation of more robust stock assessments (refer to Section 8).

2.2.2.3 In-State Bycatch and Discards

There is little information on bycatch or discards of shad in any commercial fisheries within the Delaware Estuary; excepting the Delaware Bay Striped Bass fishery, which is discussed in detail in Section 2.2.2.1.3. Otherwise, American Shad has not been reported as bycatch from other commercial fisheries operating within the Delaware River Basin to either the States of New Jersey or Delaware. Neither state requires the reporting of discarded shad from any commercial fisheries within the Delaware River Basin; thus, no information is available.

2.3 Other Influences on Stock Abundance

In addition to harvest and natural mortality, other factors can also impact American Shad populations. The Co-op has identified several such influences: (1) water pollution block, (2) the Atlantic Multidecadal Oscillation which correlates with Delaware River stock indicators, (3) Striped Bass-American Shad interactions (4) potential effects from overfishing and ocean bycatch, (5) impacts of hatchery restoration, and (6) impingement and entrainment.

2.3.1 Water Pollution Block

During the late 1800s, there was evidence indicating that shad were spawning in the freshwater tidal areas of the mainstem estuary as well as several tributaries of the lower Delaware River. It was presumed that the principal spawning area was located just south of Philadelphia, in the tidal freshwater estuary, prior to 1900. The prevalence of spawning in tidewater near

Burlington was documented by the huge fishery there, as well as the hatchery effort that took place at that location (Gay 1892).

Beginning as early as the 1910s (Philadelphia 1914), and certainly prevalent by the 1940 and 1950s (Sharp 2010), heavy organic and nitrogenous biochemical oxygen demand (NBOD) loading around Philadelphia, Pennsylvania, caused severe declines in dissolved oxygen. By the 1960s, continuous dissolved oxygen data collected by the USGS (see USGS-NWIS at waterdata.usgs.gov/nwis) and modeling by the Federal Water Pollution Control Administration (FWPCA 1966) demonstrated a zone of over 30 miles of the Delaware Estuary with hypoxic and anoxic conditions that persisted, on average, for 5 months each year, beginning in late spring and extending well into the fall. Hypoxia continued to be a major factor through the 1970s and into the 1980s, whereupon point-source remediation efforts by the Delaware River Basin Commission (begun in 1967) and the Federal Clean Water Act (1972 revisions) led to both a narrowing of the spatial and temporal hypoxia window each summer/fall and an overall increase in dissolved oxygen levels, even during the worst summer conditions.

The resulting “D.O. blocks” made parts of the lower Delaware River uninhabitable for fish during the warmer months of the year (Sykes and Lehman 1957) and may have severely depressed successful out-migration of juvenile shad from the river and the tidal freshwater estuary in the fall. A remnant of the American Shad run in the Delaware River survived by migrating upstream early in the season, when water temperatures were low and flows were high, before the D.O. block set up. These fish, because of their early arrival, migrated far up the Delaware to spawn. Out-migrating juveniles survived by moving downriver late in the season during high flows and low temperatures, thus avoiding the low oxygen waters present around Philadelphia earlier in the fall. As a result of this zone of hypoxia in the tidal estuary, the majority of spawning for decades took place above the Delaware Water Gap in the non-tidal river more than 115 river miles upstream.

Environmental regulation for stricter control of discharge proved beneficial for reducing the annual D.O. blocks. By the year 2000, the goal set for the tidal estuary in 1967 for a daily average dissolved oxygen concentration of 3.5 mg/L was being attained almost without exception, although this 3.5 mg/L dissolved oxygen target was a compromise below the oxygen standards typically set under the Clean Water Act (Figure 48). Nevertheless, the restoration of dissolved oxygen in the Delaware Estuary both removed the primary migration block for shad and other migratory fishes and provided sufficient oxygen for at least the partial restoration of spawning and rearing within the formerly hypoxic zones of the estuary (Silldorff 2015). For American Shad, such restoration was demonstrated, in part, through the NJDFW tidal seine surveys which showed increasing abundance of young-of-year shad throughout the summer and fall (see Pyle 2015). In addition, ichthyoplankton surveys during 2002, 2003, and 2004, documented direct evidence and consistent presence of eggs, larvae, and juvenile American Shad within all tidal estuary zones that historically experienced hypoxia (summarized in Silldorff

2015).

American Shad can now freely pass through the urban Philadelphia corridor of the Delaware Estuary both during the spring spawning run as well as the fall out-migration period. In addition, the continued recovery of dissolved oxygen has been associated with increasing use of the tidal freshwater estuary as a key part of the overall spawning effort by American Shad in the Delaware River system.

2.3.2 Atlantic Multidecadal Oscillation (AMO)

North Atlantic sea surface temperatures have been found to exhibit long-duration oscillation for at least the last 150 years (Schlesinger and Ramankutty 1994; Enfield *et al* 2001). This includes most of the North Atlantic Ocean between the equator and Greenland. Kerr (2000) termed this oscillation the Atlantic Multidecadal Oscillation (AMO) to distinguish it from the atmospheric North Atlantic Oscillation (NAO). Models of the ocean and atmosphere that interact with each other indicate that the AMO cycle involves changes in the south-to-north circulation, including the Gulf Stream current, and overturning of water and heat in the Atlantic Ocean. When the overturning circulation decreases, the North Atlantic temperatures become cooler.

The AMO delineates cool and warm phases that may last for 20-40 years at a time and a difference of about 1°F between extremes. These changes are probably a natural climate oscillation and have been measured for at least 150 years. A positive AMO indicates a warm phase while a negative AMO indicates a cool phase. The AMO is currently in what is considered a warm phase since the mid-1990s (AMO Kaplan SST V2 data is provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, from their Web site at http://www.esrl.noaa.gov/psd/).

The AMO affects air temperatures and rainfall over much of North America including the frequency of major droughts in the Midwest and Southwest such as those during the 1930s and the 1950s. Between AMO warm and cool phases, Mississippi River outflow varies by 10% while the inflow to Lake Okeechobee, Florida varies by 40% (Enfield *et al* 2001). It is also reflected in the frequency of weak tropical storms that mature into severe Atlantic hurricanes, with at least twice as many severe hurricanes during warm phases. In the 20th century, the climate swings of the AMO have alternately camouflaged and exaggerated the effects of global warming, and made attribution of global warming more difficult to ascertain.

In an attempt to determine if there was any evidence of a relationship between the AMO and measures of the American Shad stock within the Delaware River Basin, the Co-op first compared the AMO to the Lewis haul seine CPUE (Figure 49). The Lewis haul seine represents the longest catch per unit effort within the Basin. The Co-op analyzed various portions of the

AMO dataset but determined the smoothed January to December average was the best fit for final analysis. A five-year moving average was developed for all data to decrease yearly variability. This was a similar methodology as used for the most recent ASMFC weakfish stock assessment which used a 10 year average (ASMFC 2009).

The smoothed Lewis haul seine CPUE index is calculated as a catch per haul with haul data collected back to 1925. From 1925 to 1971, the smoothed Lewis haul seine CPUE averaged less than seven fish per haul except for the brief period during 1961-1965. The Lewis haul seine CPUE increased steadily from 1972 to 1990, similar to the AMO. A quick decline ensued through 1997 with a continued steady decline until 2007. There has been a slight increase in recent years.

No correlation is evident between the Lewis haul seine CPUE and the AMO from 1925 to 1971. As noted earlier, this period also coincided with very poor water quality (i.e., dissolved oxygen pollution block) within the Delaware River. As water quality improved from the 1970s into the 1990s, the American Shad population within the Delaware River also improved. From 1972 to 1989, the smoothed Lewis haul seine CPUE correlated well with the smoothed AMO with an $R^2 = 0.7986$ (Figure 50). This correlation disintegrates during the 1990s suggesting a problem with the stock that is not related to the AMO. The Lewis haul seine to AMO analysis showed a negative correlation for the time period of 1990 to 2015 with an $R^2 = 0.7401$ (Figure 51).

Additional analyses were conducted between the AMO and the Smithfield Beach CPUE from 1990 to 2015. The first few years of this survey was associated with high catches but declined rapidly throughout the remainder of the time series until recent years. The Smithfield Beach to AMO analysis showed a negative correlation for the time period of 1990 to 2015 with an $R^2 = 0.7473$ (Figure 52). This corroborates data reported earlier from the Lewis haul seine for the same time period.

In conclusion, this analysis suggests that long-term sea surface temperature change may have an impact on abundance of American Shad within the Delaware Basin. The Lewis haul seine CPUE correlates well with the AMO during the AMO index's rise in the 1970s and 1980s but there is a disconnect that occurs during the 1990s that currently is unexplainable. Potential sources of the discontinuity include decline in adults due to overharvest; bycatch discards in ocean fisheries; increased predation from Striped Bass or other species; or other unknown interruption of the spawning runs during this time period.

2.3.3 Overfishing and Ocean Bycatch

Excessive losses to directed fishing and bycatch are often implicated as causative factors in fish stock declines. Directed commercial harvest occurs in spawning rivers on adults and until 2005, in ocean waters. Recreational harvest of American Shad generally occurs during spawning migrations. American Shad taken while fishing for other species is called bycatch and it can occur in both rivers and the ocean.

Potential impacts of recent directed ocean harvest on American Shad are more difficult to identify. Ocean harvest has been poorly quantified. Moreover, limited tagging data suggests that ocean harvest is made up of many Atlantic coast populations. Since the stock of origin is generally not known, it is very difficult to identify losses that are specific to the Delaware River stock. Some sense for relative losses on a coast-wide basis can be obtained from reported landings. The Delaware shad population appeared to decline most precipitously during the early 1990s. Mean annual harvest for states north of North Carolina during the first half of the 1990s was 1,148,893 lbs per year from ocean waters and 413,510 lbs from in river fisheries (ASMFC 2007). Reported annual ocean harvest of American Shad from outside the 200 mile limit off of Mid-Atlantic and New England states was 310,000 lbs (Northwest Atlantic Fisheries Organization http://www.nafo.int/about/frames/about.html catch statistics for ocean waters outside of the EEZ). Recent ASMFC shad assessments have drawn conflicting conclusions about impacts of this ocean harvest. ASMFC (1998) concluded that there was no evidence that the ocean harvest was affecting coast-wide stocks. ASMFC (2007) hypothesized that coastal harvest was affecting some stocks including that in the Delaware River. Amendment 1 to the Interstate Fishery Management Plan for Shad and River Herring (ASMFC 1999), began a phase-out of directed harvest of American Shad in state coastal waters beginning in 2000. A total ban has been in effect by U.S. Atlantic coastal states since 2005.

Incidental Ocean Harvest

Quantification of the impact of bycatch and incidental fisheries on Delaware River American Shad remains difficult. Two fishery management plans have identified alternatives to reduce catch of American Shad in their Fishery Management Plans (FMP). The Mid Atlantic Fisheries Management Council's (MAFMC) Amendment 14 of the Atlantic Mackerel, Squid and Butterfish FMP (MAFMC 2014) and the New England Fishery Management Council's (NEFMC) Amendment 5 to the Atlantic Herring FMP (NEFMC 2014) both identified shad and river herring as incidental catch in these directed fisheries and acknowledged the need to minimize catch of shad and river herring. Both of these plans, through the amendments identified above and subsequent framework adjustments:

- Implemented more effective monitoring of river herring and shad catch at sea;
- Established catch caps for river herring and shad; and
- Identified catch triggers and closure areas.

Fishery observer data is used to estimate and monitor the river herring and shad captured by Atlantic Herring and Atlantic Mackerel vessels that land more than 3mt per trip. The methodology was developed with data on river herring and shad catch (Table 36) and quotas

(Table 37) presented by the Greater Atlantic Regional Fisheries Office (GARFO) of the NOAA Fisheries.

While the data do provide us with an estimate of the incidental catch of river herring and shad in these fisheries, catch by species is not identified. However, Amendment 14 of the Mackerel, Squid and Butterfish FMP does present species specific data by region and fleet from earlier years (Table 38). Observed annual American Shad catch between 1989 and 2010 ranged from 17mt to 104mt with an annual average of 48mt. In some years, large portions of the incidental catch were not identified to the species level. If we apply the same proportion of American Shad composition from the known catch to the unknown catch, the total estimated American Shad catch in the same time period ranged from 20mt to 139mt with an annual average of 62mt.

The proportion of known bycatch that was characterized as shad varied considerably among years, with an average proportion of annual shad catch equal to 18% and a median proportion of 13%. To get a general sense of the scale of potential shad harvest of these fisheries, the median proportion of known shad harvest between 1989 and 2010 was applied to more recent harvest years (Table 39). Unfortunately, it is impossible to determine which American Shad stock was impacted by the harvest from this mixed stock fishery.

The Co-op recommends that the Technical Expert Working Group for river herring to continue its work exploring opportunities to minimize the impacts of bycatch harvest, including developing catch caps for other fisheries as appropriate. The Co-op also recommends the continued implementation of the voluntary avoidance network and supports efforts to maximize the observer coverage in fisheries that land significant amounts of river herring as bycatch.

2.3.4 Impacts of Restoration Stocking

The PFBC has been stocking otolith-marked American Shad fry as part of their restoration program for the Delaware River Basin (Table 40). Eggs collected from Delaware River shad have been used in restoration efforts on other rivers, but since 2000, all Delaware River shad fry have been allocated to the Lehigh, and Schuylkill rivers. Occasionally, excess production was stocked back into the Delaware River at Smithfield Beach (2005 – 2008). Egg-take operations on the Delaware River have resulted in the use of an average of 756 adult shad brood fish per year, 1996 - 2015. Eggs from these shad are fertilized and transported to the PFBC's Van Dyke Anadromous Research Station where they are hatched, otolith-marked and stocked in areas above dams where fish passage projects are in place.

The contribution of hatchery-reared fry to the returning population was estimated by interpretation of oxytetracycline daily tagging patterns within the otolith microstructure

(Hendricks *et al*. 1991). The total hatchery contribution at Smithfield Beach was low ranging from 0.0 to 7.8% (Table 41), suggesting that hatchery-reared fry are not a significant component of the Smithfield Beach catch. The PFBC restoration program focuses shad fry stockings within the Lehigh and Schuylkill river main stems. Both the Lehigh River (RM 183) and Schuylkill River (RM 92) connect to the Delaware River main stem well downriver of Smithfield Beach (RM 218). Presumably shad impressed with the water quality signatures of either tributary would not likely occur further upriver at Smithfield Beach; rather, preferring homing to their natal source. The poor catches of marked shad at Smithfield Beach suggest straying is not a frequent occurrence. In addition, below the confluence of the Lehigh River with the Delaware River, Hendricks *et al.* (2002) demonstrated the occurrence of hatchery stocked shad in the Raubsville (RM 176) collections. Hatchery origin fish favored the west side of the river, presumably homing to the Lehigh River where they were stocked as fry. Contributions of hatchery shad to the catch at Raubsville varied 0.0 – 11%, among years.

Limited success has occurred in returning a self-sustaining spawning shad run to either the Lehigh or Schuylkill rivers by the PFBC American Shad restoration program. Greatest success has been achieved within the Lehigh River. The percentage of wild shad within the lower three miles of river (i.e., between the Easton, RM 0.0 and Chain, RM 3.0 dams) has increased since monitoring began in 1996. Initially the wild component of the Lehigh River spawning run was relatively poor, with the majority of the run composed of hatchery stocked shad. From 1996 – 2001, the wild component varied 2.0 – 9.4%, averaging 6.3%; the wild component increased slightly from 11.0 to 19.4% in 2002 and 2004, respectively (averaging 15%). By 2005-2015 the wild component varied between 26.3 – 67.7% (averaging 42.5%). The wild component was best represented in 2015, composing over two-thirds of the Lehigh River spawning run. Thus, over the years, the wild component has been increasing; yet, the hatchery component remains integral to the Lehigh River spawning run.

Returning shad into the Schuylkill River are mostly originating from hatchery stocked shad fry (Table 41). Hatchery origin shad composed 91%-100% of the annual returning run 2007 – 2010. In those years, wild shad (i.e., unmarked otoliths) composed < 10%. Yet, catches of shad during 2011 – 2014 were suggestive of an improved the wild component (i.e., 12% – 16% of the spawning run. But, wild shad were not observed in the 2015 catch (i.e., 0% contribution). Without maintenance hatchery shad fry stockings into the Schuylkill River, any anticipated annual returning shad spawning run would be very poor.

Self-sustaining spawning runs in to the Lehigh and Schuylkill rivers have not materialized after 31 years of restoration efforts. It is the conclusion of PFBC, American Shad passage into the Lehigh River is inefficient and inadequate to support the restoration of a self-sustaining population. The Lehigh River shad spawning runs remain well below the original expectations of successfully annually passing 165,000 – 465,000 wild shad (PFBC 1988). The observed peak passage in 2001 (n = 4,470) represents 0.9% - 2.7% of PFBC's restoration goal. Furthermore, 4.0% (n = 179) of the 2001 spawning run were determined to be of wild origin, representing less than 0.1% of the original restoration goal. Even in 2015, when the wild contribution was the greatest (i.e., 67.7%), the wild component remained less than 0.1% of the original restoration goal. This also assumes the wild shad caught from the Lehigh River, were indeed homing to the Lehigh and not straying from the Delaware River. The termination of the PFBC restoration program of the Lehigh River would undoubtedly severely reduce the Lehigh River spawning run size. Thus, the continued operation of the fishways would only provide, at best, a nominal dedicated spawning run into the Lehigh River.

To describe potential alternatives for improved shad passage into the Lehigh River, in 2012, PFBC in partnership with the Wildlands Conservancy and American Rivers/NOAA Community Grant Program, supported a feasibility study to investigate a suite of engineering options. Study findings suggested improvements of shad passage were best accomplished by full dam removal of the Easton and/or Chain dams (KCI Technologies Inc. 2013). Several key limitations were identified including, the need for pumping of water to support the flooding of both the Lehigh and Delaware canals, potentially negatively impacting various existing bridges and sewage pipelines (i.e. requiring additional support and/or armoring), and various user groups dependent on present day pools maintained by the existing dams. Achieving improved passage requires considerable focused cooperation between dam owners, user groups, and stakeholders, as well as utility owners in the vicinity of the structures. Any improvement is dependent on the willingness of the owners (i.e., Easton Dam owned by PA Dept. Conservation and Natural Resources; Chain Dam owned by the City of Easton) being in agreement to advance modifications. To date, the owners have not expressed interest in pursuing dam removal.

Similarly, annual spawning runs of American Shad into the Schuylkill River have been disappointing. The original restoration goal of an annual run size of 300,000 – 850,000 wild shad (PFBC 1988) has not been realized. Typically, observed runs remain less than 0.1% of this goal at Fairmount Dam fishway passage (Table 11; Figure 29). Modifications to the fishway have been accomplished for improving passage (i.e., 2008); however, returning runs continue to be poor. The invasive Flathead Catfish has severely impacted successful passage of shad and river herring. These large predators reside within the various pools of the fishway and have been observed to prey on passing shad and herring. Removal of the catfish was accomplished on several occasions, but other catfish immediately took up residence in the fishway, making catfish removal efforts ineffective.

Success for restoring American Shad to their once natal waters of the Lehigh and Schuylkill rivers appears bleak. The traditional hatchery methodology used for restoration in either tributary is not sufficient for generating a run size of the magnitude originally envisioned. Yet without maintenance fry shad stockings, any future spawning run into either tributary would most likely be nominal. The PFBC will continue maintenance shad fry stockings to continue annual spawning runs in both tributaries. Yet, PFBC will also investigate the feasibility of alternative methodology for possibly increasing the magnitude of annual hatchery stockings.

2.3.5 Impingement and Entrainment

Nearly 10 percent of Americans rely on the waters of the Delaware River Basin for drinking and industrial use (DRBC 1998). Power generating facilities, refineries, and other industries rely on withdrawal of surface water from the Delaware River to cool their industrial processes, with most industrial water withdrawals requiring continuous once-through use of water. This results in the suction of fish and other aquatic organisms into the industrial water intake structures where they either become trapped against the intake screens (impingement-I) or actually get taken further into the cooling system (entrainment-E). Both I&E can result in the death of fish and other organisms. Larger individuals become impinged and smaller organisms such as eggs and larvae become entrained. Impingement does not necessarily result in 100% mortality of affected organisms, but entrainment is considered 100% lethal to fish eggs and larvae. When fish spawn in spring and early summer in the Delaware River, the resulting eggs and larvae are vulnerable to entrainment; as fish grow larger during the balance of the year, they become susceptible to impingement. Therefore, losses to I&E are ongoing throughout the calendar year.

There are several large water intake systems at energy projects on the Delaware River. Recent estimates of impingement and entrainment (I&E) rates at water intake systems for American Shad in the Delaware River indicate that individual projects can entrain millions of American Shad eggs and larvae annually, and impinge tens of thousands of juveniles (Table 42). In a river system with numerous intake facilities that occur in spawning and nursery grounds for American Shad, the cumulative impacts to the population could be substantial.

To put the American Shad impingement rates into perspective, the Pennsylvania State Fish Hatcheries annually released 474,271 fry, on average, into the Delaware River Basin (Table 40). Considering additional mortality between the fry and juvenile stage, from various projects with intakes, impingement rates are likely far greater than resource agency stocking efforts to protect and restore American Shad to the Delaware River. Impingement data for other important fisheries suggest that impacts may be occurring on Striped Bass and Weakfish populations, reducing the number of fish that would later be available for recreational and commercial fishing. Recent estimates derived by staff from the Delaware Department of Natural Resources and Environmental Control, Division of Fish & Wildlife (DFW) suggest that losses of early life stages of Striped Bass at the Project translate into losses of Adult Equivalents that rivals or even exceeds current commercial and recreational harvest in Delaware (Ed Hale, DFW, pers. comm.). Losses of large numbers of forage species also reduce the food resources available in the river, further impacting fish communities in the Delaware River.

Recognizing the considerable I&E losses on the Delaware River Basin shad populations (and other fishes), routine quantification of I&E shad losses would provide for better estimation of anthropogenic mortality. Co-op members also agree improved best management practices to eliminate or reduce I&E losses would be prudent. Current available data preclude annual estimation of mortality by these facilities. We concede data collection/reporting and improved technologies place an additional monetary burden on operators with water intakes, but the paucity of information hinders development of a more robust stock assessment of Delaware River Basin shad populations.

3. Sustainable Fishery Benchmarks and Management Actions

The Co-op proposes a series of relative indices for monitoring trends in the American Shad population in the Delaware River Basin. The benchmarks were derived to allow the existing fishery to continue. The benchmarks have been set to respond to any potential decline in stock. Thus all benchmarks are viewed as conservative measures. The benchmark measures for maintaining sustainability are in order of their importance as follows:

1. Non-tidal JAI index
2. Tidal JAI index
3. Smithfield Beach adult CPUE survey
4. Commercial harvest to Smithfield Beach relative abundance ratio
5. Mixed stock landings

3.1 Benchmarks

3.1.1 Non-tidal JAI index

This JAI is based on annual catch data standardized by environmental covariates using GLM methodology. Only data originating from Phillipsburg, Delaware Water Gap, and Milford Beach are included in the JAI. The benchmark was based on data from years 1988-2015 (Table 4, Figure 53). Failure is defined as the occurrence of three consecutive JAI values below a value of the 25th percentile where 75% of the values are higher from the reference period (1988-2015). Exceeding the benchmark will trigger management action. The period of 1988 to 2015 was selected as these years encompass the years when sampling methodology was consistently applied to all sampling stations included in the JAI calculations; however no sampling occurred at any non-tidal station between 2008 and 2011. The non-tidal JAI fell below this target most recently in 2013 and 2015.

3.1.2 Tidal JAI index

This JAI is based on annual geometric means of the catch data from stations near Trenton to Delaware Memorial Bridge. The benchmark was based on data from years 1987-2015 (Table 4, Figure 54). Failure is defined as the occurrence of three consecutive JAI values below a value of 4.00 (i.e., the 25th percentile where 75% of the values are higher). Exceeding the benchmark will trigger management action. The period of 1987 to 2015 was selected as these encompass the years when sampling methodology was consistent among stations. The tidal JAI has been at or above this target since 2009.

3.1.3 Smithfield Beach CPUE Index

This index is based on the annual CPUE (shad/net-ft-hr*10,000) in the PFBC egg-collection effort at Smithfield Beach and represents the entire data series available from 1990 through 2015 (Figure 55, Table 28). This index represents a fishery-independent measure of the spawning run success as survivors after the fishery. The benchmark is defined as the 25th percentile of the time-series where 75% of values are higher. Failure is defined as the occurrence of three consecutive CPUE values below the benchmark value of 37.5. Exceeding the benchmark will trigger management action. The index has been higher than the benchmark since 2010.

3.1.4 Ratio of Commercial Harvest to Smithfield Beach Relative Abundance Index

This index is defined as the ratio of survivors after the fishery as indexed by the Smithfield Beach gill net CPUE divided by the total Delaware River stock landed by commercial fishers as reported to the States of New Jersey and Delaware. It is based on data from 1990-2015 (Figure 56, Table 28). The benchmark is defined as the 85th percentile of the time-series where 15% of values are higher. Failure is defined as the occurrence of three consecutive values above a value of 36.5. Exceeding the benchmark will trigger management action. The ratio estimate exceeded the benchmark four times in 1993, 1996, 2001, and 2004 for the entire time-series. This index is particularly appealing since it is sensitive to changes in both harvest and abundance (CPUE).

3.1.5 Mixed Stock Landings

This index is defined as the total pounds landed from the mixed stock, which consists of 60% of the landings south of a demarcation line from Bowers Beach, DE to Gandys Beach, NJ. The index was based on data from 1985-2015 (Figure 57, Table 33). The benchmark is defined as the 75th percentile of the time-series where 25% of values are higher. Failure is defined as the occurrence of 2 consecutive values above a value of 47,650 lbs. Exceeding the benchmark will trigger management action. This index provides additional harvest protections for American

Shad stocks with origins outside of the Delaware River, some of which have closed commercial fisheries. This index has been below the benchmark since 2006.

3.2 Management Actions

All management actions are subject to the severity and frequency of the breach of the established benchmarks and will be applied to all waters within the basin. For instance, if the Smithfield Beach CPUE falls below the benchmark for three consecutive years but the JAI is increasing and appears in no danger of doing the same, the action taken will be less severe than if the JAI was decreasing and in jeopardy of falling below its own benchmark. If both indices were to exceed the benchmarks simultaneously, swift action such as a harvest closure may be justified. Additional and more severe management action may be taken in time if one or more indices continue to fall below the benchmark after the initial management action. The Co-op will review these benchmarks annually to determine if management action is necessary, and if so, to detail appropriate management based on the options below.

There are many restrictions already in place for the commercial fishery that limit participation. These include limited entry, seasons, and gear restrictions throughout the Delaware Bay. The recreational fishery is limited to three fish in all areas, excepting Delaware jurisdictional waters where the recreational shad fishery is nominal. The following options regarding breach of the Delaware River benchmarks may require amending current regulations.

A) If the non-tidal or tidal JAI benchmark is exceeded:

Option 1: closure of commercial fishery; recreational catch and release only

Option 2: reduce commercial fishery by 50% through gear restrictions, seasons, trip limits, or quota reduction; reduce recreational fishery to 1 fish bag limit

Option 3: reduce commercial fishery by 25% through gear restrictions, seasons, trip limits, or quota reduction; reduce recreational fishery to 2 fish bag limit

B) If the Smithfield Beach adult CPUE benchmark is exceeded:

Option 1: closure of commercial fishery; recreational catch and release only

Option 2: reduce commercial fishery by 50% through gear restrictions, seasons, trip limits, or quota reduction; reduce recreational fishery to 1 fish bag limit

Option 3: reduce commercial fishery by 25% through gear restrictions, seasons, trip limits, or quota reduction; reduce recreational fishery to 2 fish bag limit

C) If both the tidal JAI and Smithfield Beach adult benchmarks are exceeded:

Option 1: closure of commercial fishery; recreational catch and release only

Option 2: reduce commercial fishery by 50% through gear restrictions, seasons, trip limits, or quota reduction; reduce recreational fishery to 1 fish bag limit

D) If the harvest to Smithfield Beach adult CPUE ratio benchmark is exceeded:

Option 1: closure of commercial fishery; recreational catch and release only

Option 2: reduce commercial fishery by 50% through gear restrictions, seasons, trip limits, or quota reduction; reduce recreational fishery to 1 fish bag limit

Option 3: reduce commercial fishery by 25% through gear restrictions, seasons, trip limits, or quota reduction; reduce recreational fishery to 2 fish bag limit

E) If the mixed stock landings benchmark is exceeded:

Option 1: gill nets with stretch mesh greater than or equal to 4 inches and less than 7 inches will be prohibited below the mixed stock demarcation line during February 1st through May 31st. Harvest of American Shad as bycatch (American Shad $\leq$ 50% of harvest by weight) is still permissible below the demarcation line from Bowers Beach, DE to Gandys Beach, NJ

During the implementation of the 2012 SFP, indices for the four sustainable fishery benchmarks (tidal and non-tidal JAI, Smithfield Beach CPUE, and the ratio of commercial harvest to Smithfield Beach) stayed above or below their specified benchmark levels for the specified time periods, therefore no management action was implemented during the 2012 SFP.

3.3 Benchmark Summary

Index	Benchmark Value	Years of Index for Benchmark	Benchmark Level	Management Trigger	Data Values
Non-Tidal JAI (GLM of Big 3)	145.9*	1988-2015	25^{th} percentile	3 consecutive years below benchmark	Table 4, Figure 53
Tidal JAI (GM)	4.00	1987-2015	25^{th} percentile	3 consecutive years below benchmark	Table 4, Figure 54
Smithfield Beach CPUE Index	37.5	1990-2015	25^{th} percentile	3 consecutive years below benchmark	Table 11, Figure 55
Ratio of Comm. Harvest to Smithfield Beach	36.5	1990-2015	85^{th} percentile	3 consecutive years above benchmark	Table 28, Figure 56
Mixed Stock Landings	47,650	1985-2015	75^{th} percentile	2 consecutive years above benchmark	Table 33, Figure 57

*This value may change slightly each year based on re-analysis of data using the GLM.

4. Proposed Time Frame for Implementation

The Co-op proposes that this plan be re-evaluated on a five-year cycle. The tenure for the 2017 SFP is expected to cover the period 2017 through 2021. Thereafter the next planned update should be initiated in 2020. All datasets will be updated annually for assessing the exceeding of any benchmarks requiring immediate management action. The mixed stock benchmark will be reevaluated upon completion of the 2017 genetics study to determine the extent that the mixed stock travels into the Delaware Bay, or at such time when new data are available. All sustainability benchmarks will be reviewed annually after completion of annual ASMFC compliance reports.

The Co-op views the 2017 SFP as a working document. Over the tenure of the 2017 SFP, Co-op members will continue investigations of recommended actions herein and/or as new opportunities become available. Petitions arising to ASMFC for updating the 2017 SFP may be initiated prior 2020.

5. Future Monitoring Programs

5.1 Fishery Independent

5.1.1 Juvenile Abundance Indices

The tidal beach seine program conducted by NJDFW will continue indefinitely, given its importance to their Striped Bass monitoring requirements.

The non-tidal seine program will continue through a collaborative effort during the duration of this SFP (2017-2021). The index will be generated from catches from Phillipsburg, Water Gap, and Milford. The inclusion of Trenton and the upper freshwater sites in the East Branch to the index will be reevaluated for the next SFP update. The continuance of this program is dependent on the collaboration among Co-op members ability to commit personnel resources without dedicated budgeted funding.

5.1.2 Adult Stock Monitoring

Spawning stock

The PFBC will continue to fully support the fishery independent survey at Smithfield Beach (gill net survey) for, at a minimum, the next five years (2017-2021). The objective is to obtain biological data on the spawning stock as well as an index of relative abundance. Additionally, all caught shad will be strip spawned in support of the PFBC American Shad restoration program for the Lehigh and Schuylkill rivers.

Total mortality

Due to the uncertainty associated with ageing of shad scales and otoliths, confidence in ageing is low. The Co-op will not use mortality estimates as targets for managing the Delaware River stock. However, scale and otoliths will continue to be collected and the Co-op will re-evaluate the use of mortality estimates as shad ageing techniques improve.

Co-op members will focus on finalizing the Delaware River specific ageing protocols. Inclusive of this effort are the scheduling/assignment for production ageing of scale microstructures for future collection and the considerable backlog of historical collections; reaffirming interpretation of repeat spawning marks; and evaluation of otolith microstructures.

Hatchery evaluation

Otoliths of all hatchery-reared American Shad larvae stocked by PFBC into the Delaware River Basin are marked with oxytetracycline to distinguish hatchery-reared shad from wild, naturally-produced shad (Hendricks *et al*. 1991). Since 1987, larvae were marked with unique tagging patterns accomplished by multiple marks produced by immersions 3 or 4 days apart.

Determinations of origin are interpreted from the presence of florescent tagging patterns in the otolith microstructure. Hatchery contribution is determined for specimens collected in the Schuylkill and Lehigh rivers above the first dam and in the Delaware River at Smithfield Beach. The proportion of hatchery fish present in juvenile or adult population will continue to be monitored as per ASMFC Amendment 3.

5.2 Fishery Dependent

5.2.1 Commercial Fishery

The States of Delaware and New Jersey will conduct fishery dependent surveys as required by ASMFC Amendment 3. Landings by geographic location will be noted to determine the extent of harvest on the mixed stock fishery.

5.2.2 Recreational Fishery

Comprehensive angler use and harvest surveys are monetarily prohibitive. The NPS/PFBC angler logbooks are considered unreliable by Co-op members for characterizing the recreational shad fishery. Without dedicated funding, Co-op members are unable to support a comprehensive creel survey. Co-op members anticipate no quantifiable source of data will be available for documenting angler use and harvest over the tenure of the SFP.

6. Fishery Management Program

6.1 Commercial Fishery

Delaware: The State of Delaware has no regulations that have been specifically adopted to reduce or restrict the landings of American Shad in the Delaware Estuary. However, there are regulations that apply to the commercial fishery in general that limit commercial fishing. Additionally, we have introduced measures to control for the expansion of landings in the lower bay. Existing regulation affecting the Striped Bass fishery will remain the same, such as limited entry, limitations on the amount of gear and annual mandatory commercial catch reports. Area and gear restrictions will remain the same (see Section 2.2).

New Jersey: New Jersey waters are open to gill netting for the majority of the year but the current directed commercial fishery for American Shad occurs primarily during March through April of each year depending on environmental conditions. New Jersey regulations are listed in Table 17. Limited entry is in place; permits are not gear specific. All permits are currently non-transferable except to immediate family members.

Pennsylvania and New York: Both Pennsylvania and New York do not permit the commercial harvest of American Shad within the Delaware River Basin.

6.2 Recreational Fishery

Within the jurisdictional waters of New Jersey, New York, and Pennsylvania for the Delaware River main stem, all impose a three shad daily possession limit with no size limit or closed season. Within the tidal portion of the Delaware River, Bay, and their tributaries, New Jersey imposes a six shad daily possession limit, with a maximum of three American shad, with no size limit or closed season. The State of Delaware continues with a ten fish/day, combined American and Hickory shad, with no size limit or closed season. Little effort is expended by recreational anglers for American Shad in Delaware waters with no reported harvest.

The Lehigh and Schuylkill rivers represent the two largest tributaries to the Delaware River, draining 3,529.7 km^2 and 4,951.2 km^2, respectively. Both of these tributaries in their entirety are contained within Pennsylvania. Beginning January 1, 2013, regulations were modified to reflect recreational catch and release only and prohibited commercial harvest of American Shad.

Bycatch and Discards

New Jersey and Delaware do not require mandatory reporting of bycatch and discards in their commercial fisheries. In the recreational fishery many anglers are practicing catch-and-release, there are no plans to regulate this other than with possession limits which are already in place.

7. Data Needs for Improved Characterization of the Delaware River American Shad Population

To some extent American Shad remain an enigma for the Delaware River Basin as well as coast-wide. While current knowledge has provided insight into the returning adult spawning run, YOY production and recreational/commercial exploitation, we essentially have a very limited knowledge of landscape-scale and temporal variation of shad within the Basin similar to other basins along the Atlantic Coast.

To conduct a data rich stock assessment for American Shad in the Delaware River Basin, additional data collection is necessary. Information collected annually from our commercial and recreational fishery sectors both within the Delaware River/Bay and other estuary systems could be used to model fishing mortality (F) and spawning stock biomass (SSB) of Delaware River origin fish using a Statistical Catch at Age model (SCAA). Using a SCAA we would be able to estimate the abundance at age, age specific selectivity, fishing mortality (F) and catchability (q) for each year.

7.1 Existing Data

The following data sources are currently available to be used in a stock assessment. These data will continue to be collected through their respective surveys so that they continue to be available for future assessments. The resultant time-series support trend analysis from which professional judgments for associated management benchmarks are enacted.

- Commercial landings (pounds landed, CPUE as are reported to the states of New Jersey and Delaware)
- Age and repeat spawn structure of adult spawners (result of the aging sub-committee)
- Index(ices) of adult abundance (CPUEs from Smithfield Beach and Lewis Haul Seine)
- Index(ices) of YOY abundance (CPUE from beach seining at tidal and non-tidal sites)
- Coefficient of Variation for Indices

7.2 Estimated Parameters from Existing Data Sources

The following data can be estimated from currently available data provided in section 8.1.

Age determination among Co-op members is considered preliminary, as draft protocols continue to be further refined. One obstacle to full Co-op support of age-based modeling is consistent and dedicated personnel for scale/otolith processing and age interpretation. The Ageing Protocol in Appendix A is the first step toward consistency going forward.

- Age specific Natural Mortality (M)
- Proportion Mature at Age (result of the ageing sub-committee)

7.3 Required Data for Fully Supporting a Data Rich Stock Assessment

The following data are not currently being collected or are being collected on a limited basis without sufficient sample sizes to provide for adequate analysis. Collection of these data on an annual basis is necessary to conduct a more data rich stock assessment.

- Commercial age at length
- Commercial weights at age
- Commercial bycatch (numbers)
- Commercial discards (numbers)
- Commercial discard mortality rate
- Commercial bycatch size and age structure (inland, estuaries and ocean fisheries – by NMFS statistical area and fishery)
- Recreational landings (numbers) by state
- Recreational bycatch (numbers) by state
- Recreational discards (numbers) by state

- Recreational discard mortality rate
- Recreational age at length
- Recreational weights at age
- Index(ices) of Age 1 abundance
- Percent stock composition within the Delaware Bay/Estuary at points along an estuarine gradient

7.4 Additional Data Needs

In addition to the data required for a more data-rich stock assessment, additional data are necessary to better understand the Delaware River Basin American Shad stocks.

7.4.1 Proportion of Mixed Stock Fishery

Tagging and genetics studies have indicated that some portion of the American Shad captured in the Delaware Bay are spawning stock from other Atlantic Coast Rivers. A multi-year, robust genetic or tagging study within the entire expanse of the bay will best provide a delineation point for mixed stock circulation in the bay, above which the majority of fish are solely Delaware River Stock. In addition, better reporting of capture location for the Delaware River/Bay commercial harvest occurs is necessary to better characterize the impact of the fishery on the Delaware River stock as well as stock of other Atlantic Coast rivers.

- Delineation point for mixed stock
- Location of capture of commercial harvest

7.4.2 Weight and Size Characterization at Different Collection Points

Length and age may differ depending on collection location and gear type used in the basin. Understanding differences in the population demographics by location and gear can inform management decisions on protecting or exploiting different portions of the American Shad population.

- Compare length frequency for different collection sources (i.e. Lewis Haul Seine, tagging, commercial catch)
- Prespawn weights for adult American Shad

7.4.3 Improve Existing Data Collection and Benchmark Evaluation

Currently, samples are taken from American Shad to generate age data. The Co-op has been working on standardizing ageing techniques between the basin states to produce a more rigorous and reliable ageing data set. Those techniques have been finalized (Appendix A) and need to be implemented. In addition, the Co-op has conducted some analysis looking at the power of our current benchmarks to detect changes in the American Shad population. An evaluation of the non-tidal JAI has indicated that the current benchmark is adequate, but the survey has low power to detect change in the population. The power analysis should be conducted on other benchmarks as well to determine our ability to detect change in our other surveys used as the basis for the Sustainable Fishing Plan. Co-op members have expanded the non-tidal fixed station YOY beach seine survey to include two sites located in the upper Delaware River Basin (i.e., Skinners Falls and Fireman's Launch). The intent is to allow examination of YOY production in reaches not historically surveyed. Support for this effort remains on an *ad hoc* basis. The Co-op needs to secure long-term commitment for the continuance of surveying these sites.

- Finalize ageing techniques and data
- Tidal JAI power analysis to evaluate benchmark
- Standardization of Smithfield Beach CPUE and power analysis of the time-series
- Investigate benefits/losses to transitioning the non-tidal beach seine survey from fixed station sampling into a more rigorous survey design such as a stratified random design, for example
- Secure expansion of the non-tidal YOY sampling to include the upper Delaware non-tidal reaches

7.4.4 Additional Fishery-Independent Monitoring Programs

Reliance of characterizing the adult shad spawning run singly upon Smithfield Beach as representative of the entire Delaware River Basin is a poor assumption. Sampling on a larger geographic scale is needed to better characterize the variation of spawning adult population in the Basin. Returning spawning adult shad appear to be utilizing the upper Delaware Estuary reaches as spawning grounds, as water quality continues to improve. Without an adult monitoring program in the upper Delaware Estuary, validation of the tidal JAI will remain intangible. Similarly, shad are known to spawn in the upper Delaware Basin, yet, this has not been suitably quantified.

- Investigate the feasibility for initiating a fishery-independent annual monitoring of returning shad in the upper Delaware River Basin and Delaware Estuary/Bay
- Investigate the feasibility for initiating telemetry studies to characterize adult spawning behavior and residency to particular locales

7.4.5 Characterize Loss from Non-traditional Fishery Harvest sources

Losses of shad from the Delaware River population beyond either recreational or commercial harvest occur. Impingement and entrainment from various water intakes are known to be considerable sources of mortality. Yet available data quantifying this loss is not consistently reported.

- Collaborate with regulatory agencies for improving reporting rates of I&E losses of shad

- Investigate the feasibility for initiating a survey to quantify density of eggs and larvae of American Shad in the Delaware River to better quantify impacts of specific water intake structures and inform mitigation measures at intake structures that have a substantial impact on shad populations

7.4.6 Multi-species Management

Understanding how different species of predators and prey interact is an important component to managing fish stocks. American Shad are prey species for a suite of inshore and offshore predators. Shad also share resources with other prey species. Better management of American Shad stocks can occur if we consider other species that interact with or depend upon American Shad.

- Pursue other data sources for potentially relating interactions between various predators and resource competitors.

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9. Figures

Figure 1. The Delaware River watershed.

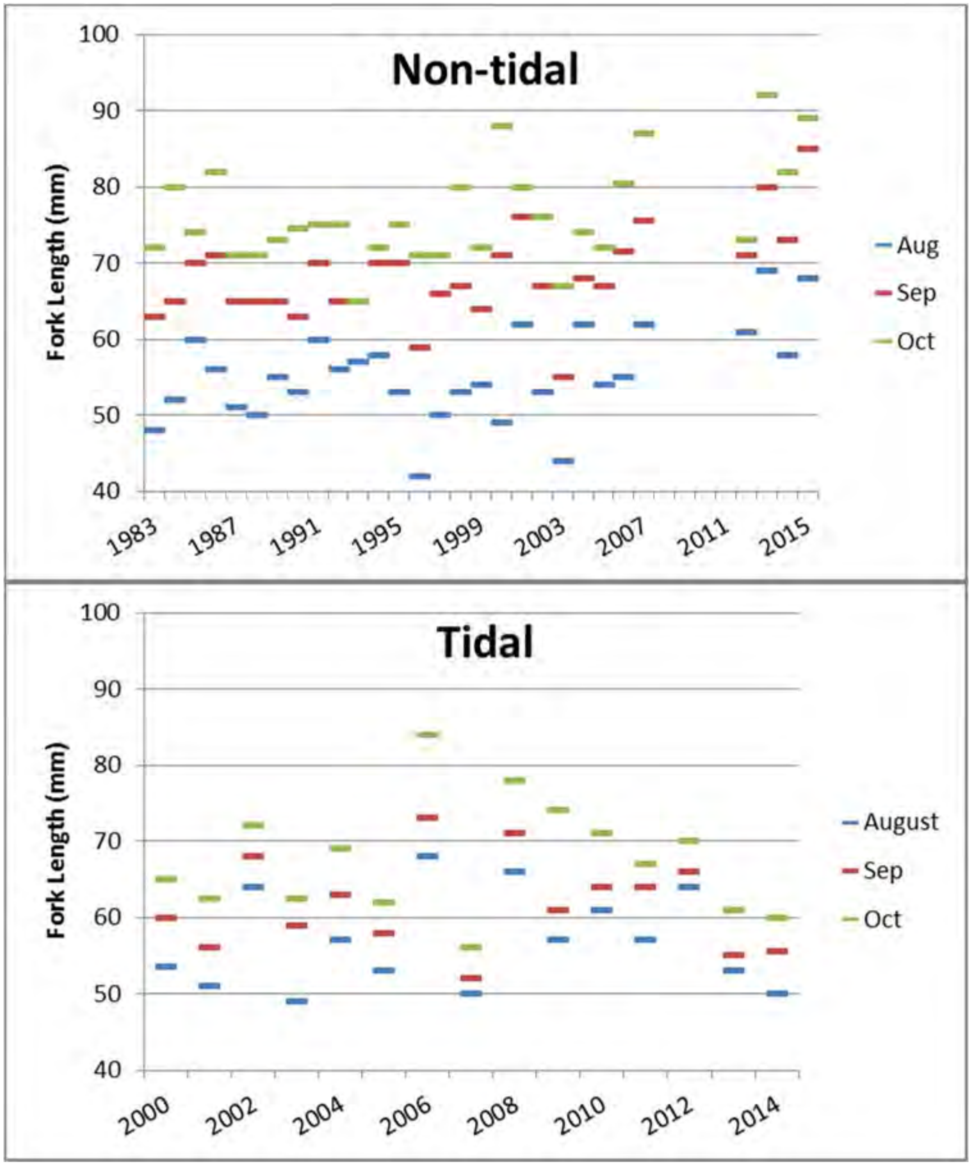


Figure 2. Distribution of YOY American Shad median fork lengths by month for the non-tidal and tidal beach seining. Medians are inclusive of those fork lengths collected from the traditional non-tidal sites: Trenton, Phillipsburg, Delaware Water Gap and Milford Beach.

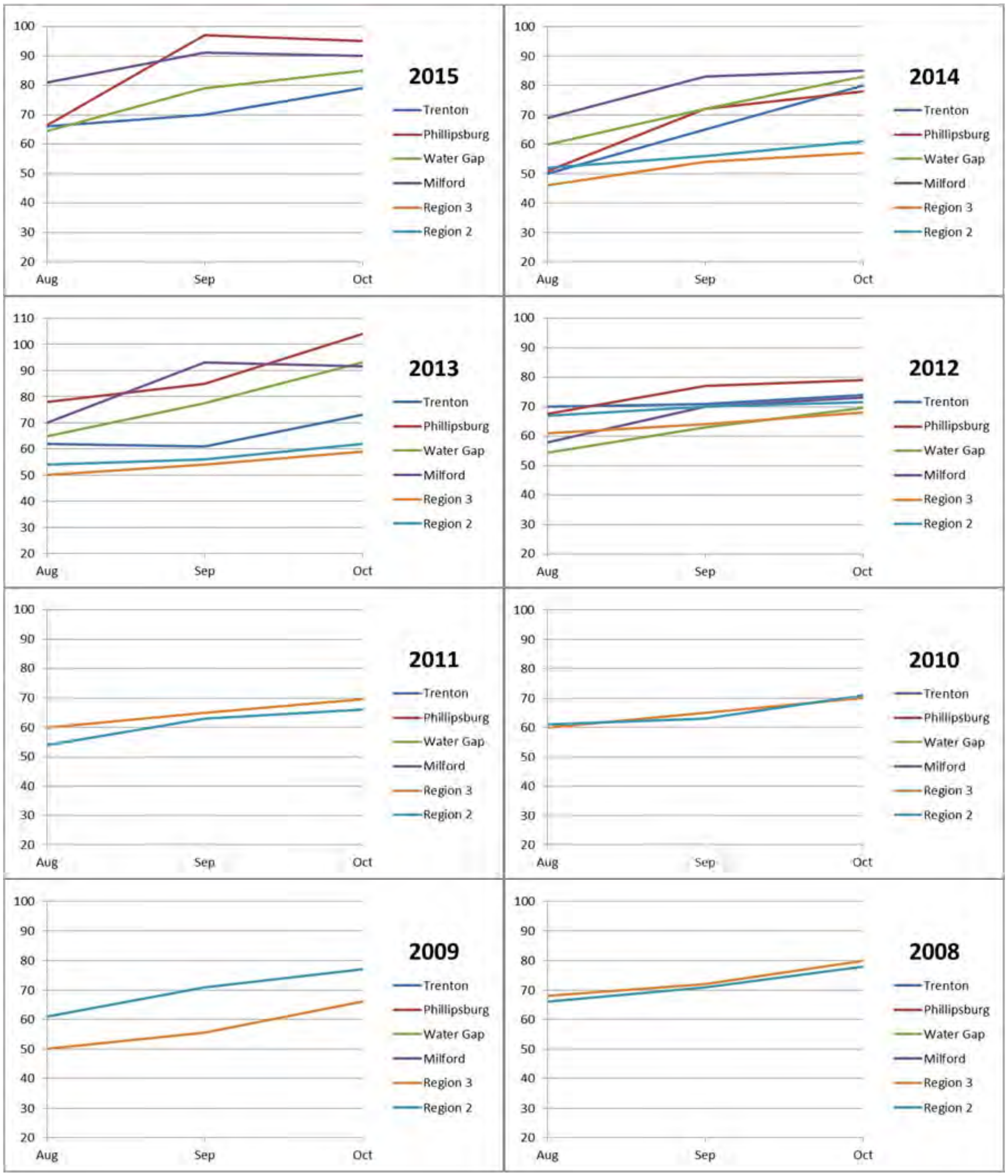
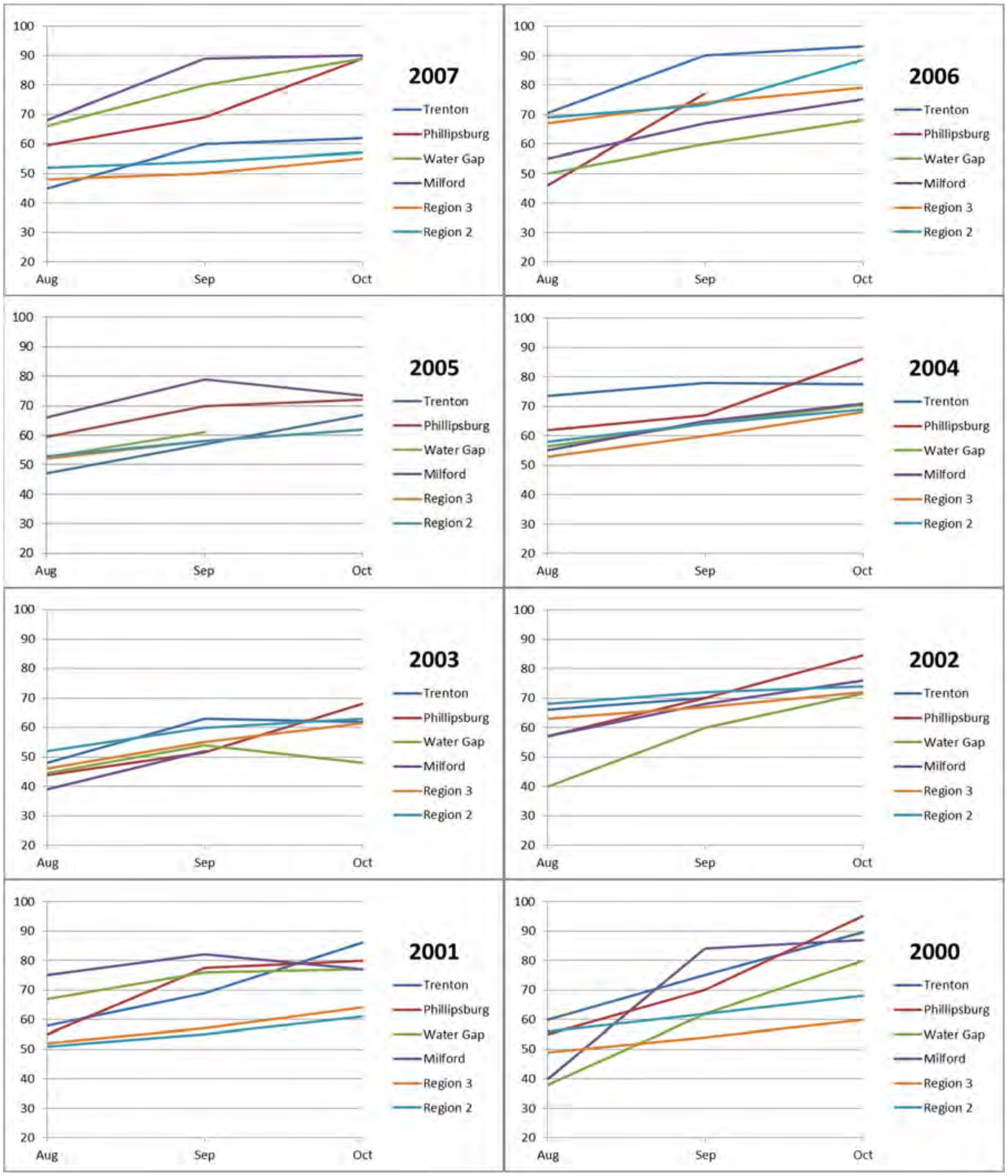


Figure 3. Distribution of YOY median fork lengths, by month and location, for the non-tidal and tidal beach seining.



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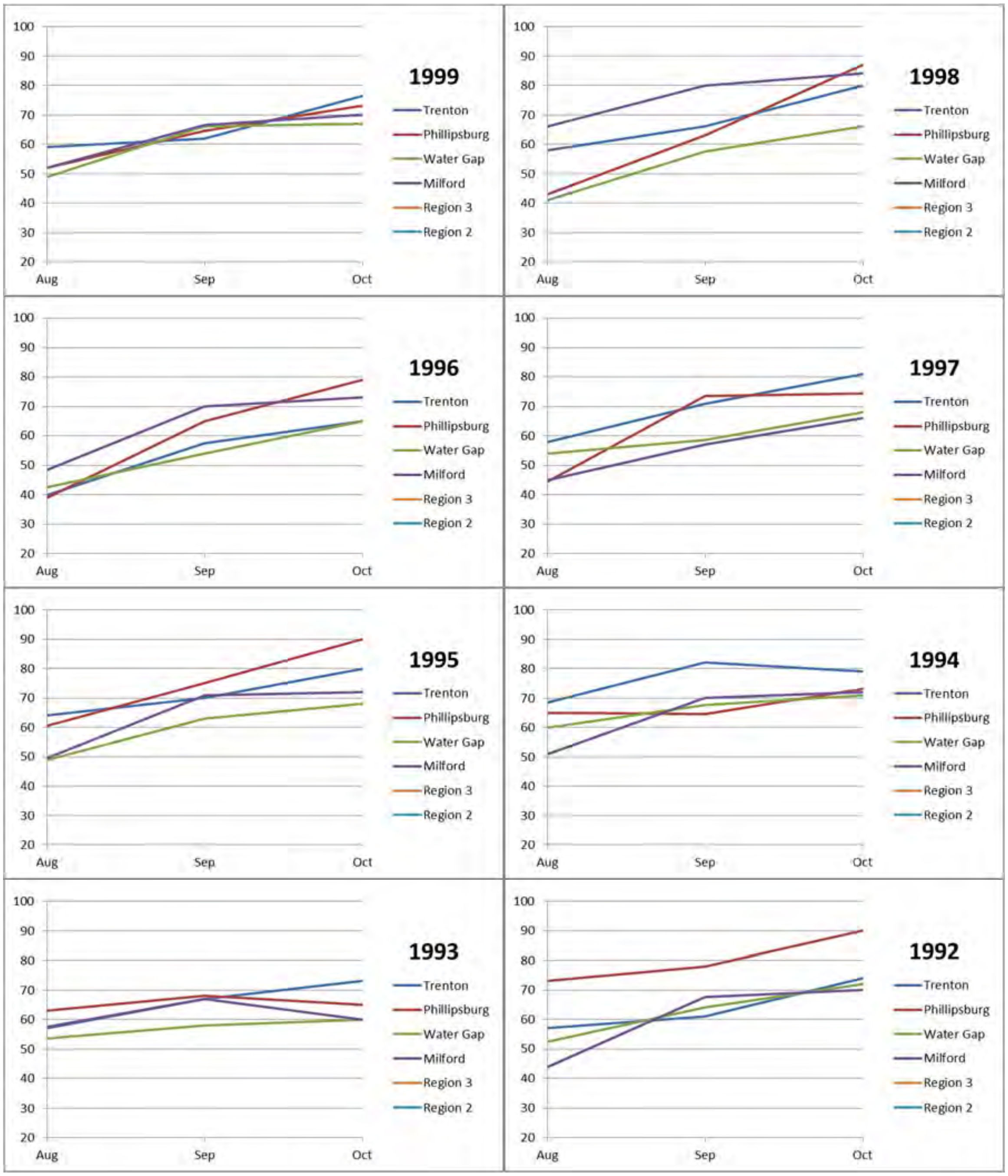


Figure 3. Cont.

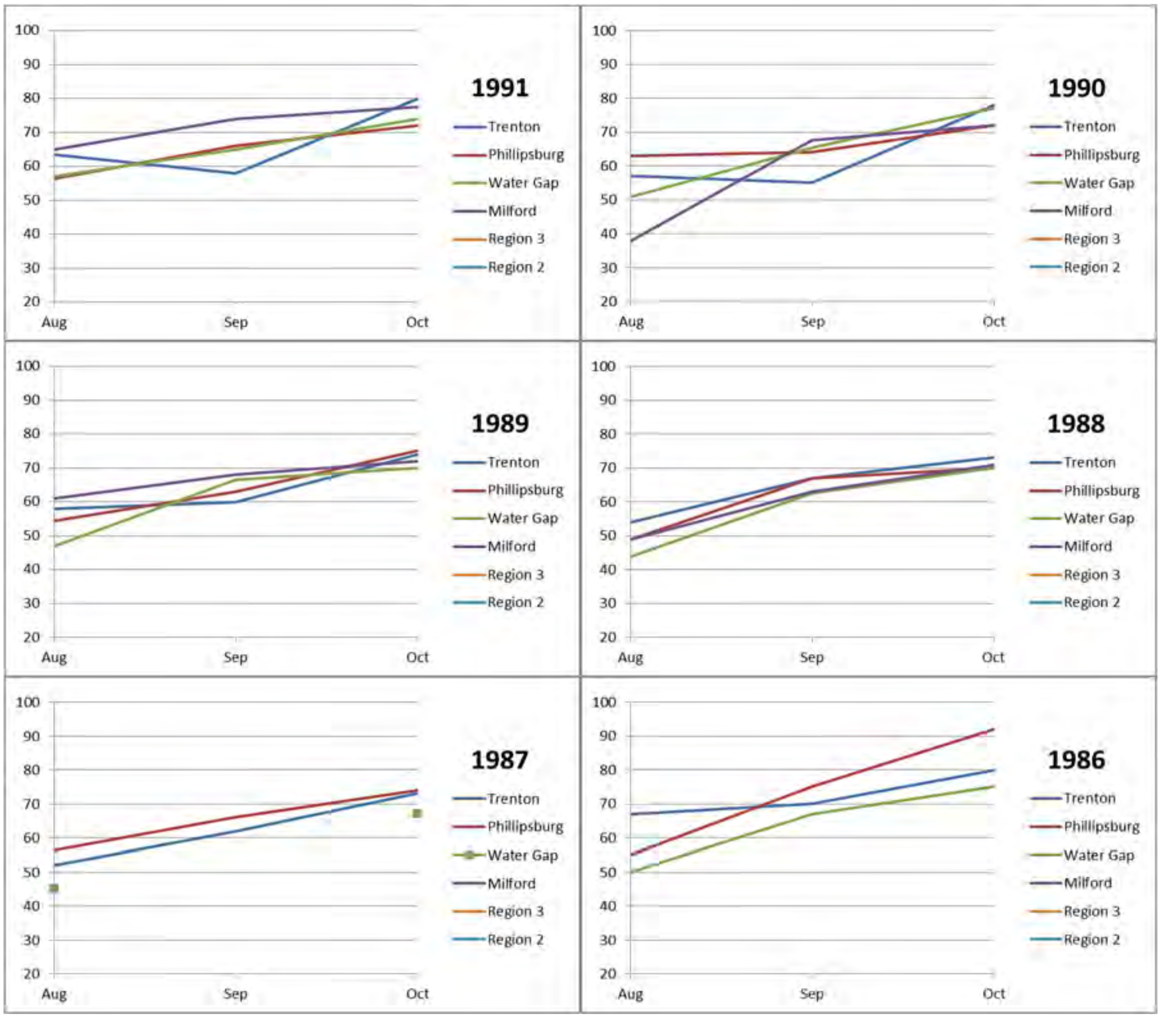


Figure 3. Cont.

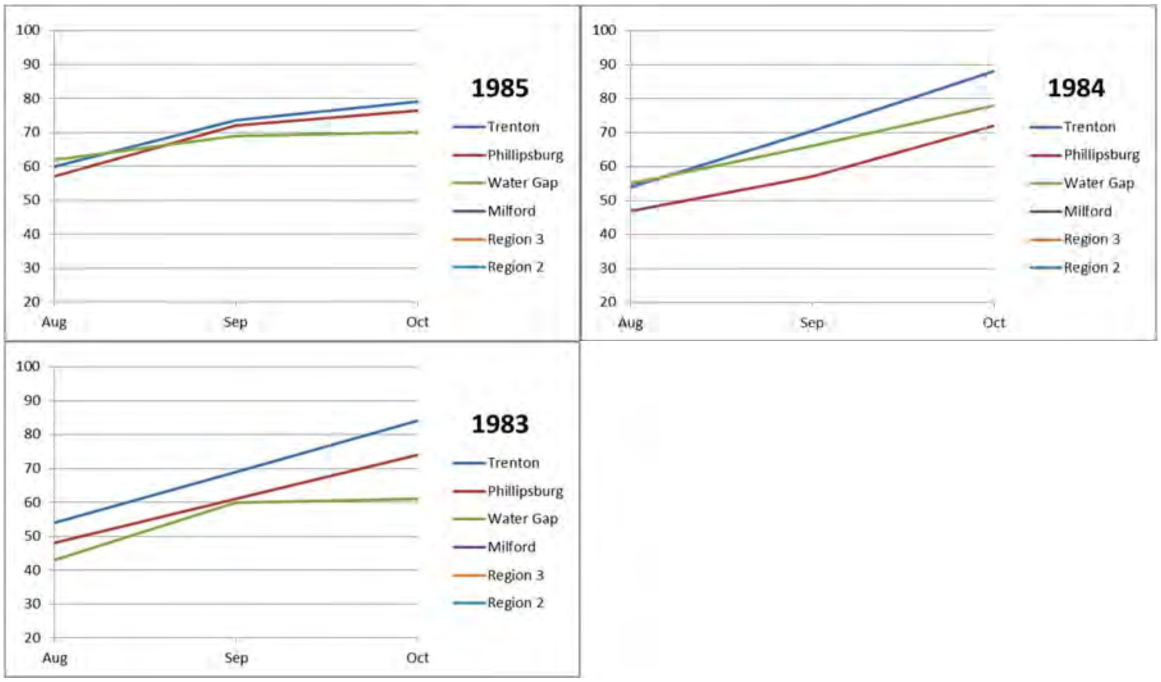


Figure 3. Cont.

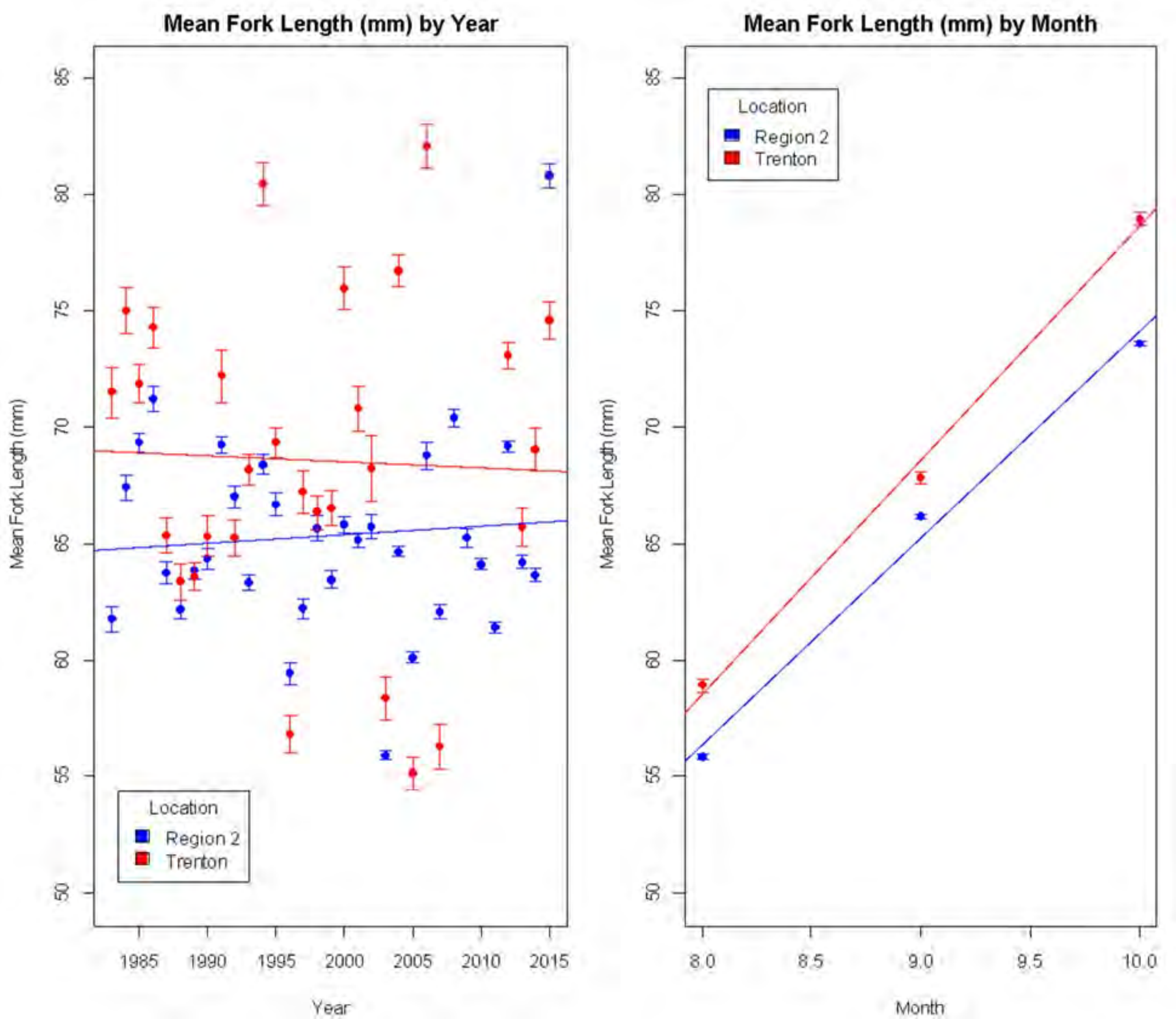


Figure 4. Comparison of YOY shad fork lengths between the upper estuary (Region 2) and Trenton sites.

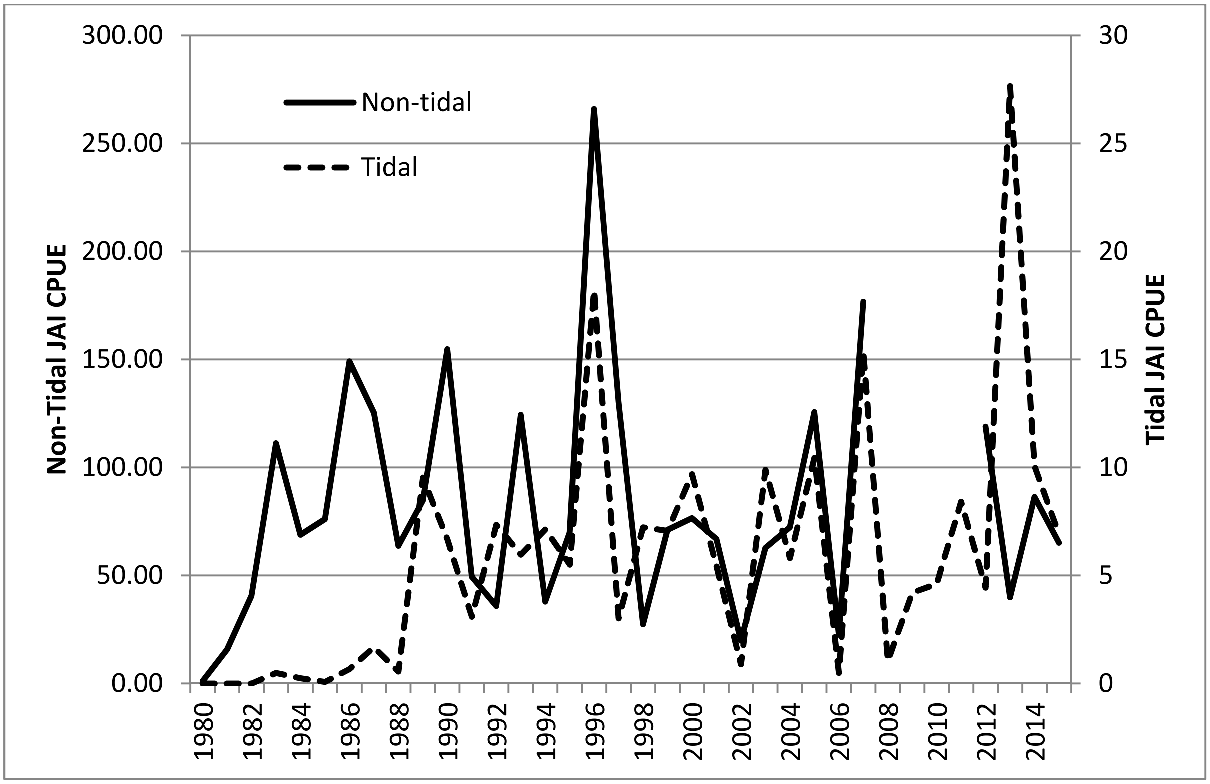


Figure 5. Non-tidal (based on the four historic sites Trenton, Phillipsburg, Delaware Water Gap and Milford Beach) and tidal Delaware River American Shad JAIs both expressed as Geometric means: 1980 – 2015.

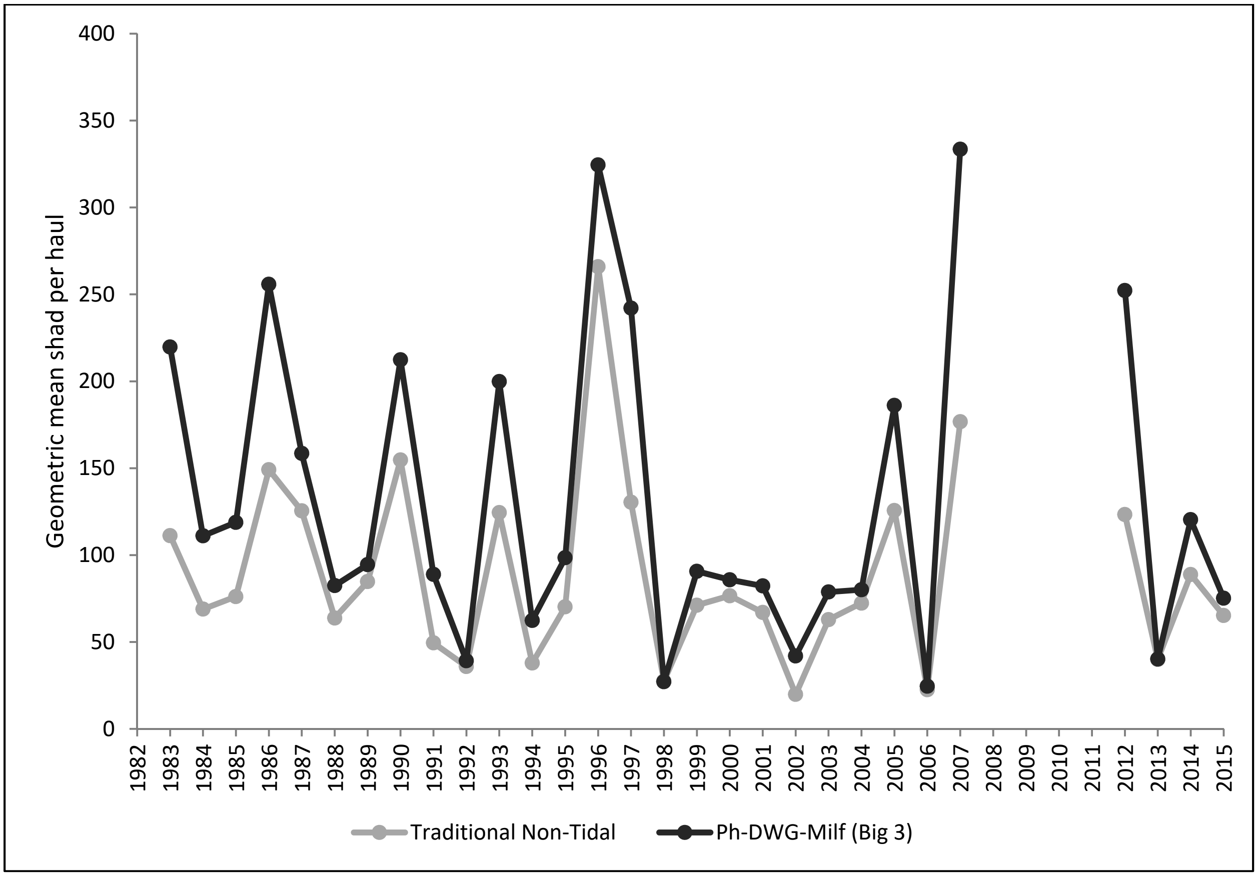


Figure 6. Geometric means for the non-tidal JAI from the traditional (i.e., Trenton, Phillipsburg, Delaware Water Gap and Milford Beach) and new non-tidal (i.e., Phillipsburg, Delaware Water Gap and Milford Beach, collectively informally referred to as the Big 3) sampling sites.

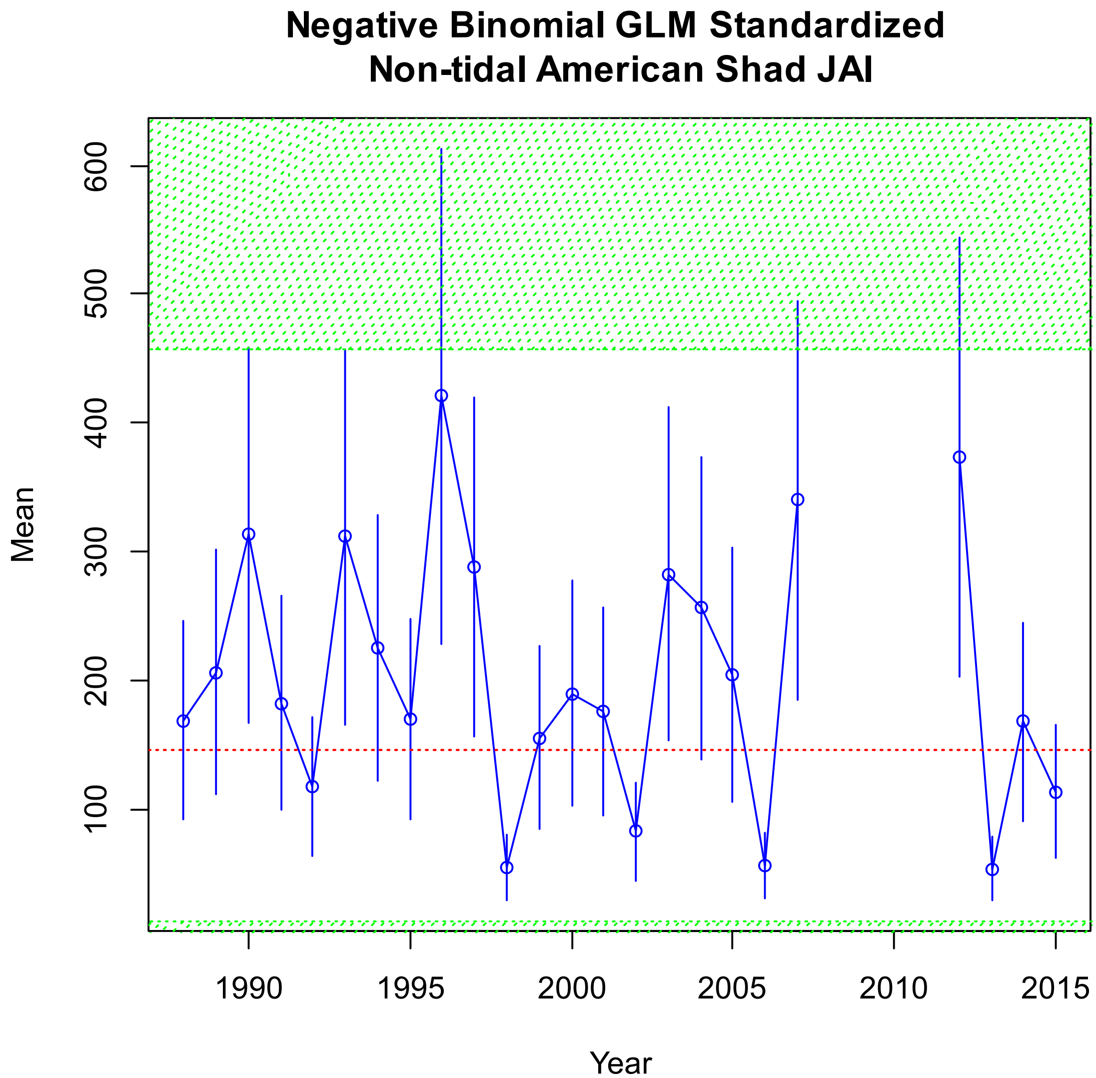


Figure 7. The Delaware River non-tidal American Shad JAI (GLM) with 25th percentile benchmark (red dotted line) from 1988 – 2015 with 95 % confidence intervals. The green boxes represent our survey detectability over a five year period with power = 0.80. Only the Big 3 non-tidal sites (i.e. Phillipsburg, Delaware Water Gap and Milford Beach) were inclusive in this analysis.

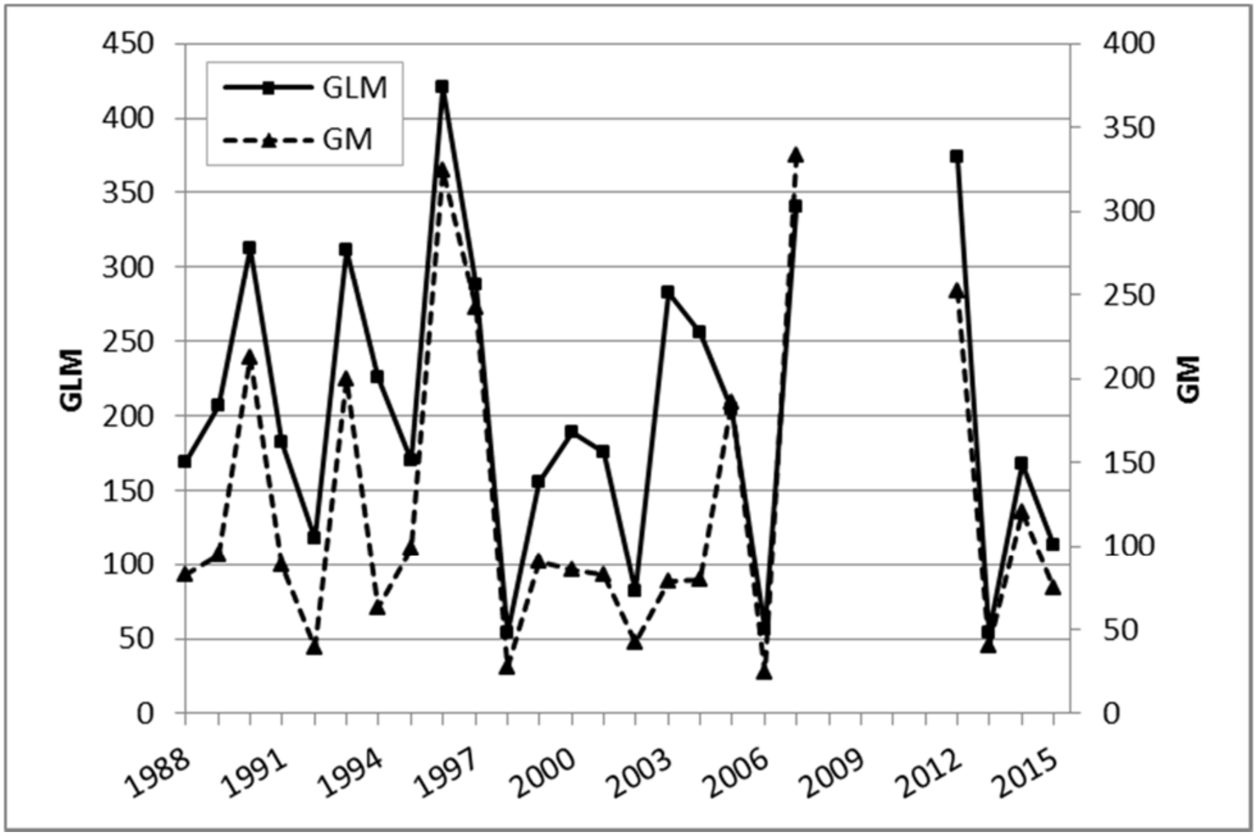


Figure 8. Comparison of non-tidal JAI as represented by geometric mean (GM) and generalized linear model (GLM) from Phillipsburg, Delaware Water Gap, and Milford Beach from 1988 to 2015.

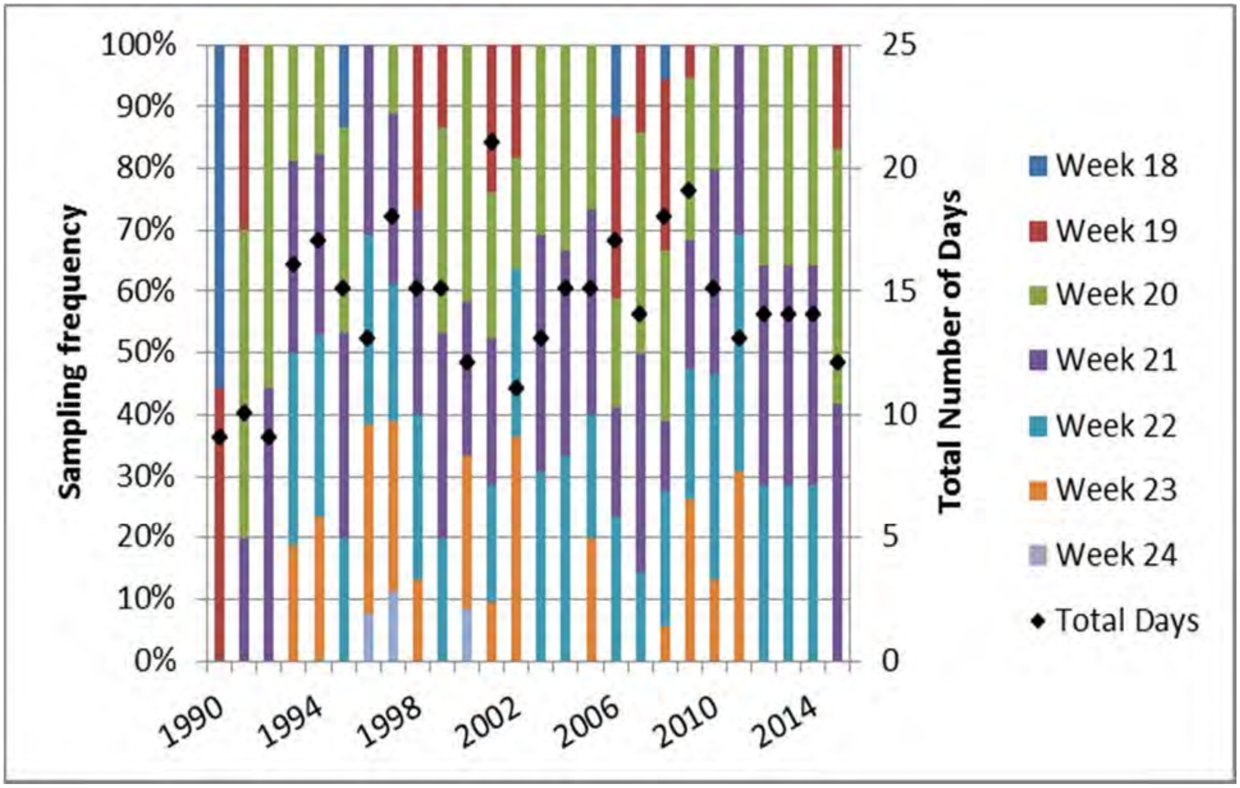


Figure 9. Sampling frequency and total number of days for gill netting American Shad at Smithfield Beach.

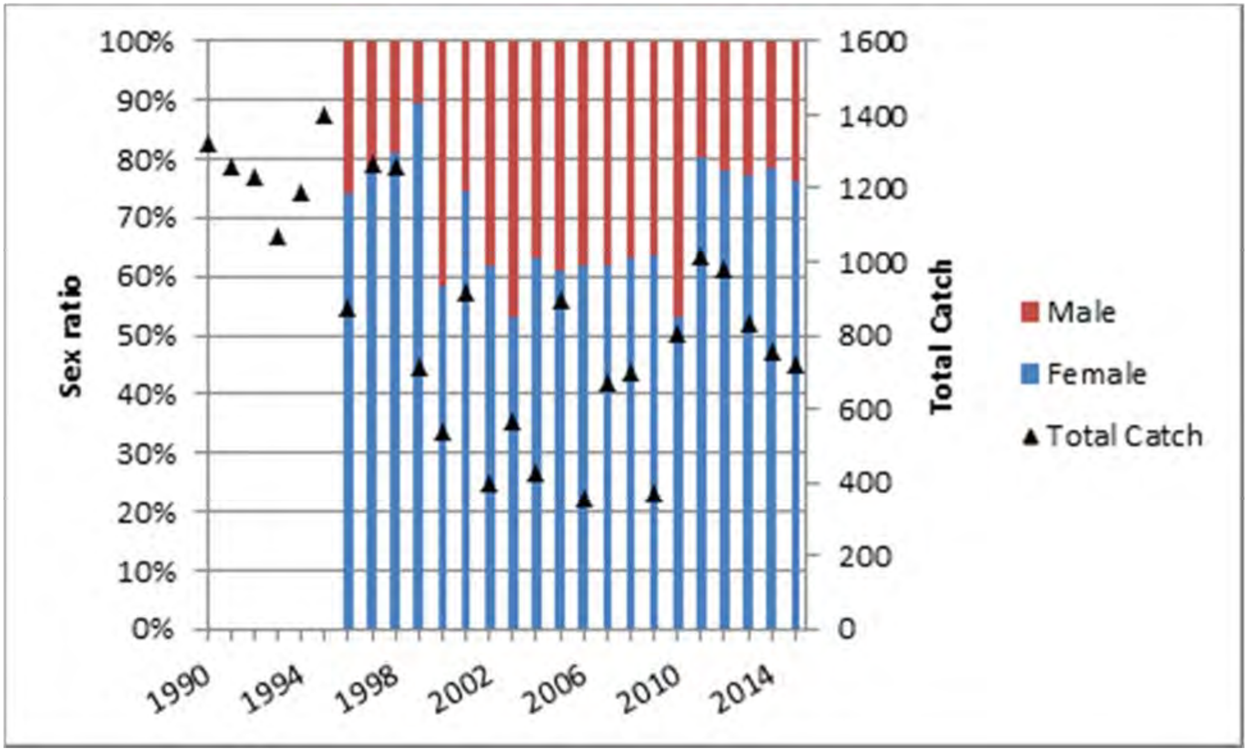


Figure 10. Total catch of American Shad at Smithfield Beach, by gender. No biological data were recorded prior to 1996. Observed sex ratio is dependent on the frequency of mesh sizes deployed in any given year.

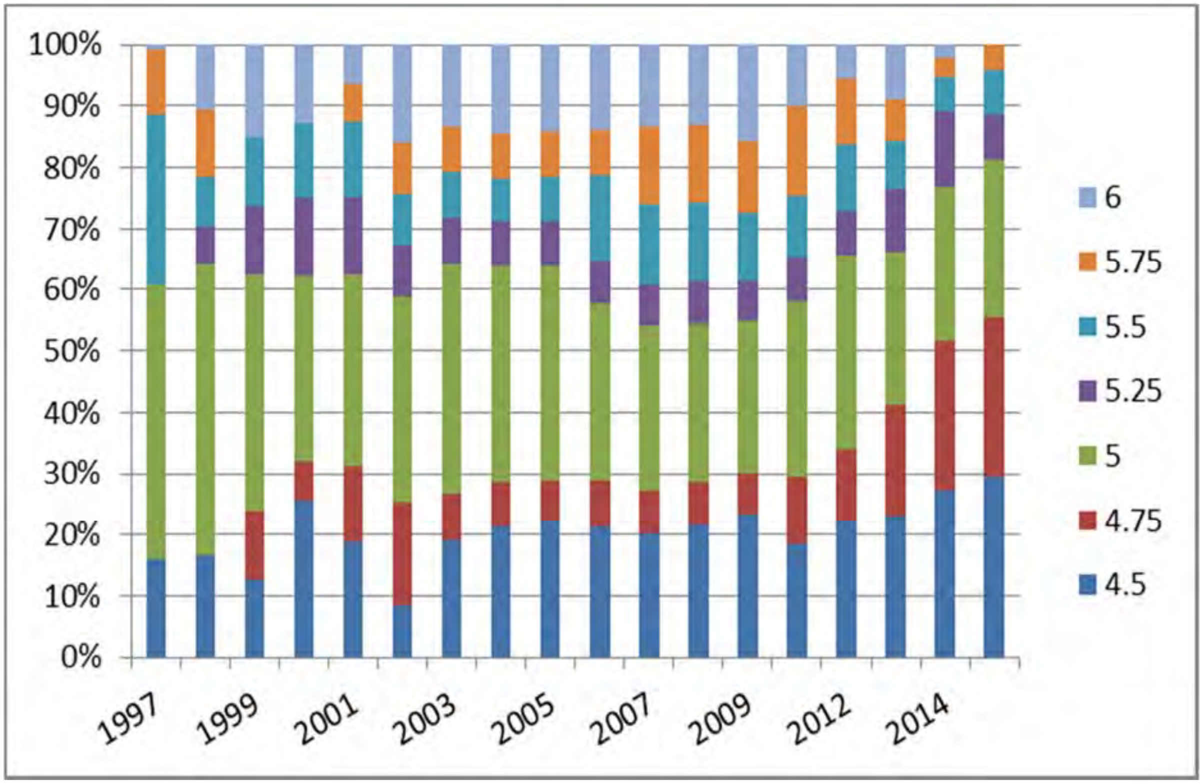


Figure 11. Percent frequency of gill net deployment of stretch mesh sizes (stretch inches) at Smithfield Beach.

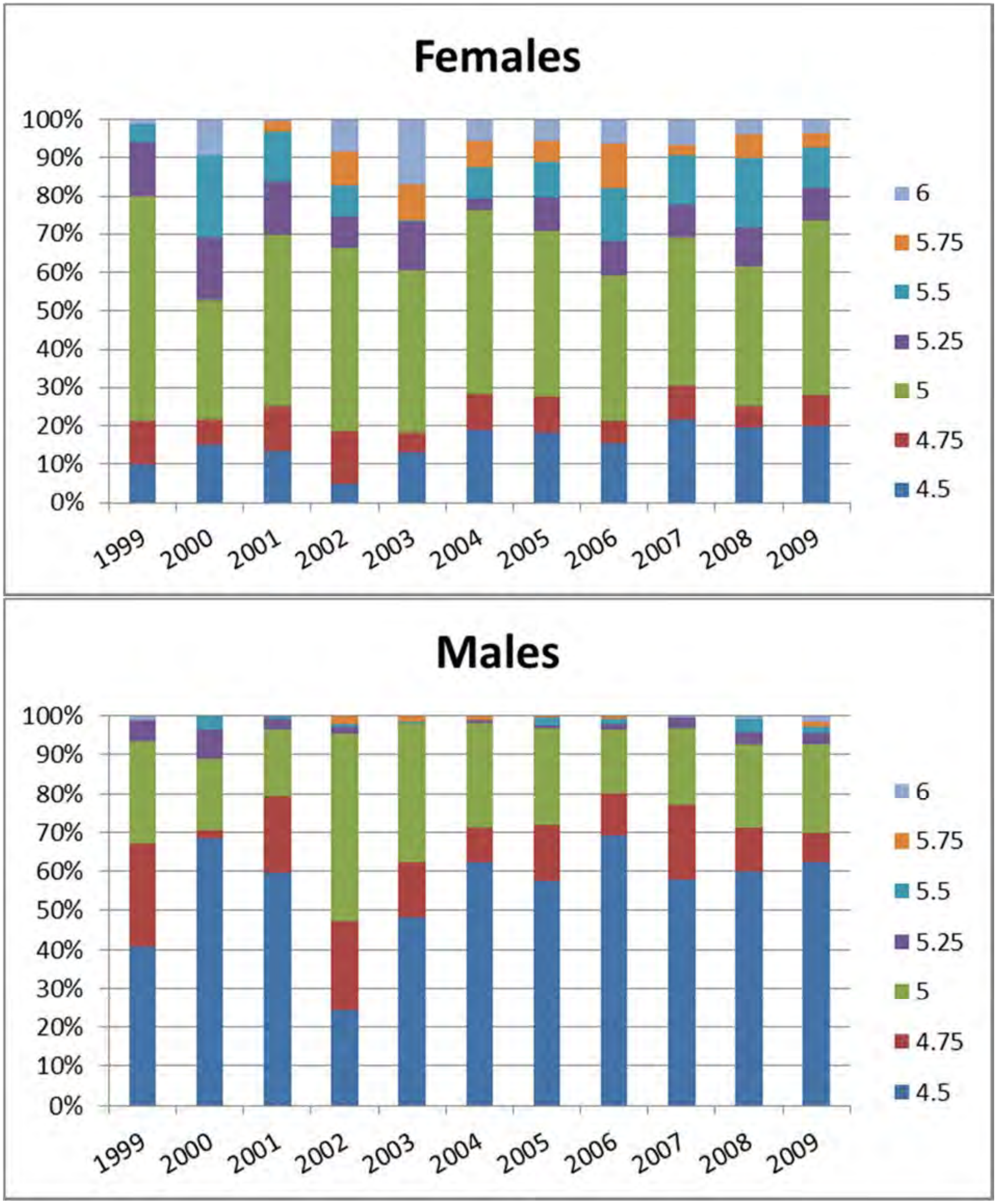


Figure 12. Percent of annual total catch of shad at Smithfield Beach for each mesh size (stretch inches) deployed, by year. Catch was only reported by mesh size 1999 through 2009.

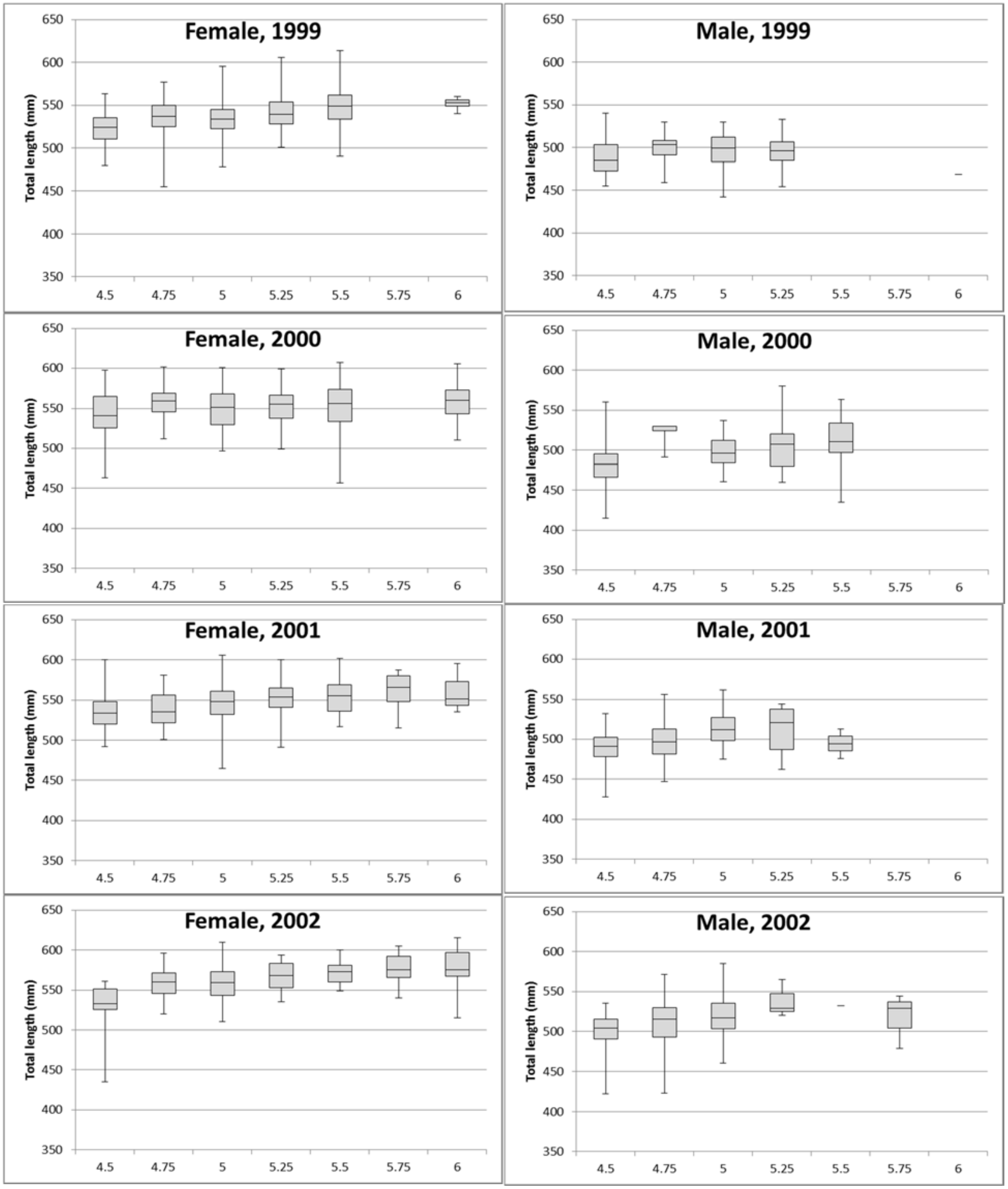


Figure 13. Total length distributions of shad caught at Smithfield Beach by mesh size (stretch inches). Whiskers represent minimum and maximum values; the box represents 25th and 75th percentiles, and the line median sizes.

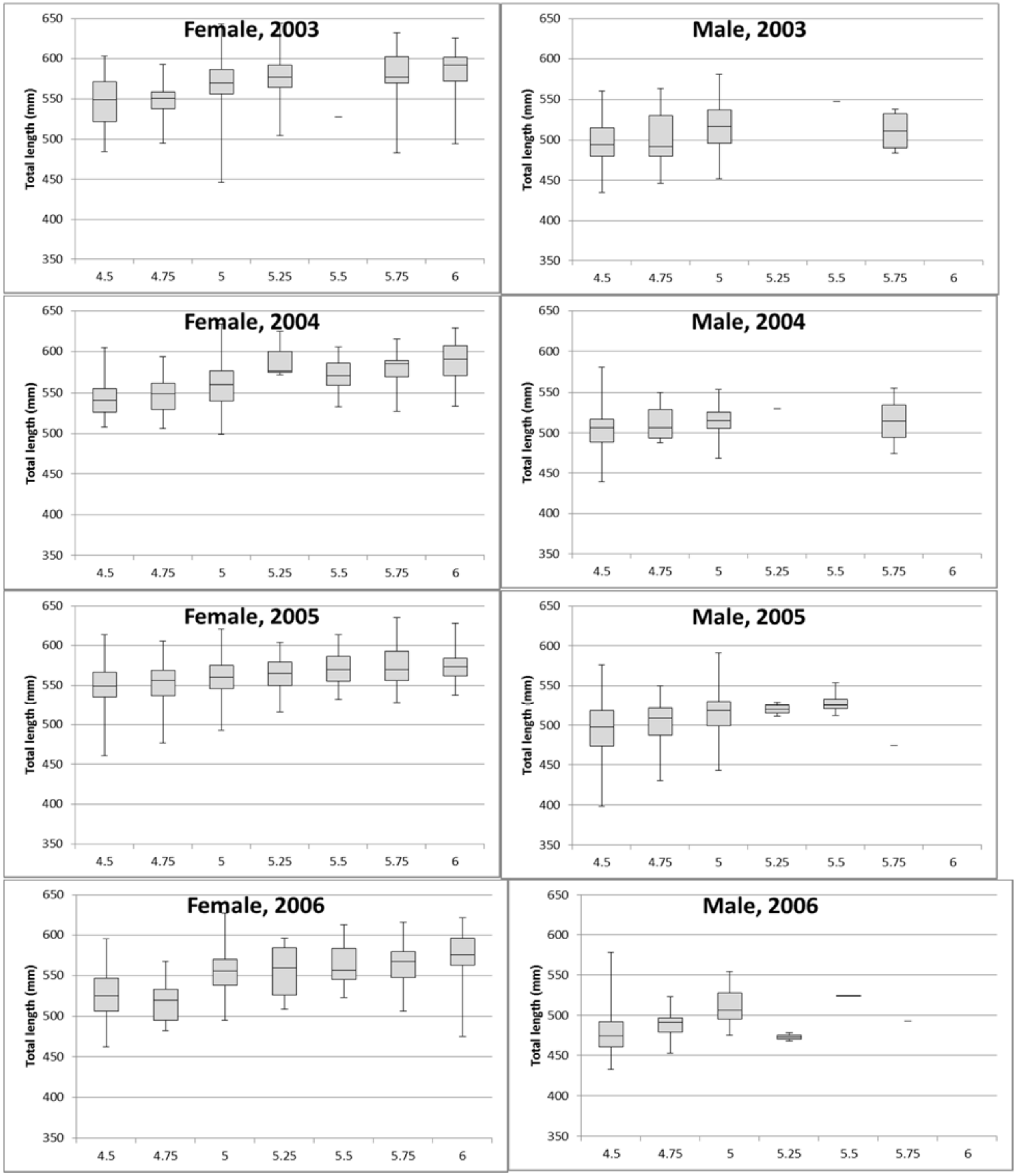


Figure 13. Continued.

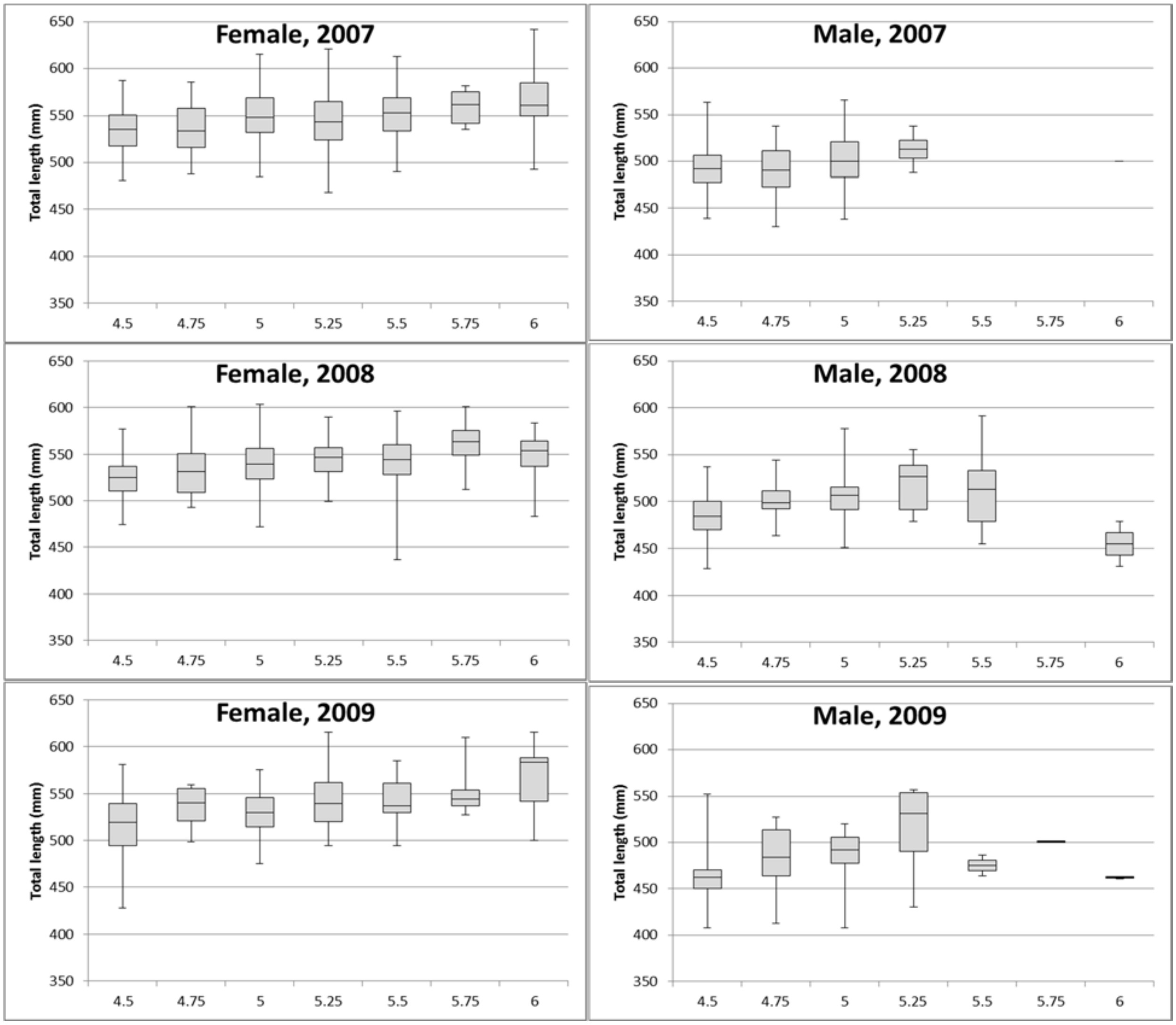


Figure 13. Continued.

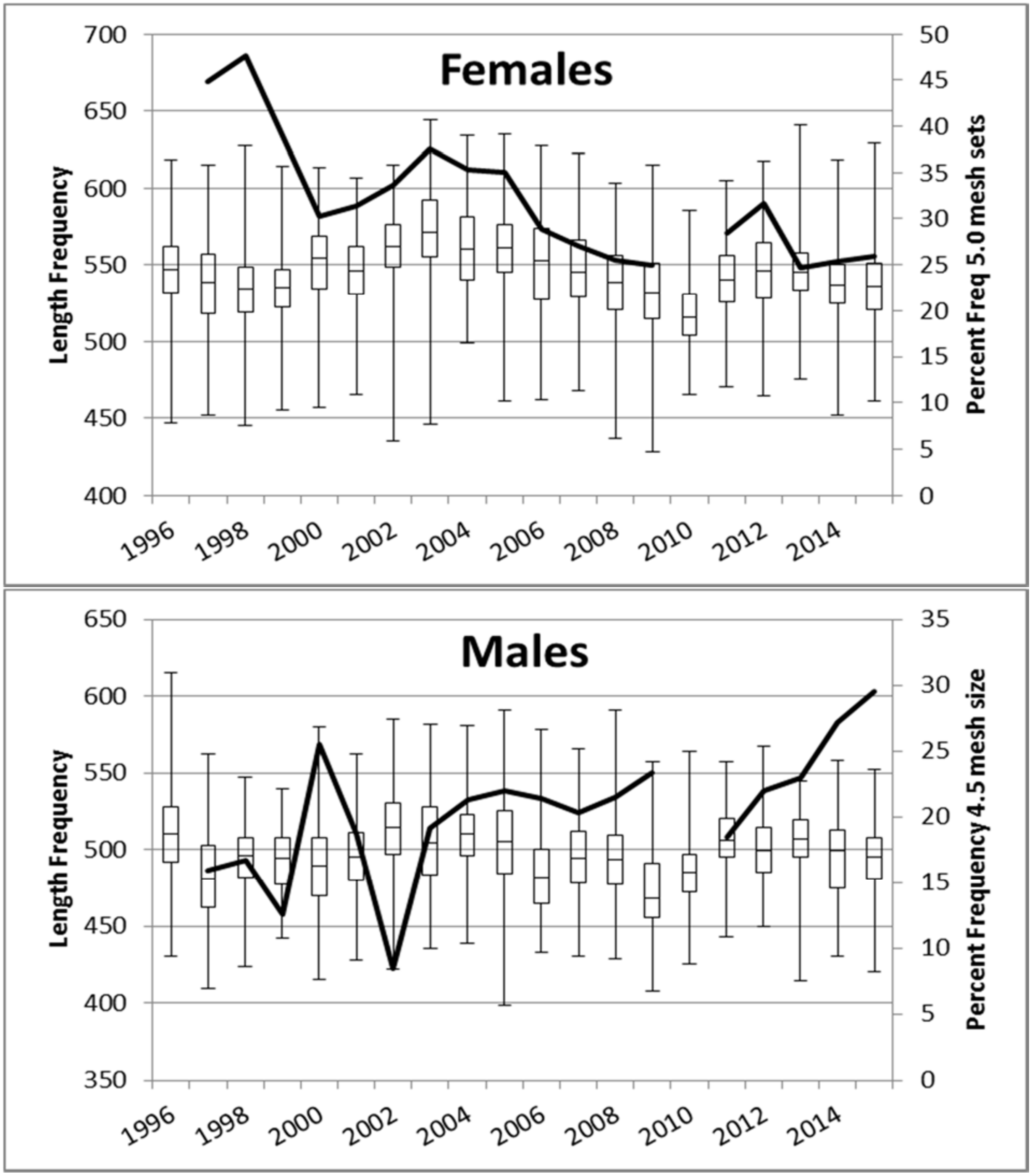


Figure 14. Total length distributions of female and male American Shad overlaid by the frequency of deployment of 5.0 inch (females only) and 4.5 inch (males only) mesh sizes, by year. Whiskers represent minimum and maximum values; the boxes representing 25th, 50th and 75th percentiles.

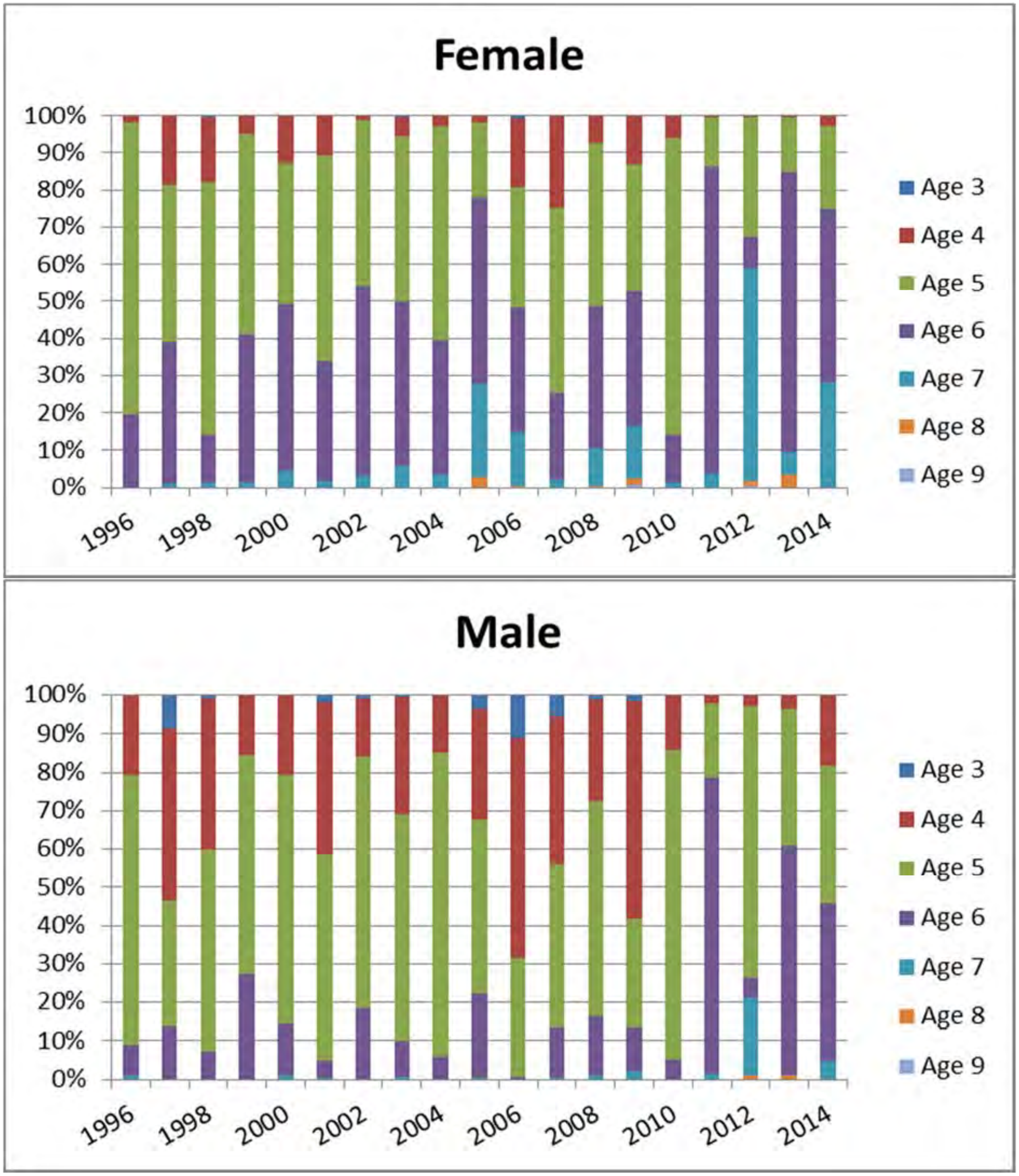


Figure 15. Distribution of age for female and male American Shad captured at Smithfield Beach. No biological information was collected prior to 1996. Assigned ages do not represent the combined agreement of Co-op members as per the Co-op's Ageing Protocol (Appendix A).

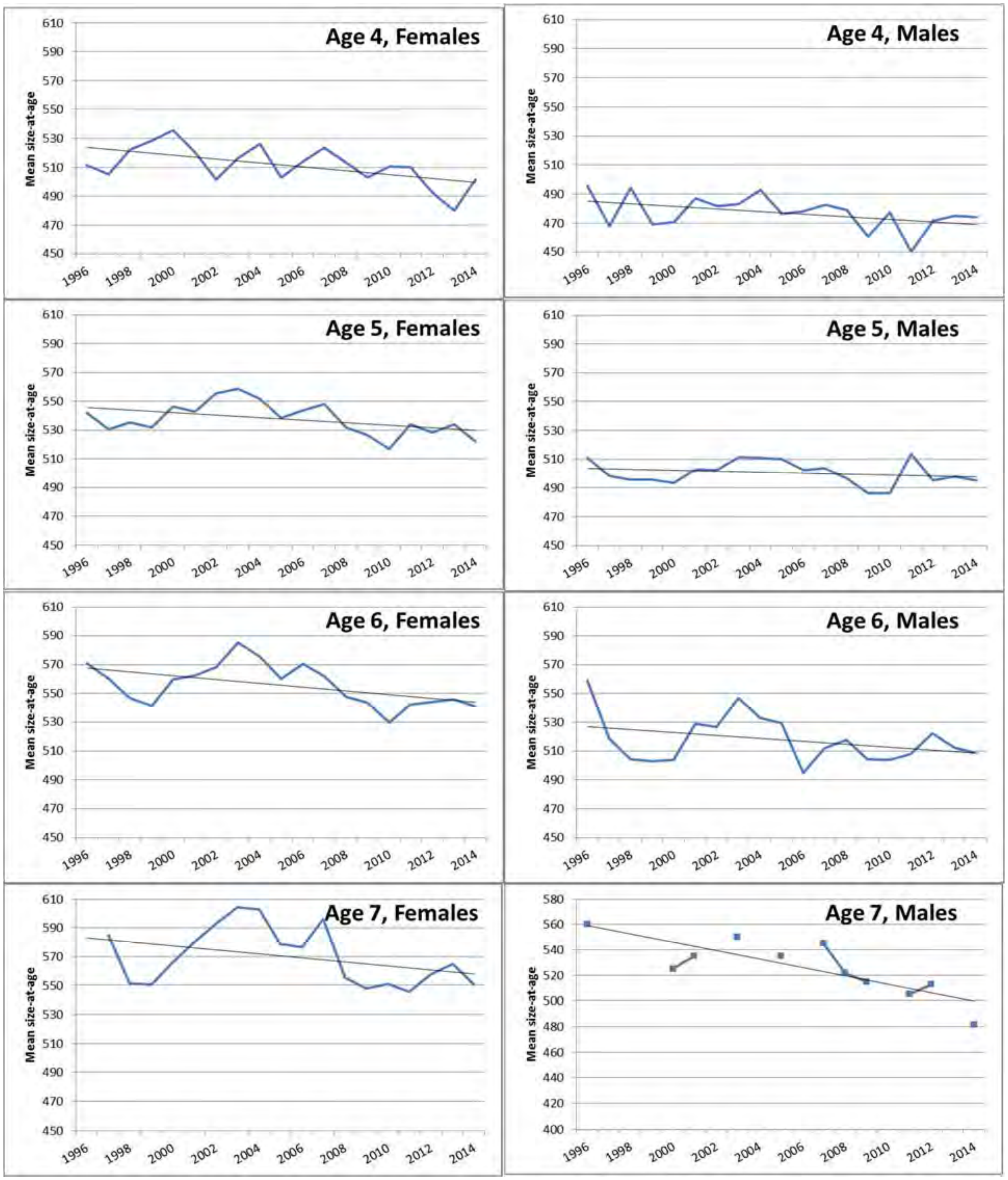


Figure 16. Mean size-at-age (mm TL) for female and male American Shad collected from Smithfield Beach, by age class.

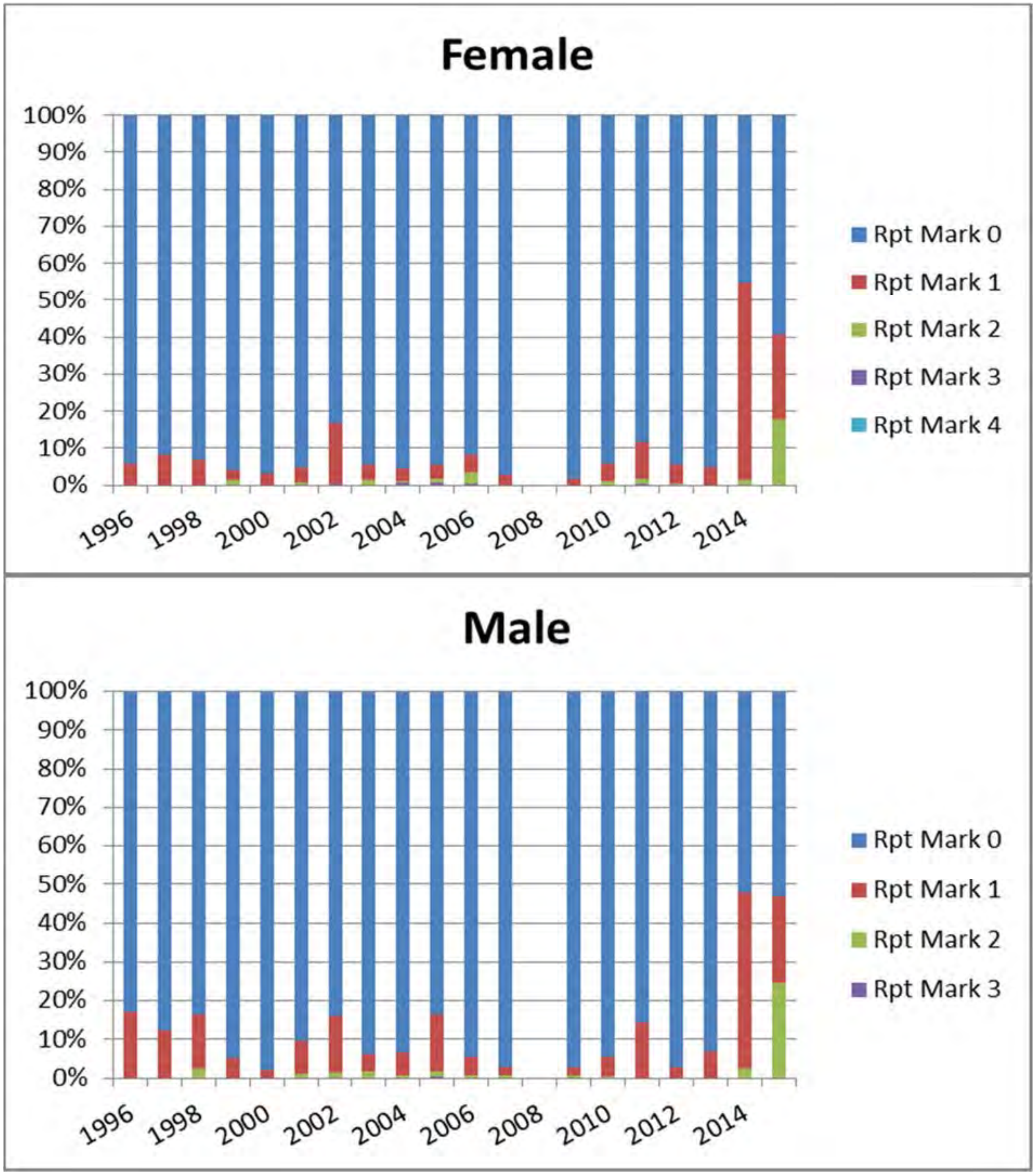


Figure 17. Percent frequency of repeat spawning marks as identified from scale microstructure from shad collected at Smithfield Beach. Scales collected during 2008 have not been processed.

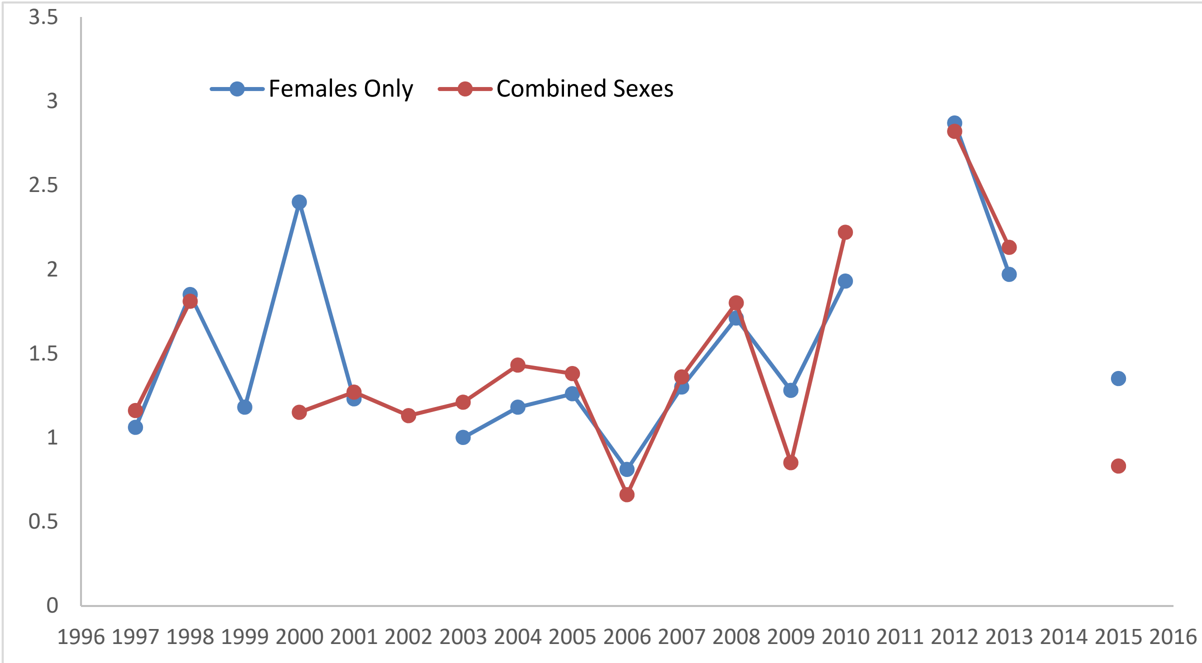


Figure 18. Chapman-Robson bias-corrected total instantaneous mortality (Z) estimates derived from American Shad collected at Smithfield Beach.

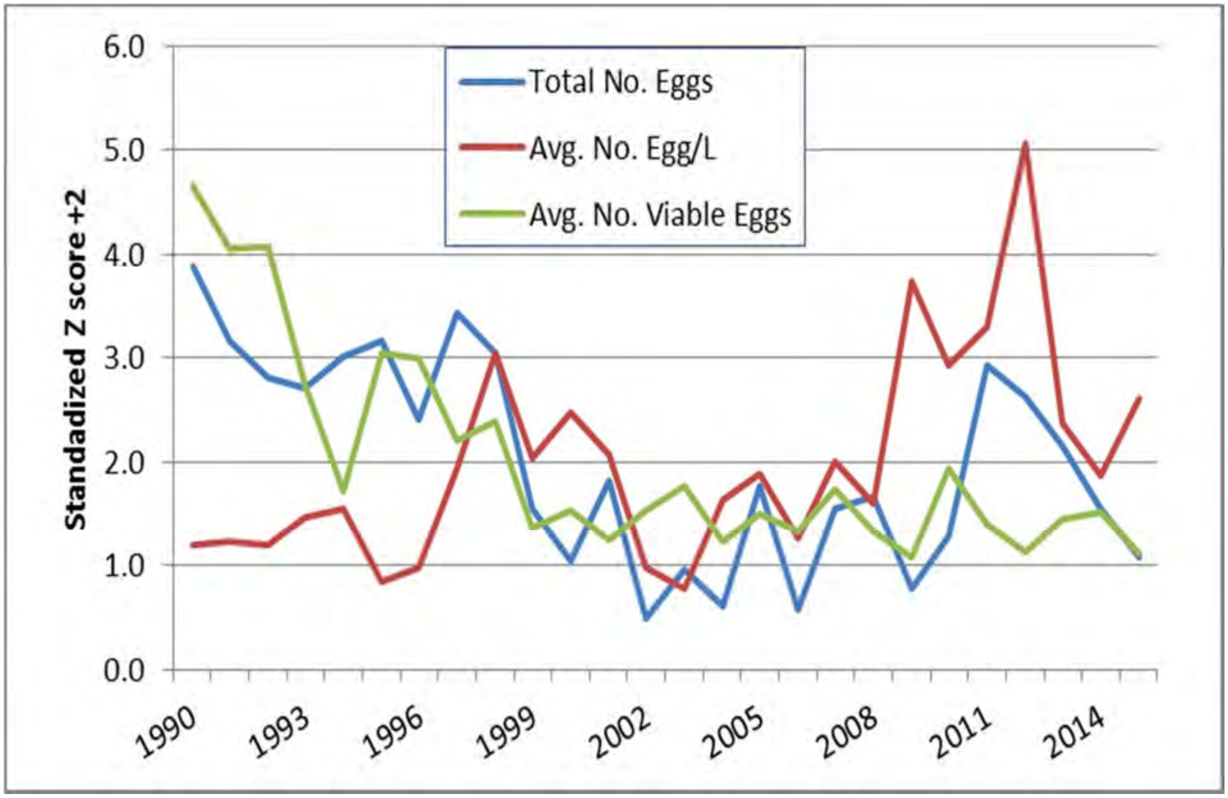


Figure 19. Annual egg harvest characteristics at Smithfield Beach.

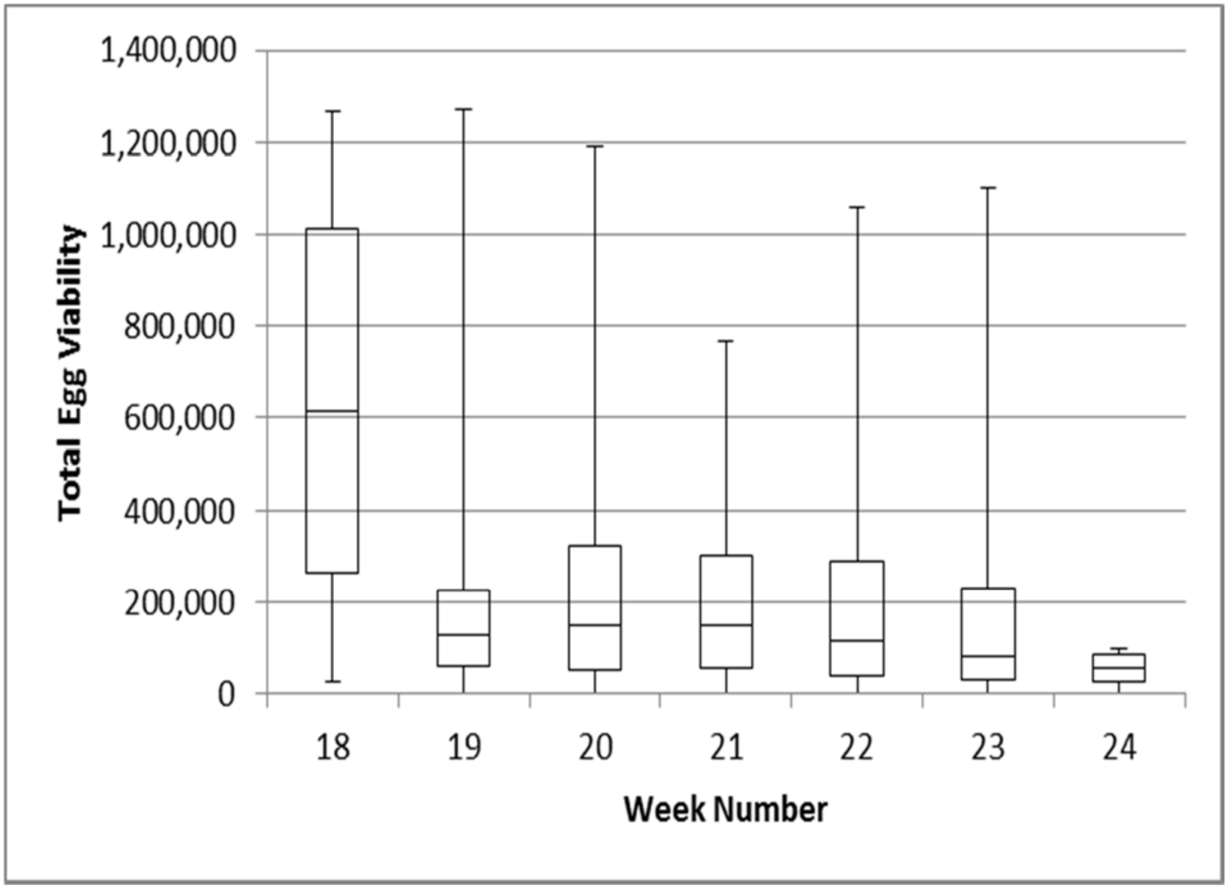


Figure 20. Quartile and median distribution for total egg viability by sampling week, harvested from Smithfield Beach. Whiskers represent minimum and maximum values; the box represents 25th and 75th percentiles; and horizontile line within the box as the median.

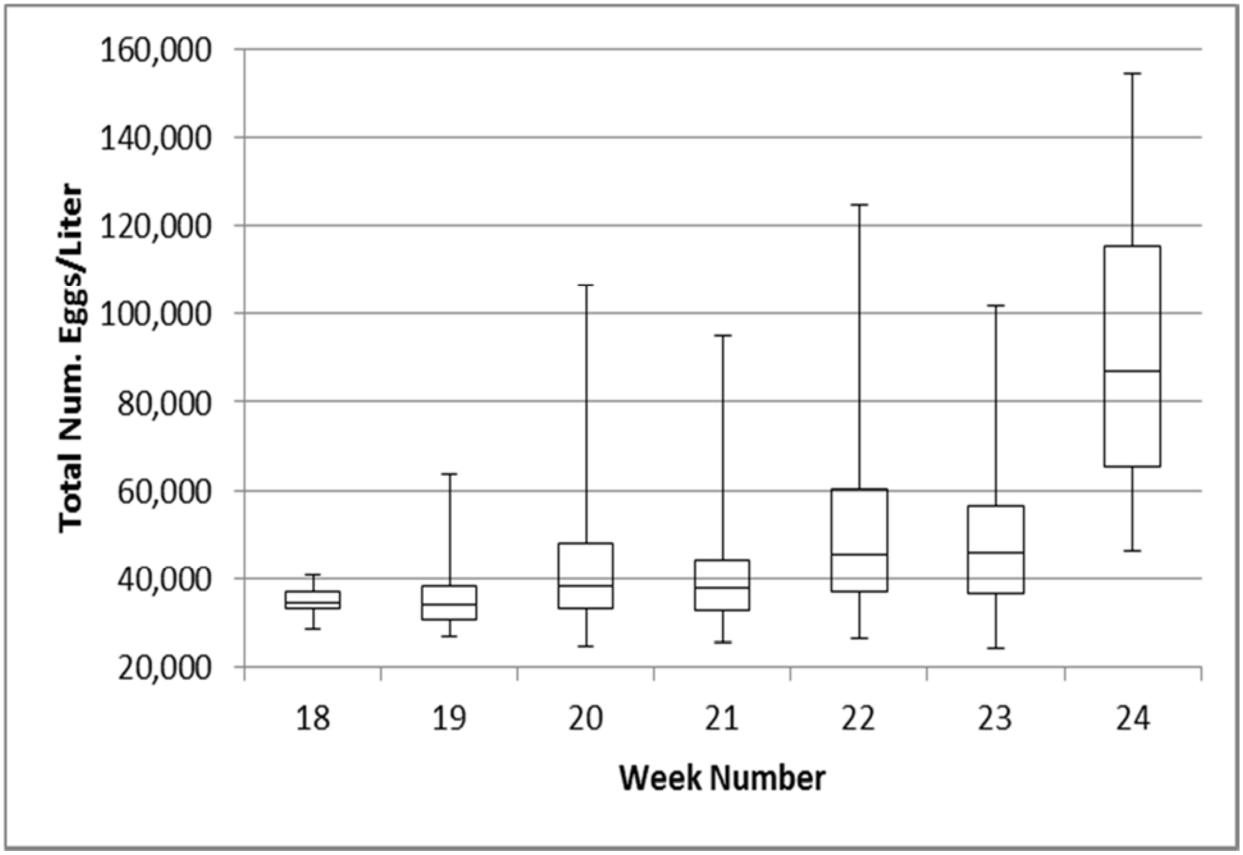


Figure 21. Quartile and median distribution for total number of eggs per liter by sampling week, harvested from Smithfield Beach. Whiskers represent minimum and maximum values; the box represents 25th and 75th percentiles; and horizontile line within the box as the median.

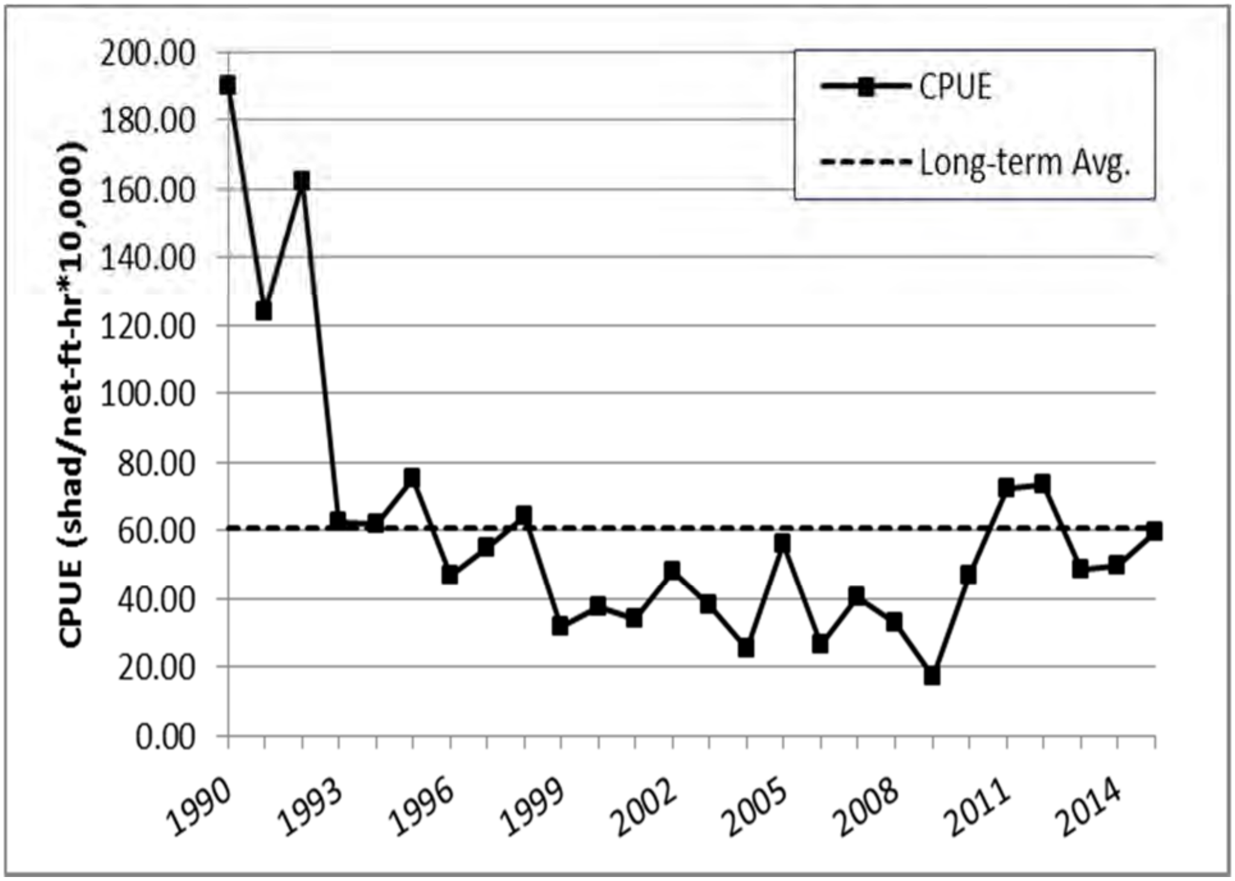


Figure 22. CPUE for American Shad collected from the Delaware River at Smithfield Beach (RM 218) by gill net (shad/net-ft-hr * 10,000).

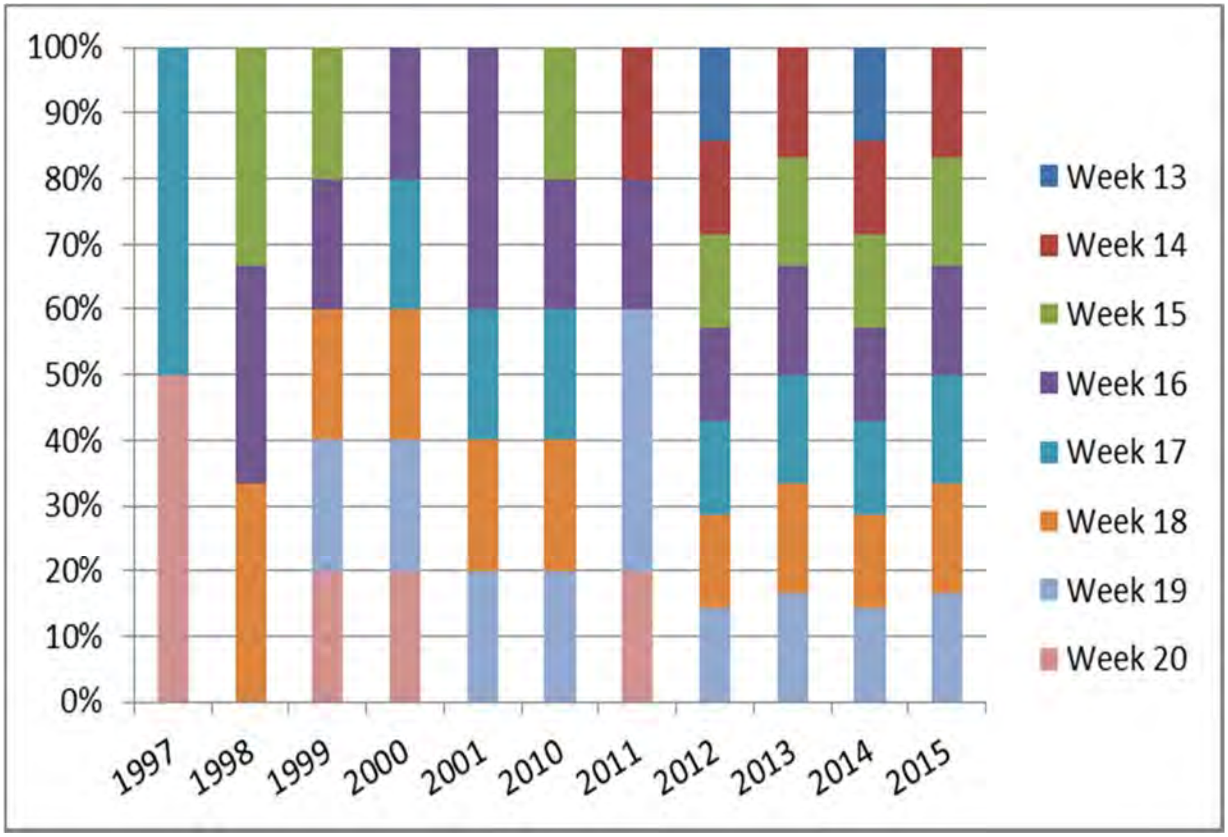


Figure 23. Electrofishing sampling frequency at Raubsville (RM 176) for American Shad as they migrate upriver. Week number is defined as the occurrence of January 1st as week one.

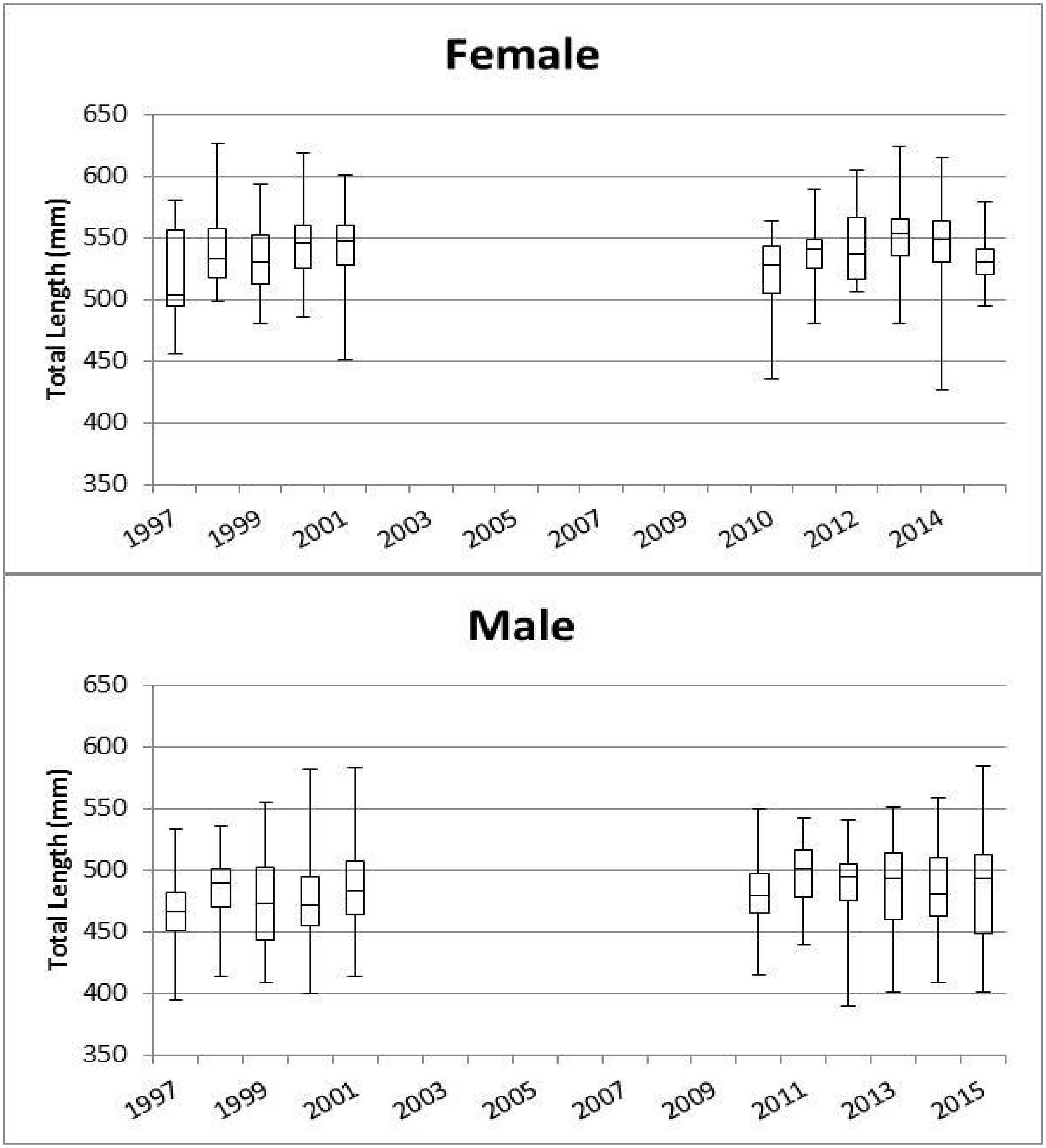


Figure 24. Length frequencies of shad collected at Raubsville (1997-2001; 2010-2015). The boxes represent the lower box 25th, 50th and 75th percentiles. Whiskers are the minimum and maximum lengths.

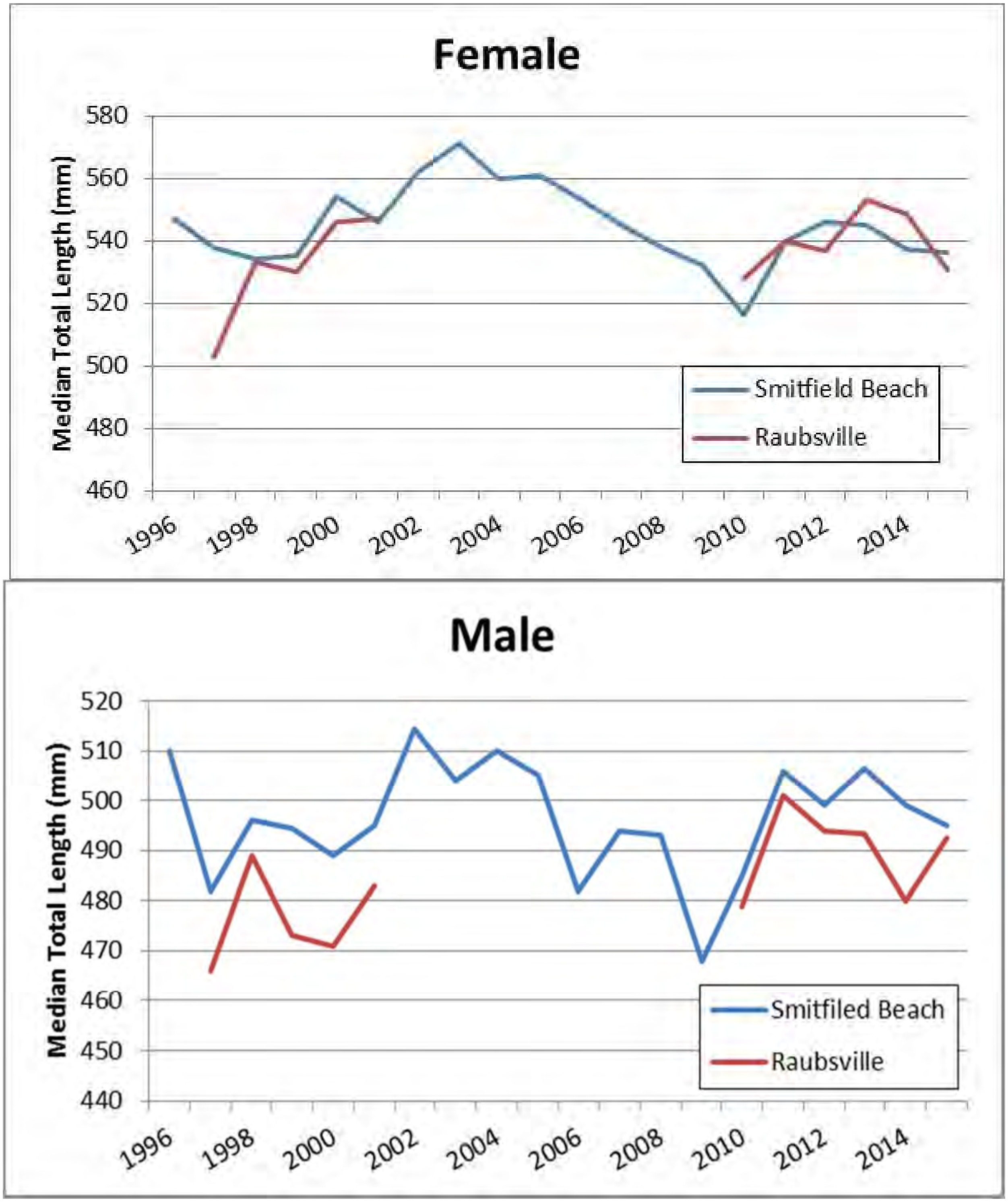


Figure 25. Median sizes (mm TL) of American Shad collected from Smithfield Beach (all mesh sizes combined) and Raubsville.

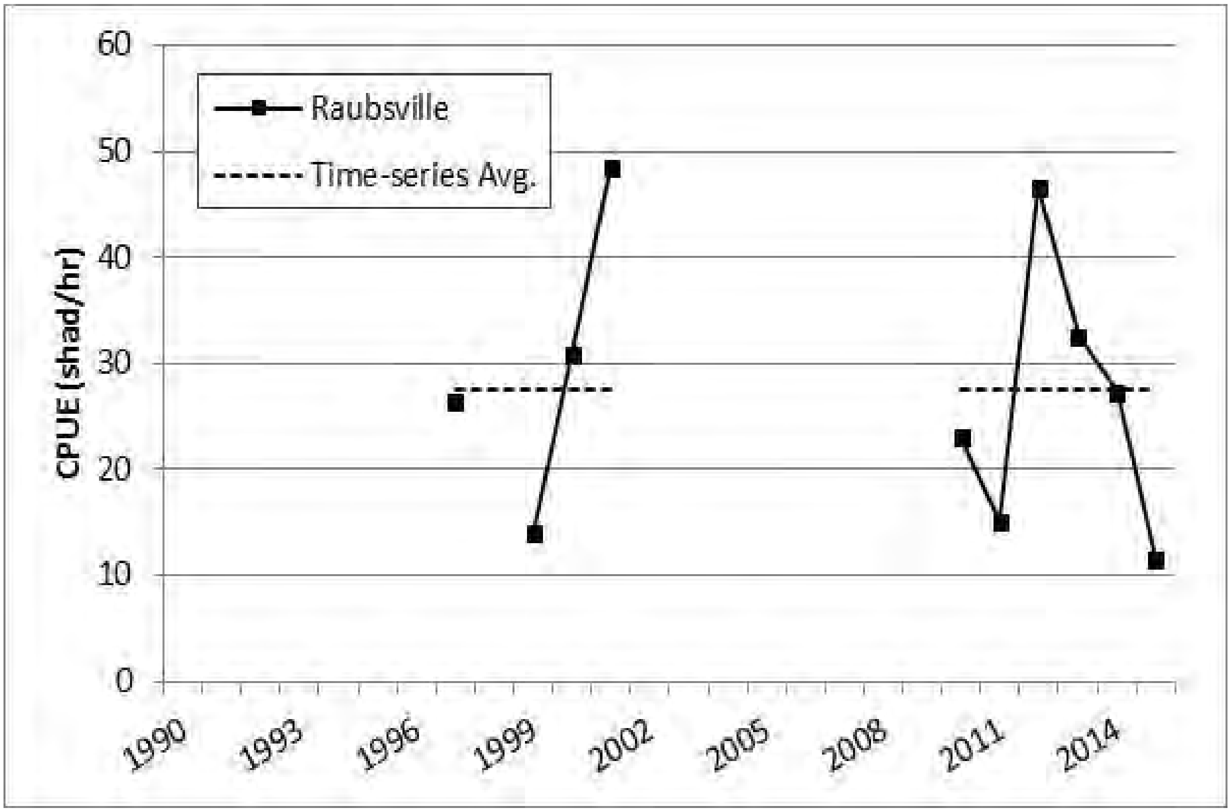


Figure 26. Raubsville electrofishing CPUE of American Shad.

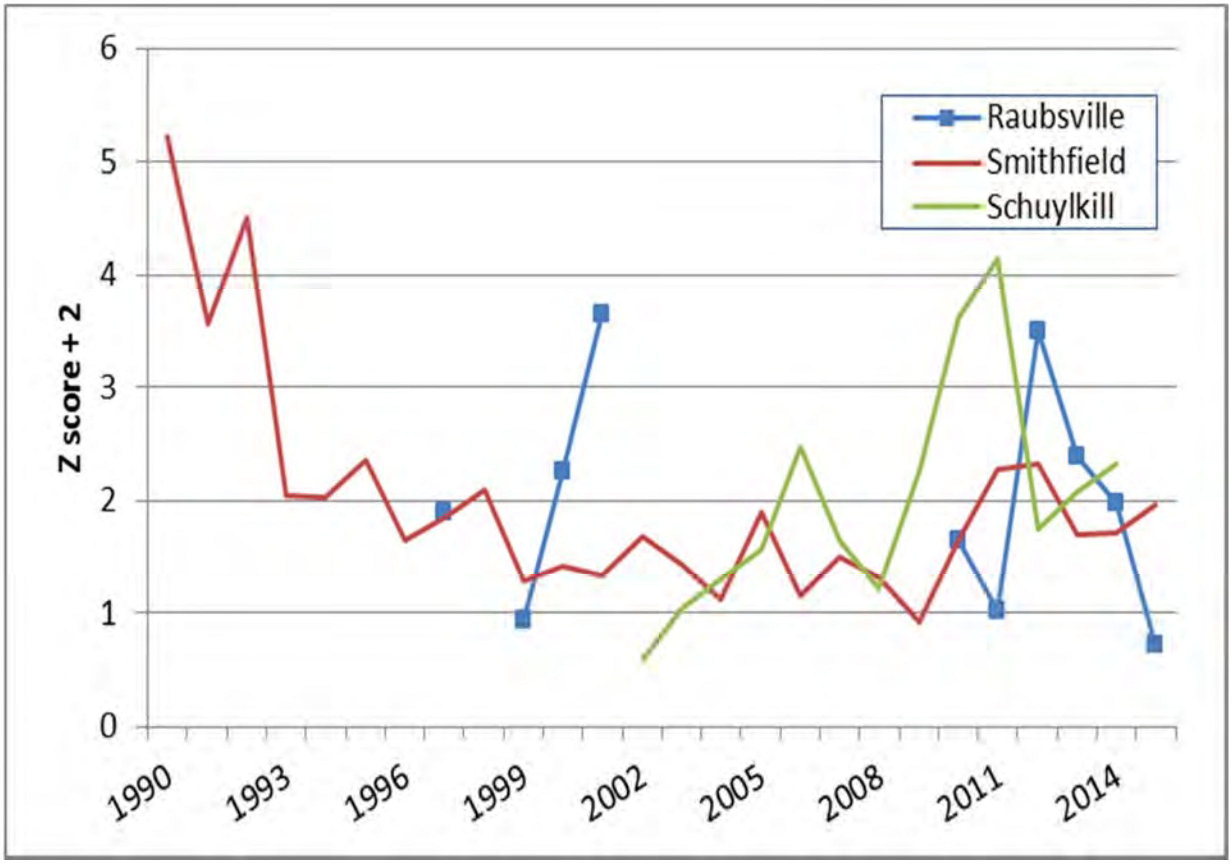


Figure 27. Comparison of CPUEs from monitoring programs at Smithfield Beach (i.e., gill netting) and Raubsville (i.e., electrofishing) on the main stem Delaware River; and CPUE from the tidal main stem of the Schuylkill River (i.e., electrofishing). Indices are represented as standardized Z scores plus two.

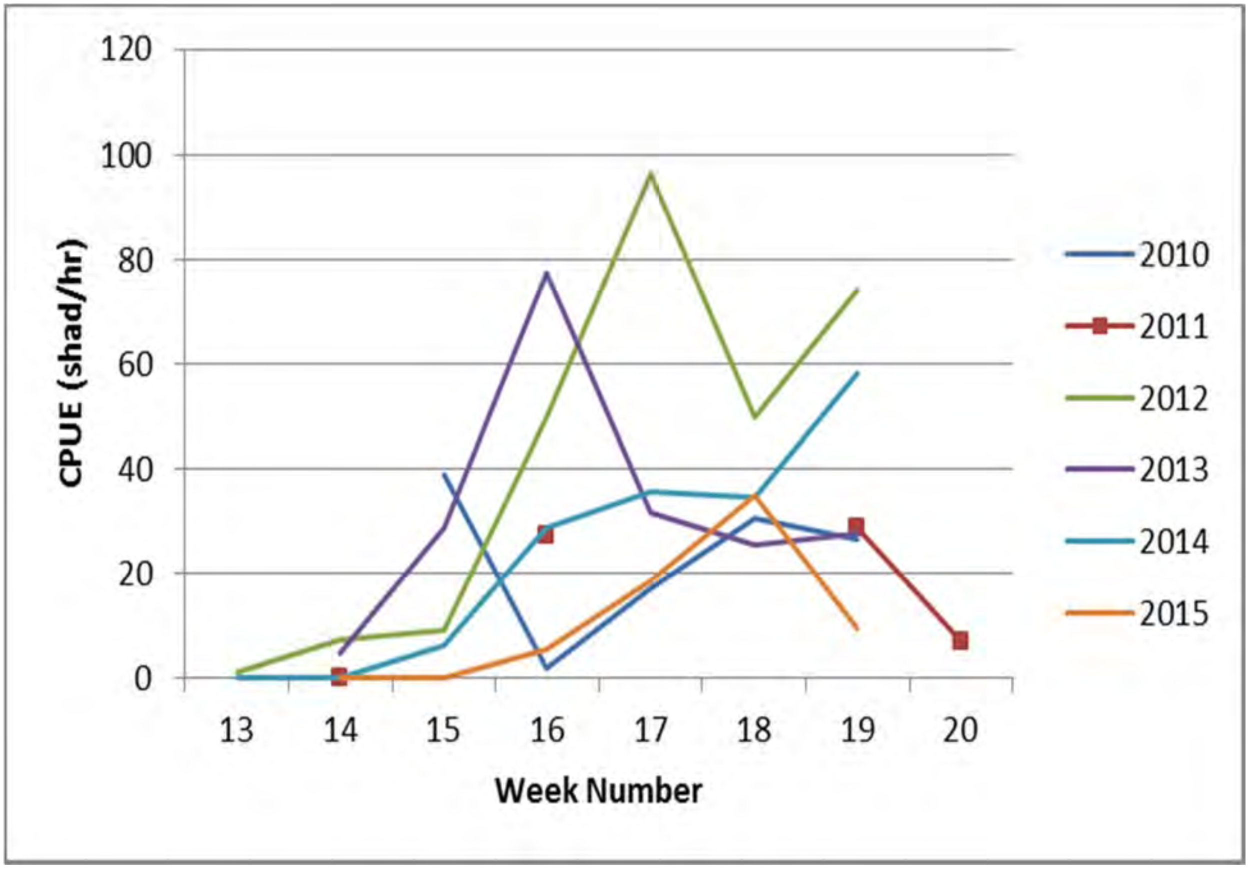


Figure 28. Weekly electrofishing CPUE estimates from the Raubsville monitoring. Week number is defined as the occurrence of January 1st as week one.

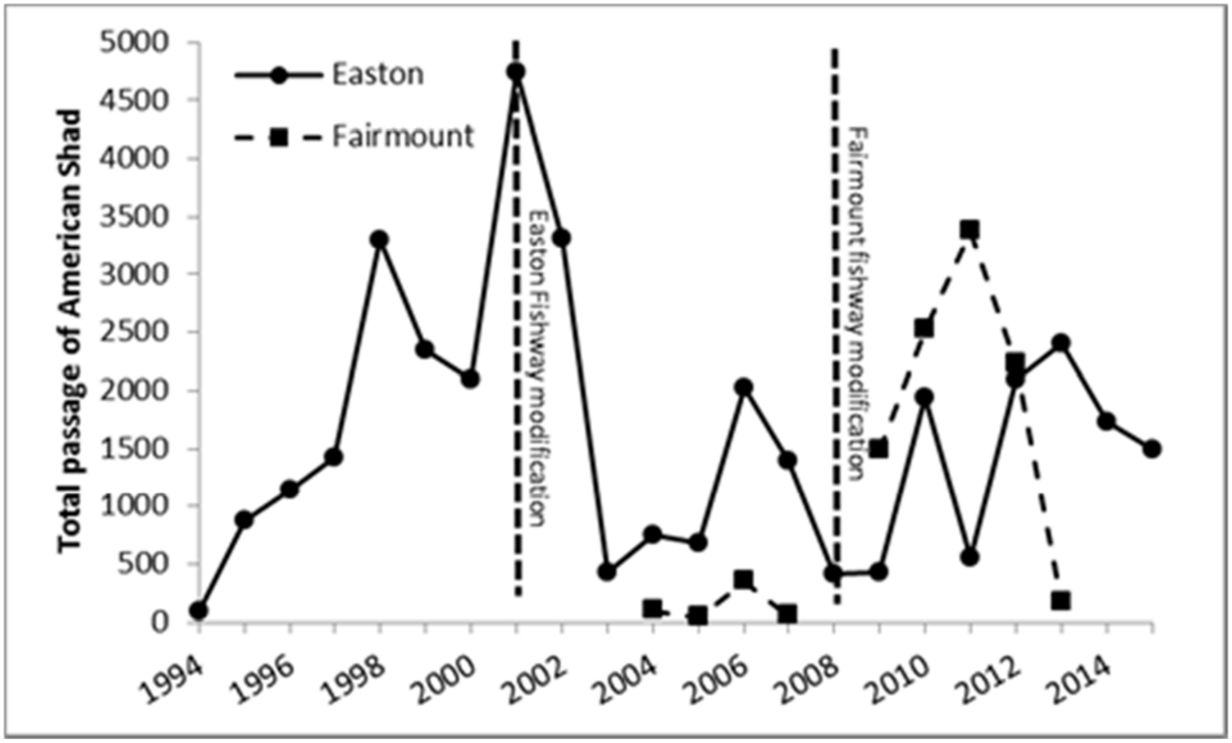


Figure 29. Upstream fish passage trends for the Lehigh (Easton Dam) and Schuylkill (Fairmount Dam) rivers. A predictive regression based on electrofishing CPUE was substituted for video surveillance beginning in 2013 for estimating total passage into the Lehigh River.

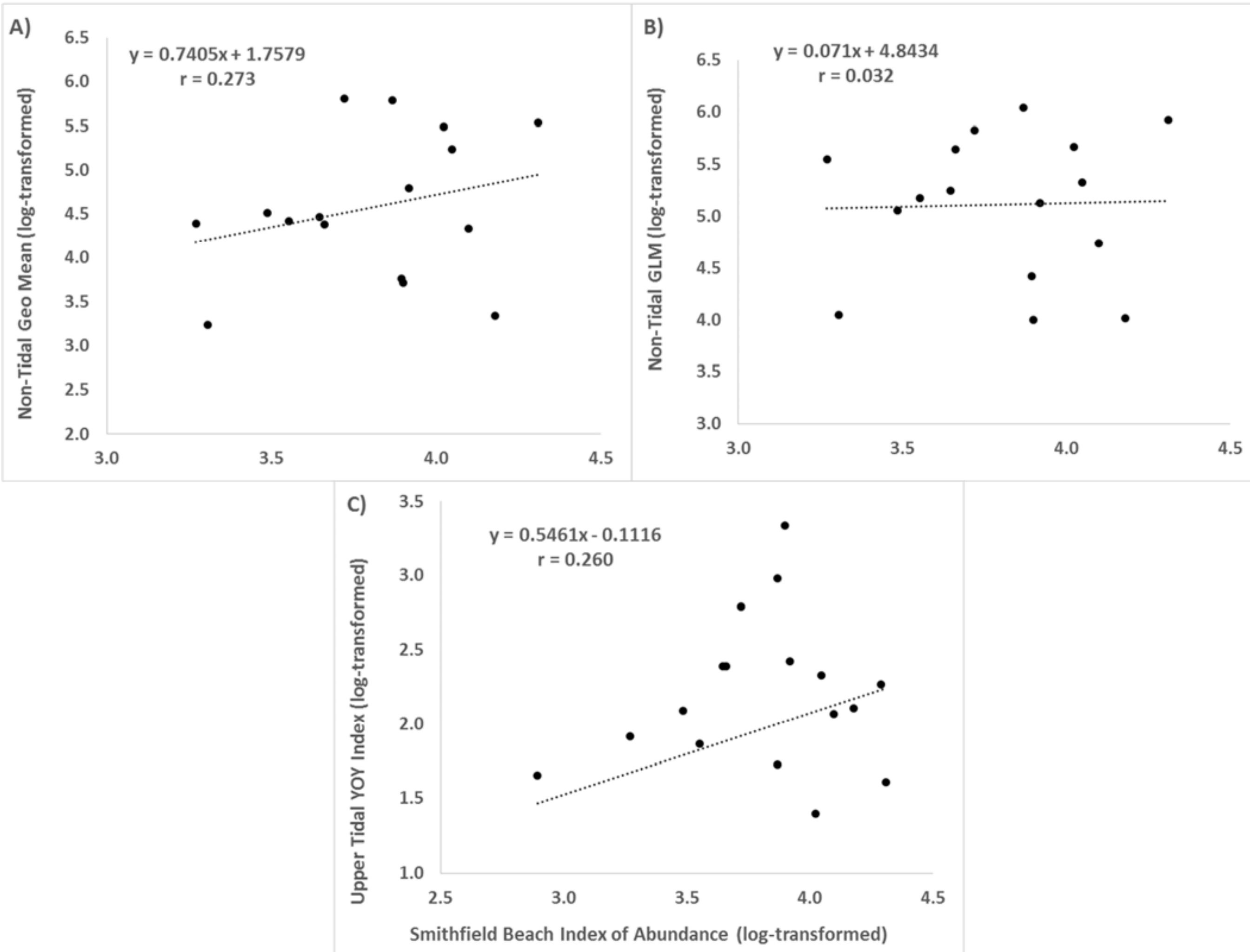


Figure 30. Correlations between the JAI indices (A – Non-tidal geometric mean; B – Non-tidal GLM; C – Tidal geometric mean) vs the Smithfield Beach Adult Index. All values are log-transformed.

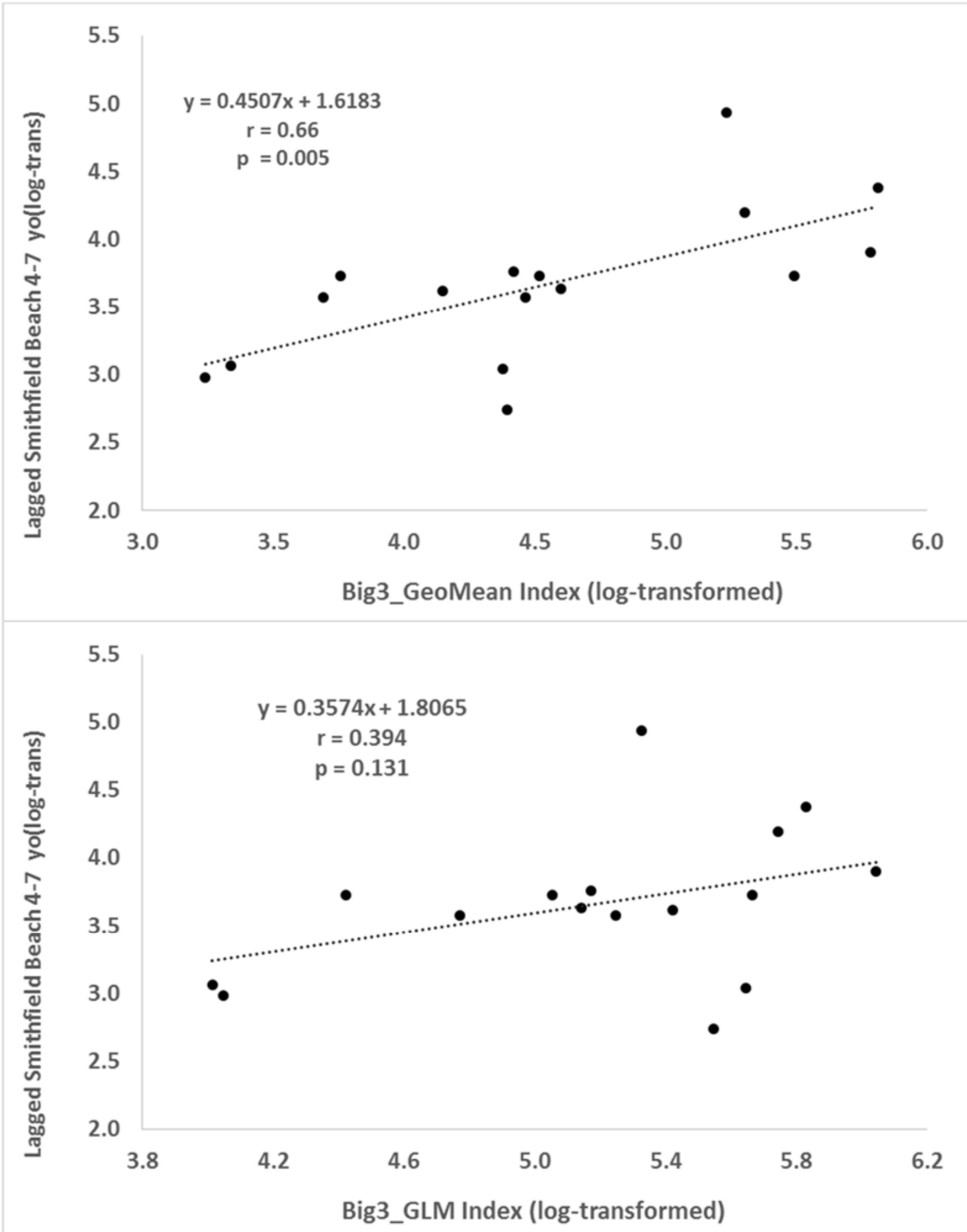


Figure 31. Correlations between the two non-tidal JAI indices vs the lagged Age 4-7 Index calculated from the Smithfield Beach Index. All values are log-transformed.

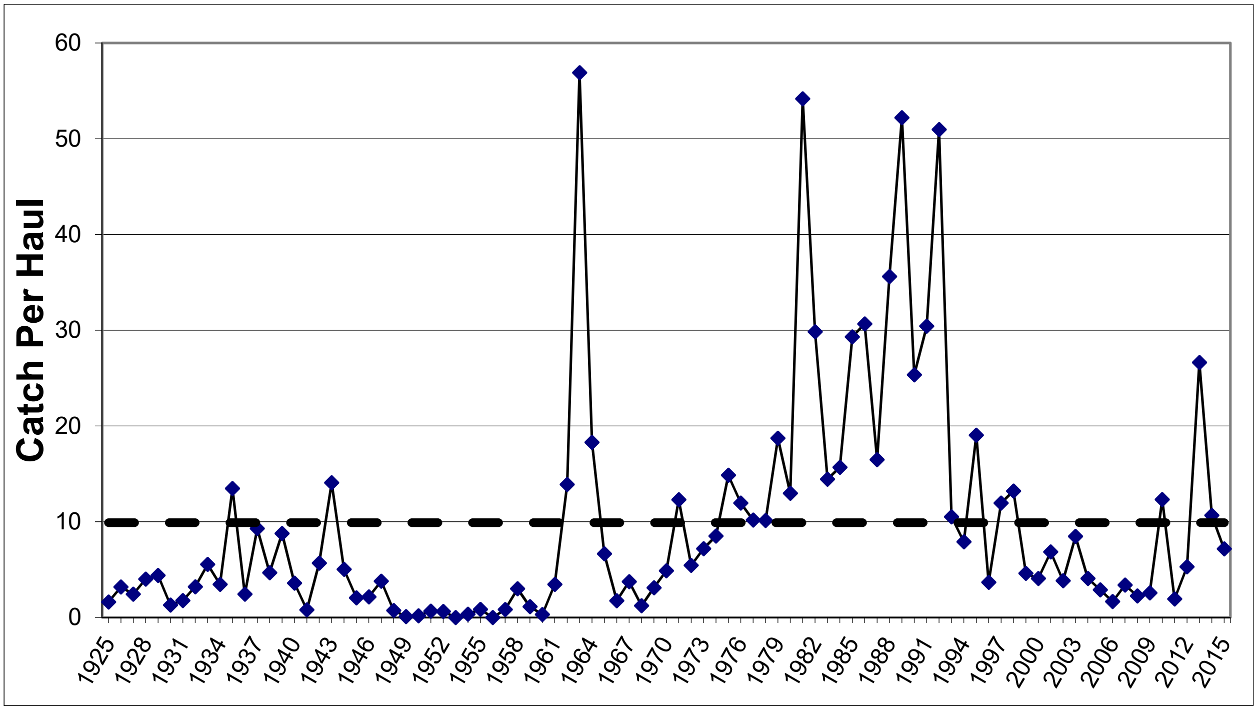


Figure 32. Lewis haul seine CPUE (shad/haul), 1925-2015. Dashed line represents the time series average.

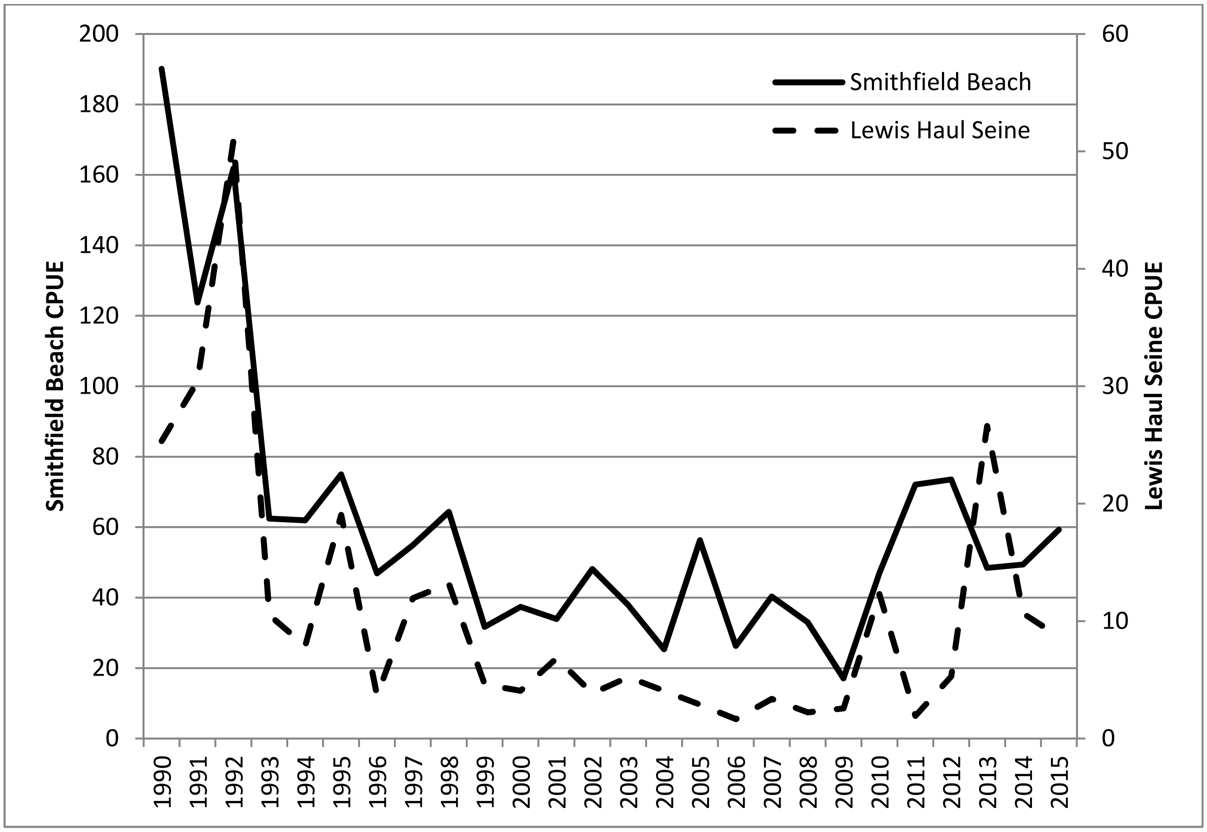


Figure 33. Trends in relative abundance as estimated from Smithfield Beach (shad/net-ft-hr*10,000) and Lewis haul seine (shad/haul), 1990-2015.

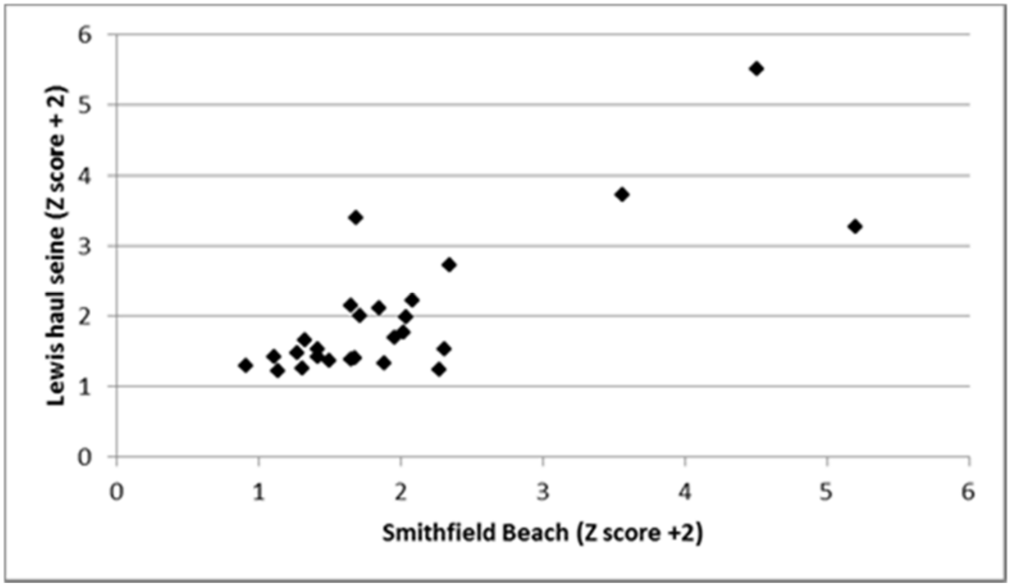


Figure 34. Correlation between Smithfield Beach and Lewis haul seine, 1990-2015.

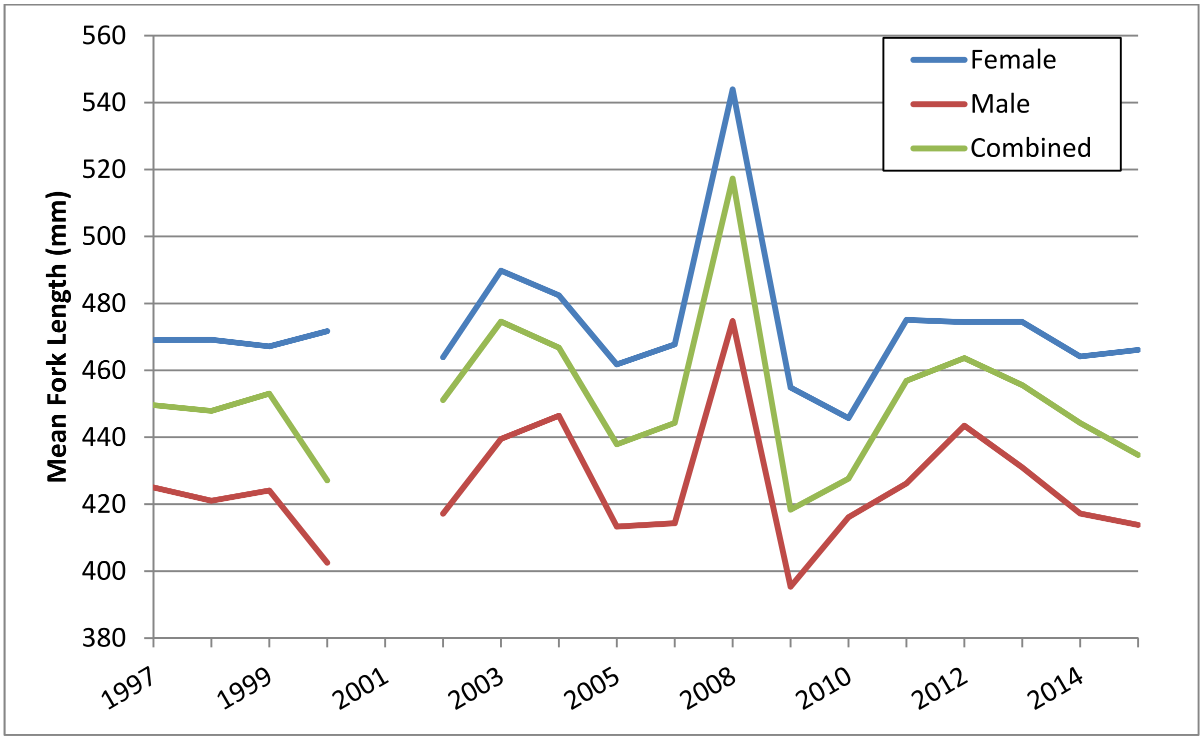


Figure 35. Mean fork lengths of male and female American Shad collected in the Lewis haul seine from 1997-2015.

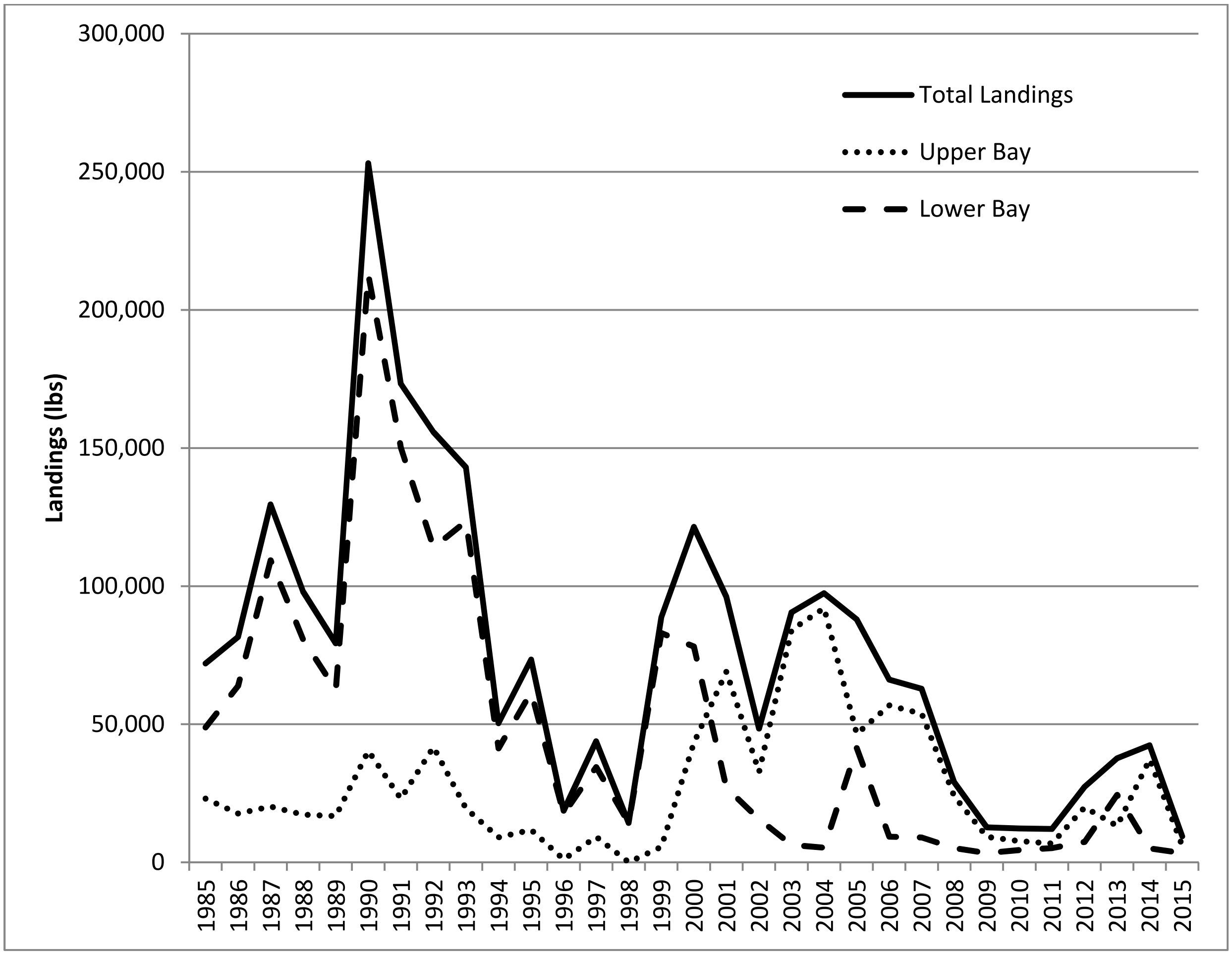


Figure 36. American Shad landings in the State of New Jersey separated into Upper Bay/River (north of Gandys Beach) and Lower Bay (south of Gandys Beach), reporting regions.

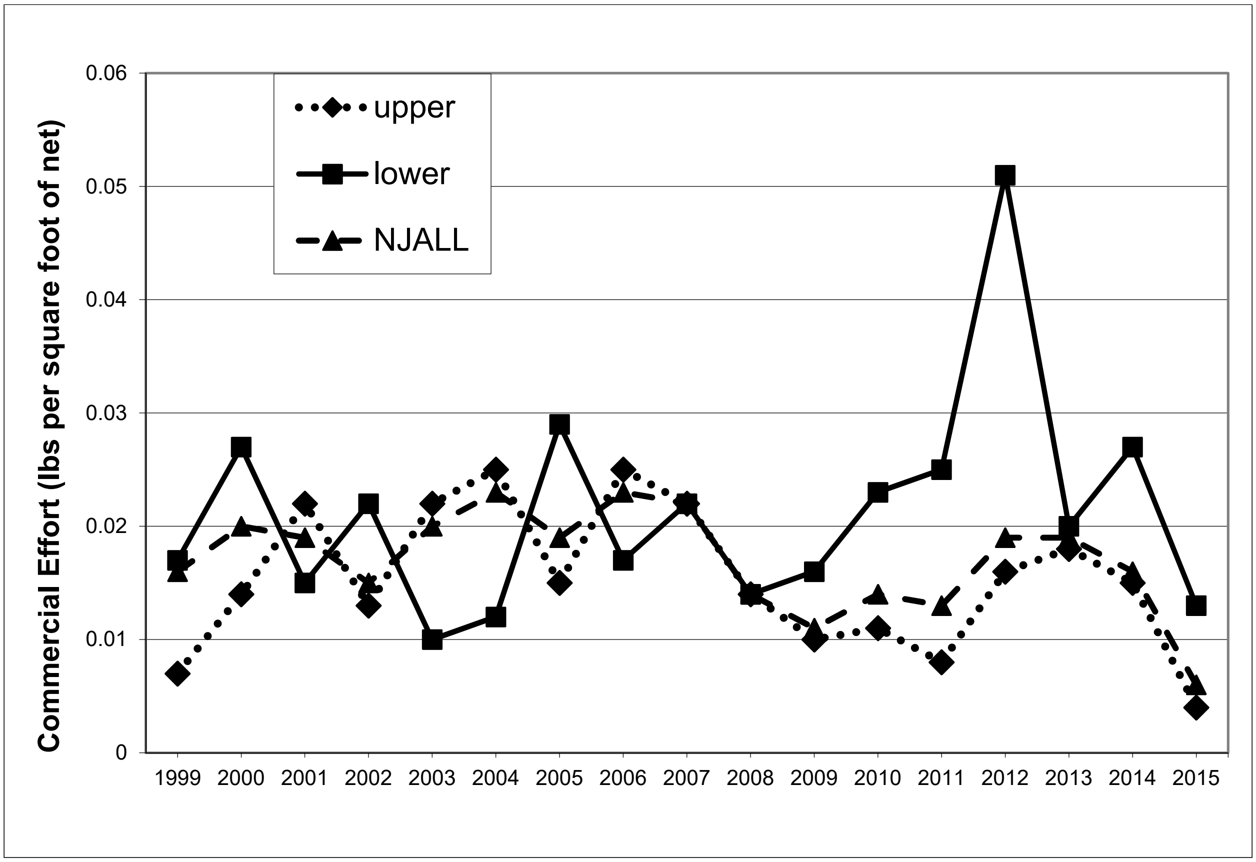


Figure 37. New Jersey commercial American Shad CPUE from 2000-2015. Effort is separated into Upper Bay/River (north of Gandys Beach) and Lower Bay (south of Gandys Beach), reporting regions.

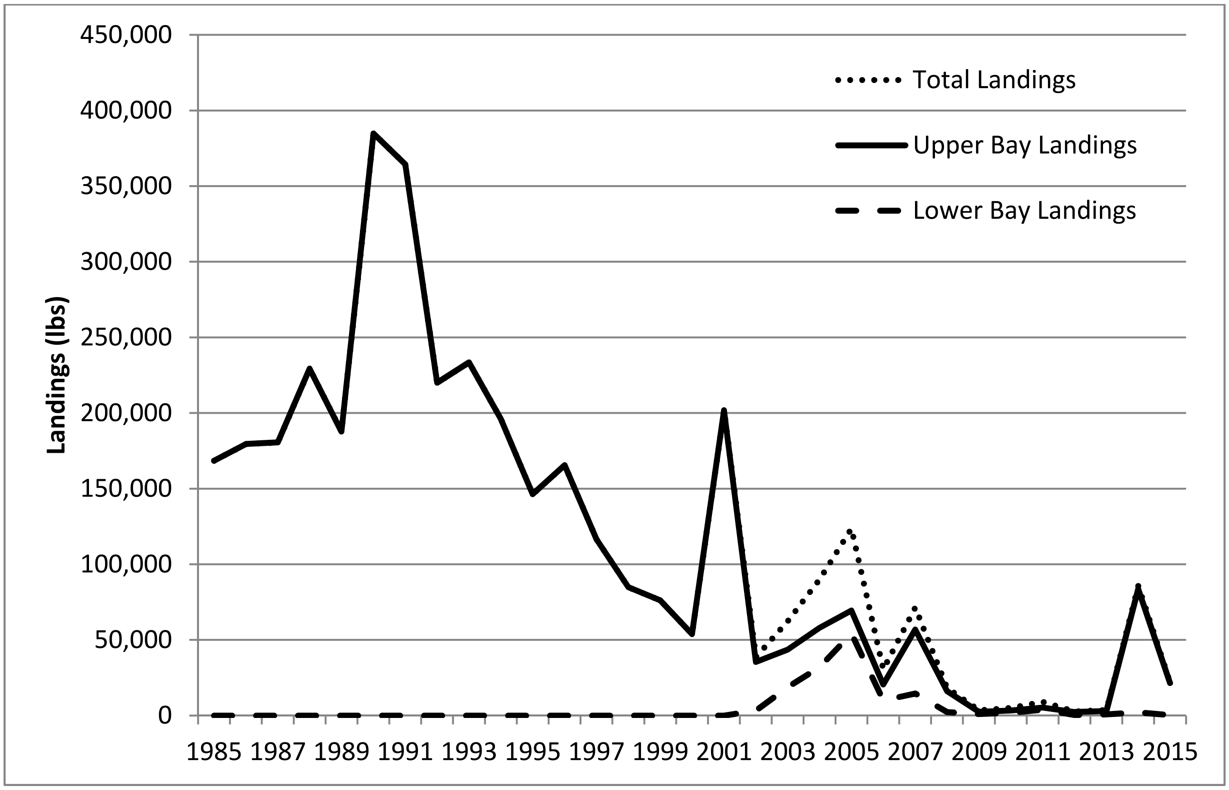


Figure 38. American Shad landings in the State of Delaware separated into upper bay (north of Bowers Beach) and lower bay (south of Bowers Beach), reporting regions.

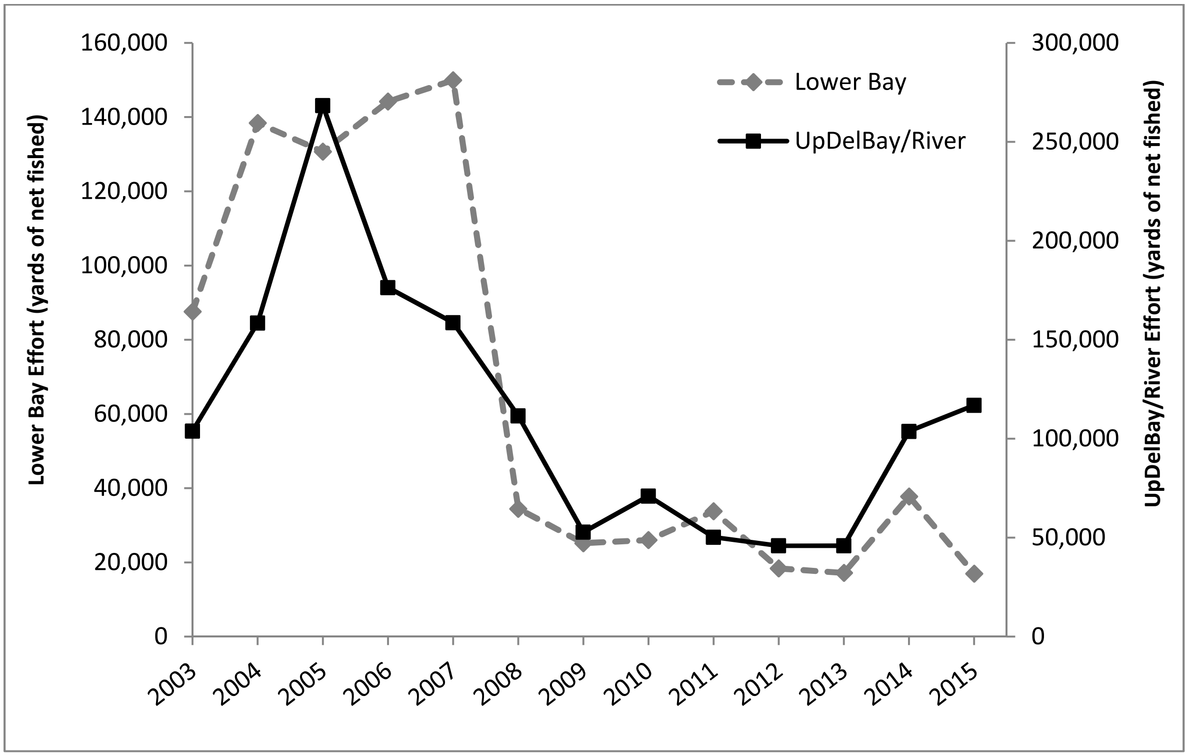


Figure 39. State of Delaware commercial fishery effort in yards of net fished for the Delaware River and Bay (1990-2015). Effort was separated into upper bay (north of Bowers Beach) and lower bay (south of Bowers Beach), reporting regions.

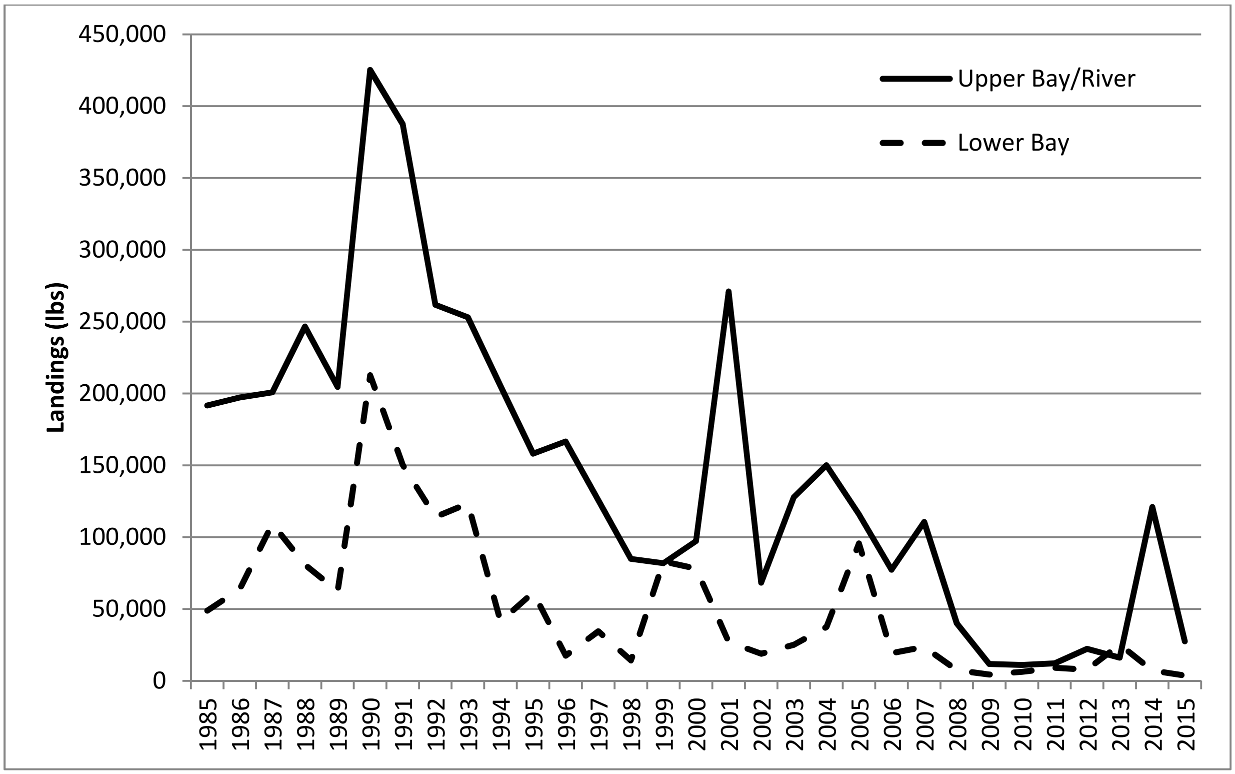


Figure 40. Combined landings for American Shad commercial harvest for the states of Delaware and New Jersey: 1985-2015. The Upper Bay / River is defined by those landings occurring above the Bowers Beach, DE to Gandys Beach, NJ. Lower Bay is defined by those landings occurring below that line.

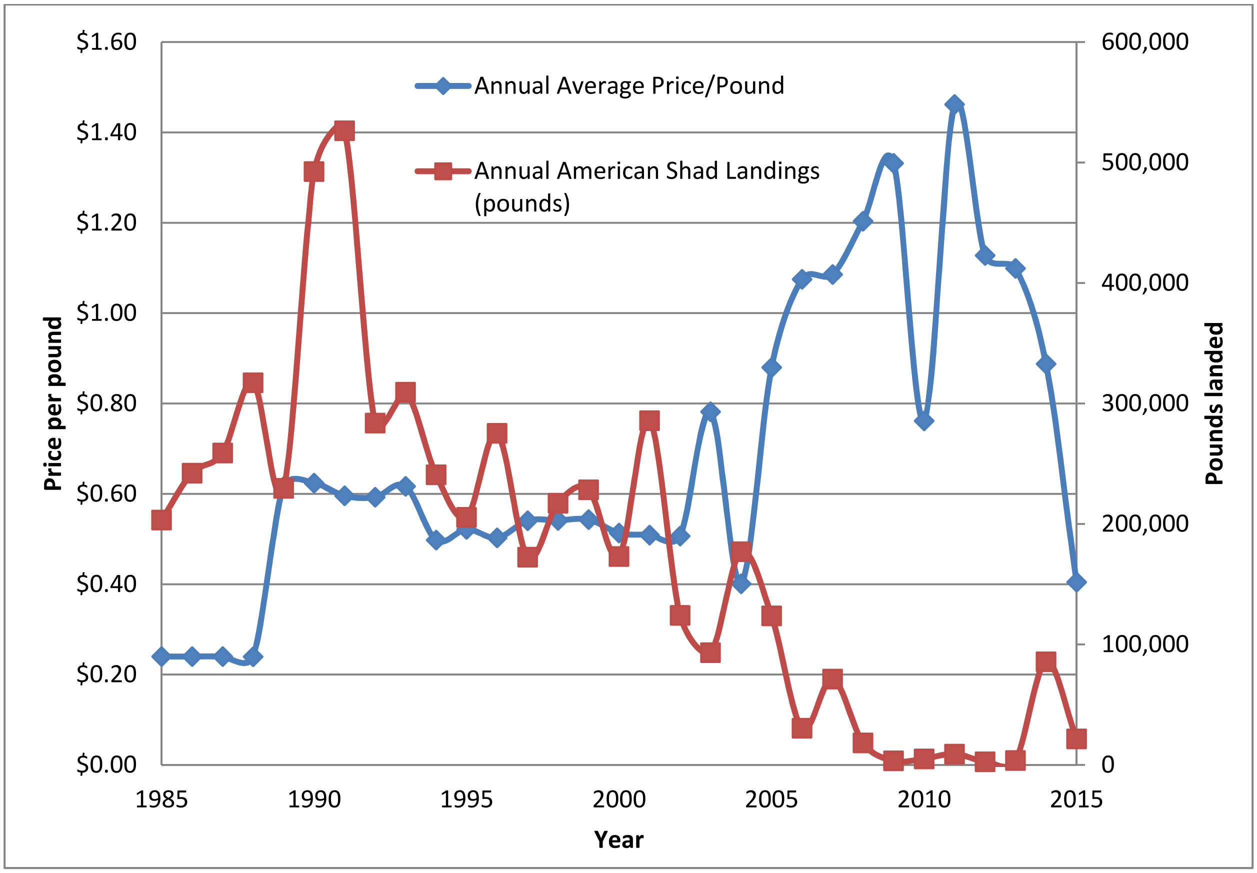


Figure 41. Pounds landed and market value for American Shad landed in the State of Delaware from 1985-2015.

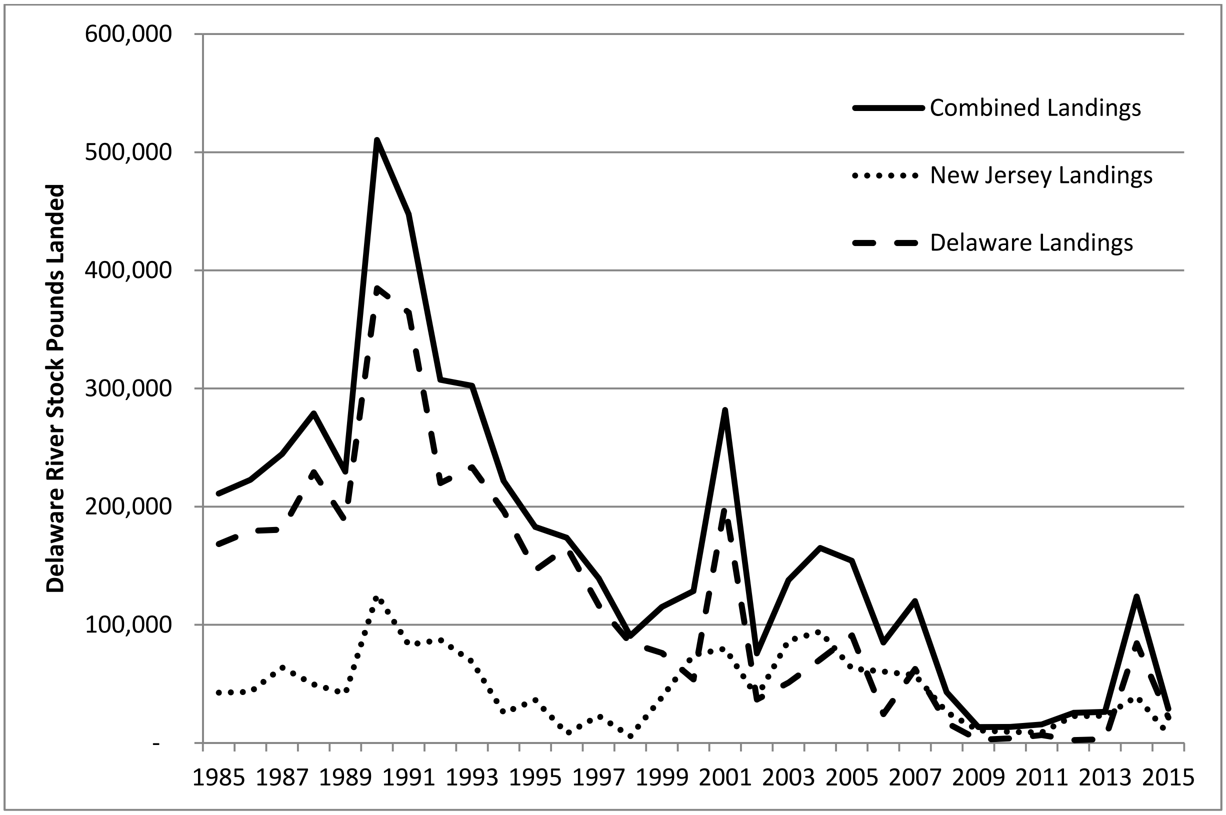


Figure 42. Pounds of Delaware River stock American Shad landed in the Delaware Bay.

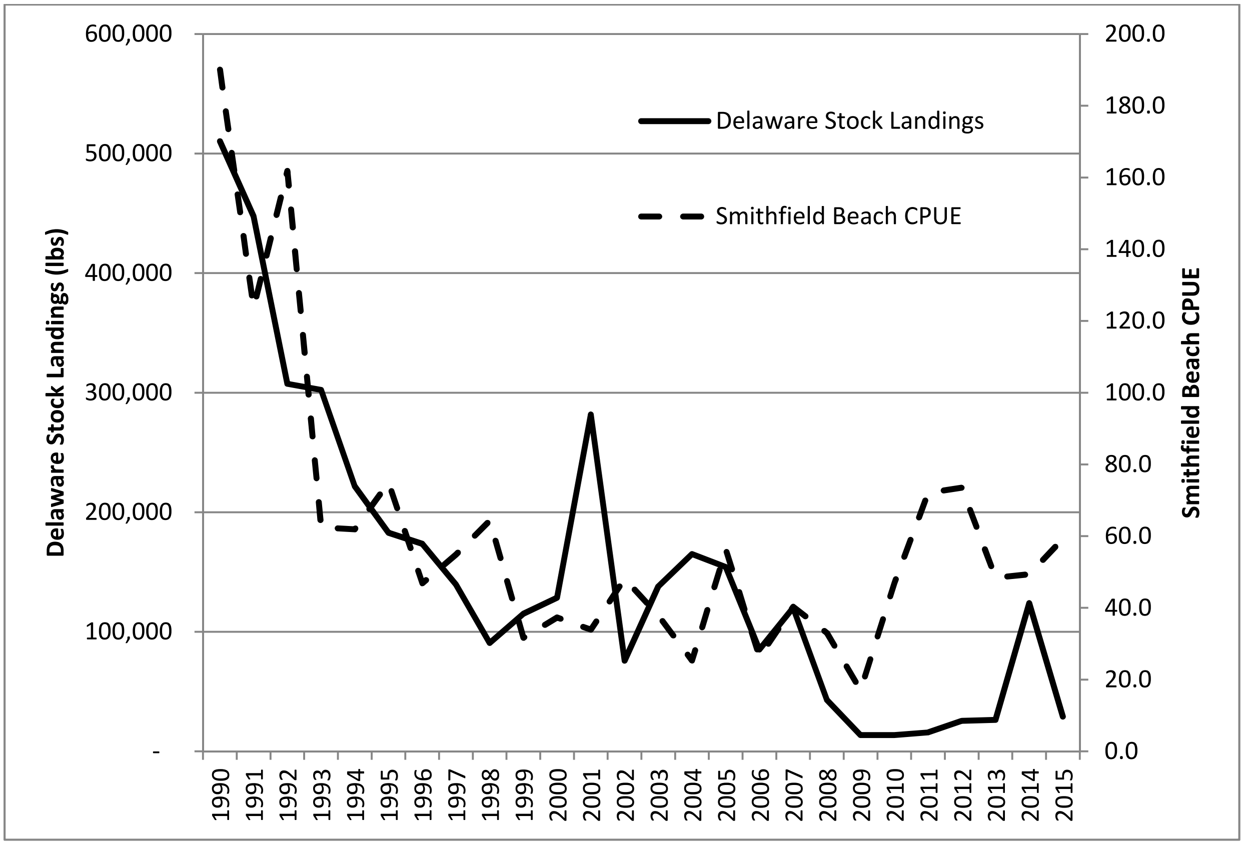


Figure 43. Comparison of trends between Delaware River stock landings and Smithfield Beach CPUE.

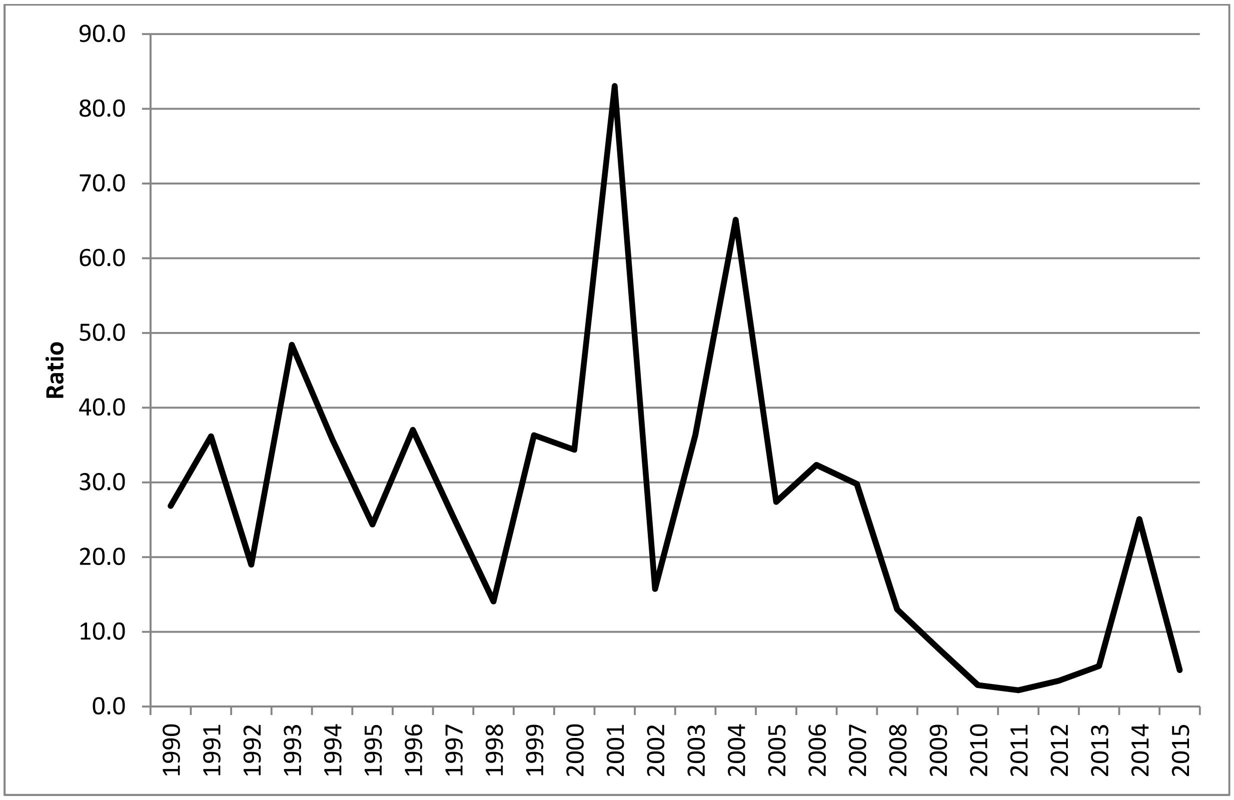


Figure 44. Ratio of Delaware River stock landings divided by Smithfield Beach CPUE (divided by 100). Early Period (NMFS estimations) is defined as 1990-1999, Late Period (mandatory reporting) is defined as 2000-2015.

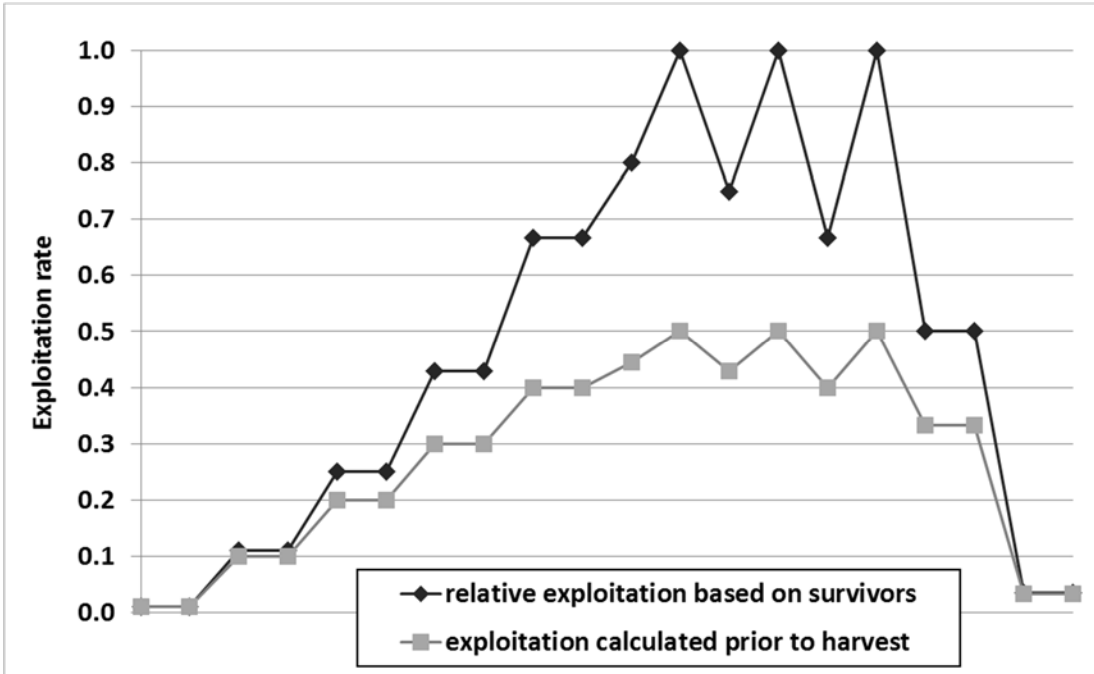


Figure 45. Comparison of exploitation rates based on the population prior to harvest (pop) and on survivors following harvest (survivors).

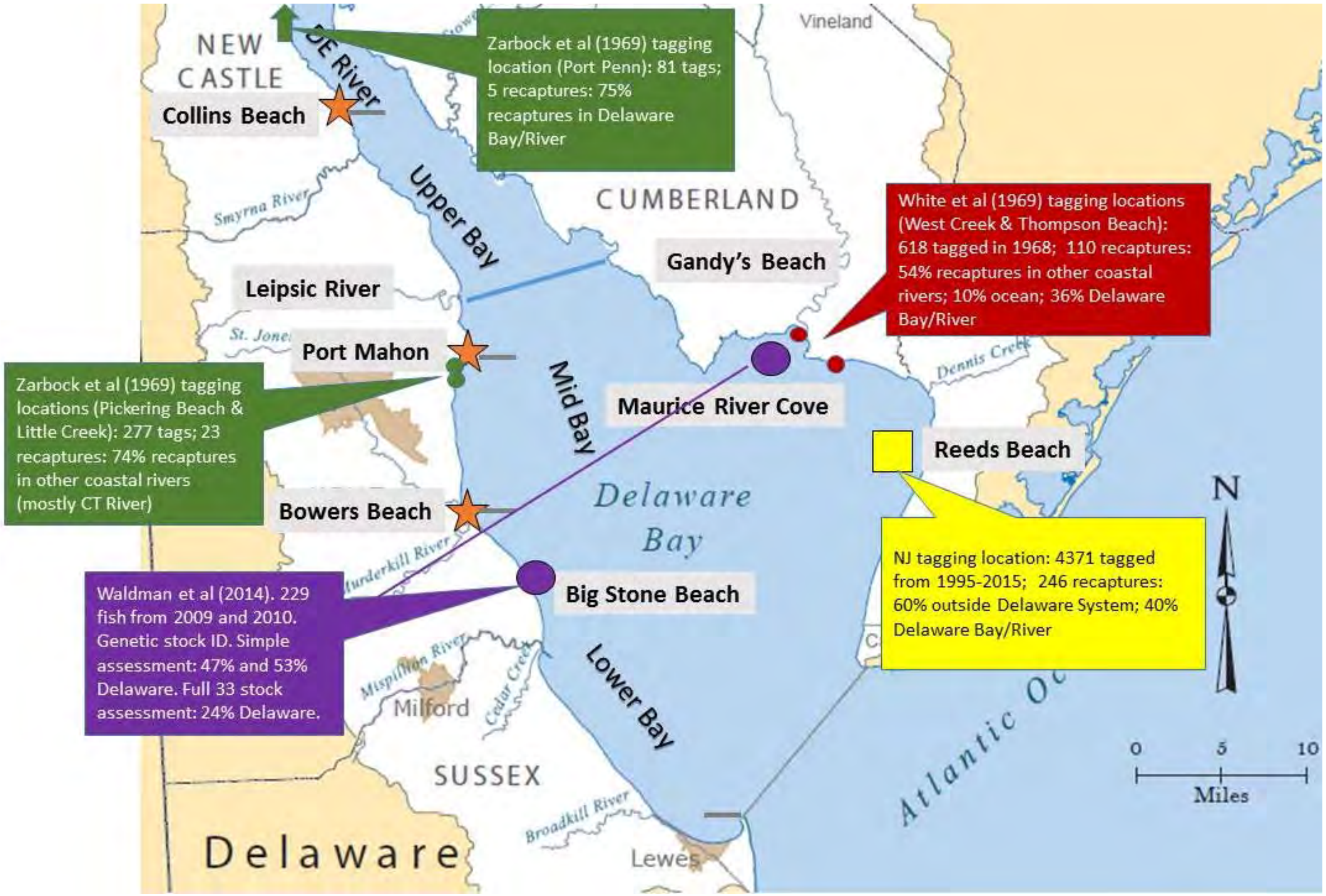


Figure 46. Map of the lower Delaware River and Bay, delineating harvest reporting regions for Delaware (orange), location of recent tag releases (yellow), location of historic tag releases (red and green), location of genetics studies (purple) and delineation line listed in 2012 SFP (blue).

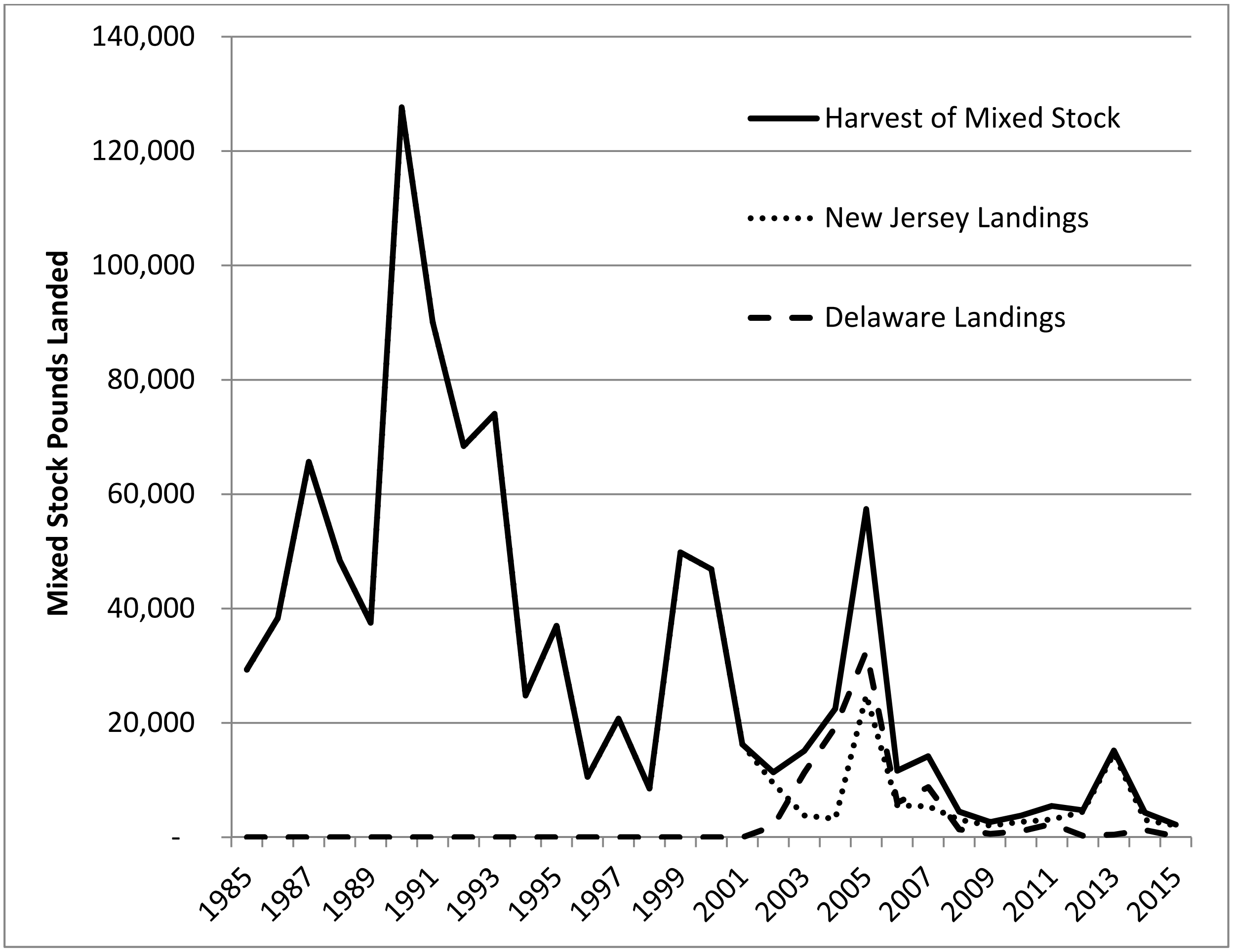


Figure 47. Pounds of mixed stock American Shad landed in the Delaware Bay. New Jersey represented 100% of the landings from 1985 to 2001.

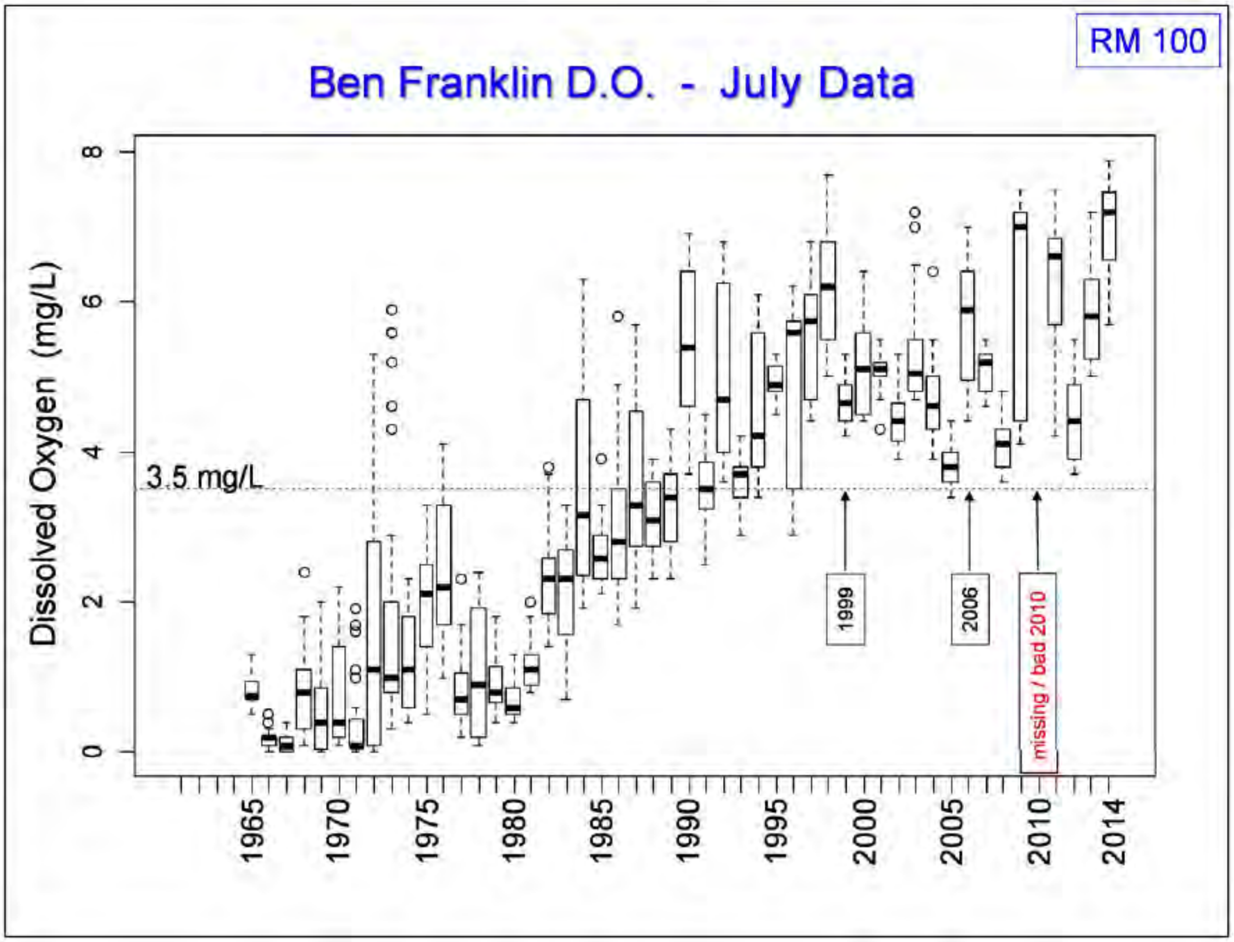


Figure 48. Box and whisker plot of dissolved oxygen concentrations during July, 1965-2014 at the Ben Franklin Bridge (RM 100). Data available at *waterdata.usgs.gov.*

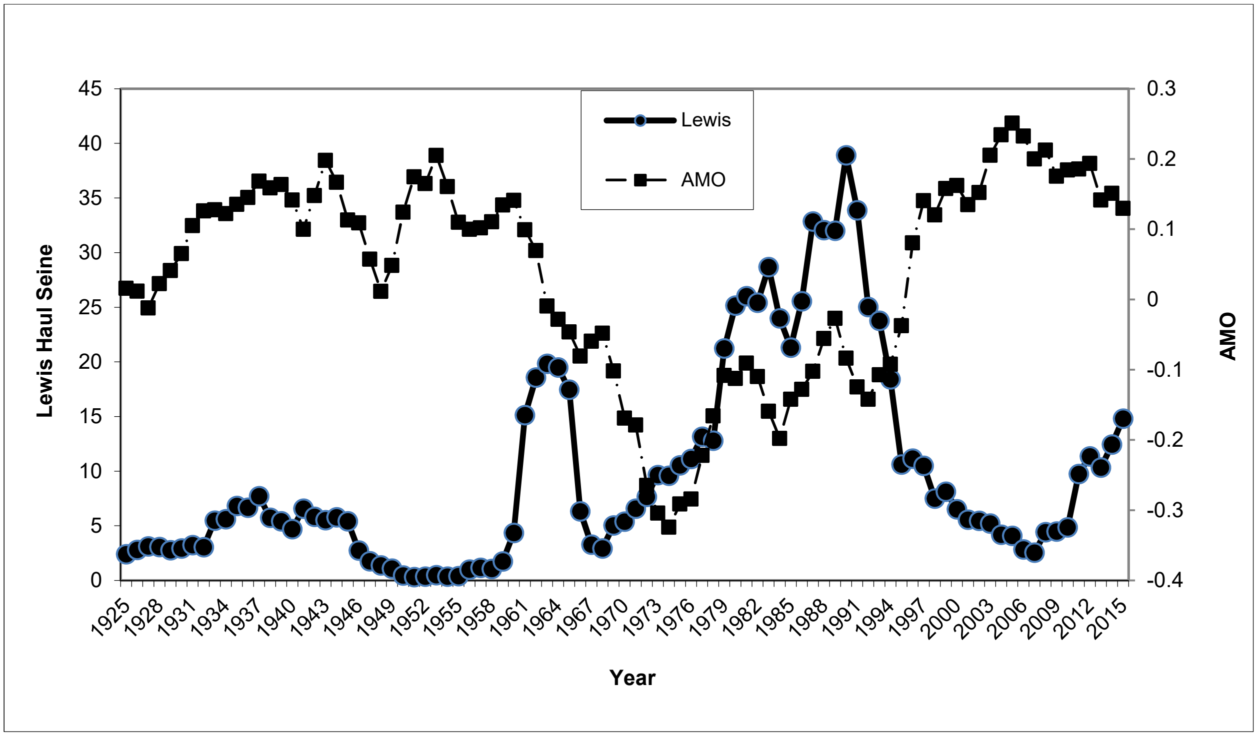


Figure 49. Five-year smoothed Atlantic Multidecadal Oscillation (AMO) compared to five-year smoothed Lewis haul seine CPUE: 1925 - 2015.

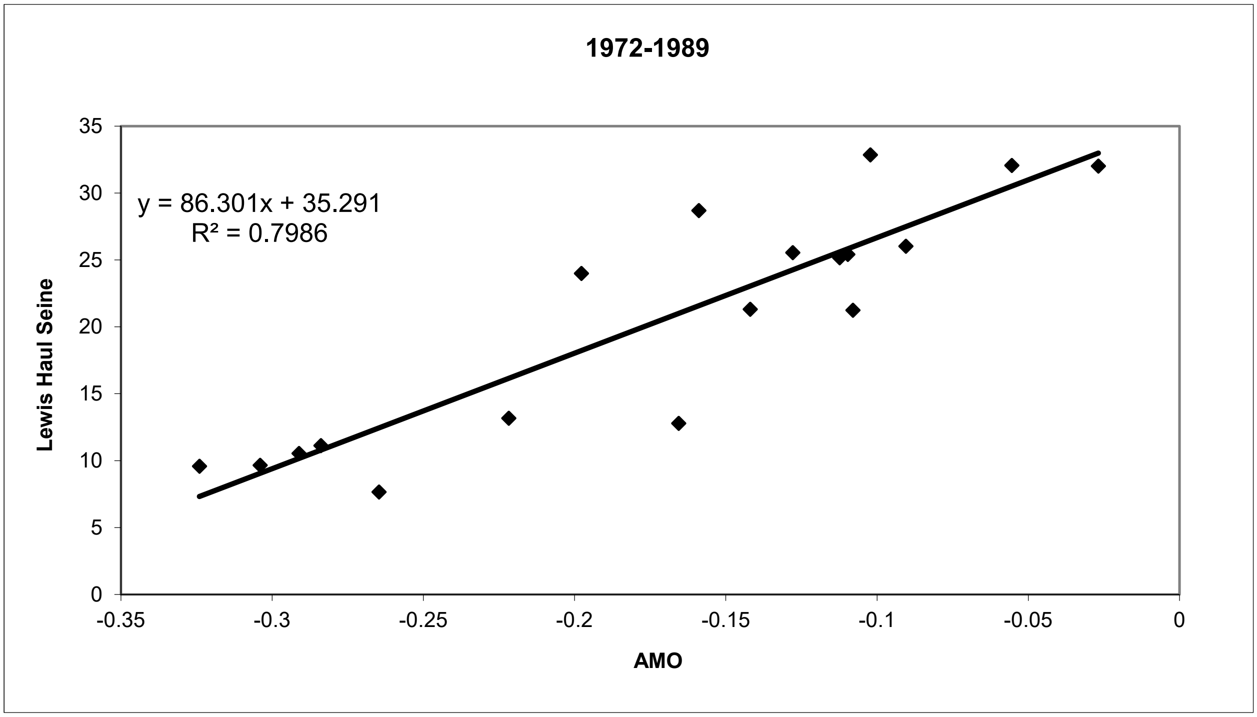


Figure 50. Scatter plot of the five-year smoothed Atlantic Multidecadal Oscillation (AMO) compared to five-year smoothed Lewis haul seine CPUE: 1972 - 1989.

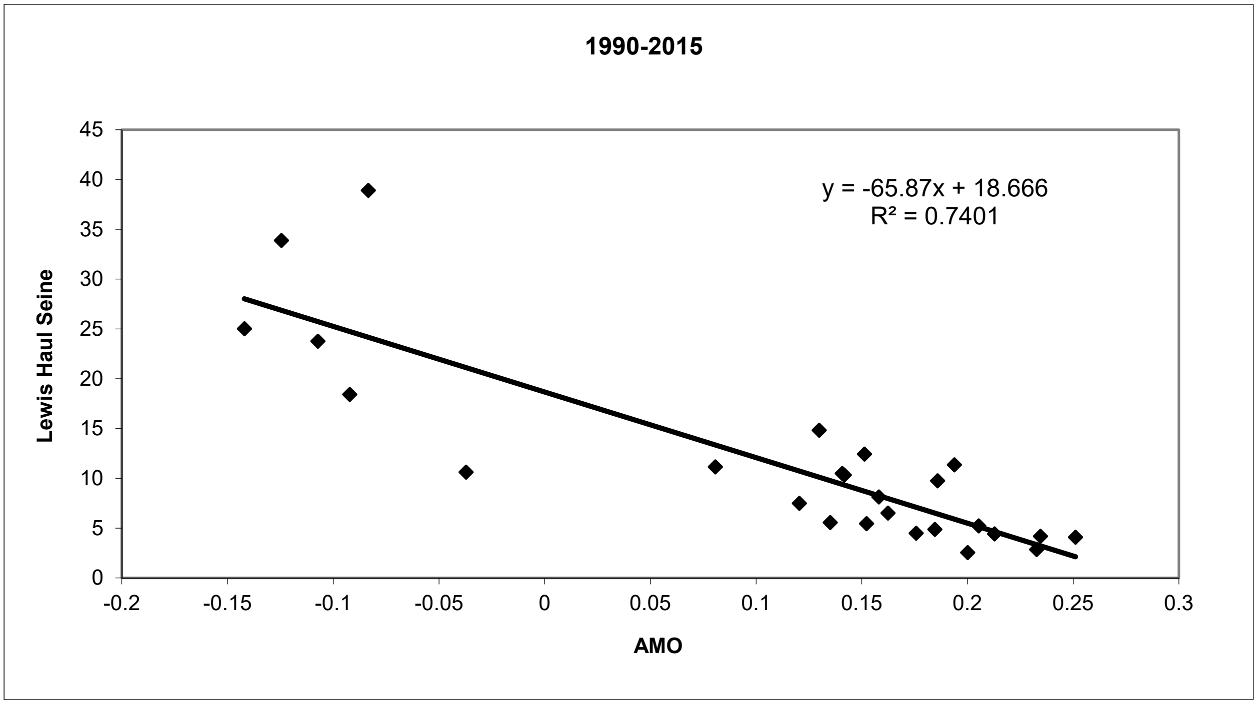


Figure 51. Scatter plot of the five-year smoothed Atlantic Multidecadal Oscillation (AMO) compared to five-year smoothed Lewis haul seine CPUE: 1990 - 2015.

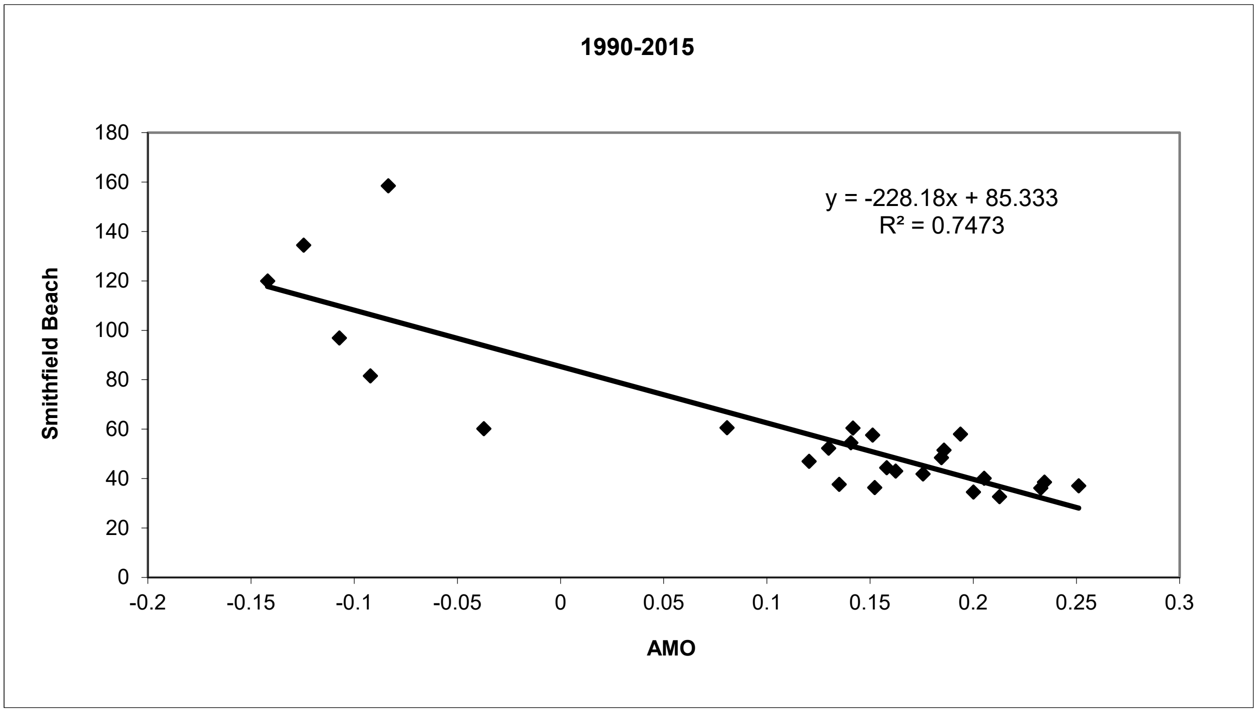


Figure 52. Scatter plot of the five-year smoothed Atlantic Multidecadal Oscillation (AMO) compared to five-year smoothed Smithfield Beach CPUE: 1990 - 2015.

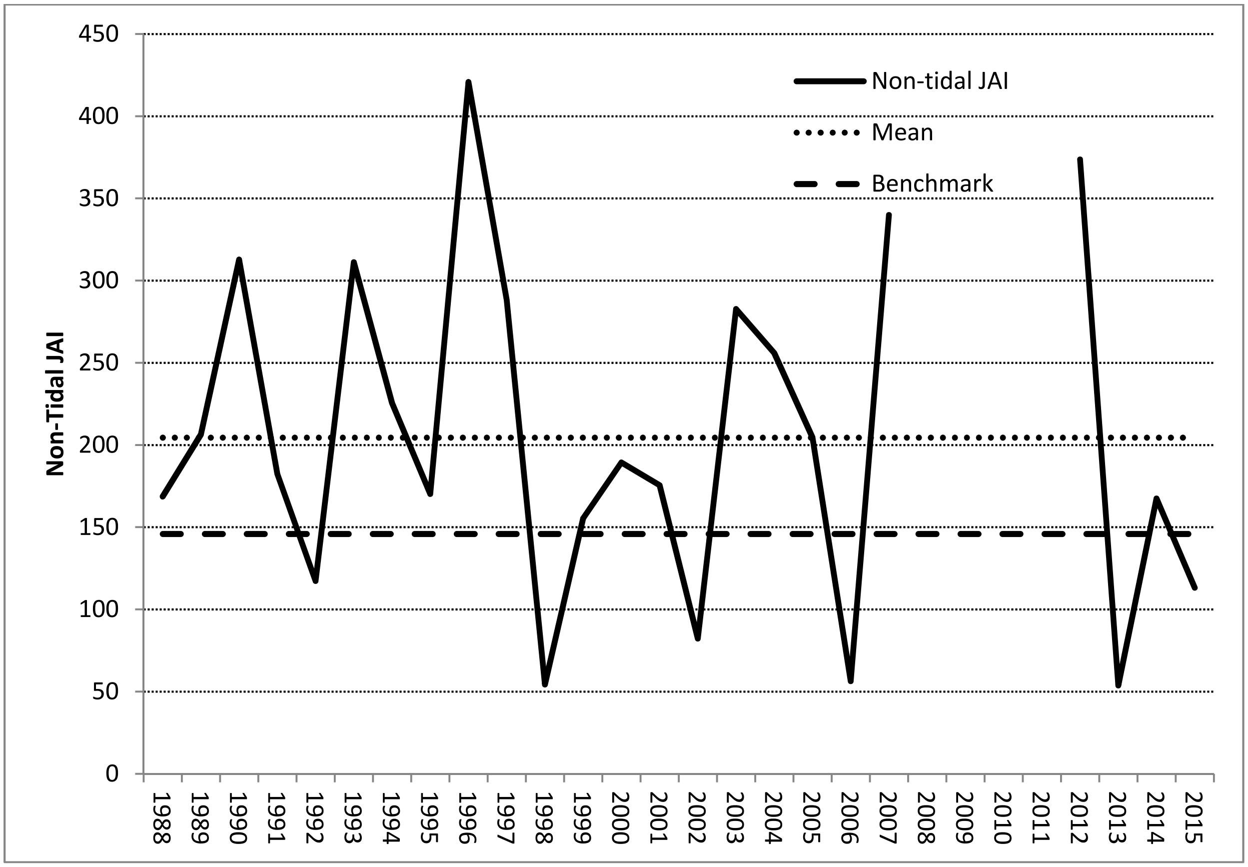


Figure 53. The Delaware River non-tidal American Shad JAI (GLM) with a 25th percentile benchmark: 1987 – 2015. The GLM estimates are based on catches only from the Big 3 sites (i.e., Phillipsburg, Delaware Water Gap and Milford Beach). Note that the benchmark value may change annually based on updated GLM analysis.

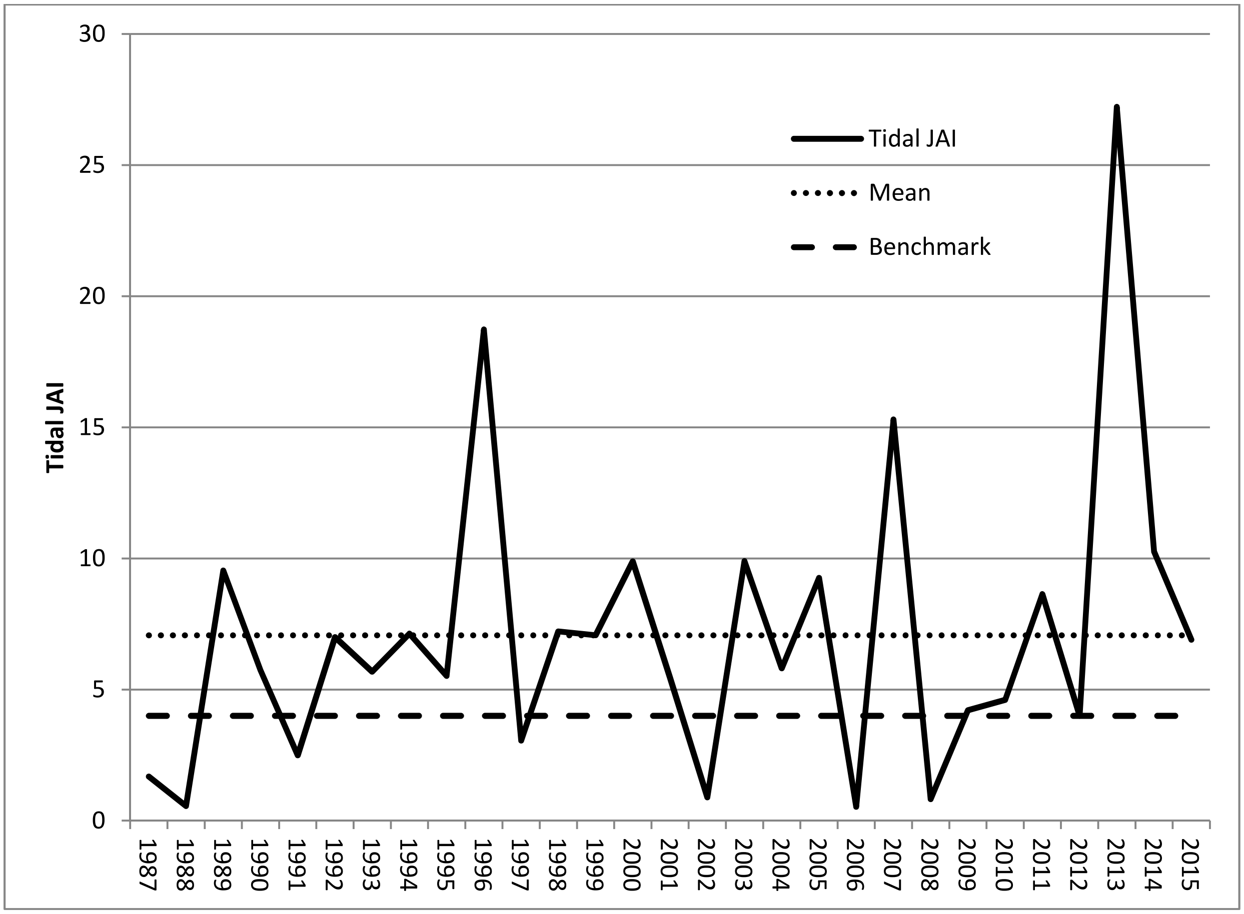


Figure 54. The Delaware River tidal American Shad JAI (GM) with a 25th percentile benchmark: 1987 – 2015. The GM values are based on catches from Region 2 and 3 of the NJDFW tidal seine sites.

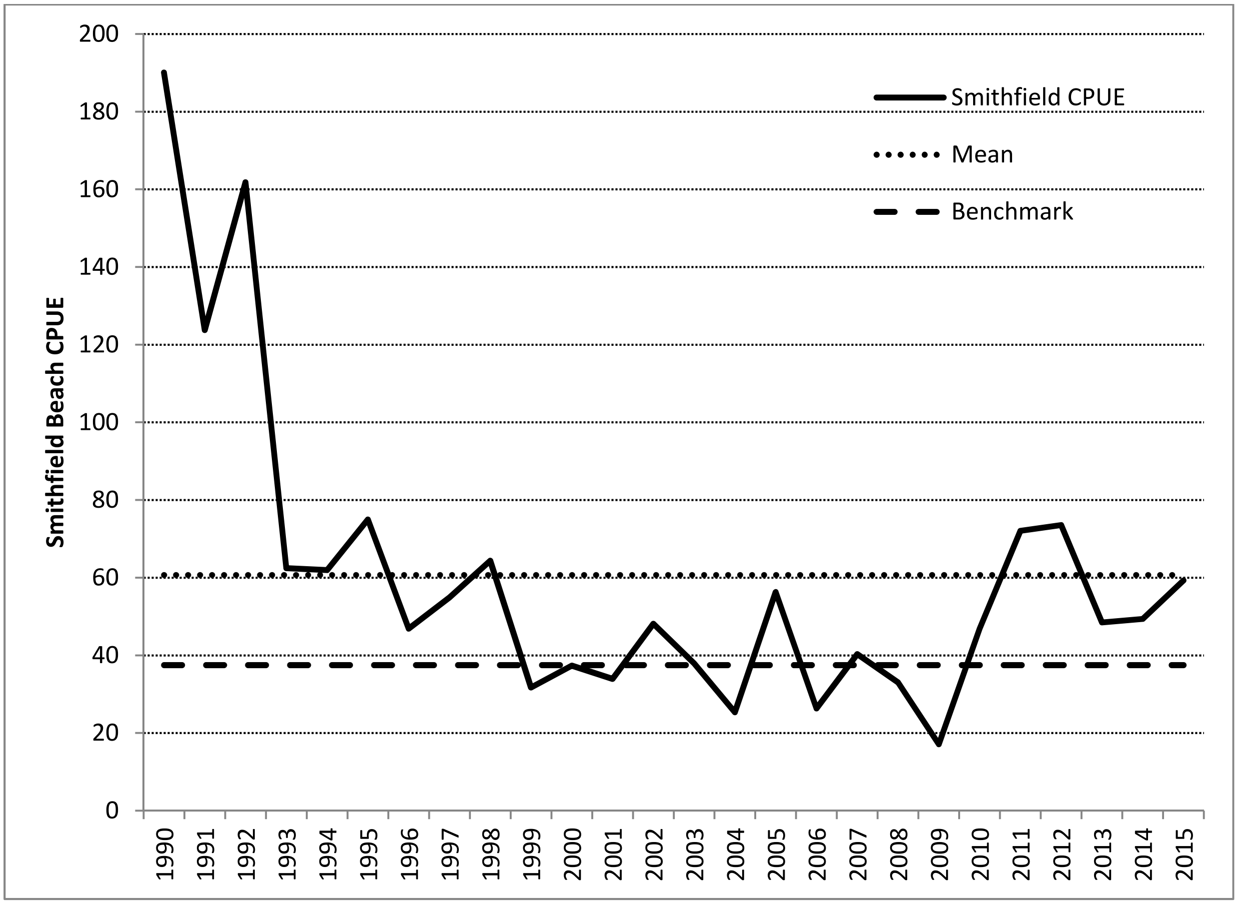


Figure 55. The Delaware River spawning adult American Shad index at Smithfield Beach (RM 218) with a 25th percentile benchmark: 1990 – 2015.

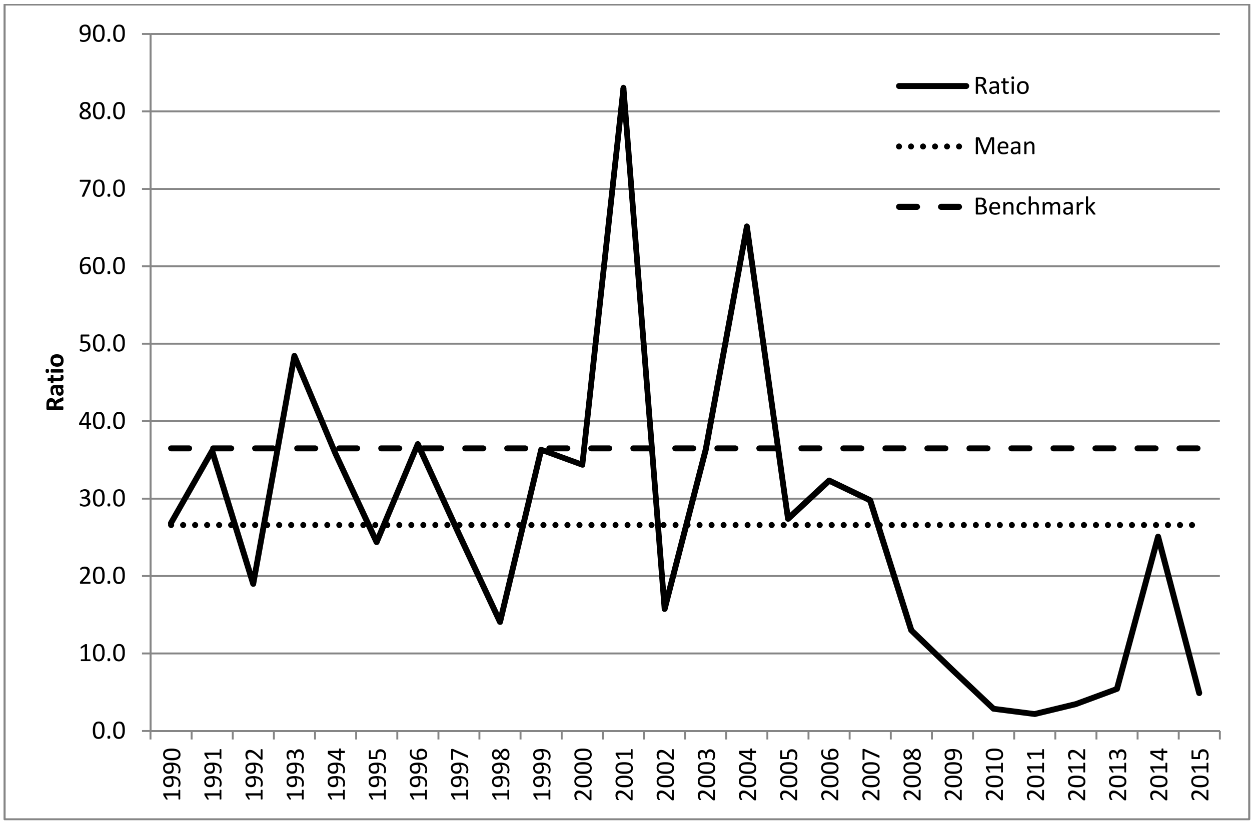


Figure 56. Ratio of Delaware River stock landings divided by Smithfield Beach CPUE (divided by 100) with an 85th percentile benchmark: 1990-2015.

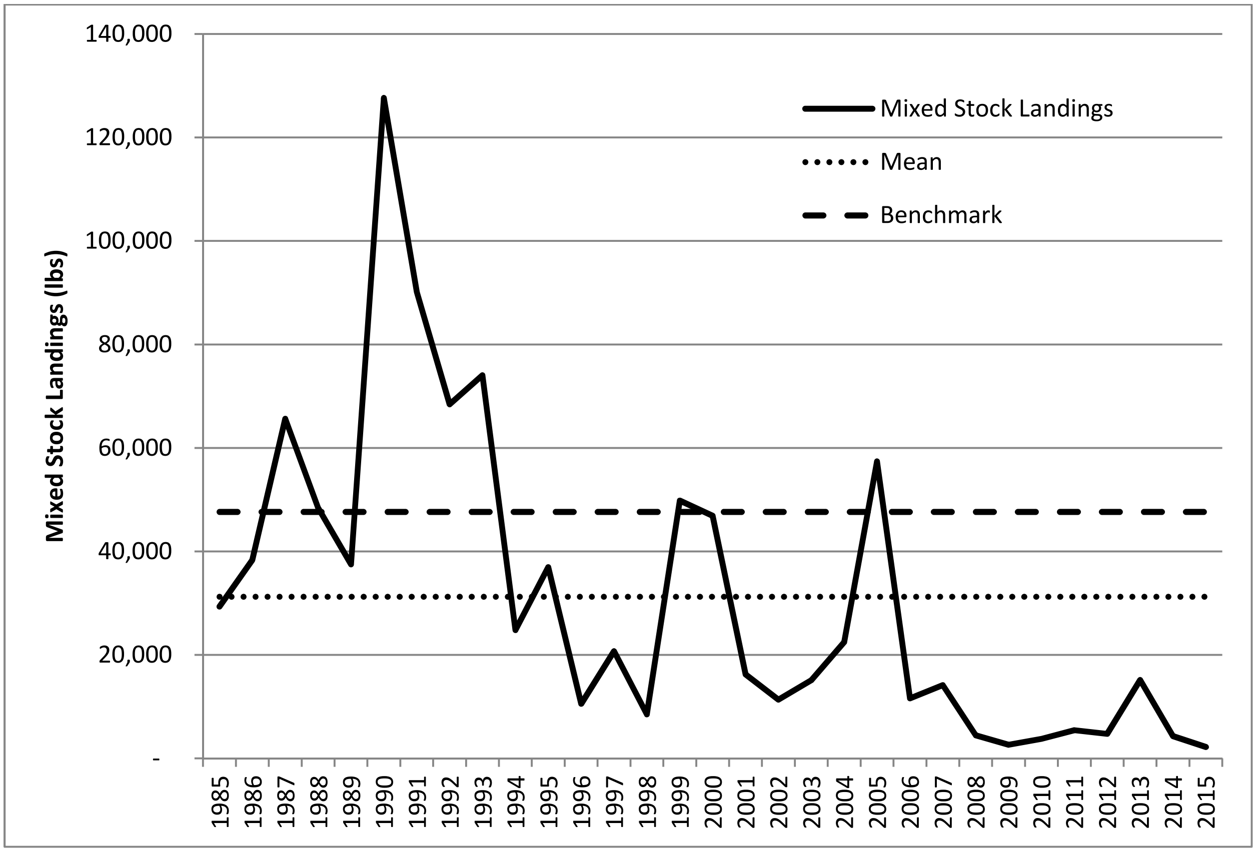


Figure 57. Landings in the Delaware Bay from the mixed stock fishery with a 75th percentile benchmark: 1990-2015.

10. Tables

Table 1. Total catch (N) of YOY American Shad collected during the 2015 synoptic exploratory surveys in the upper Delaware River.

		Fyke		Beach seine			
Site	Visual	Upper	Lower	Haul 1	Haul 2	Haul 3	Haul 4
	July						
Skinners Falls	0	N/A	N/A	47	95	9	4
Buckingham	N/A	N/A	N/A	0	0	0	0
Balls Eddy	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Fireman's Launch	0	N/A	N/A	0	0	0	0
	August						
Skinners Falls	100+	0	0	2	9	29	21
Buckingham	0	0	0	N/A	N/A	N/A	N/A
Balls Eddy	0	0	0	0	0	0	0
Fireman's Launch	0	0	0	0	0	0	0
	September						
Skinners Falls	100+	N/A	N/A	0	1	13	14
Buckingham	N/A	N/A	N/A	0	1	0	0
Balls Eddy	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Fireman's Launch	0	N/A	N/A	0	8	0	3
	October						
Skinners Falls	N/A	N/A	N/A	6	4	1	1
Buckingham	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Balls Eddy	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Fireman's Launch	N/A	N/A	N/A	0	3	1	2

Table 2. Descriptive statistics of fork lengths (mm) collected from non-tidal beach seine sites, by month and year. Data are inclusive of lengths collected at the traditional non-tidal sites: Trenton, Phillipsburg, Delaware Water Gap and Milford Beach.

Year	N	Min.	25th Quart.	50th Quart.	75th Quart.	Max.	Avg.	Std.
August								
1983	266	30	41.25	48	55	86	49.1	10.0
1984	229	29	46	52	58	80	52.5	10.6
1985	259	32	54	60	68	96	61.7	11.6
1986	250	34	49	56	65	103	57.8	12.2
1987	249	33	46	51	57	77	52.2	8.7
1988	361	32	45	50	56	115	52.1	11.2
1989	375	28	48	55	62	94	55.5	10.6
1990	385	20	45	53	63	85	53.7	13.2
1991	294	42	55	60	67	90	61.3	8.3
1992	274	27	48	56	68	85	57.3	13.3
1993	398	37	52	57	65.75	94	59.0	10.2
1994	240	29	48.75	58	67	88	58.0	12.3
1995	349	29	46	53	63	86	53.8	11.3
1996	400	23	36	42	54	91	45.3	13.1
1997	375	27	44	50	58	89	51.2	11.3
1998	310	26	41.25	53	63	87	52.2	14.6
1999	366	28	45	54	62	80	53.5	10.6
2000	356	20	39.75	49	63.25	101	53.0	17.9
2001	346	36	54.25	62	71	89	62.9	12.1
2002	251	25	40	53	61.5	84	51.4	12.7
2003	399	22	38	44	50.5	90	45.1	10.9
2004	395	30	53	62	74	112	63.3	15.8
2005	398	32	47	54	64	84	56.3	11.1
2006	318	25	45	55	65	97	56.1	14.6
2007	374	29	50	62	69	93	60.9	13.8
2012	298	36	53.25	61	68	93	60.9	10.0
2013	347	27	58	69	81	105	68.8	15.0
2014	311	32	50	58	66	101	58.8	13.0
2015	355	22	60.5	68	78	101	68.7	13.1

Table 2. Cont.

Year	N	Min.	25th Quart.	50th Quart.	75th Quart.	Max.	Avg.	Std.
September								
1983	256	46	57	63	70	103	64.2	9.4
1984	254	44	60	65	73	96	66.4	10.4
1985	235	47	66	70	75	112	71.6	9.2
1986	267	45	65	71	77	107	71.7	10.2
1987	194	47	59	65	75	106	67.6	11.8
1988	393	45	59	65	72	100	66.3	10.6
1989	334	44	59.25	65	71	87	65.1	7.8
1990	351	39	55	63	72	101	64.7	12.2
1991	234	50	65	70	75	97	70.1	8.5
1992	298	45	60	65	74	100	66.9	10.2
1993	335	42	58	65	72	94	65.5	9.8
1994	325	40	62	70	78	125	70.4	11.7
1995	306	50	65	70	75	96	70.3	9.1
1996	355	37	54	59	68	91	61.7	11.0
1997	331	39	57	66	74	117	66.3	12.4
1998	327	31	58	67	76.5	95	67.2	12.1
1999	376	46	60	64	70	101	65.7	8.7
2000	345	41	62	71	81	118	71.5	12.7
2001	330	49	68	76	84	103	76.2	10.7
2002	208	38	60	67	73.25	93	66.7	10.1
2003	377	30	46	55	65	97	56.5	13.7
2004	401	40	61	68	75	110	68.5	11.8
2005	369	47	59	67	75	101	67.8	11.2
2006	332	34	59	71.5	87	105	72.3	16.1
2007	352	40	65.75	75.5	85	110	75.4	13.8
2012	360	47	65	71	76.25	106	71.2	10.1
2013	296	42	64	80	92	119	78.2	16.2
2014	380	37	65	73	82.25	128	74.4	13.7
2015	362	37	75	85	96	201	85.6	16.6

Table 2. Cont.

Year	N	Min.	25th Quart.	50th Quart.	75th Quart.	Max.	Avg.	Std.
October								
1983	242	48	61	72	83	110	73.0	13.2
1984	299	48	73	80	87	110	79.6	9.9
1985	252	57	69	74	80	95	75.0	7.9
1986	255	61	75	82	90	130	83.9	11.3
1987	261	55	67	71	76	95	71.8	7.3
1988	229	53	65	71	75	96	70.8	7.2
1989	332	50	67	73	76.25	92	71.9	7.5
1990	368	47	68	74.5	82	132	75.0	11.2
1991	339	55	70	75	80	116	75.5	8.5
1992	271	48	69	75	82	110	76.8	12.0
1993	323	48	58	65	73	99	66.2	10.2
1994	323	48	69	72	78	114	74.0	8.9
1995	315	52	69	75	85	113	77.4	11.6
1996	399	52	64	71	78.5	113	71.5	9.3
1997	302	52	64	71	78	104	71.3	9.5
1998	272	54	70.75	80	87	113	79.1	11.3
1999	291	55	68	72	76.5	124	73.1	9.6
2000	297	51	80	88	95	127	87.6	12.0
2001	379	60	74	80	85	116	80.2	9.3
2002	276	54	70	76	81	105	77.0	9.6
2003	122	43	62	67	72.75	100	67.5	9.1
2004	128	55	69.75	74	79.25	105	74.9	9.2
2005	200	51	66.75	72	76.25	101	72.0	7.7
2006	178	48	71.25	80.5	89	115	80.4	12.7
2007	343	50	81	87	92	110	85.1	10.6
2012	313	60	70	73	77	100	73.9	6.7
2013	309	17	84	92	104	203	92.5	17.1
2014	400	45	76	82	88	125	81.9	9.3
2015	339	53	81	89	96	124	88.1	10.7

Table 3. Descriptive statistics of fork lengths (mm) collected from tidal beach seine sites, by month and year.

Year	N	Min.	25th Quart.	50th Quart.	75th Quart.	Max.	Avg.	Std.
August								
2000	654	27	48	53.5	58.75	71	52.7	8.1
2001	559	35	48	51	55	74	52.0	6.3
2002	127	45	58.5	64	67.5	74	62.4	6.7
2003	1889	28	46	49	54	80	50.1	6.4
2004	858	37	53	57	61	83	56.4	6.6
2005	927	38	50	53	55	74	52.8	4.2
2006	70	58	65	68	71.75	83	68.3	4.5
2007	1093	34	48	50	54	67	50.6	4.7
2008	95	44	62	66	69	81	65.3	6.3
2009	684	31	50	57	63	78	56.2	9.0
2010	609	41	56	61	65	77	60.7	6.2
2011	655	32	52	57	62	77	57.1	7.1
2012	362	43	58	64	69	85	63.1	7.9
2013	1134	29	49	53	56	70	52.5	5.6
2014	881	32	45	50	54	86	50.1	6.4
September								
2000	581	40	54	60	65	90	59.6	7.5
2001	492	40	53	56	60	78	56.6	5.9
2002	143	51	64.5	68	71	91	67.7	6.3
2003	942	43	55	59	63	83	59.5	5.6
2004	399	48	60	63	67	90	63.2	5.7
2005	550	43	55	58	61	99	58.2	5.3
2006	56	63	71	73	78	124	74.7	8.4
2007	851	40	50	52	55	67	52.5	4.2
2008	163	57	68	71	75	83	70.9	5.1
2009	325	37	53	61	70	90	61.7	11.0
2010	415	46	60	64	69	83	63.8	6.6
2011	466	45	60	64	67	82	63.6	5.8
2012	465	49	62	66	70	90	66.0	6.5
2013	1085	25	52	55	59	79	55.4	5.5
2014	610	40	52	55.5	60	80	55.4	5.9

Table 3. Cont.

Year	N	Min.	25th Quart.	50th Quart.	75th Quart.	Max.	Avg.	Std.
October								
2000	507	49	60.5	65	70	95	65.5	6.7
2001	248	50	59	62.5	69	94	64.3	7.5
2002	70	57	68	72	75	82	71.4	4.6
2003	382	51	60	62.5	66	82	62.9	4.9
2004	416	54	66	69	72	83	68.8	4.8
2005	433	45	59	62	65	102	62.6	5.4
2006	73	59	78	84	89	95	82.9	7.7
2007	485	43	53	56	60	84	56.6	5.5
2008	75	65	74	78	81	92	77.6	5.3
2009	130	57	68	74	80	99	74.1	8.0
2010	340	57	67	71	74	87	70.6	5.2
2011	398	49	63	67	71	81	67.0	5.7
2012	402	53	67	70	74	88	70.6	5.4
2013	918	47	58	61	64	117	61.2	5.5
2014	547	35	56	60	64	85	60.1	6.4

Table 4. Juvenile tidal and non-tidal abundance indices for Delaware River American Shad. Historic sites include Trenton, Phillipsburg, Delaware Water Gap and Milford Beach. The Big 3 sites include Phillipsburg, Delaware Water Gap and Milford Beach. GM = geometric mean; GLM = generalized linear model mean.

Year	Trenton (GM)	Phillipsburg (GM)	Del. Water Gap (GM)	Milford (GM)	Non-tidal (GM) (Historic)	Non-tidal (GM) (Big 3)	Non-tidal (GLM) (Big 3)	Tidal (GM)
1980	1.15				1.15			0
1981	2.95	74.4			15.80			0
1982	30.4	56.8			40.62			0
1983	31.8	443.6	137.4		111.19	219.7		0.48
1984	27.3	200.5	64.4		68.87	111.0		0.23
1985	30.9	121.6	116.1		76.09	118.8		0.06
1986	22.8	215.5	303.5		149.12	255.8		0.67
1987	83.6	160.7	154.6		125.39	158.5		1.68
1988	29.3	25.6	178.0	121.1	63.74	82.4	168.63	0.56
1989	61.0	32.7	256.3	99.3	84.73	94.5	206.37	9.54
1990	72.4	143.4	670.0	102.9	154.74	212.4	312.81	5.74
1991	7.9	48.2	106.6	136.1	49.43	88.9	182.33	2.49
1992	27.1	67.1	60.2	15.2	35.86	39.2	117.23	7.00
1993	32.1	155.2	387.3	137.1	124.41	199.8	311.26	5.68
1994	8.0	39.2	154.5	39.7	37.85	62.4	225.59	7.13
1995	25.1	89.1	94.9	112.7	70.14	98.4	170.20	5.52
1996	146.3	209.8	646.7	251.5	265.95	324.4	420.81	18.73
1997	16.6	273.0	265.2	195.9	130.4	242.1	288.24	3.05
1998	28.5	13.8	50.4	28.3	27.46	27.1	54.31	7.22
1999	34.2	160.9	94.9	48.5	71.13	90.6	155.41	7.07
2000	54.9	153.9	157.1	27.1	76.57	85.8	189.38	9.89
2001	29.5	209.4	56.4	58.5	66.95	82.2	175.53	5.45
2002	1.4	47.2	59.8	25.9	19.78	41.9	82.25	0.89
2003	31.7	245.2	25.9	75.4	62.78	78.7	282.66	9.90
2004	53.4	65.2	63.6	123.4	72.34	80.0	255.90	5.81
2005	43.7	125.2	411.6	162.8	125.64	186.1	204.56	9.26

Table 4. Cont.

Year	Trenton (GM)	Phillips-burg (GM)	Del. Water Gap (GM)	Milford (GM)	Non-tidal (GM) (Historic)	Non-tidal (GM) (Big 3)	Non-tidal (GLM) (Big 3)	Tidal (GM)
2006	17.4	8.7	39.8	41.3	22.53	24.5	56.29	0.53
2007	25.7	288.7	553.6	231.9	176.75	333.5	339.97	15.30
2008								0.82
2009								4.21
2010								4.61
2011								8.64
2012	11.1	267.6	428.9	139.6	118.91	252.2	373.71	4.00
2013	39.3	51.6	26.1	48.0	39.90	40.2	53.67	27.22
2014	36.3	108.8	144.6	109.9	86.42	120.3	167.51	10.26
2015	42.9	99.9	45.3	95.9	66.08	75.2	113.17	6.9
2006-2015 Average	28.8	137.6	206.4	111.1	85.10	141.0	184.05	8.25
Long-term Average	34.6	135.6	198.4	101.2	87.00	132.0	204.49	7.07
Time Series	1980-2015	1981-2015	1983-2015	1988-2015	1980-2015	1983-2015	1988-2015	1987-2015

Table 5. Correlation matrix of geometric CPUEs (log-transformed).

	Trenton	Phillipsburg	Del. Water Gap	Milford
Phillipsburg	0.26	-	0.44	0.46
Del. Water Gap	0.25	0.44	-	0.63
Milford	0.30	0.46	0.63	-
Phillipsburg/Del. Water Gap / Milford	***0.33***	0.78	0.85	0.83
Tidal	***0.48***	0.38	0.13	0.13

Table 6. Distribution of American Shad total lengths (mm) caught at Smithfield Beach by stretch mesh size, all years combined (1999-2009).

Mesh	count	min	25th	50th	75th	max	avg	std
Female								
4.5	659	428	517	534	552	614	535	27.4
4.75	392	455	525	544	560	606	542	24.8
5	1899	446	530	547	566	643	548	26.0
5.25	473	468	535	552	570	644	553	25.9
5.5	471	437	536	556	573.5	614	556	25.3
5.75	191	483	550.5	571	586.5	635	569	26.8
6	222	475	554	573	591	629	571	29.7
Male								
4.5	1264	398	470	489	507	581	489	26.8
4.75	309	413	484	499	518	571	500	26.4
5	555	408	493	510	526	591	509	25.2
5.25	54	430	488	511.5	530.75	580	510	31.2
5.5	33	435	500	521	532	591	516	33.5
5.75	13	474	484	500	530	555	507	28.3
6	6	431	461.5	466	476.5	500	467	22.7

Table 7. Total length (mm) distribution of American Shad collected at Smithfield Beach separated by gender and year.

Year	count	min	25th	50th	75th	max	avg	std
Female								
1996	643	447	532	547	562	618	546.7	25.39
1997	996	452	518	538	557	615	536.9	29.68
1998	1022	445	519	534	548	627	534.4	23.25
1999	638	455	522	535	547	614	535.0	19.99
2000	316	457	534	554	569	613	551.2	25.70
2001	685	465	531	546	562	606	546.5	22.40
2002	248	435	548	562	576	615	561.8	23.47
2003	299	446	555	571	592	644	569.6	31.32
2004	269	499	540	560	581	634	560.2	27.02
2005	545	461	545	561	576	635	559.9	25.74
2006	220	462	527	553	574	627	550.9	33.02
2007	414	468	529	545	566	622	545.9	27.41
2008	440	437	521	538	556	603	538.8	26.12
2009	236	428	515	532	551	615	532.8	28.64
2010	427	465	504	516	531	585	517.7	20.63
2011	811	470	526	540	556	605	540.4	21.02
2012	762	464	528	546	564	617	545.8	25.89
2013	645	475	533	545	558	641	545.1	19.85
2014	593	452	525	537	550	618	536.8	23.98
2015	547	461	520.5	536	551	629	536.2	23.84

Table 7. Cont.

Year	count	min	25th	50th	75th	max	avg	std
Male								
1996	220	430	491.75	510	528	615	510.8	31.16
1997	273	409	462	481	503	562	482.8	27.72
1998	235	424	482	496	507.5	547	494.9	19.77
1999	76	442	477	494.5	507.5	540	493.0	21.34
2000	225	415	470	489	508	580	488.9	26.29
2001	233	428	480	495	511	562	495.8	22.25
2002	154	422	497	514.5	530	585	512.1	26.30
2003	257	435	483	504	528	582	504.9	29.86
2004	156	439	495.75	510	523	581	508.7	21.65
2005	351	398	484	505	525	591	501.6	31.27
2006	136	433	464.75	482	500	578	483.4	25.43
2007	255	430	478	494	511.5	566	494.4	24.04
2008	257	429	477	493	509	591	494.1	25.56
2009	136	408	455.75	468	491.25	557	472.8	28.01
2010	380	425	472.75	485	497	564	485.0	18.44
2011	200	443	494.75	506	520	557	506.9	20.32
2012	216	450	485	499	514	567	499.6	21.35
2013	190	414	495	506.5	519.75	545	505.1	20.38
2014	162	430	475	499	512.75	558	494.6	26.01
2015	172	420	480.75	495	507.25	552	492.5	22.14

Table 8. Percent frequency of American Shad ages interpreted from scale microstructures collected at Smithfield Beach. No biological information was collected prior to 1996. Assigned ages do not represent the combined agreement of Co-op members as per the Co-op's Ageing Protocol (Appendix A). Scale ages for 2015 are unavailable as they are still being processed by Co-op members.

Year	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10
Female										
1996	0.0	0.0	0.0	1.9	78.7	19.5	0.0	0.0	0.0	0.0
1997	0.0	0.0	0.0	18.6	42.3	38.3	0.9	0.0	0.0	0.0
1998	0.0	0.0	0.6	17.3	67.9	12.9	1.3	0.0	0.0	0.0
1999	0.0	0.0	0.0	5.0	53.9	39.7	1.4	0.0	0.0	0.0
2000	0.0	0.0	0.0	12.7	38.1	44.8	4.4	0.0	0.0	0.0
2001	0.0	0.0	0.0	10.6	55.6	32.1	1.8	0.0	0.0	0.0
2002	0.0	0.0	0.0	1.2	44.8	50.8	3.2	0.0	0.0	0.0
2003	0.0	0.0	0.3	5.4	44.5	44.1	5.7	0.0	0.0	0.0
2004	0.0	0.0	0.0	3.0	57.6	36.1	3.3	0.0	0.0	0.0
2005	0.0	0.0	0.0	1.7	20.3	50.1	25.0	2.9	0.0	0.0
2006	0.0	0.0	0.9	18.4	32.3	33.6	14.3	0.5	0.0	0.0
2007	0.0	0.0	0.0	24.7	50.1	23.0	2.2	0.0	0.0	0.0
2008	0.0	0.0	0.0	7.3	44.0	38.1	10.1	0.5	0.0	0.0
2009	0.0	0.0	0.0	13.1	34.2	36.3	13.9	1.7	0.8	0.0
2010	0.0	0.0	0.0	5.9	80.1	12.6	1.2	0.2	0.0	0.0
2011	0.0	0.0	0.0	0.5	13.3	82.6	3.7	0.0	0.0	0.0
2012	0.0	0.0	0.0	0.5	32.0	8.8	57.0	1.3	0.4	0.0
2013	0.0	0.0	0.0	0.3	14.7	75.5	5.9	3.6	0.0	0.0
2014	0.0	0.0	0.0	3.0	22.1	46.7	28.2	0.0	0.0	0.0

Table 8. Cont.

Year	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10
Male										
1996	0.0	0.0	0.0	20.6	70.4	8.1	0.9	0.0	0.0	0.0
1997	0.0	0.0	8.8	44.7	33.0	13.6	0.0	0.0	0.0	0.0
1998	0.0	0.0	0.8	39.4	52.5	7.2	0.0	0.0	0.0	0.0
1999	0.0	0.0	0.0	15.6	57.1	27.3	0.0	0.0	0.0	0.0
2000	0.0	0.0	0.0	20.5	65.2	13.4	0.9	0.0	0.0	0.0
2001	0.0	0.0	1.7	39.9	53.6	4.3	0.4	0.0	0.0	0.0
2002	0.0	0.0	0.7	15.2	65.6	18.5	0.0	0.0	0.0	0.0
2003	0.0	0.0	0.4	30.4	59.2	9.2	0.8	0.0	0.0	0.0
2004	0.0	0.0	0.0	14.7	79.5	5.8	0.0	0.0	0.0	0.0
2005	0.0	0.0	3.7	28.6	45.3	22.1	0.3	0.0	0.0	0.0
2006	0.0	0.0	11.0	57.4	30.9	0.7	0.0	0.0	0.0	0.0
2007	0.0	0.0	5.5	38.3	43.0	12.9	0.4	0.0	0.0	0.0
2008	0.0	0.0	1.2	26.4	55.9	15.4	1.2	0.0	0.0	0.0
2009	0.0	0.0	1.5	56.6	28.7	11.0	2.2	0.0	0.0	0.0
2010	0.0	0.0	0.0	14.2	80.5	5.3	0.0	0.0	0.0	0.0
2011	0.0	0.0	0.0	2.0	19.4	77.1	1.5	0.0	0.0	0.0
2012	0.0	0.0	0.0	2.8	70.7	5.1	20.5	0.9	0.0	0.0
2013	0.0	0.0	0.0	3.7	35.3	60.0	0.0	1.1	0.0	0.0
2014	0.0	0.0	0.0	18.4	35.6	41.1	4.9	0.0	0.0	0.0

Table 9. Mean size-at-age for female and male American Shad caught at Smithfield Beach.

Year	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9
Female							
1996		512	542	571			
1997		505	531	560	585		
1998	565	522	536	547	551		
1999		528	532	541	551		
2000		536	546	560	566		
2001		521	543	562	580		
2002		502	555	569	593		
2003	445	516	558	586	604		
2004		526	551	576	603		
2005		503	538	560	579	597	
2006	495	514	544	571	577	595	
2007		524	548	562	596		
2008		513	532	548	555	560	
2009		503	527	544	548	548	560
2010		511	517	530	551	555	
2011		510	534	542	546		
2012		493	528	544	558	562	565
2013		480	534	546	565	560	
2014		502	522	541	550		

Table 9. Cont

Year	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9
Male							
1996		496	511	559	560		
1997	458	468	498	519			
1998	465	494	496	504			
1999		469	496	503			
2000		471	493	504	525		
2001	450	487	503	529	535		
2002	425	482	502	527			
2003	435	483	511	547	550		
2004		493	511	533			
2005	443	476	510	529	535		
2006	464	478	502	495			
2007	470	483	504	512	545		
2008	452	479	497	518	522		
2009	420	461	487	504	515		
2010		477	486	504			
2011		450	514	508	505		
2012		472	496	522	513	535	
2013		475	498	512		505	
2014		474	496	509	481		

Table 10. Chapman-Robson bias-corrected Z estimates for American Shad collected at Smithfield Beach.

	Females Only		Combined Sexes	
	Z	SE	Z	SE
1997	1.06	0.06	1.16	0.534
1998	1.85	0.15	1.81	0.2
1999	1.18	0.506	*	*
2000	2.4	0.174	1.15	0.435
2001	1.23	0.423	1.27	0.382
2002	*	*	1.13	0.533
2003	1	0.5	1.21	0.321
2004	1.18	0.397	1.43	0.278
2005	1.26	0.312	1.38	0.25
2006	0.81	0.323	0.66	0.206
2007	1.3	0.348	1.36	0.313
2008	1.71	0.225	1.8	0.234
2009	1.28	0.155	0.85	0.216
2010	1.93	0.068	2.22	0.063
2011	*	*	*	*
2012	2.87	1.256	2.82	0.982
2013	1.97	0.476	2.13	0.553
2014	*	*	*	*
2015	1.35	0.21	0.83	0.286

* denotes insufficient number of age classes (less than three)

Table 11. Annual indices of American Shad from long-term monitoring program time-series. Smithfield Beach (Smithfield) and Raubsville occur on the Delaware River main stem, representing relative abundances (i.e., CPUE) from gill netting (shad/net-ft-hr *10,000) and electrofishing (shad/hr) efforts, respectively. The Raubsville CPUE is reported as a total and separated into PA and NJ CPUEs. Total passage is also reported for the Lehigh and Schuylkill rivers from fishway monitoring at the Easton and Fairmount dams, respectively. An electrofishing (shad/hr) survey is also accomplished in the tidal Schuylkill River immediately below the Fairmount Dam.

		Raubsville					
Year	Smithfield	Total	PA	NJ	Lehigh	Schuylkill	
	CPUE	CPUE	CPUE	CPUE	N	N	CPUE
1990	190.09						
1991	123.72						
1992	161.84						
1993	62.44						
1994	61.93				87		
1995	75.00				873		
1996	46.88				1141		
1997	54.89	26.32			1428		
1998	64.34				3293		
1999	31.69	13.96			2346		
2000	37.36	30.88	24.33	39.81	2094		
2001	33.93	48.48	40.05	78.41	4740		
2002	48.13				3314		9.72
2003	37.93				422		128.92
2004	25.34				754	91	197.20
2005	56.28				675	41	265.74
2006	26.31				2023	345	504.96
2007	40.31				1397	56	287.10
2008	33.01				408		177.09
2009	17.07				425	1485	449.67
2010	46.88	22.99	28.21	21.36	1935	2521	806.03
2011	72.08	15.06			558	3366	948.02
2012	73.54	46.59	35.87	55.36	2096	2227	314.90
2013	48.45	32.53	32.05	44.05	2364*	166	401.38
2014	49.38	27.24	24.67	51.19	1682*		468.55
2015	59.28	11.38	13.12	12.45	1430*		
* Total passage is estimated from electrofishing CPUE upriver in the Lehigh River.							

Table 12. Ages and relative abundance index for Smithfield Beach (sexes combined).

	Ages								Total	Relative
	2	3	4	5	6	7	8	9	aged	abundance
1996	0	1	8	42	26	12	4	0	93	46.88
1997	0	3	23	22	18	8	0	0	74	54.89
1998	0	1	25	114	46	15	9	0	210	64.34
1999	0	1	55	94	53	2	0	0	205	31.69
2000	0	4	42	122	114	48	7	0	337	37.36
2001	0	4	141	365	194	32	7	0	743	33.93
2002	0	2	21	115	175	46	12	1	372	48.13
2003	0	4	102	132	214	64	6	1	523	37.93
2004	0	2	48	199	99	64	6	0	418	25.34
2005	0	10	143	340	247	30	7	1	778	56.28
2006	0	2	81	146	72	45	3	0	349	26.31
2007	0	3	54	318	315	32	10	2	734	40.31
2008	0	1	65	212	304	68	3	0	653	33.01
2009	0	2	91	105	121	36	5	0	360	17.07
2010	0	0	45	656	73	9	2	0	785	46.88
2011	0	0	7	45	329	10	0	0	391	72.08
2012	0	0	4	165	29	180	6	2	386	73.54
2013	0	0	12	97	305	21	18	0	453	48.45
2014	0	0	77	111	168	132	1	0	489	49.38

Table 13. Smithfield Beach index at Age. Calculated by multiplying annual relative abundance index by the annual relative proportion of observed age class.

	Index at age - sexes combined			
	4	5	6	7
1996	4.03	21.17	13.11	6.05
1997	17.06	16.32	13.35	5.93
1998	7.66	34.93	14.09	4.60
1999	8.50	14.53	8.19	0.31
2000	4.66	13.52	12.64	5.32
2001	6.44	16.67	8.86	1.46
2002	2.72	14.88	22.64	5.95
2003	7.40	9.57	15.52	4.64
2004	2.91	12.06	6.00	3.88
2005	10.34	24.60	17.87	2.17
2006	6.11	11.01	5.43	3.39
2007	2.97	17.46	17.30	1.76
2008	3.29	10.72	15.37	3.44
2009	4.31	4.98	5.74	1.71
2010	2.69	39.18	4.36	0.54
2011	1.29	8.30	60.65	1.84
2012	0.76	31.44	5.53	34.29
2013	1.28	10.37	32.62	2.25
2014	7.78	11.21	16.96	13.33

Diagonal shading represents year classes

Table 14. Correlation values for non-tidal JAI indices vs lagged Smithfield Beach age class indices. Big 3 represents catches from the non-tidal Phillipsburg, Delaware Water Gap and Milford Beach seine sites.

	Pearson				Spearman			Power analysis n=16 sig.level=.05	
Correlation	r	t	df	p-value	r	s	p-value	Pearson	Spearman
Big3_GeoMean vs 4-5 yo	0.586	2.70	14	0.017	0.538	314	0.034	0.70	0.61
Big3_GeoMean vs 4-6 yo	0.646	3.17	14	0.007	0.659	232	0.007	0.81	0.83
Big3_GeoMean vs 4-7 yo	**0.660**	**3.29**	**14**	**0.005**	**0.753**	**168**	**0.001**	**0.83**	**0.95**
Big3_GLM vs 4-5 yo	0.394	1.60	14	0.131	0.350	440	0.180	0.34	0.27
Big3_GLM vs 4-6 yo	0.402	1.64	14	0.122	0.438	382	0.091	0.35	0.41
Big3_GLM vs 4-7 yo	**0.394**	**1.60**	**14**	**0.131**	**0.441**	**380**	**0.089**	**0.34**	**0.42**

Table 15. Lewis haul seine catch-per-unit effort (CPUE – catch per haul) for American Shad in the Delaware River from 1925 to 2015.

Year	CPUE		Year	CPUE		Year	CPUE
1925	1.62		1961	3.46		1997	11.96
1926	3.18		1962	13.89		1998	13.20
1927	2.43		1963	56.90		1999	4.60
1928	4.00		1964	18.29		2000	4.07
1929	4.39		1965	6.65		2001	6.84
1930	1.30		1966	1.75		2002	3.85
1931	1.77		1967	3.74		2003	5.23
1932	3.20		1968	1.22		2004	4.07
1933	5.54		1969	3.10		2005	2.89
1934	3.45		1970	4.88		2006	1.66
1935	13.47		1971	12.30		2007	3.38
1936	2.43		1972	5.44		2008	2.24
1937	9.29		1973	7.19		2009	2.57
1938	4.68		1974	8.51		2010	12.31
1939	8.77		1975	14.85		2011	1.93
1940	3.59		1976	11.95		2012	5.30
1941	0.80		1977	10.18		2013	26.63
1942	5.68		1978	10.13		2014	10.67
1943	14.07		1979	18.72		2015	8.68
1944	5.02		1980	12.97			
1945	2.05		1981	54.17			
1946	2.15		1982	29.83			
1947	3.79		1983	14.44		Time Series Average	9.89
1948	0.73		1984	15.68			
1949	0.09		1985	29.30		2006-2015 Average	7.54
1950	0.18		1986	30.67			
1951	0.66		1987	16.49			
1952	0.63		1988	35.62			
1953	0.00		1989	52.20			
1954	0.35		1990	25.35			
1955	0.84		1991	30.42			
1956	0.00		1992	50.96			
1957	0.83		1993	10.52			
1958	3.00		1994	7.90			
1959	1.13		1995	19.05			
1960	0.32		1996	3.67			

Table 16. Biological data collected by the Lewis haul seine fishery from their annual catches of American Shad at Lambertville, NJ as contracted by the Co-op. The count is not reflective of the total number caught, only those subsampled. Age was estimated from scale microstructure and was not determined for 2009 and 2015.

		Fork Length (mm)			Age		
Year	N	Min	Max	Avg	Min	Max	Avg
Female							
2008	48	469	602	543.9	4	7	5.5
2009	34	395	560	454.9			
2010	112	395	500	445.7	4	7	5.4
2011	27	410	518	475.1	4	7	5.5
2012	94	40	560	474.4	4	8	5.6
2013	237	410	575	474.5	4	7	5.3
2014	141	323	530	464.2	4	7	5.3
2015	98	154	558	466.1			
Male							
2008	30	377	539	474.7	3	6	4.8
2009	54	110	460	395.4			
2010	176	340	479	416.1	3	7	5.0
2011	16	383	490	426.2	3	6	5.1
2012	50	400	497	443.5	4	7	5.1
2013	182	346	485	431.0	3	6	4.5
2014	104	320	490	417.2	3	6	4.4
2015	147	276	485	413.8			

Table 17. New Jersey commercial fishing regulations for 2015.

System	Season	Gear Limits	Mandatory Reporting	Other Restrictions
Delaware Bay, River, & tidal tribs	Gill nets: Feb 1-Dec 15 ----------------- Haul Seine: Nov 1-Apr 30	Stretch mesh min.: 2.75” Feb 1-Feb 29 *3.25” Mar 1-Dec 15 Length: 2400’ Feb 12-May 15 1200’ May 16-Dec 15 --- 2.75" min. stretch mesh, max length 420'	YES	Limited entry; gear restrictions in defined areas

*except with special permit

Table 18. Number of permits issued to New Jersey fishermen and number reporting landings annually in the Delaware Bay 2000-2015.

Year	Total Permits Issued	Active Permits	Permits Reporting Landings
2000	-	-	28
2001	-	-	29
2002	-	-	21
2003	-	-	24
2004	-	-	24
2005	-	-	24
2006	-	-	25
2007	-	-	17
2008	-	-	14
2009	-	-	16
2012	83	51	11
2013	61	47	13
2014	61	47	11
2015	61	47	9

Table 19. Commercial landings in the state of New Jersey. Upper and lower bay landings are delineated by harvest occurring north and south of Gandys Beach, NJ.

Year	Total Landings (lbs)	Upper Bay Landings (lbs)	Lower Bay Landings (lbs)
1985	72,000	23,100	48,900
1986	81,600	17,700	63,900
1987	129,600	20,200	109,400
1988	98,000	17,300	80,700
1989	79,300	16,800	62,500
1990	253,113	40,364	212,749
1991	173,301	23,092	150,209
1992	155,800	41,765	114,035
1993	142,980	19,552	123,428
1994	50,371	9,066	41,305
1995	73,432	11,811	61,621
1996	18,663	1,100	17,563
1997	43,799	9,250	34,549
1998	14,255	75	14,180
1999	88,706	5,670	83,036
2000	121,431	43,299	78,132
2001	96,138	69,098	27,040
2002	48,417	32,746	15,671
2003	90,520	84,198	6,322
2004	97,458	92,073	5,385
2005	87,984	46,543	41,441
2006	66,154	56,847	9,307
2007	62,828	53,818	9,010
2008	29,034	23,877	5,157
2009	12,645	9,264	3,381
2010	12,220	7,721	4,499
2011	12,054	6,855	5,199
2012	27,368	19,923	7,445
2013	37,659	13,204	24,455
2014	42,378	37,319	5,059
2015	9,418	6,013	3,405

Table 20. New Jersey's gill net effort data for the American Shad commercial fishery.

Year	No. of Fishermen			No. of Man-days			Square Feet of Net			Pounds Harvested			Pounds/Square Foot		
	Upper Bay	Lower Bay	Comb.	Upper Bay	Lower Bay	Comb.	Upper Bay	Lower Bay	Comb.	Upper Bay	Lower Bay	Comb.	Upper Bay	Lower Bay	Comb.
2012	8	3	11	44	38	82	1,338,500	117,600	1,456,100	19,923	7,445	27,368	0.016	0.051	0.019
2013	9	4	13	54	55	109	1,369,040	654,000	2,023,040	13,204	24,455	37,659	0.018	0.020	0.019
2014	3	8	11	82	34	116	2,458,400	186,480	2,644,880	37,319	5,059	42,378	0.015	0.027	0.016
2015	7	2	9	52	38	90	1,357,200	256,000	1,613,400	6,013	3,405	9,418	0.004	0.013	0.006

Table 21. Fork length of American Shad captured in New Jersey's tagging gill net surveys.

Year	Number	Mean Fork Length (mm)			Range	Std. Dev.	Stretch Mesh (inches)
		Male	Female	Sexes Combined			
1995	107			483.70	405-605	30.8	5.5-6
1996	294			467.70	384-567	33.6	4.5-6
1997	500			448.40	346-600	34.1	5-6
1998	554			460.40	383-605	28.5	5-6
1999	753			465.10	375-563	26.2	5-5.75
2000	425			455.90	382-547	25.2	5-6
2001	663			474.10	396-615	29.6	5-6
2002	273	452.80	483.10	476.80	375-573	32.9	5-6
2003	170	451.40	477.40	472.20	401-538	27.1	5-6
2004	51	447.50	497.40	489.60	414-575	38.7	5-6.5
2005	220	445.20	477.50	470.60	402-586	36.7	5-6.5
2006	73	453.60	484.00	480.30	406-584	37.3	5.5
2007	42	444.50	478.20	476.60	426-571	32.9	5.5-6.5
2008	0						
2009	11	423.30	477.90	455.00	387-523	46.0	5-6
2010	85	430.90	457.90	447.10	366-518	32.3	5-6
2011	17	444.71	489.58	473.05	425-538	34.0	5-6
2012	18	435.67	485.67	477.33	459-515	26.7	5-6
2013	17		481.32	481.32	443-507	16.7	5.5-6
2014	18	444.25	485.77	476.11	395-525	33.6	5.5-6
2015	10	457.00	481.20	469.10	437-500	11.0	5.5-6

Table 22. Sex composition of New Jersey's commercial gill net shad landings: 1996–2015.

Year	Female (%)	Male (%)
1999	82.6	17.4
2000	86.0	14.0
2001	83.8	16.2
2002	69.4	30.6
2003	80.3	19.7
2004	77.9	22.1
2005	73.9	26.1
2006	79.5	20.5
2007	80.6	19.4
2008	77.5	22.5
2009	80.4	19.6
2010	67.2	32.8
2011	76.4	23.6
2012	85.6	14.4
2013	87.4	12.6
2014	90.7	9.3
2015	84.9	15.1
AVG	**80.2**	**19.8**

Table 23. Delaware's gill net effort for the American Shad commercial fishery. Upper and lower bay landings are delineated by harvest occurring north and south of Bowers Beach, DE.

Year	No. of Fishermen				No. Vessel Trips				Net Yards Fished				Pounds Harvested				Pounds/Net Yard			
	Upper Bay/River Anchor	Upper Bay/River Drift	Lower Bay Anchor	Lower Bay Drift	Upper Bay/River Anchor	Upper Bay/River Drift	Lower Bay Anchor	Lower Bay Drift	Upper Bay/River Anchor	Upper Bay/River Drift	Lower Bay Anchor	Lower Bay Drift	Upper Bay/River Anchor	Upper Bay/River Drift	Lower Bay Anchor	Lower Bay Drift	Upper Bay/River Anchor	Upper Bay/River Drift	Lower Bay Anchor	Lower Bay Drift
2003	18	12	8	2	271	85	117	4	71,145	32,743	85,100	2,500	38,290	5,161	18,742	118	0.54	0.16	0.22	0.05
2004	19	13	9	3	348	76	186	21	125,140	33,300	121,040	17,400	53,779	4,221	31,242	851	0.43	0.13	0.26	0.05
2005	23	23	4	3	302	270	107	69	138,440	129,900	68,310	62,400	46,377	22,961	35,114	19,113	0.33	0.18	0.51	0.31
2006	26	12	8	7	308	121	154	37	117,325	59,050	107,820	36,400	18,265	2,211	8,814	1,235	0.16	0.04	0.08	0.03
2007	23	17	6	8	270	114	135	67	117,540	41,100	99,275	50700	49,668	7,157	10,402	4,211	0.42	0.17	0.10	0.08
2008	22	15	3	6	212	108	5	49	65,689	45,870	3,800	30,675	13,930	2,137	34	2,232	0.21	0.05	0.01	0.07
2009	19	14	2	6	99	38	5	22	30,352	22,450	5,000	20,200	2,032	404	92	918	0.07	0.02	0.02	0.05
2010	13	12	1	4	85	54	12	24	40,800	30,250	3,050	23,000	1,529	1,694	409	1,387	0.04	0.06	0.13	0.06
2011	17	10	1	5	98	50	13	33	30,830	19,400	5,200	28,600	3,531	1,721	1,159	2,722	0.11	0.09	0.22	0.10
2012	10	7	0	6	63	45	0	28	21,850	24,050	0	18,400	1,216	1,095	0	429	0.06	0.05	0.00	0.02
2013	10	9	0	3	45	63	0	18	14,900	31,000	0	17,200	778	1,715	0	784	0.05	0.06	0.00	0.05
2014	11	4	1	5	173	13	1	44	97,435	6,300	1,000	36,800	83,400	299	2	2,093	0.86	0.05	0.00	0.06
2015	11	4	0	4	143	27	0	20	96,500	20,380	0	17,000	21,091	420	0	254	0.22	0.02	0.00	0.01

Table 24. Number of permits issued to Delaware fishermen and number reporting American Shad landings annually.

Year	Total Permits Issued	Active Permits	Permits Reporting Landings
2000	110	84	56
2001	111	75	53
2002	108	72	46
2003	110	70	41
2004	110	66	44
2005	111	67	52
2006	111	63	45
2007	111	59	41
2008	111	56	38
2009	111	60	35
2010	111	56	29
2011	111	56	30
2012	111	59	20
2013	111	54	20
2014	111	52	19
2015	111	51	19

Table 25. Commercial landings in the state of Delaware. Upper and lower bay landings are delineated by harvest occurring north and south of Bowers Beach, DE.

Year	Total Landings (lbs)	Upper Bay Landings (lbs)	Lower Bay Landings (lbs)
1985	168,483	168,483	0
1986	179,511	179,511	0
1987	180,582	180,582	0
1988	229,302	229,302	0
1989	187,787	187,787	0
1990	384,855	384,855	0
1991	364,385	364,385	0
1992	220,014	220,014	0
1993	233,449	233,449	0
1994	196,140	196,140	0
1995	146,328	146,328	0
1996	165,474	165,474	0
1997	116,516	116,516	0
1998	84,813	84,813	0
1999	76,222	76,222	0
2000	53,887	53,887	0
2001	201,834	201,834	0
2002	38,710	35,466	3,244
2003	62,422	43,562	18,860
2004	90,093	58,000	32,093
2005	123,610	69,383	54,227
2006	30,525	20,476	10,049
2007	71,438	56,825	14,613
2008	18,339	16,067	2,272
2009	3,446	2,436	1,010
2010	5,019	3,223	1,796
2011	9,133	5,252	3,881
2012	2,740	2,311	429
2013	3,732	2,943	789
2014	85,794	83,699	2,095
2015	21,765	21,511	254

Table 26. The State of Delaware summary of biological data collected from New Jersey commercial fishers: 1999-2015.

Year	Number	Mean TL (mm)	Mean WT (lbs)
1999	370	510	4.8
2000	250	506	N/A
2001	250	521	3.5
2002	189	517	N/A
2003	186	528	4.0
2004	37	548	4.6
2005	190	539	4.6
2006	294	523	5.3
2007	245	512	4.9
2008	N/A	N/A	N/A
2009	N/A	N/A	N/A
2010	150	510	N/A
2011	335	534	4.3
2012	432	541	4.2
2013	251	533	3.5
2014	270	473	3.0
2015	299	507	2.8

Table 27. Landings of Delaware River stock of American Shad from 1985-2015. Delaware River stock consists of 100% of upper bay landings and 40% of lower bay landings from Delaware and New Jersey combined. Landings are separated relative to the Bowers Beach, DE to Gandys Beach, NJ line.

Year	Upper Bay Landings Combined (lbs)	Lower Bay Landings Combined (lbs)	Total Delaware River Stock Landings (lbs)	Delaware River Stock Landings in New Jersey	Delaware River Stock Landings in Delaware
1985	191,583	48,900	211,143	20%	80%
1986	197,211	63,900	222,771	19%	81%
1987	200,782	109,400	244,542	26%	74%
1988	246,602	80,700	278,882	18%	82%
1989	204,587	62,500	229,587	18%	82%
1990	425,219	212,749	510,319	25%	75%
1991	387,477	150,209	447,561	19%	81%
1992	261,779	114,035	307,393	28%	72%
1993	253,001	123,428	302,372	23%	77%
1994	205,206	41,305	221,728	12%	88%
1995	158,139	61,621	182,787	20%	80%
1996	166,574	17,563	173,599	5%	95%
1997	125,766	34,549	139,586	17%	83%
1998	84,888	14,180	90,560	6%	94%
1999	81,892	83,036	115,106	34%	66%
2000	97,186	78,132	128,439	58%	42%
2001	270,932	27,040	281,748	28%	72%
2002	68,212	18,915	75,778	51%	49%
2003	127,760	25,182	137,833	63%	37%
2004	150,073	37,478	165,064	57%	43%
2005	115,926	95,668	154,193	41%	59%
2006	77,323	19,356	85,065	71%	29%
2007	110,643	23,623	120,092	48%	52%
2008	39,944	7,429	42,916	60%	40%
2009	11,700	4,391	13,456	79%	21%
2010	10,944	6,295	13,462	71%	29%
2011	12,107	9,080	15,739	57%	43%
2012	22,234	7,874	25,384	90%	10%
2013	16,147	25,244	26,245	88%	12%

Table 27. Cont.

Year	Upper Bay Landings Combined (lbs)	Lower Bay Landings Combined (lbs)	Total Delaware River Stock Landings (lbs)	Delaware River Stock Landings in New Jersey	Delaware River Stock Landings in Delaware
2014	121,018	7,154	123,880	32%	68%
2015	27,524	3,659	28,988	25%	75%

Table 28. Delaware Stock landings, Smithfield Beach CPUE and the Ratio of the landings divided by Smithfield CPUE divided by 100.

Year	Delaware Stock Landings	Smithfield Beach CPUE	Ratio
1990	510,319	190.1	26.8
1991	447,561	123.7	36.2
1992	307,393	161.8	19.0
1993	302,372	62.4	48.4
1994	221,728	61.9	35.8
1995	182,787	75.0	24.4
1996	173,599	46.9	37.0
1997	139,586	54.9	25.4
1998	90,560	64.3	14.1
1999	115,106	31.7	36.3
2000	128,439	37.4	34.4
2001	281,748	33.9	83.0
2002	75,778	48.1	15.7
2003	137,833	37.9	36.3
2004	165,064	25.3	65.1
2005	154,193	56.3	27.4
2006	85,065	26.3	32.3
2007	120,092	40.3	29.8
2008	42,916	33.0	13.0
2009	13,456	17.1	7.9
2010	13,462	46.9	2.9
2011	15,739	72.1	2.2
2012	25,384	73.5	3.5
2013	26,245	48.5	5.4
2014	123,880	49.4	25.1
2015	28,988	59.3	4.9
2006-2015 Average	49,523	46.6	12.7
1990-2015 Average	151,127	60.7	26.6

Table 29. American Shad tag returns, by year, from fish tagged in Delaware Bay: 1995-2015.

Year	American Shad Tagged	Recaptures
1995	107	10
1996	294	14
1997	500	36
1998	554	38
1999	753	46
2000	425	32
2001	663	35
2002	273	15
2003	170	7
2004	51	0
2005	220	9
2006	73	2
2007	42	1
2008	0	0
2009	11	1
2010	85	3
2011	17	0
2012	18	0
2013	17	0
2014	18	2
2015	10	1

Table 30. Recaptures of American Shad tagged and released in the Delaware Bay.

Recapture Location	Number of Reports	Percent of Reports
St. Lawrence River, Quebec	1	0.4
New Brunswick, Canada	3	1.2
Shubenacadie River, Nova Scotia	1	0.4
Atlantic Ocean and Rivers, RI	3	1.2
Connecticut River	40	16.3
Hudson River	43	17.5
Atlantic Ocean, NY	2	0.8
Atlantic Ocean, NJ	38	15.4
Delaware Bay/River	98	39.8
Atlantic Ocean, DE	4	1.6
Atlantic Ocean, MD	2	0.8
Atlantic Ocean, VA	1	0.4
Chesapeake Bay and Tribs	7	2.8
Atlantic Ocean and Rivers, NC	2	0.8
Santee River, SC	1	0.4

Table 31. Commercial landings (pounds) of American Shad reported to the State of Delaware, with the harvest that occurred at Mid Bay and above (Bowers Beach to the Delaware state line), Upper Bay and above (Port Mahon to the Delaware state line), and Lower Bay (Bowers Beach to the mouth of Delaware Bay).

	Pounds Landed				Percent of Landings		
Year	Total Landings	Upper Bay and North	Mid-Bay and North	Lower Bay	Upper Bay and North	Mid-Bay and North	Lower Bay
1985	168,483	168,483	168,483	0	100	100	0
1986	179,511	179,511	179,511	0	100	100	0
1987	180,582	180,582	180,582	0	100	100	0
1988	229,302	229,302	229,302	0	100	100	0
1989	187,787	187,787	187,787	0	100	100	0
1990	384,855	384,855	384,855	0	100	100	0
1991	364,385	364,385	364,385	0	100	100	0
1992	220,014	220,014	220,014	0	100	100	0
1993	233,449	233,449	233,449	0	100	100	0
1994	196,140	196,140	196,140	0	100	100	0
1995	146,328	146,328	146,328	0	100	100	0
1996	165,474	165,474	165,474	0	100	100	0
1997	116,516	116,516	116,516	0	100	100	0
1998	84,813	84,813	84,813	0	100	100	0
1999	76,222	76,222	76,222	0	100	100	0
2000	53,887	53,887	53,887	0	100	100	0
2001	201,834	201,834	201,834	0	100	100	0
2002	38,710	34,832	35,466	3,244	90	92	8
2003	62,422	37,397	43,562	18,860	60	70	30
2004	90,093	41,732	58,000	32,093	46	64	36
2005	123,610	45,572	69,383	54,227	37	56	44
2006	30,525	16,516	20,476	10,049	54	67	33
2007	71,438	52,748	56,825	14,613	74	80	20
2008	18,339	12,793	16,067	2,272	70	88	12
2009	3,446	1,385	2,436	1,010	40	71	29
2010	5,019	1,204	3,223	1,796	24	64	36
2011	9,133	3,005	5,252	3,881	33	58	42
2012	2,740	1,605	2,311	429	59	84	16
2013	3,732	1,685	2,943	789	45	79	21
2014	85,794	14,708	83,699	2,095	17	98	2
2015	21,765	19,484	21,511	254	90	99	1

Table 32. Recapture locations of Hudson River and Delaware Bay tagged American Shad from 1995-2015.

	Tagging Location	
	Hudson River	Delaware Bay
Total Recaptured	172	246
Number of Hudson River Tagged Recaptures	151	43
Percent of Hudson River Tagged Recaptures	87.8%	17.5%
Number of Delaware Bay Tagged Recaptures	5	98
Percent of Delaware Bay Tagged Recaptures	2.9%	39.8%
Number of Tagged Shad Recaptured outside of Delaware Bay or Hudson	16	105
Percent of Tagged Shad Recaptured outside of Delaware Bay or Hudson	9.3%	42.7%
Recaptures in Delaware River/Bay		
Number North of Leipsic/Gandys Line	0	63
Percent North of Leipsic/Gandys Line	0.0%	25.6%
Number North of Bowers/Gandys Line	1	65
Percent North of Bowers/Gandys Line	0.6%	26.4%
Number South of Bowers/Gandys Line	4	23
Percent South of Bowers/Gandys Line	2.3%	9.4%
Number from Unk. Delaware Bay/River Location	0	10
Percent from Unk. Delaware Bay/River Location	0.0%	4.1%

Table 33. Total American Shad landings (pounds) by state and reporting region and the assignments of landings to Delaware River and mixed stock fisheries.

Year	Total Landings	New Jersey Upper Bay Landings	New Jersey Lower Bay Landings	Delaware Upper Bay Landings	Delaware Lower Bay Landings	Harvest North of Demarcation	Harvest South of Demarcation	Harvest of Delaware Stock	Harvest of Mixed Stock
1985	240,483	23,100	48,900	168,483	0	191,583	48,900	211,143	29,340
1986	261,111	17,700	63,900	179,511	0	197,211	63,900	222,771	38,340
1987	310,182	20,200	109,400	180,582	0	200,782	109,400	244,542	65,640
1988	327,302	17,300	80,700	229,302	0	246,602	80,700	278,882	48,420
1989	267,087	16,800	62,500	187,787	0	204,587	62,500	229,587	37,500
1990	637,968	40,364	212,749	384,855	0	425,219	212,749	510,319	127,649
1991	537,686	23,092	150,209	364,385	0	387,477	150,209	447,561	90,125
1992	375,814	41,765	114,035	220,014	0	261,779	114,035	307,393	68,421
1993	376,429	19,552	123,428	233,449	0	253,001	123,428	302,372	74,057
1994	246,511	9,066	41,305	196,140	0	205,206	41,305	221,728	24,783
1995	219,760	11,811	61,621	146,328	0	158,139	61,621	182,787	36,973
1996	184,137	1,100	17,563	165,474	0	166,574	17,563	173,599	10,538
1997	160,315	9,250	34,549	116,516	0	125,766	34,549	139,586	20,729
1998	99,068	75	14,180	84,813	0	84,888	14,180	90,560	8,508
1999	164,928	5,670	83,036	76,222	0	81,892	83,036	115,106	49,822
2000	175,318	43,299	78,132	53,887	0	97,186	78,132	128,439	46,879
2001	297,972	69,098	27,040	201,834	0	270,932	27,040	281,748	16,224
2002	87,127	32,746	15,671	35,466	3,244	68,212	18,915	75,778	11,349
2003	152,942	84,198	6,322	43,562	18,860	127,760	25,182	137,833	15,109

Table 33. Cont.

Year	Total Landings	New Jersey Upper Bay Landings	New Jersey Lower Bay Landings	Delaware Upper Bay Landings	Delaware Lower Bay Landings	Harvest North of Demarcation	Harvest South of Demarcation	Harvest of Delaware Stock	Harvest of Mixed Stock
2004	187,551	92,073	5,385	58,000	32,093	150,073	37,478	165,064	22,487
2005	211,594	46,543	41,441	69,383	54,227	115,926	95,668	154,193	57,401
2006	96,679	56,847	9,307	20,476	10,049	77,323	19,356	85,065	11,614
2007	134,266	53,818	9,010	56,825	14,613	110,643	23,623	120,092	14,174
2008	47,373	23,877	5,157	16,067	2,272	39,944	7,429	42,916	4,457
2009	16,091	9,264	3,381	2,436	1,010	11,700	4,391	13,456	2,635
2010	17,239	7,721	4,499	3,223	1,796	10,944	6,295	13,462	3,777
2011	21,187	6,855	5,199	5,252	3,881	12,107	9,080	15,739	5,448
2012	30,108	19,923	7,445	2,311	429	22,234	7,874	25,384	4,724
2013	41,391	13,204	24,455	2,943	789	16,147	25,244	26,245	15,146
2014	128,172	37,319	5,059	83,699	2,095	121,018	7,154	123,880	4,292
2015	31,183	6,013	3,405	21,511	254	27,524	3,659	28,988	2,195
2006-2015 Average	56,369	23,484	7,692	21,474	3,719	44,958	11,411	49,523	6,846
Time Series Average	196,289	27,730	47,387	116,475	4,697	144,206	52,084	165,039	31,250

Table 34. Recreational catch in the Delaware River by various investigators. Upper Delaware River: the non-tidal reach upriver of Port Jervis, New York (RM 253.6); non-tidal: above head-of-tide at Trenton, New Jersey (RM 133.4); tidal: below head-of-tide; and Delaware River: boundary waters of Eastern Pennsylvania.

Year	River reach	No. anglers	Total catch	Total Harvest	Catch rate (shad/hr)
Marshall (1971)					
1971	Non-tidal		25,204		
Lupine et al (1980)					
1980			7,386		0.47
Lupine et al (1981)					
1981			12,767		0.67
Hoopes et al. (1983)					
1982	Upper Del. River		37,323	31,725	
Miller and Lupine (1988)					
1986	Non-tidal	65,690	56,320	27,471	0.19
NJDEP (1993)					
1992			46,780	5,146	1.10
Miller and Lupine (1996)					
1995	Non-tidal		83,141	16,628	0.25
NJDFW (2001)					
2000					0.77
Volstad et al. (2003)					
2002	Non-tidal		34,091	6,312	0.13
2002	Tidal		1,190	315	0.008
PFBC/NPS Angler Diary					
2001	Del. R.	62	1,375	81	0.11
2002	Del. R.	52	708	67	0.06
2003	Del. R.	50	345	24	0.03
2004	Del. R.	45	330	36	0.03
2005	Del. R.	42	330	12	0.03
2006	Del. R.	35	35	0	0.01
2007	Del. R.	41	359	16	0.05
2008	Del. R.	33	207	14	0.02
2009	Del. R.	36	569	6	0.10
2010	Del. R.	30	216	14	0.04
2011	Del. R.	34	112	2	0.02
2012	Del. R.	14	19	19	0.002
2013	Del. R.	23	46	46	0.004
2014	Del. R.	9	13	13	0.001

Table 35. Recreational harvest of American Shad in the Delaware Estuary & Bay, as estimated by the Marine Recreational Information Reporting program. Total harvest reflected the estimated numbers of fish taken, per year. The Proportional standard error (PSE) express the standard error of an estimate as a percentage of the estimate and is a measure of precision. A PSE value greater than 50 indicates a very imprecise estimate.

	Delaware		New Jersey	
Year	Total Harvest	PSE	Total Harvest	PSE
1989			0	
1990				
1991	0			
1992	0			
1993				
1994	2,018	57.1	9,871	59.5
1995				
1996				
1997			2,242	100.0
1998				
1999	760	76.1		
2000			0	
2001			14,383	64.1
2002	2,068	61.7		
2003	3,577	100.0		
2004	0			
2005	0			
2006	0			
2007	0			
2008	0			
2009			0	
2010	1,724	103.3	7,678	99.0
2011	3,194	101.9		
2012			4,110	99.7
2013	0			

Table 36. River herring and shad catch by Atlantic Mackerel and Atlantic herring vessels, 2014 - 2015. Data summarized by NMFS from vessels via the Vessel Monitoring System (VMS), the Vessel Trip Report System (VTR), Dealer Reports, and the Northeast Fisheries Observer Program.

Estimated river herring/shad catch (mt)	**2014**	**2015**
Atlantic mackerel vessels	6.42	12.87
Atlantic herring vessels - ALL	N/A	176.5
Atlantic herring: GOM Mid-water trawl	N/A	11.1
Atlantic herring: Cape Cod Mid-water trawl	N/A	0.7
Atlantic herring: Southern New England bottom trawl	N/A	100.7
Atlantic herring: Southern New England mid-water trawl	N/A	64

Table 37. River herring and shad quotas for Atlantic Mackerel and Atlantic herring vessels, 2014-2015, and anticipated quota for Atlantic herring vessels 2016-2018.

Annual harvest cap for river herring/shad (mt)	**2014**	**2015**	**2016-18 (proposed)**
Atlantic mackerel vessels	236	89	82
Atlantic herring vessels - ALL	312	312	361
Atlantic herring: GOM Mid-water trawl	86	86	76.7
Atlantic herring: Cape Cod Mid-water trawl	13	13	32.4
Atlantic herring: Southern New England bottom trawl	89	89	122.3
Atlantic herring: Southern New England mid-water trawl	124	124	129.6

Table 38. Species-specific total annual incidental catch (mt) across all fleets and regions. Midwater trawl estimates were only included beginning in 2005. Modified from Amendment 14 of the Atlantic Mackerel, squid and butterfish Fishery Management Plan for the Mid Atlantic Fishery Management Council.

Year	Alewife Catch (mt)	American Shad Catch (mt)	Blueback Herring Catch (mt)	Herring Unk. Catch (mt)	Hickory Shad Catch (mt)	Total Catch (mt)	Total identified catch (mt)	Proportion of known catch that is American Shad	Estimated unknown catch that is American Shad (mt)	Total estimated American Shad catch (mt)
1989	20.4	58.9	19.6	7.1	0.0	106.0	98.9	0.60	4.2	63.1
1990	55.3	25.8	78.9	331.3	0.0	491.4	160.1	0.16	53.4	79.2
1991	68.2	104.3	115.4	110.5	39.4	437.7	327.3	0.32	35.2	139.5
1992	30.6	79.8	458.2	387.5	0.0	956.1	568.5	0.14	54.4	134.2
1993	40.5	51.0	210.6	18.6	0.0	320.6	302.0	0.17	3.1	54.1
1994	5.5	70.3	40.2	9.8	0.2	126.0	116.2	0.61	5.9	76.2
1995	6.4	17.2	213.5	51.9	0.0	288.9	237.1	0.07	3.8	20.9
1996	482.0	40.0	1803.4	28.7	26.6	2380.8	2352.1	0.02	0.5	40.5
1997	41.3	37.0	982.0	67.6	18.3	1146.2	1078.6	0.03	2.3	39.3
1998	80.9	55.3	49.3	0.4	39.2	225.1	224.7	0.25	0.1	55.4
1999	3.9	15.7	206.7	128.8	56.8	411.8	283.0	0.06	7.2	22.9

Table 38. Cont.

Year	Alewife Catch (mt)	American Shad Catch (mt)	Blueback Herring Catch (mt)	Herring Unk. Catch (mt)	Hickory Shad Catch (mt)	Total Catch (mt)	Total identified catch (mt)	Proportion of known catch that is American Shad	Estimated unknown catch that is American Shad (mt)	Total estimated American Shad catch (mt)
2000	28.4	74.4	55.5	22.0	0.1	180.2	158.3	0.47	10.3	84.7
2001	93.0	61.9	120.1	2.1	80.6	357.8	355.7	0.17	0.4	62.3
2002	2.7	24.1	173.2	76.5	1.4	277.9	201.4	0.12	9.1	33.2
2003	248.4	21.4	332.5	15.3	14.3	631.9	616.6	0.03	0.5	21.9
2004	99.7	18.2	81.5	176.7	35.0	411.2	234.5	0.08	13.7	31.8
2005	347.4	78.2	220.0	7.2	19.4	672.3	665.1	0.12	0.8	79.1
2006	57.6	29.3	187.5	232.0	13.4	519.8	287.7	0.10	23.6	52.9
2007	484.0	55.1	180.1	105.3	4.8	829.3	724.0	0.08	8.0	63.1
2008	145.0	52.4	526.6	328.0	7.8	1059.8	731.8	0.07	23.5	75.9
2009	158.7	59.5	202.0	180.1	10.9	611.2	431.1	0.14	24.9	84.4
2010	118.5	46.1	125.0	86.5	1.1	377.3	290.8	0.16	13.7	59.8

Table 39. Estimated American Shad harvest (mt), based on median rate of known shad bycatch 1989-2010 applied to actual harvest in 2014-2015.

Estimated American Shad catch (mt)	**2014**	**2015**
Atlantic mackerel vessels	0.83	1.67
Atlantic herring vessels - ALL	N/A	22.9
Atlantic herring: GOM Mid-water trawl	N/A	1.44
Atlantic herring: Cape Cod Mid-water trawl	N/A	0.09
Atlantic herring: Southern New England bottom trawl	N/A	13.09
Atlantic herring: Southern New England mid-water trawl	N/A	8.32

Table 40. Number of American Shad fry stocked in the Delaware River Basin.

Year	Delaware	Lehigh	Schuylkill
1985		600,000	251,980
1986		549,880	246,400
1987		489,980	194,575
1988		340,400	
1989		2,087,700	316,810
1990		793,000	285,100
1991		793,000	75,000
1992		353,000	3,000
1993		789,600	
1994		642,200	
1995		1,044,000	
1996		993,000	
1997		1,247,000	
1998		948,000	
1999		501,000	410,000
2000		447,900	535,990
2001		675,625	490,901
2002		85,025	2,000
2003		783,013	1,000,448
2004		366,414	521,583
2005	169,802	668,792	545,459
2006	52,782	293,083	253,729
2007	47,587	276,000	540,655
2008	158,151	696,785	486,774
2009		210,584	161,938
2010		347,522	380,000
2011		473,366	643,361
2012		301,112	200,429
2013		402,089	338,084
2014		584,730	439,136
2015		247,649	198,855

Table 41. Hatchery contribution for adult American Shad collected from the Delaware River (Smithfield Beach and Raubsville), the Lehigh River, and the Schuylkill River.

Location Gear	Smithfield Beach gill net		Raubsville electro.		Lehigh R electro.		Schuylkill R electro.	
Year	N	Percent	N	Percent	N	Percent	N	Percent
1997	88	0.00%	No collections		No collections			
1998	234	3.80%	No collections		No collections			
1999	208	0.00%	8	5.30%	104	91.00%		
2000	330	3.00%	14	10.90%	99	91.00%		
2001	198	4.00%	12	8.30%	103	92.00%		
2002	378	1.10%	No collections		99	89.00%		
2003	245	7.80%	No collections		No collections			
2004	414	1.20%	No collections		60	80.00%		
2005	776	0.50%	No collections		13	62.00%		
2006	350	1.40%	No collections		55	73.00%		
2007	746	2.80%	No collections		40	58.00%	22	91.6%
2008	667	1.00%	No collections		41	51.00%	28	100%
2009	367	1.10%	No collections		27	63.00%	24	96.0%
2010	470	0.20%	1	0.90%	96	67.00%	25	100%
2011	409	0.50%	0	0.00%	16	56.00%	22	88.0%
2012	412	1.00%	80	2.50%	62	42.60%	21	84.0%
2013	454	0.20%	146	2.70%	76	73.70%	25	84.0%
2014	488	1.40%	129	3.10%	80	58.80%	25	88.0%
2015	Not Examined		62	0.0%	62	32.3%	4	100 %

Table 42. American Shad impingement and entrainment data for selected water intake structures for power generation facilities on the Delaware River and major tributaries.

		During Study		Annual Estimates	
Power Generation Facility	Years of Data Collection	Number Entrained	Number Impinged	Number Entrained	Number Impinged
Cromby Phoenixville, PA*	2005/2006	0	47	0	716
Delaware City Refinery New Castle, DE	1998/2000	Not reported	417	Not reported	Not reported
Eddystone Eddystone, PA	2005/2006	76	95	2,044,000	657
Edge Moor Wilmington, DE	1999/2001	43	3,684	Not reported	Not reported
Fairless Hills Fairless Hills, PA	2005/2006	170	0	892,422	0
Salem Salem, NJ	2002/2004	0	Not reported	0	88,189
Schuylkill Philadelphia, PA	2005/2006	0	6	0	398
Trainer Refinery Trainer, PA	2001	12,716,936	0	Not reported	Not reported

*Cromby is located on the Schuylkill River which currently has very limited American Shad upstream passage. Impingement occurs on hatchery stocked individuals at this time.

Appendix A: Delaware River American Shad (*Alosa sapidissima*) Ageing Protocol

Delaware River American Shad (*Alosa sapidissima*) **Ageing Protocol**

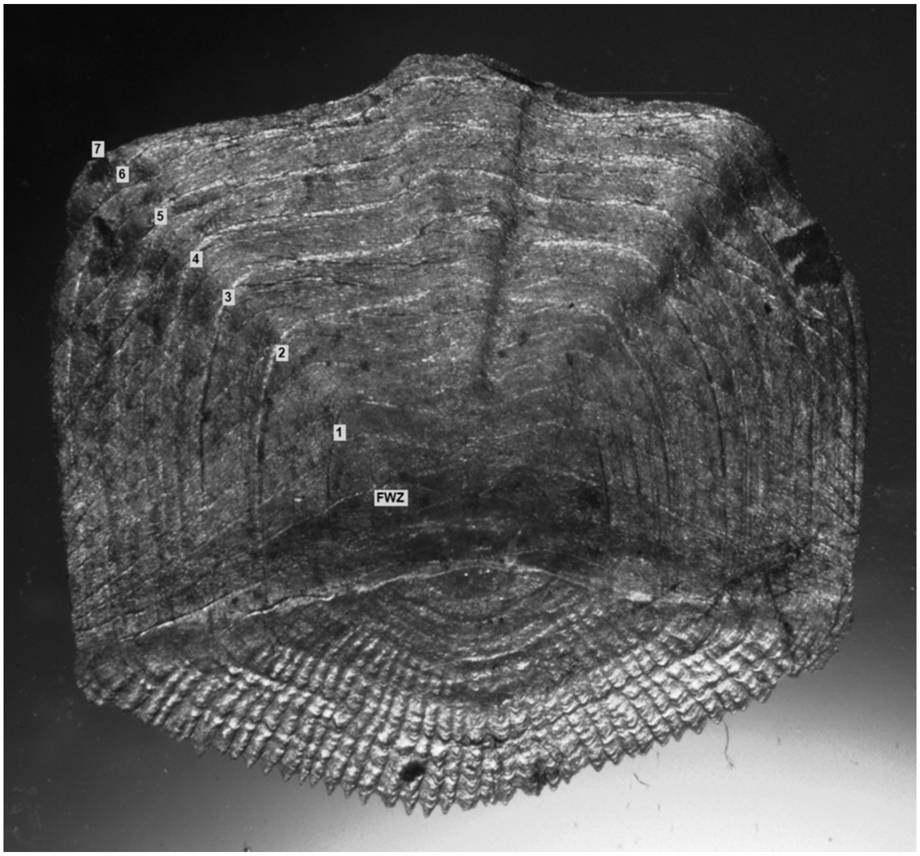
Prepared by:

The Delaware River Basin Fish & Wildlife Management Cooperative

Delaware Division of Fish and Wildlife • New Jersey Division of Fish and Wildlife

Pennsylvania Fish and Boat Commission • New York Division of Fish, Wildlife & Marine Resources

U.S. Fish and Wildlife Service • National Marine Fisheries Service



December 15, 2014

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I. Introduction

American Shad (*Alosa sapidissima*), an anadromous fish, return to their natal freshwaters in the spring for spawning. Eggs, fry and young-of-the-year (YOY) juveniles develop in freshwater during summer. Juveniles subsequently emigrate to estuarine/oceanic waters in fall. Adults reside in the coastal waters of the eastern Atlantic Ocean, seasonally migrating up/down the coastline. Indigenous to the Delaware River basin, shad are considered iteroparous spawners, meaning many individual adults perish after spawning; whereas, other adults survive, returning to oceanic waters until migrating into freshwater again in following year(s) for spawning. Yearling shad, however, are known to reside in estuarine waters.

American Shad are critical for maintaining the ecological and cultural integrity of coastal river systems. Returning adults and subsequent eggs, fry, and juveniles are a vital forage basis for a plethora of aquatic and terrestrial predators and scavengers, throughout the early spring through late fall. American Shad are also a desired gamefish and contribute significantly to the cultural and recreational values of the Delaware River fisheries. Thus, supporting a solid self-sustaining population of American Shad translates into a robust forage basis and fisheries opportunities for river systems.

Within the Delaware River, management of American Shad is a joint effort among the Delaware River Basin Fish and Wildlife Management Cooperative (Co-op), under the direction of the Atlantic States Marine Fisheries Commission (ASMFC). In February 2012, the ASMFC accepted the Co-op's American Shad Sustainability Plan (SFP). Population benchmarks and management actions are detailed in the SFP for the sustainability of the Delaware River American Shad population and fisheries.

The SFP identified the need for developing age-based benchmarks. Prior to the SFP, ageing American Shad scales and otoliths were accomplished on an *ad hoc* basis. Most scale/otolith (>1,000 annually) collections were accomplished by the Pennsylvania Fish and Boat Commission (PFBC) at Smithfield Beach (RM 218) and/or Raubsville (RM 176). Both sites are located well above head-of-tide at Trenton Falls (RM 133). Scales from these sites tend to be heavily damaged due to reabsorption/erosion of scale edge material. It is believed, shad reabsorbed scale material to support the energetic cost associated with their upstream migration into freshwater, in some cases over 200 miles upriver to Hancock, New York (RM 330), and then be able to successfully reproduce. The New Jersey Division of Fish and Wildlife (NJDFW) also annually collects samples from the lower Delaware

Estuary; and the Delaware Department of Natural Resources and Environmental Control (DNREC) annually purchases scale samples from shad bycatch in the Delaware Estuary Striped Bass fishery. Each agency individually collected and aged their samples, with little inter-agency discussion of ageing protocols or quality controls.

The interpretation of scale microstructure is an arduous task. Historically, ageing protocols were largely reliant on methods described by Cating (1956). Annuli of a particular age, Ages 1 - 3, were identified by counting transverse grooves above the base line. Each annulus was assigned based on the counts. For example, Age 2 was defined to be between approximately 8 – 11 (average 10) transverse grooves. McBride *et al*. (2005), and Duffy *et al*. (2012,) questioned the validity of ageing American shad by scales, suggesting annuli were not related to transverse groove counts. The inconclusiveness of ageing shad scales in the Delaware River prevented inclusion of age-based benchmarks in the 2007 ASMFC American shad stock assessment (ASMFC 2007). Since 2007, scales and otoliths have been annually collected by Co-op members and aged (*ad hoc* basis), but remained unused for management purposes.

Concomitantly, PFBC was ageing American shad otoliths. Known-age shad were derived from chemical marking (OTC) daily tagging patterns in fry otoliths, which were then stocked in the Lehigh and Schuylkill rivers, tributaries to the Delaware River. Returning adult shad were harvested and origin and year-of-release was determined by the presence of the daily tagging pattern. Daily tagging patterns required grinding the otolith to view the core; whereas, ageing was accomplished by viewing the whole otolith. Known-age was the simple subtraction of year-at-capture minus year-of-release. Yet, known-age otoliths, gave no indication of which otolith microstructures were true annuli versus false/double bands. Ambiguity in correctly identifying true otolith annuli and how to assign Age 1 resulted in readers' under- or over-estimating the known-age, typically by a single year. Furthermore, repeat spawning cannot be ascertained from otoliths, only from scales. Poor agreement was also found between estimates of age derived by scales to known-age totals. Hence, the utility of otoliths for ageing Delaware River American shad has limited success or acceptance.

Since the implementation of the SFP, the Co-op has begun revisiting ageing Delaware River American shad scales. The goal was to determine if Co-op members could consistently age American shad via scales under a single agreed upon set of protocols. In September 2012, an initial two-day ageing workshop was held (Hancock, New York) by Co-op members. Scales and otoliths were viewed by the collective group, with extensive discussions on how each agency identified and aged scales and otoliths. Personnel were in general agreement on interpreting various scale microstructures; assignment of Age 1 was quickly identified as problematic among agencies. A review of otoliths also quickly revealed similar problematic issues. Co-op members decided to focus on pursuing scales for determining shad ages. A follow up ageing workshop was held a year later (September 2013 at Hancock, New York) were scales and protocols were further discussed.

An outcome of the second ageing workshop was a blind test set of scales and initial set of ageing protocols. The intent of the blind test set was to provide a measure of agreement between agency personnel. Only date, location-of-capture and scales were included. Scales were randomly selected by size class from four locations: Smithfield Beach (n = 25), Raubsville (n = 25), Lambertville (n = 25), and upper Delaware Estuary (n = 25). Personnel with various levels of experience ageing American shad scales then derived ages and frequency of repeat spawning marks for each scale. Agencies were allowed to age the scales using their own preferred methods, but all readers would age the same scale samples.

Comparison of age assignments among readers were analyzed using a standard precision template developed by NOAA's Northeast Fisheries Science Center. Templates can be found at http://www.nefsc.noaa.gov/fbp/age-prec/. Precision was evaluated by examination of the mean coefficient of variation (CV), percent agreement and the Bowker's test of symmetry. Ageing laboratories around the world view a measure of mean CV of 5% or less to be acceptable (Compana (2001). Mean CV's of the blind test set ranged from 3.66% and 21.14%. Percent agreement ranged from 76% agreement to 4 % agreement. Readers from within the same agency consistently had the lowest CV's and highest percent agreement. Readers with minimal experience ageing shad scales consistently had the highest CV's and lowest percent agreement when compared to all readers regardless of experience. Therefore, age determinations of inexperienced readers must be interpreted with caution. Co-op members agreed that the differences between experienced readers from various agencies were in the identification of the first annulus, resulting in a one year discrepancy of assigned ages.

Based on the blind test results, Co-op members held a third ageing workshop, December 2014 at New Paltz, New York. The intent was for Co-op members familiar with American shad scale ageing to develop an agreed upon reference set of scales. A reference set would aid in uniformity of identifying scale structures, possibly increasing consistency of age derivations. Differences in scale microstructure interpretations were discussed including, identification characteristics and assignment of annuli, identification of the first annulus and repeat spawning marks. A total of 50 specimens were accepted as reference scales. In order to assess the suitability of the reference set, the Co-op sought third party confirmation from the Massachusetts Division of Marine Fisheries ageing lab in Gloucester, MA. The reference set was independently examined by the Massachusetts ageing lab. Results of their age determinations were compared to the Co-op ages using a standard precision template as described above. Percent agreement was 73.6% with a CV of 3.65%. These values fall within the accepted ranges for precision. A final result of the December 2014 workshop is an agreed reference set and updating of the informal ageing protocol, for Co-op member use.

The goal for these workshops (and future workshops) is to train and re-train Co-op members in interpreting American shad scale microstructures. Specific objectives are to: (1) develop and use a standard ageing protocol for assisting Co-op members to consistently interpret American shad scale microstructure for age and repeat spawning marks; (2) provide the mechanism for production ageing of Delaware River American shad scales; and (3) provide a mechanism for developing total mortality estimates usable as benchmarks in an American shad SFP.

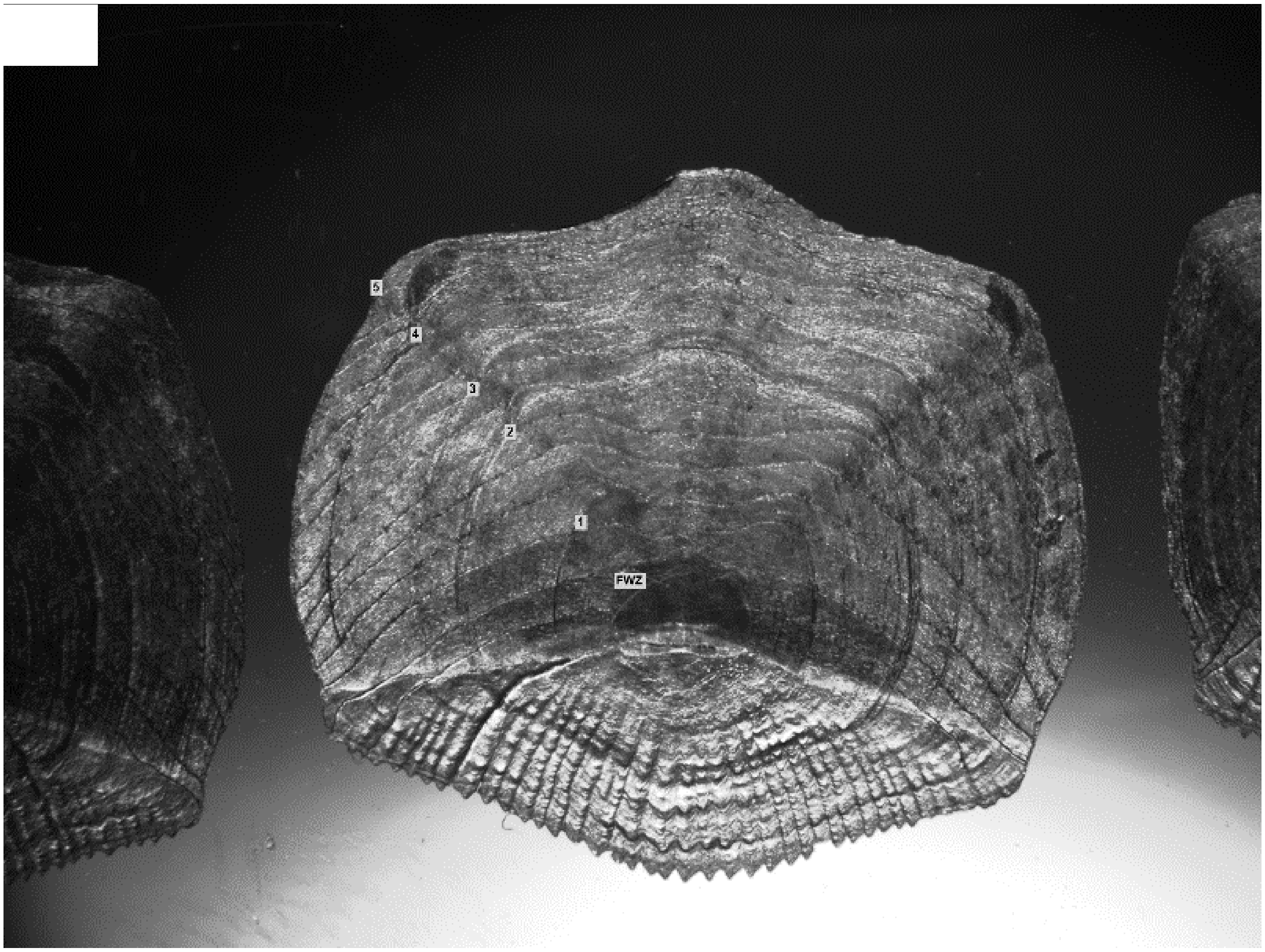
II. Scale Sample Collection

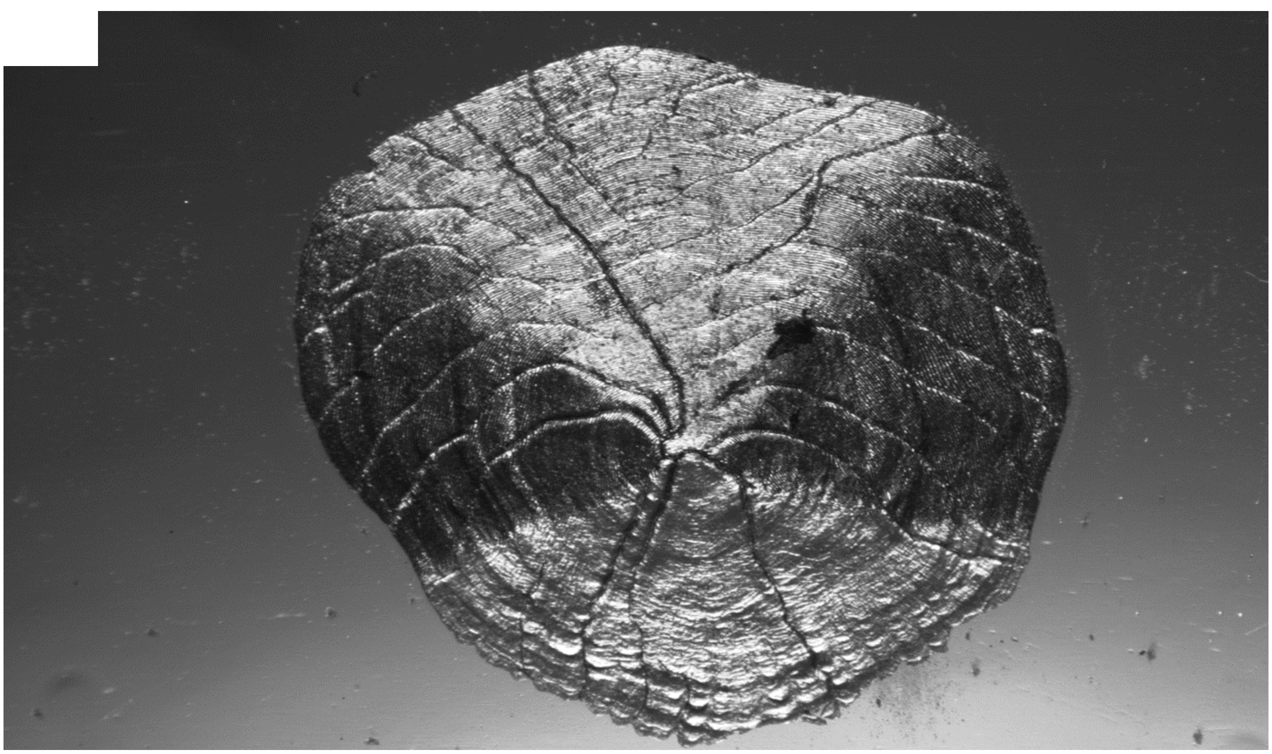
- Each fish is given its own unique sample ID (river, year, and fish number)
- Total Length (mm), fork length (mm), weight (g), sex (male or female), stage of maturity (gravid, ripe/running/ spent), capture date and sample ID number are recorded on scale envelopes and data sheet.
    - Total length (mm) is the distance between the tip of the mouth (when closed) to the tip of the caudal fin (when gently compressed).
    - Fork Length (mm) is the distance between the tip of the mouth (when closed) to the center of the caudal fin (the bottom of the "V")
    - The illustration demonstrates total and fork length. Note the picture has the mouth open. The line is placed when the mouth is assumed to be when closed.

- Scales are collected just ventral of the dorsal fin
    - Before removal use a knife to remove the slime coat and any dirt from the area scales are to be removed on the carcass.

  - Ensure the knife is also free of any dirt, slime and previous fish scales.
- Scales taken near the dorsal fin, high up on the fish back tend to be more circular and not conducive for age determination. These are to be avoided.

- Remove approximately 20 or more scales and place into an envelope with the corresponding sample ID number.
- Scales are to look like rounded squares (A), not oblong (B) (See pictures below).


5
4
3
2
1
FWZ



III. Scale Preparation and Mounting

- Scales must be cleaned before age assignment
- Scales should be directly read
- To reduce unnecessary handling, a cursory visual inspection of each scale to be cleaned/mounted should be able to identify regenerated scales (Figure 1). Any regenerated scale should **NOT** be mounted or used for age interpretation.

A. Preferred Cleaning Method

- Make up a Pancreatin solution 500mL water with 3.5g Pancreatin. Place on a stir plate and let mix for approx. 10 mins.
- After initial 10 minute stir, reduce the speed of the stir plate to low and allow to continue to mix slowly.
- Select approximately 10 “good” scales, (i.e., avoid regenerated scales) and place into a centrifuge tube (one sample per centrifuge tube).
- Then fill each centrifuge tube with 15-20mL of Pancreatin solution then place in a sonicator.
- Each batch will contain 10 samples, sonicate for 15mins.
- Remove samples from sonicator and empty scales into a fine mesh strainer on sample at a time.
- Wipe, rinse and dry scales. Make sure scales are dry; any moisture between slides will cause distortion when viewing the scales under magnification.
- Either immediately mount (preferred) or store in a folded piece of paper in the original scale envelope.

B. Alternative Cleaning Method

- Minimally, scales need to be thoroughly soaked to loosen adhered tissue using a solution of liquid detergent and water
- Gently wipe, rinse and dry scales.
    - o After soaking, rubbing the scales between fingers will move most of the debris, and then gently blot with paper towels.
- Either immediately mount (preferred) or store in a folded piece of paper in the original scale envelope.

C. Mounting

- It is critical that scales are completely dry
- Reading directly off the scales eliminates difficulties inherent in less than quality impressions. Interpretations of age from scale impressions, however, are generally as dependable as the direct procedure, but tend to require greater processing time

Direct viewing

- Scales can be viewed directly in either a digital computer system or microfiche.
  - If possible directly viewed scales can be mounted between two glass slides tapping the ends together and labeling one with the corresponding sample ID number.
    - Multiple scales from the same shad specimen should be mounted between the slides. A minimum of three scales need to be mounted. More should be mounted if space on the slide is available.
    - Glass mounted scales are typically stored separately in plastic sleeves in a three-ring binder
  - If viewing with a microfiche, typically, mounting between glass slides is impractical, due to limited focus
    - In this case, a series of cleaned scale(s) can be placed on the microfiche bottom plate
    - A minimum of three scales from the sample need to be on the viewing plate
    - Any scales not mounted are stored in the original scale packet

Impressions

- Historically, impressions of scales were taken and viewed under a microfiche. Age is interpreted from the impression rather than directly from the scale. This procedure has fallen into disfavor and is presented here as a historical reference. This procedure uses the "rough" side of the scale to form an impression in acetate under heat and pressure. The ridge/valleys of the scale are then reflected in the pressed acetate
- Pressing scales requires the use of a Carver heated 12 ton press (Model 2112), two aluminum base plates (6in x 6in), two pieces of thin cardboard (cereal box material), two polished stainless steel impression plates (6inx6in), and one piece of acetate (6in x 6 in).
  - Pressing involves creating a "sandwich". The acetate is to be oriented between the stainless steel plates (polished side towards acetate) and then the thin cardboard (to protect the stainless steel plates) and then Aluminum base plates.
  - Any scratches in the stainless steel plates are pressed into the acetate. Hence the use of the cardboard to reduce this possibility.
  - Prior to loading the press the heating plate should be set at 100 degrees Celsius
- Acetate is to be scored to produce 10-1in x 3 in segments
- Acetate sheets need to be cut to the shape of the stainless steel pressing plates. These sheets can hold multiple scale samples, thus the order of sample number is to be written as the acetate is prepared
- Create the bottom of the "sandwich" by placing the base plate on the table, followed by the cardboard, then stainless steel plate (polished side up towards the acetate), then the scored acetate.
- A series (minimum of three per specimen), cleaned, <u>dry</u> scales are placed on the acetate. Usually 5-8 scales can be mounted per specimen.
  - **IMPORTANT:** Scales have a "smooth" side and a "rough" side. Scales must be oriented "rough" side facing down onto the acetate in order for a proper impression. The scales can be examined using tweezers or fingernails to determine the "rough" side.

- Once all scales are loaded on the acetate, carefully complete the “Sandwich” with the remaining stainless steel plate (polished side down towards the acetate), then the cardboard, then the remaining base plate.
- Carefully, place the “sandwich” in the press
- Once the “sandwich” is in the press the hydraulic pump should be set at 5000 psi and allowed to bake (@ 100 ^{o}C) for 5 minutes
- After 5 minutes, using leather gloves, remove the plates from the press and allow to cool for approximately 10 minutes.
- Once cooled, the acetate can be removed and cut into individual sections
- Assign proper identification to each piece as it is cut from the acetate and place into corresponding scale envelope
    - Acetate should be marked with the specimen ID
    - These may also be stored separately from the scale envelope, such as slide trays to reduce scratches and/or unnecessary bending.

IV. Scale Interpretation

A. Magnification

- A consistent magnification should be set for all scale samples. Increased magnification (i.e., zooming in) to highlight a specific area of the scales, should only be used to identify edge structure.
    - For instance, increased magnification may help determine a repeat spawning mark
- Typically, a broader view of the scale (as opposed to focusing in on specific points) tends to provide better consistency of identifying scale structures (Figure 2).
    - Magnification should be set to view the scale in its entirety on the display screen. Readers should not need to continuously adjust magnification or scale position on the screen to identify scale structure.

B. Scale orientation

- Scale orientation on a view screen is generally individual reader preference. Yet, general convention of most readers is to orient the scale with the anterior portion to the top of the viewing screen (Figure 2).
    - The anterior potion of the scale is the embedded portion of the scale in the fishes’ skin. This portion of the scale has varying contrasts, but generally looks flat/smooth.
    - The posterior portion of the scale is exposed to the elements. This portion of the scale appears as rows of “teeth” and has a rough appearance. Annuli typically appear as dark bands. Typically readers orient the posterior portion to the bottom of the viewing screen.
    - The dorsal side is towards the back/top of the shad closest to the dorsal fin of the fish. On the viewing screen, if the anterior portion of the scale is oriented to the top of the screen, then the dorsal side is to the readers’ right.

- The ventral side is towards the belly of the fish. On the viewing screen, if the anterior portion of the scale is oriented to the top of the viewing screen, then the ventral side is to the readers' left.

C. Identifying regenerated scales

- Regenerated scales represent replacement of lost scales (Figure 1). They are easily identified by their "chaotic" appearance in the scale focus, lacking any organized structures. These scales are formed by extreme rapid growth to ensure protection of exposed skin.
  - Regenerated scales are not to be used for age determination or repeat spawning marks.
  - Regenerated scales formed at a younger age generally have a relatively smaller disruption of scale structure, than scales lost at an older age. Occasionally, the periphery of a regenerated scale, however, may illustrate consistent ageing structures that may only help clarifying difficult structures on other scales and not be used in age/repeat spawning mark assignments.

D. Identifying the base line

- The baseline is the separation between the posterior (portion of the scale exposed) from the anterior (portion embedded in the fish skin) of the scale. This is typically viewed as a heavy groove across most of the scale, running between the dorsal and ventral sides (Figure 2).

E. Identifying transverse grooves

- Transverse grooves appear as thin dark lines crossing the entire scale (Figure 2).
- Generally, transverse grooves are oriented dorsal to ventral sides for the scales. They are typically parallel with the base line.

F. Identifying the freshwater zone

- The freshwater zone (FWZ) is typically the first dark area near the scale focus that travels through both anterior and posterior portions of the scale and indicates the time spent in the freshwater portion of the estuary before entering saltwater. It is NOT the first annulus (Figure 3).
  - Usually, but not always, the FWZ may appear as a concentric ring in both the anterior and posterior portions of the scale (Figure 3)
  - On rare occasions, double banding may be associated with the FWZ in the posterior portion of the scale (Figure 3).

G. Identifying annuli

- An annulus (annuli – plural) is identified as a smooth band that MUST be visible through both the anterior AND posterior portion of the scale (Figure 4).
  - Annuli appear as concentric rings for multiple ages. In the anterior portion, they have a slight convex shape on the dorsal and ventral sides.

    - Readers should be able to trace annuli on all sides (anterior, posterior, dorsal and ventral) of the scale.
  - Frequently, annuli can appear to be a “broad” or “wide” band (Figure 5), rather than a concise line.
  - Increasing/decreasing contrasting light may improve identification of annuli. If using a microfiche, colored acetate may be used to change contrasting lighting.
  - Along the sides of the scale (ventral and dorsal), annuli are generally perpendicular to transverse grooves.
- Each scale should be viewed for annuli from several different focal views to confirm annuli are visible around the scale (Figure 6).
  - Annuli are easier to determine in the anterior portion of the scale, but can become obscured with false annuli and/or double banding.
  - When reading the anterior portion of the scale, typically readers orient the scale with the anterior portion of the scale to the top of the viewing screen, such that anterior is “up” and posterior is “down” relative to its projection.
  - Readers typically, look at the anterior portion first reading from the middle of the scale, either “up” to the left or right. Annuli are then traced into the posterior and through the “peak” of the anterior portion of the scale.
  - Reader may also start on the outside edge and work towards the middle as well.
- The first annulus (i.e., Age 1) is typically not readily apparent or “strong” (Figure 7). Meaning when viewing the scale, readers’ typically interpret the first readily apparent mark as Age 2.
  - Age 1 is usually in close proximity to the FWZ, but on occasion may be relatively distant from the FWZ. Usually, the dark FWZ is followed by a slightly lighter shade. The Age 1 annulus generally resides in this lighter shade.
  - Occasionally the Age 1 annulus is very apparent (Figure 4). When this occurs, recognizing its relative positioning to the FWZ and Age 2 annulus will help identify Age 1 annulus in other specimens’ scales.
- The second annulus (Age 2) is typically easily identified (Figure 7). It tends to be a strong mark (i.e., high contrast) in the anterior portion of the scale, easily traced into the posterior.
  - The relative position of Age 2 annulus can be variable, appearing closer to Age 3 than Age 1 annuli or vice versa.
  - Usually the Age 1 annulus is difficult to readily identify. Thus, readers typically use the inner most annulus that is readily apparent as the Age 2 annulus.
    - Once Age 2 is assigned, readers can usually find Age 1 and FWZ, using the posterior portion of the scale if both are weakly defined in the anterior.
- The appearance of Age 3 annulus or older annuli tend to be similar to Age 2 annulus.
  - The distance (or “spacing”) between annuli can be variable. Spacing may conform to traditional theory: greatest distances between the younger annuli (i.e., Age 1, 2, and 3); and smaller distances between the older annuli (Figure 7). Yet, in some shad, the just the opposite has been observed. (Figure 8).
- Severe scale erosion on the edge in the current year or previous years (i.e., repeat spawning) may eliminate previous years’ annulus or multiple annuli structures.
  - In cases of severe erosion, the very tip “peak” of the anterior portion and/or the posterior portion of the scale are the only remaining areas of the scale for identifying annuli (Figure 9).

    - Edge erosion is typically greater on the dorsal and ventral sides relative to the anterior and posterior edges where edge erosion is relatively less.
    - One common feature aiding identification of lost annuli on the dorsal/ventral edges is the "Y" effect (Figure 10).
        - When tracing annuli along in the anterior edge, annuli appear to converge near the corners of the anterior edges into a single band along the dorsal/ventral edges, then separate into separate bands, just below the base line in the posterior portion of the scale. This convergence/separation visually looks like the letter "Y". If viewing the scale with the anterior portion of the scale oriented to the top of the viewing screen, the "Y" effect in the posterior is upside-down.
        - In the case of multiple years being lost on the dorsal/ventral edges, multiple annuli in the anterior/posterior will appear to converge/separate.
- Occasionally, a high contrasting band occurs almost directly on the outer edge (Figure 11). Conventional thought is: shad form annuli during the spring spawning run in May. Thus, the appearance of this annuli right at the edge of the scale may be the start of the year-of-capture's annulus. Without confirmation of the timing of annuli formation, however, this mark is not counted as an age, using the scale edge as the year-of-capture annulus.
- The outer edge of the scale is counted as an annulus, if specimen is collected in early spring.
    - The convention of counting the outer edge as annulus originates in Cating (1953).
- False annuli appear similar to annuli in the anterior portion of the scale, BUT do not cross the base line into the posterior portion of the scale (Figure 12). This is the key characteristic for distinguishing false annuli from annuli.
    - False annuli tend to be dark, concise, concentric lines in the anterior portion.
    - False annuli commonly appear as "double banding" (Figure 13).
    - False annuli can have relatively greater separation (i.e., spacing) from annuli.
- Double banding are false annuli (Figure 13). Their appearance is similar to a false annuli, typically a dark, concise, concentric line in the anterior portion, but they are typically in close proximity (i.e., little separation/spacing) from an annuli. Hence, the annuli and the false annuli are collectively referred to as a double band.
    - It is not uncommon to have multiple false annuli between annuli.

H. Identifying repeat spawning marks (SPM).

- The presence of a repeat spawning mark(s) is interpreted as the returning individual shad has spawned in previous year(s). Repeat spawning marks are created by the loss of scale material along the outer edge, and in subsequent years new scale material is deposited beyond the original damaged edge; resulting in non-uniformity appearance to the scale microstructure. This is most pronounced along the dorsal and ventral sides.
    - Multiple repeat spawning marks may be illustrated for a shad, indicating it has returned to its natal waters in multiple years.
    - A scale interpreted as having a single repeat spawning mark, suggest the shad has spawned twice: once in a previous year, and currently in the year-of-capture.
    - First-time spawners do not have any repeat spawning marks - their first spawning event is the year-of-capture.

- Scale erosion is generally greater on the dorsal and ventral sides of the scale relative to less erosion on the anterior and posterior edges. Sever cases of lost edge material may include more than one annuli either partially or wholly eliminating annulus(i) from the dorsal and ventral sides.
- Spawning marks are identified as annuli with breaks, fractures, jagged (jiggety) bands (Figure 14) as opposed to non-spawning mark annuli that have smooth band formation (Figure 7).
  - Typically female shad return to natal waters at Age 4 or Age 5; Male shad return at Age 3 or 4. Thus, repeat spawning marks can be expected to begin to occur at these ages.
    - Precocious shad have been known to return earlier and or yearling shad are known to reside in estuarine waters. These behaviors may result in a repeat spawning mark type mark at young ages. Given the inability to differentiate between spawning and residency in estuarine waters, any disruptions of smooth annuli are to be interpreted as repeat spawning marks.
  - Sever erosion of edge material may eliminate multiple annuli
    - In the corners of the anterior, annuli will appear to converge into a single band along the dorsal and ventral edges, then separate into distinct bands in the posterior. This is called a “Y” effect (Figure 10). The convergence of annuli visually appears as the letter “Y” (assuming the scale is oriented with the anterior portion to the top of the viewing screen). In the posterior, the “Y” will be upside-down.
    - Cating (1956) also describes a “Y’ effect. Although, Cating (1956) did not label the microstructure as a “Y”.
  - A “pocket” or “bell” (Figure 15) may be evident on the base line, suggestive of repeat spawning mark(s). This structure is when erosion on the base line forms a strong concave edge.
    - “Y” effects may be distinguishable below the pocket.
    - Subsequent growth may camouflage a pocket in previous years.
  - Breaks in transverse grooves across an annulus can be an indication of a repeat spawning mark and should be considered but is not a required criterion for determining a repeat spawning mark (Figure 16).
  - Repeat spawning marks must be present on both ventral/dorsal sides and must be present over most of the annulus on either side.
  - Repeat spawning marks observed at Smithfield Beach tend to be straight (“flat line”) opposed to following the scale edge contour (Figure 17).
- Skipped spawning occurs. Meaning shad spawn, survive and return to the ocean, but do not return for spawning in the following year (Figure 18).

I. Assignment of age and repeat spawning marks
- View several scales (minimum of three) prior to age assignment to identify <u>consistent</u> scale markings among all scales. Dissimilar scales should be removed from age analysis, possibly eliminating the entire sample.
  - Patterns in annuli formations often become apparent to the reader after viewing many specimens when production ageing. Recognizing patterns will develop with the readers’ experience. Recognizing patterns will also aid in with consistency of ageing the scales.

        - For instance, the distances (i.e., spacing) between annuli tend to be the same among shad in a given year. Exceptional differences in distances between annuli (great or small) tend to be found similar among annuli.
    - All scales mounted or a minimum of three scales per specimen should be reviewed/assessed for age. Identified annuli should be apparent in the majority of the scales reviewed per specimen.
- Final age assignment is based on the derived age from the majority of the scales of an individual specimen.
    - Ageing of shad should be accomplished without any knowledge of other biological information (i.e., length, weight, gender, etc.) that could unduly influence age assessments.
    - Age is the total number of concentric identified annuli plus the scale edge, which is counted as an annulus (Figures 4 and 7).
    - The Delaware River American Shad tend to be a "young" population. Typically most of the returning spawning adults are ages 4 to 6. In exceptional year classes, older shad, ages 7 to 9 have been observed, but more as a rarity.
- Frequency of repeat spawning assignment is the total number of repeat spawning marks observed in the majority of mounted scales
    - The scale edge is not interpreted as a repeat spawning mark. Thus, if no SPMs are identified within the scale from previous years (i.e., the shad is a first-time spawner), then the repeat spawning mark is assigned a value of zero (0).
    - In instances of sever erosion and subsequent loss of multiple annuli, this sample should be discarded for assignment of repeat spawning marks.
    - Frequency of repeat spawning marks in Delaware River American Shad tends to be low. First-time spawners have been observed at age 8 and as young as age 3. Most Delaware River shad are first-time spawners, meaning no SPMs are evident. The year-of-capture is the first-time they are returning to spawn. Second-time spawners are uncommon, meaning only one SPM is evident in the scale microstructure. Two and three SPMs are a rarity.
- First impressions are important. When viewing a scale, get an overall impression of the scale prior to attempting to identify specific annuli/spawning marks. Then through the process of identifying specific annuli/repeat spawning marks attempt to rectify with the first impression.
- Occasionally, first impressions of scales suggest structures are difficult to readily identify. Rather than attempting to work through the scale, instead pass over to a different scale from the same specimen. Not all scales are as easily interpreted. Structures on one scale may be difficult to identify, but are readily apparent on another scale from the same specimen.

V. Reference Set

A. Utility

- The goal of the reference set is to keep all readers of Delaware River American Shad scales as consistent as possible.

- Actual scales (slide mounted and impressed) are archived by the Pennsylvania Fish and Boat Commission.
- Picture references (labeled (Appendix A) and un-labeled (Appendix B) pictures) are available on the Co-op ftp site or compact disk. Please contact Daryl Pierce, Pennsylvania Fish and Boat Commission, dapierce@pa.gov, 570 – 588 - 6388 for access.

- A reference set of agreed upon scale ages and repeat spawning marks has been defined by Co-op members.
  - The initial reference set (n = 50) was derived in December 2014 workshop, by members from NYDEC, DNREC, and PFBC. This set was evaluated by the Massachusetts Division of Marine Fisheries resulting in acceptable standards of precision.
  - Scale samples will be added or deleted in future ageing workshops.
  - The frequency of updating the reference set will be on an "as needed" basis, by Co-op member consensus.
  - If possible, third party confirmation will be sought for all reference set additions.
  - Unique specimen identifiers will be assigned to all reference samples. Only location and date captured are to be included with any reference samples. No biological data (i.e., length, weight, gender, etc.) is permissible.
- Prior to production ageing, readers will re-familiarize themselves with interpreting shad scales using the reference set.
  - Readers will attempt to assess age/repeat spawning frequency on the unmarked reference set.
  - Derived ages can then be compared to the agreed upon age/repeat spawning frequencies.
  - Differences greater than a CV 5% would indicate the reader should spend more time familiarizing themselves with scale structure identification.

B. Individual scale descriptions

- Listed below are individual scales in the reference set. Information included is the year-of-capture (all in May), date (month/year) accepted into the reference set, Location-of-capture, Specimen ID, age, total number of repeat spawning marks (SPM), and specific commentary for highlighting particular scale characteristics.
  - Pictures are organized by Specimen ID.
  - Accompanying pictures of each specimen are available in Appendix A with identifying microstructures labeled. Appendix A allows for training for recognizing microstructures.
  - Appendix B is the same picture of each specimen in Appendix A, but microstructures remain unlabeled. Appendix B allows a reader to "test" their consistency of scale interpretation, prior to production ageing.
    - When "testing" using Appendix B, the reader should allow sufficient time (i.e., a few days) to pass prior to testing, avoiding associating Specimen ID ages from Appendix A to the unlabeled scale.

Reference American shad scale set (ver. Dec 2014, original set)						
Year-of-capture	Accepted	Location	Specimen ID	Age	SPM	Comments
2012	Dec 2014	known age	3046	7	0	
2012	Dec 2014	known age	3130	7	0	Went conservative with SPM; age 6 is eroded away
2012	Dec 2014	known age	3134	7	2	
2012	Dec 2014	known age	3405	6	0	
2012	Dec 2014	known age	5034	5	0	
2012	Dec 2014	known age	5043	5	0	
2012	Dec 2014	known age	5136	3	0	
2012	Dec 2014	Raubsville	12-R-1	5	0	Very weak annulus at age 3
2012	Dec 2014	Raubsville	12-R-2	4	0	
2012	Dec 2014	Raubsville	12-R-3	5	0	
2012	Dec 2014	Raubsville	12-R-5	5	0	
2012	Dec 2014	Raubsville	12-R-8	5	0	
2012	Dec 2014	Raubsville	12-R-11	4	0	
2012	Dec 2014	Raubsville	12-R-15	5	0	
2012	Dec 2014	Raubsville	12-R-16	5	0	
2012	Dec 2014	Raubsville	12-R-18	5	0	
2012	Dec 2014	Raubsville	12-R-19	5	1	
2012	Dec 2014	Raubsville	12-R-20	5	1	Good example of straight edge erosion
2012	Dec 2014	Raubsville	12-R-21	5	0	
2012	Dec 2014	Raubsville	12-R-22	7	0	

2012	Dec 2014	Raubsville	12-R-23	7	1	
2012	Dec 2014	Raubsville	12-R-24	5	0	Good example of atypical band width
2012	Dec 2014	Raubsville	12-R-25	7	0	Beautiful scale, supermodel style
2012	Dec 2014	Smithfield	12-S-1	8	1	Skip spawn: Spawn mark (SPM) at 6, no SPM at 7; 7 close to edge, but crosses the baseline in both spots. Tough to see last annulus on microfiche
2012	Dec 2014	Smithfield	12-S-2	7	1	Supermodel
2012	Dec 2014	Smithfield	12-S-3	5	0	
2012	Dec 2014	Smithfield	12-S-4	5	0	False annulus between year 2 and 3 (cannot follow it all the way around)
2012	Dec 2014	Smithfield	12-S-6	6	0	
2012	Dec 2014	Smithfield	12-S-7	5	0	Good example where 1st annulus is pretty far from freshwater zone. False check between 3 & 4
2012	Dec 2014	Smithfield	12-S-8	5	0	Went conservative on spawn mark (on left side of many scales, but not right side)
2012	Dec 2014	Smithfield	12-S-9	6	0	High uncertainty scale, good example of an annulus being eroded away (age 5)
2012	Dec 2014	Smithfield	12-S-11	5	0	
2012	Dec 2014	Smithfield	12-S-12	5	1	
2012	Dec 2014	Smithfield	12-S-13	7	1	

Reference American shad scale set (ver. Dec 2014, original set)						
Year-of-capture	Accepted	Location	Specimen ID	Age	SPM	Comments
2012	Dec 2014	Smithfield	12-S-14	5	0	
2012	Dec 2014	Smithfield	12-S-15	8	0	

2012	Dec 2014	Smithfield	12-S-16	6	0	
2012	Dec 2014	Smithfield	12-S-18	6	0	Three looks strongest above baseline, but 2 strongest below. 5 eroded on both edges but mostly on the right side
2012	Dec 2014	Smithfield	12-S-19	7	0	False band on outside, near edge. Not calling it an annulus
2012	Dec 2014	Smithfield	12-S-20	6	0	Contentious spawn mark, not on all scales; weak 2 above baseline
2012	Dec 2014	Smithfield	12-S-21	7	0	
2012	Dec 2014	Smithfield	12-S-23	7	1	Nice picture for potential SPM, go to fiche for best view of SPMs
2012	Dec 2014	Smithfield	12-S-24	7	1	Double banding at age 5
2012	Dec 2014	upper bay	12-UB-1	5	0	
2012	Dec 2014	upper bay	12-UB-2	5	0	Good example of double banding, especially at age 2
2012	Dec 2014	upper bay	12-UB-5	5	0	Tough read, scale clarity a little poor
2012	Dec 2014	upper bay	12-UB-8	6	0	
2012	Dec 2014	upper bay	12-UB-10	5	1	Good example of jiggety spawn mark
2012	Dec 2014	upper bay	12-UB-12	9	4	Middle scale is the best, 8 SPM eats into 7 annulus. Weakish 3
2012	Dec 2014	upper bay	12-UB-14	7	1	Weak 5
2012	Dec 2014	upper bay	12-UB-16	7	3	Crazy one, looks like there is a SPM at age 3, then skip spawn at 4
2012	Dec 2014	upper bay	12-UB-18	5	0	
2012	Dec 2014	upper bay	12-UB-20	6	0	The toughest part of this one is determining first annulus

VI. Production Ageing

- Ageing will be done by at least one experienced reader from each of the Co-op member states. The Co-op will facilitate distributing the samples between state agencies.
- Criterion(a) for acceptance of ages/repeat spawning marks

- Comparison of age and repeat spawning mark assignments among readers will be analyzed using a standard precision template developed by NOAA's Northeast Fisheries Science Center. Templates can be found at http://www.nefsc.noaa.gov/fbp/age-prec/. Precision will be evaluated by examination of the mean coefficient of variation (CV), percent agreement and the Bowker's test of symmetry. Ageing laboratories around the world view a measure of mean CV of 5% or less to be acceptable (Compana (2001). Production ageing results with a mean CV of greater than 5% will be rejected and not used to calculated mortality estimates.

- The Co-op will attempt to age the entire sample; however, if sample sizes become too large to analyze in a timely manner, we will take a random subsample of 10 fish per length bin (Coggins et al. 2013).

VII. Calculation of total mortality (Z)

- Total mortality (Z) estimates will be calculated using a bias-correction Chapman and Robson (1960) mortality estimator described in Smith et al., 2012.

$$Z = log_e\ (1 + \underline{T} - T_C - \frac{1}{N}) - \frac{(N-1)(N-2}{N[N(\underline{T} - T_C) + 1][N+N(\underline{T} - T_C)-1]}$$

where:

$\underline{T}$ is the mean age of fish in the sample greater than or equal to age T_C

T_C is age of full recruitment

N is the sample size of fish greater than or equal to age T_C

VIII. References

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IX. Glossary

Annuli (plural)/Annulus (singular) – A concentric ring that can be traced through the anterior and posterior portions of the scale. These bands are typically lighter in contrast relative to growth areas. They may occur as tight concise lines and/or wide broad lines in the anterior portion of the scale.

Anterior portion – This is the portion of the scale that remains embedded in the fish's skin. This portion of the scale has varying contrasts, but generally looks smooth. Typically, readers orient the anterior portion of the scale to the top of the viewing screen.

Band – A general term referencing a concise line giving the appearance being concentric on the scale. These may potentially be annulus(i) or false annulus(i).

Banding – A general term for collectively referring to multiple bands.

Base line – The base line separates the anterior from the posterior portions of the scale. It typically appears as a dark heavy band running between the ventral and dorsal scale edges.

Dorsal side – This is the edge of the scale that is oriented to the dorsal fin of the fish. On the viewing screen, if the anterior portion of the scale is oriented to the top of the screen, then the dorsal side is to the readers' right.

Double band – These are false annuli that appear as dark bands in the anterior portion of the scale, but are typically not present in the posterior portion. Usually there is little separation (i.e., spacing/distance) between the annuli and a second band. Collectively the annuli and the false annulus are called a double band.

False annulus(i) – These are structures that appear as dark bands in the anterior portion of the scale, but are not present in the posterior portion. False annuli can be in close proximity of the annuli (i.e., double band), or well separated from other annuli. Speculation on potential causes for false annuli formation may be related to growth changes, available food/starvation, diet shifts, etc.

Flat line – Refers to a repeat spawning mark appearing as a straight edge along the dorsal and ventral sides. This mark is formed by scale erosion in previous years spawning, when the scale is evenly eroded, forming a very straight line. As with any erosion, flat lines may have eroded past multiple annuli. Occurrences of "Y" effects are usually associated with a flat line.

Focus – This represents the center of the scales growth. The focus is the center of the freshwater zone located on the base line, halfway between the dorsal and ventral sides. Typically, the anterior portion of the scale is relatively larger (~ two-thirds) than the posterior portion of the scale. Thus, the focus is not in the physical center of the scale.

Fresh water zone (FWZ) – This appears as a concentric small dark area in the middle of the scale just above the base line.

Jiggety – Refers to the ragged appearance of an annulus. Scale erosion occurs as shad return to freshwater for spawning. The erosion of the scale edge is not uniform, leaving a "ragged", "fragmented", or "jagged" edge. Subsequent scale growth deposits material on the scale edge, but does not reform a uniform edge of the erosion from the previous edge. Erosion of the scale margins are most pronounced on the ventral and dorsal edges.

Peak – references the very anterior most part of the scale.

Pocket/Bell – At the base line, scale erosion on the ventral and dorsal edges often erode in a concave shape.

Posterior portion – This is the portion of the scale exposed to the elements. This portion of the scale appears as rows of "teeth" and has a rough appearance. Annuli typically appear as dark bands. Typically readers orient the posterior portion to the bottom of the viewing screen.

Repeat spawning mark/Spawning mark/SPM – This is an annulus(i) that appears jiggety suggesting the individual shad spawned at that age. Each annulus identified as a SPM, is cumulatively counted. A repeat spawner is a shad that is returning to its natal water for the second-time (or more). For example, the presence of one SPM indicated the shad spawned once in a previous year, and has returned again in a following year (i.e., year-of-capture). SPMs are most easily identified on the dorsal and ventral sides of the scale. Occasionally an exceptionally disruptive SPM (erosion) will also be evident in the anterior. Scale erosion may eliminate multiple annuli, in such cases, a SPM is referring to a single event of the oldest annulus, since all previous scale material (annulus(i) and SPMs) may have been lost. Skip spawners are those shad demonstrating a SPM, then appear not to spawn in the following year (i.e., the annulus is a smooth band, not jiggety), then returning again in a future year to spawn again.

Strong/Weak – This is a descriptive term for characterizing how apparent an annulus is on the scale. Well defined annuli that immediately jump out to the reader are "strong". They are easily identified throughout the scale. Annuli that are difficult to immediately pin point are "weak" or not readily apparent to the reader. The annuli may not be traceable throughout the entire scale, such that sections of the annuli are not discernable in various portions of the scale.

Ventral side – This is the edge of the scale that is oriented to the belly of the fish. On the viewing screen, if the anterior portion of the scale is oriented to the top of the viewing screen, then the ventral side is to the readers' left.

Y effect - When tracing annuli along in the anterior edge, annuli appear to converge near the corners of the anterior edges into a single band along the dorsal/ventral edges, then separate into separate bands, just below the base line in the posterior portion of the scale. This convergence/separation visually looks like the letter "Y". If viewing the scale with the anterior portion of the scale oriented to the top of the viewing screen, the "Y" effect in the posterior is upside-down.

North Carolina American Shad Sustainable Fishery Plan

2020 Update to Resolve Regulatory Inconsistencies

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EXECUTIVE SUMMARY

In accordance with the guidelines provided in Amendment 3 to the Interstate Fishery Management Plan for Shad and River Herring, North Carolina submits the following American Shad Sustainable Fishery Plan (SFP) for consideration by the Shad and River Herring Management Board (Board) to continue commercial and recreational fisheries in North Carolina. North Carolina's first Sustainable Fishery Plan for American Shad was approved by the Board in May 2012 for 2013 through 2017. The purpose of this plan is to update and modify sustainable management measures for 2018 through 2022 that will allow for maintenance and rebuilding of American Shad populations in North Carolina. The proposed plan includes the same sustainability parameters of relative fishing mortality (relative *F*) and abundance indices, but relative *F* will now be computed by dividing commercial landings by a hind cast 3-year average of a survey index whereas the previous plan used a centered 3-year average. Indices of relative abundance and estimates of relative *F* were calculated for each system using data from the previous plan, updated through 2017. Proposed thresholds (75th and 25th percentiles) for sustainability parameters have now been set using available survey data through 2017 and will remain fixed during the next 5-year management period. North Carolina requests recreational and commercial fisheries in all coastal rivers, and will use the management measures to ensure sustainability of these fisheries.

This document was updated on March 13, 2020 to satisfy a Board directive for North Carolina to correct regulatory inconsistencies in the 2018 SFP. Updates to the document are highlighted in yellow.

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INTRODUCTION

American Shad (*Alosa sapidissima*) are currently managed under Amendment 3 to the Atlantic States Marine Fisheries Commission (ASMFC) Interstate Fishery Management Plan for Shad and River Herring. The Amendment contains coastwide information on biology, stock status and management of American Shad and can be found on the ASMFC website at www.asmfc.org. Amendment 3 required states and jurisdictions to develop sustainable fishery plans (SFP) by January 2013, which were to be reviewed by the ASMFC Shad and River Herring Technical Committee and approved by their Board, in order to maintain commercial and recreational fisheries (with the exception of catch and release fisheries) for American Shad by (ASMFC 2010). A sustainable fishery is defined in Amendment 3 as "those that demonstrate their stock could support a commercial and/or recreational fishery that will not diminish future stock reproduction and recruitment". North Carolina's first SFP for American Shad was approved by the ASMFC Shad and River Herring Management Board in May 2012 for 2013 through 2017 (NCDMF and NCWRC 2012). The purpose of this plan is to update and modify sustainable management measures for 2018 through 2022 that will allow for the continued maintenance and rebuilding of American Shad populations in North Carolina.

The most recent stock assessment of American Shad stated that populations in the Albemarle Sound and Roanoke River are stable and low, whereas a determination of stock status could not definitively be assigned for the Tar-Pamlico, Neuse and Cape Fear rivers due to limited information (ASMFC 2007a). It should be noted that areas south of Albemarle Sound are in a zone where stocks transition from iteroparity (spawn multiple times over a lifetime) to semelparity (spawn only once followed by death), which can also impact the ability to determine stock status.

Sustainable fishery parameters are being submitted for consideration for the following areas: Albemarle Sound/Roanoke River, Tar-Pamlico River, Neuse River, and Cape Fear River.

REQUEST FOR FISHERIES

A sustainable fishery is defined in Amendment 3 as one that demonstrates shad stocks could support a commercial and/or recreational fishery that will not diminish future stock reproduction and recruitment. In the first American Shad SFP for North Carolina, a suite of potential sustainability parameters was considered, and it was decided to develop sustainability parameters for each river system based on relative abundance and relative fishing mortality rate (relative *F*). Relative abundance was calculated using available fisheries-independent survey data that were considered appropriate for measuring the abundance of American Shad and were expressed in terms of catch-per-unit-effort (CPUE). The standard deviations of the annual CPUE index values were also calculated to demonstrate the variability of these values. Environmental conditions on the spawning grounds, especially flow rates, are a major source of the variability associated with these indices. However, sample protocols accommodate variations in stream flow and fish distribution within the survey areas.

Relative *F* is calculated by dividing landings by a fisheries-independent index of relative abundance (Sinclair 1998). Imprecision in the survey index can cause estimates of relative *F* to be noisy. The noise can be dampened by using an average of the survey index over adjacent years in place of point estimates in the denominator. Herein, relative *F* was computed by dividing commercial landings by a hind cast 3-year average of a survey index. Note that in the previous SFP relative *F* was computed by using a centered 3-year average, resulting in the first and last year of the time series based only on two years of data. The centered average was considered the best option to calculate relative *F* with the short time series of survey data available. However, with an additional five years of data the hind cast 3-year average is determined to be more appropriate, as it ensures the value of the final year in the time series (which can trigger management action) remains unchanged once calculated. In the Albemarle Sound/Roanoke River system, the survey data used in the calculations of relative *F* were subset to reflect the applicable season and gear restrictions for mesh size in the commercial fishery. For the other systems, it is not possible to subset the independent survey data to gear or months of the commercial fishery, due to available survey data for months and the electrofishing survey design. Therefore, relative *F* calculations for the Tar-Pamlico, Neuse, and Cape Fear River were subset to fishery-dependent commercial landings and fishery-independent survey data for March through April.

Indices of relative abundance and estimates of relative *F* were calculated for each system using data from the previous plan, updated through 2017. Thresholds (75th and 25th percentiles) for sustainability parameters will now be computed for set years in all systems. In the previous plan, thresholds were recalculated annually with the addition of another year of data, and there were concerns that the thresholds could slowly decline to extremely low levels without ever being exceeded. The thresholds for this plan will be fixed using the time series for the available survey data through 2017, for all surveys. Thresholds will be reevaluated during the next 5-year review of the plan.

The objective of this SFP update is to refine the calculations of the abundance indices and relative *F* estimates that currently serve as sustainability parameters in each system. Sustainability parameters are based on the female segment of the stock because the commercial fishery targets roe American Shad; roe landings can account for as much as 90% of the total American Shad landings in a year.

While scales have been collected for aging from both fisheries-dependent and fisheries-independent programs since 1972, there was concern regarding the reliability of scales for determining age for the following reasons: first, the scouring that allows for identification of spawning marks could result in loss of annuli and therefore inconsistent scale readings; and second, although increases in average age and percent of older individuals were observed, these were also associated with decreases in average length and weight. Because of these concerns and continued discrepancies between North Carolina Division of Marine Fisheries (DMF) and North Carolina Wildlife Resources Commission (WRC) in the determination of age and spawning marks, age data were not considered for sustainability parameters in any of the systems (See Appendix 1 of the 2012 SFP for additional detail).

The updated sustainability parameters are described below for each system and summarized in Table 1. The selected sustainability parameters will be reported in annual compliance reports and any management actions will be noted. Potential management actions are included in a separate section to eliminate repetition within each of the river system sections, although any action or suite of actions could be specific to and independent of each system.

1.1 Albemarle Sound/Roanoke River

Stock Status

The 2007 ASMFC stock assessment stated American Shad stocks in the Albemarle Sound and Roanoke River were low but stable and suggested a benchmark total mortality rate (Z_{30}) of 1.01

(ASMFC 2007b). Annual estimates of mortality (*Z*) from the assessment indicate that values have fluctuated around the benchmark since 2000.

Commercial Fisheries

The Albemarle Sound area has traditionally accounted for the largest proportion of the state's commercial harvest (Figure 2). Since 2001, American Shad landings from the Albemarle Sound area accounted for over 50% of the total American Shad harvest in North Carolina. Landings from gill nets comprised over 90% of the overall harvest across the same time period.

Recreational Fisheries

Recreational fisheries for Striped Bass (*Morone saxatilis*) and Hickory Shad (*Alosa mediocris*) have existed on the Roanoke River for many years, but little effort, catch or harvest of American Shad have been documented in annual creel surveys. However, creel surveys conducted by the WRC have traditionally focused on Striped Bass effort and harvest; therefore, estimates of American Shad harvest could be underestimated. The spring 2006 Roanoke River creel report estimated a directed harvest of 103 American Shad and release of 541 fish, but the harvest estimate was expanded from only seven observations (McCargo et al. 2007). Annual estimates of American Shad harvest have not been calculated for the Roanoke River fishery since 2006 when the ASMFC suspended the recreational harvest reporting requirements. Additionally, little to no focused recreational effort for American Shad occurs in the Albemarle Sound or tributaries, including the Roanoke River, as most effort is focused on Striped Bass. American Shad are most likely targeted by bank anglers in the Roanoke River, however anecdotal evidence from WRC biologists and enforcement officers indicates American Shad catch and harvest on the Roanoke River is minimal. WRC has not been able to expand the Roanoke River creel survey to include bank anglers due to limited staff availability and funding. The existing creel survey conducted by DMF in the Albemarle Sound and tributaries other than the Roanoke River also targets Striped Bass anglers, but recreational American Shad harvest is rarely documented. Despite the shortcomings of North Carolina creel surveys for estimating American Shad effort and harvest, directed recreational effort for American Shad is minimal because most recreational fisheries occur on the spawning grounds, most of which occur in Virginia portions of Chowan River tributaries. Recreational harvest from these tributaries, including Virginia portions of the Meherrin, Nottaway, and Blackwater rivers, that drain into the Chowan River is unknown. Through recent tagging data (see Section 1.11.2 for additional detail) we know that a large portion of American Shad are ascending the Chowan River, instead of the Roanoke River, to reach spawning grounds located in these Virginia systems. Additional cooperation between both Virginia and North Carolina is needed to properly evaluate the impact of the recreational fishery to the Chowan River spawning stock.

Sustainability Parameters

Data used in the development of sustainability parameters include independent gill net survey (IGNS) data collected by DMF, electrofishing data collected on the Roanoke River spawning grounds by WRC, and commercial landings data collected through the DMF Trip Ticket Program (see Section 0 for complete descriptions of these surveys).

A mortality benchmark of $Z = 1.01$ was calculated for the Albemarle Sound from the 2007 stock assessment, but there was concern that the total mortality estimate for a population in which the age distribution is contracting will not necessarily show an increase if there is no change in the slope that the *Z* estimate is based upon. As noted above, concerns regarding the reliability of scales for determining age highly influenced the workgroup's decision not to use age data and the *Z* benchmark for sustainability parameters.

The following sustainability parameters and thresholds were evaluated for the Albemarle Sound area:

Female CPUE (electrofishing survey): The female CPUE index based on the WRC electrofishing survey was calculated as the number of fish per minute using data collected from March through May (Figure 3).

- <u>Time series</u>: 2001–2017.
- <u>Threshold</u>: Three consecutive years of values below the 25th percentile (where 75% of all values are greater) from the fixed time series 2001-2017.

Female CPUE (IGNS): The female CPUE index based on the DMF IGNS was calculated as the number of fish per haul using data collected during January through May (Figure 4).

- <u>Time series</u>: 2000–2017. Although the IGNS has been conducted since 1991, use of the 2000–2017 time series will allow for more consistent comparison with the female CPUE index from the Roanoke River electrofishing survey, which has been conducted annually since 2000.
- <u>Threshold</u>: Three consecutive years of values below the 25th percentile (where 75% of all values are greater) from the fixed time series 2000-2017.

Female Relative F (IGNS): Female relative *F* based on the DMF IGNS was calculated using commercial gill net landings of roe shad in Albemarle Sound (February through April, 2000-2013; March, 2014-2017) and a female index derived from data collected in the 5.0, 5.5 and 6.0-inch mesh sizes of the IGNS (February through April, 2000-2013; March, 2014-2017; Figure 5). The mesh sizes selected most accurately reflect those used by the commercial fleet. In the development of the 2012 SFP, the fishery independent index for the Albemarle Sound/Roanoke River was truncated to represent the commercial season, February through April. When the commercial season was reduced to March 3 through March 24, the IGNS was subset to the month of March for female relative *F* calculation from 2014 to 2017. This has increased the variability in the point estimates for relative *F* and reduced the sample size used in the IGNS index.

- <u>Time series</u>: 2002–2017. See description of time series for female CPUE based on the DMF IGNS.
- <u>Threshold</u>: Three consecutive years of values above the 75th percentile (where 25% of all values are greater) from the fixed time series 2002-2017.

The sustainability parameters selected for Albemarle Sound/Roanoke River were female CPUE based on the IGNS, female CPUE based on the electrofishing survey and female relative *F* based on the IGNS. Relative *F* based on the IGNS was chosen over relative *F* based on the electrofishing survey because the electrofishing survey is limited to the Roanoke River and so was not considered representative of Albemarle Sound as a whole. The commercial fishery only occurs in Albemarle Sound and its tributaries, except for the Roanoke River. From 1994 to 2017 only 68 pounds of American Shad were landed from the Roanoke River. The IGNS occurs in the same areas of the Albemarle Sound as the commercial fishery, so the calculation of relative *F* based on the IGNS rather than the electrofishing index was determined to be more appropriate. Exceeding the threshold for Female CPUE (IGNS) or Female Relative *F* (IGNS) will trigger management action.

Female CPUE (electrofishing survey) will be used in conjunction with a second index for triggering management action (see Section 0 for additional detail).

Results from recent telemetry studies indicate a substantial portion of American Shad tagged in the Albemarle Sound migrate up the Chowan River and into the Meherrin and Nottaway rivers, to date, there have been no tag detections in the Blackwater River. More research into the contribution from these systems is needed, but it appears the Chowan River tributaries are important spawning areas for American Shad entering the Albemarle Sound (See Section 1.11.2 for additional detail). Additionally, electrofishing surveys in the Meherrin, Blackwater and Nottaway rivers are conducted infrequently by the Virginia Department of Game and Inland Fisheries and cannot be used in the development of sustainability parameters.

The IGNS index of female relative abundance for Albemarle Sound has shown slight variation over time (Figure 4) and was below the threshold starting in 2011 for three consecutive years, triggering management action in 2014. The female abundance index derived from the electrofishing survey was above the threshold throughout most of the time series, except for 2006, 2010, and 2016 (Figure 3). This index demonstrated an increase from 2006 to 2008 but decreased in 2009 and dropped below the threshold in 2010. The index increased through 2014 to the highest value of the time series, before declining to below the threshold in 2016, and increasing again in 2017.

Estimates of female relative *F* derived from the IGNS also varied with time. The index exceeded the threshold in 2011 through 2014 and remained below the threshold for the past three years (Figure 5).

Areas Covered by Sustainability Parameters

Monitoring and sustainability parameters in the Albemarle Sound/Roanoke River are representative of the entire Albemarle Sound and tributaries of the Chowan River basin (Meherrin, Nottoway, Blackwater rivers) and Roanoke River basin including the Cashie and Eastmost rivers. Monitoring in the Albemarle Sound/Roanoke River are also representative of the Currituck Sound and its tributaries (Northwest and North Landing rivers). The Currituck Sound connects to the Albemarle Sound near the coast. Remaining tributaries of the Albemarle Sound include Alligator River, Scuppernong River, Mackeys Creek, Salmon Creek, Edenton Bay, Yeopim River, Perquimans River, Little River, Big Flatty Creek, Pasquotank River, Croatan Sound and Roanoke Sound.

Fishery-independent monitoring is performed throughout the Albemarle Sound, including the western tributaries and the Currituck Sound through fishery independent gill net, trawl, and seine surveys (see section 1.11.2 for more details). Only fishery-independent data from the western portion of the Albemarle Sound and Roanoke River are used to develop the sustainability parameters. The primary spawning rivers for American shad entering the Albemarle Sound are the Chowan River and Roanoke River systems. Monitoring and sustainability parameters inform management of all tributaries. It is important to note that while fishery-independent monitoring outside of the western Albemarle Sound is not used to calculate sustainability parameters, monitoring of adults and juveniles are occurring in an effort to track trends in abundance. Management measures taken as a result of sustainability plan triggers will be implemented throughout all Albemarle Sound tributaries including Currituck Sound.

Fishery-dependent data are monitored by the North Carolina Trip Ticket Program (NCTTP) which collects trip level commercial harvest data for the entire Albemarle Sound. Specific waterbody locations within the Albemarle Sound can be recorded on the trip ticket to monitor if harvest is increasing in a particular area, that may require additional monitoring.

Additional Considerations

In 2005, state and federal fisheries management agencies in North Carolina and Virginia reached a Settlement Agreement with Dominion North Carolina Power regarding Federal Energy Regulatory Commission (FERC) relicensing of the Gaston and Roanoke Rapids lakes hydroelectric dams in the Roanoke River basin. Among the mitigation measures required by relicensing was a long-term, well-funded, and coordinated program to restore American Shad in the Roanoke basin. Measures outlined in this effort included improvements in hatchery production of fry, continued intensive monitoring of fry stocking success upstream and downstream of the mainstem reservoirs, development of techniques to estimate American Shad population size, and prescriptions for diadromous fish passage. This restoration effort is coordinated by the Diadromous Fish Restoration Technical Advisory Committee (DFRTAC), which includes representatives from U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), Virginia Department of Game and Inland Fisheries (VDGIF), WRC, DMF and Dominion Power. The license states that Dominion is required to design and implement upstream passage for American Shad when population estimates of 20,000 fish have been observed in two years. The target was developed based on a combination of 10% of the projected run size using the 50 shad per acre rule of thumb for riverine habitat between the dam and the river mouth (St. Pierre 1979) and very limited historic landings information. Multiple hydroacoustics research projects have attempted to estimate American Shad populations in the Roanoke River. The average run size estimate during 2006–2011 was 39,000 American Shad, suggesting the American Shad population had reached the target to begin fish passage efforts at Roanoke Rapids Dam (Hightower et al. 2013). Population estimation using the hydroacoustics techniques developed during this research is expensive and labor intensive; the estimates are also imprecise due to the uncertainty involved with assigning species to run count estimates and the difficulty conducting drift gill net studies in the lower Roanoke River. Additionally, evaluations of fry stockings upstream of dams indicate fish spawned upstream would have little contribution to the population because of low downstream passage rates. Consequently, Dominion Power (with support of state and federal partners) has annually petitioned the FERC for a delay of the design of a fish passage program at Roanoke Rapids Dam. The DFRTAC continues to meet and evaluate the status of the Roanoke Rapids Dam FERC license agreement, including provisions for passage of American Shad.

The previous plan recommended development of creel survey methods to better estimate effort, catch, and harvest of American Shad in the Roanoke River. The existing creel survey conducted each spring on the Roanoke River targets Striped Bass effort and only estimates effort, catch, and harvest for anglers fishing from boats. Few American Shad are encountered each year during the existing Roanoke River creel survey. American Shad are most likely targeted by bank anglers; however, due to inadequate funding and staff availability, WRC has not been able to expand the Roanoke River creel survey to include bank anglers. Anecdotal evidence from WRC biologists and enforcement officers indicates American Shad catch and harvest on the Roanoke River is minimal.

Finally, DMF conducts an annual review of research priorities for all managed species. A top priority has consistently been expansion of existing surveys to meet the need for more accurate JAIs for species of importance. However, lack of funding and staff resources has delayed sufficient expansion of the alosine seine survey.

1.2 Tar-Pamlico River

Stock Status

Stock status could not be determined for the Tar-Pamlico River based on the 2007 ASFMC stock assessment (ASMFC 2007b). There were no definitive trends in abundance, although it was noted that the electrofishing CPUE for the Tar River was higher than in other North Carolina rivers since 2000. A Z_{30} of 1.01 is suggested (ASMFC 2007a).

Commercial Fisheries

Commercial landings of American Shad have declined significantly since the mid-1980s and have remained low and variable without trend since 1994 (Figure 2). Almost all harvest occurs in gill nets.

Recreational Fisheries

A recreational fishery does exist, and estimates of angler effort and catch are calculated using creel surveys. Previously, these surveys rotated among the Tar, Neuse, and Cape Fear rivers. Annual creel surveys coordinated between both DMF and WRC jurisdictions began in 2012 on the Tar-Pamlico and Neuse rivers, and on the Cape Fear River in 2013. Estimates of angler effort and catch are calculated through creel surveys noted in the fishery dependent section of this plan. A confounding factor in the creel survey is that anglers often indicate they targeted "shad" because American and Hickory Shad co-occur in the Tar-Pamlico River. The 2016 Tar-Pamlico creel survey determined recreational anglers caught 4,237 American Shad during 5,115 trips targeting American Shad, Hickory Shad, and non-specific shad species. Of the total catch, 1,417 American Shad were harvested (Table 2). The recreational daily creel limit is 10 American and Hickory Shad in the aggregate.

Sustainability Parameters

Data used in the development of sustainability parameters for the Tar-Pamlico system include electrofishing data collected by WRC and commercial landings data collected through the DMF Trip Ticket Program (see Section 7 for complete descriptions of these surveys). There is no directed long-term JAI survey for the Tar-Pamlico system. An IGNS has been conducted consistently in the Tar-Pamlico, Pungo, and Neuse river tributaries of Pamlico Sound since 2004, but additional analysis is needed.

The following sustainability parameters and thresholds were evaluated for the Tar-Pamlico River system:

Female CPUE (electrofishing survey): The female CPUE index based on the WRC electrofishing survey was calculated as the number of fish per minute using data collected from March through May (Figure 6).

- Time series: 2000–2017. The electrofishing survey has been conducted annually since 2000 on the Tar River.
- Threshold: Three consecutive years of values below the 25th percentile (where 75% of all values are greater) from the fixed time series 2000-2017.

Female Relative F (electrofishing survey): Female relative *F* based on the WRC electrofishing survey was calculated using commercial landings of roes by all gear types from the Pamlico River and the female CPUE index from the Tar River electrofishing survey (Figure 7). Because the electrofishing survey primarily occurs during March through April, only commercial landings from those months were used in the calculations.

- Time series: 2002–2017. The electrofishing survey has been conducted on the Tar River annually during these years.
- Threshold: Three consecutive years of values above the 75th percentile (where 25% of all values are greater) from the fixed time series 2002-2017.

The sustainability parameters selected for the Tar-Pamlico River were the female CPUE index and female relative *F*, both derived from the WRC electrofishing survey. Exceeding the threshold for any of the selected parameters will trigger management action (see Section 0).

Female relative abundance of American Shad derived from the electrofishing survey in the Tar River has been relatively stable over the time series except for two notably high years in 2003 and 2004 (Figure 6). The index was below the threshold in 2006, 2007 and 2009 but above the threshold in all other years.

Estimates of relative *F* for female American Shad derived from the electrofishing survey were below the threshold during 2003 to 2006 (Figure 7). These estimates of female relative *F* exceeded the threshold in 2002, 2007, 2009, and 2012. The 2017 estimate is well below the threshold.

Areas Covered by Sustainability Parameters

Monitoring and sustainability parameters in the Tar-Pamlico River are representative of the entire Tar-Pamlico River basin, including tributaries. Management measures taken as a result of sustainability plan triggers will be applied at the basin level and will include all tributaries.

Additional Considerations

There is potential to improve upstream passage in this system. The WRC, USFWS, Pamlico-Tar River Foundation, and the Albemarle Pamlico National Estuary Partnership have engaged in conversations with the Rocky Mount Mills Dam owner and hydroelectric operator. In addition to interest in providing American Shad access to potential spawning habitat upstream of Rocky Mount Mills Dam, concern exists that hydropeaking operations (periodic spikes in flow) at Rocky Mount Mills Dam compromise the quality of existing spawning habitat. The dam owners agreed to cease hydropeaking during the anadromous spawning season, and the powerhouse has been out of operation for several years. The current owners of the dam have intentions to resume hydroelectric operation, and they are considering fish passage improvements as well.

A cooperative effort between DMF and WRC to improve the frequency and design of recreational creel surveys on the Tar-Pamlico and Neuse rivers began in spring 2012. Creel surveys have occurred annually since that time and include increased coverage on both rivers, which has improved estimates of recreational harvest.

As noted previously, DMF conducts an annual research prioritization exercise for all managed species. One of the top priorities has consistently been expansion of existing surveys to provide accurate juvenile abundance indices (JAI) for all commercially and recreationally important species. Meeting this priority is unlikely, due to the lack of funding available to the DMF to expand current monitoring programs.

1.3 Neuse River

Status of Stocks

Stock status could not be determined for the Neuse River based on the 2007 ASFMC stock assessment (ASMFC 2007b). There were no definitive trends in abundance over the most recent five to ten years of the assessment. A Z_{30} of 1.01 was suggested (ASMFC 2007a).

Commercial Fisheries

Commercial landings of American Shad have declined since 1972. There have been several peaks throughout the time series, but landings have remained low and variable without trend since the early 2000s (Figure 2). Harvest occurs almost entirely from gill nets.

Recreational Fisheries

Estimates of angler effort and catch are calculated through creel surveys noted for previous systems in the fishery-dependent section of this plan. The 2016 Neuse River creel survey determined total recreational catch to be 1,641 American Shad out of a total of 9,574 trips targeting American Shad, Hickory Shad, and non-specific shad species (Table 3). The majority of American Shad catch is released, as harvest was estimated to be only 252 American Shad in 2016. Additionally, as mentioned above a confounding factor in the creel survey is that anglers often indicate they targeted “shad” because American and Hickory Shad co-occur in the Neuse River system. A 1-fish daily limit on American Shad within the aggregate 10-fish recreational creel limit for American and Hickory Shad has been implemented in Coastal, Joint, and Inland Waters of the Neuse River.

Sustainability Parameters

Data used in the development of sustainability parameters for the Neuse River system include electrofishing data collected by WRC and commercial landings data collected through the DMF Trip Ticket Program (see Section 7 for complete descriptions of these surveys). There is no directed JAI survey for the Neuse River. As noted previously, there is an IGNS in the tributaries of Pamlico Sound. While the IGNS for the Neuse River area of the survey has been conducted since 2004, additional time is needed to properly evaluate this survey as an index for American Shad because effort is calculated differently than the Albemarle Sound IGNS. The following sustainability parameters and thresholds were evaluated for the Neuse River system:

Female CPUE (electrofishing survey): The female CPUE index based on the WRC electrofishing survey was calculated as the number of fish per minute using data collected from March through May (Figure 8).

- Time series: 2000–2017. The electrofishing survey has been conducted consistently since 2000 on the Neuse River.
- Threshold: Three consecutive years of values below the 25th percentile (where 75% of all values are greater) from a fixed time series of 2000-2017.

Female Relative F (electrofishing survey): Female relative *F* based on the WRC electrofishing survey was calculated using commercial landings of roes by all gear types from the Neuse River and the female CPUE index from the Neuse River electrofishing survey (Figure 9). Because the electrofishing survey primarily occurs during March through April, only commercial landings from those months were used in the calculations.

- Time series: 2002–2017. This time period reflects the years the electrofishing survey has been conducted on the Neuse River.
- Threshold: Three consecutive years of values above the 75th percentile (where 25% of all values are greater) from a fixed time series of 2002-2017.

The sustainability parameters selected for the Neuse River were the female CPUE index and female relative *F*, both derived from the WRC electrofishing survey. Exceeding the threshold for any of the selected parameters will trigger management action (see Section 0).

The electrofishing index of relative abundance for female American Shad in the Neuse River has been variable and remained above the threshold for the past seven years. The index was below the threshold in 2000, 2002, 2006, 2007, and 2010 (Figure 8). Relative *F* estimates for female shad derived from the electrofishing survey have been below the threshold since 2008 (Figure 9).

Areas Covered by Sustainability Parameters

Monitoring and sustainability parameters in the Neuse River are representative of the entire Neuse River basin, including tributaries. Management measures taken as a result of sustainability plan triggers will be applied at the basin level and will include all tributaries.

Future Considerations

Access to American Shad spawning habitat is affected by streamflow conditions on the Neuse River, and the variability in timing and strength of streamflow can determine where American Shad spawn. During high flow events, many American Shad migrate upstream to Milburnie Dam (rkm 352), which is the first mainstem dam on the Neuse River. Milburnie Dam is scheduled to be removed in 2017, and the removal will open approximately 25 km of additional spawning habitat to American Shad in the mainstem Neuse River. Future monitoring will determine if American Shad alter their migratory behavior in response to the dam removal. Additionally, further research is needed to determine how spawning success might be related to streamflow. The removal of Milburnie Dam, however, is expected to improve anadromous fish spawning habitat in the Neuse River, especially during high streamflow events.

As noted in the previous section, an annual creel survey rotation prior to 2012 as well as efforts by DMF to expand creel surveys upstream have improved recreational effort and catch/harvest estimates. Annual creel surveys in the Neuse River are anticipated to continue. Expansion of existing surveys to provide accurate JAIs for all commercially and recreationally important species is a DMF priority. Meeting this priority is unlikely, due to the lack of funding available to the DMF to expand current monitoring programs.

Similarly, a representative JAI for American Shad may be a future possibility depending on resources available to expand or reconfigure existing independent surveys.

1.4 Cape Fear River

Stock Status

Similar to the Tar-Pamlico and Neuse rivers, the stock status on the Cape Fear River is unknown, although a Z_{30} of 1.01 was recommended in the latest assessment (ASMFC 2007a, 2007b). Of all the river systems in North Carolina, the Cape Fear is likely to have the highest proportion of fish that are semelparous (spawn once followed by death).

Commercial Fishery

Commercial landings have displayed several cyclical peaks since 1972, although each successive peak has been slightly lower than the previous. Landings were somewhat low throughout the 2000s (Figure 2). As with the other river systems, the vast majority of landings are from gill nets. There has been very little harvest from other gears.

Recreational Fishery

Like the other systems mentioned, a comprehensive creel survey was initiated in 2013 to identify and estimate recreational American and Hickory Shad effort and catch within the Cape Fear River system. In 2016, the estimate of total recreational catch was 21,011 American Shad from a total of 5,132 trips targeting American Shad, Hickory Shad, and non-specific shad species. Approximately 50% of the American Shad catch was harvested (Table 4). In 2013, the daily creel limit was reduced to a maximum of five American Shad within the 10-fish shad aggregate daily limit. It is important to note that Hickory Shad are encountered infrequently in the Cape Fear River and most of the recreational effort is focused on American Shad.

Sustainability Parameters

Data used in the development of sustainability parameters for the Cape Fear system include electrofishing data collected by WRC and commercial landings data collected through the DMF Trip Ticket Program (see Section 7 for complete descriptions of these surveys). There is no directed JAI survey for the Cape Fear River. While there was an IGNS from 2003–2007, it was a fixed- station survey rather than a stratified random design and was therefore not used in any sustainability parameter calculations.

The following sustainability parameters and thresholds were evaluated for the Cape Fear River system:

Female CPUE (electrofishing survey): The female CPUE index based on the WRC electrofishing survey was calculated as the number of fish per minute using data collected from March through May (Figure 10).

- Time series: 2001–2017. The electrofishing survey has been conducted annually since 2001 on the Cape Fear River.
- Threshold: Three consecutive years of values below the 25th percentile (where 75% of all values are greater) from the fixed time series 2001-2017.

Female Relative F (electrofishing survey): Female relative *F* based on the WRC electrofishing survey was calculated using commercial landings of roes by all gear types from the Cape Fear River and the female index from the Cape Fear River electrofishing survey (Figure 11). Because the electrofishing survey primarily occurs during March through April, only commercial landings from those months were used in the calculations.

- Time series: 2003–2017. This time period reflects the years the electrofishing survey has been conducted on the Cape Fear River.
- Threshold: Three consecutive years of values above the 75th percentile (where 25% of all values are greater) from the fixed time series 2003-2017.

The sustainability parameters selected for the Cape Fear River were the female CPUE index and female relative *F*, both derived from the WRC electrofishing survey. Exceeding the threshold for any of the selected parameters will trigger management action (see "Potential Management Measures").

Relative abundance of female American Shad from the electrofishing survey in the Cape Fear River was low from 2005 through 2011, and values were below the threshold from 2006 to 2011 (Figure 10). Since 2011, relative abundance of female American Shad has been above the threshold and continued to increase through 2015. Estimates of female relative *F* have remained below the threshold since 2012 (Figure 11).

Areas Covered by Sustainability Parameters

Monitoring and sustainability parameters in the Cape Fear River are representative of the entire Cape Fear River basin and tributaries, including the Black River. Fishery-independent monitoring is performed in the Cape Fear River mainstem through adult electrofishing and gill net surveys (see section 1.11.2 for more details). Fishery-dependent monitoring is preformed through NCTTP trip level commercial harvest monitoring and recreational creel sampling. The adult electrofishing survey occurs upstream of the mouth of the Black River. American shad are not suspected to use the Black River for spawning and any fish staging in the Black River would likely be intercepted in the electrofishing survey that occurs at the base of the Lock and Dam 1, 2, and 3 on the Cape Fear River. It is important to note that while fishery-independent monitoring outside of the electrofishing survey is not used to calculate sustainability parameters, monitoring of adults and juveniles are occurring in the Cape Fear River mainstem below the lock and dam, in an effort to track trends in abundance. Management measures taken as a result of sustainability plan triggers will be applied at the basin level and will include all of the mainstem Cape Fear River and its tributaries including the Black River.

Additional Considerations

Collaborative habitat enhancement projects that focus on fish passage and increasing spawning habitat have been implemented on the Cape Fear River in recent years. Each year, WRC recommends a locking schedule to the USACE to pass anadromous fishes upstream of locks and dams during the spring spawning run. In 2012, a rock arch fishway was constructed below Lock and Dam 1 (LD-1) to facilitate volitional, upstream fish passage. Telemetry studies conducted to evaluate American Shad usage of the rock arch fishway indicate American Shad passage efficiency at the LD-1 fishway ranged 53–65% and was consistent with prior estimates from locking procedures (Raabe et al. 2016). Electrofishing surveys corroborate the telemetry studies, as electrofishing catch rates have increased at the upper two locks and dams and decreased at LD-1 over the last five years. These results indicate American Shad are readily passing LD-1. With presumed historic spawning grounds, upstream of Lock and Dam 3 (LD-3), substrate was strategically placed below Lock and Dam 2 (LD-2) in 2013 to increase the potential spawning habitat for anadromous fish that pass the rock arch fishway but fail to navigate the lockage system. Locking at LD-1 has ceased at this point but continues for LD-2 and LD-3 to facilitate fish passage. American Shad spawning activity has been observed by Commission staff (Bennett Wynne, WRC retired, personal communication), and American Shad eggs have been collected just downstream of LD-2 (Dawn York, Cape Fear River Partnership, personal communication). Therefore, fish that migrated to LD-2 but failed to migrate farther upstream could reproduce and benefit from the habitat enhancement efforts. In recent years, 2016 and 2017, WRC staff have encountered eggs below LD-3 (Clinton Morgeson, WRC, personal communication). The Cape Fear River Partnership, including local, state, and federal agencies, as well as private groups, continues to plan fish passage enhancement projects on the remaining locks and dams on the main stem Cape Fear River.

Based on the construction efforts and changing conditions, DMF and WRC recommended a two-year review of the 75th percentile threshold for female relative *F* in the 2012 SFP as calculation of this parameter was likely to be heavily influenced by drought, floods, and changes in fish passage. There was also concern that restoration efforts might influence electrofishing catch rates due to improvements in fish passage with completion of the rock arch fishway. After review in 2015, no changes were recommended for the Cape Fear system. North Carolina will continue to evaluate American Shad relative abundance and sustainability metrics in the context of improvements in habitat and passage benefiting anadromous fishes in the Cape Fear River.

1.5 Pee-Dee River

The Pee-Dee River originates in North Carolina before flowing into South Carolina and emptying into Winyah Bay with approximately 25 km of American Shad spawning habitat located in the North Carolina portion of the Pee-Dee River. Neither NCWRC nor NCDMF have the resources to conduct monitoring activities in this system. However, South Carolina Department of Natural Resources maintains monitoring programs in the Pee-Dee River, which is considered a surrogate monitored system to the Little River. Monitoring programs in place for the Pee-Dee River run of American Shad are considered by the Shad and River Herring TC and Management Board to be adequate and sustainable at current levels. The approved sustainability target for the Pee-Dee River run is 3.41 kilograms of American Shad per unit of effort (92 meters of gill net per hour). Should the annual metric of catch per unit effort of American Shad fall below the sustainability target for three consecutive years, management responses will be applied. Potential management actions may include gear restrictions, season changes, catch limits, or closure. Additional information on the sustainability target for the Pee-Dee River can be found in the South Carolina SFP for American Shad.

Additionally, Duke Energy began electrofishing surveys in 2016 to monitor the American Shad population in the North Carolina section of the Pee-Dee River downstream of their hydroelectric facility at Blewett Falls Dam. This survey, along with SCDNR monitoring further downstream will be used to evaluate trends in American Shad and could eventually be used to develop sustainability metrics when the time series reaches appropriate length. Commercial and recreational fisheries were approved in the South Carolina SFP issued in 2012. Commercial harvest of American Shad is prohibited in the North Carolina portion of the Pee-Dee River, but recreational harvest of 10 American Shad per day is allowed under an exception to the statewide recreational creel limit of 1-American Shad per day, as amended in 2019. This recreational creel limit is consistent with the creel limit in South Carolina. We propose maintaining the recreational fishery in the North Carolina portion of the Pee-Dee River and defer American Shad management and determination of sustainability to South Carolina. Should metric benchmarks be triggered in the Pee-Dee River, NCWRC will complement management actions in North Carolina waters to maintain consistency with South Carolina when appropriate.

1.6 Little River

The Little River is a small coastal river that flows primarily through Little River, South Carolina. The river runs the border between North Carolina and South Carolina, before emptying into the Atlantic Ocean at the Little River Inlet, South Carolina. A large portion of the river forms part of the Atlantic Intracoastal Waterway. American shad may travel to the Waccamaw River (South Carolina) through the Little River but this is not a known spawning river. Neither NCWRC nor NCDMF have the resources to conduct monitoring activities in this system. However, South Carolina Department of Natural Resources maintains monitoring programs in the Pee-Dee River, which is considered a surrogate monitored system to the Little River. Monitoring programs in place for the Pee-Dee River run of American Shad are considered by the Shad and River Herring TC and Management Board to be adequate and sustainable at current levels. The approved sustainability target for the Pee-Dee River run is 3.41 kilograms of American Shad per unit of effort (92 meters of gill net per hour). Should the annual metric of catch per unit effort of American Shad fall below the sustainability target for three consecutive years, management responses will be applied. Potential management actions may include gear restrictions, season changes, catch limits, or closure. Should metric benchmarks be triggered in the Pee-Dee River, complementary management responses will be applied to the Little River in both North Carolina and South Carolina. Additional information on the sustainability target for the Pee-Dee River can be found in the South Carolina SFP for American Shad.

1.7 Other Areas

The areas included in the sustainability parameters submitted for consideration above contain the known American Shad spawning populations in North Carolina, and those systems support the only directed recreational and commercial fisheries in the state. However, American Shad are incidentally encountered in commercial fisheries prosecuted within other non-spawning rivers and coastal sounds. Commercial harvest from these areas is a very small proportion of annual American Shad harvest (Figure 2) and is primarily considered incidental bycatch. For example, commercial harvest from the New and White Oak rivers (two coastal, blackwater rivers) combined averaged only 140 pounds per year between 1994 and 2016. Recreational effort and harvest in areas outside of spawning rivers is most likely non-existent. In the New and White Oak rivers, recreational creel survey intercepts from 2004 to present have not indicated American or Hickory Shad as target species and no American or Hickory Shad have been reported in the catch. While there are currently no independent surveys for American Shad outside of spawning rivers, surveys for other species rarely encounter American Shad. We propose to maintain current harvest seasons (February 15-April 14) to allow commercial harvest of incidental bycatch because these fish will most likely be dead discards and the amount of harvest is minimal. The areas without specified sustainability parameters will fall under default management measures listed in tables 8 and 9. North Carolina will continue to monitor commercial landings through the North Carolina Trip Ticket Program to ensure landings remain low. Dedicated monitoring programs or area closures will be implemented if sudden increases in landings, indicating targeted effort, occur.

MANAGEMENT MEASURES

1.8 Potential Management Measures

The environmental circumstances under which a sustainability threshold may be reached can vary among systems. Therefore, different management measures may be used for each system in addressing the triggers. One or more potential management measures presented here and may be used singly or in combination:

- Restrictions on length of season to reduce effort (e.g., March 1–April 14) not to extend beyond the estuarine striped bass quotas being filled (avoids waste of striped bass and shad)
- Trip limits (this may result in discards)
- Reduce allowable number of yards (the 1,000-yard limit in Albemarle Sound could be considered in other areas)
- Area/season closure (e.g., area closure at mouth of Roanoke River from February–mid-November since 1988)
- Only allow fishing certain days of the week (lift days)
- Recreational creel reduction

- Commercial harvest quota (although possible, this could be difficult to implement given existing resources)

If two years of sustainability parameters exceeding thresholds are observed, a suite of management measures could be proactively developed and presented to Finfish and Regional Advisory Committees.

1.9 Management Measures implemented 2013-2017

Changes in management (season lengths, creel limits) since implementation of the SFP in 2013 have been noted in Section 6 and are summarized for convenience in Tables 8 and 9.

Although harvest is an obvious potential contributor to population declines, significant habitat degradation has also occurred in all the river systems. It is unlikely that American Shad populations in North Carolina will recover and expand without considerable resources being dedicated to habitat restoration for this species. Our management goals, however, are intended to sustain population levels as additional habitat is protected or improved through aquatic habitat conservation measures and increased passage opportunities of American Shad beyond impediments that block migration to historic spawning grounds.

<u>Cape Fear River</u>

At the request of the ASMFC Shad and River Herring Technical Committee during development of the 2012 SFP, additional analysis was conducted for the Cape Fear River. This was based on the female relative *F* parameter being over the 75^{th} percentile threshold for two consecutive years, as well as the female CPUE from the electrofishing survey being very close to the threshold for six consecutive years. An 11% percent reduction in commercial harvest was required to bring female relative *F* down to the threshold.

Additional analyses (see Appendix 2 of the 2012 SFP) were conducted to determine the commercial and recreational reductions in harvest that would provide an additional conservation buffer. It was determined that equivalent reductions in harvest for both commercial and recreational sectors would provide the greatest benefit given that commercial and recreational harvest in 2011 were roughly equivalent. Management options that resulted in a 25% reduction in harvest for each sector were calculated, and it was determined that a shortened commercial season and a reduction in the recreational creel limit would best meet the required reductions in harvest. While commercial and recreational harvests have fluctuated somewhat since regulatory changes were implemented, both the electrofishing index and relative *F* index have remained above and below their respective thresholds since 2012. A commercial season from February 20 through April 11 and a recreational creel limit of five fish within the 10-fish aggregate resulted in the necessary 25% reduction.

1.10 Proposed Management Measures for 2018

The following management measures are proposed to be effective January 1, 2018.

<u>Recreational</u>
Albemarle Sound/Roanoke River, Neuse River

- Recreational creel limit of 1-fish for American Shad in Joint and Coastal Waters to complement the WRC 1-fish limit in Inland Waters of these systems (no change to existing DMF and WRC rules).

Tar-Pamlico River

- Recreational creel limit of 10-fish for American Shad in the Joint, Coastal and Inland Waters of the Tar-Pamlico River and its tributaries (no change to existing DMF and WRC rules).

Cape Fear River

- Recreational creel limits of 5-fish for American Shad in the Inland, Joint and Coastal Waters of the Cape Fear River and its tributaries (no change to existing DMF and WRC rules).

Commercial
Albemarle Sound

- Commercial season of March 3-24.

Tar-Pamlico River, Neuse River

- Commercial season of February 15-April 14.

Cape Fear River

- Commercial season of February 20-April 11.

While none of the selected sustainability parameters for any of the river systems have exceeded the triggers for management since 2013, the above measures are considered prudent given the results of the 2007 stock assessment as they pertain to North Carolina. Future changes to creel limits for American Shad in the Inland Waters of the other river systems will also be complemented by DMF for Joint and Coastal Waters.

ANCILLARY INFORMATION AND FUTURE CONSIDERATIONS

The focus on female indices for the sustainability parameters in all systems is based on the conclusion that changes in female abundance combined with impacts from various environmental parameters could prove challenging to stock improvement given that the commercial fishery targets roe shad. Major fluctuations in female abundance could potentially impact future recruitment and landings. The use of sex ratios as a sustainability parameter was considered, but it was determined that the sex ratios from both the IGNS (in the Albemarle system and potentially the other systems) and the electrofishing surveys were more suitable for use as long-term trends rather than short-term (i.e., three year) indicators of stock health due to the impact of environmental variability on the data. The intent of the agencies is to monitor the sex ratios from each of the surveys for trends and use this information to help inform future management.

An IGNS has been conducted consistently in the Tar-Pamlico, Pungo, and Neuse Rivers and tributaries of the Pamlico Sound since 2004. Unlike the Albemarle Sound IGNS, American Shad captured in this IGNS program do not have sex assigned in the program data for effort, if age structures are collected sex is assigned and reported in a separate aging program. Only a proportional estimate of sex can be applied to the small sample size. Additionally, effort is calculated differently, by gang of nets, compared to the Albemarle Sound IGNS which calculates effort per individual net. Additional analysis into the data caveats is needed to properly evaluate this survey as a new index of abundance for this plan.

The use of repeat spawning data was also considered as a potential sustainability parameter. However, inconsistencies in determination of repeat spawning marks made it difficult to set a target or threshold. Because repeat spawning continues to be tracked annually as part of the required monitoring program, it will also be used as ancillary information for determining future management. Should greater confidence in repeat spawning data be attained in the future, they may be considered for developing a formal sustainability parameter.

Sustainability parameters have been updated annually in compliance reports, as well as via annual appendices to the SFP detailing changes in management measures. DMF and WRC also jointly review the performance of the plan on an annual basis to determine management measures for the following season.

Finally, during the preparation of this update, both DMF and WRC discussed exploring several additional sustainability parameters, as well as potential future modifications to existing sustainability parameters:

- Consider alternate means of calculating effort from the IGNS and possible incorporation of IGNS from Tar-Pamlico and Neuse as parameters;
- Consider incorporating uncertainty in relative *F* estimates;
- Consider use of alternative modeling approaches that can incorporate environmental parameters as model factors;
- Consider alternative ways to calculate relative *F* including using recreational catch estimates and total catch from the IGNS.

If appropriate, North Carolina would submit a revised SFP for Technical Committee review to allow for inclusions or modifications described above.

STOCK MONITORING PROGRAMS

The following descriptions represent the entirety of stock monitoring programs used to assess the health of American Shad in North Carolina. All programs are included in annual compliance reports and as noted in the program descriptions, specific details can be found in past compliance reports.

1.11 Fishery-Independent Monitoring

1.11.1 Juvenile Abundance

A juvenile abundance index is calculated for Albemarle Sound area using data from the alosine seine survey that has been conducted annually since 1972. Eleven core seine stations are sampled monthly in the western Albemarle Sound area during June–October of each year. During September, thirteen additional seine samples are taken to determine distribution and annual variations of alosines in the nursery area. All stations are sampled with an 18.5-m (60-ft) bag seine. Relative abundance data are collected for Blueback Herring, Alewife, American Shad and Hickory Shad from the 11 core stations.

Samples are sorted by species and 30 randomly selected individuals of each alosine species present are measured. Other species present are also noted. Water temperature, salinity, and other environmental characteristics are counted, measured, and recorded. As noted previously, this survey was designed specifically for blueback herring and is not considered a reliable indicator of juvenile American Shad abundance.

No juvenile abundance indices exist for the Tar-Pamlico, Neuse and Cape Fear River systems.

1.11.2 Adult Stock Monitoring

Spawning Area Survey

An annual spawning stock survey and representative sampling for biological data is required from Albemarle Sound and its tributaries, Tar-Pamlico, Neuse, and Cape Fear Rivers for American Shad. Sampling in these areas was initiated in 2000.

WRC personnel collect American Shad from the Roanoke, Tar, Neuse and Cape Fear systems annually during February–June. A boat-mounted electrofishing unit (Smith-Root 7.5 GPP) is used (1 or 2 dip netters) to capture fish during daylight hours, and electrofishing times are recorded in seconds. To minimize size selection during sampling in all river systems, shad are netted as they are encountered regardless of size. Relative abundance of each year-class is indexed by CPUE expressed as the number of fish captured per hour of electrofishing. However, CPUE is converted to fish per minute for sustainability indices described above. American Shad broodstock collections are usually excluded from calculations of CPUE unless collections occur during regular sampling activities. Because broodstock are sacrificed when hatchery spawning is complete, otoliths from broodstock are aged and used to develop age length keys in most years. Total length (mm), weight (g), and sex are recorded for all captured fish. Sampling protocols are unique to each river system and have been refined throughout the survey period. River-specific descriptions of spawning area surveys are provided in the following sections.

Roanoke River

American Shad surveys have been conducted in the Roanoke River from 2001 through 2017. The surveys occur in the mainstem Roanoke River near the Gaston Boating Access Area at river kilometer (rkm) 225. The survey area encompasses the most upstream American Shad spawning habitat in the Roanoke River, and further migration beyond the survey area is blocked by Roanoke Rapids Dam at rkm 227 (approximately 2 km upstream of the survey area). In 2000–2007, sampling was concurrent with Striped Bass surveys in the same sample area and was restricted to April and May. Beginning in 2008, sampling was started earlier in March when water temperatures approach 10ºC and continued weekly until low-flow conditions restrict boat navigation or until spawning appears complete (typically end of May or first of June). One dip netter was used 2000–2004 and 2010–2011, whereas two dip netters were used 2005–2009 and 2012–2017. Also in earlier years (2000–2012), two or three shoreline sample sites approximately 1 km each were sampled per week. In 2013–2017, however, samples were conducted at nine sampling sites once per week during the survey period. Electrofishing commenced at the upstream portion of each 500-m site and continued downstream the entire transect. Sites were randomly selected from shoreline and mid-channel habitats along the 3-km stretch downstream of the Hwy 48 bridge. Total electrofishing effort increased from previous years, but the new sample protocol still occurs in the same area as previous years.

Tar River

American Shad spawning area surveys have been conducted on the mainstem Tar River from 2000 through 2017, and survey protocols have changed relatively little throughout the survey period. One dip netter is used to capture fish during daylight hours. Electrofishing samples are conducted weekly during March–May. Sampling begins when water temperatures approach 10ºC. Sample sites are located within one of three approximately 15-km segments that encompass most of the American Shad spawning habitat in the Tar River. Segment 1 contains the river stretch from Rocky Mount Mill Dam downstream to the Dunbar Boating Access Area (BAA). Segment 2 includes the river stretch from Dunbar BAA downstream to the Bell's Bridge BAA. Segment 3 continues from the Bell's Bridge BAA downstream to the Tarboro town ramp. Normally, one sample of approximately 30 minutes of electrofishing time is conducted within a segment during a sample day. Typically, only one 30-minute sample is conducted per week, yet, depending on flows, attempts are made to conduct another 30-minute sample in a different segment, or at least in a different site of the same segment, during that same week. Sample sites within a segment vary from week to week and are selected from areas that appear to have preferred American Shad habitat. Angling activity is avoided. Flows and water temperature determine which segment is sampled on a particular day. Moderate to high flows and warmer water temperatures tend to cause American Shad to move further upstream into segment 1. There are certain minimum river levels required to allow access to the river for electrofishing, yet the majority of American Shad sampling is concentrated in segment 1 when flows are greater than 300 cfs. Flooding often prevents access to the river for sampling, but high water subsides quickly in the Tar River and at least one sample site per week is usually possible.

Neuse River

American Shad electrofishing surveys have been conducted in the Neuse River from 2000 through 2017 and one dip netter is used to capture fish during daylight hours. Electrofishing samples are conducted weekly during March–May. Sampling begins when water temperatures approach 10ºC and ends when spawning appears to be complete. Sampling is conducted near known spawning areas at Goldsboro, NC (rkm 240) and Raleigh, NC (rkm 350). Sampling begins at the downstream Goldsboro location in March, and the Raleigh location is added to the weekly sampling regime once 30–40 American Shad are collected in one day at the Goldsboro location. Weekly sampling locations are contingent upon water levels because low flows limit navigability. The Raleigh location is only accessible at moderate to high flows and is dropped from weekly sampling when flows are not adequate for safe and effective sampling. When conditions improve, sampling is resumed at the Raleigh location. Sampling locations have been consistent throughout the survey period, but sampling protocols at each location have varied over time. In early years of the survey, two sample sites were sampled at each location. The sample sites were 2–3 km long and took over one hour of electrofishing time to complete. Since 2015, two or three sample sites are sampled at each location, but the sites have been shortened to around 1 km and electrofishing effort has been reduced. Nevertheless, the same areas have been consistently sampled throughout the survey.

Cape Fear River

Sampling for American Shad has occurred in the Cape Fear River from 2001 through 2017. In most years, one dip netter was used to collect American Shad, but two dip netters have been used 2015–2017 to avoid gear saturation caused by increases in American Shad abundance. In all survey years, sampling occurred at three fixed sample sites adjacent to the base of each of three locks and dams found on the river. Since 2010, sampling efforts have been standardized by electrofishing for 30 minutes downstream of each lock and dam—15 minutes from the middle of each dam down each shoreline. Sampling at each site is attempted weekly when water temperatures approach 10ºC and is ended when spawning appears complete. Prior to 2010, however, sampling was more sporadic and did not always occur at each site every week. Other areas in the Cape Fear River upstream of the locks and dams (Buckhorn Dam and Smiley's Falls) are also sampled, but data from sites other than the locks and dams are not included in annual relative abundance analyses. Sampling at the locks and dams is possible under most flow conditions, but flood events can periodically prevent sampling.

Independent Gill Net Survey (IGNS)

Since 1991, DMF has been conducting an independent gill net survey throughout the Albemarle Sound area. The survey was designed for Striped Bass data collection and occurs November through May each year. However, American Shad are captured during the survey and size, age and sex data are collected. Forty-yard segments of gill net from 2.5- through 7.0-inch stretched mesh, in half-inch increments, as well as 8.0, and 10.0-inch stretched mesh are utilized. The sound is divided into zones and grids and random sites are selected within these areas. Lines of float and sink nets are set in both shallow and deep strata if they are present in the grid.

The IGNS in the Pamlico Sound area began 2001, while the rivers (including Pamlico, Pungo and Neuse rivers) began in 2003. The Cape Fear River was added in 2007 and the Core Sound area will begin fully in 2018. The survey runs from February through mid-December and utilizes a different methodology than that conducted in the Albemarle Sound. Thirty-yard segments of gill net are used, ranging from 3.0-inch stretched mesh through 6.5-inch stretched mesh in half-inch increments. The catch from the gang of nets comprises a single sample, unlike the Albemarle where each mesh net is tallied for effort. Each gang of nets is fished in both shallow and deep strata, and sites are preselected at random from within strata-grids.

Albemarle Sound American Shad Movement Study

The Roanoke River and Chowan River tributaries are known spawning rivers for American Shad entering Albemarle Sound. Despite the restoration efforts and research that has occurred in the Roanoke River, the proportion of American Shad migrating up the Chowan River or Roanoke River is largely uncertain. The NMFS and DMF have been conducting an acoustic telemetry study to determine migratory patterns of Albemarle Sound American Shad. The objective of this study was to determine which river basins are used by adult American Shad during the spawning run in 2013, 2014, 2016, and 2017. The study used an existing array of acoustic receivers placed at inlets and throughout Albemarle Sound and the Roanoke River. DMF, WRC, and NCSU maintain and operate these receivers to track movement of Atlantic Sturgeon, Striped Bass, and Largemouth Bass. The study area encompassed the Albemarle Sound, and its associated sounds (Croatan and Currituck) and rivers: North, Pasquotank, Little, Perquimans, Chowan, Roanoke, Scuppernong, and Alligator in northeastern North Carolina and the Meherrin, Nottaway, and Blackwater in southeastern Virginia. Adult American Shad were captured in gill nets with mesh sizes ranging from 4.5 to 6 inches at locations north and south of North Carolina Highway 32 bridge. This area is a funneling point for American Shad that have entered the Albemarle sound to reach spawning grounds on either the Chowan River (north) or the Roanoke River (south). American Shad were implanted with VEMCO V9-2x-A69-1601 coded acoustic transmitter and a PIT tag (only in 2013). Tagged fish were measured and assigned sex if possible. Fish were tagged by inserting the tag through the esophagus into the stomach. Fin clips were taken in 2016 and 2017 to determine hatchery contribution from Roanoke River stocked fish. The acoustic transmitter released a frequency every 90 seconds and tag life was expected to be around two years.

Since 2013, a total of 191 American Shad have been tagged. Table 7 shows the numbers of fish tagged, detected, and that made spawning runs up the Roanoke or Chowan Rivers. The fish that were detected but did not make spawning runs either demonstrated strong fall back behavior and presumably left the sound or are thought to have died.

Shad movement data gathered by this study suggest that a large portion of the spawning stock entering the Albemarle Sound is ascending the Chowan River to spawn. Future studies are needed to determine potential genetic differences between Chowan River and Roanoke River spawning stocks. Any genetic differentiation between the two rivers can be used to further evaluate spawning stock contribution within the Albemarle Sound population and can allow for more refined management and restoration efforts. Fin clips have been collected from the commercial fishery for future genetic analysis.

1.11.3 Size, Age and Sex Determination

Spawning Area Survey

Sex is determined for each captured fish by applying directional pressure to the abdomen toward the vent and observing the presence of milt or eggs. Each fish is measured for total length in millimeters. Scales are removed from the left side of each fish between the lateral line and the dorsal fin. To estimate age, scales are examined at 33X magnification on a microfiche reader and annuli are counted. Spawning marks are recorded separately. Shad that cannot be aged are assigned ages based on the gender specific age-length key developed for each river and included in CPUE and size-distribution analyses. Beginning in 2011, American Shad have been aged using otoliths, or age distributions have been calculated by applying age-length keys from years when otolith ages were aged up to 10 fish per 10-mm size bin (by sex) are sacrificed for otolith extraction. Broodfish were used to develop age-length keys in addition to spawning area survey fish.

Independent Gill Net Survey

Each fish is measured for fork length and total length. Sex is always determined for fish captured in the Albemarle Sound IGNS. Each fish is sexed by applying directional pressure to the abdomen toward the vent and observing the presence of milt or eggs. Scales are collected from the left side of each fish between the lateral line and the dorsal fin. Scales are prepared and aged according to the Cating (1953) method.

1.11.4 Total Mortality Estimates

Survival estimates are calculated using the Robson and Chapman (1961) method. Robson and Chapman showed that estimates of annual rates of survival can be made from the catch curve of a single season if the population is exposed to unbiased fishing gear beyond the age of recruitment and if year-class strength and survival rate remain constant from year to year. Annual mortality rates are calculated based on observed samples of individuals at age. Only age groups that are fully recruited to the gear are included in the calculations and the resulting estimates only apply to the fully recruited individuals.

1.12 Hatchery Evaluation

1.12.1 Roanoke River American Shad Restoration Project

Since 1998, over 72 million American Shad fry have been stocked in the Roanoke River downstream of Kerr (US Army Corps of Engineers), Gaston (Dominion Power) and Roanoke Rapids (Dominion Power) reservoirs at Weldon, NC. Since 2003, American Shad fry have also been stocked upstream of Kerr Reservoirs at Altavista, Clover Landing, VA; in Gaston Reservoir at Bracey, VA; and Roanoke Rapids Lake near Roanoke Rapids, NC (Table 5). These stocking activities serve as migratory obstruction mitigation required by Federal Energy Regulatory Commission (FERC) relicensing of the Gaston and Roanoke Rapids hydropower dams. The stockings upstream of dams are experimental to evaluate escapement of American Shad and determine the benefits of future fish passage efforts.

In the early years of the restoration project, WRC followed protocols of other states involved in American Shad restoration efforts and obtained broodfish for fry production from nearby rivers having adequate shad stocks. American Shad broodfish were collected by electrofishing from the

Tar, Neuse, Cape Fear, and Roanoke rivers from 1998–2010. Hormone injection was used to initiate spawning in the hatchery from 1998 to 2008, but in 2009, for the first time, broodfish were not injected with hormone (LHRHa or sGnRHa pellets) upon arrival at the hatcheries and prior to being transferred to circular spawning tanks. In 2011, only broodfish collected from the Roanoke River were utilized for production. Upon collection, broodfish are placed in circular tanks with oxygen and continuously circulating water onboard the electrofishing boats and are then transferred to large circular, trailer-mounted tanks for transport to the hatcheries.

Annual contribution of hatchery-origin American Shad to the Roanoke River population is evaluated for multiple cohorts of returning adults during the spring spawning run and for out-migrating juveniles during fall of the stocking year. Evaluation of hatchery contribution to the Roanoke River American Shad population was conducted using oxytetracycline (OTC) marks from 1998–2009. Subsequent testing proved OTC marking procedures and analyses were unreliable, and the WRC initiated use of genetic microsatellite markers for parentage-based tagging (PBT) methods in 2010. With the PBT method, each spawning tank contains a genetically discrete batch of broodfish, from which the progeny can be uniquely identified. Fin clips from all American Shad broodfish were stored in numbered vials containing non-denatured, spectrophotometric grade ethanol to later be referenced for determining hatchery origin of at-large fish produced in a given year. All PBT analyses were conducted by the genetics laboratory at the North Carolina Museum of Natural Sciences (NCMNS). Daily OTC marking techniques have not been used since the switch was made to PBT analysis. Fin clips from adult American Shad are collected during spawning stock surveys, and broodfish are also cross-referenced for potential hatchery contribution of stockings from previous years. Broodfish fin clips combined with fin clips collected during weekly samples are collectively referred to as at-large adults

Parentage-based-tagging efforts were initiated in 2010, and the early results (i.e., 2010–2014) cannot capture potential hatchery contribution from year classes before 2010. Thus, percent contribution of hatchery fish is underestimated and should be considered a minimum prior to 2015. Hatchery contribution from these early years should not be used to make inferences regarding the overall hatchery contribution of the spawning stock but can be used to assess hatchery contribution for specific year classes.

In 2012, a total of 289 fin clips was assessed using PBT techniques. Only one fish was determined to be of hatchery origin and was matched with broodfish from the 2010-year class. In 2013, a total of 26 out of 527 at-large adults was found to be of hatchery origin; 25 were matched to the 2010-year class and one to the 2011-year class. In 2014, a total of 708 fin clips was processed, and 90 were determined to be of hatchery origin (12.7%). Of the total, 54 were matched with broodfish from the 2010-year class, 34 from the 2011-year class, and 2 from the 2012-year class. In 2015, 233 of 543 processed fin clips were found to be of hatchery origin (42.9%); 66 were matched with the 2010-year class, 141 with the 2011-year class, 23 with the 2012-year class, and 3 with the 2013-year class. In 2016, 522 fin clips were processed, and 293 were determined to be of hatchery origin (56.1%); 33 were matched with broodfish from 2010, 191 matched with the 2011 broodfish, 38 matched with the 2012 broodfish, and 31 matched with the 2013 broodfish. Between 2010 and 2014, all hatchery-origin fish were stocked at Weldon (below Roanoke Rapids Dam). In 2016, one of the hatchery identified fish was stocked into the Staunton River, upstream of Kerr Reservoir. This is the first conclusive evidence of a fish being stocked above Kerr Reservoir being captured as an adult on the spawning grounds.

In 2016, a sample of fin clips was obtained from shad intercepted in the Albemarle Sound. A total of 4 out of 117 (3.4%) Albemarle Sound fish was determined to be of hatchery origin; the hatchery fish were from the 2011 and 2012 year classes. In 2017, 5 of 126 (4.0%) fin clips from Albemarle Sound American Shad were determined to be stocked fish. The 2011, 2012 and 2013 year classes were represented in the 2017 stocked fish. In both years, the hatchery contribution in the Albemarle Sound sample was lower when compared with hatchery contribution on the spawning grounds, indicating that Roanoke River spawning fish do not make up the majority of the Albemarle stock. Subsequent years of sampling will continue to investigate this relationship by obtaining fin clips from the Chowan River (when possible), Roanoke River, and Albemarle Sound.

Out-migrating juvenile American Shad are typically collected at night in the lower Roanoke River near Plymouth, NC from September to November using boat-mounted electrofishing gear. Since 2010, hatchery contribution of the out-migration has been assessed using PBT methods and has ranged from 2.7% (2012) to 44.8% (2014); average hatchery contribution was 21% over the survey period. To identify bottlenecks in passage in the Roanoke River, genetically distinct batches of fry were systematically stocked in the Staunton River upstream of Kerr Reservoir, Gaston Reservoir, Roanoke Rapids Lake, and Weldon. Hatchery fish identified in the out-migration can be conclusively matched to their stocking location; from 2010 through 2015 only hatchery-origin juveniles stocked at Weldon were collected. In 2016, however, six hatchery origin juveniles from the out-migrating sample were determined to be stocked in Roanoke Rapids Lake. Results from experimental fry stockings suggest fry spawned upstream of the reservoirs would contribute to the out-migrating juvenile population at a much lower rate than fry spawned downstream of the reservoirs. Thus, it may not be prudent to pass spawning adults upstream of the reservoirs until methods to improve downstream passage are developed.

1.12.2 Neuse River American Shad Restoration Project

The WRC began an American Shad restoration stocking program in the Neuse River in 2012. The goal of the Neuse River American Shad stocking program is to supplement the wild population by stocking fry produced from one spawning tank of approximately 100 broodfish each year. American Shad broodfish are collected from the Neuse River near Goldsboro, NC and are transported to Edenton National Fish Hatchery where they can spawn and fry are reared for approximately 7 days. American Shad fry are stocked in the Neuse River near Goldsboro, NC. Evaluation of hatchery contribution to the Neuse River American Shad population is conducted using the same PBT methods as described for the Roanoke River restoration program. A total of 4,893,186 American Shad fry have been stocked in the Neuse River at the NC Hwy 117 bridge near Goldsboro, NC since 2012, and hatchery contribution to out-migrating juvenile samples has been low (0–13%; Table 6). Hatchery contribution to returning adults has also been low. In 2016, which was the first-year hatchery fish were potentially available as age-4 adults, only 9 of 411 (4%) adults tested with PBT analysis were of hatchery-origin. Contribution of stocked fish may increase slightly in the future as more hatchery cohorts will move into the spawning population, but it appears the stocking program is contributing very little to the overall American Shad population in the Neuse River.

1.13 FISHERY-DEPENDENT MONITORING

1.13.1 Commercial Fishery

Total Catch, Landings and Effort

American Shad landings data are collected through the North Carolina Trip Ticket Program. The number of participants by gear utilized and the total number of positive trips can be determined. For the Albemarle Sound area, the following assumptions are made: (1) trips landing over 100 pounds of shad are considered directed trips, and (2) the maximum yardage used in directed trips is 1,000 yards. The total yardage for each area is determined by multiplying the number of participants by the maximum yardage per area. The catch-per-yard (CPY) is determined by dividing the number of pounds harvested by the total yardage estimate of gill nets fished and multiplied by 1,000 yards. This will result in the pounds landed per 1,000 yards. Catch estimates for other areas are determined similarly.

Size, Age and Sex Composition of Catch

Commercial landings from all four systems (Albemarle Sound, Tar-Pamlico River, Neuse River and Cape Fear River) are sampled to obtain size, age, sex and repeat spawning information. A target of 200 samples from each system has been in place since 1999. For specific information regarding exact number of samples collected per area, please see previous compliance reports.

1.13.2 Recreational Fishery

Total Catch, Landings and Effort

The North Carolina Fisheries Reform Act of 1997 required the MFC to establish limits on recreational use of commercial fishing gear. An individual holding a Recreational Commercial Gear License (RCGL) can use limited amounts of specified commercial gear to catch seafood for personal consumption or recreational purposes. The holder of the RCGL must comply with the recreational size and creel limits, and RCGL catch cannot be sold. During 2002, DMF began a RCGL survey to estimate the harvest by these license holders. The survey was discontinued in 2009 due to budget reductions.

An annual creel survey occurs on the Roanoke River each year. The survey targets Striped Bass catch and effort but also collects information on American Shad and other species, although American Shad catch is low due to the fishing method.

1.13.2.1 Central Southern Management Area Catch, Landings, and Effort

A rotating creel survey occurred on the Tar, Neuse and Cape Fear rivers prior to 2012. A comprehensive creel survey was initiated in 2012 to identify and estimate recreational American and Hickory Shad effort and catch within these systems, which are collectively known as the Central Southern Management Area (CSMA). The CSMA was originally established for purposes of estuarine striped bass management and includes all Internal Coastal, Joint, and contiguous Inland waters of North Carolina south of a line from Roanoke Marshes Point across to Eagle Nest Bay to the South Carolina state line. The areas surveyed in the CSMA include the Neuse, Trent, Tar/Pamlico, Cape Fear and Pungo rivers. The Neuse River basin drains over 6,200 square miles of land with over 3,000 miles of streams and rivers. The mouth of the main channel is six miles across – the widest in the United States. Over 1.3 million residents reside within this river basin. Major tributaries include Crabtree, Swift, and Contentnea creeks, along with the Eno, Little, and Trent rivers. Survey points included 45 boat ramps and fishing access points from Millburnie Park in East Raleigh to Lee's Landing on Broad Creek. The river was divided in three segments, with all access points in Goldsboro and above classified as the upper zone, sites on Contentnea Creek and downstream from Goldsboro to Core Creek were considered the middle zone, and those downstream from Core Creek, the lower zone. Prior to 2012, the Neuse River was comprised of only two zones with all sites above Contentnea Creek considered the upper.

The Tar/Pamlico River watershed drains over 5,500 square miles with over 2,400 miles of streams and rivers. Major tributaries include Cokey Swamp, Swift, Fishing, and Tranters creeks, and the 30-mile Pungo River near Belhaven, North Carolina – the main tributary in the lower basin. Access points surveyed on the Tar/Pamlico River include 19 boat ramps and access sites from Battle Park in Rocky Mount to the Quarterdeck Marina in Bath, NC. This system was divided into upper and lower zones, with sites upstream of Greenville, North Carolina considered the upper zone. The Pungo River was surveyed at the Leechville ramp (NC-264 bridge), the Belhaven WRC ramp, Wrights Creek WRC ramp, and Cee Bee Marina on Pungo Creek.

The Cape Fear River is the southernmost river within the CSMA and was included to target shad (American and hickory) beginning in 2013.

1.13.2.1.1 Sampling Procedures

Recreational fishing statistics from the CSMA were calculated through a non-uniform stratified access-point creel survey (Pollock et al. 1994). Site probabilities were set in proportion to the likely use of the site according to time of day, day of the week, and season. Probabilities for this survey were assigned based on observed effort from past years and direct observation by creel clerks. Morning and afternoon periods were assigned unequal probabilities of conducting interviews, with each period representing half a fishing day. A fishing day was defined as the period from one hour after sunrise until one hour after sunset. Monthly sampling periods for each river and zone were stratified accordingly, and all weekend and holiday dates along with two randomly selected weekdays were chosen from each week for sampling.

Tar/Pamlico River anglers in the upper zone were interviewed throughout the spring months (January-May), while anglers in the lower zone were interviewed year-round based on the evidence of a year-round fishery and no seasonal closures. Two creel clerks were assigned to this river, with one surveying the upper zone January through May and one clerk surveying the lower zone from January through December. The three zones within the Neuse River were covered with one creel clerk per zone. The lower zone was surveyed from January to December while middle zone surveys were conducted January-May and the upper zone surveys from February-May. The Pungo River was surveyed throughout the year with one creel clerk.

Returning fishing parties were interviewed by a creel clerk at the selected access point to obtain information regarding party size, effort, total number of fish harvested and/or released, primary fishing method, and location. Harvested fish were identified, counted, measured nearest mm fork length (converted to centerline length and total length for appropriate species), and weighed to the nearest 0.1 kg, while information on discarded fish was obtained from the angler to acquire the number and status of discarded individuals. The age structures were given to the Fisheries Management section of DMF for age determination. Creel clerks also obtained socioeconomic information from the angler, including age, state and county of residence, sex, ethnic background, marital status, number of individuals within household, and trip information and expenditures

1.13.2.1.2 Analysis

Effort and Catch Estimations

Samples were reduced to shad species effort and catch only. Results were stratified by river, access point, and time of day. Catch was defined as the sum of harvested fish and discarded fish. Discarded fish equaled the sum of fish caught in excess of creel limits (over-creel), legal-sized fish caught and released, and sub-legal fish returned to the water. Daily effort and catch for each river were calculated by expanding observed numbers by the sample unit probability (time of day probability divided by access area probability). Total catch estimates for the CSMA and catch estimates for each zone and type of day were calculated based on the Horvitz-Thompson estimator for non-uniform probability sampling as such:

$$C = \sum_{i=1}^{n} (c_i / p_i)$$

where a sample of number (n) units is taken, and the probability of the *i*th unit being in the sample is denoted by P_i (Pollock et al. 1994). Total effort over the CSMA and each individual zone and type of day were estimated in the same fashion, as were other extrapolated data. Approximate standard errors (SE) of the catch and effort estimates within zone and type of day were calculated according to:

$$SE = \sqrt{N^2 \left(\frac{s^2}{n} \right)}$$

where s^2 is the variance of the observations, n is the number of days sampled, and N is the number of days of that type available for sampling (Pollock et al. 1994). Estimated catch per unit effort (CPUE) values were obtained by dividing estimated catch by estimated shad spp. trips as well as angler hours (angler-h) in order to identify trends in fishing pressure and angler success. Size structure of shad spp. in harvests was described for each zone using length-frequency distributions of observed samples. Fishing party characteristics and methods used during shad spp. trips reported by anglers were documented by river and day type. The database was created using Access© and statistical analyses were performed with SAS 9.1©. Beginning in 2012, the Wildlife Resources Commission (WRC) Portal Access To Wildlife Systems (PAWS) was used to house these data and estimate effort and catch. DMF and WRC staff have been verifying calculations to ensure consistency with the previous work.

Angler Demographics and Economic Analysis

The CSMA Creel Survey socioeconomic questionnaire included questions to identify characteristics of the shad spp. angling population. Demographics of anglers were reported according to age, residency, gender, ethnic background, marital status, and expressed as a percentage of the total angling population throughout the CSMA. Mean values were calculated. Results were further grouped by river and day type. Anglers were considered to be local, regional, or out-of-state residents. Local anglers resided within the county, while regional anglers resided elsewhere in North Carolina. The socioeconomic questionnaire also included questions regarding trip length, distance traveled, party size, and expenses on lodging, food, ice, bait, equipment rental, and boat fuel and oil. Mean weighted expenditures per trip were reported by river and day type. Lodging and rental expenses were rarely encountered and therefore are not included within this report. The weighted mean of each expenditure was totaled to provide an average trip cost.

For specific information regarding catch and harvest of American Shad, please see previous compliance reports.

1.14 Bycatch and Discards

Bycatch and discard information are not currently collected on commercial trip tickets. The only mechanism that exists to capture commercial bycatch and discards of American Shad in other fisheries is an observer program conducted by DMF to monitor sea turtle and sturgeon interactions in gill nets, as required under the Incidental Take Permits (ITP) for both. The state-wide sea turtle

ITP was approved first in September 2013 followed by the Atlantic Surgeon ITP in July 2014. Prior to the approval of the Sturgeon ITP there was little observer coverage in the Western Albemarle Sound and the rivers when the directed American Shad fishing season occurs because there are very few encounters with sea turtles in these areas during that time of year. Observer coverage has increased in recent years, under the Sturgeon ITP because there have been encounters with sturgeon in these areas and times of year where directed American Shad fishing occurs. Even though observer coverage in the area have increased, gear, area, and seasonal restrictions are thought to have kept shad discards relatively low.

Recreational creel surveys capture discard and release information of American Shad and non-target species, but hook-and-line discard mortality is not estimated. Please see previous compliance reports for this information.

FISHERY MANAGEMENT PROGRAM

American Shad are jointly managed by the North Carolina Marine Fisheries Commission (MFC) and the North Carolina Wildlife Resources Commission (WRC). The Division of Marine Fisheries (DMF) implements MFC rules for American Shad in the Atlantic Ocean as well as the Coastal and Joint waters of North Carolina, while the WRC Inland Fisheries Division manages American Shad in the state's recreational fishery in Inland Waters. The known extent of American Shad in North Carolina river systems is shown in Figure 1. This Plan is developed by the American Shad Working Group (ASWG) which consists of biologists from both DMF and WRC. The ASWG meets annually to review sustainability parameters and develop associated actions for the management of American Shad in North Carolina's Inland, Joint, and Coastal waters.

1.15 Commercial Seasonal Restrictions (statewide)

From the 1950s to 1965, a January 1 through May 1 commercial season existed in Coastal Waters, while a January 1 through June 1 season existed in Inland Waters throughout the state. From 1966 through 1994, no seasonal restrictions existed for the commercial fishery. Since 1995, a commercial season of January 1 through April 14 has been in place in Coastal and Joint waters although the fishery is rarely opened prior to February 1 each year. Implementation of this seasonal restriction reduced harvest, as a large portion of the commercial American Shad harvest historically occurred after April 14 and into May. On July 1, 1996, WRC designated American Shad as a game fish in Inland Waters; the game fish designation prohibited sale of American Shad taken from Inland Waters thereby ending commercial harvest in Inland Waters of the state.

In 2013, under the first year of the North Carolina American Shad SFP, the commercial seasons were restricted to February 15 through April 14 in all systems except for the Cape Fear River (Table 8). In the Cape Fear River, the commercial season was restricted to February 20 through April 11. Following the 2013 season, thresholds in the Albemarle Sound/Roanoke River system were exceeded for three consecutive years (2011,2012, and 2013) triggering further management action; as a result, the commercial season was reduced to March 3 through March 24 to constrain harvest. This season has remained in place for the Albemarle Sound/Roanoke River system since 2013.

1.16 Commercial Gear Restrictions

Albemarle Sound/Roanoke River

Beginning in 1987, western Albemarle Sound (also referred to as Batchelor Bay) has been closed to the use of gill nets from February through mid-November. While the purpose of the closure is

Striped Bass conservation, this measure has also afforded protection for American Shad. From 1988 through 1990, limits of 1,000 to 2,000 yards were implemented for 5.25-inch stretched mesh and larger gill nets in Albemarle Sound, and nets could only be set 5 days per week. In April 2016, the MFC adopted a permanent rule implementing yardage restriction for nets with a mesh length of 4.0-inch stretched mesh or greater, the maximum length of gill net shall not exceed 2,000 yards per vessel in all Internal Coastal Waters regardless of the number of individuals involved.

Since 1998, commercial restrictions in Albemarle Sound have been consistent and include a prohibition on the use of gill nets with a mesh size of 3.5–5.0 inches stretched mesh and a limit of 1,000 yards on the use of 5.25-inch and greater (floating) stretched mesh during the open shad season. When the season closes, these nets are removed from the water. The Albemarle Sound is the only system for which mesh size restrictions and yardage limits exist during the shad season.

The Roanoke River has been closed to the use of anchored gill nets since 1991 and drift gill nets since 1993 which greatly reduced harvest of American Shad.

Tar-Pamlico River, Neuse River

Since 2016 a statewide rule limits the amount of large mesh (4.0-inch and greater) gill net set in internal Coastal waters to no more than 2,000 yards per vessel. Prior to 2016 a former rule was suspended in the majority of internal Coastal waters as a result of sea turtle conservation measures to institute no more than 2,000 yards per vessel of 4.0–6.5-inch gill net in the Tar-Pamlico and Neuse systems. Additionally, in certain sections of the Tar-Pamlico and Neuse rivers, gill nets with a mesh size less than five inches must be attended at all times.

Also, it is unlawful to use gill nets of any mesh size in Joint Fishing Waters from midnight on Friday to midnight on Sunday each week (except for portions of Albemarle and Currituck sounds). These existing gill net measures have likely reduced American Shad harvest since they have remained in effect since the spring 2012 fishing season and will remain in effect indefinitely.

Cape Fear River

There are different gill net restrictions then described above for the Tar-Pamlico and Neuse systems (i.e. mesh lengths, spacing, set/retrieval days and times) for the Cape Fear system. Nets can be set in lengths no greater than 100 yards and must have at least a 25-yard space between each individual length of net. Only single overnight sets are allowed; nets can be set one hour prior to sunset and must be retrieved within one hour of sunrise, with no sets allowed Friday, Saturday or Sunday evenings, and the maximum yardage allowed is a 1,000-yard limit per vessel.

It is unlawful to use gill nets of any mesh size on weekends in the Cape Fear system. This measure will remain in effect indefinitely.

1.17 Recreational Restrictions

Prior to 1995, no recreational restrictions existed for American Shad and Hickory Shad. Beginning in 1995, it became unlawful to take American Shad and Hickory Shad by any method except hook-and-line from April 15– December 31 in Coastal Waters. Additionally, from 1995 through 1998, there was a recreational season during January 1 through April 14. Beginning in 1999, statewide rules implemented by DMF and WRC made it unlawful to possess more than 10 American Shad and Hickory Shad in the aggregate in all Coastal and Inland Waters. On August 1, 2019, WRC amended the statewide rule for harvesting shad in Inland Waters to include no more than one American Shad in the 10-shad aggregate. The statewide rules apply to all waters of the state unless exceptions are specified. Exceptions to the statewide rules are described in the following sections.

The changes noted here have been implemented via rule in Inland Waters by the WRC and via proclamation in Coastal and Joint Waters by DMF.

Albemarle Sound/Roanoke River

In 2008, the WRC implemented a 1-fish American Shad limit within the 10-fish aggregate creel limit for American and Hickory Shad in the Inland Waters of the Roanoke River. In 2013, under the first year of the North Carolina American Shad SFP, a 1-fish American Shad limit within the 10-fish aggregate creel limit was implemented by DMF in the Joint and Coastal waters of the Albemarle Sound drainage including Currituck Sound, Roanoke River and all other tributaries. All Inland Waters of the Albemarle Sound drainage except the Roanoke River remained under the statewide rule of 10 American Shad and Hickory Shad in the aggregate until the statewide rule for Inland Waters was changed by WRC to one American Shad per day on August 1, 2019.

Due to the size of the Albemarle Sound there is no recreational effort for American Shad in the sound itself, and little to no effort is concentrated in the tributaries of the Albemarle Sound. Recreational effort mainly occurs in the Roanoke River where the focus of angler effort is on Striped Bass and Hickory Shad; American Shad catch is primarily incidental. In Virginia, the Meherrin, Nottaway, and Blackwater Rivers drain into the Chowan River, which a substantial portion of the spawning stock entering the Albemarle Sound ascend to spawn. Recreational effort in these Virginia systems is not taken into consideration under this plan. While the impact of recreational harvest in Virginia waters is unknown, the creel limit in Virginia portions of these rivers was a 10-fish aggregate for American and Hickory Shad until Virginia established a statewide moratorium for American Shad harvest on January 1, 2019.

Neuse River

A WRC rule implementing a 1-fish limit for American Shad in the Inland Waters of the Neuse River became effective in August 2012. DMF complemented the 1-fish limit in Joint and Coastal Waters in 2013 under the first iteration of the North Carolina American Shad SFP. American Shad harvest in Inland Waters of the Neuse River basin was incorporated into the statewide rule for Inland Waters on July 1, 2019.

Tar-Pamlico River

The 10 American and Hickory Shad aggregate creel limit applies throughout the waters of the Tar-Pamlico River and its tributaries.

Cape Fear River

In November 2013, the WRC implemented a 5-fish limit for American Shad within the 10-fish aggregate creel limit in the Inland Waters of the Cape Fear River. DMF complemented the 5-fish limit in Coastal and Joint Waters in 2013.

Atlantic Ocean

Possession of American Shad is prohibited.

All other internal waters

Recreational harvest of American Shad is very rare in internal waters other than those described above. Current regulations as of July 1, 2019, however, allow for a daily harvest of up to 10 American and Hickory Shad, in the aggregate in Joint and Coastal Waters but only 1 American Shad in the 10-fish aggregate in Inland Waters. This regulation includes all waters not mentioned in the above sections, except harvest of up to 10 American Shad per day is allowed in the North Carolina portion of the Pee Dee River.

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TABLES

Table 1. North Carolina Sustainable Fishery Plan for American Shad summary of management thresholds and triggers for 2018-2022.

System	Index	Threshold Value	Time Series	Threshold Level	Management Trigger
Albemarle/ Roanoke	Roanoke River Female CPUE	0.131	2001-2017	25th percentile	3 consecutive years below the threshold; does not trigger management by itself
Albemarle/ Roanoke	Albemarle Sound Female CPUE	0.0277	2000-2017	25th percentile	3 consecutive years below the threshold
Albemarle/ Roanoke	Female Relative *F*	1,740,876	2002-2017	75th percentile	3 consecutive years above the threshold
Tar/Pamlico River	Female CPUE	0.384	2000-2017	25th percentile	3 consecutive years below the threshold
Tar/Pamlico River	Female Relative *F*	20,243	2002-2017	75th percentile	3 consecutive years above the threshold
Neuse River	Female CPUE	0.1275	2000-2017	25th percentile	3 consecutive years below the threshold
Neuse River	Female Relative *F*	198,625	2002-2017	75th percentile	3 consecutive years above the threshold
Cape Fear River	Female CPUE	0.112	2001-2017	25th percentile	3 consecutive years below the threshold
Cape Fear River	Female Relative *F*	186,354	2003-2017	75th percentile	3 consecutive years above the threshold

Table 2. Tar-Pamlico River recreational creel survey estimates for trips targeting Shad species (including hickory and American Shad) in numbers and pounds of fish, 2012-2016.

		Effort				Catch					
		Trips (#)	PSE	Hours	PSE	Harvest (#)	PSE	Pounds (lb)	PSE	Discard (#)	PSE
American	2012	490	37.2	1,399	47.6	899	41.9	1,711	41.9	4,257	33.5
	2013	106	78.4	125	85.1	2,484	23.6	6,841	24.1	7,057	41.4
	2014	20	100.0	3	100.0	162	66.6	0	0.0	1,302	74.6
	2015	54	100.0	54	100.0	1,006	47.7	3,262	47.7	2,784	78.7
	2016	1,347	31.1	5,806	51.4	1,417	37.2	807	0.0	2,820	34.0
Hickory	2012	321	47.0	486	46.6	403	61.0	0	0.0	7,286	38.0
	2013	0	0.0	0	0.0	2,250	58.2	2,970	58.3	5,490	55.3
	2014	190	66.2	248	73.1	341	70.1	0	0.0	2,052	56.6
	2015	107	73.7	398	75.3	864	64.4	1,009	65.1	3,848	57.9
	2016	295	52.5	2,086	68.9	1,409	70.9	0	0.0	11,590	67.2
Shad Species	2012	321	47.0	486	46.6	403	61.0	0	0.0	7,286	38.0
	2013	7,314	17.9	16,455	19.9	234	100.0	0	0.0	6,079	34.0
	2014	2,420	22.9	5,701	35.5	0	0.0	0	0.0	17	100.0
	2015	3,521	24.9	9,200	34.5	0	0.0	0	0.0	2,105	88.2
	2016	3,473	27.1	10,160	38.9	0	0.0	0	0.0	0	0.0

Table 3. Neuse River recreational creel survey estimates for trips targeting Shad species (including hickory and American Shad) in numbers and pounds of fish, 2012-2016.

		Effort				Catch					
		Trips (#)	PSE	Hours	PSE	Harvest (#)	PSE	Pounds (lb)	PSE	Discard (#)	PSE
American	2012	8,268	34.7	17,528	29.0	354	104.2	2,141	38.2	511	47.0
	2013	395	28.4	869	27.2	1,384	47.2	3,197	48.7	2,699	62.2
	2014	426	70.1	1,181	82.1	416	51.3	0	0.0	964	61.4
	2015	344	42.5	1,135	43.4	94	76.1	0	0.0	132	46.3
	2016	451	56.2	1,481	35.1	252	47.3	0	0.0	1,389	60.6
Hickory	2012	11,659	28.3	23,157	26.1	10,672	27.4	11,998	28.5	29,041	39.8
	2013	570	39.8	1,517	43.4	12,810	28.4	13,030	26.2	14,138	29.6
	2014	181	65.6	886	60.7	14,557	44.3	16,492	47.0	27,100	39.4
	2015	300	50.7	1,259	48.8	10,418	28.5	10,213	31.5	12,186	42.6
	2016	225	68.7	415	78.4	10,851	36.6	11,140	36.4	29,276	58.0
Shad Species	2012	11,659	28.3	23,157	26.1	10,672	27.4	11,998	28.5	29,041	39.8
	2013	14,840	14.9	31,249	19.1	0	0.0	0	0.0	765	57.7
	2014	12,779	22.0	30,532	30.5	0	0.0	0	0.0	136	100.0
	2015	6,775	21.2	15,393	30.2	0	0.0	0	0.0	136	75.3
	2016	8,898	18.3	25,741	28.1	0	0.0	0	0.0	899	61.8

Table 4. Cape Fear River recreational creel survey estimates for trips targeting Shad species (including hickory and American Shad) in numbers and pounds of fish, 2013-2016.

		Effort				Catch					
		Trips (#)	PSE	Hours	PSE	Harvest (#)	PSE	Pounds (lb)	PSE	Discard (#)	PSE
American	2013	0	0.0	0	0.0	20,243	21.1	46,522	21.0	6,438	73.7
	2014	114	84.5	188	88.0	7,234	25.3	23,027	25.6	0	0.0
	2015	0	0.0	0	0.0	4,136	32.7	11,502	32.2	6,125	39.3
	2016	4,550	15.0	18,820	22.5	10,265	22.1	28,427	22.8	10,746	28.6
Hickory	2013	0	0.0	0	0.0	13	0.0	0	0.0	135	100.0
	2014	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
	2015	0	0.0	0	0.0	12	100.0	0	0.0	0	0.0
	2016	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Shad Species	2013	12,334	22.3	54,807	22.1	2,050	44.8	4,029	44.8	26,457	38.5
	2014	2,820	17.9	11,762	22.2	174	84.0	0	0.0	10,300	56.4
	2015	3,414	22.2	13,933	26.3	0	0.0	0	0.0	264	71.7
	2016	582	60.7	3,681	72.0	0	0.0	0	0.0	648	79.7

Table 5. American Shad fry stocked into the Roanoke River Basin from 1998–2016. Stockings downstream of the lower-most dam occur at Weldon, NC, stockings upstream of John H. Kerr Dam occur at either Altavista or Clover Landing, VA, stockings upstream of Gaston Dam occur at Bracey, VA, and stockings upstream of Roanoke Rapids Dam occur at Roanoke Rapids, NC. Hatchery evaluation techniques have transitioned from Oxytetracyclene (OTC) marks to parentage-based tagging methods using genetic microsatellite markers.

		Fry Totals (millions) by Stocking Location						
Year	Total Fry Stocked (millions)	Weldon, NC	Altavista, VA	Clover Landing, VA	Bracey, VA	Roanoke Rapids, NC	Hatchery Evaluation Technique	Age Class at-large
1998	0.5	0.5	-	-	-	-	OTC	18
1999	0.3	0.3	-	-	-	-	OTC	17
2000	0.8	0.8	-	-	-	-	OTC	16
2001	2.1	2.1	-	-	-	-	OTC	15
2002	0.8	0.8	-	-	-	-	OTC	14
2003	2.3	1.2	1.1	-	-	-	OTC	13
2004	2.3	1.2	1.1	-	-	-	OTC	12
2005	2.5	1.3	1.2	-	-	-	OTC	11
2006	2.4	1.4	1.0	-	-	-	OTC	10
2007	4.3	2.2	2.1	-	-	-	OTC	9
2008	8.2	4.3	3.9	-	-	-	OTC	8
2009	8.6	4.5	4.1	-	-	-	OTC	7
2010	7.8	6.9	0.9	-	-	-	OTC/PBT	6
2011	4.4	4.0	-	0.4	-	-	OTC/PBT	5
2012	4.8	3.8	-	1.0	-	-	OTC/PBT	4
2013	4.5	2.4	-	1.3	0.8	-	PBT	3
2014	7.5	3.5	-	1.4	2.6	-	PBT	2
2015	4.8	2.6	-	0.8	1.5	-	PBT	1
2016	3.8	1.3	-	-	-	2.5	PBT	0
Total	72.7	45.1	15.4	4.9	4.9	2.5		

Table 6. American Shad fry stocked into the Neuse River Basin at NC Highway 117 bridge near Goldsboro and juvenile hatchery contribution based on parentage-based tagging analysis, 2012–2016.

Year	Fry Stocked	Out-migrating Juvenile Hatchery Contribution
2012	573,582	2%
2013	1,184,303	6%
2014	1,377,375	13%
2015	708,045	1%
2016	609,720	0%*
2017	440,161	NA
Total	4,893,196	

*Sample size was only 7 fish

Table 7. American Shad movement study results in numbers of fish tagged in the Albemarle Sound and numbers of tagged fish detected on spawning runs in the Roanoke and Chowan River from 2013-2017.

			Spawning Run	
Year	Tagged	Detected	Roanoke	Chowan
2013	7	5		1
2014	53	35	2	8
2016	56	29		2
2017	75	58	2	22

Table 8. Commercial harvest seasons for American Shad 2012-2017.

System	**2012***	**2013**	**2014**	**2015**	**2016**	**2017**
Albemarle Sound Roanoke River	2/1 - 4/14	2/15 - 4/14	3/3 - 3/24	3/3 - 3/24	3/3 - 3/24	3/3 - 3/24
Tar-Pamlico	2/1 - 4/14	2/15 - 4/14	2/15 - 4/14	2/15 - 4/14	2/15 - 4/14	2/15 - 4/14
Neuse	2/1 - 4/14	2/15 - 4/14	2/15 - 4/14	2/15 - 4/14	2/15 - 4/14	2/15 - 4/14
Cape Fear	2/1 - 4/14	2/20 - 4/11	2/20 - 4/11	2/20 - 4/11	2/20 - 4/11	2/20 - 4/11
All Other Areas	2/1 – 4/14	2/15 – 4/14	2/15 – 4/14	2/15 – 4/14	2/15 – 4/14	2/15 – 4/14

*last year prior to SFP implementation

Table 9. Recreational creel restrictions for American Shad 2012-2017. All numbers represent limits within an overall 10-fish aggregate creel limit for American and Hickory Shad combined.

System	2012*	2013	2014	2015	2016	2017
Albemarle Sound (AS) Roanoke River (RR)	AS-10-fish RR-1-fish	AS-10-fish IW AS-1-fish CJW RR-1-fish	AS-10-fish IW AS-1-fish CJW RR-1-fish	AS-10-fish IW AS-1-fish CJW RR-1-fish	AS-10-fish IW AS-1-fish CJW RR-1-fish	**AS-10-fish IW AS-1-fish CJW RR-1-fish
Tar-Pamlico	10-fish	10-fish	10-fish	10-fish	10-fish	10-fish
Neuse	1-fish IW 10-fish CJW	1-fish	1-fish	1-fish	1-fish	1-fish
Cape Fear	10-fish	5-fish	5-fish	5-fish	5-fish	5-fish
All Other Areas	10-fish	10-fish	10-fish	10-fish	10-fish	10-fish

*last year prior to SFP implementation; IW=Inland Waters; CJW = Coastal and Joint Waters, blank=all waters

** All Inland Waters of the Albemarle Sound drainage except the Roanoke River remained under the statewide rule of 10 American Shad and Hickory Shad in the aggregate until the statewide rule for Inland Waters was changed by WRC to one American Shad per day on August 1, 2019.

FIGURES

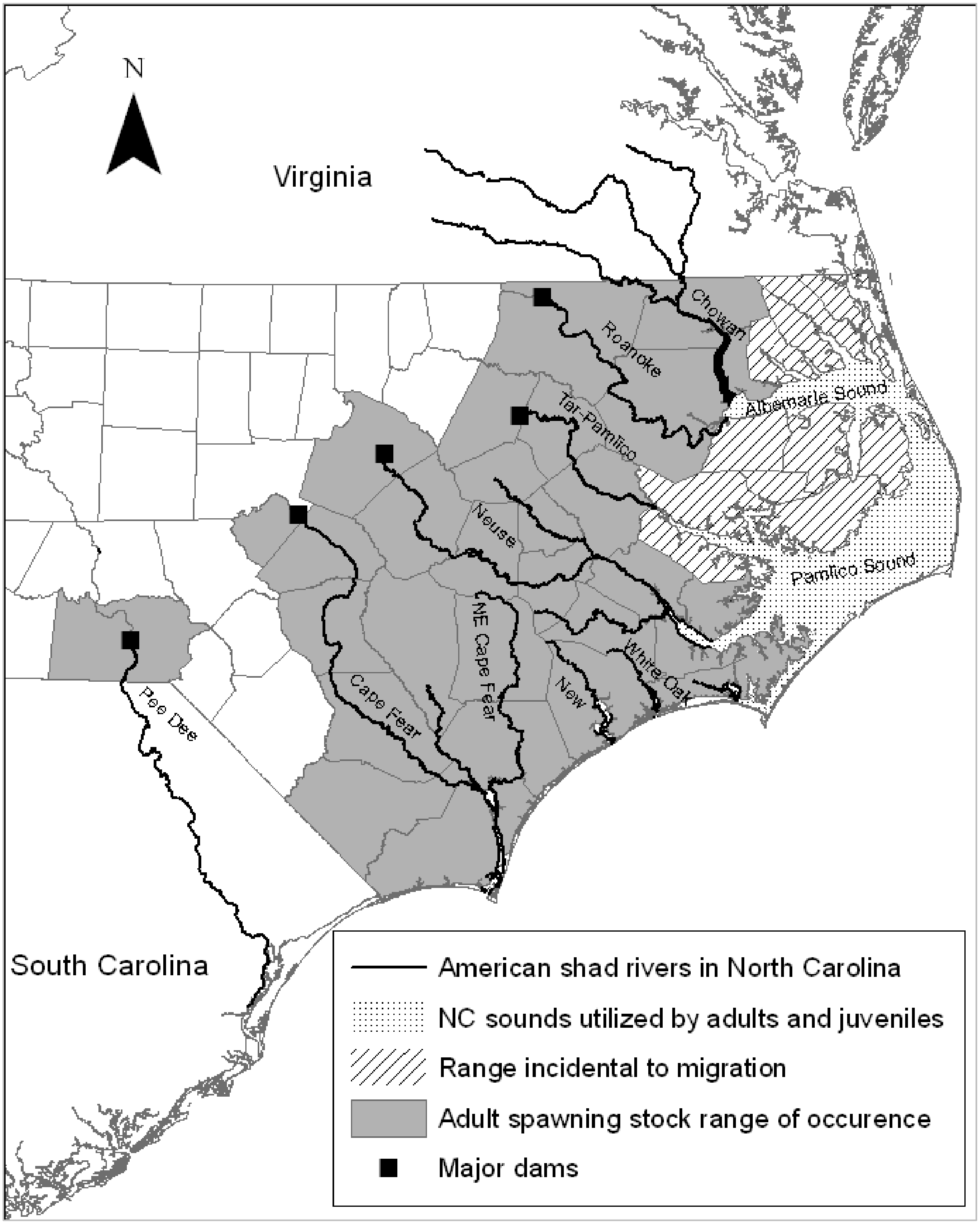


Figure 1. North Carolina river systems depicting the extent of American Shad occurrence and habitat use.

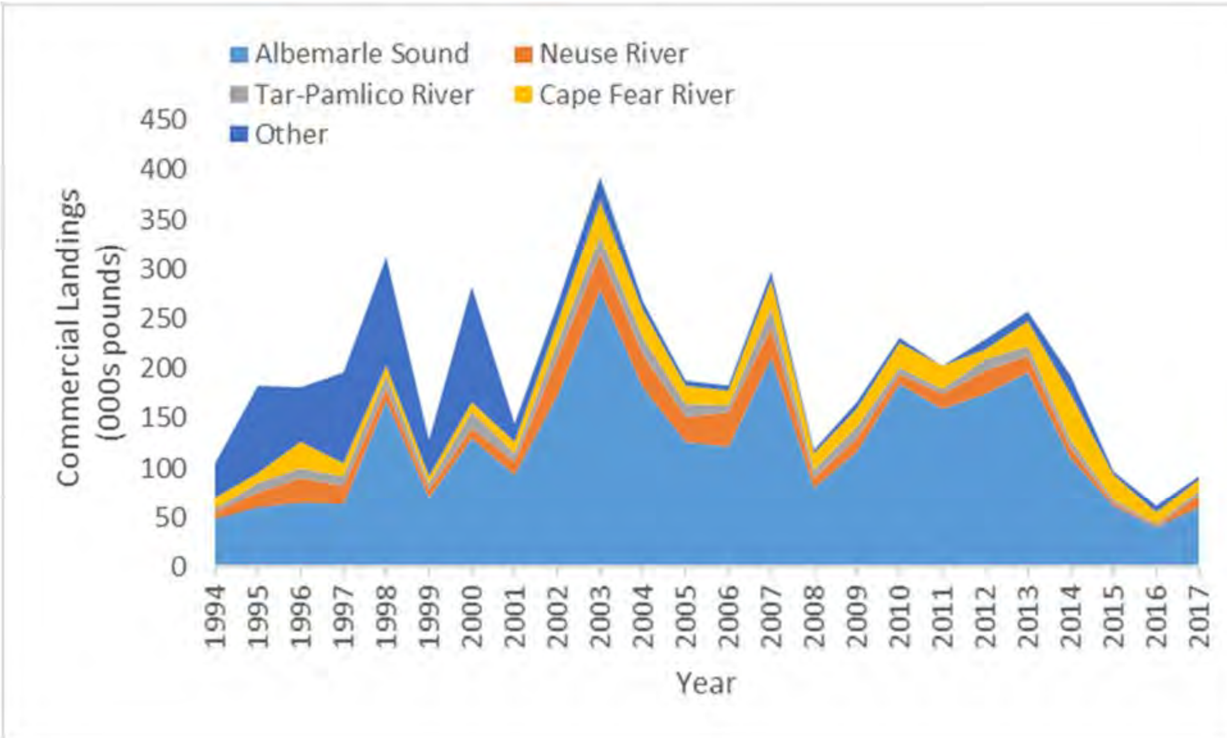


Figure 2. Commercial landings of American Shad in North Carolina by water body, 1994–2017.

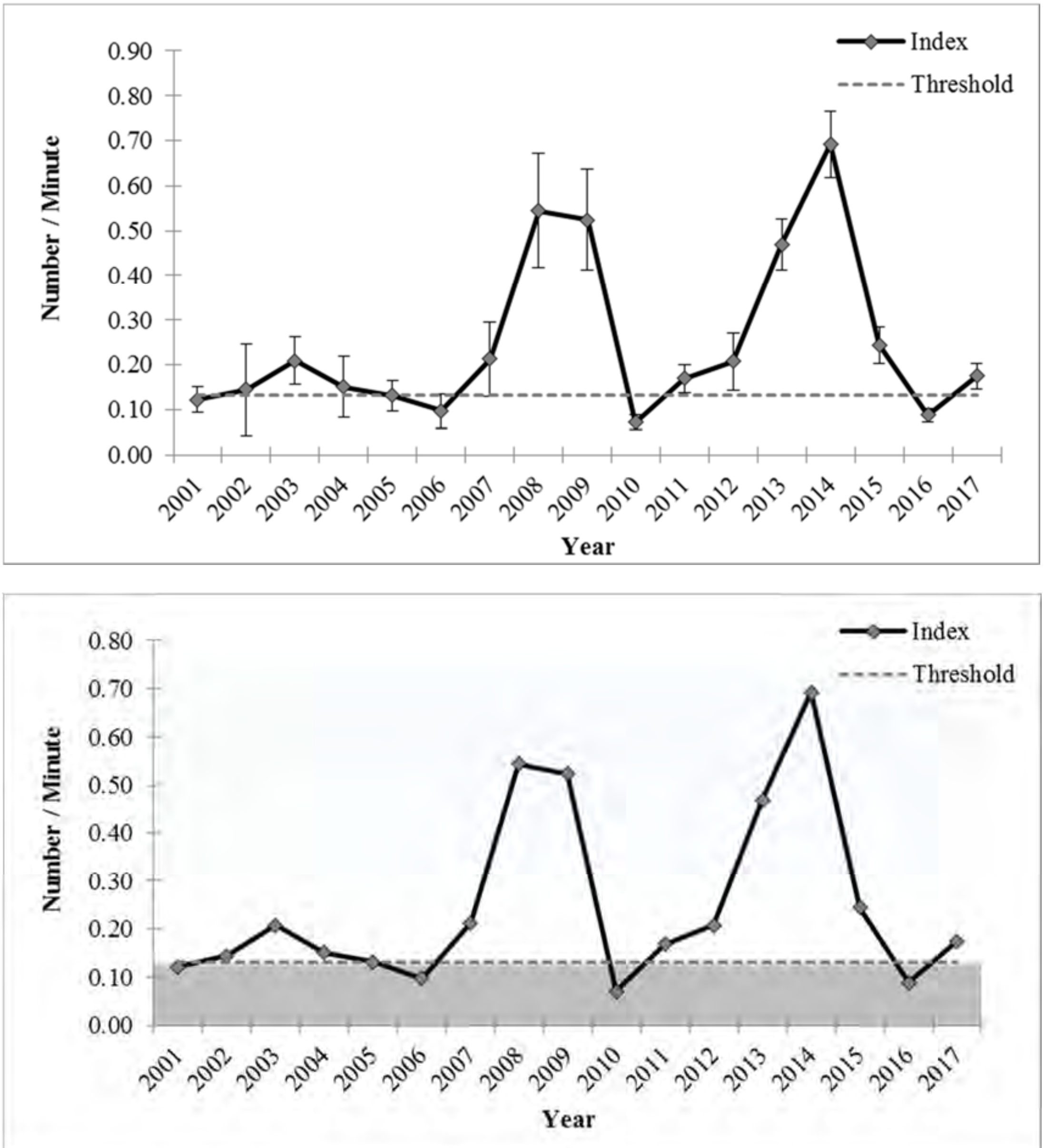
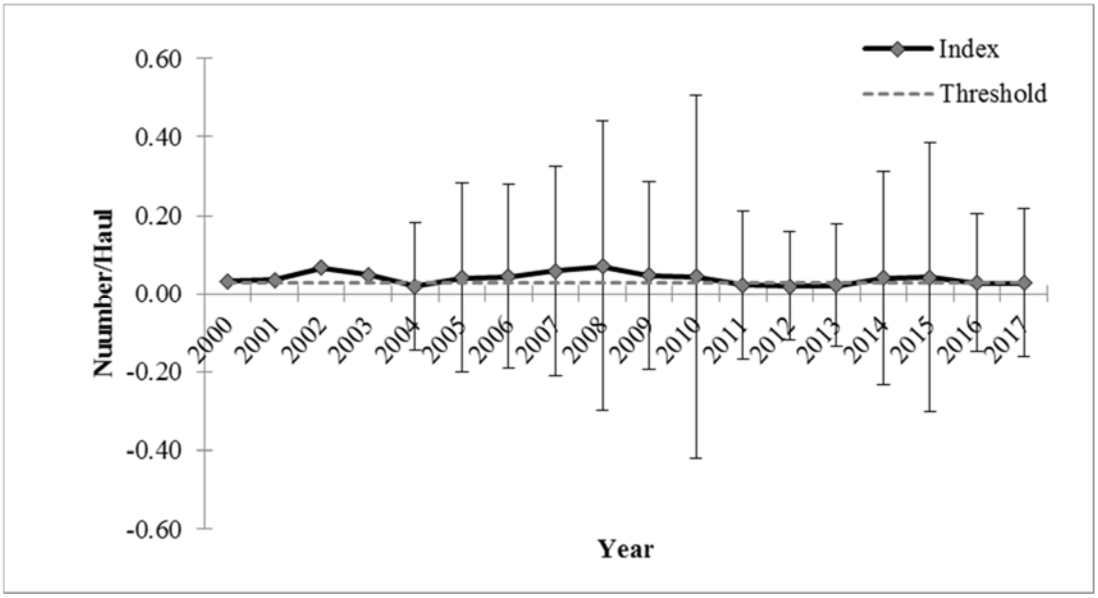


Figure 3. Female index from electrofishing survey (March–May) for Roanoke River, 2001-2017. Threshold represents 25th percentile (where 75% of all values are greater). Error bars represent ±1 standard deviation (top graph). Values in gray are below the threshold (bottom graph).



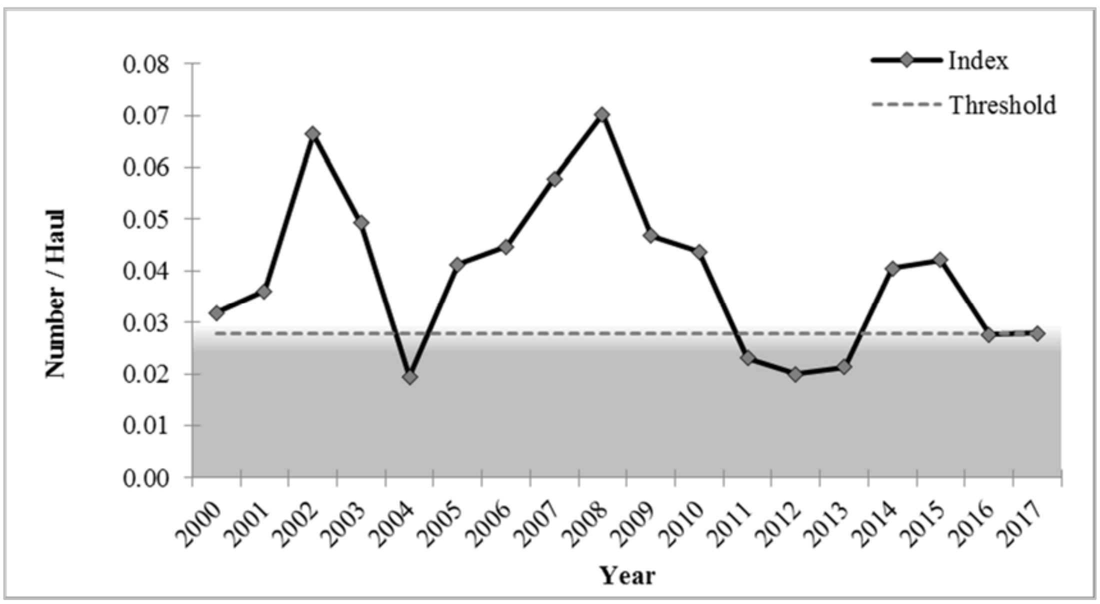
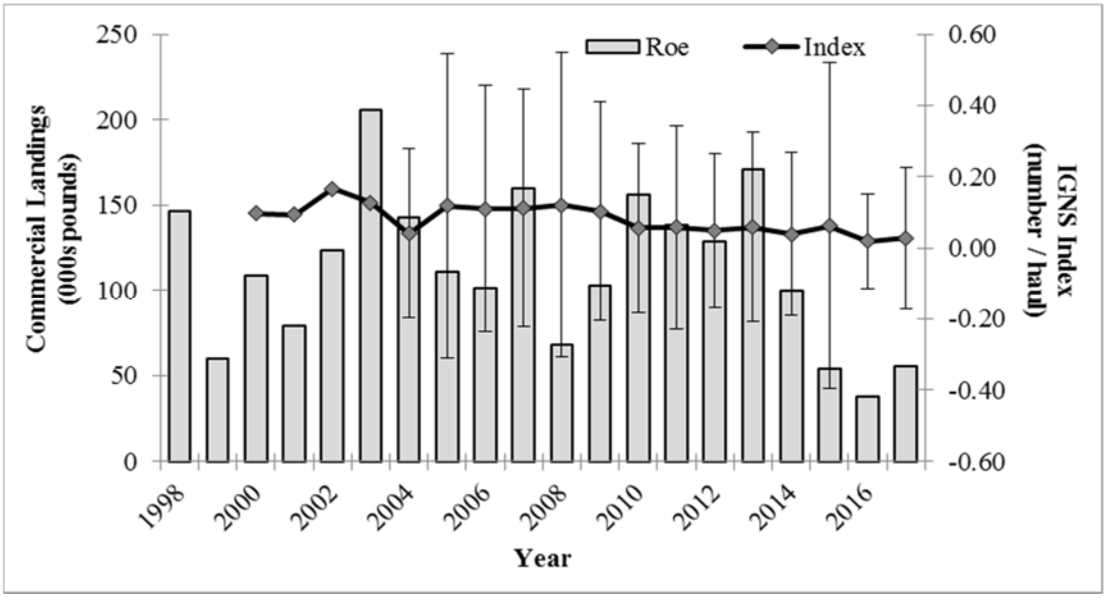


Figure 4. Female index from IGNS (January–May) for Albemarle Sound, 2000–2017. Threshold represents 25th percentile (where 75% of all values are greater). Error bars represent ±1 standard deviation (top graph). Values in gray are below the threshold (bottom graph).



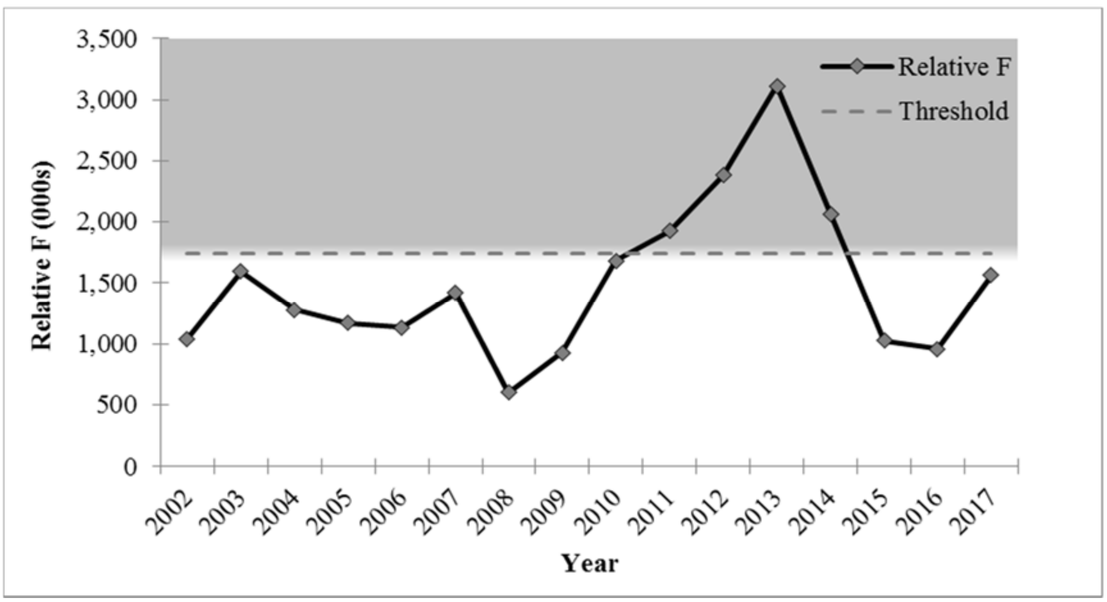


Figure 5. Commercial gill net landings of roes (1998-2013 February–April, 2014-2017 March) compared to the female IGNS index (5.0, 5.5 and 6.0-inch mesh sizes, 1998-2013 February–April, 2014-2017 March; top graph) and annual estimates of female relative *F* based on these data (bottom graph) for Albemarle Sound, 2002–2017. The error bars in the top graph represent ±1 standard deviation. The threshold represents the 75th percentile (where 25% of all values are greater), values in gray are exceeding the threshold.

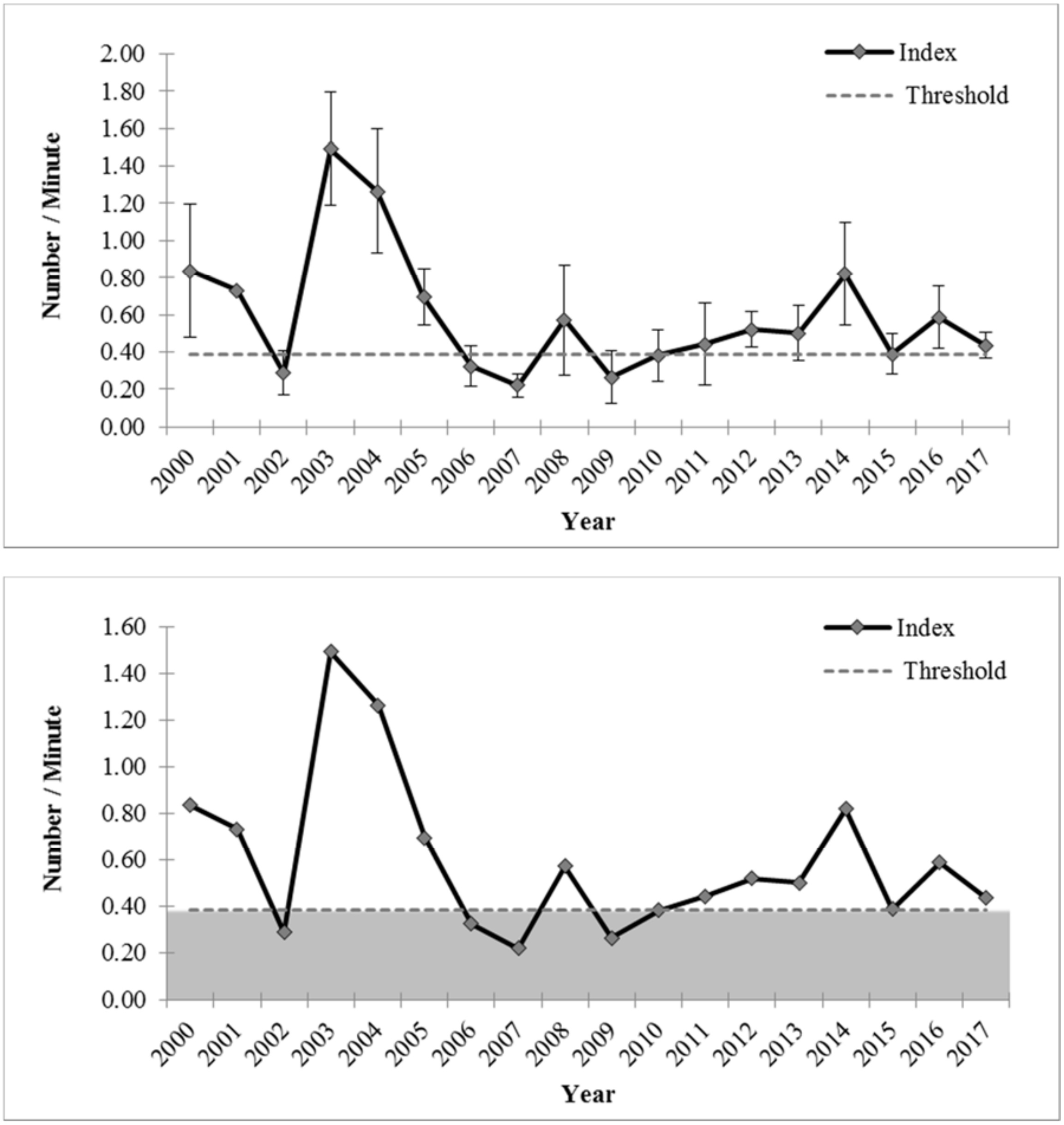
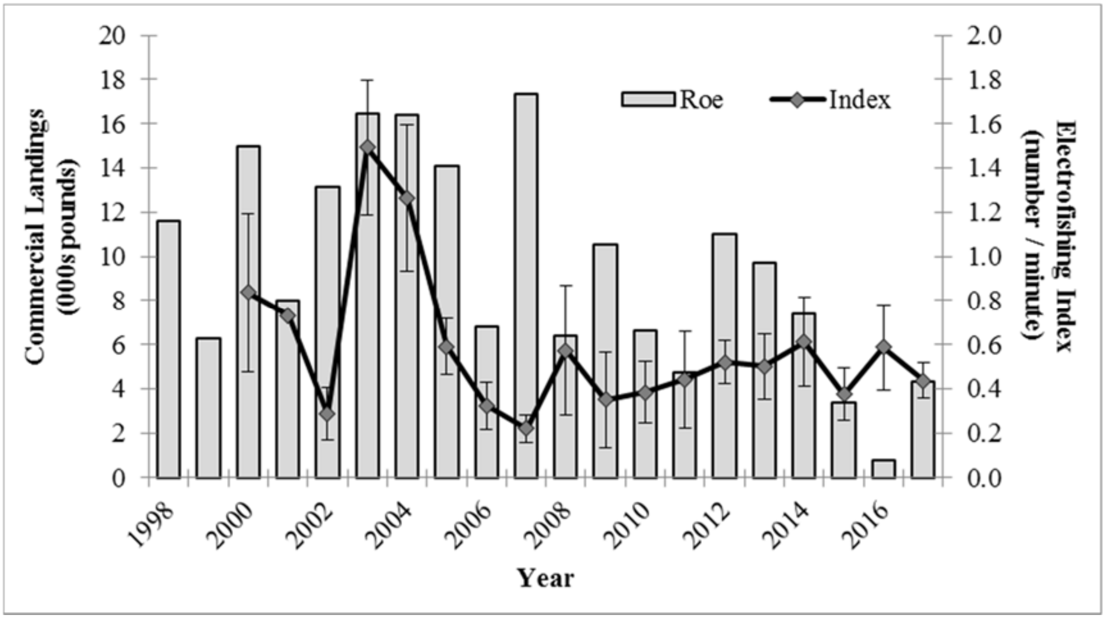


Figure 6. Female electrofishing index (March–May) for the Tar-Pamlico River, 2000–2017. The threshold represents the 25th percentile (where 75% of all values are greater). Error bars represent ±1 standard deviation (top graph). Values in gray are below the threshold (bottom graph).



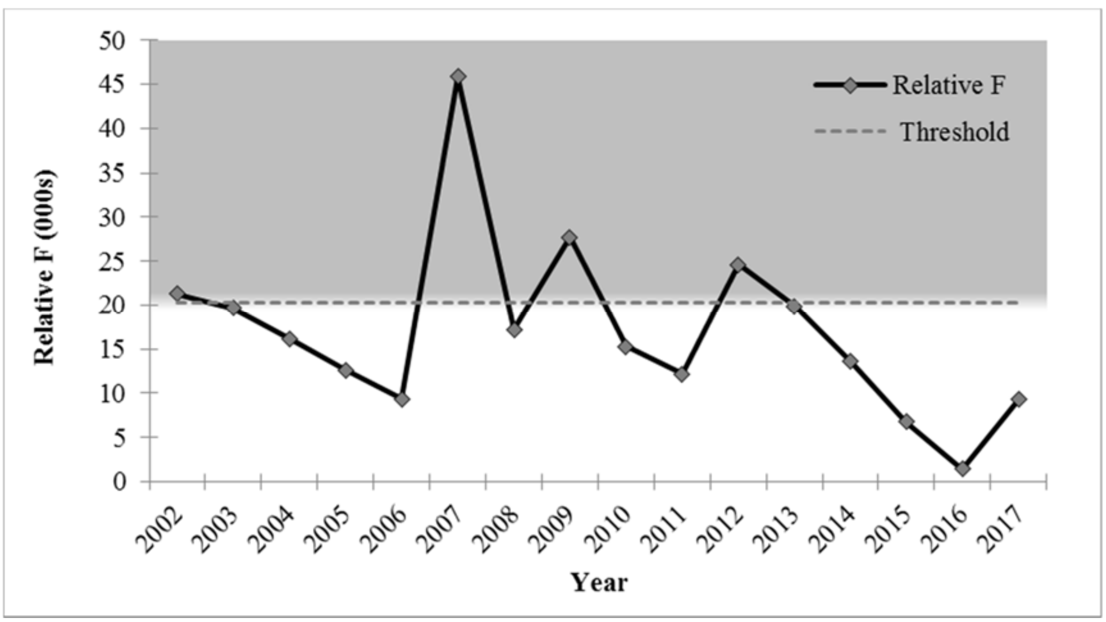
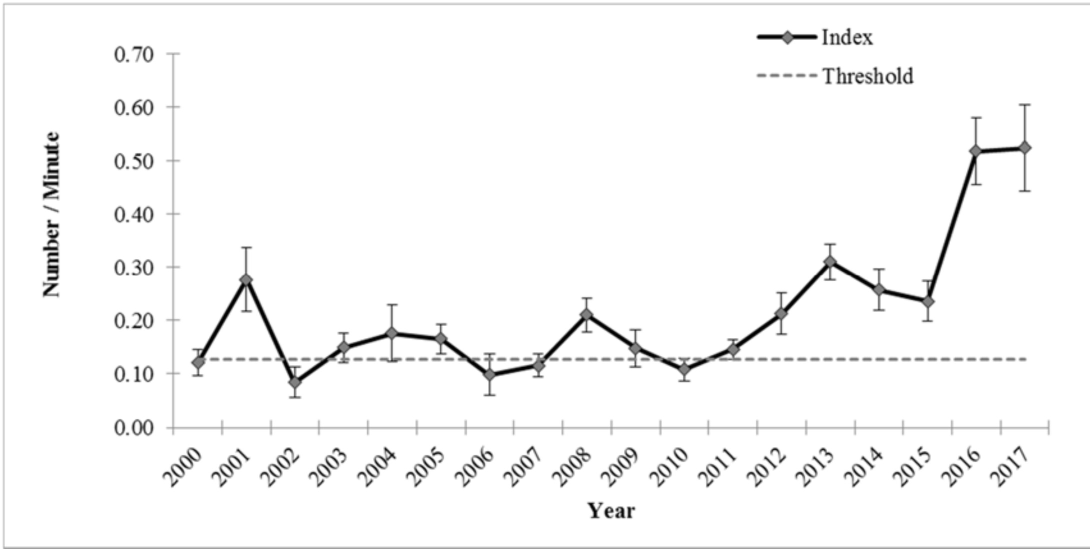


Figure 7**.** Commercial landings of roes by all gear types (March-April) compared to the female electrofishing index (March–April, 2000-2017; top graph) and annual estimates of female relative *F* based on these data (bottom graph) for the Tar-Pamlico River, 2002–2017. The error bars in the top graph represent ±1 standard deviation. The threshold represents the 75th percentile (where 25% of all values are greater), values in gray are exceeding the threshold.



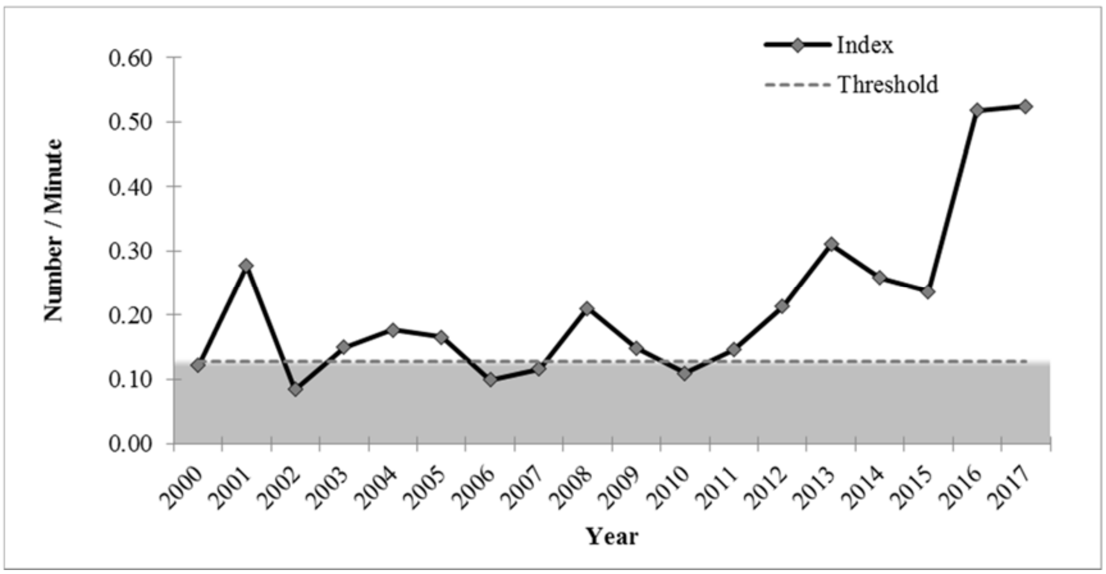
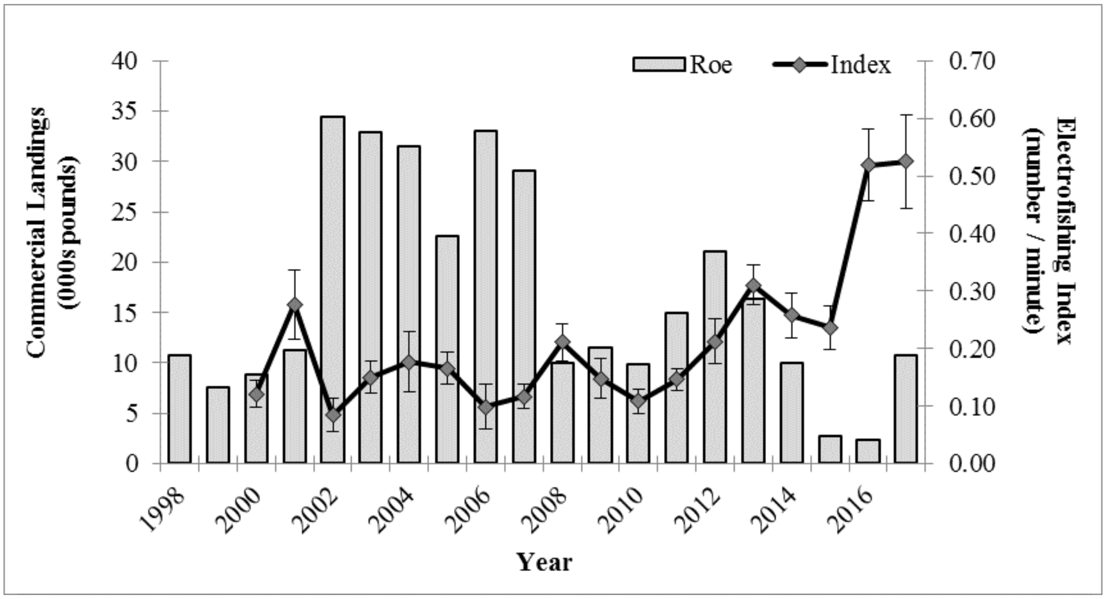


Figure 8. Female electrofishing index (March–May) for the Neuse River, 2000–2017. The threshold represents the 25th percentile (where 75% of all values are greater). Error bars represent ±1 standard deviation (top graph). Values in gray are below the threshold (bottom graph).



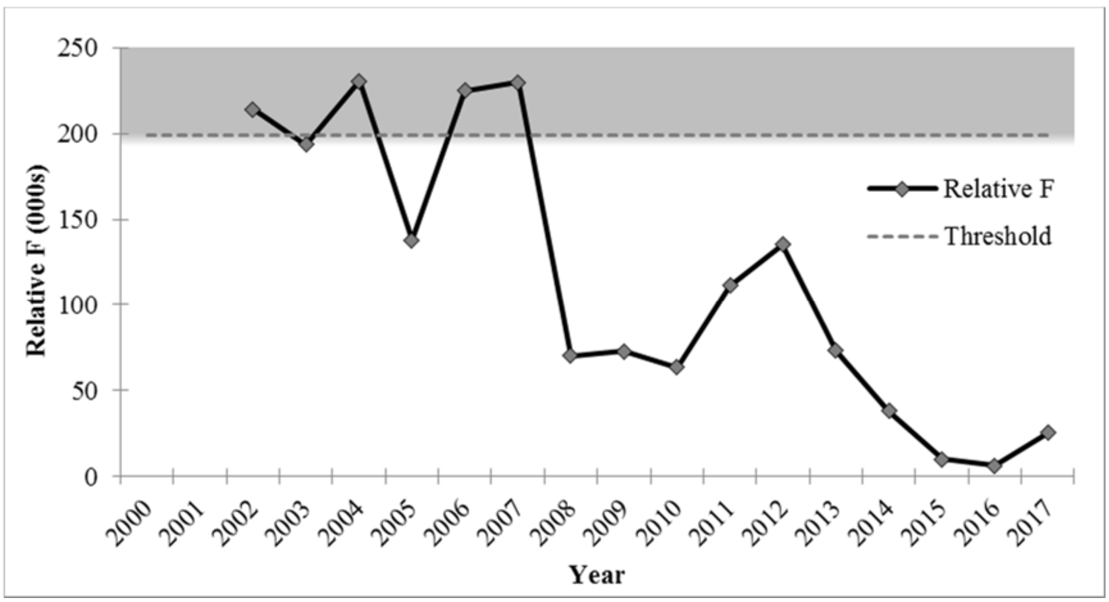


Figure 9. Commercial landings of roes by all gear types (March-April) compared to the female electrofishing index (March-April, 2000-2017; top graph) and annual estimates of female relative *F* based on these data (bottom graph) for the Neuse River, 2002–2017. The error bars in the top graph represent ±1 standard deviation. The threshold represents the 75^{th} percentile (where 25% of all values are greater), values in gray are exceeding the threshold.

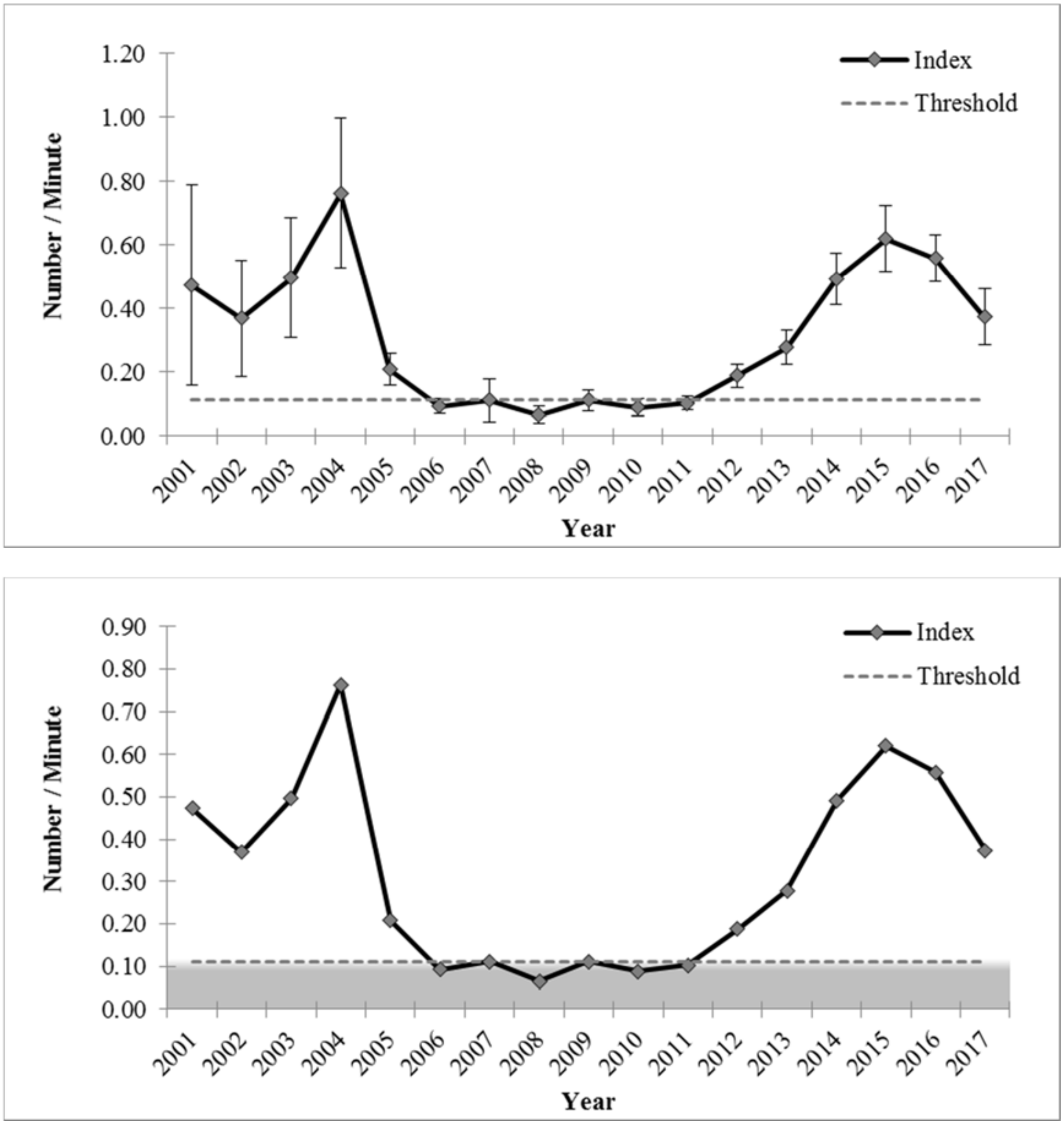
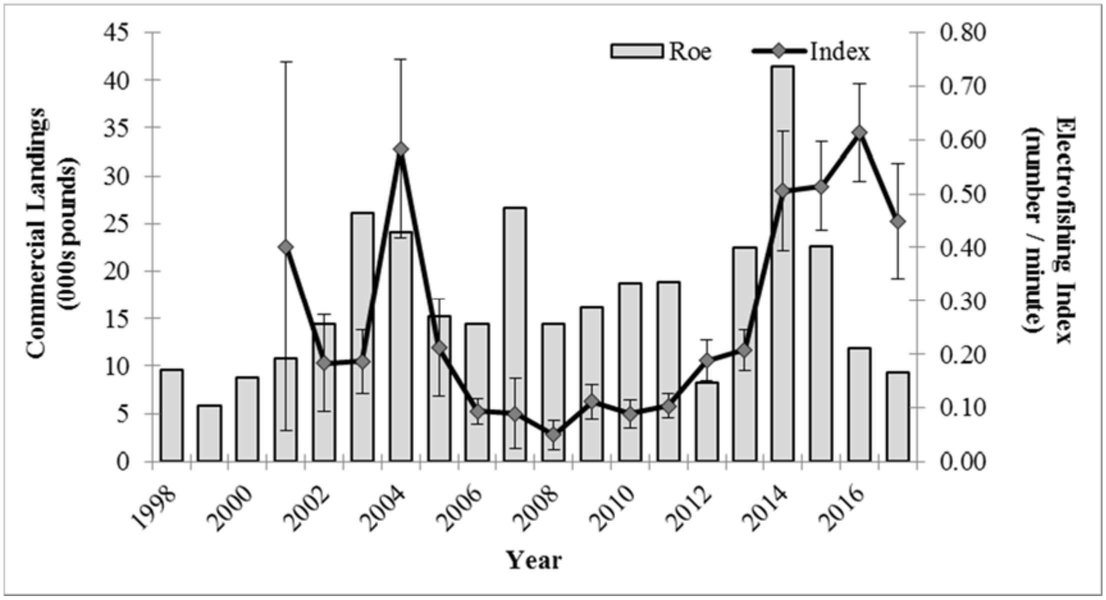


Figure 10. Female electrofishing index (March–May) for the Cape Fear River, 2001–2017. The threshold represents the 25th percentile (where 75% of all values are greater). Error bars represent ±1 standard deviation (top graph). Values in gray are below the threshold (bottom graph).



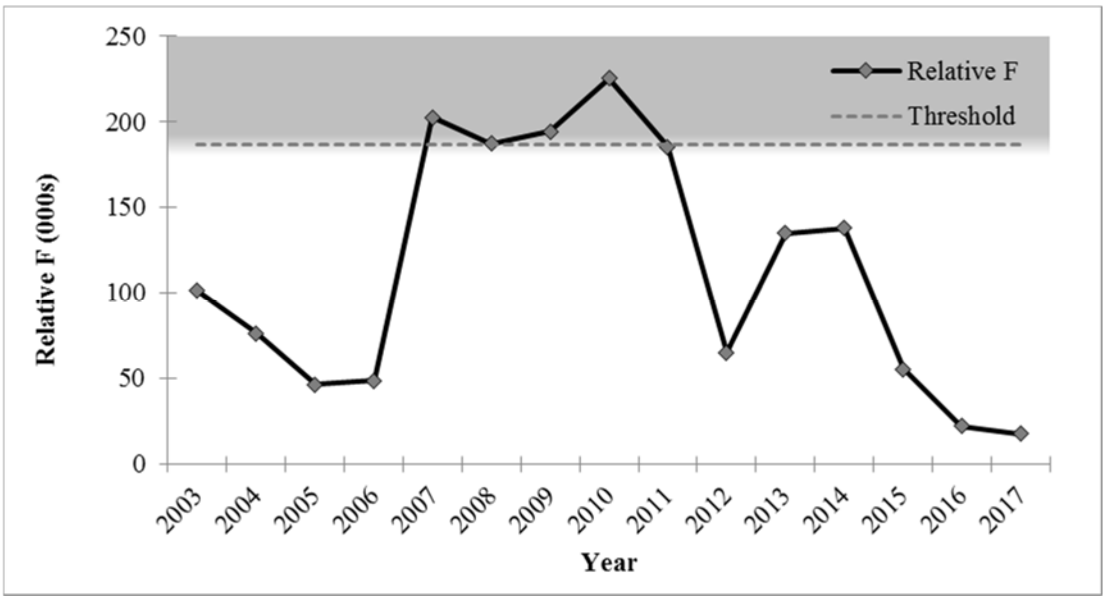


Figure 11. Commercial landings of roes by all gear types (March-April) compared to the female electrofishing index (March-April; top graph) and annual estimates of female relative *F* based on these data (bottom graph) for the Cape Fear River, 2003–2017. The error bars in the top graph represent ±1 standard deviation. The threshold represents the 75th percentile (where 25% of all values are greater), values in gray are exceeding the threshold.

Blueback Herring Sustainable Fishing Plan Update for South Carolina

Prepared by

Bill Post, Ellen Waldrop, and Chad Holbrook

March 16, 2020

DNR

South Carolina Dept. of Natural Resources

Wildlife and Freshwater Fisheries and Office of Fisheries Management

Updated-ASMFC River Herring Sustainable Fishing Plan for South Carolina

Introduction:

The purpose of this sustainable fisheries management plan is to allow existing river herring fisheries that are productive and cause no threat to future stock production and recruitment to remain in place and close all others. Some excerpts from the stock status review for SC's river herring were used in this document (ASMFC 2008). The review, which was prepared and submitted to the ASMFC shad and river herring board by SCDNR and the Stock Assessment Subcommittee (SASC), summarizes SC's fisheries for river herring.

Historically, river herring (blueback herring *Alosa aestivalis*) occurred in most of South Carolina's major rivers (Figure 1). Commercial fisheries for blueback herring in South Carolina occur to a limited extent in open rivers such as Winyah Bay tributaries (Lowther's lake area in the Pee Dee River), but the majority of river fishing activity occurs in hydro-electric tailraces of the Santee-Cooper River system (Figure 2). It remains the most important and the most closely monitored fishery in the state. A brief history of the Santee-Cooper Complex is detailed in Appendix 1. Recreational fisheries for blueback herring exist, but only as a bycatch to the American shad fishery.

Management of blueback herring in South Carolina is shared between the Marine Resources and Freshwater Divisions of the Department of Natural Resources (SCDNR). Management units are defined by stock and the complex of river(s) utilized. Management units include all rivers and tributaries within each area complex: Winyah Bay (Sampit, Lynches, Pee Dee, Bull Creek, Black, and Waccamaw Rivers) and the Santee-Cooper Rivers complex.

Current regulations:

The SCDNR manages commercial herring fisheries using a combination of seasons, gear restrictions, and catch limits. In 1964, commercial blueback herring fishing in Cooper River was restricted to daylight hours with a dip net not more than three feet in diameter and a limit of 100 lb (45.4 kg) per person per day. By 1969, regulations had been liberalized to allow nets with six foot diameters, fishing until ten o'clock p.m., and no limit on the harvest. Between 1966 and 1969, herring were abundant and the fishery expanded. Fishing success declined in the early 1970s and a limit of 600 kg of herring per person day was imposed in 1975. Today, the commercial fishery for blueback herring has a 10 bushel daily limit (227 kg) per boat in the Cooper and Santee Rivers and the Santee-Cooper Rediversion Canal. Seasons generally span the spawning season. All licensed fishermen have been required to report their daily catch and effort to the SCDNR since 1998. Current regulations are summarized in Appendix 2.

The recreational fishery has a 1 bushel (22.7 kg) fish aggregate daily creel for blueback herring in all rivers; however very few recreational anglers target blueback herring. Additionally, legislation to change the daily limit to a more reasonable limit has been developed and vetted through an internal working group and is awaiting introduction to the S.C. General Assembly.

Brief description - Current status of the stocks:

a. Landings:

Reported commercial landings data of river herring in South Carolina are available from the National Marine Fisheries Service and the state. Landings reported to the NMFS prior to 1979 were collected from major wholesale outlets located near the coast and probably did not account for inland landings which were generally not sold at these outlets. NMFS data collected since 1979 usually include inland landings. However, the wholesale dealer reporting system utilized by the NMFS may not include herring landings because herring sold as bait to licensed bait dealers may not be reported. In 1998, the state of South Carolina instituted mandatory reporting of commercial catch and effort.

In 1969, the South Carolina Department of Natural Resources instituted a commercial creel survey to estimate catch and effort in the fisheries in the Santee Cooper system. Surveys occur at landings used to off-load and transport catch. The majority of herring harvested from the Cooper River (1969-1989) were landed at two locations between the hours of six p.m. and ten p.m. daily. Creel clerks stationed at these locations interviewed individual fishermen as the catch was unloaded. The time, date, type of gear used, catch, and number of fishermen aboard were recorded as each boat landed. The survey was expanded to the major landing below the St. Stephen Dam on the Rediversion Canal starting in 1990 as water flow and fish abundance declined in the Cooper River and increased in the Santee River and the Rediversion Canal. During low flow years when flow is reduced in the Rediversion Canal, herring and the fishery moves to the Santee River below the Wilson Dam or to the Cooper River downstream of Pinopolis Dam. Surveys have been infrequent at those locations. Weight of harvest was estimated from the number of bushels of herring landed and a mean bushel weight of 25.4 kg (Cooke 1998). Numbers of adult blueback herring landed were estimated by dividing kg landed by the mean weight of an adult herring (0.14 kg). Although some landings are occasionally missed during the creel survey, the survey produces the most reliable estimates of catch and effort available for South Carolina waters. Landings were not estimated for reservoir fisheries with landings of mixed species and size composition.

SCDNR has conducted an annual recreational creel survey for American shad since 2001 to estimate exploitation and catch-per-unit-effort in the recreational fishery of the Santee Cooper system. These data consist of access point creel surveys (at end of a party's fishing day) for at least 2 h/d, 4 d/week along with effort estimates made by counting boats below the Pinopolis Dam, the Wilson Dam, or the Rediversion Canal at approximately 1400h each day of survey. Previous data demonstrated that a 1400h boat count measures maximum daily fishing pressure. Blueback herring are caught in this fishery; however, they are not targeted and are caught in minimal numbers.

SCDNR also conducted sportfishing creel surveys on the Cooper and Santee Rivers in 1981 - 1982 and 1991 - 1993 to evaluate the impact of the Rediversion Canal on these recreational fisheries (Cook and Chappelear 1994). These surveys examined the total recreational fisheries on each river, but did not provide data on catch of blueback herring. Thus, the surveys could only be used to indicate change in the size of the fishery.

Recreational creel surveys were conducted on the Savannah River in the late 1990s by the Georgia Department of Natural Resources in 1997 and SCDNR in 1998 and 1999. Estimates of catch from these surveys varied from year to year largely due to dramatically different flow conditions. Catch estimates from each of these creel surveys were provided by Boltin (1999).

b. Fishery Independent Indices:

A variety of sample efforts have been conducted to assess the condition of blueback herring stocks in South Carolina. Annual passage counts at the St. Stephen Dam on the Santee-Cooper Rediversion Canal provide the longest times series of data (Table 1). Periodic electro-fishing and gill net sampling occurred in the Santee River below the Wilson Dam and population estimates were obtained for several years at that location. Population estimates (1980-1990) were orders of magnitude larger than passage for the same time frame (Table 2). In addition, annual electro-fishing sampling has been conducted in Winyah Bay and the Santee, Cooper, Edisto, and Combahee Rivers. Ichthyoplankton surveys were made for several years on the Santee and Cooper Rivers. More recently, annual gillnetting has occurred to assess CPUE for adult herring returning to the Santee River. As part of another program, electrofishing sampling now occurs in Lakes Marion and Moultrie (Santee-Cooper Lakes) to assess juvenile recruitment in rivers upstream of impoundments. However, the latter three surveys do not provide a long enough data series to provide sustainability.

c. Fishery Dependent Indices:

Over 1,000,000 kg of river herring were reported from South Carolina commercial fisheries in 1969. Landings declined precipitously soon after. They rebounded to a high of approximately 260,000 kg in the early 1980s and again in the 1990s. They have fluctuated at less than 70,000 kg since 2001. The bulk of the reported landings since 1989 have come from the Santee-Cooper system. Reported landings for the Pee Dee River of the Winyah Bay system have remained at less than 1,000 kg per year since mandatory reporting was initiated in 1998.

Annual variation in reported landings since the early 1970s was influenced by changes in allowable catch over the years. Landings in the Santee Cooper system were also affected by changes in discharge from the three dams and concurrent changes in fish migration and gear effectiveness.

Annual estimates of catch in kg, effort in person days, and kg catch/person day (CPUE) are available since 1969 from surveys of the Santee-Cooper fishery (Figure 3). Estimates of all three parameters have fluctuated widely over the time series. Highest estimates of landings and CPUE occurred early in the time series in the Cooper River prior to the diversion of water from the Cooper to the Santee system.

Many factors likely affected effort and landings. To evaluate potential causes of change, we separated data from the Cooper River into two times series (1969 - 1974 and 1975 – 2008) and subset data for the Santee River to those from 1975 – 2008. We then normalized the estimates by dividing annual values by the series mean. Sub setting the Cooper River data reduced the influence of the relatively large estimates obtained early in the time series on the rest of the data. Normalizing the time series placed all parameters on a comparable scale. Effort and landings were highly correlated in both the Cooper River fisheries (1969-1974, r^2=0.90; 1975-2008, r^2=0.85) and the Santee River fisheries (1990-2008, r^2=0.94) (Figure 4). Effort played an important role in dictating landings. However, CPUE was also related to effort. If we assume that CPUE was a measure of relative stock abundance, then we can speculate that changes in stock abundance and related fishing success led to changes in effort and then in landings.

CPUE in the Santee River fishery increased rapidly following increased flows from rediversion. CPUE leveled off in the mid to late 1990s and then declined abruptly following a severe drought that lasted from 1999 through mid 2002. Santee River CPUE has fluctuated without trend since that time. The initial CPUE increase in the Santee River fishery likely resulted from a combination of herring from the Cooper River stock that began to migrate into the Santee River as flow increased and improved production from improved spawning and nursery habitat. We do not know if reduced CPUE since the drought resulted from declining stock levels or from low fishing success caused by low water levels. Fishing did not occur, or was severely limited in 2002, and harvest estimates were not made.

4. Fisheries to be Closed:

a. Commercial: Winyah Bay (Sampit, Lynches, Bull Creek, Black, and Waccamaw Rivers). **Note: SC believes these fisheries are sustainable based on past and present anecdotal data, but since these data are not statistical in nature and under stipulations of Amendment 2, we must close these fisheries.**

5. Fisheries Requested to be Open:

a. Commercial: The Great Pee-Dee River and Santee-Cooper Rivers complex

b. Recreational: Little River
Winyah Bay System (Sampit, Lynches, Great Pee Dee, Little Pee Dee, Bull Creek, Black, and Waccamaw Rivers)
The Santee-Cooper Rivers complex
Ashepoo River
Combahee River
Edisto River
Savannah River

6. Sustainability

Systems with a sustainable fishery are defined as those that demonstrate their river herring stocks could support a commercial and / or recreational fishery that will not diminish potential future stock reproduction and recruitment. If fisheries exceed sustainability benchmarks, management action will be taken (Table 1). Additionally, if a river system is closely tied or included within the basin boundary to another river system where monitoring occurs, that river will then be managed under the sustainability metrics and management response of the monitored river (Fig 4). River basin boundaries included will be the Pee Dee, Santee, Edisto, Salkehatchie, and Savannah. Note: Pee Dee and Savannah River Basin boundaries include portions of NC and GA respectively.

Commercial

Little River

No commercial fishing for river herring is allowed.

Winyah Bay System (Sampit, Lynches, Bull Creek, Black, Little Pee Dee, and Waccamaw Rivers).

No commercial fishing for river herring is allowed.

Great Pee-Dee River

The Pee Dee River is part of the Winyah Bay System which also includes the Sampit, Black, Waccamaw, and Little Pee Dee Rivers. It is a large free flowing river up to river kilometer (rkm) ~302 where the first barrier (Blewett Falls Dam) is located in NC (Figure 7). The Pee Dee River herring fishery takes place in a small oxbow lake area known as Lowthers Lake located at rkm 176 just north of I-95 and Darlington, SC. The herring fishery for the Pee-Dee River is so insignificant (<472 kg avg. for years 1998-2015; in some years <3 kg), it is believed fishing on this river is not having an overall negative impact on herring populations (Table 5, Figure 8). The number of licensed fishermen is declining with each passing year and those that remain in the fishery are subsistence fishermen who only use fish for personal consumption. As part of the requirements for the previous plan, SC collected fishery dependent biological data to assess the relative fitness of the Pee Dee River herring fishery. Scales for ageing, sex, and length information were collected from up to 100 fish during 2011, 2013, 2014, and 2015. Results show normal age distribution, some degree of repeat spawning, and no significant declines in overall length (Figures 9-10, Table 6). SC requests to maintain this fishery with a 1,000kg harvest cap for the season. During this time, length and age data from the spawning stock will continue to be collected and analyzed. Status of the fishery will continue to be measured by three year running averages of total landings. If at any time, landings exceed the proposed cap for three consecutive years, regulation changes would be considered for this fishery. Based on documented low landings (1,000 kg. is equivalent to < 4 days' allowable catch in the commercial fishery) and results of biological data, SC believes this is a reasonable request for the small Pee Dee River herring fishery.

Santee-Cooper Rivers complex (Wateree, Congaree, Broad, Wando, Ashley, Cooper, Santee Rivers)

The term 'relative exploitation", as appears on Table 2, is calculated as estimated harvest in numbers divided by a minimum population estimate in numbers. The minimum population estimate is calculated as the harvest in numbers plus the passage in numbers at the St. Steven's lift on the Rediversion Canal. Since only a portion of fish in the Rediversion Canal and the Santee River actually move above the St. Steven's Dam, the minimum population estimate is an underestimate of the actual population. During years when both passage counts and population estimates were made (1986-1990), the minimum population estimates averaged 2.3 percent of the population estimate (Table 3). Consequently, estimates of relative exploitation in Table 2 are gross overestimates of the true exploitation rate for the Santee stock. To account for this, adjusted exploitation rates were developed using "scalar" values. These were created by dividing minimum population estimates by population estimates for years when population estimates occurred and calculating a mean for those years (0.023, Table 4). In an attempt to address variation and the possibility that the relationship between population size and fish passage has changed over time, an additional scaler was created in the same manner using the lower confidence limits from the population estimates (0.440, Table 4). When compared to other years in this range, the estimate for 1988 appeared to be an outlyer. As a result, a final scaler was created using the lower confidence limits, but excluding the estimates for 1988 (0.052,Table 4). All scalers (0.023, 0.440, 0.052) were then multiplied by the annual relative exploitation to produce adjusted and more realistic estimates of exploitation rates (Table 2). SC believes the estimate using the 0.052 scaler (lower bound without 1988 value) is the most appropriate and realistic to depict approximate exploitation from this fishery.

Adjusted exploitation rates using the 0.052 scaler were very low and no trend was apparent among years. By comparison, u_{msy} (target exploitation rates) for blueback herring of the Chowan River, North Carolina was $u_{msy} = 0.67$, while that for herring of the Connecticut River, Connecticut and St. John River, New Brunswick were $u_{msy} = 0.75$ (Crecco and Gibson 1990). Adjusted estimates of u imposed by the commercial fishery in the Rediversion Canal are well under all of these benchmarks. Continued harvest at these low rates should be sustainable and should allow for recruitment and future stock reproduction. In addition, numbers of blueback herring passed (438,746), at St. Stephen Dam in 2009, exceeded the past 5 years combined. During the years 1980-1990 concurrent population estimates of the Santee stock below the Rediversion Canal were orders of magnitude greater than fish passed at the dam. Also, recent declines in commercial landings correlate directly to a notable reduction in trips (Figure 5).

SC proposes that the "interim" sustainability benchmark of u = 0.050 continues to be used to manage the Santee-Cooper River herring fishery. Status of the fishery relative to this benchmark will continue to be measured by three year running averages of the scaled annual relative exploitation rates. Annual exploitation rates will be estimated by multiplying annual estimates of relative exploitation by 0.052. Since the development of the original plan, three year running average scaled exploitation rates have not exceeded the sustainability benchmark of 0.050 (Figure 6).

ACE Basin (Ashepoo, Combahee, Edisto, and Salkehatchie Rivers)

No commercial fishing for river herring is allowed.

Savannah River (Coosawhatchie and Savannah)

No commercial fishing for river herring is allowed.

Recreational

Little River

No recreational monitoring occurs in this river system. However, since the Little River is included within the Pee Dee River Watershed boundary, sustainability metrics and management response for the commercial Great Pee Dee River will be applied for this river.

Winyah Bay System (Sampit, Lynches, Bull Creek, Black, Great Pee Dee, Little Pee Dee, and Waccamaw Rivers)**.**

No recreational monitoring occurs in this river system. However, since the Little River is included within the Pee Dee River Watershed boundary, sustainability metrics and management response for the commercial Great Pee Dee River will be applied for this river.

Santee-Cooper River Complex (Wateree, Congaree, Broad, Wando, Ashley, Cooper, Santee Rivers)

No recreational monitoring occurs in the Santee-Cooper River Complex. However, since the all rivers are included within the Santee River Watershed boundary, sustainability metrics and management response for the commercial Santee River will be applied for this river.

ACE Basin (Ashepoo, Combahee, Edisto, and Salkehatchie Rivers)

No recreational monitoring occurs in the Ace Basin Rivers. These rivers are included in SC's Alternative Management Plan for river herring.

Savannah River (Coosawhatchie and Savannah)

No recreational monitoring occurs in the Savannah River Complex. These rivers are included in SC's Alternative Management Plan for river herring.

7. Adaptive Management

SCDNR will continue to monitor both fish passage and the commercial fishery landings in the Santee-Cooper system. In addition, fishery independent sampling for spawning adults in the lower Santee River will continue annually.

If collected data indicates changes in exploitation or decreasing abundance in juveniles, action will be taken by SCDNR. These actions may include increasing days for escapement, limiting seasons, etc. In the event these actions are not successful in reversing negative trends, SCDNR would then be forced to close this fishery.

Several recommendations were included for SC as part of the stock status review for river herring. They are highlighted in the following:

"We recommend that age data be obtained from blueback herring of the Santee River, the Santee-Cooper Rediversion Canal, and the Cooper River and that the commercial creel survey of tailrace fisheries in the system be continued." Age and harvest data are important to understanding current stock dynamics and factors affecting recent river herring abundance. "We also recommend that a sample program be developed or existing programs be improved to track annual production of young."

SC has since implemented all suggested recommendations as part of ASMFC/ACFCMA funded work or by utilizing other SCDNR funding sources. With the dissolution of Anadromous Fish Conservation Act funds, SCDNR was forced to be creative in order to meet requirements of Amendment 2. To complete all mandated goals annually, personnel from other areas and funding sources have been used. Once these funds expire it is anticipated SCDNR will simply not have adequate personnel to complete the work. Furthermore, to date SCDNR has had ~48% cut from the state's appropriated operating budget and is expecting more cuts. If a reduction in force (RIF) is implemented and project personnel are affected, SCDNR will not be able to meet the requirements.

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Figure 1. South Carolina Rivers.

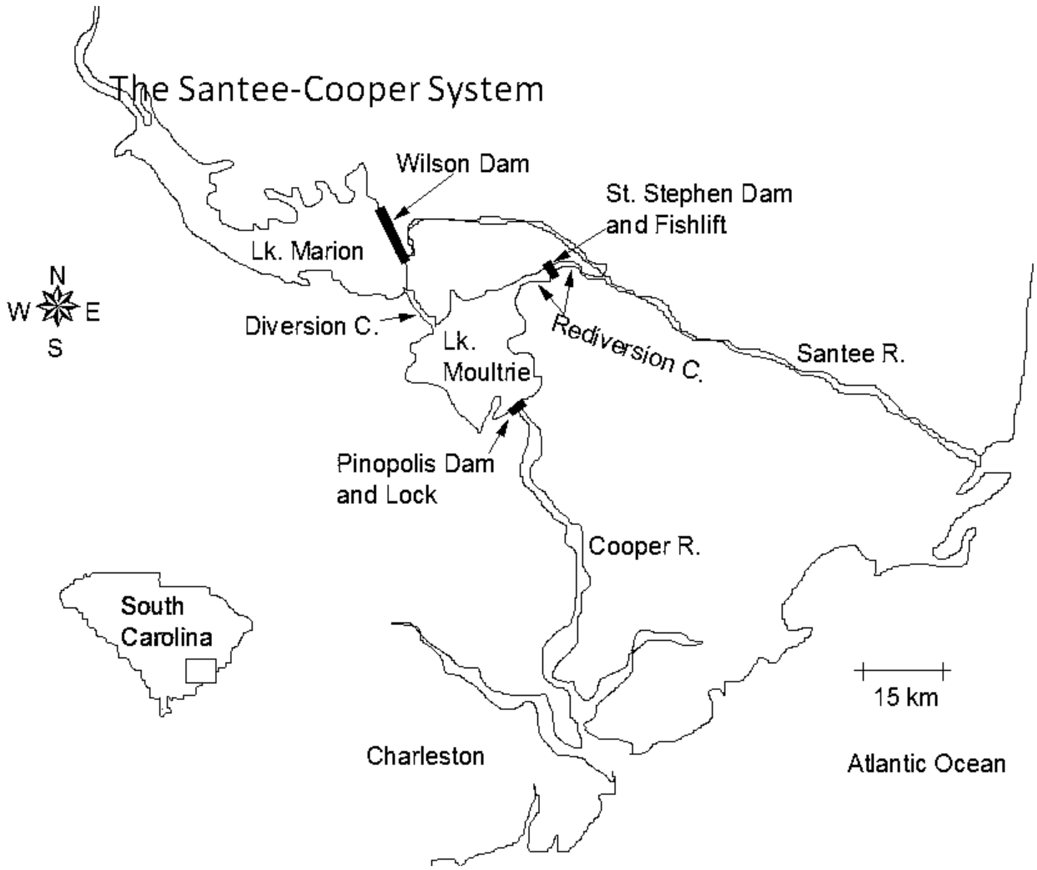


Figure 2. Santee-Cooper Rivers complex in South Carolina.

Table 1. Sustainability values and triggers.

Index	Benchmark Value	Years included in index	Management trigger
Santee-Cooper Rivers Complex	u = 0.050	1990-2015	3 consecutive years below benchmark
Pee Dee River	1000kg	1998-2015	3 consecutive years below benchmark

Table 2. Annual number of blueback herring passed at the St. Stevens Fish Lift, Santee-Cooper Rediversion Canal; harvested in the commercial fishery, minimum population size*, relative exploitation.

							Scalar M-R	Scalar M-R LCI all years		Scalar M-R LCI w/o 1988	
Year	Metric Tons	Harvest Data (Kg)	Number caught (Lbs/.3)	Passage	Minimum Population	Relative Exploitation	0.023	0.440	3-yr running avg.	0.052	3-yr running avg.
1990	1.28	1280	9,408	71,000	80,408	0.12	0.003	0.053		0.006	
1991	9.83	9830	72,251	400,000	472,251	0.15	0.003	0.066		0.008	
1992	91.77	91770	674,510	589,000	1,263,510	0.53	0.012	0.233	0.117	0.027	0.014
1993	180.92	180920	1,329,762	345,000	1,674,762	0.79	0.018	0.348	0.216	0.041	0.025
1994	128.91	128910	947,489	298,000	1,245,489	0.76	0.018	0.335	0.305	0.039	0.036
1995	206.89	206890	1,520,642	561,000	2,081,642	0.73	0.017	0.321	0.335	0.038	0.039
1996	265.06	265060	1,948,191	1,452,285	3,400,476	0.57	0.013	0.251	0.302	0.030	0.036
1997	142.24	142240	1,045,464	176,814	1,222,278	0.86	0.020	0.379	0.317	0.045	0.037
1998	179.61	179610	1,320,134	112,466	1,432,600	0.92	0.021	0.405	0.345	0.048	0.041
1999	**120.38**	**120380**	**884,793**	**182,798**	**1,067,591**	**0.83**	**0.019**	**0.365**	**0.383**	**0.043**	**0.045**
2000	**134.83**	**134830**	**991,001**	**695,586**	**1,686,587**	**0.59**	**0.014**	**0.260**	**0.343**	**0.031**	**0.040**
2001	**24.29**	**24290**	**178,532**	**1,862,015**	**2,040,547**	**0.09**	**0.002**	**0.040**	**0.222**	**0.005**	**0.026**
2002	**0**	**0**	**0**	**421,459**	**421,459**	**0**	**0**	**0**	**0.100**	**0**	**0.012**
2003	52.25	52250	384,038	86,909	470,947	0.82	0.019	0.361	0.134	0.043	0.016
2004	9	9000	66,150	35,545	101,695	0.65	0.015	0.286	0.216	0.034	0.025
2005	35.04	35040	257,544	175,184	432,728	0.6	0.014	0.264	0.304	0.031	0.036
2006	7.5	7500	55,125	105,129	160,254	0.34	0.008	0.150	0.233	0.018	0.027
2007	50.7	50700	372,645	49,343	421,988	0.88	0.021	0.387	0.267	0.046	0.031
2008	**0**	**0**	**0**	**8,503**	**8,503**	**0**	**0**	**0**	**0.179**	**0**	**0.021**
2009	71.6	71600	526,260	438,746	965,006	0.55	0.013	0.242	0.210	0.029	0.025
2010	69.6	69600	511,560	217,750	729,310	0.70	0.016	0.309	0.183	0.036	0.022
2011	37.6	37600	276,360	336,210	612,570	0.45	0.011	0.199	0.249	0.023	0.029
2012	**18.9**	**18900**	**138,915**	**37,117**	**176,032**	**0.79**	**0.018**	**0.348**	**0.285**	**0.041**	**0.034**
2013	**33.5**	**33500**	**246,225**	**113,860**	**360,085**	**0.68**	**0.016**	**0.301**	**0.282**	**0.036**	**0.033**
2014	**52.1**	**52120**	**383,082**	**171,200**	**554,282**	**0.69**	**0.016**	**0.304**	**0.318**	**0.036**	**0.037**
2015	**22.5**	**22500**	**165,375**	**244,631**	**410,006**	**0.40**	**0.009**	**0.178**	**0.261**	**0.021**	**0.031**

*number lifted + number harvested in fishery

Drought years or mechanical failures at the fish lock

Table 3. Mark recapture population estimates of blueback herring in the Santee River, South Carolina.

Year	N	CV	Confidence Interval Lower	Upper
1980	5,895,796	0.25	3,012,000	8,780,000
1981	4,054,521	0.23	2,236,000	5,873,000
1982	664,151	0.17	400,000	888,000
1983	2,352,005	0.45	297,000	4,407,000
1984	2,625,000	0.24	1,417,000	3,833,000
1985	6,205,353	0.71	0	14,822,650
1986	9,061,064	0.41	1,817,496	16,304,632
1987	3,805,457	0.29	1,657,618	5,953,296
1988	5,507,918	0.50	116,348	10,899,488
1989	5,501,964	0.22	3,153,678	7,850,250
1990	9,353,003	0.22	5,358,472	13,347,534

Table 4. Calculation of scalar for adjusting relative exploitation rate for the Santee River.

Year	Minimum Population	M-R Population	M-R Lower CI	M-RLower CI w/o 1988	min/M-R	min/M-R LCI	min/M-R LCI w/o 1988
1986	187,000	9,061,064	1,817,496	1,817,496	0.021	0.103	0.103
1987	74,000	3,805,457	1,657,618	1,657,618	0.019	0.045	0.045
1988	232,000	5,507,918	116,348		0.042	1.994	
1989	147,000	5,501,964	3,153,678	3,153,678	0.027	0.047	0.047
1990	71,162	9,353,003	5,358,472	5,358,472	0.008	0.013	0.013
				Scalar	0.023	0.440	0.052

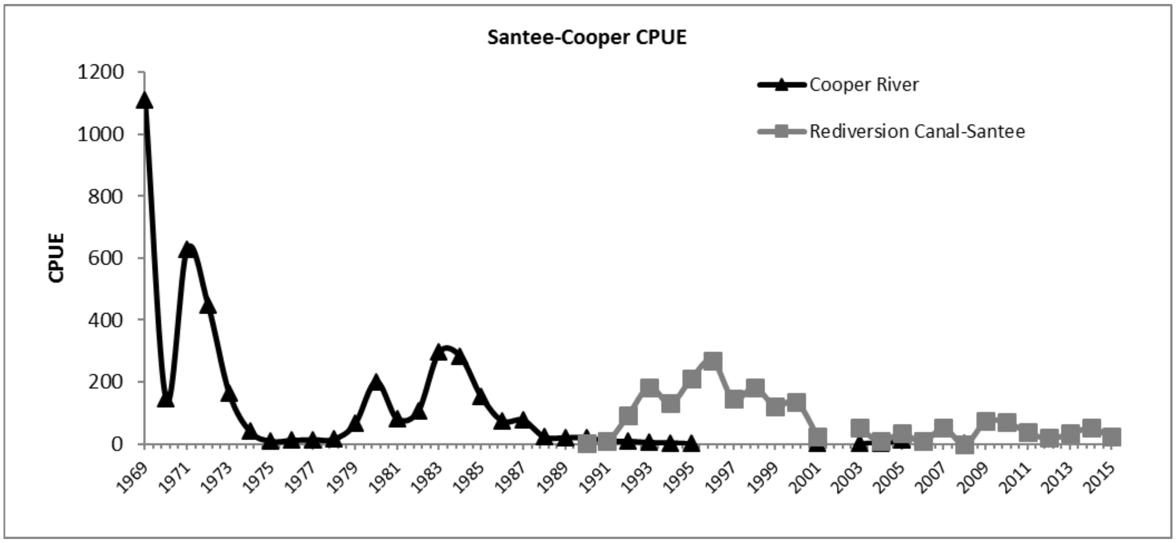
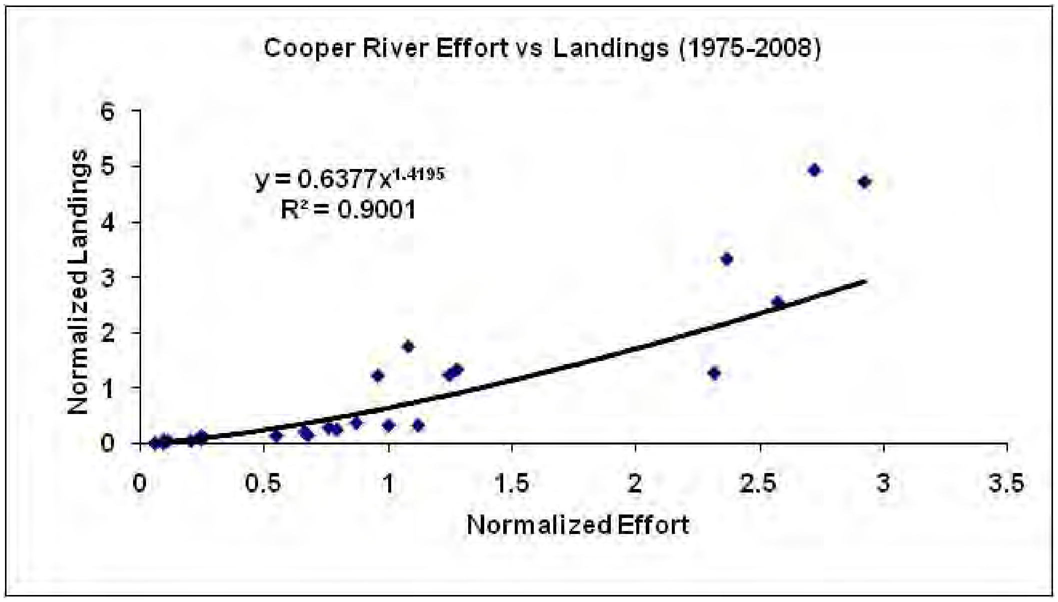


Figure 3. Estimated effort (CPUE) in the commercial fishery for blueback herring in the Cooper River and the Santee-Cooper Rediversion Canal, South Carolina.



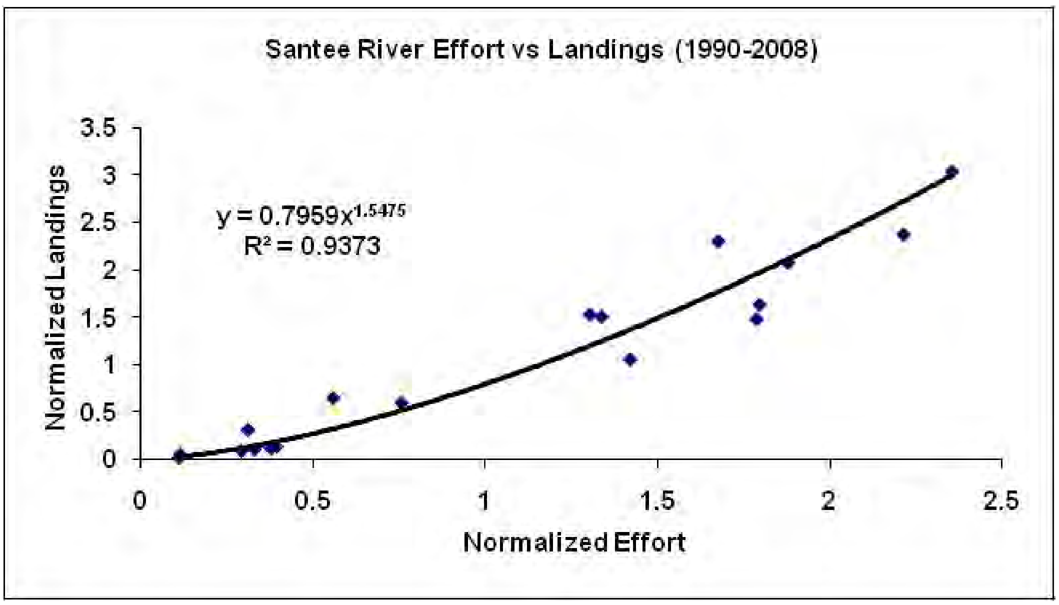


Figure 4. Normalized effort vs. normalized landings in the commercial fisheries of the Cooper and Santee Rivers, South Carolina.

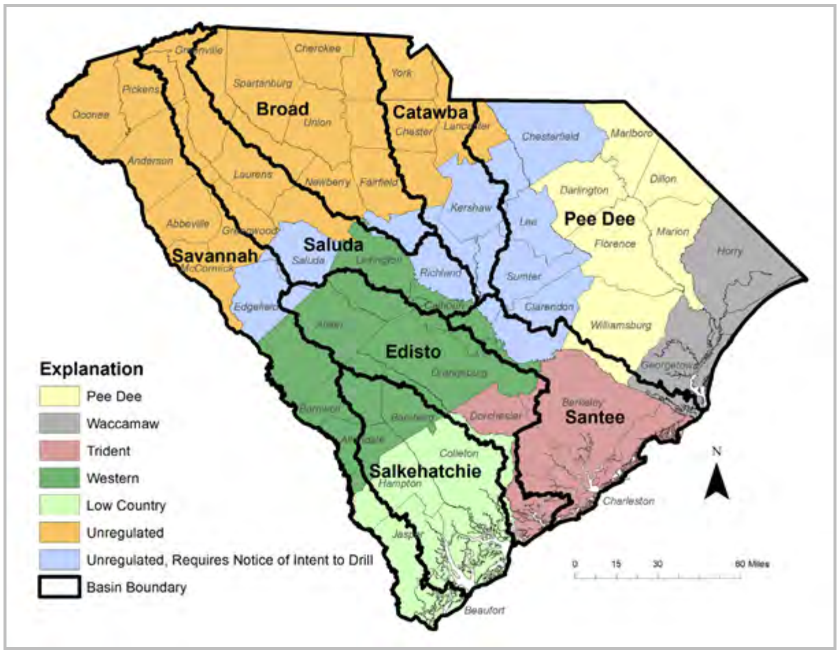


Figure 7. SC river systems defined by river basin boundaries

(https://www.clemson.edu/public/water-assessment/).

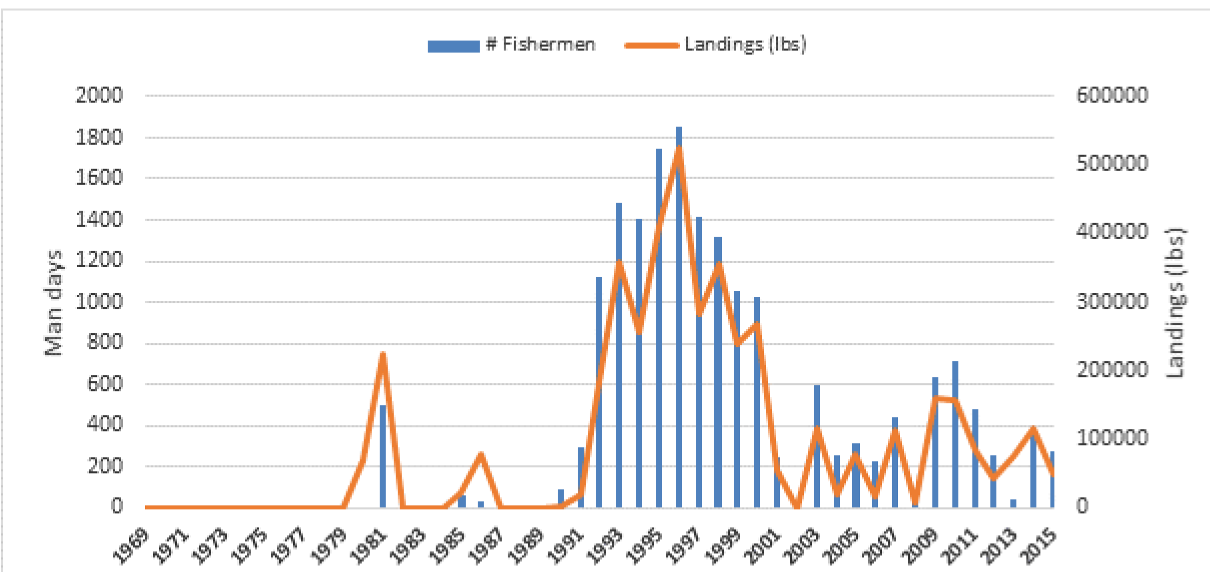


Figure 5. Number of Santee River fishermen versus pounds of herring harvested 1969-2015.

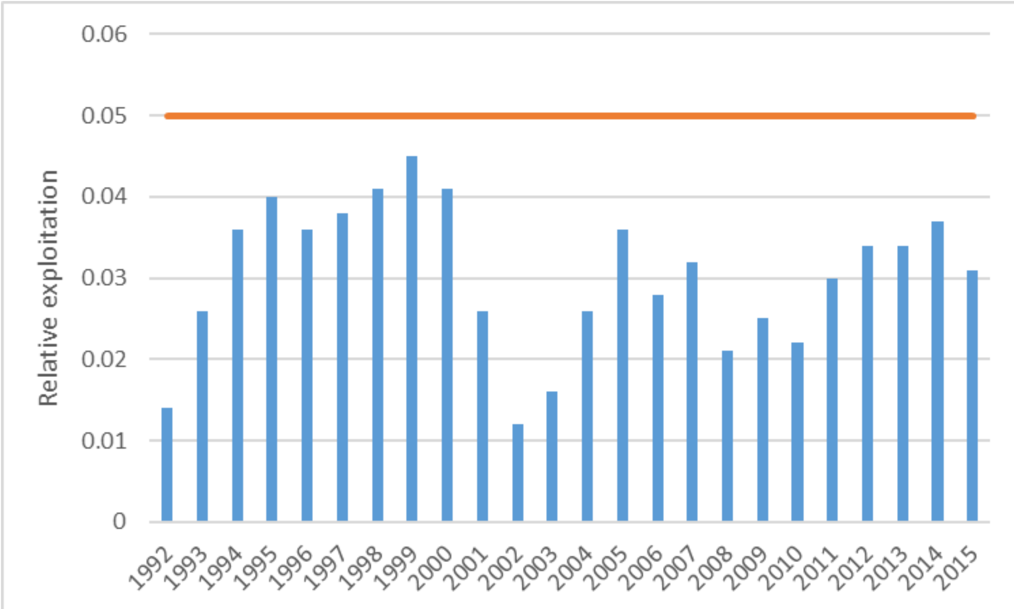


Figure 6. Relative exploitation for the Santee blueback herring fishery compared to .050 benchmark target (1992-2015).

Table 5. Landings of blueback herring from the Pee-Dee River (1998-2015).

Year	Kg.
1998	2
1999	15
2000	323
2001	817
2002	131
2003	350
2004	93
2005	162
2006	14
2007	259
2008	643
2009	660
2010	999
2011	894
2012	855
2013	758
2014	767
2015	919

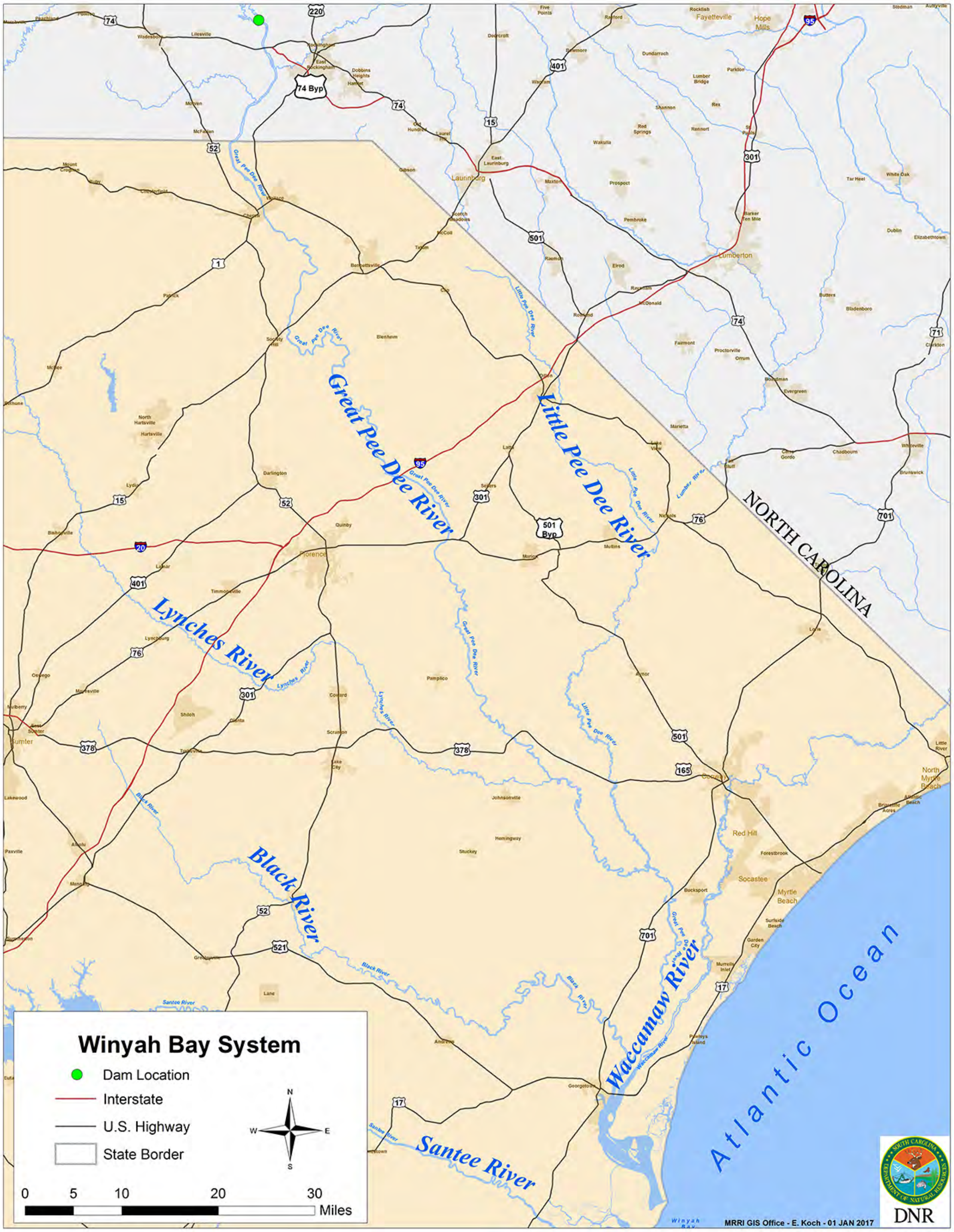


Figure 7. Winyah Bay System including the Pee Dee River.

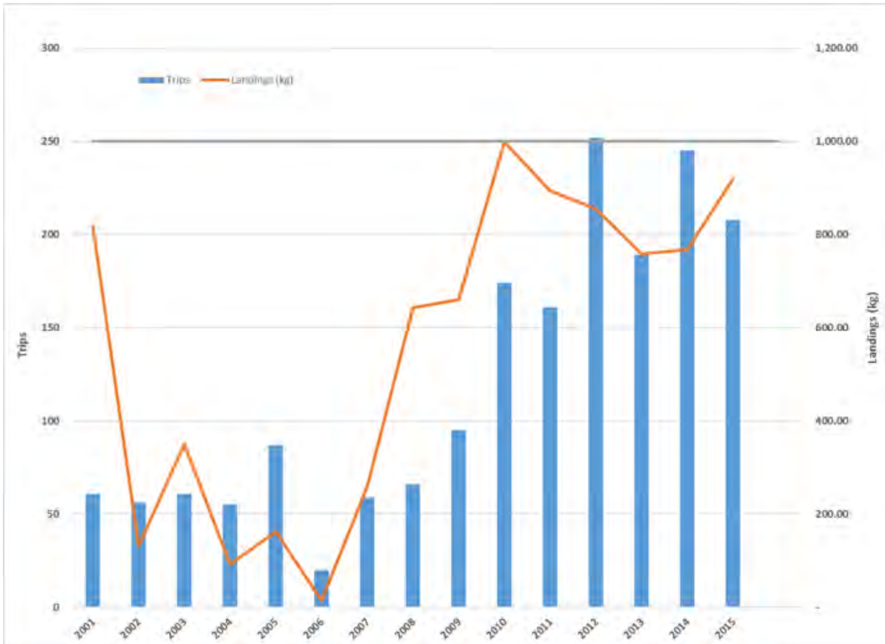


Figure 8. Pee-Dee River blueback herring landings compared to number of trips (2001-2015).

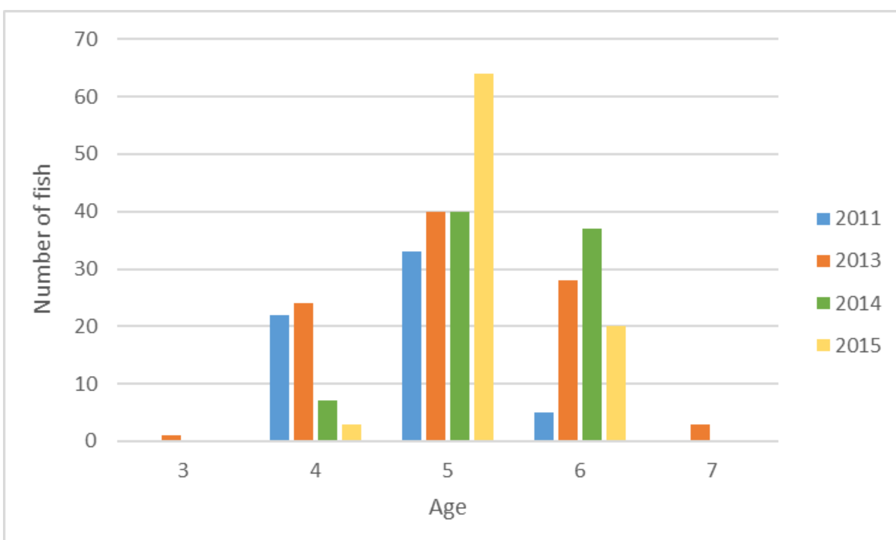


Figure 9. Pee-Dee River blueback herring age distribution (2011, 2013-2015).

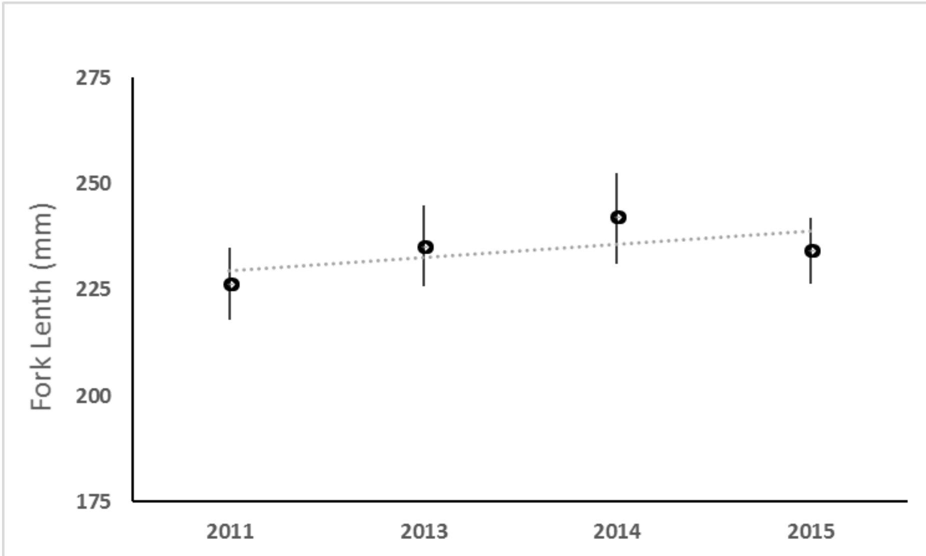


Figure 10. Pee-Dee River blueback herring mean fork length and standard deviations for 2011 and 2013-2015.

Table 6. Percent of repeat spawning Pee-Dee River blueback herring (2011, 2013-2015).

	2011	2013	2014	2015
% with one spawning mark	33	28	25	15
% with two spawning marks	5	11	1	2
% repeat spawners	38	41	26	17

Appendix 1. Brief description of the Santee-Cooper Complex

In 1938, the South Carolina Public Service Authority (SCPSA) initiated the Santee-Cooper Diversion Project. The project dammed Santee River at river km 143.201 and the headwaters of Cooper River creating two reservoirs joined by a canal (Figure 2). The canal allowed Santee River water to be diverted into Lake Moultrie and the Cooper River. Benefits provided were flood control, improved navigation, and hydroelectric power production. Wilson Dam, a flood control structure constructed on Santee River (river km 143) created Lake Marion. Pinopolis Dam (river km 77), a hydroelectric facility and navigation lock, impounded diverted water from Lake Marion along with the headwaters of Cooper River to form Lake Moultrie. In 1957, it was documented that blueback herring, passed into the lakes during boat lockings, provided as much as 25% of the diet of adult Santee-Cooper striped bass (Stevens 1957). Since then, the SCPSA has operated the lock three to six times daily during the spring spawning run, to allow blueback herring to enter the lake system. This action not only supplemented the system's forage base but also provided anadromous fish access to additional spawning areas. From 1975 to 1984, a hydroacoustic survey estimated 2.2 - 10.8 million blueback herring (mean = 5.7 million) were admitted into Lake Moultrie annually (Christie and Barwick 1984).

As a result of the Santee-Cooper Diversion Project, increased flows down the Cooper River from diverted Santee River water accelerated shoaling in Charleston Harbor (USACE 1975). The Cooper River Rediversion Project was proposed to reduce shoaling by reducing the flow to Charleston Harbor. In 1985, the U.S. Army Corps of Engineers (USACE) finished construction of a 9.5-mile canal to re-divert approximately 75% of the Cooper River flow back into Santee River. The project set a maximum weekly average discharge of 127 cms for Cooper River with the remainder being diverted to Santee River via the new Rediversion Canal. During periods of low water inflow (i.e. below 127 cms), virtually all water released from Lake Moultrie flows down Cooper River. This is because power generation at Pinopolis Dam is more efficient than at the new hydro-facility. Discharge is not regulated at the St. Stephen Dam on the Rediversion Canal. Wilson Dam still releases a continuous 14.6 cms from Lake Marion into Santee River. Concern that reduced discharge to Cooper River would attract fewer blueback herring, decreasing the number that annually migrated through Pinopolis Lock into the Santee-Cooper lakes arose. The USACE predicted that while fisheries resources may decline on Cooper River they would increase on Santee River (USACE 1975). To maintain the number of anadromous fish entering the lakes, the USACE constructed a fish lock on the Rediversion Canal to allow Santee River fish access to Lake Moultrie.

In 1985, water flowing from the Cooper River was re-diverted to the Santee River. A fish lock, constructed at the St. Stephen Dam on the Rediversion Canal, was designed to mitigate the decline of fish passage on the Cooper River. Despite this effort, total fish passage rapidly declined after Rediversion. High or intermittent discharges from the St. Stephen Dam hindered fish from entering the lock. In 1990, a flow agreement with the SCPSA was initiated allowing the lock to function more effectively and the numbers of fish passed to increase. Blueback herring passage through the two facilities has never equaled the pre-Rediversion levels that occurred at the navigation lock though. Modifications to the fish lock entrance channel to increase passage efficiency have been ongoing since construction. Phase I of the modifications was completed for the 1995 season. The modification provided a corridor for fish passage that was protected from the turbulence of hydro-production, and is essentially a collection gallery that moved the entrances to the lock farther downstream. Phase IIA provided adjustable weir gates installed in the gallery prior to the 1997 season. Phase IIB became operational about halfway through the 2000 season and included a bypass siphon system that can deliver an additional attraction flow of 14 cms around the facility rather than through the fish lock grating. A juvenile separating device was also constructed to safely pass out-migrants downstream from this attraction flow.

Appendix 2. Summary of current regulations on take of blueback herring in South Carolina.

General

There is no run of the river commercial fishing activity for herring in any statewide waters except the Santee-Cooper Complex and the Pee Dee River.

Season

The open season is 15 February - 15 April in the Pee Dee River. The open season in the Santee River is 15 February - 1 May. The open commercial season for the Rediversion Canal of Santee River and the Tailrace Canal of Cooper River is 1 March – 30 April of each year.

Harvest Limits

The allowable daily take of herring for net fisheries is 10 US bushels per boat in the Tailrace Canal of the Cooper River and 10 US bushels per boat in the Rediversion Canal. There are no other caps or quotas in effect for commercial herring fisheries in South Carolina.

Gears

Approved commercial gears are anchored (set or stationary) and drift gill-nets in all open riverine waters seaward of dams, with the exceptions of open portions of the Santee and Cooper River where other gears are allowed. Circular drop-nets up to six feet in diameter, lift-nets and cast-nets are the only gears allowed in the upper Tailrace Canal of the Cooper River and in the open portions of the Rediversion Canal of the Santee River. Lift-nets, cast-nets, and hook & line may be used within the Santee-Cooper Lakes and cast-nets and/or hook & line are legal gear in other inland reservoirs. Legal minimum mesh size for gill-nets is 2 1/2" stretched mesh in all State waters open to such gear. The length of any gill-net may not exceed one half of the width of the waterway where it is fished. Gill-nets may not be fished within 200 yards of any previously deployed net. Regulatory changes implemented in 2001 restricted net lengths to a maximum of 200 yards in freshwaters and 300 yards in inland marine waters.

Lift Periods

There is a weekly 84-hour lift period in effect for the Pee Dee River during the open gill-netting season. The use of nets in the Cooper River Tailrace Canal is allowed only from sunrise until 10:00. Fishing with nets in the Rediversion Canal is allowed from 7:00 PM - 12:00 midnight EST or 8:00 PM – 12:00 AM EDT, with no lift period. Portions of several rivers are closed to commercial gear.

Actual regulations can be found at: http://www.scstatehouse.gov/code/t50c005.php, under Article15.

American Shad Sustainable Fishing Plan Update for South Carolina

Prepared by

Bill Post, Ellen Waldrop, and Chad Holbrook

March 16, 2020

South Carolina Dept. of Natural Resources

Wildlife and Freshwater Fisheries and Office of Fisheries Management

Updated-ASMFC American Shad Sustainable Fishing Plan for South Carolina

Introduction:

The purpose of this sustainable fisheries management plan is to allow existing shad fisheries that are productive and cause no threat to future stock production and recruitment to remain in place and close all others. Excerpts from the ASMFC 2007 stock assessment for SC's American shad were used in this document (ASMFC 2007). The assessment, which was prepared and submitted to the ASMFC shad and river herring board by SCDNR and the Stock Assessment Subcommittee (SASC), summarizes SC's fisheries for American shad.

American shad (*Alosa sapidissima*) are found in at least 19 rivers of South Carolina (Waccamaw, Great Pee Dee, Little Pee Dee, Lynches, Black, Sampit, Bull Creek, Santee, Cooper, Wateree, Congaree, Broad, Wando, Ashley, Ashepoo, Combahee, Edisto, Coosawhatchie, and Savannah rivers). Many have historically supported a commercial fishery, a recreational fishery, or both, including the Winyah Bay system (primarily the Waccamaw and Pee Dee rivers), the Santee-Cooper system, Ashley, Edisto, Ashepoo, Combahee, Coosawhatchie, and Savannah Rivers (Figure 1).

Figure 1. Map of major South Carolina drainage basins and river systems with American shad (*Alosa sapidissima*) fisheries or historical American shad runs.

Currently, commercial fisheries exist in Winyah Bay, Waccamaw River, Pee Dee, Black, Santee, Edisto, Combahee, and Savannah rivers, while the Sampit, Ashepoo, Ashley, and Cooper rivers no longer support commercial fisheries. With the closure of the ocean-intercept fishery beginning in 2005, the Santee River and Winyah Bay complex comprise the largest commercial shad fisheries in South Carolina. Recreational fisheries exist in the Cooper, Savannah, Edisto, and Combahee rivers, as well as the Santee River Rediversion Canal.

Data for American shad are available to assess trends in fishery and stock status for the following river systems in South Carolina: the Pee Dee run (consisting of Winyah Bay, Waccamaw and Great Pee Dee rivers), Santee River, Cooper River, Edisto River, Combahee River, and Savannah River. Additional data for the Savannah River are provided by Georgia Department of Natural Resources (GADNR).

The South Carolina Department of Natural Resources (SCDNR) manages American shad populations and collects fishery-independent and fishery-dependent data for the major shad rivers in the state. SCDNR has collected voluntary landings data by river system since 1979 and instituted mandatory catch and effort reporting in 1998. There are still some gaps in these data, but they provide the broadest temporal and spatial view of American shad stocks in South Carolina. As part of fishery independent sampling, SCDNR also conducted tag-return studies in the gill-net fisheries for several rivers, but these were not used to determine stock status, because in recent years, fishers have grown skeptical that providing tag returns to SCDNR led to new more restrictive changes in the fishery and may lead to future closures. In the past, these studies rotated among rivers and ran 2 to 5 years per river before moving to a different river. However, due to growing concern for the species, SCDNR began conducting this monitoring in multiple "reference" rivers during the shad season. During these studies, SCDNR collected biological information to support other studies (e.g., age, repeat spawning, length and weight data). In some systems, SCDNR also conducted creel surveys (Cooper River and Savannah River), fish counts (Santee River), and young of the year (YOY) sampling (Santee-Cooper system, Pee Dee River, Edisto River, and Savannah River).

This plan primarily draws upon investigations conducted by the SCDNR's Marine Resources Division and Division of Wildlife and Freshwater Fisheries to provide a river-specific assessment of relative stock status for American shad. The general approach to this document was to (1) characterize fisheries by the magnitude and trend of landings data (Catch Per Unit Effort=CPUE) and note if the system still supports a viable fishery and (2) review supporting fishery-dependent and fishery-independent data sets and conduct analyses for each river system when applicable.

Current Regulations:

South Carolina manages its shad fisheries using a combination of seasons, gear restrictions, and catch limits (Appendix 1.) implemented over several management units: Winyah Bay and Tributaries (Waccamaw, Great Pee Dee, Little Pee Dee, Lynches, Black and Sampit rivers); Santee River; Charleston Harbor (Wando, Cooper, and Ashley rivers); Edisto River; Ashepoo River; Combahee River;Coosawhatchie River; Savannah River within South Carolina; Ocean Waters; and Lake Moultrie, Lake Marion, Diversion Canal, Intake Canal of Rediversion Canal and all tributaries and distributaries.

The first river-specific commercial regulations for American shad in South Carolina were enacted in 1993 for the Edisto River in response to SCDNR's studies that identified overfishing as a major contributor to a perceived trend of population decline [Act # 343 of the 1992 South Carolina General Assembly].

Beginning with the 1998 commercial shad-netting season, all licensed fishermen are required to report their daily catch and effort to the SCDNR. In 2000, Act #245 of the 2000 South Carolina General Assembly was passed in response to the perceived population status of shad populations in each of the state's river systems supporting an American shad fishery. This Act led to the closure of the commercial gill-net fishery on the Coosawhatchie River and a substantial reduction in potential gill-net fishery effort for other systems supporting small American shad stocks in South Carolina, including the Combahee, Ashepoo, and Ashley rivers (www.dnr.sc.gov).

Significant changes in shad and herring regulations became effective in 2001 with the passage of the Marine Resources Act of 2000, which gave the SCDNR authority to implement a permit program for the State's shad and herring fisheries. All commercial shad and herring fishery license holders were issued permits that could be used to "restrict the number of nets for taking shad…in any body of water where the number of nets or fishermen must be limited…to prevent congestion of nets or watercraft, or for conservation purposes". The number and conditions of permits can be controlled "to designate areas, size and take limits, hours, type and amount of equipment, and catch reporting requirements," and enabled SCDNR to phase out the ocean-intercept fishery by 2005. In addition, a recreational aggregate creel limit of 10 American and hickory shad per person was implemented in all state waters, except for the Santee River in which a 20 fish creel limit was set.

Further proposed restrictions in the previous SFMP document, to address sustainability, were implemented in 2013 and were the first changes in SC's shad fishery since the closure of the ocean-intercept fishery in 2005. These changes (Appendix 3), in concert with changes required by the National Marine Fisheries Service (NMFS) to account for by-catch of sturgeon (Appendix 2), without a doubt, far exceeded by a wide margin, any restrictions imposed on SC's shad fishery to date.

Brief description – Current status of the stocks:

a) Landings:

South Carolina has monitored commercial fisheries for American shad within state waters since 1979. The NMFS landings data before 1979 were collected from major wholesale outlets located near the coast; therefore, it is likely that inland landings were not completely accounted for in these years, since many shad fishermen claim not to sell their catch and keep it for personal consumption. No landings were attributed to the South Carolina ocean-intercept fishery before 1979. SCDNR has landings by system since 1979 for the Atlantic Ocean (i.e., the ocean-intercept fishery), Winyah Bay, Waccamaw River, Pee Dee River, and Santee River. These data were used in the 2007 shad stock assessment by SC and ASMFC. Data collected since 1979 generally include inland landings and should be considered as a separate time series. Those time series begin in 1998 when the mandatory reporting requirement was instituted for the statewide fishery.

There are some discrepancies between SCDNR and NMFS American shad landings. One reason for this is that NMFS uses dealer landings reports for their records; however, many shad fishermen claim not to sell their catch and keep it for personal consumption.

The Cooper River supports an active recreational fishery below the Pinopolis Dam tailrace in the late winter to early spring. SCDNR has conducted a creel survey from 2001 to 2015 to estimate exploitation and catch-per-effort in this recreational fishery. SCDNR also conducted sportfishing creel surveys on the Cooper and Santee Rivers from 1981 to 1982 and 1991 to 1993 in order to evaluate the impact of the Rediversion Canal on these rivers' recreational fisheries (Cooke and Chappelear 1994). These surveys examine the total recreational fisheries on each river for each study period.

Recreational creel surveys were conducted on the Savannah River in the late 1990s by GADNR (1997) and SCDNR (1998 and 1999). Estimates of catch from these surveys varied from year to year largely due to dramatically different flow conditions, as 1998 was a "flood" year and 1999 a "drought" year. Catch estimates from each of these creel surveys are available in Boltin (1999); however, the year-to-year estimates were highly dependent on the impacts of the river flow on the recreational fishery. In 1997, no additional information on the flow was reported. Due to requirements of Amendment 3 to ASMFC's shad and river herring fishery management plan, SCDNR conducted creel surveys beginning in 2011, however, due to the deteriorating wing wall at the New Savannah Bluff Lock and Dam, recreational fishing is no longer permitted at this location.

b) Fishery Independent Indices:

Spawning stock:

Fishery-independent CPUE data were collected using 12.7 cm stretch mesh drift gill nets for the years 1994–2015. In the past, as approved by Amendment 1 of ASMFC's shad and river herring fishery management plan (FMP), these studies rotated among rivers and ran 2 to 5 years per river before changing river systems. However, due to growing concern for the species, SCDNR began conducting this monitoring on multiple "reference" rivers during the season. During these studies, SCDNR collected biological information to support other studies (e.g., age, repeat spawning, length and weight data).

Juvenile Surveys:

Trawl sampling studies were conducted for juvenile American shad in the fall of 1985 in the Edisto River and Winyah Bay using 4.9 and 7.6 m otter trawls. Sampling in the Edisto River occurred from September through November with 32 trawls that caught two American shad. Winyah Bay sampling took place October and November. Nineteen trawls over five stations yielded three American shad. Data were also collected from another SCDNR trawl project in the Santee River where 15 juvenile American shad and 30 juvenile blueback herring were collected. These programs were discontinued after a single sampling season. However, due to growing concerns to prove sustainability, SCDNR began yearly sampling for YOY in 2009 in some systems and 2010 in others. In addition, YOY sampling in the Santee Cooper Lake System occurred as part of yet another SCDNR study in 2008.

c) Fishery Dependent Indices:

Historical commercial shad landings from NMFS are available for South Carolina back to 1880 with the highest reported landings occurring in 1896 (304,819 kg). NMFS reporting agents compiled landings recorded before 1979. Landings data are available for 11 years between 1880 and 1926 with a range of 94,349 to 304,819 kg and a mean of 188,615 kg. Beginning in 1927, a continuous data stream of landings is available to the present, except for the 1940s (WWII). Landings generally declined from the late 1800s throughout the twentieth century reaching a low in the 1970s, with annual landings averaging 16,477 kg from 1973 to 1976.

With the onset of mandatory reporting in 1998, South Carolina shad fishermen were required to report effort and landings data. In 2000, 2,727 commercial shad fishing trips were reported to SCDNR. The number of reported trips generally decreased from 2000 to 2015 with 1,281 trips taken in 2015. Nearly all fishermen (>95%) have submitted at least one monthly report since 2000, while only 60 to 70 percent report some catch (SCDNR records). It is likely that the ocean-intercept fishery closure in 2005 contributed to the decrease in landings from the 2004 amount of 170,212 kg.

With the closing of the ocean-intercept fishery in 2005, the Santee River and Winyah Bay now constitute the largest remaining commercial shad fisheries in South Carolina with Santee River landings comprising 58 percent and Winyah Bay landings 38 percent of the 2005 statewide total. In 2015, shad trips in Winyah Bay complex and Santee River accounted for 35 percent and 46 percent of the total shad trips, respectively.

d) Other: none

e) Commercial fisheries closed in the previous plan

a. Waccamaw River (Bull Creek to North Carolina border)
b. Ashley River
c. Charleston Harbor
d. Wando River
e. Ashepoo River

Fisheries requested to be Open

Commercial

a. Pee Dee River run (Winyah Bay, Waccamaw, and Great Pee Dee River)
b. Black River
c. Santee Cooper Rivers Complex (Santee and Cooper Rivers)
d. Edisto River
e. Combahee River
f. Savannah River

Recreational

a. Little River
b. Winyah Bay System (Sampit, Lynches, Great Pee Dee, Little Pee Dee, Bull Creek, Black, and Waccamaw Rivers).
c. The Santee-Cooper Rivers Complex (Wateree, Congaree, Broad, Rediverson Canal, Lake Moultrie, Lake Marion, Diversion Canal, North Santee River and Bay, South Santee River, Wando River, Cooper River, Charleston Harbor, Wando and Ashely Rivers).
d. Ashepoo River
e. Combahee River
f. Edisto River
g. Salkehatchie River
h. Coosawhatchie River

f) Sustainability

Systems with "sustainable fisheries" are defined as those that demonstrate shad stocks could support a commercial and / or recreational fishery that will not diminish potential future stock reproduction and recruitment. Data used, in most cases, are landings (CPUE) that occurred since the 2007 stock assessment (i.e. after 2004). Sustainability for SC rivers is determined by catch trends (both using fishery-independent and fishery-dependent data), and in some cases, juvenile abundance. In addition to these, as part of requirements of Amendment 3, SC already imposed several gear restrictions, cap limits, and changes to the legal fishing season. Furthermore, in response to the National Marine Fisheries Service (NMFS), SC further restricted the fishery to account for and limit the by-catch of sturgeon in the shad fishery. In 2013, statewide gear restrictions were implemented (Appendix 2). These restrictions, while resulting in an 88 percent reduction of by-catch of Atlantic and shortnose sturgeon, also no doubt led to more protection for adult shad during spawning runs. Sustainability targets have been developed by using fishery-dependent data (landings/CPUE) and/or fishery-independent data collected since the last year of data included in the stock assessment and using the 25th percentile of the annual mean (Table 1). Additionally, if a river system is closely tied or included within the basin boundary to another river system where monitoring occurs, that river will then be managed under the sustainability metrics and management response of the monitored river (Figure 2). River basin boundaries included will be the Pee Dee, Santee, Edisto, Salkehatchie, and Savannah. Note: Pee Dee and Savannah River Basin boundaries include portions of NC and GA respectively.

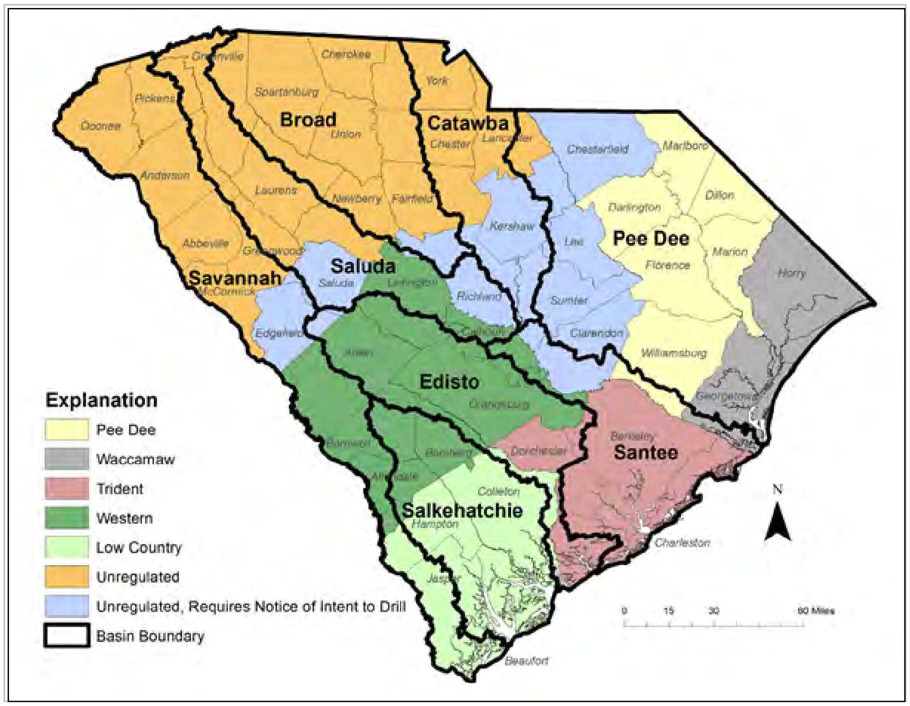


Figure 2. South Carolina river systems defined by river basin boundaries

(https://www.clemson.edu/public/water-assessment/).

Commercial

Pee-Dee River Run (Winyah Bay, Waccamaw to Bull Creek, and Great Pee Dee River)

In order for American shad to enter the Pee Dee River, they must first swim through the Winyah Bay and the lower most portion of the Waccamaw River. Therefore, SCDNR will refer to this as the Pee Dee River Run of shad. There is little doubt some shad continue up the Sampit and Waccamaw Rivers, but those rivers/river segments are not being considered in this sustainability option and were closed to fishing in 2013 (Figure 3).

Figure 3. Map of the Winyah Bay system highlighting the "Pee Dee run" of American shad.

SCDNR uses both fishery-independent and fishery-dependent data to justify the continued existence of this fishery. The 2007 stock assessment concluded "that, overall, these shad stocks have remained stable or increased slightly since the late 1970s." More recent catch rates (kg of shad captured in a 92 m net fished for one hour) also indicate a stable trend (Figure 4). In fact, during the 2011 fishing season, fisheries were suspended twice for two weeks at a time, due to the excess of shad at the local fish markets. SCDNR also conducts fishery-independent sampling in the Waccamaw River using gear comparable gear (92 m floating/drift gill net with 12.7 cm stretch mesh) and observed similar catch rates (CPUE = kg of shad/ 92 m net fished for 1 hour). SCDNR will continue this sampling on an annual basis.

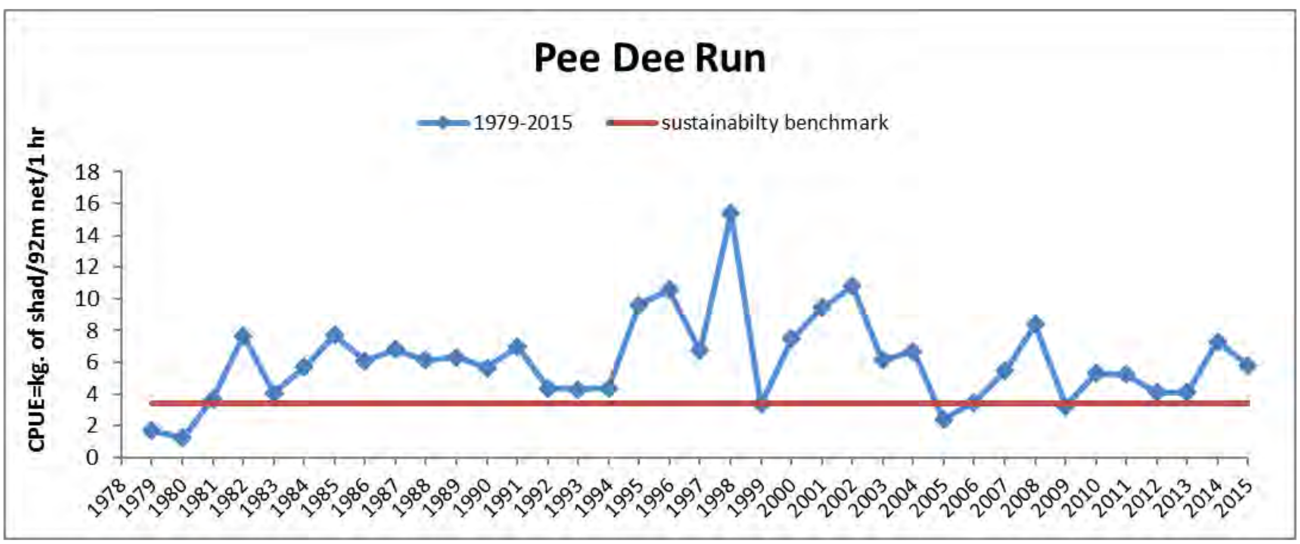


Figure 4. Commercial catch per unit effort (kg. fish per 92-m net hr) of American shad and sustainability target for the Pee Dee Run

Beginning in 2010, SCDNR also collected YOY shad from this system during the summer outmigration. Shad with lengths ranging from 77–137 mm were collected using electro-fishing gear. Catch rates (CPUE = number of shad caught per hour) were equal to 31.28. This was also somewhat comparable to efforts from another SCDNR survey conducted in 2008 which yielded a CPUE of 47 for American shad. However, during this study, more sites were used over a broader reach of river during this project and unfortunately, due to ongoing budget cuts, sampling for this project was discontinued. However, YOY sampling is consistent with results from 2010 and will continue on an annual basis.

SC requests to maintain this fishery at current levels with annual monitoring to occur as mentioned. The Pee Dee run is considered by SCDNR to be sustainable at current levels and with newly passed regulation changes, migrating shad should receive additional protection which will only help the sustainability of the species. The approved sustainability benchmark of 3.41 was developed by using the 25th percentile of the annual mean for CPUE's for the last 10 years. If the CPUE's fall below the sustainability target for 3 consecutive years, management action will be taken. Potential management actions are gear restrictions, season changes, catch limits, or closure.

Black River

The 2007 stock assessment concluded, "This relatively small river is perceived to have undergone significant American shad stock declines over the past 25 years." More recent CPUE (kg of shad/ 92 m net fished for 1 hour) data (2000–2015) suggest that while catches are low, they remain consistent and, given the low effort, appear to be stable in more recent years. Currently, the Black River commercial shad fishery consists of only 2 fishermen and neither fisherman depends on their catch for commercial purposes. Because the number of fishers decreased since 2011, landings data for this river are confidential are not provided in this plan. However, it should be noted, catch rates for this river did not fall below the approved sustainability benchmark. Additionally, the Black River remains an undammed river with low flow rates which pale in comparison with those from the dammed Santee River (5912 cfs) or Pee Dee River (11,267 cfs) for the same time series.

SC requests to maintain this fishery at reduced levels. The Black River run of shad is considered by SCDNR to be sustainable at lower levels and with newly passed regulations, migrating shad should also receive additional protection. If catch rates (CPUE = kg of shad/ 92 m net fished for 1 hour) for the Black River run commercial fishery fall below 0.97 for 3 consecutive years, changes by SCDNR to the commercial regulations will be implemented. This sustainability benchmark was developed by using the 25th percentile of the annual mean for CPUE's for the last 10 years. Potential management actions could be gear restrictions, season changes, catch limits, or closure.

Regulatory changes mentioned earlier, greatly affected fishing effort and gear used in the Winyah Bay System Rivers. These changes may be responsible for the perceived increase in catch rates in recent years. In any event, SC believes current restrictions (shortened season, allowable nets reduced by 90 percent, restrictions on recreational netters gear, 50 percent reduction for recreational anglers limit, and ultimately capping the fishery at current levels) in combination with those required statewide by NMFS for the incidental by-catch of sturgeon, will provide adequate protection for spawning shad for years to come.

Santee Cooper River Complex

Santee River

SCDNR has both fishery-independent and fishery-dependent data to justify the continued existence of this fishery. The 2007 stock assessment concluded, "the Santee River American shad stock in the Santee River benefited greatly from the Rediversion project." Catch rates (CPUE), used in the assessment, indicated a stable if not increasing trend. More recent CPUE (kg of shad/ 92 m net fished for 1 hour) data suggest that those trends continue (Figure 5). As mentioned earlier, during the 2011 fishing season, fisheries were suspended twice for two weeks at a time, due to the excess of shad at the local fish markets.

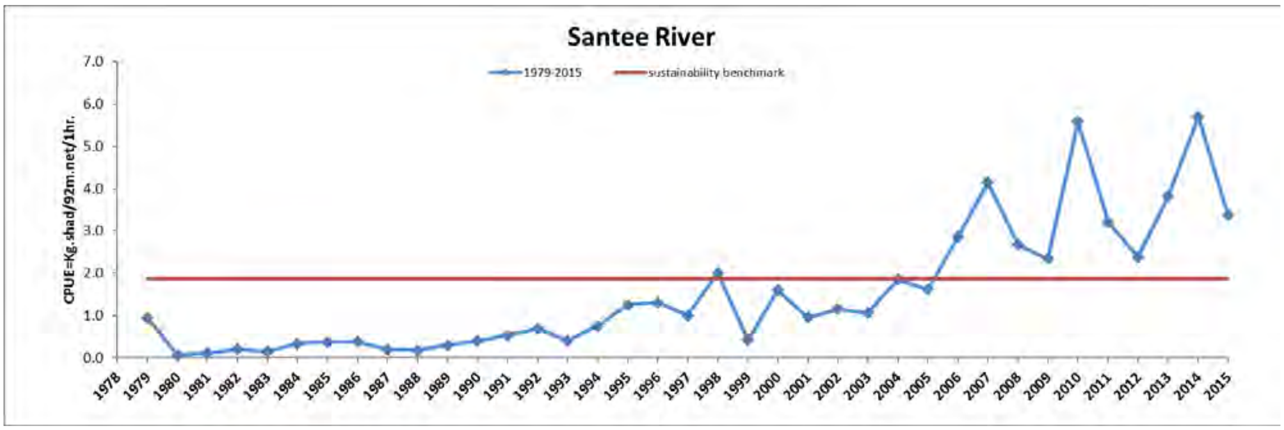


Figure 5. Commercial catch per unit effort (kg fish per 92 m net hour) of American shad and sustainability target for the Santee River.

SCDNR also conducts fishery-independent sampling in the Santee River using comparable gear (92 m floating/drift gill net with 12.7 cm stretch mesh) to provide trends of abundance for the spawning stock. Catch rate (CPUE = kg of shad/ 92 m net fished for 1 hour) data for this sampling (2008–2015) is included in Figure 6.

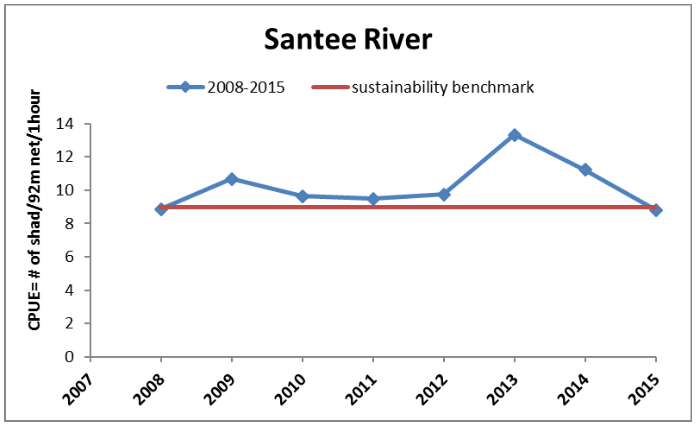


Figure 6. Fishery-independent catch per unit effort (kg. fish per 92-m net hr) of American shad and sustainability target for the Santee River.

SC requests to maintain the Santee River fishery at current levels with annual monitoring to occur as mentioned. This run is considered by SCDNR to be sustainable at current levels and with new regulations, migrating shad should receive additional protection. SC proposes that a catch rate sustainability benchmark of 1.8 (kg of shad/ 92 m net fished for 1 hour) be used to manage the Santee River commercial shad fishery. In addition, fishery-independent sampling catch rates (CPUE) for the Santee River must not fall below 9. These sustainability benchmarks were developed by using the 25th percentile of the annual mean for CPUE's for the last 10 years or in the case for the fishery independent data all available data. If catch rates or CPUE's fall below the sustainability targets for 3 consecutive years, management action will be taken. Potential management actions could be gear restrictions, season changes, catch limits, or closure.

Cooper River

No commercial fisheries exist on the Cooper River by SC regulation. However, there is a recreational fishery that exists below Pinopolis Dam. SCDNR conducts annual creel surveys to assess catch rates in this fishery. The Cooper River fishery is concentrated near Pinopolis Dam from the sanctuary line (0.2 km downstream of the dam) to about one km downstream of the dam. Since the fishery season is relatively short (about 2 months) effort and catch-per-unit-effort were estimated daily to increase precision. Data collection, consisting of either angler surveys, effort estimates, or both were conducted for virtually all days during each year's study period, which was defined subjectively by angler presence and manpower availability. During survey periods, a creel clerk interviews shad fishermen as they land their boats. An average of 6 hours of survey periods are conducted during daylight hours. Creels take place during these time periods because it was determined these were times when the most effort was being exhibited. Effort estimates consists of counting boats in the fishery, which is virtually entirely visible from the Pinopolis Dam, several times daily; this estimate assumes that the maximum daily count equals total daily effort. Catch rate (CPUE = kg of shad/ 92 m net fished for 1 hour data from these surveys has been collected, beginning in 2000, and is used to manage the fishery. CPUE for 2015 equaled 2.09, this is consistent with previous 4 years (Figure 7).

SC requests to maintain this fishery at current levels with annual monitoring to occur as mentioned. The Cooper River run is considered by SCDNR to be sustainable at current levels. SC proposes that a sustainability CPUE benchmark of 0.81 (25th percentile of the annual mean of CPUEs for the last 10 years) be used to manage the Cooper River recreational shad fishery. If CPUEs for Cooper River recreational fishery fall below 0.81 for 3 consecutive years, changes by SCDNR to the recreational regulations will be considered. Potential management actions could be gear restrictions, season changes, catch limits, or closure.

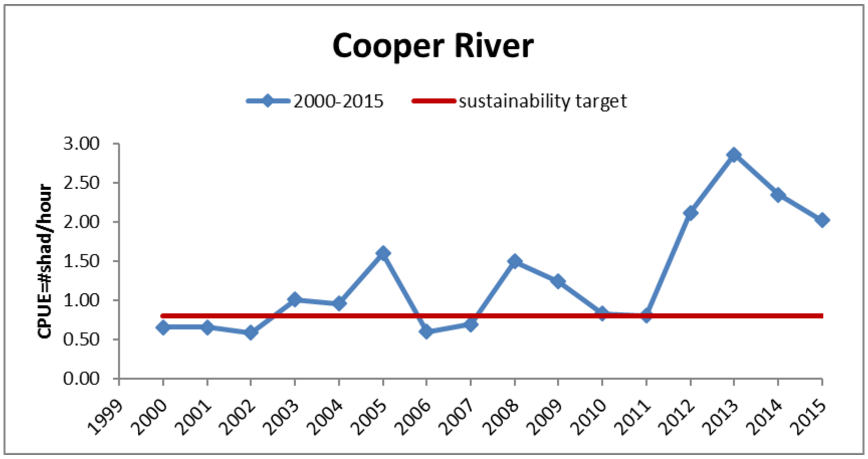


Figure 7. Annual catch per unit effort (# of shad per hr.) and sustainability target for the Cooper River recreational shad fishery.

Edisto River

The 2007 stock assessment concluded "that recent estimates of commercial CPUE have been very low for the Edisto River for time series (1979 to 2005) and average for 13 of the last 15 years, but have rebounded a bit since 1997." More recent CPUE (kg of shad/ 92 m net fished for 1 hour) data suggest that while catches are low, they remain consistent (Figure 8). In addition, the ACE Basin Rivers (Ashepoo, Combahee, and Edisto) have been under "drought" conditions for the majority of recent years. In fact, the average flow during those years was 1,453 cfs. This is extremely low considering in "normal" years, flows are ~ 4,500 cfs. Also, the Edisto River is SC's longest undammed river and flows are considerable lower from those of the Santee River (5,912 cfs) or Pee Dee River (11,267 cfs) for the same time series.

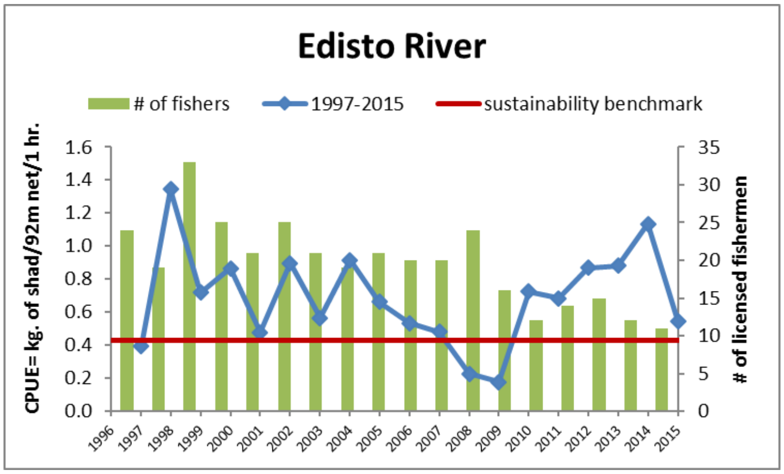


Figure 8. Commercial catch per unit effort (kg fish per 92 m net hr) of American shad and sustainability target for the Edisto River.

SCDNR collected fishery-independent data only for the years for years 1994–1998. During these years, shad were captured using a 92 m floating/drift gill net with 12.7 cm stretch mesh. Catch rates (CPUE = kg of shad/ 92 m net fished for 1 hour) remained relatively consistent for these years. SCDNR tried to duplicate this effort in 2006 and 2007. Unfortunately, due to copious incidental catches of longnose gar (*Lepisosteus oseus*), sampling was discontinued. These fish were encountered during each sampling trip which made catching shad problematic. When numerous gar became entangled, the net became very inefficient at catching shad. The average catch rate for gar for the sampling periods was 4.86 fish per 92 m net per hour.

SC requests to maintain this fishery at reduced levels with annual monitoring to occur as mentioned. The Edisto River run of shad is considered by SCDNR to be sustainable at lower levels in combination with new regulation changes, migrating shad should receive additional protection. If catch rates (CPUE = kg of shad/ 92 m net fished for 1 hour) for the Edisto River run commercial fishery fall below 0.43 for 3 consecutive years, changes by SCDNR to the commercial regulations will be implemented. This sustainability benchmark was developed by using the 25th percentile of the annual mean for CPUE's for the last 10 years. Potential management actions could be gear restrictions, season changes, catch limits, or closure.

Regulatory changes in 1993 and 2000 mentioned earlier greatly affected fishing effort and gear used in the ACE Basin (Ashepoo, Combahee, and Edisto) rivers. These changes may be responsible for the perceived increase in catch rates in recent years. In any event, SC believes current restrictions coupled with 2013 regulatory changes (shortening the season, cutting allowable nets by 80 percent, restrictions on recreational netters gear, reducing the recreational anglers limit by 50 percent, and ultimately capping the fishery at current levels) and in combination with those required statewide by NMFS for the incidental by-catch of sturgeon, will provide adequate protection for spawning shad for years to come.

Combahee River

The 2007 stock assessment concluded "This relatively small river is perceived to have undergone significant American shad stock declines over the past 25 years." More recent CPUE (kg of shad/ 92 m net fished for 1 hour) data suggest that while caches are low, they remain consistent in the most recent years (Figure 10). Currently, the Combahee commercial shad fishery consists of only 1 fisherman and he doesn't use the catch for commercial purposes. Because the number of fishers decreased since 2011, landings data for this river are confidential are not provided in this plan. However, it should be noted, catch rates for this river did not fall below the approved sustainability benchmark. In addition, the ACE Basin Rivers (Ashepoo, Combahee, and Edisto) have been under "drought" conditions for the majority of recent years. In fact, the average flow during those years was 182 cfs. This is extremely low considering in "normal" years, flows are ~ 600 cfs. Also, the Combahee River remains an undammed river and flows are extremely low compared with those from the Santee River (5,912 cfs) or Pee Dee River (11,267 cfs) for the same time series.

SCDNR collected fishery-independent data for the years for years 1993 and 1999. During these years, shad were captured using a 92 m floating/drift gill net with 12.7 cm stretch mesh. Catch rates (CPUE = kg of shad/ 92 m net fished for 1 hour) were 0.27 for 1993 and 0.21 in 1999. Like the Edisto River sampling, copious incidental catches of longnose gar (*Lepisosteus oseus*), led to the termination of sampling efforts. These fish were encountered during each sampling trip which made catching shad extremely problematic. When numerous gar became entangled, the net became very inefficient for catching shad.

SC requests to maintain this fishery at reduced levels. The Combahee River run of shad is considered by SCDNR to be sustainable at lower levels and with new regulations, migrating shad should receive additional protection. If catch rates (CPUE = kg of shad/ 92 m net fished for 1 hour) for the Combahee River run commercial fishery fall below 0.53 for 3 consecutive years, changes by SCDNR to the commercial regulations will be implemented. This sustainability benchmark was developed by using the 25th percentile of the annual mean for CPUE's for the last 10 years. Potential management actions could be gear restrictions, season changes, catch limits, or closure.

Regulatory changes in 1993 and 2000, mentioned earlier, greatly affected fishing effort and gear used in the ACE Basin (Ashepoo, Combahee, and Edisto) rivers. These changes may be responsible for the perceived increase in catch rates in recent years. In any event, SC believes current restrictions coupled with 2013 changes (shortening the season, cutting allowable nets by 90 percent, restrictions on recreational netters gear, reducing the recreational anglers limit by 50 percent, and ultimately capping the fishery at current levels) and in combination with those required statewide by NMFS for the incidental by-catch of sturgeon, will provide adequate protection for spawning shad for years to come.

Savannah River

Because the Savannah River occurs in both SC and GA and as part of new ASMFC mandates required in Amendment 3 to the shad and river herring fishery management plan, annual shad monitoring for this system is a cooperative effort between SCDNR and GADNR. Combined, fishery-independent and fishery-dependent data are available to justify the continued existence of this fishery. The 2007 stock assessment concluded, “Over the past century, the magnitude of shad landings from the Savannah River has declined tenfold although the CPUE data available since 1979 indicates some stability in the current level of exploitation at a level much reduced compared to historical production.” Catch rates (CPUE), used in the assessment, indicated a stable trend. More recent CPUE (kg of shad/ 92 m net fished for 1 hour) data from SC suggest that those trends continue (Figure 9). Catch rates for GA fishermen are available, but due to confidentiality agreements, are not supplied in this document. However, between the years 2001–2015, fishermen caught no fewer than 25 kg of shad per trip.

During the 2010–2015 seasons, GADNR conducted fishery-independent sampling for adult American shad in the Savannah River at the New Savannah Bluff Lock and Dam (NSBL&D), near Augusta, GA (~RKM 302). Shad were collected during their spawning migration (March, April, and May) using electro-fishing gear. Catch rates (CPUE = number of shad/hour) for 2015 were 480.6. This is an increase from CPUE’s of 269.5 that were observed in 2010. This sampling will continue on an annual basis to better assess the abundance of spawning stocks in the Savannah River.

SCDNR also conducted a creel survey of recreational fishermen, at NSBL&D in 2011, 2012, 2013. Sampling was structured similarly to the Pinopolis Dam creel on the Cooper River, SC. However, due to logistical problems, staff was unable to start the creel until well into the shad season. This, unfortunately, led to incomplete angler catch data for those seasons. Creel sampling continued on an annual basis, however, due to the deteriorating wing wall at the NSBL&D, recreational fishing is no longer permitted at this location.

SC and GA request to maintain this fishery at current levels with annual monitoring to occur as mentioned. The Savannah River run is considered by SCDNR and GADNR to be sustainable at current levels and with imposed regulation changes in 2013 taking hold, migrating shad should receive additional protection, which will only help the sustainability. Additionally, before the 2011 season, GA implemented new regulations to protect spawning shortnose sturgeon. This regulation moved the upper commercial boundary downstream approximately 103 RKM. In an effort to protect sturgeon and also remain consistent in a shared border river, SC passed similar regulations. These regulations provide ~136 more river kilometers of additional spawning habitat for shad unobstructed by commercial gear. SC proposes that a sustainability benchmark for CPUE (kg of shad/ 92 m net fished for 1 hour) of 2.4 be used to manage the Savannah River shad fishery. GA proposes that a sustainability benchmark for CPUE (kg of shad per trip) of 25.5 be used to manage the Savannah River shad fishery. If either SC or GA falls below the proposed benchmark for 3 consecutive years, changes by SCDNR and GADNR commercial regulations will be considered. These sustainability benchmarks were developed by using the 25^{th} percentile of the annual mean for CPUE’s for the last 10 years, or in GA’s case, all available data. Potential management actions could be gear restrictions, season changes, catch limits, or closure.

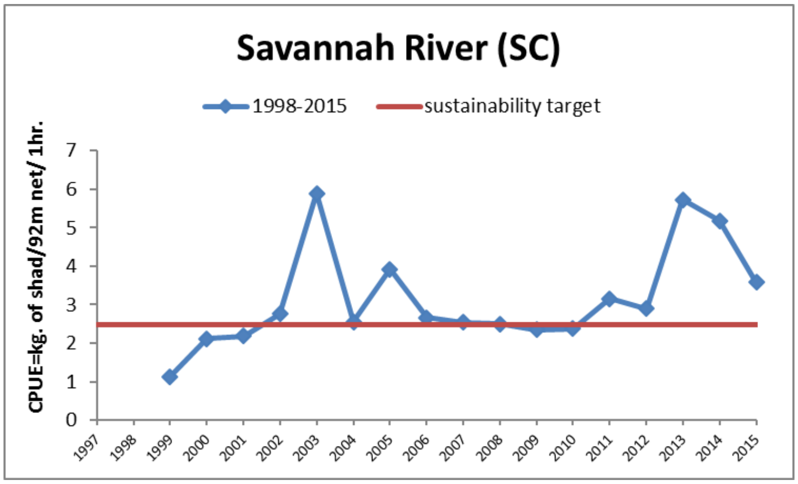


Figure 9. SC's annual commercial catch-per-unit-effort (CPUE) of American shad and sustainability target for the Savannah River.

Recreational

Little River

No recreational monitoring occurs in this river system. However, since the Little River is included within the Pee Dee River Watershed boundary, sustainability metrics and management response for the commercial Great Pee Dee River will be applied for this river.

Winyah Bay System (Sampit, Lynches, Great Pee Dee, Little Pee Dee, Bull Creek, Black, and Waccamaw Rivers).

No recreational monitoring occurs in these river systems. However, since all rivers are included within the Pee Dee River Watershed boundary, sustainability metrics and management response for the commercial Great Pee Dee River will be applied for these rivers.

Santee-Cooper River Complex (Wateree, Congaree, Broad, Rediverson Canal, Lake Moultrie, Lake Marion, Diversion Canal, North Santee River and Bay, South Santee River, Wando River, Cooper River, Charleston Harbor, Wando and Ashely Rivers).

No recreational monitoring occurs in these river systems. However, since all rivers are included within the Santee River Watershed boundary, sustainability metrics and management response for the commercial Santee River will be applied for these rivers.

ACE Basin (Ashepoo and Salkehatchie Rivers)

No recreational monitoring occurs in these rivers. However, since they are included within the Edisto and Salkehatchie River Watershed boundaries, sustainability metrics and management responses for the commercial Edisto and Combahee Rivers will be applied for these rivers.

Savannah River (Coosawhatchie and Savannah)

No recreational monitoring occurs in these rivers. However, since they are included within the Savannah River Watershed boundary, sustainability metrics and management responses for the commercial Savannah River will be applied for these rivers.

Table 1. Sustainability values and triggers.

Index	Survey	Benchmark Value	Years included in index	Management trigger
Pee Dee River Run	Fishery dependent	3.41 kg/ 92 m net/hr.	1979-2015	3 consecutive years below benchmark
Black River	Fishery dependent	0.97 kg/ 92 m net/hr.	2000-2015	3 consecutive years below benchmark
Santee-Cooper Rivers Complex	Fishery dependent	1.8 kg/ 92 m net/hr.	1979-2015	3 consecutive years below benchmark
Santee-Cooper Rivers Complex	Fishery independent	9.0 shad/ 92 m net/hr.	2008-2015	3 consecutive years below benchmark
Santee-Cooper Rivers Complex	Fishery dependent	0.81 shad/hr.	2000-2015	3 consecutive years below benchmark
Edisto River	Fishery dependent	0.43 kg/ 92 m net/hr.	1997-2015	3 consecutive years below benchmark
Combahee River	Fishery dependent	0.53 kg/ 92 m net/hr.	1998-2015	3 consecutive years below benchmark
Savannah River	Fishery dependent	2.4 kg/ 92 m net/hr.	1998-2015	3 consecutive years below benchmark

g) Adaptive Management

SCDNR will continue to monitor fish passage, commercial fisheries, and recreational landings in SC rivers. In addition, fishery independent sampling to assess spawning adults and juvenile abundance will continue annually.

If collected data indicates changes in exploitation or decreasing abundance in juveniles, action will be taken by SCDNR. These actions may include increasing days for escapement, limiting seasons, etc. In the event these actions are not successful in reversing negative trends, SCDNR would then be forced to close those fisheries.

Several recommendations were included for SC as part of the stock assessment for American shad. They are highlighted in the following:

Commercial Landings and Effort

1. Increase compliance with mandatory catch and effort reporting from commercial fishery, particularly in the Santee River, Winyah Bay system, Savannah River, and Edisto River.

2. Continue the "volunteer CPUE" series to compare with CPUE series developed from comprehensive mandatory reporting database.

3. Input volunteer commercial catch and effort from field reports into digital format so raw data are available for future analysis.

4. Collect age, length, weight, and spawning history information from shad caught in commercial fisheries in the Santee River, Winyah Bay system, Savannah River, and Edisto River.

5. Age validation study of American shad from South Carolina rivers (especially, Santee River, Winyah Bay system, Savannah River, and Edisto River).

Tagging

1. Continue monitoring of river systems (Santee River, Waccamaw River, and Edisto River) on rotating basis (yearly rather than a 3 year schedule).

2. Improve tagging study design (e.g., develop high-reward design, telemetry studies to get estimates of migration abortion, double tagging study to estimate tag loss, and tag-mortality study) to improve relative exploitation estimates.

3. Conduct tagging studies for duration of shad migration and continue to collect effort information from sampling collections (e.g., soak time, net length, and mesh size) to permit development of CPUE calculations.

Creel Surveys

1. Continue to conduct creel surveys in rivers with notable recreational fisheries (Savannah River and Cooper River); if necessary, conduct creel surveys on a rotating basis.

Fish Passage

1. Develop species specific upstream and downstream passage efficiency at all rivers with priority given to Santee-Cooper system dams.

2. Develop species specific counts at Pinopolis fish lock on the Cooper River.

Juvenile Abundance Index

1. Investigate juvenile abundance on at least one river (e.g., Santee River, Waccamaw River, or Edisto River).

General

1. Collect environmental covariates (tidal stage, flood stage, flow rate, water temperature, cloud cover, water clarity, annual precipitation, etc.) to aid development of CPUE indices.

SC has since implemented all suggested recommendations and in some cases exceeded them, with the exception of those at the Pinopolis fish lock. A fish counter system was installed at that site as a trial test for feasible fish counting methods. A more permanent counter is part of a requirement under the new FERC license, and will be installed within the first two years after the license if issued.

Nevertheless, SC continues sampling as part of ASMFC/ACFCMA funded work or by utilizing other SCDNR funding sources. Furthermore, with the dissolution of Anadromous Fish Conservation Act funds, SCDNR was forced to be creative in order to meet requirements of Amendment 3. To complete all mandated goals annually, personnel from other areas and funding sources have been used. Once these funds expire it is anticipated SCDNR will simply not have adequate personnel to complete this work. Additionally, to date SCDNR has experienced a 60 percent reduction in funds from the state's appropriated operating budget and is expecting additional cuts. If a reduction in force (RIF) is implemented and project personnel are affected, SCDNR will not be able to meet these requirements.

Additional recommendations

Several recommendations were suggested and added to this plan by the Shad and River Herring Technical Committee, these include:

- Consider joint coordination with NC on the Great Pee Dee River similar to what is occurring on the Savannah River (GA).
- Consider ways to develop current juvenile indices to perhaps be used in future updates to the plan.
- Consider discussions with GA to develop consistent management measures for the Savannah River in the event that either state falls below the sustainability benchmark for 3 consecutive years.
- In the future, consider using biological metrics, where available, as an additional benchmark for all State indices.

References

ASMFC (Atlantic States Marin Fisheries Commission). 2007. American shad stock assessment peer review report. Washington, D.C.

Appendix 1.

Summary of South Carolina Shad Laws by Water or Fishery Area

SECTION 50-5-1506. Zones, seasons, times catch limits, size limits, methods, and equipment for taking shad.

In addition to other provisions of law, the following provisions govern seasons, times, methods, equipment, size limits, and take limits in commercial fishing for shad in the waters of this State specified below:

(a) Black River, Great Pee Dee River, Little Pee Dee River, Lynches River, Waccamaw River from Big Bull Creek to Winyah Bay, Winyah Bay, and all tributaries and distributaries thereto as follows:

(i) Pee Dee River and tributaries above U.S. Highway 701 and Black River:

(1) Season: January 15 through April 15;

(2) Times: noon Monday through noon Saturday;

(3) Methods and equipment: Any lawful method and equipment;

(4) Size and take limits: No limits.

(ii) Remainder of Winyah Bay system including all of Big Bull Creek and Waccamaw River with tributaries below the entrance of Big Bull Creek:

(1) Season: January 15 through April 1;

(2) Times: Monday noon to Saturday noon, local time;

(3) Methods and equipment: No restriction provided drift nets of not more than nine hundred feet in length are allowed in Waccamaw River between Butler Island and U.S. Highway 17 during lawful times;

(4) Size and take limits: No limits.

(b) Santee River below Wilson Dam including the Rediversion Canal below St. Stephen Dam, North Santee River and Bay, South Santee River, and all tributaries and distributaries thereto as follows:

(i) Rediversion Canal from St. Stephen Dam seaward to the seaward terminus of the northern dike of the Rediversion Canal:

Season: No open season;

(ii) Rediversion Canal from the seaward terminus of the northern dike of the Rediversion Canal seaward to Santee River:

(1) Season: January 15 through April 15;

(2) Times: 7:00 a.m. to 7:00 p.m. local time, Tuesday and Thursday;

(3) Methods and equipment: Any lawful method and equipment;

(4) Size and take limits: No limits.

(iii) Wilson Dam seaward to U.S. Highway 52 bridge:

Season: No open season.

(iv) U.S. Highway 52 bridge seaward to S.C. Highway 41 bridge:

(1) Season: January 15 through April 15;

(2) Times: 7:00 a.m. to 7:00 p.m. local time, Tuesday and Thursday;

(3) Methods and equipment: Any lawful method and equipment;

(4) Size and take limits: No limits.

(v) S.C. Highway 41 bridge seaward:

(1) Season: January 15 through March 15;

(2) Times: Monday noon to Saturday noon, local time;

(3) Methods and equipment: Any lawful method and equipment;

(4) Size and take limits: No limits.

(c) Wando River and Cooper River seaward to the U.S. Highway 17 bridges, Charleston Harbor, Ashley River, and all tributaries and distributaries thereto as follows:

(i) Tailrace Canal from Wadboo Creek to the Jefferies Power Plant:

Season: No open season.

(ii) Cooper River from Wadboo Creek to U.S. Highway 17:

Season: No open season.

(iii) Ashley River seaward to its confluence with Popper Dam Creek:

(1) Season: No open season;

(2) Reserved

(3) Reserved

(4) Reserved

(iv) Remainder of the Charleston Harbor system:

(1) Season: No open season;

(2) Reserved

(3) Reserved

(4) Reserved

(d) Edisto River Estuary, Edisto River, North and South Branches (Forks) of the Edisto River, and all tributaries and distributaries thereto as follows:

(i) Above U.S. Highway 15 bridge:

(1) Season: February 1 through March 30;

(2) Times: Tuesday noon to Saturday noon, local time;

(3) Methods and equipment: Any lawful method and equipment;

(4) Size and take limits: No limits.

(ii) Seaward of U.S. Highway 15 bridge and above U.S. Highway 17 bridge:

(1) Season: February 1 through March 30;

(2) Times: Tuesday noon to Saturday noon, local time;

(3) Methods and equipment: Any lawful method and equipment;

(4) Size and take limits: No limits.

(iii) Seaward of U.S. Highway 17 bridge:

(1) Season: February 1 through March 30;

(2) Times: Wednesday noon to Friday midnight, local time;

(3) Methods and equipment: Any lawful method and equipment;

(4) Size and take limits: No limits.

(e) Ashepoo River and all tributaries and distributaries thereto as follows:

(1) Season: No open season;

(2) Reserved

(3) Reserved

(4) Reserved

(f) Combahee River and all tributaries and distributaries thereto as follows:

(i) Tributaries and distributaries, except main stems of Salkehatchie Rivers:

Season: No open season.

(ii) Main river including main stems of Salkehatchie Rivers:

(1) Season: February 1 through March 15;

(2) Times: For anchored nets, Tuesday noon to Friday noon, local time; for driftnets, Monday noon to Saturday noon, local time;

(3) Methods and equipment: Any lawful method and equipment;

(4) Size and take limits: No limits.

(g) Coosawhatchie River and all tributaries and distributaries thereto as follows:

Season: No open season.

(h) South Carolina portions of Savannah River and all tributaries and distributaries thereto as follows:

(i) Main river below U. S. Highway 301 and above U. S. Interstate Highway 95:

(1) Season: January 1 through April 15;

(2) Times: 7:00 a.m. Wednesday to 7:00 p.m. Saturday, local time;

(3) Methods and equipment: Any lawful method and equipment;

(4) Size and take limits: No limits.

(ii) Tributaries and distributaries above U.S. Interstate Highway 95 bridge:

Season: No open season.

(iii) Seaward of U.S. Interstate Highway 95 bridge.

(1) Season: January 1 through March 31. Taking or attempting to take shad with anchored nets is prohibited at all times in the Savannah River's Little Back River, Back River and the north channel of the Savannah River downstream from the New Savannah Cut;

(2) Times: 7:00 a.m. Tuesday to 7:00 p.m. Friday, local time;

(3) Methods and equipment: Any lawful method and equipment;

(4) Size and take limits: No limits.

(i) Atlantic Ocean territorial sea as follows:

(1) Season: No open season;

(2) Reserved

(3) Reserved

(4) Reserved

River Herring Alternative Management Plan for South Carolina

Prepared by

Bill Post and Ellen Waldrop

March 16, 2020

South Carolina Department of Natural Resources

Wildlife and Freshwater Fisheries and Office of Fisheries Management

Introduction:

Historical fisheries for river herring (e.g. blueback herring) in the waters of the ACE Basin (Ashepoo, Combahee, Salkehatchie, and Edisto Rivers) and Savannah River (Savannah and Coosawhatchie Rivers) watersheds, South Carolina (SC) are negligible. No commercial fisheries occur in any of these rivers and opportunities for both recreational and commercial fishers to land river herring exist at other specific locations in the state where fish aggregate (e.g. dams). The South Carolina Department of Natural Resources (SCDNR) monitors these locations with daily creels, because it is where the majority of fishing occurs annually. River herring harvest is recorded to help enumerate approximate run size and escapement.

The purpose of SC's alternative management plan for river herring is to allow waters of the ACE Basin and Savannah River watersheds to remain open for recreation purposes. This plan is submitted to fulfill requirements of Amendment 2 to the Interstate Fishery Management Plan for Shad and River Herring (River Herring Management).

Management of blueback herring in SC is shared between the Marine Resources and Freshwater Fisheries Divisions of SCDNR. Management units are defined by stock and the complex of river(s) utilized.

ACE Basin and Savannah River Watersheds (Figure 1)

Commercial River Herring Fishery

There are no recorded landings for river herring and no commercial fishing is allowed.

Recreational River Herring Fishery

SC's recreational fishery has a 1 bushel (22.7 kg) fish aggregate daily creel for blueback herring in all rivers throughout the state; however very few if any recreational anglers target blueback herring.

Additionally, legislation to change the current daily limit to a more reasonable creel has been developed and vetted through an internal working group and is awaiting introduction to the SC General Assembly.

As mentioned, SC is unaware of any directed recreational fishing for river herring. However, recreational creel surveys funded by the National Marine Fisheries Service (NMFS) (e.g. Marine Recreational Information Program [MRIP]) show no harvest or directed effort for river herring in any of the ACE Basin Rivers or Savannah River watersheds (Figure 2).

Fishery-Independent Monitoring

SCDNR conducts a fishery-independent effort utilizing electrofishing gear in both the Edisto and Savannah Rivers. This has been done annually since 2010 to assess American shad recruitment in these rivers. Surveys are performed from August through November (24 weeks) and are designed to collect young-of-year (YOY) juvenile American shad, but any fish collected are enumerated and measured. Sampling events occur weekly at numerous predetermined nursery sites to establish the relative abundance of juvenile shad in SC watersheds. In addition, these data collection efforts assist with determining distribution, growth rates, feeding habits, and timing of out-migration. In the 10 years that this survey has been conducted, only 28 herring have been observed during electrofishing efforts. Similarly, an electrofishing survey conducted by Georgia Department of Natural Resources targeting adult American shad in the Savannah River at the first barrier (New Savannah Lock and Dam) yielded no river herring for the same time series.

SCDNR also conducts telemetry studies on the ACE Basin and Savannah River watersheds to track Atlantic and shortnose sturgeon behavior. Beginning in 2010, an extensive array of ~300 ultrasonic receivers was deployed in SC's major river systems and throughout intercoastal waterways (Figure 3). In most cases, receivers are located a few kilometers apart from the mouth of rivers (river kilometer [rkm] 0) to potential spawning areas for sturgeon (rkm ~321). In order to ensure proper operation, collect movement data, and minimize loss, receivers are downloaded regularly.

From 2010 to present, ~113 receivers were downloaded regularly in the ACE Basin and Savannah River watersheds (Figures 4–6). Telemetry data were collected during all months to ensure all available sturgeon detections were recorded, with increased effort during spring months when both Atlantic and shortnose sturgeon spawn. This also coincides with shad and river herring adult migrations in these rivers. During download trips, most areas of rivers in the ACE Basin and Savannah River watersheds were traveled by boat. At no time did staff encounter any individuals targeting shad or river herring, most were traditional float fishers using bait targeting gamefish.

Management Recommendation

Amendment 2 to the shad and river herring FMP states, in the absence of a sustainable fishery management plan for river herring, the Management Board can approve an alternative management program proposed by a state or jurisdiction if the state or jurisdiction can show to the Management Board's satisfaction that the alternative proposal will have the same conservation value as the measure contained in this amendment or any addenda prepared under Adaptive Management.

SC currently has no fisheries for river herring (commercial or recreational) in the ACE Basin or Savannah River watersheds. Because river herring are considered functionally absent in these areas, it is impossible to develop a sustainable fishing plan with any credible metrics.

SCDNR plans to continue current fishery-dependent and fishery-independent monitoring for the foreseeable future. In the event that the MRIP survey reveals positive directed harvest of river herring for 3 consecutive years indicating exploitation by recreational fisheries is occurring, SCDNR will initiate a review process to demonstrate sustainability for that river system. If sustainability cannot be demonstrated, SCDNR will initiate regulatory changes for these rivers systems. Regulatory changes that may be considered range from catch and release fishing only to full closure.

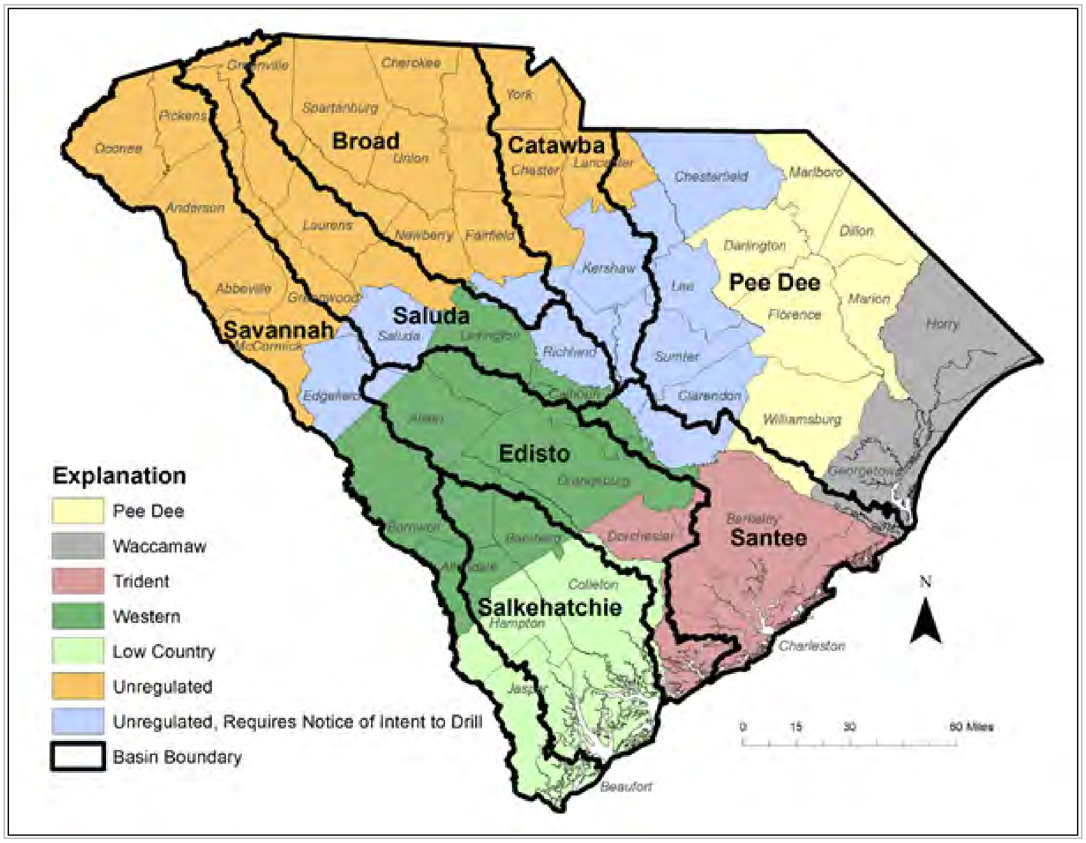


Figure 1. South Carolina river systems defined by river basin boundaries

(https://www.clemson.edu/public/water-assessment/).

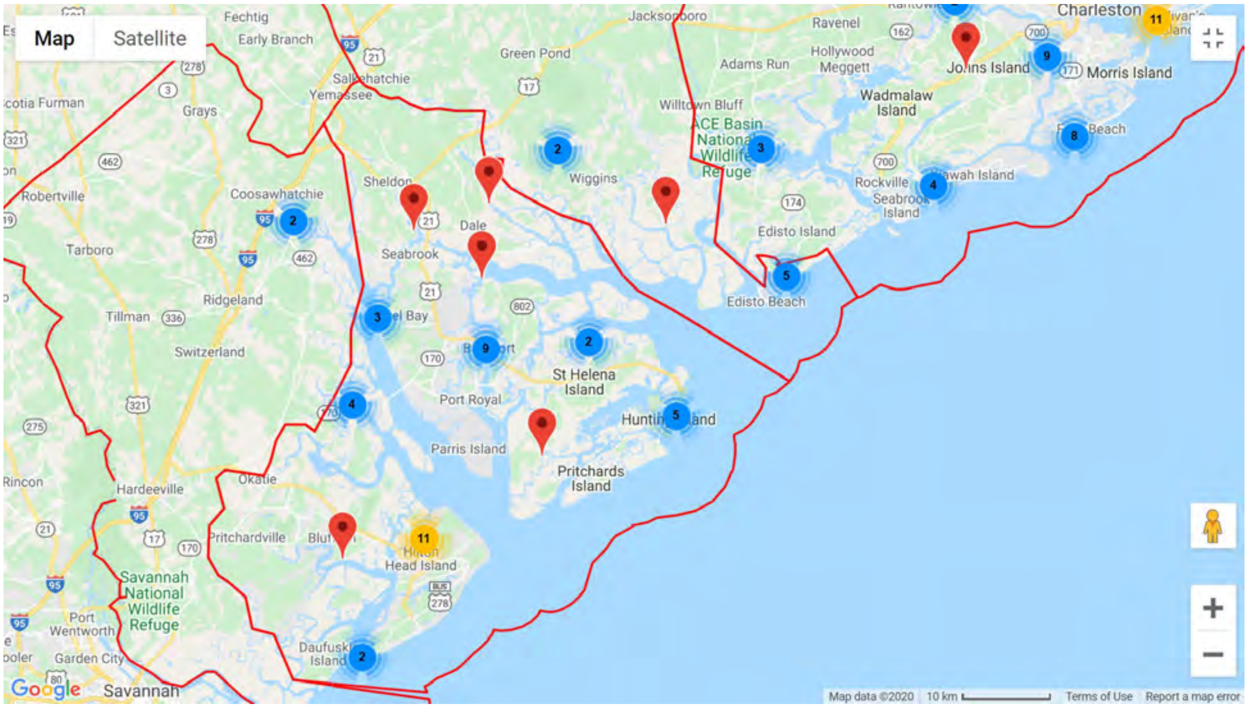


Figure 2. Example of MRIP creel sampling sites for ACE Basin and Savannah watersheds. Note: All 144 sites not shown in this figure, use interactive web tool provided at NOAA webpage.

https://www.st.nmfs.noaa.gov/msd/html/siteRegister.jsp

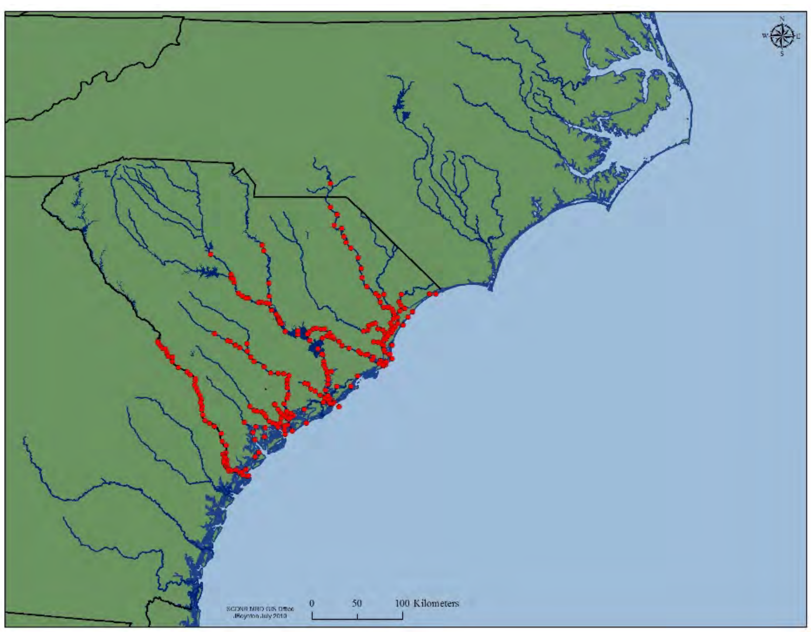


Figure 3. SC's ultrasonic telemetry array.

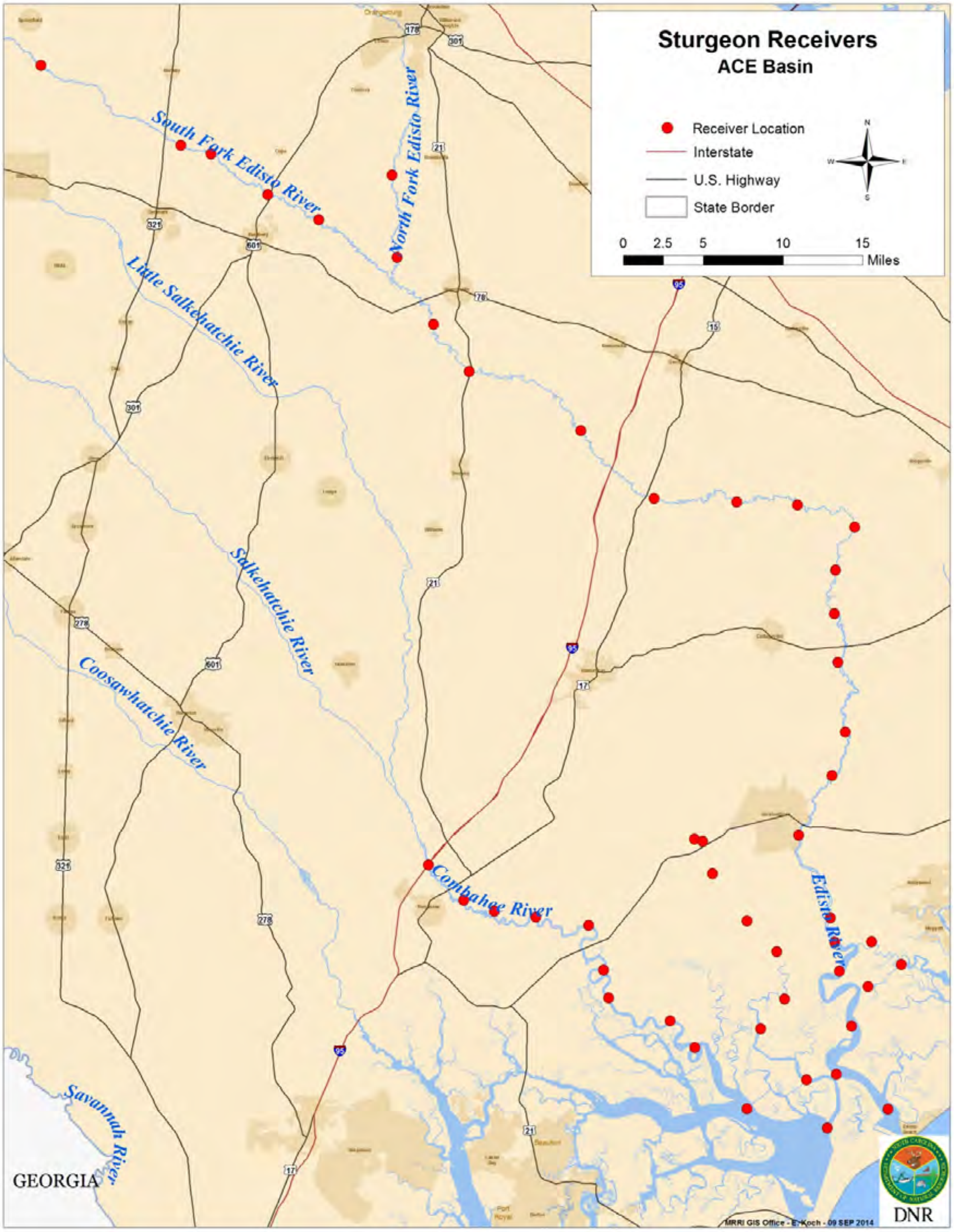


Figure 4. Receiver location in the ACE Basin Rivers.

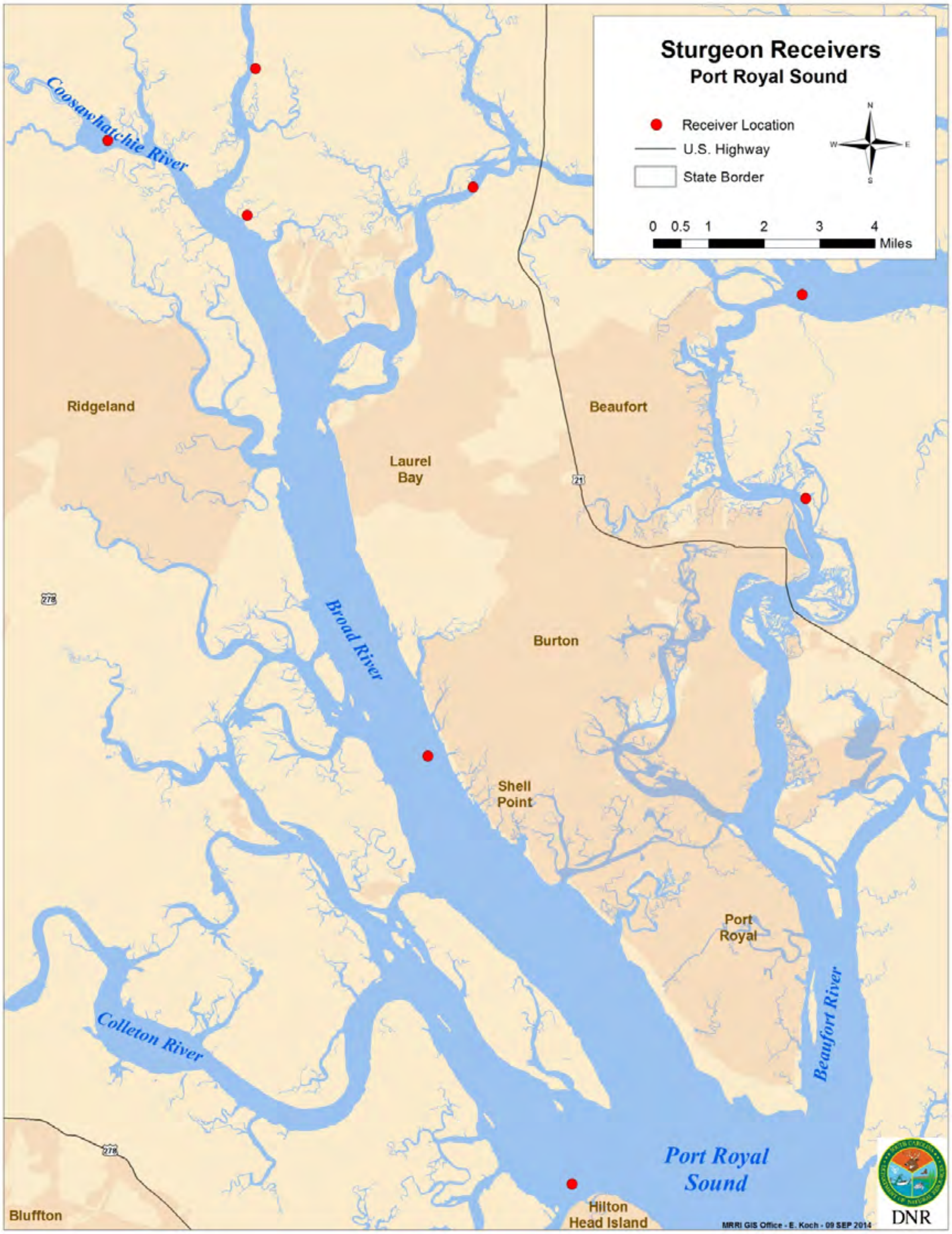


Figure 5. Receiver location in the Port Royal and Coosawhatchie River.

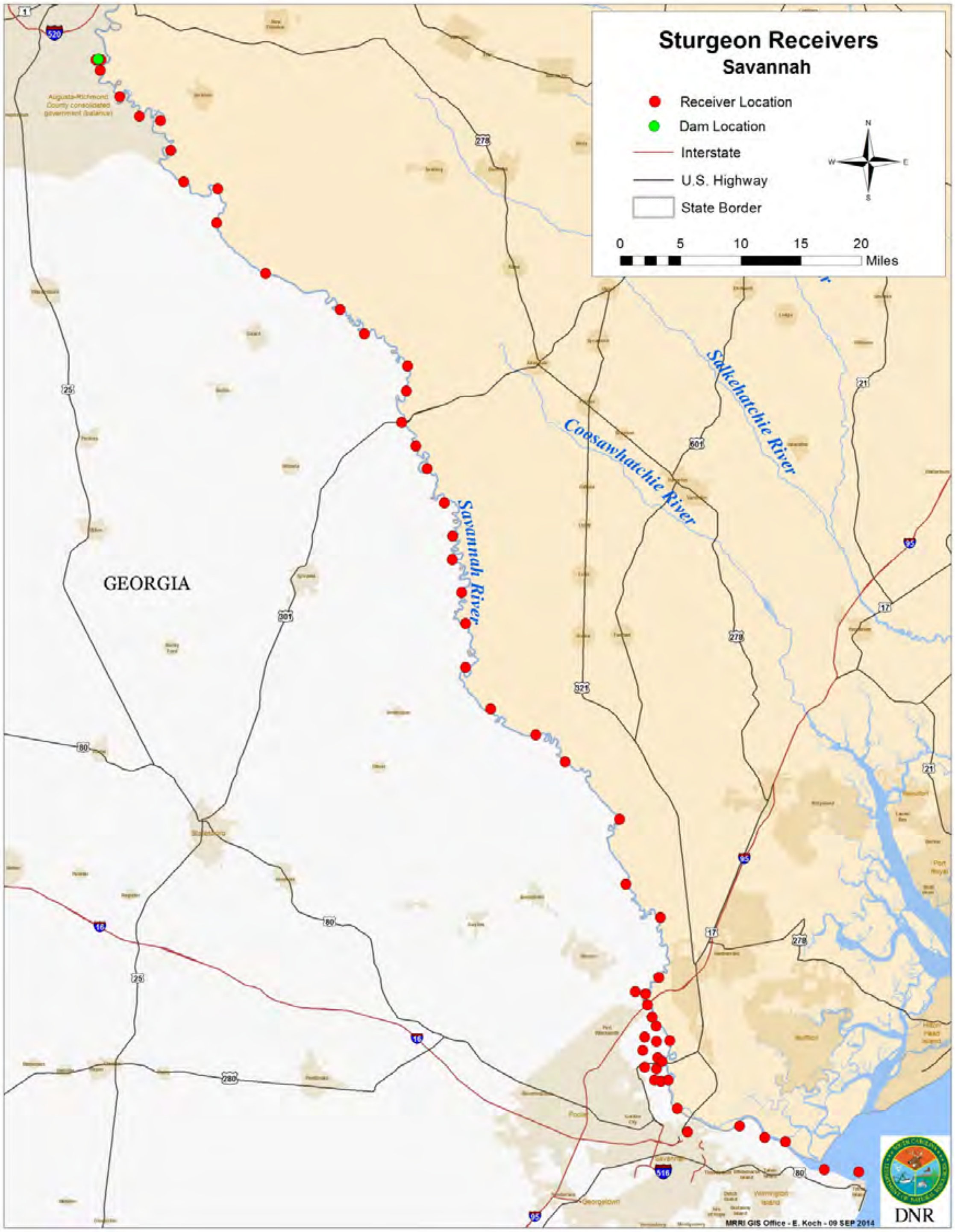


Figure 6. Receiver location in the Savannah River System.

ASMFC American Shad Sustainable Fishing Plan for Georgia

Submitted by

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ACCEPTED: OCTOBER 2017
PROPOSED UPDATE: JUNE 2020

Introduction:

The purpose of Georgia's sustainable fisheries management plan for American shad is to allow the continuation of existing American shad fisheries in Georgia rivers where it has been determined continuation of fishing will not adversely impact the Atlantic Coast American shad stock. The plan fulfills requirements of Amendment 3 to the Interstate Fishery Management Plan (FMP) for Shad and River Herring (American Shad Management). Georgia's current shad FMP was accepted in October 2017.

Management of American shad in Georgia is shared between the Georgia Department of Natural Resources' (GADNR) Wildlife Resources Division's Fisheries Management Section (FMS) and GADNR's Coastal Resources Division (CRD). The river complex utilized by fish stocks defines Georgia's management units. Historically, all of Georgia's Atlantic-slope rivers (Savannah, Ogeechee, Altamaha, Satilla, St. Mary's) supported a commercial fishery for American shad (Fig. 1). However, in recent years, commercial landings of American shad have been reported from only two (Altamaha and Savannah) of these five rivers. Known recreational shad fisheries exist only at the New Savannah Bluff lock and dam (NSBL&D) on the Savannah River, the Ogeechee River, and Ocmulgee River. However, in 2014 the Army Corps of Engineers closed public access to the NSBL&D due to safety concerns. This closure greatly reduced the bank fishery for American shad on the Georgia side of the river, which was by far the largest portion of the fishery. There have been no reports of commercial landings from the Satilla or St. Mary's rivers since 1989.

During 2010, the Georgia Board of Natural Resources adopted new commercial shad fishing rules based on a recommendation from GADNR. These changes modified the temporal and spatial components of the commercial shad fishing efforts along Georgia's Atlantic-slope rivers, both to provide the basis for American shad sustainability plans and to address shortnose sturgeon bycatch issues. Following these changes, the St. Mary's and Satilla rivers were officially closed to commercial shad fishing. The Ogeechee River commercial shad fishery was also closed prior to the 2014 commercial shad season due to lack of participation during the 2012 and 2013 seasons and to reduce concerns of potential sturgeon bycatch issues. These three rivers will remain closed to commercial American shad fishing. Additionally, prior to this change, the entire Altamaha River and lower portions of the Ocmulgee River and Oconee River (which join to form the Altamaha River) were open to commercial and recreational fishing.

Georgia's Commercial American Shad Fisheries

The commercial shad (American and hickory) season is open each year from January 1 to March 31. Drift and set gill nets with mesh sizes of at least 4-½ inches (stretch mesh) are legal gear in the Altamaha and Savannah Rivers. From 2015 – 2018, shad fishermen were required to possess a letter of authorization (LOA) in conjunction with a commercial fishing license to fish in Georgia's commercial shad fishery. These LOA's were adopted because Georgia's general commercial fishing license doesn't specify the targeted fishery. Effective April 2018, Georgia began requiring shad fishermen to purchase a shad endorsement stamp, which provides better information about participation in Georgia's commercial shad fishery.

The Altamaha River, formed by the confluence of the Ocmulgee and Oconee rivers, supports the state's largest commercial shad fishery and is Georgia's largest watershed, draining 37,192 km2. Despite having dams on the Oconee and Ocmulgee rivers, the main-stem Altamaha flows unimpeded (e.g. no dams) for approximately 220 kilometers to the Atlantic Ocean. Historically, the entire river and lower portions of the Oconee and Ocmulgee River were open to commercial fishing. However, currently only that portion of the Altamaha River from the U.S. Hwy 1 Bridge (rkm 183) downstream to the Atlantic Ocean is open to commercial fishing (Fig. 1). Including the waters of its major tributaries, this is an area approximately 347 rkm, or 65% smaller, than previously open to commercial shad fishing. The Altamaha River is open Monday through Friday below Seaboard Railroad bridge (SBR) and Tuesday through Saturday above SBR crossing (Fig. 1). Drift and set gill nets are the gear types used to commercially fish for shad throughout the river. Most full-time commercial fishermen focus their efforts in the lower 60 kilometers of the river. Drift nets are the most prevalent gear type in the lower river, whereas set nets are the more prevalent gear type in the upper river (upstream of Jesup, GA).

The Savannah River drains a watershed of approximately 17,022 km2 and forms the boundary between Georgia and South Carolina. It is open to commercial shad fishing from the U.S. Hwy 301 Bridge (rkm 192) downstream to the Atlantic Ocean, an area approximately 103 rkm or 35% smaller than previously open to commercial shad fishing (Fig. 1). The Savannah River is open from Tuesday through Friday east of the I-95 Bridge and Wednesday through Saturday west of the I-95 Bridge (Fig. 1). Commercial fishing gear consists of drift and set gillnets, with most effort occurring in the lower portion of the river. The first barrier to upstream migration on the Savannah River is the NSBL&D located at river km 301, just south of Augusta, GA and approximately 109 rkm above commercial fishing waters. American shad once passed through this dam via lockage, but in recent years the U.S. Army Corps of Engineers (USACE) has declared the facility unsafe to operate, so fish are not being passed through the lock at this time. The dam is now a true migration barrier and is the uppermost reach of the American shad migration in the Savannah River. The USACE is currently overseeing the Savannah Harbor Expansion Project, which has mitigation plans to install a migratory fish passage at the dam that, once in place, will allow American shad to access further upriver habitats above the dam. Three additional dams (located from river km 333 – river km 355) are above the NSBL&D. At this time, construction of the fishway is scheduled to begin in January 2021.

Georgia's Recreational American Shad Fisheries

Recreationally, Georgia has a statewide 8 shad (American and/or hickory) daily creel limit. Small-scale recreational fisheries for American shad are known to still exist in the Savannah, Ogeechee, and Ocmulgee rivers. In 2014, the Army Corps of Engineers closed public access to the NSBL&D due to safety concerns. This closure essentially eliminated the bank fishery for American shad on the Georgia side of the river, which was by far the largest portion of the recreational fishery. Consequently, this once prevalent recreational fishery on the Savannah has virtually ceased existing.

Georgia has periodically conducted recreational creel surveys on the Ogeechee River specifically targeting the recreational shad fishery. The most recent of those was completed in 2015. The creel survey estimated that 463 American shad were harvested with a total harvest weight of 473 Kg. Anglers also released 27 American shad, and zero hickory shad were harvested by anglers.

Anecdotal information from fishermen suggests some recreational fishing may occur on the Ocmulgee River, but no creel surveys are being conducted on this river. The accounts of fishermen capturing shad on this river have not been substantiated, and it is the belief of GADNR that any significant effort on this river would be known through anecdotal or various media outlets.

Creel surveys have been a popular tool used on several Georgia rivers to collect data from anglers. Numerous recreational creel surveys have been conducted on the Altamaha and Satilla rivers in recent years and American shad have never been observed in angler harvest. While GADNR does not conduct creel surveys on the Oconee or St. Mary's rivers, there is no information to suggest any evidence or reports of anglers capturing American shad.

Landings

Reported commercial landings of American shad are available from the National Marine Fisheries Service and the State of Georgia through CRD, which has recorded river-specific landings since 1962. In 2001, Georgia instituted a mandatory reporting system that requires an individual record (trip-ticket) to be completed at the time of sale for each catch sold to a seafood dealer. Data collected includes the river of capture, type of gear, total net soak time, etc. Numbers of wholesale dealers processing shad have declined over time, and from 2010 to 2013 there were less than 3 dealers that purchased shad from commercial fishermen. Due to the low number of dealers and corresponding confidentiality agreements, commercial landings data obtained from trip-tickets on the Altamaha and Savannah rivers during 2010-2013, along with the 2014 Savannah River commercial landings data, must be excluded from reports (Fig. 2).

Recreationally, landings data has been collected by the GADNR via periodic creel surveys on the Ogeechee River since 1986 to estimate harvest and catch-per-unit-effort (CPUE). The number of American shad caught per hour of fishing time has varied from a low of 0.2 shad/hour in 1986 and 2010 to a high of 0.75 fish/hour in 2015. It is important to note that flow conditions can have a significant impact on angler catch rates in this fishery. Total effort and fish harvested has ranged from a high of 2,210-angler hrs and 1,053 shad harvested in 1996 to a low of 620-angler hrs in 2015 and a low of 10 shad harvested in 2000. Effort data from the last five creel surveys has averaged 1,148-angler hrs and total shad harvested has averaged 424 fish.

Recreational creel surveys were conducted on the Savannah River in the late 1990s by the GADNR (1997) and South Carolina Department of Natural Resources (1998 and 1999). Estimates of catch from these surveys varied from year to year, largely due to dramatically different flow conditions. Catch estimates from each of these creel surveys were provided by Boltin (1999). Additionally, SCDNR has additional creel data from the SCDNR since 1999 (Bill Post, pers. communication).

Fishery Dependent Indices

Reported American shad landings from the Altamaha River reached a high of 471,700 lbs in 1968 and then declined for several years. Landings averaged approximately 299,000 lbs during 1962-1969 and approximately 130,000 lbs during 1970-1979. Reported Altamaha River shad landings peaked in 1987 at 193,469 lbs and again in 1995 at 121,811 lbs (Fig. 2). During 1980-2000, total reported shad landings averaged 89,739 lbs. Since 2000, total reported shad landings have averaged around 34,776 lbs. Landings for the last ten years have averaged approximately 37,437 lbs. Savannah River landings data was supplied to the SCDNR and will be combined with their landings data and reported in the South Carolina sustainability plan.

Since 2000, commercial shad fishing effort has been quantified based on total number of reported commercial trips. The highest recorded statewide effort was 860 commercial fishing trips for the Altamaha River in 2000 (Fig. 3). During 2000-2005, commercial fishermen averaged approximately 420 trips/yr in the Altamaha River, while during the 2006-2015 period commercial fishermen averaged approximately 264 trips/yr.

Fishery Independent Indices

GADNR has utilized gill net surveys to generate population size and exploitation rate estimates for American shad through mark and recapture efforts in the Altamaha River since 1982 and CPUE since 1986. The American shad population was also estimated in 1967.

Adult shad electrofishing surveys were initiated in 2010 on the Ogeechee (Fig. 4) and Savannah (Fig. 5) rivers in preparation for future monitoring under the sustainability plans to be submitted pursuant to requirements of Amendment 3 to the Interstate Fishery Management Plan for Shad and River Herring (Shad and River Herring ISFMP). GADNR staff conducts these surveys twice a month for three months during the spawning immigration. Since 2010, the Ogeechee River adult shad electrofishing surveys have averaged around 15 shad per hour, and the Savannah River adult shad electrofishing surveys have averaged around 300 shad per hour. The reason that the Savannah River electrofishing catch rates are much higher than the Ogeechee River catch rates is because the electrofishing samples on the Savannah River are concentrated immediately below the NSBL&D. The Ogeechee River is undammed and electrofishing samples are not concentrated below a migration barrier so efforts are much less effective.

GADNR estimated juvenile American shad abundance from trawl surveys on the Altamaha River during 1982-1991 and the Ogeechee River during 1982-1985. Although, it is important to note, juvenile catch rates could not be correlated to estimated spawning populations nor future adult spawning return rates, so juvenile sampling ceased after 1991. However, GADNR reinstated a juvenile sampling program utilizing a 50-ft seine in 2010 on the Altamaha, Ogeechee, and Savannah rivers in preparation for future monitoring under the sustainability plans to be submitted pursuant to requirements of Amendment 3 to the Shad and River Herring ISFMP. Seine mesh size and site locations are standardized. GADNR staff annually sample 3-6 sites/river twice a month from July-September, as water levels allow. Since 2011, the Altamaha, Ogeechee, and Savannah River juvenile shad geometric means have averaged around 24.2, 7.9, and 7.6 shad per seine haul, respectively (Fig. 6). No juvenile sampling was completed in 2013 due to high water. The decrease in juvenile shad sampled on the Ogeechee and Savannah Rivers from 2014 to 2015 should be attributed to water level issues and changes in manpower of the monitoring staff, and not a true depiction of a decrease in juvenile shad abundances.

Altamaha River

Management of shad in the Altamaha River is done through analyzing data from fishery-independent monitoring. GADNR has produced annual Lincoln-Peterson population estimates and exploitation rates from a tagging study that was initiated in 1982. Adult American shad are captured via gill nets in the lower section of the Altamaha River and tagged with a T-bar anchor tag produced by Floy Tag & Mfg, Inc. Tagging efforts are conducted on Saturday, Sunday, or Monday each week of the commercial shad season that runs from January 1 through March 31. These days were chosen because the commercial fishery is closed in different portions of the river on these days, thus allowing the fish to naturally disperse before potential recapture by commercial fishermen. Before the start of the season, 500 tags are randomly assigned values of $4, $10, $50, or $100. Two percent of the tags receive a $100 value, 3% are $50, 20% are worth $10, and 75% worth $4. Tag values are not printed on the tag. Upon capturing a tagged fish, commercial fishermen are required to remove tags and mail them into GADNR to receive the monetary award. GADNR keeps record of the number of fish tagged (M) and recaptured (R) and then utilizes reported commercial landings data to produce the total number of fish captured (C). In an effort to account for non-reported commercial landings and produce a more accurate estimate of "C", GADNR conducted a roaming creel survey from 1982-1992. After the 10-year creel survey was completed, GADNR staff developed a statistically based formula to account for non-reporting. From 1993 to present, "C" is calculated by entering the total reported commercial drift net landings into the formula "C"= $((2.322\text{x}10^{-6})+(0.214/\text{Reported Landings})^{-1}))$.

From 1982 to present, the estimated size of the adult American shad population in the Altamaha River has ranged from a low of 70,396 shad in 1990 to a high of 560,023 fish in 2014 (Fig. 7). After 1996, estimated shad abundance declined for six consecutive years, through 2002, before showing a moderate rebound through 2006. The population estimates decreased again through 2010. However, the 2011 mark and recapture efforts revealed a sharp increase in American shad abundance with a population estimate of 277,824 fish. This upward trend peaked in 2014 at 560,023 which is the highest population estimate in the time series. Population estimates have averaged around 236,000 American shad in the Altamaha River American shad run for the last ten years.

Trends in GADNR tagging CPUE data appear to be like those observed in GADNR's mark and recapture population estimates (Fig. 8) and have ranged from a low of 0.59 shad/ft-hr in 2005 to a high of 3.66 shad/ft-hr in 1998 (Fig. 9). CPUE, for the last ten years, has averaged 2.4 shad/ft-hr in the Altamaha River American shad run.

From 1982 through 1992, exploitation rates estimated from recaptures of tagged fish averaged 43.63%, which was often above the previous 40% maximum sustainable yield recommended by ASMFC in the Addendum to Amendment 1, before declining to present levels (Fig. 7). Since 1990, the exploitation rates have been below ASMFC's recommended 40% maximum sustainable yield. From 1993-2003, exploitation of American shad averaged 26.1%, ranging from 17.7% to 33%. From 2004-2010, exploitation of American shad averaged 19.7%, ranging from 13.7% to 23.6%. On January 1, 2011, new commercial regulations went into effect that closed approximately 65% of the Altamaha River system. This change resulted in a decrease in exploitation rates. Following these new regulations, from 2011-2015, exploitation of American shad averaged 11.5%, ranging from 8.6% to 12.7%. Total exploitation has averaged around 16%, for the last ten years, for the Altamaha River American shad run. As an additional measure to ensure the conservation of this stock, a temporary American shad stocking program was initiated in 2014. This 5-year stocking program, which ceased in 2019, resulted in American shad being annually stocked above migration barriers in an attempt to re-establish shad in section of the Oconee and Ocmulgee rivers.

Juvenile sampling on the Altamaha River was initiated in 2010, and 291 juvenile shad were collected in 12 seine hauls utilizing a combination of two 50-ft bag seines (one with ½-inch mesh and one with 3/8-inch mesh). The resulting geometric mean was 14.6 shad/haul. However, staff observed juvenile shad escaping through both of these nets. Therefore, catch rates would have been higher if a smaller mesh seine had been utilized. Since 2011, GADNR has utilized a 50ft bag seine with ¼-inch mesh to sample juvenile shad. Annual geometric means continue to fluctuate since 2011, though such fluctuations are not only the result of biological influences but intermittent high-water events occurring during the sampling season which hinders access to sampling sites. During July 1968, Godwin and Adams (1969) utilized a similar seine to collect juvenile shad and reported an arithmetic mean of approximately 15 shad/haul. Despite annual fluctuations in observed juveniles, American shad reproduction appears to be at a sufficient level to sustain the population.

The ASMFC American Shad Stock Assessment Sub-committee (SASC) utilized CPUE data through 2005 from GADNR tagging efforts on the Altamaha River as an indicator that the Altamaha stock was in decline when the 2007 stock assessment was completed. During 2006-2015, CPUE data from GADNR's tagging efforts averaged 2.4 shad/ft-hr, which is 112.4% higher than the average of 1.13 shad/ft-hr observed from 2000-2005 (Fig. 9). This fact, along with the apparent increase in population abundance, decreased exploitation rates, and recent juvenile abundance data, supports the fact that the current fishery appears to be sustainable. In addition, GADNR believes that the changes in the 2011 regulations have allowed sufficient escapement of adults and helped ensured that fishery harvest will not adversely impact the Atlantic Coast American Shad population. Over the years, the attrition of commercial fishermen has also lessened effort and exploitation on American shad in the Altamaha River and even more so on the Savannah River. For example, there were only two commercial shad fishermen on the Savannah River in 2015, and one of these fishermen retired from shad fishing after the 2015 season.

The SASC and TC expressed concerns with utilizing population estimates and exploitation rates generated from annual tagging efforts as stock indicators since GADNR has not studied non-reporting rates, tag loss, tagging mortality, post tagging movements, or repeated the 1980's creel survey to validate the formula that accounts for non-reporting of commercial landings. Instead, the TC recommends using annual CPUE data as a benchmark. Therefore, GADNR continues to monitor the Altamaha stock through a fishery independent gill netting survey to develop annual CPUE data for use as a stock abundance indicator. GADNR utilizes a CPUE benchmark of 75% of the mean for 3 consecutive years. In the last fishery management plan, the TC asked GADNR to consider two potential CPUE benchmark means. The first would utilize the entire time series of data (1983-2011) to calculate the mean, resulting in a benchmark

CPUE of 1.11 shad/ft-hr (Fig. 9). The second option was to exclude the first seven years and utilize data from 1993 through 2011 to present and would establish a CPUE benchmark of 1.29 shad/ft-hr. GADNR believed it to be more appropriate to utilize the entire time series of data to establish the benchmark CPUE since it encompasses a greater degree of environmental and population variability. The Altamaha shad population has historically shown the capacity to rebound after 7 consecutive years below this benchmark, and historically a benchmark of 1.29 shad/ft-hr would not have triggered action any more frequently than a benchmark of 1.11 shad/ft-hr. Consequently, a benchmark of 1.11 shad/ft-hr (accepted in October 2017) will be used as a sustainability measure for both the commercial and recreational fisheries going forward (Table 1). If gill netting CPUEs drop below 1.11 shad/ft-hr for 3 consecutive years, GADNR will evaluate commercial fishing regulations and harvest data and consider modifications to the Altamaha fishery to ensure the fishery remains sustainable.

In the future, utilization of a juvenile index of abundance may be added once GADNR has collected several years of data to establish a CPUE benchmark appropriate to the Altamaha River. When the 2007 stock assessment was completed, the SASC utilized available data as an indicator that the Altamaha stock was in decline. Since that time, GADNR's relative abundance data from 2005-2015 was 112% higher than observed relative abundance from 2000-2005. This increase, combined with increases in population estimates, decreased exploitation rates, and JIA data all point to healthy and sustainable stock.

Despite conducting a creel survey on the Altamaha River for over 20 years, no recreational fishing is known to occur in the river. Since the river is open to commercial fishing, GADNR proposed utilizing the same sustainability benchmark that is used for the commercial fishery, which is a gill netting CPUE below 1.11 shad/ft-hr for 3 consecutive years. This benchmark was accepted by the TC and continues to be in place. However, the most recent SFMP did not contain insight on how GA would manage shad recreationally in the two rivers that form the Altamaha (Oconee and Ocmulgee rivers). Though no commercial fishing for shad is allowed in the Ogeechee and Ocmulgee rivers, recreational fishing is allowed. To address the lack of a management trigger for the Oconee and Ocmulgee rivers, GADNR proposes applying the same recreational management strategies (e.g. closures, creel changes, etc.) implemented on the Altamaha to also apply to the Ocmulgee and Oconee Rivers.

Savannah River

Management of shad on the Savannah River has historically been done using landings data provided by commercial fishermen. Specifically, GADNR and SCDNR worked collaboratively to establish a joint sustainability benchmark for the Savannah River using data from roe shad landed in Georgia associated with the commercial drift-net fishery. The agreed upon sustainability benchmark was a commercial roe drift gillnet CPUE of 9.03 kg shad/trip for 3 consecutive years. However, participation in the commercial drift net fishery has declined in recent years, and zero (0) landings were reported from this sector of the fishery in 2019 and 2020. As a result, GADNR staff felt it necessary to examine other potential available datasets from fishery-independent work being done on the Savannah River. Since 2010, GADNR staff have conducted electrofishing surveys for adult American shad each year between the months of Feb – June at the New Savannah Bluff Lock and Dam (NSBLD) on the Savannah River. The NSBLD is the first barrier to upstream migration on the Savannah River and is located at river km 301, just south of Augusta, GA and approximately 109 rkm above commercial fishing waters. American shad once passed through this dam via lockage, but in recent years the U.S. Army Corps of Engineers (USACE) has declared the facility unsafe to operate, so fish are not being passed through the lock at this time. The dam is now a true migration barrier and is the uppermost reach of the American shad migration in the Savannah River. When feasible, GADNR staff conduct electrofishing surveys for adult American shad during each of the aforementioned months. Since 2010, annual CPUEs (# fish/hr) for the NSBLD electrofishing efforts have ranged from 59 fish/hour to 430.01 fish/hour (Figure 5), averaging 246.2 fish/hr during the 10-year time series. As a result of ongoing concerns with changing commercial fishery dynamics in the Savannah River (declining participation by commercial drift-netters, etc.) as seen in both GA and SC, GADNR recommended to the TC in May that consideration be given to utilizing data from the electrofishing survey at the NSBLD to establish a sustainability metric for manage shad in the Savannah River. Specifically, GADNR proposed using the 25th percentile (61.56 fish/hr) for 3 consecutive years as a sustainability benchmark for the Savannah River (both commercial and recreational fisheries). This proposed change was discussed in a TC call on 6/25/20 and approved by the TC . Under this change, if the adult shad CPUE falls below 61.56 fish/hr for 3 consecutive years, GADNR will take the same approach it does for other managed rivers and evaluate and identify the causes thereof and initiate appropriate actions (Table 1).

Additional fishery-independent surveys conducted on the Savannah River include a juvenile electrofishing survey done by SCDNR. This juvenile survey is done in late summer and has proven to be a valuable dataset as well. As part of the TC recommendation on 6/25/20 allowing GADNR to use the fishery-independent NSBLD electrofishing survey as the primary metric to determine sustainability, GADNR has also agreed to work with SCDNR to utilize their juvenile electrofishing survey as a secondary metric to assess the shad population in the river. GADNR will remain in contact with SCDNR to examine annual results of these surveys and respond as necessary to any observed declines.

Ogeechee

The Ogeechee River was officially closed to commercial fishing due to lack of participation and potential sturgeon interactions. There are no plans to re-open the commercial fishery on the Ogeechee River. A temporary 5-year American shad stocking program was initiated in 2014 as an additional measure to ensure the conservation of this stock. Adult American shad are monitored via electrofishing and juveniles are sampled with a 50’ bag seine.

The Ogeechee River is one of the rivers in Georgia known to have a recreational shad fishery. The GADNR initiated an electrofishing survey in 2010 for adult American shad and the CPUE has averaged 14.8 fish/hr over a 7-year period. The GADNR was approved in October 2017 to use the 25th percentile for 3 consecutive years as a sustainability benchmark for the recreational fishery (Table 1). Consequently, if the adult shad CPUE falls below 3.7 fish/hr for 3 consecutive years, the GADNR would need to establish conservation measures to ensure the sustainability of the fishery.

Satilla and St. Mary's Rivers

The Satilla and St. Mary's rivers are currently closed to commercial shad fishing and there are no plans to open these rivers. Technically, the Satilla and St Mary's river are open to recreational harvest of shad. However, several recreational creel surveys have been conducted on the Satilla River in recent years (2006-2014) and American shad have never been observed in angler harvest. While the GADNR does not have any recreation creel survey data for the St. Mary's River, there has never been any evidence or reports of anglers incidentally capturing American shad. Additionally, annual spring electrofishing surveys targeting sportfish populations indicate that American shad abundance is extremely low in both rivers. There is very little chance of incidental angler interactions due to the low abundance of shad in these rivers.

Because it will be impossible to develop a sustainable fishing plan with any credible metrics for two river systems where American shad are currently at such low abundance as to be functionally absent, GADNR recommends applying management strategies triggered and implemented on the Altamaha River to also apply to the Satilla and St. Mary's rivers. Geographically, the Altamaha River is the closest system with adequate monitoring and a sustainability metric. Consequently, the application of any triggered management responses conducted on the Altamaha River onto the Satilla and St. Mary's will prevent GADNR from having to seek a modification of Georgia state law to prohibit the harvest of American shad in these two rivers, which we believe will result in no demonstrable conservation benefit.

Summary of Georgia's Sustainable Fisheries Management Plan

The GADNR will continue to monitor and manage the commercial and recreational shad fisheries through fishery-dependent and -independent sampling on the Altamaha, Ogeechee, and Savannah rivers. Data from the Savannah River will be shared with SCDNR, and the agencies will work cooperatively towards the management of this population. The management benchmarks identified in Table 1 will be used as triggers for management decisions for each river system.

If three consecutive years of data show that CPUE of adults is decreasing, GADNR would evaluate and identify the causes thereof and initiate appropriate actions. Potential actions may include reducing the number of fishing days, modifying season dates, or altering legal fishing gears. In the event, such actions are not successful in reversing negative trends, GADNR would then consider closing the fishery in that river system.

Table 1. Management Benchmarks and Triggers

River System	Index	Years Included in Index	Benchmark Value	Benchmark Level	Management Trigger
Altamaha (commercial & recreational)	Gillnet CPUE Index	1983-2015	1.11 shad/ft-hr	25th percentile	3 consecutive years below the benchmark
Savannah (commercial & recreational)	NSBLD Electrofishing CPUE Index	2010-2019	61.56 shad/hr	25th percentile	3 consecutive years below the benchmark
Ogeechee (recreational)	Electrofishing CPUE Index	2010-2015	3.7 shad/hr	25th percentile	3 consecutive years below the benchmark

Future Considerations

Georgia will continue to actively pursue effective management strategies that will allow the continued sustainability of our shad fishery. In recent years, fishery managers in Georgia have seen positive trends in our shad populations, particularly in the Altamaha River, which supports our largest shad population and fishery. As previously mentioned, GADNR's relative abundance data in the Altamaha River from 2005-2015 was 112% higher than observed relative abundance from 2000-2005. This increase, combined with increases in population estimates, decreased exploitation rates, and juvenile indices data all point to a healthy and sustainable stock. In an effort to pursue effective shad management beyond traditional data collection efforts, fishery managers will continue conducting various monitoring programs conducted annually since 2010, including juvenile sampling in the Ogeechee, Altamaha, and Savannah rivers and an electrofishing survey targeting adults in the Ogeechee River. Data from these efforts, which may include length, age, or other biological metrics, may eventually be considered with traditional management benchmarks to inform fishery managers in decision making efforts. Additionally, future considerations may include additional assessments of the impacts of a new fish passage structure at the NSBL&D, should such a structure be developed. Managers will also continue to evaluate the effectiveness of stocking efforts in the Altamaha and Ogeechee that occurred annually from 2014 – 2019, and data from these efforts may also be considered for use in future management decisions. Finally, considerations may be given in the future for collecting genetic samples for analysis of shad stocks in Georgia to better identify and understand stock compilation.

Literature Cited

Godwin, W.F. and J.G. Adams. 1969. Young Clupeids of the Altamaha River, Georgia.

GA Game and Fish Comm., Mar. Fish. Div., Contribution. Ser. No. 15.

Figure 1. Georgia Atlantic-Slope Rivers. The larger lines are the upper boundaries to the commercial American shad fishery and the smaller lines are the boundary lines for different open days of the fishery.

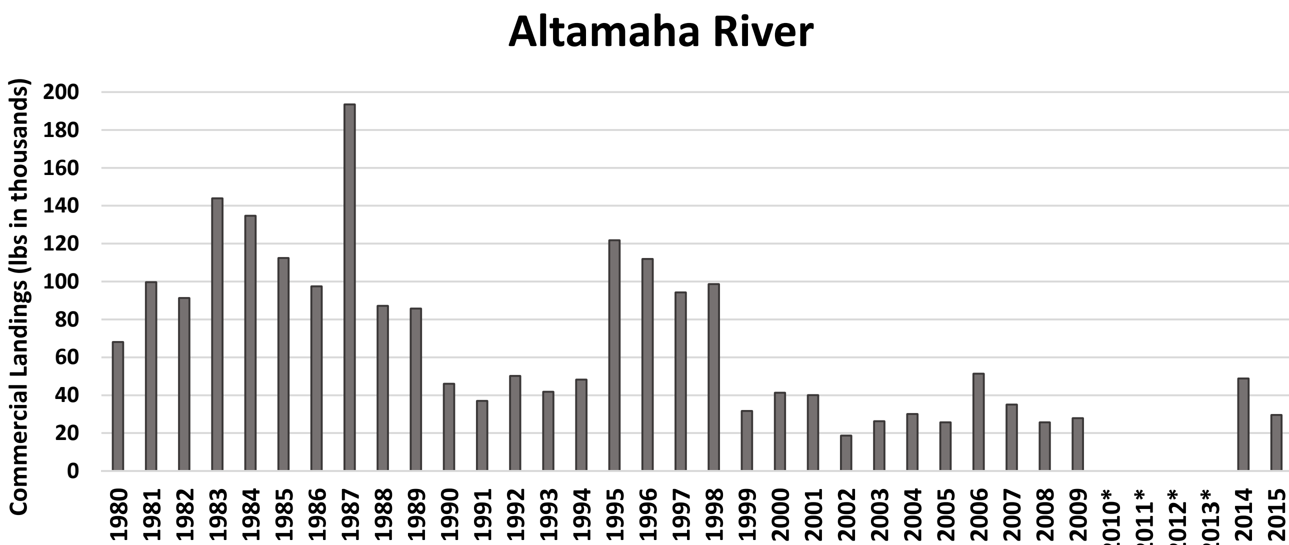

Figure 2. Reported commercial landings, reported by pounds in thousands, of American shad from the Altamaha River, Georgia. Due to confidentiality agreements, data from 2010*-2013* have been excluded.

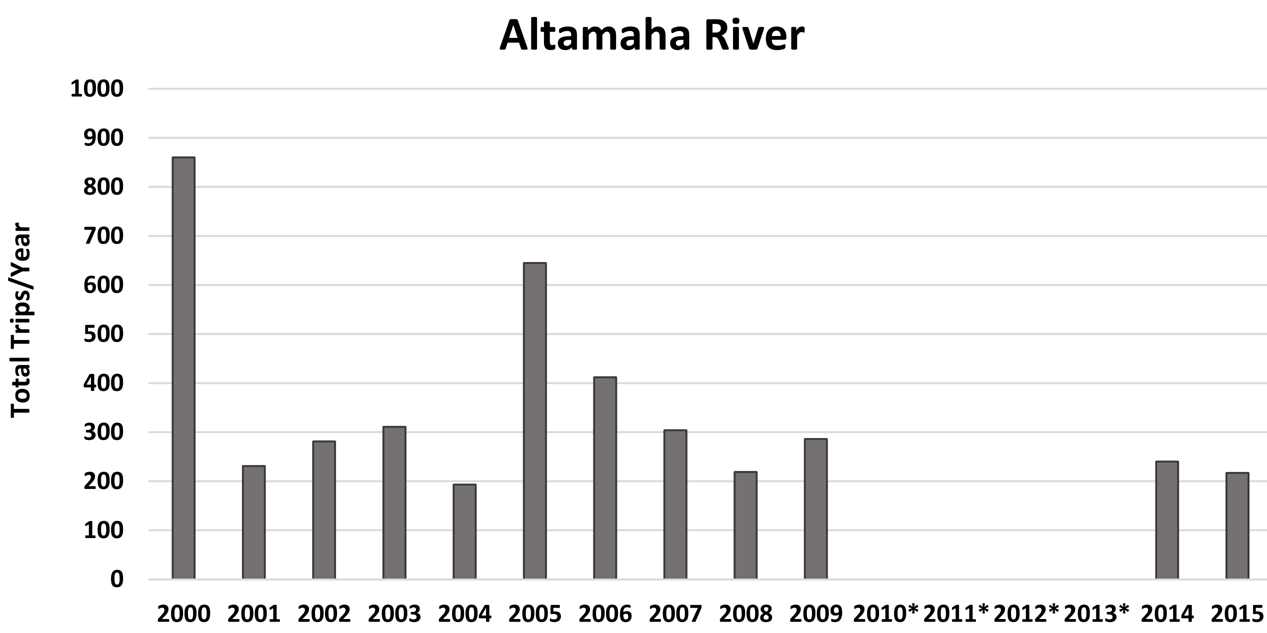

Figure 3. Total commercial fishing effort for American shad in the Altamaha River. Due to confidentiality agreements, data from 2010*-2013* have been excluded.

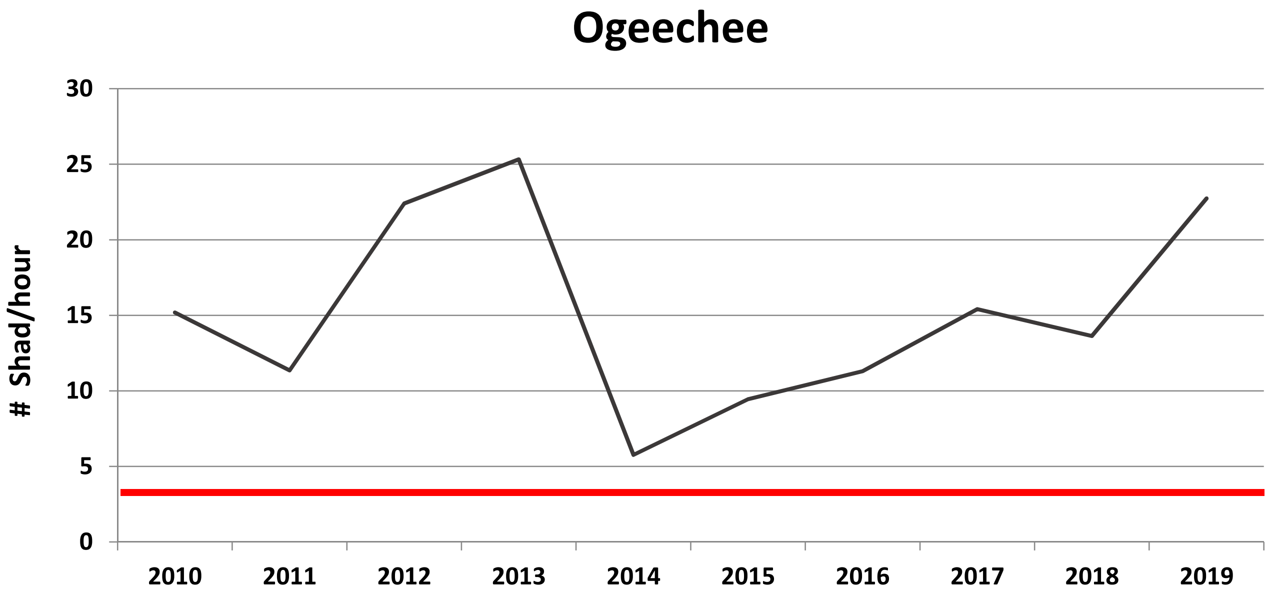

Figure 4. Ogeechee River adult American shad electrofishing CPUE's and the 3.7 shad/hr sustainability benchmark developed by GADNR.

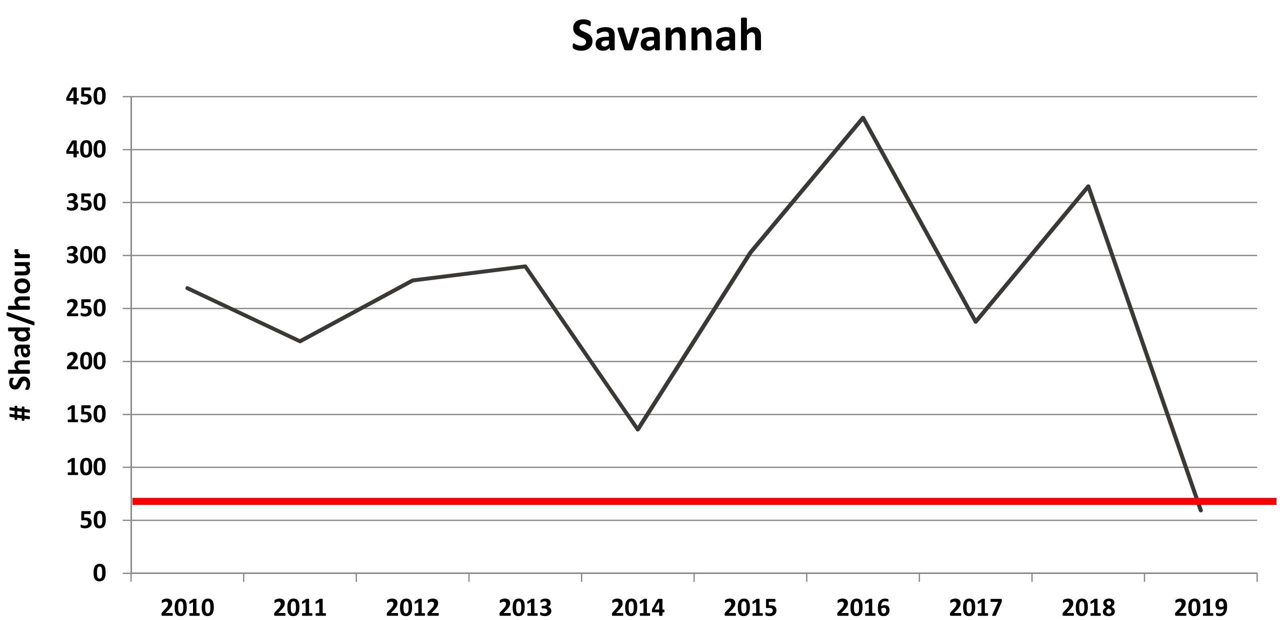

Figure 5. Savannah River adult American shad electrofishing CPUE's collected below the New Savannah Bluff Lock and Dam and the 61.56 shad/hr sustainability benchmark developed by the GADNR.

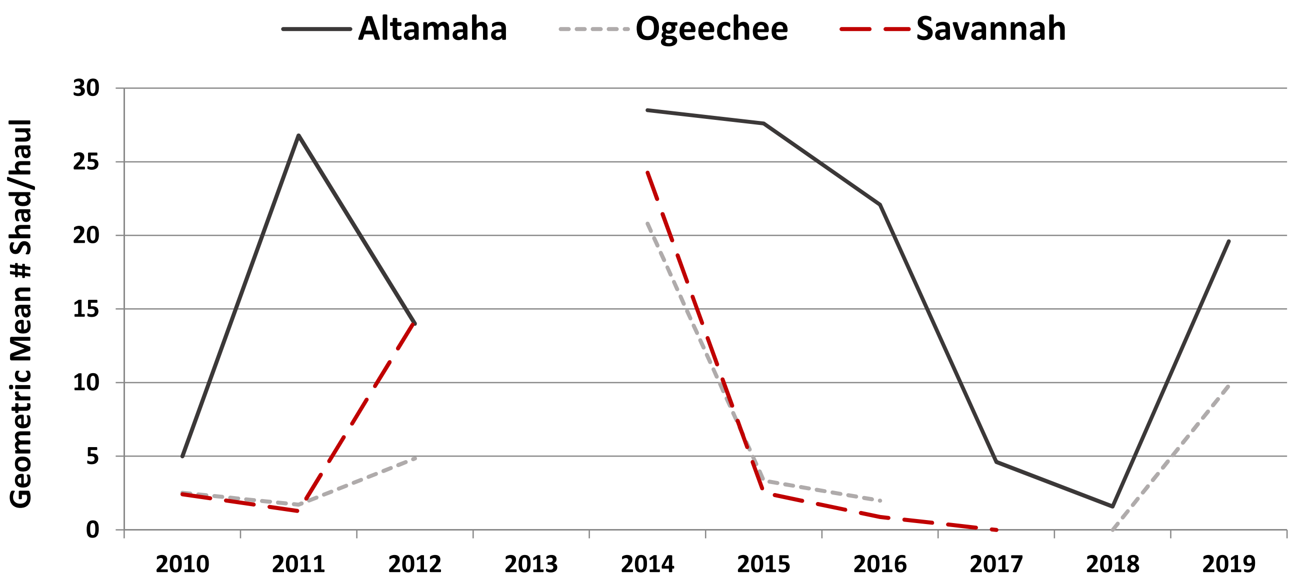

Figure 6. Juvenile American shad sampling program, initiated in 2010, utilizing a 50-ft bag seine on the Altamaha, Ogeechee, and Savannah rivers for monitoring under the sustainability plans to be submitted pursuant to requirements of Amendment 3 to the Interstate Fishery Management Plan for Shad and River Herring (American Shad Management).

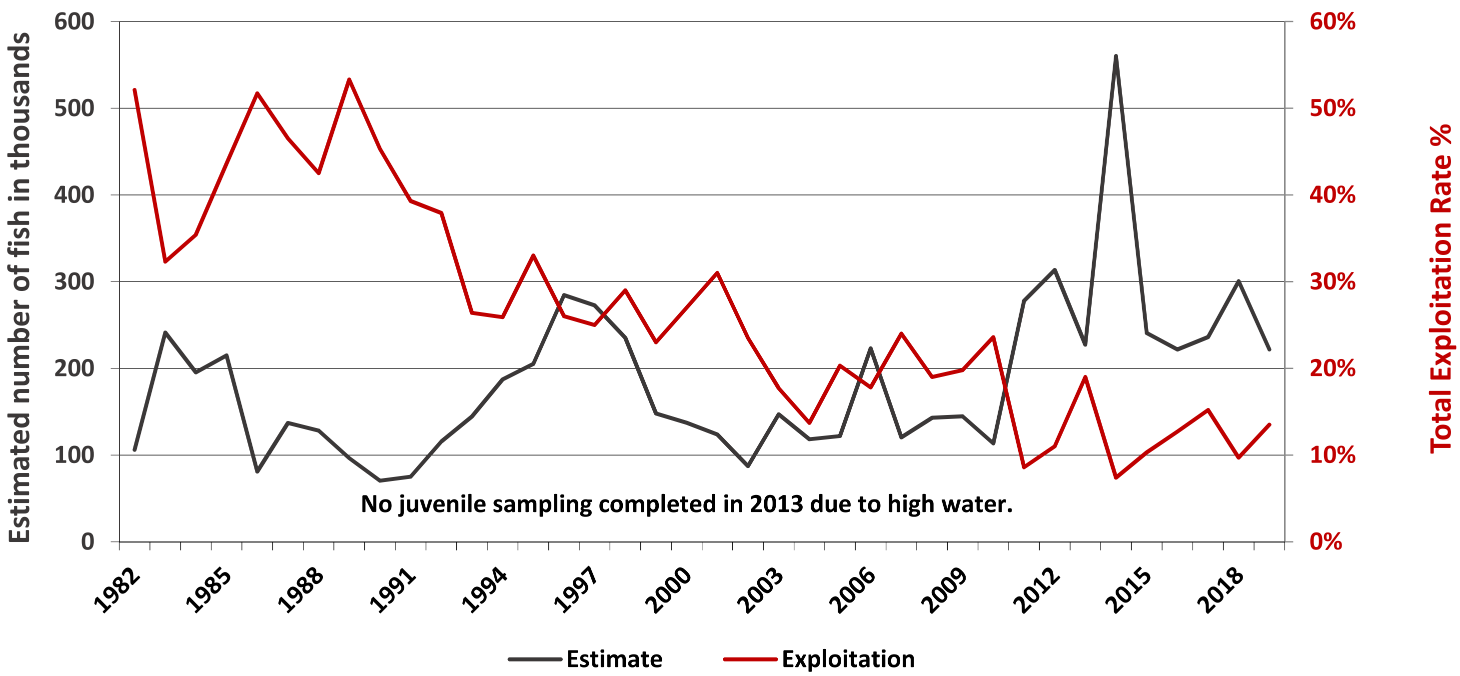

Figure 7. Population estimates and exploitation rates from the Altamaha River American shad run.

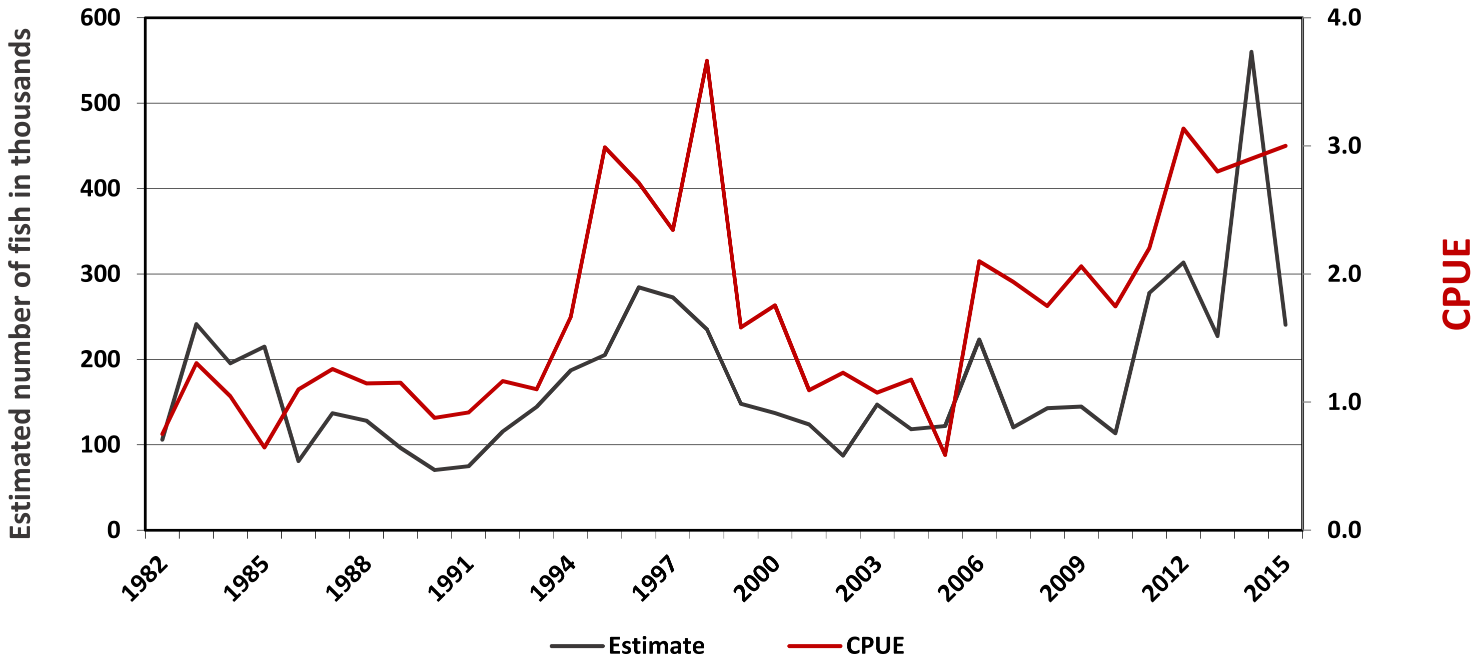

Figure 8. Altamaha River fishery-independent catch-per-unit-effort (CPUE-number caught per foot-hour) of American shad and population estimates from GADNR mark and recapture efforts.

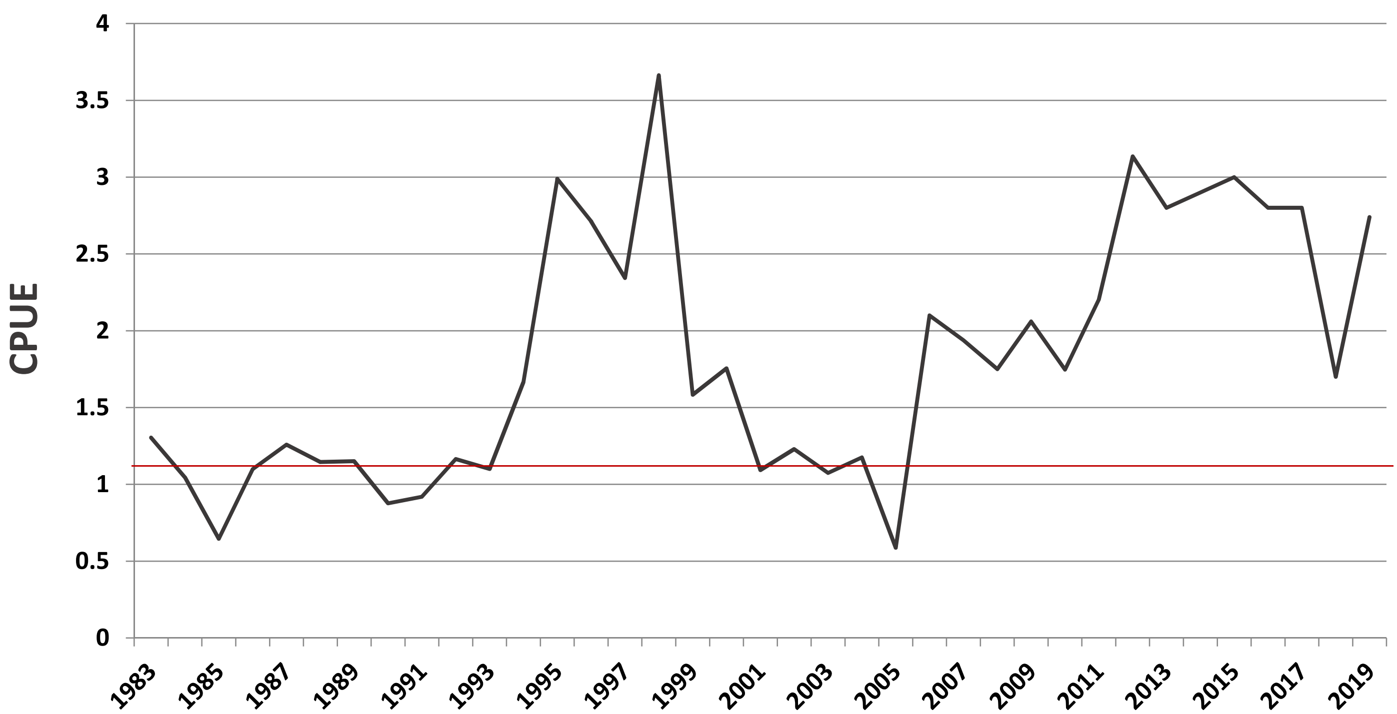

Figure 9. Altamaha River fishery-independent catch-per-unit-effort (CPUE-number caught per foot-hour) of American shad and the 1.11 shad/ft-hr benchmark developed from GADNR gill-net tagging data.

ASMFC Alternative Management Plan for River Herring for Georgia

Submitted by

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Introduction:

Historical fisheries for river herring (e.g. blueback herring, etc.) in the open waters of Georgia are negligible. The purpose of Georgia's alternative management plan for river herring is to allow waters to remain open. This plan is submitted to fulfill requirements of Amendment 3 to the Interstate Fishery Management Plan for Shad and River Herring (River Herring Management).

Management of river herring in Georgia is shared between the Georgia Department of Natural Resources' (GADNR) Wildlife Resources Division's Fisheries Management Section (FMS) and GADNR's Coastal Resources Division (CRD). The major rivers in Georgia utilized by fish stocks include the Savannah, Ogeechee, Altamaha (formed by the Oconee and Ocmulgee rivers), Satilla, and St. Mary's rivers. Commercial fishing for river herring in these rivers is not allowed, and no historical landings exist. Recreationally, river herring are unregulated in Georgia, and GADNR is unaware of recreational effort.

Georgia's Commercial River Herring Fishery and Landings

There are no recorded landings of river herring from Georgia. Under this Alternative Management Plan, it is proposed that commercial fishing for river herring remain closed.

Georgia's Recreational River Herring Fishery

Though the GADNR is unaware of any directed recreational fishing for river herring, their harvest is unregulated. Numerous recreational creel surveys funded by the NMFS (e.g. MRIP) or GADNR (e.g. Altamaha, Ogeechee, and Satilla river creel surveys) show no harvest or directed effort for river herring. The GADNR doesn't have current recreational creel survey data for the St. Mary's river, but anecdotal creel information from anglers on the river indicates no evidence or reports of anglers incidentally catching river herring.

Fishery-Dependent Monitoring

The absence of a commercial fishery for river herring in Georgia prevents the establishment of commercial fishery-dependent indices for the species. Recreationally, fishery-dependent data collection is done through creel surveys. However, MRIP surveys (year-round) and GADNR creel surveys conducted annually on the Altamaha River (from April – November; Fig. 1) and every 5 years on the Ogeechee River have found zero recreational harvest of river herring. It is anticipated that all current creel surveys (MRIP, GADNR) will continue into the foreseeable future.

Fishery-Independent Monitoring

GADNR conducts multiple fishery-independent monitoring efforts that may land river herring. These efforts involve two gear types. In the Savannah River, a fishery-independent effort utilizing electrofishing gear near the New Savannah Bluff Lock and Dam has been done annually since 2010 to assess American shad (Fig. 2). This survey is performed February through June. In the ten years that this survey has been conducted, only three river herring have been observed during electrofishing efforts, further supporting the notion that river herring abundance in the river is extremely low. Similarly, an electrofishing survey targeting American shad in the Ogeechee River (conducted between February and June) has yielded no river herring. Additional electrofishing efforts conducted annually by the GADNR include those targeting multiple species of scale fish in the Altamaha, Satilla, and St. Mary's rivers. These standardized surveys entail 1-hour fishing efforts conducted at 10-12 sites within each river (Fig. 3 - 5). Again, no river herring have been observed in any of these efforts thus far.

A second gear type used in fishery-independent surveys are seines. As part of the American shad FMP for Georgia, GADNR estimates juvenile American shad abundance annually utilizing a 50-ft seine on the Altamaha, Ogeechee, and Savannah rivers. Seine mesh size ($^1/_4$ inch) and site locations are standardized. GADNR staff annually sample 3-6 sites/river 1-2 times a month from July through September. Incidental captures of river herring (e.g. blueback herring) do occur and are recorded. Since 2011, over 13,300 juvenile American shad have been captured in 260 seine hauls. By comparison, 267 juvenile blueback herring were captured in these same hauls. Annual geomean calculations for blueback herring continually remain well below one fish/haul. Consequently, creating a sustainability benchmark based on such low abundance would be ineffective and difficult at best. This difficulty is further exacerbated by the fact that seine gear is affected by river levels, and the potential for data to not be collected during high-water periods would further inhibit the use of this data for management benchmarks and triggers.

Management Recommendation

The TC has recommended that, in the absence of a sustainable fishery management plan for river herring, the GADNR consider: A) establishing a catch-and-release only fishery; or B) pursue an Alternative Management Plan for the species. Indications are that populations of river herring in Georgia have historically been low, and no fisheries for the species (commercial or recreational) have been identified. Furthermore, in Table 15 of Amendment 2 to the Interstate Fishery Management Plan for Shad and River Herring, it is stated that "there are currently no known river herring populations in Georgia. Should populations be established, the Management Board has the authority to require a fisheries independent monitoring program be implemented" (ASMFC website). Because river herring are considered functionally absent in Georgia rivers, it would be impossible to develop a sustainable fishing plan with any credible metrics. A modification of Georgia state law to prohibit the harvest of river herring will result in no demonstrable conservation benefit, thus we do not consider a catch-and-release only fishery desirable.

In an effort to examine herring abundance in our state waters, the GADNR will continue fishery-independent *Alosid* monitoring via electrofishing on the Savannah and Ogeechee rivers, along with standardized sampling efforts via electrofishing on the Altamaha, Satilla, and St. Mary's rivers. In an effort to monitor the directed recreational harvest of various species, including herring, in Georgia, the GADNR proposes to continue the use of fishery-dependent creel surveys. These include fishery-dependent creel samplings conducted by MRIP coastwide and GADNR river-specific efforts.

GADNR plans to continue fishery-dependent and -independent monitoring for the foreseeable future. Using all available creel data (MRIP, GADNR), we propose that should we encounter a positive event of a harvest in a single year we will examine the specifics of that harvest and consider if additional data collection efforts are warranted. In the event that creel surveys indicate positive harvest of river herring for three consecutive years, GADNR will take the necessary steps to ensure sustainability for that river system. These steps will include the pursuit of establishing a formal sustainable fishery management plan or pursuit of a regulatory change (e.g. catch and release, closure of river, etc.), if deemed necessary.

Annual Reporting

In an effort to further identify the current status of river herring in Georgia, we propose to present the results of annual fishery-independent (e.g. electrofishing surveys) and fishery-dependent (e.g. creel surveys) data in the annual Shad and River Herring Compliance Report. Such results may be presented in written, tabular, or graphical form. The reporting of this data should provide additional insight into the status of river herring abundance in Georgia.

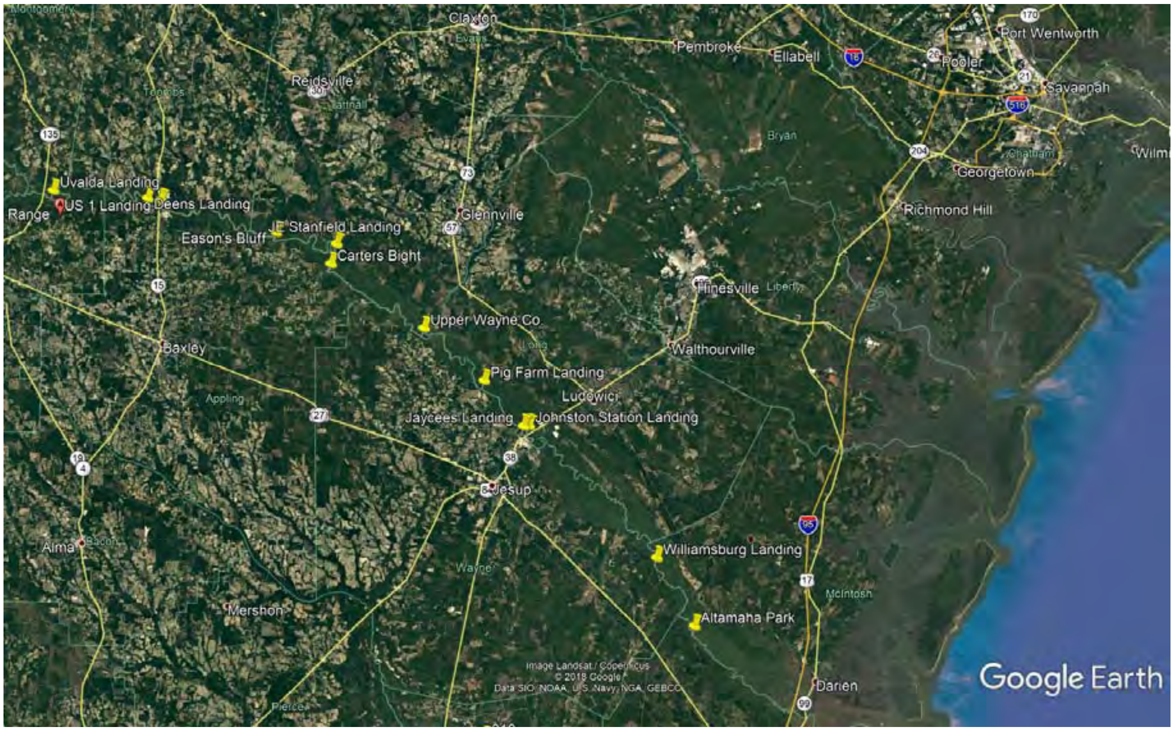

Figure 1. GADNR creel sites on the Altamaha River

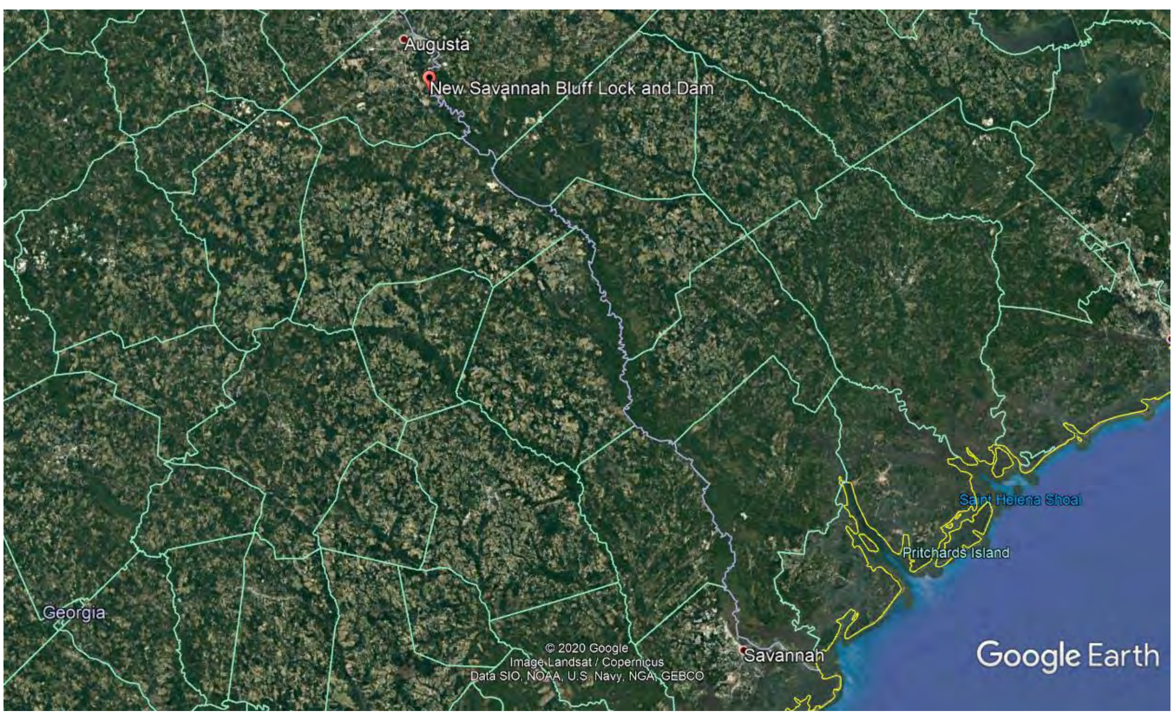

Figure 2. GADNR *Alosid* electrofishing site on the Savannah River

Figure 3. Standardized sampling sites on the Altamaha River

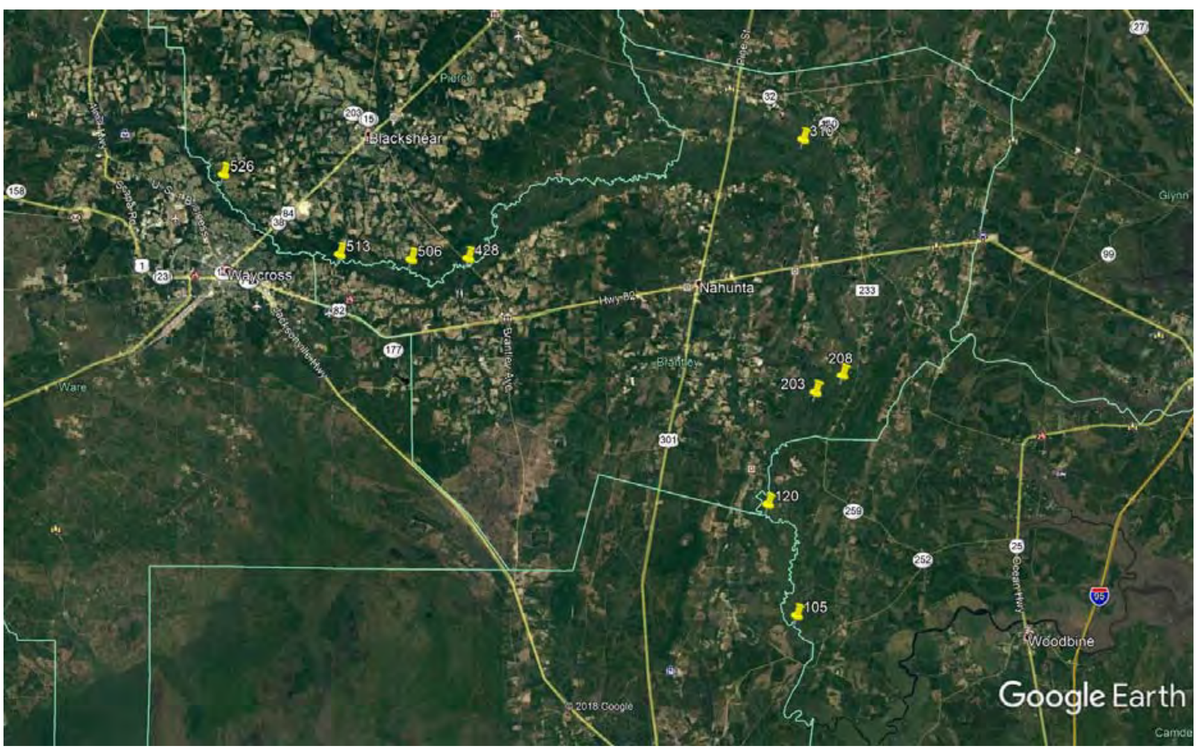

Figure 4. Standardized sampling sites on the Satilla River

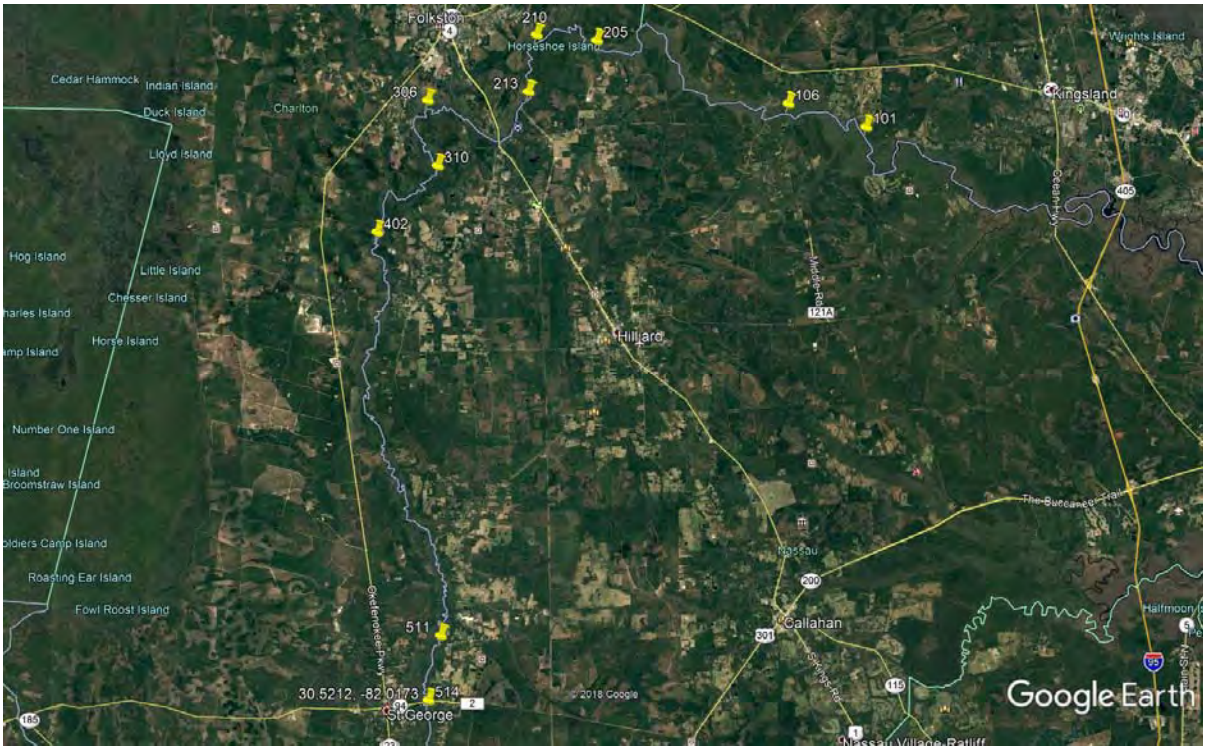

Figure 5. Standardized sampling sites on the St. Mary's River

American Shad Sustainable Fishing Plan for the St. Johns River System, Florida
(Updated to include St. Johns River Tributaries)

DRAFT

Prepared by

Reid Hyle

Submitted to ASMFC TC for Review

March 16, 2020

Reviewed by TC via Confernce Call March 30, 2020

Revised April 7, 2020 to move waters other than the St. Johns River system into an Alternative Management Plan

On Behalf of

Florida Fish and Wildlife Conservation Commission

Fish and Wildlife Research Institute and Division of Marine Fisheries Management

System Descriptions:

St. Johns River and Tributaries

The St. Johns River in Florida drains 22,900 km^2 along east central Florida from Vero Beach to Jacksonville. The primary spawning run of American Shad in Florida historically was and currently is in the St. Johns River. Spawning occurs from late December to early May in most years, with peak activity from mid-January to mid-March. (Walburg 1960, Williams and Bruger 1972, McBride and Holder 2008). The spawning grounds have been documented from rkm 230 to rkm 433 near the headwaters (Williams and Bruger 1972, Williams et al. 1975). Of that distance 160km can be classified as river and 43 km as lake. Primary spawning grounds were in river habitats between rkm 275 and rkm 360 (Williams and Bruger 1972). Contemporary egg collection (Miller et al. 2012b) and telemetry (Dutterer et al. 2011) confirm that spawning grounds still exist between rkm 230 and a weir at rkm 415. The mainstem run of the St. Johns River supported significant commercial fisheries in the 19th and 20th centuries and continues to support a small recreational fishery.

Some tributaries to the St. Johns River that are thought to include American Shad spawning habitat are the Econlockhatchee River which enters the St. Johns at rkm 317 in the heart of the spawning grounds, the Wekiva River which enters the St. Johns between Lake Monroe and Lake George at rkm 255, the Ocklawaha River which enters the St. Johns in tidal freshwater at rkm 168 near Welaka, and Black Creek at rkm 74. Potential spawning habitat in these systems is limited.

The Econlockhatchee River is the second largest tributary to the St. Johns River encompassing a watershed area of 700 km^2 with a stream length of 57 km. It discharges into the St. Johns River at rkm 317. American Shad spawning has been documented in the lower Econlockhatchee River (Williams and Bruger 1972). It is not known if the Econlockhatchee River supports its own run of American Shad or if it attracts strays from the adjacent St. Johns River spawning grounds. However, recent electrofishing and telemetry surveys have located adult shad from rkm 4 to rkm 14 during the spawning season (McBride and Holder 2008, Holder et al. 2012, Dutterer et al. 2011, Hyle 2019) in all years that sampling has occurred. There is evidence that the Econlockhatchee River provides some amount of alternative habitat for American Shad in the upper St. Johns River during periods of extreme low flow in the St. Johns River (Hyle 2019).

The Wekiva River is a spring fed tributary to the St. Johns River and shares extensive floodplain forest with the St. Johns River in its lower reaches. Preliminary investigations for the previous stock assessment found a few spawning capable American Shad in the lower reaches of the Wekiva River. Blueback Herring and Hickory Shad were more common (Mcbride et al. 2008, McBride 2007). A preliminary field study found suitable substrate and velocity for American Shad in only 7.6 km of river (Miller and Mace 2019).

The Ocklawaha River is the largest tributary of the St. Johns River at 118 kilometers in length. It is the largest Atlantic drainage river in Florida obstructed by a dam in its lower reaches. There is no record of a spawning run of American Shad in the Ocklawaha River pre-dating construction of the dam in 1968. There are anecdotes from veteran commercial fishermen of American Shad present in the Ocklawaha River prior to dam construction (Jordan 1994) but no confirmation. There are modern anecdotes of shad present below the dam but recent efforts to locate spawning American Shad in the Ocklawaha River below the dam have yielded none (Holder et al. 2012).

Black Creek is a small tributary of about 200 km^2 that drains from the ridge that separates the Suwannee River watershed from the St. Johns River. An Ichthyoplankton survey in 1972 and 1973 collected a very small number of American Shad eggs and larvae from Black Creek and a fish camp along the river reported that some anglers caught shad there (Williams et al. 1975). Most recently, one ripe female American Shad was captured in the north fork of Black Creek in exploratory electrofishing that occurred during the 2004 and 2005 spawning seasons (McBride 2007).

Florida's Commercial American Shad Fishery

There have been no reported landings of American Shad from any commercial fishery in Florida state waters since 2000.

Florida's Recreational American Shad Fishery

Recreational hook and line sport fishing for American Shad was popular on the St. Johns River by the 1950s and 1960s (Nichols 1959, 1966a; Walburg and Nichols 1967). In 1958 there were an estimated 6,000 boat trips by anglers targeting American Shad in the St. Johns River that harvested 63,693 American Shad. The average effort was about 5,000 angler hours from 1993 to 2005 with total catch ranging from 1,860 fish to 12,106 shad and harvest from 328 to 1,509 fish (McBride and Holder 2008). Recreational fishing for American Shad is known to occur only on the St. Johns River and the Econlockhatchee River. Fishing occurs on the St. Johns River between rkm 279 and 370 with a majority occurring near access points at rkm 285, 290, and 316. A limited amount of recreational fishing occurs in the Econlockhatchee River which drains into the St. Johns River at rkm 317. The Econlockhatchee recreational fishery operates in tandem with the adjacent St. Johns River and uses a common access point.

No directed recreational fishing for American Shad or incidental catch of American Shad has been documented in Florida waters other than in the middle/upper St. Johns River and adjacent Econlockhatchee River. MRIP has not detected American Shad fishing or catch to occur in the coastal systems (Nassau, Pelicer, Tomoka). FWC has regular contact with recreational fishing clubs (e.g. First

Coast Fly Fishing Club, Mosquito Lagoon Fly Fishing Club, Orlando Kayak Fishing Community) from Jacksonville to Orlando. None report fishing for American Shad outside the St. Johns River.

Regulation

Effective January 1997, hook and line fishing is the only allowable gear to fish for any Alosa species (Chapter 46-52.001 [2], Florida Administrative Code [FAC]) and the possession of more than an aggregate of 10 American, hickory, or Alabama shad is unlawful (Chapter 46-52.001 [3], FAC). A saltwater fishing license is also required of most anglers to fish for Alosa species in Florida

Stock Monitoring Programs

a) Fishery Independent

i. Juvenile abundance indices (JAI)

The relative abundance of young of the year American Shad in the St. Johns River has been assessed annually as catch per tow by a bow mounted push net since 2007. A standard sample night comprises 12 5-minute tows at stations selected at random within a 40 kilometer long sampling reach. Two representative index reaches were selected in 2010 based on a pilot project that ran from 2007 to 2009; one in the river run between river kilometer 210 and 260 and one in tidal freshwater between river kilometer 125 and 165 (Figure 1). Index sampling occurs bi-weekly from the end of March until the CPUE drops below 10% of the peak nighly average. The initial sustainable fishing plan did not identify which sampling index should be used as a benchmark citing a lack of information about which location would best perform in describing recruitment success or failure. The JAI from the tidal freshwater reach was correlated to year class strength in the spawning stock in subsequent years (Figure 2). The JAI has been highly variable but generally increasing (Figure 4). River discharge during the spawning season accounts for a large proportion of the interannual variability in JAI in the lower St. Johns River (Figure 5). The lower St. Johns River American Shad JAI appears to predict both recruitment to the spawning stock and recruitment response to a significant environmental variable.

The index sampling area on the St. Johns River between rkm 125 and 165 is downstream of all tributaries except Black Creek. It encompasses juvenile production from the entire system except from Black Creek.

ii. **Spawning stock survey**

The spawning stock survey tracks the relative abundance of adult American shad by electrofishing the spawning stock. The spawning stock index is reported as the geometric mean catch per standard sample. The current benchmark is that three consecutive years with the CPUE below the 25th percentile

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of the time series will trigger a management action. Sampling occurs biweekly from January through March between river kilometers 314 and 357 (Figure 3). A standard sample day includes 10 standard samples at randomly selected sites within the reach. Sampling will continue on an annual basis. Biological samples are collected for length, sex composition, and aging (beginning in 2011) from these electrofishing collections. This is the longest continuous index currently running on the St. Johns River. The CPUE was at the 25th percerntile in the upper river reach between river kilometer 314 and 357 in both 2015 and 2016 (Figure 6). River discharge was above the 90th percentile during the spawning season in both years and this seems to have altered the distribution of fish within the sampling areas. Two peak season sampling trips also occur between river kilometers 279 and 297 (Figure 3). The CPUE was the highest and second highest in the time series between river kilometers 279 and 297 in 2015 and 2016 respectively.

Electrofishing samples also occur annually on the Econlockhatchee River as water levels permit. However, these are not included as part of standard long term index monitoring because the system does not appear to behave independently of the St. Johns River (Hyle et al. 2019) and because drought conditions preclude often sampling in the Econ.

Several tributaries were sampled in between 2006 and 2011 to look for the presence of American Shad. Shad were located only in the Econlockhatchee River and in channel braids along the main river. None were located in other tributaries (Holder et al. 2011, Figure 7).

b) Fishery Dependent

A roving creel survey of recreational anglers was conducted between the mouth of Lake Jesup (river kilometer 285) and just south of Iron Bend (river kilometer 298) in 11 out of 13 years from 1992 to 2005 (McBride and Holder 2008). This creel documented declining effort and relatively stable catch rates (Figure 8 and Figure 9). An access point creel was introduced in 2011 and will continue annually as funds allow. The access point creel covers the old creel area (Mullet Lake Creel Area) via two boat ramps and an upstream area (Puzzle Lake Creel Area) via one boat ramp (Figure 3). Canvassing anglers on the water indicated that greater than 95% of shad fishing effort originates at these ramps. These ramps are the primary access points to the ~14 km of river in which most shad fishing occurs. The angler success rate in the Mullet Lake Creel Area from 2011 to 2016 was 0.92 fish/hour compared to the 0.71 fish/hour average for shad between 1992 and 2005 (McBride and Holder 2008). There has been no trend in angler CPUE (Figure 9) but effort continues to decline in the Mullet Lake Creel Area (Figure 8). Effort increased in the Puzzle Lake Creel Area though 2014 but was low in 2015 and 2016 due to high water related access difficulty. Angler harvest has been >20% catch for all years 1992 to present.

A benchmark angler catch rate of 1 fish per angler hour was selected as a restoration target based on the previous roving creel (ASMFC 2007). However, the nature of the fishery has changed. The fish camp at river kilometer 287, from which much of the shad fishing effort occurred in the past, has closed and some fishing effort has shifted to another section of river (Figure 8). Additionally, fishing techniques have changed from primarily trolling to primarily fly fishing. Therefore we do not believe that angler catch rate should be used as a stand alone benchmark. Annual monitoring of this fishery through an access point creel will continue as long as funding is available.

This angler survey captures fishing effort and CPUE from the Econlockhatchee River because most anglers that target American Shad in the Econlockhatchee River originate their trips at the boat ramp that serves the "Puzzle Lake Creel Area" in the St. Johns River.

Sustainable Fishery

FWC requests to maintain the recreational fishery in Florida without changing gear restriction or bag limits. Recreational fishing is known only for the St. Johns River and adjacent Econlockhatchee River and it is appropriate to maintain sustainability benchmarks from this primary run.

The fishery independent American Shad spawning stock monitoring and fishery dependent creel survey both overlap all known American Shad recreational fishing areas. The primary JAI survey occurs downstream of all significant tributaries except Black Creek. Management actions necessary for any part of the St. Johns River American Shad population will apply to the entire watershed.

a) Fishery Independent Spawning Stock Index Benchmark (Table 1)

The 25th percentile of the fishery independent spawning stock index 2003 through 2016 was 4.04 (Table 1, Figure 6). Three consecutive years below the 25th percentile will trigger a management review. Data informing this index cover the population that is subject to fishing.

b) JAI Benchmark (Table 1)

The 25th percentile of the JAI from the lower St. Johns River river during the period 2007 to 2016 was 2.33. Three consecutive years below this level will trigger a management review. This index captures juvenile production from all waters upstream of rkm 125 which covers the St. Johns River and all tributaries other than Black Creek.

c) Future Benchmark to Incorporate Fishery Dependent Data

In the St. Johns River, FWC will continue to monitor the ratio of fishery metrics (e.g. effort, catch, harvest) to fishery independent abundance indexes with the intention of developing a benchmark based on a 'relative exploitation index'.

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Table 1. Florida St. Johns River American Shad Management Benchmarks and Triggers

River System	Index	Index Years	Benchmark Value	Benchmark Level	Management Trigger
St. Johns River	Spawning Stock Electrofishing CPUE	2003-2016	4.04 shad/standard sample	25th percentile	3 consecutive years below the benchmark
St. Johns River	Pushnet Juvenile Abundance Index	2007-2016	2.33 shad/standard sample	25th percentile	3 consecutive year below the benchmark

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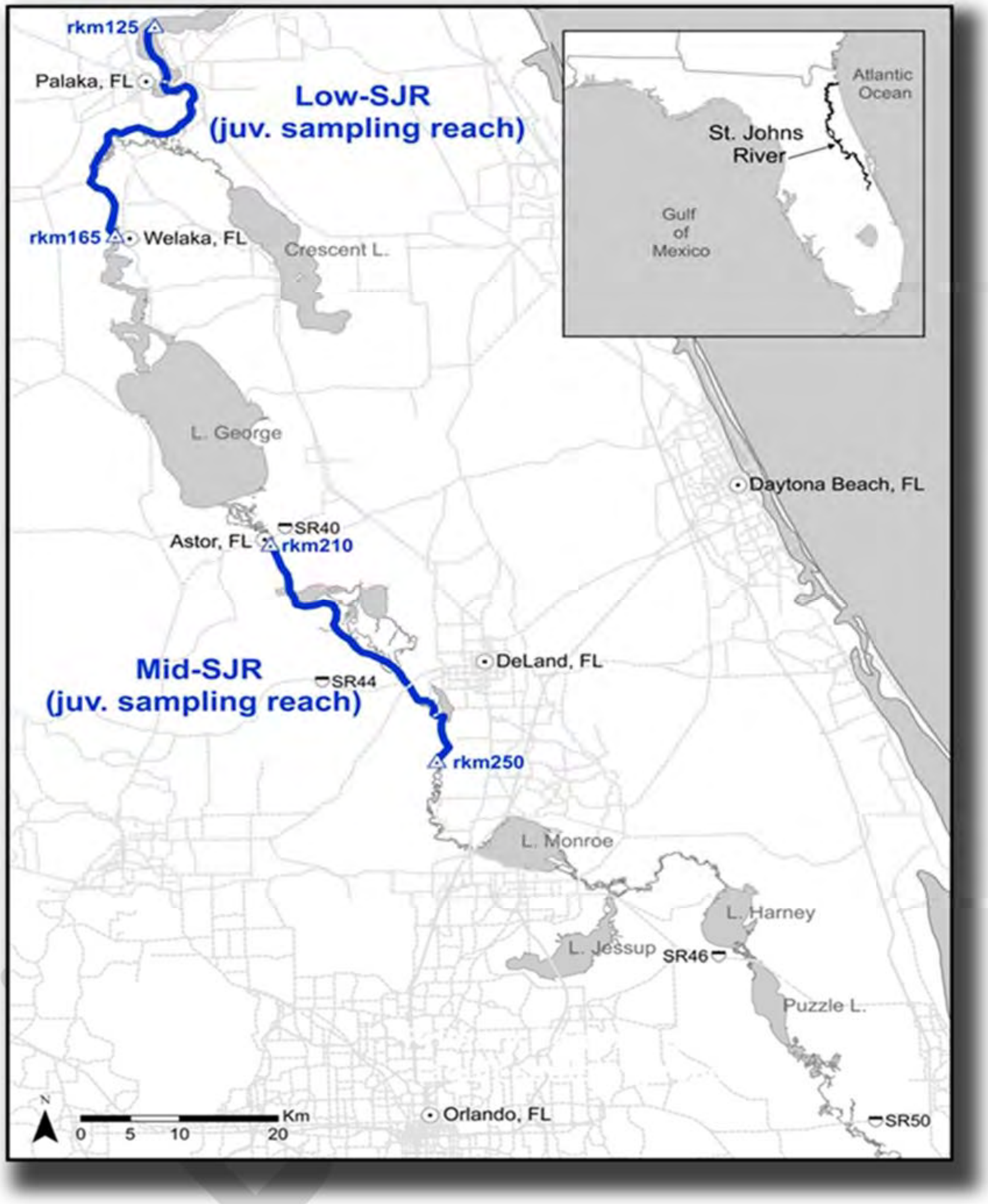

Figure 1. Middle and lower St. Johns River. Diurnal tides extend up to Lake George. Spawning grounds begin between Lakes George and Monroe but are primarily south of Lake Monroe. Juvenile sampling by pushnet in 2007-2009 extended from rkm 125 to 305 from spring to fall. From 2010 forward, the Mid-SJR Sampling Reach (rkm 210-260) and the Low SJR Sampling Reach (rkm 125-165) are sampled biweekly from the end of the spawning season until the nightly CPUE drops below 10% of the seasonal peak.

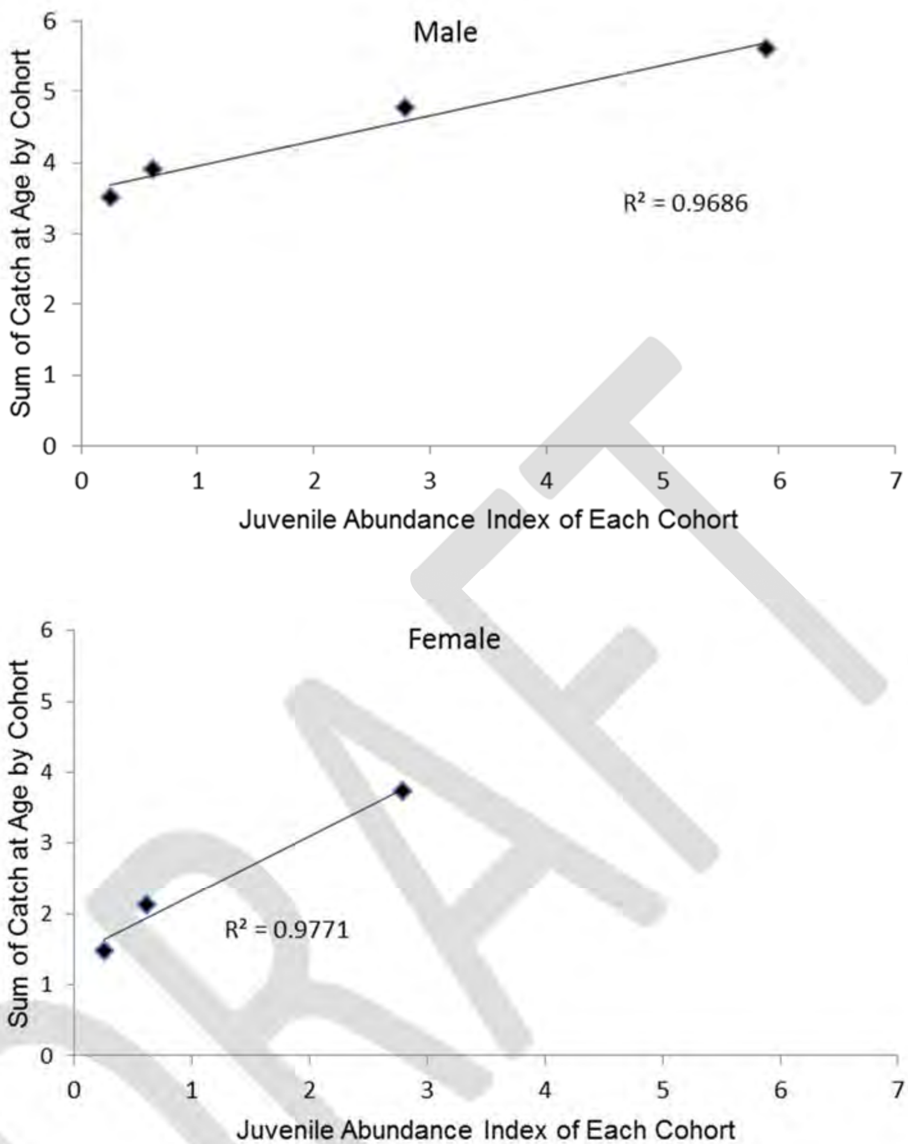

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Figure 2. The CPUE at Age of the adult spawning stock versus the JAI in prior years. The electrofishing CPUE was summed across years for each age of each sex, ages 3 through 6 for males and ages 3 through 7 for females. This produced a sum of CPUE at Age for the 2007 through 2010 year classes of male American Shad and the 2007 through 2009 year classes of female American Shad. That value was tested for correlation with JAI. Males are in the top figure and females in the lower. Both simple linear regressions are significant at 0.05. As both regressions are short, the relationship will be tested with more robust methods as additional data are gathered.

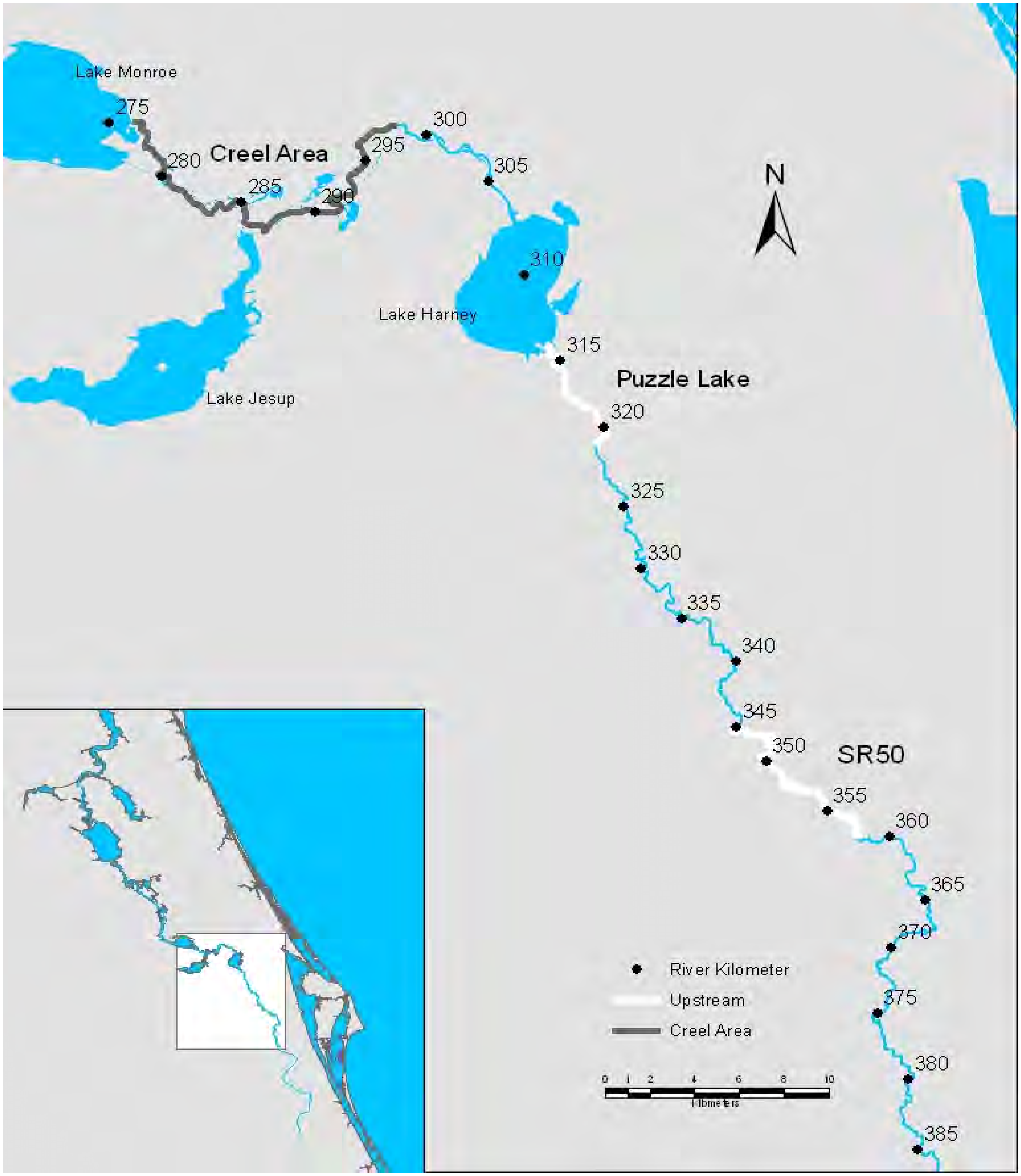


Figure 3. Upper St. Johns River. Primary spawning grounds occur from river kilometer (rkm) 276 to 378. Fishery independent monitoring for adult American shad occurs at Puzzle Lake (rkm 314-320), at State Road 50 (SR50, rkm 345-357), and at the Mullet Lake Creel Area (rkm 279-297) annoted on this figure as "Creel Area". The recreational fishery occurs mainly at the Creel Area and Puzzle Lake.

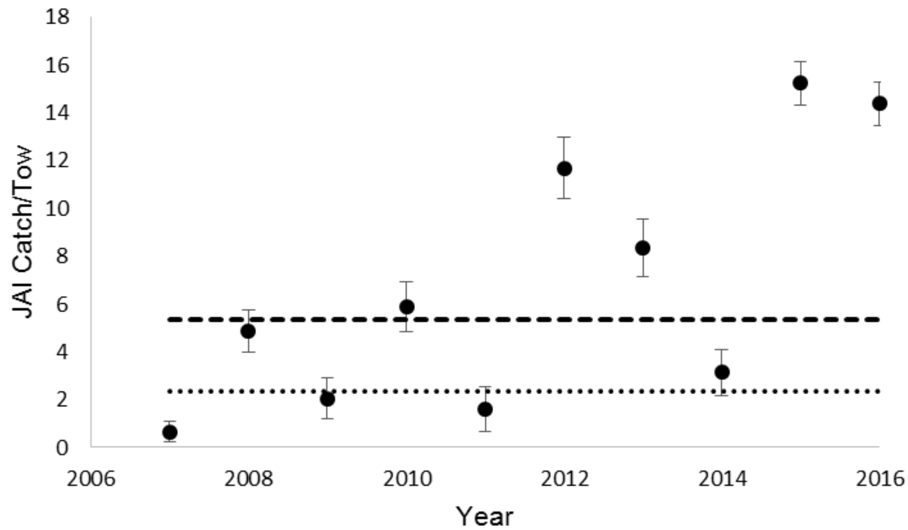


Figure 4. The summer juvenile abundance index, calculated as Geometric Mean, of American Shad from the lower St. Johns River, Florida from 2007 to 2016. Median is the dash line. 25th percentile is the dotted line.

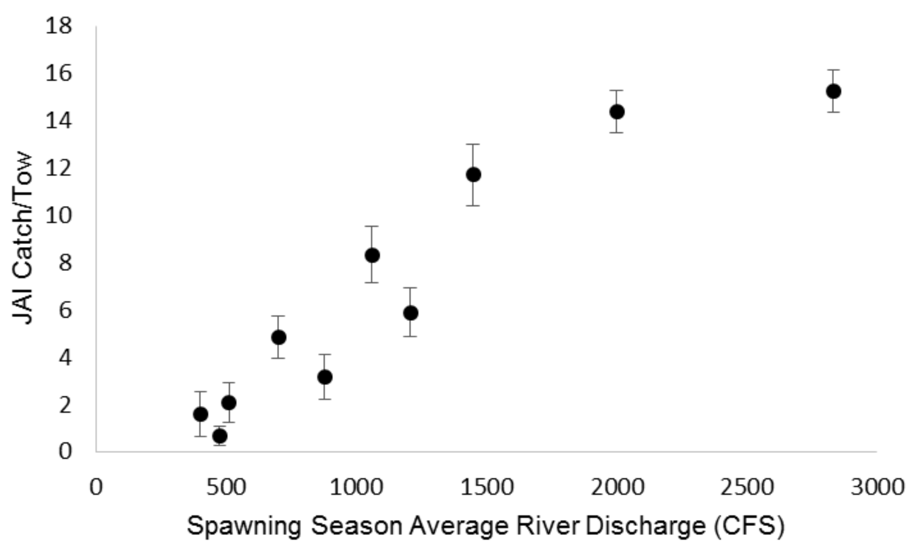
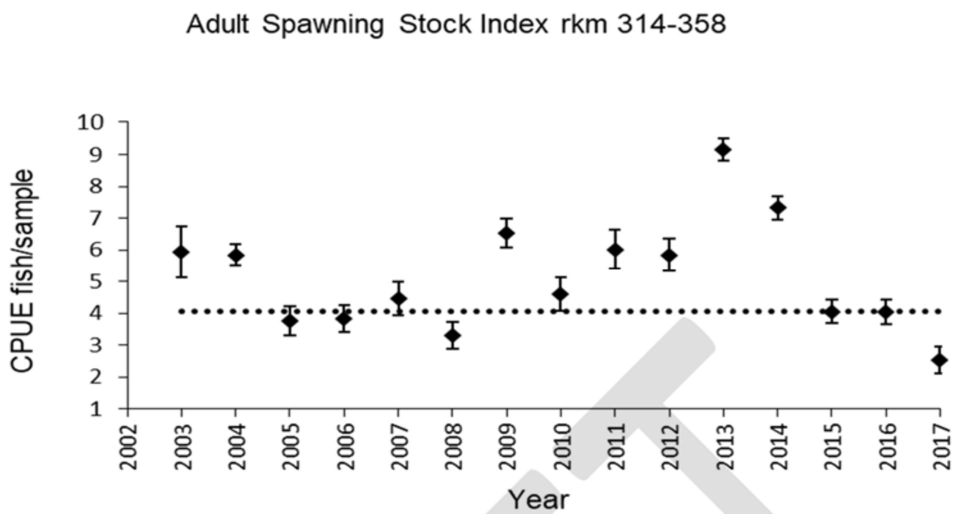


Figure 5. The summer juvenile abundance index of Amerian Shad from the lower St. Johns River, Florida from 2007 to 2016 versus the mean spawning season (January through March) discharge at USGS Gage 02232500 on the spawning grounds of the St. Johns River near State Road 50 in Christmas, Florida.



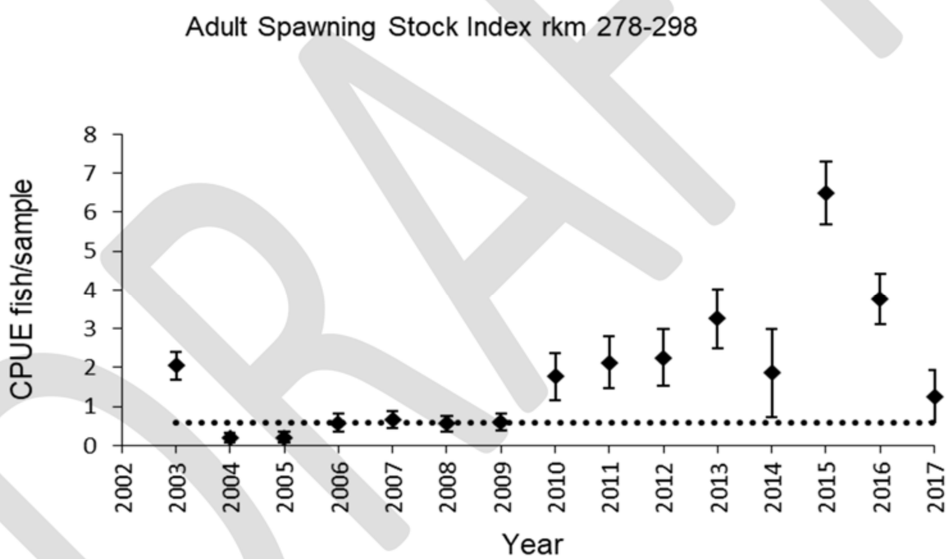


Figure 6. Electrofishing catch per unit effort (geometric mean catch per 10 minute transect) of American Shad from the St. Johns River in each of two areas. Dashed line is the media. Dotted line is the 25th percentile. The spawning stock index from rkm 314-358 was designated as the index for a fishery independent benchmark in the initial SFMP.The water level in 2015 and 2016 was above the 90th percentile of historic levels during the spawning season and may have impacted the electrofishing survey's ability to correctly index relative abundance by causing the distribution of fish on the spawning ground to shift downstream.

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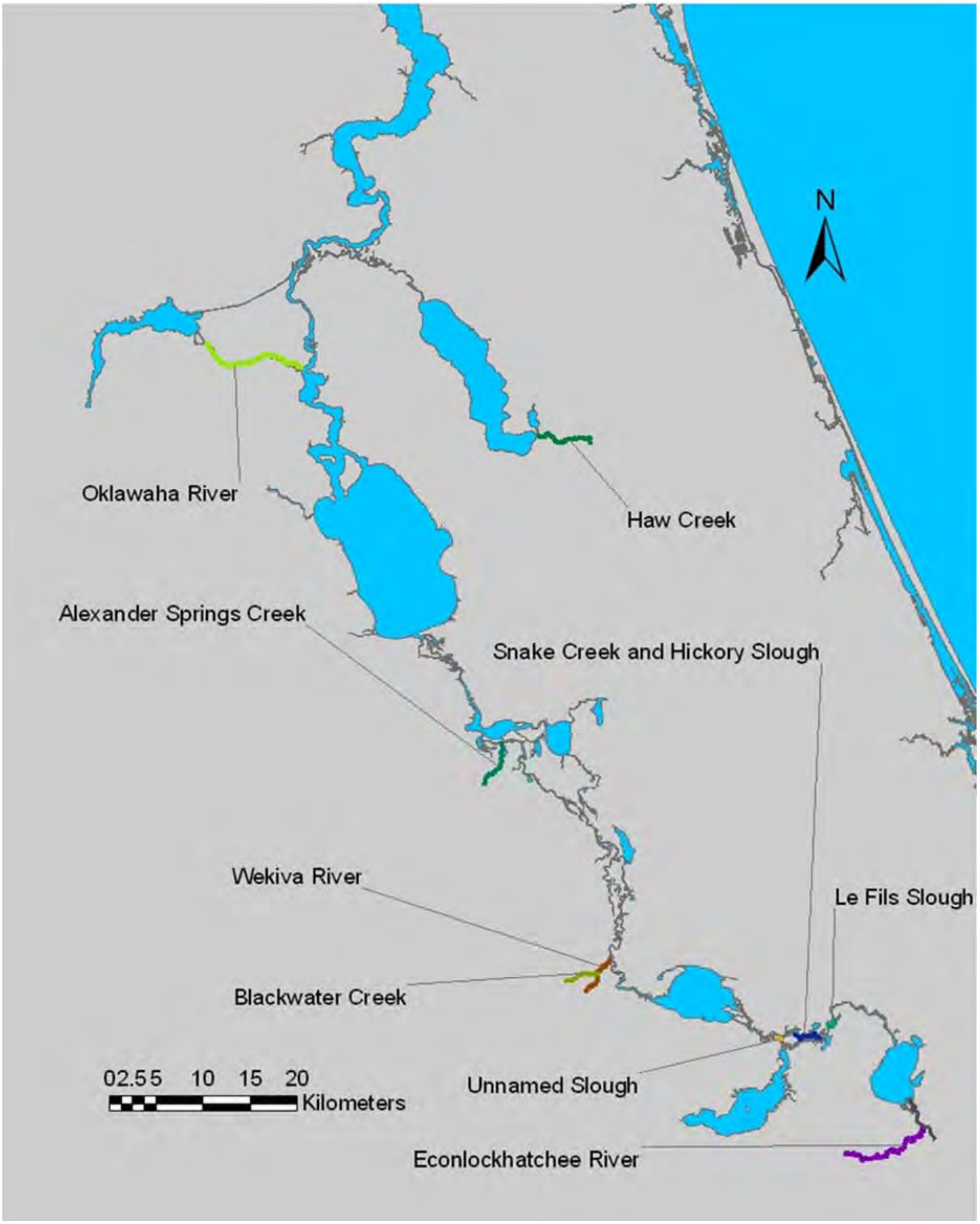

Figure 2. Tributaries of the St. Johns River that were sampled between 2006 and 2011 to detect American Shad and other *Alosa* species.

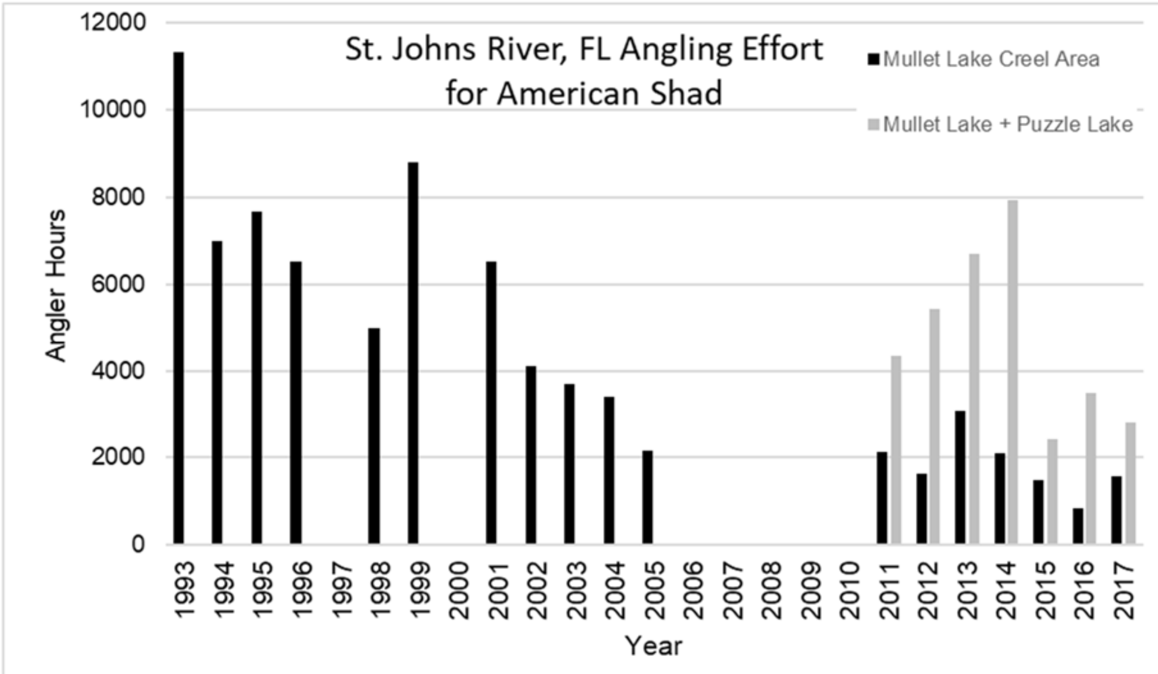

Figure 7. Recreation effort for American Shad in the St. Johns River, Florida expressed as angler-hours. An additional stratum was added in 2011 as effort shifted away from the orginial area. "Mullet Lake Creel Area" is still treated as a unique stratum for comparison to the 1993 to 2005 data.

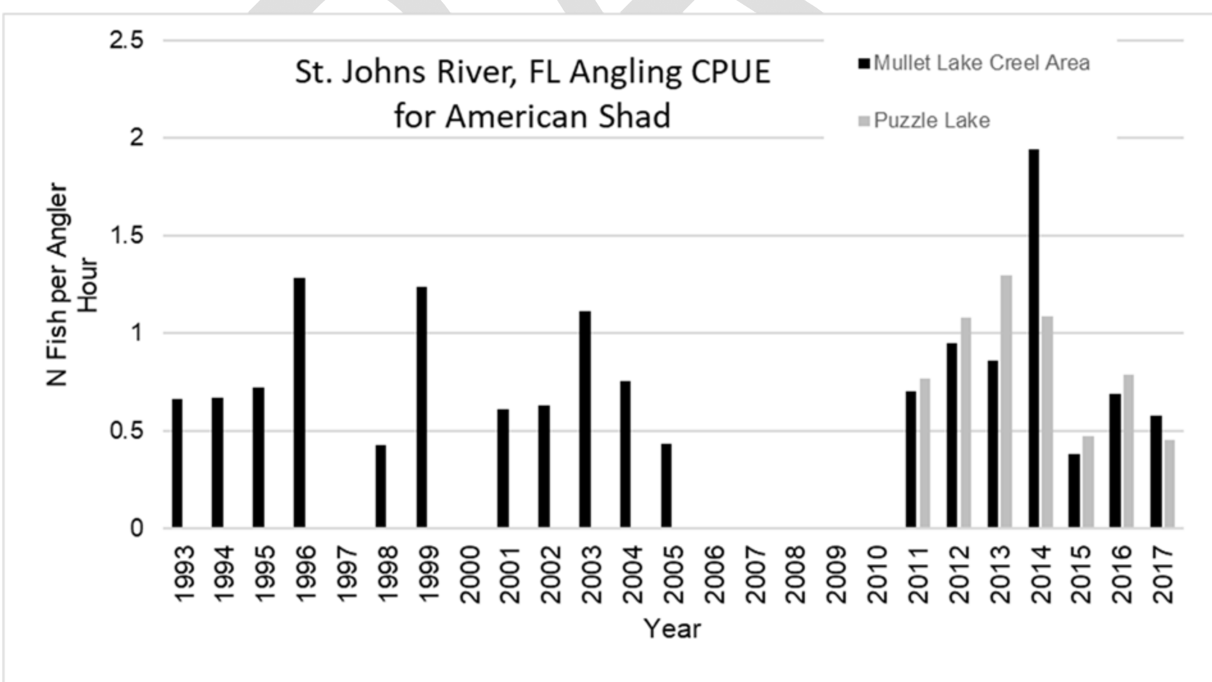

Figure 8. The catch per unit effort of American Shad from the recreational fishery in the St. Johns River, Florida from the Mullet Lake Creel Area stratum and averaged across both creel strata from 2011 to 2016.

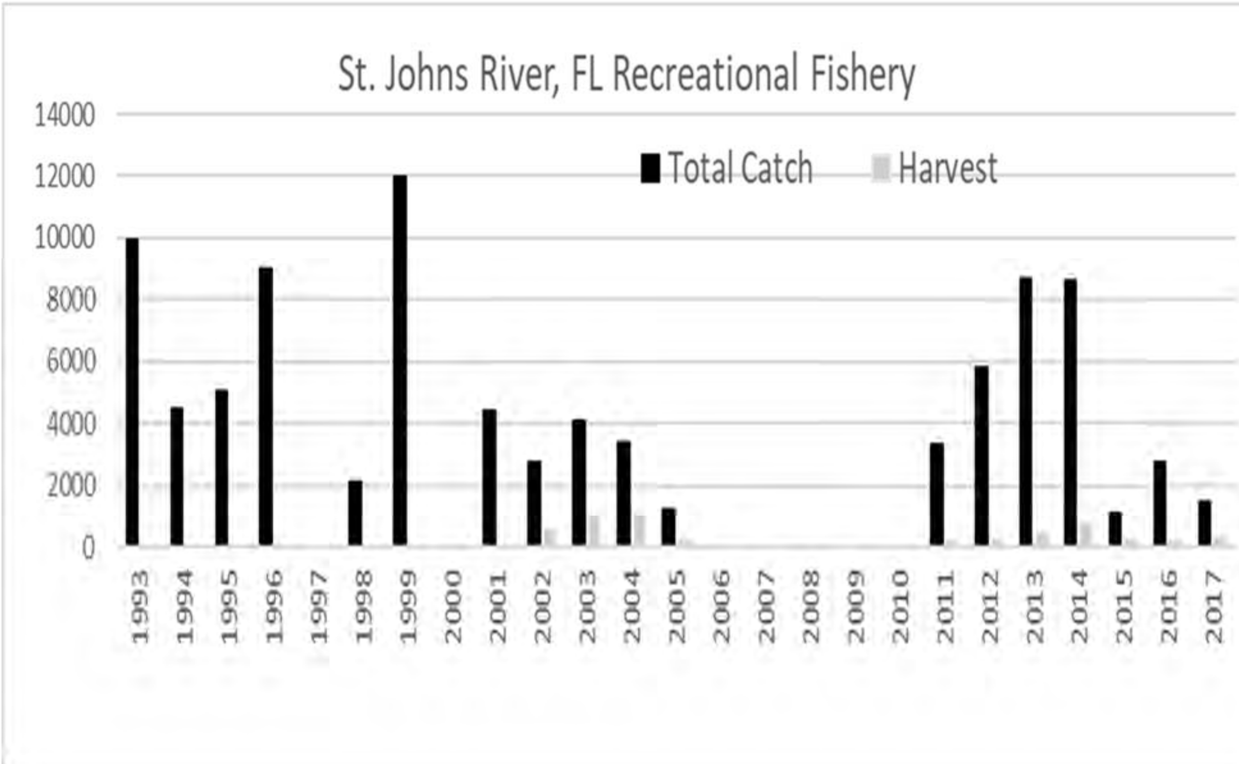

Figure 9. The total catch and harvest of American Shad in the recreational fishery in the St. Johns River, Florida.

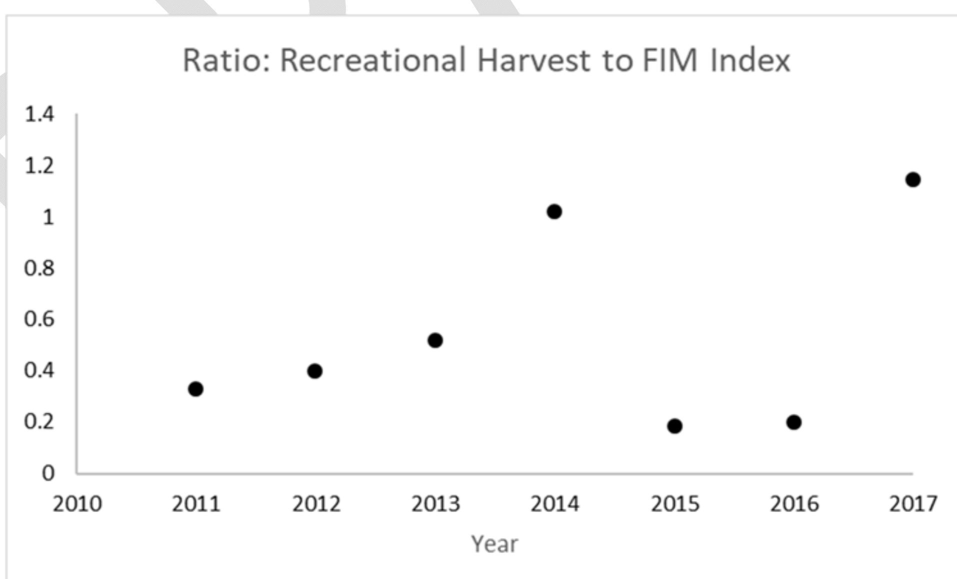

Figure 10. Relative harvest index. This is calculated as the ratio of the total number of American Shad harvested by the recreational fishery to the annual geometric mean electrofishing CPUE multiplied by 100. These data may be suitable to create a benchmark that combines fishery catch/harvest data and independent monitoring data in the future.

ASMFC Alternative Management Plan for Shad and River Herring in Florida

Prepared by

Reid Hyle

Submitted to ASMFC TC for Review

March 16, 2020

Final Revisions: May 7, 3030

On Behalf of

Florida Fish and Wildlife Conservation Commission

Fish and Wildlife Research Institute and Division of Marine Fisheries Management

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This alternative management plan for American Shad and Blueback Herring in Florida addresses American Shad management outside of the St. Johns River System and Blueback Herring in all state waters.

System Descriptions

The St. Johns River in Florida drains 22,900 km^2 along east central Florida from Vero Beach to Jacksonville. The primary spawning runs of American Shad *Alosa sapidissima* and Blueback Herring *Alosa aestivalis* in Florida historically were and currently are in the St. Johns River. Spawning of *Alosa spp*. occurs from late December to early May in most years, with peak activity from mid-January to mid-March for American Shad and Blueback Herring (Walburg 1960, Williams and Bruger 1972, Williams et al. 1975, McBride and Holder 2008, McBride et al. 2010). The spawning grounds of American Shad have been documented from rkm 230 to rkm 433 near the headwaters (Williams and Bruger 1972, Williams et al. 1975). Of that distance 160km can be classified as river and 43 km as lake. Primary spawning grounds of American Shad were in river habitats between rkm 275 and rkm 360 (Williams and Bruger 1972). Contemporary egg collection (Miller et al. 2012b) and telemetry (Dutterer et al. 2011) confirm that American Shad spawning grounds still exist between rkm 230 and a weir at rkm 415. Blueback Herring spawning area overlap American Shad and may extend further downstream but the specific habitats have not been identified (Williams et al. 1975). The mainstem run of the St. Johns River supported significant commercial fisheries of shad and river herring in the 19^{th} and 20^{th} centuries and continues to support a small recreational fishery for American Shad but not Blueback Herring.

Other Atlantic Coast Systems North of Cape Canaveral

The Nassau River is a small river restricted to the coastal plain between the St. Marys River and the St. Johns River. It has a drainage area of ~1,000 square miles (ACOE 1999). There is a passing reference to "a few fish" being taken from the Nassau River in Walburg and Nichols 1967 and no contemporary records of shads being taken in the Nassau River. Most of the stream is under tidal influence. There are no contemporary records of *Alosa* in the Nassau River.

Pelicer Creek and the Tomoka River are small coastal streams with drainages areas of 412 and 385 km^2 respectively and stream lengths of <16 km. There are considered part of the "Northern Coastal Basin" that drain into a shared lagoon (SJRWMD 2003, Brown and Orel 1995). Neither received mention of having *Alosa* fisheries in the mid-20^{th} century federal studies e.g. Walburg and Nichols 1967 and Williams and Grey 1975. Rulifson et al. 1982 extended the probable range of *Alosa* as far south as the Tomoka River. That finding was based on questionaires of then Florida Game and Freshwater Fish Commission biologists and verbal records mentioned in Williams and Grey 1975. No specimens were recorded or vouchered and no quantity of fish or confirmation of spawning of *Alosa* in these small systems south of the St. Johns River have been documented. A faunal survey in the 1990s that recorded 59 species of fish in the Tomoka River did not record any *Alosa* species.

American Shad and Blueback Herring appear to be functionally absent from the Nassau River, Pelicer Creek, and the Tomoka river. Pelicer Creek and Tomoka River are likely outide the natural range of American Shad and Blueback Herring.

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Florida Blueback Herring Fisheries

There has not been a fishery for Blueback Herring *Alosa aestevalis* in Florida for more than 30 years. Blueback Herring were likely an important commercial fishery in Florida in the 19th and early 20th centuries but catch data are unreliable. Landings of 'alewife' were reported up to a peak around 1 million pounds in the early 20th Century. However, 'alewife' were often the combined landings of Blueback Herring, Hickory Shad (*Alosa mediocris*), and Menhaden (*Brevoortia* spp.). It is unclear what proportion of the the landings was herring though herring were harvested and salted for market at the time. By the mid-20th Century, herring harvest was limited to bycatch in other fisheries that was sold as crab and catfish bait (Williams et al., 1975). Those bycatch fisheries were ultimately closed by various gear restrictions in Florida. Blueback Herring in Florida are not harvested by either commercial or recreational anglers and no harvest has been recorded since the 1960s. Almost all landings that did occur were in the St. Johns River.

There is no active management of Blueback Herring in Florida. Blueback herring are known to occur or to have occurred in the St. Johns and St. Marys rivers. Blueback Herring could possibly occur in other Atlantic Coast streams but there is none but old annecdotes of *Alosa spp.* small systems like the Nassau River, Pellicer Creek, and Tomoka River. Florida has not established a sustainable fishing plan for Blueback Herring because of the absence of any fisheries so herring fishing remains open by default. This plan is submitted as an alternative plan in fulfillment of Amendment 3 to the Interstate Fishery Management Plan for Shad and River Herring, River Herring Management.

Florida American Shad Fisheries

American Shad *Alosa sapidissima* fishery and management history is described in the American Shad Sustainable Fishing Plan for the St. Johns River System, Florida. Commercial and recreational fishing for American Shad in Florida has been restricted to the St. Johns River for several decades. There has not been any commercial landing of American Shad reported from anywhere in Florida since 2000.

Recreational Fisheries American Shad Outside of the St. Johns River

No directed recreational fishing for American Shad or incidental catch of American Shad has been documented in Florida waters other than in the middle/upper St. Johns River and adjacent Econlockhatchee River (Walburg and Nichols 1967, Walburg, 1960, and Williams and Bruger 1972). MRIP has not detected American Shad fishing or catch to occur in the coastal systems (Nassau, Pelicer,

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Tomoka). FWC has regular contact with recreational fishing clubs (e.g. First Coast Fly Fishing Club, Mosquito Lagoon Fly Fishing Club, Orlando Kayak Fishing Community) from Jacksonville to Orlando. None report fishing for American Shad outside the St. Johns River.

Regulations

Blueback herring are not specifically managed in Florida but several regulations affect the ability to harvest them should fishing occur.

New pound net licenses were no longer issued for the St. Johns River after 1982. Existing pound net licenses were non-transferable (FAC 68A-23.003) and no pound nets are operating on the St. Johns River, Florida.

The Florida Constitution was amended by voter referendum to prohibit entanglement nets larger than 500ft2 in state waters. This net ban became effective on July 1, 1995 (Art. X, Sec. 16).

As of January 1, 1997 hook and line is the only permissible gear for all *Alosa* in Florida (FAC 68B-52.001) and Blueback Herring are incorporated in the 10 fish daily bag limit for *Alosa* in aggregate (Chapter 46-52.001 [3], FAC). A saltwater fishing license is required of most anglers to fish for Alosa species in Florida.

Fishery Dependent Monitoring

A creel survey is conducted annually on the St. Johns River. The survey is focused on American Shad but occurs in an area that overlaps Blueback Herring spawning grounds. There is also a creel survey from Januarly through April that rotates between Lakes George, Monroe, and Crescent. These lakes are natural wide spots in the lower St. Johns River. No significant river herring catch, harvest, or directed effort has been recorded in these creels. There is one recent instance of Blueback Herring being reported in a creel survey. A few anglers fly fishing for American Shad in 2018 did catch Blueback Herring but they reported them as 'baby shad' that were promptly released. That was a year of high abundance (Figure 1). There is no Fishery Dependent Monitoring by FWC on the St. Marys River or the other coastal systems; Nassau River, Pellicer Creek, and Tomoka River. MRIP has not detected any Blueback Herring harvest in the small coastal systems, St. Marys, or St. Johns River. The FWC creels in the St. Johns and MRIP should continue indefinitely.

Fishery Independent Monitoring

FWC conducts spawning stock and juvenile sampling for American Shad in the St. Johns River. Both of these surveys encounter Blueback Herring. These surveys could produce a CPUE based abundance index

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for both life stages. The spawning stock survey is a standardized electrofishing survey from January through March and the time series is 2003 through the present. The juvenile survey is standard pushed trawl that runs bi-weekly from March through July. These data are reported in the annual compliance report to ASMFC (Figure 1). The pushnet is effective at capturing YOY Blueback Herring (Table 1). Georgia DNR conducts a standardized electrofishing survey on the St. Marys River that has not to date encountered Blueback Herring. There are no credible records of Blueback Herring runs in the Nassau River, Pellicer Creek, or Tomoka River so directed fishery independent sampling there is not planned.

Management Alternative

Florida seeks to leave the current regulations in the Florida Administrative Code unchanged until either 1) there is evidence that harvest of Blueback Herring is occurring anywhere in the state; or 2) there is evidence that harvest of American Shad outside the monitored St. Johns River system is occurring.

No commercial gears that could result in incidental catch of shad or river herring, such as pound nets, gill nets, or haul seines, are operating in Florida waters. No recreational fisheries are known to be catching or harvesting Blueback Herring anywhere in Florida or American Shad outside of the monitored St. Johns River.

The ASMFC TC recommended that FWC consider implementing a catch and release fishery or request an Alternative Management Plan for Blueback Herring in the absence of a sustainable fishery management plan. Blueback Herring and American Shad are effectively absent from all drainages in Florida except the St. Johns River. It is not possible to develop useful metric of sustainability in these systems. Monitoring in the St. Johns River could yield index based bench marks for Blueback Herring similar to those for American Shad if needed. However, the absence of any harvest, directed catch, or significant incidental catch preclude there being any conservation benefit to changing Florida Administrative Code to prohibit the harvest of Blueback Herring or American Shad beyond the exising gear and bag restriction that currently covers all *Alosa* species.

FWC proposes to continue its existing fishery dependent and fishery independent monitoring that focus on the St. Johns River where there are known populations of American Shad and Blueback Herring and where there is a monitored recreational fishery for American Shad. FWC will rely on the American Shad creel survey and other angler creel surveys to monitor for the existence Blueback Herring catch or harvest in the St. Johns River. FWC will rely on MRIP and contact with recreational fishing organizations to detect *Alosa spp.* recreational catch in waters outside of the St. Johns River Basin. FWC will keep informed of GADNR monitoring of the St. Marys River for information about Blueback Herring or American Shad harvest and coordinate a response with Georgia DNR if data warrant. FWC will add reporting of data collected in accordance with this alternative management plan to its annual Shad and River Herring FMP compliance report.

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If any source detects non-zero Blueback Herring harvest anywhere in Florida for three consecutive years or American Shad harvest outside the St. Johns River basin then Florida FWC will initiate a process to demonstrate sustainability for the river system where harvest has occurred. If sustainability cannot be demonstrated, Florida FWC will institute regulatory changes for these rivers systems up to harvest prohibition.

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Table 1. Example pushnet catch of Blueback Herring from the St. Johns River from the 2019 annal compliance report. It is the Geometric mean catch per standard sample of juvenile *Alosa sapidissima* (ASAP) and *Alosa aestivalis* (AAES) collected by pushnet during 2018 in the two index areas.

River Kilometer 210-249

Date	N Samples	ASAP	SD	AAES	SD
27-Mar	12	0.23	0.47	94.25	1.28
11-Apr	12	0.00	0.00	31.50	1.69
24-Apr	12	16.88	1.80	21.95	1.98
9-May	12	4.21	1.48	9.94	1.58
22-May	12	3.68	1.39	0.78	1.29
07-Jun	12	0.35	0.80	0.00	0.00

River Kilometer 125-164

Date	N Samples	ASAP	SD	AAES	SD
25-Apr	12	2.39	1.24	3.65	1.94
08-May	12	6.57	1.36	6.57	2.68
23-May	12	7.96	0.42	3.72	1.39
06-Jun	12	3.51	1.26	9.41	1.56
19-Jun	12	2.60	1.98	0.64	0.76
02-Jul	12	1.11	1.24	2.88	2.64
17-Jul	12	0.78	1.25	0.26	0.57

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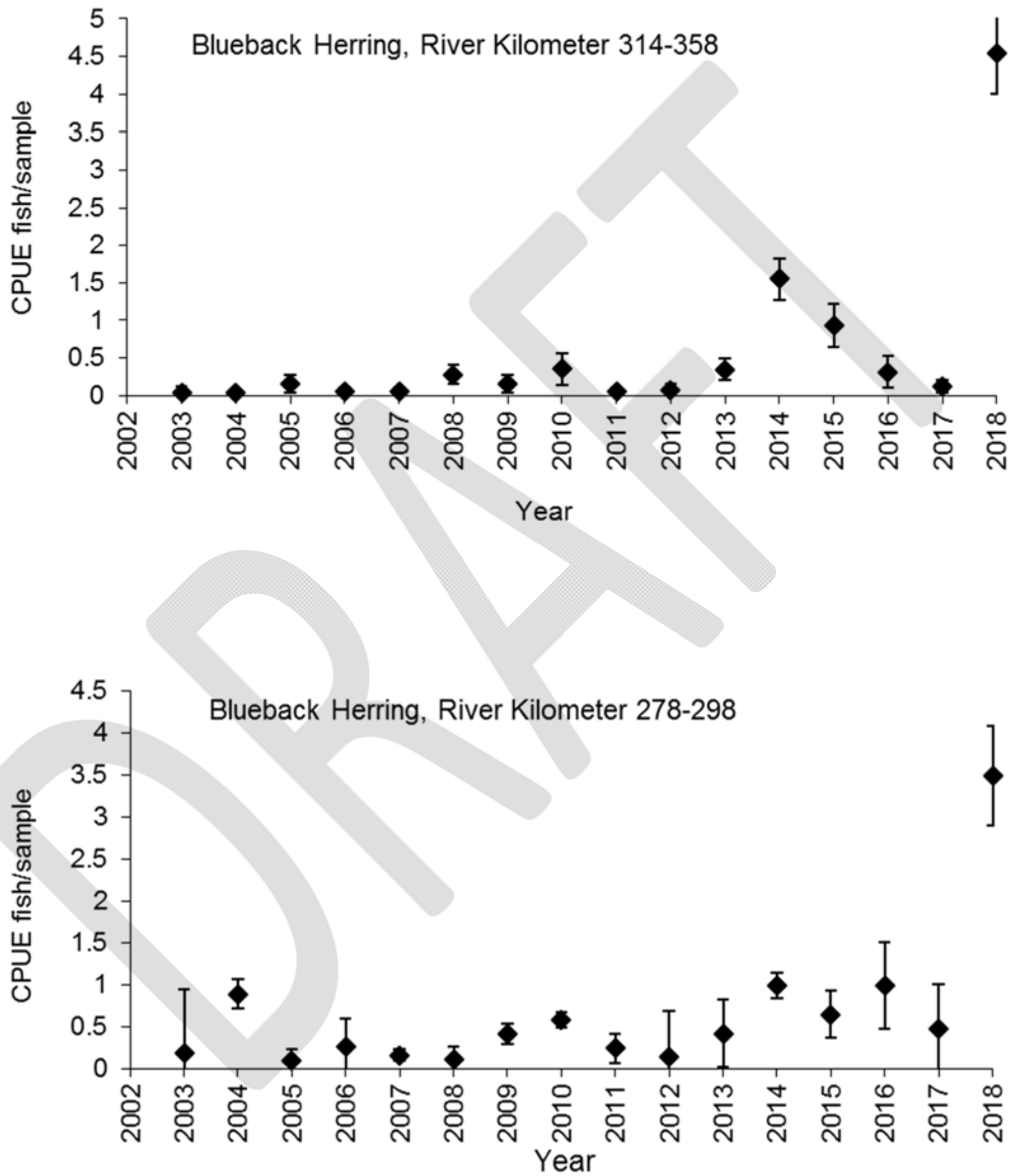
Figure 1. Annual geometric mean electrofishing catch per transect of Blueback Herring from the St. Johns River, Florida *Alosa* spawning stock survey. Each transect consisted of 10 minutes of electrofishing effort within a randomly selected 1km portion of the river. **As of 2010 the primary survey segment of the river is between river kilometer (rkm) 314 and 358 and sampling reach from rkm 278 to 298 was reduced to 20 peak-season transects.



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MEMORANDUM

TO: Shad and River Herring Management Board

FROM: Shad and River Herring Technical Committee

DATE: July 13, 2020

SUBJECT: TC recommendation on proposed change to Georgia shad SFMP

The Shad and River Herring Technical Committee (TC) met via conference call and webinar on June 25, 2020, to review a proposed change to the Savannah River sustainability metric used in Georgia's Sustainable Fishery Management Plan (SFMP) for American shad. An overview of the proposed change and a summary of the TC recommendations are included below, and a copy of Georgia's proposal containing additional detail is attached.

Technical Committee Attendance: Mike Brown (ME), Mike Dionne (NH), Ken Sprankle (FWS), Brad Chase (MA), Patrick McGee (RI), Wes Eakin (NY), Josh Tryninewski (PA), Brian Neilan (NJ), Johnny Moore (DE), Rob Bourdon (MD), Joseph Swann (DC), Ellen Cosby (PRFC), Holly White (NC), Jeremy McCargo (NC), Bill Post (SC), Jim Page (GA), Reid Hyle (FL), Ruth Haas-Castro (NOAA), Jeff Kipp (ASMFC)

Public Attendance: Ellen Waldrop (SC), Greg Sorg (SC), Kyle Hoffman (SC)

Proposed Change to Georgia SFMP for American Shad

Jim Page (GADNR) presented a proposal to change the sustainability metric used in the GA American shad SFMP. The change is proposed to address concerns that due to declines in fishery participation, the current sustainability metric is inadequate for monitoring the Savannah River American shad stock. Currently, the GA SFMP establishes a sustainability benchmark for American shad in the Savannah River based on the catch per unit effort (CPUE) index from the commercial roe drift gillnet fishery. However, in recent years drift-net participation has greatly diminished. By 2018, only one fisherman reported drift-net landings to Georgia, and in 2019 there were no Savannah River drift-net shad landed in Georgia and no effort reported; additionally there have been no landings reported for 2020.

As the lack of drift-net landings impedes the viability of a commercial CPUE-based metric, GA proposes a new metric based on fishery-independent electrofishing surveys for adult American shad each year between February and June at the New Savannah Bluff Lock and Dam (NSBLD) on the Savannah River. GADNR staff have conducted the surveys for 10 years and it is planned to continue indefinitely. GADNR proposes to replace the old sustainability benchmark with the 25th percentile of the electrofishing CPUE (61.56 fish/hour) for the Savannah River (both commercial and recreational fisheries). If the CPUE falls below this level for 3 consecutive years a management response will be triggered as described in the SFMP.

TC Discussion and Recommendations

<u>The TC recommends approval of the proposed change to the GA shad SFMP.</u> The TC evaluated the data provided and agreed that the commercial CPUE-based metric appears to be inadequate for management use. The TC agreed that the new sustainability metric based the electrofishing surveys is superior, given the time series is now 10 years and will not be impacted by changes in the fishery.

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Currently, South Carolina and Georgia manage shad in the Savannah River under different sustainability metrics; therefore the TC also recommended that each state's SFMP explicitly state that they will monitor and respond as necessary to the other state's sustainability metric. In future SFMP updates, the TC agreed that an effort should be made to improve the consistency of sustainability metrics for shared stocks/water bodies. Additionally, some TC members expressed that SFMPs should be more specific with regard to what management actions will be triggered by falling below sustainability benchmarks. These issues will continue to be discussed by the TC Task Group, which will develop additional recommendations for improving the fishery management plan guidelines or requirements for SFMPs.

Proposed Change for the Savannah River Management Index and Benchmark for the Georgia American Shad Sustainable Fishery Management Plan

Submitted by

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Introduction:

The Georgia Department of Natural Resources (GADNR) is tasked with managing the various fisheries occurring within in our state, including those for American shad. As part of that management effort, the GADNR composed a sustainable fishery management plan (SFMP) for American shad in Georgia. Adopted in 2017, the purpose of Georgia's SFMP for American shad is to allow the continuation of existing American shad fisheries in Georgia rivers where it has been determined continuation of fishing will not adversely impact the Atlantic Coast American shad stock. Georgia's SFMP fulfills requirements of Amendment 3 to the Interstate Fishery Management Plan (IFMP) for Shad and River Herring (American Shad Management).

Historically, all of Georgia's Atlantic-slope rivers (Savannah, Ogeechee, Altamaha, Satilla, St. Mary's) supported a commercial fishery for American shad. However, in recent years, commercial landings of American shad have been reported from only two (Altamaha and Savannah) of these five rivers. Of these two, the Altamaha River continues to hold the largest commercial fishing effort and yields the majority of statewide commercial landings, though some effort continues on the Savannah River. For the Savannah River, the recent declines in fishermen participation have resulted in a need to re-examine current management strategies for the river.

Need:

While commercial fishing on the Altamaha has remained relatively stable over time, commercial fishing participation in the Savannah River has declined. Reductions in fish markets, ongoing attrition by fishermen leaving the business, and fishing gear preferences by remaining fishermen have resulted in a significant shift in the dynamics of the current shad fishery on the Savannah River and the subsequent commercial landings data provided to the GADNR. As a result, management practices being employed under the current SFMP are becoming difficult to apply and are likely to become obsolete unless conditions change.

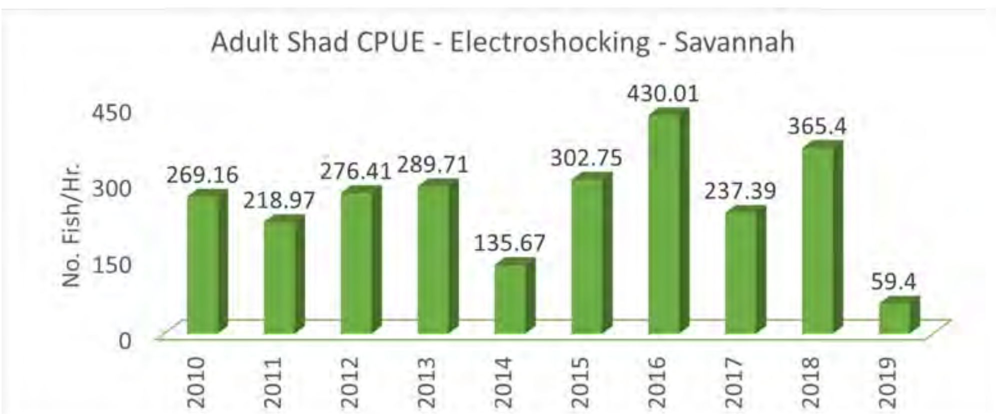
Historically, the Savannah River has had at least a handful of commercial fishermen targeting shad in the river. Though some fishermen have utilized set-nets in the river, many fishermen historically have chosen to utilize drift-nets as their preferred fishing gear. With this knowledge in mind, fishery managers determined that, based on available data (2001-15), the best management strategy for managing shad on the Savannah River would be to utilize drift-net caught roe shad landed in Georgia to develop a sustainability benchmark. Managers recommended the sustainability benchmark be a commercial roe drift gillnet CPUE of 9.03 kg shad/trip for 3 consecutive years, meaning that 3 consecutive years of having the annual CPUE fall below 9.03 kg shad/trip would trigger an appropriate management response (Table 1). This management benchmark has worked well until recently when drift-net participation in the river greatly diminished. By 2018, only one fisherman reported drift-net landings to Georgia, and in 2019 there were no Savannah River drift-net shad landed in Georgia and no effort reported. As such, the lack of drift-net landings in 2019 prevent the determination of a CPUE. While this could have been a one-time anomaly, no reported effort or landings of drift-net shad to Georgia in the Savannah River have been received for the 2020 season, which ended in March. While there is a potential for 2020 landings to be received later, fishermen are required by law to have shad landings turned in by April 10th, thus such likelihood is very minimal.

Table 1. Current Management Benchmarks and Triggers

River System	Index	Years Included in Index	Benchmark Value	Benchmark Level	Management Trigger
Altamaha (commercial & recreational)	Gillnet CPUE Index	1983-2015	1.11 shad/ft-hr	25th percentile	3 consecutive years below the benchmark
Savannah (commercial & recreational)	Commercial Roe Drift Gillnet CPUE Index	2001-2015	9.03 kg shad/trip	25th percentile	3 consecutive years below the benchmark
Ogeechee (recreational)	Electrofishing CPUE Index	2010-2015	3.7 shad/hr	25th percentile	3 consecutive years below the benchmark

As a result of the continued decline in participation in the commercial drift-net fishery in the Savannah River, GADNR staff feel it is prudent to examine other potential datasets from fishery-independent work being done on the Savannah River. Since 2010, GADNR staff have conducted electrofishing surveys for adult American shad each year between the months of Feb – June at the New Savannah Bluff Lock and Dam (NSBLD) on the Savannah River. The NSBLD is the first barrier to upstream migration on the Savannah River and is located at river km 301, just south of Augusta, GA and approximately 109 rkm above commercial fishing waters. American shad once passed through this dam via lockage, but in recent years the U.S. Army Corps of Engineers (USACE) has declared the facility unsafe to operate, so fish are not being passed through the lock at this time. The dam is now a true migration barrier and is the uppermost reach of the American shad migration in the Savannah River. When feasible, GADNR staff conduct electrofishing surveys for adult American shad during each of the aforementioned months. Stunned shad are scooped in dip nets, placed in a holding tank, and processed at the conclusion of the sampling period. Processing of fish entails collecting lengths, weights, and recording sex for each fish. A CPUE, defined as the number of fish per hour, is generated for each event and an annual CPUE (inclusive of all sampling events) is generated at the conclusion of the sampling season. Since 2010, annual CPUEs for the NSBLD electrofishing efforts have ranged from 59 fish/hour to 430.01 fish/hour (Figure 1), averaging 246.2 fish/hr during the 10-year time series.

Table 2. Annual CPUE of American Shad Captured During Electrofishing Surveys at NSBLD



Proposed Action

As a result of ongoing concerns with the changing commercial fishery dynamics in the Savannah River (declining participation by commercial drift-netters, etc.) as seen in both GA landings and SC landings, we have come to a point in time where strong consideration must be given to using a different metric to manage shad in the Savannah River. For 10 years GADNR staff have conducted the electrofishing surveys at the NSBLD in the Savanah River, and it is our intent to continue doing so indefinitely. Though numbers fluctuate annually, this survey has consistently produced adult American shad, and we believe it can be a good indicator of abundance to monitor the Savannah River stock. Utilizing the entire 10-year (2010-19) time series of data, the shad CPUE has averaged 246.2 fish/hr. Based on this, the GADNR proposes to use the 25th percentile (61.56 fish/hr) for 3 consecutive years as a sustainability benchmark for the Savannah River (both commercial and recreational fisheries). Consequently, if the adult shad CPUE falls below 61.56 fish/hr for 3 consecutive years, GADNR would evaluate and identify the causes thereof and initiate appropriate actions. Potential actions may include reducing the number of fishing days, modifying season dates, or altering legal fishing gears. In the event, such actions are not successful in reversing negative trends, GADNR would then consider closing the fishery in that river system.

Action Pros and Cons

In proposing this action and change in management metric, we have identified some of the pros and cons of such a proposed change. They are as follows:

Pros:

- Allows GADNR to use fishery-independent surveys that are independent of fishermen and thus are not affected by fishermen attrition, market changes, changes in preferred fishing gear by individuals, etc.
- Proposed electrofishing survey has been done for 10 years, so adequate time series available.
- Fish captured in electrofishing survey are of same/similar size to those harvested by commercial and/or recreational fishermen (e.g. all adults).

Cons:

- Electrofishing survey site (e.g. NSBLD) is river-level dependent and can be difficult/impossible to sample during high-water events.
- The Army Corps of Engineers (USACE) has been in discussion for several years to install a migratory fish passage at the NSBLD. Should it ever come to fruition, alteration of the current structure would allow fish to pass and potentially reduce observed catch rates.

Summary

In recognizing the pros and cons of the proposed change, we (GADNR) remain confident that this change is necessary and appropriate. We acknowledge that the NSBLD is river-level dependent and may not be able to be sampled under high-water conditions, but in 10 years of sampling we have been able to adequately complete sampling at the dam at least 9 of those years (the only exception was 2019, when water flows remained consistently high for an extended time, and we were unable to sample in March and April). Additionally, we understand that the potential exists for alterations to be made to the dam by the USACE. However, if or when these will be done is unknown and certainly are not expected in the immediate future. What is certain is that, should commercial fishery trends on the Savannah River continue, it will be challenging if not impossible to adequately monitor the stock and produce the annual commercial CPUE necessary compare to the established benchmark so we can remain in compliance with our current SFMP.