Atlantic States Marine Fisheries Commission

Shad and River Herring Management Board

February 1, 2017
9:30 – 10:30 a.m.
Alexandria, Virginia

Draft Agenda

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

1. Welcome/Call to Order *(J. Clark)* 9:30 a.m.
2. Board Consent 9:30 a.m.
    - Approval of Agenda
    - Approval of Proceedings from October 2016
3. Public Comment 9:35 a.m.
4. Consider Approval of Shad and River Herring Sustainable Fishery Management Plans (SFMPs) **Final Action** 9:45 a.m.
    - Review SFMPs and Technical Committee Memo *(B. Chase)*
        - New York – Updated River Herring SFMP
        - Delaware River Basin Cooperative – Updated Shad SFMP
        - Maine – Updated River Herring SFMP
5. Consider Approval of Florida's American Shad Habitat Plan **Final Action** 10:15 a.m.
    - Review Habitat Plan and Technical Committee Memo *(B. Chase)*
6. Elect Vice-Chair **Action** 10:25 a.m.
7. Other Business/Adjourn 10:30 a.m.

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

MEETING OVERVIEW

Shad and River Herring Management Board Meeting
February 1, 2017
9:30 – 10:30 a.m.
Alexandria, Virginia

Chair: John Clark (DE) Assumed Chairmanship: 2/17	Technical Committee Chair: Brad Chase (MA)	Law Enforcement Committee Representative: Furlong (PA)
Vice Chair: VACANT	Advisory Panel Chair: Pam Lyons Gromen	Previous Board Meeting: October 25, 2016
Voting Members: ME, NH, MA, RI, CT, NY, NJ, PA, DE, MD, DC, PRFC, VA, NC, SC, GA, FL, NMFS, USFWS (19 votes)		

2. Board Consent

- Approval of Agenda
- Approval of Proceedings from October 2016

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

4. Consider Approval of Sustainable Fishery Management Plans (Final Action)

Background

- The New York Division of Marine Resources submitted an updated Sustainable Fishery Plan (SFMP) to harvest river herring in the Hudson River and its tributaries.
- The Delaware River Basin Cooperative submitted a revised SFMP to harvest shad, which includes a request to move the mixed stock demarcation line.
- The Maine Department of Marine Resources submitted a revised SFMP, which includes a request to open the Card Mill Stream in the town of Franklin for commercial harvest.
- The Technical Committee reviewed the documents and provided recommendations to the Board.
- **Sustainable Fishery Management Plans in Briefing Materials, Technical Committee Memo in Supplemental Materials**

Presentations

- Overview of the SFMPs and Technical Committee Recommendations by B. Chase

Board actions for consideration at this meeting

- Approval of the Sustainable Fishery Management Plans

5. Consider Approval of the American Shad Habitat Plan from Florida (Final Action)
Background • Florida Division of Marine Fisheries Management submitted a Habitat Plan for American Shad in the St. Johns River, Econlockhatchee River, and St. Marys River • **Habitat Plan in Briefing Materials, Technical Committee Memo in Supplemental Materials**
Presentations • Overview of the Habitat Plan and Technical Committee Recommendation by B. Chase

6. Elect Vice-Chair

7. Other Business/Adjourn

DRAFT PROCEEDINGS OF THE

ATLANTIC STATES MARINE FISHERIES COMMISSION

SHAD AND RIVER HERRING MANAGEMENT BOARD

The Harborside Hotel
Bar Harbor, Maine
October 25, 2016

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

2. **Approval of Proceedings of May, 2016** by Consent (Page 1).

3. **Move to approve the Nemasket River, Massachusetts Sustainable Fishery Management Plan for river herring (Page 3).** Motion by Bill Adler; second by David Simpson. Motion passes unanimously (Page 3).

4. **Move to adjourn** by Consent (Page 5).

ATTENDANCE

Board Members

Terry Stockwell, ME, proxy for P. Keliher (AA)
Steve Train, ME, GA
Sen. Brian Langley, ME (LA)
Cheri Patterson, NH, proxy for D. Grout (AA)
Mike Armstrong, MA, proxy for D. Pierce (AA)
William Adler, MA (GA)
Sarah Ferrara, MA, proxy for Rep. Peake (LA)
Eric Reid, RI, proxy for Sen. Sosnowski (LA)
David Borden, RI (GA)
Dave Simpson, CT (AA)
Lance Stewart, CT (GA)
Rep. Melissa Ziobron, CT, proxy for Rep. Miner (LA)
John McMurray, NY, proxy for Sen. Boyle (LA)
Steve Heins, NY, proxy for J. Gilmore (AA)
Emerson Hasbrouck, NY (GA)
Russ Allen, NJ, proxy for D. Chanda (AA)
Adam Nowalsky, NJ, proxy for Asm. Andrzejczak (LA)
Tom Moore, PA, proxy for Rep. Vereb (LA)
Andy Shiels, PA, proxy for J. Arway (AA)
Loren Lustig, PA (GA)
John Clark, DE, proxy for D. Saveikis (AA)
Craig Pugh, DE, proxy for Rep. Carson (LA)
Roy Miller, DE (GA)
Lynn Fegley, MD, proxy for D. Blazer (AA)
Ed O'Brien, MD, proxy for Del. Stein (LA)
Rachel Dean, MD (GA)
Bill Goldsborough, MD DNR (Chair)
Rob O'Reilly, VA, proxy for J. Bull (AA)
Cathy Davenport, VA (GA)
Michelle Duval, NC, proxy for B. Davis (AA)
David Bush, NC, proxy for Rep. Steinburg (LA)
Malcolm Rhodes, SC (GA)
Ross Self, SC, proxy for R. Boyles (AA)
Pat Geer, GA, proxy for Rep. Nimmer (LA)
Spud Woodward, GA (AA)
Nancy Addison, GA (GA)
Jim Estes, FL, proxy for J. McCawley (AA)
Martin Gary, PRFC
Mike Millard, USFWS
Derek Orner, NOAA

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

Ex-Officio Members

Brad Chase, Technical Committee Chair
Larry Furlong, Law Enforcement Representative

Staff

Bob Beal
Toni Kerns
Ashton Harp
Amy Hirrlinger

Guests

The Shad and River Herring Management Board of the Atlantic States Marine Fisheries Commission convened in the Stotesbury Grand Ballroom of the Bar Harbor Club, Harborside Hotel, Bar Harbor, Maine, October 25, 2016, and was called to order at 5:48 o'clock p.m. by Chairman William J. Goldsborough.

CALL TO ORDER

CHAIRMAN WILLIAM J. GOLDSBOROUGH: This is the Shad and River Herring Management Board; here in the final hour of the day. We'll try and get through this quickly with your help. My name is Bill Goldsborough; I am your Chairman, at least for this meeting, more on that later.

APPROVAL OF AGENDA

CHAIRMAN GOLDSBOROUGH: You all have the agenda. Does anybody have any changes to the agenda? Seeing none; the agenda is approved as drafted.

APPROVAL OF PROCEEDINGS

CHAIRMAN GOLDSBOROUGH: The proceedings from our last meeting, which was in May, are in your package, too. Does anyone have any changes for them? Seeing none; the proceedings are also adopted. I will now allow public comment.

Since nothing on the agenda has had a public comment period, I will allow anything, even on the agenda to be brought up. Does anybody in the public want to address the board? Seeing none; we'll move on.

TECHNICAL COMMITTEE REPORT ON THE NEMASKET RIVER SUSTAINABLE FISHERY MANAGEMENT PLAN

CHAIRMAN GOLDSBOROUGH: Agenda Item Number 4, Review the Technical Committee Report on the Nemasket River Sustainable Fishery Management Plan, and that will be –

MR. BRAD CHASE: Good afternoon, I am going to present a Sustainable Fishery Management Plan to harvest river herring from the Nemasket River in Massachusetts. It is a joint plan developed by the Middleborough-Lakeville Herring Fishery Commission and the Massachusetts Division of Marine Fisheries.

It is the first fishery that has been proposed to open since the state closed all fisheries in 2005. First, let me run through the present status of river herring in Massachusetts very briefly. We have about 80 runs in the state and 33 of these runs have monitoring. About 14 of these have a census level approach, where they use electronic counters or video stations; and of these, we sample in eight of these for biological data.

At the Nemasket River it is a volunteer visual count, and most of the counts in the state have this level of counting. There are about 33 of these that have this type of counts. You can see the red brackets here show the different coastal advantage areas in Massachusetts. We've tried to have a couple counts in each of these major areas.

There are only four counts that have any real duration to them. We have four counts that go back 20 years or more. What I've done here is combine those counts to show an index for those different areas. What you can see, the start of the series going back to 1996, the numbers have been about between a million and two million herring coming back each year. Then you can see a decline around 2002, and that really was seen throughout the east coast as herring runs declined. It led to a lot of the closures. We closed our fishery after the 2005 season. After that you can see a very modest increase and improvement, and then a ramping up around 2011 to 2012. That led to some optimism and some interest in possibly looking at opening harvest again.

We received a request from the Nemasket River herring fishery in 2013 to consider opening the fishery. It is probably the largest run in the state, it has the most available spawning and nursery habitat; about 5,000 acres. It is a very popular long term herring run. They have a herring festival, it is a two-day festival that draws 2 to 3,000 people each year, and they have one of the longest counts at 21 years.

Working with the commission, we developed a plan. The metrics are fairly straightforward. The sustainability measure is based on the visual herring count. This is a random stratified design, and it uses a sustainability target of 10 percent of the time series mean as the targeted harvest level. There is also a primary action threshold at 25th percentile of the run count series.

What happens, if there are two consecutive years at or below this level, the harvest would be cut in half to 5 percent of the time series mean. If there were three consecutive years below this threshold, the harvest would cease. Here is the run count that forms a basis for the plan; 1996 to 2015. What you can see is some fluctuations before the ban.

The ban is shown at 2006, and you can see that large decline around 2002 that prompted the ban. Since then, we've seen a very modest increase and then a ramping up in recent years; and for the past four years, the numbers have been over a half a million fish per year in the count. You can see the time series mean running across the data series, the 75 percent of the time series mean as well as the first quartile.

The blue line running across the bottom is the targeted 10 percent of the time series mean, so that would be the harvest amount. This slide just adds 2016. Those numbers didn't go into the plan, because the plan was already developed before those numbers were available. But you can see that total count estimate was, sitting at the time series mean, about 560,000 fish. It really wouldn't change things if you add this year.

You can see the last five years have been at or above the time series mean; whereas the previous nine years were below. We have had some modest improvements. The management that's proposed is similar to what was done in previous years. They used to have the run open four days a week for the entire season, allowing 48 fish per permit holder per week, unlimited resident permits, and then 2 to 300 permits for nonresidents.

Now what's proposed again is to harvest 10 percent of the time series mean; about 55,000 river herring and again have unlimited permits for residents of the two towns; 250 permits for nonresidents; a five-week season that is open three days a week and then a bag limit of 20 fish per permit holder per week; and also to have daily catch tickets to document each harvest event.

With these numbers, the expected harvest would be five weeks times 20 fish per permit holder or 100 fish per permit holder. If there were 900 permits, the total maximum harvest would be 90,000 fish. What is assumed in this plan is there would be a 50 percent harvest rate; the maximum potential harvest, which would be 45,000 fish, which would keep the harvest under the 10 percent of the time series mean. The Technical Committee for shad and river herring received this proposal, they reviewed it. We had a conference call on October 2nd, to discuss it.

The TC wanted to have a single option for management. There were three options that were proposed. What happened, they asked for a revision for that management scenario where there would be a more conservative approach, to try to avoid overharvest. That was put into the plan that is before the board today. I would be happy to take any questions.

CHAIRMAN GOLDSBOROUGH: Any questions? Emerson.

MR. EMERSON C. HASBROUCK: Just looking at the chart that's in the documents and I see that the Nemasket River flows northward right, up towards Bridgewater. Where does it meet tidal waters?

MR. CHASE: It's a tributary to the Taunton River, and so it flows northward to the Taunton River, which then flows south again towards Mount Hope Bay.

CHAIRMAN GOLDSBOROUGH: Any other questions for Brad? Very good, you guys must be hungry. Okay, let's move on to considering approval of the plan. Bill.

MR. WILLIAM A. ADLER: **Should I make a motion that this board approves the request of the Nemasket River? Would that be appropriate? I'll so move.**

CHAIRMAN GOLDSBOROUGH: Thank you, Bill, is there a second? Second Dave Simpson. Let's get that up on the board. Is there any discussion? Mike.

MR. MICHAEL ARMSTRONG: I would urge you to approve this very conservative plan. At 10 percent harvest, it is less harvest than any plan you've approved yet, and the local commission is really tremendous stewards of this resource. This will have the most eyes on the harvest of anything you've approved.

MR. TERRY STOCKWELL: As a Commonwealth northern border, we have a long history of successful sustainable fishery management plans that the communities have supported and enabled. I one hundred percent support this motion.

MR. ADAM NOWALSKY: I just noted the TCs comment about the revised management option on Page 7. Would this motion be that revised option, or would we need to modify it accordingly?

MR. CHASE: Yes, the plan has been revised already, so it would be for the present single option for management.

CHAIRMAN GOLDSBOROUGH: Any other discussion? Are we ready to vote? Let's read the motion into the record. Move to approve the Nemasket River Massachusetts Sustainable Fishery Management Plan for River Herring; motion by Mr. Adler, second by Mr. Simpson. **All in favor, please raise your right hand; opposed, abstentions and null votes. The motion passes unanimously.** I hope you all weren't slighted by the lack of a caucus. It didn't seem necessary.

TIMETABLE FOR THE FIVE-YEAR UPDATE OF SHAD AND RIVER HERRING SUSTAINABLE FISHERY MANAGEMENT PLANS

CHAIRMAN GOLDSBOROUGH: Okay, let's move on to discussing the timetable for the five-year update of the Sustainable Fishery Management Plans. Ashton.

MS. ASHTON HARP: There was a TC meeting where we discussed the Nemasket River Sustainable Fishery Plan, and we also discussed the timetable for updating all of the sustainable fishery management plans for river herring and shad. The TC decided that they are going to do the updates in 2017, and the board will be presented with one of two kinds of reports.

The SFP could be updated, which means the same measures but new data. In the Executive Summary, there will be specifically a summary that will say how the existing sustainable measures have supported harvest without diminishing potential future stock reproduction and recruitment. Alternatively, a state can submit a revised SFP which may include revised sustainability targets and/or new rivers.

For river herring, you'll see there are six states with SFPs. Maine and New York will present their SFMPs at the February board meeting. The other states, North Carolina and South Carolina, will present at the May board meeting.

For the shad SFPs, all states are going to present in May, except for the Delaware River Basin, which is actively underway updating their plan. It will be presented at the February board meeting. I am presenting this to you guys now, because it is a considerable amount of TC work to do this, and I just want to make sure the Board is aware of the timetable in 2017. With that, I'll take any questions.

CHAIRMAN GOLDSBOROUGH: Questions for Ashton? Michelle.

DR. MICHELLE DUVAL: Ashton, I'm just wondering if the TC plans to discuss, you know the states and jurisdictions have used the data that they think are the most appropriate to develop their sustainable fishery plans, if there has been any thought or consideration to the compliance monitoring elements.

Perhaps, while reviewing those plans looking at those, because not all states and jurisdictions are necessarily using that information that is being collected. I know that we're coming up on an update of the river herring stock assessment, as well. I just didn't know if that had entered into the conversation at all.

MS. HARP: You're wondering if the update is going to be included in the compliance materials and the FMP reviews.

DR. DUVAL: No, I'm just wondering if the Technical Committee is planning to have a conversation about perhaps the utility of all the information that's currently being collected in the compliance reports, as the TC is reviewing those sustainable fishery plans. I guess I would just encourage the TC to perhaps flag any existing compliance monitoring elements that may not be necessary in the future; that's all.

MS. HARP: The TC is meeting in-person next. This can be added to the docket for TC consideration. Because I'm new to this fishery and I have started reviewing all of the compliance reports, actually multiple times, to try and wrap my head around them as well as the SFPs. I do see that there is overlap and information and efficiencies could be made. I recognize that and it can be added to the TC agenda.

CHAIRMAN GOLDSBOROUGH: Any other questions? Very good, let's move on.

REVIEW MID-ATLANTIC FISHERY MANAGEMENT COUNCIL DECISION ON POTENTIAL MANAGEMENT OF SHAD AND RIVER HERRING

CHAIRMAN GOLDSBOROUGH: I think most of you know under Agenda Item 7 that the Mid-Atlantic Council had been grappling with the question of bycatch of river herring and shad in certain offshore fisheries; and that they recently took this issue up again.

What they decided was that management of river herring and shad through a council FMP is not warranted. But they committed to working with partners on river herring and shad conservation and management going forward. Their decision to not add river herring and shad to the mackerel/squid/butterfish plan was based primarily on four factors; first, that they are already managed by this commission, you.

Second, their view that council catch caps have kept incidental catch relatively low compared to historic levels. Third, that they found no evidence that river herring and shad were targeted in federal fisheries, and finally their view that an FMP would not substantially improve condition of river herring and shad stocks.

That is a summary of what transpired on this at the recent Mid-Atlantic Council level. I don't know if anybody who participated in that wants to add anything or not. We have the council Chair, Mike Luisi here if we want to draft him into further comments, but any thoughts from the board? Very good, pretty straightforward; okay, let's move on to other business.

OTHER BUSINESS

CHAIRMAN GOLDSBOROUGH: Does anybody have any items of other business to bring to the board? I have one item, and that is to let you all know that this is my last meeting. I am retiring at the end of the year, which is very exciting and very scary at the same time. But just so you know, your next meeting will be chaired by our Vice-Chair, John Clark, from Delaware. Thank you, John.

ADJOURNMENT

CHAIRMAN GOLDSBOROUGH: Does anybody have any other business to bring to the board? Yes, Bill Adler.

MR. ADLER: Motion to adjourn?

CHAIRMAN GOLDSBOROUGH: Thank you, Bill. This meeting is adjourned.

(Whereupon the meeting adjourned at 6:07 o'clock p.m. on October 25, 2016.)

Shad and River Herring
Sustainable Fishery Management Plans

Systems with a sustainable commercial/recreational fishery are defined as those that demonstrate their shad or river herring stock can support a fishery that will not diminish potential future stock reproduction and recruitment. In order to maintain a fishery, states and jurisdictions are required to submit a Sustainable Fishery Management Plan to the Shad and River Herring Management Board. The plan must include:

1. Definition of sustainability
2. Sustainability targets; targets should include a quantifiable means of estimating improvements in populations.
3. Proposed timeframe to achieve stated objectives
4. Describe annual monitoring
    i. Data to substantiate the claim of sustainability include, but are not limited to, repeat spawning ratio, spawning stock biomass, juvenile abundance levels, fish passage counts, hatchery contribution to stocks and bycatch rates.

The existing Sustainable Fishery Management Plans (SFMP) were implemented five or more years ago. In 2017, states are reviewing existing SFMPs and submitting updated or revised SFMPs for Technical Committee and Board review. The following timeline indicates when the Board will review state-specific SFMPs.

Updated SFMP: The state is recommending status quo management, but has updated the data (landings, monitoring, etc.) within the SFMP.

Revised SFMP: The state has revised the sustainability targets and/or added new rivers.

2017 Timeline for Board Review of Updated or Revised SFMPs

2017 Board Meeting	State that will Present a New or Revised SFMP
January	
RH	Maine, New York
Shad	Delaware River Basin Cooperative
May	SFPs Due March 15th
RH	South Carolina
Shad	Georgia, Florida
August	
Shad	South Carolina, PRFC
October	
RH	North Carolina
Shad	Connecticut, North Carolina

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

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Executive Summary

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 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 shad in the Delaware River.

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. 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. 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.

<u>Fishery Participation</u>: 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.

<u>Landings</u>: 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.

<u>Biological Data</u>: 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 $u \le 0.10$, 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. 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. 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. 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

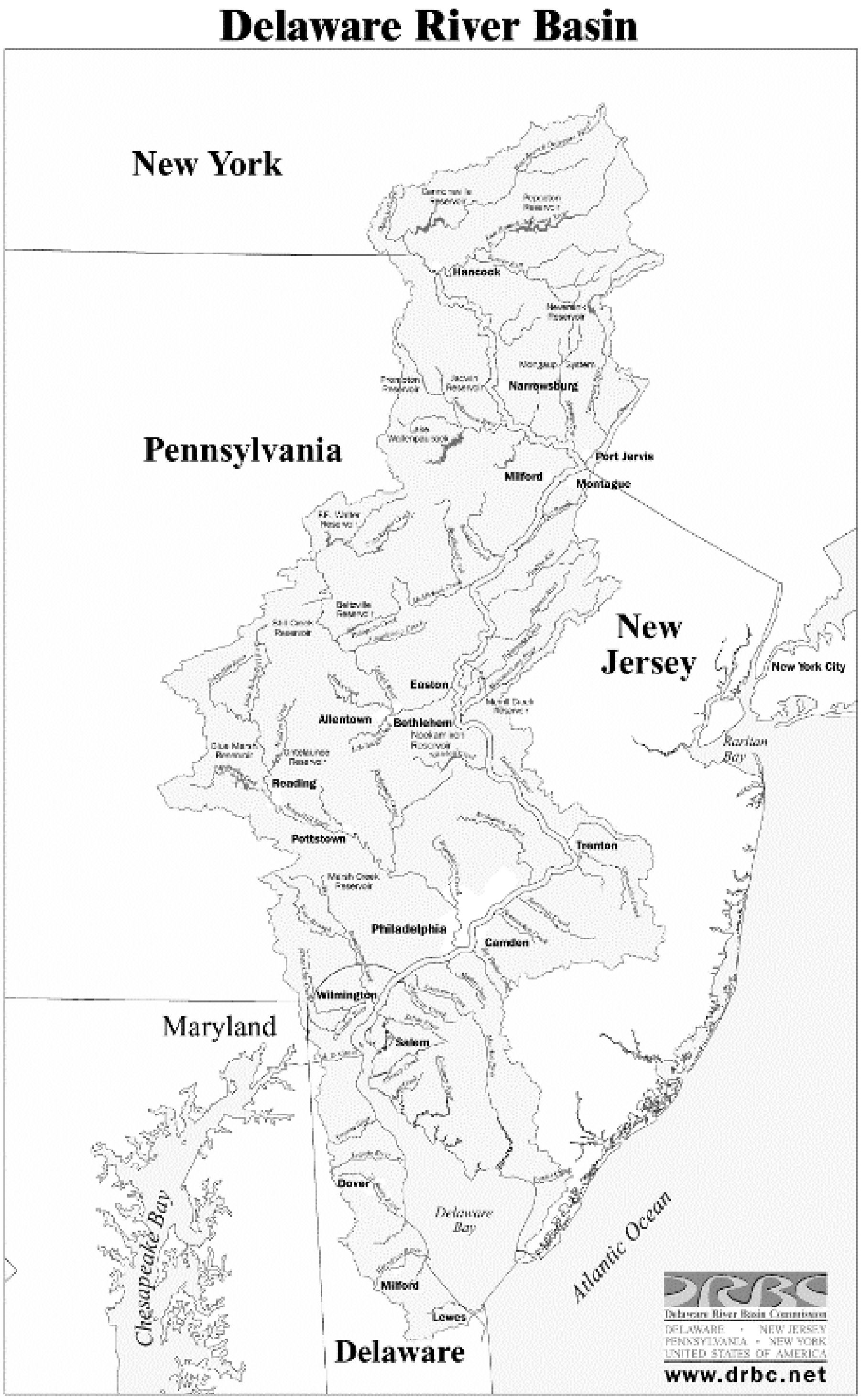


Figure 1. The Delaware River watershed.

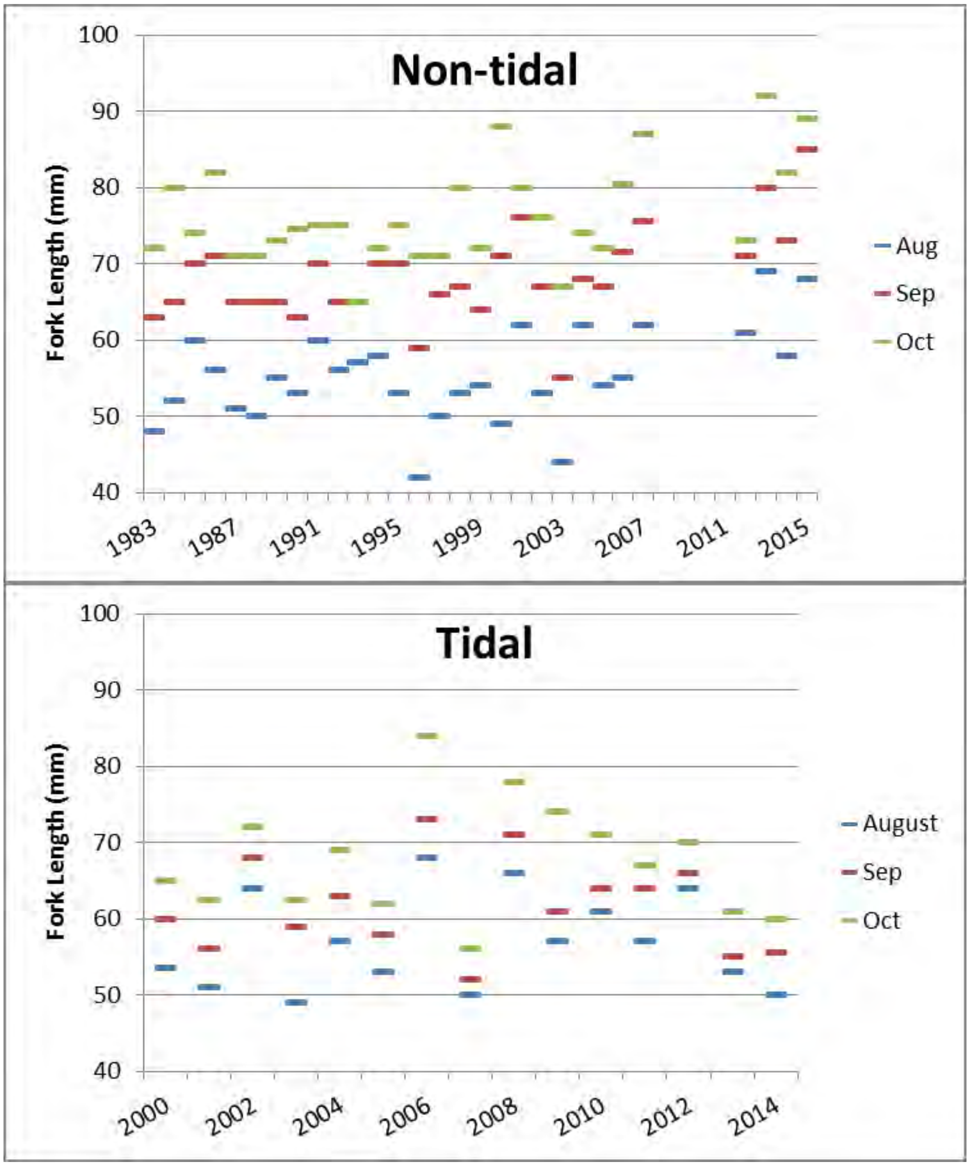


Figure 2. Distribution of YOY American Shad median fork lengths by month for the non-tidal and tidal beach seining. Medians are inclusive of those fork lengths collected from the traditional non-tidal sites: Trenton, Phillipsburg, Delaware Water Gap and Milford Beach.

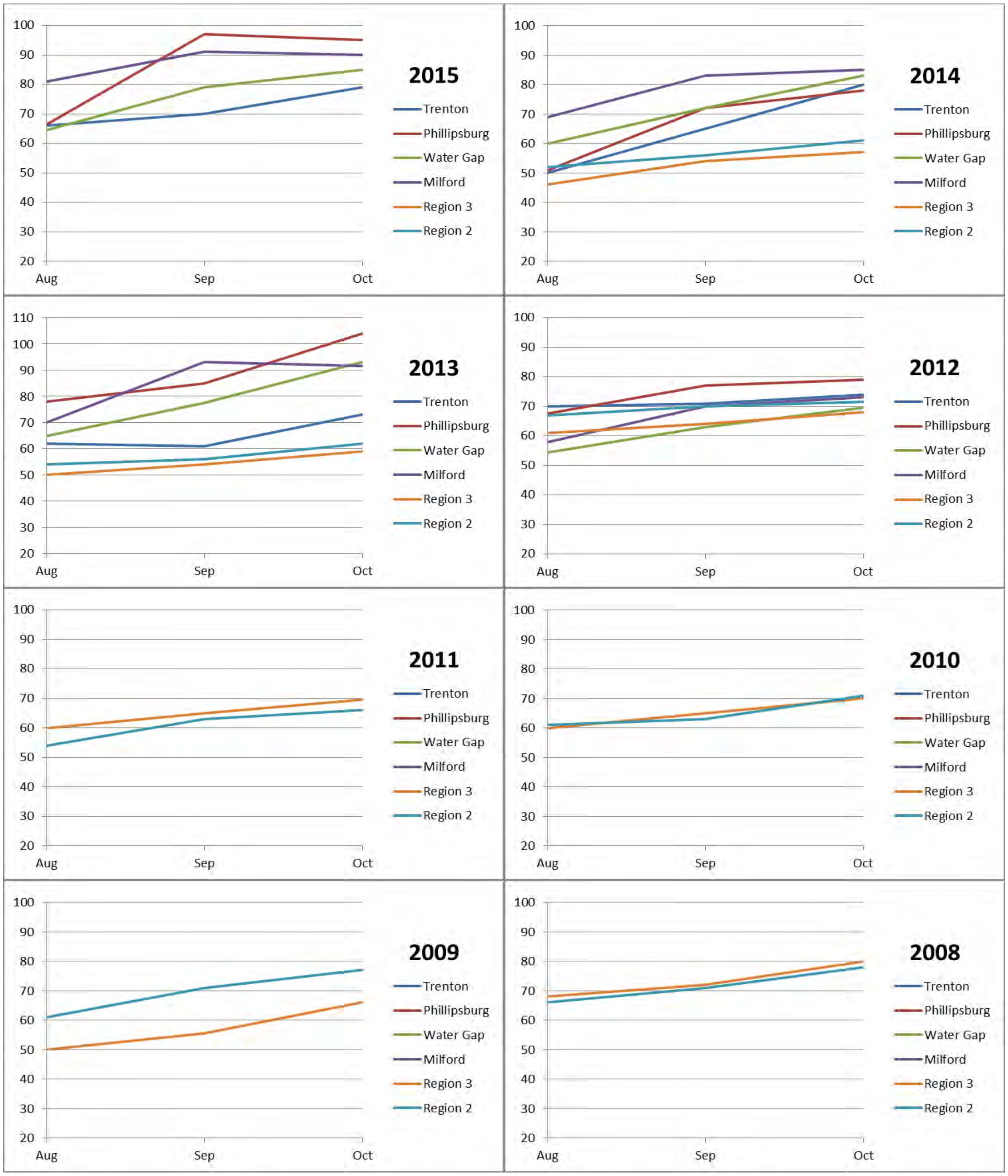
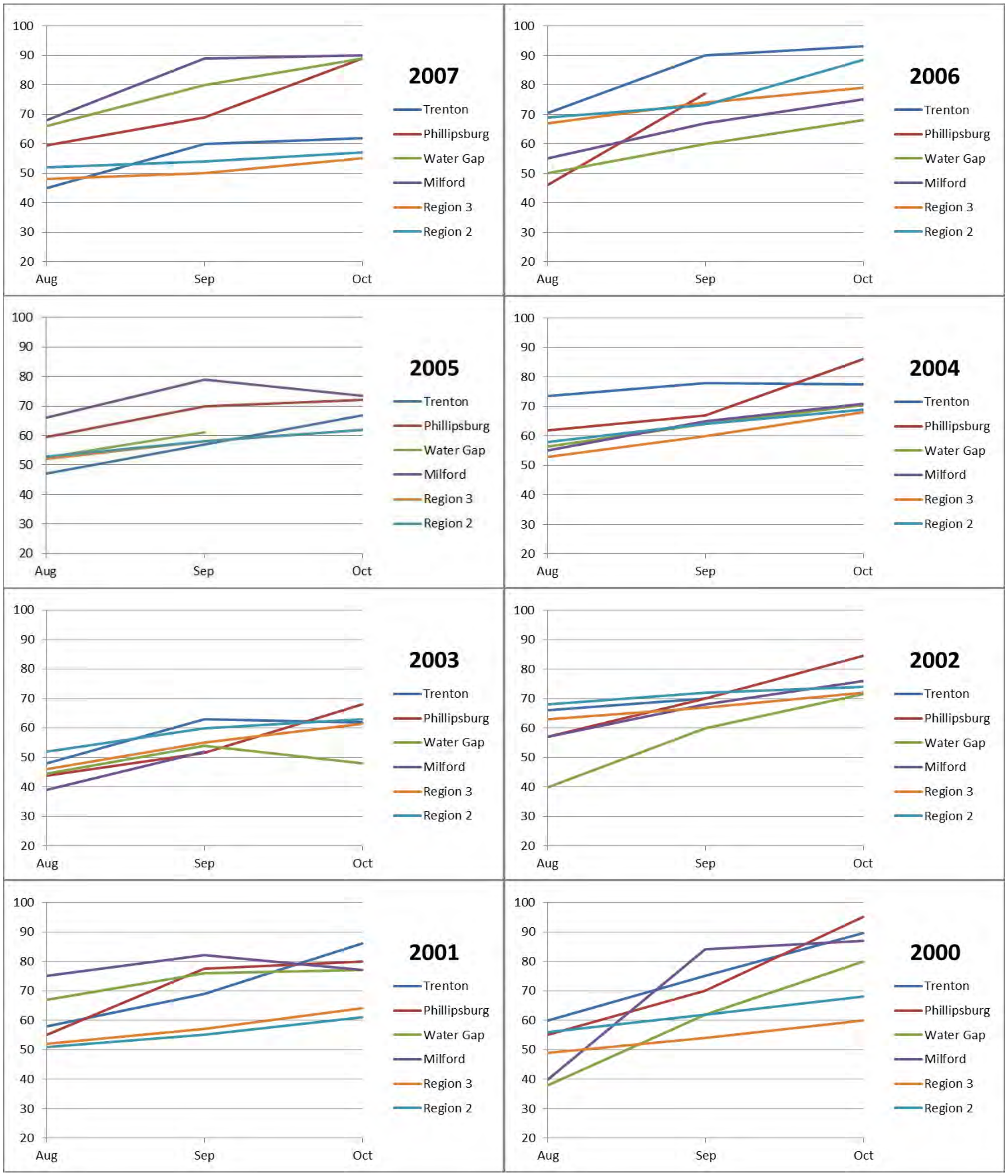


Figure 3. Distribution of YOY median fork lengths, by month and location, for the non-tidal and tidal beach seining.



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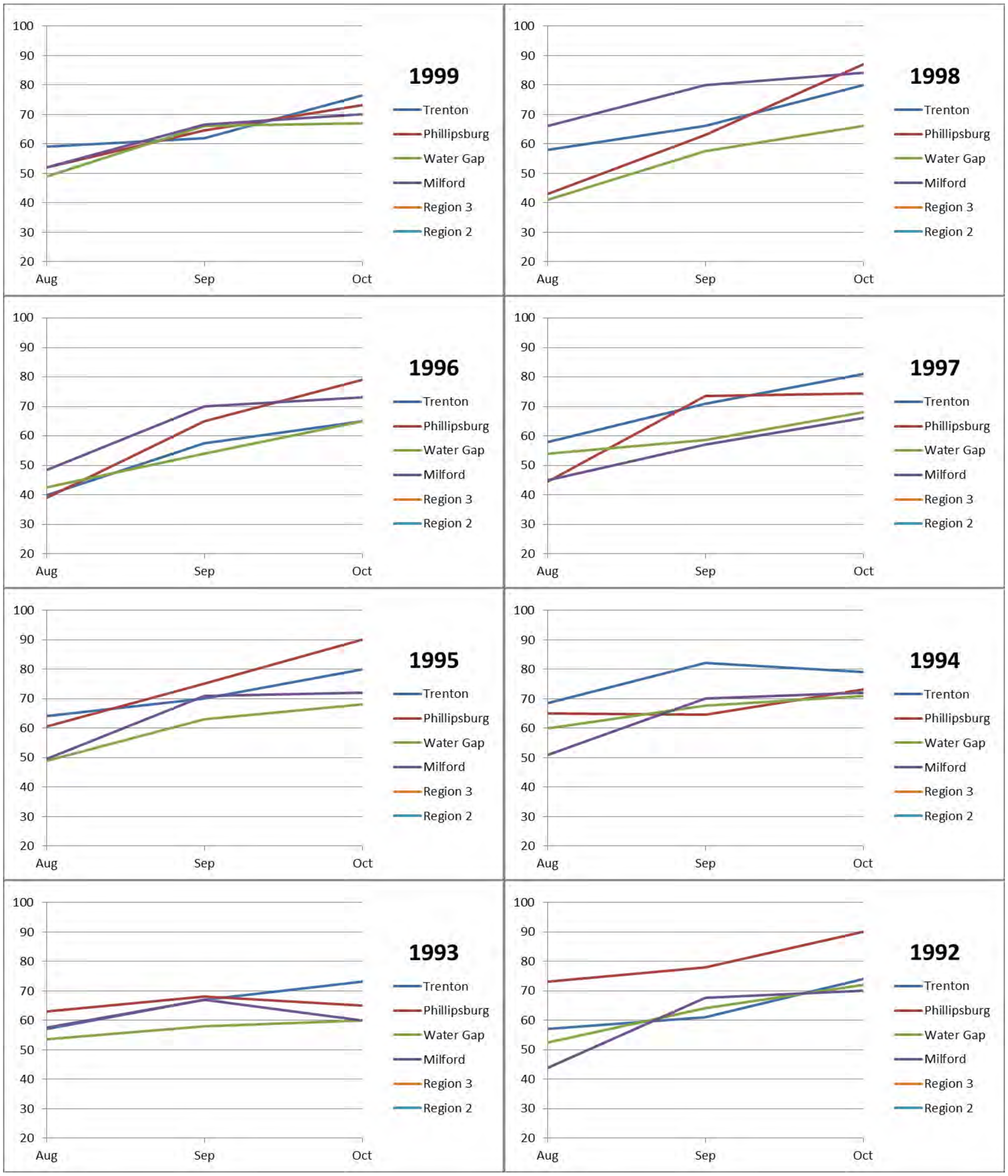

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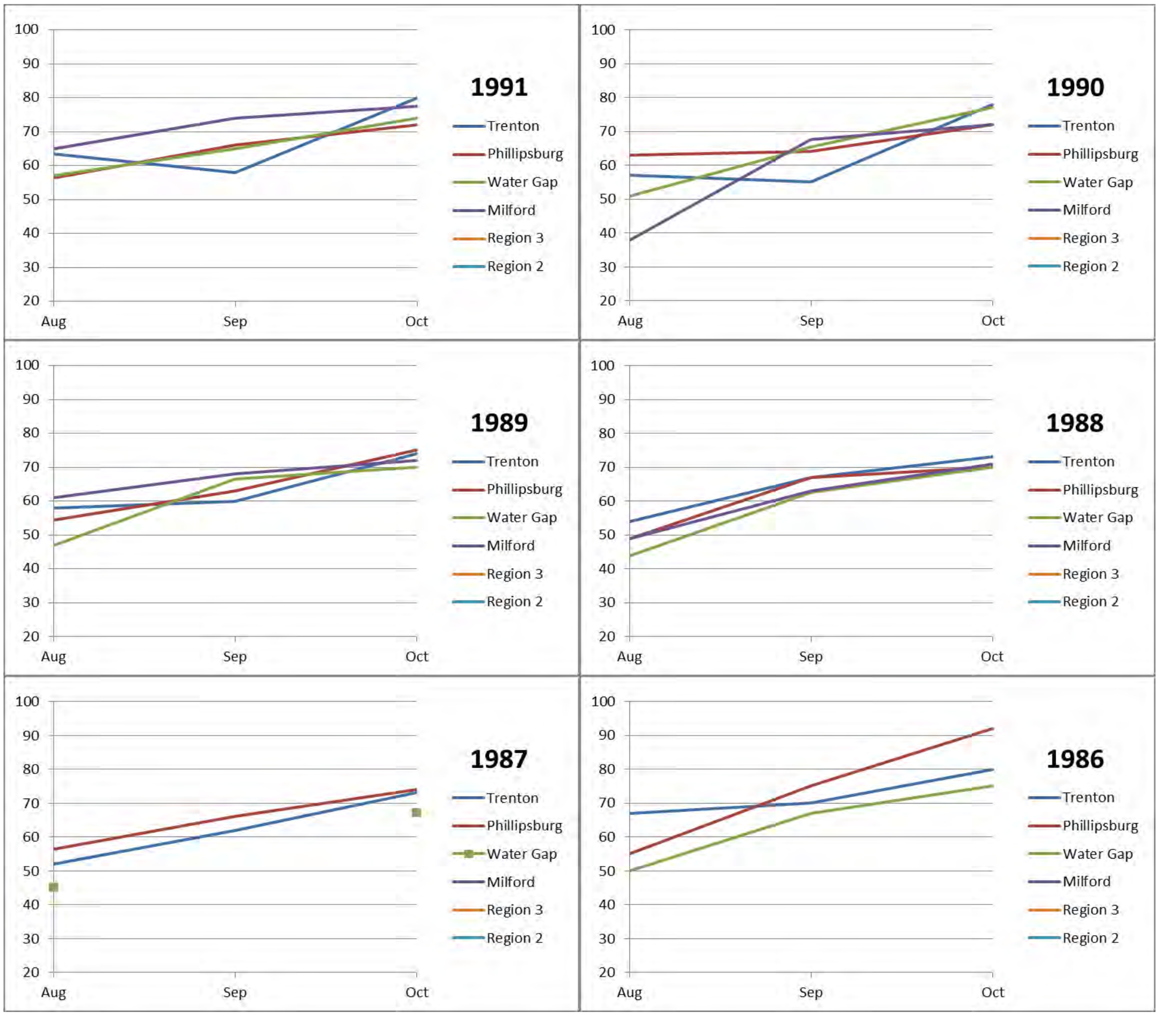

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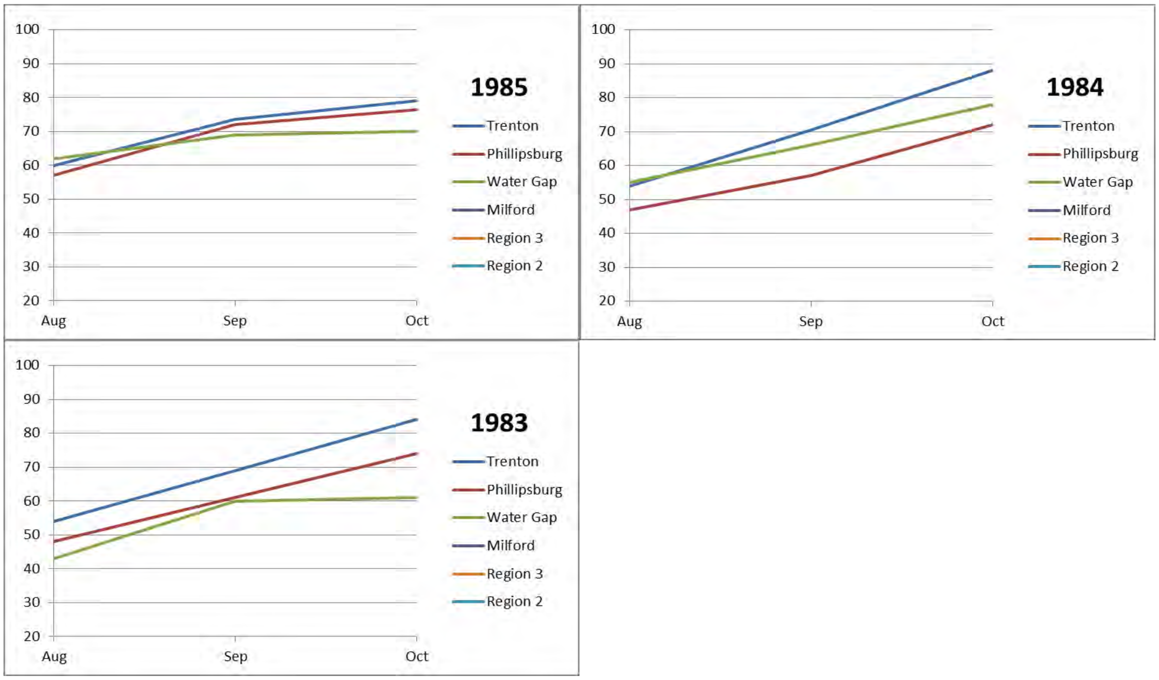

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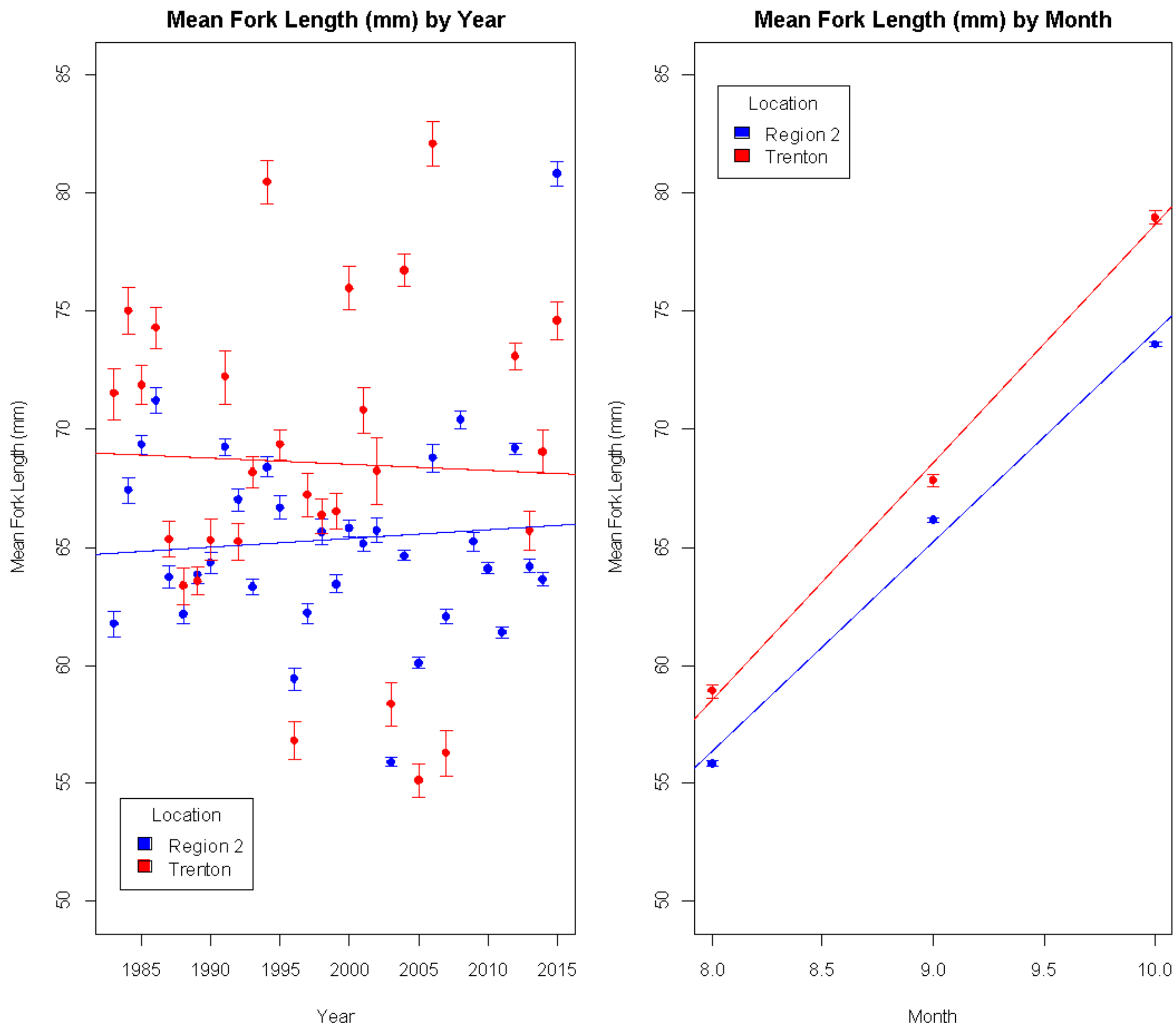


Figure 4. Comparison of YOY shad fork lengths between the upper estuary (Region 2) and Trenton sites.

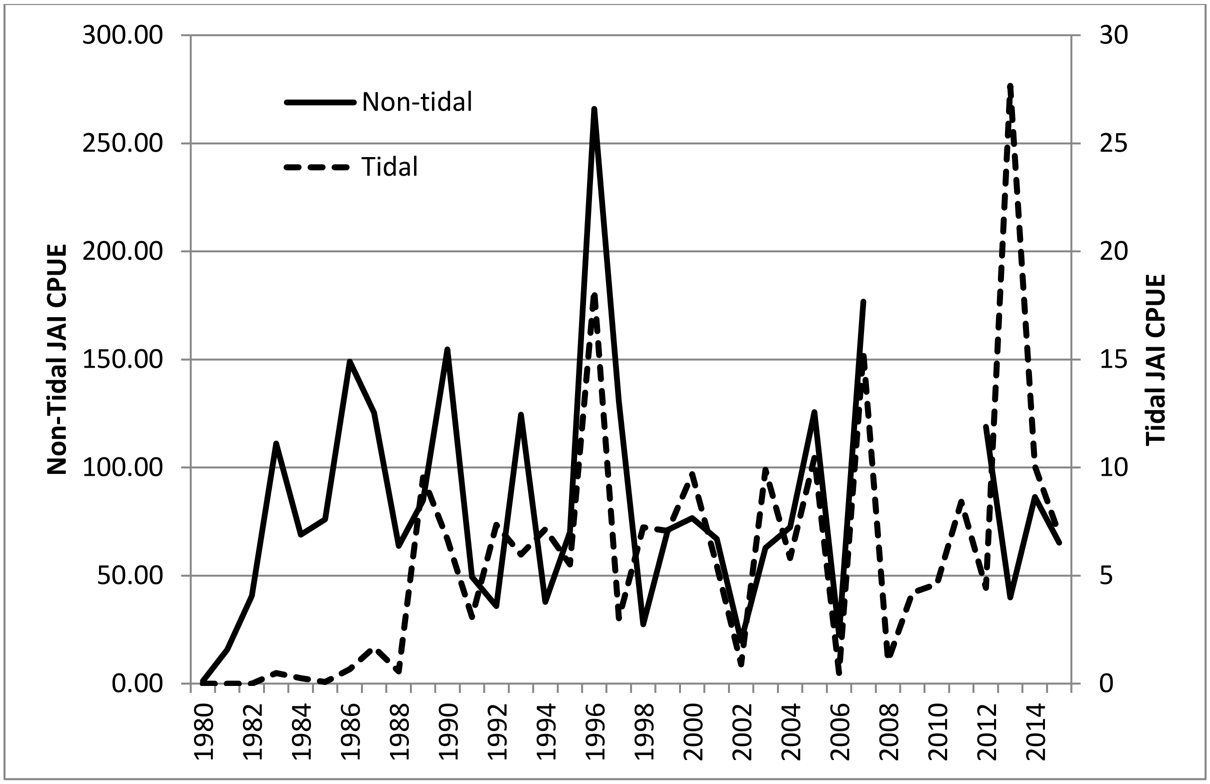


Figure 5. Non-tidal (based on the four historic sites Trenton, Phillipsburg, Delaware Water Gap and Milford Beach) and tidal Delaware River American Shad JAIs both expressed as Geometric means: 1980 – 2015.

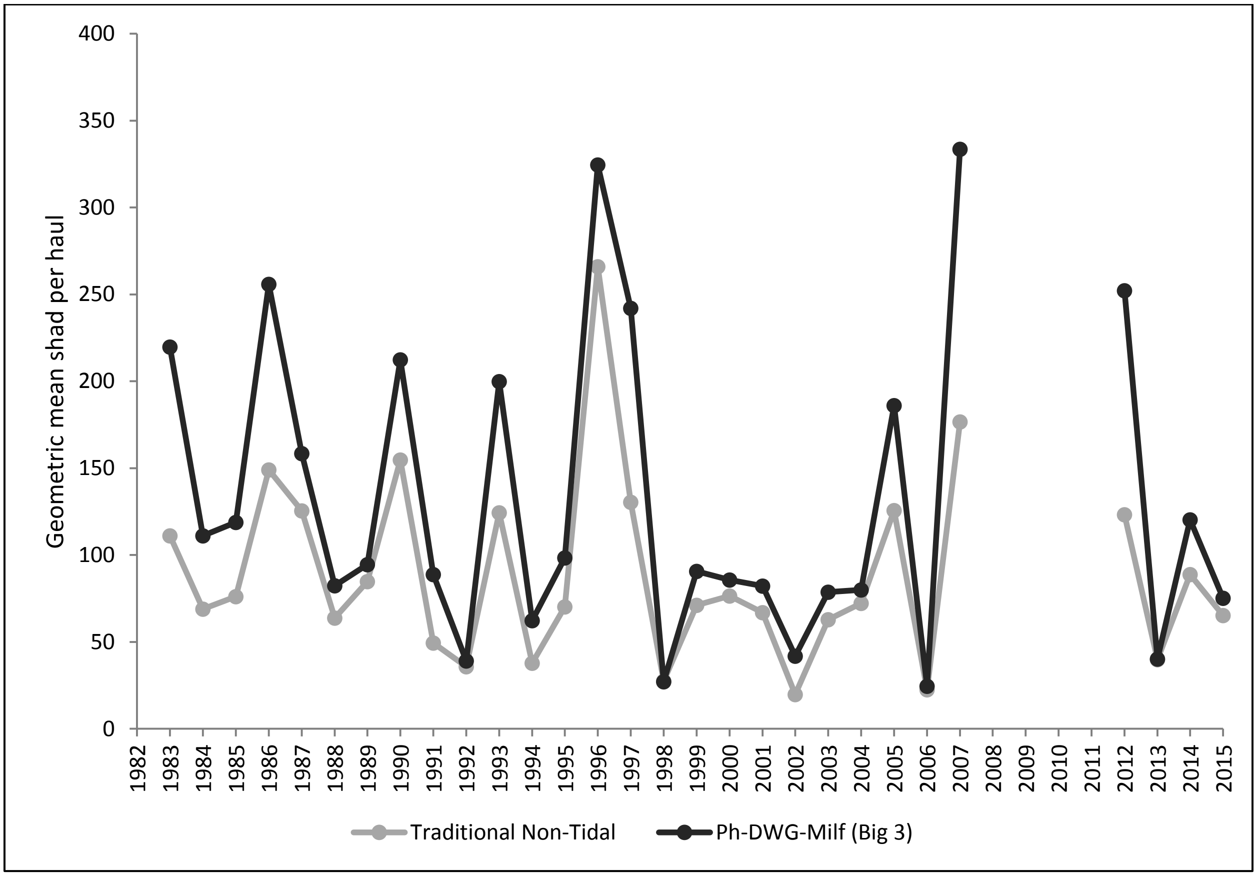


Figure 6. Geometric means for the non-tidal JAI from the traditional (i.e., Trenton, Phillipsburg, Delaware Water Gap and Milford Beach) and new non-tidal (i.e., Phillipsburg, Delaware Water Gap and Milford Beach, collectively informally referred to as the Big 3) sampling sites.

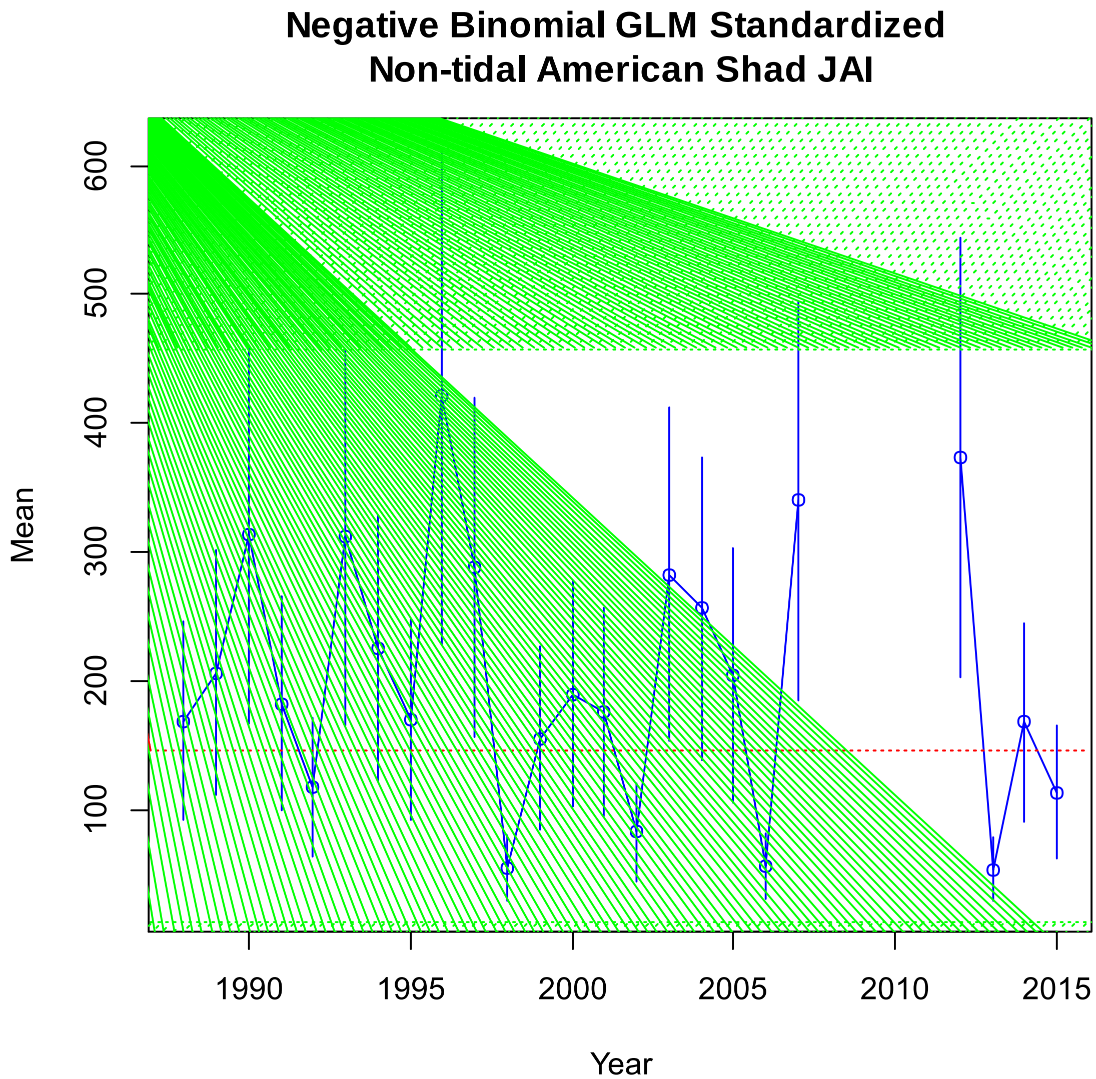


Figure 7. The Delaware River non-tidal American Shad JAI (GLM) with 25th percentile benchmark (red dotted line) from 1988 – 2015 with 95 % confidence intervals. The green boxes represent our survey detectability over a five year period with power = 0.80. Only the Big 3 non-tidal sites (i.e. Phillipsburg, Delaware Water Gap and Milford Beach) were inclusive in this analysis.

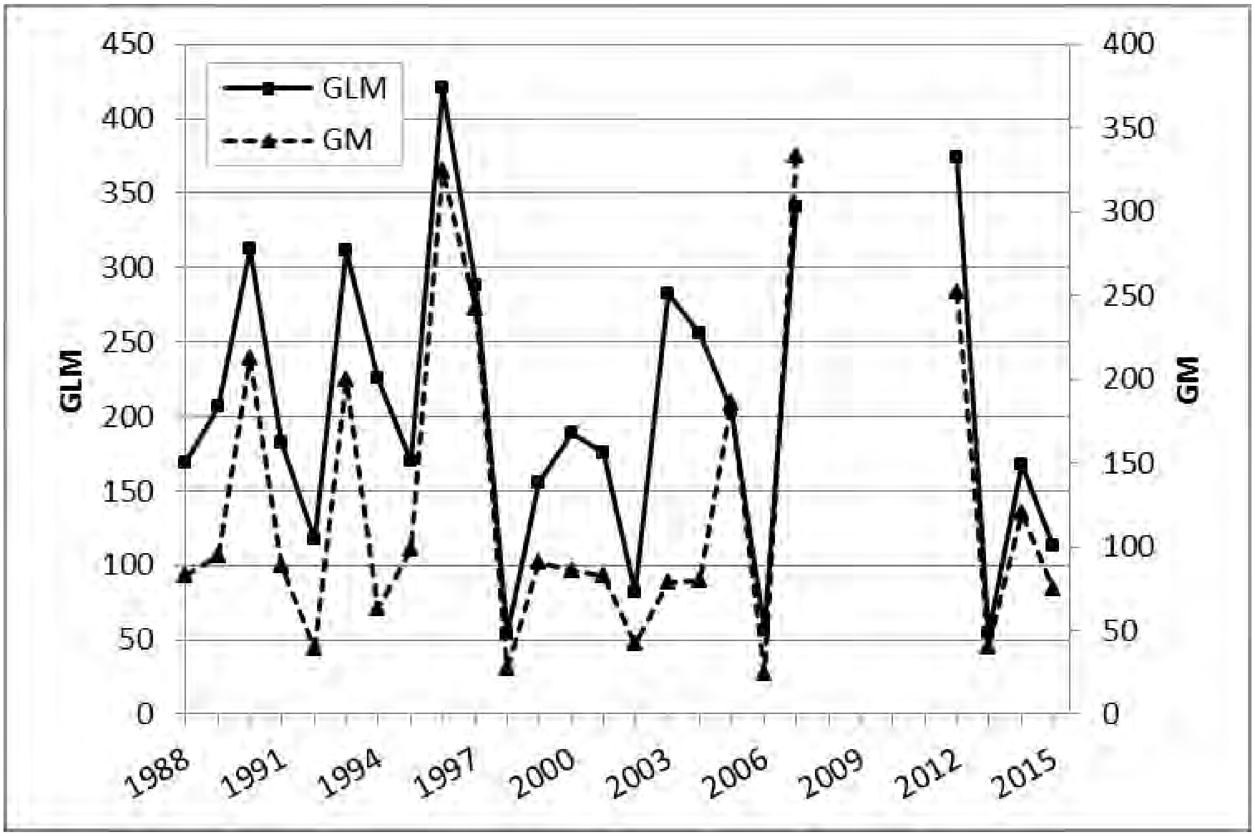


Figure 8. Comparison of non-tidal JAI as represented by geometric mean (GM) and generalized linear model (GLM) from Phillipsburg, Delaware Water Gap, and Milford Beach from 1988 to 2015.

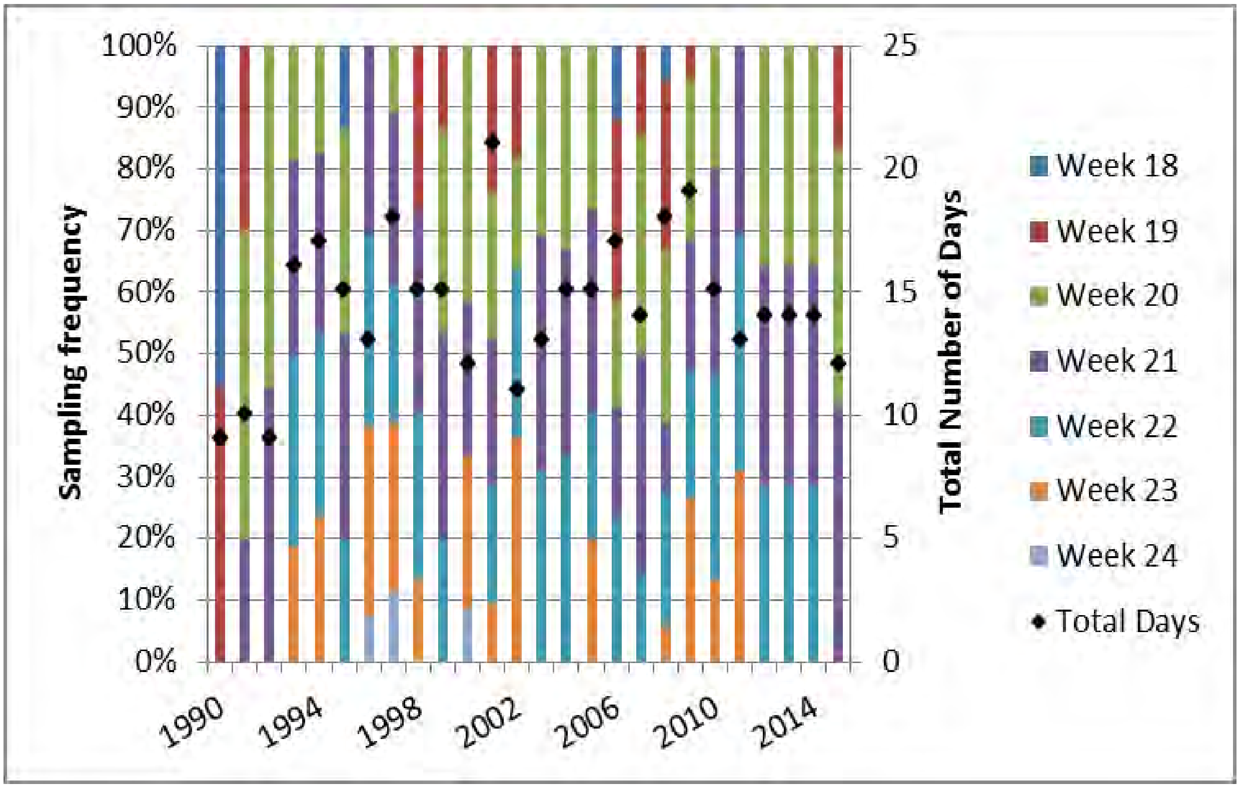


Figure 9. Sampling frequency and total number of days for gill netting American Shad at Smithfield Beach.

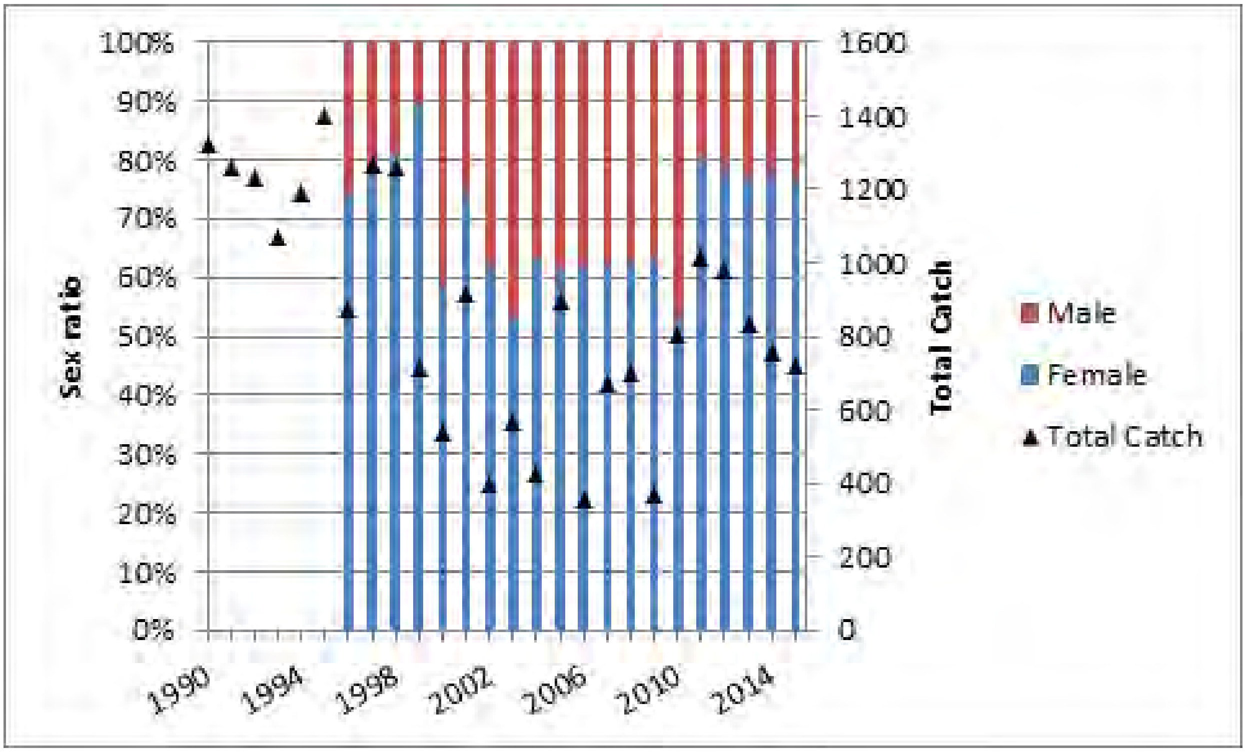


Figure 10. Total catch of American Shad at Smithfield Beach, by gender. No biological data were recorded prior to 1996. Observed sex ratio is dependent on the frequency of mesh sizes deployed in any given year.

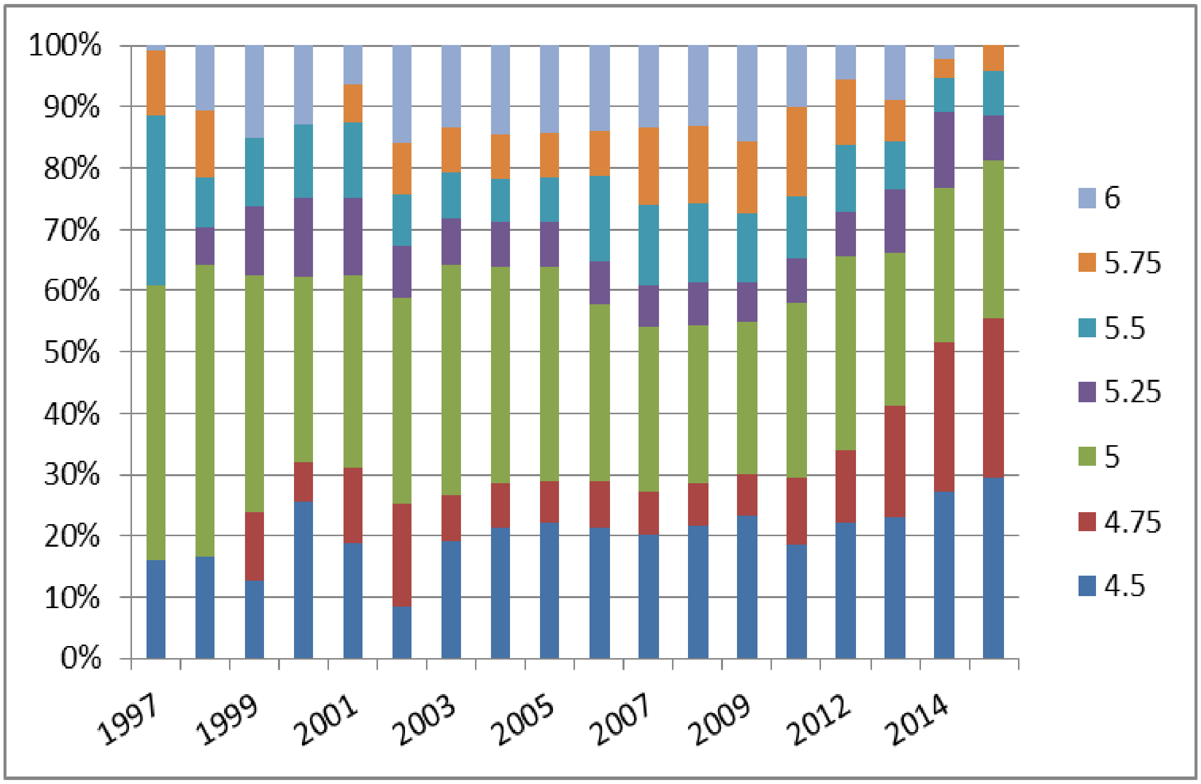


Figure 11. Percent frequency of gill net deployment of stretch mesh sizes (stretch inches) at Smithfield Beach.

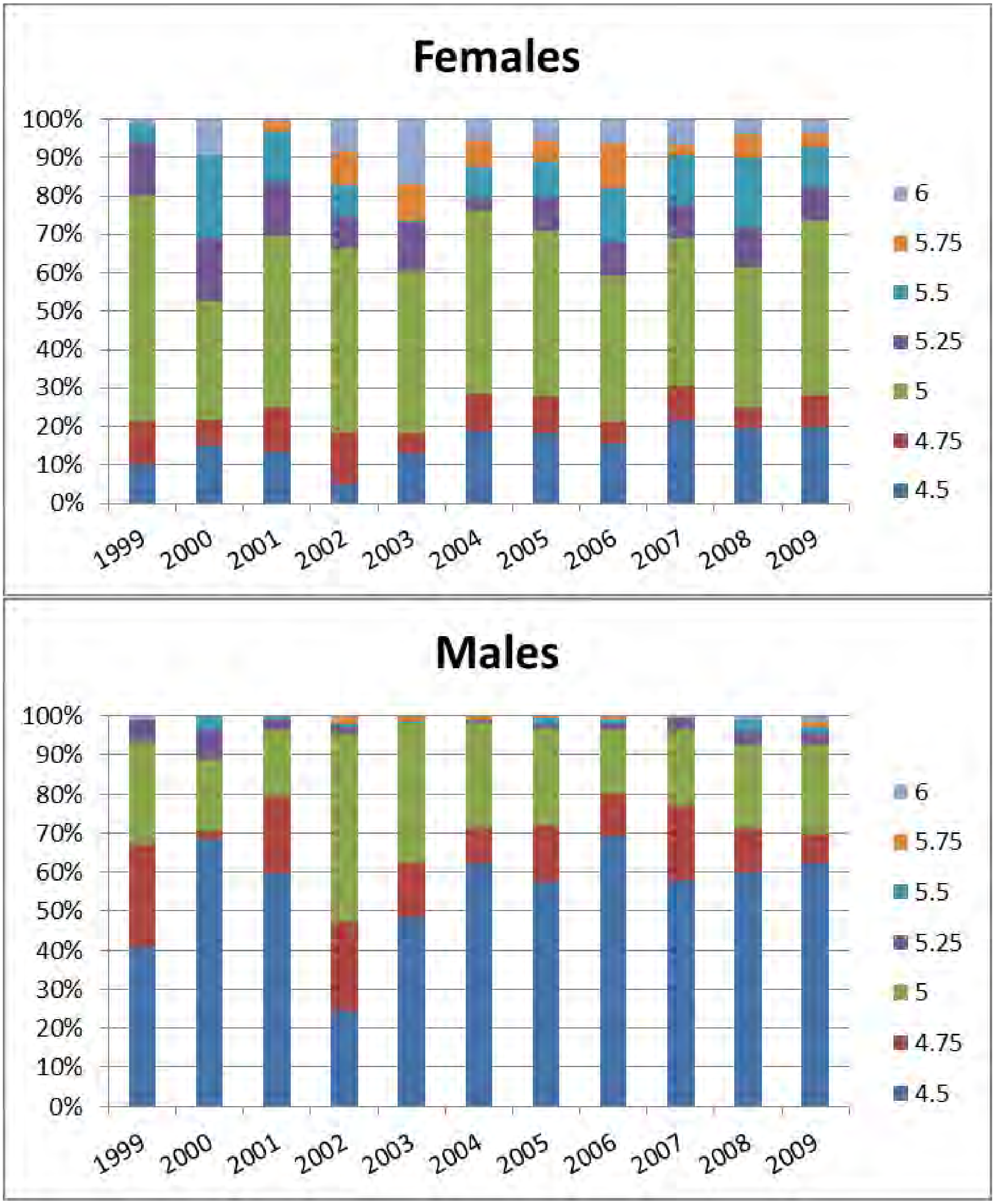


Figure 12. Percent of annual total catch of shad at Smithfield Beach for each mesh size (stretch inches) deployed, by year. Catch was only reported by mesh size 1999 through 2009.

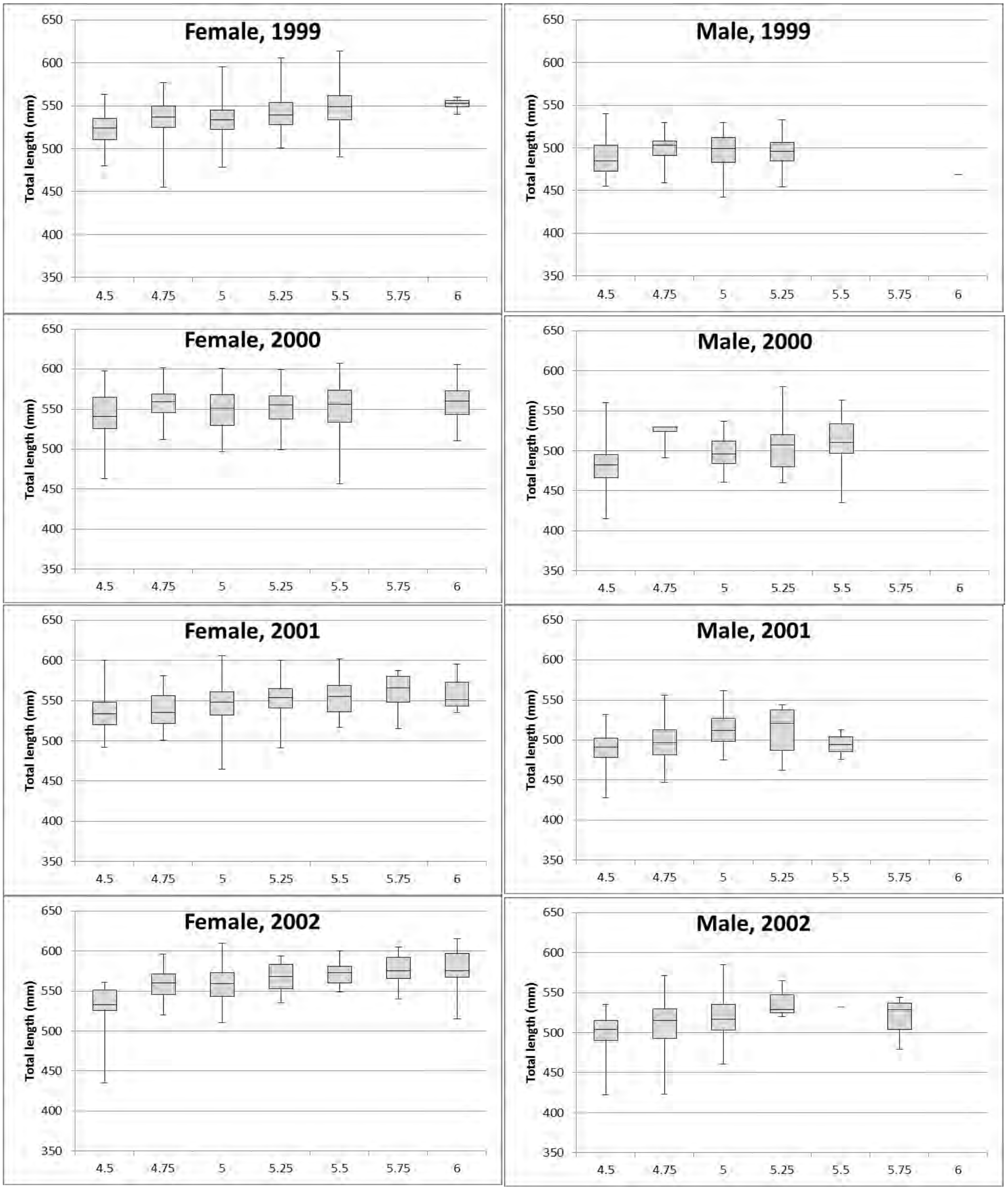
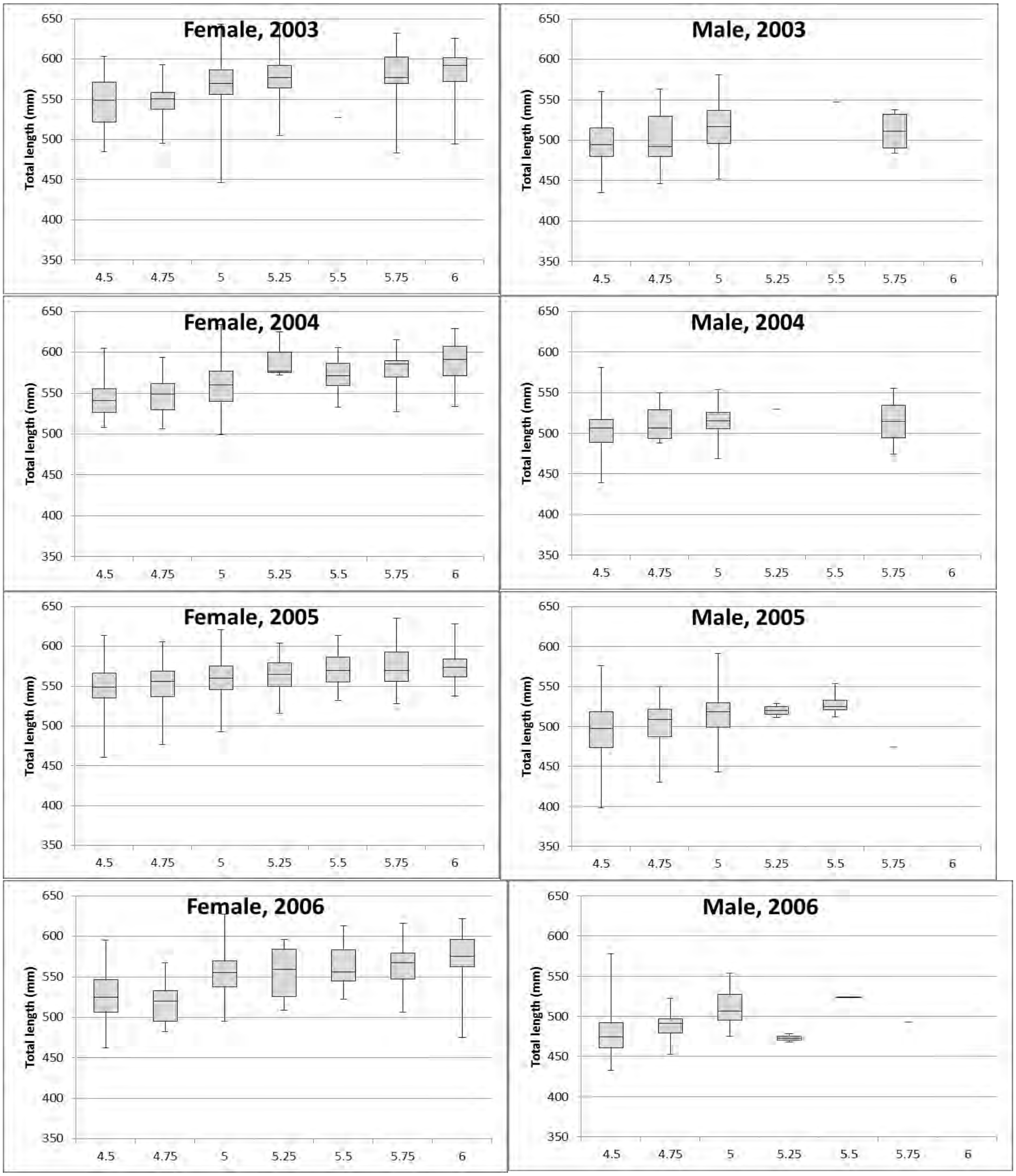


Figure 13. Total length distributions of shad caught at Smithfield Beach by mesh size (stretch inches). Whiskers represent minimum and maximum values; the box represents 25th and 75th percentiles, and the line median sizes.



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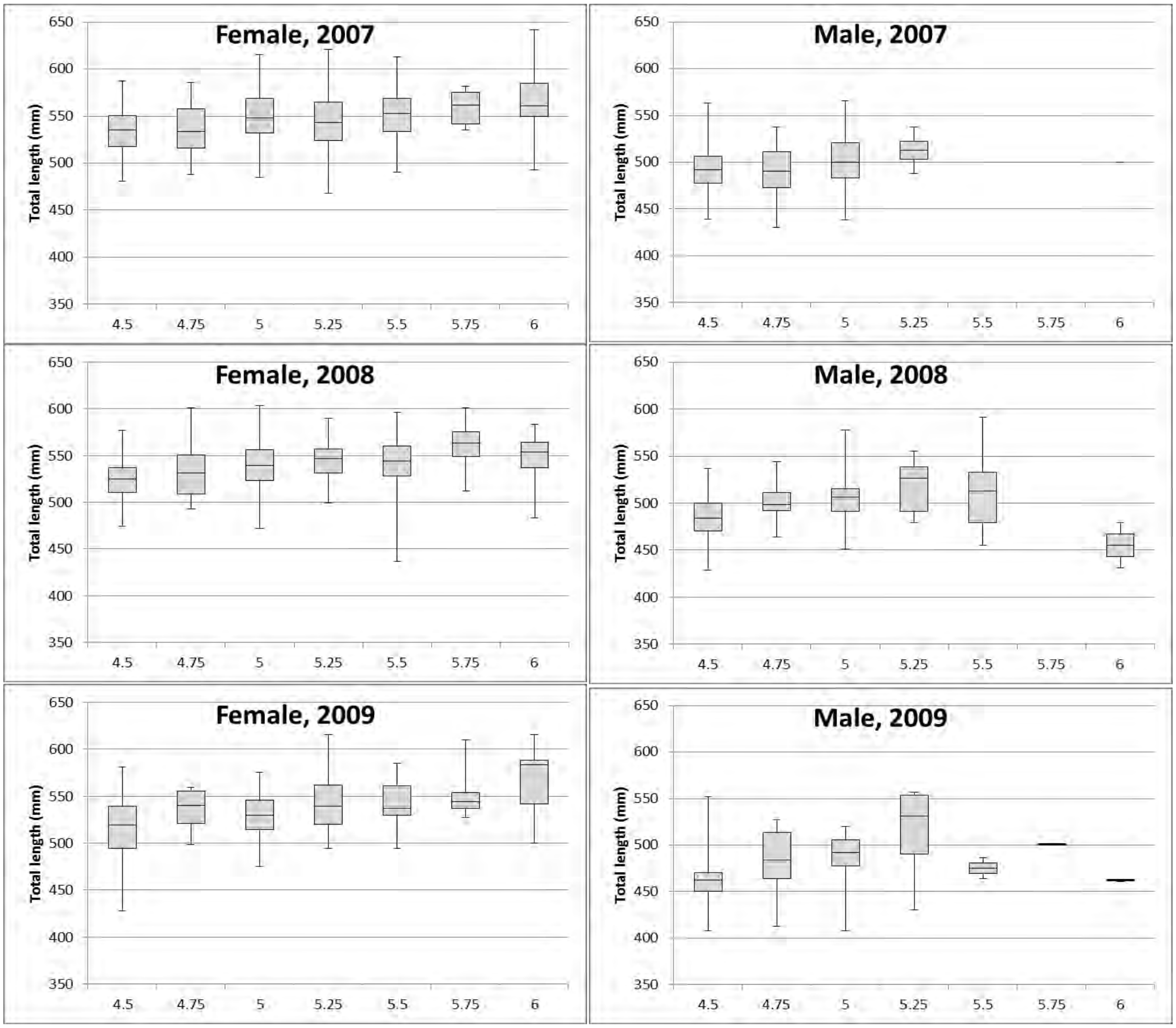

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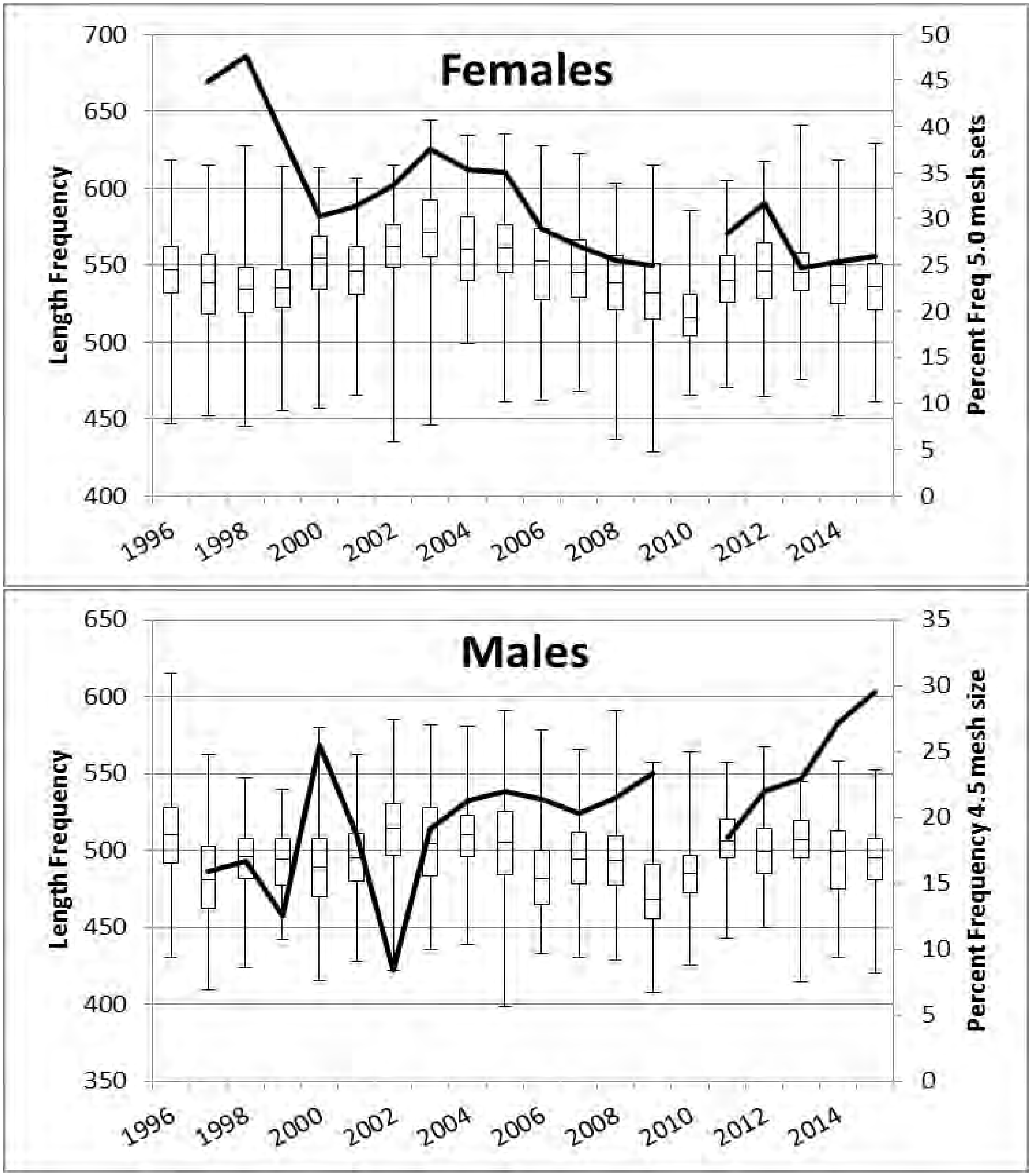


Figure 14. Total length distributions of female and male American Shad overlaid by the frequency of deployment of 5.0 inch (females only) and 4.5 inch (males only) mesh sizes, by year. Whiskers represent minimum and maximum values; the boxes representing 25th, 50th and 75th percentiles.

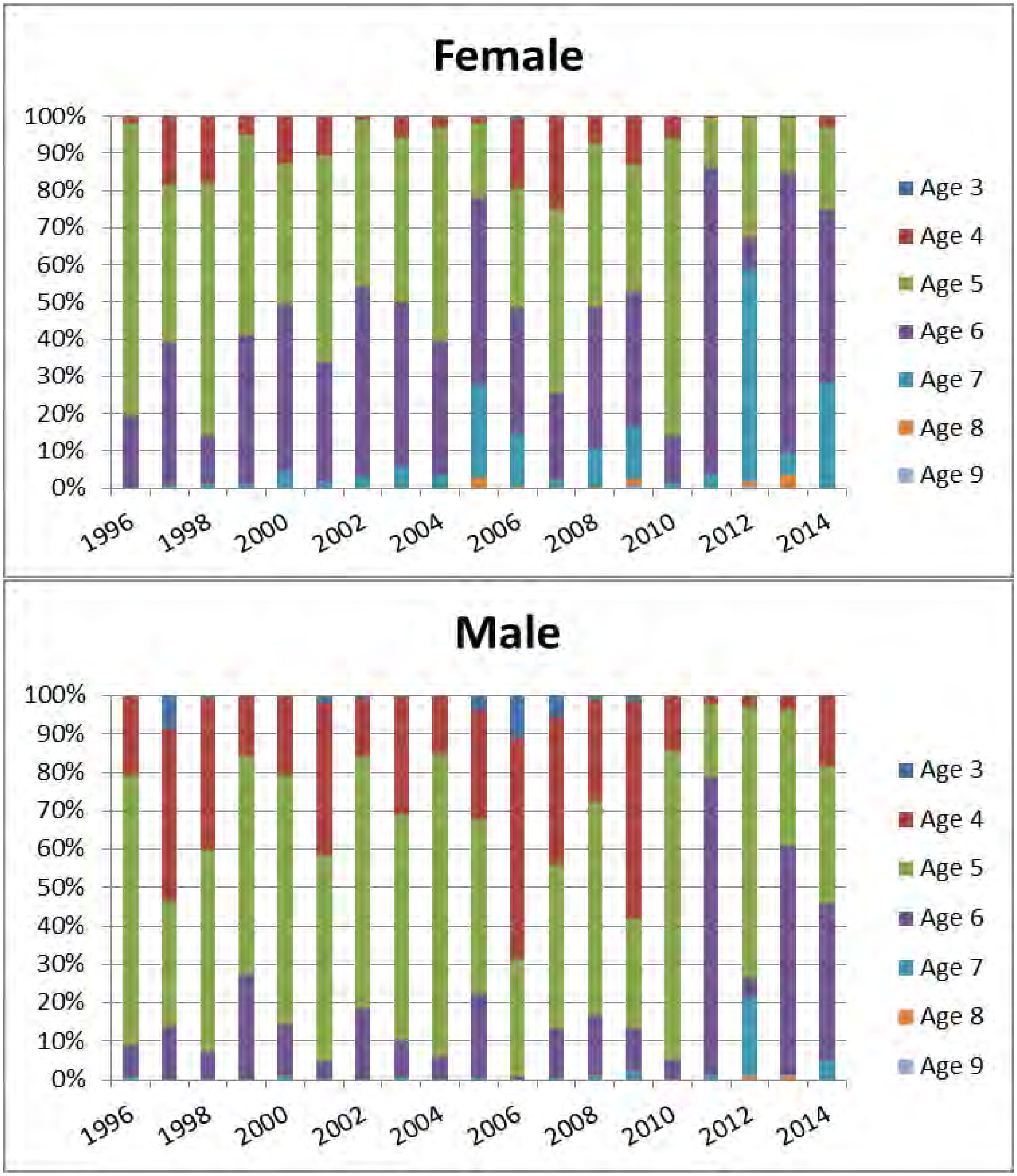


Figure 15. Distribution of age for female and male American Shad captured at Smithfield Beach. No biological information was collected prior to 1996. Assigned ages do not represent the combined agreement of Co-op members as per the Co-op's Ageing Protocol (Appendix A).

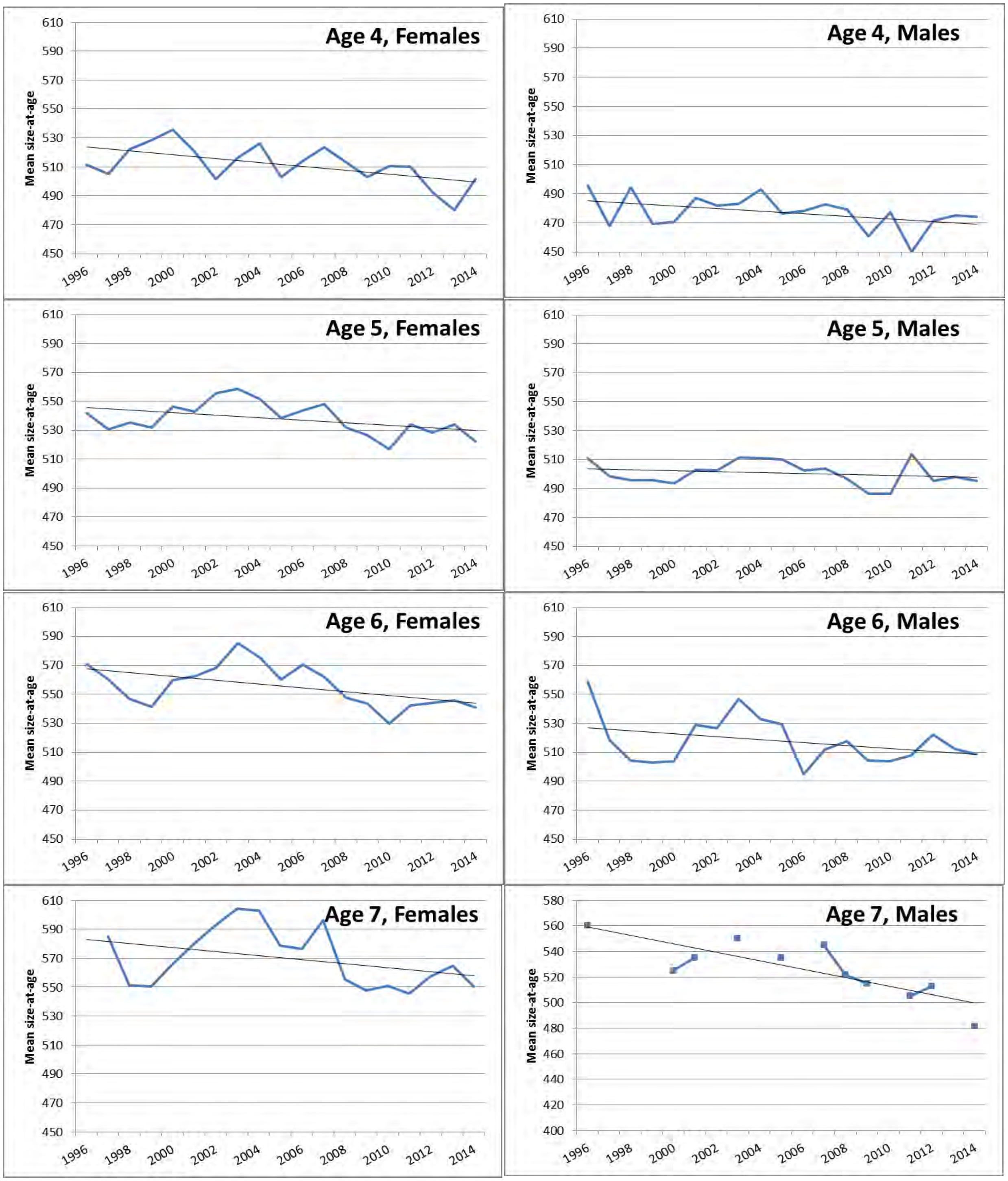


Figure 16. Mean size-at-age (mm TL) for female and male American Shad collected from Smithfield Beach, by age class.

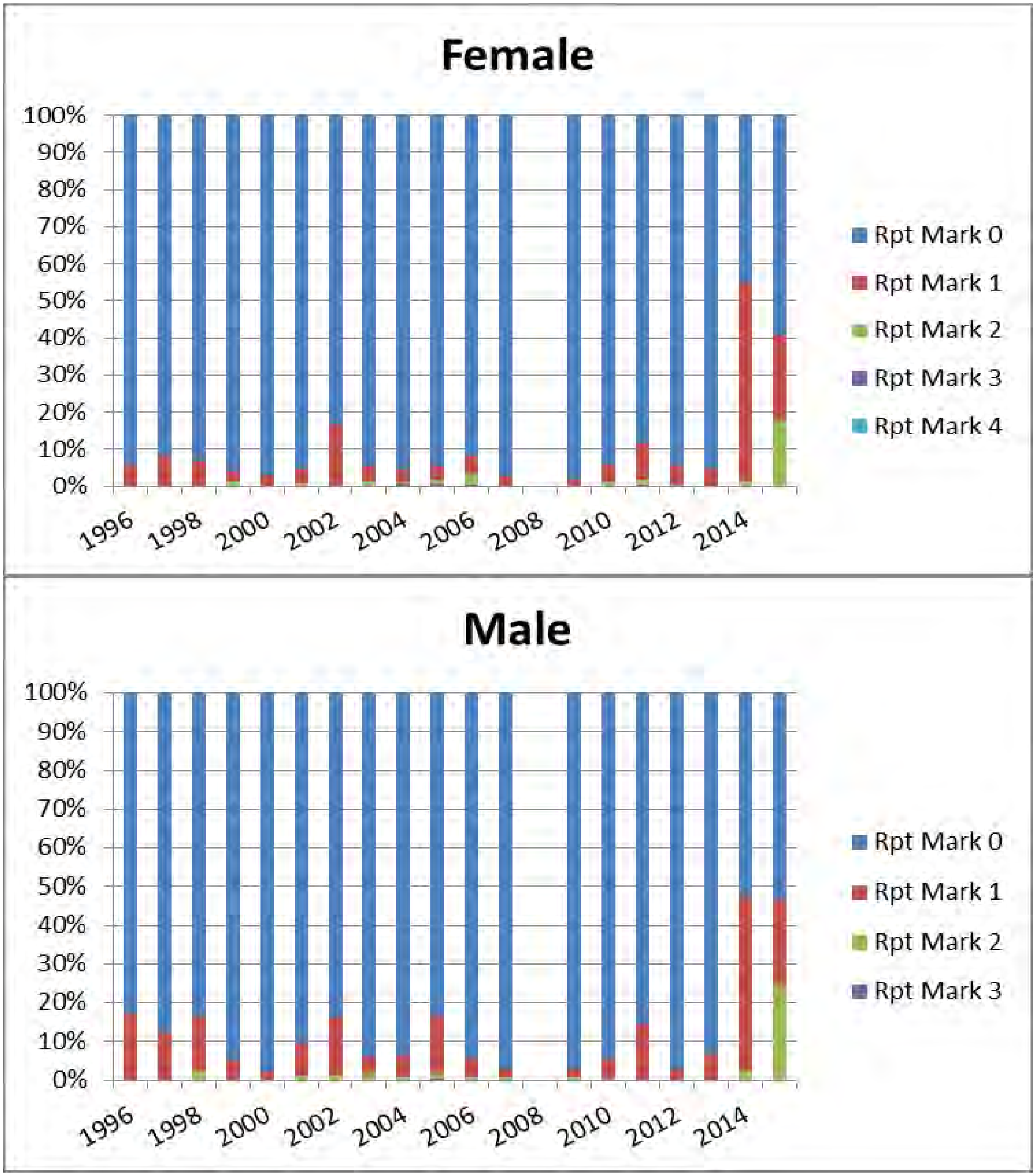


Figure 17. Percent frequency of repeat spawning marks as identified from scale microstructure from shad collected at Smithfield Beach. Scales collected during 2008 have not been processed.

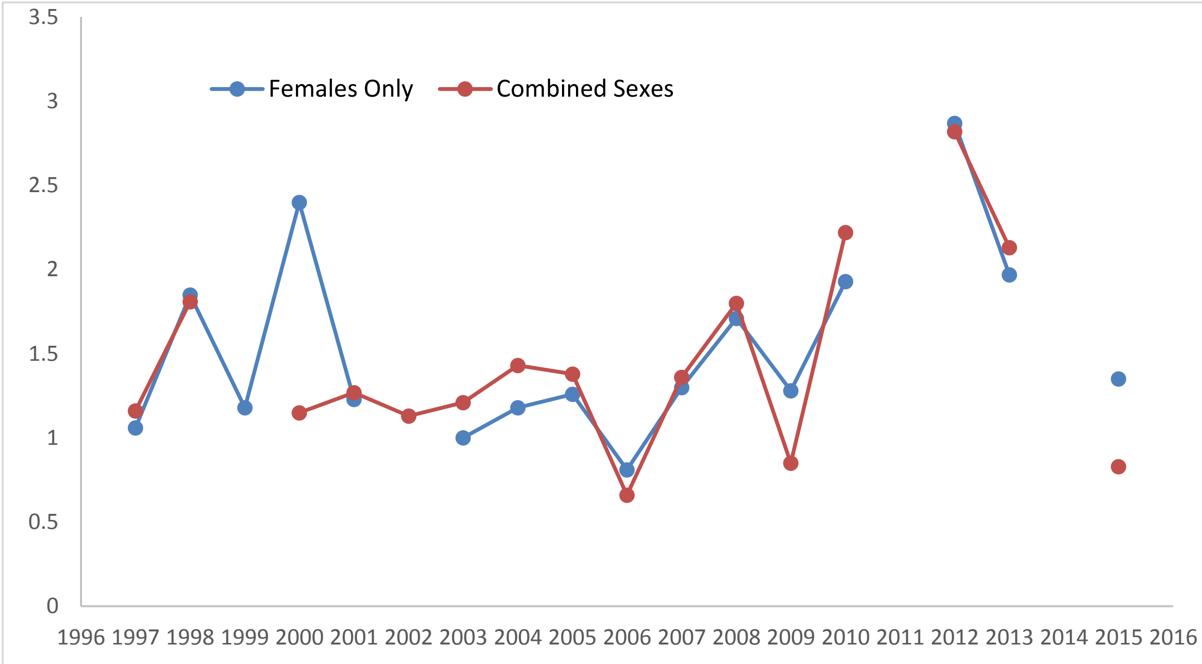


Figure 18. Chapman-Robson bias-corrected total instantaneous mortality (Z) estimates derived from American Shad collected at Smithfield Beach.

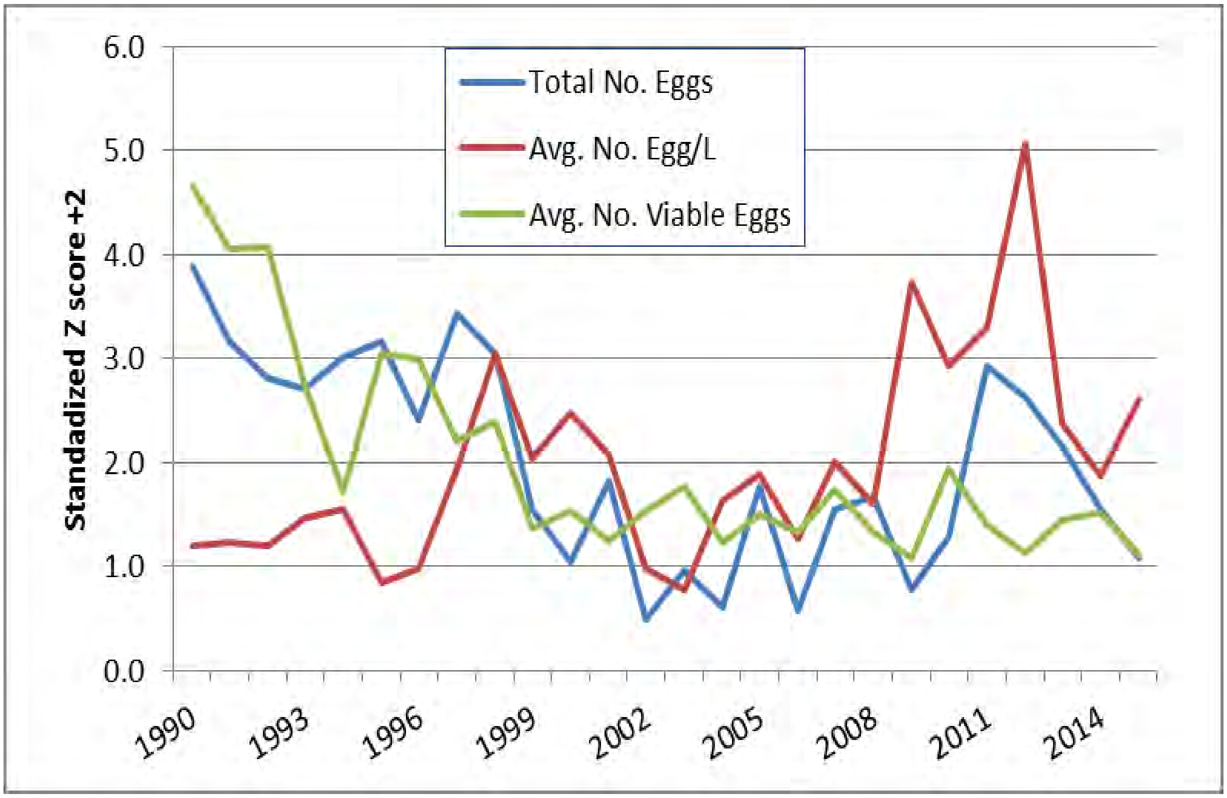


Figure 19. Annual egg harvest characteristics at Smithfield Beach.

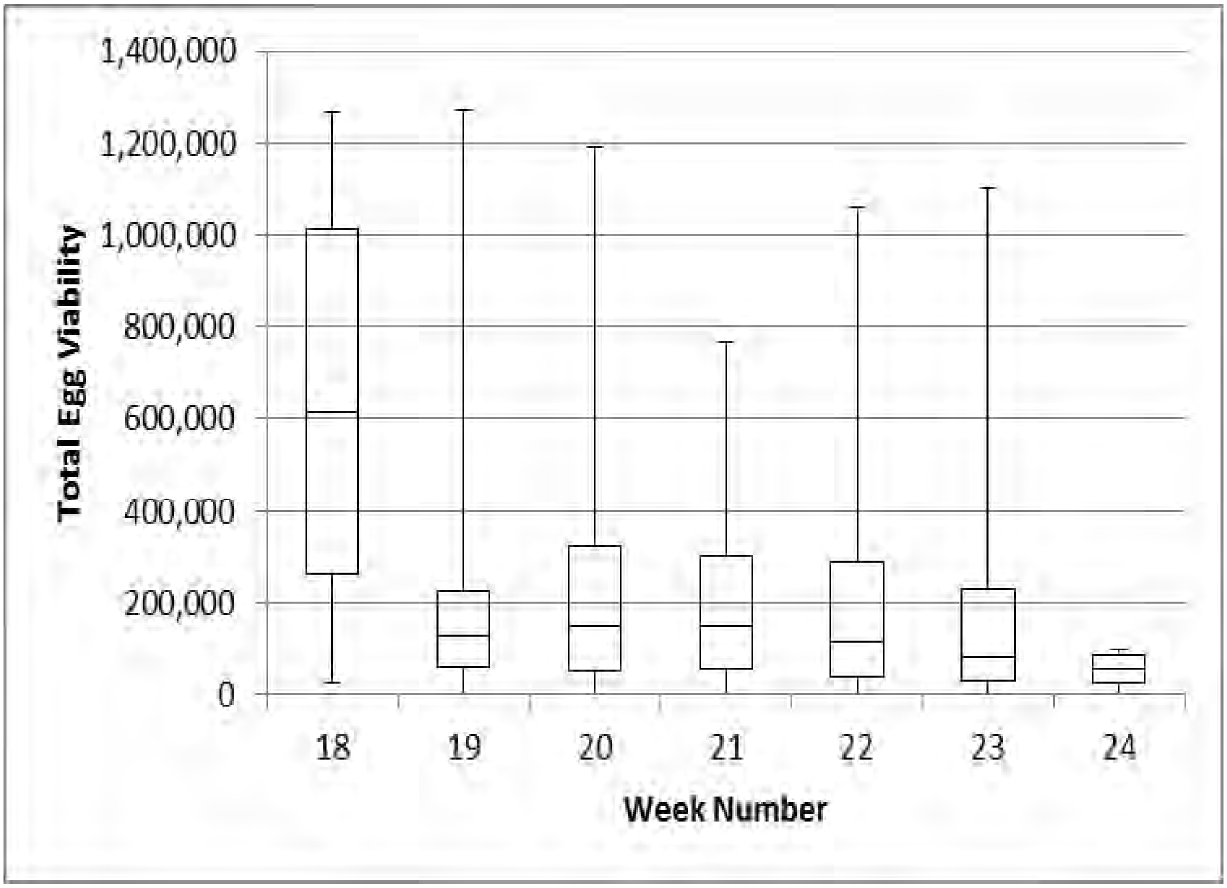


Figure 20. Quartile and median distribution for total egg viability by sampling week, harvested from Smithfield Beach. Whiskers represent minimum and maximum values; the box represents 25th and 75th percentiles; and horizontile line within the box as the median.

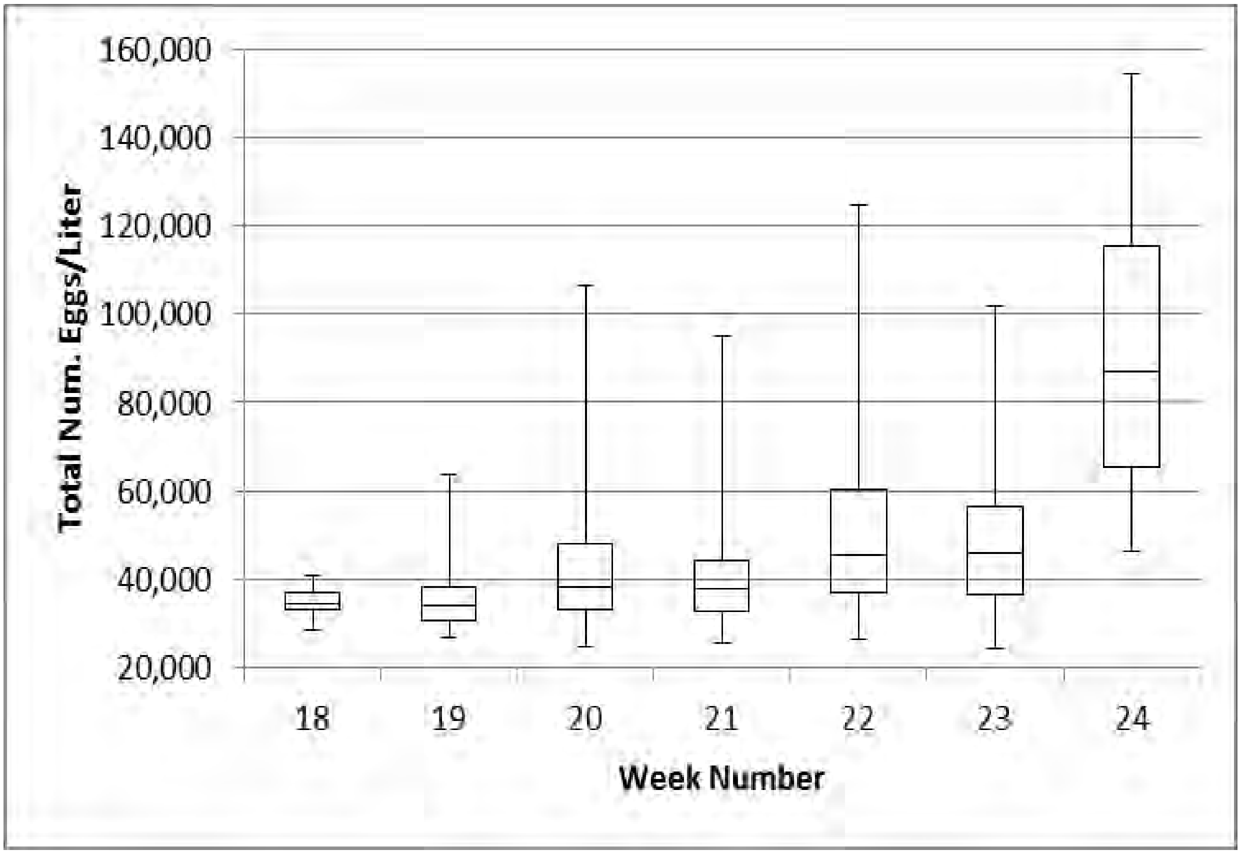


Figure 21. Quartile and median distribution for total number of eggs per liter by sampling week, harvested from Smithfield Beach. Whiskers represent minimum and maximum values; the box represents 25th and 75th percentiles; and horizontile line within the box as the median.

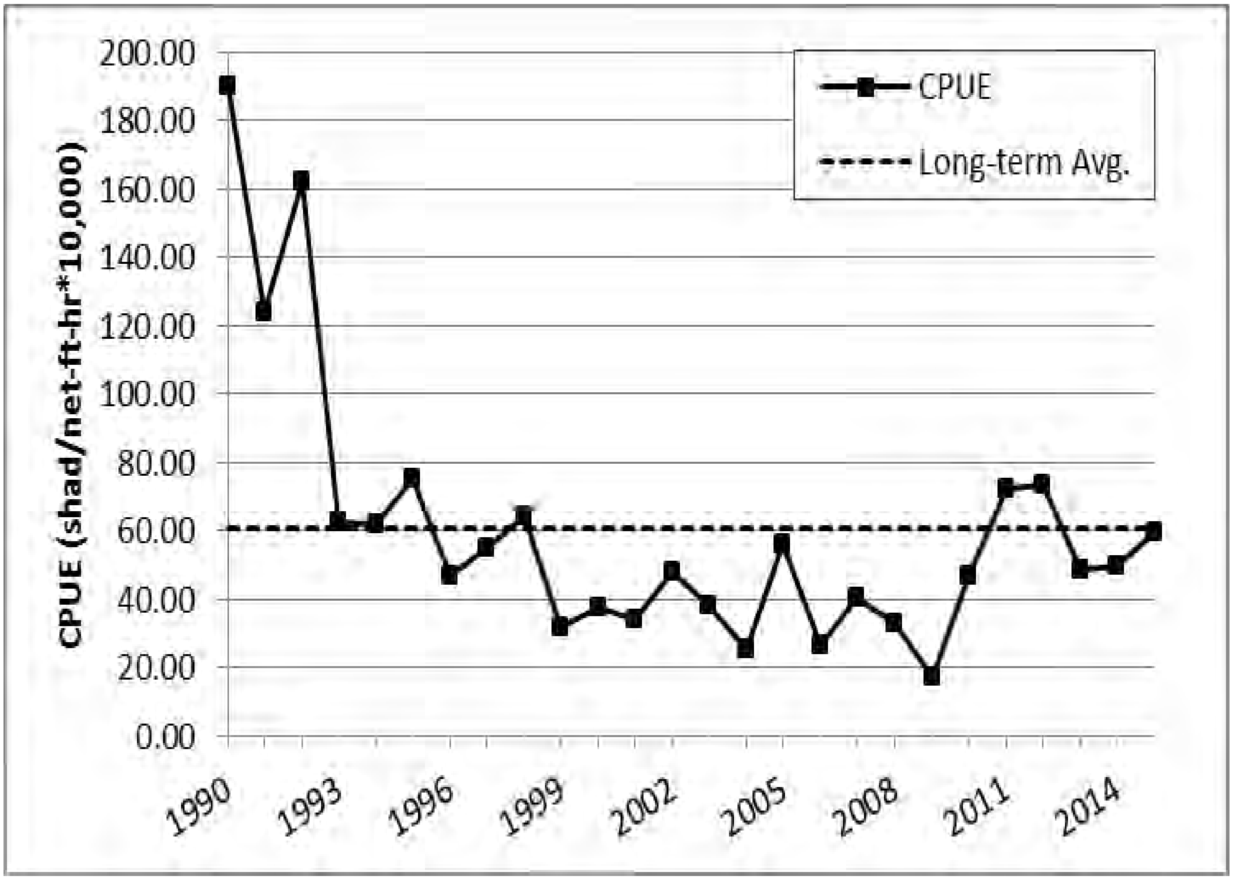


Figure 22. CPUE for American Shad collected from the Delaware River at Smithfield Beach (RM 218) by gill net (shad/net-ft-hr * 10,000).

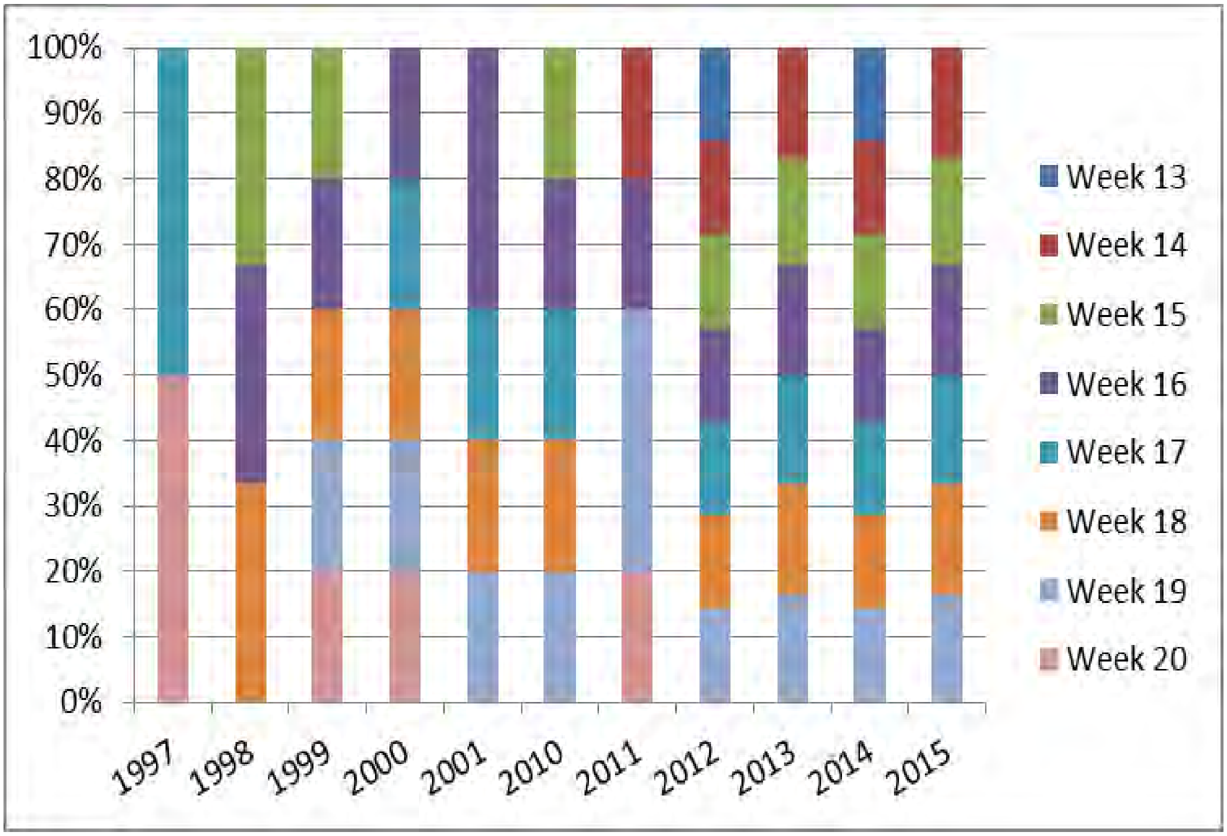


Figure 23. Electrofishing sampling frequency at Raubsville (RM 176) for American Shad as they migrate upriver. Week number is defined as the occurrence of January 1st as week one.

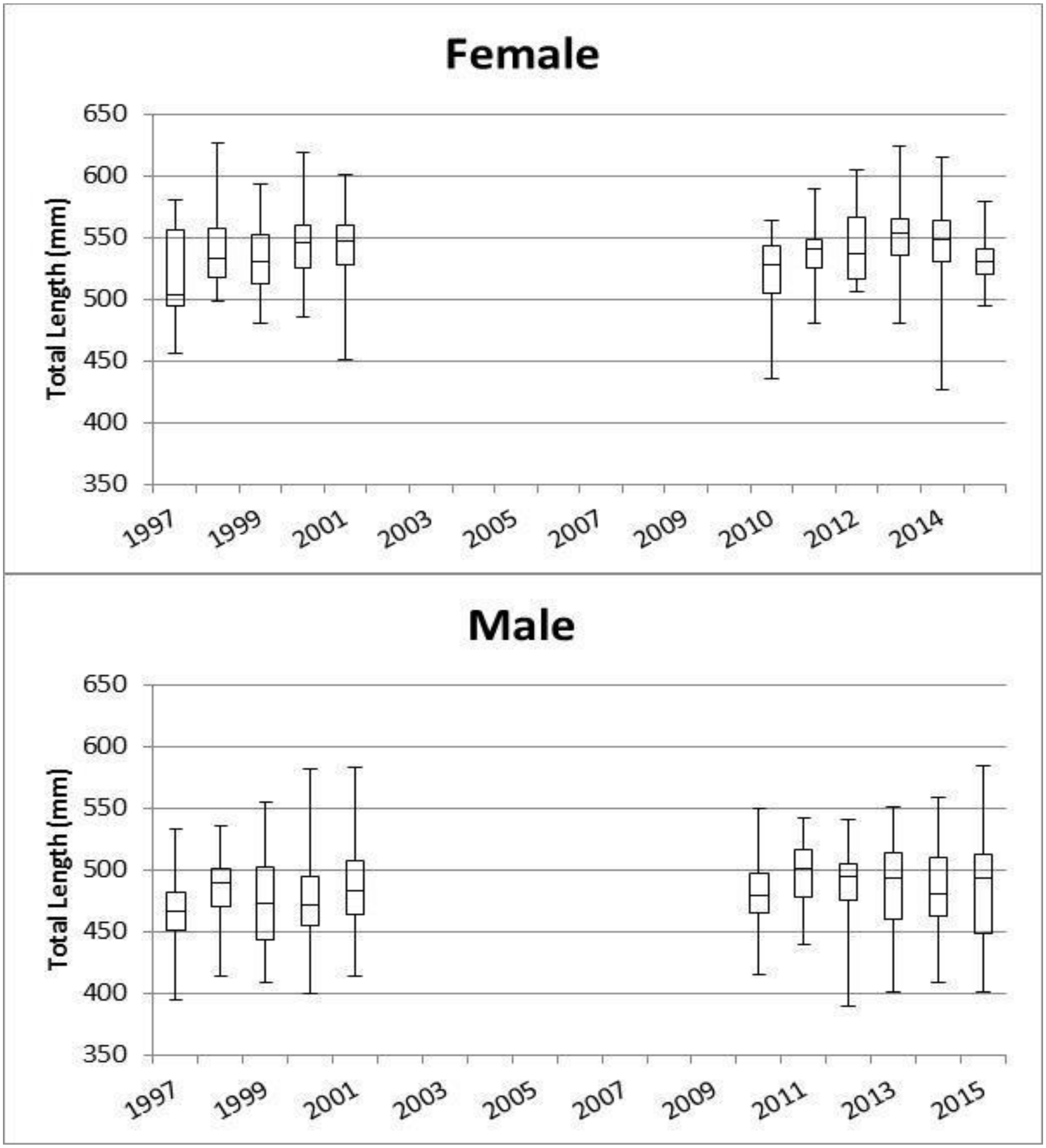


Figure 24. Length frequencies of shad collected at Raubsville (1997-2001; 2010-2015). The boxes represent the lower box 25th, 50th and 75th percentiles. Whiskers are the minimum and maximum lengths.

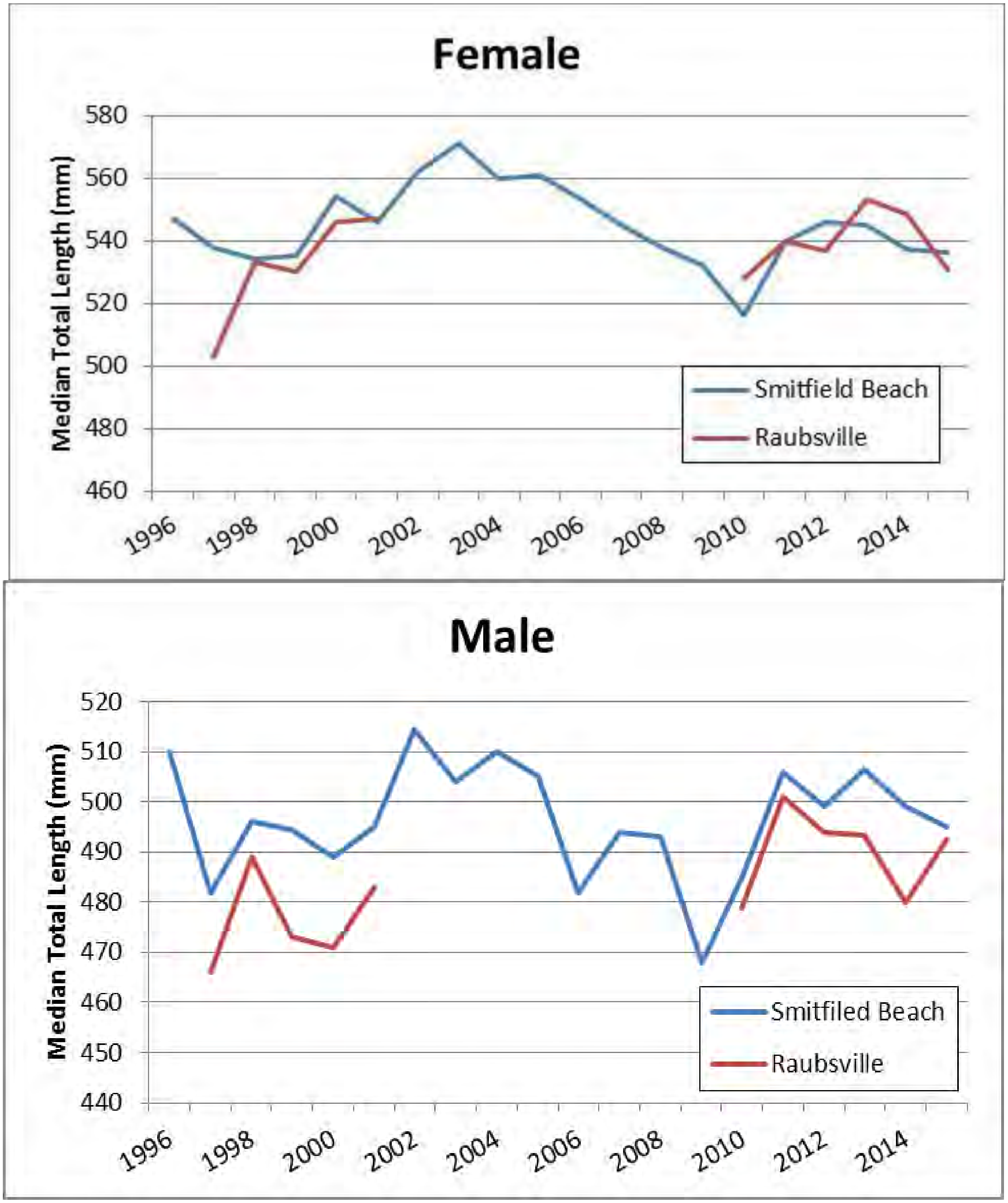


Figure 25. Median sizes (mm TL) of American Shad collected from Smithfield Beach (all mesh sizes combined) and Raubsville.

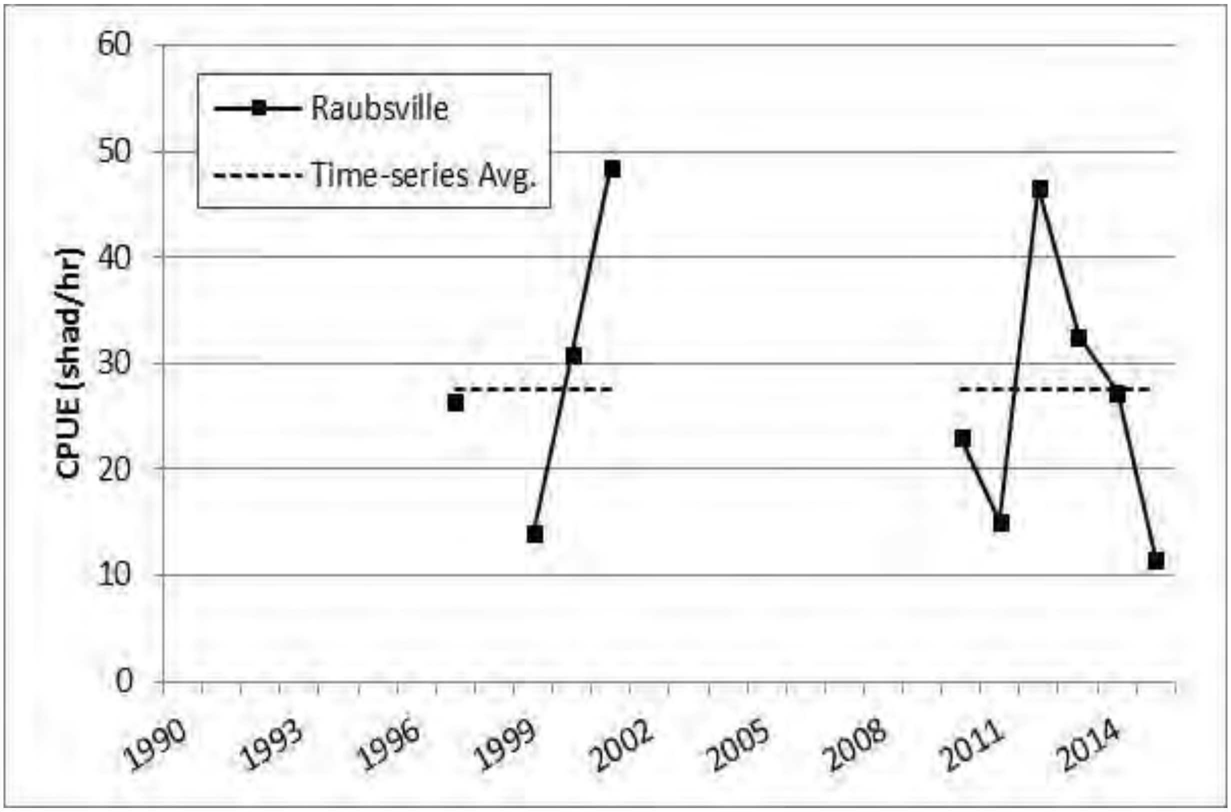


Figure 26. Raubsville electrofishing CPUE of American Shad.

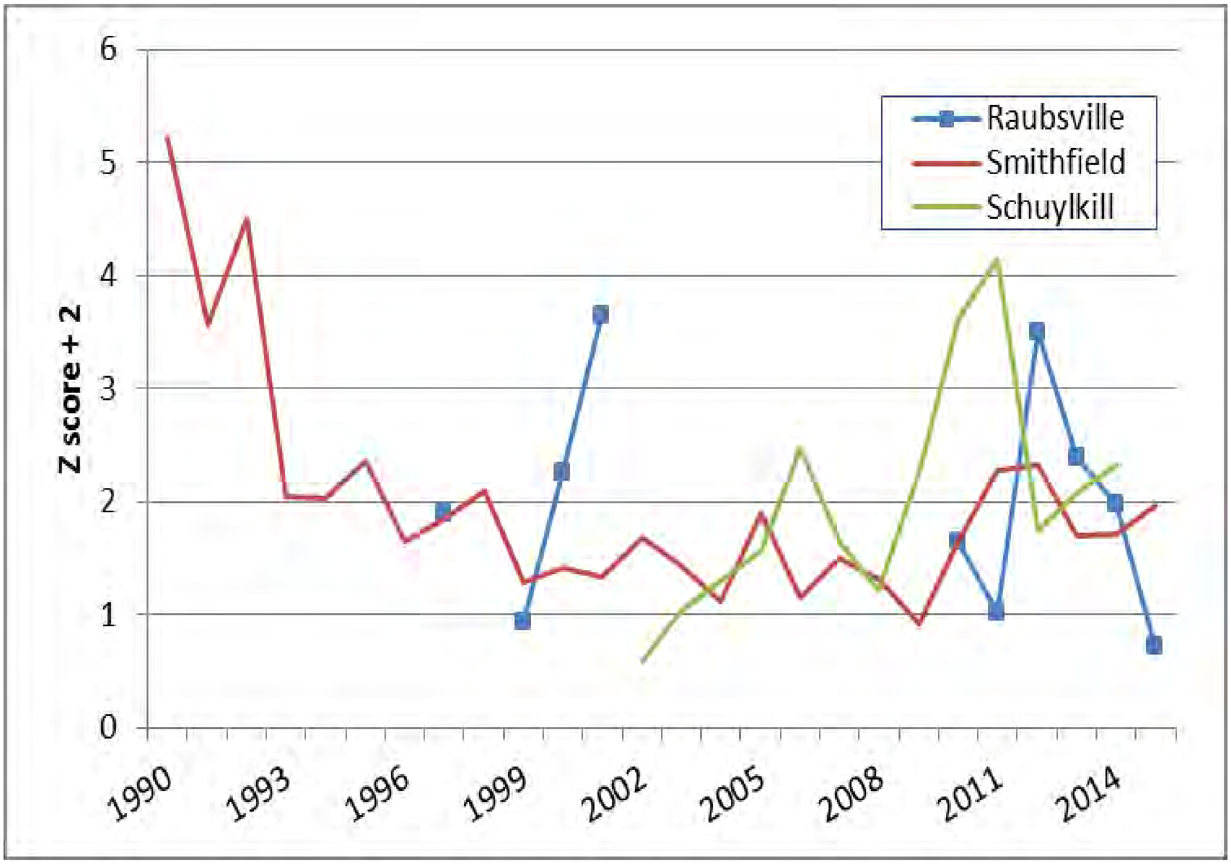


Figure 27. Comparison of CPUEs from monitoring programs at Smithfield Beach (i.e., gill netting) and Raubsville (i.e., electrofishing) on the main stem Delaware River; and CPUE from the tidal main stem of the Schuylkill River (i.e., electrofishing). Indices are represented as standardized Z scores plus two.

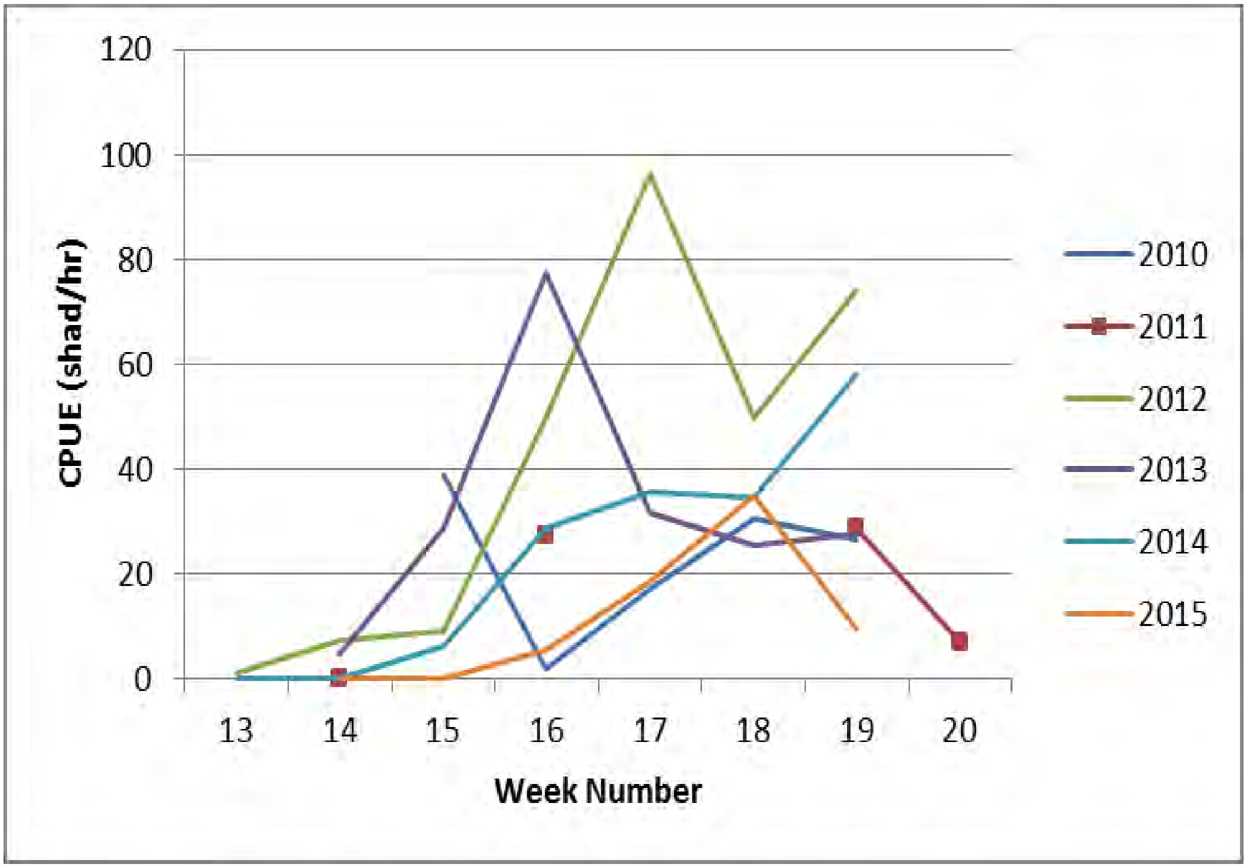


Figure 28. Weekly electrofishing CPUE estimates from the Raubsville monitoring. Week number is defined as the occurrence of January 1st as week one.

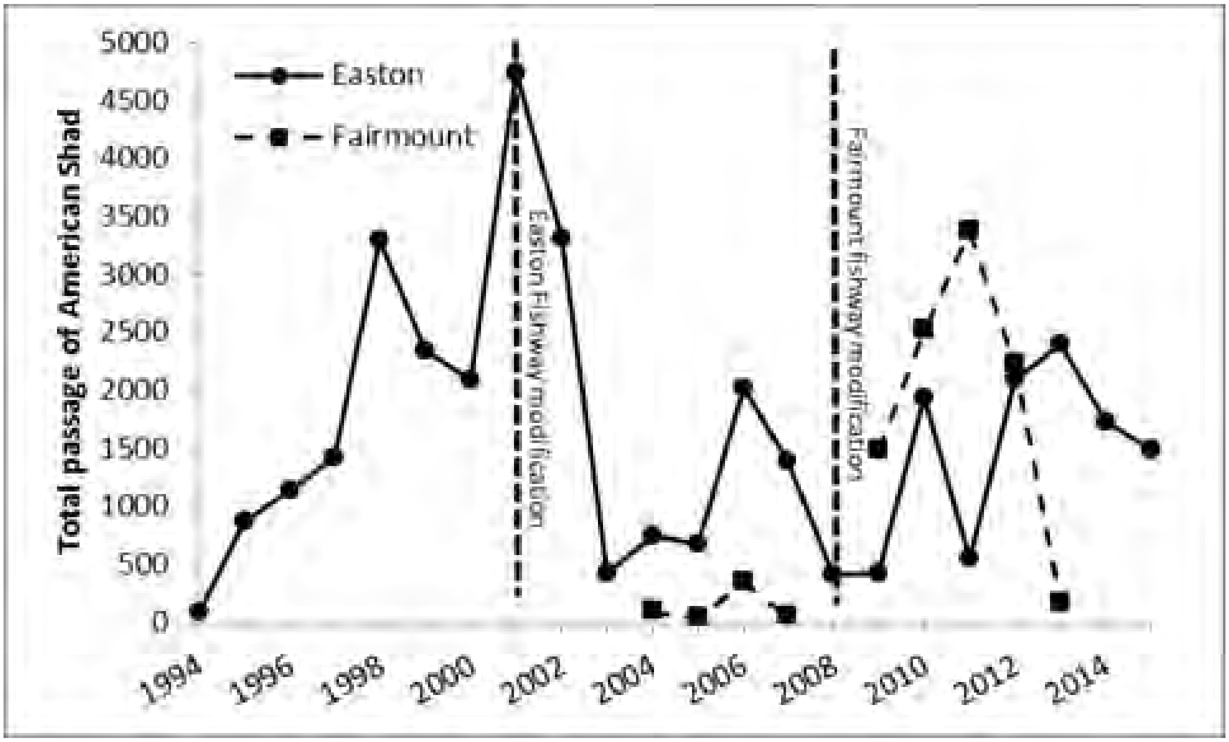


Figure 29. Upstream fish passage trends for the Lehigh (Easton Dam) and Schuylkill (Fairmount Dam) rivers. A predictive regression based on electrofishing CPUE was substituted for video surveillance beginning in 2013 for estimating total passage into the Lehigh River.

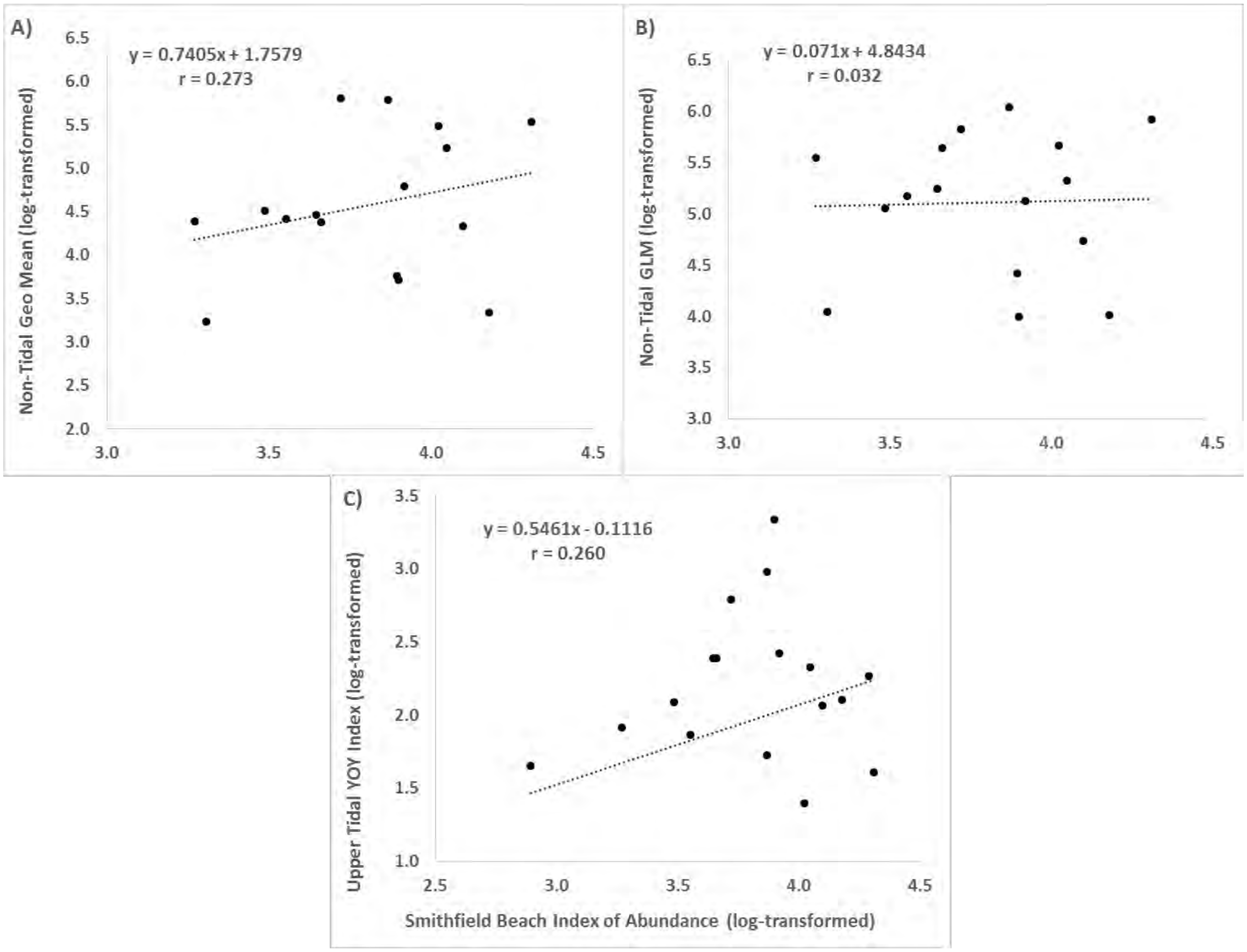


Figure 30. Correlations between the JAI indices (A – Non-tidal geometric mean; B – Non-tidal GLM; C – Tidal geometric mean) vs the Smithfield Beach Adult Index. All values are log-transformed.

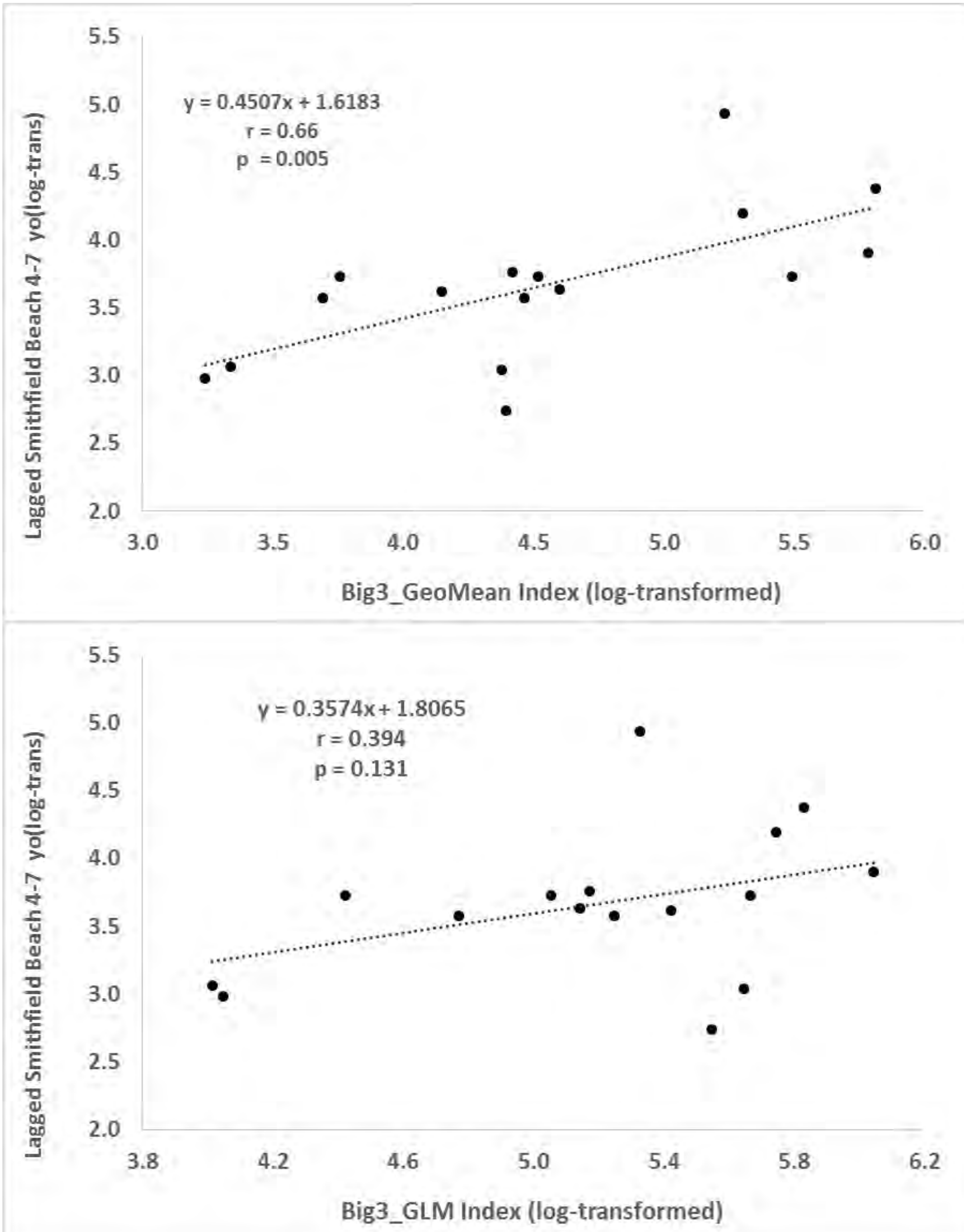


Figure 31. Correlations between the two non-tidal JAI indices vs the lagged Age 4-7 Index calculated from the Smithfield Beach Index. All values are log-transformed.

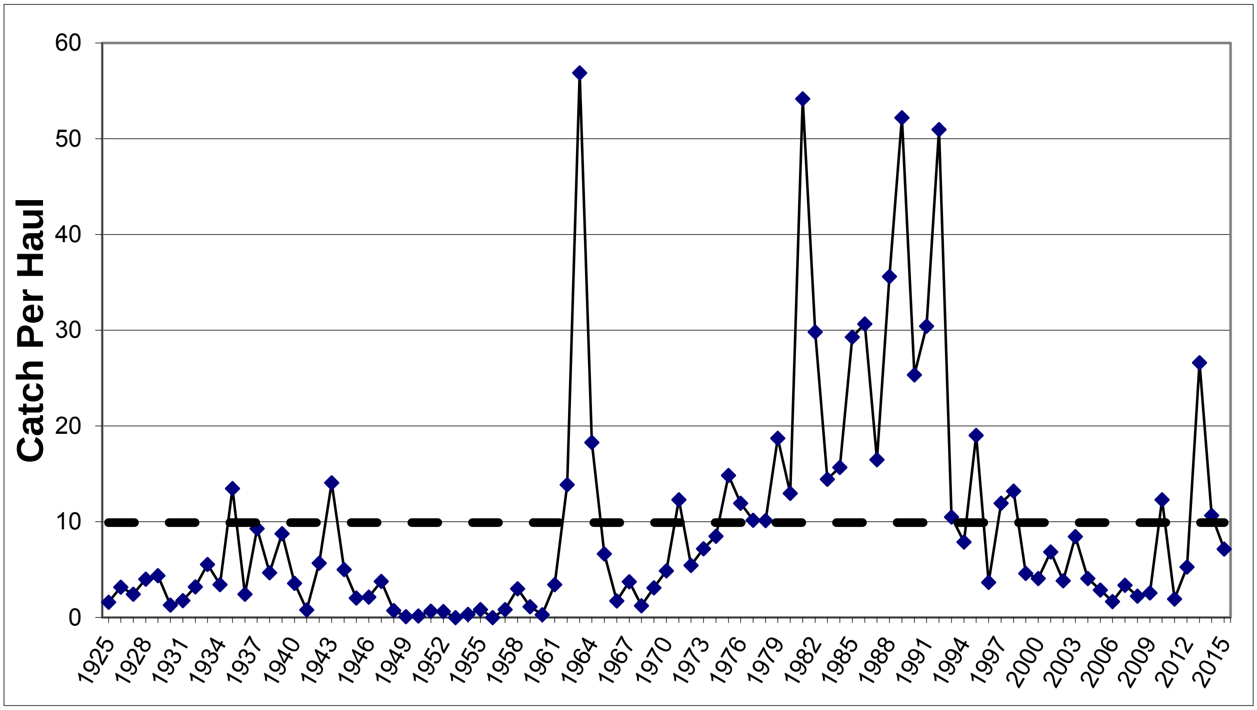


Figure 32. Lewis haul seine CPUE (shad/haul), 1925-2015. Dashed line represents the time series average.

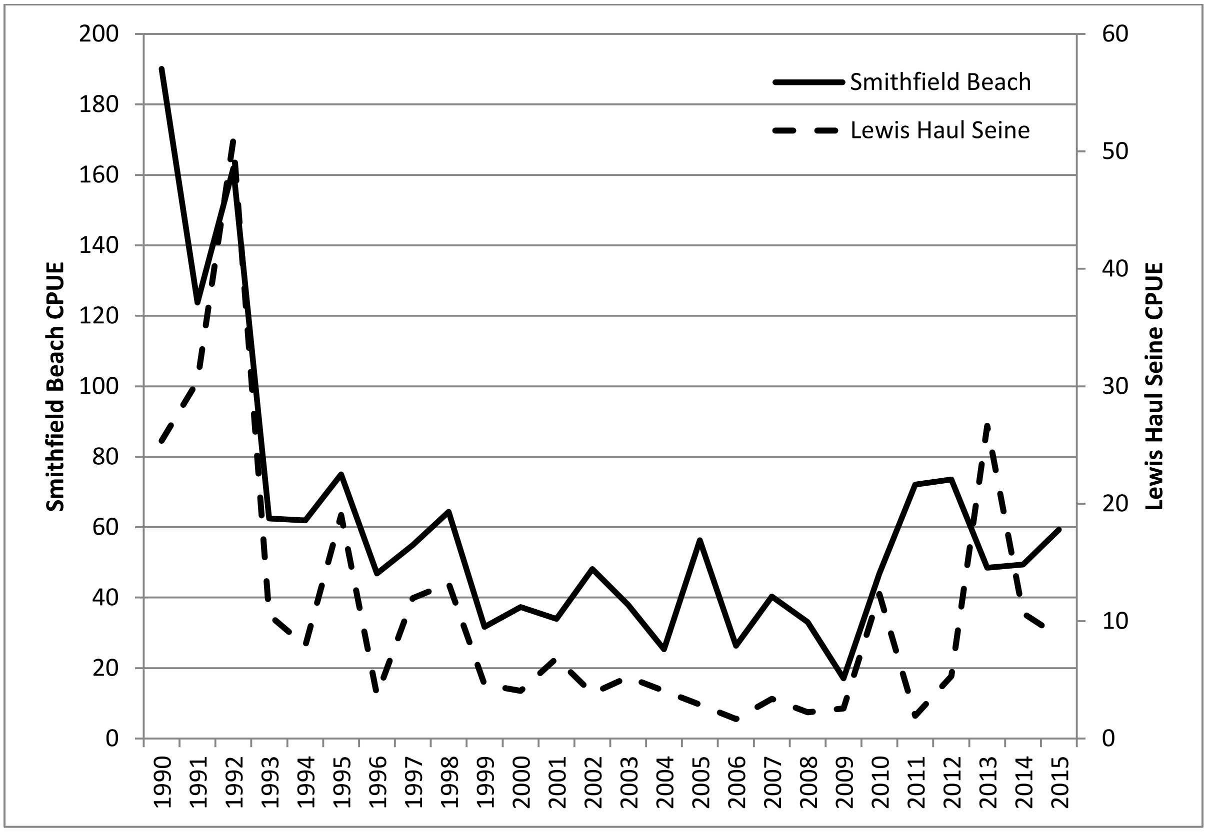


Figure 33. Trends in relative abundance as estimated from Smithfield Beach (shad/net-ft-hr*10,000) and Lewis haul seine (shad/haul), 1990-2015.

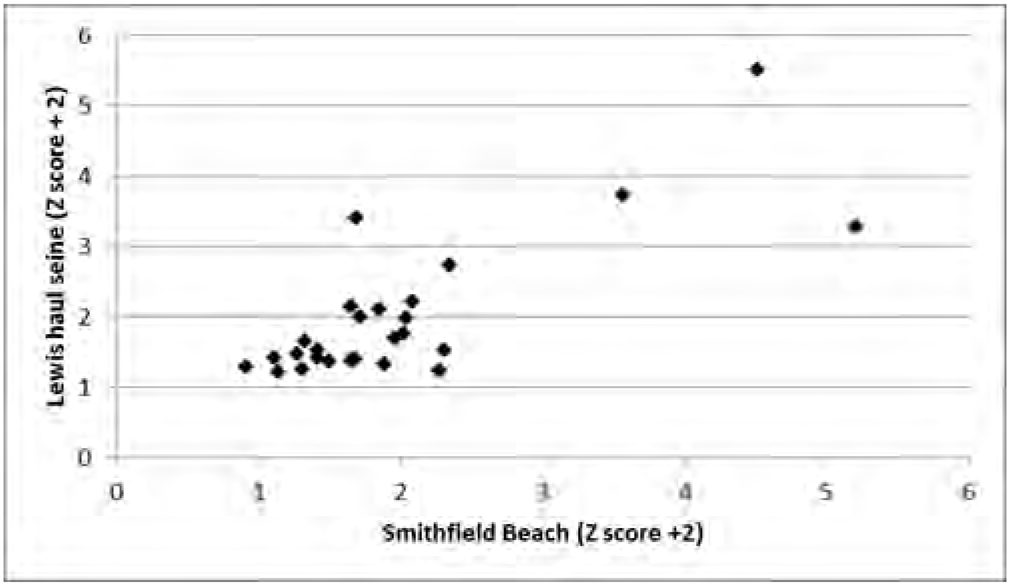


Figure 34. Correlation between Smithfield Beach and Lewis haul seine, 1990-2015.

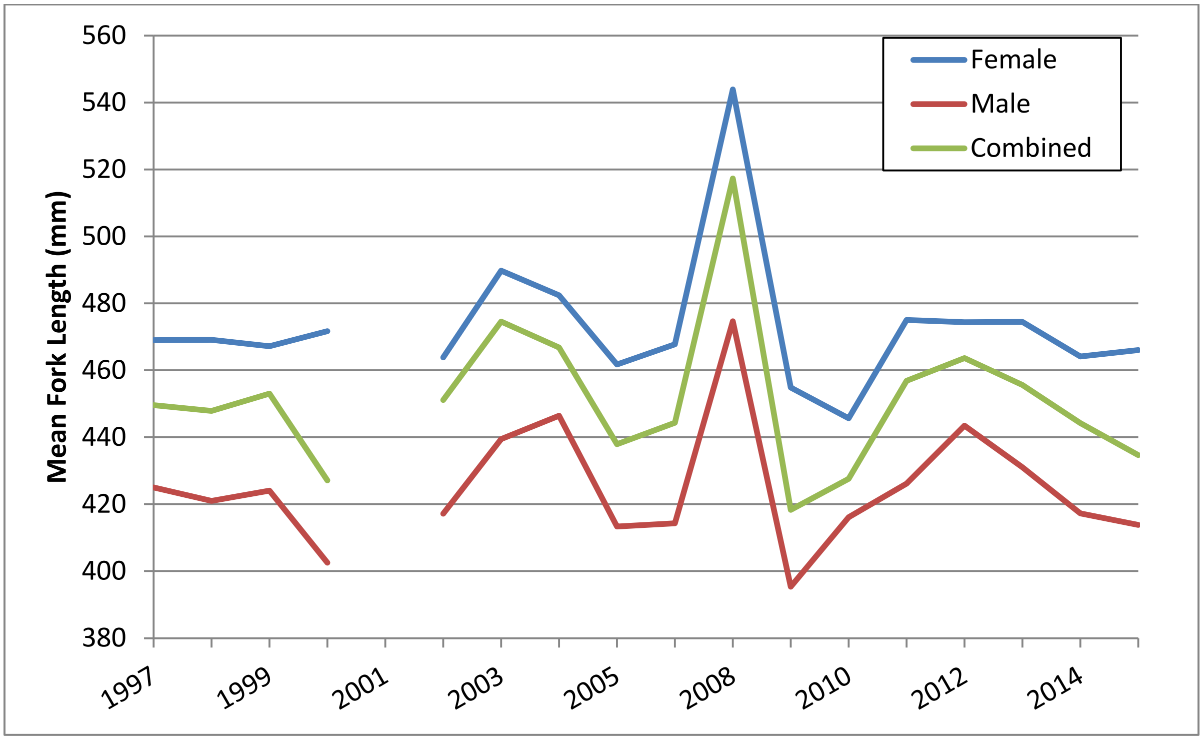


Figure 35. Mean fork lengths of male and female American Shad collected in the Lewis haul seine from 1997-2015.

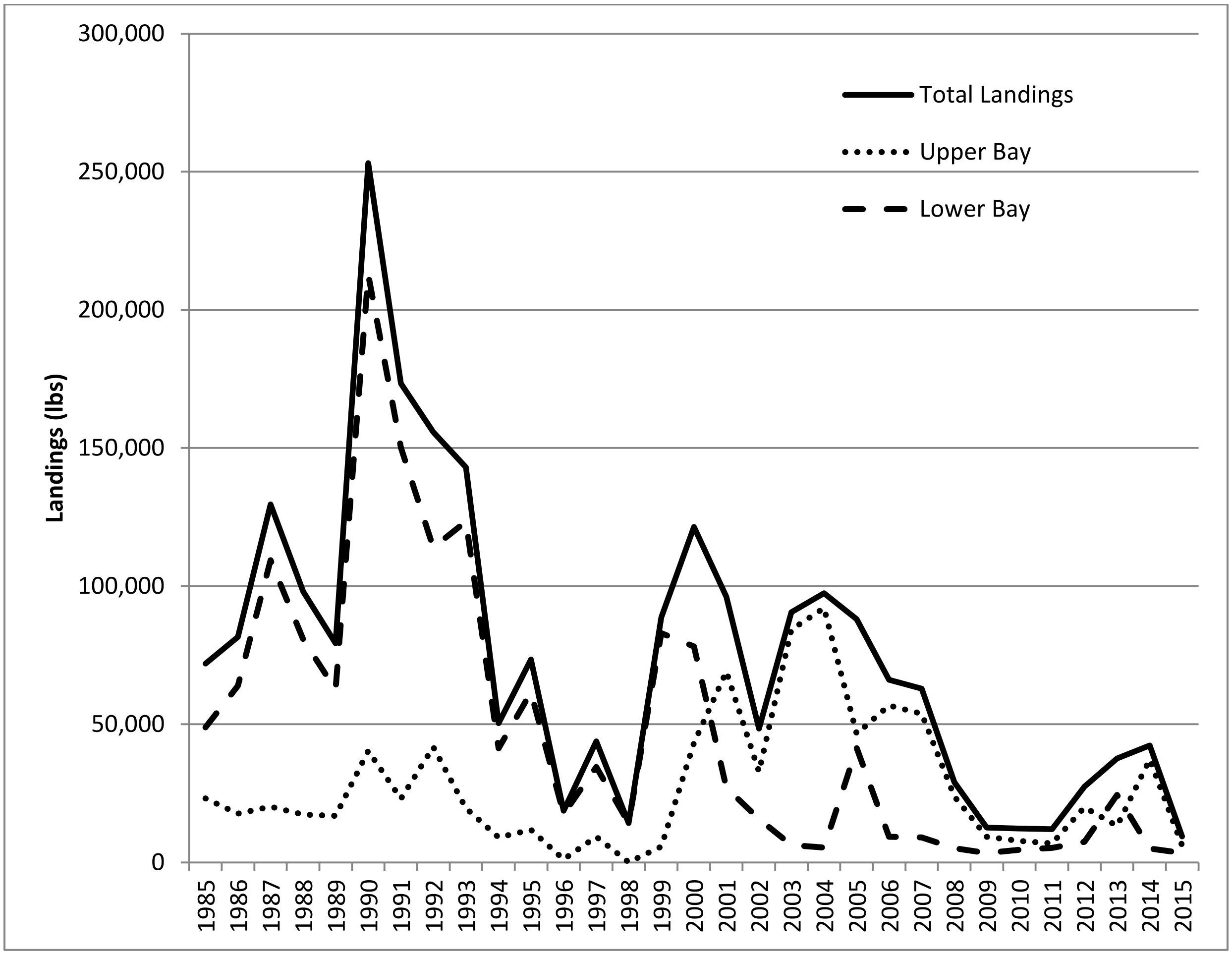


Figure 36. American Shad landings in the State of New Jersey separated into Upper Bay/River (north of Gandys Beach) and Lower Bay (south of Gandys Beach), reporting regions.

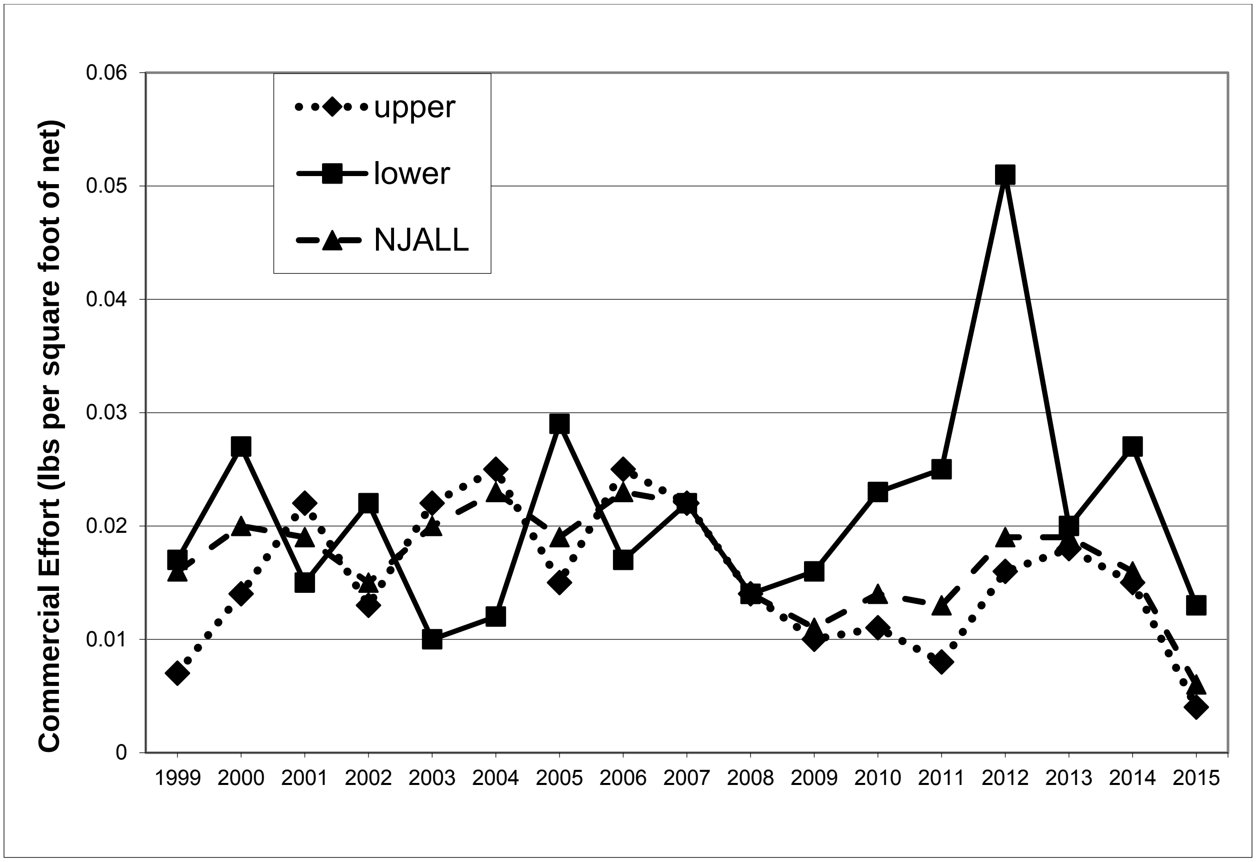


Figure 37. New Jersey commercial American Shad CPUE from 2000-2015. Effort is separated into Upper Bay/River (north of Gandys Beach) and Lower Bay (south of Gandys Beach), reporting regions.

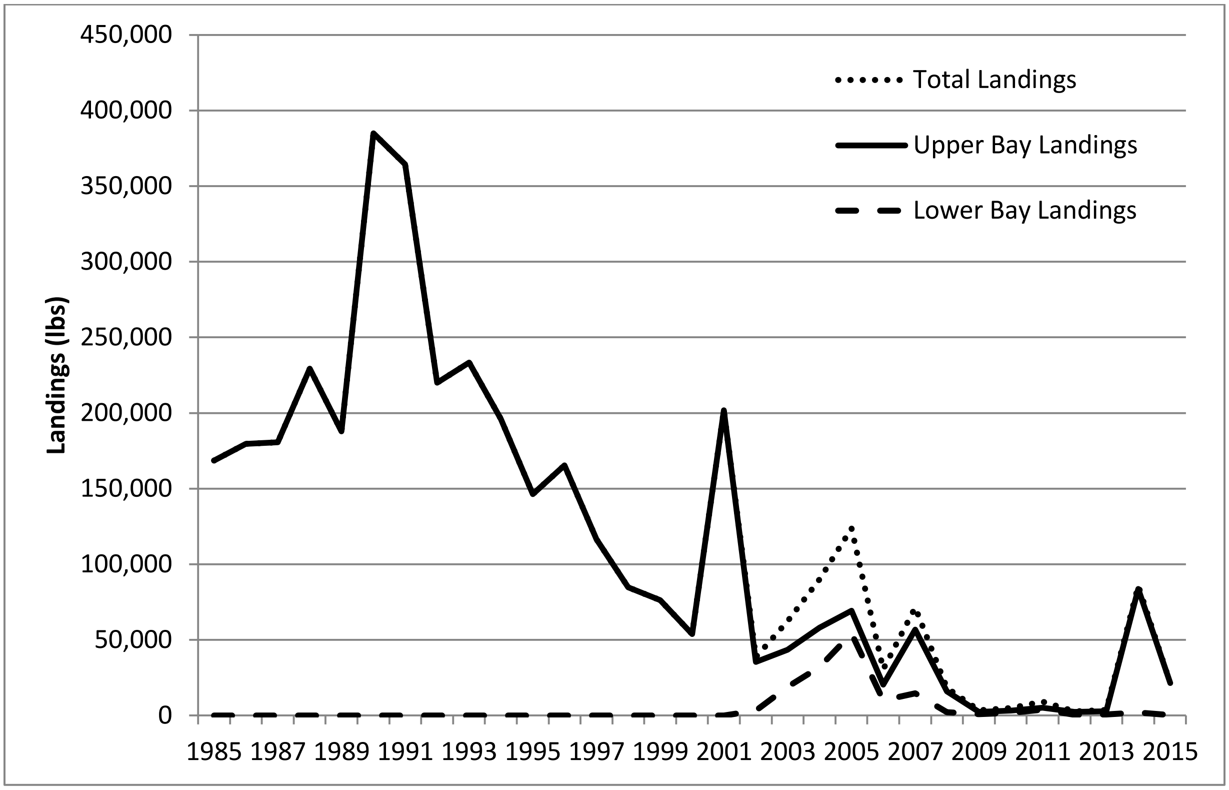


Figure 38. American Shad landings in the State of Delaware separated into upper bay (north of Bowers Beach) and lower bay (south of Bowers Beach), reporting regions.

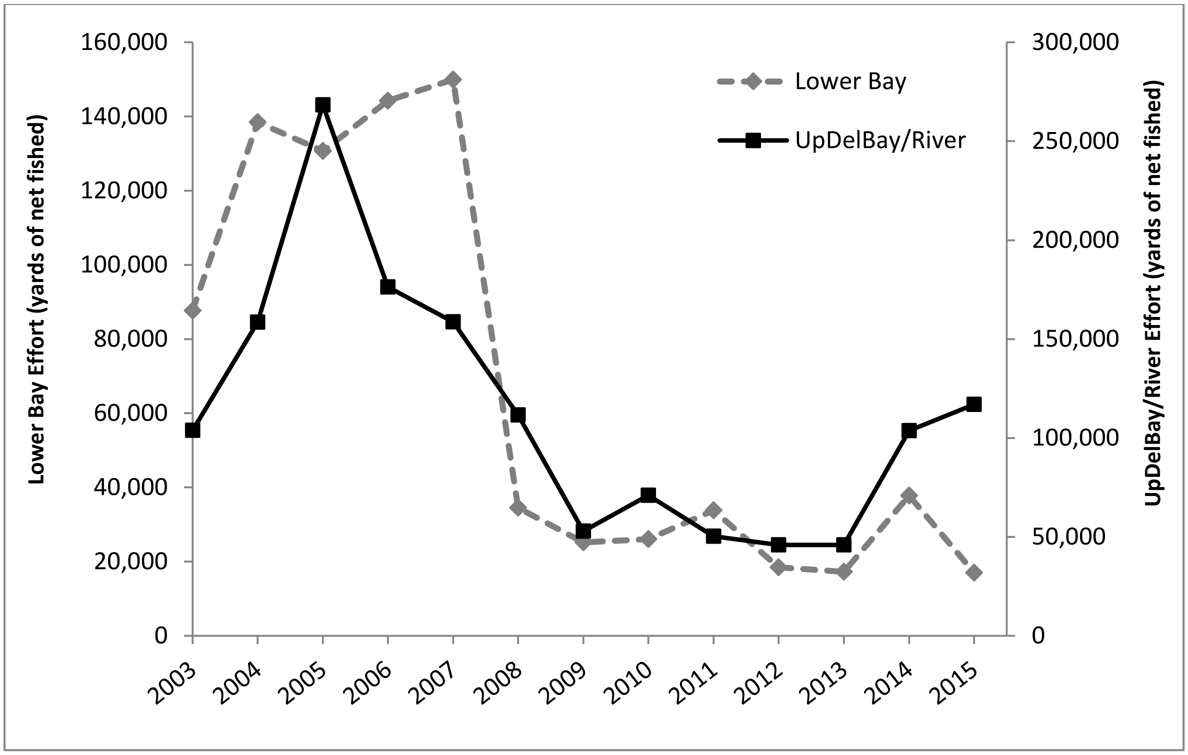


Figure 39. State of Delaware commercial fishery effort in yards of net fished for the Delaware River and Bay (1990-2015). Effort was separated into upper bay (north of Bowers Beach) and lower bay (south of Bowers Beach), reporting regions.

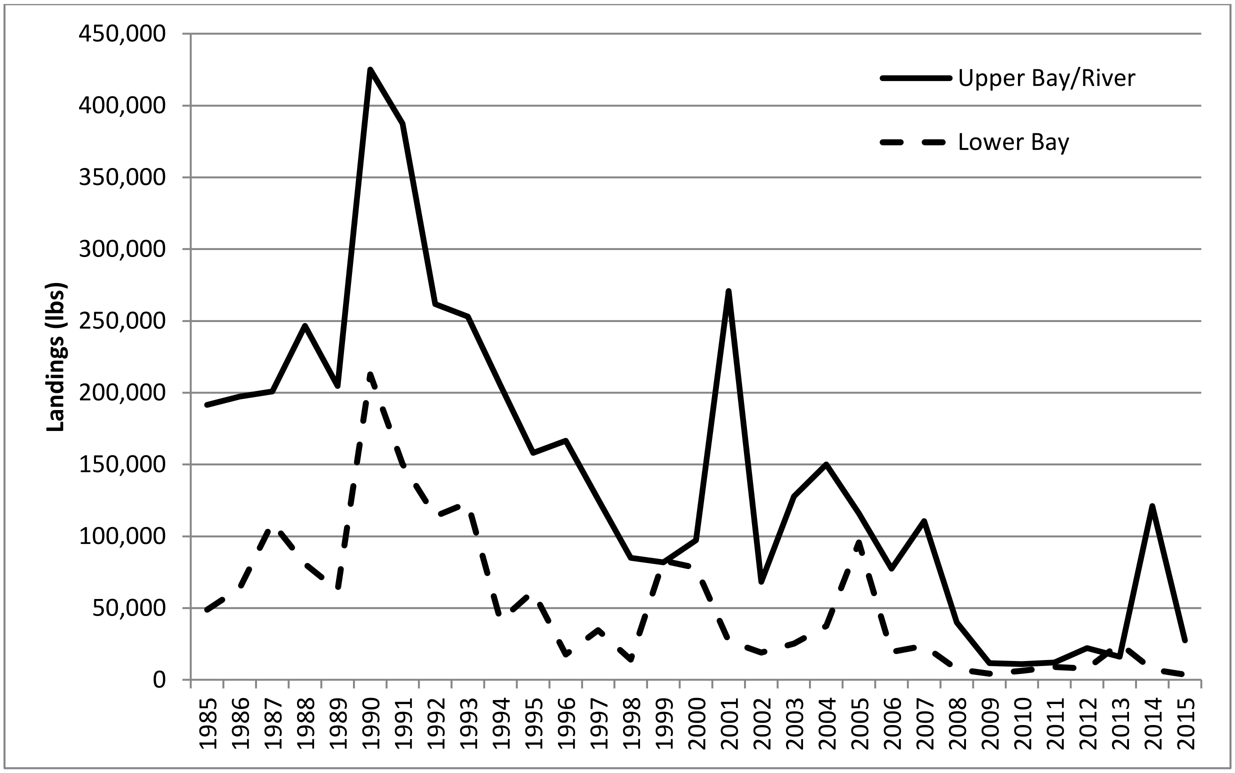


Figure 40. Combined landings for American Shad commercial harvest for the states of Delaware and New Jersey: 1985-2015. The Upper Bay / River is defined by those landings occurring above the Bowers Beach, DE to Gandys Beach, NJ. Lower Bay is defined by those landings occurring below that line.

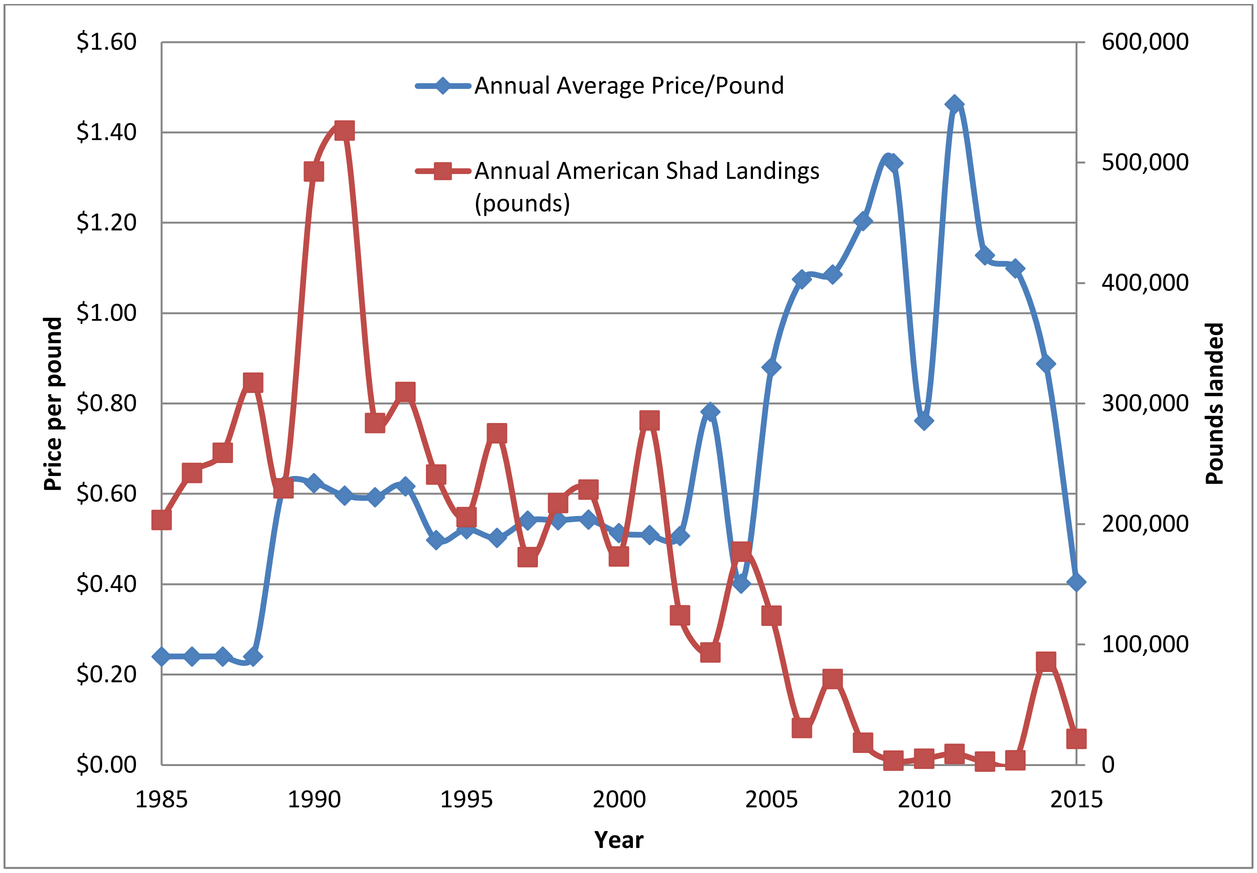


Figure 41. Pounds landed and market value for American Shad landed in the State of Delaware from 1985-2015.

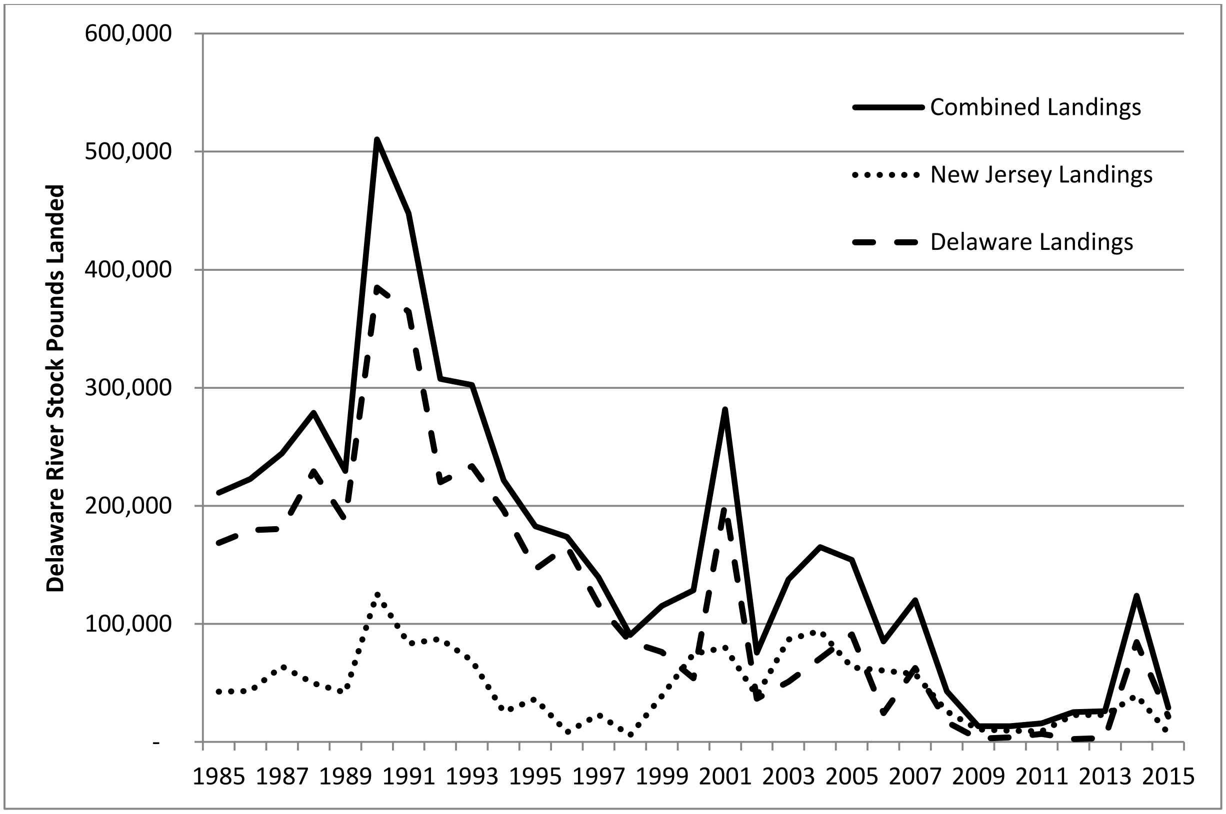


Figure 42. Pounds of Delaware River stock American Shad landed in the Delaware Bay.

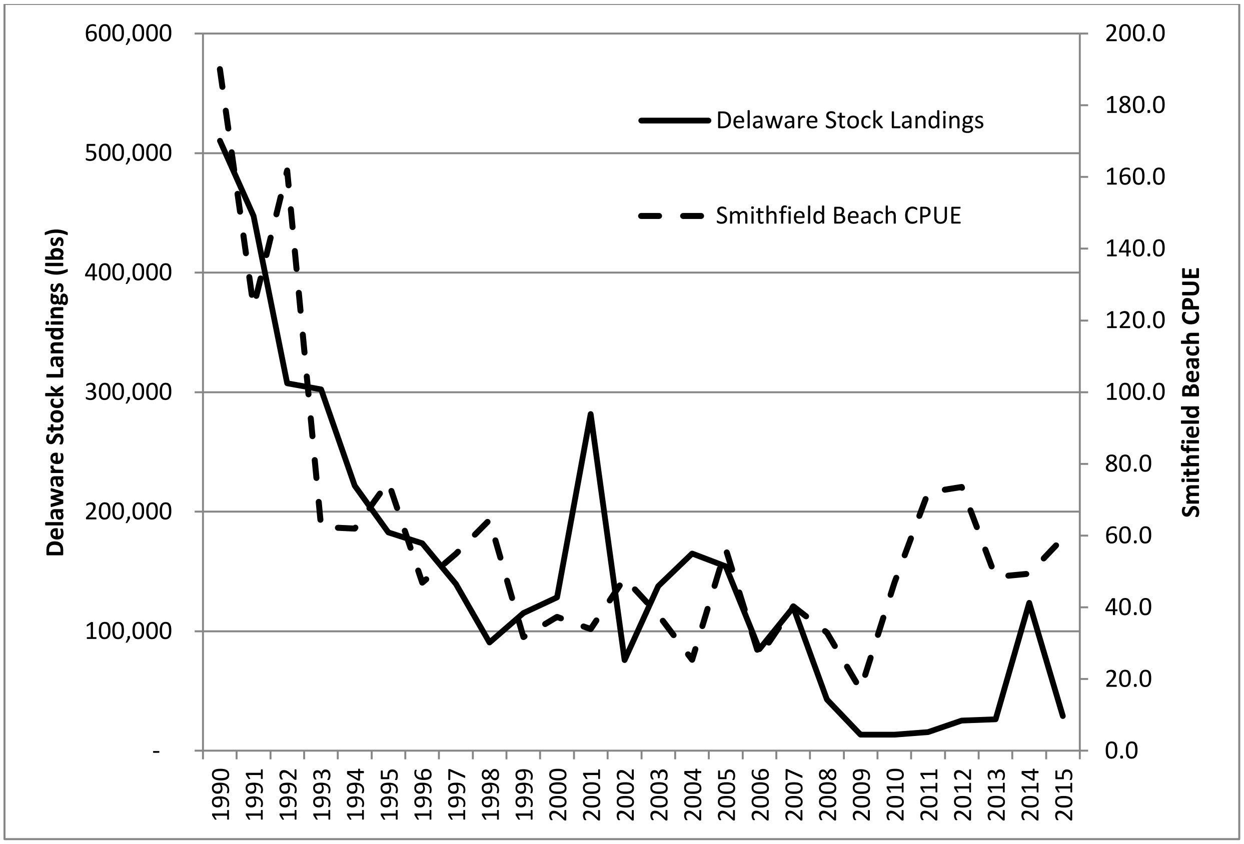


Figure 43. Comparison of trends between Delaware River stock landings and Smithfield Beach CPUE.

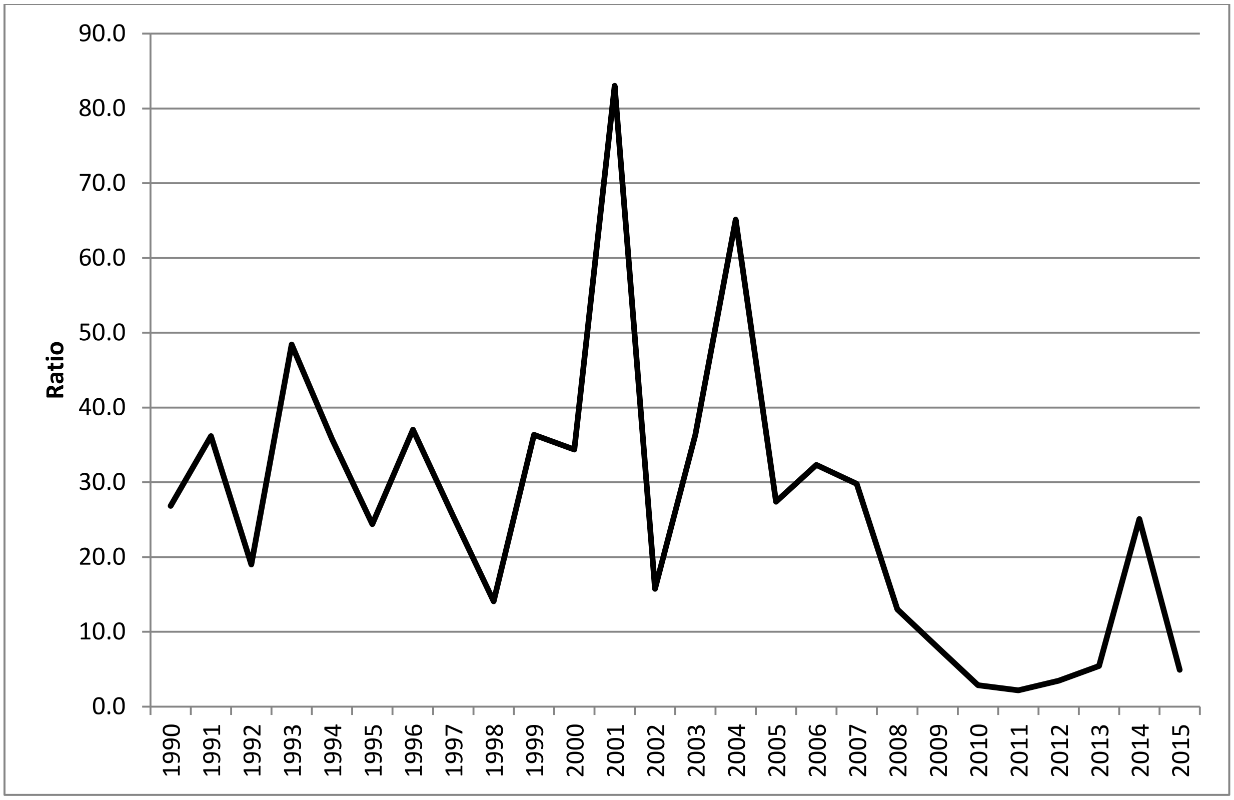


Figure 44. Ratio of Delaware River stock landings divided by Smithfield Beach CPUE (divided by 100). Early Period (NMFS estimations) is defined as 1990-1999, Late Period (mandatory reporting) is defined as 2000-2015.

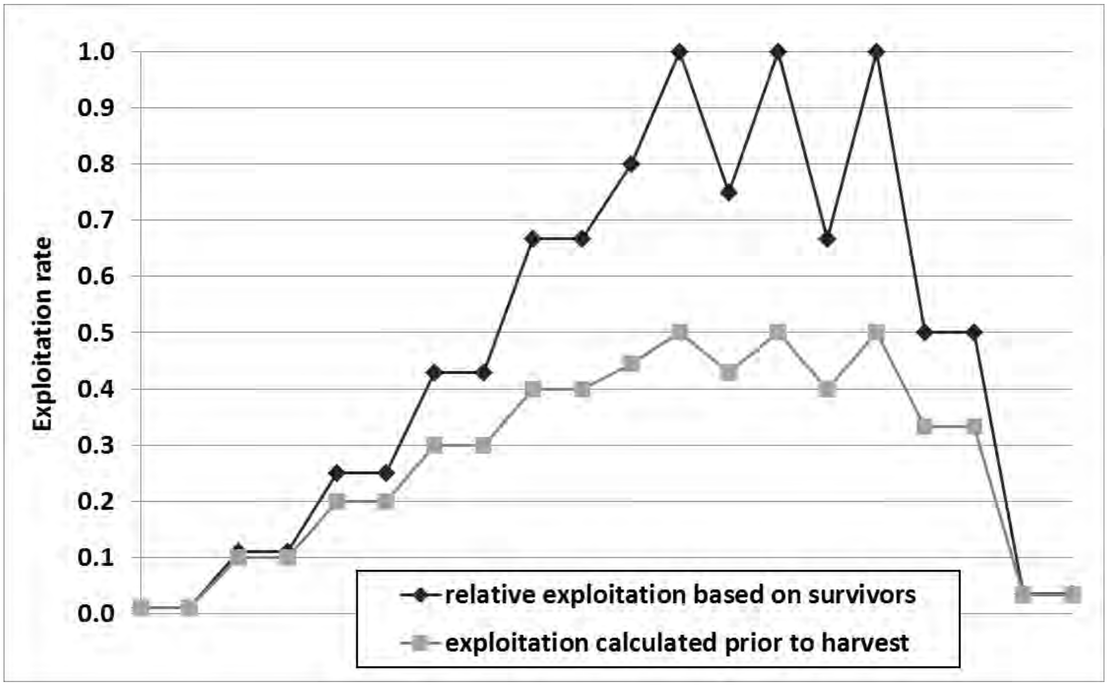


Figure 45. Comparison of exploitation rates based on the population prior to harvest (pop) and on survivors following harvest (survivors).

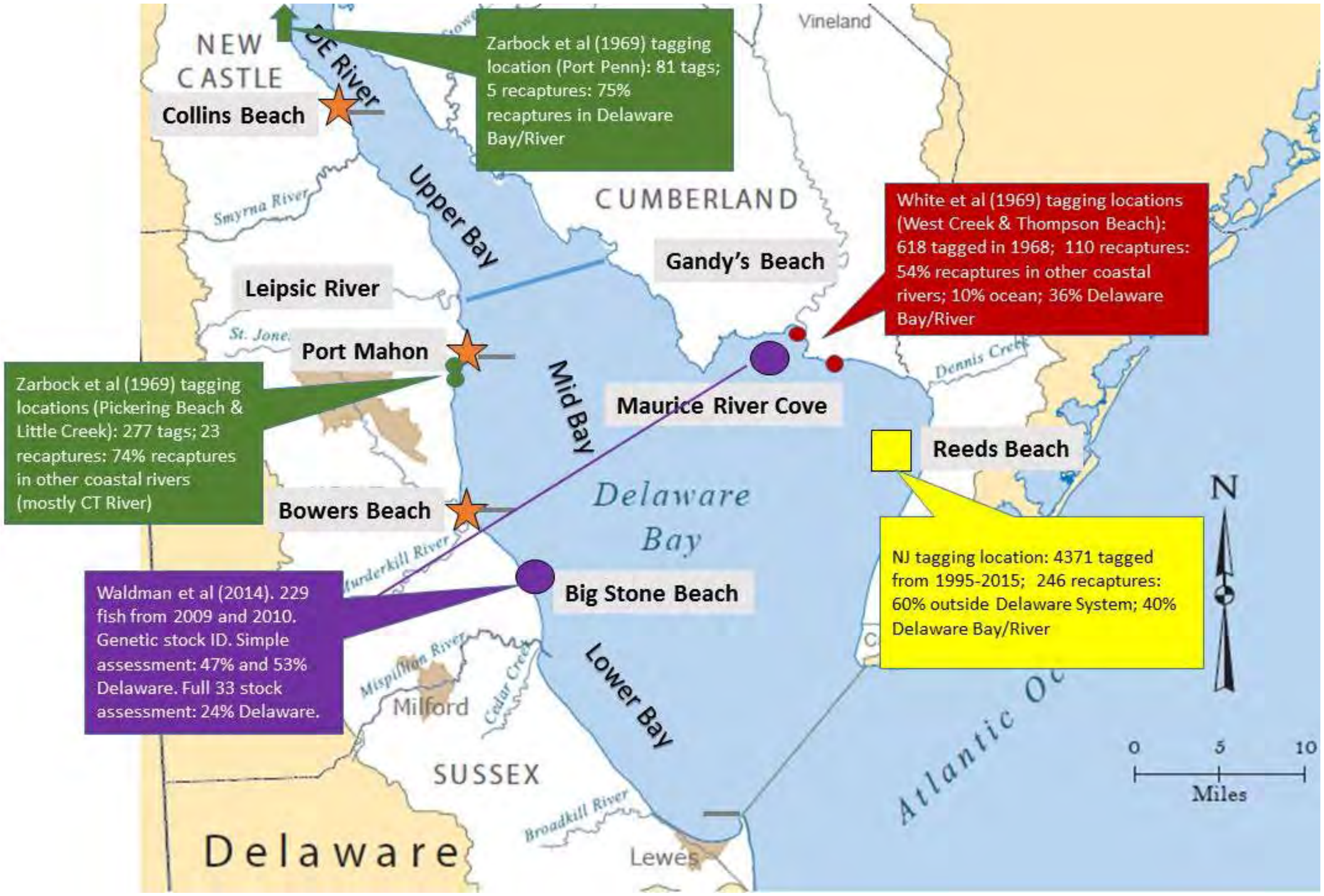


Figure 46. Map of the lower Delaware River and Bay, delineating harvest reporting regions for Delaware (orange), location of recent tag releases (yellow), location of historic tag releases (red and green), location of genetics studies (purple) and delineation line listed in 2012 SFP (blue).

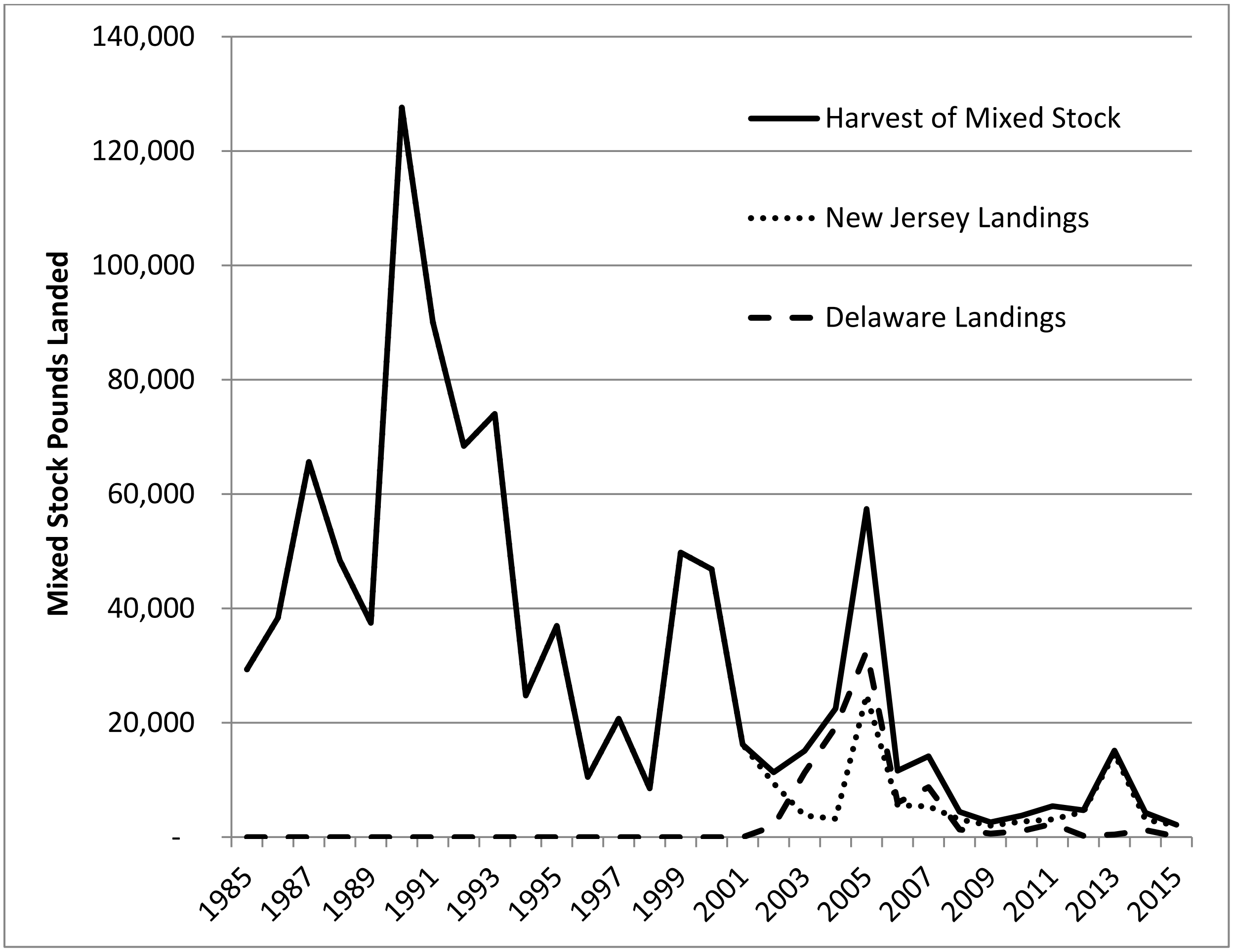


Figure 47. Pounds of mixed stock American Shad landed in the Delaware Bay. New Jersey represented 100% of the landings from 1985 to 2001.

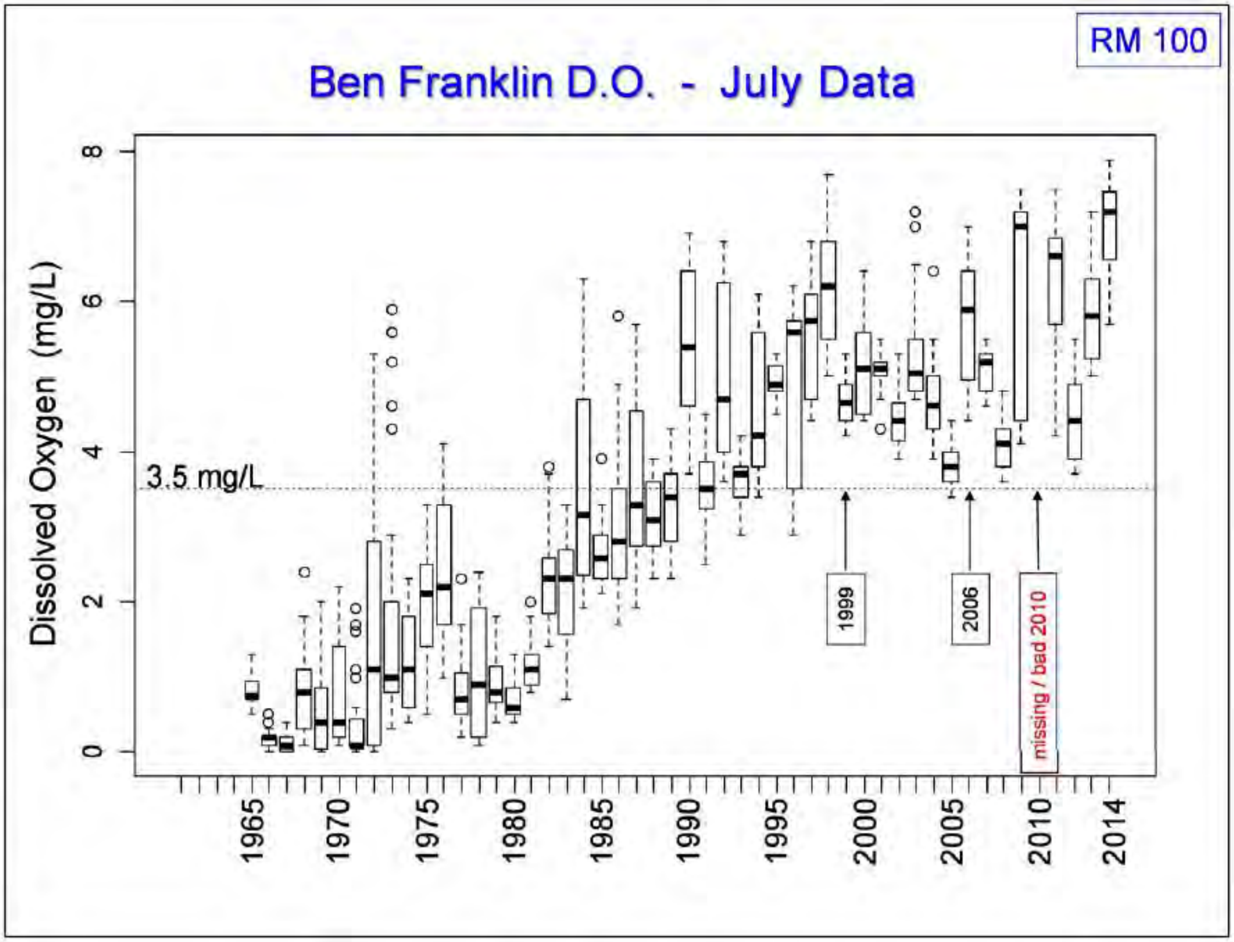


Figure 48. Box and whisker plot of dissolved oxygen concentrations during July, 1965-2014 at the Ben Franklin Bridge (RM 100). Data available at *waterdata.usgs.gov.*

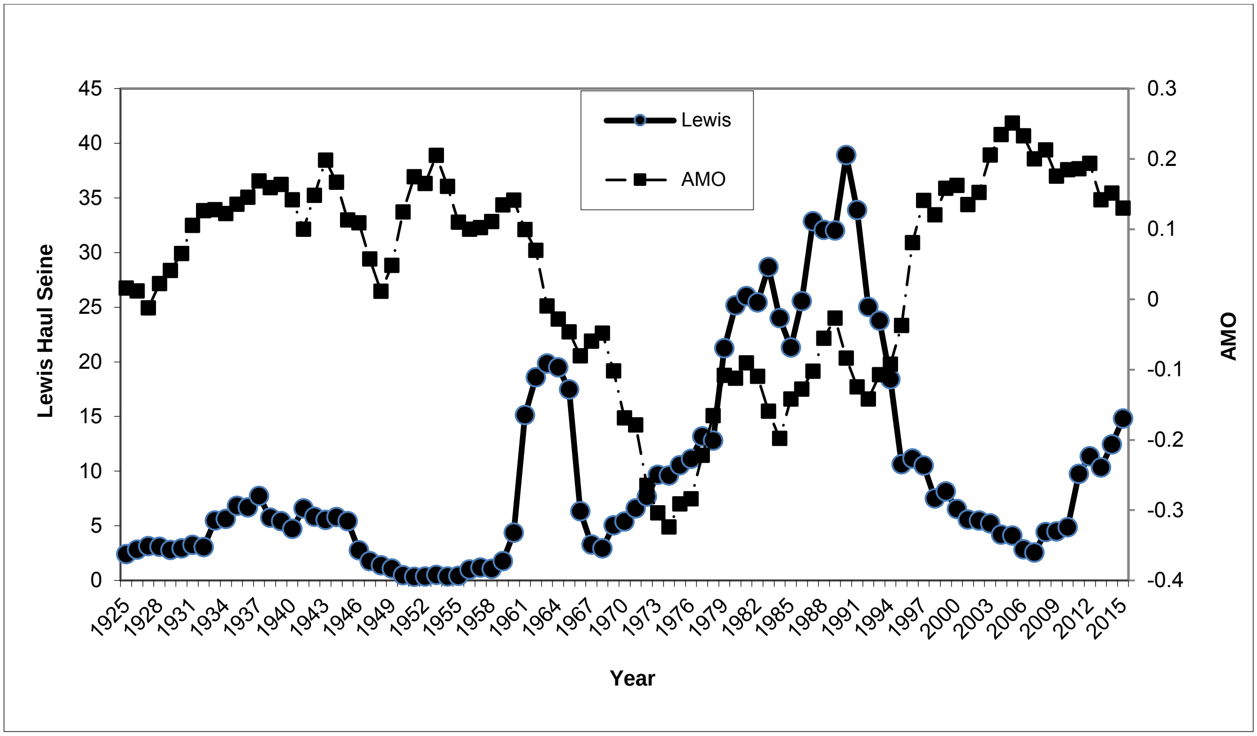


Figure 49. Five-year smoothed Atlantic Multidecadal Oscillation (AMO) compared to five-year smoothed Lewis haul seine CPUE: 1925 - 2015.

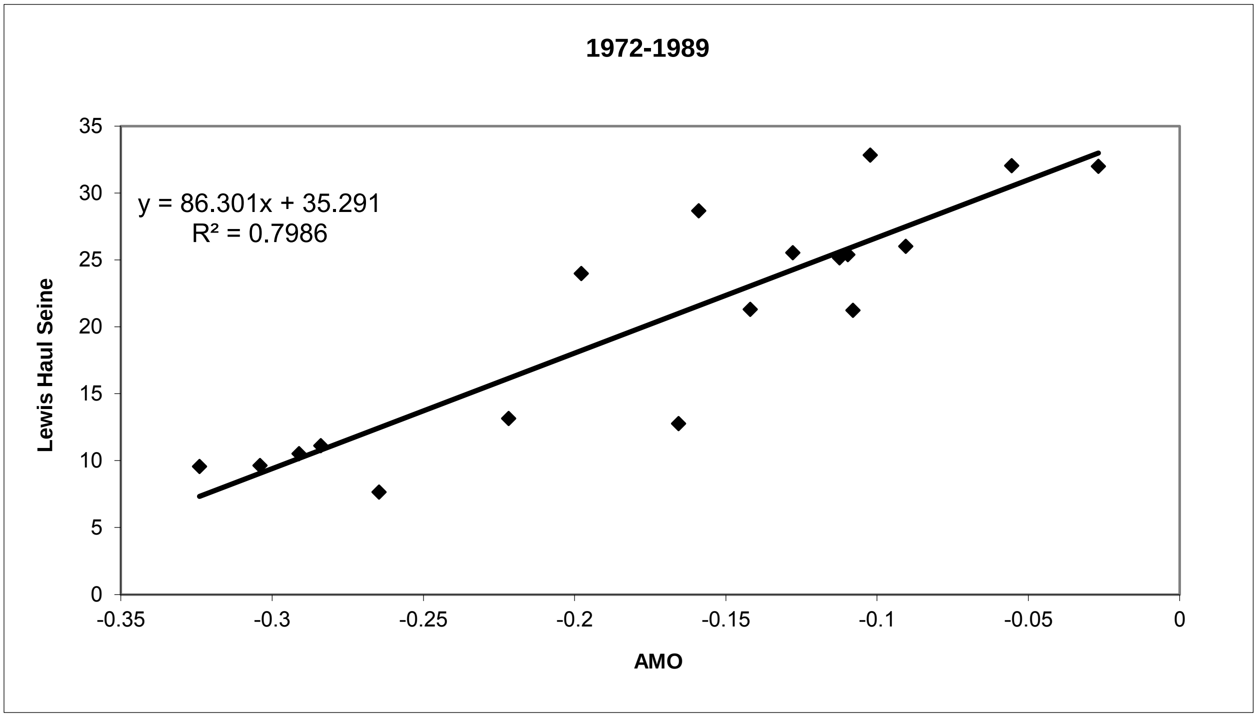


Figure 50. Scatter plot of the five-year smoothed Atlantic Multidecadal Oscillation (AMO) compared to five-year smoothed Lewis haul seine CPUE: 1972 - 1989.

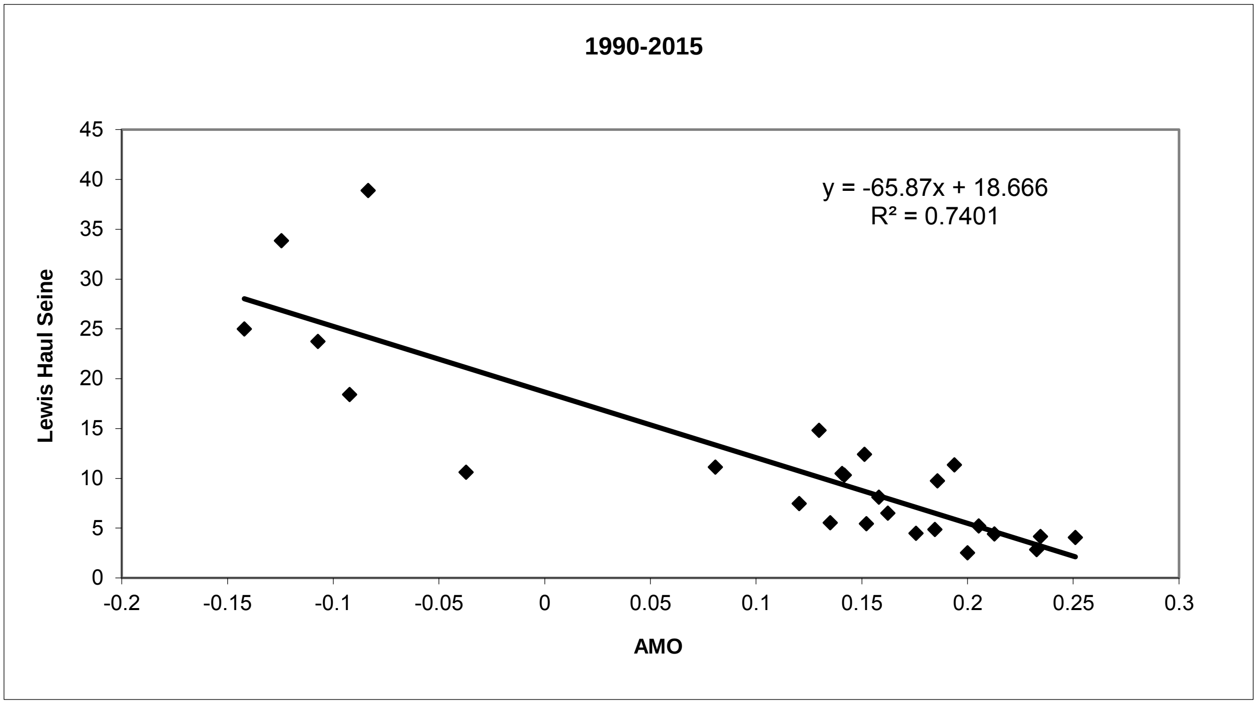


Figure 51. Scatter plot of the five-year smoothed Atlantic Multidecadal Oscillation (AMO) compared to five-year smoothed Lewis haul seine CPUE: 1990 - 2015.

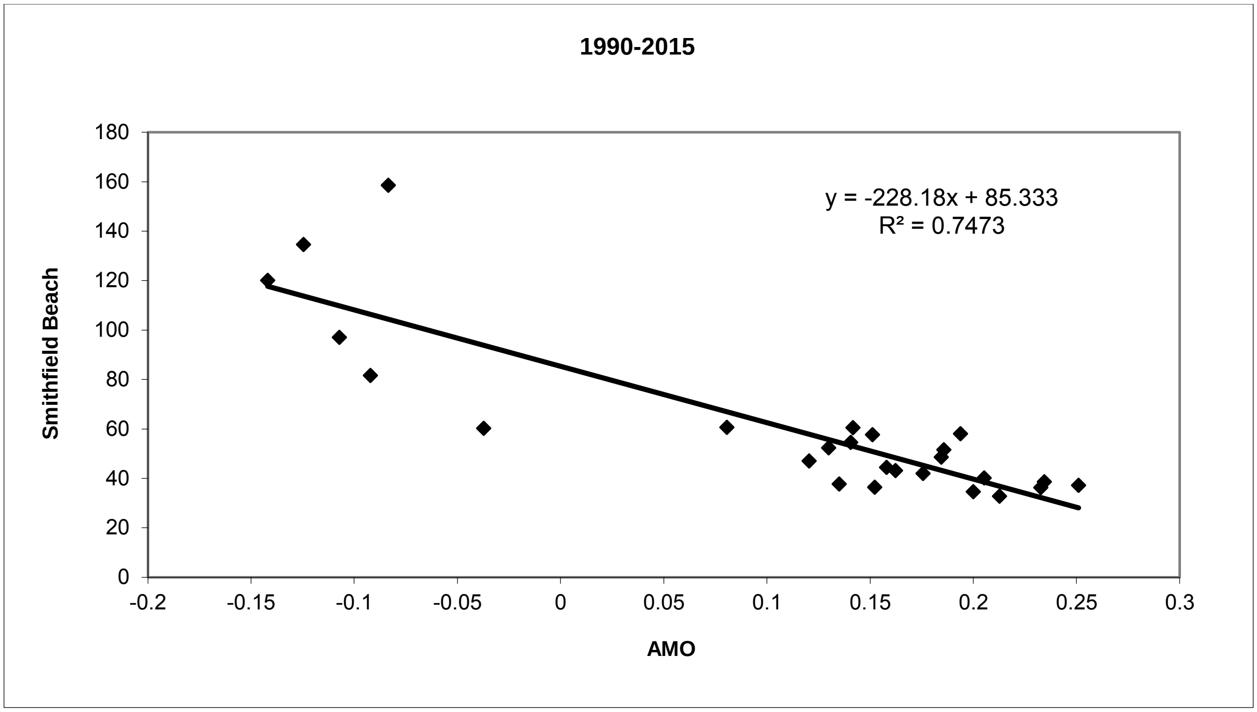


Figure 52. Scatter plot of the five-year smoothed Atlantic Multidecadal Oscillation (AMO) compared to five-year smoothed Smithfield Beach CPUE: 1990 - 2015.

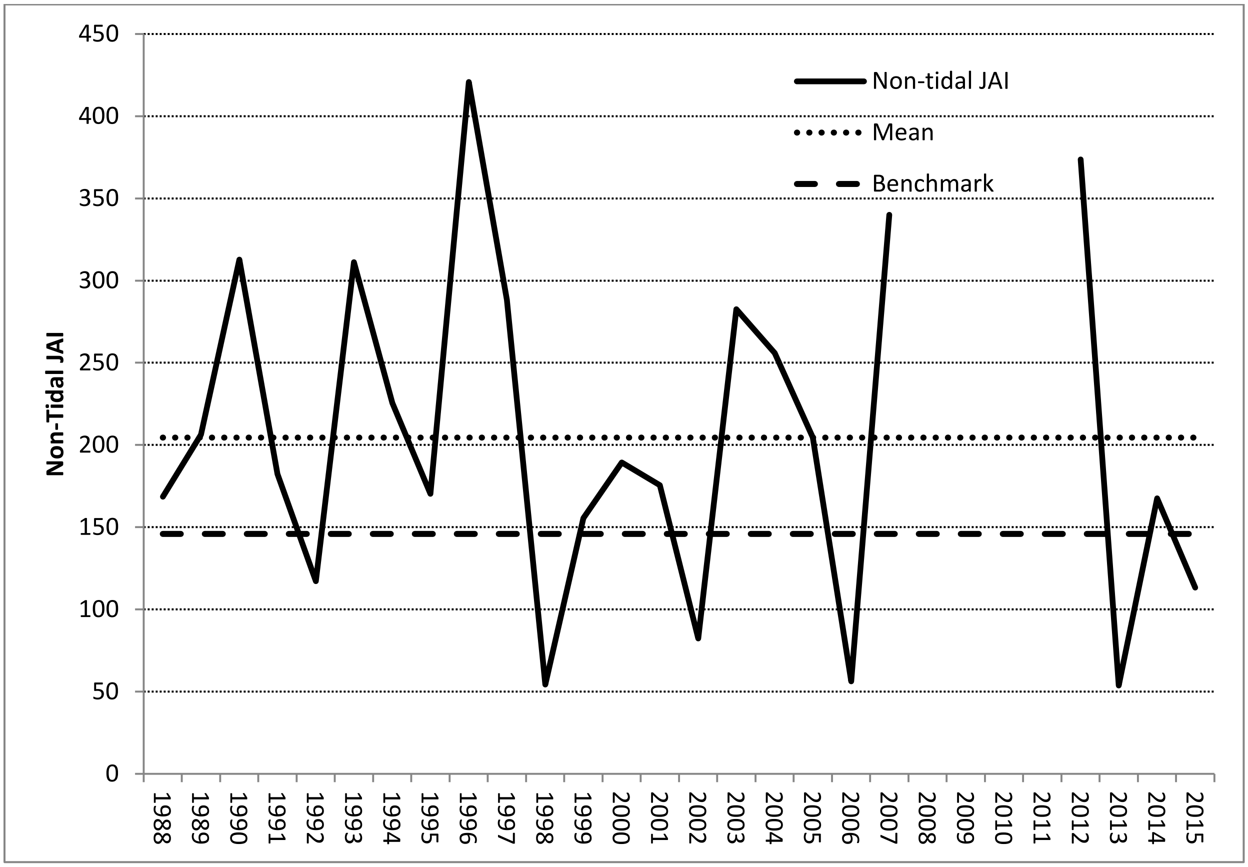


Figure 53. The Delaware River non-tidal American Shad JAI (GLM) with a 25th percentile benchmark: 1987 – 2015. The GLM estimates are based on catches only from the Big 3 sites (i.e., Phillipsburg, Delaware Water Gap and Milford Beach). Note that the benchmark value may change annually based on updated GLM analysis.

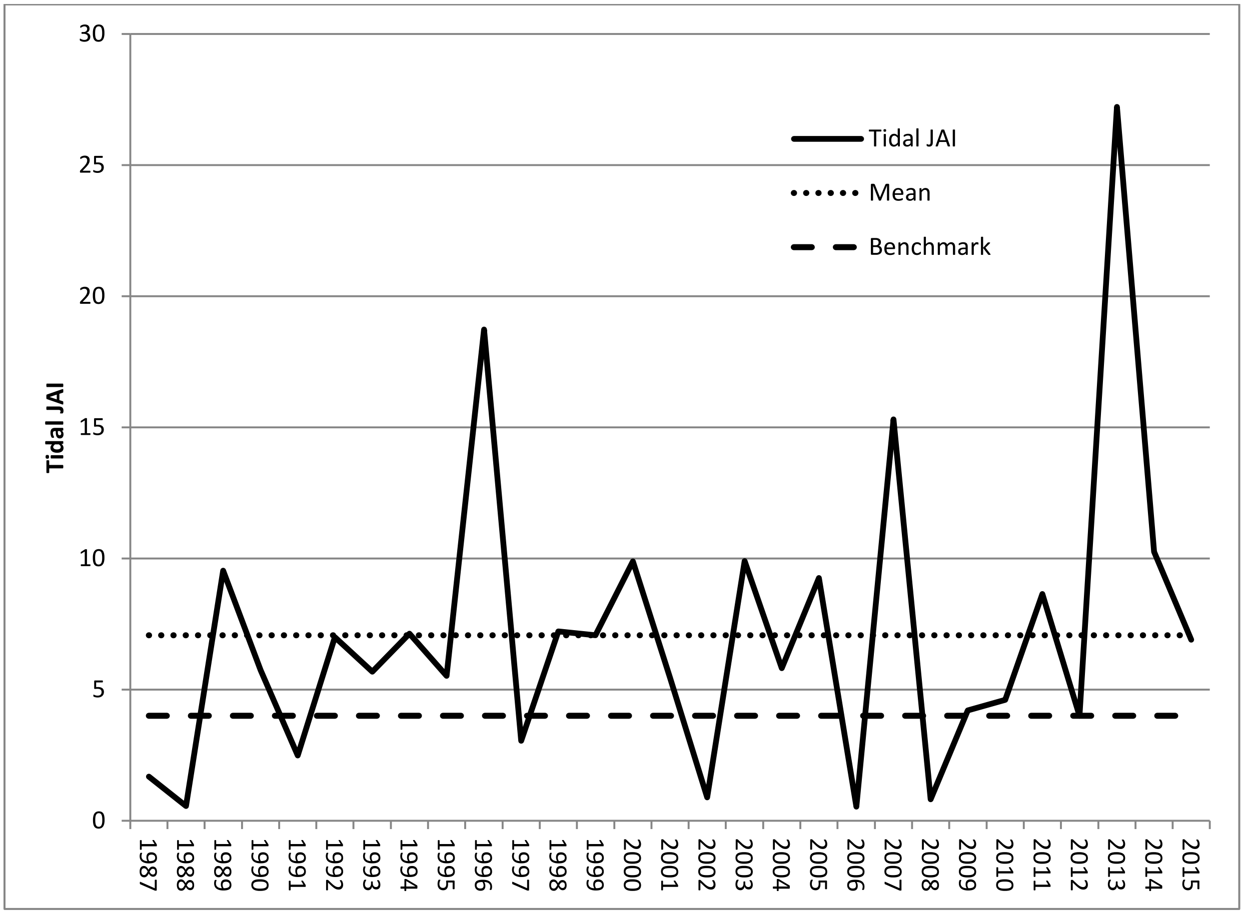


Figure 54. The Delaware River tidal American Shad JAI (GM) with a 25th percentile benchmark: 1987 – 2015. The GM values are based on catches from Region 2 and 3 of the NJDFW tidal seine sites.

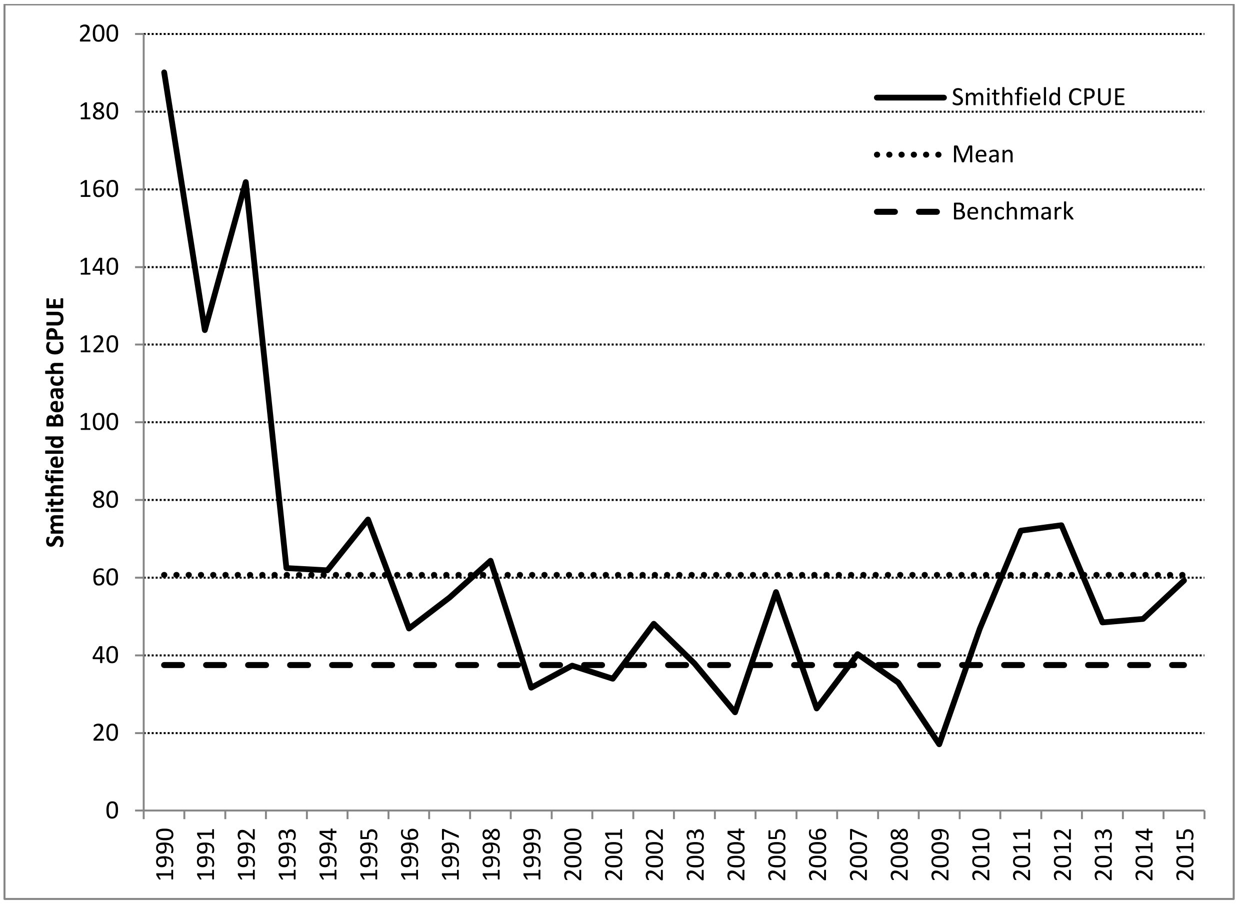


Figure 55. The Delaware River spawning adult American Shad index at Smithfield Beach (RM 218) with a 25th percentile benchmark: 1990 – 2015.

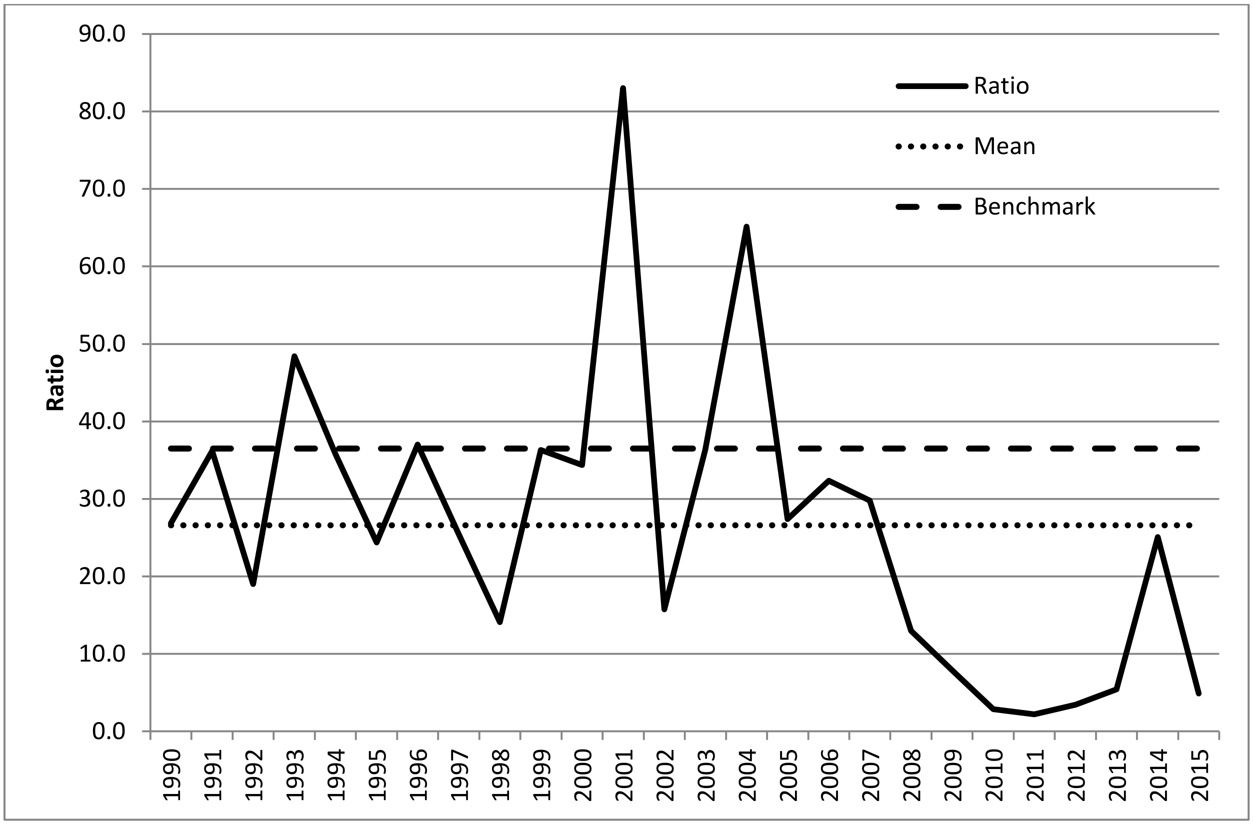


Figure 56. Ratio of Delaware River stock landings divided by Smithfield Beach CPUE (divided by 100) with an 85th percentile benchmark: 1990-2015.

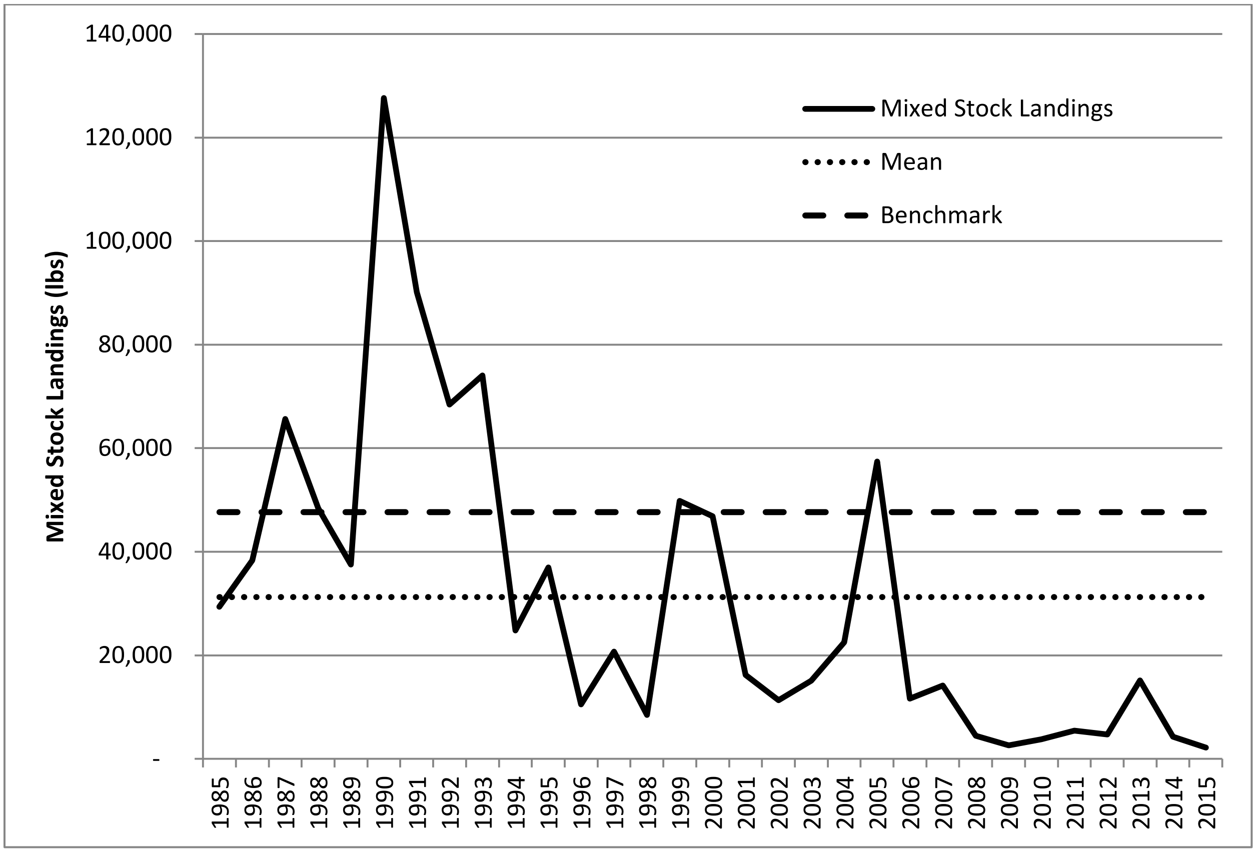


Figure 57. Landings in the Delaware Bay from the mixed stock fishery with a 75th percentile benchmark: 1990-2015.

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	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) Male	Female	Sexes Combined	Range	Std. Dev.	Stretch Mesh (inches)
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**

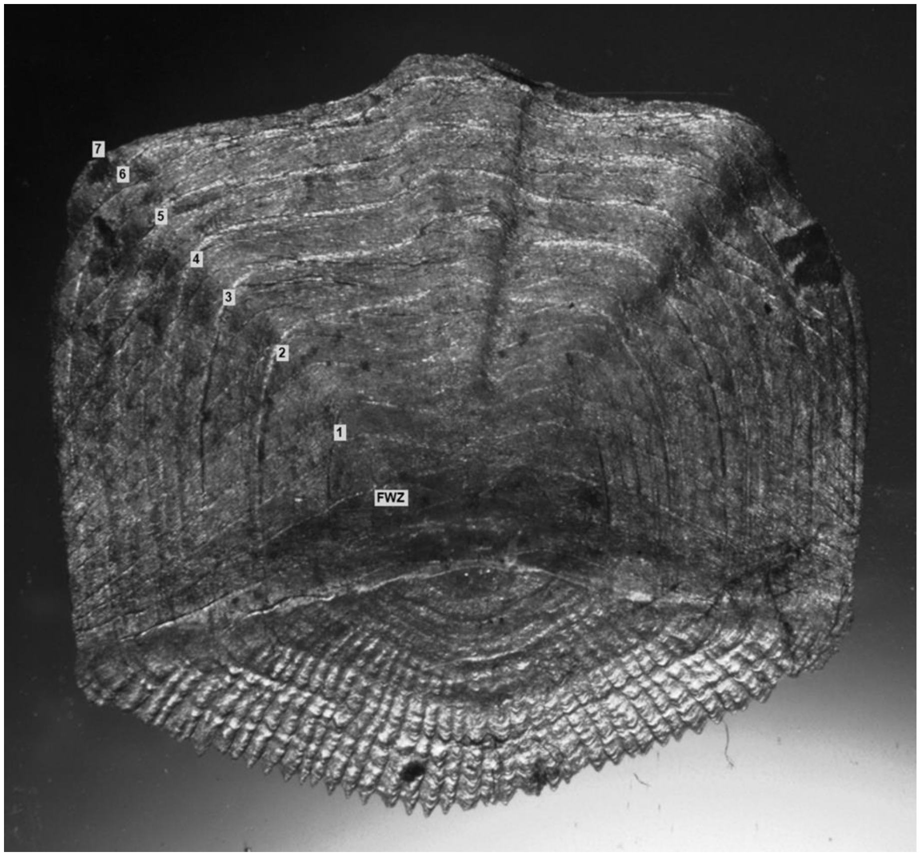
Prepared by:

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.

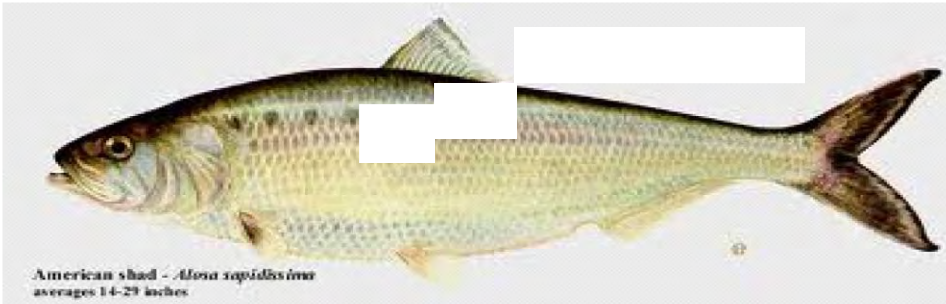
II. Scale Sample Collection

- 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.

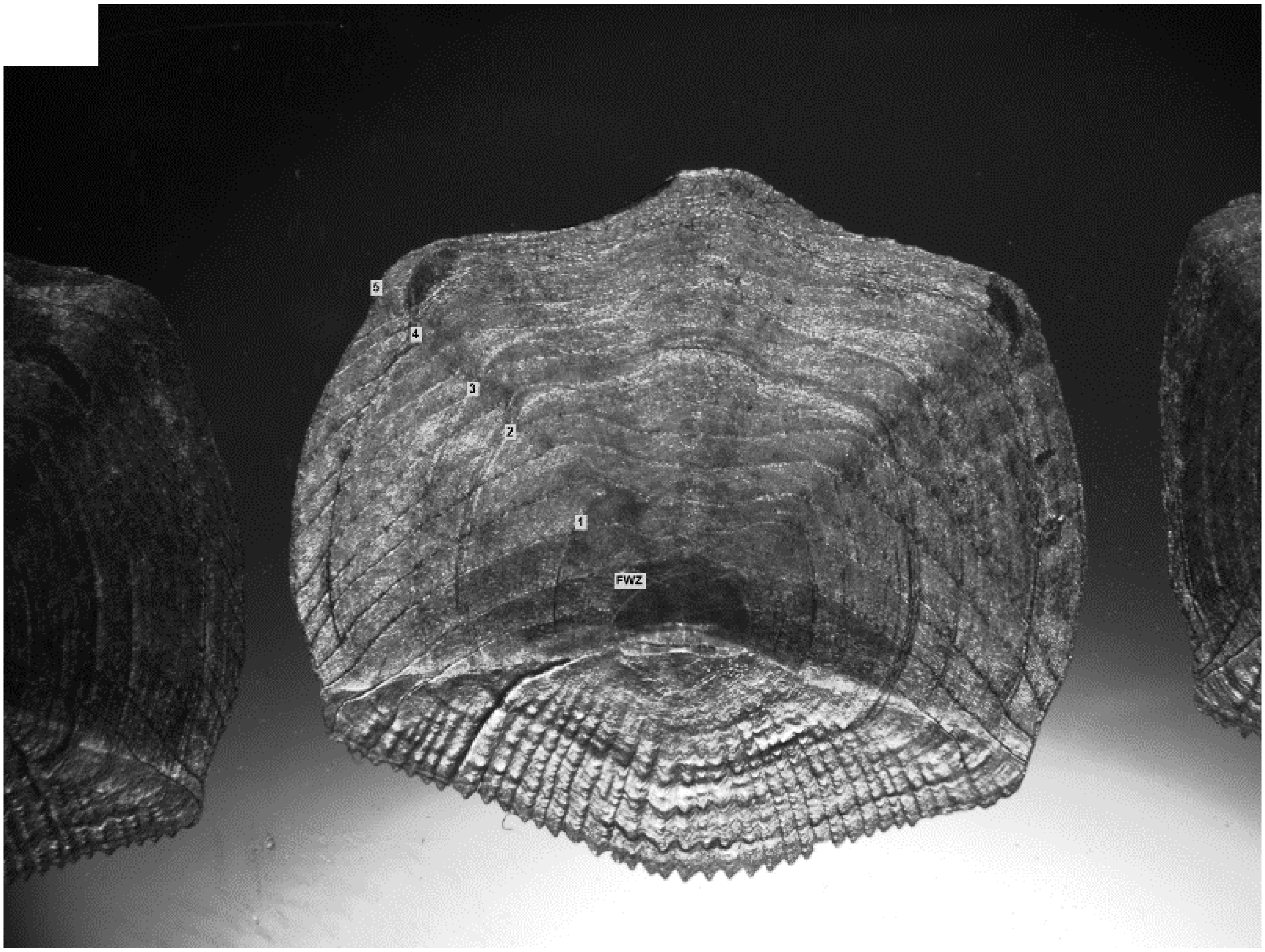
- Scales are collected just ventral of the dorsal fin
    - Before removal use a knife to remove the slime coat and any dirt from the area scales are to be removed on the carcass.

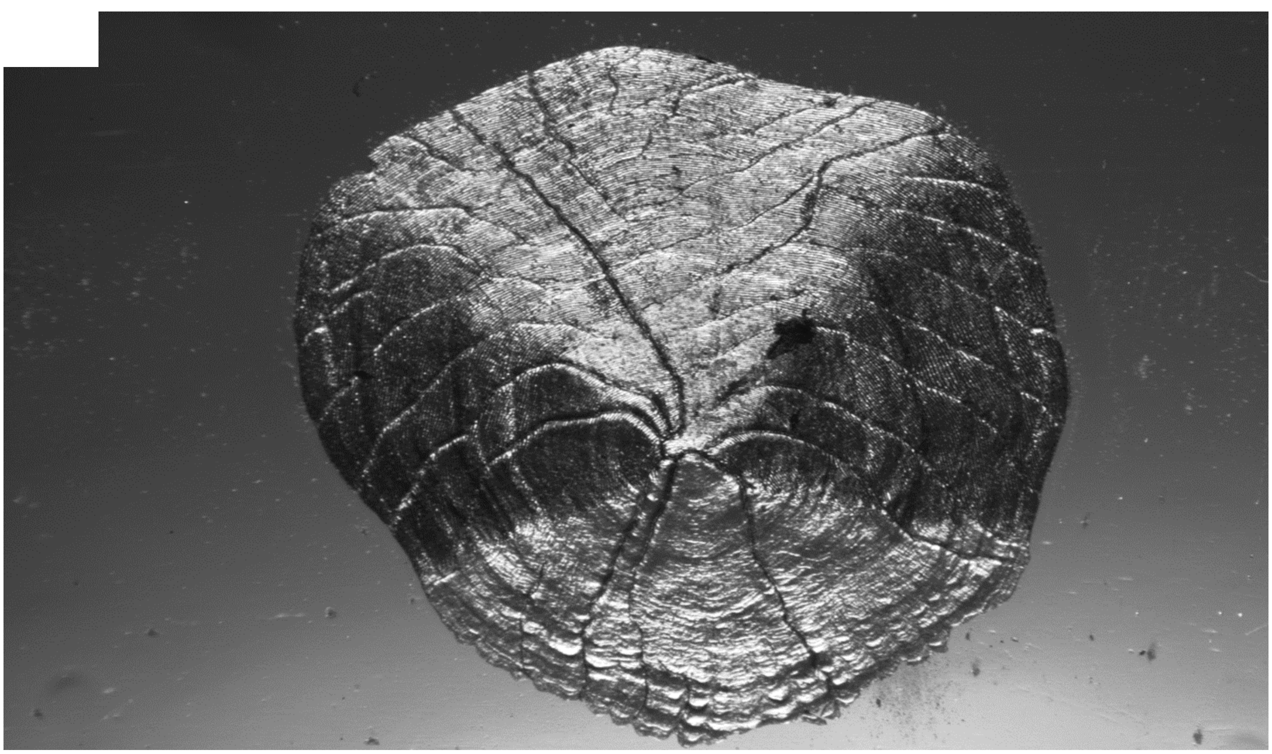
- Ensure the knife is also free of any dirt, slime and previous fish scales.

- 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.
    - 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.
  - o 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
  - o 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).
  - o 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.
  - o Any scratches in the stainless steel plates are pressed into the acetate. Hence the use of the cardboard to reduce this possibility.
  - o 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.
  - o **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.

- o 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.
  - o Regenerated scales are not to be used for age determination or repeat spawning marks.
  - o 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 <u>only</u> help <u>clarifying</u> 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).
  - o Usually, but not always, the FWZ may appear as a concentric ring in both the anterior and posterior portions of the scale (Figure 3)
  - o 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).
  - o 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.

Statement of Concern: Assignment of the Delaware Bay mixed stock harvest
New York State Department of Environmental Conservation, Division of Marine Resources

Under the Delaware River & Bay 2012 SFP, a mixed stock fishery was recognized in the Bay region of the estuary. This fishery was a significant source of mortality for American Shad (Table 1). Estimated mixed-stock landings were approximately 50% of total estuary landings from 1985-2010. The 2012 SFP demarcation scheme was adopted from the 2007 ASMFC stock assessment *verbatim*. The percentage of assignment was based on mark-recapture data, 1995-2005. The revision of the SFP confirmed the appropriateness of the of Gandy's Beach, NJ demarcation; yet, review of historical landings data demonstrated the original DE demarcation line at Leipsic River, DE was unsubstantiated. Reporting requirements preclude the parsing of commercial landings using Leipsic River. The closest reporting point to Leipsic River was Port Mahon, DE.

The revised 2017 SFP proposes assigning Bowers Beach as the demarcation point in the State of Delaware while retaining the demarcation line at the same position (Gandy's Beach) on the New Jersey side of the bay (see Figure 1). By relocating the DE demarcation line further down bay, the majority of landings (73%) will now be assigned to the Upper Bay region and all of these fish will be considered Delaware Stock only. This means 83% of the historical landings from 1985-2010 are now assigned to the Delaware stock. Since the majority of the fishery occurs between the 2012 demarcation line and the currently proposed 2017 demarcation line, this shift effectively eliminates recognition of the mixed stock fishery as a major source of harvest by Bay fishers. Establishing a benchmark using this demarcation line, without the proper evidence to the contrary, will allow the continuance of a fishery on out-of-basin shad, particularly on several collapsed stocks, without consequence. It will certainly not document, evaluate, or constrain the expansion of a mixed stock fishery, which was the intent of the 2012 SFMP.

There has been no new information to suggest that the mixed stock is any less prevalent above Bower's Beach than at the time of the 2012 SFP. Re-designating the demarcation point to the beginning point of the Lower Bay reporting region disregards the limited data that are available. Tagging and genetic studies south of Port Mahon have suggested the proportion of Delaware stock in the Mid Bay and Lower Bay reporting regions is in the vicinity of 26% - 40% (Figure 1).

We believe there is not enough data to warrant a shift in the demarcation point 12 miles south of the intended location in the 2012 SFMP, and 22 miles south of the reported location (Collins Beach). A more appropriate adjustment would declare Port Mahon as the State of Delaware shoreline demarcation point, which is within two river miles of the intended DE location in the 2012 SFMP and the corresponding demarcation point in New Jersey. This location marks the northern end of the Mid Bay reporting region and is the closest location for status quo. Any landings south of this point would be subject to the mixed stock allocation. This more conservative approach must be taken until further information on the mixed stock distribution in the bay is available. As of writing this, the USFWS secured funding for at least one year of a genetic study to clarify the distribution of mixed stocks northward into the bay. This study will take place the spring of 2017.

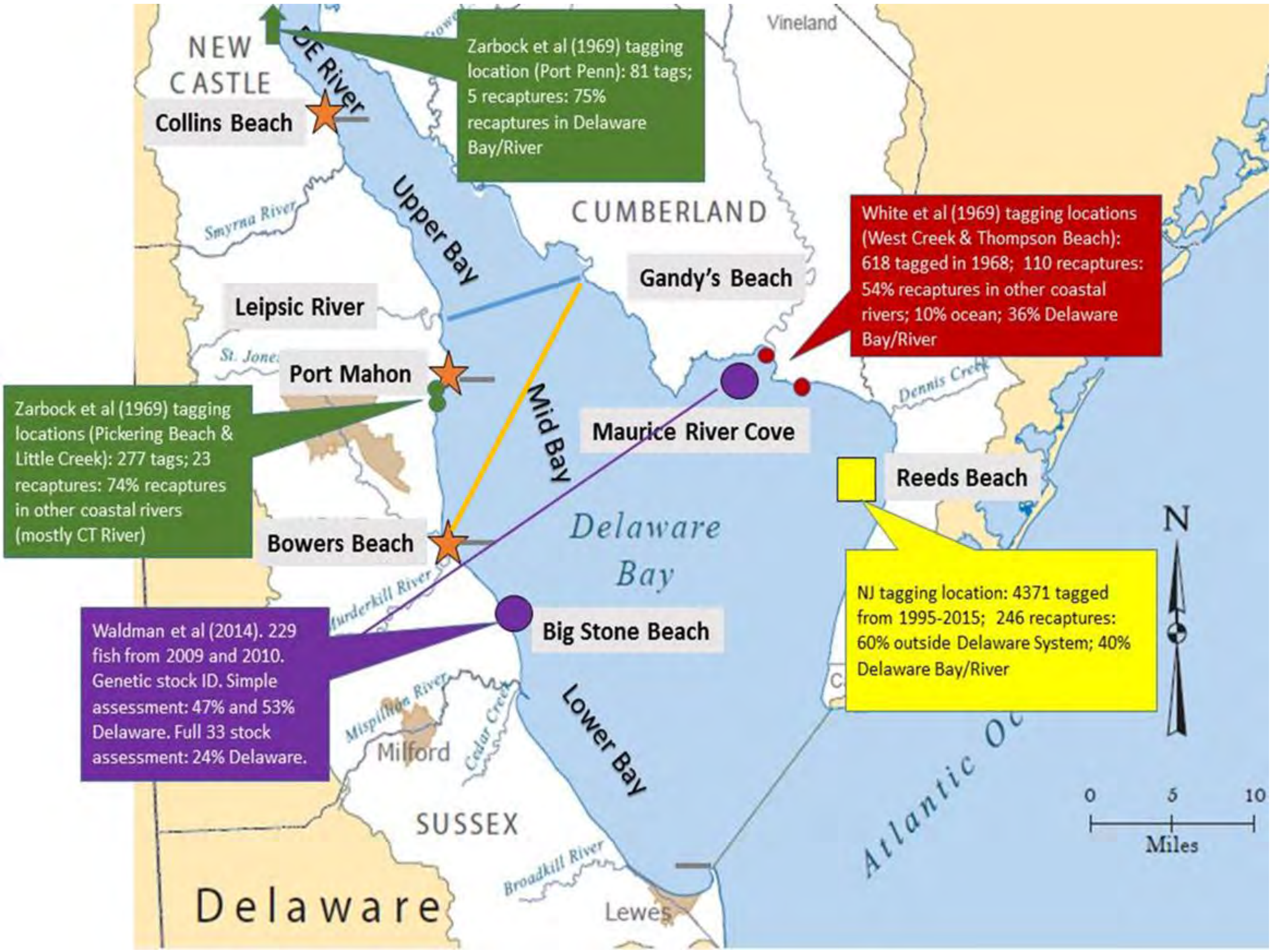

Figure 1. State of Delaware reporting regions and historical tagging information for American Shad in Delaware Bay. Stars represent the northern extent of the reporting regions. The blue line is the 2012 SFMP demarcation line for the mixed stock fishery. The orange line represents the newly proposed demarcation line.

Table 1. Landings summaries reported in the approved 2012 SFMP and proposed 2017 SFMP. Values in red represent updated landings numbers. Delaware and New Jersey landings combined.

	Landings summarized from Table 2 of the 2012 SFMP					Landings summarized from Table 27 of the 2017 SFMP				
	River	Bay	Estuary landings	Delaware stock	Mixed stock	Upper bay	Lower bay	Estuary landings	Delaware stock	Mixed stock
1985	52,397	188,086	240,483	125,751	114,732	191,583	48,900	240,483	211,143	29,340
1986	46,322	214,789	261,111	130,090	131,021	197,211	63,900	261,111	222,771	38,340
1987	30,465	279,354	310,182	139,413	170,406	200,782	109,400	310,182	244,542	65,640
1988	41,713	285,589	327,302	153,093	174,209	246,602	80,700	327,302	278,882	48,420
1989	29,049	238,038	267,087	121,884	145,203	204,587	62,500	267,087	229,587	37,500
1990	56,162	581,805	637,968	283,066	354,901	425,219	212,749	637,968	510,319	127,649
1991	34,807	502,879	537,686	230,930	306,756	387,477	150,209	537,686	447,561	90,125
1992	51,012	323,792	375,814	177,291	197,513	261,779	114,035	375,814	307,393	68,421
1993	32,560	343,823	376,429	166,651	209,732	253,001	123,428	376,429	302,372	74,057
1994	23,413	223,098	246,511	110,421	136,090	205,206	41,305	246,511	221,728	24,783
1995	26,104	193,651	219,760	101,628	118,127	158,139	61,621	219,760	182,787	36,973
1996	11,195	172,703	184,137	78,549	105,349	166,574	17,563	184,137	173,599	10,538
1997	17,723	142,592	160,315	73,334	86,981	125,766	34,549	160,315	139,586	20,729
1998	8,122	90,946	99,068	43,591	55,477	84,888	14,180	99,068	90,560	8,508
1999	7,725	157,165	164,928	69,019	95,871	81,892	83,036	164,928	115,106	49,822
2000	50,166	125,142	175,318	98,971	76,337	97,186	78,132	175,318	128,439	46,879
2001	72,775	225,192	297,972	160,600	137,367	270,932	27,040	297,972	281,748	16,224
2002	35,256	51,871	87,127	55,486	31,641	68,212	18,915	87,127	75,778	11,349
2003	88,946	63,950	152,942	113,887	39,010	127,760	25,182	152,942	137,833	15,109
2004	95,088	92,463	187,551	131,149	56,402	150,073	37,478	187,551	165,064	22,487
2005	47,220	164,374	211,594	111,326	100,268	115,926	95,668	211,594	154,193	57,401
2006	57,423	39,256	96,679	72,733	23,946	77,323	19,356	96,679	85,065	11,614
2007	55,634	78,632	134,266	86,300	47,966	110,643	23,623	134,266	120,092	14,174
2008	24,137	23,230	47,373	33,197	14,170	39,944	7,429	47,373	42,916	4,457
2009	9,686	6,730	16,091	12,311	4,105	11,700	4,391	16,091	13,456	2,635
2010	8,820	9,371	17,239	12,475	5,716	10,944	6,295	17,239	13,462	3,777
Totals	**1,013,920**	**4,818,521**	**5,832,933**	**2,893,143**	**2,939,298**	**4,271,349**	**1,561,584**	**5,832,933**	**4,895,983**	**936,950**

*corrected numbers from the 2017 SFMP

Sustainable Fishery Management Plan for New York River Herring Stocks

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and

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**Submitted for review
to the
Atlantic State Marine Fisheries Commission**

Executive Summary

Amendment 2 to the Atlantic States Marine Fisheries Commission Shad and River Herring Interstate Fishery Management Plan requires member states to demonstrate that fisheries for river herring (alewife and blueback herring) within their state waters are sustainable. A sustainable fishery is defined as one that will not diminish potential future reproduction and recruitment of herring stocks. If states cannot demonstrate sustainability to the Atlantic States Marine Fisheries Commission (ASMFC), they must close their herring fisheries.

New York State proposes to maintain a restricted river herring (alewife and blueback herring) fishery in the Hudson River and tributaries and to continue closures of river herring fisheries elsewhere in the State. This proposal conforms to Benefit 4 of the New York State Hudson River Estuary Action Agenda.

<u>Stock Status</u>

Alewife and blueback herring are known to occur and spawn in New York State in the Hudson River and tributaries, the Bronx River, and several streams on Long Island. The Hudson River is tidal to the first dam at Troy, NY (rkm 245). Data on stock status are available for the Hudson River and tributaries. Few data are available for river herring in streams in Bronx County, southern Westchester County, and on Long Island. River herring are rarely encountered in the New York portion of the Delaware River.

Hudson River: Commercial and recreational fisheries exploit the spawning populations of river herring in the Hudson River and tributaries. Most river herring taken in the Hudson and tributaries are used as bait in the recreational striped bass fishery. Recreational fishers are allowed take of river herring with a variety of small nets as well as hook and line. The magnitude of the recreational fishery for river herring is unknown for most years. However, we have estimated recreational harvest from 2007-2015 using data obtained from our Cooperative Angler Program and a statewide creel survey conducted in 2007. Estimated recreational herring harvest ranged from 78,491 fish in 2007 to 386,915 fish in 2015, with an average of 312,036 herring from 2013-2015. Based on average weights of river herring collected during that time period (2013-2015), this equates to approximately 103,300 pounds annually. To put this estimated recreational harvest in context, run counts from Black Creek, a small tributary with approximately 1.8 km of available spawning habitat, averaged 409,234 alewives (approximately 139,000 pounds) annually during the same time period. Black Creek is just one of the 68 primary tributaries to the Hudson River.

Data on commercial harvest of river herring in New York State are available since the early 1900s. Several peaks occur during the time period. The first peak was in the early 1900's (501,438 pounds) followed by a lull until the period prior to World War II when landings peaked a second time in 1935 (274,405 pounds). Post WW II there was another period of low landings until a final peak in 1982 (229,201 pounds). Combined ocean and river landings in New York waters has remained relatively low, with some data gaps, during the rest of the 1980s through present.

Since 1995, landings have been separated between the Hudson and other waters (marine) but due to optional participation and minimal enforcement of commercial reporting, any in-river reporting from 1995-1999 is unreliable. From 2000 to 2012, landings averaged 15,061 pounds, peaking in 2002 at 20,346 pounds. Following regulation changes in 2013, reported commercial landings declined to roughly 45% of the average from 2000 through 2012.

From 2013-2015, an average of 156 fishers annually purchased commercial gill net permits and approximately 121 purchased commercial scap net permits. According to the required annual reports, an average of 35% of these permitees actively fished from 2013 to 2015, and of those that used the commercial gears, roughly half of gill net users and the majority of scap net users reported catches as taken for "personal use" or "personal bait".

Fishery dependent data on river herring status since 2000 are available from commercial reports and from on-board monitoring. Annual scap net efforts were relatively steady through 2012, but dropped dramatically in 2013 when net use became prohibited in tributaries. Scap net CPUEs declined from 2000 to 2007, but have increased from 2007 to present. Drift gill net CPUEs have increased steadily since 2000, with efforts declining since 2006. Fixed gill net effort in the lower river has decreased steadily since 2000, but CPUEs have been increasing since 2010.

The extent of the loss of New York's river herring stocks through bycatch in ocean commercial fisheries remains largely unknown; however, the recent increase in the occurrence of repeat spawn marks in both species of river herring are indicative of reduced mortality while at sea.

Fishery independent data on size and age composition of river herring spawning in the Hudson River Estuary are available from 1936, intermittently since the late 1970s and annually beginning in 2012. Prior to 2012, the intermittent effort expended to catch river herring resulted in relatively low and variable catches. Data collected in 1936 (Greeley 1937) are used as reference only due to very small sample sizes. However, these data provide a historic perspective of potential maximum sizes of both species of river herring.

Mean total length and mean length at age of both river herring species in the Hudson River have increased since 2012 when sampling efforts increased and became consistent. Maximum total lengths and mean length at age of both species are approaching or have exceeded those reported in 1936 by Greeley. Since 2012, mean length at age for both species across all ages have been either stable or increasing with the majority increasing. The increases in mean length and mean length at age are indicative of reduced mortality both within river and during ocean residency.

Mortality estimates derived from age and repeat spawning data have followed similar trends in most years. Mortality estimates for alewives declined from 2012-14. In 2015, age based mortality estimates increased while repeat spawn based mortality estimates decreased. This may be due to a large year class moving through the fishery resulting in over dispersion of older fish, and is further compounded by fewer age three and age four fish observed in 2015. Mortality estimates for blueback herring have declined or remained stable since 2012.

Young-of-year (YOY) production has been measured annually by beach seine since 1980. CPUE of alewife remained low through the late 1990s and has since increased erratically. CPUE of young of year blueback herring has varied with a very slight downward trend since 1980; however, the 2014 index value was the highest in the history of the survey.

Streams on Long Island, Bronx and south shore of Westchester County:
Limited data that have been collected for Long Island river herring populations are not adequate to characterize stock condition or to choose a measure of sustainability.

Delaware River in New York:
River herring in the New York portion of the Delaware River are very rare. While there have been individual YOY fish occasionally found (Horwitz et al. 2014), we have no record of any fishing effort for either species.

Proposed Fishery for the Hudson River and Tributaries

Given the measures of stock status described above, we are proposing a continuation of the Hudson River fishery at this time. This includes a continuation of the restricted fishery in the main-stem Hudson River, a partial closure of the fishery in tributaries, and annual stock monitoring as described in the previous SFMP (Hattala et al. 2011a). As outlined in the previous plan, we propose to continue to use the sustainability target for juvenile indices which is defined as three consecutive juvenile index values below the 25^{th} percentile of the time series. We will monitor, but not set targets for mean length and mean length at age from fishery independent spawning stock sampling as well as the CPUE in the commercial fixed gill net fishery in the lower river below the Bear Mountain Bridge. We will also monitor the frequency of repeat spawning and total mortality from fishery independent sampling. Once an adequate time series of data is collected, we will investigate appropriate methods to develop mortality based benchmarks to be used as sustainability targets in future sustainable fishing plans.

A summary of existing restrictions are provided in Appendix 1. Restrictions to the recreational fishery include: a 10 fish per day creel limit for individual anglers with a boat limit of 50, a 10 fish creel limit per day for paying customers with a boat limit of 50 for charter vessels, no use of nets in tributaries, and the continuation of various small nets in the main river. Restrictions to the commercial fishery and use of commercial gears include: a net ban in the upper 28 km of the main-stem estuary, on the American shad spawning flats, and in tributaries; gill net mesh and size restrictions; a ban on fixed gears or night fishing above the Bear Mountain Bridge; seine and scap/lift net size restrictions; 36 hour lift period to all commercial net gears; and monthly mandatory reporting of catch and harvest.

Proposed Moratorium for streams on Long Island, Bronx County, the southern shore of Westchester County, and the Delaware River and its tributaries north of Port Jervis NY

Due to the inability to determine stock condition for these areas, New York State proposes to continue a closure of all fisheries for river herring in Long Island streams and in the Bronx and Westchester County streams that empty into the East River and Long Island Sound and New York's portion of the Delaware River as outlined in the previous SFMP (Hattala et al. 2011a).

This SFMP does not directly address incidental catch in the ocean, but focuses on fisheries managed exclusively by New York State. New York is working with the National Marine Fisheries Service, the New England Fishery Management Council and the Mid-Atlantic Fishery Management Council to reduce incidental river herring harvest in fisheries managed by these groups.

CONTENTS

1 INTRODUCTION

Amendment 2 to the Atlantic States Marine Fisheries Commission Shad and River Herring Interstate Fishery Management Plan was adopted in 2009. It requires member states to demonstrate that fisheries for river herring (alewife and blueback herring) within state waters are sustainable. A sustainable fishery is defined as one that will not diminish potential future reproduction and recruitment of herring stocks. If states cannot demonstrate sustainability to ASMFC, they must close their herring fisheries.

In response to Amendment 2 New York State proposed, and ASMFC approved, a Sustainable Fishery Management Plan (SFMP) (Hattala et al. 2011a). This SFMP included an experimental five year restricted fishery in the Hudson River, a partial fishery closure in tributaries, and annual stock monitoring. Monitoring includes young of year indices, and for adults: age and length characteristics, mortality estimators, and commercial fishing catch per unit effort (CPUE).

The following proposes a new five year SFMP for river herring in waters of New York State. The goal of this plan is to ensure that river herring resources in New York provide a source of forage for New York's fish and wildlife and provide opportunities for recreational and commercial fishing now and in the future.

The fisheries that existed back in colonial days in the Hudson Valley of New York undoubtedly included river herring among the many species harvested. River herring, comprised of both alewife (*Alosa pseudoharengus*), and blueback herring (*Alosa aestivalis*) were among the fish mentioned by early explorers and colonists – the French Jesuits, Dutch and English. Archaeological digs along the Hudson in Native American middens indicates that the fishery resources in the river provided an important food source to Native Americans.

Written records for river herring harvest in New York begin in the early 1900. Landings peaked in the early 1900s and in the 1930s and then declined through the 1980s. Landings increased again through 1998, but have since declined. Factors in addition to fishing have affected the stocks: habitat destruction (filling of shallow water spawning habitat; loss of access to tributary spawning habitat through the construction of dams and culverts) and water quality problems associated with pollution that caused oxygen blocks in major portions of the river (Albany and New York City). Water quality has improved over the last 30 years.

New York State does not augment wild river herring stocks with hatchery progeny. The New York City Parks Department initiated an experimental restoration program in which alewife were captured in a Long Island Sound tributary in Connecticut and released in the Bronx River above the first barrier. Limited returns to the river suggest that some reproduction has occurred from these stockings. A variety of non-governmental organizations along with state and federal agencies are working on development of fish passage for river herring on Long Island streams and Hudson River tributaries.

2 MANAGEMENT UNITS

The management unit for river herring stocks in New York State comprises three sub-units. All units extend throughout the stock's range on the Atlantic coast.

- The largest consists of the Hudson River Estuary from the Verrazano Narrows at New

York City to the Federal Dam at Troy including numerous tributary streams (Figure 1).
- The second is made up of all Long Island streams that flow into waters surrounding Long Island and streams on the New York mainland (Bronx and Westchester Counties) that flow into the East River and/or Long Island Sound (Figure 2).
- The third subunit consists of the non-tidal Delaware River and tributaries upriver of Port Jervis, NY.

2.1 Description of the Management Unit Habitat

2.1.1 Hudson River and tributaries

Physical description and habitat use:

The Hudson River flows from Lake Tear of the Clouds in the Adirondacks to the Battery in New York City. It is influenced by tides to the Federal Dam in Troy, 245 km from the Battery. The salt front moves, depending on freshwater inputs from Hudson River tributaries and tidal flow, and generally varies in location from Tappan Zee (rkm 45) to Newburgh (rkm 95). The river includes two major estuarine bays: Haverstraw Bay (rkm 55) and Tappan Zee Bay (rkm 45). These bays are mainly shallow water less than four meters deep where the river extends up to five and a half kilometers from shore to shore. The river also includes a narrow and deep section, the Hudson Highlands, where the river is less than one kilometer wide and over 30 meters deep (Stanne et al., 2007).

The Hudson River below the Federal Dam at Troy has approximately 68 primary tributaries, most of which provide some spawning habitat for river herring (Schmidt and Lake 1996). The largest of these tributaries is the Mohawk River, which enters the Hudson two kilometers north of the Troy Dam. Diadromous fish access to the Mohawk River, and portions of the non-tidal Hudson above the Federal Dam, is possible only through the Erie Canal and Champlain lock system. Fish passage for migratory species at the Troy dam is required by a 2009 FERC relicensing settlement agreement and is in the design phase. Other major tributaries of the Hudson River, all in the estuary, include the Croton River, Wappingers Creek, Rondout Creek, Esopus creek, Catskill Creek, and Stockport Creek.

River herring in the Hudson River spawn in the spring. Alewives are the first to enter the estuary, arriving as early as mid-March and spawning through mid-May. Blueback herring arrive slightly later, generally in April and spawning into early June (Hattala et al. 2011a; Eakin, Cornell University, unpublished data). River herring spawn in the entire freshwater portion of the Hudson and its tributaries up to the first impassible barrier. Adults of both species spawn in Hudson River tributaries, but also spawn in shallow waters of the main-stem Hudson. The nursery area for river herring includes the spawning reach and extends south to Newburgh Bay (rkm 90) encompassing the freshwater portion of the estuary.

Some river herring migrate upstream of the Federal Dam through the Champlain and Erie Canal lock systems. We do not know: 1) if a significant number of river herring move upstream of the dam relative to the entire Hudson River spawning population 2) how many post-spawn adult river herring survive their return trip out of the canal system or 3) if the juvenile herring are able to survive and return to the Hudson River below the Federal Dam. Construction of passage on the Federal Dam will facilitate upstream and downstream migration.

2.1.2 Long Island and Westchester County

Physical description and habitat use:

Freshwater tributaries in the New York portion of the Atlantic Ocean and Long Island Sound watershed are also important for New York river herring (Figure 2). This watershed drains most of the New York City Metropolitan Area, all of Long Island, and portions of Westchester County. The Atlantic Ocean coastline extends 189 kilometers from Rockaway Point to Montauk Point. The watershed includes 840 kilometers of freshwater rivers and streams.

The herring runs in streams on Long Island are comprised almost exclusively of alewife (B. Young, NYSDEC retired, personal communication). Most streams are relatively short runs to saltwater from either head ponds (created by dammed streams) or deeper kettle-hole lakes. Either can be fed by a combination of groundwater, run-off, or area springs. Spawning occurs mid-March through May in the tidal freshwater below most of the barriers. Natural passage for spawning adults into the head ponds or kettle lakes is present in very few streams.

There have been limited efforts to understand river herring runs on Long Island since 1995. Several known runs of alewives on Long Island occur in East Hampton, Southampton, Riverhead and Brookhaven. With the advent of a more aggressive restoration effort in Riverhead on the Peconic River other runs have come to light. Since 2006, an annual volunteer alewife spawning run survey has been conducted. This volunteer effort predominantly documents the presence or absence of alewives in Long Island coastal streams. In 2010, a volunteer investigation was initiated to quantify the Peconic River alewife run. Size and sex data have been collected annually since 2011. A first order estimate of the Peconic River spawning run size has been attempted since 2010; attempts have been made to improve these observations with video counts with limited success. These efforts have been undertaken to understand the Long Island coastal streams and to improve the runs that exist there.

We have no record of river herring in any of the streams in southern Westchester County. In the Bronx River (Bronx County) alewives were introduced to this river in 2006 and 2008 and some adult fish returned in 2009 (Jackman and Ruzicka 2009). Monitoring of this run is in its early stages.

2.1.3 Delaware River

River herring in the New York portion of the Delaware River are very rare. While there have been individual young-of-year (YOY) fish occasionally found (Horwitz et al 2014), we have no record of any fishing effort for either species.

2.2 Habitat Loss and Alteration

Hudson River Estuary

Hudson River tributaries provide important habitat to both migrating and resident fishes, as well as other wildlife. Barriers to upstream and downstream movement exist in tributaries to the Hudson River, many of them in relatively short distance upstream from the confluence with the

Hudson River. While many of these barriers are natural features, such as waterfalls and ledges, there exist numerous anthropogenic barriers, including dams (some opportunistically built on top of existing natural barriers), undersize and improperly positioned culverts, and undersized bridges. Thus, many opportunities exist to remove man-made barriers in order to restore historical upstream and downstream access to important habitats for both diadromous and resident fishes. Based on NOAA's 2009-2014 evaluation of 67 lower Hudson tributaries, the first barrier upstream from the Hudson are man-made on 27 tributaries, while 37 are natural and three are undetermined (Alderson and Rosman 2014). After further assessment to consider where barrier removal is practical and beneficial to river herring, this research estimated that 56 tributary kilometers have the potential to be opened to river herring via the removal of 27 barriers on 14 tributaries. The largest gains in total stream miles can be found on the following five tributaries: Claverack, Croton, Moodna, Rondout, and Sparkill Creeks. Restoration opportunities on these five tributaries could enhance access to river herring habitat for an estimated 35.8 kilometers. Removal of man-made barriers in the Hudson River Estuary is a high priority because of the potential for habitat gains and the perceived limitation of number of opportunities for large-scale restoration.

The introduction of zebra mussels in the Hudson in 1991, and their subsequent explosive growth in the river, quickly caused pervasive changes in the phytoplankton (80% drop) and micro- and macro-zooplankton (76% and 50% drop respectively) communities (Caraco et al. 1997). Water clarity improved dramatically (up by 45%) and shallow water zoobenthos increased by 10%. Given these massive changes, Strayer et al. (2004) explored potential effects of zebra mussel impact on YOY fish species. Most telling was a decrease in observed growth rates and abundance of YOY fishes, including open-water species such as alewife and blueback herring. A decade later, Strayer et al. (2014), reporting on the improvement in zooplankton and macrobenthos inhabiting deep water indicated that abundance of juvenile alewives increased during the late zebra mussel invasion period while post-yolk sac larval abundance did not. The abundance of post-yolk sac and juvenile American shad and post-yolk sac river herring declined during the early to later zebra mussel invasion period. It is not yet clear how this constraint affects annual survival and subsequent recruitment.

Another factor that is not well researched or understood is the potential barriers posed by the railroads along both the east and west sides of the Hudson River. Tributaries once flowed freely, with unobstructed hydraulics, from the upland valley to the wide estuary. While these connections still exist, they are much different today than they were historically. Tributaries are forced through bridge and culvert constrictions under the tracks as they make their way to the Hudson River. The impact of this funneling effect on access from the Hudson into tidal tributary mouths is not well understood.

Long Island and Westchester County

Most streams on Long Island and in Westchester County were impacted by human use as the population expanded. Many streams were blocked off with dams to create head ponds, initially used to contain water for power or irrigation purposes for agriculture. The dams remain; only a few with passage facilities. Many streams were also negatively affected by the construction of highways, with installations of culverts or other water diversions which impact immigrating fishes.

2.3 Habitat Restoration

Hudson River Estuary

The Hudson River Estuary Habitat Restoration Plan (Miller 2013) has identified a number of river and tributary restoration activities that will benefit river herring, including barrier mitigation and side channel restoration. Recent research has highlighted important barrier removal opportunities for river herring habitat in the Hudson River Estuary (Alderson and Rosman, 2014). Mitigation of these barriers is an important priority for many researchers, non-profits, and local governments in the estuary, and features prominently in the Hudson River Estuary Program's Action Agenda 2015-2020 (2015).

In May 2016, the first dam upstream of the confluence with the Hudson River was removed from the Wynants Kill, a relatively small tributary in Troy, NY, downstream of the Federal Dam. Within days of the May 2016 removal, hundreds of herring moved past the former dam location into upstream habitat. Subsequent sampling efforts yielded river herring eggs, providing evidence that river herring were actively spawning in the newly available habitat. This dam removal will provide an additional half kilometer of spawning habitat for river herring that has not been available for 85 years.

There are also a number of side-channel restoration projects under development that will improve habitat for river herring in the estuary. Side channels within the river bed provide important shallow water and intertidal habitats that are isolated from the higher energy regime of the main channel. These side channels historically occurred in the northern third of the estuary as part of a braided river-channel system dominated by vegetated shallows and intertidal wetlands. These habitats were destroyed on a large scale in the early twentieth century, particularly in the upper estuary, as a result of dredge and fill activities associated with construction of the federal navigation channel.

Gay's Point (rkm 196) has been identified as a potentially suitable location for side channel creation. The site consists of an artificially created tidal embayment that is separated from the main river channel by dredge spoils. Contiguous backwaters, such as those at Gay's Point, typically have lower current velocities, greater sediment deposition resulting in finer substrates, higher water temperatures, and lower dissolved oxygen levels than side channels with relatively unimpeded flow. Increasing tidal flow through the embayment at Gay's Point is anticipated to improve water quality, provide coarser-grained bed materials, and ultimately create more productive spawning, nursery, and foraging habitat for river herring. This project is currently under way and is being overseen by the New York State Department of Environmental Conservation.

Long Island and Westchester County

Initial barrier mitigation to benefit river herring was summarized in the last SFMP, and included restoration of herring runs on the Carmans and Peconic Rivers (Hattala et al. 2011a), and rudimentary fish passage at Beaver Lake, Oyster Bay. Since 2011, additional completed barrier mitigation projects that benefit alewife include the installation of passage devices at five locations (Canaan Lake, Brookhaven; Twin Ponds, Centerport; Argyle Lake, Babylon; Udall's Mill Pond, Saddle Rock; and Massapequa Creek, Massapequa); a box culvert modification at Alewife creek, Southampton; and a dam removals at Harrison Pond in Smithtown and at Crab

Meadow. Additionally, the installation of fish passage devices on the Bronx River and at the Edwards Avenue dam in Riverhead may provide additional spawning habitat once further barriers have been mitigated.

Barrier mitigation remains a priority for a number of environmental groups and local, state, and federal agencies. We are aware of at least six additional projects that are likely to occur in the next five years.

3 STOCK STATUS

Following is a description of all available data for the Hudson's river herring stocks, plus a brief discussion of their usefulness as stock indicators. Sampling data are summarized in Tables 1 and 2. Sampling was in support of Benefit 4 of the Hudson River Estuary Action Agenda and was partially funded by the Hudson River Estuary Program.

3.1 Fisheries Dependent Data

3.1.1 Commercial Fisheries

Ocean Harvest

Range of the New York river herring along the Atlantic coast is from the Bay of Fundy, Canada and Gulf of Maine south to waters off Virginia (NAI 2008; Eakin 2016).

Directed Ocean Harvest

Directed ocean harvest within state waters of river herring was effectively eliminated through the passage of Amendment 2 to the Atlantic States Marine Fisheries Commission Shad and River Herring Interstate Fishery Management Plan in 2009. The amendment requires member states to demonstrate that fisheries for river herring within their state waters are sustainable. As of 2016, five states (Maine, New Hampshire, New York, North Carolina, and South Carolina) have approved plans in place and none of these plans identifies directed ocean harvest as a component of their sustainable fishery management plan.

Incidental Ocean Harvest

Quantifying the impact of bycatch and incidental fisheries on Hudson River herring remains difficult. Two Federal councils have identified alternatives to reduce catch of river herring in their Fishery Management Plans (FMP). The Mid Atlantic Fisheries Management Council's (MAFMC) Amendment 14 of the Atlantic Mackerel, Squid and Butterfish FMP and the New England Fishery Management Council's (NEFMC) Amendment 5 to the Atlantic herring FMP 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 American shad catch at sea
- Established catch caps for river herring and American shad

- Identified catch triggers and closure areas

Fishery observer data are used to estimate and monitor the river herring and American shad captured by Atlantic herring and Atlantic mackerel vessels that land more than three metric tons (mt) per trip using methodology developed by the Greater Atlantic Regional Fisheries Office (GARFO), of the NOAA Fisheries. River herring and American shad bycatch and bycatch quotas are presented in Table 3 and Table 4.

While the data in Table 3 and Table 4 provide us with an estimate of the incidental catch of river herring and American shad in these fisheries, it does not identify the bycatch by species. However, Amendment 14 of the Mackerel, Squid and Butterfish FMP does present species-specific data by region and fleet from earlier years (Table 5). Observed annual alewife catch between 1989 and 2010 ranged from 2.7 mt to 484 mt with an annual average of 119 mt. Observed annual blueback herring catch between 1989 and 2010 ranged from 19.6 mt to 1,803 mt with an annual average of 290 mt. In some years, large portions of the incidental catch was not identified to species. If we apply the same annual proportion of river herring composition from the known catch to the unknown catch, the total estimated river herring catch in the period 1989-2010 ranged from 42.8 mt to 2,313 mt with an annual average of 499 mt.

We were only able to locate data that distinguished catch by species for the time period 1989-2010. More recent data present incidental harvest data by fishery, but do not distinguish among species. In order to get a general sense of the magnitude of potential harvest from these fisheries (Table 6), we applied the average proportion of known harvest that was river herring from the historic data (80%, from Table 5) to the combined river herring and American shad catch. Unfortunately, it is impossible to determine which river herring stock(s) were affected by the harvest from these mixed stock fisheries. Directed and incidental harvest from New York waters are shown in Figure 3.

Commercial Gear Use in the Hudson River

The current commercial fishery in the Hudson River exploits the spawning migration of both alewife and blueback herring. River herring may be commercially caught in the Hudson River from March 15th to June 15th, dates inclusive. The primary use of commercially caught herring is for bait in the recreational striped bass fishery. An annual commercial Hudson River permit allows use of the following gears: gill nets, scoop/dip/scap nets, seines, fyke nets, and trap nets. Permit holders are required to report effort and harvest to the Department. In response to Amendment 2, more stringent regulations were put into place in 2013. Highlights include the closure of tributaries to nets, net size restrictions for scap nets, and monthly reporting. Changes in regulation are listed in bold in the second column of Table A in Appendix 1.

Fishing effort and commercial gear use has historically been different south of the Bear Mountain Bridge (rkm 75) than in the northern reaches. This is roughly the location of the salt front in the spring. As such, this bridge is used as a demarcation for gear use. The fishery below the Bear Mountain Bridge intercepts fish moving to freshwater spawning areas, while the fishery north of the bridge targets river herring in their spawning aggregation areas.

The intercept fishery is a fixed gill net fishery that occurs in the main-stem river from rkm 40 to rkm 75 (Piermont to Bear Mountain Bridge, Figure 1). In this stretch, the river is fairly expansive (up to 5.5 km) with wide, deep-water (~ six to eight m) shoals bordering the channel. Most fishers in this portion of the fishery choose specific locations within these shoals and sample in the same locations each year. The fishermen generally fish these nets from 12-24 hours per trip. Since 2013, an average of 22 active fishers annually participated in this lower river fixed gill net fishery. Nets are 7.6 to 91 m long, with meshes ranging from 4.4 to 8.9 cm stretch.

Fishermen in the freshwater portion of the fishery, above Bear Mountain Bridge, use drift gill nets to sample the main-stem of the Hudson River. This gear is used up to rkm 225 (Castleton) where the river is much narrower (1.6 to 2 km wide). Since 2013, an average of 49 fishers annually participate in this mid river gill net fishery. Nets range in length from 6 to 183 m with mesh size ranges from 3.8 to 8.9 cm stretch. These nets must be tended at all times, and most are fished for less than two hours per trip. Though restricted from use in the 2013 regulation changes, commercial reports indicate fixed gill nets have been used in roughly 19% of gill net trips above Bear Mountain since 2013. We are working with both the fishermen and law enforcement to resolve this issue.

Scap nets (also known as lift and/or dip nets) is the other major gear used in the freshwater river herring fishery. Prior to 2013, this gear was primarily used in the major river herring spawning tributaries. The current scap/lift net fishery occurs in main-stem river from roughly rkm 90 to rkm 228 (Cornwall-on-Hudson to Port of Albany). Scap/lift nets range in size from 0.28 to 59.7 m^2. On average, 31 fishers have annually reported the use of this gear type since 2013.

It is important to note that many commercial permit holders are recreational anglers taking river herring for personal use as bait or food. Over the last three years, an average of 156 gill nets and 121 scap nets permits were sold annually. According to the required annual reports, however, only 35% of the permitees actively fished from 2013 to 2015 (Table 7), and of those that used the commercial gears, roughly half of gill net users and the majority of scap net users reported catches as taken for “personal use” or “personal bait” (Figure 4).

Commercial Landings and License Reporting

Recorded landings of river herring in New York State began in the early 1900s (Figure 3). Anecdotal reports indicate that herring only played a small part in the historic commercial fishing industry in the Hudson River. Total New York commercial landings for river herring include all herring caught in all gears and for both marine and inland waters. Several different time series of data are reported including several state sources, National Marine Fisheries Service (NMFS), and more currently Atlantic Coastal Cooperative Statistics Program (ACCSP). NMFS data do not specify river or ocean source(s) and landings are often reported as either alewife or blueback herring, but not both in a given year. It is unlikely that only one species was caught. From 1995 to the present, the Department has summarized landings and fishing effort information from mandatory state catch reports required for Hudson River marine permits. Full compliance for this reporting started in 2000. All Hudson River data are sent to NMFS and ACCSP for incorporation into the national databases.

Because of the discrepancies among the data series and the lack of information to assign the landings to a specific water body source, only the highest value from all sources is shown in Figure 4. This method limits double counting. Several peaks occur during the time period. The first peak was in the early 1900’s (501,438 pounds) followed by a lull until the period prior to World War II when landings peaked a second time in 1935 (274,405 pounds). Post WW II there was another period of low landings until a final peak in 1982 (229,201 pounds). Combined ocean and river landings in New York waters has remained relatively low, with some data gaps, during the rest of the 1980s through present. In 1966, roughly 4.2 million pounds were landed (omitted on Figure 4), followed by a series of years of low landings with another peak in 1982. Landings were low, with some data gaps during the rest of the 1980s through present.

Hudson River Landings

Since 1995, landings are separated between the Hudson and other waters (marine). However due to optional participation and minimal enforcement of commercial reporting, any in-river reporting from 1995-1999 is unreliable. It is likely that additional effort was shifted to river herring catches during this time-period than is reported. Moving forward, analyses on in-river landings begin in 2000.

The primary outlet for harvest taken by commercial Hudson River permits is for the in-river bait industry. From 2000 to 2012, nearly all reported commercial river herring landings were split between scap/lift nets (~49% of the catch) and gill nets (~16% drift and ~35% fixed) (Figure 5). From 2000 to 2012, combined landings averaged 15,061 pounds, peaking in 2002 at 20,346 pounds. Post regulation change in 2013, landings declined to roughly 45% of the average from 2000 through 2012. Scap nets accounted for the largest portion of this decline. This is a result of the ban on nets from tributaries, where most commercial scap netting occurred. As the demand for bait has probably not diminished, we expected an increase in landings for the other gears. Though there was a slight increase in drift gill net landings, a big portion of this missing harvest has likely shifted to non-commercial gears, such as hook and line, cast nets, and small scap nets. These personal use gears do not have a mandatory reporting requirement.

Commercial Discards

From 1996 to 2015, river herring were not reported as discards on any mandatory reports targeting herring in the Hudson River or tributaries.

Hudson River Commercial Harvest Rates – Mandatory Reports

Relative abundance of river herring is tracked through catch per unit effort (CPUE) statistics of fish taken from the targeted river herring commercial fishery in the estuary. All commercial fishers fill out monthly mandatory reports. Reports include catch, discards, gear, effort, and fishing location for each trip. CPUEs are calculated as total catch divided by total effort (square yards of net * hours fished), separately by gear type (fixed gill nets, drift gill nets, and scap nets). Annual mean CPUEs are summarized differently based on the location of fishing effort.

Above the Bear Mountain Bridge (rkm 75) and within the spawning reach, drift gill nets and scap nets are the primary gears. In this section of river, fishermen catch fish that are either staging or moving into areas to spawn. Gears are generally not deployed until fish are present. CPUEs for gears above the Bear Mountain Bridge are calculated as total annual catch/total annual effort. Below the Bear Mountain Bridge (rkm 75) and thus below the spawning reach, fixed gill nets are the primary commercial gear. In this section, nets are fished in roughly the same location each year by a consistent group of fishermen. These fishermen capture fish moving upriver to spawning locations and run size is determined by number (density) of spawners each week as well as duration (number of weeks) of the run. Annual CPUEs in this reach are calculated as the sum of weekly CPUEs to best capture the periodicity of run. Annual efforts and CPUEs for the main commercial river herring gears are shown in Figure 6. Values for drift gill and scap net values in Figure 6 are only for trips above rkm 75, while fixed gill net values are only for trips made below rkm 75.

As shown in Part A of Figure 6, drift gill net CPUEs have increased steadily since 2000, with efforts declining since 2006. Annual drift gill net trips by river section above the Bear Mountain Bridge are shown in Table 8. On average, 74% of drift gill net trips take place in the Saugerties and Catskill reaches. Based on historical information on spawning (Schmidt et al. 1994; Schmidt and Lake 2000) as well as the recent results from the fishery independent survey described in Section 4.2.1, these sections make up a small portion of the habitat available for spawning. In addition, there are two significant stretches of river where gill net use is prohibited. Due to the opportunistic nature of the upriver fishery (fishermen only fish when river herring are present), as well as the large amount of variability in effort within the freshwater spawning reach, we do not believe this dataset to be reliable annual abundance indicator.

Annual scap net CPUEs and efforts are shown in Part B of Figure 6. Efforts were relatively steady through 2012, but dropped dramatically in 2013 when net use became illegal in tributaries. Scap net CPUEs declined from 2000 to 2007, and have increased from 2007 to present. Due to significant changes in the fishery due to regulation, we do not think this commercial gear is a reliable relative abundance indicator.

Part C of Figure 6 shows effort and CPUEs for the lower river fixed gill net fishery. Effort in this fishery has decreased steadily since 2000, but the annual sum of weekly CPUEs has been increasing since 2010. Because most river herring must pass through this fishery on the way to freshwater spawning reaches and tributaries, it has the best chance at sampling the entirety of the spawning stocks of both species. As such, these CPUEs likely provide the best abundance indicator of the three main commercial gears.

Hudson River Commercial Harvest Rates – Monitoring Program

Up until the mid-1990s, the Department's commercial fishery monitoring program was directed at the American shad gill net fishery, a culturally historic and economically important fishery. We expanded monitoring to the river herring fishery in 1996, but remain limited by available manpower and the ability to connect with the fishers. Monitoring focuses on the lower river fixed gill net fishery since we considered it to be a better measure of annual abundance trends (see section above).

Data are obtained by observers onboard commercial fishing vessels. Technicians record numbers of fish caught, gear type and size, fishing time, and location. Scale samples, lengths and weights are taken from a subsample of the fisher's catch. CPUE is based on gear type and location and is calculated by the method used for summarizing mandatory report data (above).

Since 1996, staff monitored 107 trips targeting river herring (lower river: 93; mid and upper river: 14) (Table 9). Annually, these trips were sporadic and sample sizes were low, from zero to 20 trips per year. Because of these few annual trips and samples, the resulting CPUE is considered unreliable for tracking relative abundance. However, as shown in Figure 7, the commercial monitoring CPUE for fixed gill nets in the lower river follows the same trend as the lower river CPUE from the same gear in the mandatory commercial catch reports (correlation value 0.81, $p < 0.001$). This is indicative that our monitoring efforts capture trends in the reported fishery, and with increased sample sizes for commercial monitoring, we expect this relationship to improve. In addition, active monitoring provides the only data on catch composition of the commercial harvest and we consider these data to be useful.

Commercial Harvest Monitoring- Catch Composition, Size and Age Structure

Catch composition in the fixed gill net fishery varies annually, most likely due to small sample sizes and when the samples occurred (early or late in the run) (Table 10). Annual observed landings ranged from 44 to 2,450 fish, with alewives observed more often than blueback herring. The sex ratio of alewives was nearly equal (~ 50:50) in all years; however, female blueback herring were observed more often than male blueback herring most likely due to the size selectivity of gill nets fished.

Mean lengths and weights of dockside subsamples are shown in Figure 8. Though sample sizes are relatively low for certain years, there is an increasing trend in length and weight for both species since 2010. This trend is similar to the one observed for both species in the spawning stock survey (Section 3.2.2 below).

Age data for samples collected during the commercial monitoring program were processed and analyzed in the methods described in Appendix 2. Ages were estimated for a subsample of the scale samples in 2012 and we used an age length frequency table from these data to estimate ages for the remaining scale and length samples from the 2012 commercial fishery. Mean length at age for 2012 commercial samples were then compared to the mean length at age for fish taken in the Fishery Independent survey in 2012 (Figure 9). As there was little deviation in mean length at age for both species among the surveys, we used the annual age-length keys (see *Age and Repeat Spawn* in Section 3.2.2 below) derived from samples collected during the Fishery Independent Survey to estimate the respective year's commercial fishery age structure from 2013-2015.

Table 11 displays the age structure for dockside samples taken from 2012 to 2015. Mean age for sexes of both species is trending upward, which corresponds with the increase in mean lengths during the same time period as well as the increasing trend in the fishery independent age dataset described in Section 3.2.2.

Long Island, Bronx and Westchester Counties:

As of 2013, commercial river herring fisheries have been closed in the marine and coastal district of NY.

3.1.2 Recreational Fishery

Hudson River and tributaries: The recreational river herring fishery exists throughout the main-stem Hudson River, and its tributaries including those in the tidal section and above the Troy Dam (Mohawk River). Some recreational herring fishers use their catch as food (smoking/pickling). However, the recreational river herring fishery is driven primarily by the need for bait in the recreational striped bass fishery.

In concert with the change in commercial regulations in 2013, new regulations were put into place for the recreational fishery in response to Amendment 2. Regulations for recreational take are found in Table B of Appendix 1. The most significant changes were creel limit of 10 fish per day or 50 fish per boat, as well as the prohibition of personal net use in tributaries. All 2013 changes are denoted in bold in Table B.

The magnitude of the recreational fishery for river herring is unknown for most years. NYSDEC contracted with Normandeau Associates, Inc. (NAI) to conduct creel surveys on the Hudson River in 2001 and 2005 (NAI 2003 and 2007). Estimated catch of river herring in 2001 was 34,777 fish with a 35.2% retention rate. When the 2001 data were analyzed, NAI found that the total catch and harvest of herring was underestimated due to the angler interview methods. In the 2001 survey, herring caught by fishers targeting striped bass were only considered incidental catch, and not always included in herring total catch and harvest data. Fishers were actually targeting herring and striped bass simultaneously. Corrections were made to the interview process for the 2005 survey and estimated catch increased substantially to 152,117 herring (Table 12). We also adjusted the 2001 catch using the 2005 survey data. The adjusted catch rose to 93,157 fish.

We also evaluated river herring use by striped bass anglers using data obtained from our Cooperative Angler Program (CAP). The CAP was designed to gather data from recreational striped bass anglers through voluntary trip reports. Volunteer anglers log information for each striped bass fishing trip including fishing time, location, bait use, fish caught, length, weight, and bycatch. From 2006 through 2015, volunteer anglers were asked to provide specific information about river herring bait use. Due to the difficulties associated with differentiating between alewife and blueback herring, anglers were only asked to report the catch as river herring. The annual proportion of angler days where river herring was used for bait ranged from 25% (2007) to 57 % (2013) with a mean of 46%. The proportion of river herring used by anglers that were caught rather than purchased increased through the time period (Table 12). River herring caught per trip varied from 1.6 to 6.7 with the highest values in the last three years. Herring purchased per trip ranged from 0.63 to 1.7.

In an attempt to estimate recreational river herring harvest, we calculated the total number of herring caught or purchased by striped bass anglers as the estimated number of striped bass trips from a statewide creel survey conducted in 2007 (Connelly and Brown 2009) adjusted annually to reflect the potential change in fishing effort using CAP data multiplied by the annual proportion of angler days using herring in the CAP, multiplied by the number of herring caught or purchased per trip in the CAP. Estimates of river herring use by striped bass anglers ranged from 78,491 fish in 2007 to 386,915 fish in 2015 with an increasing trend of herring use from 2006 to 2015. To put potential recreational herring harvest in context, the average estimated annual recreational harvest from 2013-2015 was 312,036 herring. During the same time period, counts from Black Creek, a small tributary to the Hudson with approximately 1.8 km of available spawning habitat, averaged 409,233 alewives (roughly 139,000 pounds) annually (see Table 13 and *In-stream Fish Counter* in Section 3.2.1 below). Black Creek is only one of the 68 primary tributaries to the Hudson River.

This analysis should be interpreted with caution and viewed only as potential recreational river herring harvest scenarios. It should also be noted that these estimates are derived from a group of dedicated striped bass anglers who presumably exert more effort than a typical angler and thus we view these estimates as the maximum potential recreational herring harvest. Until a creel survey can be conducted, this is the Department's best estimate of recreational herring harvest.

The number of river herring taken from the Hudson River and tributaries for personal use as food by recreational anglers is unknown but expected to be minimal.

Long Island, Bronx and Westchester Counties: As of 2013, recreational river herring fisheries have been closed in the marine and coastal district of NY.

3.2 Fishery Independent Surveys

3.2.1 Spawning Stock Surveys – Hudson River

Haul Seine Survey

In 1987, the Department added river herring sampling to the existing American shad and striped bass spawning stock survey. Sampling occurred sporadically and when time allowed. From 1987 to 1990, two small mesh (9.5 mm) beach seines (30.5m and 61m) were used with limited success. In 1998, the Department specifically designed a small haul seine (91 m) with an appropriate mesh size (5.1 cm) to target river herring. Similar to the gear design for the American shad and striped bass seine survey to minimize size and age bias (Kahnle et al. 1988), the Department designed the herring seine to capture all sizes present with the least amount of bias. The current herring haul seine design consists of two 46 m long by 3.7 m deep wings attached to a round, center-located bag measuring 1.2 meters in diameter and 3.7 m long. The entire net is 5.08 cm stretch mesh made of twisted nylon twine. The top float line includes fixed foam floats every 0.6 m and fixed chains to the lead line (bottom of seine) every 0.75 m.

To meet the requirements outlined in Amendment 2 (ASMFC 2009) for the mandatory fishery-independent monitoring programs, in 2012 New York established the river herring spawning stock survey. The objectives of the survey are to evaluate species, size, and sex composition of spawning river herring; and then develop the methodology to use the gear to perform an annual assessment of the Hudson River's river herring spawning stock. We set a sampling target of four sample days per week (March 15 to June 15). We targeted a minimum of five beaches to be sampled each day. Data were used to evaluate sample sites for future sampling use as well as collect spawning adult river herring in the area.

In 2012, we sampled sites in the river from the Tappan Zee (rkm 45) to Albany (rkm 232) (Figure 1). Despite much effort in 2012, no river herring were caught in the southern part of the river from Poughkeepsie south to the Tappan Zee. These areas were dropped in 2013, and we pared down the sampling area to the mid and upper river sections where river herring were most readily caught. Currently, we focus each sampling day of the week on one river reach from Kingston (rkm 136) to Albany (rkm 232) (Figure 1). Reaches are broken down as follows: Kingston (rkm 136-169), Catskill (rkm 170-190), Coxsackie (rkm 191-213), and Albany (rkm 214-232). Within each reach, we randomly selected sites from a map of all known beaches within the Hudson River Estuary. After scouting, we removed any sites from the list that no longer had beaches or had major sampling obstructions. We currently sample 15 fixed sites spread throughout the four reaches.

After each haul, technicians examine each fish for species, gender, and spawning condition. We take a ten fish subsample of each gender and species and measure total length, weight, and obtain a scale sample. When possible, we measure an extra 30 fish from each sex and species for each sampling event. All other incidental catch is tallied by species; we measure and remove scale samples from sport fishes.

In-stream Fish Counter

In 2013, we conducted a pilot study using an in-stream fish counter in Black Creek. Black Creek is a small tributary located at rkm 135, just south of Kingston, NY and has a known river herring spawning run. The primary objective was to determine if a fish counting device was an appropriate method to collect absolute abundance data for river herring in small tributaries. Our secondary objectives were to identify when river herring migrate into tributaries and identify parameters that may influence those migrations (i.e. moon phase, water level, water temperatures).

The study design consisted of a stream wide weir to guide river herring through a Smith Root SR-1601® multichannel fish counter. NYSDEC staff built the counting head using four inch PVC tubes stacked in two rows of four, forcing fish through one of eight individual counting tubes (Figure 10). We installed the counter system at the end of March each year, close to the head of tide, and it remained in place until the end of May. Staff attempted to visit the counter on a daily basis. During site visits, technicians recorded fish counts on the counter system, along with any applicable environmental observations, such as weather conditions, temperature, and water level. Once the daily count was recorded, the counter was reset to zero. We also conducted multiple visits during the same day in order to compare day versus night migrations of river herring into the tributary. In 2013, we incorporated a trap into the design of the weir, attached to the counter exit directly up stream of the weir to determine species composition of the fish passing through the counter and assess the accuracy of the electronic counter. The trap was closed on five occasions at various times throughout the run in 2013. We then attempted to use these trapping results as a correction factor to the final count data; however, it was very difficult to capture every fish in the trap due to the stream substrate as well as impaired visibility. At this time we do not have an accurate correction factor. To address this, we installed a video camera system in 2014 to verify counts and create an accurate correction factor. We are currently analyzing video footage to assess the accuracy of the electronic counter and develop an appropriate correction factor.

Monitoring of Black Creek has continued on an annual basis since 2013 and annual count data are reported in Table 13. Historic evidence shows the spawning run in Black Creek to be exclusively made up of alewife (Schmidt and Lake 2000). This has been verified in all years of monitoring, as all mortalities and all live captured river herring at or near the weir were identified as alewife. The annual count data from Black Creek is used as ancillary data to support trends identified in the relative abundance indices described in section 3.2.2 and provide a reference for landings in the commercial and recreational fisheries (Table 13).

3.2.2 Hudson River Spawning Stock - Characteristics

Annual Catches

Prior to 2012, the intermittent effort (n-hauls) expended to catch river herring resulted in relatively low and variable catches (Table 14). However, with the focused survey, catches and hauls have increased greatly since 2012 (Table 14).

Since 2012, alewife catches have been on average 73.6% male and 26.4% female (Figure 11). The high ratio of male alewives may indicate a possible sex bias in the sampling technique for alewives. We suspect that males either remain out in the main river close to shore whereas most female alewives could be further offshore, unavailable to our gear or they could be staging near tributary entrances. Mid-Hudson tributary sampling conducted by Schmidt and Lake (2000), as well as our own effort (see above, *In-stream Fish Counter*), resulted in more equal sex ratios.

Sex ratios of blueback herring have been more even. On average, blueback herring consisted of 44.6% males and 55.4% females (Figure 11). We suspect that bluebacks may be more susceptible to our gear because they prefer to spawn in shallow shoals of the main-stem river.

Relative Abundance Indices

In 2012, exploratory sampling was conducted to identify beaches that we could sample and catch adult river herring on a consistent basis. Based on those results, we have focused sampling efforts between the Kingston (rkm 146) and Albany (rkm 223) reaches (Table 15). We are currently exploring the most appropriate method to calculate relative abundance indices for adult river herring. We need additional years of data to be able to identify any potential biases in collection protocols or environmental conditions that may influence catches. Once an appropriate method is identified and we have an adequate time series of data, we propose to use the adult relative abundance index as sustainability target.

Growth

We examined growth characteristics using the Von Bertanlanffy and Gompertz Growth models (Ricker 1975). Both models use the annual age and associated lengths and weights of aged samples from the fishery independent survey. Samples from the commercial fishery were not included due potential size and sex selectivity of the gears. We developed preliminary estimates of growth on an annual basis, by sex and species, and to include all year-classes. These provide a good snapshot of the growth characteristics of each species, but can be highly influenced by inter-year class variation and changes in fishing mortality. Once we have longer time series of ages, lengths, and weights, we will have much more robust growth estimates and associated error values.

We did not feel comfortable in presenting the growth model outputs (Linf, K and t0, etc.) in this report. Von Bertanlanffy and Gompertz growth models are often used in stock assessments to provide a smoothed estimate of length and weight at age for input into more sophisticated assessment models (i.e. use of biomass at age inputs to estimate mortality benchmarks). Data for these models require a sufficient range of values to accurately describe the growth to be estimated. A longer time series of data that includes better representation of older fish is needed to more accurately estimate representative values of growth model parameters.

Mean Total Length and Weight

Mean total length and weight of fish has been calculated when adequate sample sizes occurred (Figure 12). Prior to 2008, most sample sizes were relatively small and thus not reliable. From 2001 to 2008, mean total length of male alewife declined slightly, but then increased to present.

Mean total length of female alewife has also steadily increased since 2008. Mean total length of blueback herring has slightly increased for both sexes since 2009 to the present. Mean weights for both sexes of alewives were slightly declining from 2008 to 2013 but since have been increasing. Male blueback herring mean weights have been stable with a slight increase in 2015 while female blueback herring mean weights have been steadily increasing since 2010.

Maturity

Maturity was estimated from age at first spawn, subtracting the number of spawning marks from the age of each fish. We then calculated maturity schedule as percent mature at age present in the river for each species and sex using all sampled age classes. As with growth rates, annual variations in recruitment and fishing mortality have significant impacts on maturity schedules. To address these potential problems, we will compare inter-annual maturity estimates with those calculated by year class once enough long-term age and spawning mark data are available.

Age data from 2012-2015 indicate that alewife herring primarily begin to spawn at age three and are fully mature by age five (Figure 13). Blueback herring begin to spawn at age two and the majority reach full maturity by age four (Figure 13).

Age and Repeat Spawn

Through training sessions and workshops with aging experts such as the Massachusetts Division of Marine Fisheries and other Atlantic Coast agencies (ASMFC 2014.), we developed criteria for determining what constitutes an annulus and spawning mark in Hudson River fish. (Details in Appendix 2). We did not use prior accepted aging methods such as Cating (1953, previously used for American shad) or Marcy (1969, used for river herring) due to their reliance on transverse grooves to estimate annuli location.

We also revised the scale selection and preparation protocols. For each catch event, we took scale samples from random subsamples of ten individuals of each sex and species. We removed scales as described above in the fisheries dependent methods, from the left side of the fish directly below the dorsal fin above the midline (Rothschild 1963; Marcy 1969; Hattala 1999) and placed them in an individually identified envelope. In the lab, technicians numbered scale envelopes and entered them into a database along with the associated sampling program (fishery independent or dependent) data: gear type, species, sex, and length. As annual sample sizes were large for most projects in this study, we needed to accurately determine ages of a sub-sample of fish collected. We followed Ketchen (1950) method of selecting a stratified sub-sample of fixed numbers of fish aged per 10 mm length bin. In 2012 and 2013, we separated the scale samples by sampling program, species, and sex. Next we randomly selected 30 fish per 10 mm length bin. All fish were aged when there were fewer than 30 fish in a length bin. Due to time restraints and based on new literature (Coggins et al. 2013), we have been examining 15 fish per length bin since 2014.

The sub-sample of aged fish were used to developed annual age-length keys for each species and sex (Losech 1987; Devries and Frie 1996; Davis and Schultz 2009). Sex-specific age-length keys were then used to estimate numbers at age of each sex and species for the entire sample for each year. The resulting estimated numbers at age were used to calculate mean length at age as well as mortality estimates reported in *Mortality Estimates* below.

Age and repeat spawn data for both species of river herring are reported in Tables 16 and 17. From 2012 to 2015 during our fisheries independent sampling, we collected 4,712 scales samples from alewives and assigned ages to a stratified random subsample of 1,122 scale samples. Female alewives ranged from age two to nine with zero to five repeat spawn marks and ranged from 68% to 36% virgin fish (Figure 14). Since 2012, mean age of female alewives has been stable to slightly increasing. Male alewives ranged two to eight years of age with zero to five repeat spawn marks. Male alewives ranged from 82% to 51% virgin fish (Figure 14). Mean age of male alewives has been stable to slightly increasing since 2012.

From 2012 to 2015, we collected 2,673 scale samples from blueback herring and assigned ages to 847 of those samples. Female blueback ages ranged from three to seven with zero to three repeat spawn marks. Female bluebacks ranged from 79% to 52% virgin fish (Figure 14). Mean age of female bluebacks has remained stable without a trend since 2012. Male bluebacks ranged in age from two to six with zero to three repeat spawn marks and ranged from 92% to 59% virgin fish (Figure 14).

Alewife males and females are on average larger than blueback males and females of the same age. Max total lengths and mean length at age of both species are approaching or have exceeded those reported in Greeley 1937 (Table 18, Figure 15). Since 2012, mean length at age for both species across all ages has been either stable or increasing with the majority increasing. Along with increasing mean length at age, the overall age structure for both species has expanded with increased repeat spawning occurrence. The increase in the occurrence of repeat spawning marks (Figure 14) suggests a higher survival rate during both post-spawn emigration and during ocean residency.

Mortality Estimates

Total instantaneous mortality rates were calculated on an annual basis since 2012 for age data and 2009 for repeat spawn data using a bias-correction Chapman and Robson mortality estimator described in Smith et al. (2012).

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 or spawning marks to be included in the respective analyses (ASMFC 2012).

Mortality estimates for both species were calculated using age and repeat spawn data independently (Table 19, Figure 16). Mortality derived from age data for alewives declined or remained stable from 2012-2014. In 2015, estimates for both sexes of alewives increased; however, we feel that this increase is due to a large year class moving through the fishery resulting in over dispersion of older fish and is further compounded by fewer age three and age four fish observed in 2015. Fewer age three and four year old fish may be an artifact of major weather events that severely impacted the Hudson River; Hurricane Irene and Tropical Storm Lee in 2011 and Hurricane Sandy in 2012. The impact on the survival of YOY and yearling river herring resulting from these storm events is unknown, however, the next few years of monitoring will provide insight into the potential magnitude of their effects.

Blueback herring age based mortality estimates have been stable since 2012 for both sexes with a slight increase in 2015 (Table 19, Figure 16). Since 2012, both sexes of blueback herring have been comprised of primarily three and four year old fish. Despite blueback herring being dominated by two year classes, a few older fish with increased occurrences of repeat spawning marks are beginning to appear in the fishery (Tables 16 and 17).

Mortality estimates have been derived from repeat spawning data since 2009 and have followed the same trends as mortality estimates derived from age data with the only exception in 2015 (Table 19, Figure 16). In 2015, alewife and female blueback mortality estimates derived from age data were higher than those derived from repeat spawn data. This is due to increase repeat spawn occurrence and a reduction in the number of virgin fish.

Mortality estimates derived from repeat spawn data for both sexes of alewives slightly increased from 2009-2011 and since have been declining (Table 19, Figure 16). Female blueback herring mortality estimates were stable from 2009-2012. Male blueback herring mortality estimates were increasing from 2009-2012. From 2012-present both sexes of blueback herring mortality estimates derived from repeat spawn data have been declining.

In most instances, the mortality estimates based on spawning marks were higher than those calculated from ages (Table 19, Figure 16). This may be a result of the age based method using the most abundant number at age as age at full recruitment. In doing so, we may include ages of the population that may not actually be fully recruited. Once an adequate data set is available for age based mortality estimates, we will compare long-term trends between the two methods. This will identify any potential discrepancies in our mortality estimation methods.

3.2.3 Spawning Stock Surveys – Long Island

Young (2011) sampled alewife in the Peconic River 32 times throughout the spawning season in 2010. Sampling occurred by dip net just below the second barrier to migration at the lower end of a tributary stream. A rock ramp fish passage facility was completed at the first barrier near the end of February 2010. The author collected data on total length and sex and estimated the number of fish present based on fish that could be seen below the barrier. Peak spawning occurred during the last three weeks of April. The minimum estimate of run size was 25,000 fish and was the total of the minimal visual estimates made during each sample event. Males ranged from 243-300 mm with a mean length of 263 mm. Females ranged from 243-313 mm with a mean of 273 mm.

3.2.4 Volunteer and Other River Herring Monitoring

The Environmental Defense's South Shore Estuary Reserve Diadromous Fish Workgroup (SSER) have begun to incorporate citizen volunteers into the collection of data on temporal variation and physical characteristics associated with spawning of river herring in tributaries. These data were not provided by the fishery dependent and independent sample programs discussed above. The volunteer programs also bring public awareness to environmentally important issues.

Long Island Streams

The SSER began a volunteer survey of alewife spawning runs on the south shore of Long Island in 2006. The survey is designed to identify alewife spawning in support of diadromous fish restoration projects. The survey also evaluates current fish passage projects (i.e. Carmans River fish ladder), and sets a baseline of known spawning runs. Data were available for surveys in 2006 – 2008. Monitoring occurred on six to nine targeted streams annually, with volunteer participation ranging from 24 to 68 individuals. Monitoring takes place from March through May. Alewife were seen as early as March 5 (2006) and as late as May 31 (2008). Data indicated that alewife use multiple streams in low numbers. It is not clear whether each stream supports a spawning population since total sightings were very low. The Carmans and Swan Rivers showed the most alewife activity and likely support yearly spawning migrations. The first permanent fish ladder on Long Island was installed in 2008 on the Carmans River. Information gathered during this study will aid in future construction of additional fish passage (Kritzer et al. 2007a, 2007b, Hughes and O'Reilly 2008). Byron Young continues to monitor alewife, mostly in the Peconic River. In 2016, the Peconic run was above average. Fish were first observed on March 2, and last observed on May 16, representing a nearly 10 week spawning season (B. Young, retired, NYS Deptartment of Environmental Conservation, personal communication).

In addition to the SSER, other interested individuals have also monitored Long Island runs (see Appendix Table A). Anecdotal data provides valuable information on tracking existing in-stream conditions, whether streams hold active or suspected runs, interaction with human land uses, and suggestions for improvement (L. Penney, Town of East Hampton, personal communication). A rock ramp was constructed around the first barrier to migration on the Peconic River in early 2010 (B. Young, retired, NYS Dept of Environmental Conservation, personal communication). The Seatuck Environmental Association set up an automated video counting apparatus at the upriver end of this ramp. Data are still being analyzed. A video can be viewed on their website at https://www.seatuck.org/index.php/fish-counting

The Department has conducted a similar river herring volunteer monitoring program annually since 2008 for tributaries of the Hudson River Estuary (Dufour et al. 2009, NYSDEC 2010, Hattala et al. 2011b). We designed this project to gather presence–absence and temporal information about river herring spawning runs from the lower, middle, and upper tributaries of the estuary. Between nine and 11 tributaries were monitored annually by 70 to 213 volunteers in 2008, 2009, and 2010. Herring were seen as early as 31 March and as late as 1 June. River herring were observed in all but one of the tributaries. However, several tributaries with known strong historical runs had very few sightings. Water temperature seemed to be the most important factor determining when herring began to run up a given tributary. Sightings of herring were most common at water temperature above 50 degrees F. Tributaries in the middle part of the estuary warmed the fastest each spring and generally had the earliest runs.

3.2.5 Young-of-the-Year Abundance

Since 1980, the Department has produced an annual measure of relative abundance of YOY alewife and blueback herring in the Hudson River Estuary. Although the program was designed to sample YOY American shad, it also provides data on the two river herring species. Blueback herring appear more commonly than alewife throughout the time series. In the first four years of the program, sampling occurred river-wide (rkm 0-252), bi-weekly from August through October, beginning after the peak in YOY abundance occurred. The sampling program was altered in 1984 to concentrate in the freshwater middle and upper portions of the estuary (rkm 88-225), the major nursery area for young American shad and river herring. Timing of sampling was changed to begin in late June or early July and continue biweekly through late October each year. Gear is a 30.5 m by 3.1 m beach seine of 6.4 mm stretch mesh. Collections are made during the day at 28 fixed sites in nearshore habitats spanning four reaches of the freshwater portion of the river. Catch per unit effort is expressed as the annual geometric mean of fish per seine haul for weeks 26 through 42 (July through October). This period encompasses the major peak of use in the middle and upper estuary.

From 1980 to 1998, the Department's geometric mean YOY annual index for alewife was low, with only one year (1991) having over one fish per haul. Since 1998, the index has generally increased through 2012, and has been stable at roughly one fish per haul since 2013 (Figure 17).

From 1980 through 1994, the Department's geometric mean YOY annual index for blueback herring averaged about 24 fish per haul, with only one year (1981) dropping below 10 fish per haul (Figure 17). After 1994, the mean dropped to around 17 fish per haul. The largest index value for the time series occurred in 2014, which was just over 50 fish per haul.

The underlying reason for the wide inter-annual variation in YOY river herring indices is not clear. The increased inter-annual variation in relative abundance indices of all three alosines may indicate a change in overall stability in the system. Further investigation into temporal and environmental variables that may contribute to this high variability is necessary. By the next SFMP (2022), we will evaluate different standardized models to best account for the influence of covariates, such as salinity, water temperature, and sampling week on YOY catches.

4 PROPOSED FISHERY CLOSURES

4.1 Long Island, Bronx County and Westchester County

Limited data that have been collected for Long Island river herring populations are not adequate to characterize stock condition or to choose a measure of sustainability. Moreover, there are no long-term monitoring programs in place that could be used to monitor future changes in stock condition.

For the above reasons, New York State proposes to continue a closure of all fisheries for river herring in Long Island streams and in the Bronx and Westchester County streams that empty into the East River and Long Island Sound as outlined in previous SFMP (Hattala et al. 2011a).

4.2 Delaware River

We have very limited data that suggest river herring occur in New York waters of the Delaware River. New York State proposes to continue the closure of fishing for river herring in New York waters of the Delaware River as outlined in the previous SFMP (Hattala et al. 2011a). This closure conforms to similar closures of the Delaware River and Bay by the states of Pennsylvania, New Jersey, and Delaware.

5 PROPOSED SUSTAINABLE FISHERY

5.1 Hudson River and Tributaries

New York State proposes to continue a restricted fishery in the main-stem Hudson River coupled with a continued partial closure of the fishery in all tributaries (see Appendix 1). We do not feel the current data warrant a complete closure of all fisheries. We propose that the restricted fishery would continue for an additional five years concurrent with annual stock monitoring. The additional five years will provide us with ten consecutive years of data collected under the same methodologies. Sustainability targets will be set using juvenile indices. We will continue monitor, but not yet set targets for mean length and mean length at age from fishery independent spawning stock sampling and CPUE in the commercial fixed gill net fisheries in the lower river below Bear Mountain Bridge until additional years of data are obtained. We will also monitor age structure, frequency of repeat spawning, and total instantaneous mortality (Z). Stock status will be evaluated during and after an additional five year period and a determination made whether to continue or change restrictions.

6 PROPOSED MEASURES OF SUSTAINABILITY

6.1 Targets

Juvenile Indices

We propose to set a sustainability target for juvenile indices using data from the time period of 1983 through 2015 for both species. We will use a more conservative definition of juvenile recruitment failure than described in section 3.1.1.2 of Amendment 2 to the ASMFC Interstate Fisheries Management Plan for Shad and River herring (ASMFC 2009). Amendment 2's definition is that recruitment failure occurs when three consecutive juvenile index values are lower than 90% of all the values obtained in the base period. We will be more conservative and use a 75% cut off level. The resulting sustainability target value is the 25^{th} percentile of the time series, such that three consecutive years with index values below this target would trigger management action. The target for alewife is 0.37 and the target for blueback herring is 7.53 (Figure 17).

6.1.1 Management Actions

New York State will take immediate corrective action if the recruitment failure limit is met for three consecutive years. Potential management actions may include but are not limited to: area closures, gear restrictions, and permit fee restructuring. Corrective actions will remain in place until the juvenile index value is above the juvenile recruitment failure level set in Amendment 2 to the ASMFC Interstate Fisheries Management Plan for Shad and River herring for three consecutive years.

6.2 Sustainability Measures

There are several measures of stock condition of Hudson River herring that can be used to monitor relative change among years. However, these measures have limitations (described below) that currently preclude their use as targets. These include frequency of repeat spawning, mean length, mean length at age and total mortality in fishery independent samples as well as catch per unit effort (CPUE) in the reported commercial harvest. We propose to monitor these measures in concert with the sustainability target to evaluate consequences of a continued fishery.

Mean Length and Mean Length at Age

Mean total length and mean length at age reflects age structure of the populations and thus some combination of recruitment and level of total mortality. Mean total length and mean length at age of both river herring species in the Hudson River system have been increasing since sampling efforts increased and became consistent in 2012. Max total lengths and mean length at age of both species are approaching or have exceeded those reported in Greeley (1937). The increases in mean length and mean length at age are indicative of reduced mortality both within river and during their ocean residency. However, the ocean bycatch fishery is a large unknown and not solely controlled by New York State to effect a change. We propose to continue monitoring mean total length and mean length at age during the proposed fishery.

Catch per Unit Effort in Report Commercial

We suggest that CPUE values of the reported harvest reflect general trends in abundance. However, annual values can be influenced by changes in reporting rate and thus we do not feel that CPUE should be used as a target at this time. Once we have an adequate time series of age data, we will attempt to validate the commercial CPUEs with our relative abundance surveys (YOY and adult relative abundance indices) following methods described by Hattala and Kahnle (2007).

Repeat spawning and Total Mortality

We will continue to monitor the frequency of repeat spawning and total mortality (Z). Once an adequate time series of data is collected, we will investigate appropriate methods to develop a mortality based benchmark and use that benchmark as a sustainability target in future sustainable fishery management plans.

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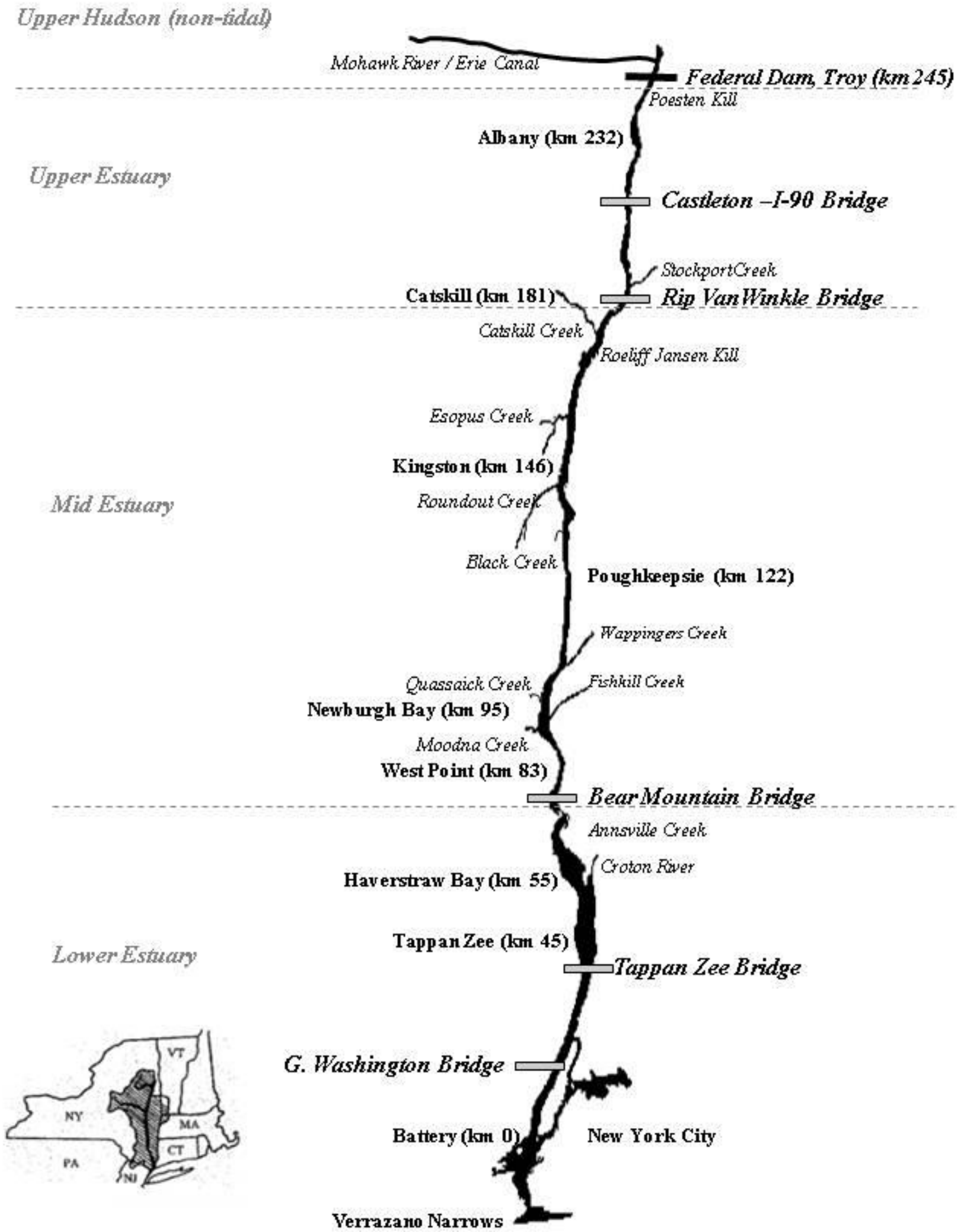


Figure 1. Hudson River Estuary with major spawning tributaries for river herring.

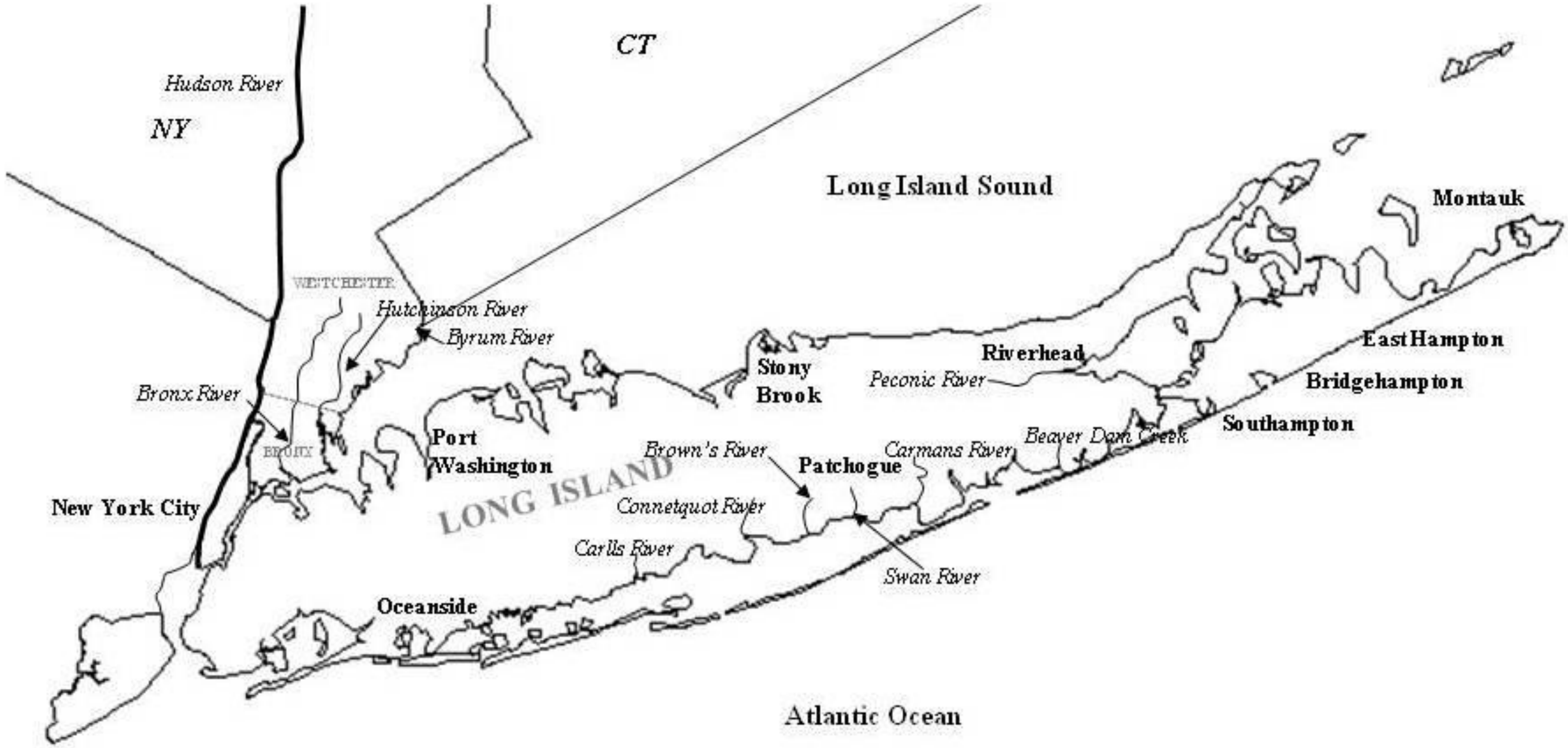


Figure 2. Long Island, Bronx and Westchester Counties, New York, with some river herring (primarily alewife) spawning streams identified.

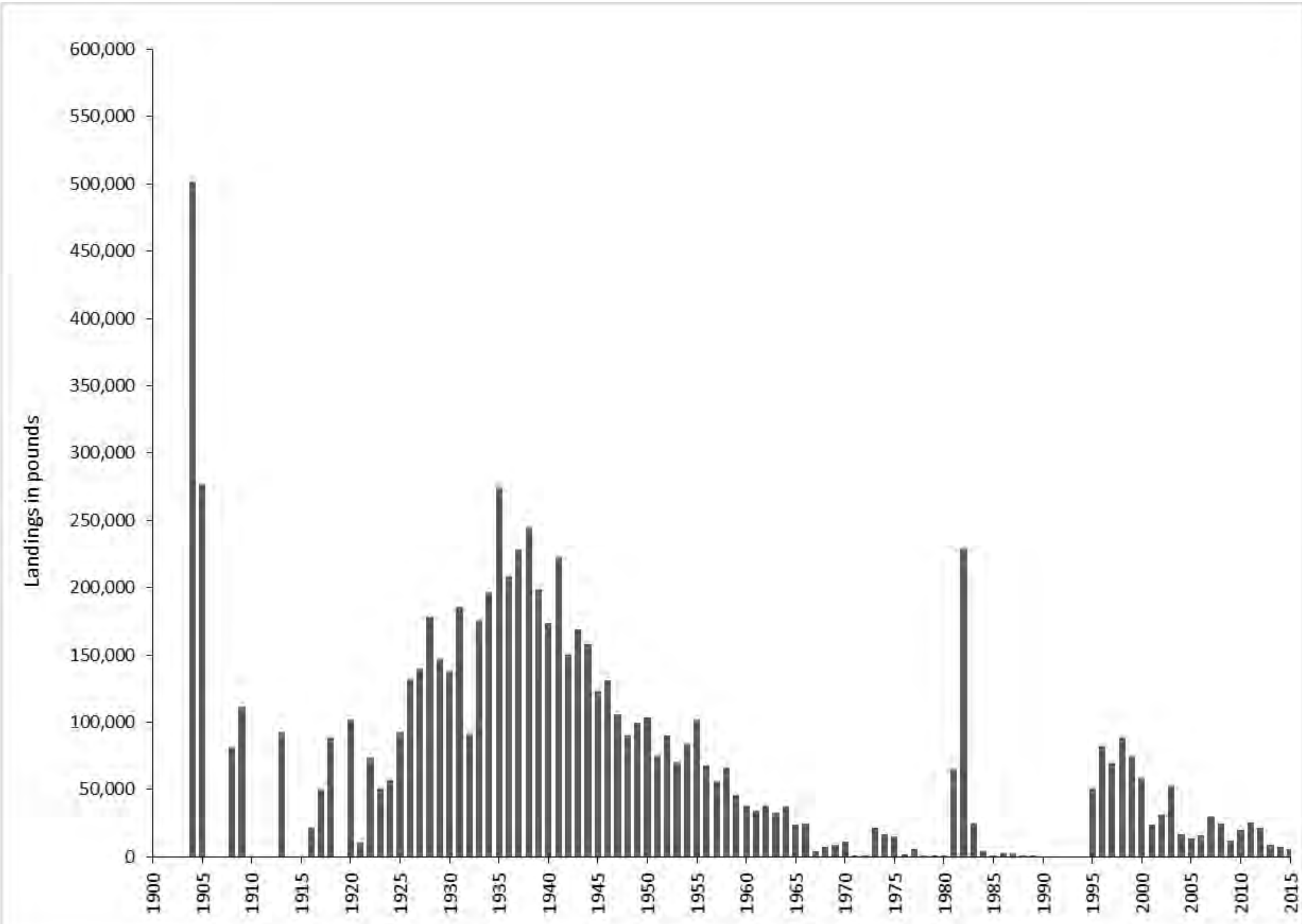


Figure 3. Pounds of river herring landed in New York waters.

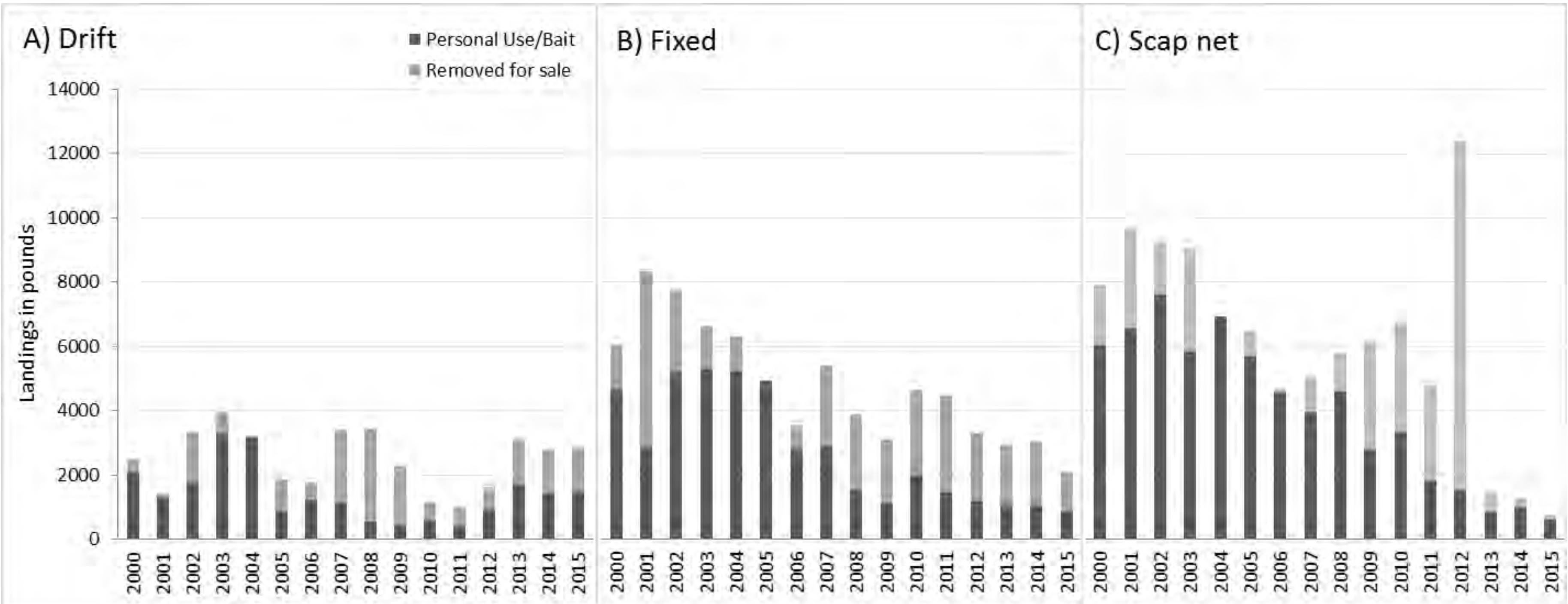


Figure 4. Dispositions of commercially caught river herring as reported in mandatory trip reports.

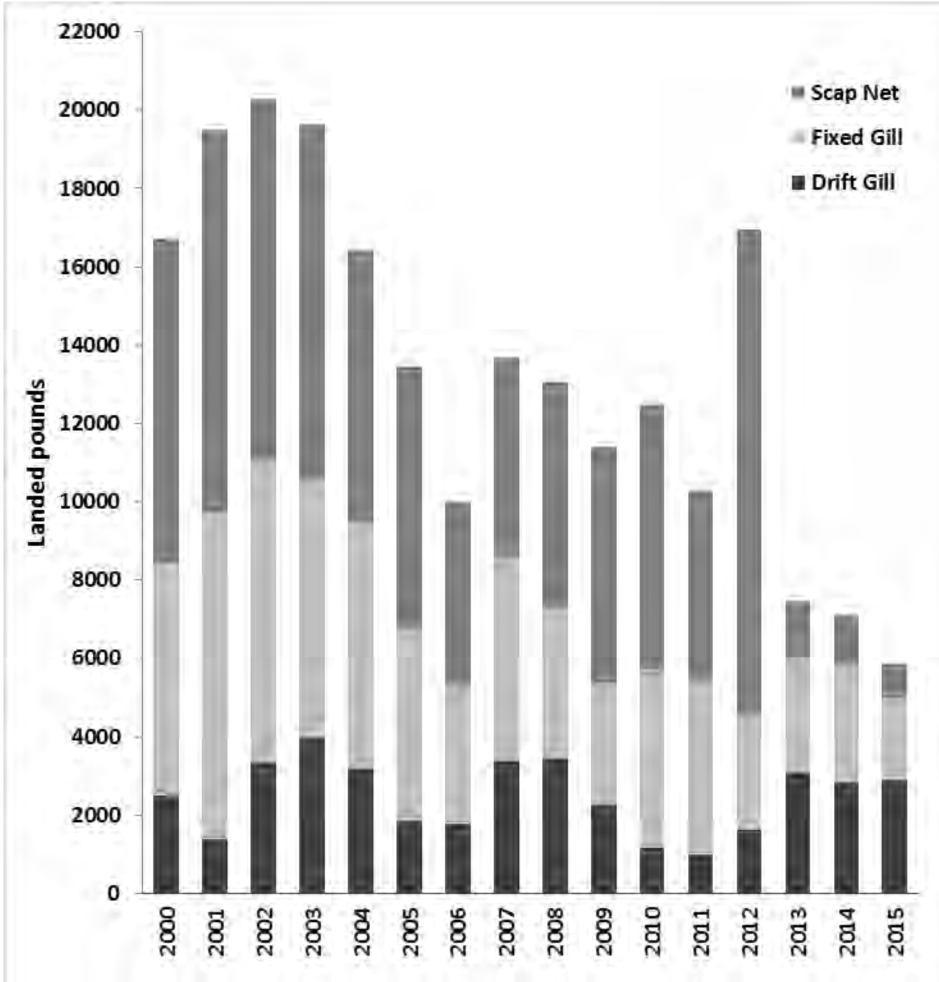


Figure 5. Annual total landed pounds of river herring separated by gear type. Catch includes targeted river herring trips only.

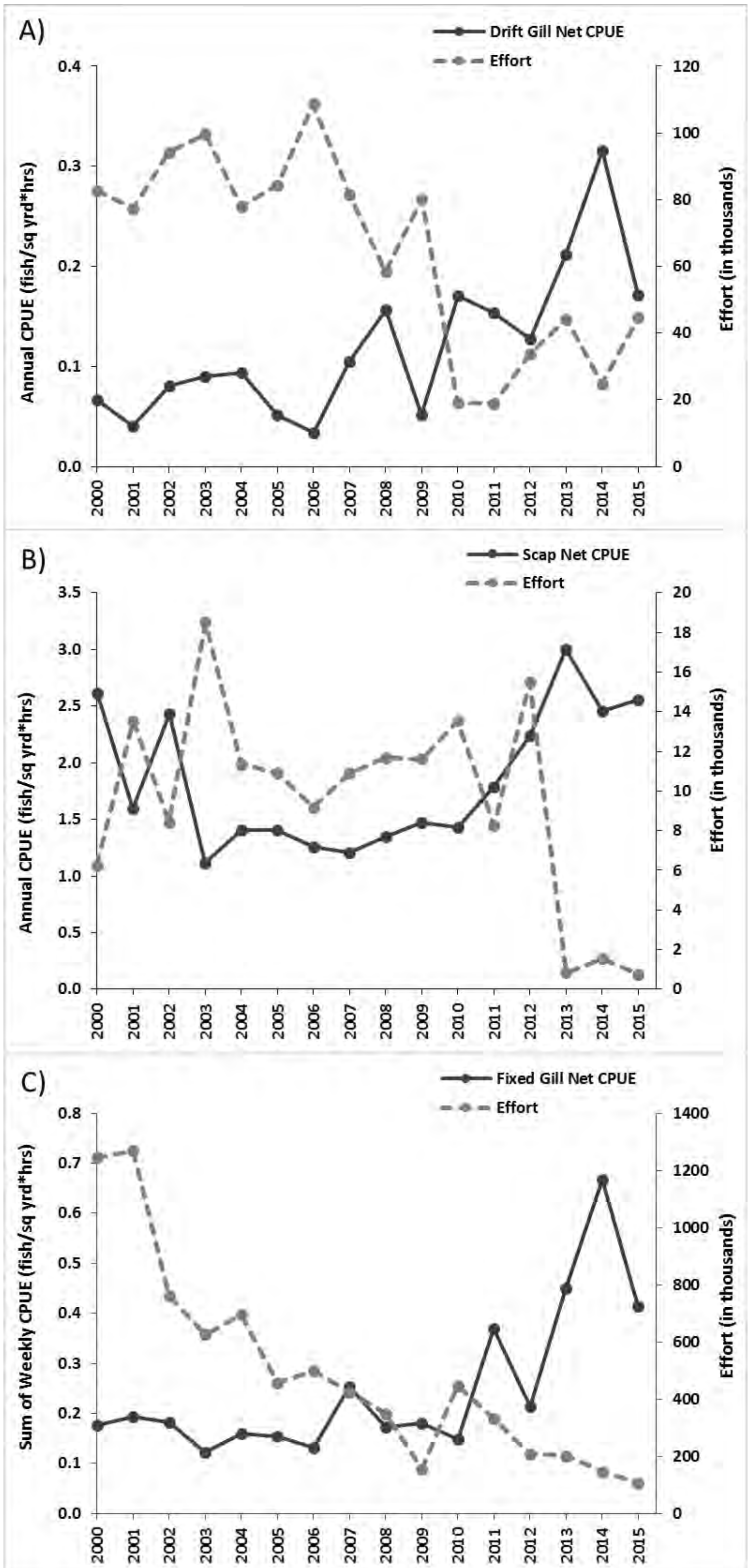


Figure 6. Efforts (sq yd net area * hours) and CPUEs from mandatory commercial reports. A) Drift gill net fishery above rkm 75; CPUE is total catch/total effort. B) Scap net fishery above rkm 75; CPUE is total catch/total effort. C) Fixed gill net fishery below rkm 75; CPUE is the sum of weekly catch/weekly effort.

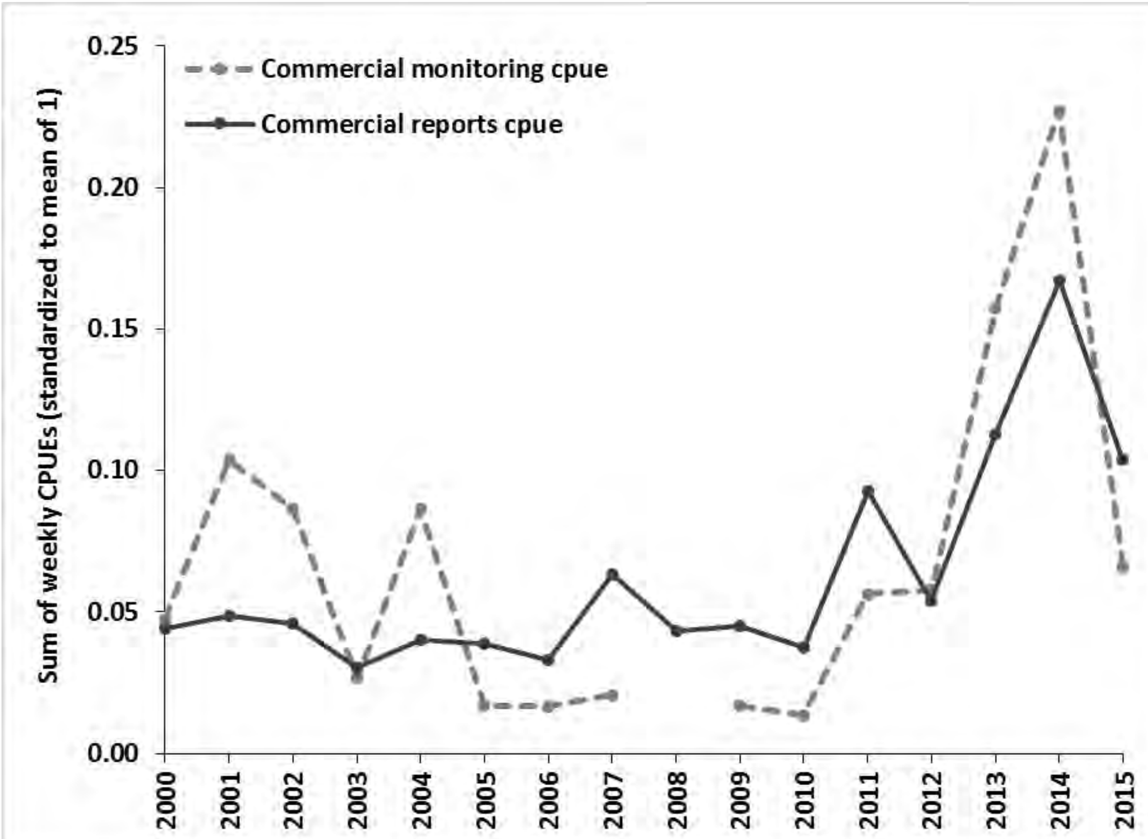


Figure 7. Comparison of the sum of weekly CPUEs calculated from commercial monitoring and mandatory commercial reports of the fixed gill net fishery below the Bear Mountain Bridge (rkm 75). Values are standardized to a mean of 1.

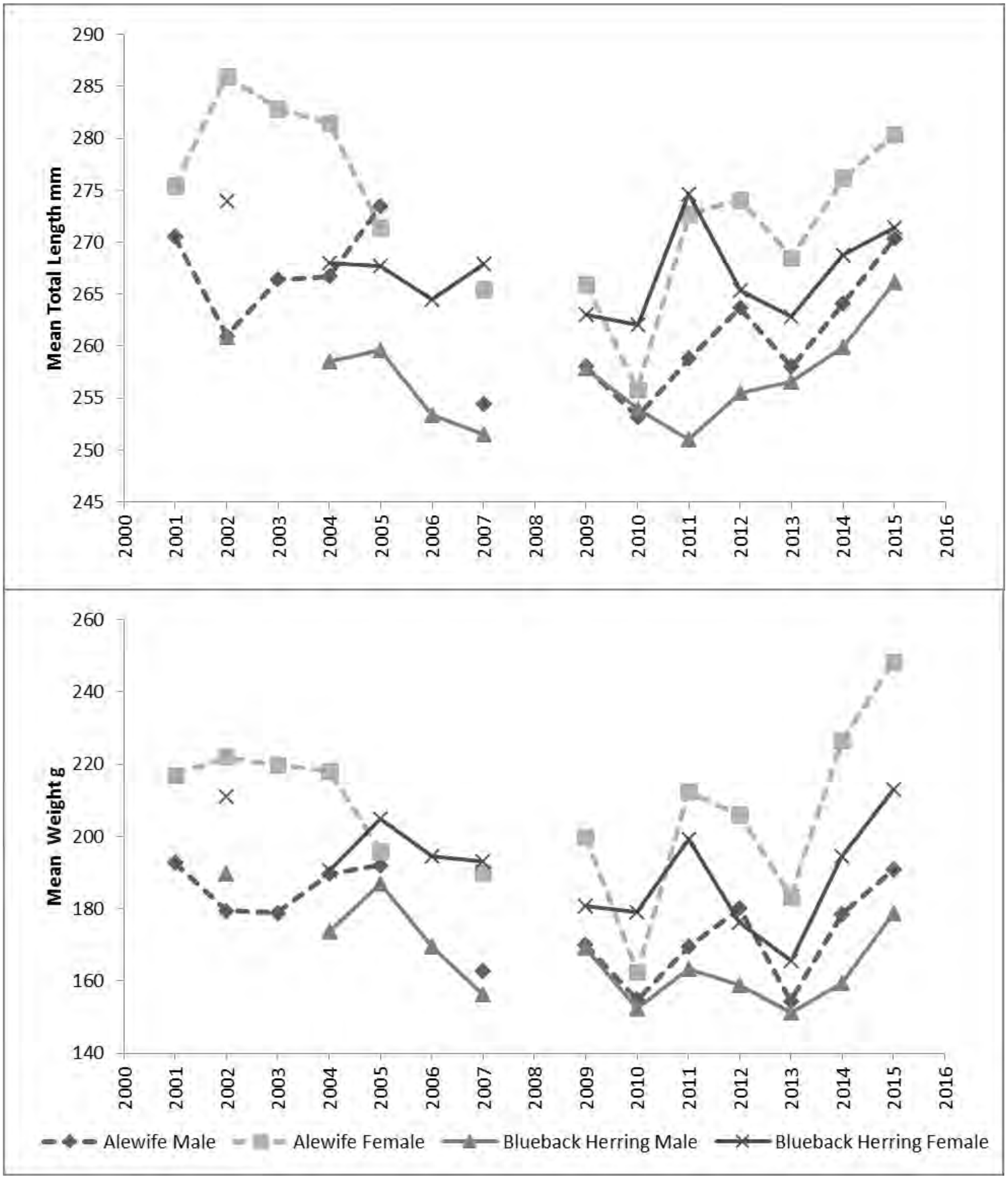


Figure 8. Mean length and weight of river herring collected in fishery dependent sampling in the commercial fishery in the Hudson River.

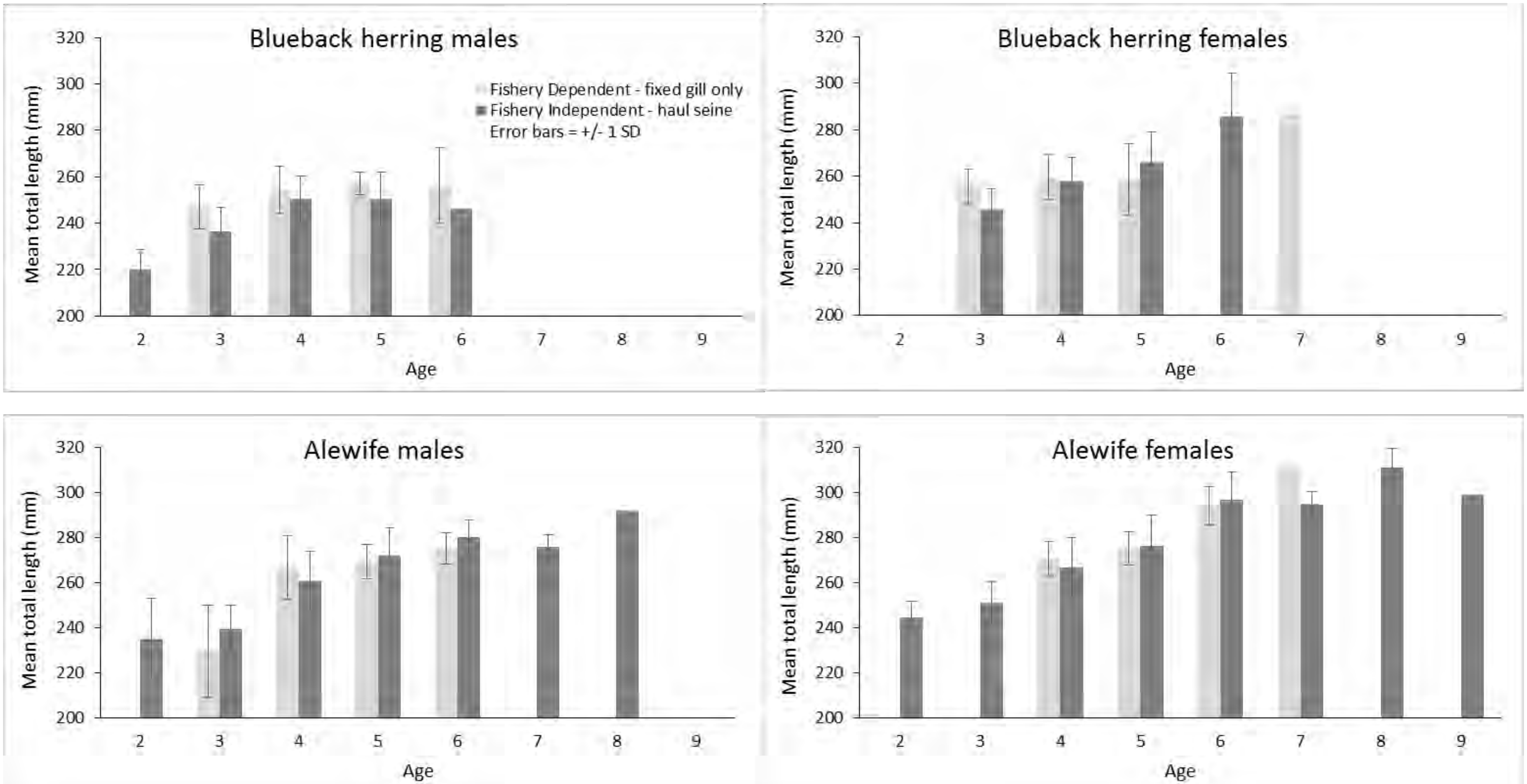


Figure 9. Comparison of length at age of river herring sampled in the lower-river fixed gill net commercial fishery versus the fishery independent survey.

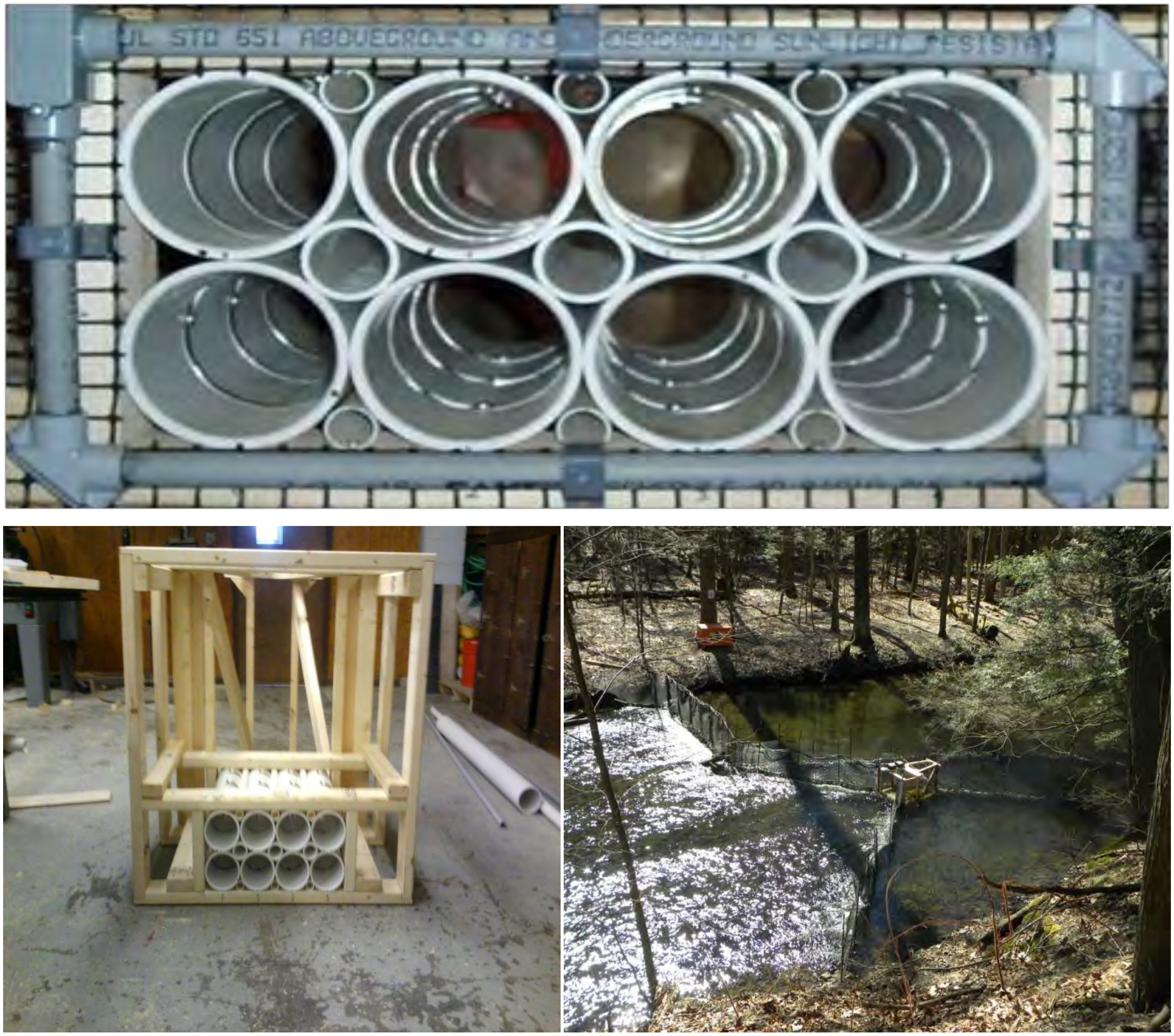


Figure 10. Top: Front view of the counter head that consists of eight four inch PVC tubes fitted with three stainless steel clamps, acting as sensors that measure water conductivity. Bottom left: View of fish counter head during construction. Bottom right: View of in-stream weir and fish counter.

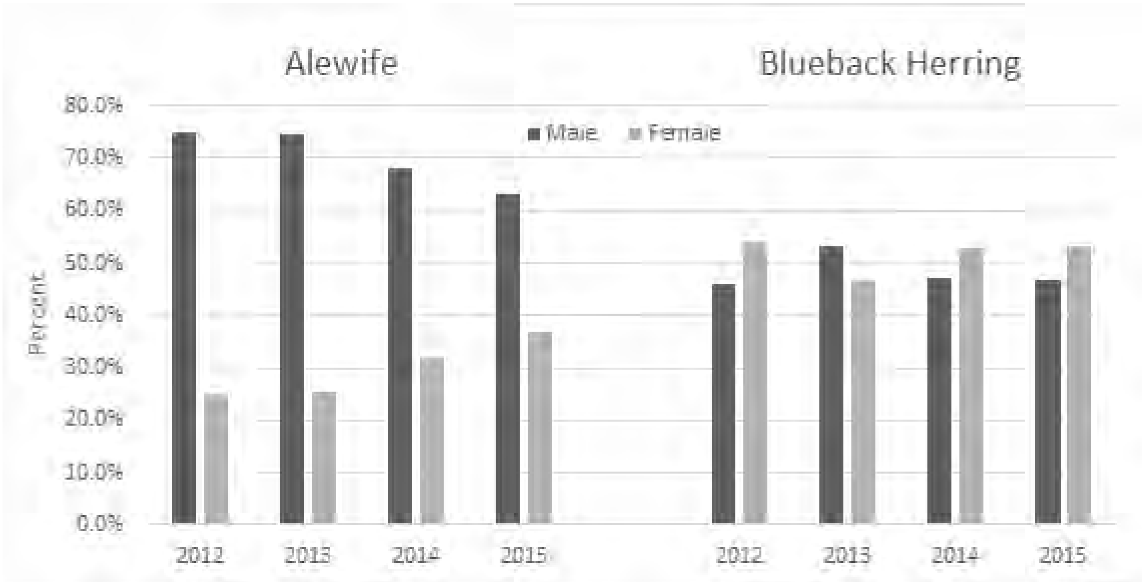


Figure 11. Annual sex ratios from river herring collected during the fisheries independent survey.

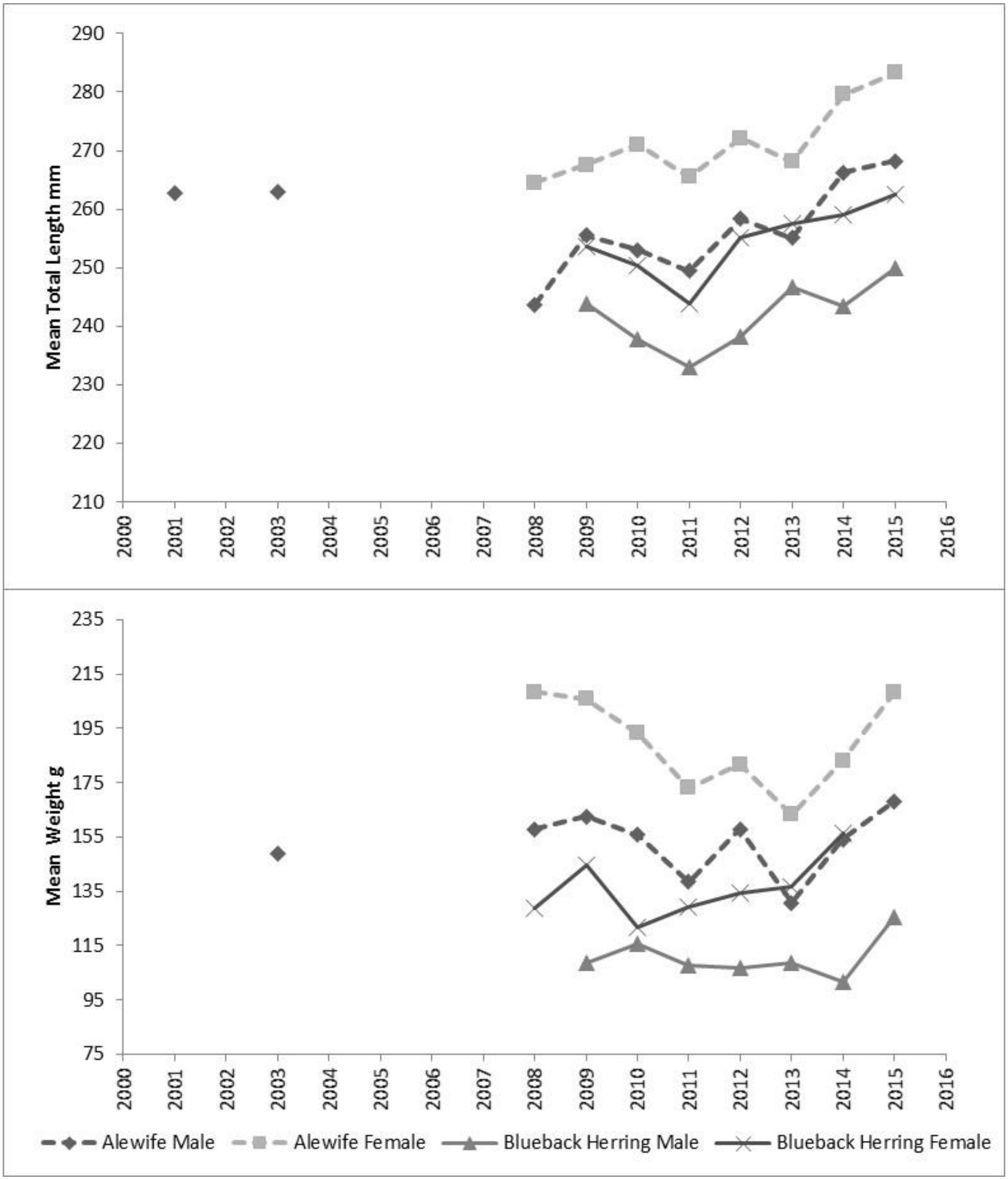


Figure 12. Mean length and weight of river herring collected during fishery independent sampling of the spawning stock survey.

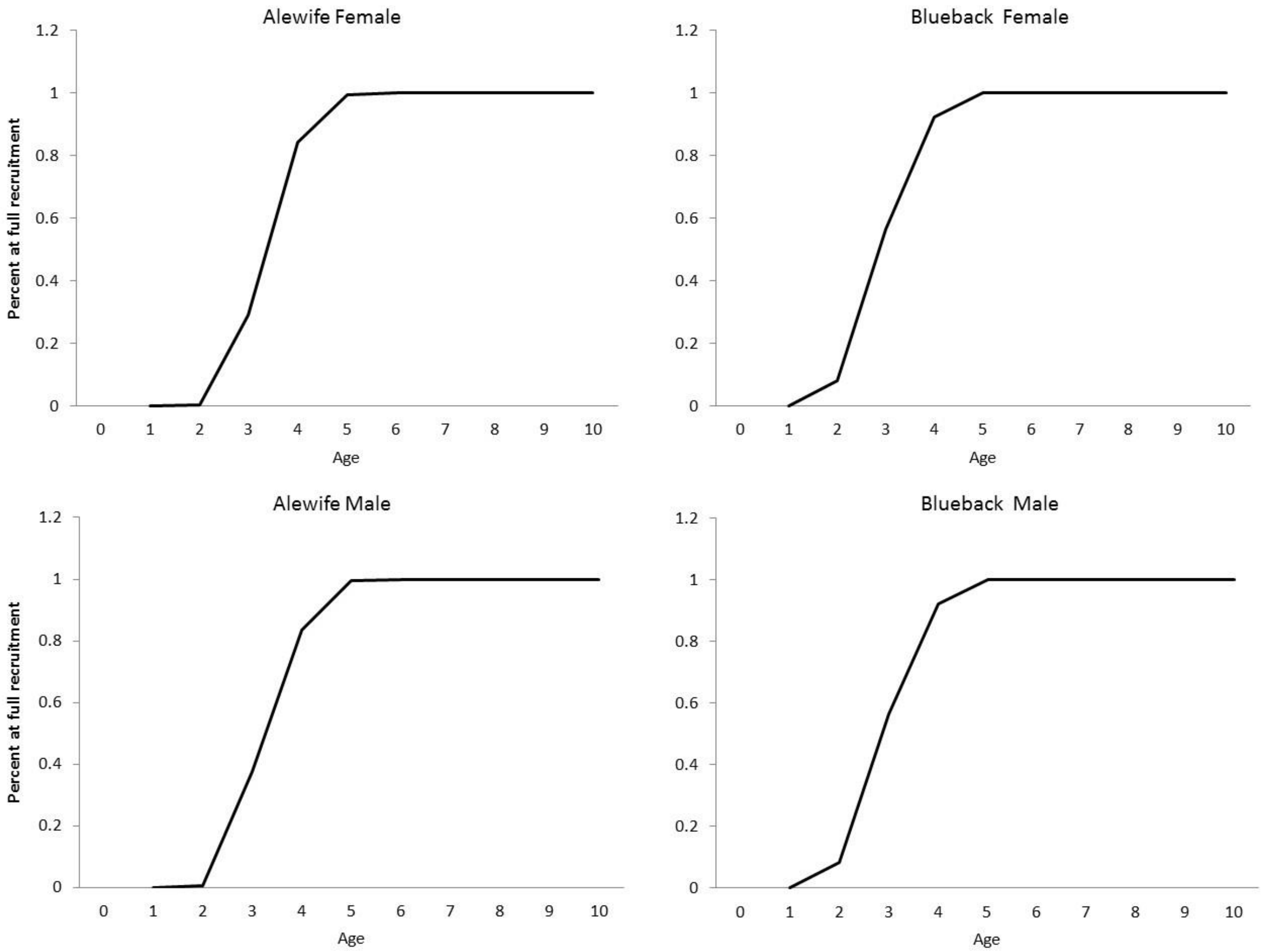


Figure 13. Maturity schedule for alewife and blueback herring derived from 2012-15 age data.

Figure 14. Frequency of repeat spawning occurrence for both species of river herring collected during fisheries independent sampling.

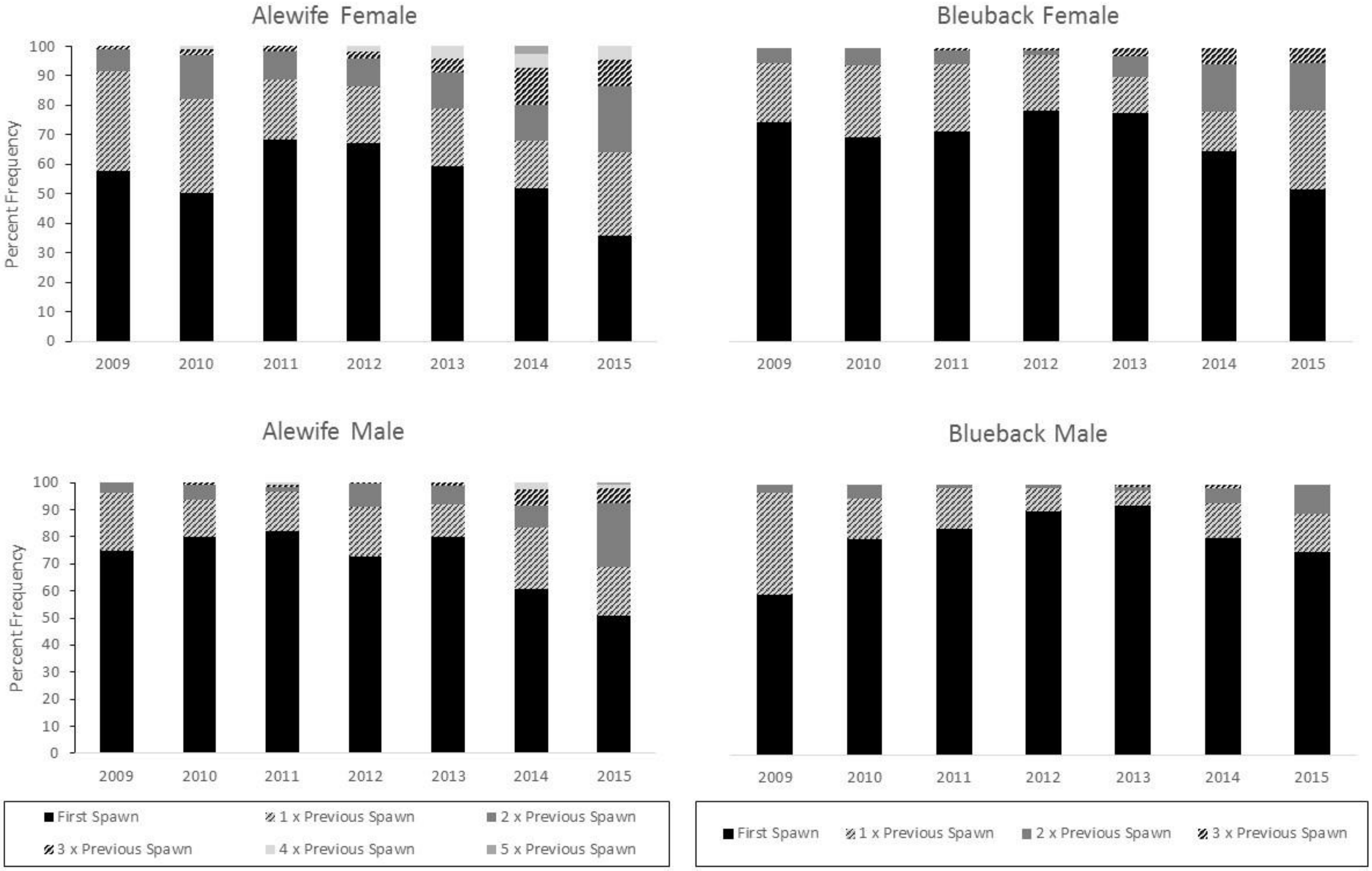


Figure 15. Mean length at age for river herring from fisheries independent sampling.

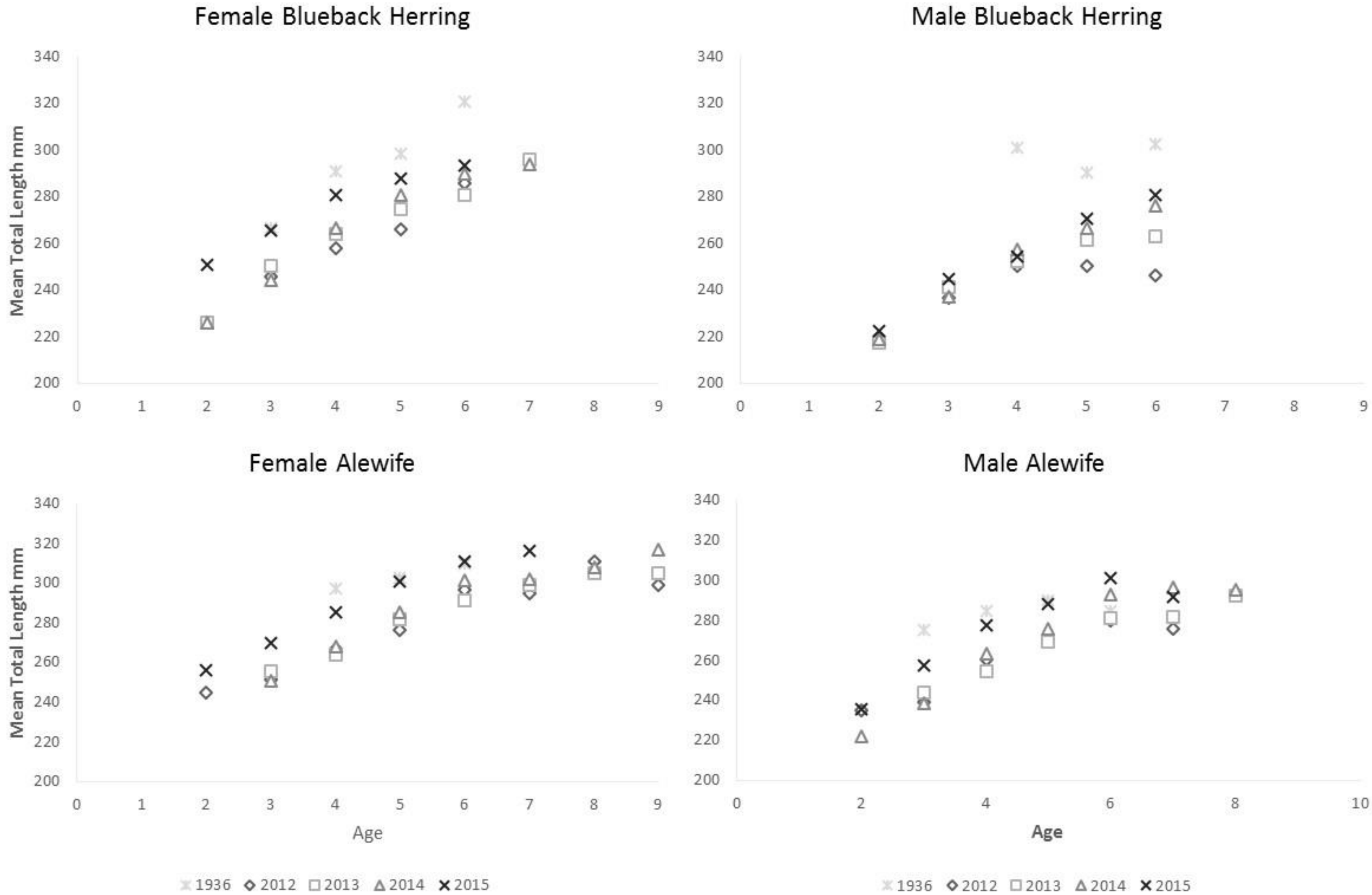


Figure 16. Chapman-Robson mortality estimates for both species of river herring collected during fisheries independent sampling.

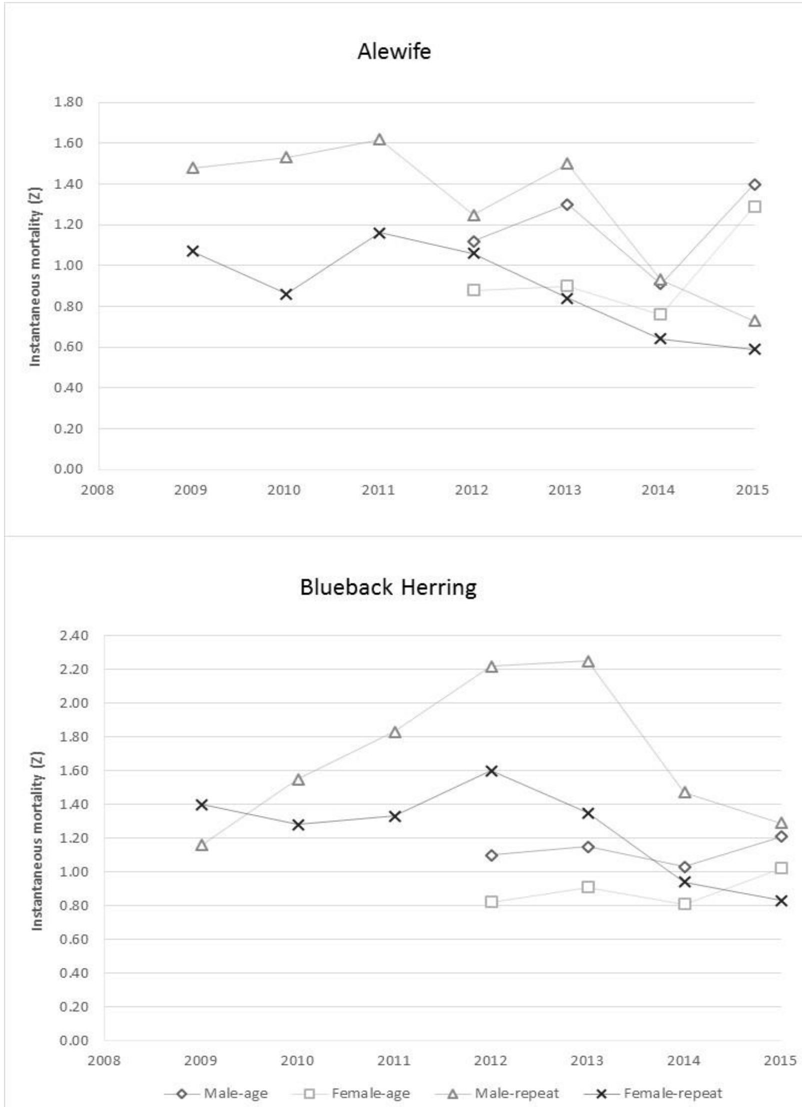


Figure 17. Young-of-year abundance indices for both river herring species.

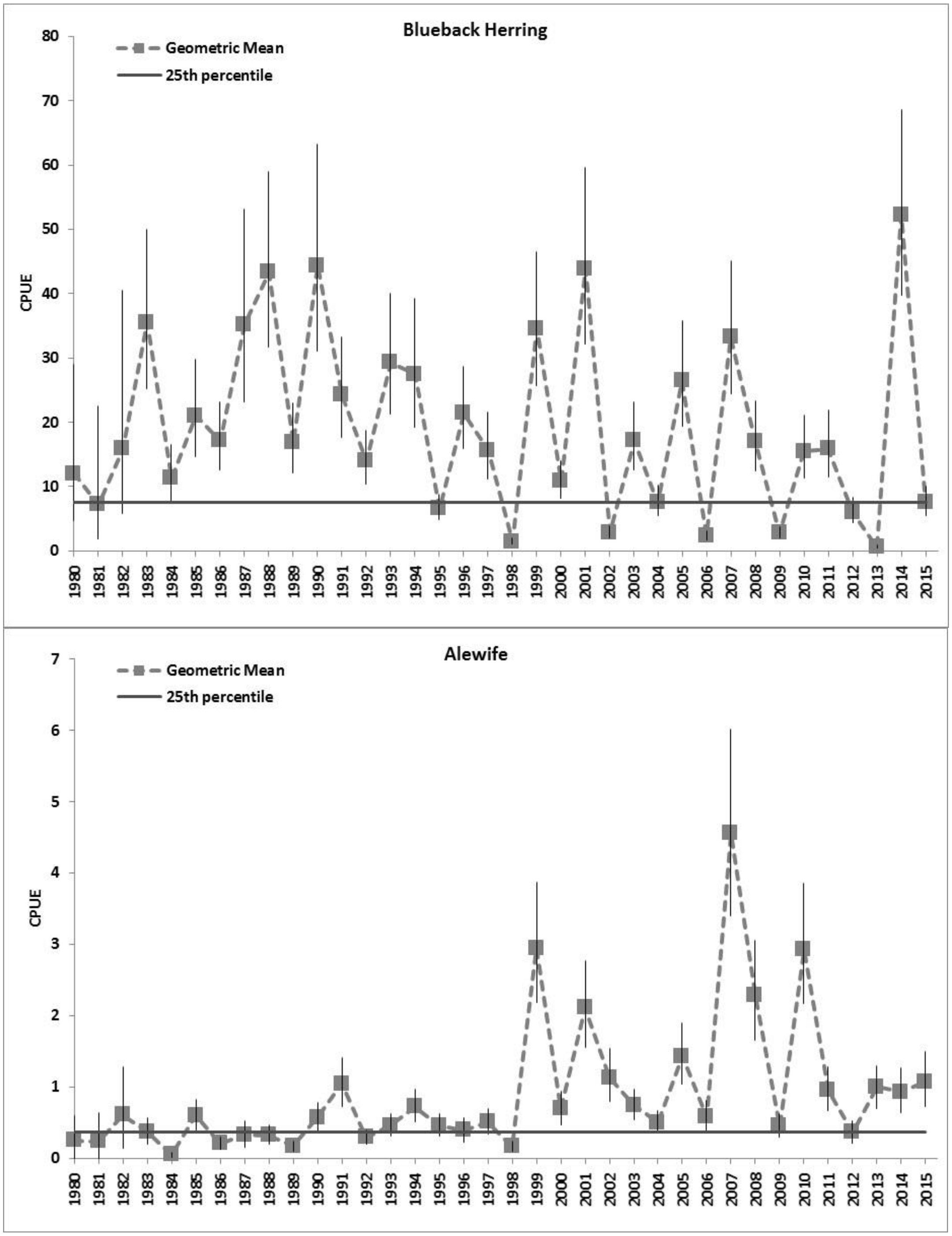


Table 1. Summary of available fishery-dependent river herring data in Hudson River and Marine District of New York.

Data Type	Time period/ Details	Description	Usefulness as index
Fishery Dependent - Commercial			
Harvest	Historic data: -1904-1994: NMFS -1994-present: Hudson (see below)- NYSDEC; Marine waters- VTR/dealer report since 2002 -1994- present: transfer of historic NMFS data to ACCSP, data available in confidential and non-confidential form	- Provide catch and effort data - Not separated by area (river v marine) - River data reporting rate unknown	- Gives historic perspective - Provides trend data for state as a whole, but does not separate river(s) from ocean until 1994.
Marine monitoring	River herring most likely occur as bycatch in variety of fisheries	No port sampling in NY for 'herring'	
Hudson River Mandatory reports	- Began in 1995 through the present - Enforcement of reports in 2000 - Catch and effort statistics	- Data from 2000 to present good - Reporting rate unknown - Data separated by gear used: - Fixed gill net below Bear Mountain Bridge (BMB); passive gear below spawning area; consistent manner of fishing; weekly sum of CPUE approximating "area under curve" method - In spawning area above BMB - Drift gill (main-stem HR only) - active gear - Fixed gill (main-stem HR only) - less effort than below BMB - Scap/lift net (main-stem HR only)	Emigration area CPUE - Fixed GN below BMB: o Good indicator of abundance o increasing trend Spawning area CPUE o Drift GN - variable o Scap - Flat
Hudson R. Fishery Monitoring	- Began in 1999 through the present - Onboard monitoring - Catch and effort statistics - Catch subsample	- Number of annual trips are low; co-occurs & staffing conflicts with FI sampling - Catch samples increased after 2012 - NEED improved sample size to be useful	- Characterize catch
Fishery Dependent - Recreational			
Harvest (primarily sought as bait for striped bass; some harvest for personal consumption)	Creel surveys: - 2001, river-wide, all year - 2005, spring only - 2007, state-wide angler survey; effort for striped bass	- 2001: provides point estimate of effort for striped bass, ancillary river herring (RH) data - 2005 provides point estimate of RH harvest & effort for striped bass	Combination of effort for striped bass and point estimate of RH harvest; combine with below CAP data to estimate magnitude of recreational harvest for 2005 to the present.
Cooperative Angler Program	Data 2006-present	Diary program for striped bass anglers; includes data for RH catch or purchase, use by trip	Good RH use per trip- used above with rec. harvest to estimate total recreational harvest

Table 2. Summary of available fishery-independent river herring data in Hudson River, New York.

Data type	Time period/Agency	Description	Usefulness as index
Fishery Independent- Hudson River			
Spawning stock	1936: Biological Survey	Historic data, low sample size of 25 fish, species, sex, length & age	Indication of size change to present
	2001 to present: NYSDEC spawning stock survey	Focused spawning stock survey; >300 fish collected most years; species, sex, length & scales (ageing complete from 2012-2015)	Early sample design precluded use for catch-per-unit-effort data. Fixed site sampling since 2012 is geared toward an adult index. Mortality estimates from scales 2012-present and from spawn marks 2009-present
Young-of-year Indices		- July-Oct sampling within nursery area - Geometric mean number per haul Catchability may be affected by habitat change 2006 to present; documents presence/absence of river herring in Hudson tributaries and in some Long Island streams - July-Oct sampling within nursery area - Geometric mean number per haul Catchability may be affected by habitat change	- Both species index variable - Alewife increasing - Blueback slight decreasing trend Selected conservative target of 25th percentileNot yet useful as index; provide a mechanism to improve future sampling for adult runs Both species index variable - Alewife increasing - Blueback slight decreasing trend Selected conservative target of 25th percentile

Table 3. River herring and American shad catch in metric tons (mt) 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	na	176.5
Atlantic herring: GOM Mid-water trawl	na	11.1
Atlantic herring: Cape Cod Mid-water trawl	na	0.7
Atlantic herring: Southern New England bottom trawl	na	100.7
Atlantic herring: Southern New England mid-water trawl	na	64

Table 4. River herring and American 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 5. 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)	Unknown Catch (mt)	HICKORY SHAD Catch (mt)	Total Catch (mt)	Total identified catch (mt)	Proportion of known catch that is River Herring	Estimated unknown catch that is River Herring (mt)	Total estimated River Herring catch (mt)
1989	20.4	58.9	19.6	7.1	0.0	106.0	98.9	0.40	2.9	42.8
1990	55.3	25.8	78.9	331.3	0.0	491.4	160.1	0.84	277.9	412.2
1991	68.2	104.3	115.4	110.5	39.4	437.7	327.3	0.56	62.0	245.6
1992	30.6	79.8	458.2	387.5	0.0	956.1	568.5	0.86	333.1	821.9
1993	40.5	51.0	210.6	18.6	0.0	320.6	302.0	0.83	15.5	266.5
1994	5.5	70.3	40.2	9.8	0.2	126.0	116.2	0.39	3.8	49.5
1995	6.4	17.2	213.5	51.9	0.0	288.9	237.1	0.93	48.1	268.0
1996	482.0	40.0	1803.4	28.7	26.6	2380.8	2352.1	0.97	27.9	2313.3
1997	41.3	37.0	982.0	67.6	18.3	1146.2	1078.6	0.95	64.1	1087.4
1998	80.9	55.3	49.3	0.4	39.2	225.1	224.7	0.58	0.2	130.4
1999	3.9	15.7	206.7	128.8	56.8	411.8	283.0	0.74	95.8	306.3
2000	28.4	74.4	55.5	22.0	0.1	180.2	158.3	0.53	11.6	95.5
2001	93.0	61.9	120.1	2.1	80.6	357.8	355.7	0.60	1.3	214.4
2002	2.7	24.1	173.2	76.5	1.4	277.9	201.4	0.87	66.8	242.8
2003	248.4	21.4	332.5	15.3	14.3	631.9	616.6	0.94	14.4	595.3
2004	99.7	18.2	81.5	176.7	35.0	411.2	234.5	0.77	136.6	317.9
2005	347.4	78.2	220.0	7.2	19.4	672.3	665.1	0.85	6.1	573.6
2006	57.6	29.3	187.5	232.0	13.4	519.8	287.7	0.85	197.6	442.7
2007	484.0	55.1	180.1	105.3	4.8	829.3	724.0	0.92	96.6	760.8
2008	145.0	52.4	526.6	328.0	7.8	1059.8	731.8	0.92	301.0	972.6
2009	158.7	59.5	202.0	180.1	10.9	611.2	431.1	0.84	150.6	511.3
2010	118.5	46.1	125.0	86.5	1.1	377.3	290.8	0.84	72.4	316.0
Average	119.0	48.9	290.1	107.9	16.8	582.7	474.8	0.80	90.3	499.4

Table 6. Estimated river herring harvest (mt), based on average rate of known river herring bycatch 1989-2010 applied to actual harvest in 2014-15.

Estimated American shad catch (mt)	**2014**	**2015**
Atlantic mackerel vessels	5.14	10.30
Atlantic herring vessels - ALL	na	141.20
Atlantic herring: GOM Mid-water trawl	na	8.88
Atlantic herring: Cape Cod Mid-water trawl	na	0.56
Atlantic herring: Southern New England bottom trawl	na	80.56
Atlantic herring: Southern New England mid-water trawl	na	51.20

Table 7. Recent records of type of commercial licenses sold for the New York portions of the Hudson River Estuary.

	Gill Nets				Scap Nets		Gill net		Scap Net	
Year	N-Fishers	Shad/herring Gill Net	Gill Net	Total GN permits sold	N-Fishers	Permits sold	N-Fishers reporting herring	% Reporting	N-Fishers reporting herring	% Reporting
1995	112	47	75	122	2	2	5	4%	2	100%
1996	134	54	88	142	2	2	4	3%	2	100%
1997	112	45	74	119	35	35	22	20%	24	69%
1998	140	65	119	184	46	46	33	24%	33	72%
1999	145	77	68	145	31	31	40	28%	20	65%
2000	223	108	123	231	443	449	67	30%	124	28%
2001	190	87	83	170	345	348	67	35%	127	37%
2002	232	141	120	261	291	338	87	38%	113	39%
2003	238	144	106	250	237	278	96	40%	115	49%
2004	275	160	127	287	245	291	89	32%	106	43%
2005	255	162	111	273	215	255	68	27%	80	37%
2006	290	179	129	308	229	273	92	32%	87	38%
2007	290	178	130	308	201	244	87	30%	75	37%
2008	277	173	119	292	182	219	78	28%	85	47%
2009	254	159	108	267	168	199	76	30%	78	46%
2010	181	0	185	185	161	190	74	41%	73	45%
2011	177	0	181	181	144	164	62	35%	61	42%
2012	154	0	155	155	128	151	66	43%	51	40%
2013	157	0	166	166	112	127	77	49%	33	29%
2014	150	0	152	152	109	124	47	31%	27	25%
2015	148	0	150	150	96	112	58	39%	33	34%

Table 8. Drift gill net trips by river section above Bear Mountain Bridge (rkm 75). From mandatory commercial reports stating mesh less than or equal to 3.5” stretch mesh. Note: Kingston Flats rkm’s are not exclusive and trip rkm’s are based on fishermen descriptions, so any rkm 148-149 trips are moved to the Kingston reach and rkm 154-155 trips are listed with the Saugerties reach.

	West Point rkm 75 - 89	Cornwall rkm 90 - 98	Poughkeepsie rkm 99 - 122	HydePark rkm 123 - 135	Kingston rkm 138 - 147	Kingston Flats rkm 148 - 155	Saugerties rkm 156 - 171	Catskill rm 172 - 200	Coxsackie rkm 201 - 216	Albany rkm 217 - 245
2000			2		3		104	88	2	
2001			1	7	3		31	120	5	
2002		5	3	5	14		37	168	6	
2003				8	10		59	184	14	
2004		2		8	3		37	188	20	
2005				1	12		60	145	17	
2006			1	10	16		69	87	25	
2007		1	11	13	32	**Area closed to gill nets**	57	62	19	**Area closed to gill nets**
2008				4	24		49	67	13	
2009			11		17		64	45	11	
2010			12	3	26		28	38	11	
2011			10	1	10		22	33	1	
2012			20	1	34		34	33	3	
2013		8	13		58		82	88	11	
2014		6	6		69		58	54	8	
2015		10	14		25		44	68	12	
Mean	0.0	5.3	8.7	5.5	22.3	0	52.2	91.8	11.1	0
% of all years	0%	3%	4%	3%	11%	0%	27%	47%	6%	0%

Table 9. Number of river herring monitoring trips and catch per unit effort (CPUE) in the Hudson River commercial gill net fishery from 1996 through 2015. Only Trips where effort was calculated. Confidential data are in red.

YEAR	Fixed gill nets below Bear Mtn Bridge					Drift gill nets			
	Trips	Effort^	Catch	Annual CPUE	Sum of Weekly CPUE	Trips	Effort^	Catch	Annual CPUE
1996	0					1	91	43	0.472
1997	5	6830.6	208	0.030	0.055	0			
1998	0					0			
1999	4	11372.2	421	0.037	0.065	0			
2000	5	15650.0	545	0.035	0.126	1	160	7	0.044
2001	7	26688.9	1221	0.046	0.276	0			
2002	8	32222.2	1328	0.041	0.230	0			
2003	2	4800.0	171	0.036	0.071	0			
2004	11	41164.4	1826	0.044	0.230	0			
2005	1	9600.0	428	0.045	0.045	0			
2006	2	5591.1	246	0.044	0.044	1	378	0	0.000
2007	4	25777.8	299	0.012	0.055	2	4767	36	0.008
2008	0					0			
2009	3	19266.7	468	0.024	0.045	0			
2010	1	4326.7	154	0.036	0.036	0			
2011	4	6531.6	329	0.050	0.150	0			
2012	20	50916.4	1066	0.021	0.154	6	7013	560	0.080
2013	4	10719.8	1382	0.129	0.419	1	178	112	0.630
2014	7	14612.8	2161	0.148	0.605	1	2843	289	0.102
2015	5	8435.0	605	0.072	0.176	1	637	197	0.309

^Sq yd net area * hours

Table 10. Observed landings and dockside subsamples for commercial river herring trips made in the Hudson River Estuary for 2001 through 2015. Only trips where effort was calculated is presented. Confidential data in red.

On-board Observations of Commercial Trips																					
		Alewife					Blueback herring					Unidentified "river herring"									
	N of	Number			Sex ratio		Number			Sex ratio		Number			Sex ratio				Percent		
Year	trips	M	F	U	M	F	M	F	U	M	F	M	F	U	M	F	Total		Alewife	Blueback	Unknown
2001	7	192	178	851	0.52	0.48											1,221		100%	0%	0%
2002	8			43			19	41	1225	0.32	0.68						1,328		3%	97%	0%
2003	2			171													171		100%	0%	0%
2004	11	124	168	8	0.42	0.58	5	6		0.45	0.55	500	796	297	0.39	0.61	1,904		16%	1%	84%
2005	1			428										28			456		94%	0%	6%
2006	3			1					246								247		0%	100%	0%
2007	6			14					53					268			335		4%	16%	80%
2008	0											44					44		0%	0%	100%
2009	3	187	179	4	0.51	0.49	37	61		0.38	0.62						468		79%	21%	0%
2010	1	23	28	1	0.45	0.55	11	88	3	0.11	0.89						154		34%	66%	0%
2011	4	163	148	0	0.52	0.48	3	5		0.38	0.63			10			329		95%	2%	3%
2012	26	439	568	121	0.44	0.56	54	70	68	0.44	0.56			383			1,703		66%	11%	22%
2013	5	615	586	1	0.51	0.49	98	305		0.24	0.76						1,605		75%	25%	0%
2014	8	750	830	5	0.47	0.53	236	629		0.27	0.73						2,450		65%	35%	0%
2015	6	202	291	12	0.41	0.59	77	185		0.29	0.71			35			802		63%	33%	4%

Table 11. Age structure of river herring samples from the commercial fishery. 2012 commercial scale samples were aged; 2013-2015 ages were estimated using age-length keys derived from fishery independent samples.

	Age									
	2	3	4	5	6	7	8	9	Total	Mean Age
Alewife Male										
2012	4	71	110	37	4	5			231	3.91
2013		26	37	15	3	1			83	3.97
2014		32	82	102	2	1	1		221	4.37
2015		4	42	53	18	1	1		118	4.77
Alewife Female										
2012	1	30	155	121	25	11	2	1	346	4.54
2013		19	39	12	5	1			76	4.07
2014		23	106	62	18	11	3	2	225	4.58
2015		14	41	67	18	4	1		146	4.73
Blueback herring Male										
2012	2	18	40	11	3				75	3.94
2013	0.2	10	9	4	2				25	3.91
2014	0.3	17	55	25	2				99	4.11
2015		7	8	17	1				33	4.35
Blueback herring Female										
2012		32	68	34	2	2			137	4.09
2013		13	11	6	2	1			32	3.92
2014		26	63	23	13	5			130	4.29
2015		6	16	16	4	1			43	4.53

Table 12. Estimated recreational use and take of river herring by Hudson River anglers.

Year	Herring Use* % of all CAP Trips using herring as bait	N-SB Trips using RH	N bought / trip	N caught / trip	Total RH use/trip	% change in annual effort of CAP data	Estimated SB trips**	Trips using herring as bait**	Estimated Herring Use
2001							53,988	39,500	93,157**
2005	89%						72,568	64,500	152,117**
	Cooperative Angler Program Data								
2006	48%	263	1.47	2.57	4.04				
2007	25%	335	1.66	1.80	3.46		90,742	22,685	78,491***
2008	33%	474	0.86	1.64	2.50	+21%	109,557	36,154	84,969***
2009	35%	508	0.63	3.80	4.43	+9%	98,739	34,559	148,303***
2010	52%	532	0.67	4.80	5.48	+1	91,513	47,587	258,150***
2011	48%	885	0.71	4.35	5.06	+14%	103,532	49,695	251,285***
2012	53%	749	1.10	4.76	5.86	-1%	89,735	47,650	278,627***
2013	57%	611	1.04	5.23	6.27	-11%	80,703	46,001	288,579***
2014	55%	512	0.74	5.30	6.04	-14%	78,438	43,141	260,613***
2015	54%	571	0.66	6.04	6.70	+18%	106,961	57,759	386,915***

*Data from NYSDEC - HRFU Cooperative Angler Program (unpublished data)
**Creel survey data: NAI 2003, NAI 2007; 2001 estimated use modified using 2005 RH use per trip* 2001 trips using herring as bait; From 2008 to 2015 estimated using the percent change in annual effort of the CAP data*2007 SB trips from NYSDEC statewide angler survey
***Estimate calculated from the average RH/trip (CAP) and Estimated SB trips from 2007 NYSDEC statewide angler survey adjusted annually using the percent change in effort from CAP data

Table 13. Annual daily count data from Black Creek and commercial and estimated recreational herring harvest.

	Black Creek Daily Alewife Count Data							Hudson River Harvest		
	Min	Max	Mean	SD	SE	Total Counts	n (days)*	Commercial Harvest**	Recreational Harvest***	Total
2013	25	40571	4380.53	7710.69	1124.72	205,885	47	24,612	288,579	313,191
2014	294	58416	18458.75	13206.45	2334.59	590,680	32	20,805	260,613	281,418
2015	26	45186	13064.74	12146.56	2114.45	431,136	33	15,634	386,915	402,549

*Number of days count data were recorded
**Number harvested of combined river herring species from Hudson River commercial reports
***Estimated harvest numbers of combined river herring species derived from CAP data and 2007 NYSDEC statewide angler survey

Table 14. Annual catch and effort (n-hauls) for alewife and blueback herring.

Year	Annual Catch (Alewife)	Annual Catch (Blueback)	Annual Effort * (N-hauls)	Annual CPUE (Alewife)	Annual CPUE (Blueback)
			Historical survey data		
2001	1336	28	8	167.00	3.50
2003	417	7	11	37.91	0.64
2004	0	10	2	0.00	5.00
2005	120	41	12	10.00	3.42
2006	27	3	3	9.00	1.00
2007	53	0	6	8.83	0.00
2008	235	21	15	15.67	1.40
2009	660	182	20	33.00	9.10
2010	265	44	56	4.73	0.79
2011	74	80	21	3.52	3.81
			Current survey data		
2012	2146	1304	165	13.01	7.90
2013	4865	4056	117	41.58	34.67
2014	11231	3054	114	98.52	26.79
2015	4328	3030	107	40.45	28.32

*Only includes hauls when gear performed well without any major issues i.e. no hangs, rips in net, or lifting of the lead line

Table 15. Sampling efforts (n-hauls) and catches per river section from 2012-15.

	2012			2013			2014			2015		
River section	N-sites	N-hauls	N-herring caught	N-sites	N-hauls	N-herring caught	N-sites	N-hauls	N-herring caught	N-sites	N-hauls	N-herring caught
Albany	6	37	1978	3	21	4273	3	26	3440	3	21	2247
Catskill	14	52	529	9	38	1639	7	30	3118	5	33	1851
Coxsackie	15	47	477	10	34	2269	5	30	5908	5	33	2113
Kingston	14	46	468	6	32	787	5	36	1898	4	32	1178
Newburgh	4	11	-	-	-	-	-	-	-	-	-	-
Poughkeepsie	14	3	1	-	-	-	-	-	-	-	-	-
IndianPoint	5	6	-	-	-	-	-	-	-	-	-	-
Croton-Haverstraw	3	10	-	-	-	-	-	-	-	-	-	-
TappanZee	6	6	-	-	-	-	-	-	-	-	-	-
Totals	81	218	3453	28	125	8968	20	122	14364	17	119	7389

Table 16. Age structure of river herring from fisheries independent sampling.

Year	Age* 2	3	4	5	6	7	8	9	Total	Mean Age
Alewife Male										
2012	27	385	726	308	91	21	2		1559	4.08
2013		615	782	276	48	15	1		1737	3.89
2014	1	372	933	1233	61	18	29		2647	4.43
2015		105	430	544	203	12	8		1302	4.70
Alewife Female										
2012	5	76	210	175	32	11	7	2	518	4.44
2013		148	275	84	58	17	12	1	596	4.26
2014		83	537	383	137	75	27	5	1247	4.75
2015		56	179	372	114	30	8		759	4.87
Blueback Herring Male										
2012	64	157	89	16	3				329	3.20
2013	34	483	209	44	17				787	3.40
2014	83	308	205	51	1				649	3.35
2015	3	412	168	44	3				630	3.42
Blueback Herring Female										
2012		152	168	61	4				385	3.78
2013	1	364	203	97	21	1			687	3.67
2014	7	320	274	77	36	9			723	3.78
2015		248	262	162	36	9			716	4.02

* Numbers at age are estimated using age-length keys that are derived on an annual basis

Table 17. Repeat spawn data of river herring from fisheries independent sampling.

Year	Repeat spawn marks* 0	1	2	3	4	5	Total	Mean RS	% Virgin	% Repeat
Alewife Male										
2009	229	65	12	0			306	0.29	0.75	0.25
2010	165	28	11	2			206	0.27	0.80	0.20
2011	101	18	2	1	1		123	0.24	0.82	0.18
2012	138	35	19	1			193	0.39	0.72	0.28
2013	150	23	13	2			188	0.29	0.80	0.20
2014	52	19	7	4	2		84	0.63	0.62	0.38
2015	54	19	25	6	1	1	106	0.91	0.51	0.49
Alewife Female										
2009	70	41	9	1			121	0.51	0.58	0.42
2010	51	32	15	2	1		101	0.71	0.50	0.50
2011	84	25	12	2			123	0.45	0.68	0.32
2012	124	36	17	5	3		185	0.52	0.67	0.33
2013	116	39	24	9	8		196	0.74	0.59	0.41
2014	42	13	10	10	4	2	81	1.10	0.52	0.48
2015	32	25	20	8	4		89	1.18	0.36	0.64
Blueback Herring Male										
2009	38	24	2				64	0.44	0.59	0.41
2010	63	12	4				79	0.25	0.80	0.20
2011	66	12	1				79	0.18	0.84	0.16
2012	294	28	7				329	0.13	0.89	0.11
2013	118	7	2	1			128	0.11	0.92	0.08
2014	57	9	4	1			71	0.28	0.80	0.20
2015	48	9	7				64	0.36	0.75	0.25
Blueback Herring Female										
2009	44	12	3				59	0.31	0.75	0.25
2010	46	16	4				66	0.36	0.70	0.30
2011	80	26	5	1			112	0.35	0.71	0.29
2012	107	26	2	1			136	0.24	0.79	0.21
2013	121	19	11	4			155	0.34	0.78	0.22
2014	48	10	12	4			74	0.62	0.65	0.35
2015	41	21	13	4			79	0.75	0.52	0.48

* Numbers of repeat spawn marks are derived from actual scale readings

Table 18. Mean lengths (mm) at age for river herring from fisheries independent sampling.

	1936				2012				2013				2014				2015			
	Alewife		Blueback		Alewife		Blueback		Alewife		Blueback		Alewife		Blueback		Alewife		Blueback	
Ages	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
2					235.0	244.7	219.9				217.2	226	222.0		218.7	226.0			222.5	
3	275.0			266.2	239.3	251.0	236.5	245.7	244.1	255.7	241.3	250.3	238.6	250.4	236.8	244.0	235.5	256.2	244.6	250.9
4	284.8	297.4	301.0	290.8	260.5	266.8	250.2	257.9	254.2	263.8	252.3	263.7	263.5	267.7	257.3	266.6	257.2	269.8	254.3	265.2
5	289.8	302.8	290.1	298.2	271.9	276.1	250.2	266.0	269.2	281.7	261.2	274.8	275.5	285.5	266.3	280.4	277.4	285.1	270.3	280.6
6	284.5	309.6	302.4	320.8	280.1	296.8	246.0	285.5	280.9	291.3	263.0	280.7	292.6	301.3	276.0	289.7	288.0	300.6	280.5	287.5
7					275.8	295.0			281.4	299.2		296.0	296.3	302.0		294.0	301.0	310.9		293.3
8					292.0	311.0			292.0	304.8			295.3	307.6			291.5	316.0		
9						299.0				305.0				317.0						

Table 19. Instantaneous mortality estimates derived from age data and repeat spawn data using a bias-correction Chapman and Robson mortality estimator described in Smith et al. (2012).

	Age								Repeat Spawn							
	Alewife				Blueback				Alewife				Blueback			
	Male		Female		Male		Female		Male		Female		Male		Female	
Year	Z	SE	Z	SE	Z	SE	Z	SE	Z	SE	Z	SE	Z	SE	Z	SE
2009									1.48	0.12	1.07	0.22	1.16	0.41	1.40	0.09
2010									1.53	0.12	0.86	0.01	1.55	0.12	1.28	0.13
2011									1.62	0.21	1.16	0.09	1.83	0.13	1.33	0.10
2012	1.12	0.09	0.88	0.19	1.10	0.22	0.82	0.35	1.25	0.15	1.06	0.06	2.22	0.11	1.60	0.14
2013	1.30	0.10	0.90	0.08	1.15	0.12	0.91	0.13	1.50	0.19	0.84	0.08	2.25	0.44	1.35	0.19
2014	0.91	0.45	0.76	0.13	1.03	0.26	0.81	0.18	0.93	0.05	0.64	0.08	1.47	0.15	0.94	0.18
2015	1.40	0.22	1.29	0.04	1.21	0.15	1.02	0.20	0.73	0.13	0.59	0.17	1.29	0.28	0.83	0.12

8 Appendix 1

Table A. Summary of historical and current commercial fishery regulations for alewife and blueback herring in New York State (2013 regulation changes in bold).

<table>
<tr><th>Regulation</th><th>2013 to Present</th><th>Regulation link</th></tr>
<tr><td>Season</td><td>Mar 15 – Jun 15</td><td>6 CRR-NY 36.3 (a)</td></tr>
<tr><td>Creel/ catch limits</td><td>None</td><td></td></tr>
<tr><td rowspan="4">Commercial Gear (Marine permit)</td><td>Gill nets as commercial gear
- 600 ft or less
- 3.5 in stretch mesh or smaller
- No fishing at night in HR above Bear Mt Bridge
- Drift gill nets only allowable gill nets above Bear Mt Bridge
- Gill nets above Bear Mt Bridge must be tended at all times</td><td>6 CRR-NY 36.3 (c)
6 CRR-NY 36.3 (b)
6 CRR-NY 36.3 (3)(i)
6 CRR-NY 36.3 (7)
6 CRR-NY 36.3 (2)(iv)
6 CRR-NY 36.3 (5)</td></tr>
<tr><td>Seine as commercial gear
- No size restrictions below Castleton/I90</td><td>6 CRR-NY 36.3 (c)</td></tr>
<tr><td>Scoop/Dip/Scap net as commercial gear
- 10' x 10' maximum</td><td>6 CRR-NY 36.3 (c)</td></tr>
<tr><td>Fyke/hoop/trap nets as commercial gear
- No size restrictions</td><td>6 CRR-NY 36.3 (c)</td></tr>
<tr><td>Commercial Gear (Bait license)</td><td>Cast Net as bait collection gear
- 10 ft maximum diameter</td><td>To find the law click here, on ENV, find Article 11, click on Title 13, click ECL 11-1315</td></tr>
<tr><td rowspan="3">Closed areas</td><td>No gill nets above I90 - Castleton Bridge</td><td>6 CRR-NY 36.3 (2)(ii)</td></tr>
<tr><td>No nets on Kingston Flats</td><td>6 CRR-NY 36.3 (2)(i)</td></tr>
<tr><td>No nets in any tributary (including Mohawk River)</td><td>6 CRR-NY 36.3 (2)(i)</td></tr>
<tr><td>Escapement (no fishing days)</td><td>36 hr lift period for all commercial gears
Friday 6AM – Saturday 6PM</td><td>6 CRR-NY 36.3 (4)</td></tr>
<tr><td rowspan="5">Marine Permit Fees (established 1911)</td><td>Gill net $0.05/foot</td><td rowspan="5">6 CRR-NY 35.1</td></tr>
<tr><td>Scap net <10 sq ft $1.00</td></tr>
<tr><td>Seine $0.05/foot</td></tr>
<tr><td>Trap nets $3 to $10</td></tr>
<tr><td>Fyke net $1 to $2</td></tr>
<tr><td>Marine Permit Reporting</td><td>Mandatory daily catch & effort; Vessel Trip Reports (VTRs) due monthly</td><td>6 CRR-NY 36.1 (a)(1)</td></tr>
<tr><td>Transport and sale</td><td>- Commercially caught anadromous river herring must be sold and used in the Hudson River and tributaries to first impassable barrier and within the transport corridor
- May also be sold or transferred to locations in the Marine District
- Transport within DEC Reg. 3 requires a bait transport permit
- Retail sale of live and frozen anadromous river herring requires
o Fish health certification on premises
o Receipt to purchaser (valid for 10 days)
- Retail sale of dead packaged anadromous river herring requires
o Preservation other than freezing
o Each package must be labeled with
▪ Name of packager-processor
▪ Name of fish species
▪ Quantity of fish
▪ Means of preservation</td><td>6 CRR-NY 35.3 (d)

6 CRR-NY 35.3 (c)(1)

6 CRR-NY 35.3 (c)(2)

6 CRR-NY 35.3 (c)(3)(ii)
6 CRR-NY 35.3 (c)(3)(iii)(a)
6 CRR-NY 35.3 (c)(4)</td></tr>
</table>

Table B. Summary of historical and current recreational fishery regulations for alewife and blueback herring in New York State (2013 regulation changes in bold).

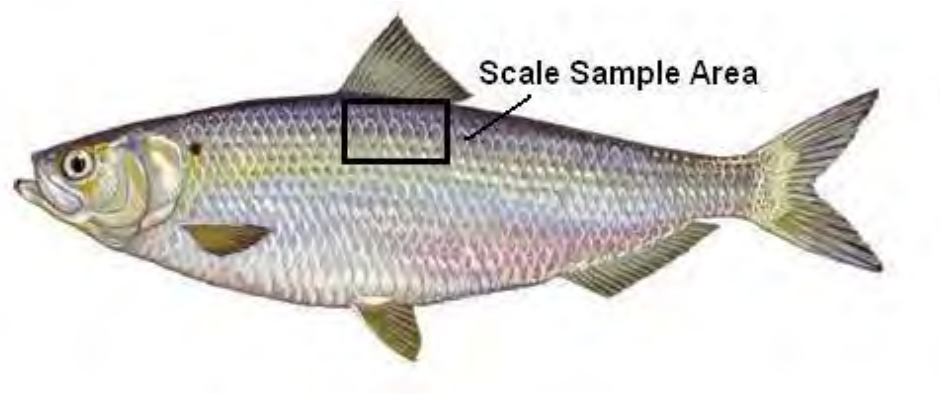
Regulation	2013 to Present	Regulation link
Season	Mar 15 – Jun 15	6 CRR-NY 10.10 (c)(2)
Creel/ catch limits (personal use)	**10 per day per angler or a maximum boat limit of 50 per day for a group of boat anglers (whichever is lower)**	6 CRR-NY 10.10 (c)(2)
Creel/ catch limits (party or charter)	- **10 per day per angler or a maximum boat limit of 50 per day for a group of boat anglers (whichever is lower)** - **Operator of party or charter north of Tappan Zee bridge may possess anadromous river herring in excess of individual recreational possession limit as long as** o **Register with Hudson River Fisheries Unit** o **Must display a valid Hudson River herring decal on port side of vessel**	6 CRR-NY 10.10 (c)(4)(i) 6 CRR-NY 10.10 (c)(4)(ii) 6 CRR-NY 10.10 (c)(4)(iii) 6 CRR-NY 10.10 (c)(4)(iii)(c)
Recreational gear (personal use)	Angling	6 CRR-NY 10.10 (c)(2)
	Seine – not exceeding 36 square feet	6 CRR-NY 10.10 (c)(3)(ii)(e)
	Scap net – - **Not exceeding 16 square feet** - Only one net	6 CRR-NY 10.10 (c)(3)(ii)(d) 6 CRR-NY 10.10 (c)(3)(ii)(b)
	Dip/Scoop – - Not exceeding 14 inches in diameter or 13 inches by 13 inches square - Only one net	6 CRR-NY 10.10 (c)(3)(ii)(c) 6 CRR-NY 10.10 (c)(3)(ii)(b)
	Cast net – not exceeding 10 feet in diameter	6 CRR-NY 10.10 (c)(3)(ii)(f)
Closed areas	- **No nets in any Hudson River tributary (including Mohawk R)** o **Nets must be stowed prior to entering a tributary** - **All other waters of NY State closed to the take of anadromous river herring**	6 CRR-NY 10.10 (c)(3)(i) 6 CRR-NY 10.10 (c)(3)(iii) 6 CRR-NY 10.10 (c)(2)
Transport restrictions	Herring taken in the Hudson River and tributaries (up to first impassable barrier) for personal use: - May only be used in the Hudson River and tributaries up to first impassable barrier - May only transported overland within the transportation corridor	6 CRR-NY 10.1 (f)(3)(iii) 6 CRR-NY 10.1 (f)(3)(iii)(c)
Escapement (no fishing days)	None	
License	Marine Registry	6 CRR-NY 10.10 (c)(1)(i)
Reporting	None	

9 Appendix 2

River Herring (Blueback *Alosa aestivalis*, Alewife *Alosa psuedoharengus*) **Aging Protocol**
New York Department of Environmental Conservation adopted from the Massachusetts Division of Marine Fisheries

Sample Collection

- Each fish is given its own sample ID (river, year, and fish number).
- Length, weight, sex, species, capture date and sample ID number are recorded on envelopes and data sheet.
- Fork length and total length are recorded on data sheet for every sample.
- Otoliths are extracted, wiped clean, and placed in a microcentrifuge tube with corresponding sample ID number.
- Otoliths are extracted using a scalpel and forceps. Slice off the top part of the head exposing the brain cavity. Slice should be shallow starting at the back of the skull slicing forward.
- Scoop out any brain matter.
- Using forceps extract the otic membrane (otoliths should be in the otic membrane).
- Scales collected just ventral of the dorsal fin, before removal use knife to remove dirt and slime coat from scales.
- Take approximately 20 scales and place into an envelope with the corresponding sample ID number.



Structure Processing

Otoliths

- Must be careful with otolith processing structures are very fragile.
- Water is used to clean off any dried blood.
- Dried with a paper towel then placed back into microcentrifuge tube.

Scales

- Make up a Pancreatin solution 500 mL water with 3.5g Panreatin. Place on stir plate and let mix for approximately 10 mins.
- Place approximately 10 scales into a centrifuge tube (one sample per centrifuge tube).
- Avoid selecting regenerated scales.
- Fill each centrifuge tube with 15-20mL of Pancreatin solution then place in sonicator.
- Each batch will contain 10 samples, run for 15 mins.

- Remove samples from sonicator and empty scales into a fine mesh strainer one sample at a time.
- Wipe, rinse, and dry scales.
- Place scales between two glass slides tapping the ends together and labeling one side with the corresponding sample ID number.

Age Interpretation

Both aging structures are viewed using a digital camera fixed with adjustable zoom optics and Image-Pro Insight® software.

Otoliths

- Set scope lens to 1.0x with reflected light.
- Immerse otoliths in mineral oil sulcus down on top of a black background.
- Annuli counted from the middle outward, counting the edge as the last annuli.
- Annuli are identified at the edge of the hyaline bands.
- The pararostrum is the clearest part of the otolith to age.

Scales

- Set scope lens to 0.5x with transmitted light.
- Annuli are identified as continuous, concentric lines that must pass through the baseline (first transverse groove that separates the anterior and posterior portions of the scale) and are present in both the anterior and posterior portions of the scale.
- Adjust the mirror and lighting so the annuli can be viewed crossing over the baseline.
- Annuli counted from the middle outward, counting the edge as the last annuli. (Fig. 1 & 2)
- The first dark band is the freshwater zone not the first annuli. (Fig. 1 & 2)
- Slight variations in scale appearance between alewife and blueback herring in terms of aging. (Fig. 1 & 2)
- False annuli will not cross over the baseline and cannot be followed throughout the scale. (Fig. 3)
- Typically the second annulus is the “strongest” looking. (Fig. 4 & 5)
- Annuli can become crowded together at the edge of the scale, but will separate back out beneath the baseline. Should be counted as separate annuli. (Fig. 6)
- Annuli can resorb back over previous annuli, but will separate back out beneath the baseline. Should be counted as separate annuli. (Fig. 6)
- Spawning marks are identified as annuli with breaks and fractures running through the band as opposed to non-spawning mark annuli that has smooth band formation. (Fig. 6)
- Spawning marks are typically easier to identify than normal annuli due to obvious irregularities visible on the scale.
- Annuli and spawning marks must be identified on multiple scales from the same fish in order to be considered a true annulus or spawning mark.

Production Aging

Two independent age and repeat spawn mark determinations as well as agreement on age and repeats are sought for each fish. When possible, a third independent reader resolves differences, however; in the event a third reader is unavailable, the two agers will review each disagreed upon sample in an attempt to reach a consensus age. If a consensus age cannot be resolved the sample will be excluded from any further analysis.

Comparison of age and repeat spawning mark assignments among readers are 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 is evaluated by examination of the mean coefficient of variation (CV), percent agreement and the Bowker's test of symmetry. Aging laboratories around the world view a measure of mean CV of 5% or less to be acceptable (Compana 2001).

References

Compana, S.E. 2001. Accuracy, precision and quality control in age determination, including a review of the use and abuse of age validation methods. Journal of Fish Biology 59: 197-242

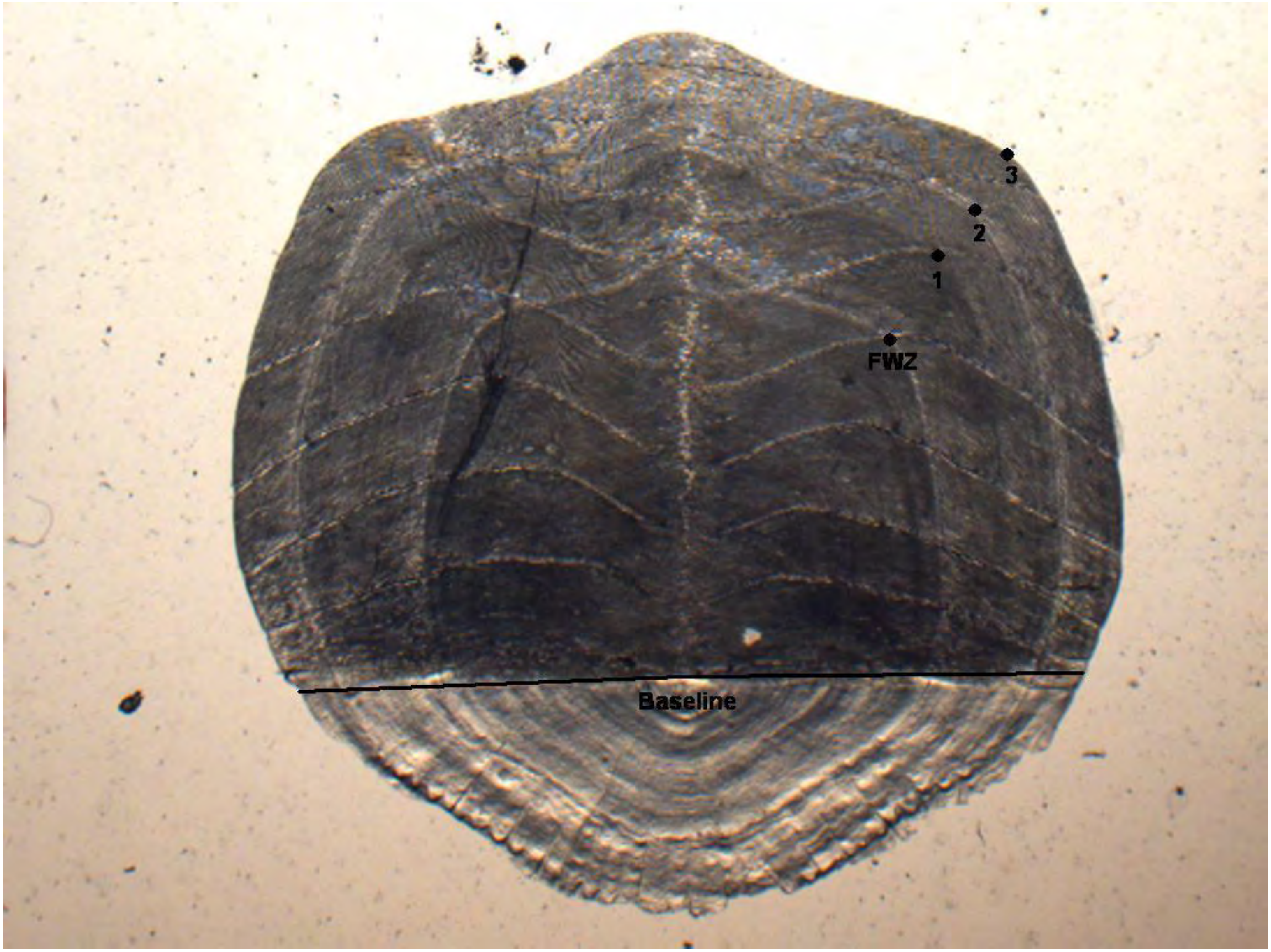


Figure 1. This 3 year old alewife has its baseline, fresh water zone (FWZ) and annuli all marked. Note the straight baseline and large FWZ typical of alewives.

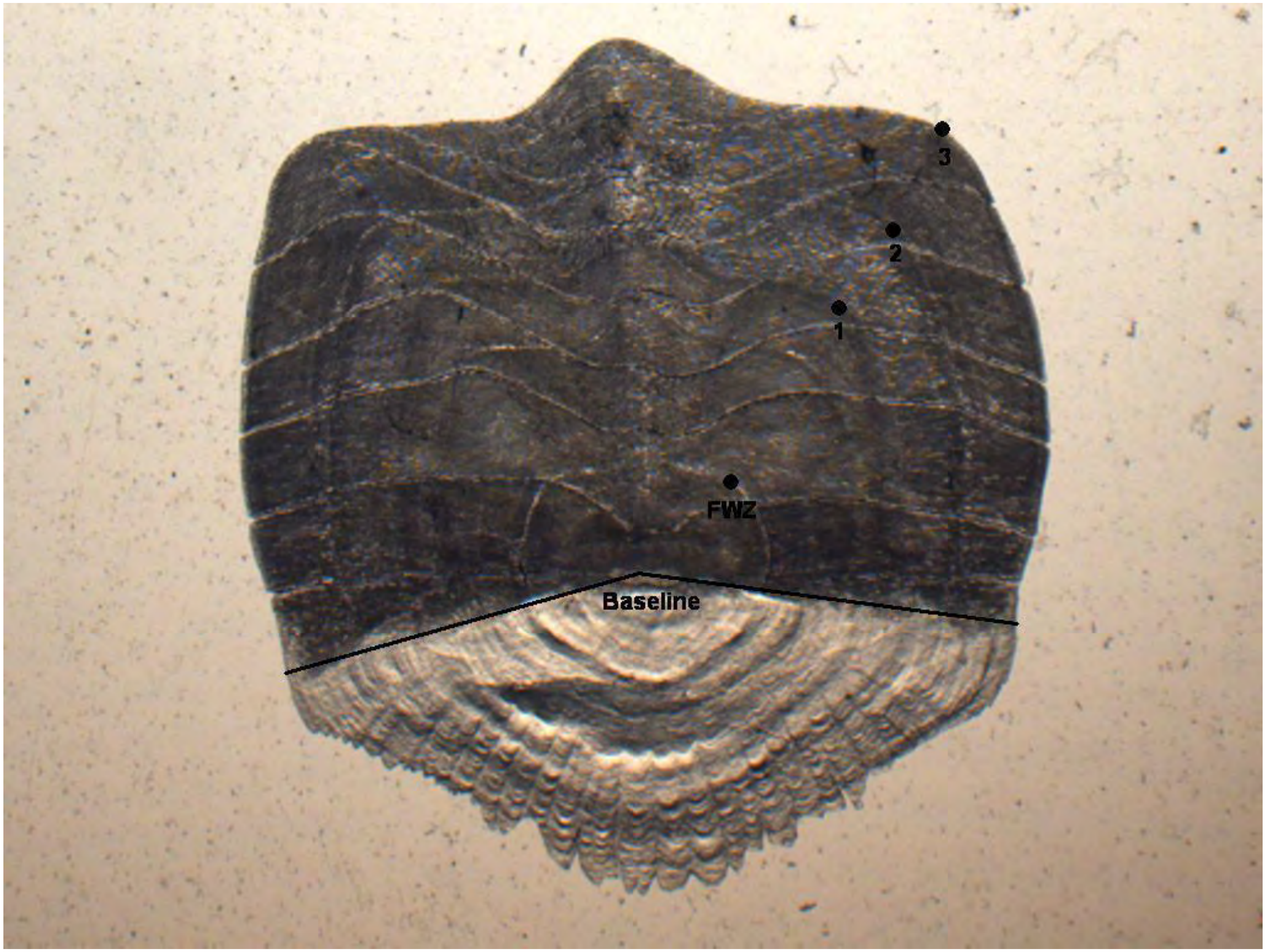


Figure 2. The baseline, fresh water zone (FWZ) and annuli are all marked on this blueback scale. Note the small FWZ and angled baseline typical of bluebacks.

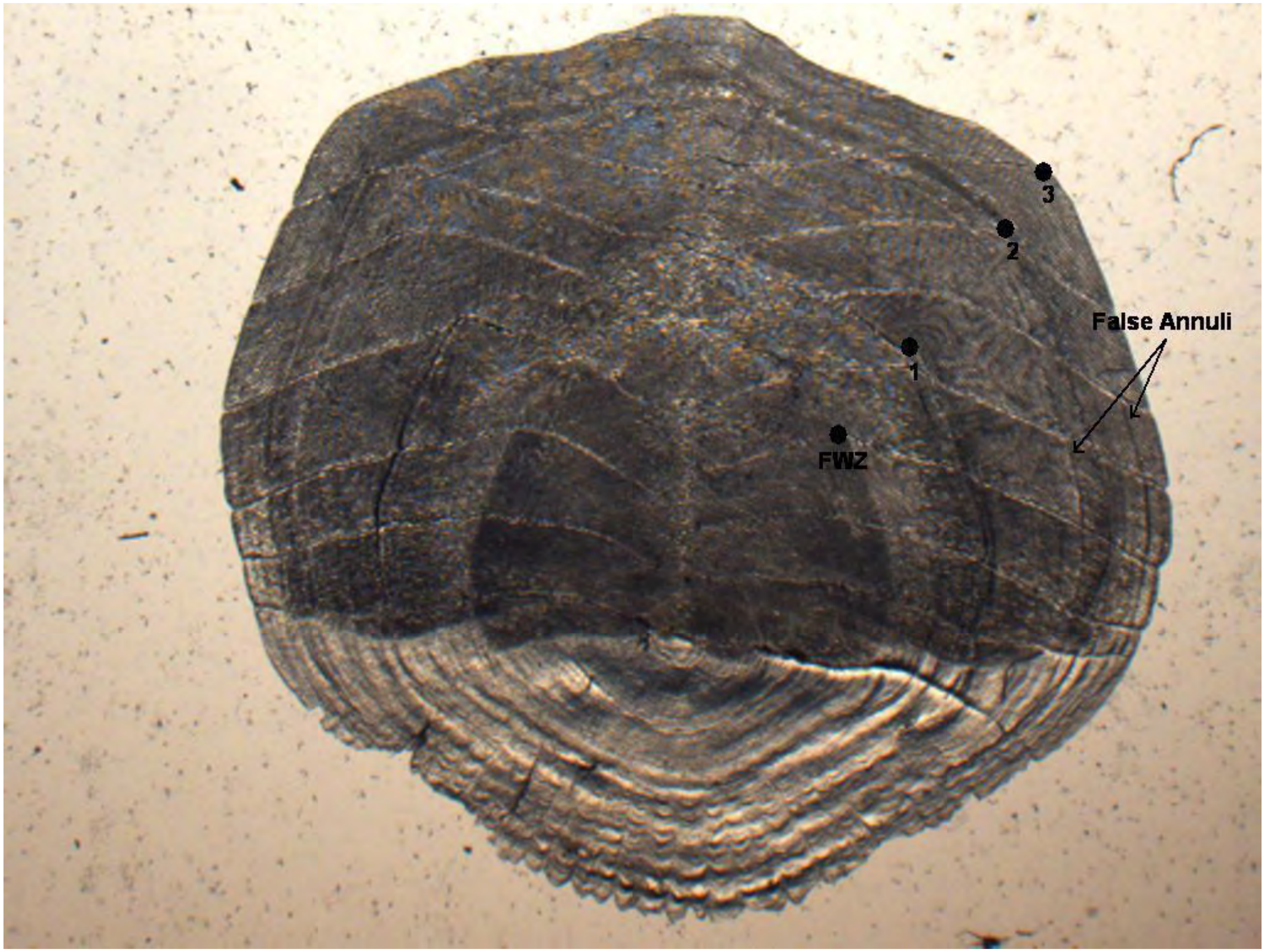


Figure 3. This three year old alewife has two false annuli, one on either side of annulus 2.

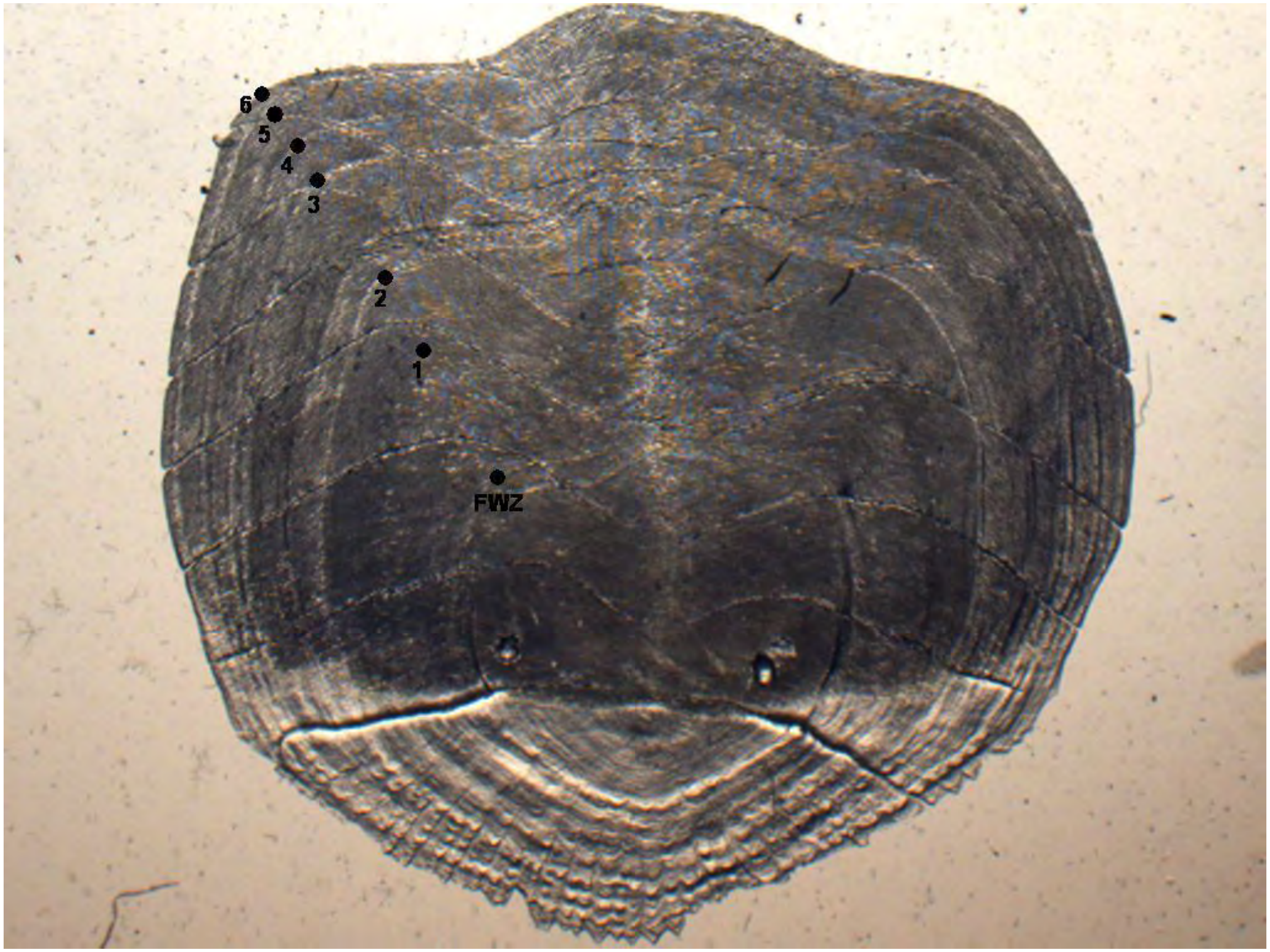


Figure 4. A six year old alewife. Note how weak the first annulus appears compared to the second.

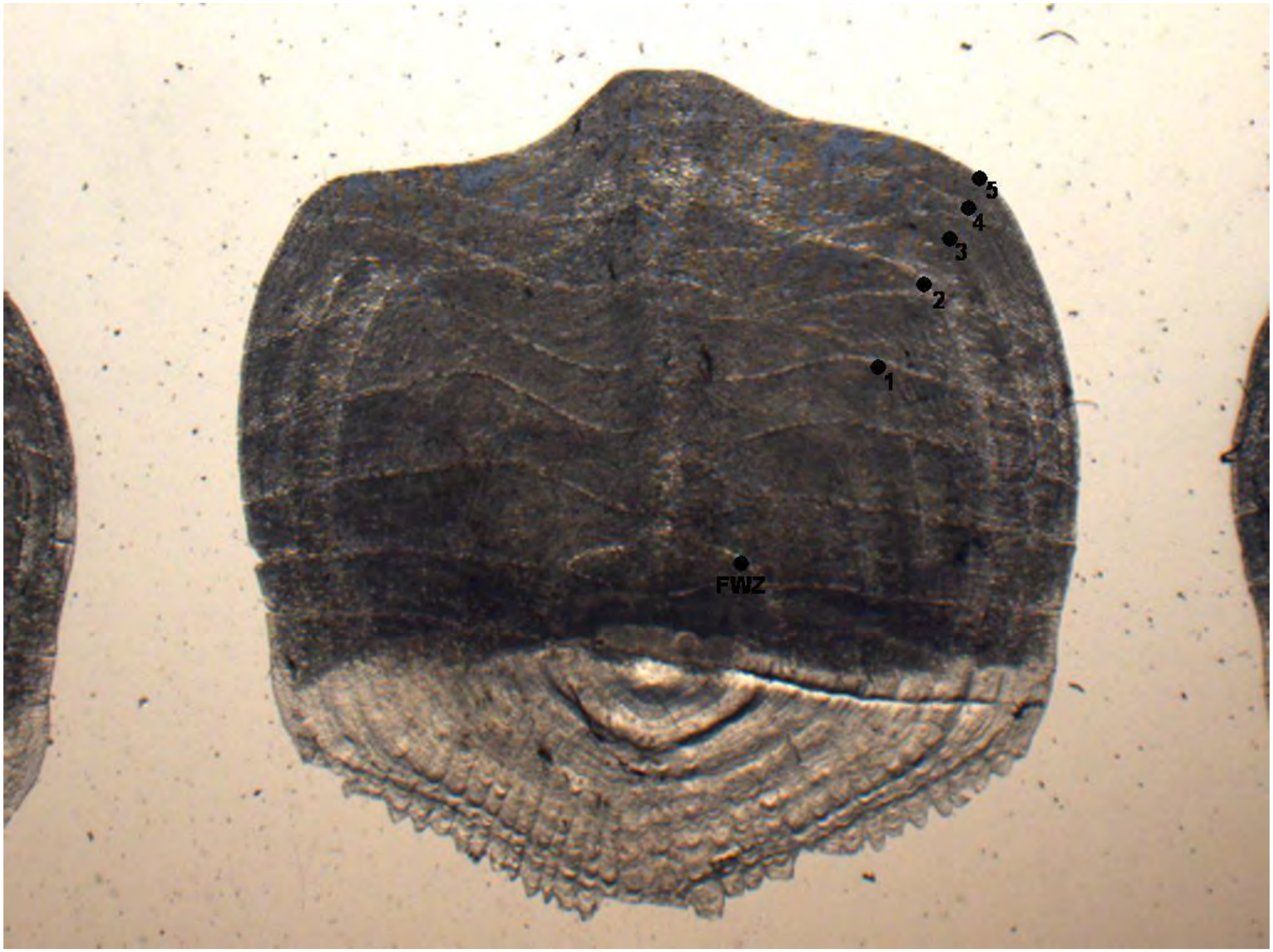


Figure 5. This five year old blueback has the typical strong second annulus.

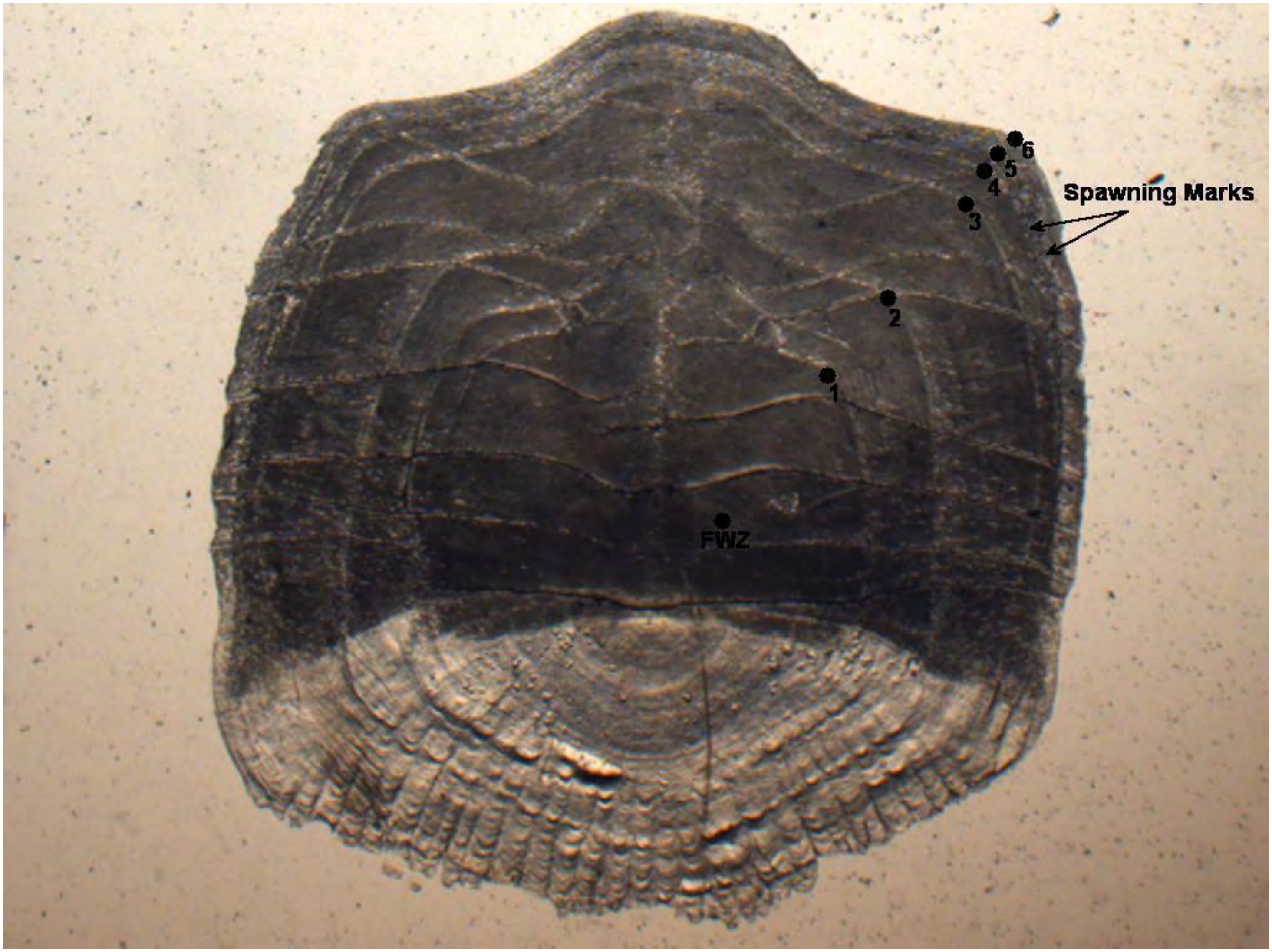


Figure 6. This six year old blueback has spawning marks at its 4th and 5th annuli.

December 1, 2016

Ms. Nancy W. Beard
Citizen Participation Specialist I
Hudson River Estuary Program
New York State Department of Environmental Conservation
21 South Putt Corners Road
New Paltz, NY 12561

Dear Ms. Beard:

In response to your email of November 22, 2016 to the HREMAC regarding comments on the update to the Five-Year River Herring Sustainable Fishing Management Plan, Riverkeeper supports the planned submission of the update to the ASMFC Shad and River Herring Technical Committee.

Yours sincerely,

Dan Shapley
Water Quality Program Director

Paul Gallay
President and Hudson Riverkeeper

dhb:PG/DS

MAINE DEPARTMENT OF MARINE RESOURCES

2016 Maine River Herring Sustainable Fisheries Plan Update

Bureau of Resource Management

12/9/2016

******FOR ASMFC SHAD AND RIVER HERRING MANAGEMENT BOARD REVIEW ONLY******

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

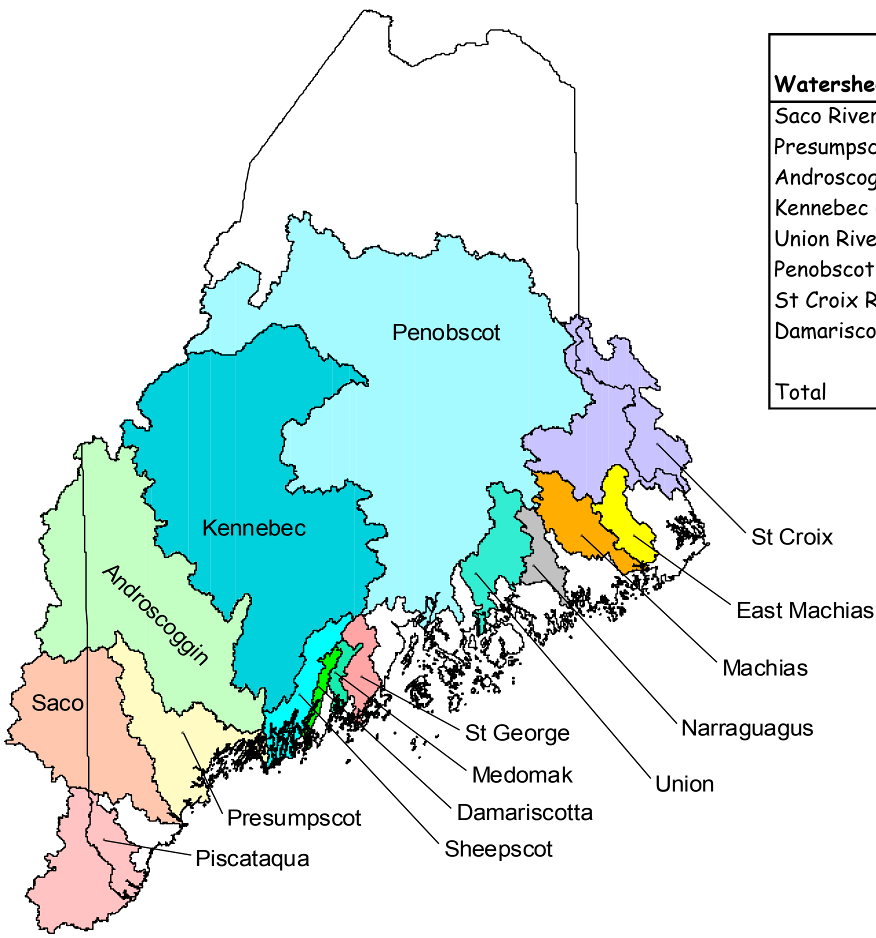
Maine has forty municipalities with the exclusive right to commercially harvest river herring. The State of Maine, in conjunction with the municipalities, and in accordance with cooperative river herring management plans, reviews these plans on an annual basis. Currently, twenty-four municipalities actively 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 Northport	Pitcher Pond
Arrowsic	Sewall Pond		
Bath*		Mount Desert	Somes Pond
Phippsburg*	Winnegance Pond	Newcastle* Nobleboro*	Damariscotta Lake
West Bath*			
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.

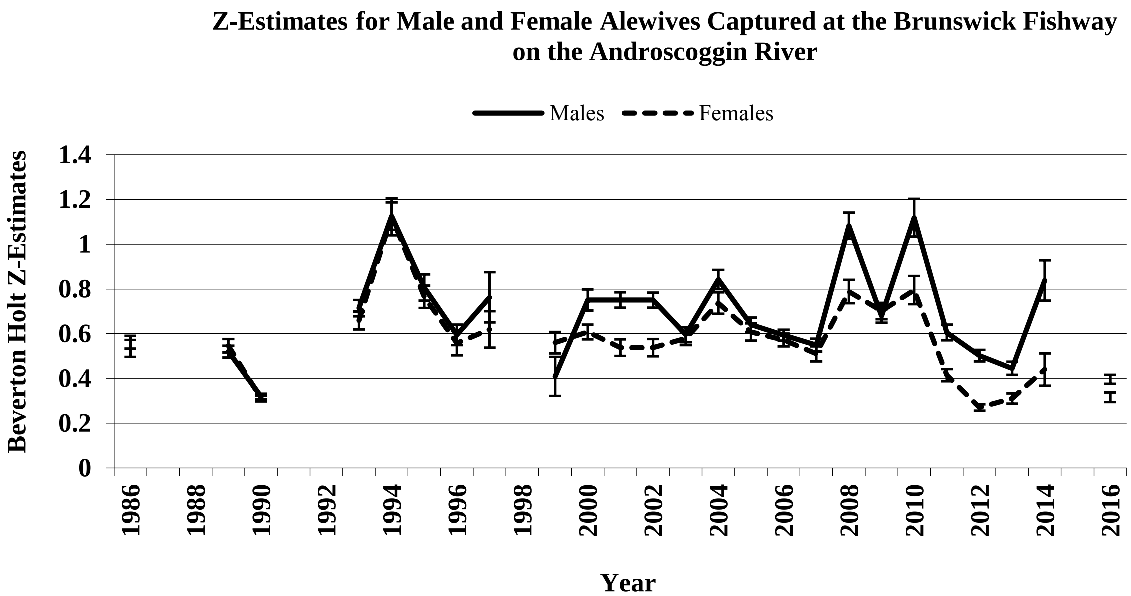


Figure 3. Fisheries independent estimates of male Z-values using Catch Curve, Heinke and Chapman-Robson.

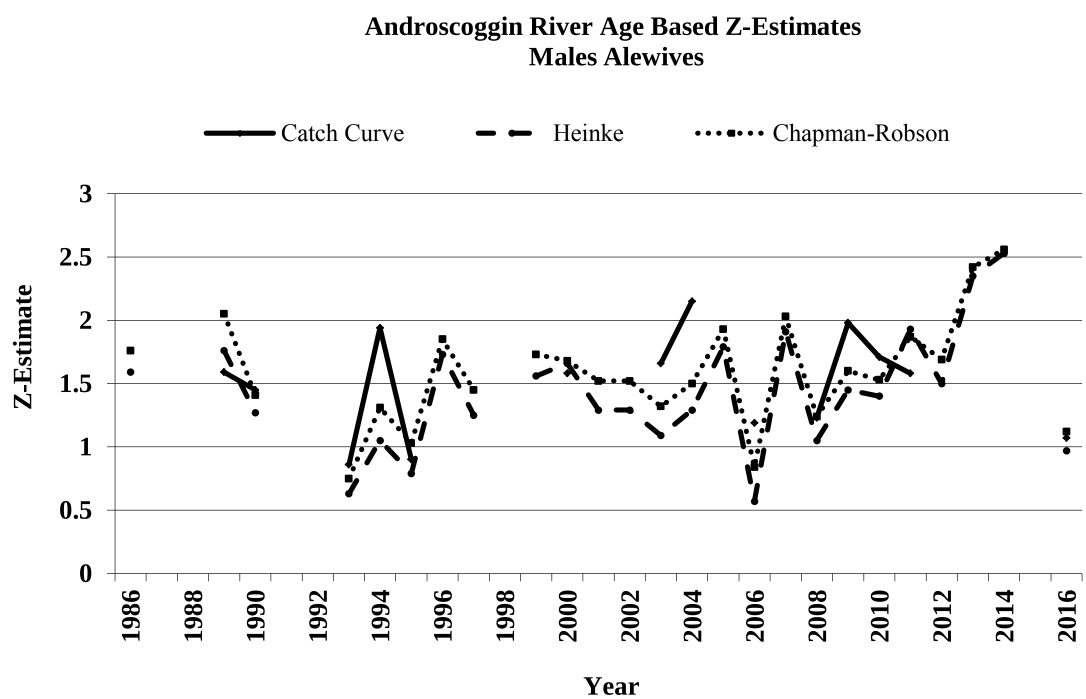
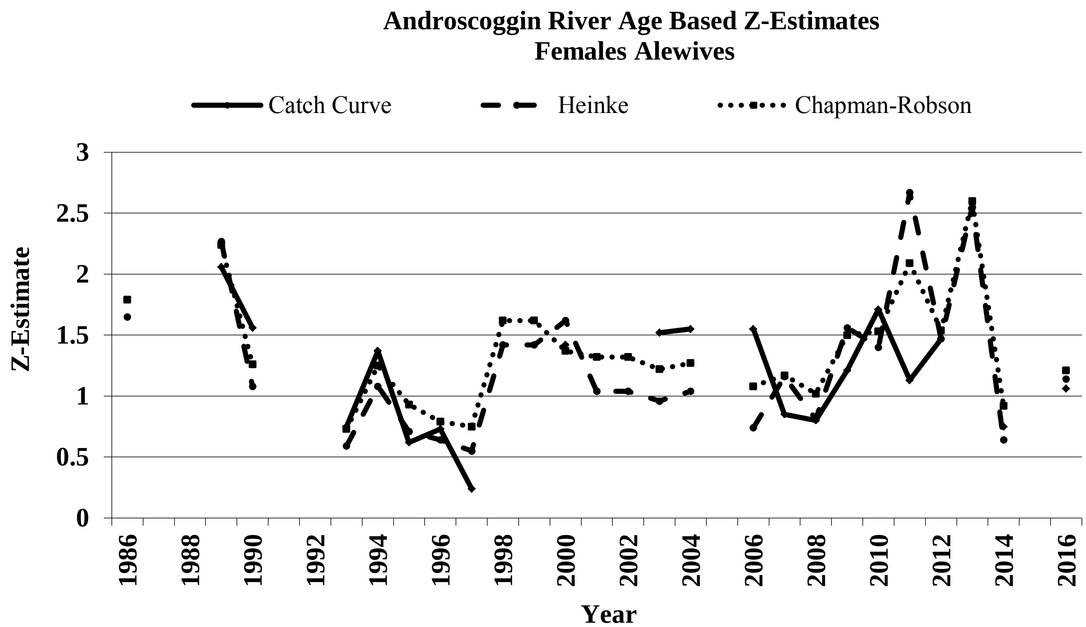


Figure 4. Fisheries independent estimates of female Z-values using catch curve, Heinke and Chapman-Robson.



- 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 those 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

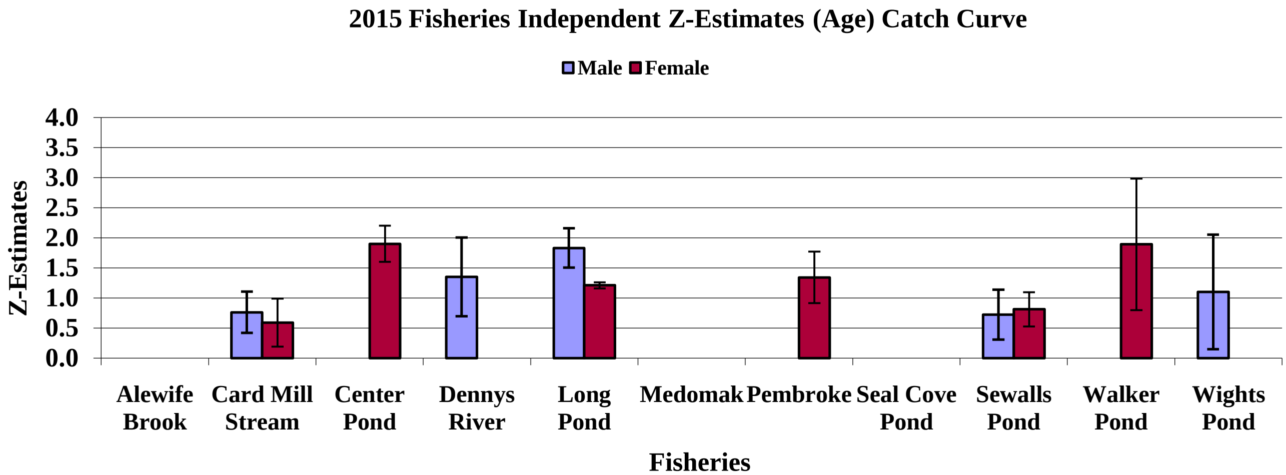
Sexes Combined

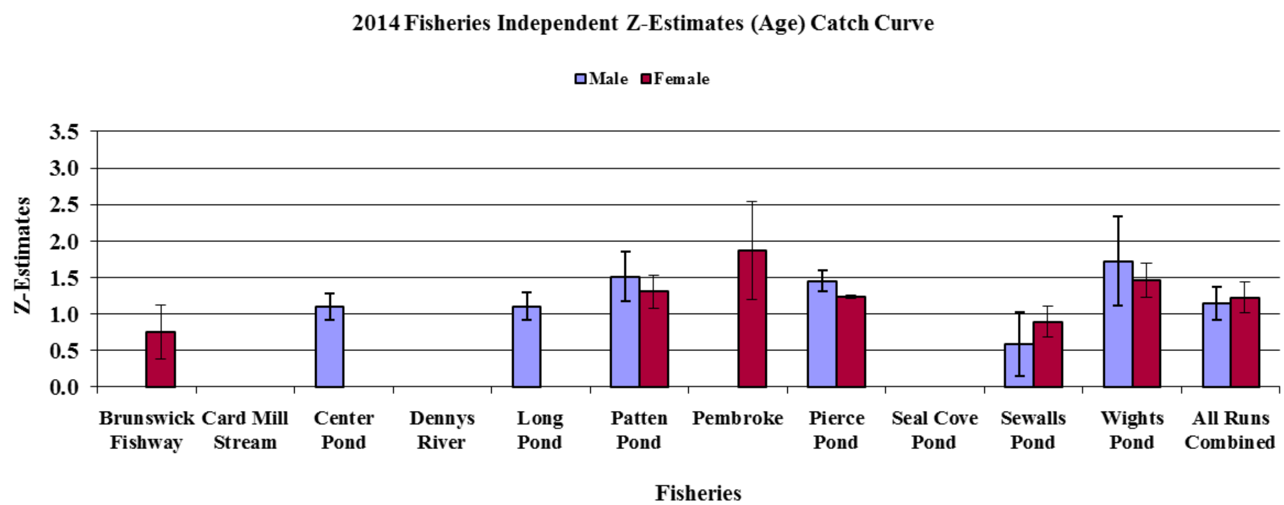
Fisheries Dependent Data — Age Based Z-Estimates

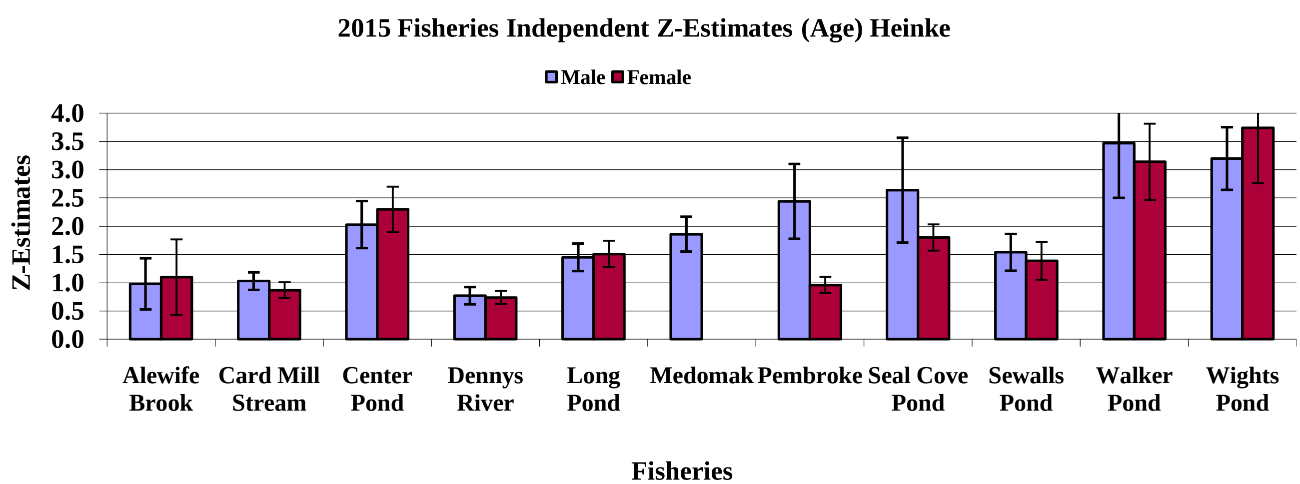
2014	Catch Curve				Heinke				Chapman-Robson			
	Male		Female		Male		Female		Male		Female	
Fishery	Z	SE	Z	SE	Z	SE	Z	SE	Z	SE	Z	SE
Alna	0.5	0.23			0.49	0.06	1.39	0.34	0.67	0.09	1.57	0.388
Benton	1.65	0.02	1.08	0.62	1.70	0.33	2.56	0.53	1.72	0.34	1.99	0.37
Damariscotta	0.71	0.18	1.04	0.28	0.98	0.16	0.94	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

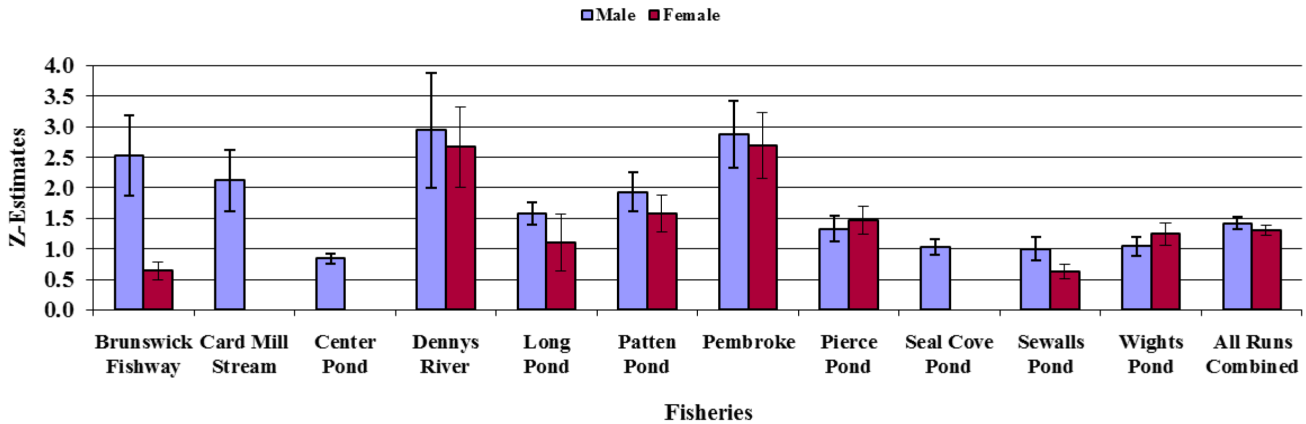
Figure 5. Fisheries independent estimates of Z for 2014 and 2015.



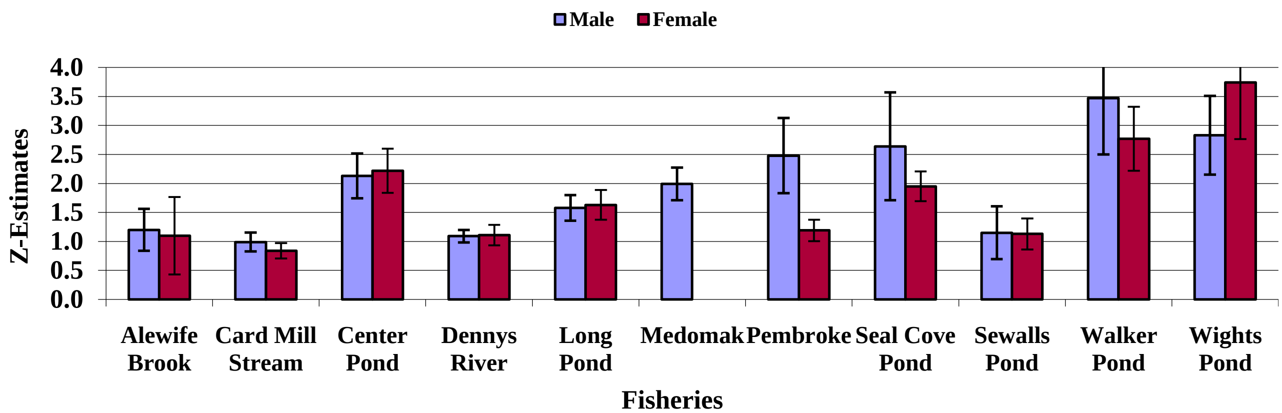




2014 Fisheries Independent Z-Estimates (Age) Heinke



2015 Fisheries Independent Z-Estimates (Age) Chaman-Robson



2014 Fisheries Independent Z-Estimates (Age) Chapman-Robson

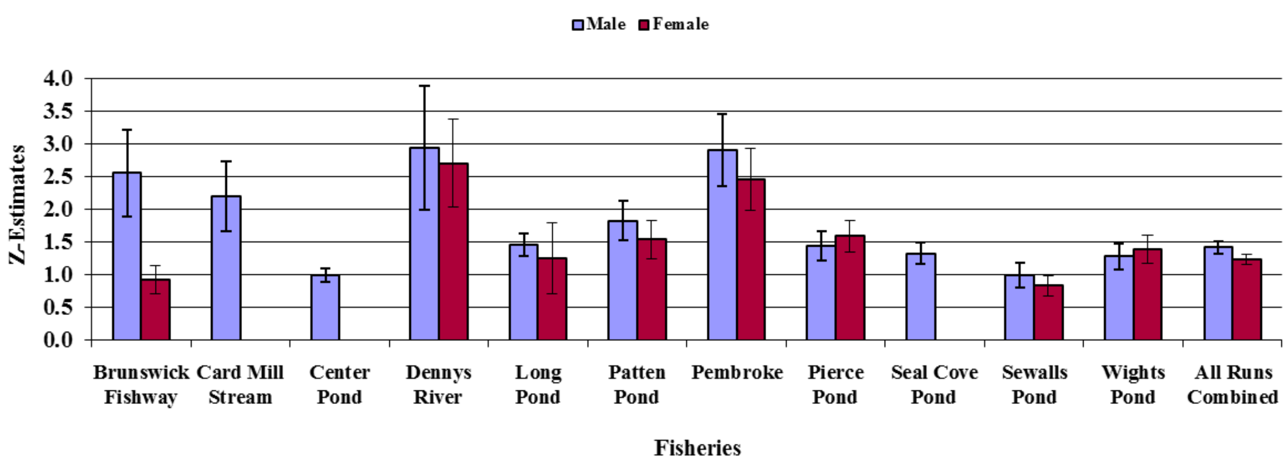
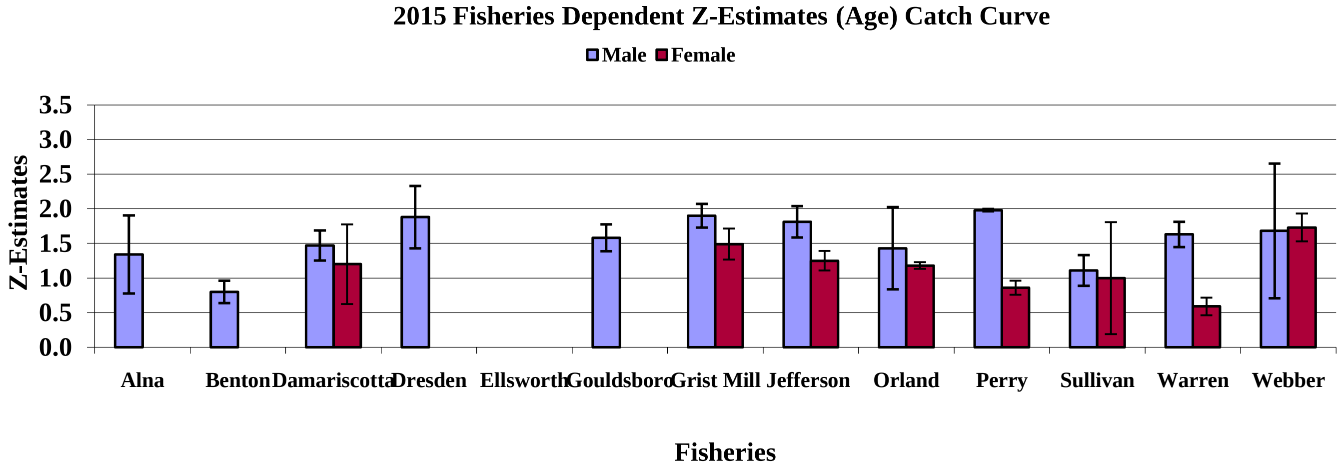
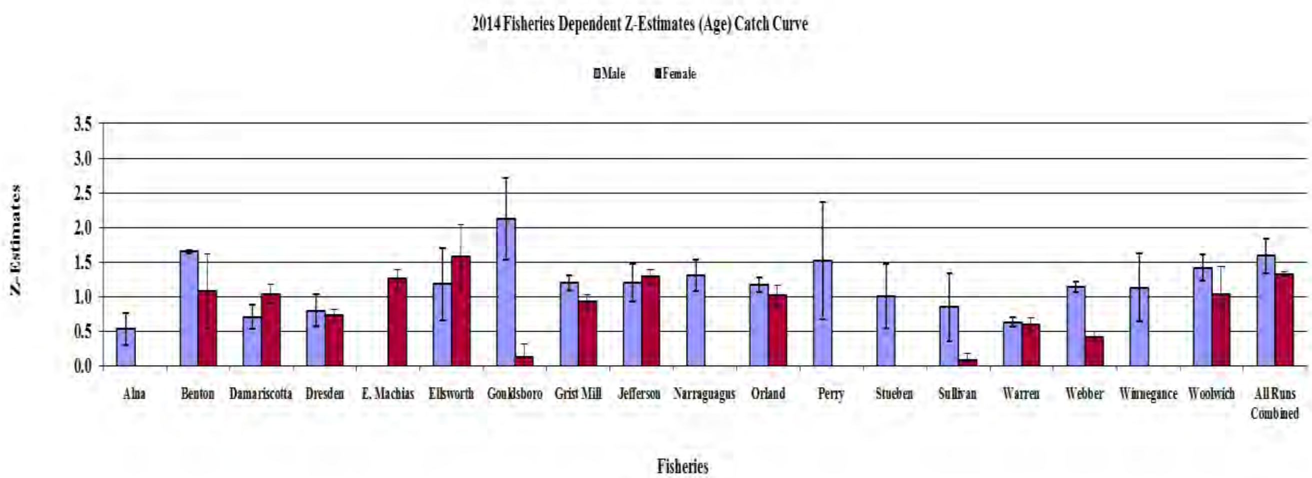
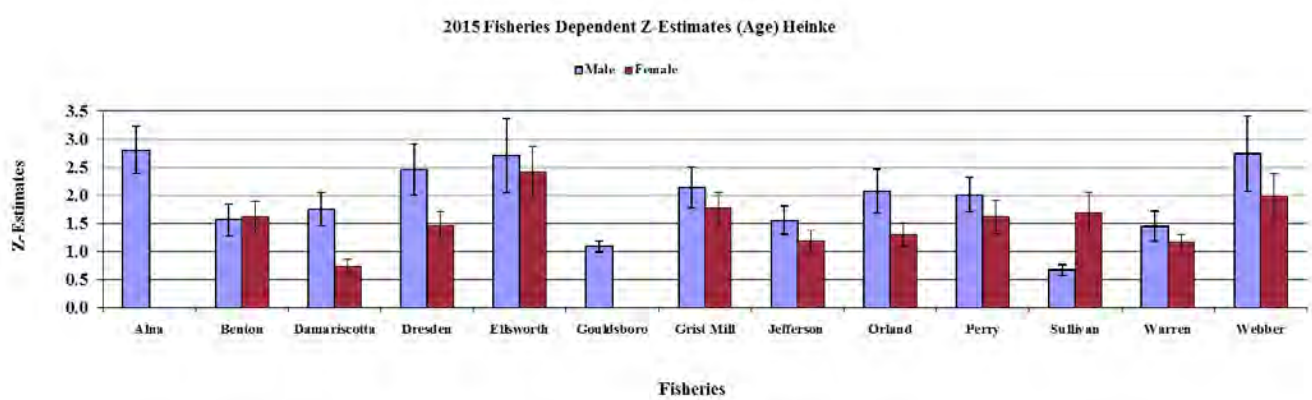
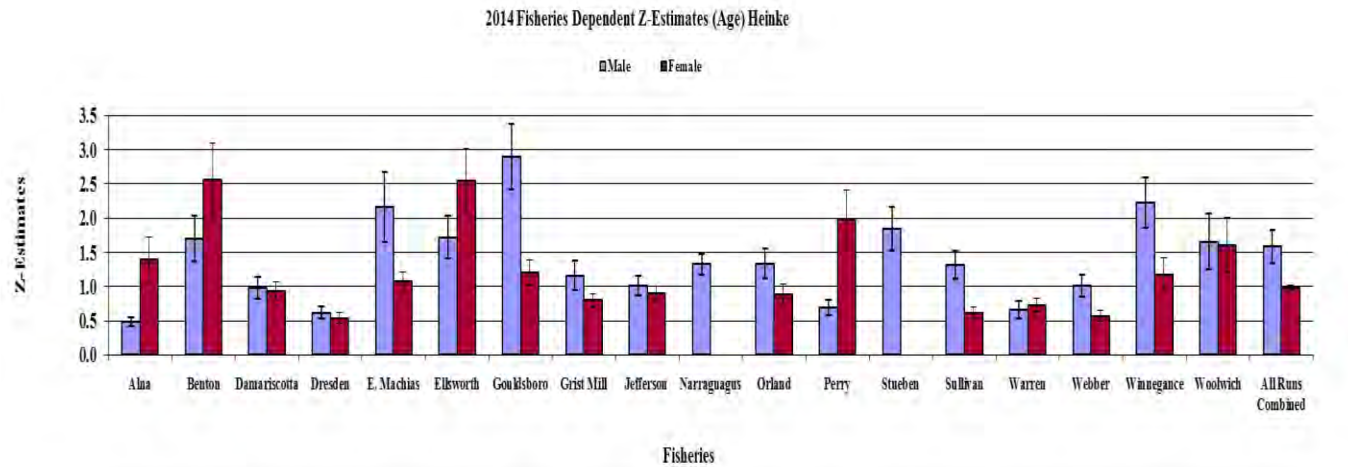


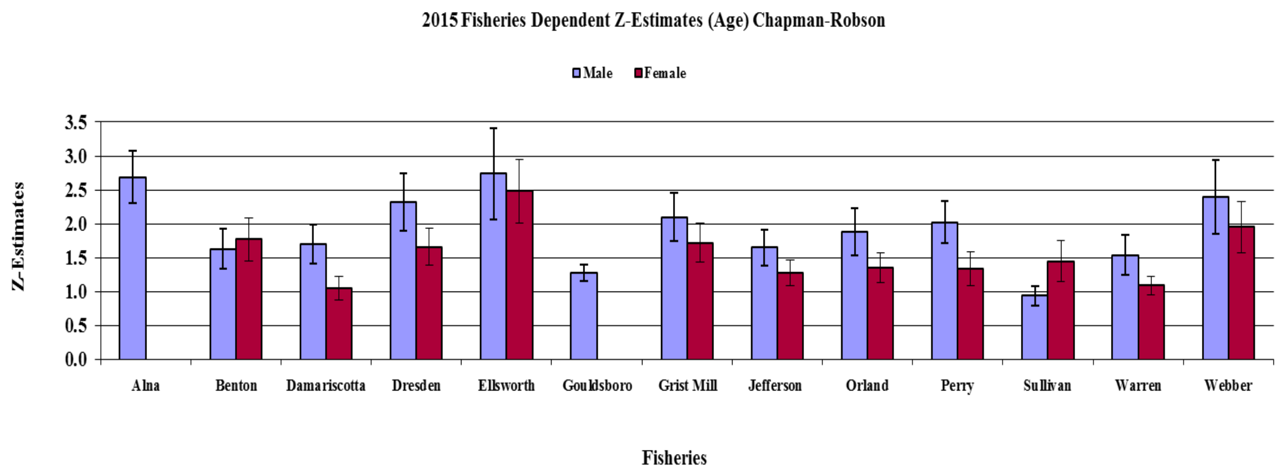
Figure 6. Fisheries dependent estimates of Z for 2014 and 2015.

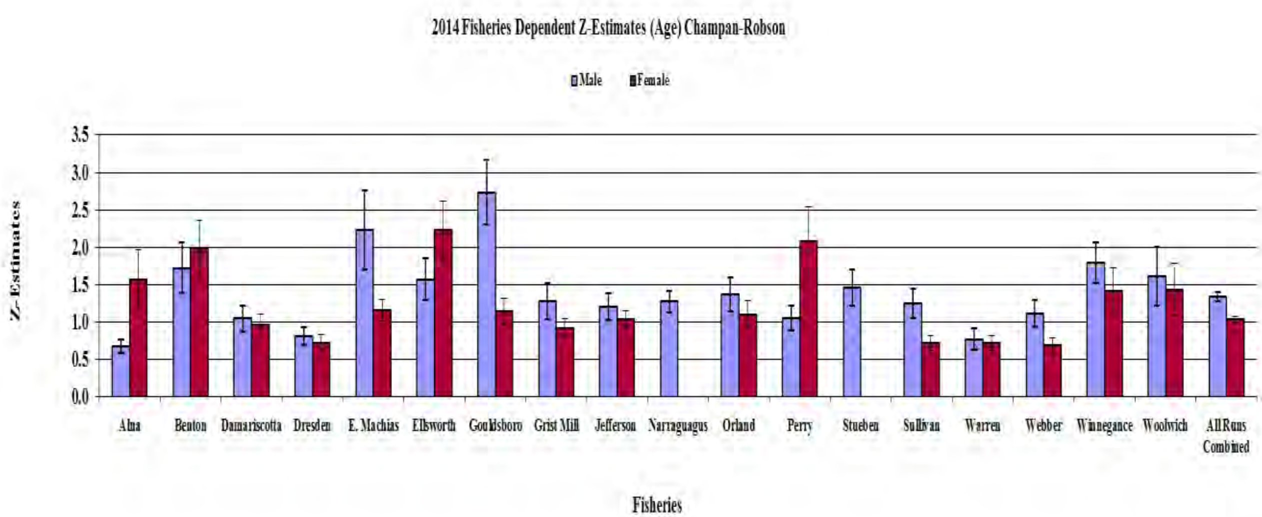







2014 Fisheries Dependent Z-Estimates (Age) Heinke
Male
Female
Z-Estimates
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Alna
Benton
Damariscotta
Dresden
E. Machias
Ellsworth
Gouldsboro
Grist Mill
Jefferson
Narraguagus
Orland
Perry
Stueben
Sullivan
Warren
Webber
Winnegance
Woolwich
All Runs Combined
Fisheries


2015 Fisheries Dependent Z-Estimates (Age) Chapman-Robson
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) Champan-Robson
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

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. The mortality estimates are calculated using the Catch-Curve method to remain consistent with the previous management plan

Fishery Specific Information

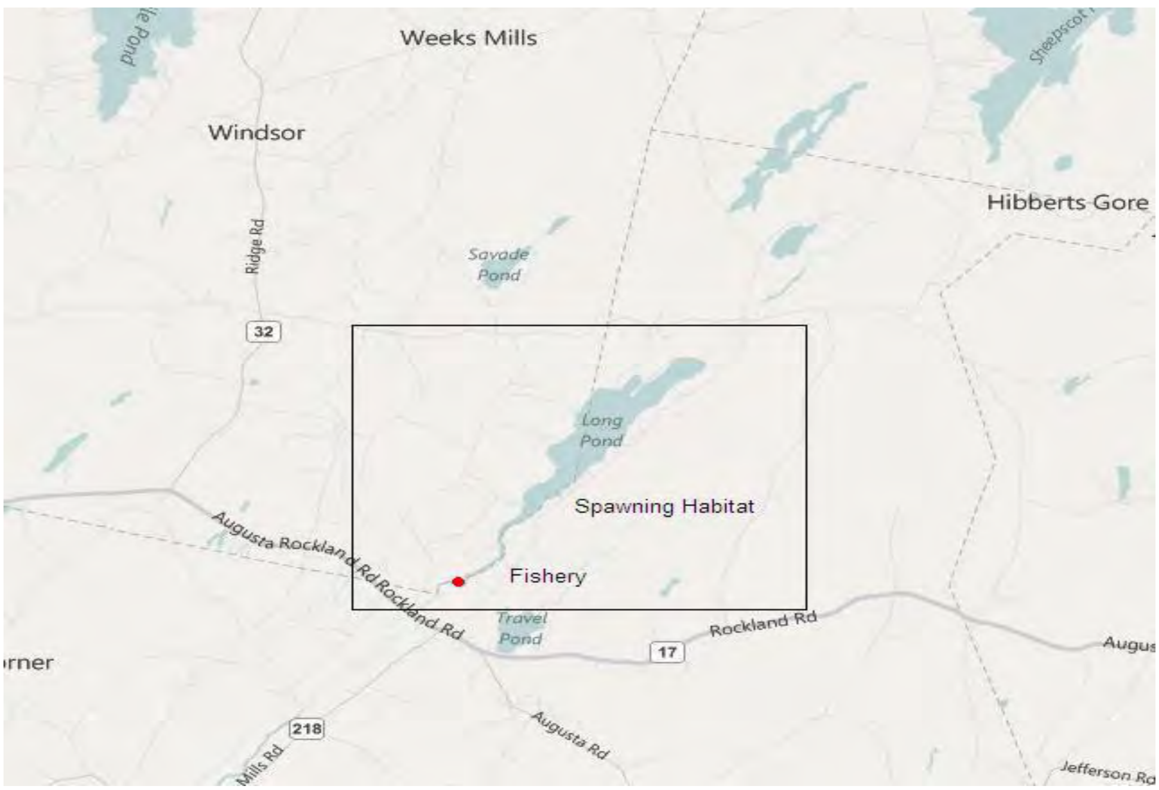
Alna Commercial Fishery:
The Maine Department of Marine Resources manages this system for a commercial escapement of 35 fish per acre. The spawning escapement needs for this system are 20,000 river herring passed upstream by the harvester throughout the season. The management plan has always achieved 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.

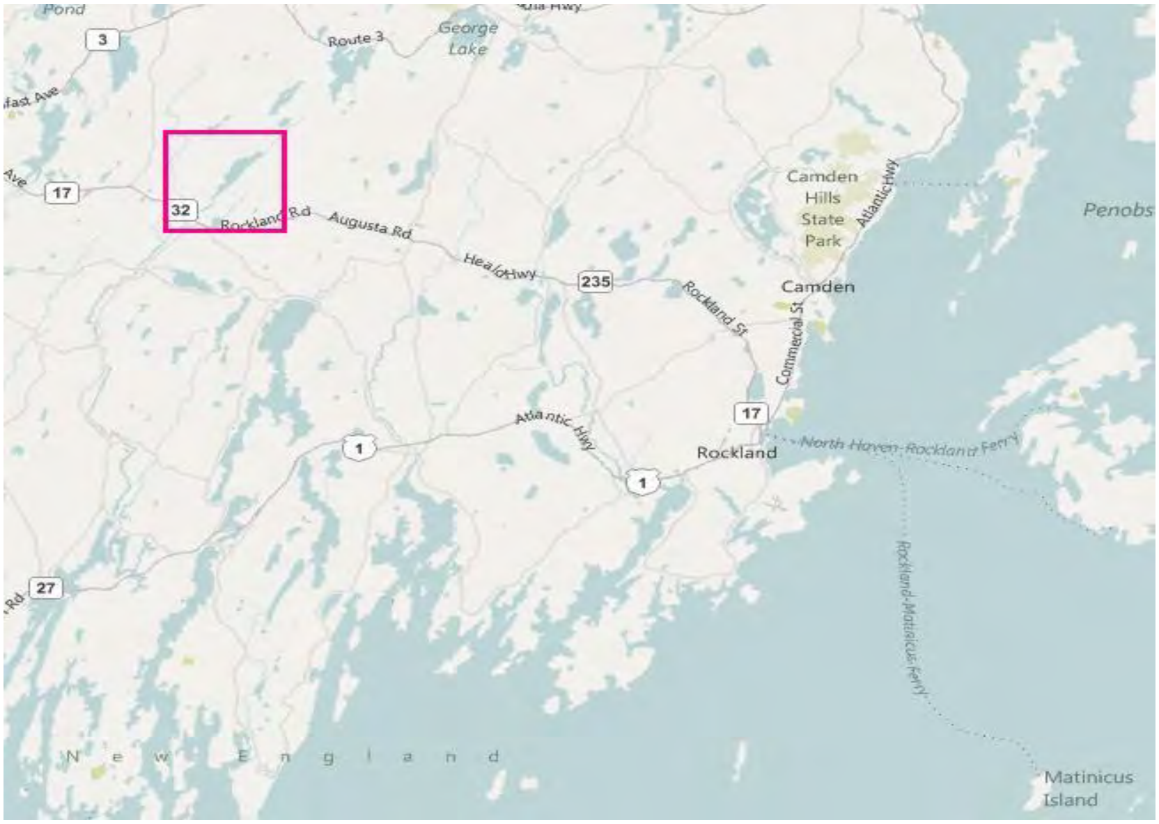
The west branch of the Sheepscot River leading to Branch Pond contains very few river herring. For several years the DMR stocked Branch Pond to propagate an artificial run while planning and designing a fishway to provide access to Branch Pond. An old mill sits directly on top of the outlet stream and 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.

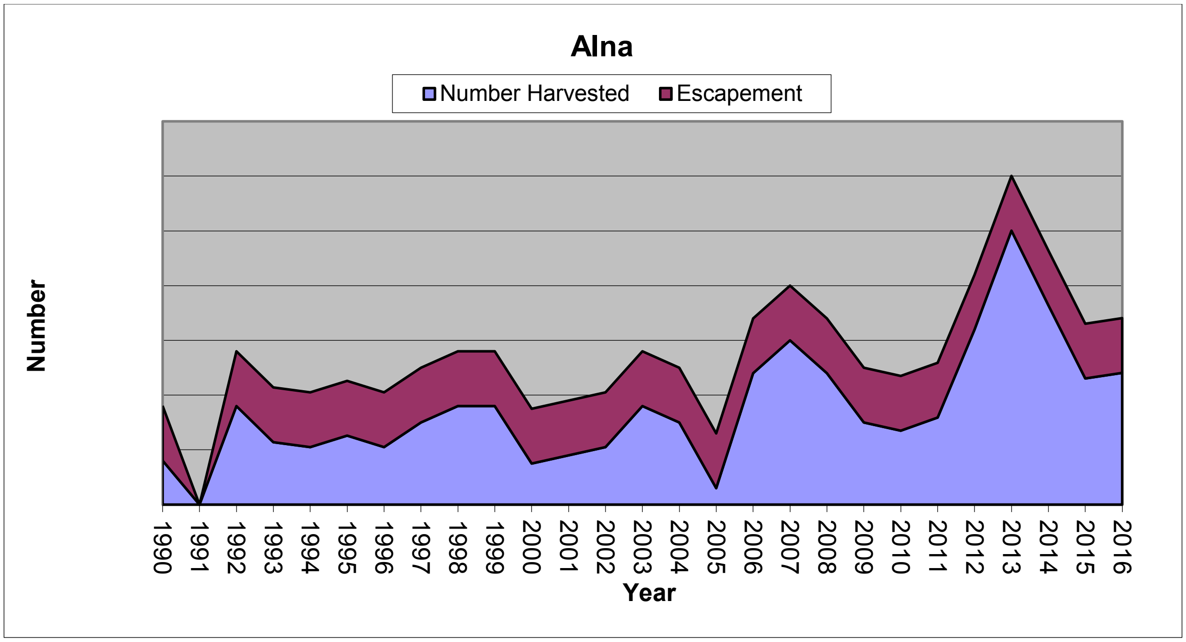
Town	River	Lake size (acres)	Threshold (N/acre)
Alna	Sheepscot	571	35

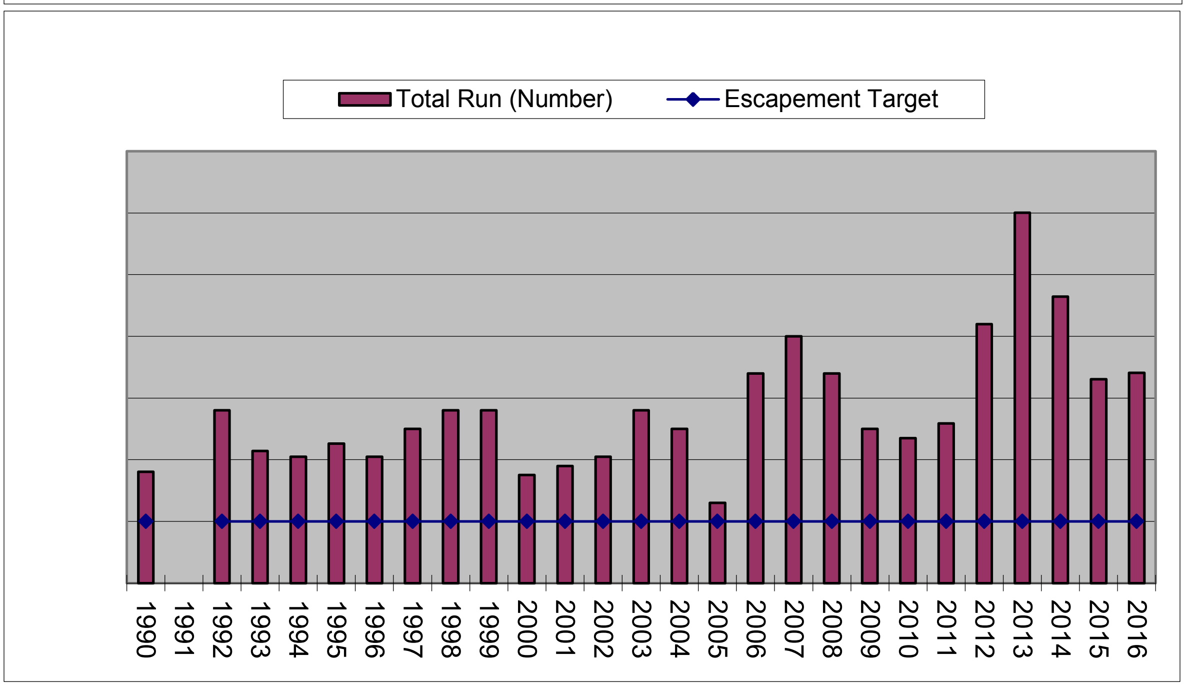




Year	Municipality	River	% repeat spawners by year and frequency	R-0	R-1	R-2	R-3	Z-value
2015	Coopers Mills	Sheepscot	9.1	91.00	8.00	0.00	1.00	1.44
2014	Coopers Mills	Sheepscot	41.0	59.00	36.00	5.00		1.23
2013	Coopers Mills	Sheepscot	33.8	66.20	32.30	1.00	0.50	1.81
2012	Coopers Mills	Sheepscot	7.2	92.76	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



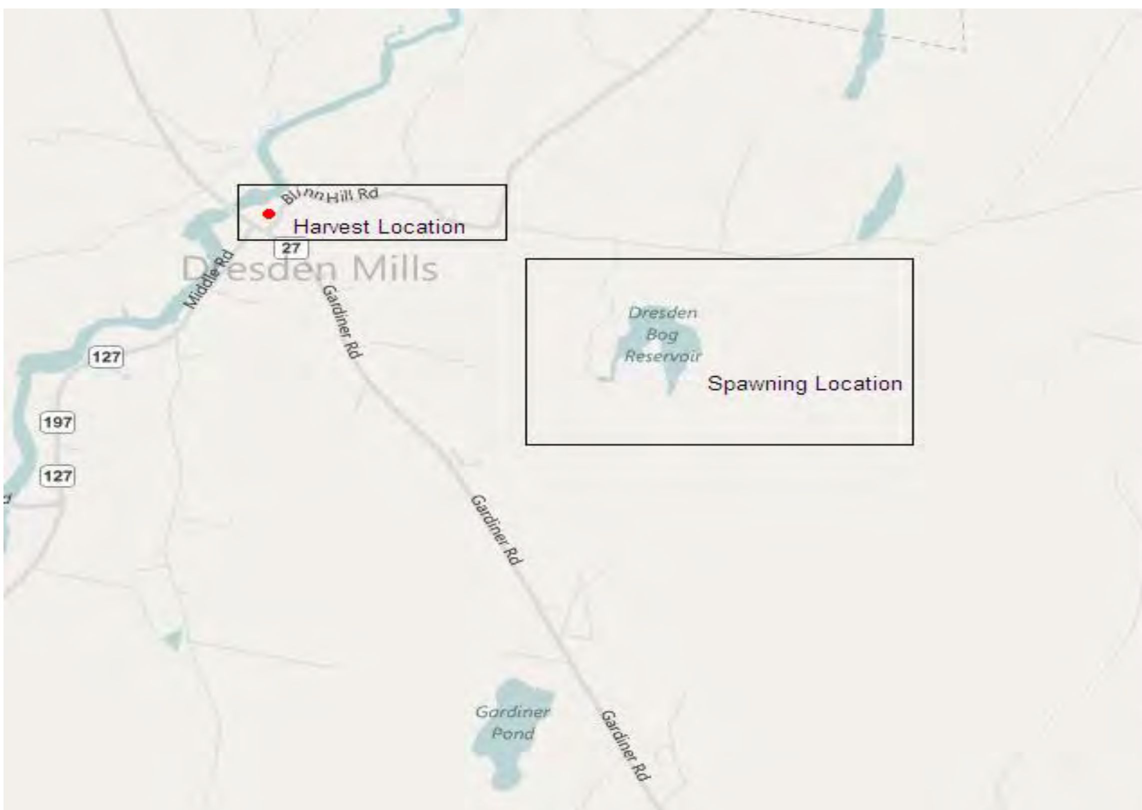


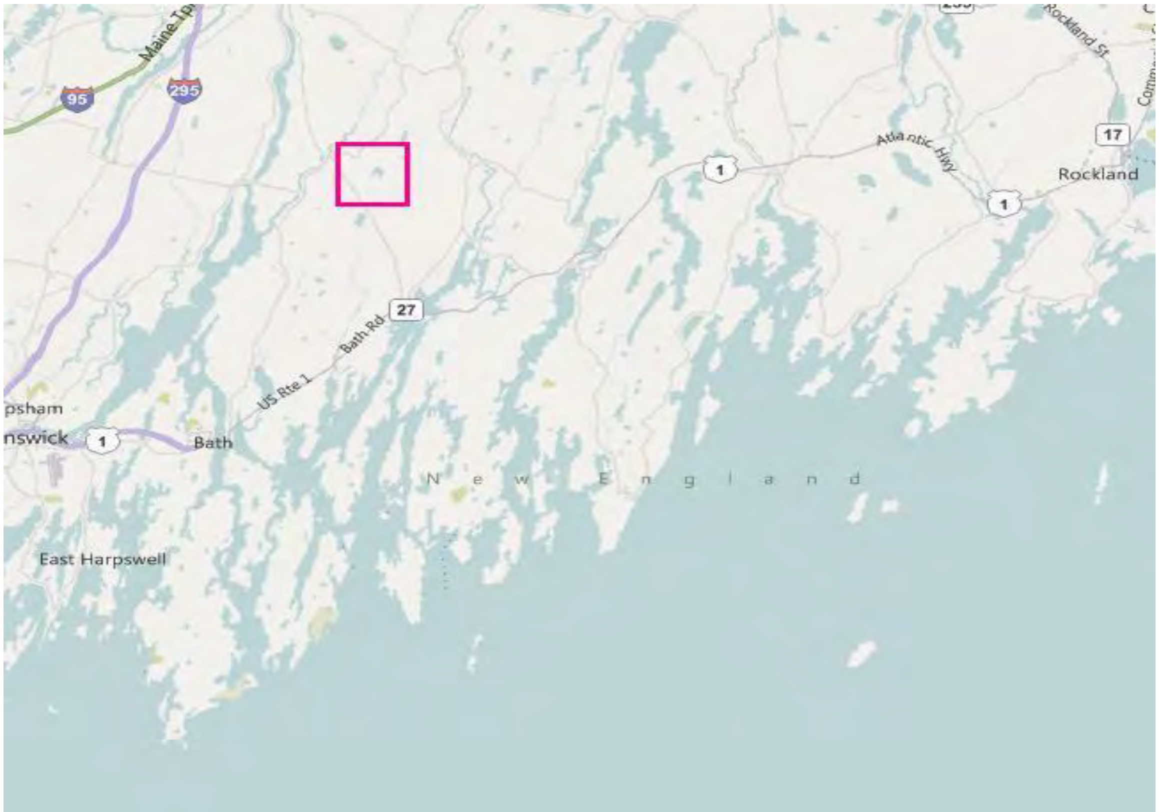
Dresden Commercial Fishery:

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.

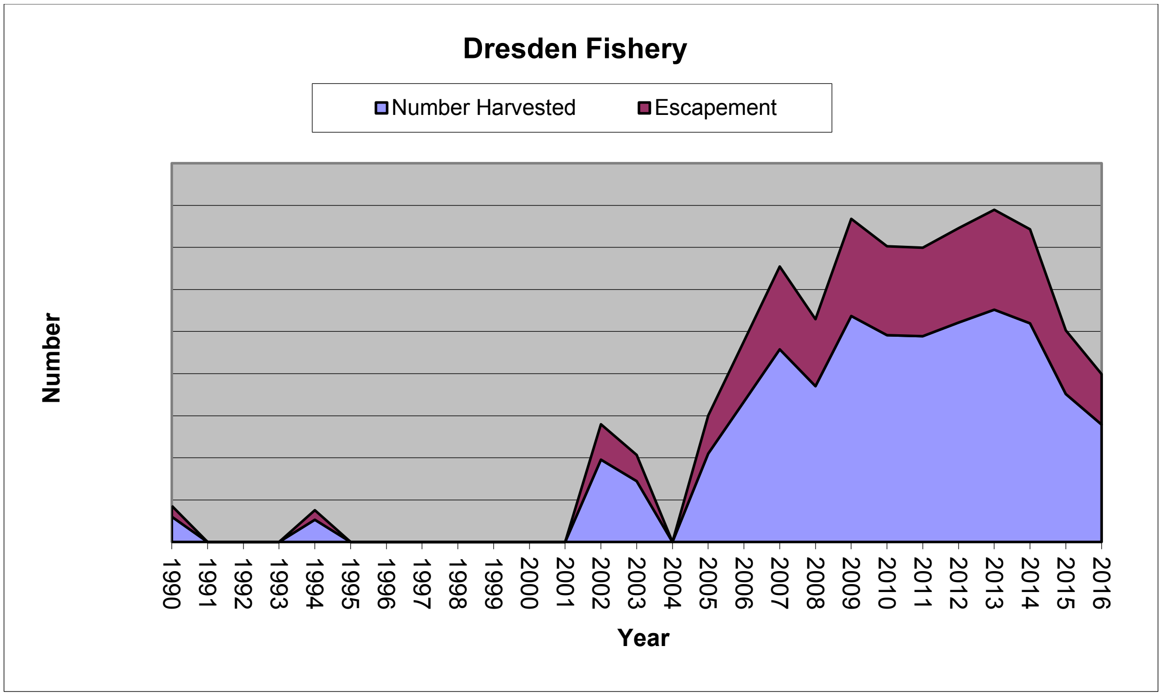
Town	River	Lake size (acres)	Threshold (N/acre)
Dresden	n/a	170	35

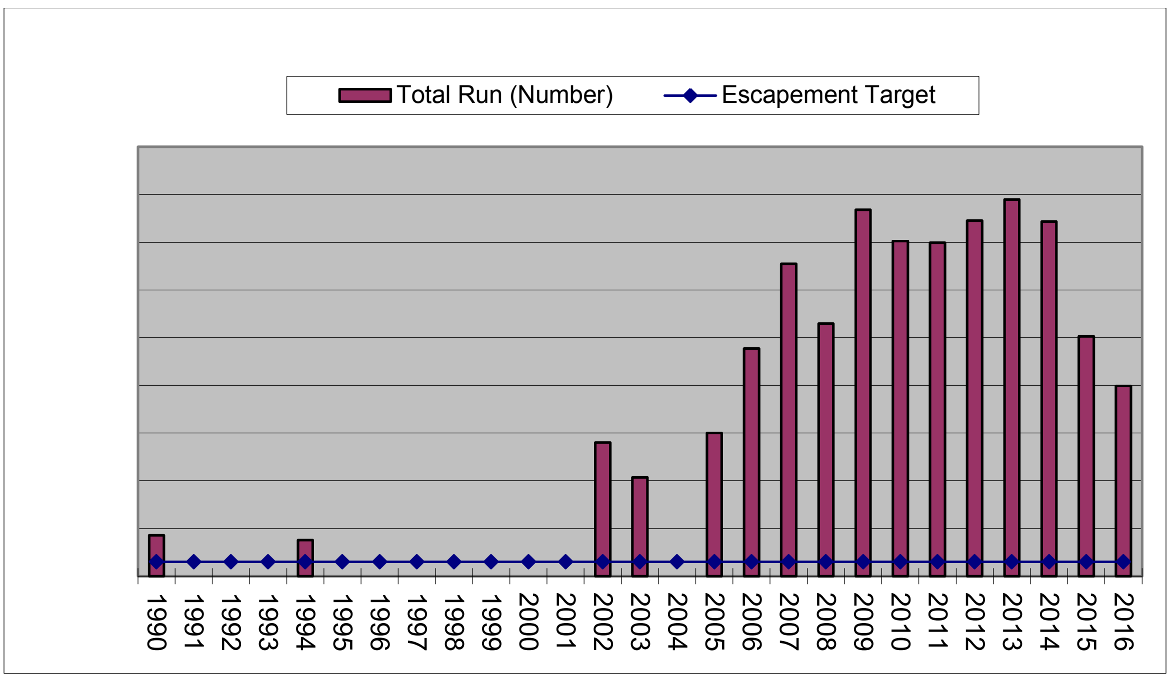




Year	Municipality	River	% repeat spawners by year and frequency	R-0	R-1	R-2	R-3	Z-value
2015	Dresden	Eastern River	45.5	54.55	41.41	4.04		1.3
2014	Dresden	Eastern River	29.0	71.00	19.00	8.00	2.00	1.16
2013	Dresden	Eastern River	50.5	49.45	24.17	9.89	16.48	0.42
2012	Dresden	Eastern River	24.5	75.52	18.56	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



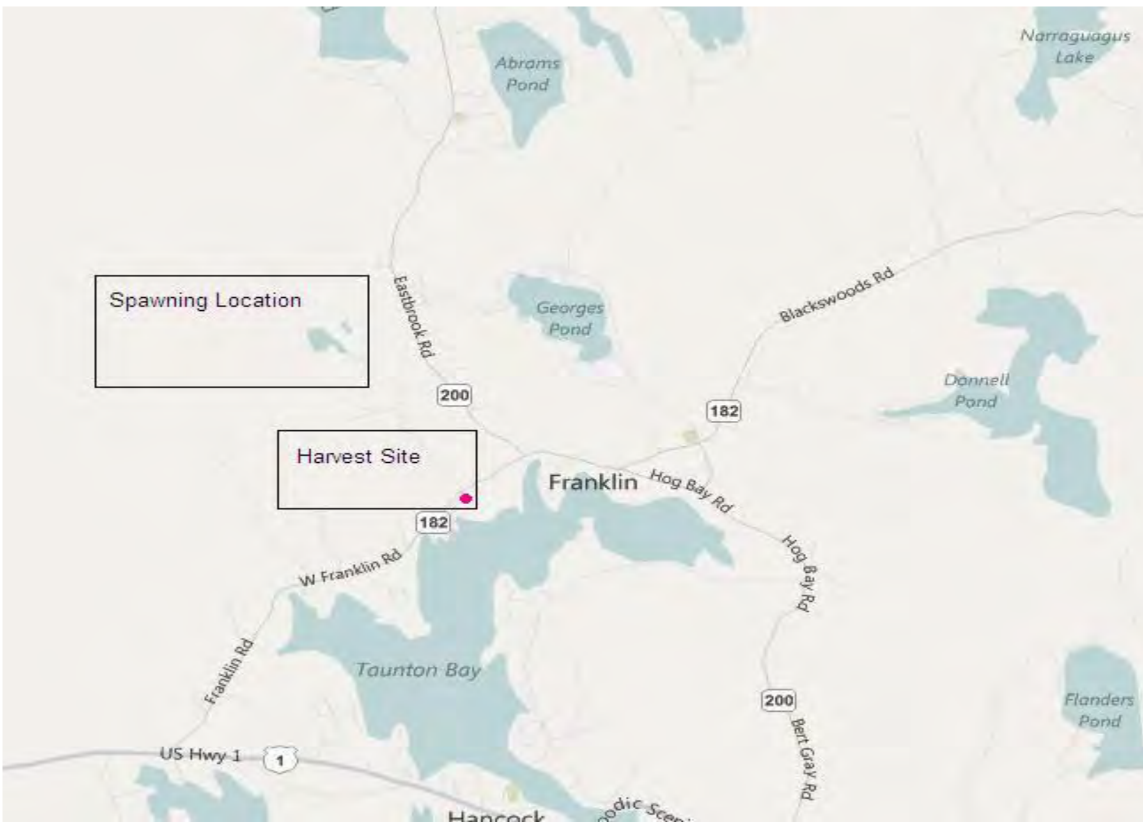


Franklin Commercial Fishery:

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



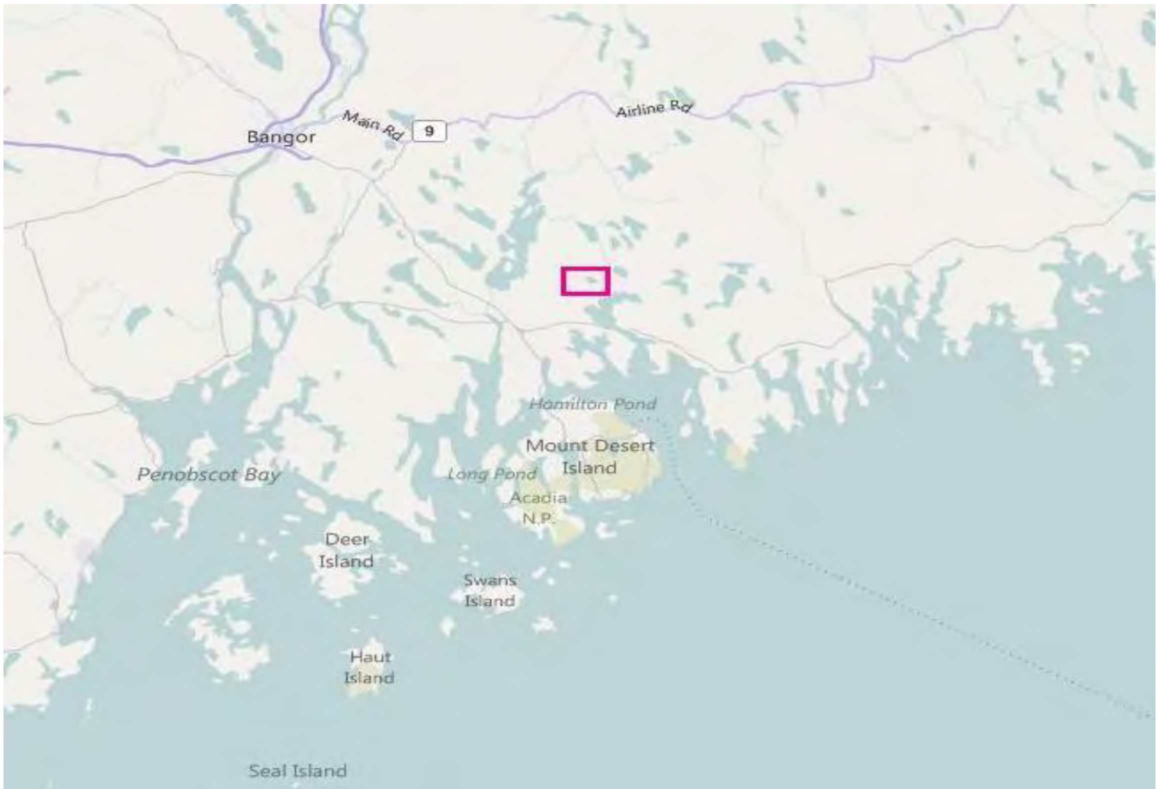
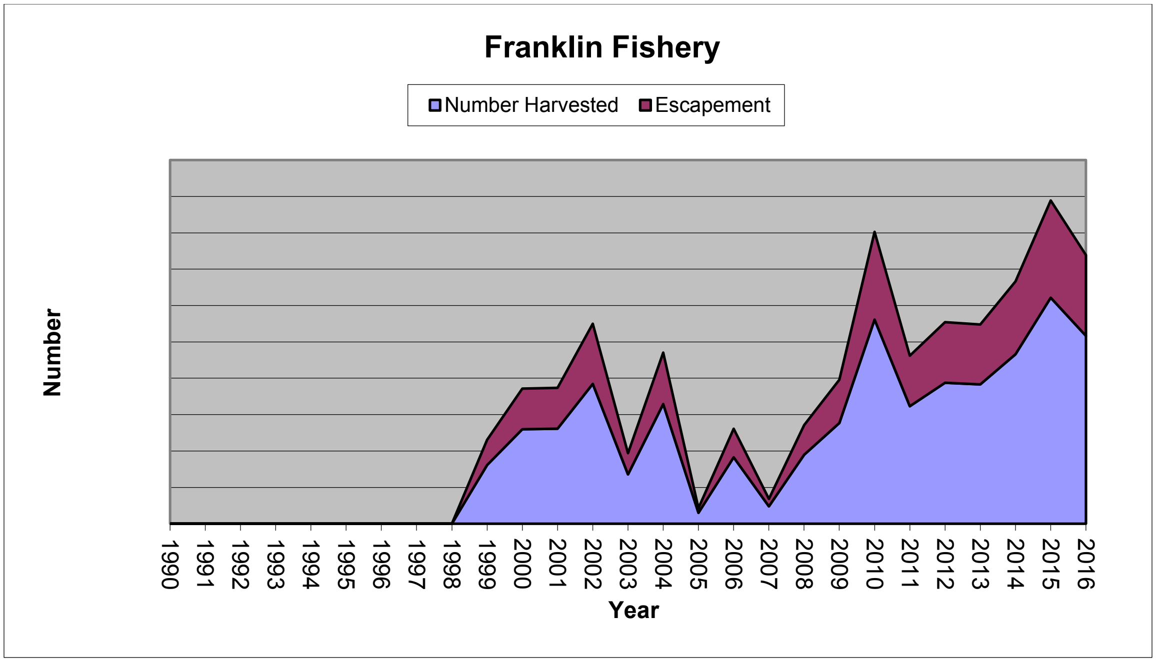
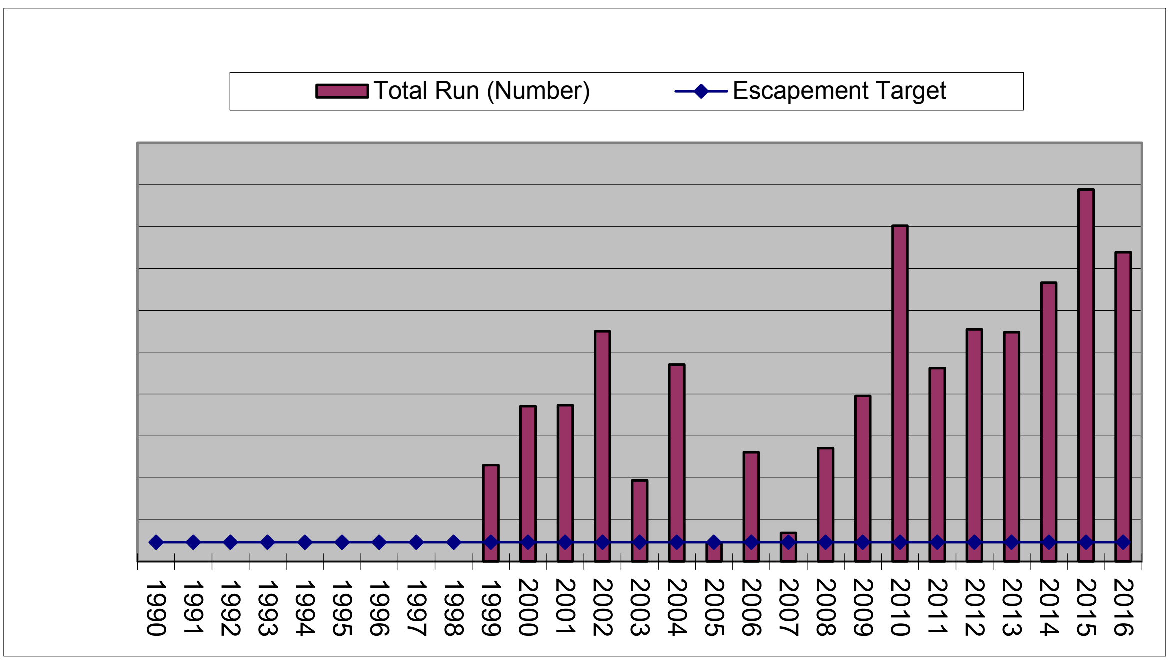


Figure 6. Harvest location for Great Pond in Franklin, Maine.

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
Bogues Corner
Manks Corner
Whitney Corner
Spawning Habitat
Alna
Atlantic Hwy
Waldoboro
South Pond
Nobleboro
Sprague Corner
Harvest Site
Salt Bay
Knowlton Corner
Damariscotta
Pemaquid Pond
Medomak
Bremen
Wiscasset
27
Friendship
Edgecomb
Walpole
Bristol


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

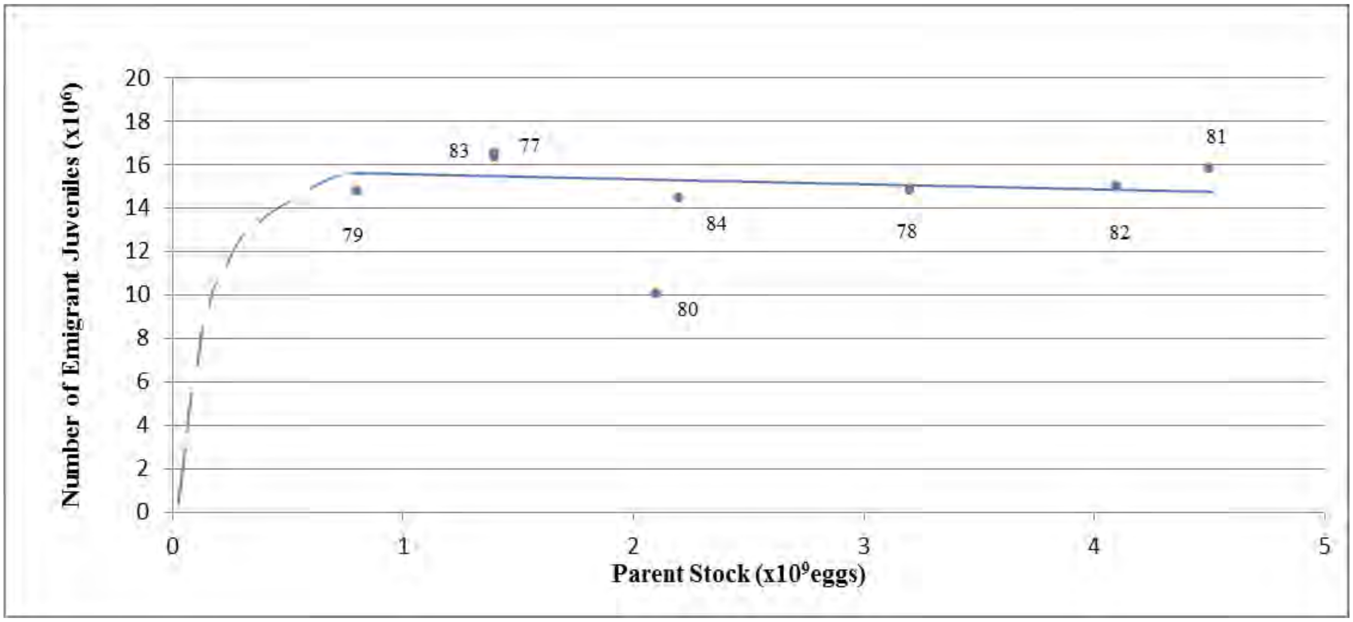


Figure 1. Relationship between an index of parental stock abundance (estimated annual egg deposition) and numbers on emigrating juvenile alewives, Damariscotta Lake, Maine, 1977-1984 (*r = +0.03; P > 0.05).*

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

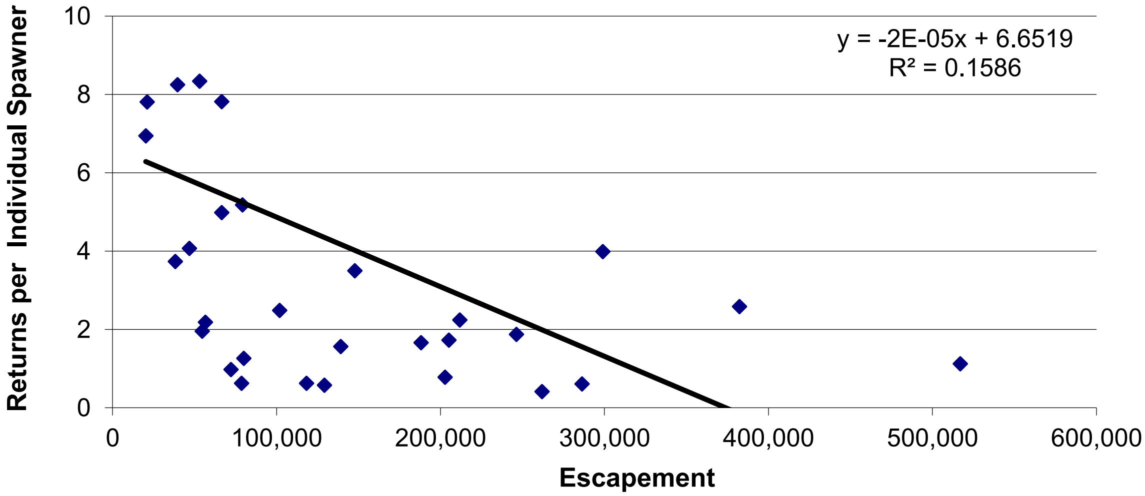
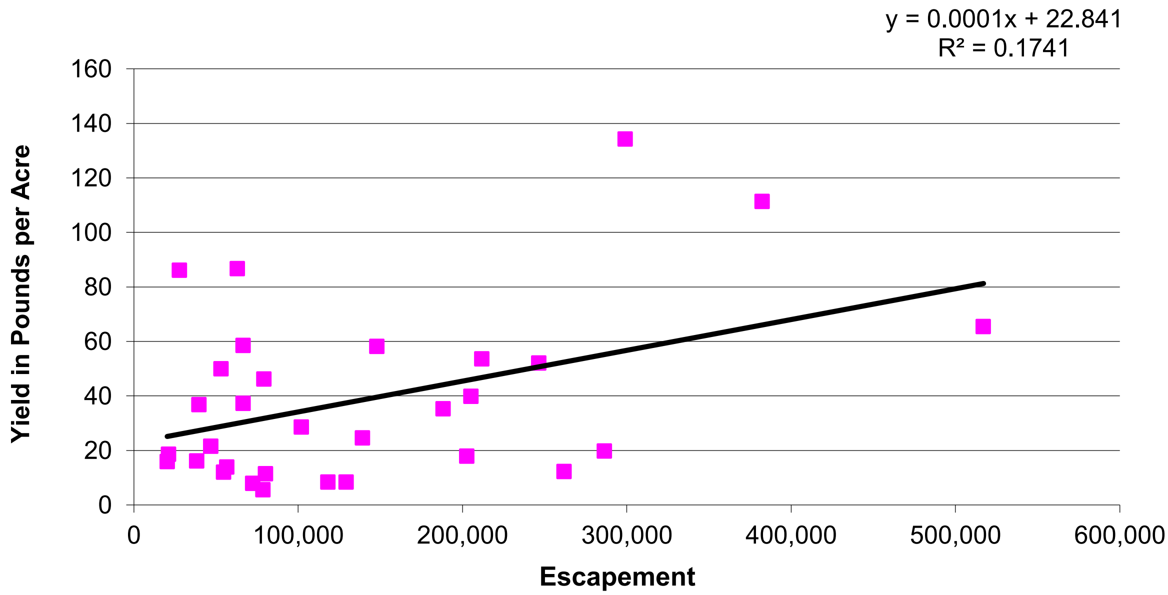


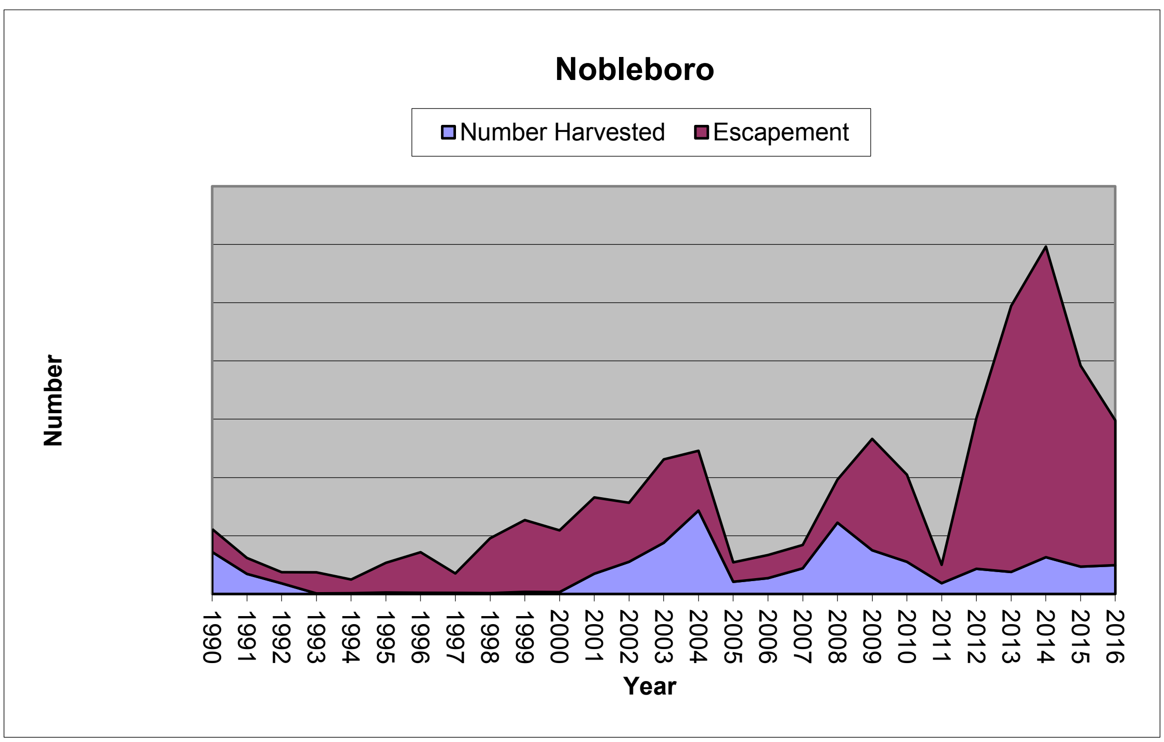
Figure 8. Yield in pounds per acre vs. escapement for the period 1977 – 2012



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



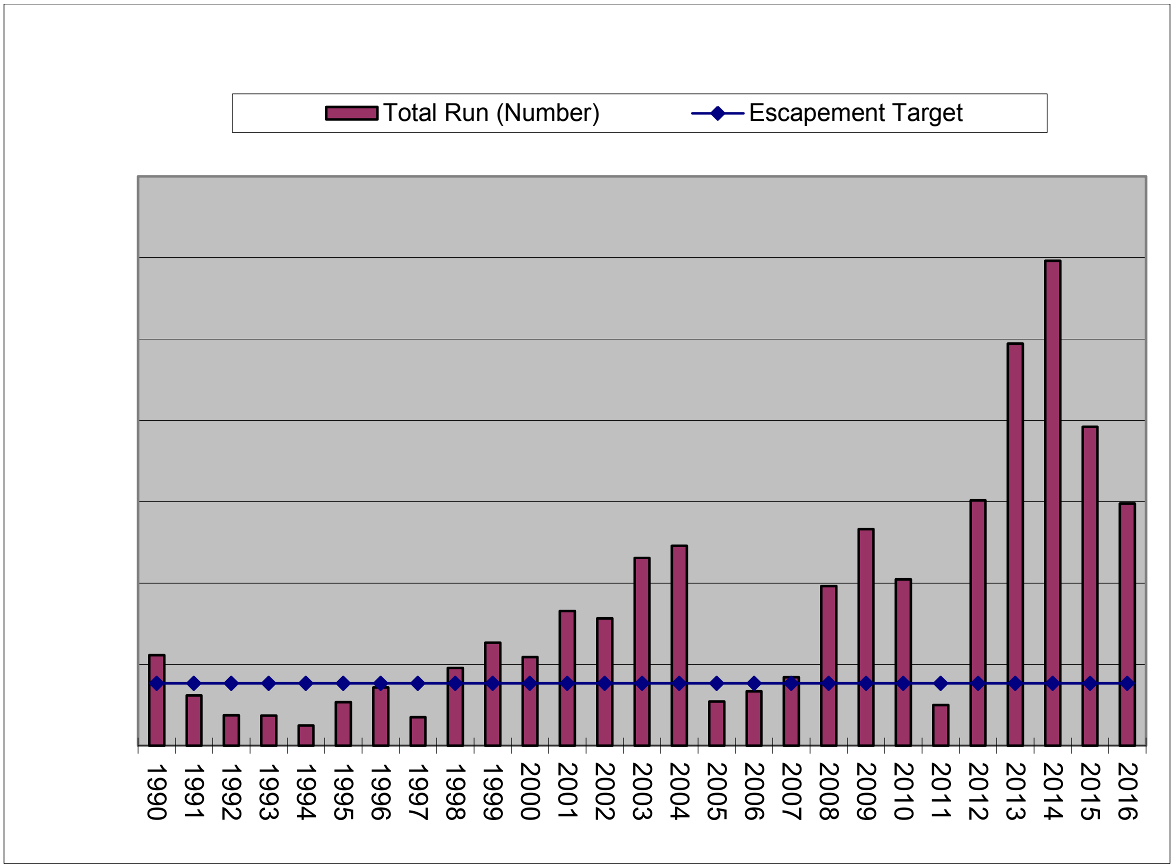


Figure 10. Entrance to the Damariscotta Fishway.

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.

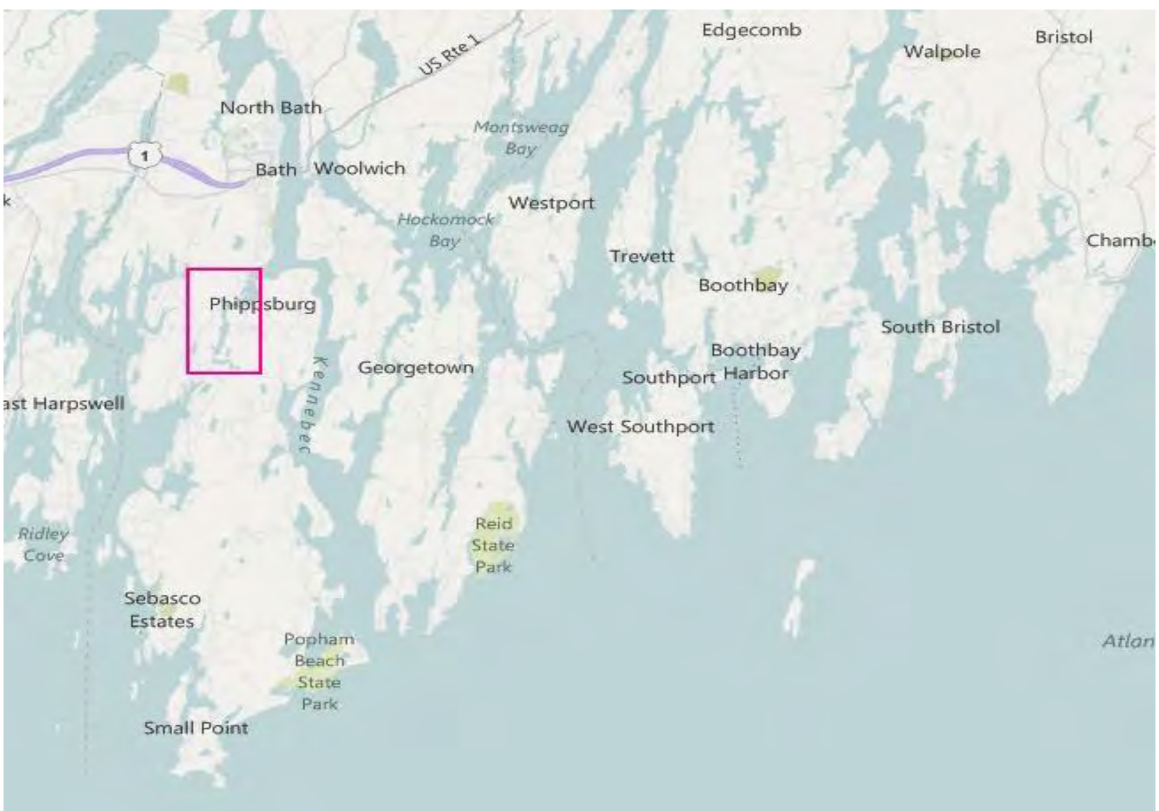
The fishery at Winnegance Lake is currently on the watch list. Though the fishery currently meets the minimum escapement levels in the plan, the annual run is below expectations. The cause for the decline in the annual run is not clear. There are several factors that may be impacting annual returns. 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
Robinhood Cove
Ridley Cove
Reid State Park
Sebasco Estates
Sagadahoc Bay
Atkins
24

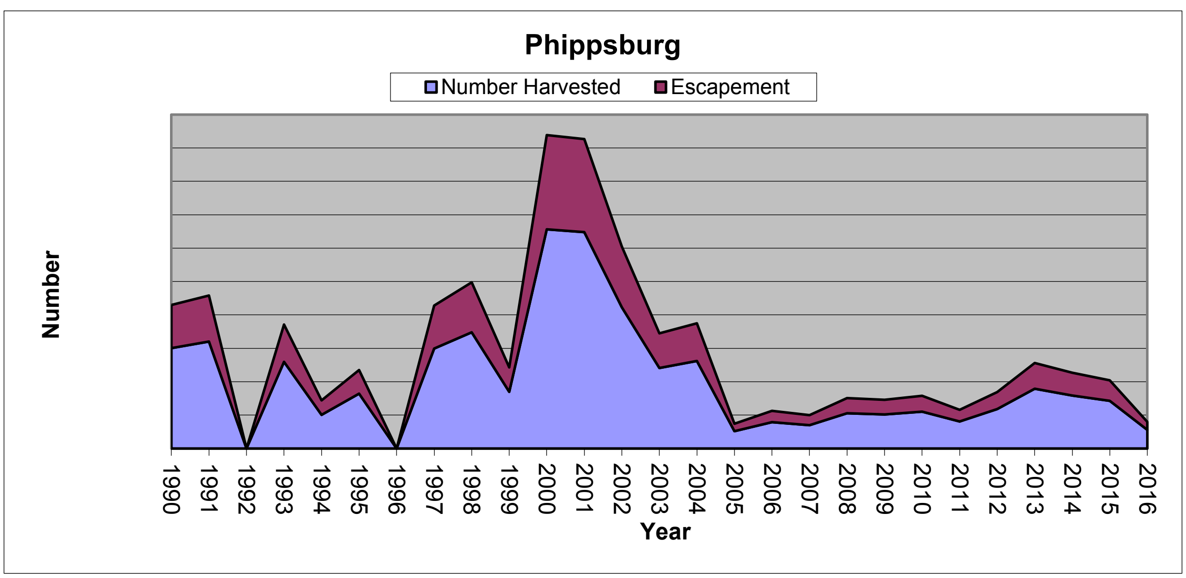


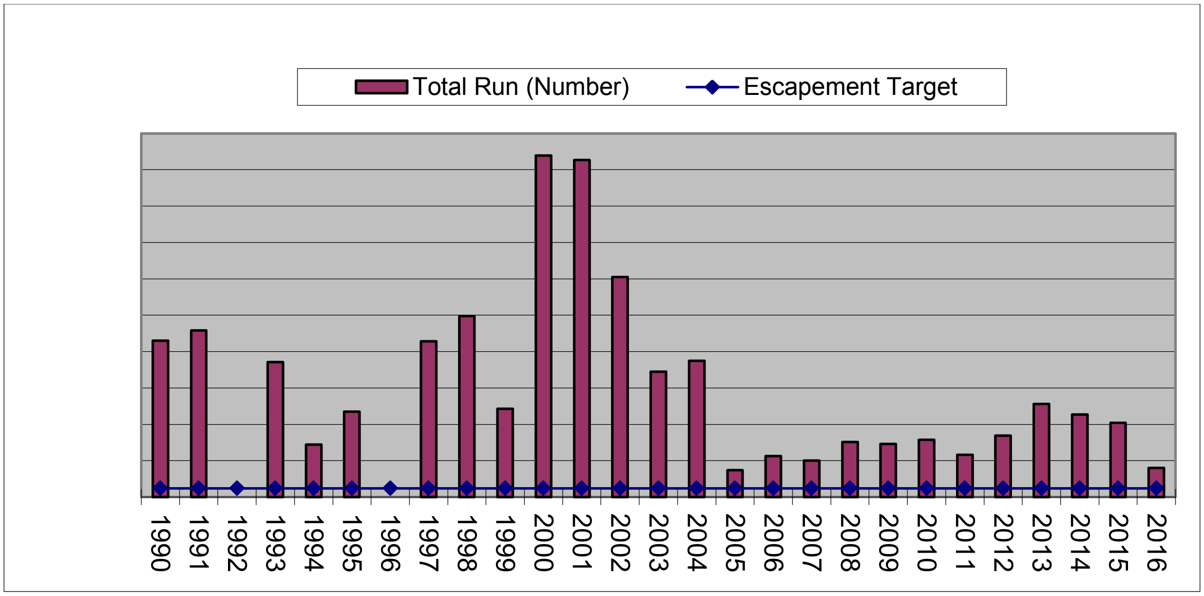
Edgecomb
Walpole
Bristol
North Bath
US Rte 1
Montsweag Bay
Bath
Woolwich
Westport
Hockomock Bay
Trevett
Chamb
Boothbay
Phippsburg
South Bristol
Georgetown
Kennebec
Boothbay Harbor
Southport
ast Harpswell
West Southport
Ridley Cove
Reid State Park
Sebasco Estates
Popham Beach State Park
Atlan
Small Point

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



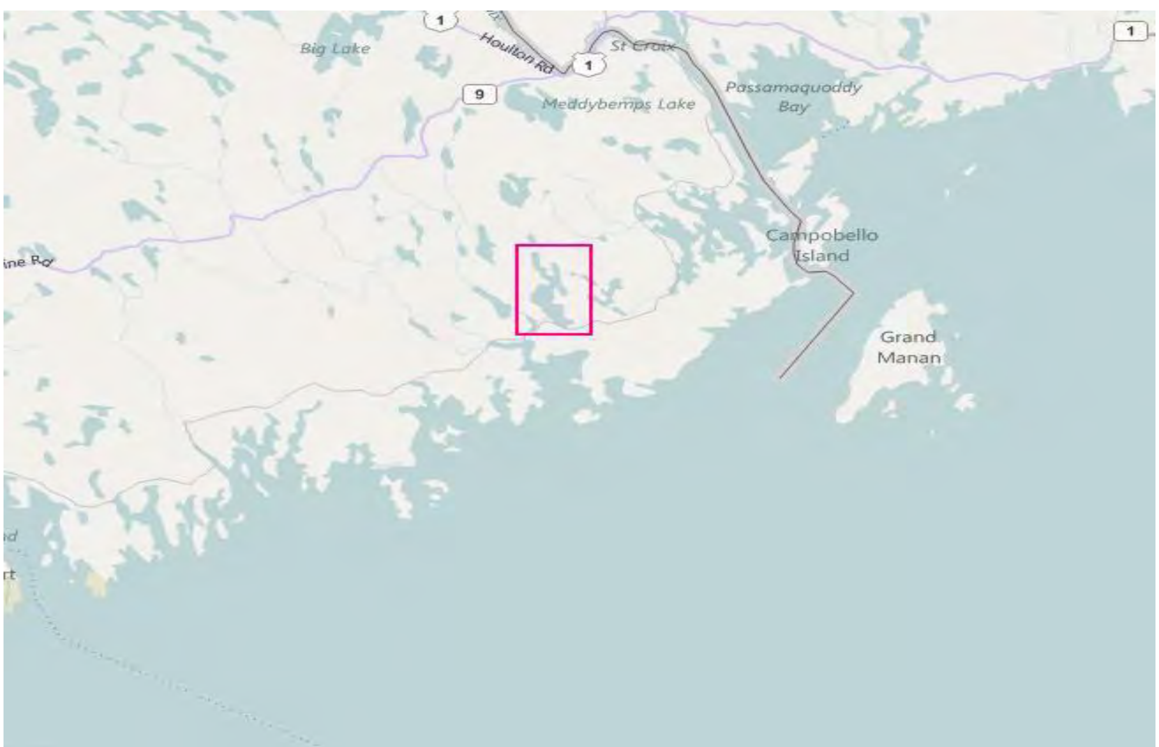


East Machias Commercial Fishery:
The Maine Department of Marine Resources manages Gardiner Lake for a commercial escapement of less than 35 fish per acre but there is no specific target for this system established at this time. The spawning escapement need for this system is 176,225 river herring passed 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.

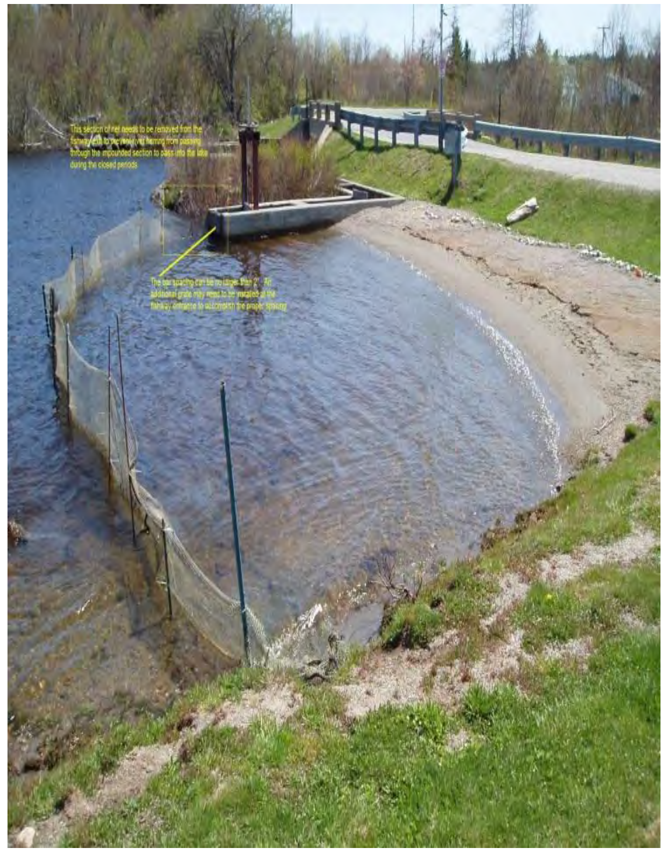
The main stem East Machias River system has a large run of river herring that is unexploited. The main stem river remains closed as a conservation measure while allowing a larger harvest at the first tributary on the river at the outlet of Gardiner Lake (Figures 13 -14). An estimated run of 2.1 – 4.5 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

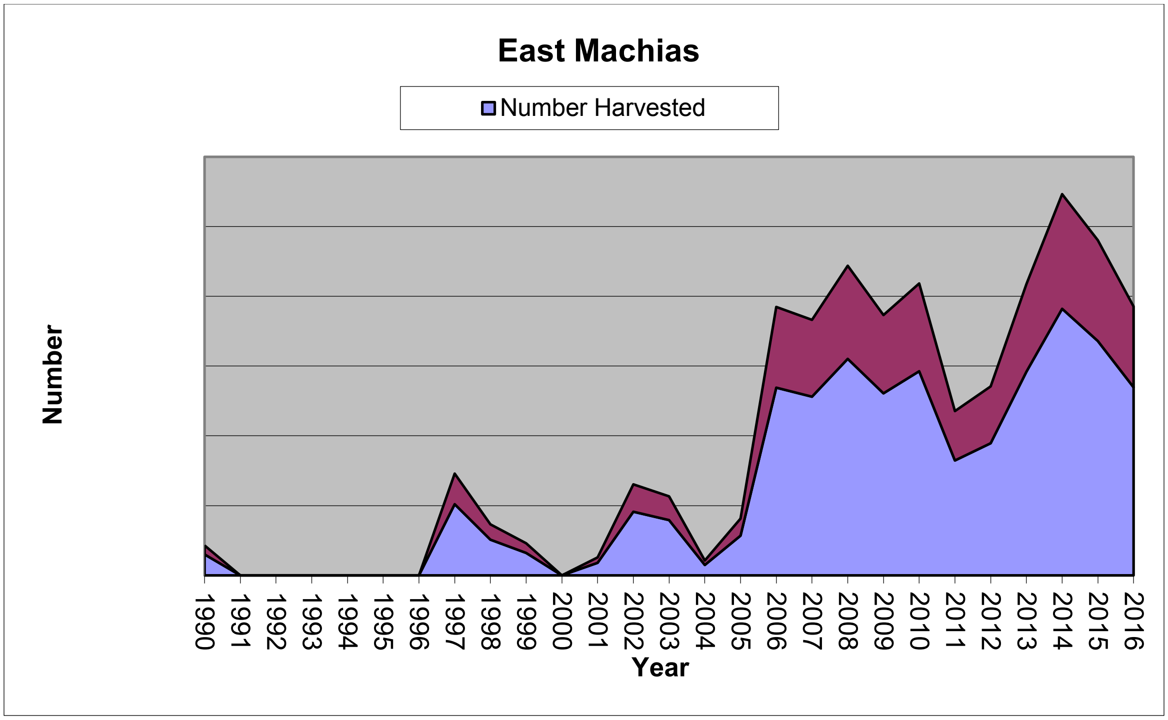


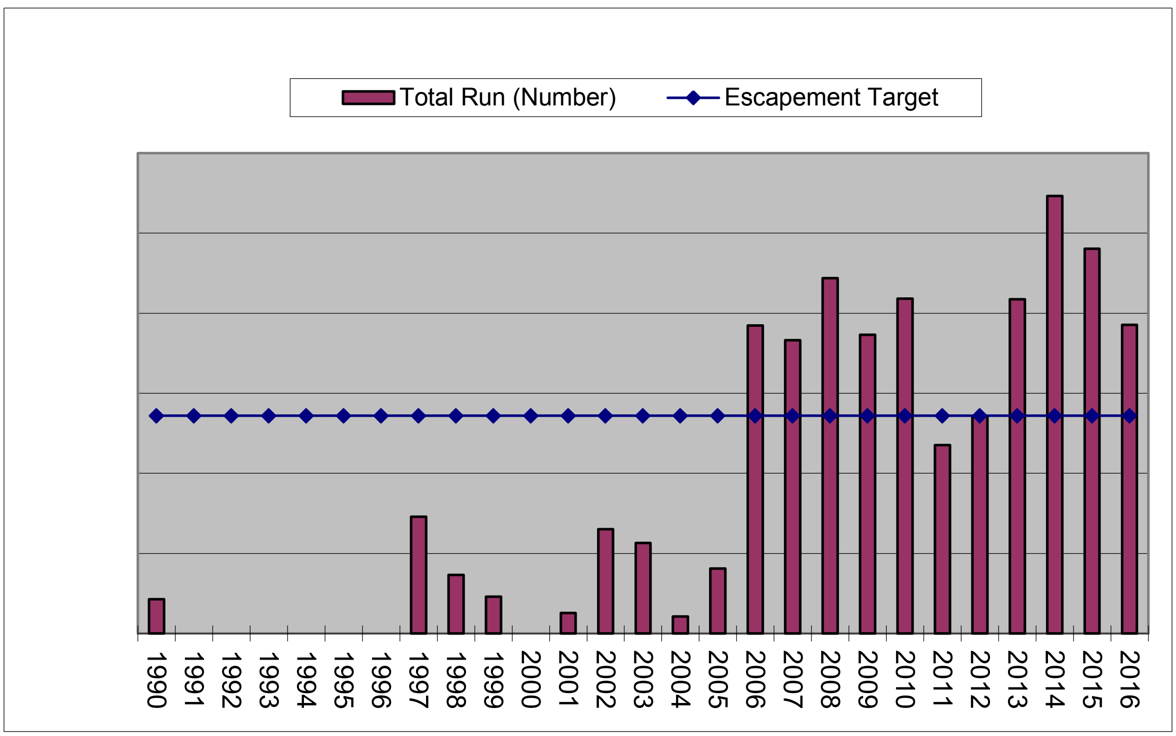
Figures 13 - 14. Chase Mill Stream is a tributary to the East Machias River. Fishing gear is deployed at the top of the fishway to capture returns to Gardiner Lake.



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



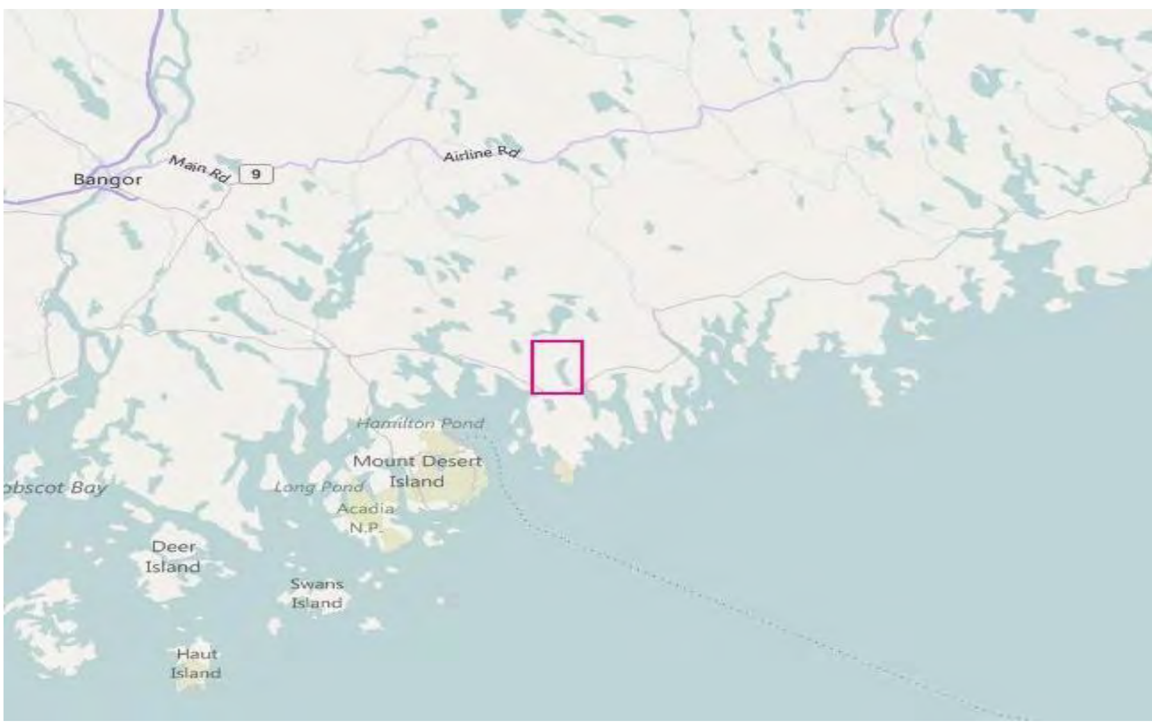


Gouldsboro Commercial Fishery:

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.

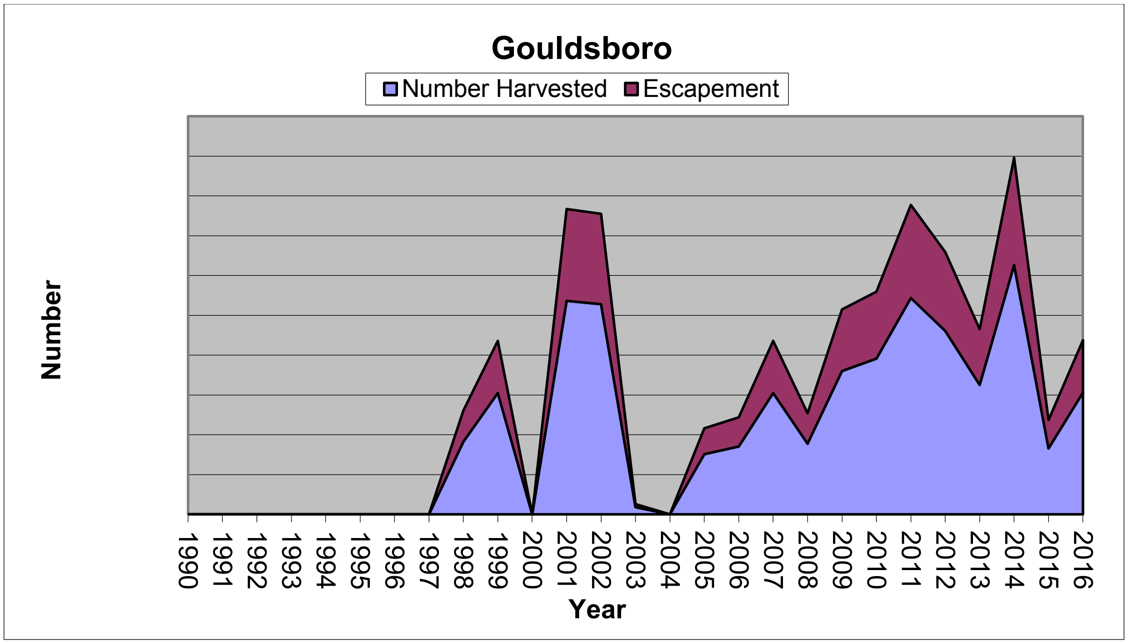
Town	River	Lake size (acres)	Threshold (N/acre)
Gouldsboro	n/a	100	35

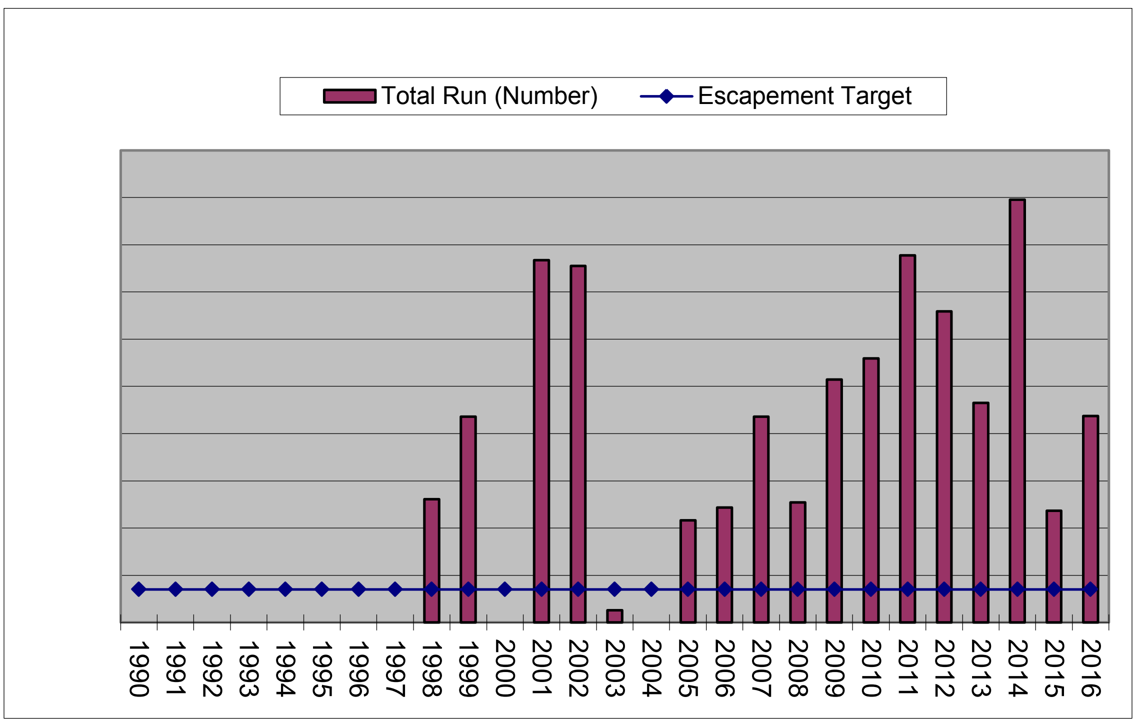


Figures 15-17. Fishway, fishing location, and trap deployed in the Gouldsboro alewife fishery.

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



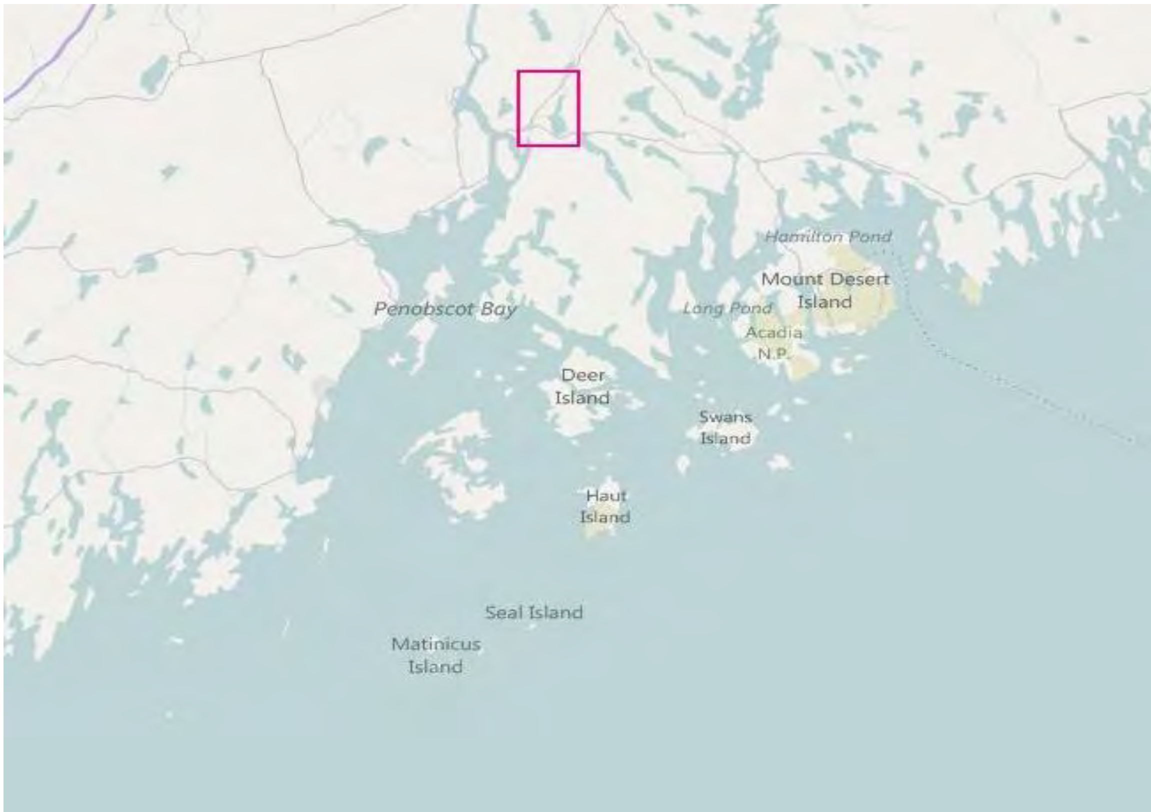


Orland Commercial Fishery:

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.

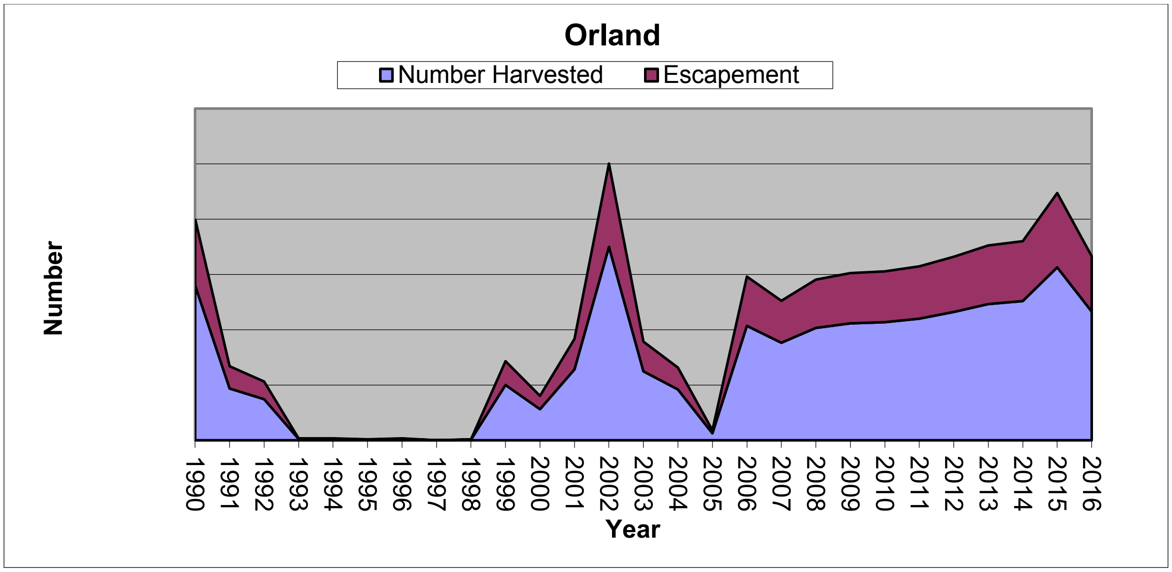
Town	River	Lake size (acres)	Threshold (N/acre)
Orland	Orland	1,133	35

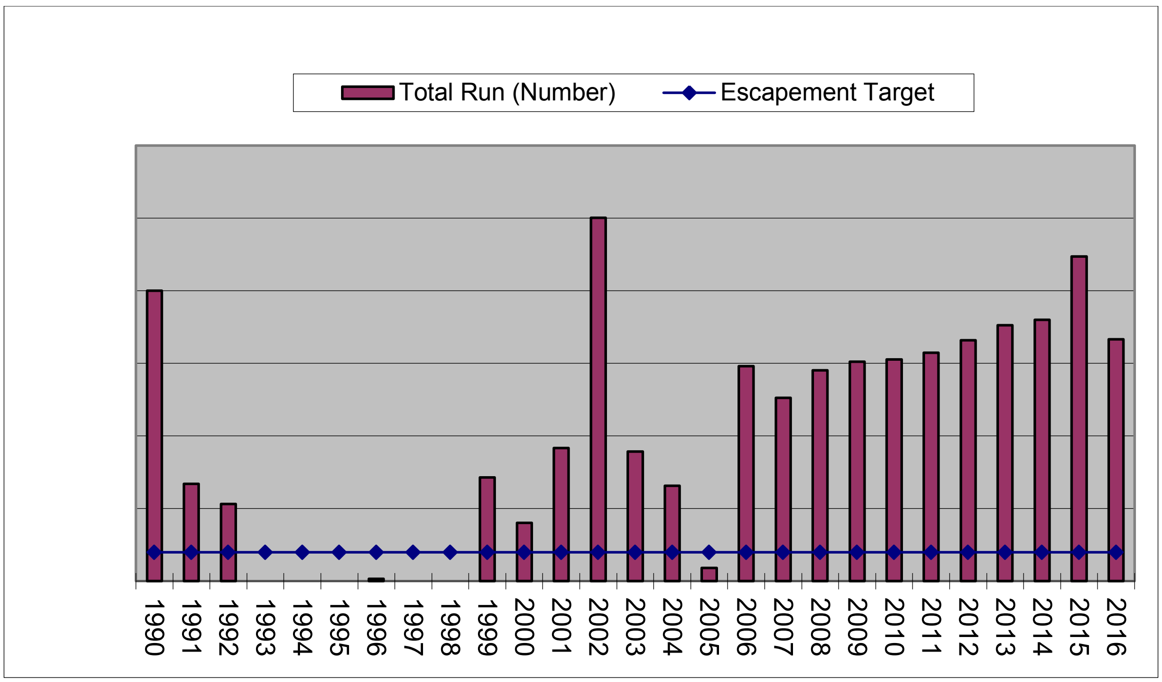


Figures 18-20. Tidal weir and commercial catches of river herring in May 2010 (bottom left) and May ~ 1970 (bottom right).

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



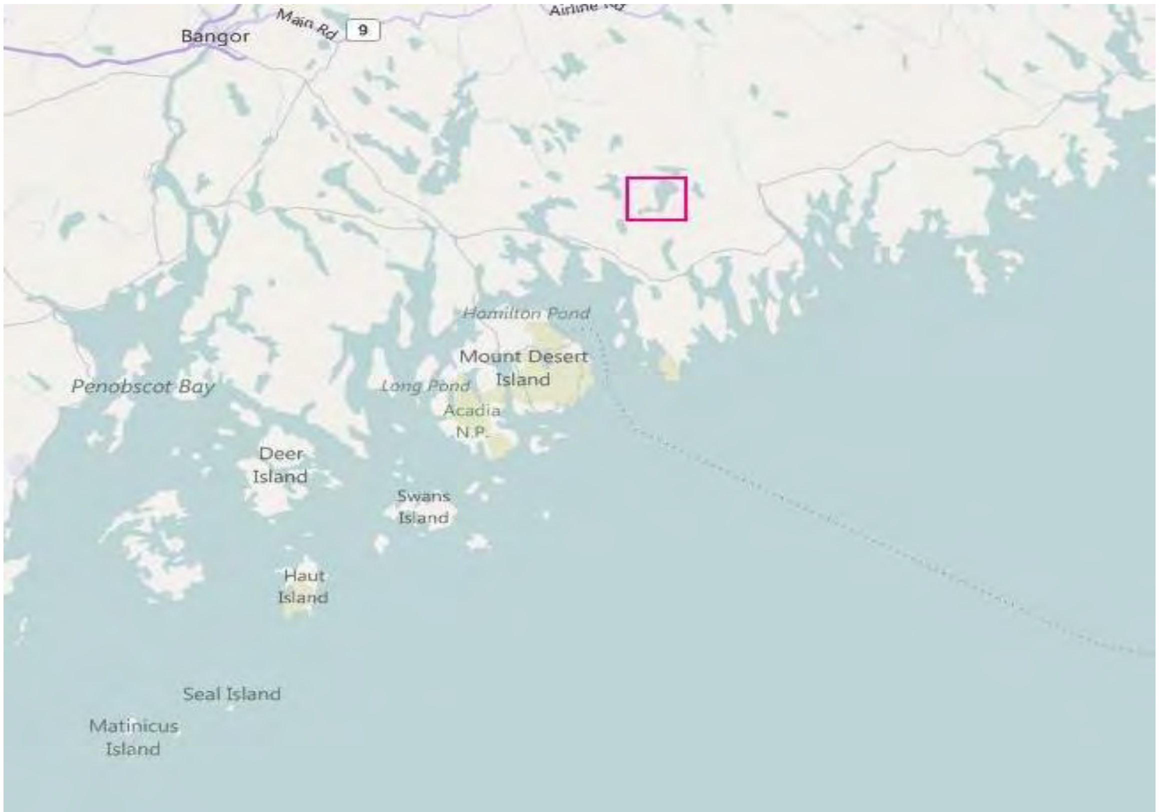


Steuben Commercial Fishery:

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.

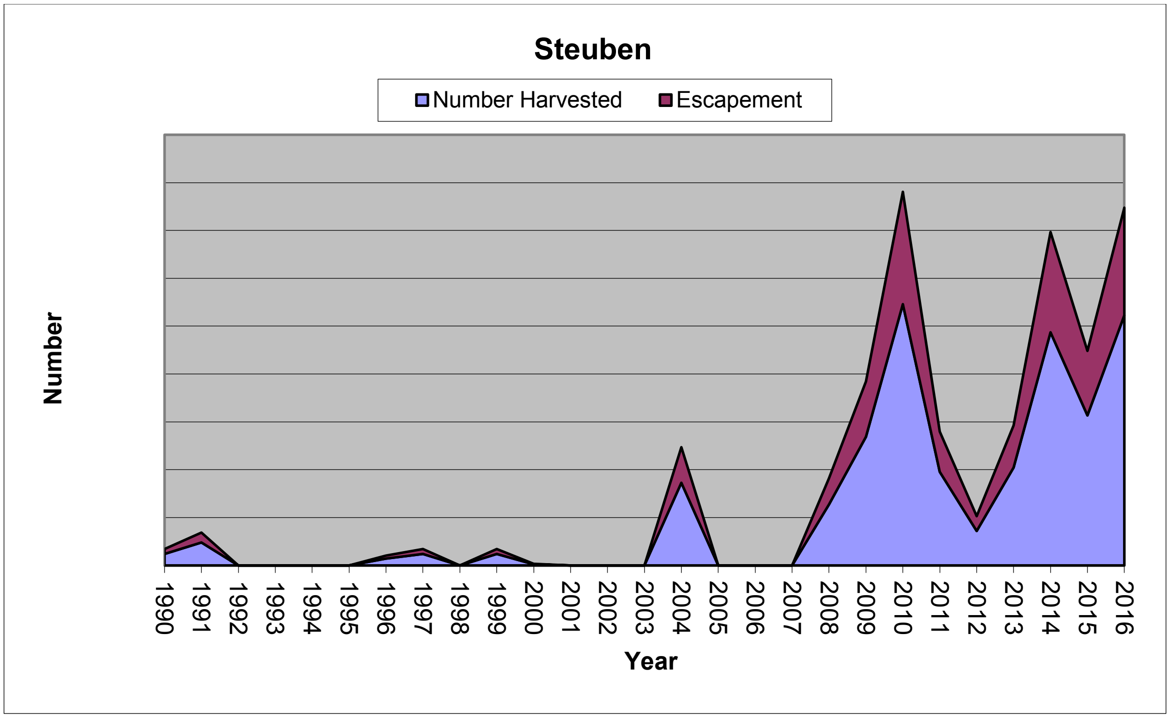
Due to water quality issues associated with its oligotrophic characteristics, Tunk Lake produces very small juvenile alewives that emigrate to sea from July – October. The lake is nutrient poor and is not as productive as other lakes in the region. It is unlikely that increased escapement beyond the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

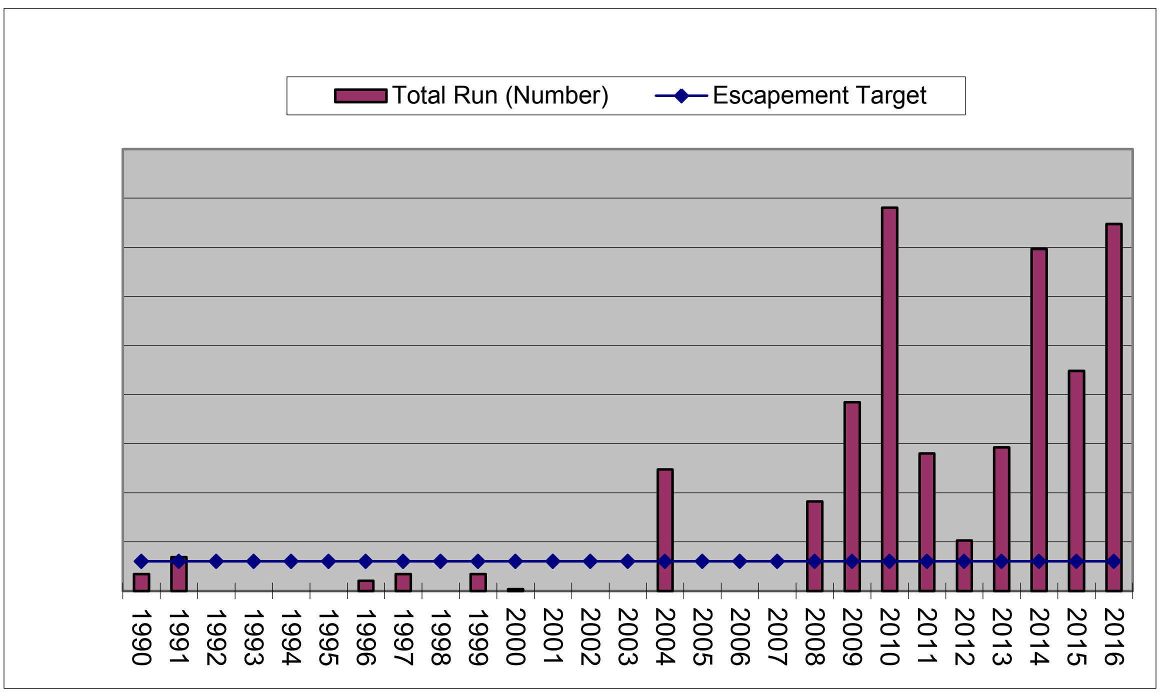
Town	River	Lake size (acres)	Threshold (N/acre)
Steuben	n/a	2,071	3



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

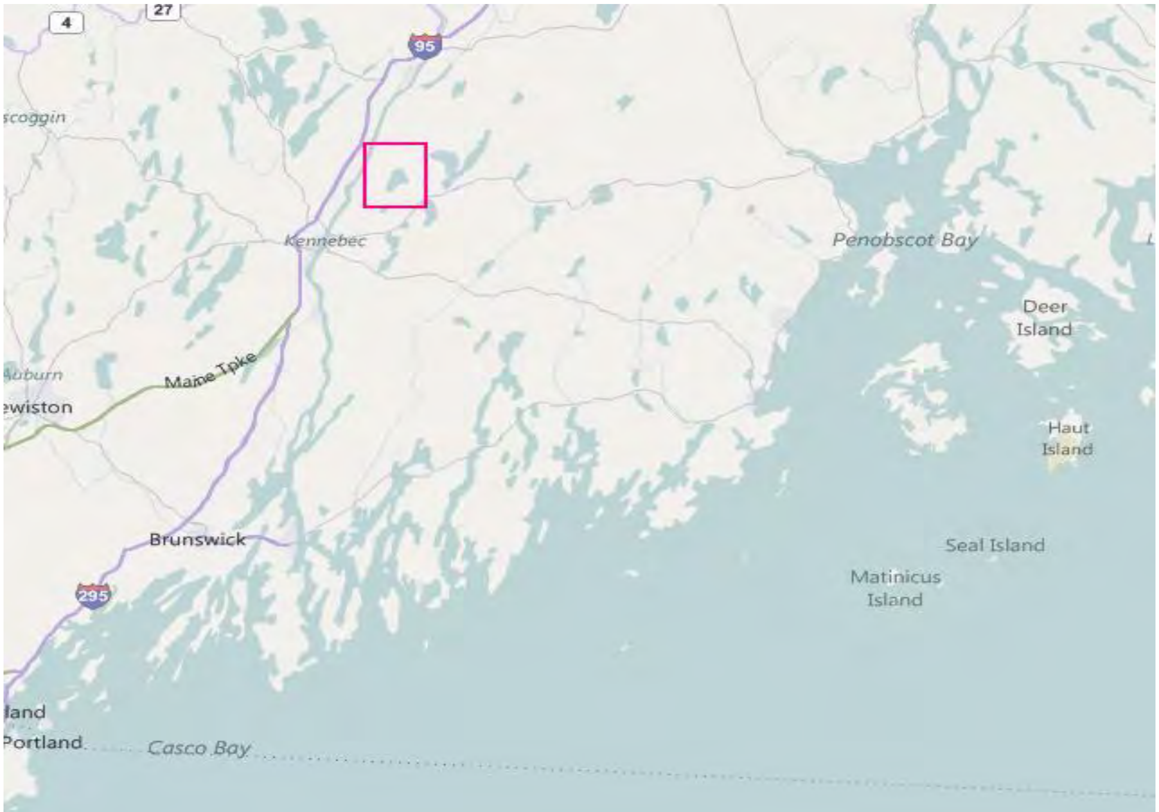
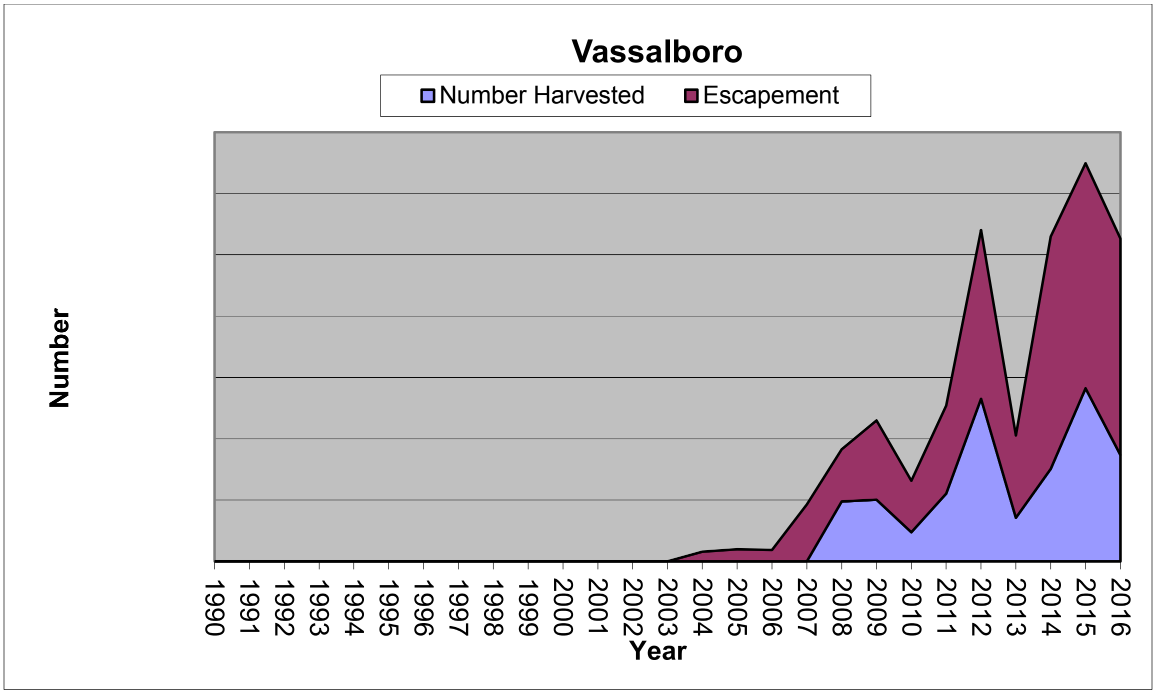
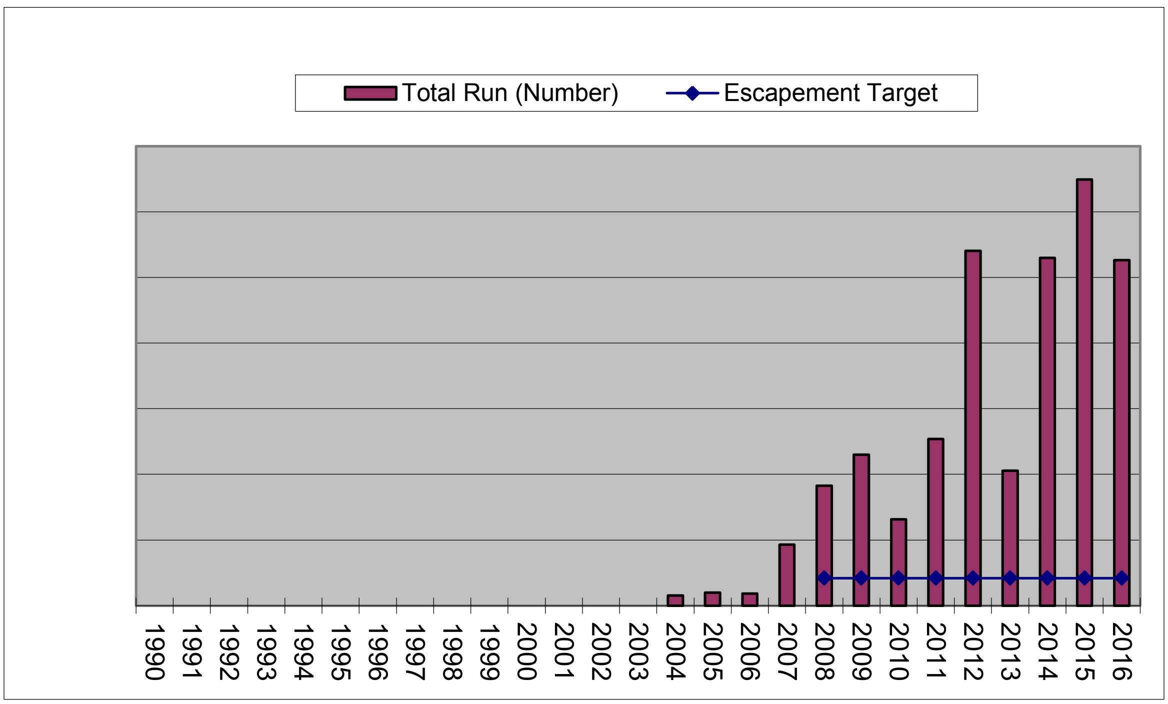


Figure 21. Outlet dam at Webber Pond. The commercial fishery occurs upstream and to the left of the dam.

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.

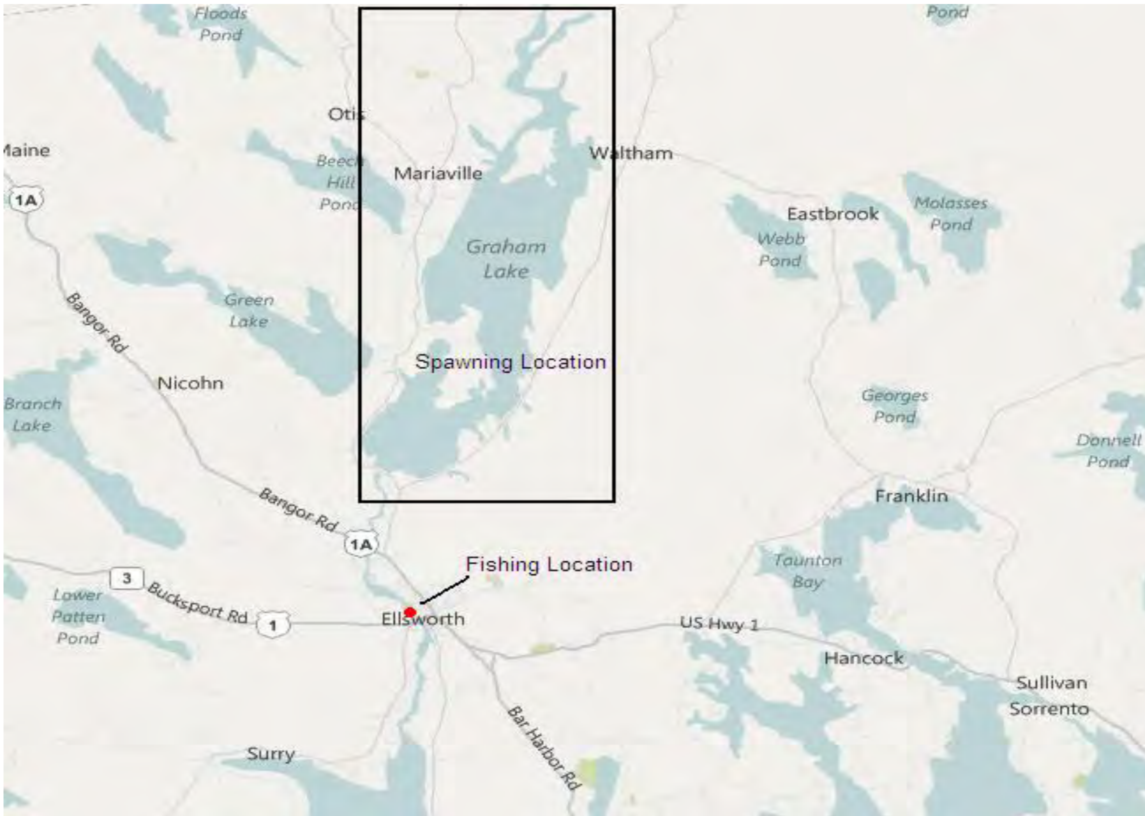
In accordance with the 2015-2017 Union River Fisheries Management Plan, the company currently stocks a minimum of 315,000 alewives annually upstream into Graham and Leonard lakes. Once the initial 150,000 alewives are captured and stocked upstream, harvesting is allowed Monday through Friday each week, 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.

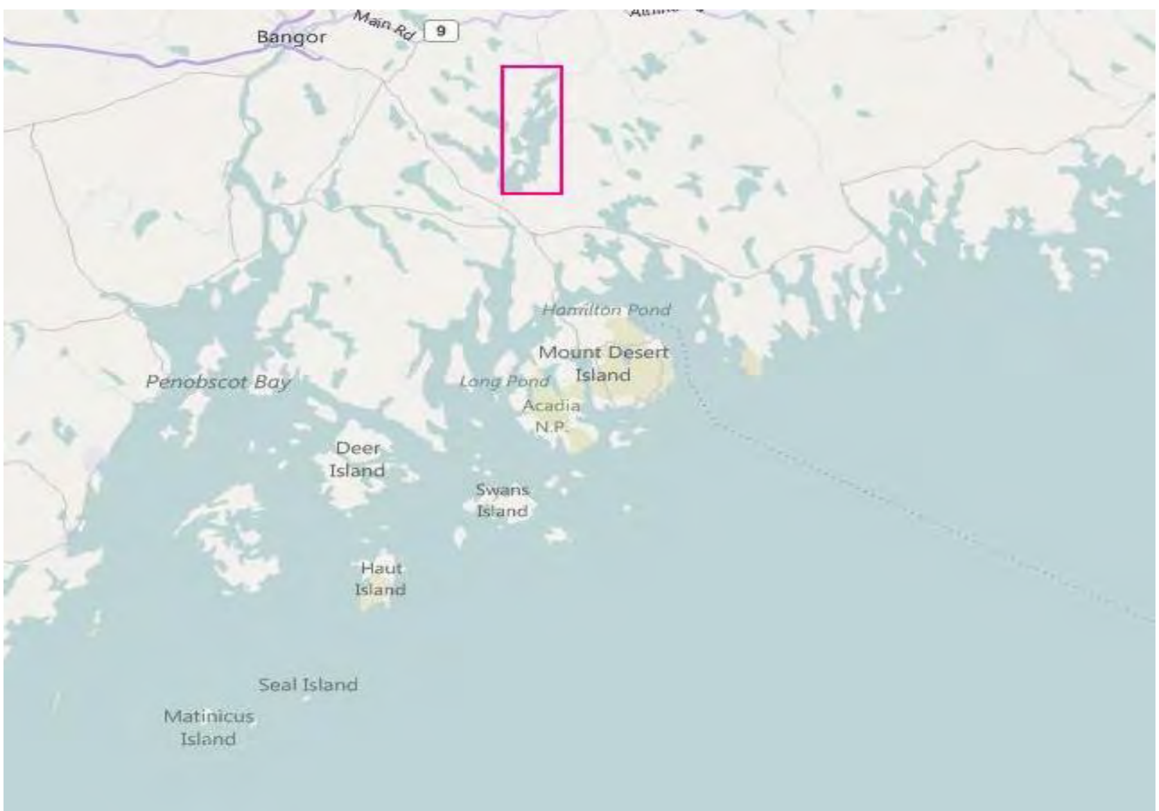
In addition to the downstream passage at the Graham Lake Dam, migrating fish are also known to pass through the turbines at Ellsworth. This can result in high mortality for both adult and juvenile river herring. The number of repeat spawning fish returning to the Union River is low compared to all other 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.

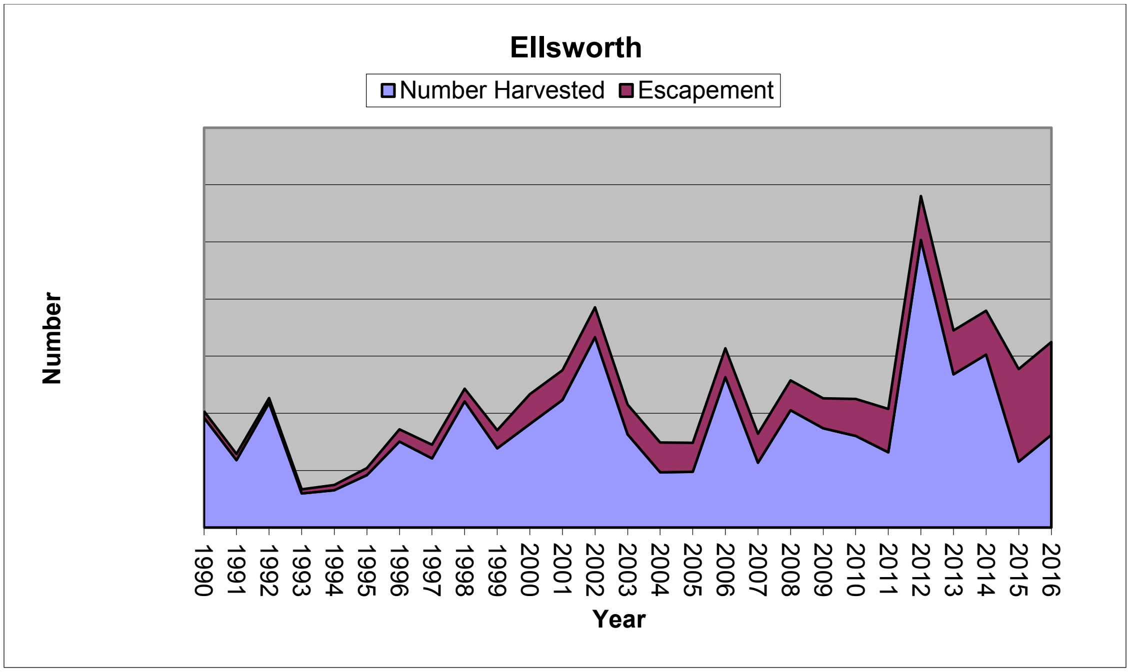
Town	River	Lake size (acres)	Threshold (N/acre)
Ellsworth	Union River	7,865	41

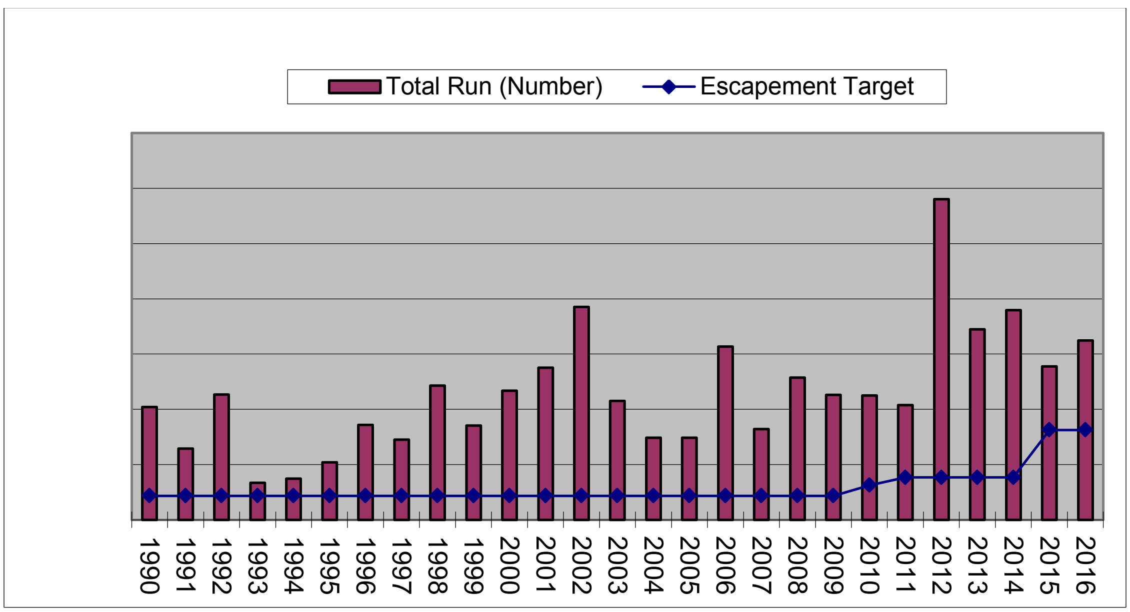

Floods Pond
Pond
Otis
Maine
1A
Beech Hill Pond
Mariaville
Waltham
Eastbrook
Molasses Pond
Webb Pond
Graham Lake
Bangor Rd
Green Lake
Spawning Location
Nicohn
Branch Lake
Georges Pond
Donnell Pond
Franklin
Bangor Rd
1A
Fishing Location
Taunton Bay
3
Bucksport Rd
Lower Patten Pond
1
Ellsworth
US Hwy 1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


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



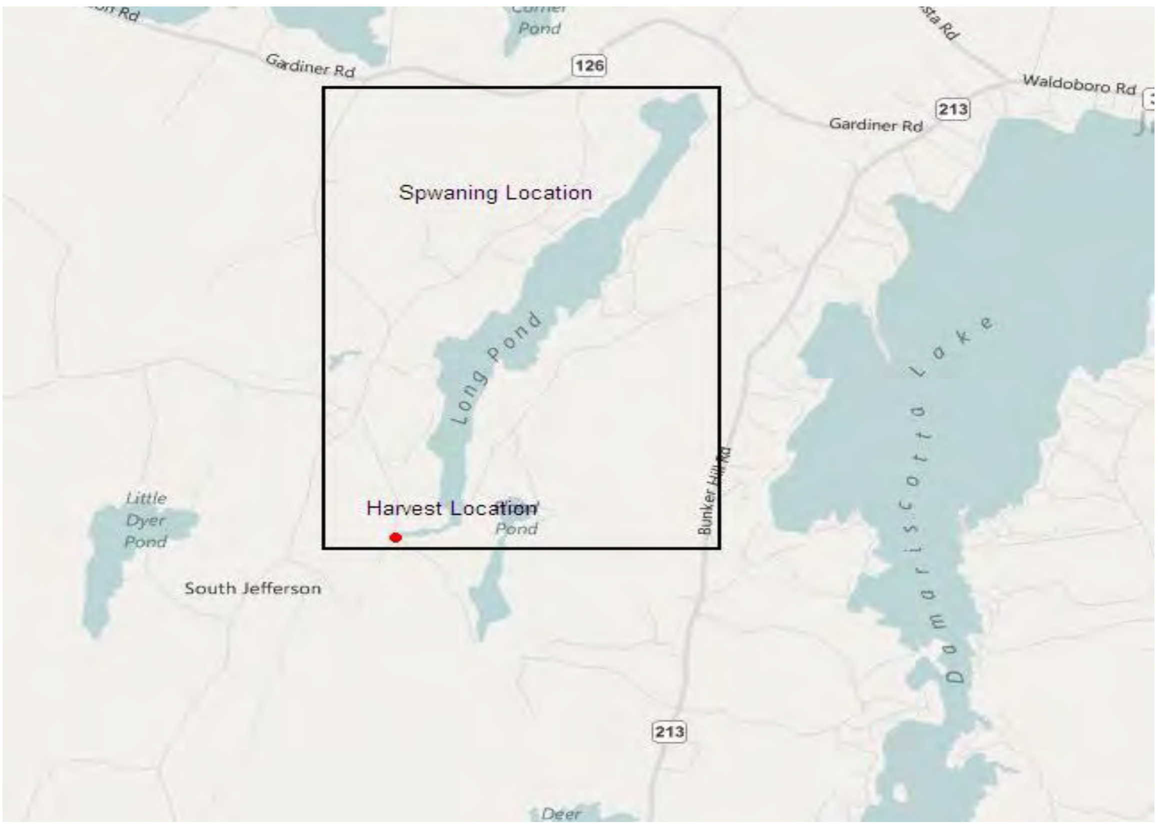


Jefferson Commercial Fishery:

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.

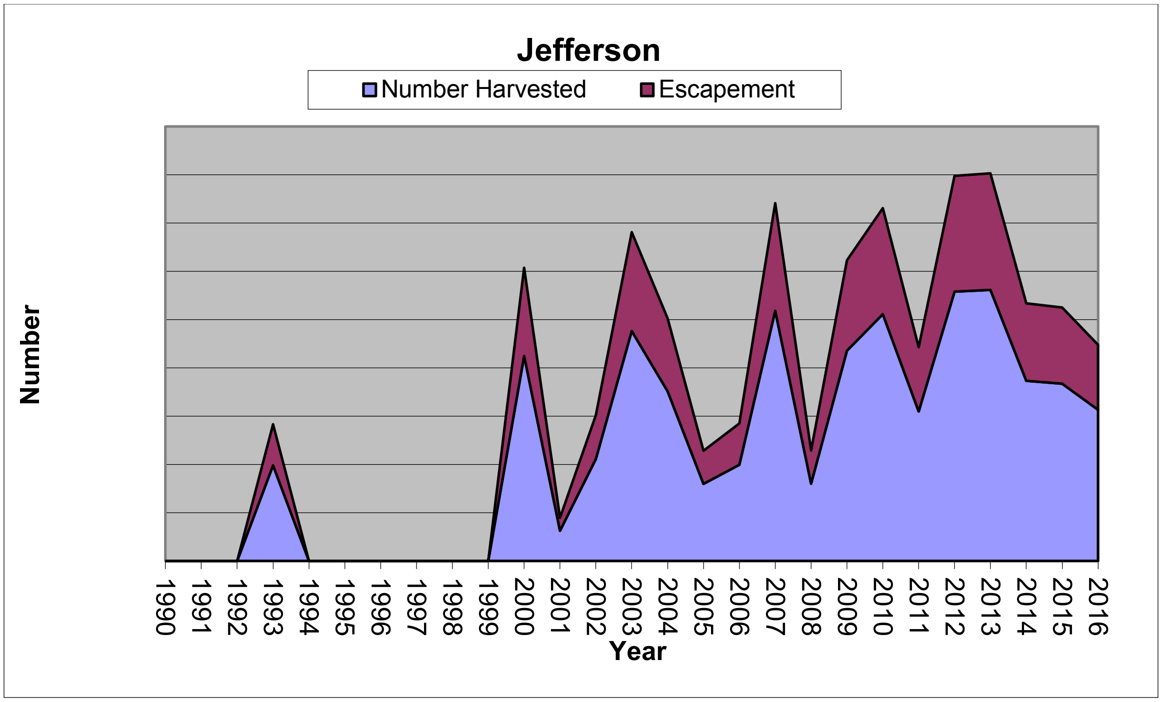
Town	River	Lake size (acres)	Threshold (N/acre)
Jefferson	Dyer River	425	35

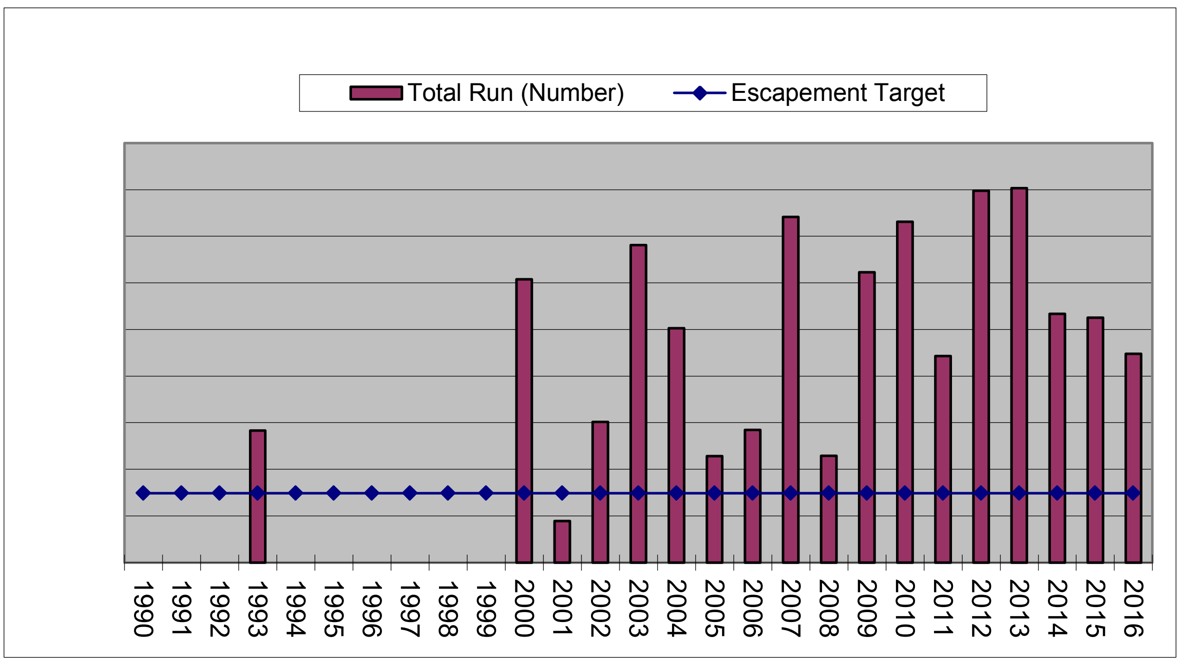


Figures 22 - 24. Outlet stream from Dyer-Long Pond, fishway leading into the pond and alewife trap at the pond outlet.


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:

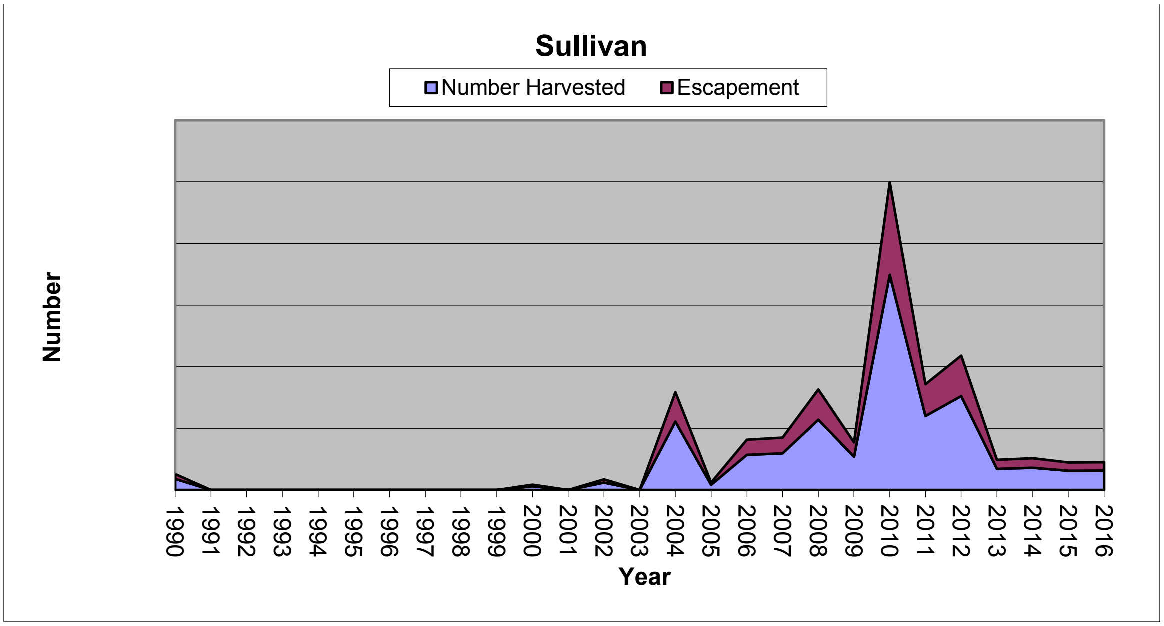
The Maine Department of Marine Resources manages this system for a minimum commercial escapement of 35 fish per acre. The spawning escapement need for this system is 3,222 river herring passed upstream during the three required closed days in the fishery each week. The management plan has achieved returns 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.

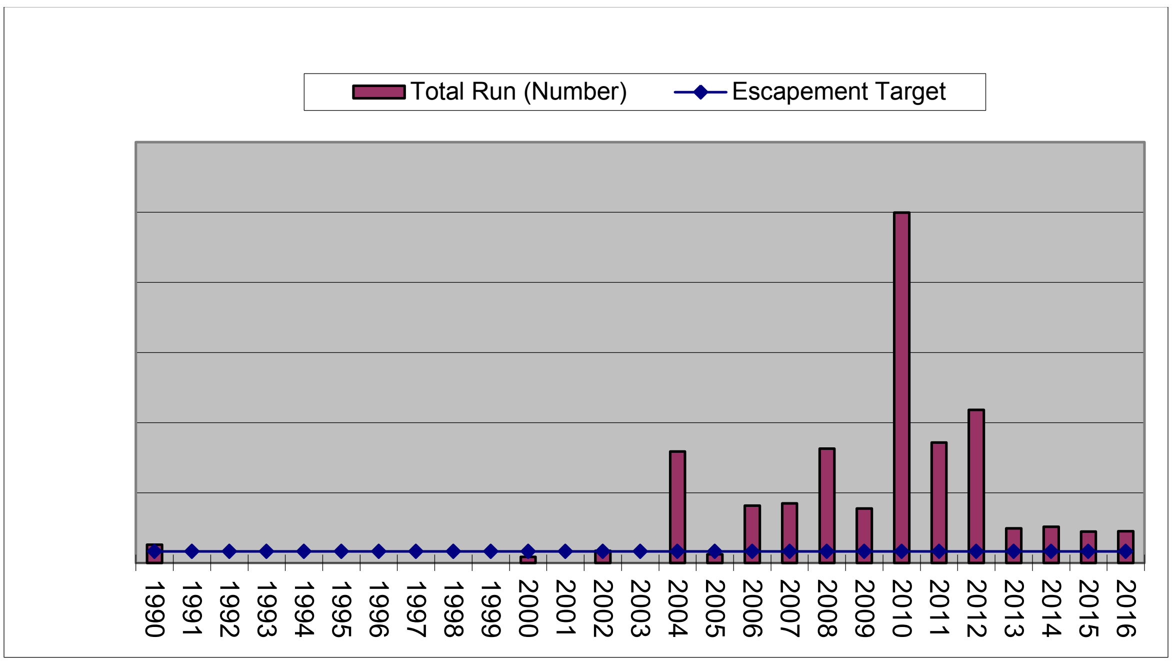
Town	River	Lake size (acres)	Threshold (N/acre)
Sullivan	n/a	92	35

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



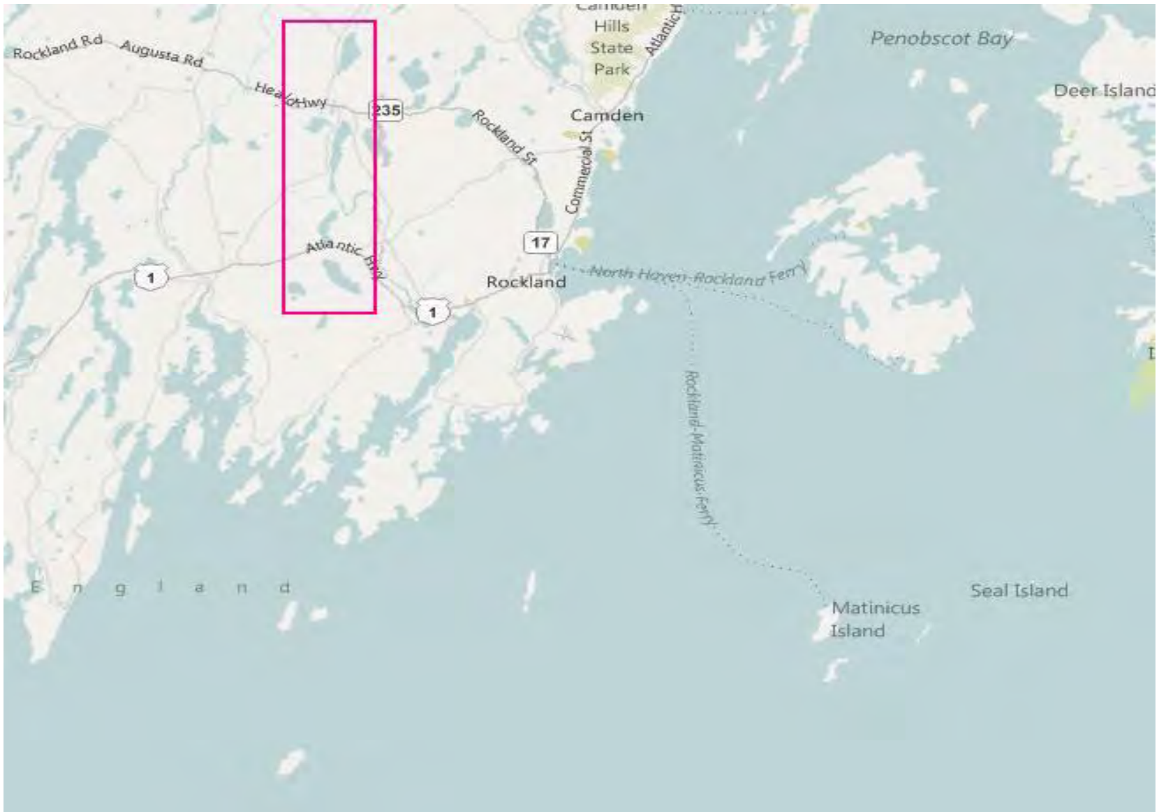


Warren Commercial Fishery:

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.

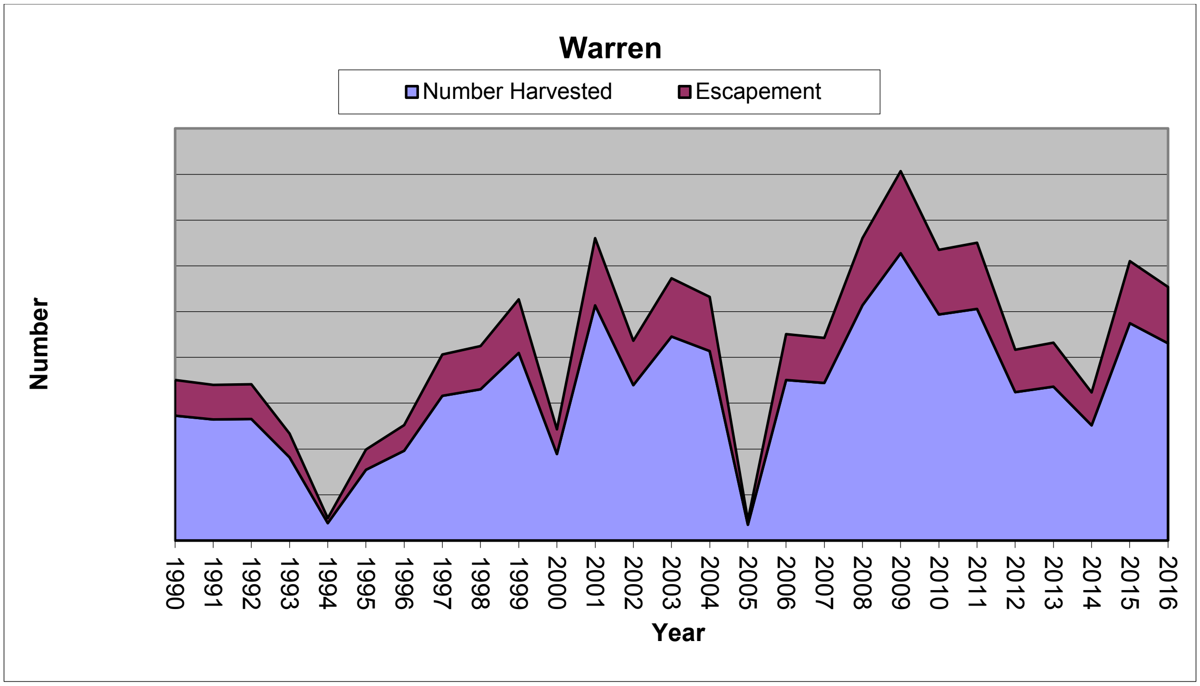
Town	River	Lake size (acres)	Threshold (N/acre)
Warren	St. George	1,889	35

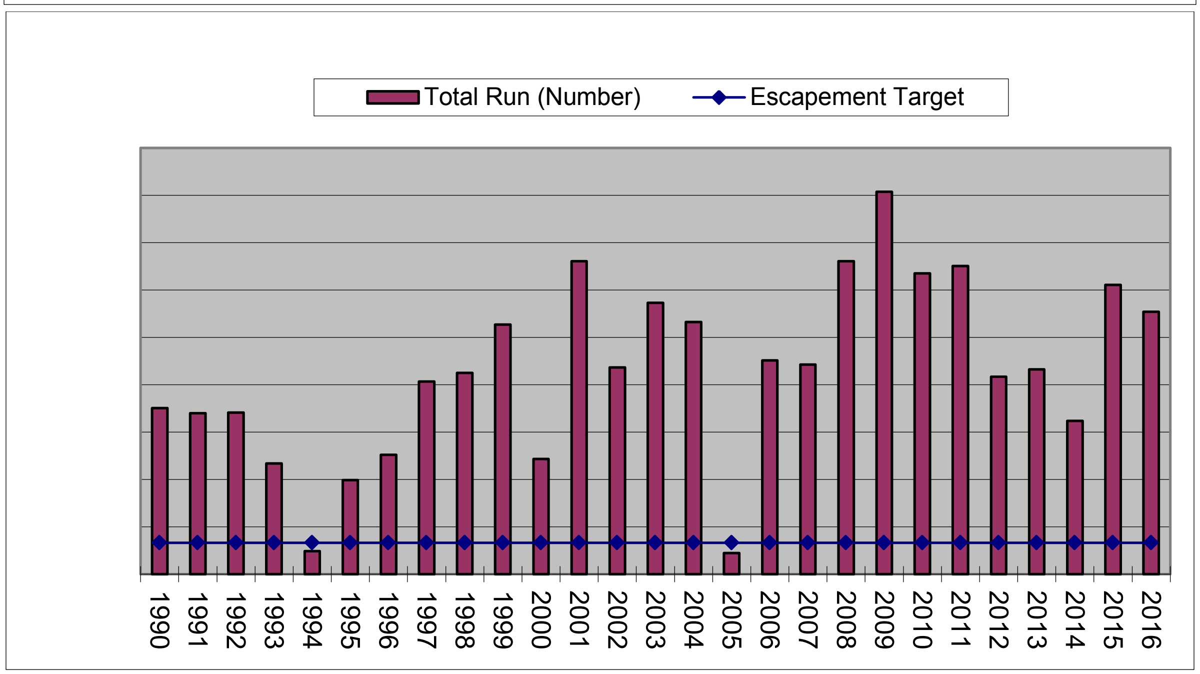


Year	Municipality	River	% repeat spawners by year and frequency	R-0	R-1	R-2	R-3	Z-value
2015	Warren	St .George	23.7	76.32	13.16	5.26	5.26	0.89
2014	Warren	St .George	37.6	62.38	20.79	6.93	9.90	0.66
2013	Warren	St .George	35.1	64.90	27.40	4.80	2.80	1.12
2012	Warren	St .George	44.4	55.60	30.50	8.60	5.30	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.

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.

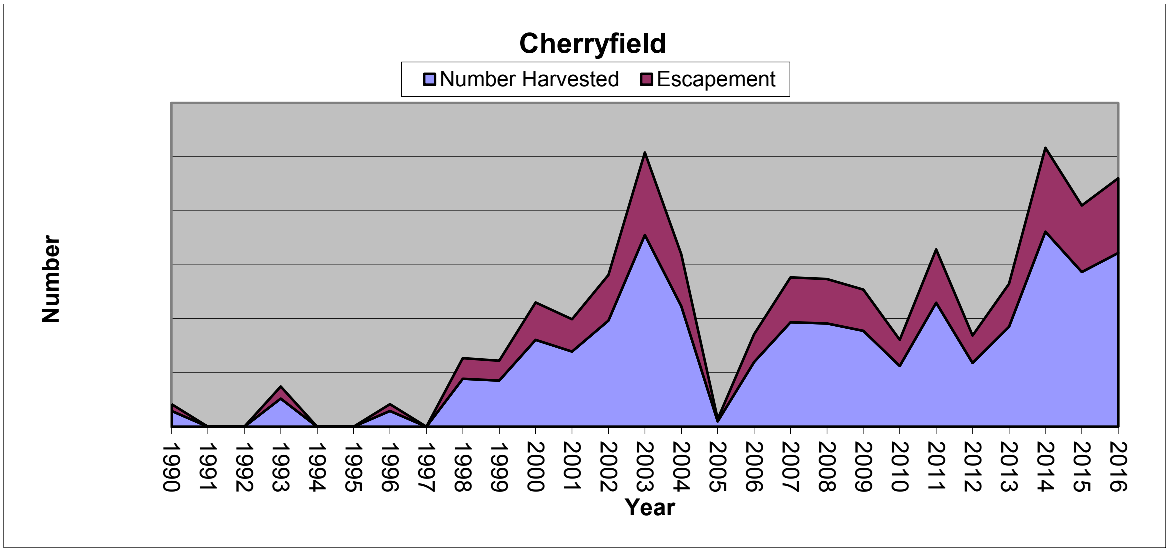
The Narraguagus River is an Atlantic salmon river with a significant number of alewives spawning in the lakes upstream of the dam located just above the head of tide (Figure 27). A small run of American shad also spawn in the river above the dam and provide sport fishing opportunities for the region. 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.

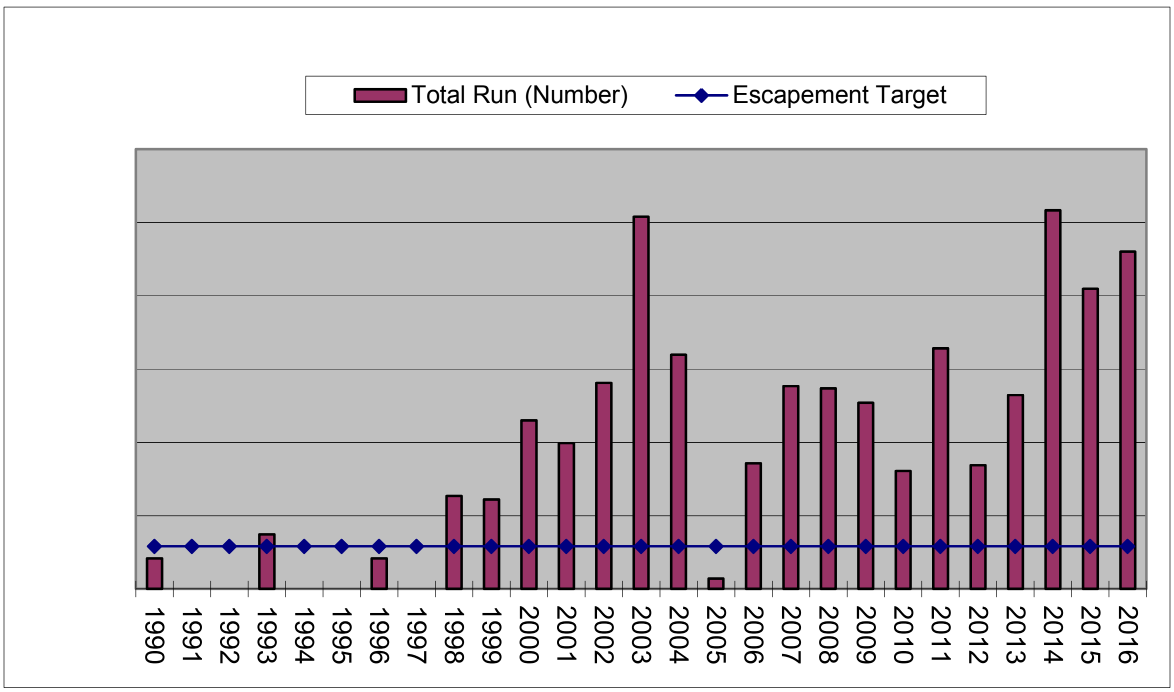
Town	River	Lake size (acres)	Threshold (N/acre)
Cherryfield	Narraguagus	830	35

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





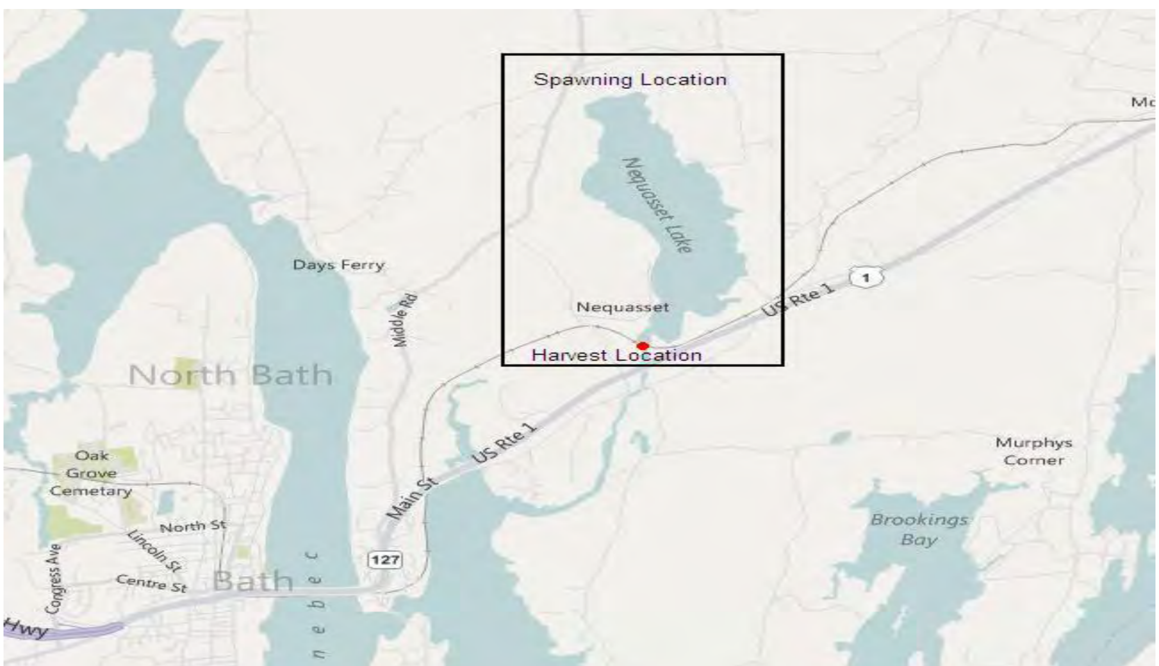
Woolwich Commercial Fishery:

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



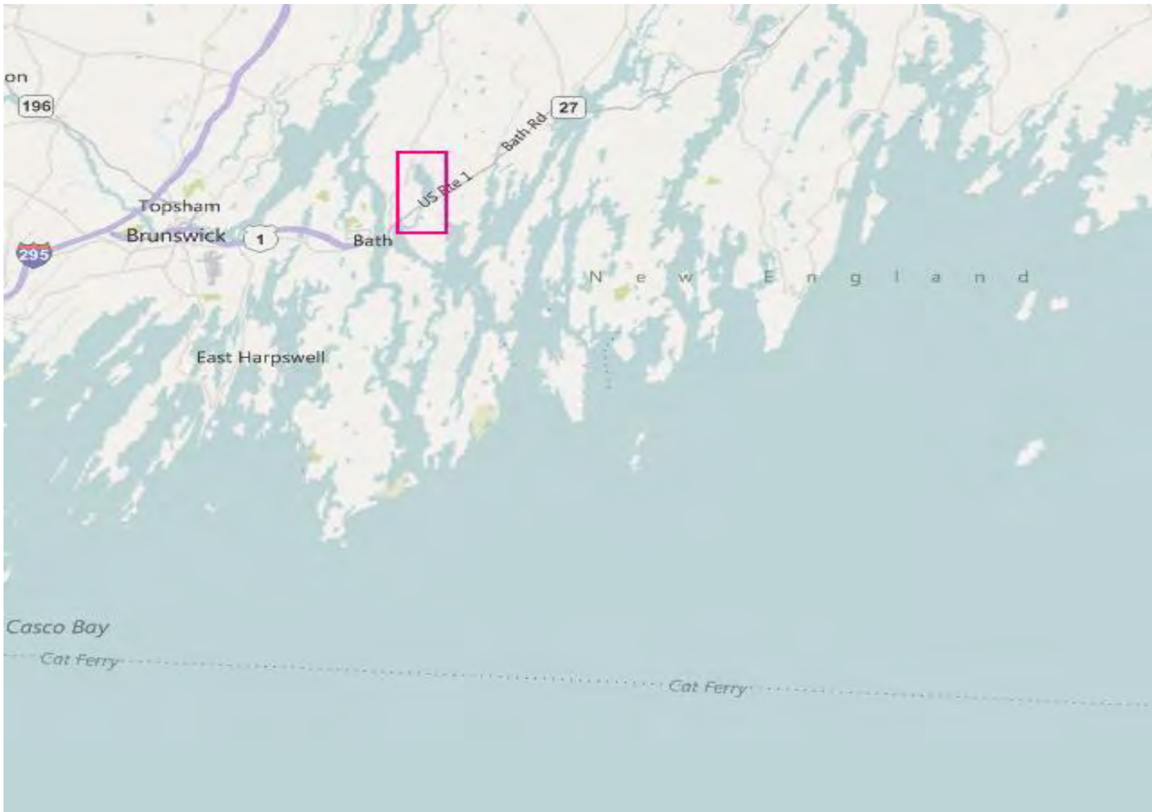
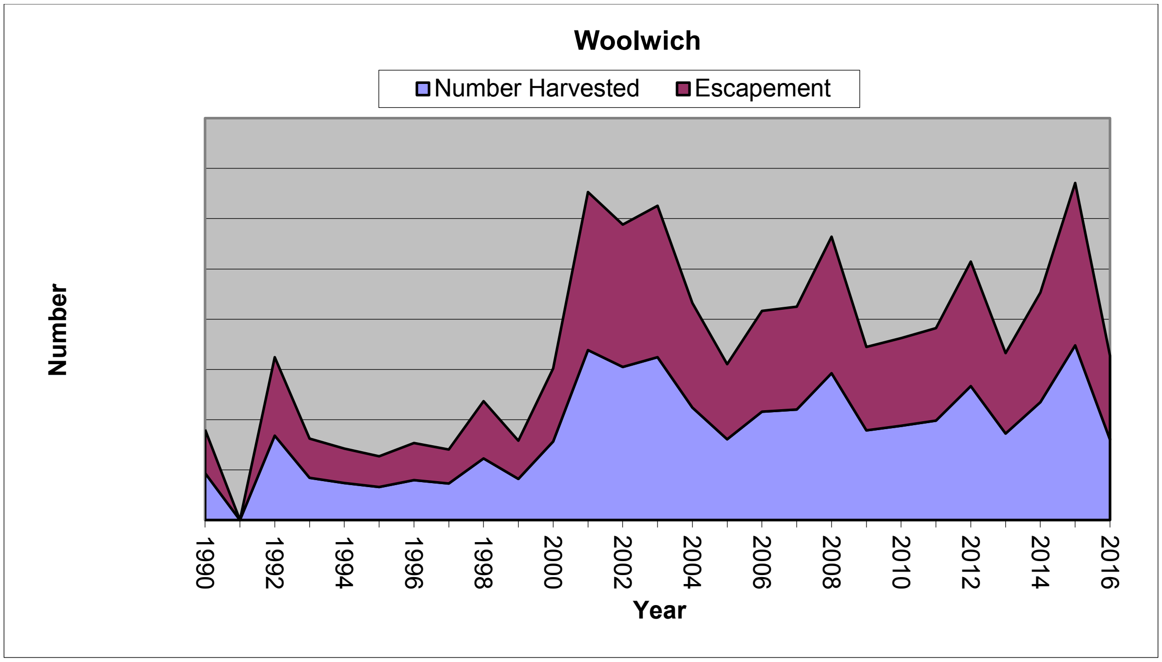


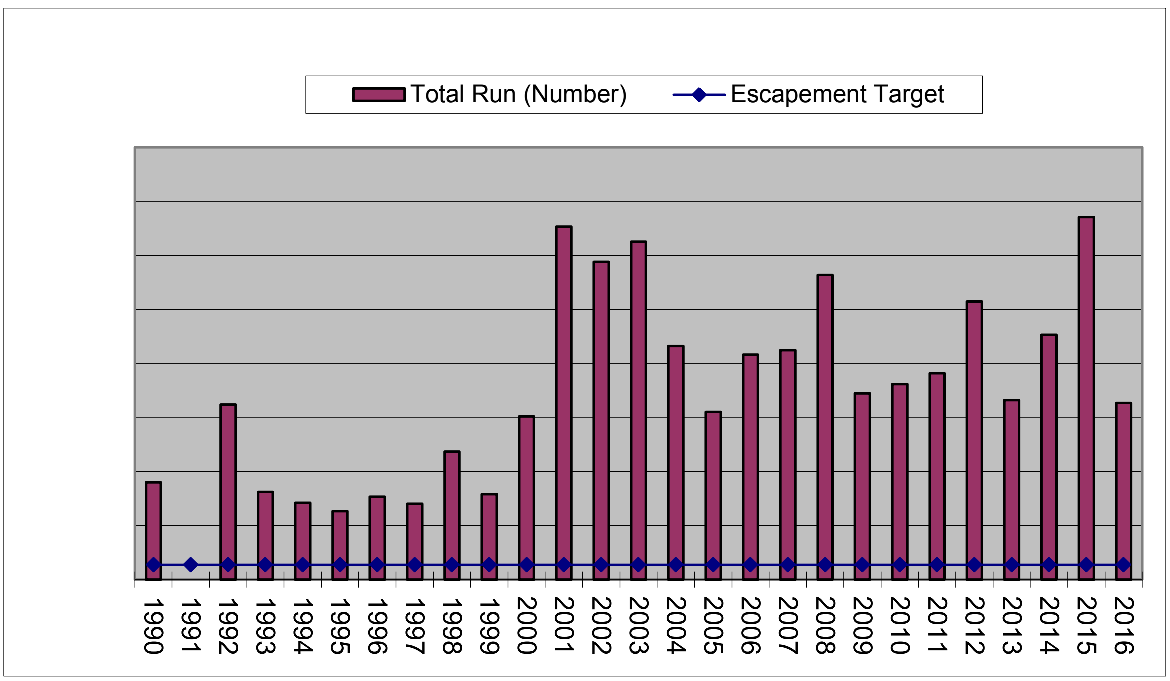
Figure 28. Historic picture of the Nequasset Mill and fish passage to spawning habitat and the trapping facility prior to 2014 rebuild.

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



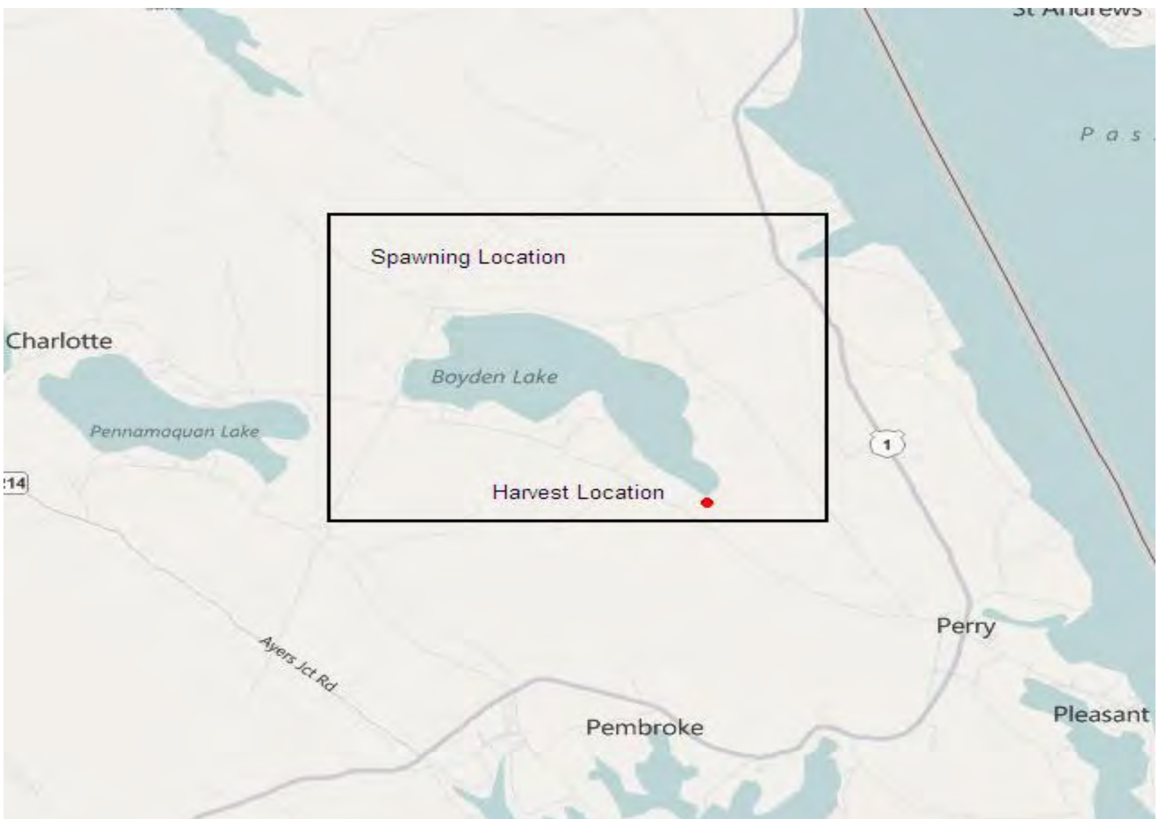


Perry Commercial Fishery:

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



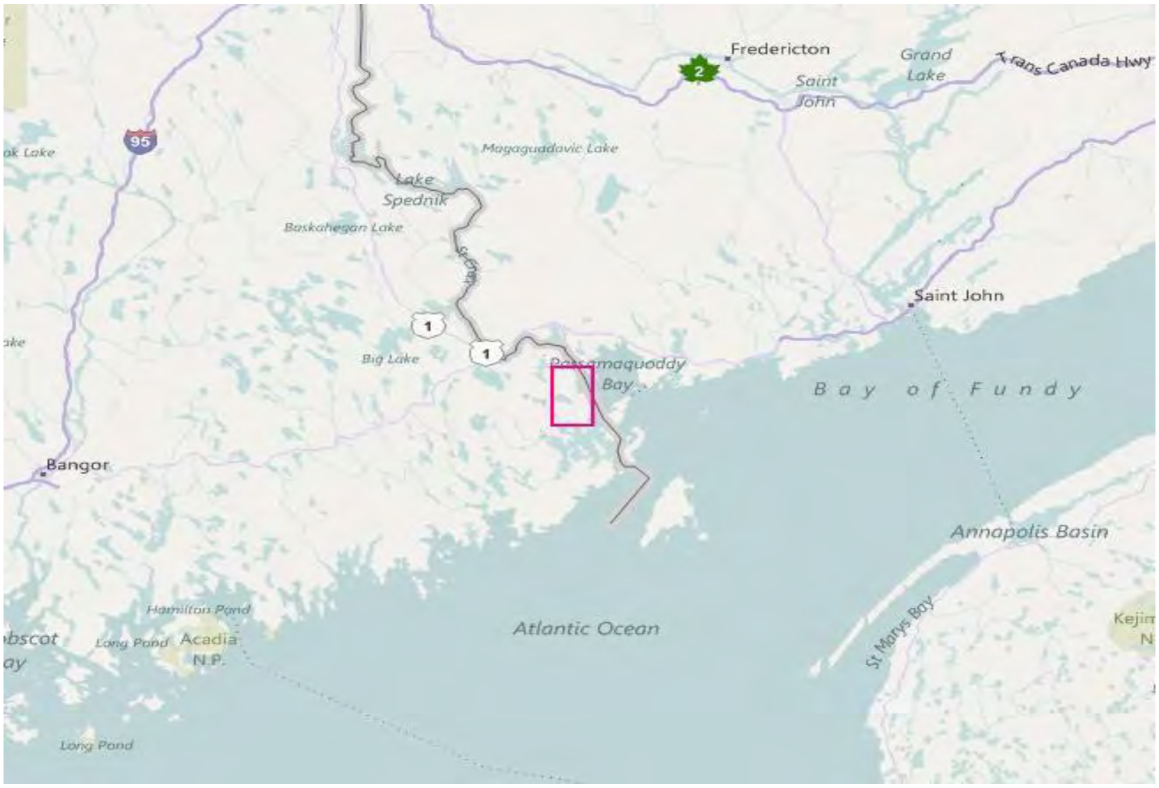
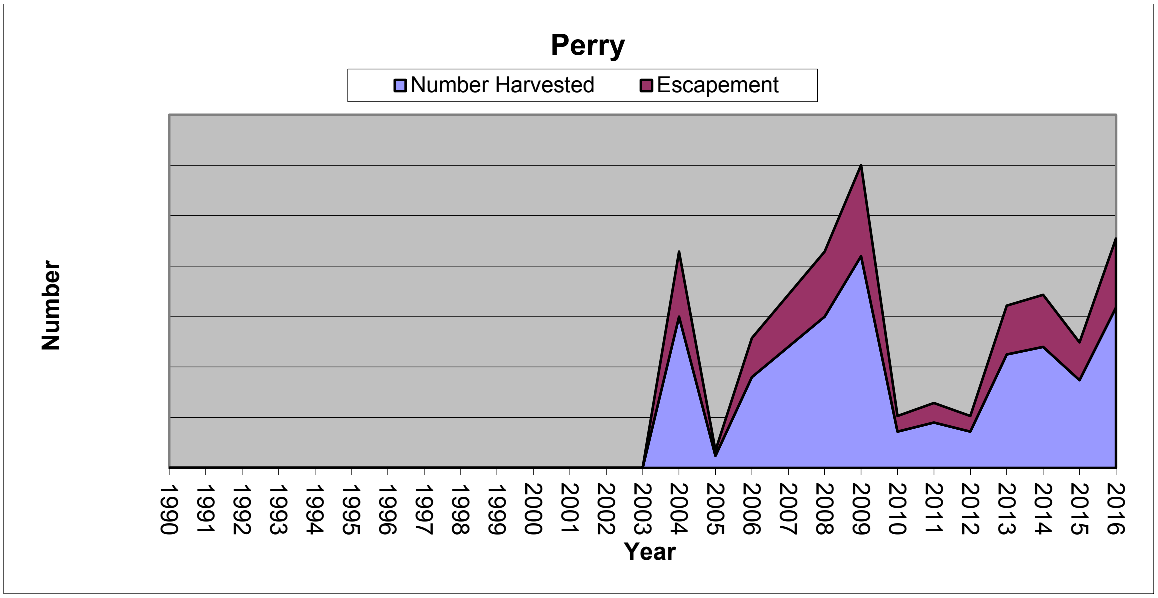
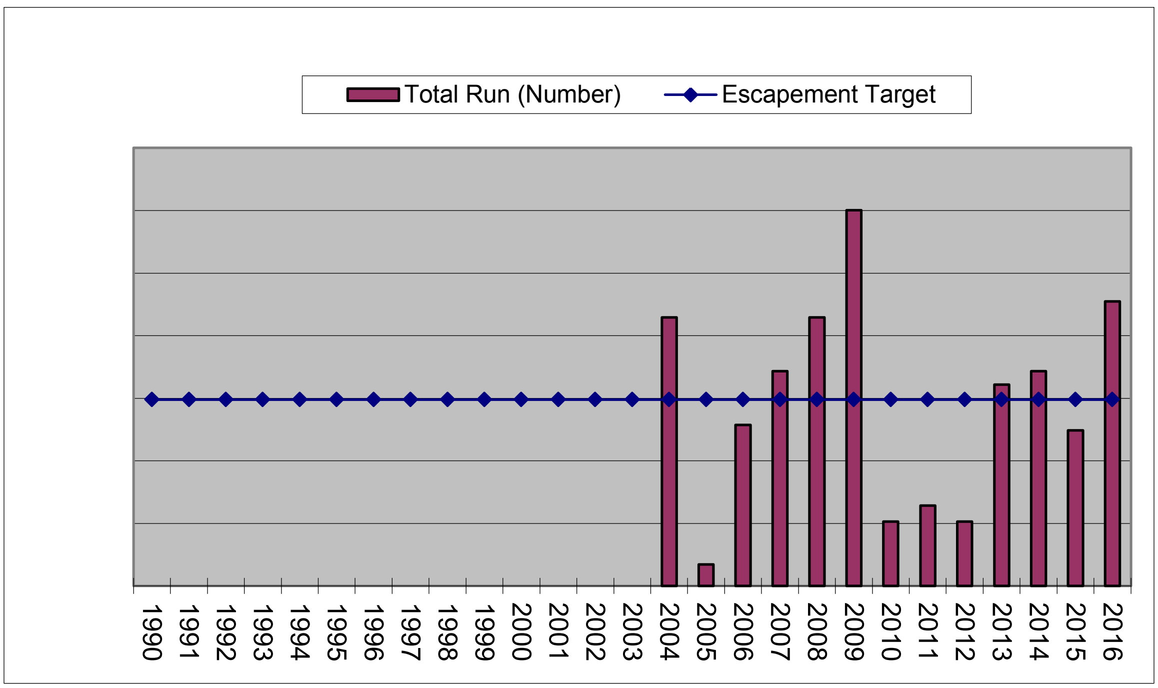


Figure 30. Dam and fishway under high flow conditions in 2006. Note harvest box and sluice pipe located at the corner pool of the fishway used to transport harvested fish into totes.

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



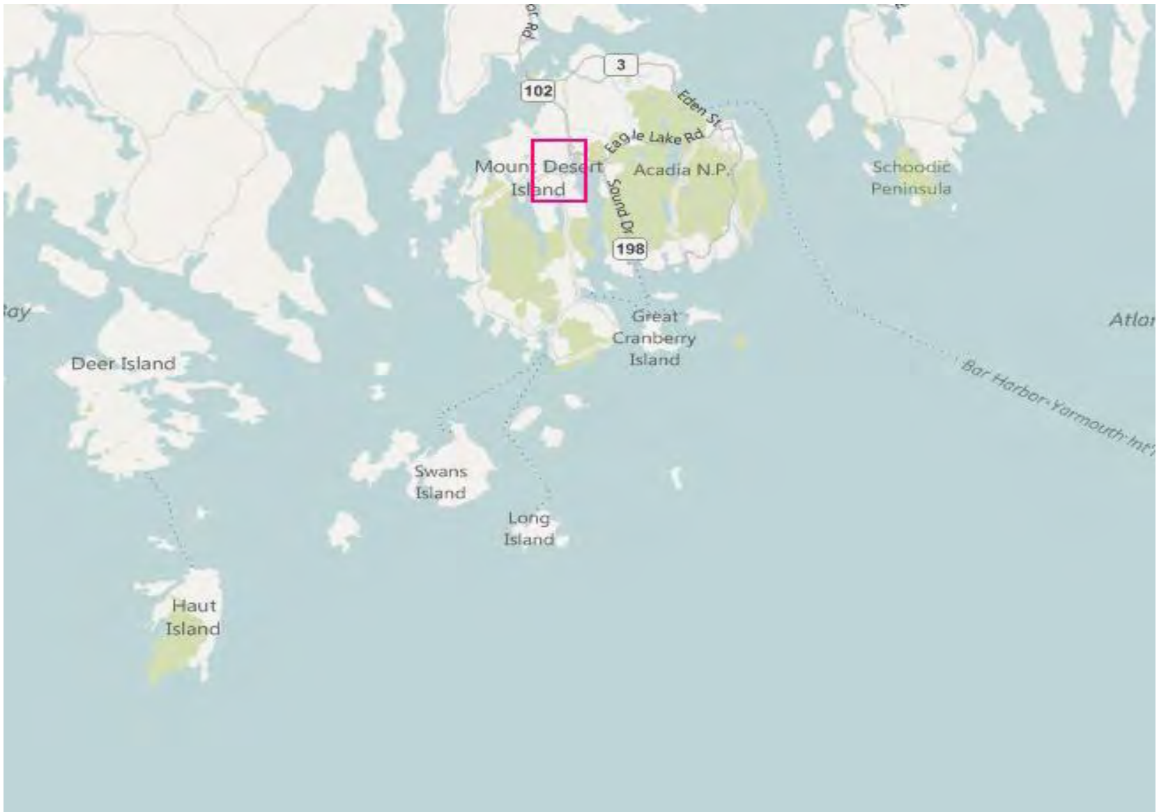


Mount Desert Commercial Fishery:

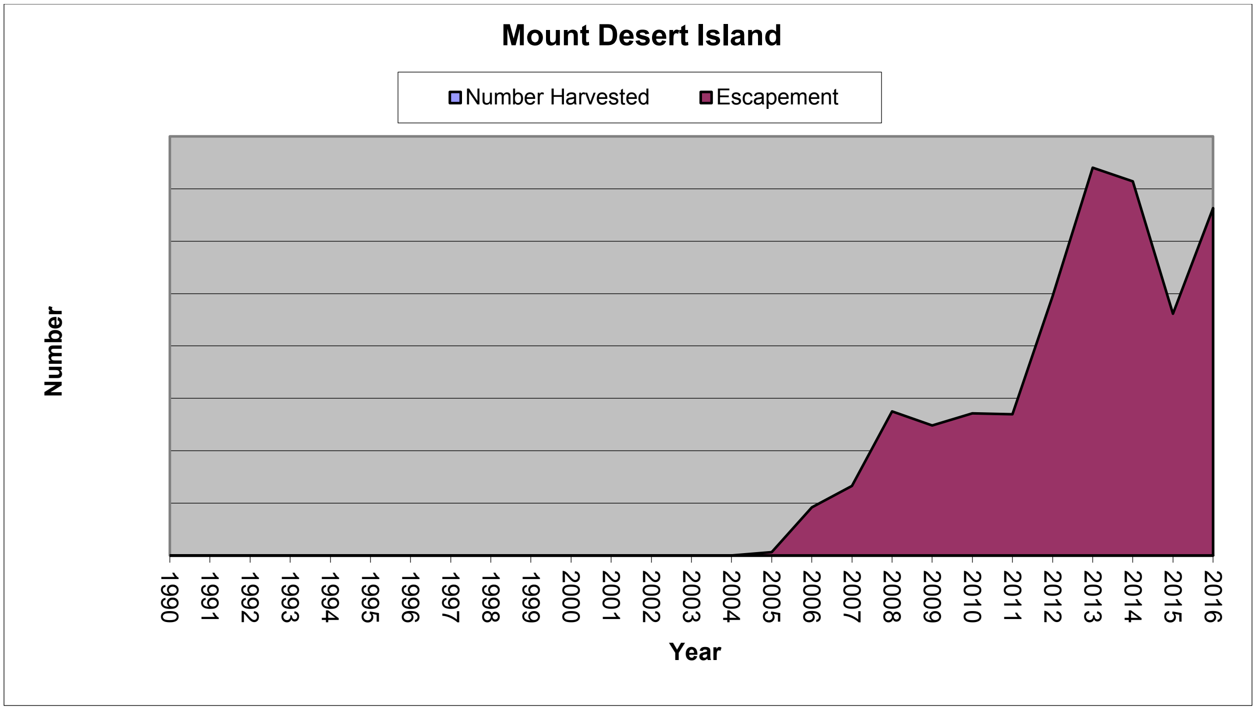
The Maine Department of Marine Resources manages this system for a minimum commercial escapement of 35 fish per acre. The spawning escapement need for this system is 3,640 river herring passed upstream. The municipality of Mount Desert selects to keep the run closed for conservation at this time, though 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.

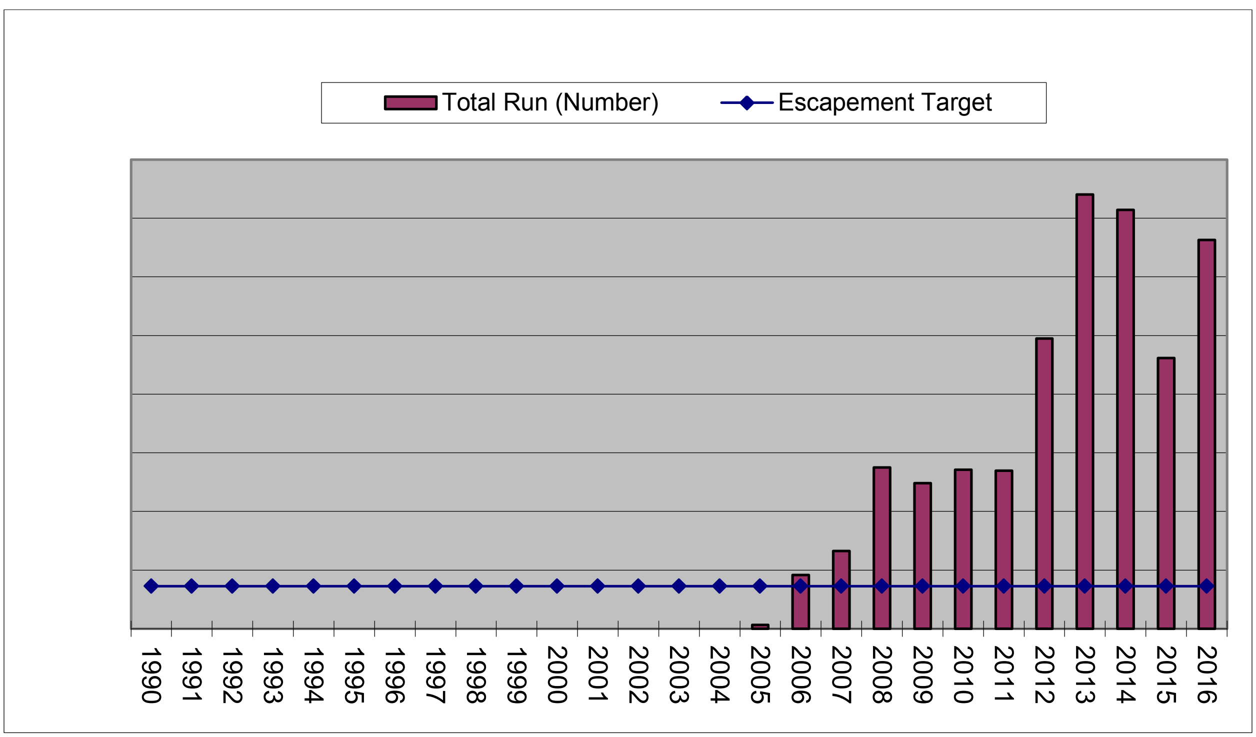
The fishway is a tidal fishway that is accessible only as the tide rises to meet the fishway entrance (Figures 31-32). This limits the opportunities for fish to access the fishway and spawning location upstream. This is common at several commercial harvest locations throughout the state. This emphasizes 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.





******FOR ASMFC SHAD AND RIVER HERRING MANAGEMENT BOARD REVIEW ONLY******

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

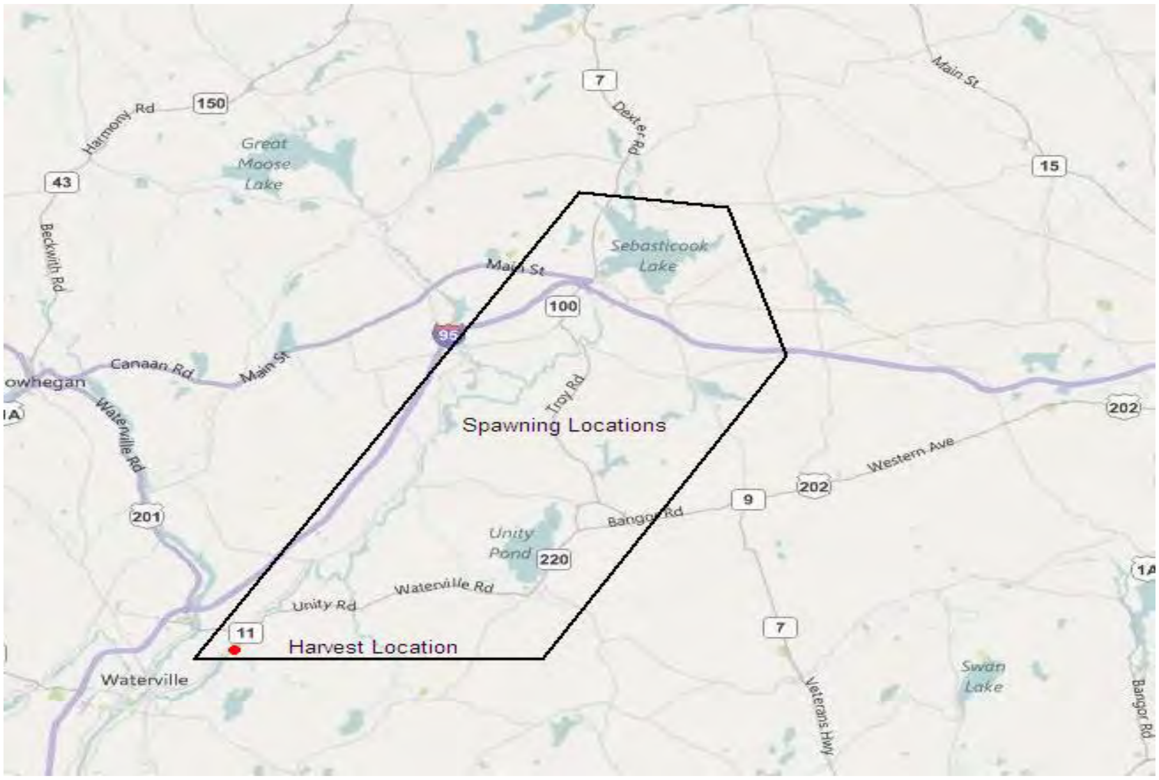
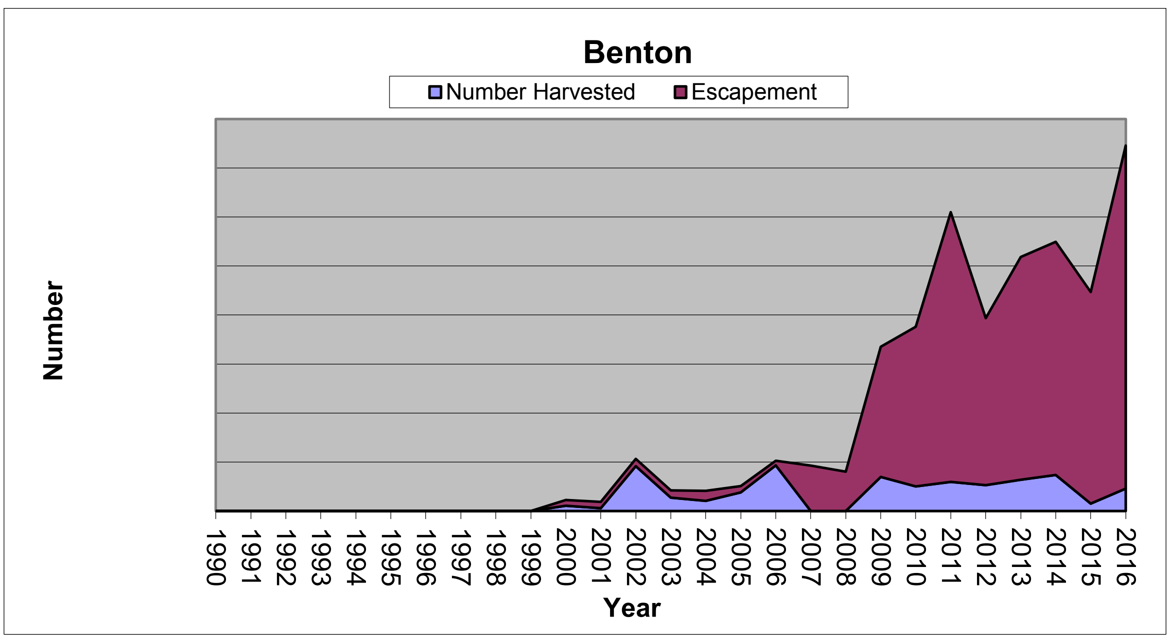
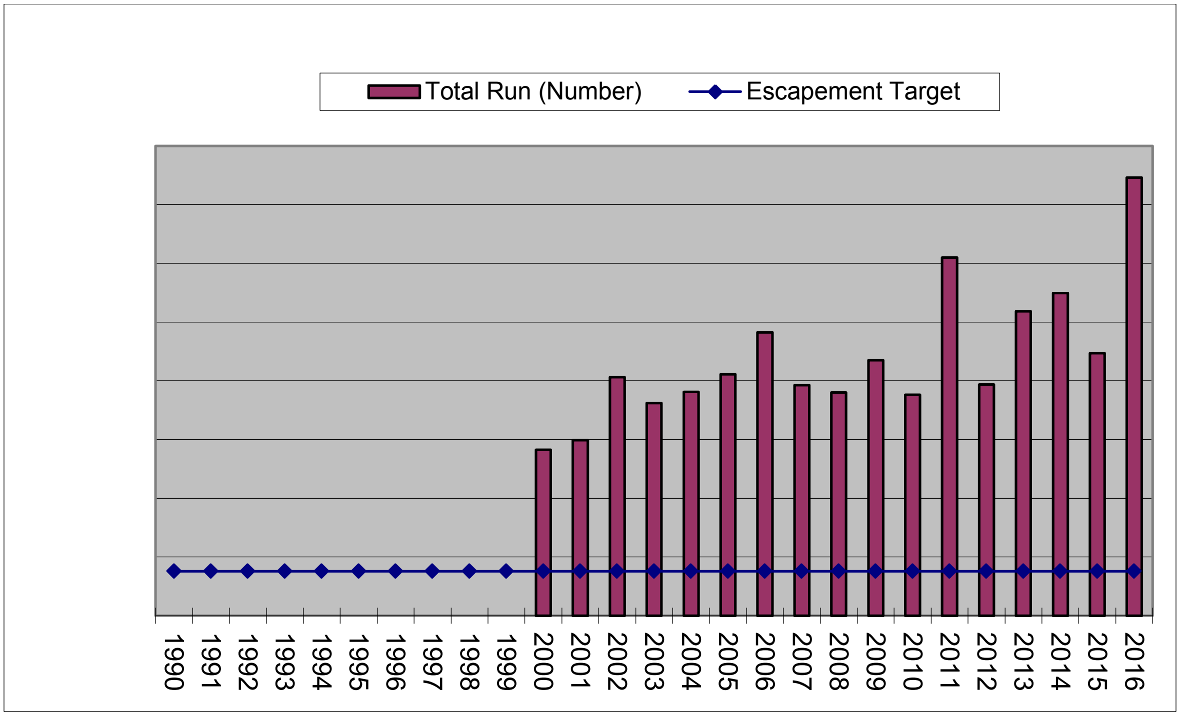


Figure 33. Benton Falls Hydropower Station. The commercial fishery occurs below the dam.

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

Fishing areas not controlled by a joint state/municipal management plan are open to recreational harvest. 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. Most recreational catches of river herring are used as bait to catch striped bass 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. Municipalities control most locations with accessible river herring runs through exclusive rights granted by the Department of Marine Resources.

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)

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.

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

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.

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.

The 2017 ASMFC River Herring Stock Assessment update may provide additional guidelines to review and monitor river herring fisheries coastwide.

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**

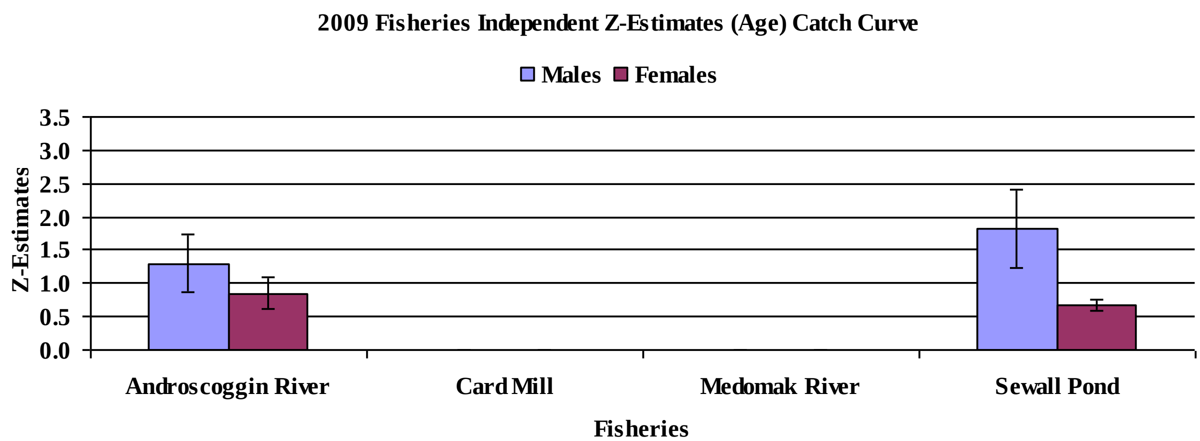
2009	Catch Curve				Heinke				Chapman-Robson			
	Male		Female		Male		Female		Male		Female	
Fishery	Z	SE	Z	SE	Z	SE	Z	SE	Z	SE	Z	SE
Damariscotta	-	-	-	-	2.56	0.92	1.87	0.60	2.56	0.92	1.95	0.63
Dresden	1.12	0.23	0.92	0.13	0.67	0.09	1.13	0.23	0.93	0.13	1.18	0.24
E. Machias	*2.00*	*0.63*	-	-	*1.22*	*0.15*	-	-	*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

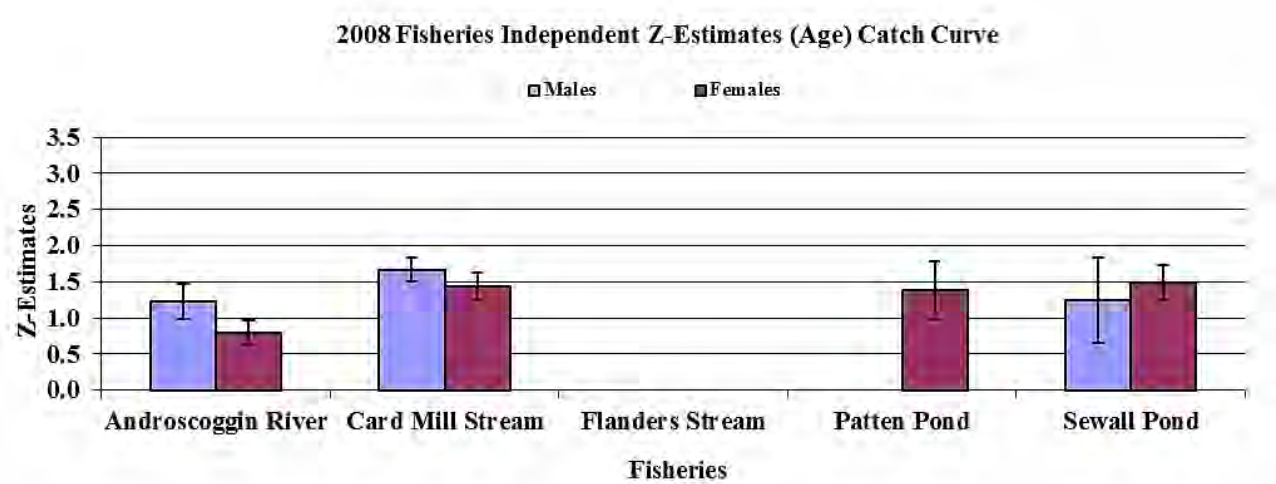
Sexes Combined

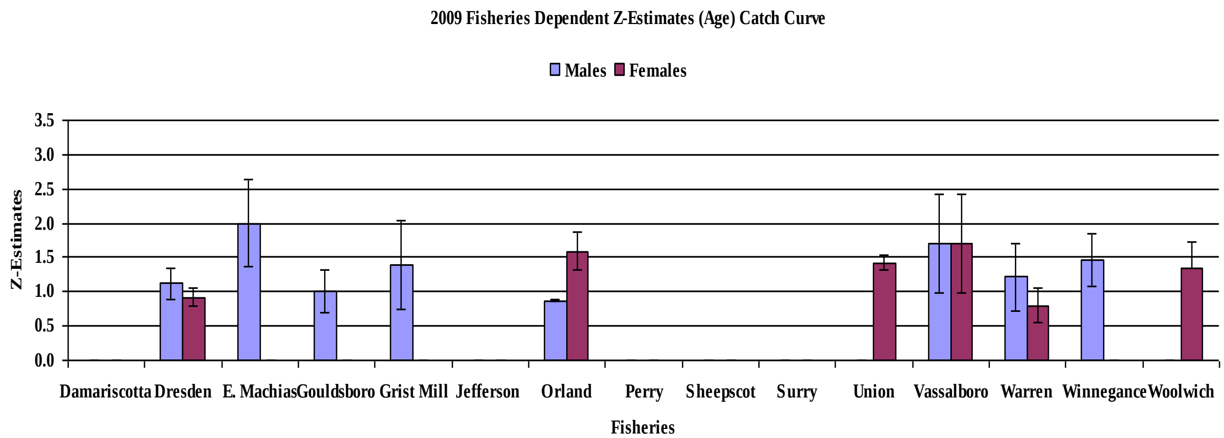
Fisheries Dependent Data **Age Based Z-Estimates**

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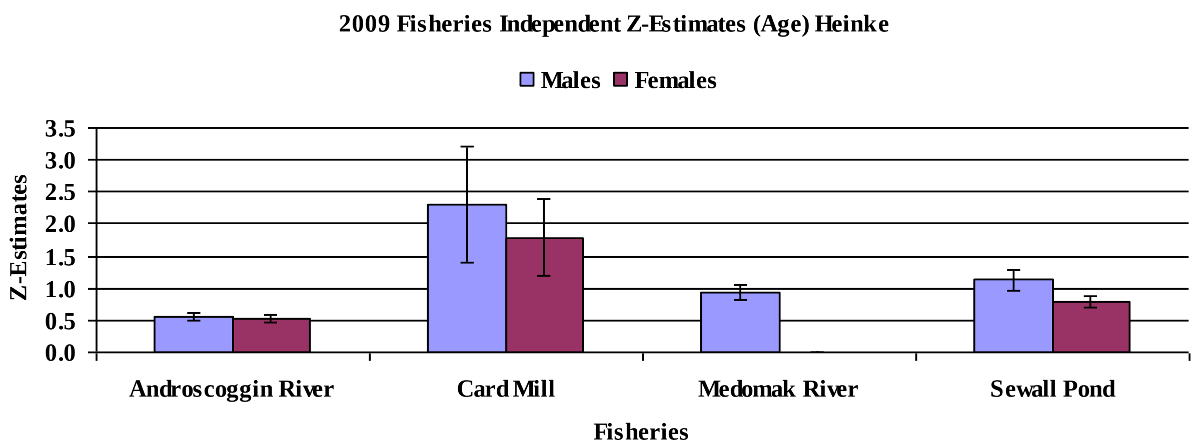
Sheepscot
Surry
Union
Vassalboro
Warren
Winnegance
Woolwich
Fisheries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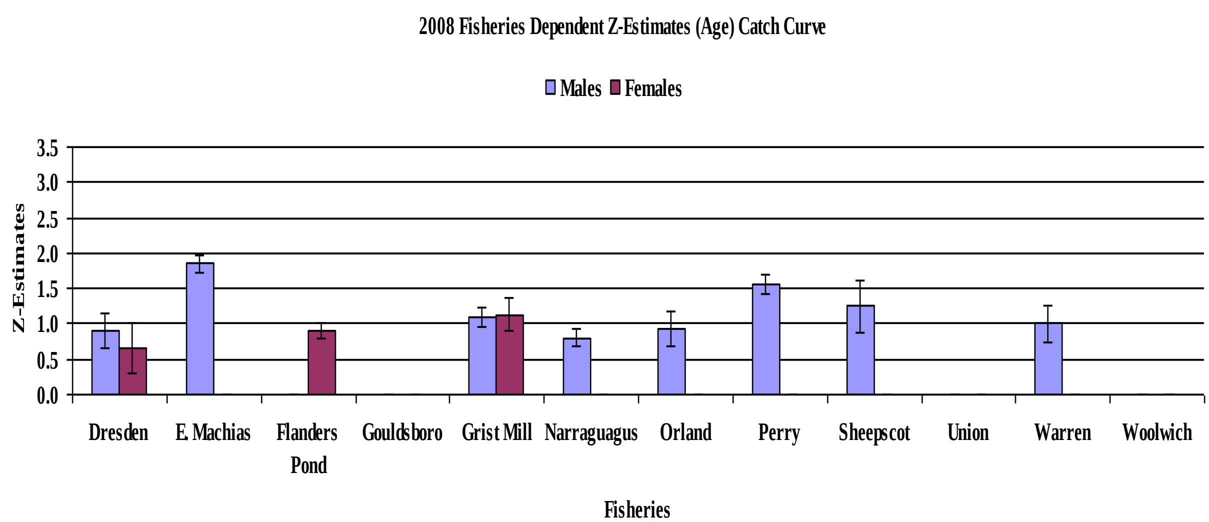
Card Mill
Medomak River
Sewall Pond
Fisheries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Females
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Dresden
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Orland
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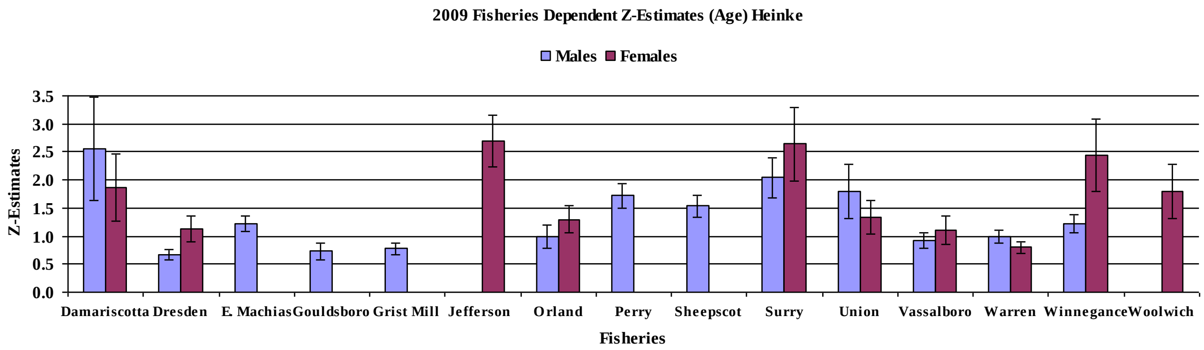
Woolwich
Fisheries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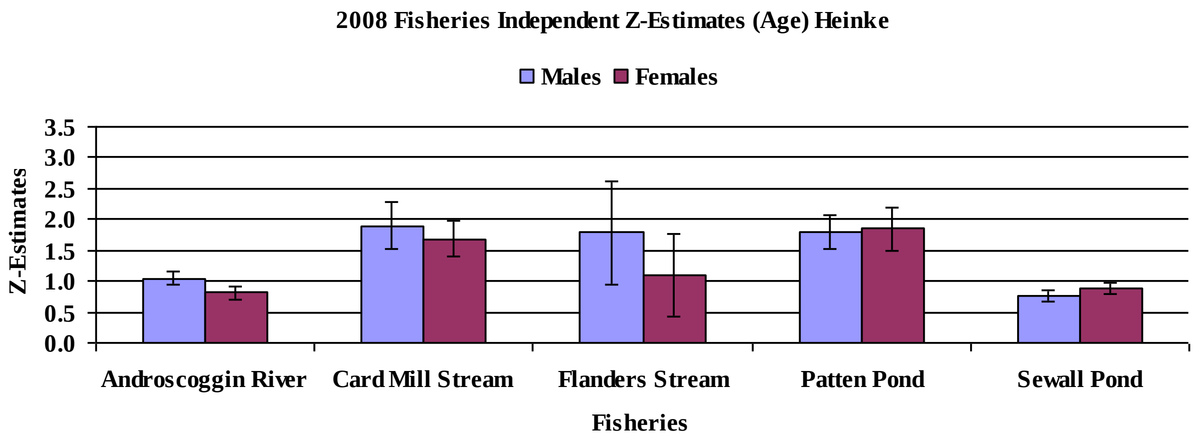
Damariscotta Dresden E. Machias Gouldsboro Grist Mill Jefferson Orland Perry Sheepscot Surry Union Vassalboro Warren Winnegance Woolwich
Fisheries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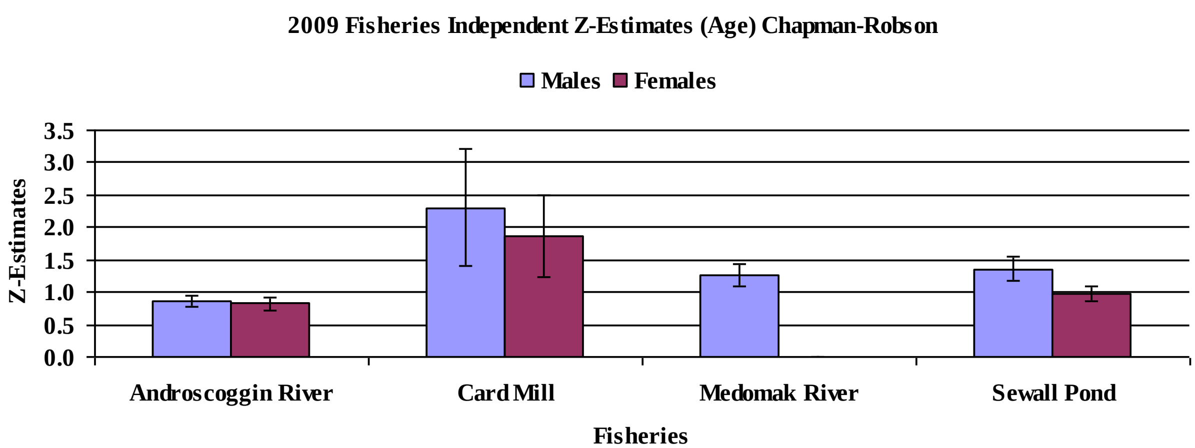
Card Mill Stream
Flanders Stream
Patten Pond
Sewall Pond
Fisheries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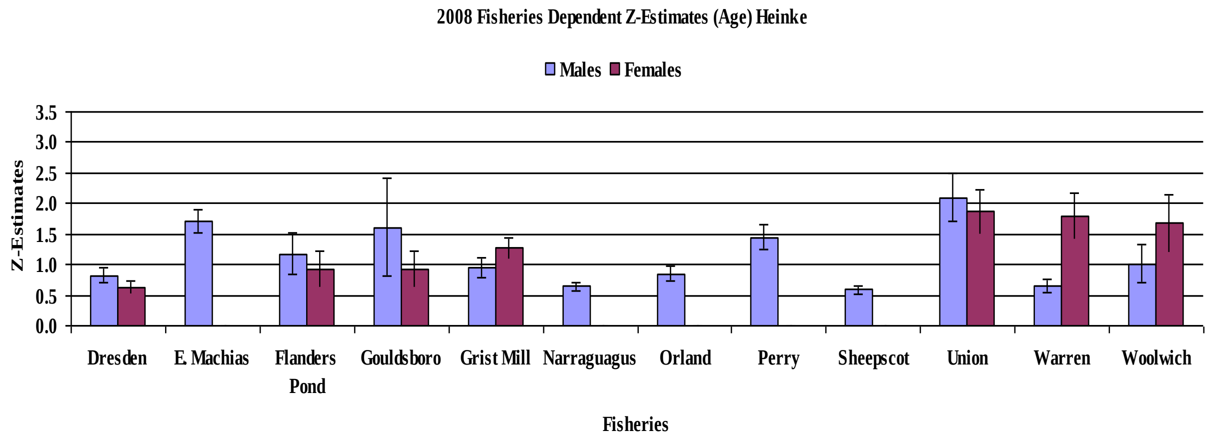
Card Mill
Medomak River
Sewall Pond
Fisheries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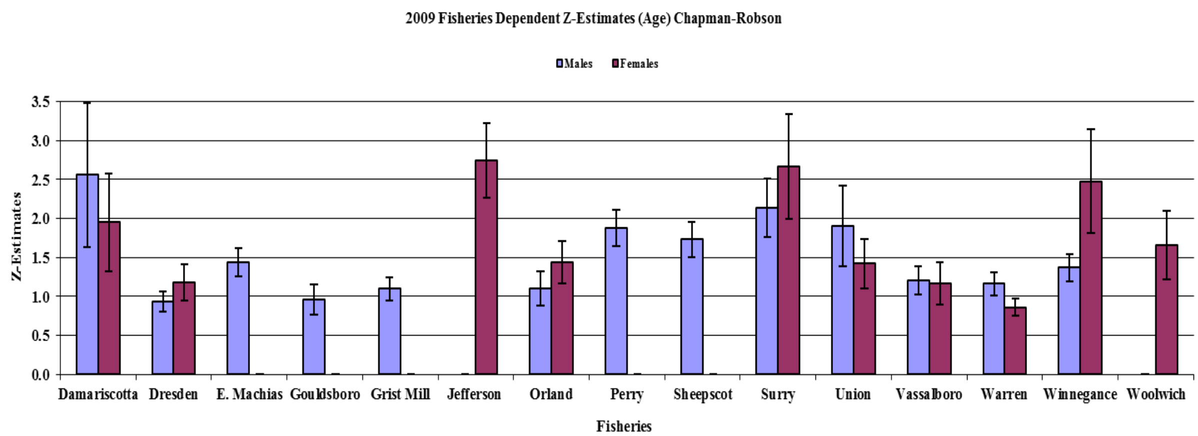
Fisheries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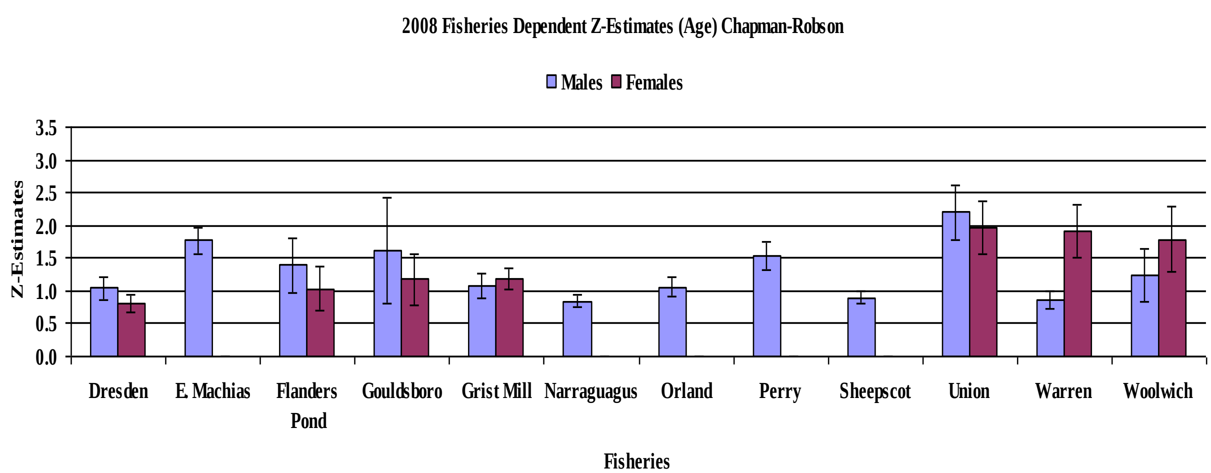
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Females
Z-Estimates
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Dresden
E. Machias
Flanders Pond
Gouldsboro
Grist Mill
Narraguagus
Orland
Perry
Sheepscot
Union
Warren
Woolwich
Fisheries

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 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.

STATE OF MAINE
DEPARTMENT OF MARINE RESOURCES
21 STATE HOUSE STATION
AUGUSTA, MAINE
04333-0021

PAUL R. LEPAGE
GOVERNOR

PATRICK C. KELIHER
COMMISSIONER

December 15, 2016

Ashton Harp
River Herring Fishery Management Coordinator
Atlantic States Marine Fisheries Commission
1050 N. Highland Street, Suite 200 A-N
Arlington, VA 22201

Re: Request to amend the Maine Sustainable Fisheries Management Plan to add Card Mill Stream in the Town of Franklin, Maine.

Dear Ms. Harp:

The Maine Department of Marine Resources requests to amend the current Sustainable Fisheries Management Plan to include Card Mill Stream in the town of Franklin, Maine. The Town of Franklin and the previous harvester request that Card Mill Stream be reopened to commercial harvest of river herring.

In 2010 the Department did not have sufficient biological data to justify keeping Card Mill Stream open to the commercial harvest of river herring. In 2011, Card Mill Stream was closed to commercial fishing as part of Maine's compliance with Amendment 2 to the Shad and River Herring Fisheries Management Plan. Since 2008 the State of Maine and Town of Franklin have worked to collect the biological information needed to move forward with a management plan for Card Mill Stream and Donnell Pond.

Attached are the data, justification and proposed management plan that would be implemented if this request is approved by the Management Board. If you have additional question please contact Michael Brown at (207) 624-6341

Sincerely,

Oliver Cox
Director, Division of Sea Run Fisheries and Habitat
Bureau of Marine Science

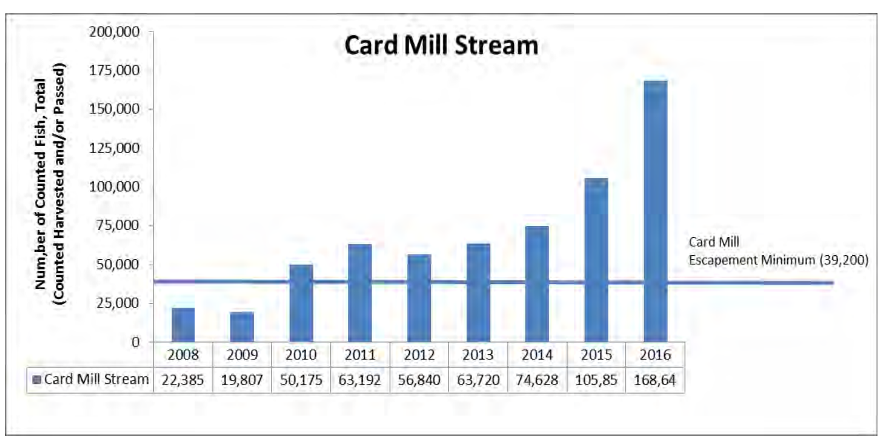
Proposed Donnell Pond River Herring Fisheries Management Plan and Sample Results 2008-2016

Prepared by the Maine Department of Marine Resources, Division of Sea-Run Fisheries

Summary:

Donnell Pond is a 1,120 acre oligotrophic lake located in T9SD and Franklin Twps at the base of Schoodic Mountain in Hancock County Maine. Donnell Pond has a maximum depth of 119 feet and supports a number of coldwater sport fish species including landlocked salmon, brook trout, lake trout rainbow smelt, and alewife (*Alosa pseudoharengus*). Much of the shore line remains undeveloped and a significant portion of the lake is owned by the Maine Bureau of Public Lands.

Donnell has supported a commercial fishery for river herring from 1969 to 2011. Harvest records indicate that the largest harvest recorded was 1,792 bushel in 1975 and the lowest recorded harvest was 29.5 bushel in 2007. Donnell Pond was harvested sporadically during the period 1985 through 2011. Harvest occurred only during the years of 1985, 1999, 2000, 2006, 2007 and 2011. The Maine Department of Marine Resources and the Town of Franklin decided to close the fishery at Donnell Pond in 2011 to assess the fishery. This management action was initiated to collect biological information to document unsustainability as required by Amendment 2. Due to the oligotrophic nature of the lake Donnell Pond is not as productive as some water of similar size and is most similar to the run harvested in the Maine town of Stueben which originates from the oligotrophic waters of Tunk Lake. Juvenile fish from both systems tend to be small and migrate from the lake early in July through mid-October. Run timing for adult prespawn alewives at Donnell Pond is early May through mid-June. Alewife is the only known river herring species documented in Donnell Pond, though one blueback herring was sampled in Card Mill Stream which is the migration route from the estuary to Donnell Pond.



The Atlantic States Marine Fisheries Commission adopted Amendment 2 to the Shad and River Herring Fisheries Management Plan in 2010, which, citing a concern about the coast-wide decline in river herring populations stated that all river herring (alewife and blueback herring) fisheries must close in 2012 unless states can demonstrate the population can be sustainably harvested. To comply with Amendment 2, the DMR closed all alewife and blueback herring harvests that it felt could not demonstrate a self-sustaining run and allow concurrent harvest which would not impact future broodstock availability.

The Donnell Pond run was closed to commercial harvesting in 2011 when the State of Maine and the Town of Franklin determined that the run was not large enough to harvest a significant number of river herring and maintain broodstock levels. In support of the Town of Franklin and the Donnell Pond river herring population the Department agreed to provide broodstock to increase the initial run size at Donnell Pond. In 2008 Donnell Pond received one supplemental stocking of 2,310 prespawn alewives from the Lockwood Dam on the Kennebec River. For the years 2009 through 2016 broodstock for the lake was the result of natural runs of native fish up Card Mill Stream and into Donnell Pond.

Darrell Young has collected biological samples from 2008 through 2016 from river herring making their annual spring migration into spawning habitat at Donnell Pond via Card Mill Stream. The biological samples, scale analysis by fisheries staff and run count data provide biological information including length at age, age distribution, and the number of repeat spawners we used to assess the health of the river herring population returning to Donnell Pond. The results of the data from fish sampled from Card Mill Stream and returning to Donnell Pond are described below for the years 2008-2016.

Species Composition:

Alewife

Blueback Herring

Scale samples collected from the Card Mill and adjacent Grist Mill runs indicate that these runs are composed almost entirely of alewives. However, one blueback herring was found in 2009 in Card Mill Stream (Table 1). This fish was likely a stray blueback herring from a neighboring run. Additional blueback herring may be encountered if sampling is performed later in the season, but historically blueback herring were never harvested commercially at the Donnell harvest location. The latest sampling date has been June 1 (in 2012). Sampling into June may show more blueback herring because blueback herring run later than alewives. The one blueback herring found in the samples may also have been a product of stocking efforts. The river herring stocked from the Lockwood Dam on the Kennebec River have both alewife and blueback herring as part of their runs. When Donnell Pond was stocked 2008, some blueback herring may have been transported as part of the stocking effort.

Table 1. Species Compsition for Card Mill Stream/Donnell Pond

	Alewife	Blueback Herring
Franklin - Card Mill Stream		
2008	100.00%	
2009	99.20%	0.80%
2010	100.00%	
2011	100.00%	
2012	100.00%	
2013	100.00%	
2014	100.00%	
2015	100.00%	
2016	100.00%	

Gender Ratio:

The gender information for the Franklin runs was recorded at the time of sample collection and shows a relatively equal proportion of males to females in most years (Table 2). The Card Mill Stream samples

Table 2. Sex Ratios for Card Mill Stream/Donnell Pond Alewife Run

	Female	Male
Franklin - Card Mill Stream		
2008	52.5%	47.5%
2009	52.0%	48.0%
2010	45.6%	54.4%
2011	47.4%	52.6%
2012	50.0%	50.0%
2013	41.3%	58.7%
2014	53.0%	47.0%
2015	47.0%	53.0%
2016	50.0%	50.0%

indicate males were slightly more, or as numerus most years. During 2013 a significantly larger number of males were sampled compared to all other years sampled. The reason for the large difference between male and females during 2013 is unknown.

Age Distribution:

Both alewife and blueback herring in Maine are fully recruited to the spawning run at age-4. In Maine, we see some age-3 river herring in our biological samples but do not expect to see large number of 3-year old fish participating in the spring spawning runs. River herring at Donnell Pond do not die after they spawn and attempt to migrate back to coastal waters. The next spring these fish will make a second spawning migration into freshwater rivers and streams. River herring in Maine have been observed to make as many as 5 annual spawning migrations, every year from age-4 until it they were captured at age-8. Analysis of the Card Mill Stream samples indicated an increasing number of repeat spawners returning to Donnell Pond.

Table 3. Proportion at Each Age for Card Mill Stream/Donnell Pond

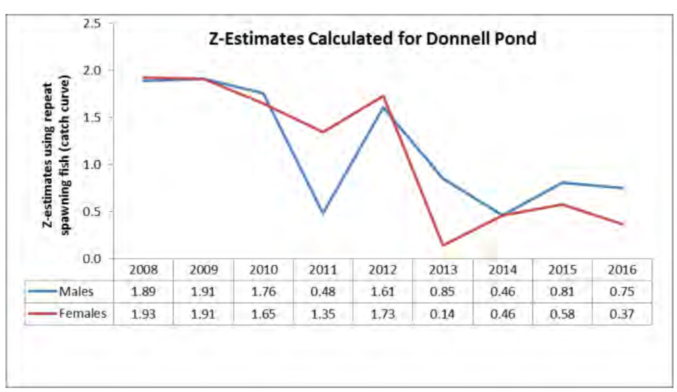
	Age-3	Age-4	Age-5	Age-6	Age-7^{+}
Card Mill Stream					
2008	23.0%	63.0%	11.0%	3.0%	
2009	14.8%	70.4%	14.8%		
2010	2.5%	82.3%	12.7%	2.5%	
2011	3.5%	71.2%	25.4%		
2012		87.6%	11.1%	1.4%	
2013	4.4%	21.6%	66.1%	7.9%	
2014	9.0%	40.0%	7.0%	41.0%	3.0%
2015	8.5%	53.2%	21.3%	4.3%	12.8%
2016	1.0%	36.0%	48.0%	12.0%	3.0%
Mean	**8.3%**	**58.4%**	**24.2%**	**10.3%**	**6.3%**

Length and age information yields important insights into the health of a fish population. As a general rule, the presence of a variety of age classes is indicative of a healthy population. Populations containing older and larger individuals, which have a relatively high reproductive potential, are considered healthier than those containing only younger or smaller individuals. While all alewife runs in Maine are dominated by age-4 fish, we find that a run with an evenly distributed age structure is more stable over time (Table 3). To achieve an accurate picture of the age distribution of the run into Donnell Pond the population was sampled each week for four consecutive weeks. Early in the season, older fish age 5-8 dominated the run. Later in the season the run was comprised of younger fish, ages 3-4. The run at Donnell Pond indicates an improvement in age class structure and an increasing number of fish age 7^{+} during 2014 – 2016.

Table 4. Z-estimates and Sample Numbers for Donnell Pond

(repeat spawners)	Males	Females	Sample Number	Repeat Spawning
2008	1.89	1.93	100	8.1%
***2009**	1.91	1.91	125	22.2%
2010	1.76	1.65	160	21.8%
2011	0.48	1.35	165	31.6%
2012	1.61	1.73	100	13.9%
2013	0.85	0.14	100	76.2%
***2014**	0.46	0.46	100	52.3%
2015	0.81	0.58	100	34.0%
2016	0.75	0.37	100	60.0%

*sexes combined



In general, a run comprised of older fish corresponds to higher survivability and lower mortality rates. Mortality rates can be influenced by many factors, including at-sea mortality, success of juvenile emigration from spawning areas, direct harvest, bycatch and adult mortality during the spawning run. Runs with consistently low mortality rates are indicative of stable populations and indicate the potential for supporting a sustainable harvest.

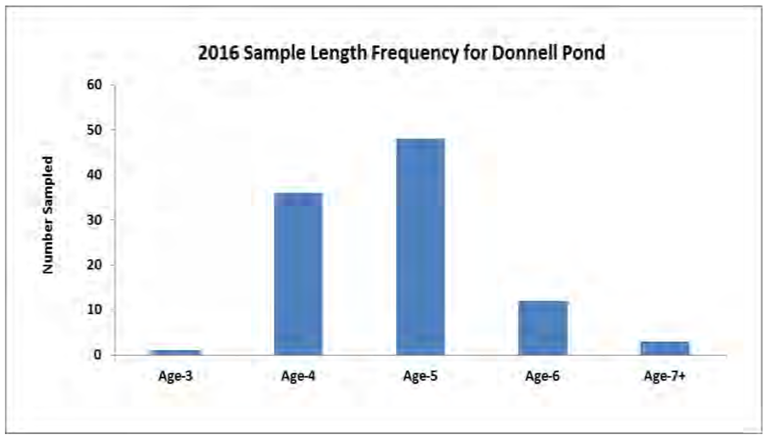
The Z-estimates calculated from the scale samples collected from 2008 through 2016 show declining mortality rates for males and females (Table 4). The corresponding number of repeat spawning fish returning to Donnell Pond supports the observations that older, multi-year spawning fish are contributing to the population. The Z-estimates calculated for Donnell Pond are lower than the majority of our existing commercial river herring fisheries.

Length Distribution and Length at Age:

In general, populations containing larger individuals, which have a relatively high reproductive potential, are considered healthier than those where fish are smaller. In some cases, we can identify a stressed fish population as the average size of all the fish in the run decreases over time. The average size of an alewife run may get smaller because of selective fishing pressure on larger individuals, or because of environmental constraints like limited food availability. Some populations may be smaller, however, not because of environmental stress or fishing pressure, but because they are a different "stock" of fish, whose genetic make-up influences their size. Comparing the average length at each age among different runs, and among different years for the same run, indicate whether the population may be experiencing stress, or together with other information like genetics, if the lengths of the fish in the run may be representative of an individual "stock".

Table 5. Average Length at Age for Card Mill Stream/Donnell Pond

		Age-3	Age-4	Age-5	Age-6	Age-7
Card Mill Stream						
2008		252.8	268.6	282.4	294.3	
2009		252.3	267.2	281.6	295.1	
2010		235.0	265.7	286.2	289.0	
2011		235.0	270.3	280.6		279.0
2012			263.0	284.0	305.0	
2013		254.0	275.5	279.9	299.6	
2014		255.0	270.9	274.1	282.1	312.0
2015		253.4	266.5	281.4	290.9	301.1
2016		245.0	263.1	279.6	288.0	281.8
Mean		**247.8**	**267.9**	**281.1**	**293.0**	**293.5**



Twenty-five fish were sampled from Card Mill Stream each week throughout the run. As the run into Donnell Pond progressed, it was comprised of an increasing number of smaller individuals. These fish were not only younger than the fish sampled at the beginning of the run, but also smaller at each age. For example, a four-year-old alewife sampled during the first week of the run might be larger than a four-year-old alewife that comes during the last week of the run. The length data collected indicates that the mean length of fish increased with age (Table 5) and that lengths at age-3, age-4, and age-5 is fairly stable among the years. In addition, the numbers of fish greater than age five have increased since the fishery was closed in 2011.

Repeat Spawning:

From analyzing river herring scales we can determine if an individual is making its first spawning migration, or whether the fish spawned in one or more previous years. During the spawning migration river herring reabsorb portions of their scales. The distinct marks left on that result from scale erosion are called spawning checks. We term this behavior of returning in subsequent years to spawn "repeat spawning". When a fish is a "repeat spawner" it means it successfully migrated to the spawning grounds, then back out to the ocean, and then back to freshwater again the next year. A run with a high proportion of "repeat spawners" indicates a stable spawning population over time. Runs with low numbers of "repeat spawners" may have a problem with passage obstructions or over-harvesting. Samples from the Donnell Pond run show that the proportions of repeat spawning fish have increased since 2012 (Table 6).

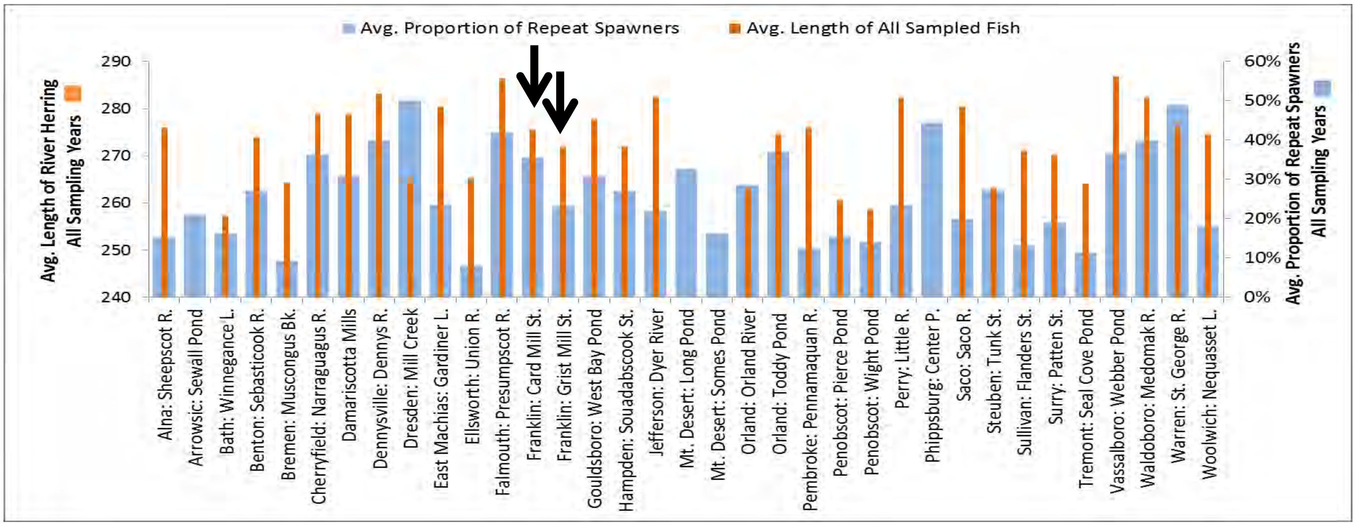
Table 6. Proportion of River Herring that Spawned in Previous Years

	First Time Spawners	Spawned in 1 Prev. Year	Repeat Spawned 2X	Repeat Spawned 3X
Card Mill Stream				
2008	92.0%	6.0%	2.0%	
2009	77.8%	22.2%		
2010	78.5%	19.0%	2.5%	
2011	68.4%	29.8%	1.0%	1.0%
2012	86.1%	12.5%	1.4%	
2013	23.8%	68.3%	7.9%	
2014	13.0%	47.0%	37.0%	3.0%
2015	66.0%	17.0%	8.0%	9.0%
2016	40.0%	44.0%	13.0%	3.0%

Comparing the Card Mill Samples to Other Runs:

Samples from the river herring runs in the town of Franklin (Donnell Pond and Grist Mill Stream) can be compared to other runs in the state where biological samples are collected. In comparison to other runs, the average length of the river herring from Card Mill Stream was larger than 16 of the other 32 sampled runs, and smaller than 16 other runs. Statistically, this means that the average length of fish from Card Mill Stream falls into the "2nd Quartile", where about 50% of runs have lengths larger than the river herring from Card Mill Stream, and about 25% of runs have lengths smaller. Comparing the proportion of "repeat spawners" at Card Mill Stream to other runs, 25 of 35 other sampled runs have fewer "repeat spawners", while 10 have a higher proportion of "repeat spawners". Statistically, this puts the Card Mill Stream run into "3rd Quartile", where 25% of the other runs have a higher proportion of "repeat spawners", and about 50% of runs have fewer "repeat spawners".

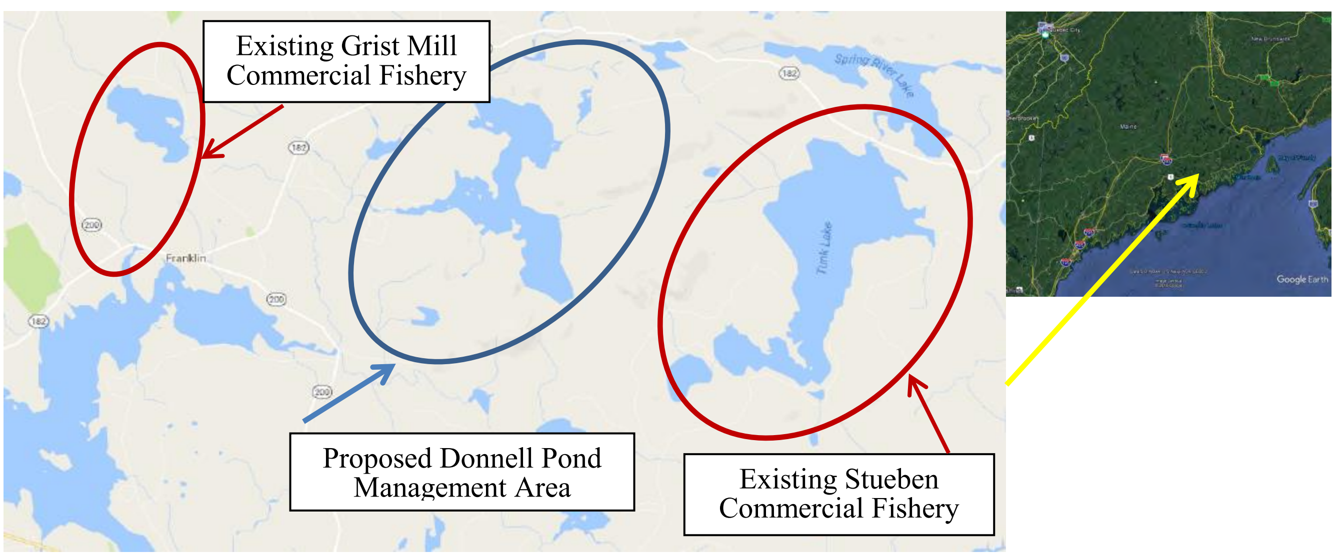
For the Grist Mill Stream run, the closest existing commercial fishery to Donnell Pond, the average length of the river herring was larger than 12 of the other 32 sampled runs, and smaller than 19 other runs. Statistically, this means that the average length of fish from Grist Mill Stream falls into the "2nd Quartile". Comparing the proportion of "repeat spawners" at Grist Mill Stream to other runs, 15 of 35 other sampled runs have fewer "repeat spawners", while 19 have a higher proportion of "repeat spawners". Statistically, this puts the Grist Mill Stream run into "2nd Quartile", where 50% of the other runs have a higher proportion of "repeat spawners", and about 25% of runs have fewer "repeat spawners".



Management Units:

During the development of Amendment 2 the Department of Marine Resources chose to continue to manage each river herring run individually versus development of a statewide or river system management plan. Tagging studies conducted in Maine indicate high site fidelity for alewives during their spawning runs and believe these runs are distinct populations. Implementing management measures based on distinct spawning populations achieves management goals specific to the population being managed.

The proposed management unit for the Donnell Pond alewife fishery will be Donnell Pond and Card Mill Stream which leads from tidewater to Donnell Pond.



Sustainability Measures:

Continue annual fisheries dependent sampling and periodic fisheries independent sampling to collect information on the health of the population of river herring returning to Donnell Pond. Run count, escapement, age, length frequency, repeat spawning, mortality estimates and harvest data will collected and analyzed annually to measure run metrics and assess run health.

Sustainability Target (Threshold):

The sustainability threshold for Donnell Pond is escapement of broodstock equal or greater than 35 spawning fish per surface acre of Donnell Pond.

Proposed Harvest Management:

The proposed management for Donnell is similar to that in all Maine's commercial river herring fisheries. Harvest will be limited to one individual from the onset of the river herring run to June 5th, which is the end of the directed municipal river herring fishery in Maine. In addition, an extra closed day will be added to allow an estimated escapement rate of 57% of the total run after the initial sustainability threshold id achieved for Donnell Pond (39,200 fish)

Proposed Harvest Plan for Donnell Pond:

- Allow only one harvester to lease the harvest right to Donnell Pond.
- Require passage of first 39,200 river herring to guarantee minimum broodstock escapement for Donnell Pond.
- Allow harvest from sunrise Sunday to sunset Wednesday during the season and ending June 5th of the fishing year.
- Prohibit harvest from sunset Wednesday to sunrise Sunday during the season and ending June 5th of the fishing year

Sustainability Threshold and Management Action from Maine's SFMP:

The sustainability threshold of 35-fish per acre of spawning habitat was developed through a combination of studies, observations, and documented commercial catches over a 13 year period. Maine uses this sustainability threshold as a baseline for continuing commercial fisheries that require escapement of broodstock from river specific populations.

Since 1984, MDMR has used 235 fish/acre to estimate 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.

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.

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. 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 the population achieves the escapement goal.

American Shad Habitat Plan

State of Florida

Florida Fish and Wildlife Conservation Commission
Fish and Wildlife Research Institute
Division of Marine Fisheries Management

Reid Hyle
reid.hyle@myfwc.com

July 2014

Introduction

Amendment 3 to the Interstate Management Plan for Shad and River Herring cites habitat loss and degradation as major factors in the decline of and continued depression of populations of American Shad along the Atlantic coast and requires member states to develop habitat plans for American Shad in their jurisdiction. This plan is submitted to serve as the required habitat plan for the State of Florida. It outlines historic and current habitats available to American Shad in Florida and identifies known threats to those habitats as well as efforts to mitigate those threats.

The primary spawning run of American shad in Florida historically was and currently is in the St. Johns River. The only other river lying within Florida in which spawning has been documented historically (Williams and Bruger 1972) and recently (Holder et al. 2011, Dutterer et al. 2011) is the Econlockhatchee River which is a tributary to the St. Johns River. The St. Marys River is along the eastern border between Georgia and Florida historically supported a population of American Shad. This plan includes these three systems.

The Ocklawaha River is the largest tributary of the St. Johns River and 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. However, the Ocklawaha River is discussed briefly at the end of this plan because advocates for removal of the dam often cite American Shad as among migratory species that would benefit from dam removal.

St. Johns River

1) Habitat Assessment

   General: The St. Johns River emerges from the headwater marsh in Indian River and Brevard Counties and flows approximately 450 km north to the mouth in Jacksonville. Several broad shallow lakes lie within the run of the river. Stream gradient is small with the river bottom dropping 4 m between rkm 450 and rkm 314. The river bottom is at or below mean sea level downstream of rkm 314. American Shad spawn in the St. Johns River from January through April which corresponds to the declining flows of Florida’s dry season (Kelly and Gore 2008).

   a. Spawning Habitat
      i. Historic spawning grounds were documented from rkm 230 to rkm 433 near the headwaters (Williams and Bruger 1972). Of that distance 160

km 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).

ii. A weir built at the outlet of Lake Washington (rkm 415) in 1976 blocks access to approximately 14 km of potential spawning habitat in the uppermost river. Current spawning habitat identified by egg collection (Miller et al. 2012b) and telemetry (Dutterer et al. 2011) is between rkm 230 and the weir at rkm 415. Primary spawning areas are still between rkm 275 and 360. Approximately 146 kilometers of potential habitat remains available for spawning depending on water level.

b. Rearing Habitat

i. Historical in-river and estuarine rearing habitat included 95 km of river between Lake George and Lake Harney, 260 km^2 of lakes within the run of the river, and 105 km of tidal freshwater estuary between Black Creek and Lake George.

ii. All historical rearing habitats are still available.

2) Threats

a. Barriers

i. Low head dam at rkm 415. Crest height of 3.8m NAVD 1988 is 1 m above the river surface at low stage.

1. Action: None. Dam obstructs access to less than 10% of historical spawning habitat. Preferred habitat is between rkm 275 and rkm 360.
2. Regulatory Contact: St. Johns River Water Management Disctrict (SJRWMD).

b. Water Withdrawals Inventory and Assessment

i. Consumptive use permits are coordinated through the SJRWMD. There is a proposal to allow withdrawal of up to a total of 262 million gallons per day (mgd) of surface water from the basin with a total of 155 mdg from several sites along the middle and upper St. Johns River. The District completed the St. Johns River Water Supply Impact Study (WSIS) in 2012 (Lowe et al. 2012). The intent of the WSIS "was to provide a comprehensive and scientifically rigorous analysis of the potential environmental effects to the St. Johns River associated with annual average surface water withdrawals as high as 262 mgd" (155 mgd from the St. Johns River and 107mgd from a tributary). Chapter 12 focused on fishery impacts of the proposed withdrawals with special consideration given to anadromous herrings in appendix 12-C (Miller et al. 2012a and 2012b). Key findings are as follows.

1. WSIS found that impingement/entrainment of anadromous herring eggs and larvae could occur at all proposed intake sites and could be potentially significant at two locations under consideration. The WSIS recommended reducing the impingement/entrainment risk to alosines by considering: intake designs that are safer for ichthyoplankton, alternative intake locations to avoid core spawning locations of American Shad, and curtailing withdrawals on the spawning grounds during the spawning season at sites with high egg/larval abundance.
2. WSIS found that optimal spawning habitat for American Shad as delineated by depth and velocity shrinks under low flow conditions. WSIS finds that access to spawning grounds and acreage of spawning grounds will not be adversely affected by withdrawals due to offsetting effects of base flow augmentation by the Upper Basin Restoration Project. The frequency and duration of low flow events are expected to decline only slightly under modeled expected scenarios.

FWC should coordinate closely with SJRWMD after consumptive use requests for surface water withdrawals have been submitted by an applicant, to ensure the requested withdrawals will not negatively impact American Shad. In particular, withdrawals should not interfere with the ability of American Shad to reach their spawning grounds, nor should potential egg/larval entrainment be excessive. Coordination should include review of potential hydrologic impacts of the proposed withdrawals, assistance with selection of preferred withdrawal sites and assistance with intake design.

c. Water Quality
   i. Nutrient loads are high in the St. Johns River Basin which results in cyanobacteria dominated algae blooms and occasional hypoxia both in freshwater reaches and in the brackish estuary near the river mouth (Hendrickson et al. 2003). Algae blooms may occur in the lower river from summer through early fall which can negatively alter zooplankton communities (Paerl et al. 2002). Reduction in DO may impact larval and juvenile American Shad nursery habitat and/or juvenile emigration corridors. Florida Department of Environmental Protection (FDEP) has established Total Maximum Daily Loads (TMDL) for nitrogen, phosphorus, and/or DO in the upper, middle, and lower St. Johns River

(Gao 2006, 2009, Magley and Joyner 2008). TMDL implementation is carried out through two primary routes.

1. Nutrient reductions are being carried out following guidelines outlined in Basin Management Action Plans (BMAPs) for the lower and middle SJR as well as Lake Jesup (FDEP 2008, 2012, 2010). BMAPs were developed by committees representing state agencies as well as public and private entities. BMAPs address both point and non-point sources of nutrient loads to the St. Johns River Basin. Specific BMAP action items include tasks such as upgrades to wastewater treatment plants, wastewater reclamation, stormwater retrofits, urban structural BMPs, urban nonstructural BMPs, agricultural BMPs, environmental education, and water quality credit trading. Watershed response to BMAPs is tracked through water quality monitoring carried out by FDEP and SJRWMD. BMAP progress is subject to annual review by the TMDL Executive Committee or Basin Working Group overseeing the water body/basin of concern.
2. Florida Water Management Districts are instructed by the Surface Water Improvement and Management (SWIM) Act to develop plans to improve the quality and management of surface water. Plans are cooperative with relevant state agencies and affected local governments participating in plan development. Plans have been developed for the upper, middle, and lower St. Johns River (SJRWMD 2002, 2007, 2008).

FWC should monitor the progress of implementation plans to ensure that water quality goals protect American Shad and communicate additional research findings as needed. FWC will be working closely with FDEP to ensure that DO standards are protective of all fish communities.

d. Channelization and Dredging

i. Historic alterations in the non-tidal river: Navigational improvements occurred in the non-tidal portion of the river between 1884 and 1945.To enhance navigation numerous bends were cut off by excavating new channels in the river between Lake George's southern inlet (rkm 199) and Lake Monroe's outlet (rkm 265).This excavation straightened the main river channel and created numerous new oxbows. Sandbars were removed to establish a minimum depth of four meters between Palatka and Sanford. Further alteration of the non-tidal portion of the river is not planned.

ii. Jacksonville is an active harbor for cargo. Deepening of the lower 32 km of the river from the mouth to Jacksonville Harbor is likely. US Army Corps of Engineers has prepared a project assessment including environmental impact assessment (USACE 2014). No immediate threat to shad migration or rearing is apparent from this project. Some loss of lower nursery zone could occur due to salt water intrusion. FWC Fish and Wildlife Research Institute (FWRI) Freshwater Fisheries Research section has added parts of the lower St. Johns River estuary to its list of water bodies for long term fishery montoring. FWRI Fishery Independent Monitoring conducts monthly sampling in the lower St. Johns River from the river mouth to rkm 134.

e. Land Use

i. The marshes of the upper basin were drained for agriculture and livestock grazing from 1900 through 1970. As much as 62 percent of the floodplain upstream of Lake Harney was drained and much water was diverted out of the basin. Following passage of the National Environmental Policy Act focus of management of the upper basin turned towards flood control, marsh restoration and enhancement, and improved water quality. The 166,500 acre Upper St. Johns River Basin Flood Control Project consists of four water management areas, four marsh conservation areas and two marsh restoration areas managed by the St. Johns River Water Management District and the USACE (SJRWMD 2007).

ii. Other land use impacts result primarily from urbanization and associated stormwater management challenges. These impacts and their mitigation are quantified in previously mentioned SWIM and BMAP plans as well as in flow modeling in the WSIS.

f. Climate Change

i. The St. Johns River, Florida hosts the southernmost spawning run of American Shad on the U.S. Atlantic Coast. Predicted global warming could shorten the spawning season by advancing the date at which temperature exceeds that suitable for spawning. The river bottom of spawning grounds between rkm 230 and 314 is below sea level. Current mean water surface height of the St. Johns River is above sea level down to rkm 230. Predicted sea level rise could impact these lower spawning reaches. Altered dry season rainfall patterns could change the quantity and quality of water available for spawning and rearing.

ii. Florida FWC has formed a Climate Change Team that includes a Steering Committee and four employee workgroups on adaptation, research and monitoring, communication and outreach, policy and opportunity.

Econlockhatchee River

1) Habitat Assessment

   General: 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.

   a. Spawning Habitat: There are no barriers. Historical extent of spawning in the Econlockhatchee River is unknown. Recent electrofishing and telemetry surveys have located adult shad from rkm 4 to rkm 14 during the spawning season (Holder et al. 2012, SJRWMD 2011).
   b. Rearing Habitat: Econlockhatchee River shares rearing habitat with the St. Johns River.

2) Threats
   a. Water Quality: Stormwater Management. Portions of the Econlockhatchee River watershed are densely developed which affects stormwater flow patterns and pollution. Management of associated run off is covered by the Middle St. Johns River Basin SWIM plan (SJRWMD 2002). Stormwater diversion and reclamation could reduce pollutant loads to the Econlockhatchee River but could also reduce base flow during the winter dry season in which American Shad spawn.

St. Marys River

The St. Marys River originates in the Okeefenokee swamp and flows 203 km to the Atlantic Ocean along the eastern border between Georgia and Florida. Head of the tide extends to rkm 88 and salt water extends to rkm 30-35. The St. Marys River is managed by the Georgia Department of Natural Resources (GaDNR) and the St. Johns River Water Management District (SJRWMD) in cooperation with St. Marys River Management Committee (SMRMC). The St. Marys River Management Committee (SMRMC) is a quasi-governmental advisory panel established by Interlocal Agreement between Baker and Nassau counties in Florida and Camden and Charlton counties in Georgia. The SMRMC has five voting representatives from each county: one county commissioner and four appointed members (two riverfront landowners or representatives of corporations with riverfront property and two at-large members). One representative from the St. Johns River Water Management District (SJRWMD) and one representative from the Georgia Department of Natural Resources (GDNR) serve as non-voting members.

1) Habitat Assessment

   All historic spawning and rearing habitat is still available. Neither has been quantified.

2) Threats
   a. GDNR Environmental Protection Division has identified a stretch of the lower St. Marys River with hypoxic summer conditions.
      i. GDNR has developed a TMDL for dissolved oxygen and is working with local governments and conservation organization to implement measures to reduce organic loads and improve dissolved oxygen conditions in the affected river reach.
   b. Florida Department of Environmental Protection has developed a water quality assessment as a road map for developing plans to improve water quality in the basin (FDEP 2007).

Ocklawaha River

The Ocklawaha River is the largest tributary of the St. Johns River but it does not have a documented historical spawning run of American Shad. It flows 119 kilometers from Lake Griffin to the St. Johns River and there is a dam located at rkm 19 that was constructed in 1968 (Senator George Kirkpatrick Dam). The Ocklawaha River is mentioned in this plan because some advocates for dam removal cite American Shad among the species of migratory fish that would benefit from removal of the dam.

Habitat above and below the dam appears suitable for American Shad to spawn. However, records of a spawning run of or fishery for American Shad from the Ocklawaha River have not been found. One specimen was noted in a dissertation entitled “Fishes of the St. Johns River System” (McLane 1955). 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). The absence of a documented historical or current run of American Shad in the Ocklawaha River precludes a need for a restoration plan. However, the prospect of dam removal may warrant further investigation into whether shad historically used or could use in the future the Ocklawaha River.

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