Atlantic States Marine Fisheries Commission

Shad and River Herring Management Board

May 3, 2022
10:15 – 11:45 a.m.
Hybrid Meeting

Draft Agenda

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

1.	Welcome/Call to Order *(L. Fegley)*	10:15 a.m.
2.	Board Consent • Approval of Agenda • Approval of Proceedings from October 2021	10:15 a.m.
3.	Public Comment	10:20 a.m.
4.	Consider American Shad Habitat Plans/Updates *(B. Neilan)* **Action** • Connecticut River • Merrimack River	10:30 a.m.
5.	Consider American Shad and River Herring Sustainable Fishery Management Plan Updates *(B. Neilan)* **Action** • New York (River Herring) • Delaware River Basin Cooperative (American Shad)	10:45 a.m.
6.	Consider Technical Committee Report on Board Task on Prioritizing Systems for Shad Recovery and Developing Inventory of Available Data to Support Development of Fish Passage Criteria *(B. Neilan)* **Possible Action**	11:00 a.m.
7.	Consider Fishery Management Plan Review and State Compliance for 2020 Fishing Year *(J. Boyle)* **Action**	11:15 a.m.
8.	Update on the 2023 River Herring Benchmark Stock Assessment • Review and Populate Stock Assessment Subcommittee Membership *(K. Drew)*	11:30 a.m.
9.	Review and Populate Advisory Panel Membership (*T. Berger)* **Action**	11:40 a.m.
10.	Other Business/Adjourn	11:45 a.m.

The meeting will be held at The Westin Crystal City (1800 Richmond Highway, Arlington, VA; 703.486.1111) and via webinar; click here for details

Atlantic States Marine Fisheries Commission

MEETING OVERVIEW

Shad and River Herring Management Board
May 3, 2022
10:15 a.m. – 11:45 a.m.
Hybrid Meeting

Chair: Justin Davis (CT) Assumed Chairmanship: 2/21	Technical Committee Chair: Brian Neilan (NJ)	Law Enforcement Committee Representative: Warner (PA)
Vice Chair: Lynn Fegley (MD)	Advisory Panel Chair: Pam Lyons Gromen	Previous Board Meeting: October 19, 2021
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 19, 2021

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 American Shad Habitat Plans/Updates (10:30-10:45 a.m.) Action
Background • Amendment 3 to the Shad and River Herring FMP requires all states and jurisdictions to submit a habitat plan for American shad. A majority of the habitat plans were approved by the Board in February 2014, and it was anticipated that they would be updated every five years. • An updated habitat plan for the Connecticut River and a new habitat plan for the Merrimack River were submitted for TC review and Board consideration at the May 2022 meeting (**Briefing Materials**). • The Technical Committee reviewed the habitat plans and recommends Board approval (**Briefing Materials**).
Presentations • Shad Habitat Plan Updates by B. Neilan
Board actions for consideration at this meeting • Consider approval of updated shad habitat plans for the Connecticut and Merrimack Rivers

5. Consider American Shad and River Herring Sustainable Fishery Management Plan Updates (10:45-11: a.m.) Action

Background

- Amendments 2 and 3 to the Shad and River Herring FMP require all states and jurisdictions that have a commercial fishery to submit a sustainable fishing management plan (SFMP) for river herring and American shad, respectively. Plans are updated and reviewed by the Technical Committee every five years.
- Two updated SFMPs were submitted for TC review and Board consideration at the May 2022 meeting: New York River Herring SFMP, and Delaware River Coop SFMP (**Briefing Materials**).
- The Technical Committee reviewed these SFMP updates and recommends Board approval (**Briefing Materials**).

Presentations

- Shad and River Herring Sustainable Fishery Management Plan Updates for Board Consideration by B. Neilan

Board actions for consideration at this meeting

- Consider approval of updated SFMPs for NY (River Herring) and DE COOP (American Shad)

6. Consider Final Technical Committee Report on Prioritizing Systems for Shad Recovery and Developing Inventory of Available Data to Support Development of Fish Passage Criteria (11:00-11:15 a.m.)

Background

- In light of the 2020 American shad stock assessment results, which showed that barriers to fish migration are significantly limiting access to habitat for American shad, in May 2021 the TC recommended actions to address fish passage impacts on population recovery, including that dam removal and the use of fish passage performance criteria be prioritized by state and federal agencies with fish passage prescription authority. The Board sent letters to the U.S. Fish and Wildlife Service and NOAA Fisheries to support their efforts to review dam passage. Additionally, the Board tasked the TC with prioritizing systems for shad recovery and developing an inventory of available data that would support development of fish passage criteria.
- The TC identified Federal Energy Regulatory Commission (FERC) hydropower projects that are a priority for shad recovery efforts. Additionally, the TC gathered information on the types of data available for developing fish passage criteria for these priority projects.

Presentations

- Final Report on Prioritizing Systems for Shad Recovery and Developing Inventory of Available Data to Support Development of Fish Passage Criteria by B. Neilan

7. Consider Fishery Management Plan Review and State Compliance for the 2020 Fishing Year (11:15-11:30 a.m.) Action

Background

- State Compliance Reports were due on July 1, 2020
- The Plan Review Team reviewed each state report and compiled the annual FMP Review (**Briefing Materials**).

Presentations

- Overview of the FMP Review Report by J. Boyle

Board actions for consideration at this meeting

- Approve FMP Review for 2020 fishing year, state compliance reports, and *de minimis* requests

8. Progress Update on River Herring Benchmark Stock Assessment (11:30-11:45 a.m.)

Background

- The river herring benchmark stock assessment was initiated in April 2022. The data workshop is planned for July 2022, following the submission of 2022 compliance reports.

Presentations

- Update on River Herring Stock Assessment Progress by K. Drew

9. Other Business/Adjourn

Shad and River Herring 2022 TC Tasks

Activity level: Medium

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

Committee Task List
• 2023 River Herring Benchmark Stock Assessment • Updates to state Shad Habitat Plans and River Herring SFMPs • Annual state compliance reports due July 1
TC Members: Mike Brown (ME), Mike Dionne (NH), Brad Chase (MA), Patrick McGee (RI), Jacque Benway Roberts (CT), Wes Eakin (Vice Chair, NY), Brian Neilan (Chair, NJ), Josh Tryninewski (PA), Johnny Moore (DE), Matthew Jargowsky (MD), Ellen Cosby (PRFC), Joseph Swann (DC), Eric Hilton (VA), Holly White (NC), Jeremy McCargo (NC), Bill Post (SC), Jim Page (GA), Reid Hyle (FL), Ken Sprankle (MA), Ruth Hass-Castro (NOAA), John Ellis (USFWS)

DRAFT PROCEEDINGS OF THE

ATLANTIC STATES MARINE FISHERIES COMMISSION

SHAD AND RIVER HERRING MANAGEMENT BOARD

Webinar
October 19, 2021

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

INDEX OF MOTIONS

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

2. **Approval of Proceedings of May 5, 2021** by Consent (Page 1).

3. **Move to approve the Shad Habitat Plans from Virginia, District of Columbia, and New York as presented today** (Page 4). Motion by Pat Geer; second by Malcolm Rhodes. Motion carried (Page 4).

4. **Move to approve the Technical Committee recommendation to evaluate mixed-stock catch of American shad be incorporated into the Delaware River Basin Coop Sustainable Fishery Management Plan** (Page 9). Motion by John Maniscalco; second by Allison Colden. Motion carried (Page 10).

5. **Move to nominate Lynn Fegley as Vice Chair (**Page 12). Motion by Bill Hyatt; second by Mike Armstrong. Motion carried (Page 12).

6. **Move to adjourn by consent** (Page 16).

ATTENDANCE

Board Members

Megan Ware, ME, proxy for P. Keliher (AA)
Cheri Patterson, NH (AA)
Dennis Abbott, NH, proxy for Sen. Watters (LA)
Mike Armstrong, MA, proxy for D. McKiernan (AA)
Raymond Kane, MA (GA)
Rep. Sarah Peake MA (LA)
Phil Edwards, RI, proxy for J. McNamee (AA)
David Borden, RI (GA)
Eric Reid, RI, proxy for Rep. Sosnowski (LA)
Justin Davis, CT (AA)
Bill Hyatt, CT (GA)
Sen. Craig Miner, CT (LA)
John Maniscalco, NY, proxy for J. Gilmore (AA)
Emerson Hasbrouck, NY (GA)
John McMurray, NY, proxy for Sen. Kaminsky (LA)
Heather Corbett, NJ, proxy for J. Cimino (AA)
Tom Fote, NJ (GA)
Adam Nowalsky, NJ, proxy for Asm. Houghtaling (LA)
Kris Kuhn, PA, proxy for T. Schaeffer (AA)
Loren Lustig, PA (GA)
G. Warren Elliott, PA (LA)
John Clark, DE (AA)
Roy Miller, DE (GA)
Craig Pugh, DE, proxy for Rep. Carson (LA)
Lynn Fegley, MD, proxy for B. Anderson (AA)
Allison Colden, MD, proxy for Del. Stein (LA)
Russell Dize, MD (GA)
Pat Geer, VA, proxy for S. Bowman (AA)
Shanna Madsen, VA, proxy for B. Plumlee (GA)
Chris Batsavage, NC, proxy for K. Rawls (AA)
Jerry Mannen, NC (GA)
Bill Post, SC, proxy for P. Maier (AA)
Malcolm Rhodes, SC (GA)
Sen. Ronnie Cromer, SC (LA)
Doug Haymans, GA (AA)
Spud Woodward, GA (GA)
Erika Burgess, FL, proxy for J. McCawley (AA)
Marty Gary, PRFC
Dan Ryan, DC, proxy for J. Seltzer
Lowell Whitney, USFWS
Max Appelman, NOAA

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

Ex-Officio Members

Brian Neilan, Technical Committee Chair
Pam Lyons Gromen, Advisory Panel Chair

Staff

Bob Beal
Toni Kerns
Laura Leach
Lisa Carty
Maya Drzewicki
Tina Berger
Pat Campfield
Kristen Anstead
Emilie Franke
Lisa Havel
Chris Jacobs
Jeff Kipp
Savannah Lewis
Kirby Rootes-Murdy
Sarah Murray
Marisa Powell
Caitlin Starks
Deke Tompkins

Guests

Karen Abrams, NOAA
Pat Augustine, Coram, NY
Richard Balouskus, RI DEM
Meredith Bartron, US FWS
Alan Bianchi, NC DNR
Christopher Boelke, NOAA
Jason Boucher, NOAA
Rob Bourdon, US FWS
Delayne Brown, NH F&G
Jeff Brust, NJ DEP
Joe Cimino, NJ (AA)
Margaret Conroy, DE DFW
Jessica Daher, NJ DEP
Lennie Day
Mari-Beth DeLucia, TNC
Greg DiDomenico
Wes Eakin, NYS DEC
James Fletcher, Wanchese Fish

Guests (continued)

Alexa Galvan, VMRC
Lewis Gillingham, VMRC
Brendan Harrison, NJ DEP
Helen Takade-Heumacher
Jaclyn Higgins, TRCP
Kyle Hoffman, SC DNR
Miluska Olivera-Hyde, USGS
Stephen Jackson, US FWS
James Jewkes
David Kazyak, USGS
Greg Kenney, NYS DEC
David Sanderson-Kilchenstein, MD DNR
Rob LaFrance, Quinnipiac Univ
Wilson Laney
Chip Lynch, NOAA
Shanna Madsen, VMRC
Chris McDonough, SC DENR
Dan McKiernan, MA (AA)
Jason McNamee, RI (AA)
Steve Meyers
Mike Millard, US FWS
Chris Moore, CBF
Brandon Muffley, MAFMC
Kevin Milligan, USGS
Lindsey Nelson, NOAA
Tom O’Connell, USGS
Gerry O’Neill, Cape Seafoods
Derek Orner, NOAA
Alexis Park, MD DNR
Will Patten, NC DENR
Nicholas Popoff, US FWS
Will Poston, SGA
Kathy Rawls, NC (AA)
Harry Rickabaugh, MD DNR
Tara Scott, NOAA
Melissa Smith, ME DMR
Somers Smott, VMRC
Renee St. Amand, CT DEEP
Michael Stangl, DE DFW
Kevin Sullivan, NH FGD
John Sweka, US FWS
Brett Towler, US FWS
Troy Tuckey, VIMS
Beth Versak, MD DNR
Mike Waine, ASA
Jonathan Watson, NOAA
Meredith Whitten, NC DENR
Chris Wright, NOAA
Horace Wynn
Sarah York, NOAA
Erik Zlokovitz, MD DNR
Renee Zobel, NH F&G

The Shad and River Herring Management Board of the Atlantic States Marine Fisheries Commission convened via webinar; Tuesday October 19, 2021, and was called to order at 9:00 a.m. by Chair Justin Davis.

CALL TO ORDER

CHAIR JUSTIN DAVIS: Good morning, everybody. I'm going to call to order this meeting of the Shad and River Herring Management Board. My name is Justin Davis, I am the Administrative Commissioner from Connecticut, and am currently serving as the Chair of this Board.

APPROVAL OF AGENDA

CHAIR DAVIS: The first item on our agenda this morning is Approval of the Agenda. I'll ask if there are any suggested modifications or additions to today's agenda.

MS. TONI KERNS: I see no hands.

CHAIR DAVIS: Okay, great, we'll consider today's agenda approved by consent.

APPROVAL OF PROCEEDINGS

CHAIR DAVIS: Moving on, next item on the agenda is Approval of Proceedings from the May, 2021 Meeting, which were provided in the meeting materials. Are there any suggested corrections or additions to the meeting minutes from May, 2021?

MS. KERNS: I see no hands.

CHAIR DAVIS: Okay, great, we'll consider the proceedings from the May meeting approved by consent.

PUBLIC COMMENT

CHAIR DAVIS: All right, moving on to the next item on the agenda, Public Comment. At this time, I would be willing to entertain public comment on any issue not on the meeting agenda today. Toni, do we have any hands from the public?

MS. KERNS: Jim Fletcher indicated he wanted to speak, so Jim, go ahead and unmute yourself.

MR. JAMES FLETCHER: This is James Fletcher. You're talking about shad and river herring, and we are not talking about what the wastewater treatment cause PFAS. They are long lasting chemicals that show up in the water and affect everything; humans and fish. It's amazing that the Atlantic salmon was affected by this same type of chemical when they sprayed it for the spruce budworm. Is there any chance that the Shad and River Herring Management Board can have the habitat people specifically look at these chemicals?

Because as long as they are going into the water through the wastewater treatment system, trying to rebuild the shad and river herring is not going to work. A lot of these chemicals, depending on which type of chemical it is, affect the ability of the shad and river herring to osmose regulate, either when they're going to sea as young fish or when they're coming back to spawn. Is there any chance that the Shad and River Herring can specifically ask Habitat to look at these chemicals, and it's PFAS is what the wastewater treatment uses? I would ask that if we're going to try to do anything with shad and river herring, first we've got to find out what's affecting their ability to reproduce and get in and out of the fresh to brackish water. Thank you for your time.

CHAIR DAVIS: Thank you, Jim, for providing that perspective. Toni, do we have any other hands from the public?

MS. KERNS: I don't have any additional hands.

CONSIDER AMERICAN SHAD HABITAT PLANS AND UPDATES

CHAIR DAVIS: We'll move on to the next item on our agenda, which is a presentation from the Chair of our Technical Committee, Brian Neilan, concerning American Shad Habitat Plans and Updates.

MR. BRIAN NEILAN: Thank you, Mr. Chair, and good morning to the Board. My name is Brian Neilan, the

TC Rep from New Jersey and current TC Chair. Today I have for you three presentations to go over. I'm going to start with a review of recently submitted habitat plan updates from a few states since the last Board meeting.

Just a little background here. Under Amendment 3 all states and jurisdictions are required to submit habitat plans for American shad. They are meant to contain a summary of information on current and historical spawning and nursery habitat, threats to those habitats, and any habitat restoration programs currently are going on in the state or have in the past.

In February, 2020, the Board agreed that these plans should be updated every five years or so, similar to how we do our SFEs and ask the states to update existing plans, originally improved in 2014, and for the states with missing plans to submit their plans ASAP. Since then, the Board has approved 12 plans and updates from these states and river systems listed below.

Today we have another three we're going to review. Today we have three plan updates for Board consideration. Last month the TC reviewed the plans from the following jurisdictions, so Virginia, D.C. and from New York a plan for the Hudson River. After reviewing, the TC recommended that the Board approves all plans and updates.

We'll dive right in and start with the Virginia plan on the next slide. For the Virginia plan update, their plan covers the main tributaries to the Chesapeake Bay. In this case the James, York and Rappahannock Rivers. The 2021 habitat plan update information on existing threats identified in the previous report, and also identified some new additional threats.

Some highlights here from the plan update. The first additional threat was in river construction and blockage to migration. They felt that projects such as bridge and tunnel construction, maintenance, dredging, and other work in-water work have the potential for disruption of American shad migration, both from direct and indirect factors.

Some of these examples are acoustic interference or habitat alteration. They plan on addressing this threat through the enforcement of time of year restrictions on in-water development, and case-by-case consideration of appropriate mitigation measures for individual projects. Another threat they identified in this plan update was agriculture or industrial water intakes and discharges. Systems used by American shad are subject to significant withdrawals within this area that may have effect on spawning and nursery habitats. The recommended action in the plan to address this threat, was to include developing a better understanding of the amount of water intakes for agriculture, particularly in tidal streams and rivers that support American shad spawning and nursery grounds, and survey to better understand the effects of these threats.

Those are the updates for the Virginia plan. Go on to the D.C. plan. As I said, the D.C. plan was also, this is an update. It covers the portions of the Potomac and Anacostia Rivers, which fall within the borders of the District of Colombia. The updates from the previous plan include the completion of a dredging channelization project associated with the runway extension at Reagan National Airport.

There is also an update on an invasive species stomach content study. I believe they're mostly looking at invasive catfish species, so in this area blue and flathead catfish. This study is to better understand the effects of invasive predators, and what they may have on resident anadromous species.

They are still collecting samples. They mentioned they have at around a thousand stomachs at this point. They should have some good data for us on that soon. I think a lot of states are starting to see issues with invasives, especially these species of catfish. That is the D.C. habitat plan update. We can move on to the Hudson plan.

This was a new plan submitted by New York for the Hudson River. I'll go over this one a little more in depth, since it's brand new. We could start with the habitat assessment. For the habitat assessment it was determined that American shad currently had access to 91 percent of historical mainstem Hudson River habitat.

This is from the mouth of the river up to the Troy Dam. They still have access to a good amount of habitat, but the conversion of habitat during the dredging and channelization of the upper portion of the estuary during the past century, has resulted in the loss of preferred habitat. New York did a pretty thorough threat assessment.

Here are some of the highlights from that threat assessment. They looked at impingement and entrainment as a major source of possible mortality. The water withdrawals may have had a significant impact on year class strength, but some reductions rated from 16 to 52 percent reduction in year class strength, as a result of impingement and entrainment mortality.

They looked at anthropogenic habitat changes, so dredging and channelization of the mainstem Hudson River, and adjacent land use changes have resulted in the change in degradation of preferred habitat used by American shad, especially for spawning and nursery habitat, including a loss of 57 percent of inner tidal shallow water habitat now north of the city of Hudson, so that's important nursery habitat there.

Then they also identified other threats, similar to what we're seeing up and down the coast, of course climate change issues and invasive species. New York has some habitat restoration programs happening, or have been completed in the recent past. Within the Hudson River there is significant and ongoing efforts to understand and reduce the impacts of threats to American shad and spawning nursery habitats. Just a quick rundown on some of the restoration plan highlights. This includes the removal of nine dams within the Hudson River estuary since 2016, opening up some important nursery habitat, including restoring vegetative shallow water and intertidal habitats.

They highlighted a side channel restoration projection completed in 2018 out at Gay's Point near Coxsackie New York, which I think was a bit of a pilot project for them, and I think went pretty well. They should be looking to do similar restoration projects in the near future. That's the rundown of the Hudson plan. We can go to the next slide, which is the next step today, so that would be consider approval of the three plans just presented. I could take any questions, or hand it over to the Chair to go forward with the next steps.

CHAIR DAVIS: Thanks, Brian. I'll ask the Board if anybody has any questions for Brian on the presentation to this point.

MS. KERNS: I see no hands, hold on, I have Pat Geer followed by Allison Colden.

MR. PAT GEER: I'm ready to make a motion if there are no questions.

CHAIR DAVIS: Was that Pat?

MR. GEER: Yes.

CHAIR DAVIS: Okay, Pat, I'll ask Allison really quickly if she has a comment or a question before we move to a motion.

MS. ALLISON COLDEN: I just had one quick question. Maybe it's good that Pat is on his mute button. My quick question for you was, I know Virginia is in the midst of working on a shad habitat restoration plan, so I was just wondering if any of that was reflected in here, or if that would be in the next round of updates. Was there anything that you all reviewed with respect to the restoration program in Virginia's plan?

MR. NEILAN: There were general updates. I don't have that info of the top of my head right now, but I know they updated not just a threat assessment, but their plans for the future. I think they will have more concrete answers in the following plan. I think they're still in the planning process at this point.

MS. COLDEN: Okay, thank you.

CHAIR DAVIS: Brian, I just want to confirm. Are you done with your presentation on this section of the agenda, or was there another part of this presentation to come?

MR. NEILAN: No, this was it for the habitat plan.

CHAIR DAVIS: Okay, thanks, just wanted to confirm. Given that, Pat, I'll turn back to you if you're interested in making a motion.

MR. GEER: I move to approve the Shad Habitat Plans for Virginia, District of Colombia, and New York as presented today.

CHAIR DAVIS: Okay, thank you, Pat, do we have a second to the motion?

MS. KERNS: We have Malcolm Rhodes.

CHAIR DAVIS: Thank you, Dr. Rhodes. Any discussion on the motion?

MS. KERNS: No other hands.

CHAIR DAVIS: Given that, I'll ask if there is any objection to the motion.

MS. KERNS: I see no hands in objection.

CHAIR DAVIS: We'll consider this motion passed by unanimous consent.

CONSIDER TECHNICAL COMMITTEE REPORT ON METHODS FOR EVALUATING MIXED-STOCK CATCH

CHAIR DAVIS: All right, moving on to our next section of the agenda. Brian, you're back up again to give us a presentation on the Technical Committee report on methods for evaluating mixed-stock catch.

MR. NEILAN: As you said, next we have an update on the TCs task of developing methods to evaluate bycatch in mixed-stock fisheries in state waters. The task group and TC drafted a white paper on the results of this task and the work that was done, and that was included in the meeting material. It's an outline here, I'll be going over a little bit of background on the task.

The data reviewed by the task group, what methods were explored by the task group to evaluate this task, and then the TC recommendations for addressing mixed-stock fisheries, as a result of the methods that were evaluated. A quick rundown, some background here on the tasks. In August, 2020, after being presented with the results of the 2020 stock assessment, the Board tasked the TC with identifying potential paths forward to improve shad stock along the coast, in consideration of the assessment results.

Some system-specific TC recommendations were presented at the February, 2020 meeting, and also at this meeting the TC identified a need to understand and reduce impacts to external stocks of shad that were harvested in directed mixed stock fisheries. The Board then tasked the TC with the task we're about to go over here, so developing methods to evaluate bycatch removals in directed mixed-stock fisheries, in order to better understand and possibly reduce any of the impacts.

This presentation details the results of the work done for this task. To address this task, the working group developed a road map outlined to focus the scope of the task and guide discussion. We defined goals and expectations, we identified known or potential mixed-stock fisheries, we collected available data that might be relevant to understanding or identifying mixed-stock fisheries, determined the feasibility of developing modeling methods to estimate composition of mixed-stock fisheries, and we evaluated novel or existing methods of reducing or eliminating any of the effects of mixed-stock fisheries. Where we finished up and where we are today is, we've developed recommendations for the Board on eliminating mixed-stock fisheries or recommending research priorities going forward, to address this task.

During our data assessment, the task group collected datasets from up and down the coast that could be useful for identifying and quantifying mixed-stock fisheries. From the data we received, using the tagging studies and genetic analysis, this provided useful information for identifying mixed-stock fisheries in the Delaware Bay and the Winyah Bay.

For this task the Delaware Bay was evaluated given the quantity and quality of data available from this system. We had commercial landings from New Jersey and Delaware we looked at back to 1988 to the present. We had some tagging studies from back in the '90s to the present from New Jersey. A few different DNA analysis studies for identifying stock composition and stock assignment.

Then long-term general abundance surveys, including ones from out of basin stocks. Specifically, we looked at New York. The working group took a tiered approach to evaluating the data and methods available. Three tiers were developed based on the following criteria, quantity and quality of data currently available, so Tier 1 was what sort of analysis we could do right now, given the data we currently have available.

Second tier was data that could be reasonably collected without significant changes in our near-term effort, so essentially what could help improve analysis with a minimal to moderate increase in effort. Then our third tier were the ideal collection efforts that would provide information necessary to support more robust modeling efforts, such as for example a statistical catch at age model.

The first tier, which was analysis we could do right now, given the available data. The task group explored developing a relative F with the static genetic proportions based on historical tagging data. Relative F is simply calculated by taking harvest and comparing it to some fishery independent abundance index. This would limit relative F to a level established post hoc, and any management triggers would have a non-biological rationale.

In the case of the Delaware system, a static percent of total catch was assigned to the Hudson stock based on tagging surveys. We looked at total catch in the Hudson. We looked at our tagging studies that showed, depending on the year X amount of Hudson stock made up part of the total harvest. That was compared to an adult abundance index from the Hudson River, and the resulting value represents the Hudson stock-specific relative F.

From here an average relative F for the time series can be generated, and then obviously from there you could consider developing benchmarks and triggers based on this time series when harvest levels were deemed to be appropriate. That was the first tier, as I said, what we could do right now, given the available data. For a second tier, the task group explored the viability of a relative F with a time-varying stock composition. Again, this is relative F, so it's the same general method as the previous tier, but would require regular genetic sampling or tagging studies to better inform the yearly out of basin composition within the mixed stock fisheries. You can get a year-on-year percentage of assignment, versus the previous method, which relies on an average composition over the entire tagging survey time series, or you could use the small single year snapshot genetic analysis data that we have.

This will require more consistent sampling, and would allow for year-on-year specific stock composition assignment of catch would benefit that. Yearly assignment likely fluctuates on a yearly basis, so this would account for that. Finally, our third tier. This represents the ideal methods for evaluating mixed stock harvest and its effects on out of basin stocks.

Some of the methods explored were in bycatch impact analysis for a statistical catch at age model. These methods would require a significant increase in both fishery independent and fishery dependent sampling efforts, as they have a much higher data needs to be able to complete the models.

While the third-tier methods would provide the most robust analysis of mixed stock fishery impacts, the required increase in data collection and sampling efforts cannot practically be completed by the agencies involved, without a significant increase in both staff time and the resources. Here we have the TC recommendations based on the work done by the task group. After reviewing the different tiers, the TC recommends that the second-tier method be used for evaluating bycatch removals in directed mixed stock fisheries.

A reminder, this tier involves developing a relative F index based on increased genetic sampling or tagging efforts, which can provide annual stock composition of mixed stock landings. This method was preferable to the current first tier methods of applying a historical average to the stock assignment, based on tagging and DNA studies we have available as regular DNA analysis can account for yearly fluctuations in stock composition.

The states with mixed stock fisheries would develop management strategies based on these methods to reduce impacts of out of basin harvest in mixed stock fisheries. These strategies should be incorporated to current SFPs when developed. That's the TC recommendations. We're here at next steps, and obviously I can take any questions that the Board may have.

CHAIR DAVIS: Thank you, Brian for that presentation, and I'll thank the Technical Committee for the excellent work. I'll open the floor. Are there any questions for Brian?

MS. KERNS: We have John Clark followed by Lynn Fegley.

CHAIR DAVIS: Go ahead, John. Toni, is it just me or are we not hearing John?

MS. KERNS: I thought it was me. I'm not hearing John. All right, John, go ahead.

MR. JOHN CLARK: Thank you for the presentation, Brian, I was just wondering if you could briefly describe what the increase in cost would be from going from Tier 1 to Tier 2. Obviously, as you mentioned with Tier 3, it's a cost benefit we're looking at with some of these methods, and I'm just wondering what we would be looking at, in terms of increased resources if we go to Tier 2. Thanks.

MR. NEILAN: Sure, no problem. I can give you a general idea of what we looked at, at least in New Jersey, being one of the basin states this would affect us as well. Tier 1 is potentially how we operate right now, so there would be no increase in cost. Tier 2 would require regular genetic sampling of the commercial fishery, either you could have onboard observers or you could do dockside sampling.

Obviously, the onboard observers are going to add to the cost. In terms of dockside sampling, typically a little easier, especially coordinating with the fishermen, days at sea versus just meeting them at the dock. We were looking approximately if you got $100.00 a sample for DNA, and that was with the USGS lab, and they were looking at around that.

I believe we were looking at 500 samples a year, and it was going to be around $100.00 a sample for analysis and report each year, around $50,000.00. It is an increase in sampling. The TC felt that the increase, the juice was worth the squeeze here, in terms of getting that year-on-year stock assignment versus the tagging study, which was being used for the first tier.

MR. CLARK: If I could just follow up for a second, Brian. I understand that, I mean it's not a huge cost, but just judging by the Delaware Bay shad fishery, this is not a huge fishery. It seems like it's getting smaller. I don't know about the Jersey side, but it's getting harder to find even anybody in Delaware that can bone a shad. It doesn't seem like there is a huge need for me to be knowing what the mixed stock composition is on an annual basis. But as I said, just kind of wondering based on the current state of the fishery.

MR. NEILAN: Yes, I think we're seeing a similar on our side of the Bay. It is a fishery that is slowly, basically teetering out through attrition. I think the Bay harvest on our side is 10 to 20,000 pounds a year. Total Bay harvest is probably close to 40,000 pounds a year.

That being said, probably about 10,000 pounds a year assigned to the New York stock for both sides of the Bay. The TC felt that the analysis, it was beneficial to have the year-on-year sampling studies, to assign year specific assignment, just because it likely fluctuates over the years. That is the general consensus of the TC.

CHAIR DAVIS: Okay, Lynn.

MS. LYNN FEGLEY: Yes, thanks for the presentation, Brian. I think you answered by question when you were answering John's question. I was just curious who was doing the genetic analysis, where the samples were going. It's going to USGS.

MR. NEILAN: Yes, the previous studies we just, the Delaware Basin states just finished one from the US Fish and Wildlife Service, the Northeast Fisheries Science Center did a three-year study for us. The one I was looking at going forward, I was applying for some funding. USGS, they're handling the coastwide alosine repositories for DNA, and they are definitely interested in doing this DNA analysis.
MS. FEGLEY: Great, thank you.

MS. KERNS: Justin, you now have John Maniscalco followed by Roy Miller.

CHAIR DAVIS: John, you're up.

MR. JOHN MANISCALCO: First, I would like to thank the TC for doing the work on these evaluation methods. I had a lot of reservations about their first-tier approach, using that constant value. I recognize that there are costs associated with annual or even semiannual genetic sampling. But I'll just remind the Board that whereas New Jersey and Delaware have commercial and recreational fisheries on that system, anglers and commercial fishermen on the Hudson River are prohibited from taking shad, even in that catch and release kind of fishery.

There was the 4,000, 5,000, 10,000 pounds that are removed from the Delaware that are Hudson River fish, flies in the face of the prohibitions we're putting on our own fishermen. I would certainly support the Tier 2 recommendation, and I would be interested in having conversations about how we could find money to support that genetic sampling, and the observer work.

CHAIR DAVIS: Roy.

MR. ROY W. MILLER: Very quickly, Brian, you didn't mention a geographic component to the genetic sampling. Specifically, I'm referring to within the Delaware Bay system. Previous work has shown you're more likely to encounter out of basin shad in the lower portion of Delaware Bay (breaking up) for the upper portion of Delaware Bay with a lower Delaware River. I assume there would be a geographic component to that sampling. Would the emphasis be on the lower Bay fishery, such as it is, even though as already discussed it's much reduced what we'll get in 20 years?

MR. NEILAN: Sure, so I think the best way to go about it would be to target the whole fishery. We have fishermen who land both in the Delaware in the lower Bay and the upper Bay. The previous genetic sampling study we did took samples from potentially the mouth of the Bay all the way up to close to New York.

For the mixed stock fisheries purposes, we would be looking at the entire Bay as a whole. The Bay is where the fishery is being executed. Just to the mouth of the river, where it opens up into the Bay all the way down to Cape May. We would like to cover the entire fishery (faded) and kind of get a general idea of the fishery as a whole, not just the lower Bay.

The genetic sampling showed that we certainly saw out of basin harvest in the upper Bay as well. It kind of tiers as you go up the Bay into the river, obviously. The further up you go the more Delaware River fish you'll be seeing, but you will also see out of basin fish in the upper Bay as well. There is a fishery that goes on up there, so we would evaluate that as well.

CHAIR DAVIS: Do we have any more hands, Toni?

MS. KERNS: That's all our hands.

CHAIR DAVIS. Okay, so I think at this point the Board has a decision point here. I think the Board could entertain a motion to adopt the TC recommendation and recommend that the Delaware River Basin Coop Sustainable Fishery Management Plan incorporate the recommended methods.

But I thought, you know, perhaps it might be helpful before the Board decides whether or not it wants to move forward with a motion at this time, to get perspective from some of the affected jurisdictions here on whether they sort of feel comfortable at this point with the TCs recommendation.

Moving forward with incorporating that into the Sustainable Fishery Management Plan or perhaps there might be a desire for some more discussion or further digestion of the TCs report. Not to put those jurisdictions on the spot, but I think it might be helpful to get that perspective, before the Board considers what to do here.

MS. KERNS: We have John Clark and then followed by Roy Miller.

CHAIR DAVIS: Okay, John Clark.

MR. CLARK: I certainly understand the request, the making the recommendation to do this. As I said, I'm just, and I was glad to hear from John Maniscalco about the New York perspective on this. I understand that our fisheries, both commercial and recreational in the Delaware are catching Hudson shad also.

It's just one of those things where, as Brian pointed out, just the effort they're doing in New Jersey to do this on an annual basis, getting the genetic work done that's $50,000.00 that obviously there is an opportunity cost for whatever we do with shad. I'm just thinking, for example just within Delaware.

We're in the process of trying to eliminate blockages on Brandywine Creek, which is a tributary of the Delaware that in the past was heavily used by shad and river herring. You know I understand from the TC perspective that this is worth the effort, but I would just like a little more time, I think.

I understand if a motion is made it will be a recommendation that the Delaware River Basin Coop would not be required to incorporate Tier 2 methods. As I said, if we get to that point fine, but I just think at this point it might behoove us to wait a little bit on this, until we can more thoroughly analyze what would be the best things to do with shad on the Delaware.

CHAIR DAVIS: Roy Miller.

MR. MILLER: I would like to chime in with John on this. I just want to make sure that, to coin a phrase, the juice is worth the squeeze, in this particular case. I am very enthused over restoration of shad in the Brandywine System, which is a major lower tributary to the Delaware River, for those not familiar with the Basin. Money spent on that restoration, I think, is already starting to show return and payoffs. I would be hesitant to save a few thousand fish that might otherwise be bound for the Hudson System, and ignore local restoration efforts for the sake of that effort. Thank you for the opportunity of giving my opinion.

CHAIR DAVIS: Toni, do we have any other hands?

MS. KERNS: We have John Maniscalco.

CHAIR DAVIS: Okay, go ahead, John.

MR. MANISCALCO: Again, I understand the costs. In New York state we are doing coastwide genetic work to better evaluate where Hudson River fish are being caught in fisheries coastwide. We are doing habitat restoration work. We are investigating other potential causes within the river itself, to determine what is inhibiting the recovery of our shad stocks. But certainly, the loss of thousands of adults to Delaware Bay fisheries could certainly be an issue.

If we need to further develop these ideas and how they are going to be implemented, I'm certainly willing to consider that. But I do not want to see evaluation of mixed stock fisheries fall off the table, and I don't want to see the possibility of this being included in future sustainable fishery management plans be removed. Because as I said before, where there are fisheries allowed in the Delaware Bay, those fisheries are not allowed on the Hudson River, even though there is a direct impact of the Delaware Bay fisheries on Hudson River fish.

CHAIR DAVIS: Do we have any other hands, Toni?
MS. KERNS: I don't have any other hands.

CHAIR DAVIS: Okay, thanks, Toni. After hearing those perspectives from Delaware and New York, I think it's fair to say that there is a recognition of the value of this work of continuing to pursue this line, and potentially incorporate it into the sustainable fishery management plan at some point.

Also, some concerns about potential cost of the work. Opportunity costs something, I'm sure all of us who work in the Agency environment are familiar with. Given those perspectives, I guess at this point I'll turn it back to the Board and ask if anybody would like to make a motion at this time, relative to the TC recommendations.

MS. KERNS: I have John Maniscalco.

CHAIR DAVIS: Okay, go ahead, John.

MR. MANISCALCO: I would like to make a motion for the Board to approve the TC recommendation to incorporate a mixed-stock fishery evaluation to the Delaware River Basin Cooperative Sustainable Fishery Management Plan.

CHAIR DAVIS: We have a motion on the board made by John Maniscalco. Do we have a second to the motion?

MS. KERNS: Allison Colden.

CHAIR DAVIS: Allison, just to confirm, you're seconding the motion?

MS. COLDEN: Yes, that's correct.

CHAIR DAVIS: Okay, great, so we have a motion with a second. At this time, I'll ask John, would you like to speak to the motion?

MR. MANISCALCO: I mean I think I've said my piece already. I'm certainly willing to see this concept further developed. But as I said before, I don't want to see it forgotten, thanks.

CHAIR DAVIS: Okay, thanks, John. Any further discussion on the motion? Toni, do we have any hands?

MS. KERNS: John Clark.

CHAIR DAVIS: Okay, John Clark, go ahead.

MR. CLARK: Again, I'm not opposed to doing more sampling and I understand this is a recommendation. I just thought at this point that, you know again, I know the Delaware River Basin Coop is going to meet to discuss the Sustainable Fishery Management Plan, I believe it's next week.

This could very well be part of it. I just didn't think at this point, as I said, I think this is a little premature, and just to analyze more all the factors involved here. I know it's tawdry to have to consider funding in all these times, but there is truly cost as to where we get the most bang for our buck with what we spend on the shad and river herring.

CHAIR DAVIS: Toni, do we have any more hands?

MS. KERNS: No additional hands.

CHAIR DAVIS: Okay, given that I'll all the question. At this time, I'll ask everyone in favor of the motion to raise your hand.

MR. CLARK: Can we have a minute to caucus, Mr. Chair?

CHAIR DAVIS: Yes, I apologize. We'll give two minutes for a caucus, thank you. That was two minutes for a caucus, I'll ask if any states or jurisdictions feel like they need more time to caucus, please raise your hand.

MS. KERNS: I don't see any hands. Sometimes I think it might be easier for them just to call out if they need more time, if they are caucusing via their computers.

CHAIR DAVIS: Okay, thanks, Toni. Not hearing any calls for additional time, we'll go ahead and call the question here. I'll ask all states and jurisdictions in favor to raise their hands.

MS. KERNS: It looks like the hands have settled, all right, I will call out the states and jurisdictions in favor. Georgia, U.S. Fish and Wildlife Service, New Hampshire, Maine, Pennsylvania, Florida, NOAA Fisheries, New York, District of Colombia, North Carolina, Maryland, New Jersey, Massachusetts, South Carolina, and Potomac River Fisheries Commission. Did I miss any? Rhode Island, thank you, and Connecticut. I'm going to put the hands down for everybody.

CHAIR DAVIS: Okay, all those opposed, please raise your hand.

MS. KERNS: We have Delaware and Virginia.

CHAIR DAVIS: Thanks, any abstentions?

MS. KERNS: I have no abstentions.

CHAIR DAVIS: Any null votes?

MS. KERNS: No null votes.

CHAIR DAVIS: Okay, thanks, I believe the motion carries, although I don't have the count, Toni, do you have that?

MS. KERNS: Caitlin should have the count.

MS. CAITLIN STARKS: Sorry, I was just double counting, I believe I have 16 in favor, 2 opposed.

MS. KERNS: Mr. Chair, Roy Miller has his hand up.

CHAIR DAVIS: Okay, Roy Miller.

MR. MILLER: Very quickly. I'm wondering if through the Delaware River Cooperative, perhaps New York might be able to assist the lower basin states in helping fund these studies, after all it is their shad, they are concerned about. If they are able to help financially or materially, in terms of analysis or something like that with that effort. I think that would be a good faith gesture, and would be much appreciated.

MS. KERNS: We now also have John Maniscalco.

CHAIR DAVIS: Okay, go ahead, John.

MR. MANISCALCO: Roy, I certainly can't commit to anything, but you're right it is Hudson River shad that are being taken. I hope we have some fruitful conversations at the next Coop meeting about how we could get this kind of work funded.

CHAIR DAVIS: Thanks, John, do we have any other hands up at this time, Toni?

MS. KERNS: No additional hands.

PROGRESS REPORT ON PRIORITIZING SYSTEMS FOR SHAD RECOVERY AND DEVELOPING INVENTORY OF AVAILABLE DATA TO SUPPORT DEVELOPMENT OF FISH PASSAGE CRITERIA

CHAIR DAVIS: Okay, given that, I'm going to go ahead and move us on to the next item on our agenda. I think Brian will be giving us another presentation, a Progress Report on Prioritizing Systems for Shad Recovery, and Developing the

Inventory of Available Data to Support Development of Fish Passage. Brian, it's all yours.

MR. NEILAN: You guys are going to hear from me one last time here. For our last presentation I'm going to be going over the TCs progress on its shad passage prioritization task. Just a quick outline of what I'm going to go over here, just some background, some progress on the task, what the TC has done so far. Then next steps looking forward.

In August of 2020 the Board tasked the TC with identifying potential paths forward to improve shad stocks along the coast, considering the assessment results. Obviously improving shad passage directly gets to the heart of this task. In May of 2021, the Board followed a TC recommendation that the Commission send letters to agencies with relevant authorities to request prioritization of these actions when considering licensing permitting of projects that may impede access to the spawning grounds and out-migration.

The TC was tasked with prioritizing systems for shad recovery and developing an inventory of available data that would support the development of fish passage criteria. The Commission sent a letter in June of 2021 to the Fish and Wildlife Service supporting the Services efforts to require fish passage during relicensing of hydro powered projects, and ensure that performance standards of fishery related license conditions are met.

The Service responded favorably in August, and just looking forward to seeing what the TC would come up with, in terms of prioritizing different projects, based on need. For our progress on this task, the TC was tasked with prioritizing systems for shad recovery, and developing an inventory of available data to support the development of fish passage criteria.

The fish passage task group required a table of the expected FERC relicensing projects along the Atlantic coast coming up for either relicensing or applying for a first-time license. Expected between FY2020 and 2030, this list represented 150 plus projects. The TC members from each state were asked to decide whether a project in their state was a priority, based on the following criteria.

Does this system have an existing recovery plan? Does this system have existing performance standards? Does this system have upstream passage? Does it have downstream passage? Is alosine passage needed here? Is this system a state priority in general? That was what was considered when we looked at sort of whittling down the number of projects who are priority projects and systems. Continuing with our progress on the task here. From the 150 total projects initial list, we have narrowed down to 36 priority systems along the Atlantic coast. This is based on the TC members from each state reviewing the criteria I mentioned in the previous slide for each project. The TC is continuing to review the list of priority systems, and providing information on available data that could be used to support passage criteria.

That is currently where we're at, and I'm still narrowing down some of the systems. They haven't all been reviewed yet. Where we are right now, the TC will finalize our list of priority projects and the inventory of available data, and provide it to the Board for review at the next meeting, in terms of the final report, hopefully to be used for prioritizing systems with upcoming FERC relicensing to have fish passage requirements as part of their licensing requirements. That is where the TC is at with this task right now. I could take any questions anybody has.

CHAIR DAVIS: Okay, thanks, Brian. I'll thank Commission staff for their efforts in getting those letters out earlier this year, and thank Brian and the TC. We've certainly been keeping them busy lately with a variety of tasks, and we certainly appreciate all their efforts. I'll open it up to the floor. Are there any questions for Brian?

MS. TINA L. BERGER: Max Appelman has raised his hand.

CHAIR DAVIS: Okay, Max, go ahead.

MR. MAX APPELMAN: Thank you, Mr. Chair, and thank you Brian, and another thank you to the TC for working on this. You know NOAA Fisheries, we still think that the TC is in a unique position to look at the coast, you know holistically, and work towards identifying priority systems and projects.

One of the, I guess this is really just a comment. One of the concerns that I've been hearing from some of the folks that work closely with at the Agency is the concern about different states using different approaches to prioritizing systems within their state, and projects within their state. I saw that as a criterion for prioritizing, you know relicensing efforts that are coming down the pike.

I just wanted to sort of flag that that I'm hearing consistency is really important. I think that was part of where we thought the TC could come in and really step back and think of what's a consistent way to approach prioritization on a coastwide scale. Something to keep in mind as you guys continue to work on this task, and we look forward to the final report coming at the next meeting.

CHAIR DAVIS: Okay, thank you, Max. Any additional hands, Toni?

MS. BERGER: Lowell Whitney.

MR. LOWELL WHITNEY: Great, thank you, Mr. Chair. On behalf of Fish and Wildlife Service, I really appreciate the work the TC is doing in this regard. I just want to second the statement Max just made about the need to really understand the criteria that was used for the prioritization. I'm looking forward to seeing that in the final report. Also, in looking at the presentation, I do believe that NOAA received a letter as well. Again, thanks to the TC for the work on this, and we're looking forward to seeing the results.

CHAIR DAVIS: Great, thank you for that, Lowell, and certainly NOAA did receive a letter as well, so that might have been a slight oversight in the presentation. Toni, any additional hands?

MS. BERGER: No.

ELECT OF VICE-CHAIR

CHAIR DAVIS: Okay, given that, we will move on to our last item on the agenda today, which is to elect a Vice-Chair of this Board, and at this time I'm going to turn to my fellow Connecticut Commissioner Bill Hyatt, who I think will be making a motion along those lines. Bill.

MR. BILL HYATT: Sure, Mr. Chair. I move to nominate Lynn Fegley for Vice-Chair of the Shad and River Herring Management Board.

CHAIR DAVIS: Great, thank you, Bill, do we have a second to the motion?

MS. BERGER: Both John Clark and Mike Armstrong have their hands up.

CHAIR DAVIS: All right, out of deference to my Board share predecessor, I'll give the second to Mike Armstrong. I'll ask if there is any discussion on the motion. **Hearing none, any opposition to the motion?**

MS. BERGER: No hands have been raised.

CHAIR DAVIS: Great, thank you. **Thanks, and congratulations, Lynn!**

MS. STARKS: Mr. Chair, I believe we had one more presentation from Tom O'Connell.

CHAIR DAVIS: Ooh, that's right, I think I'm operating off an outdated version of the agenda. Thanks, Caitlin. Okay, so at this point I'll go ahead and ask Tom to give his presentation.

UPDATE FROM USGS EASTER ECOLOGICAL SCIENCE CENTER ON ALOSINE SCIENCE IN SUPPORT OF INTERSTATE MANAGEMENT

MR. TOM O'CONNELL: Well, it's a pleasure to get invited and to see a lot of familiar names on the attendee list, and hear some familiar voices, because it's been a little while. I really appreciate the opportunity to highlight some of the Alosine research that USGS is involved in at the Eastern Ecological Science Center.

Just for those of you that are not familiar with myself. Again, it's Tom O'Connell, and I'm the Center Director for the USGS Eastern Ecological Science Center. Many of you might be familiar with me with my time for the Maryland Department of Natural Resources Fishery Service, where I spent most of my career, including time as the State's Fisheries Director, and it's a pleasure to come back here today and join all of you.

For those of you that may be less familiar with USGS, you may be asking why is U.S. Geological Survey involved in ASMFC fishery science. It kind of goes back to a reorganization of DOI back in 1993, where there was an interest of the department to separate science from management, and a lot of the scientists across the DOI bureaus were moved over to USGS. As a result of that, you know USGS is the only non-regulatory science agency within the Department of Interior, which uniquely positions USGS to deliver ASMFC actional science, as required by the Atlantic Coastal Fisheries Cooperative Management Act of 1993, which states that the Secretary of Commerce and DOI shall implement a science program to support ASMFC.

In 2020 the Eastern Ecological Science Center was formed out of a result of a merger between two other science centers, so Leetown Science Center, which is mostly a fish and aquatic science center, and the Patuxent Wildlife Research Center, which is more of a terrestrial wildlife science center. I've been asked to serve as a center director for the new Eastern Ecological Science Center, and you can see what our vision and goals are going forward.

But ultimately it comes down to, I'm really trying to establish a culture amongst our scientists, where we have a strong engagement with partners like the Atlantic States Marine Fisheries Commission, and we're aligning our limited, appropriated budgets to the highest priorities of our partner needs, and hopefully be viewed as a go-to organization to support science needs.

We are located in the Eastern U.S. We have three main laboratories in West Virginia, Maryland and Massachusetts, as well as eight field locations where we have scientists co-located at universities or other science centers. EESC is well positioned to be the lead science center amongst USGS to support the science needs of ASMFC.

About three years ago in an effort to try to strengthen USGS partnerships, I initiated communications with USGS leadership, and obtained support for strengthening USGS science support to ASMFC, and the USGS ecosystem mission area that provides funding to our center agreed to provide $100,000.00 in each of the past three years to allow us to increase our science support to ASMFC.

Through a lot of partnerships with agencies like NOAA, National Marine Fisheries Service, U.S. Fish and Wildlife Service, states and other parts of USGS, we've been able to leverage that initial investment to support over 20 research projects that are now totaling about 2 million dollars.

I just want to make a very important point that our involvement is not meant to be competitive with other federal or state agencies, we are really viewing this as a complementary science support role. We work very closely with NOAA and Fish and Wildlife Service and other states. To make these investments as beneficial as possible, we have coordinated closely with Pat Campfield as Science Director.

Where our scientists look at your five-year science priorities document, develop ideas, and we run those through Pat and Technical Committee representatives, and get feedback on which projects would have the greatest impact to ASMFC, and those are the ones that we've been focusing in on. Another way that we're looking to provide support to ASMFC is increasing our participation on the

Science and Technical Committees, here is a number of them that USGS has representatives, not just at Eastern Ecological Science Center, but other cooperative research units that fall under USGS responsibility and other science centers. Through this increased partnership, it's been recognized that it would be valuable to establish a new memorandum of understanding between NOAA, Fish and Wildlife and ASMFC to formalize USGS Science support role.

That is going to help me solidify longer term funding, and hopefully increased funding support over time. That's a little bit about why USGS is involved, and what I wanted to do is just highlight some of the research projects that are underway at the Eastern Ecological Science Center that pertain to Alosines.

These are ten projects that are listed here. Several of them are very relevant to your discussions today. The projects range from population structure and dynamics to fish help to aquatic ecosystem, habitats, and including but not limited to fish passage design and testing, which was talked about in the Technical Committee, just the past agenda item.

I'm not going to highlight all ten of these projects, but I did want to highlight a couple of them in more detail. This first project is the Alosine genetic stock identification and tissue repository, led by Dr. Dave Kazyak, who is our Center's lead geneticist in the Dr. Tim King Genetics Lab. I'm sure many of you may have known Tim King over the years.

Dave and his team are using genetic markers to build baseline information for American shad, blueback herring and alewife. The use of single nucleotide polymorphisms will provide enhanced resolution of stock structure, greater repeatability, and cost savings when compared to previous genetic analysis using microsatellite markers.

I know there were previous conversations in regards to the funding of this work, which was approved in the TC recommendation. This is an area where USGS I think, can really prove beneficial to ASMFC. We're mostly an appropriated funded science center, and I will do my best if this remains a priority of ASMFC, to provide the funds to help support the genetic analysis.

If not fully depending on the scale of effort, we will try to at least minimize the additional cost that would be needed to support this work. Our scientists are seeking collaborators to assist with sample collection, and if any of you have individuals that are able to collect tissue samples, there is contact information here to contact, and we can provide the information needed to receive the samples, and make them part of the genetic tissue repository.

The other area I want to highlight relates to fish passage. Our Center's Conte Anadromous Research Fish Laboratory in Turner Falls, Massachusetts, has a very unique fish passage research facility located along the Connecticut River, where we have biologists, hydraulic and civil engineers working together to design and test fish passageways tailored to specific species and river systems.

These scientists, some of you may know include Alex Haro, Ted Castro-Santos, Kevin Mulligan, and Brett Towler, who has been with Fish and Wildlife Service but now working with Eastern Ecological and others. What is unique is we're able to utilize a multiscale flume testing laboratory, where scientists are able to test initial ideas at a smaller scale, until they obtain the desired performance requirements, tailored to a particular species of fish. Then as they get close to that they can build it down into a larger prototype, and put it into one of our larger flume systems, where we're able to introduce fish of interest, and be able to monitor their performance related to these designs through an advanced telemetry system that we have in the flume system.

These multi-disciplinary team of scientists are improving fishway designs. They are looking to increase the percentage of alosines that are able to find the passage, reduce the amount of time it takes for a fish to pass the ladder, and increase survival of upstream and downstream migration. This information may be pertinent to some of the performance criteria that is currently being discussed.

One project that our scientists are involved in is focused on reducing the time, and increase the proportion of fish that are passing a fishway once they enter it. This begins with looking at the fish entranceways, and this project we're looking at reducing the amount of time for fish that are approaching a fishway entrance to find it.

Increase the attraction and the proportion of fish entering it, and ultimately help increase the survival of upstream migration. Another part of our science focus on fish passage is looking at what happens when the fish actually gets into the fish ladder. This project is looking at a Novel D-cylinder design to try to improve, reduce the amount of time and increase the proportion of fish that once they enter the ladder can actually get through, and be at a health level that they can continue upstream and spawn successfully.

As many of you probably know, many historic Atlantic Coast fish ladders were designed based upon technologies developed for Pacific salmonids, which have very different swimming capabilities than the fish we're targeting on the Atlantic Coast. By having scientists that can understand the swimming behavior of these species of fish.

Then working together with our hydraulic and civil engineers, we can look at designs that are more tailored to the Atlantic species of interest like shad and herring. Then the last project I wanted to emphasizes. This project focuses on fish habitat assessments, and as many of you know, one of the biggest drivers to our Atlantic Coastal Fisheries is what's happening on the landscape.

Many of the times it's outside of our management regulatory control. This project is a project that we're working closely with NOAA, National Marine Fisheries and no end cost, where USGS is focusing on the headwaters down the tidal rivers, and NOAA is focusing on the tidal rivers down to the ocean.

What we're working to do is to increase our ability to assess the path of habitats, and understand the drivers and stressors of those habitats over the entire Chesapeake Bay Watershed. This project builds upon the National Fish Habitat Partnership, but with the richness of data in the Chesapeake Bay we're able to incorporate a lot more data, and are also looking to examine this data at a much finer spatial scale, which the local and state managers are saying is important for them to be able to utilize this information. Hopefully this project will be transferrable to other parts of the Atlantic Coast if successful. With that, I really appreciate the opportunity to present and highlight some of the work that USGS is involved in. I feel that we're just scratching the surface. We're looking to really grow this program to provide complementary science, and wanted to thank Pat Campfield and Toni Kerns and Lisa Havel and Deke Tompkins for helping us with the coordination, communication.

As well as my colleagues at NOAA, National Marine Fishery Service and U.S. Fish and Wildlife Service. We're really working together to try to complement our science to really hit the high marks of ASMFC science needs, so thank you, and happy to answer any questions you might have.

CHAIR DAVIS: Great, thanks very much for that, Tom. That's a great presentation and it's really great to see all the good science that USGS is doing in support of management of our ASMFC species. At this time, I'll ask if anybody on the Board has any questions for Tom.

MS. BERGER: I don't see any hands raised. I stand corrected, sorry, Lynn Fegley and Bill Hyatt.

CHAIR DAVIS: Okay, go ahead, Lynn.

MS. FEGLEY: I don't so much have a question as I just really want to thank Tom. You know this is pretty visionary and high time, you know that we have this linkage, and really have a means to bring to bear the scientific capacity at USGS. I just really love the fact that you are working through Pat

Campfield and reviewing those, you know those science priority reports from ASMFC. I just want to thank you for thinking this through and making it happen.

MR. O'CONNELL: Thanks a lot, Lynn, I appreciate that. We're excited about it.

CHAIR DAVIS: Okay, Bill Hyatt, you're up next.

MR. HYATT: Tom, I just had a quick question, just was wondering relative to the Chesapeake Project that you spoke about briefly. Just if you could comment on how much you folks for that project are drawing on work that was done by the North Atlantic Landscape Conservation Cooperative, or the Landscape Conservation data that they had collected over a number of years, of which USGS was an active partner.

MR. O'CONNELL: Thanks a lot, Bill. Yes, Steve Faulkner at our Center has worked with those Landscape Cooperatives. My understanding is that we're looking to build upon those efforts. One part of this effort was taking a lead to obtain data from all the different organizations pertaining to fish habitat and fish abundance throughout the Chesapeake Bay watershed.

We've successfully brought all that data together into a single database, and it's available to anybody. It's really trying to build off of the work that has already been done, and advancing that. I will follow up with Steve Faulkner's team, to make sure that my understanding is correct, but that is my assumption at right this point in time.

MR. HYATT: Excellent, thank you.

MS. BERGER: Dr. Chair, James Fletcher, there are no Board members but James Fletcher has his hand raised.

CHAIR DAVIS: Yes, sure, go ahead, Jim.

MR. FLETCHER: The question is, are you aware of the chemicals that are going into the water? You mentioned habitat, you mentioned fish passage, everything else. But I'm on a thing for years I ask about the estrogen in the water and affect in the reproduction of fish. Now it comes out that even the EPA is mentioning PFAS.

But the whole solution to the problem is to stop meniscal waste from being dumped into the water and pass it through some type of vegetative material. All of this is fine to talk about, but it's not a solution. The solution to pollution is pass the water through vegetation. Is it any chance at USGS will take on that issue? Thank you for your time.

MR. O'CONNELL: Great question, Jim, I appreciate you bringing it up. USGS has a very strong water quality monitoring program, and our Chesapeake Bay Fish Habitat specimen is working very closely to understand those drivers and stressors. We have a number of scientists, Vicky Blazer and Steve McCormick that have done a lot of work on endocrine destructors.

That is the big part of this Chesapeake Bay Habitat Assessment, is understand the status of these habitats and fish, and then try and understand what the drivers and stressors are, including contaminants like the ones you mentioned. We also just stood up a new PFAS lab in our West Virginia facility.

That is enabling us to examine PFAS contaminant levels in tissue samples of animals, and we've started some pilot projects this year. Happy to continue this conversation if there is interest of ASMFC, but we do have the expertise, we do have current projects, and be happy to discuss further if that is of any interest.

MS. BERGER: Tom Fote also has his hand raised at this point.

CHAIR DAVIS: Okay, Tom Fote, go ahead.

MR. THOMAS P. FOTE: Yes, Tom, nice to hear from you again. Too bad we can't see each other. Yes, I just wanted to point out that I sat through a presentation from USGS at the Pilots Commission discussing that you had looked at waters up in Pennsylvania that were not coming from sewer plants but coming off farmland, and the high levels of endocrine disruptive.

I really appreciate it, because that had not really been put in the forefront as it is now, so we can look at what's coming into the Susquehanna and a few other areas in the Delaware River from what's coming up from farmlands.

MR. O'CONNELL: Thanks, Tom, it's great to hear your voice, and I can't believe a meeting has almost ended without Pat Augustine making a motion. I don't know if that has ever happened.

CHAIR DAVIS: Do we have any other hands?

MS. BERGER: No.

CHAIR DAVIS: Well, thanks again, Tom for that presentation and for being here today, much appreciated.

MR. O'CONNELL: You're welcome.

CHAIR DAVIS: All right at this time I'll ask if there is any other business to come before this Board today.

MS. BERGER: No hands raised.

ADJOURNMENT

CHAIR DAVIS: Okay thank you, well then, I will thank the Board today for a productive meeting, thank Brian for the excellent presentations, and for doing most of the heavy lifting today, and thank Caitlin Starks and Commission staff for all their work in support of this Board. With that I'll entertain a motion to adjourn.

MS. FEGLEY: So moved.

CHAIR DAVIS: Okay, was that Lynn?

MS. FEGLEY: Yes, it was.

MS. BERGER: Cheri Patterson has her hand up as a second.

CHAIR DAVIS: Okay, this Board will stand adjourned, thank you everybody.

(Whereupon the meeting convened at 10:22 a.m. on October 19, 2021.)

American Shad Habitat Plan for the Connecticut River

Connecticut River Atlantic Salmon Commission

Connecticut Department of Energy and Environmental Protection
Massachusetts Division of Fisheries and Wildlife
Massachusetts Division of Marine Fisheries
New Hampshire Fish and Game Department
Vermont Department of Fish and Wildlife
U. S. Fish and Wildlife Service
National Oceanic and Atmospheric Administration Fisheries Service

December 1, 2021

Table of Contents

1 INTRODUCTION

The Atlantic States Marine Fisheries Commission's (ASMFC) Amendment 3 to the American Shad and River Herring Fishery Management Plan (FMP) requires all states to submit a Habitat Plan for shad stocks in their jurisdiction. This document is an update to the first plan submitted and approved in 2014 for the Connecticut River basin. The ASMFC requested a collaborative effort on larger, multi-jurisdictional river plans such as the Connecticut River. Two federal agencies and the four basin member state agencies contributed the Plan. The Connecticut Department of Energy and Environmental Protection (CTDEEP) submitted a statewide plan, including the Connecticut portion of the Connecticut River, to accompany the CTDEEP Sustainable Fishing Management Plan for American Shad (CTDEEP, 2017). The CTDEEP, State of Connecticut American Shad Habitat Plan was approved by the ASMFC in 2021 (CTDEEP, 2021). The Connecticut River's American Shad population is under active restoration through the multi-agency Connecticut River Atlantic Salmon Commission (CRASC), signed into federal law in 1983 with complimentary State legislation (Gephard & McMenemy, 2004). The CRASC and its predecessor organization has served as the lead in obtaining both upstream and downstream passage measures at main stem dams and in coordinating state and federal agencies, commercial river users, and other partners on management topics for this species. The CRASC Technical Committee, under the policy guidance of the Commission, maintains Shad Studies and Fish Passage subcommittees that actively work on topics including shad habitat and access to habitat. The CRASC approved an updated version of the Connecticut River American Shad Management Plan in 2017 replacing the 1994 Management Plan. The 2017 Management Plan utilized a habitat-based approach to define minimum population targets for returns to the river and for the extensive segmented habitat reaches caused by dams in the main stem and tributaries. In 2020, CRASC Commissioners approved the Addendum "Fish Passage Performance" as part of that 2017 Management Plan and included criteria for adult and juvenile shad passage performance that will be defined later in this document (CRASC, 2020). The Federal Energy Regulatory Commission (FERC) approved both documents as a Comprehensive Management Plan[1]. This plan reflects that fish passage is an essential component of any habitat considerations for the restoration and management of the Connecticut River American Shad population.

2 HABITAT ASSESSMENT

The historic upstream extent of the species range on the main stem is Bellow Falls, Vermont, at rkm 280, with three main stem dams located within this range (Table 1 and Figure 1). For this assessment, we have considered habitat in the context of the main stem and tributary barriers that have fragmented, eliminated, or reduced access and altered habitat conditions throughout the basin. Surveys for shad eggs and larvae and spawning behavior have been conducted in the main stem within the state of Connecticut (Marcy, 1976) and from Holyoke Dam (rkm 139) to the Turners Falls Dam (rkm 198), Massachusetts. Marcy (1976) identified American shad spawning in the lower main stem river at river kilometer (rkm) 26 to the most upstream study site at rkm 87, Enfield, Connecticut, with major spawning areas identified as Windsor Locks (rkm 78), Wilson (rkm 74) and Rocky Hill (rkm 51). University of Massachusetts research has shown a relatively wide distribution of documented spawning primarily from egg and fish behavior surveys between the Holyoke Dam, Massachusetts (rkm 139) and the Turners Falls Dam, Massachusetts (rkm 198)

[1] FERC's List of Comprehensive Plans July 2020 can be accessed at https://www.ferc.gov/sites/default/files/2020-07/ListofComprehensivePlans.pdf

(Gilmore, 1975; Watson, 1970; Layzer, 1974; Kuzmeskus, 1977). Shad spawning habitat is located to varying degrees upstream of dam impoundments on both the main stem and identified tributaries and are subject to shifting (over space and time) with changing river discharge (Greene, et al., 2009). The University of Massachusetts conducted studies in the late 1960s and 1970s that showed shad spawning starting at rkm 140, just upstream of Holyoke Dam, to rkm 192, at 22 sampled sites (Kuzmeskus, 1977). Most of the preferred spawning habitat in this main stem reach begins upstream of the Holyoke Dam's impoundment, beginning approximately at rkm 180 and extending upstream to the Turners Falls Dam (rkm 198). Given the lack of consistency in geographically limited habitat assessments, we are currently unable to quantify habitat designations at a fine scale.

Table 1. Main stem dams on the Connecticut River from rkm 0 upriver to the historic upstream extent of American shad range, Bellow Falls, Vermont, at rkm 280.

River Km	Barrier	Designated extent of upstream impoundment/habitat break (rkm)[A]	Purpose	Status
110	Enfield Dam (historic site), Enfield CT	0	Barge canal use	no longer present
139	Holyoke Dam, Holyoke, MA	177	Hydroelectric power	Active, with fishways
198	Turners Falls Dam, Montague, MA	226	Hydroelectric power	Active, with fishways
228	Vernon Dam, Vernon, VT	273	Hydroelectric power	Active, with fishways
280	Bellows Falls Dam, Bellows Falls, VT	-	Hydroelectric power	Active, with fishways

[A] reported impoundment distance may vary slightly, designations attempt to consider transition in habitat features in these dynamic area

As part of the FERC relicensing process for the Turners Falls Dam/Project, Northfield Mountain Pumped Storage Facility, Vernon Dam/Project, and Bellows Falls Dam/Project that started in 2012, several studies specific to American Shad spawning and habitat, in relation to hydropower project operations, were proposed by the agencies and completed by the respective companies. In December 2020, both FirstLight Power (FLP) and Great River Hydropower (GRH) filed Amended Final License Applications (AFLA's). As part of the study phase of relicensing, FirstLight Power Study Report 3.3.6, examined shad spawning, spawning habitat and egg deposition in the areas of the NMPS and Turners Falls Project (FLP, 2016). The study area covered from the Vernon Dam tailwater to the Route 116 Bridge, Sunderland, MA. Their study (using splash counts) reconfirmed findings of spawning and habitat use/types described by earlier university studies, downstream of Turners Falls Dam. Survey work also identified shad spawning activity downstream of Vernon Dam several kilometers. The impoundment of the Turners Falls Dam extends very close to the Vernon Dam (1-2 kilometers) depending on operations and river discharge among the hydroelectric projects (Vernon, NMPS, Turners Falls).

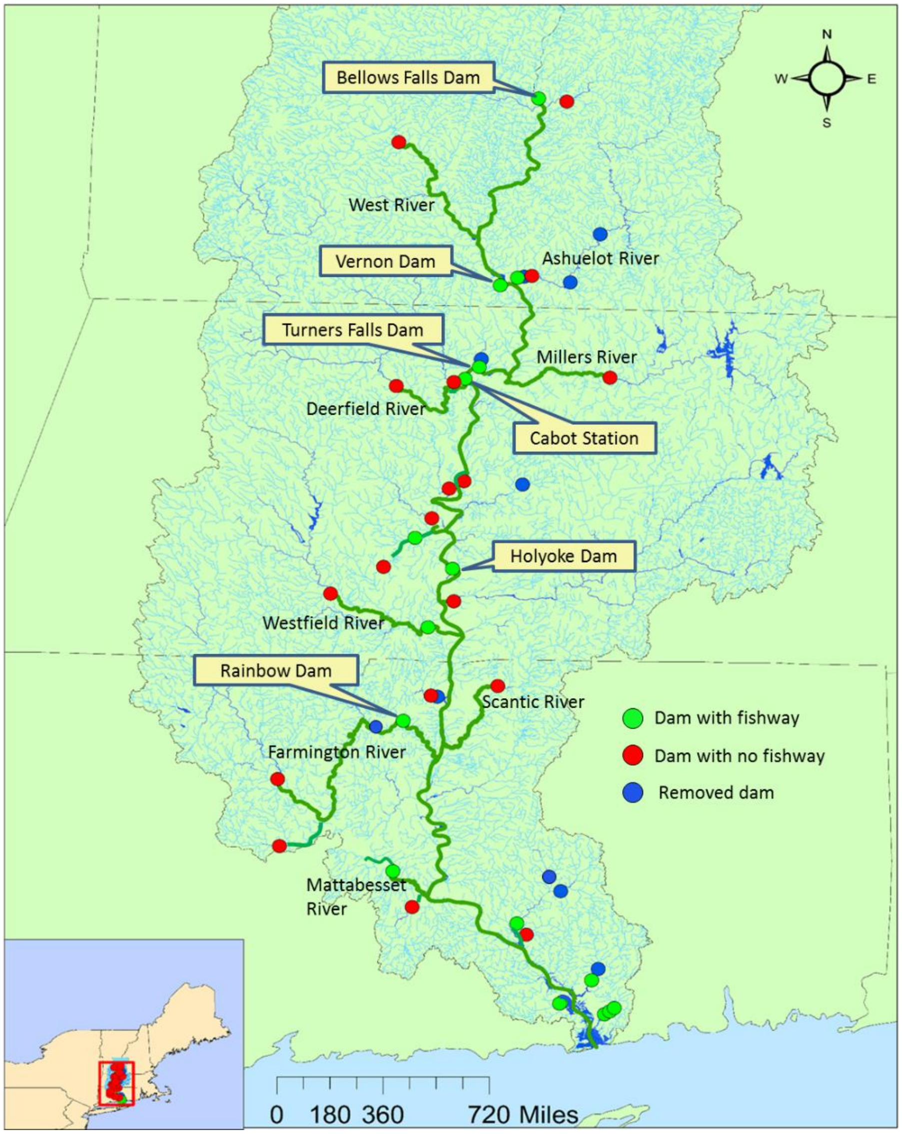

Figure 1. The current range of American shad (green line) in the Connecticut River basin.

A similar study to examine American Shad spawning activity in relation to project operations was completed between Vernon Dam and Bellows Falls Dam. The Study 21 "American Shad Telemetry Study" Final Report (2017) by TransCanada Hydro (sold to GRH same year) describes adult shad movements up to Bellows Falls Dam, ichthyoplankton net surveys for eggs, stage of development and back-calculated area of spawning origin (Normandeau, 2017). Results identifies shad spawning occurring in the riverine habitat downstream of Bellows Falls Dam as well as within the Vernon Dam impoundments and immediately downstream of Vernon Dam (surveyed to 2 km downstream). The report states that tracking of radio tagged shad and ichthyoplankton sampling identified spawning occurred most frequently over gravel-cobble substrates. Available spawning habitat was modeled based on cited criteria under a range of operational conditions. The report notes that habitat areas closest to the dams (Bellows and Vernon), are subject to the greatest variations in habitat (i.e., discharge, flow velocity, and substrate) when modeling between current minimum required flow and the maximum generation capacity. Thus, variations in sub daily hydropower operations (frequency, timing, magnitude, and duration) are a concern to the agencies for persistent spawning habitat of American Shad.

Annual monitoring of juvenile shad has occurred upstream of Vernon Dam, in the lower impoundment and immediately below Vernon Dam (2 km) by the owners of Vermont Yankee Nuclear Power Station for 15 years, concluding in 2012, with its closure. Beginning in 2017, the Massachusetts Division of Fisheries and Wildlife and the U. S. Fish and Wildlife Service, have conducted a juvenile alosine production survey from the Bellows Falls Dam to the Holyoke Dam (Mattocks, 2019). That study has shown juvenile shad present in all sampled habitat types from August through November annually, using a random stratified cell approach and boat electrofishing gear. Comparisons among river segments from this study have also shown density dependent effects for juveniles sampled in the Turners to Holyoke segment when compared with fish data from both the Bellows to Vernon segment and Vernon to Turners Falls segment (Mattocks, 2019). Insufficient upstream fish passage measures at the Turners Falls Project reduce spawner access to upstream habitat, resulting in stockpiling of production in the Holyoke Pool and underutilized juvenile habitat/production up to the Bellows Falls Dam. The FERC relicensing process will be used to address these upstream passage issues as well as downstream passage concerns in addition to habitat concerns (daily and sub daily peaking operations). The CTDEEP also has maintained a long-term juvenile alosine production survey in the mainstem river from below Holyoke Dam, MA to Essex CT. The CTDEEP survey provides a valuable long-term data set that is used in the Sustainable Fishery Management Plan for Shad (CTDEEP, 2017).

Table 2. Connecticut River estimated spawning and rearing habitat for American Shad by main stem river segment (dam location) in relation to estimated adult shad production or return potential, and minimum annual target fish passage number by barrier. Production is fish/hectare of multiple age classes in a year (203 f/ha in mainstem and 111 f/ha in tributaries).

Reach	Ha	Adjust-ment	Ha	% of total	Adult Shad Return or Production	Project	Minimum target
Main stem Mouth to Holyoke	5,677	0.85	**4,825**	**54.8**	**979,498**		
tributaries (5)	*424*		*424*	*4.8*	*47,064*		
Main stem Holyoke to Turners Falls	1,369		**1,369**	**15.5**	**277,881**	**Holyoke Fish Lift passage**	**687,088**
tributaries (2)	*109*		*109*	*1.2*	*12,099*		
Main stem Turners to Vernon	762		**762**	**8.7**	**154,691**	**Turners Falls Ladder passage**	**397,108**
Tributaries [A] (1)	*139*		*139*	*1.6*	*15,429*		
Main stem Vernon to Bellows Falls	1,042		**1,042**	**11.8**	**211,559**	**Vernon Ladder passage**	**226,988**
tributary (1)	*139*		*139*	*1.6*	15,429		
Totals	**9,661**		**8,809**	**100.0**	**1,713,651**		

[A] Millers River habitat area undefined

Historic and, in some cases, current American shad distribution include three tributaries in the State of Connecticut, five in the State of Massachusetts, one in the State of New Hampshire, and one in the State of Vermont (Table 3). Habitat information is based on the best information available which often is based on a limited qualitative assessment. It is important to note that it is difficult to categorize what type of habitats may have existed under current dam impoundments.

Table 3. The estimated spawning and rearing habitat for American Shad, by tributary in relation to estimated minimum annual adult shad production or return potential for tributaries (111fish/ha).

Tributary	Total rkm	Area (estimated) ha	Adult Shad Return or Production
Mattabesset, CT	36.3	54.5	6,044
Farmington, CT [A]	72.7	221.0	24,528
Scantic, CT	22.4	31.4	3,481
Westfield, MA	29.4	117.6	13,054
Chicopee, MA[B]		T.B.D.	
Manhan, MA	23.0	23.0	2,553
Deerfield, MA	21.5	86.0	9,546
Millers, MA[C]		T.B.D.	
Ashuelot, NH	60.0	139.0	15,429
West, VT	31.0	139.5	15,485
Total			90,119

[A] – The Pequabuck rkm and habitat area is included with the mainstem Farmington
[B] - First dam is ~1 rkm from confluence with numerous subsequent dams
[C] – Relatively high gradient tributary, more data required

3 HABITAT ACCESSIBILITY

Adult shad have varied degrees of access to main stem habitat to the historic extent of their range up to Bellow Falls Dam (VT) using a fish lift system at the Holyoke Dam (MA), three fish ladders at Turners Falls Dam (MA) where successful passage requires use of two fishways, and the Vernon Dam fish ladder (VT). Upstream fish passage efficiency remains a major concern and has been demonstrated to vary widely among these main stem facilities, with the Turners Falls fishway complex determined to be most problematic for upstream shad passage (Appendix 1). Annual shad passage counts at the second and final required ladder at Turners Falls Project have averaged 10% of the number of shad passed at the previous downstream Holyoke Dam, since some 2010 passage improvements at Turners Falls. Alternatively, the Vernon Dam fish ladder has annually passed 58% (annual average) of the shad counted passing from Turners Falls Project since 2012 fish ladder improvements, excluding the 2020 outlier season due to an entrance gate issue identified in 2021 (Appendix 1). The previously noted FERC relicensing process for Turners Falls has with company agreement, included plans to install a new upstream fish passage facility as noted in their Amended Final License Application (AFLA) submitted to FERC in December 2020 with other proposed passage and protection measures (FirstLight Hydro LLC, 2020; Northfield Mountain LLC, 2020). GRH has also submitted an Amended Final License Application with FERC (December 2020) that provides estimated funds to improve fish passage efficiencies without going into specific detail (Great River Hydro, LLC, 2020). GRH also has proposed (in consultation with the agencies and other stakeholders) operational changes that will create "more stable impoundment water surface elevations…reduce the magnitude and frequency of sub-daily operational changes in discharge from each project, by increasing the amount of time that the Projects are operated in an inflow equal outflow mode" (Great River Hydro, LLC, 2020). The proposed shift in operations will benefit American Shad habitat for all life stages and life history (spawning and migrations). Both AFLAs are presently under agency review. The federal fishery agencies are also working on fishway prescriptions and habitat recommendations as part of this FERC process and Federal Power Act authorities.

Table 4. Identified American shad tributaries of the Connecticut River basin with first and second dam locations and status of passage.

Tributary	Distance to 1st upstream dam (rkm)	First Dam	Passage provided by	2nd Dam (rkm)	Status	3rd Barrier (rkm) and notes
Mattabesset	11	StanChem	Denil Ladder	Kensington (36)	Alaskan Steepass	Natural waterfall (38)
Farmington [A]	13	Rainbow	Vertical slot	Lower Collinsville (60)	Plans for removal	Upper Collinsville (62), Denil ladder construction 2021
Scantic	21	Somersville	None, not planned	-	-	-
Westfield	7	West Springfield	Denil Ladder	Woronoco (30)	Upstream extent of habitat	-
Chicopee	2	Dwight	None	Chicopee (5)	Nothing planned at this time	-
Manhan	5	Manhan	Denil Ladder	Unnamed (18)	Upstream extent of habitat	-
Deerfield	21	Great River Hydro Dam #2	Upstream extent of habitat	-	-	-
Millers	14	Erving Paper	Partial breach	New Home (22)	Nothing planned at this time	-
Ashuelot	3	Fiske Mill	Fish lift	Lower Roberts (5)	Future U/S passage plan is based on passage trigger at Fiske	-
West	31	Townshend (ACOE)	Upstream extent of habitat	-	-	-

[A] Final barrier is Hogback Dam at rkm 72. The Pequabuck River is a tributary to the Farmington with 17 ha of habitat.

The 2020 American Shad Benchmark Stock Assessment and Peer Review Report provides a comprehensive review of the many issues with fish passage for adult and juvenile shad on both upstream and downstream passage measures (ASMFC, 2020). The Report also contains a modeling analyses to quantify losses of both habitat and adult production from dams that strongly support the need to have substantial improvements in the "performance" of fishways related to percentage rate of passage success, time to pass (delay issues), and survival from passage. These passage metrics must also be considered in their cumulative effects given fragmentations of habitat by dams in shad rivers like the Connecticut River basin. The need and benefits of having improved, achievable passage performance criteria is well supported and necessary with improvements in fish behavior research and fish passage engineering (USFWS, 2019).

Access to tributary habitat in the Connecticut River basin is often limited due to the presence of dam(s) that often are located less than 20 km from the confluence with the main stem river (Table 4).

Distances of unobstructed access to the first barrier and type of available passage are noted with status of the next barrier, in Table 4. However, as is the case on the main stem, fish passage efficiency is poorly understood on tributary dam fishways. The first dam on the Farmington River has the Rainbow Fishway, in operation since 1976, which is known to not effectively pass shad upstream. This State-owned facility is planned for a replacement in the future with some noted concerns for downstream passage effectiveness. This dam and power station are nonjurisdictional with FERC, restricting agency options on passage and protections. The Westfield River (MA) is the next major tributary with substantial habitat access provided by a Denil fishway at the West Springfield Dam. This fishway has not been evaluated, but shad passage efficiency is expected to be suitable based on the best professional judgement of agency biologists. Other substantial, but not studied tributaries that may provide shad spawning and nursery habitat include the lower Deerfield River (MA) up to its first dam (Dam 32), a distance of 21 rkm and the Millers River (MA), which like the Deerfield quickly transitions into higher gradient reaches and larger substrate types, but also includes more reaches of run habitat between riffles than the Deerfield River. Appendix 2 provides data on barrier locations, habitat, passage types and related data, specific to the Connecticut River basin that is under continued development by the Technical Committee for all American Shad river systems.

4 THREAT ASSESSMENT

4.1 Threat: Barriers to Migration Upstream and Downstream

4.1.1 Recommended Action:

The 2020 American Shad benchmark Stock Assessment and Peer Review Report provides a comprehensive review of the many issues associated fish passage for adult and juvenile shad on both upstream and downstream passage measures and includes the following quotes (ASMFC, 2020):

> *River basin management plans are increasingly placing upstream and downstream passage impacts, needs, and recommendations in the context of cumulative dam/hydropower effects and requiring passage performance measures that are quantitatively defined rather than the open-ended passage terms of "safe, effective, and timely".*
>
> "*Commerce and Interior have not included any specific performance standards that would be used to test the effectiveness of the fish passage facilities…Without specific performance standards to analyze, there is no basis for assessing the benefits of effectiveness testing for fish passage and determining whether effectiveness testing would or would not provide benefits to Alosines…*" (FERC, 2018)

The Plan's Recommended Actions relative to this threat are consistent with the objectives listed in the CRASC's Connecticut River American Shad Management Plan (2020) which includes the following fish passage management objectives:

1. Establish safe, timely, and effective upstream and downstream fish passage for returning adults, post spawn adults, and juveniles [Completed refer to Addendum]; and
2. Establish upstream passage performance measures, addressing fishway attraction, entry, internal passage efficiency and delay at these three stages, as suitable information is available, to support other objectives of this Plan [Completed refer to Addendum]; and
3. Establish downstream performance measures, for adult and juvenile life stages that maximizes survival for through-project passage and that address downstream bypass route attraction, entry, passage efficiency, and delay, as suitable information is available to support objectives of this Plan [Completed refer to Addendum].

The 2020 CRASC Plan Addendum on Fish Passage Performance includes the following Criteria or Objectives for both adult (upstream and downstream) and juvenile (downstream) American Shad for hydroelectric projects in the Connecticut River basin:

1. Upstream adult passage minimum efficiency rate is **75%**, based on the number of shad that approach within 1 kilometer of a project area[A] and/or passage barrier. Passage efficiency is [(# passed/# arrived)*100];
2. Upstream adult passage time-to-pass (1 kilometer threshold) is **48 hours or less** based on fish that are passed (requires achieving Objective #1);
3. Downstream adult and juvenile project passage minimum efficiency and survival rates are each **95%**, based on the number of shad that approach within 1 kilometer of a project area[A] and/or passage barrier and the number that are determined alive post passage (not less than 48 hours evaluation). Passage efficiency is [(# passed/# arrived)*100] and passage survival is [(# alive downstream of project/# passed)*100].
4. Downstream adult and juvenile time-to-pass is **24 hours or less,** for those fish entering the project area[A].

[A] – Project area shall be defined as comprising the river within 1 km of the up- and downstream extent of a hydropower facility and its footprint components. Where a powerhouse is separated from a dam, e.g., by a power canal, this will also include any bypassed reach of the river. The applied definition for 1 km threshold, includes situations whereby a bypassed river reach exists (with regulated/altered flows) from the development and use of a power canal system, by a hydropower operator. In such cases, the location of the dam proper may be several kilometers upstream of the terminus of the power canal system. For upstream passage, the terminus of the power canal and any associated hydropower facility will be the approach basis for the 1 km project area, not the dam. Alternately, for downstream passage, the dam and gatehouse will serve as the basis for the 1 km project approach area, not the generation facilities in the power canal.

Fishways should be evaluated for upstream passage performance (number available relative to passed and time-to-pass) and enumeration of passed fish should occur annually. Downstream passage performance should be evaluated at both main stem and tributary projects/fishways for both adults and juveniles. Study plans may include radio and PIT tags to determine rate of attraction to near field, retention in the entry area, fishway entry/fall backs, and successful passage to exit area in relation to a range of operational conditions and other factors relevant to study goal/objectives (possible survival and injury rates etc.). Available information suggests delays in both upstream and downstream passage of adult shad are occurring and should be examined and as issues are noted, measures should be implemented and/or developed to achieve CRASC passage performance criteria. Cumulative effects from passage efficiency, delay, and through project mortality are of particular concern given the number of hydroprojects in shad habitat and achieving the goals and objectives of the Plan. Ideally, pre-season, in-season and post season fishway inspections by federal Fish Passage Engineers would occur to increase the ability to identify any issues and ensure operations are following design criteria, to prevent negative impacts that can be avoided in the relatively brief passage season.

4.1.2 Fish passage/habitat access mainstem Connecticut River (MA, NH, VT)

Fish passage performance criteria from the CRASC American Shad Management Plan have been previously described. American Shad have access in the main stem Connecticut River to the historic upstream extent of their range, Bellows Falls, Vermont, using fishways of varied design and operation and efficiencies (Table 1, Figure 1, Appendix 1). Upstream passage for shad includes a fish lift system at Holyoke Dam, upgraded in 2005, as part of that dam's FERC relicensing process. Based on both historic unpublished studies on shad movement, the Holyoke fish lift system (1976-present) passed between 40 to 60% of the adult shad that entered the river mouth in the spring. Additional modifications to that facility completed in 2016, to improve up and downstream passage efficiency/protections, may have affected upstream fish passage rates (percentage passing and time to pass). A mark-recapture study using fish tagged at the mouth should be developed to answer questions on the proportion of shad passage at Holyoke in relation to the population entering the river and factors of influence on passage rates.

Upstream Passage Measures

Turners Falls Dam, Massachusetts - Upstream shad passage at Turners Falls Dam has been problematic since the opening of its three fishways in 1980. Fish are required to enter and use at least two fishway ladders at this project to bypass this barrier system. Fishway designs were based on the best available information at that time. The Cabot Station (powerhouse), at the end of a 3.4 km power canal off the Turners Falls Dam, is the primary location of shad attraction on their upstream migration and has a modified "Ice Harbor" design ladder. Fish that successfully pass that ladder must then proceed up the power canal to the Gatehouse, which contains the Gatehouse Fish Ladder (vertical slot design), that has two entrances from the canal. Fish may also migrate up the "bypassed reach" that parallels the power canal, to the base of the dam and use the "Spillway Ladder" (modified Ice Harbor design) that directs fish at its "exit" end to the entrance of the Gatehouse Ladder. Typically, spill at the dam is less than 1,000 cfs, with river flow directed to the power canal for power station use (up to 17,000 cfs). As part of the FERC relicensing process the facility owners have proposed to build a new fish lift facility at the base of the dam that would then direct fish into the Gatehouse Ladder. The discharge level in the bypassed reach, is proposed for seasonal flow increases as described in the FirstLight Power AFLA that would be tied to Shortnose Sturgeon spawning and early life stage needs in the bypass reach with recognition of fish passage needs for shad. The federal agencies are working on fish passage prescriptions (Federal Power Act; Section 18) and fish habitat recommendations (10J) for this project area currently.

Vernon Dam, Vermont/New Hampshire - Upstream passage at Vernon Dam is made possible through a fish ladder that is a modified Ice Harbor design in its lower section and serpentine vertical slot design in its upper section. This ladder became operational in 1981. Like other fishways, there have been modifications and adjustments made to address areas of concern. Following several years of low passage counts for shad, in 2011 a design feature/setting was identified as an issue by a USFWS Fish Passage Engineer. Corrective measures were completed with a marked increase in shad passage counts annually noted since 2012 (Appendix 1).

The CRASC Management Plan (2017) and its Fish Passage Performance Plan (2020) define downstream passage performance criteria for adults and juvenile shad that access habitat upstream of hydropower facilities. Cumulative effects from the multiple dams/projects in the basin may be impeding upstream habitat reach goals and objectives. The State of Connecticut Marine Fisheries Division has documented a long-term decline in the proportion of repeat spawners in the shad stock and modeling results (CRASC 2020) suggest poor downstream passage may be driving that trend.

Downstream Passage Measures

Holyoke Dam, Massachusetts - Numerous and varied downstream passage and protection measures have been explored and implemented at the Holyoke Dam to protect fish using the historic upstream habitats. Currently, the Holyoke Dam operates a Bascule Gate with a specially designed “Alden Weir” to facilitate downstream passage of spent American Shad moving towards the power stations intake/forebay to the proximally located gate. This gate is operated for downstream passage of fish from April through July, with dates or operation specified in a CRASC Downstream Passage Notification Letter, issued by the Connecticut River Coordinator. The Holyoke Dam, owned and operated by Holyoke Gas and Electric, completed substantial downstream passage improvements at the Hadley Falls Station in 2015, effective for 2016. A reduced space, full depth bar rack with 2.0 inch clear spacing was installed in front of the station intakes. A novel design downstream bypass with surface and mid-depth entrances and transfer system were placed into this rack. These bypasses direct fish to the downstream spill release from the nearby Alden Weir, in the project’s adjacent Bascule Gate. A pre-existing downstream bypass structure, this weir’s water release was hydraulically adjusted to direct water/fish at the base of the dam apron, up into the air and into a newly constructed plunge pool that was designed to meet USFWS Fish Passage Criteria. The “jump” reduces landing velocity into the pool and prevents disruption of the attraction flow/jet to the spillway fishlift entrance that passes underneath this jump. An angled retaining wall, near that fish lift entrance, that had interacted with a portion of the weir’s spill was also removed.

A second route for downstream shad passage at Holyoke includes the power canal, which has a gatehouse located at its upstream end, adjacent to the dam structure. Shad that are directed or move into the canal will swim and/or drift to a full depth angled weir that covers the entire canal approximately 1 km downstream. The weir bar spacing is designed for juvenile fish guidance as well. At the downstream corner of this acutely angled weir is the entrance to the downstream fish passage pipe. The pipe conveys fish into the tailrace of the Hadley Falls Station, where the pipe discharges directly into deep water from a height of several meters.

Turners Falls Dam - At the Turners Falls Dam/Project, adult and juvenile shad may pass using the following routes; 1) spill at the dam, 2) Station 1 through turbines (power station off the main power canal), 3) Cabot Station through turbines, 4) Cabot Station surface fish bypass/partial depth reduced rack spacing, and 5) Canal emergency spill gates. Downstream fish passage studies for both juveniles and adult shad have been completed for FERC relicensing. The agencies will be seeking the installation and operation of necessary measures to achieve CRASC downstream fish passage performance criteria for the project for adults and juveniles. These measures will likely include 1) plunge pool at the dam for spilled fish, 2) fish exclusion rack on side of power canal to Station 1, 3) full depth exclusion rack for turbines at Cabot, with downstream bypass passage entrances, 4) upgrades to existing surface bypass, sluiceway, and its associated structures.

Northfield Mountain Pumped Storage Facility, Massachusetts - The Northfield Mountain Pumped Storage Facility (NMPS) is also owned by Firstlight Power, they have also completed FERC studies examining entrainment of early life stages, adult shad upstream and downstream movements, and operational models on project area influences of flow during pumping and generation over a wide range of river discharge values. The company has proposed a full depth exclusion net seasonally installed to prevent juvenile (outmigrant size) entrainment following the CRASC downstream passage dates for juvenile shad protection (August 1 through November 15).

Vernon Dam - At Vernon Dam adult and juvenile shad may pass using the following routes; 1) spill at the dam or trash sluice, 2) through the stations turbines, 3) guidance from a partial depth and partial length louver which directs fish into the primary fish bypass pipe with a secondary, smaller bypass pipe on the Vermont near-shore side. GRH also completed downstream passage studies on both adult and juvenile shad as part of the relicensing process. The owner/operators have not proposed any specific plans for additional downstream passage measures but included dollar estimates in their AFLA (Great River Hydro, LLC, 2020). The agencies will seek the installation and operation of necessary measures to achieve CRASC downstream fish passage performance criteria for the project for adults and juveniles.

4.1.2.1 Agencies with regulatory authority:

The Connecticut River Policy Committee and its State and Federal agency members (predecessor of CRASC) had completed agreements with main stem hydropower operators that led to the installation and or operation of fish passage facilities to facilitate upstream passage on the main stem dams identified. The individual States have their independent authorities related to diadromous fish passage and management and the U. S. Fish and Wildlife Service and National Marine Fisheries Service have fishway prescription authority through the Federal Power Act, used in connection with FERC. The CRASC operates a Fish Passage Subcommittee, under its Technical Committee, which has been a forum to coordinate inter-agency staff, research, and activities with the power companies in both official and unofficial capacities, in a regular and ongoing process. The CRASC issues a schedule of Upstream Passage Operation Dates through the Connecticut River Coordinator, annually in March that specifies species, lifestage, dates and hours of operations.

4.1.2.2 Goal/Target:

The CRASC Management Plan (2020) includes goals and objectives that are quantified in terms of the entire population as well as within the river basin’s many segmented habitat reaches. Adult population targets are described as minimum values, based on run data and accessible habitat for the target reference year (1992) described in that plan. Upstream passage efficiency (proportion of arrivals to passed and time to pass) performance criteria have been developed and are part of the Management Plan Addendum approved in 2020. Downstream passage measures must also address Addendum defined passage survival rates for both adult and juvenile shad as well as time-to-pass through project (i.e., delay). Standardized pre-season fishway inspections should be conducted by USFWS Fish Passage Engineers. This work has been focused on main stem facilities given staff limitations and includes examining and addressing site specific concerns with the owner/operators. Habitats that are accessed using fishways must also provide downstream passage measures that are also defined in the plan, particularly to address cumulative effects of these projects and achieve goals and objectives.

4.1.2.3 Progress:

FERC relicensing is ongoing for Turners Falls Project, Northfield Mountain Pumped Storage Facility, Vernon Project, and Bellows Falls Project. The update to the CRASC Management Plan in 2017 and the Fish Passage Performance Addendum (2020) were important management steps to better define agency goals and objectives considered achievable and necessary in the ongoing effort to restore this population in its historic range as well as providing minimum escapement targets and stock structure metrics. The Management Plan and its Addendum are approved Comprehensive Management Plans by FERC.

In December 2020, both owners of five main stem hydroelectric projects submitted their Amended Final License Applications to FERC. At this time, FERC is in the process of considering the status of those submissions, including a June 2021 additional information submission that was required for FirstLight, in an internal review process.

Vernon Dam - At Vernon Dam, GRH has been working with the state and federal agencies on ongoing studies and improvements to that facility's fish ladder. In the fall of 2019, GRH installed a series of in-ladder modifications, designed by a USFWS Fish Passage Engineer. Relicensing study results of tagged shad within the ladder suggested a potential problem with two corner pools and the modification were made to reduce turbulence. The company continues to work on addressing potential areas of improvement for that fishway. In June of 2020 and 2021, very low river discharge levels led to occurrences of extremely low tailwater elevations at this facility that at times impacted the ladder entrance gates ability to maintain desired flow conditions. In September 2021 GRH contacted the agencies to report their identification of the issue affecting the entrance gate setting and measures to resolve that for the 2022 upstream fish passage season.

Holyoke Dam - Improvements for downstream passage were completed in 2015 at Holyoke Dam and the Hadley Falls Power Station. The fish passage modifications that will benefit American Shad include a full depth reduced space trash rack (2.0 inch clear spacing) that will help exclude adult shad from entrainment into the station's two turbines and a new surface and midwater downstream bypass entrances in that rack system. The bypasses discharge into the modified bascule gate discharge on the dam (also provides downstream passage) that was improved by the removal of a "wing" structure for the spillway ladder entrance near the edge of the dam apron. In addition, on the dam apron, the "bypass water" flow was structurally modified with a lip that projects the flow over the spillway fish entrance jet, into a constructed release pool with required depth, velocity, and area (all designs meet USFWS Fish Passage Criteria). The spillway entrance was also modified from an upper water column gate, to full depth, to facilitate sturgeon entry and passage. These measures were all in place and operating for the 2016 fish passage season.

Ongoing meetings with HGE at the Holyoke Project have resulted in adjusting operations, including effective in 2020 a new agency prescribed threshold daily count values to trigger and conclude earlier daily lift openings for peak run timing. The agencies also agreed to reduced lift operation frequency, also based on daily passage data, for the first two weeks of July.

4.1.2.4 Timeline:

The FERC relicensing process has reached a late-stage development in the process started in 2012 for the noted mainstem projects. The December 2020 AFLA submissions' by First Light Power and GRH, are in review by FERC with additional information required from Firstlight submitted in June 2021. The issuance of a Ready for Environmental Analyses by FERC would start the time windows for fish passage prescription and habitat recommendation submissions by USFWS and NOAA and State and other intervener recommendations.

4.1.3 Fish passage/habitat access Mattabesset River (CT)

The first barrier on the Mattabesset River, StanChem Dam has a Denil ladder. The next upstream barrier, Kensington Dam, had an Alaskan Steepass ladder installed in 2019. At this time, the State believes no additional fish passage measures for shad is needed upstream of Kensington Dam which provides 2km of habitat to the base of falls (Table 3).

4.1.3.1 Agencies with regulatory authority:

The State of Connecticut has legal authorities regarding dams and fish passage at this small non-hydropower dam.

4.1.3.2 Goal/Target:

Achieve goals and objectives defined in the CRASC 2017 American Shad Plan and the defined passage performance in the 2020 Addendum. An annual run of 6,000 American Shad is the minimum population target for this tributary (Table 3).

4.1.3.3 Progress:

Access to all historic habitat has been achieved.

4.1.3.4 Timeline:

No additional habitat work is planned at this time.

4.1.4 Fish passage/habitat access Farmington River (CT)

Currently upstream and downstream passage at the Rainbow Dam are management issues at this FERC non-jurisdictional dam/project (Table 3). The Rainbow Fish Ladder is a vertical slot designed and owned by the State of Connecticut. The fish ladder opened in 1976 and is planned for replacement by the State of Connecticut. There are concerns for downstream protection of outmigrating adults and juveniles given the current design (trash rack depth/clear spacing) and smaller turbine sizes of the power station. The Winchell Smith Dam, next upstream structure, is considered a possible barrier to upstream movement of shad at lower flow levels. The Lower Collinsville Dam is owned by the State and is planned for removal, no target date available. The Upper Collinsville Dam has a FERC license and planned construction for a Denil Fish Ladder in 2021. The Pequabuck River is a tributary of the Farmington River and the existing Bristol Brass Dam is the upper extent of what the State of Connecticut considers shad habitat.

4.1.4.1 Agencies with regulatory authority:

The Rainbow Dam is not a FERC licensed jurisdictional dam and the fish ladder was installed by the State of Connecticut using its own funds through an agreement with the owners. The State of Connecticut has developed design plans to replace the vertical slot fishway. The State does not have construction funds currently for a new upstream fishway.

4.1.4.2 Goal/Target:

Achieve goals and objectives defined in the CRASC 2017 American Shad Plan and the defined passage performance in the 2020 Addendum. An annual minimum run of 24,500 shad is the target for this tributary. A goal is to install a new upstream fishway at the Rainbow Dam and discontinue the use of the ladder for shad passage. Downstream passage protections for adults and juveniles have also been identified a concern. Explore options for the removal for the degraded Winchell Smith Dam that is believed to impede upstream movement in lower flow conditions. Removal of the lower Collinsville Dam will provide shad with access to the next upstream dam, Upper Collinsville that is in the process of upstream and downstream passage construction (completion fall 2021).

4.1.4.3 Progress:

Design plans for a Rainbow Dam fish lift are completed but the CTDEEP has additional information in review on best options and other related concerns (e.g., downstream passage measures). The Winchell Smith Dam will be monitored as it deteriorates, and it will be determined if removal or a fishway is necessary. Engineered plans to remove the Lower Collinsville Dam are in progress. The Upper Collinsville fish ladder is expected to be completed by late 2021.

4.1.4.4 Timeline:

Given the construction cost of the Rainbow Fish Lift system, it is unclear how long it will take to fund. The design for the Lower Collinsville Dam removal is underway but there is no firm timeline on when the dam will be removed.

4.1.5 Fish passage/habitat access Scantic River (CT)

The previous first barrier on the Scantic River, Springborn Dam was removed in 2017 by state and federal agencies. Currently, accessible shad habitat extends upstream to the Somersville Dam, an additional 4km of habitat. There are no fish passage or removal plans at this time for the Somersville Dam which is believed to be the upstream extent of shad habitat by the State (Table 3).

4.1.5.1 Agencies with regulatory authority:

The State of Connecticut has legal authorities regarding dams and fish passage at this small non-hydropower dam.

4.1.5.2 Goal/Target:

Following the removal of the Springborn Dam in 2017, the plan for the next dam remains under future consideration. An annual minimum run of 3,400 shad is the target for this tributary.

4.1.5.3 Progress:

The first upstream barrier on the Scantic River, Springborn Dam was removed by state and federal agencies in 2017, opening an additional 5 kilometers of river habitat to fishes including American Shad. Assessment of the habitat upstream of the current first mainstem barrier, Somersville Dam needs occur in addition to determining what species are currently utilizing downstream habitat.

4.1.5.4 Timeline:

Not applicable at this time.

4.1.6 Fish passage/habitat access Westfield River (MA)

All historic shad habitat is accessible with passage at the West Springfield Dam from a Denil Ladder and downstream passage measures also in place (Table 3). The next barrier on this tributary is the Woronoco Dam which is at the historic upstream extent of shad habitat.

4.1.6.1 Agencies with regulatory authority:

The Commonwealth of Massachusetts has legal authorities regarding dams and fish passage and the U. S. Fish and Wildlife Service and National Marine Fisheries Service have authority through the Federal Power Act and through FERC for licensed hydropower dam/projects. Both West Springfield and Woronoco Dam/projects are licensed by FERC.

4.1.6.2 Goal/Target:
Achieve goals and objectives defined in the CRASC 2017 American Shad Plan and the defined passage performance in the 2020 Addendum. An annual minimum run of 13,100 shad is the target for this tributary.

4.1.6.3 Progress:
There are no identified needs for other passage at this time.

4.1.6.4 Timeline:
Not applicable at this time.

4.1.7 Fish passage/habitat access Chicopee River (MA)
Accessible habitat in this tributary is restricted to approximately 2 km from its confluence with the Connecticut River. There is a high density of closely placed hydropower dams that proceed upstream from that point. The Dwight Street Dam is the first upstream barrier with a powerhouse located downstream of the dam approximately 1.0 km.

4.1.7.1 Agencies with regulatory authority
The Commonwealth of Massachusetts has legal authorities regarding dams and fish passage and the U. S. Fish and Wildlife Service and National Marine Fisheries Service have authority through the Federal Power Act and through FERC for licensed hydropower dam/projects.

4.1.7.2 Goal/Target:
There have been unexecuted plans to stock pre-spawn shad, transferred from Holyoke Fish Lift, into the impoundments of the upstream dams with follow up sampling to determine if there is juvenile production. This tributary system requires more study by the agencies considering the complexity of closely placed dams in succession.

4.1.7.3 Progress:
No pre-spawn stocking of shad or herring has occurred to date. It is possible that these stockings, with evaluation for production, may occur in the near future. Regularly occurring spring adult river herring population assessment have consistently documented high relative abundances (adult shad) in the lowermost accessible reach that is surveyed with boat electrofishing in May and June annually.

4.1.7.4 Timeline:
Not defined at this time, given other ongoing priorities.

4.1.8 Fish passage/habitat access Manhan River (MA)
A Denil fish ladder was installed at the first dam on the Manhan (Town of Easthampton) in 2014 that is located 5 miles from its mouth located in the “Oxbow” (Table 4). The ladder provides fish access to habitat up to 18 kilometers upstream where an unnamed dam occurs on its main branch. There is limited habitat for shad in the lower reaches of this system due to its small size (width and depths). This tributary has a total of 23 river kilometers with an estimated 23.0 hectares of habitat. All shad habitat is now accessible.

4.1.8.1 Agencies with regulatory authority
The Commonwealth of Massachusetts has legal authorities regarding dams and fish passage. As the Manhan Dam is non-hydro power, a cooperative approach was developed with the Town that owns the dam to operate and maintain the fish ladder.

4.1.8.2 Goal/Target:
Achieve goals and objectives defined in the CRASC 2017 American Shad Plan and the defined passage performance in the 2020 Addendum. An annual minimum run of 2,553 shad is the target for this tributary.

4.1.8.3 Progress:
No adult shad have been documented passing this fishway based on video monitoring to date. Both adult Blueback Herring and American Shad have been trucked and released by the USFWS in several years into habitat upstream of the dam.

4.1.8.4 Timeline:
Not applicable at this time.

4.1.9 Fish passage/habitat access Deerfield River (MA)
The lower Deerfield River contains an estimated 86 hectares of shad habitat upstream to the first dam, located at rkm 21.5 (Table 3). From its confluence with the Connecticut River, this tributary gains elevation rapidly moving upstream after the first dam, habitat becomes unsuitable for shad and a series of hydropower dams begin in relatively close sequence. All shad habitat is considered accessible.

4.1.9.1 Agencies with regulatory authority
The Commonwealth of Massachusetts has legal authorities regarding dams and fish passage and the U. S. Fish and Wildlife Service and National Marine Fisheries Service have authority through the Federal Power Act and through FERC for licensed hydropower dam/projects.

4.1.9.2 Goal/Target:
Achieve goals and objectives defined in the CRASC 2017 American Shad Plan and the defined passage performance in the 2020 Addendum. An annual minimum run of 9,546 shad is the target for this tributary.

4.1.9.3 Progress:
There are no identified needs for passage at this time.

4.1.9.4 Timeline:
Not applicable at this time.

4.1.10 Fish passage/habitat access Millers River (MA)
The Millers River is a large tributary system that includes a relatively rapid, increase in elevation that creates a high percentage of riffle and run habitat over rock substrate from its confluence with the Connecticut River. There are interspersed stretches of slower flat water but the quantity of suitable shad spawning, and nursery habitat is not known and requires additional study. However, adult shad tagging studies that have been conducted as part of FERC relicensing studies, as well as a USGS Conte Lab tagging study in 2011, would support the statement that this tributary was not utilized by shad based on those tagging study results. The first dam is located at rkm 14 and is partially breached with the second barrier (hydropower dam) located in at rkm 22 (Table 4).

4.1.10.1 Agencies with regulatory authority

The Commonwealth of Massachusetts has legal authorities regarding dams and fish passage and the U. S. Fish and Wildlife Service and National Marine Fisheries Service have authority through the Federal Power Act and through FERC for licensed hydropower dam/projects.

4.1.10.2 Goal/Target:

There is no estimated annual adult production run size at this time.

4.1.10.3 Progress:

There are no identified needs for shad fish passage at this time.

4.1.10.4 Timeline:

Not applicable at this time.

4.1.11 Fish passage/habitat access Ashuelot River (NH)

In 2012, the Fiske Mill Dam, the first barrier 3 km from confluence with the Connecticut River, installed a fish lift. The agencies and FERC have contacted the owner operator with concerns over fishway operation, monitoring and evaluation that remain unresolved. This project is currently in the FERC relicensing process that was initiated in January 2021. The McGoldrick Dam, which had been the next upstream dam (rkm 4), was completely removed in 2001. As shad passage at Fiske Mill Dam becomes documented, upstream passage options to pass fish upstream of both Lower Roberts (rkm 5) and Ashuelot Paper (rkm 5.5) hydropower dams will be developed. Once fish can pass these additional two dams, most targeted spawning, and nursery habitat (90%) will be completely accessible as two additional unmaintained dams have been completely removed from identified shad habitat in 2002 (Town of Winchester) and 2010 (Swanzey Woolen Mill).

4.1.11.1 Agencies with regulatory authority:

The State of New Hampshire has legal authorities regarding dams and fish passage and the U. S. Fish and Wildlife Service and National Marine Fisheries Service have authority through the Federal Power Act and through FERC for the identified dams.

4.1.11.2 Goal/Target:

Achieve goals and objectives defined in the CRASC 2017 American Shad Plan and the defined passage performance in the 2020 Addendum. An annual minimum run of 15,429 shad is the target for this tributary.

4.1.11.3 Progress:

Annual stockings of approximately 430 pre-spawn shad have been conducted by state and federal fishery agencies from 1998 through 2019. Upstream passage options for the remaining dams will be explored as adult fish are documented passing the Fiske Mill Dam. The Fiske Mill Project is in relicensing process with FERC, initiated in 2021. Both Federal agencies (USFWS and NOAA), NHFG and NH DES submitted study request letters in March of 2021 as part of that process.

4.1.11.4 Timeline:

The FERC process for Fiske Mill began in 2021. State and federal agencies expect to address what are considered passage issues and seek to determine what fish may occur below the dam. Upstream passage measures for shad around the second and third dams on the lower Ashuelot will be implemented as returning adult shad are documented at the Fiske Mill Dam fish lift.

4.1.12 Fish passage/habitat access West River (VT)

The West River is primarily a high gradient, large substrate system in the Green Mountains. Its confluence with the Connecticut River has been inundated by the Vernon Dam creating an area known as Retreat Meadows. This shallow protected off mainstem area is approximately 65 ha in size and is known to be used by juvenile shad. The first upstream barrier on the river is Townshend Flood Control Dam, of the Army Corp of Engineers at rkm 31. The extent to which adult shad migrate up and utilize this lower reach is unknown. There is no shad habitat upstream of this barrier.

4.1.12.1 Agencies with regulatory authority:

The State of Vermont has legal authorities regarding dams and fish passage and the U. S. Fish and Wildlife Service and National Marine Fisheries Service work as needed on fish passage and protection issues at USACOE Projects. There are no plans for this Dam relative to shad.

4.1.12.2 Goal/Target:

All shad habitat, estimated as 139.5 ha, is accessible in this tributary. An annual minimum run of 15,485 shad is the target for this tributary.

4.1.12.3 Progress:

There are no identified needs for shad fish passage at this time.

4.1.12.4 Timeline:

Not applicable.

4.2 Threat: Hydropower Dam and Hydropower Facility Impoundment and Discharge Fluctuations and Operations

4.2.1 Recommended Action:

The operation of hydropower facilities includes peaking operations (sub-daily) at all noted power facilities, with the single exception of the Holyoke Dam/Hadley Falls Project (modified run-of-river), which can result in substantial alterations to river discharge (timing, frequency, magnitude, duration) downstream of the facilities as well as upstream (e.g., impounding periods and the operation of NMPS). These situations may impact persistent shad habitat, quantity, and quality at a sub-hourly time scale and a daily basis. An inventory and assessment of all hydropower facilities that are not required to operate as “run-of-the-river” should be identified and evaluated for the extent and types of impacts that may affect shad habitat. This should occur on both the mainstem river and identified tributaries. The FERC relicensing process for the five identified mainstem hydropower projects included studies to determine shad spawning locations, habitat features, and operational effects on these spawning activity (Normandeau, 2017) (FLP, 2016). Changes in the quantity of habitat for species including shad based on model information for shad spawning and juveniles were also examined under dual flow (peaking operations) for a range of paired flows for Bellows Falls and Vernon projects. Study results suggest occurrences of wide- ranging sub-daily changes in flows result in changes to shad habitat (specifically project minimum discharge conditions) with modeled high peaking (based on dual flow analyses). These model results were complicated at Vernon Dam by additional downstream hydropower operations of NMPS and/or Turners Falls Project operations that were outside the scope of the study (Normandeau , 2019).

4.2.2 Agencies with regulatory authority:

The States have legal authorities regarding dams and hydropower operation through FERC, Water Quality Certification (401) and Coastal Zone Management Act, as applies. The U. S. Fish and

Wildlife Service and National Marine Fisheries Service have authority through the Federal Power Act. Fish and Wildlife Coordination Act. and the Endangered Species Act, for designated species such as Dwarf Wedge Mussel, Puritan Tiger Beetle and Shortnose Sturgeon in the Connecticut River. Both PTB and SNS have been shown to be affected by flow re-regulation and help support the position that wide ranging, rapid flow fluctuations, at a sub-daily level are conditions that may affect species habitat use and behavior at important times in life history.

4.2.3 Goal/Target:

The State and Federal agencies will seek to develop and implement measures to reduce or mitigate any documented impacts of water use (e.g., sub daily peaking generation) on shad spawning and nursery habitat based upon available information. A natural flow regime, or increased inflow equal to outflow, to the extent possible, is preferred to better represent river conditions the species evolved with.

4.2.4 Progress:

The FERC relicensing process resulted in planned studies to examine project operation discharge effects on identified shad spawning habitat and behavior below Turners Falls Dam, in the Turners Falls impoundment, below the Vernon Dam, in the Vernon Dam impoundment, and below the Bellows Falls Dam. Those studies have been submitted with State and Federal agency comment letters. Great River Hydro initiated project operations discussion with the agencies in 2020 that led to the proposed operational schedule GRH submitted in their AFLA, that reduces peaking operations in the spring through the fall with increased frequency of inflow equals outflow at projects. The agencies believe the reduction in flow re-regulation, as proposed, will be a significant improvement from the existing peaking operations at the Wilder, Bellows Falls, and Vernon facilities that will benefit American Shad and their habitat use (e.g., migration, spawning, nursery).

4.2.5 Timeline:

The FERC has received the "requested additional information" that was asked of FirstLight Power, partly on GRH's proposed operational schedule that calls for less flow re-regulation (except in winter months) in June 2021. The agencies, companies and other parties are awaiting FERC's review for completeness of the submission. Should FERC determine they now have all necessary information to proceed (from FLP and GRH) they will issue a ready for environmental analyses which will trigger the agencies time window to submit their passage and protection measures along with habitat recommendations.

4.3 Threat: Water Withdrawal

4.3.1 Recommended Action:

An inventory and assessment of all permitted water withdrawals from the mainstem and targeted tributary shad habitat should be conducted using state agency permit data. At this time, there are water withdrawals for cooling water intake structures permitted by appropriate state and or federal agencies from the mainstem river. A partial list of mainstem water diversion permits includes from upstream to downstream: West Springfield Generation Station, MA (fossil fuels); Algonquin Power, Windsor, CT (natural gas); South Meadow Plant, Hartford, CT (fossil), GenConn, Middletown, CT (natural gas/fossil), and others. Information on Water Diversion Permits can be found on individual agency websites. In addition, the NMPS facility in Northfield, MA has a pumping capacity, to its storage reservoir, of up to 15,000 cubic feet per second, and is regulated by the FERC. Pumping duration is a function of the storage reservoir's water level and number of pumps used to refill which may vary on a variety of operational factors. The FLP Pre-Application

Document to FERC (2021) states "*In the summer and winter seasons, the NMPS typically peaks twice a day – in the morning and late afternoon. During other months, commonly called shoulder months, the NMPS may be peaked one to two times a day, pending electrical demand and/or price*." The potential pumping capacity of that plant at full operational capacity, is greater than the mean monthly river discharge for eight months of the year (refer to USGS 01170500 Montague Gage data).

Water withdrawals also occur in tributaries and should also be reviewed for potential impacts to habitat. Details of the type and extent of water withdrawal and subsequent discharge for these plants and others that remain to be collectively examined should be reviewed for potential impacts to American Shad habitat and potential population impacts. Considering climate change and associated changes in precipitation (i.e., timing, magnitude) water withdrawals should be examined, and or managed more closely.

Measures to either prevent or significantly reduce entrainment of eggs, early life stages and juveniles should be considered for commercial river water users.

4.3.2 Agencies with regulatory authority:

Regulatory authority for the withdrawal of water is under State authorities and/or legislation and in some instances the Environmental Protection Agency. In the case of the NMPS facility, licensed through FERC, both the Massachusetts and the federal resources agencies have specific authorities. Massachusetts DEP also has authorities related to water quality and plant operations.

4.3.3 Goal/Target:

The State and Federal agencies will seek to develop and implement measures to reduce documented impacts of water withdrawals on early life stages and outmigrants (e.g., entrainment and/or impingement) through available regulatory or other mechanisms.

4.3.4 Progress:

The Vermont Yankee Nuclear Power Station (Vernon, VT) and Mount Tom Coal Power Station (Holyoke, MA) were closed in 2014. Inventory of water withdrawals remains a management task by the fishery agencies relative to American shad and river herring habitat.

4.3.5 Timeline:

Monitoring of permit reports, permitting and other regulatory oversight by the states and federal agencies as applicable is ongoing.

4.4 Threat: Thermal Discharge

4.4.1 Recommended Action:

An inventory and assessment of all permitted thermal discharges from the mainstem and targeted tributary shad habitat should be conducted using state agency permit data as well as data from the Environmental Protection Agency (EPA) which has responsibility for the National Pollutant Discharge Elimination System (NPDES) and/or its delegation to approved State agencies, to varying levels. Permitted water withdrawals and discharge for cooling water intake structures occur on the mainstem river, from upstream to downstream, West Springfield Generation Station, MA (fossil); Algonquin Power, Windsor, CT (natural gas); South Meadow Plant, Hartford, CT (fossil); GenConn, Middletown, CT (natural gas/fossil); and others.

4.4.2 Agencies with regulatory authority:

NPDES authority has been delegated by the EPA to the states of Connecticut and Vermont. Whereas, the Commonwealth of Massachusetts and the State of New Hampshire have not been delegated authority and work with the EPA to issue NPDES permits.

4.4.3 Goal/Target:

Goals and targets vary among regulatory agencies. A NPDES permit will generally specify an acceptable level of a pollutant or pollutant parameter in a discharge (e.g., water temperature). The permittee may choose which technologies to use to achieve that level. Some permits, however, do contain certain generic 'best management practices'. NPDES permits make sure that a state's mandatory standards for clean water and the federal minimums are being met.

4.4.4 Progress:

Industrial, municipal, and other facilities must obtain permits if their discharges go directly to surface waters since passage of this law in 1972. An inventory of NPDES permitted thermal discharges, remains to be considered as a management task by the fishery agencies relative to American shad and river herring habitat in this basin. The EPA maintains a national website of NPDES permits (https://www.epa.gov/npdes-permits).

4.4.4.1 Timeline:

The Clean Water Act limits the length of NPDES permits to five years. NPDES permits can be renewed (reissued) at any time after the permit holder applies. In addition, NPDES permits can be administratively extended if the facility reapplies more than 180 days before the permit expires, and EPA or the state regulatory agency, which ever issued the original permit, agrees to extend the permit.

4.5 Threat: Water Quality

4.5.1 Recommended Action:

State and Federal agencies should regularly assess water quality monitoring data to ensure water quality does not become impaired and to support recommendations on proposed activities that may affect water quality. Significant water treatment improvement projects are under way for the City of Hartford, CT (https://www.thecleanwaterproject.com/) and Springfield, MA (https://waterandsewer.org/wp-content/uploads/2020/02/IntegratedWastewaterPlan.pdf), with the intent of better handling high pulse rain events that in the past required the dumping of untreated waste water from road run-off (combined sewer overflow). This work can also address related threats from Climate Change due to expected expected increased high intensity, shorter duration rain events. Other strategies to improve water quality and enhance climate change resiliency include maintaining forested riparian zones and stream banks, improving stormwater treatments, and installing compatible stream crossing infrastructure such as appropriately sized culverts.

Physical, chemical, and biological monitoring of water quality should be adequately supported, primarily through existing State agency authorities, by designated agencies, to ensure sufficient temporal and spatial coverage, sampling design, and sampling intensity. Classification standards and data among the four basin states should be coordinated and shared along with necessary monitoring measures. Communication between professional fishery agency staff and water quality staff should continue to be strengthened.

4.5.2 Agencies with regulatory authority:

The Clean Water Act of 1972 is the foundation for surface water quality protection in the United States. Sections of this Act provide direction on standards to the states. The states of Vermont, New Hampshire, Massachusetts, and Connecticut all maintain surface water monitoring programs.

4.5.3 Goal/Target:

Varies by authorizing agency and standards cannot be weaker than federal identified designations. The State of New Hampshire designates the mainstem as Class B. The State of Vermont classifies the mainstem as Class B and as coldwater fish habitat. The Commonwealth of Massachusetts designates the mainstem as Class B and as warmwater fishery habitat. The State of Connecticut also classifies the mainstem and tributaries as Class B. Standards associated with these designations are available on respective state agency web sites.

4.5.4 Progress:

Water quality on the mainstem and tributaries are monitored directly by respective state agencies, federal agencies (e.g., U. S. Geological Survey) non-profit watershed groups, power companies and others. State agency water quality monitoring web sites include: Connecticut https://portal.ct.gov/DEEP/Water/Inland-Water-Monitoring/River-and-Stream-Water-Quality-Monitoring, for Massachusetts https://www.mass.gov/guides/water-quality-monitoring, for New Hampshire https://www.des.nh.gov/water/rivers-and-lakes/river-and-lake-monitoring, and for Vermont https://dec.vermont.gov/watershed/map/monitor#River%20Programs.

4.5.5 Timeline:

State agency monitoring for standard assessments is ongoing as are other programs including USGS gauge stations with water quality instrumentation.

4.6 Threat: Land Use

4.6.1 Recommended Action:

State, Federal, and local governments should continue to support existing protective measures to address poor land use practices that may affect shad habitat either directly or indirectly. These measures may occur at multiple levels of government as noted. Riparian zone vegetation protection and bank protection are examples of concerns that insufficient land use (e.g., agriculture, residential, commercial uses) regulation or enforcement may result in degraded habitat and impact water quality. In some jurisdiction local Conservation Commissions can enact or expand buffer or "no-disturb zones" adjacent to riverbanks and other wetland resources (e.g., Commonwealth of Massachusetts River Protection Act (1996) and Wetland Protection Act (2014)). States should work in collaboration to develop and support consistent regulations and enforcement measures.

4.6.2 Agencies with regulatory authority:

Land use regulatory authority may reside at the local, state and/or federal government level.

4.6.3 Goal/Target:

The codification of rules and adequate enforcement to provide riparian vegetation protection and bank protection/stability and address other potential negatively impacting land use activities will help protect aquatic habitats.

4.6.4 Progress:

Status of existing state and local government rules are not summarized here. Examples of measures that have improved protections for land in Massachusetts include local Conservation Commissions and DEP use of the Rivers Protection Act and Wetlands Protection Act to protect riparian and wetland habitats. Act 250, is Vermont's land use and development law, enacted in 1970.

4.6.5 Timeline:

Ongoing.

4.7 Threat: Climate Change

4.7.1 Recommended Action:

State and Federal agencies should identify data of value in the detection and monitoring for climate change effects on shad habitat and associated shad population dynamics or other responses (e.g., run timing) and whether those changes can successfully be adapted to by those populations. Sources of data (fishway counts, tagging studies) should be evaluated for ongoing value and whether any modifications may be necessary. Data that would be of value in this effort and are not being regularly collected (e.g., tagging studies) should be identified and developed by the State and Federal agencies as determined necessary. In freshwater, the timing, frequency, and magnitude of river discharge should be evaluated at regular intervals (spring run-off, droughts, pulse events) and related to fishery data including, but not limited to, fishway operational schedules, fish movement and behavior data, spawning success, habitats, and juvenile recruitment and outmigration. In the near-shore and marine environment, monitoring, and studies to assess shifts in conditions and habitats (e.g., water temperatures, currents, food sources, predators) should occur at regular intervals. The ASMFC 2020 American Shad Benchmark Stock Assessment and Peer Review provides modeling analyses that shows reduced growth rates and maximum size with increase sea surface temperatures (ASMFC, 2020). Additional work to understand climate change effects in freshwater and estuarine habitats on life history events and/or population level effects should also be examined.

Efforts to improve climate change resiliency should be pursued. Strategies should be developed and implemented to reduce stressors associated with climate change including drought, floods and increasing temperatures. Disaster management, urban planning, and river restoration are some strategies that can help mitigate the impacts of climate change.

4.7.2 Agencies with regulatory authority:

Regulatory authorities for climate change are not clearly in place currently. However, both State and Federal resources agencies have recognized the need to incorporate the reality of climate change as physical scientists work to develop future scenarios on effects (e.g., temperature regimes, river discharge, rainfall, snowpack) that may to varying degrees, affect species occurrence, population viability, and habitat quantity and quality.

4.7.3 Goal/Target:

It will be desirable to understand any trends in population metrics or other parameters, and any linked climate change drivers that may affect population structure, distribution, abundance, and viability. The resource agencies will seek to improve climate change resiliency and reduce other anthropogenic impacts that may exacerbate these impacts. Ultimately the agencies will seek to ensure the full restoration and long-term sustainability of this population given it is not at the extreme end of its distribution range.

4.7.4 Progress:

New or updated federal resource plans are required to include climate change.

4.7.5 Timeline:
Ongoing.

4.8 Threat: Invasive Species

4.8.1 Recommended Action:
Invasive aquatic plant species are increasing in occurrences and expanding their range within the Connecticut River basin, impacting native aquatic plant species and habitats (https://portal.ct.gov/DEEP/Fishing/General-Information/Aquatic-Invasive-Species). Eurasian water milfoil, water chestnut and most recent hydrilla have been expanding in the mainstem as well as in tributary and coves, primarily in Connecticut and Massachusetts. State agencies have been working to monitor the locations and extent of these invasive plants and work with partners on mitigation measures including pulling of plants before they go to seed. This highly labor-intensive approach includes federal agency assistance and NGOs. Boat launches in all basin states have signage explaining the issues with these invasive plant introductions, establishment, and expansion. Launches are also sometime staffed by agency representatives or volunteers that also interact to help ensure "clean, drain, dry" measures are used when trailering boats. Other invasive organisms not yet present (documented) of potential concern include range expansions of Asian mussel species (e.g., Zebra Mussel) and other organisms that have demonstrated detrimental impacts when introduced in other aquatic systems (e.g., Blue Catfish, Snakehead).

4.8.2 Agencies with regulatory authority:
State agencies have developed statutes that forbid the importation of the previously list plants and many other non-natives, with associated fines. Similarly, there are regulations requiring boaters' clean trailers or be subject to fines. Importation bans for certain identified species occur at the Federal and State level.

4.8.3 Goal/Target:
Measures that can help prevent either the direct or indirect introduction on non-native species should continue to focus on outreach and education. The development and implementation of safe and effective measure to reduce the rate of spread, or other mitigation measures should continue to be explored and evaluated.

4.8.4 Progress:
State agencies have increased efforts on education and outreach with boaters and anglers. Partnerships to manage certain areas (pulling of plants) have been developing. Aquatic Nuisance Species funding at the Federal level has been increasing in recent years due to the extent of this problem. These funds are used primarily by state agencies and have increased monitoring, assessment, and planning activities.

4.8.5 Timeline:
This work is ongoing and steadily expanding.

5 Habitat Restoration Program

Since the submission of the first plan in 2014 the following progress on both dam removals and technical fishway construction has occurred in both Connecticut and Massachusetts (Table 5). There are some other potential projects that are in early stages of development that would benefit American Shad habitat. The removal of the lower Collinsville Dam (Canton) on the Farmington River would restore shad habitat to the upper Collinsville Dam that is in final stages of upstream and downstream passage construction. The lower dam is owned by the state and has removal design plans in place currently. The agencies and partners will continue work on restoring shad habitat and habitat accessibility, including barrier removal.

Table 5. Descriptions of American Shad habitat access improvements since the first submitted Plan.

State	System	Activity	Outcome
Connecticut	Mattabesset River	Kensington Dam, steepass ladder install	Access to an additional 2 km of habitat
Connecticut	Scantic River	Removal of Springborn Dam	Access to an additional 4 km of habitat
Massachusetts	Manhan River	Completion of Easthampton Dam Denil fish ladder	Access to approximately 18 km of habitat

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APPENDIX 1.

Annual American shad fish passage counts from 1980 through 2020 for the Holyoke Dam (MA), Turners Falls Dam (MA), Vernon Dam (VT), Farmington River (CT) and Westfield River (MA). These data are influenced by changing environmental conditions (e.g., spill), facility operations, and identification of issues with improvements to fishways (e.g., 2012 at Vernon Ladder).

Year	Holyoke Dam	Turners Falls Dam Passed	TF % of Holyoke Total	Vernon Dam Passed	Vernon % of TF Total	Farmington River, Rainbow Dam Passed	Westfield River, W. Springfield Dam Passed
1980	376,066	298	0%			480	
1981	377,124	200	0%	97	49%		
1982	294,842	11	0%	9	82%	737	
1983	528,185	12,705	2%	2,597	20%	1,565	
1984	496,884	4,333	1%	335	8%	2,289	
1985	487,158	3,855	1%	833	22%	1,042	
1986	352,122	17,858	5%	982	5%	1,206	
1987	276,835	18,959	7%	3,459	18%	792	
1988	294,158	15,787	5%	1,370	9%	378	
1989	354,180	9,511	3%	2,953	31%	215	
1990	363,725	27,908	8%	10,894	39%	432	
1991	523,153	54,656	10%	37,197	68%	591	
1992	721,764	60,089	8%	31,155	52%	793	
1993	340,431	10,221	3%	3,652	36%	460	
1994	181,038	3,729	2%	2,681	72%	250	
1995	190,295	18,369	10%	15,771	86%	246	
1996	276,289	16,192	6%	18,844	116%	668	1,413
1997	299,448	9,216	3%	7,384	80%	421	1,012
1998	315,810	10,527	3%	7,289	69%	262	2,292
1999	193,780	6,751	3%	5,097	75%	70	2,668
2000	225,042	2,590	1%	1,548	60%	283	3,558
2001	273,206	1,540	1%	1,744	113%	153	4,720
2002	374,534	2,870	1%	356	12%	110	2,762
2003	286,814		0%	268		76	1,957
2004	191,555	2,192	1%	653	30%	123	913
2005	116,511	1,581	1%	167	11%	8	1,237
2006	154,745	1,810	1%	133	7%	73	1,534
2007	158,807	2,248	1%	65	3%	156	4,497
2008	153,109	4,000	3%	271	7%	89	3,212
2009	160,649	3,813	2%	16	0%	35	1,395
2010	164,439	16,422	10%	290	2%	548	3,449
2011	244,177	16,798	7%	46	0%	267	5,029
2012	490,431	26,727	5%	10,386	39%	174	10,300
2013	392,967	35,293	9%	18,220	52%	84	4,900
2014	370,506	39,914	11%	27,706	69%	536	4,787
2015	412,656	58,079	14%	39,771	68%	316	3,383
2016	385,930	54,069	14%	35,513	66%	141	5,940
2017	537,249	48,727	9%	28,682	59%	615	6,000
2018	275,232	43,146	16%	31,724	74%	341	5,752
2019	314,353	22,575	7%	12,862	57%	276	4,064
2020	362,423	41,252	11%	13,897	34%	510	5,549
Mean	324,113	18,171		9,423		445	3,693
SD	130,732	18,436		12,356		450	2,154
Low	116,511	11		9		8	913
High	721,764	60,089		39,771		2,289	10,300

American Shad Habitat Plan for the Merrimack River

Merrimack River Anadromous Fish Restoration Program

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Table of Contents

1 INTRODUCTION

The Atlantic States Marine Fisheries Commission's (ASMFC) Amendment 3 to the American Shad and River Herring Fishery Management Plan (FMP) requires all states to submit a Habitat Plan for shad stocks in their jurisdiction. This is the first Shad Habitat Plan submitted for the Merrimack River. During reviews of the first round of habitat plans, the ASMFC requested a collaborative effort on larger, multi-jurisdictional river plans such as the Merrimack River. Diadromous fish management on the Merrimack River is conducted by the Merrimack River Anadromous Fish Restoration Program (MRAFRP), which was formalized by the Merrimack River Anadromous Fish Restoration Program Strategic Plan and Status Review in 1997 and whose membership included representatives from The United States Fish and Wildlife Service (USFWS), United States Forest Service, NOAA – National Marine Fisheries Service (NMFS), New Hampshire Fish and Game Department (NHFG), Massachusetts Division of Fisheries and Wildlife (MADFW), and Massachusetts Division of Marine Fisheries (MADMF). As is the case in many coastal states, in-state jurisdiction for American Shad is shared by the marine and freshwater agencies, here MADFW and MADMF.

The MADMF has included the Merrimack River in previous American Shad Sustainable Fishery Management Plans (SFMP) for that state but not in the prior American Shad Habitat Plan (Chase et al. 2021). The prior MA American shad SFMP that included a 3 fish per day harvest limit for recreational anglers with no commercial harvest permitted (Sheppard and Chase, 2018). New Hampshire does not currently permit harvest in the portion of the river within that state and does not currently have an American Shad SFMP for any state water.

Shad management is a collaborative effort between state and federal agencies and other partners. The overarching goal established by the Merrimack River Technical Committee(MRTC) is to restore a self-sustaining annual migration of American shad to the Merrimack River watershed, with unrestricted access to all spawning and juvenile rearing habitat throughout the mainstem of river and its major tributaries (MRTC 2010). The MRAFRP, mainly through efforts by the MRTC, has served as the lead in obtaining both upstream and downstream passage measures at mainstem dams and in coordinating state and federal agencies, commercial river users, and other partners on management topics for this species. Prior to the installation of fish passage facilities at the Essex Dam in Lawrence, MA, in 1983 and the Pawtucket Dam in Lowell, MA, in 1986, the restoration plan for American shad focused on collecting shad eggs from Connecticut River adults. From 1969 to 1978 over 25 million eggs were transported and seeded into various Merrimack River locations (MRTC 1997). By 1979, the stocking effort transitioned from seeding eggs to transporting adult shad from the Connecticut River. Connecticut River adult shad translocation continued until 1996. By the mid-1990s the restoration effort shifted from out of basin transfers to collecting adult shad at the Essex Dam fish lift and releasing them at several upriver locations. Since 2009, a portion of the adult shad captured at Essex Dam are transported to the USFWS Fish Hatchery at Nashua, NH. At the hatchery, adults are spawned and fertilized eggs are cared for until they hatch. The larvae, at about 10 days old, are released upstream from the Merrimack mainstem dams near Boscawen, NH. Recently, some larvae have also been released in the Nashua River, a tributary to the Merrimack River.

Following nearly three decades of attempted restoration, the MRTC developed *A Plan for the Restoration of American Shad Merrimack River Watershed* in 2010 (MRTC 2010). This plan laid a blueprint for restoration in the watershed but was not accepted by the ASMFC as a Habitat Plan or SFMP. Most recently, the MRTC completed the Merrimack River Watershed

Comprehensive Plan for Diadromous Fishes (MRWCP), which was approved by the MRAFRP Policy Committee in the winter of 2021 and subsequently filed with and approved by the Federal Energy Regulatory Commission (FERC) as a Comprehensive Management Plan later in that year. The plan was created by representatives from USFWS, NOAA, and the member state agencies and comprises up to date information on passage and restoration potential for multiple diadromous species across the entire watershed. Restoration potential was characterized by the estimated number of fish that a habitat would be able to produce and the MRTC created priority tiers to guide future work and set near- and long-term goals. Full details for all data sources, analyses, and prioritization can be found in the Comprehensive Plan.

2 HABITAT ASSESSMENT

The Merrimack River drains the fourth largest watershed in New England. Encompassing 8,060 square kilometers (km) and containing over 15,288 river km, the majority (approximately 75%) of the drainage is in NH; the remainder is in MA (Figure 1). The Merrimack River flows 186 km from the confluence of the Pemigewasset and Winnipesaukee Rivers in Franklin, NH to where the river meets the Atlantic Ocean near Plum Island in Newburyport, MA. Many of the river's upper tributaries are high gradient with some originating above 1,220 meters (m) in the White Mountains of NH. The mainstem of the Merrimack is a mild gradient falling 76 m from its origin to tidewater. The tidal influence extends many river kilometers (rkm) inland with the head of tide generally falling between rkm 33 and 35 near Haverhill, MA (Hartwell 1970). There are nearly 3,000 documented dams in the watershed, a clear reminder of the industrial impacts and human influence on the river. In addition to dams, there are numerous other barriers or potential barriers to diadromy, in the form of crossings, culverts, and natural features. Nearly 2.6 million people live in communities in or partially in the watershed, with over 500,000 residents utilizing the river as a primary source for drinking water.

Prior to colonization, waterfalls and natural sluices found at Pawtucket Falls (rkm 69), Amoskeag Falls (rkm 119), and the outlet of Lake Winnipesaukee, were important fishing grounds among Native Americans, and later among European settlers. These natural obstacles were a challenge for all diadromous fish, and likely impassible for some. They served to concentrate the fish attempting to swim upstream, increasing their vulnerability to capture and harvest. Still, prior to the advent of mainstem dams, remarkable numbers of fish migrated to their natal tributaries, lakes, and ponds. Some accounts indicate American shad reliably reached the outlet of Lake Winnipesaukee where they were harvested in great numbers (Meader 1869).

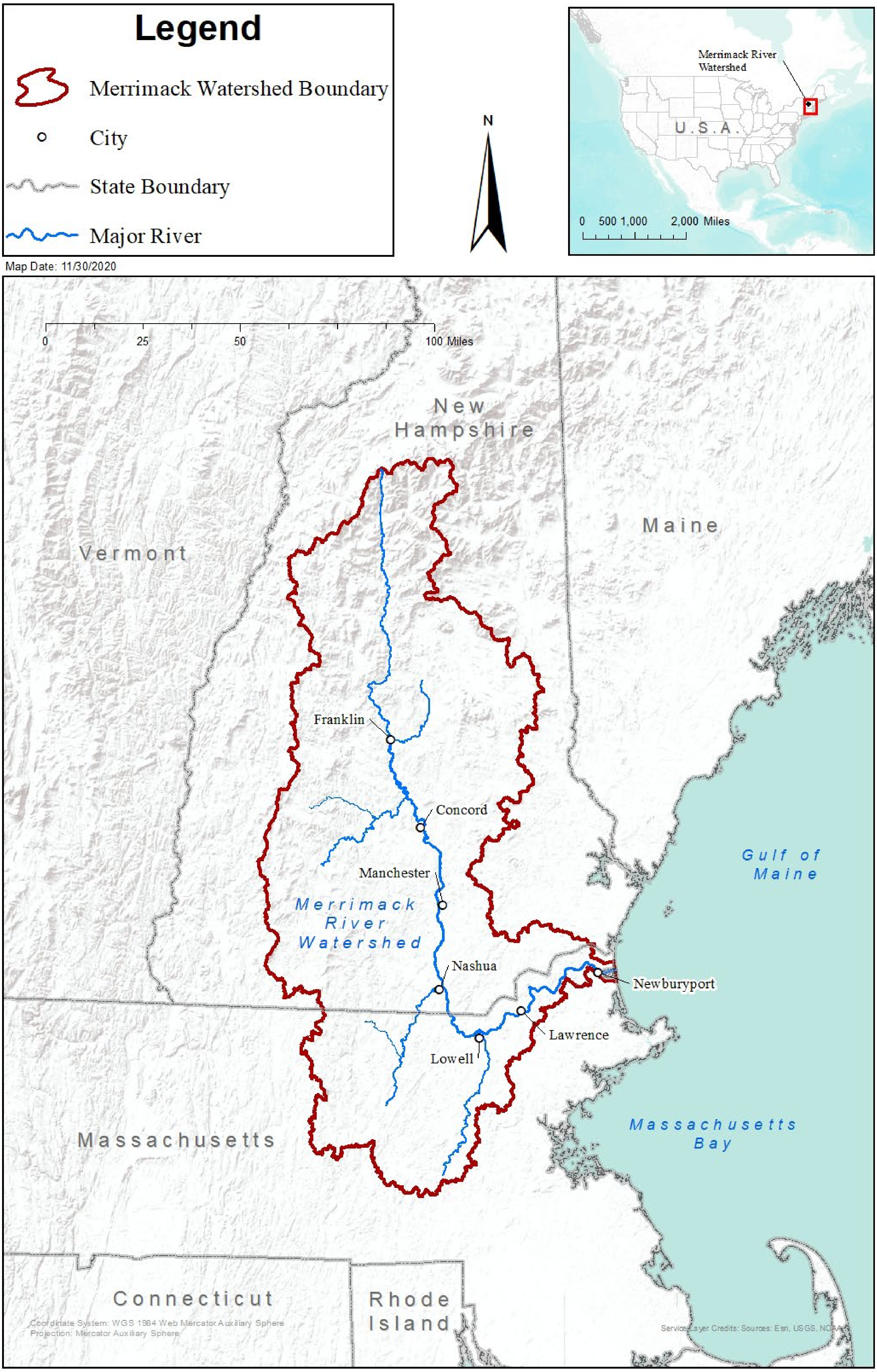

Figure 1. Merrimack River Watershed Overview

The historical American shad distribution in the Merrimack River Watershed included the entire mainstem (Table 1). In addition, major tributaries such as the Concord, Nashua, and Winnipesaukee Rivers supported runs of shad extending as far as Lake Winnipesaukee (Figure 2). Spawning occurred in Lake Winnipesaukee and in suitable areas on the mainstem and major tributary rivers. Livermore Falls, a natural barrier on the Pemigewasset, was likely the northern extent of shad distribution in the watershed. The construction of the Essex Dam in Lawrence, MA (ca. 1847) effectively eliminated the shad run with only a small remnant population persisting below the dam (MRTC 2010). Early attempts to create fish passage on mainstem dams were ineffective. When Essex and Pawtucket Dams were redeveloped in the 1980s with more contemporary fish passage structures, the population began to rebound after stocking. The present-day range ends at Hooksett Dam on the mainstem Merrimack River and at Talbot Mills Dam and Pepperell Dam on the Concord and Nashua rivers, respectively. Spawning habitat is limited to areas with fish passage on the Merrimack River, MRTC (2010) summarizes current and potential nursery habitats in the mainstem and major tributaries.

Table 1. Mainstem dams on the Merrimack River from rkm 0 upriver to the junction of the Winnipesaukee and Pemigewasset Rivers at rkm 186.

Barrier	River Km	Designated Extent of Upstream Impoundment/Habitat Break (rkm)	Purpose	Status
Essex Dam, Lawrence, MA	48	64	Hydroelectric power	Active, with fishways
Pawtucket Dam, Lowell, MA	70	106	Hydroelectric power	Active, with fishways
Amoskeag Dam, Manchester, NH	119	130	Hydroelectric power	Active, with fishways
Hooksett Dam, Hooksett, NH	132	140	Hydroelectric power	Active, without fishways
Garvin's Falls Dam, Concord, NH	140	153	Hydroelectric power	Active, without fishways

For this assessment, we have considered habitat in the context of the mainstem and tributary barriers that have fragmented, eliminated, or reduced access and altered habitat conditions throughout the basin (Figure 2). According to a recent analysis (MRTC 2021), there are over 7,729 lotic surface hectares of American shad habitat in the Merrimack River watershed with 2,914 (38%) of these hectares currently accessible. In the accessible reaches, passage inefficiencies due to poor facility design or seasonal flow regimes limit restoration goals and improvements must be made through FERC processes and engagement with dam owners.

During the initial diadromous fish restoration efforts on the Merrimack River, USFWS (Kuzmeskus et al. 1982) surveyed water depths and substrate composition. These surveys were used to identify appropriate shad spawning and nursery habitat in all sections of the mainstem Merrimack River and in many larger tributaries. This work was completed roughly 50 years ago and it is important to note that shad spawning habitat located upstream of dam impoundments on both the mainstem and identified tributaries are subject to shifting (over space and time) with changing river discharge (Greene et al., 2009). Given the lack of consistency in geographically limited habitat assessments, we are currently unable to quantify habitat designations at a fine scale.

Historic and, in some cases, current American shad distribution include one tributary in the MA, one that runs through MA and NH, and six in NH (Figure 2, Table 3). Habitat information is based on the best information available which often is based on a limited qualitative assessment. It is important to note that it is difficult to categorize what type of habitats may have existed in the natural river channel beneath current dam impoundments.

Table 2. The estimated spawning and rearing habitat for American shad, by tributary in relation to estimated minimum annual adult shad production or return potential for tributaries (100 fish/acre = 247 fish/ha).

Tributary	Total rkm of Habitat	Area (estimated) ha	Adult Shad Return or Production
Concord, MA	59.5	367.1	90,673
Nashua, MA/NH	27.9	342.8	84,672
Souhegan, NH	32.2	30.4	7,509
Piscataquog, NH	11.3	82.2	20,300
Suncook, NH*	35.3	46.9	11,605
Soucook, NH*	39.6	25.9	6,401
Contoocook, NH*	20.6	383.6	94,792
Total			315,887

*Area estimates for these rivers from MRTC 1997; all others from MRTC 2021

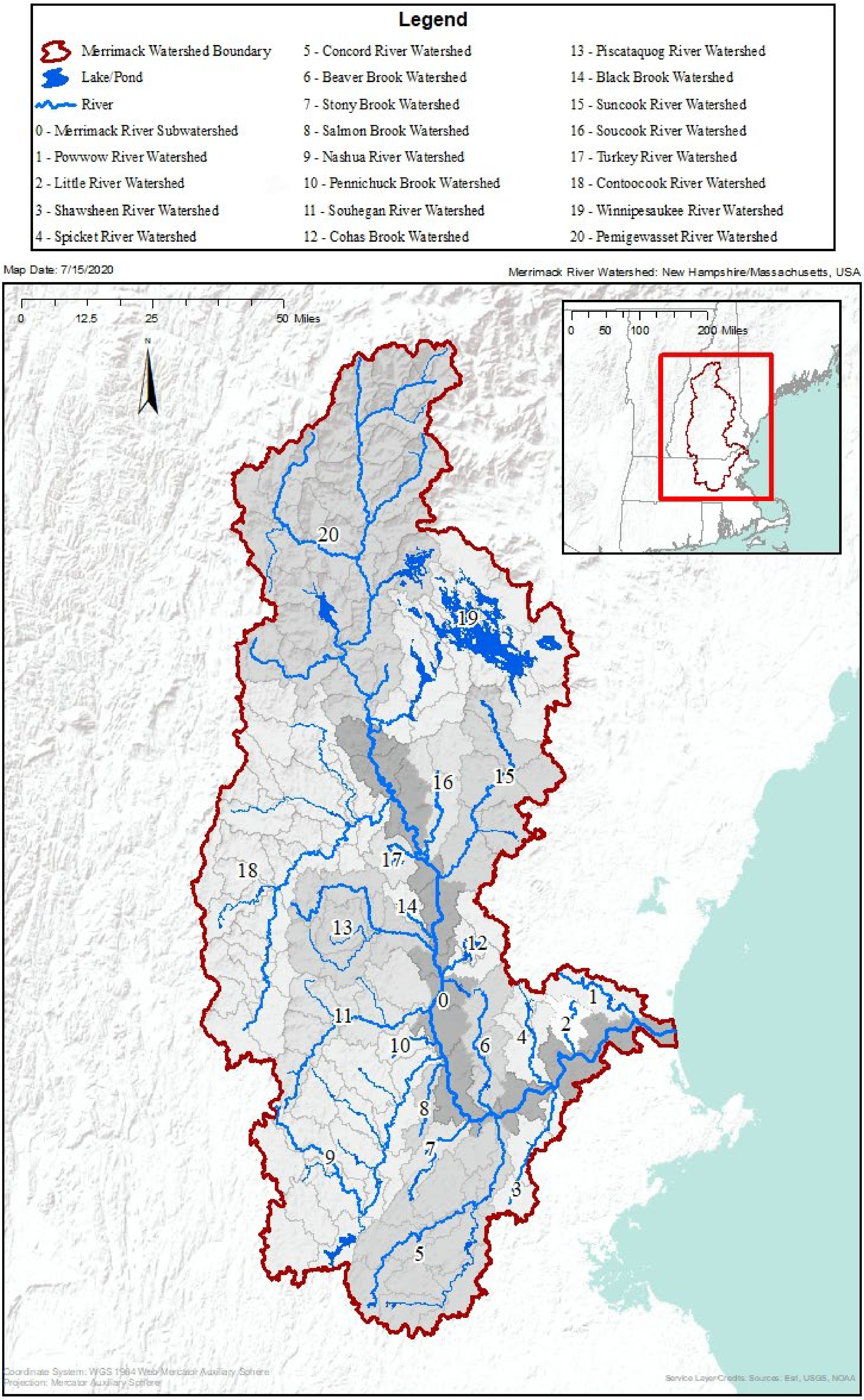

Figure 2. Sub-watersheds of the Merrimack River

3 HABITAT ACCESSIBILITY

Due to early colonization and an industrial history, the Merrimack River watershed has a high concentration of barriers; there are around 3,000 dams in various states of use and disrepair (Figure 3). Stream crossings, such as bridges and culverts, make up an additional 4,450 potential barriers. Keeping a current list of the condition and degree of all this infrastructure is daunting and there is no definitive data source. Because crossings and barriers are numerous throughout the watershed, we focused on the sites that limit passage along shad migration routes.

Adult shad have varied degrees of access to mainstem habitat up to the Hooksett Dam at rkm 132 (NH) using a fish lift system at the Essex Dam (MA), a fish lift or vertical slot fishway at Pawtucket Dam (MA), and a modified pool and weir fish ladder at the Amoskeag Dam (NH; Table 4). Upstream fish passage efficiency remains a major concern and has been demonstrated to vary widely among these mainstem facilities, with the Pawtucket Dam fish lift and Amoskeag ladder identified as having low to very low passage efficiencies. Annual shad passage counts at the Pawtucket Dam facilities have averaged 16.9% (range: 4.6% - 48%) of the number of shad passed at the downstream Essex Dam, with the highest value occurring in 2018 after the operator and MRTC agreed to open the bypass reach vertical slot ladder at Pawtucket for the entire passage season (MRTC 2021). Until recent modifications, the ladder at Amoskeag effectively blocked all shad migration. Following MRTC-directed modifications, American shad passage has been documented but overall efficiency is still unknown. Downstream passage at all facilities is varied and little is known about routing or survival (Table 3).

Table 3. Passage summary for dams on the mainstem Merrimack River

Dam	Upstream Passage Type	Upstream Passage Location	Downstream Passage
Essex Dam Lawrence, MA	Fish Lift	Power house	Surface bypass
Pawtucket Dam Lowell, MA	Fish Lift	Power house	Surface bypass
	Vertical slot ladder	Bypass reach	
Amoskeag Dam, Manchester, NH	Pool and weir	Power house	Surface bypass
Hooksett Dam, Hooksett, NH	Designed rock ramp	-	Surface bypass
Garvin's Falls Dam, Concord NH	None	-	Low-level and surface bypasses

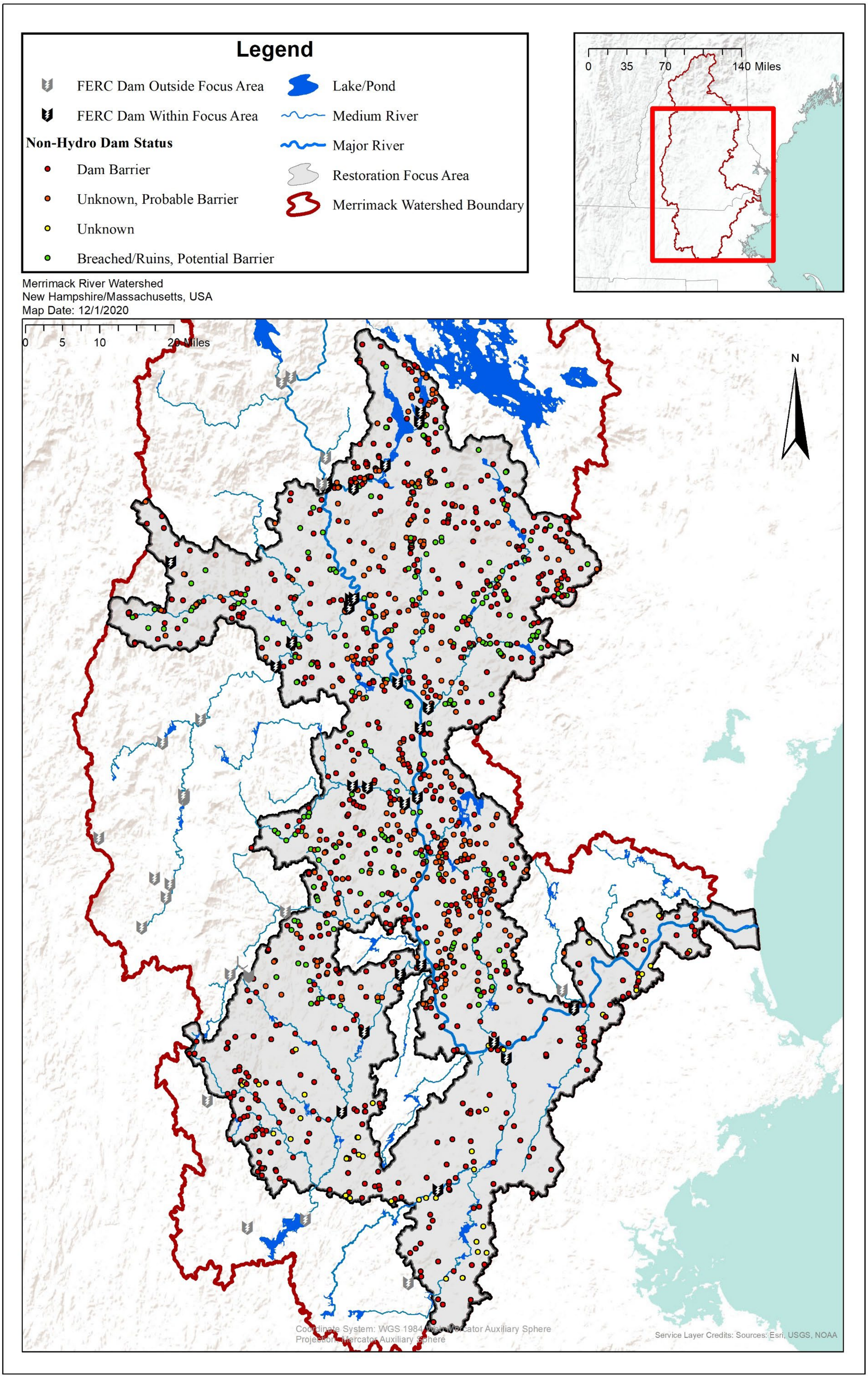

Figure 3. Barriers in the Merrimack Watershed

The only facility with informative American shad efficiency data is the Pawtucket Dam. Sprankle (2005) radio tagged American shad and found that 9% of tagged fish that approached the Pawtucket dam were able to locate and pass the fish lift. Hogan et al. (2011) used fine scale 2D and 3D modelling of tagged shad to determine that the tailrace flow field appeared to obstruct shad from locating the fish lift entrance and documented an overall efficiency of 7%. Normandeau Associates examined both up and downstream passage as part of the Initial Study Report process for the Lowell FERC Relicensing (Boott Hydro, 2020). This study confirmed extremely low efficiency at the fish lift with 43 tagged shad making 201 unique attempts to enter the forebay and pass the lift with only 37% of those attempts reaching the lift entrance and only 6% of the total events leading to passage through the lift. Cormack Jolly Seber model results yielded an overall effectiveness estimate of 30.4% (75% CI = 22.1 – 39.5%). Only two tagged fish were detected at the bypass ladder, neither of which passed. In the same study Normandeau examined downstream delay and survival of adult American shad. They found a median delay at the dam of 3.9 days for tagged shad with a range of 0.4 hours to 20.0 days. However, 30% of tagged shad passed in fewer than 24 hours and 51% passed in fewer than 96 hours. Tagged shad that approached the Project used all available routes with 26% going through the turbines, 28% using the sluice bypass, and 38% using the bypassed reach. However, tagged fish did not appear to exhibit equal survival among routes with 89% of fish using the bypassed reach, 82% of fish that used the bypass sluice, and 35% of fish that went through the turbines successfully arriving downstream at the Essex Dam. Cormack Jolly Seber models estimated that 70.0% (75% CI = 64.5 – 74.6%) of adult American shad survived downstream passage at the facility.

The 2020 American Shad Benchmark Stock Assessment and Peer Review Report provides a comprehensive review of the many issues with fish passage for adult and juvenile shad on both upstream and downstream passage measures (ASMFC 2020). The Report also contains a modeling analysis to quantify losses of both habitat and adult production from dams that strongly support the need to have substantial improvements in the "performance" of fishways related to percentage rate of passage success, time to pass (delay issues), and survival from passage. These passage metrics must also be considered in their cumulative effects given fragmentations of habitat by dams in rivers within the Merrimack watershed. The need for improved achievable passage performance criteria is well supported along with additional fish behavior research and fish passage engineering (USFWS, 2019).

Distances to and type of available passage at first barrier are noted in Table 4 along with the status of the next barrier. As is the case on the mainstem, fish passage efficiency is poorly understood at dam fishways in tributaries. On the Concord River, observations at Middlesex Falls, under multiple flows, has led to the conclusion that the breached area should be passable. However, no formal testing or rigorous monitoring has occurred. Upstream at Centennial Falls Dam, the MRTC has documented many issues with the existing ladder[1] and are currently

[1] See 2017 inspection report, FERC Accession # 20171019-5023

working with the dam owner to create a new upstream passage facility rather than attempt to repair the current Denil ladder. Volunteer monitoring on the Nashua River has not documented any shad passing at Jackson Mills or Mine Falls during the past few years of monitoring; therefore, the effectiveness of the Denil ladder at Jackson Mills for shad is unknown, as well as at the fish lift at Mine Falls. An inventory of all potential fish passage obstructions was compiled in the MRWCP (2021). The subset of obstructions relevant to American shad passage can be found in Appendix 1 to this Habitat Plan and in the related Barrier Inventory submitted with the Plan.

Table 2. Identified American shad tributaries of the Merrimack River basin with first, second, and third (where applicable) dam locations and status of passage.

Tributary	Distance to 1st Upstream Dam (rkm)	First Dam	US/DS Passage Provided by	2nd Dam (rkm)	US/DS Passage Provided by	3rd Barrier (rkm) and Notes
Concord	0.64	Middlesex Falls	breach	Centennial (2.2)	Denil/sluice	Talbot Mills (8), ongoing removal FS
Nashua	2	Jackson Mills	Denil/bypass pipe	Mine Falls (8.4)	lift/ surface bypass	Pepperell (22.9), Existing triggers
Souhegan	22.5	McLane	- /-	Goldman (22.9)	-/-	Pine Valley (32.2)
Piscataquog	3.2	Kelley's Falls	-/sluice	Gregg's Falls (11.3)	-/ surface bypass	Hadley Falls (13.8)
Suncook	0.8	China Mill	- /-	Webster (.95)	-/-	Pembroke (1.4)
Soucook	30.9	Loudon Village Dam	-/-			
Contoocook	0.5	Penacook Lower Falls	-/modified gate	Penacook Upper Falls (1.5)	-/-	Rolfe Canal (3.4)

4 THREATS ASSESSMENT

4.1 Threat: Barriers to Migration Upstream and Downstream

4.1.1 Recommended Action

One of the primary goals of the Merrimack River Comprehensive Plan (MRTC 2021) was to:

> "Restore a self-sustaining American shad population in the Merrimack River watershed, with unrestricted access to spawning and juvenile rearing habitat throughout the mainstem and major tributaries."

The MRTC's analysis identified 7 dams currently blocking more than 1,400 hectares of habitat on the Mainstem, Concord, Nashua, Souhegan and Piscataquog Rivers (Table 5; Figure 4). Fish passage at these seven dams will nearly double the accessible diadromous fish spawning and rearing habitat (termed the "Interim Plan"). Moreover, fish passage or dam removal, depending on the site, is a realistic or expected outcome for many or all dams within the next decade. Pursuing the MRWCP's interim plan is the Recommended Action to mitigate the Barrier to Migration threat.

Passage at these sites should have a large positive effect on American shad production. Potential production for alosines was estimated based on available spawning habitat under different accessibility scenarios and an expectation of 247 shad being produced for every hectare of habitat (MRTC 2010, MDMR and MDIFW 2016). American shad production potential (defined as adult fish returning to the river mouth) in accessible habitat above Essex Dam is currently 421,900 returning adult fish (Table 6). Under the Recommended Action, the production increases to 780,200 as a result of the increased access to habitat, which is just over half the estimated production of 1,446,200 adult shad if all barriers in the watershed had passage. The Recommended Action estimates a large increase in both available habitat and potential production of American shad with successful engagement at the seven dams listed in Table 6. It is vital to note that other diadromous species such as blueback herring, alewife, American eel, and sea lamprey will benefit from fish passage improvements at any dam structure in the watershed.

Table 5. List of dams where implementation of fish passage is recommended by 2030

FERC Project - #	Dam Name	State	Waterway	License Expiration Date	Hectares of Habitat Blocked
1893	Garvin Falls	NH	Merrimack River	4/30/2047	609.5
1893	Hooksett	NH	Merrimack River	4/30/2047	224.6
3025	Kelley's Falls	NH	Piscataquog River	3/31/2024	82.2
12721	Pepperell	MA	Nashua River	8/31/2055	176.0
Non-Hydro	Talbot Mills	MA	Concord River	N/A	327.4
Non-Hydro	McLane	NH	Souhegan	N/A	< 2
Non-Hydro	Goldman	NH	Souhegan	N/A	30.4

Table 6. Potential production of American shad under different habitat scenarios (scenarios only consider habitat upstream of Essex Dam)

Habitat Scenario	Hectares of Habitat	Potential # of Returning Adult American Shad
Current Scenario	1,707	421,900
Recommended Action	*1,450*	*358,300*
Total (Current + Recommended)	3,157	780,200
Ideal Scenario	14,462	1,446,200

Notably, the 2020 American Shad benchmark Stock Assessment and Peer Review Report (ASMFC, 2020) and connected modeling efforts (Stich et al 2019, Zydlewski et al 2021) have provided evidence that high survival and minimal delay during both upstream and downstream migration are essential to sustainable shad stocks in dammed rivers. Accordingly, the MRWCP established the following Passage Performance Criteria:

- For alosines, achieve and maintain a minimum of 80 percent upstream passage efficiency.
- For alosines and American eel, achieve and maintain a minimum of 95 percent downstream passage survival.
- Ensure diadromous passage facilities do not cause unnecessary delay that exceeds 24 hours at each Project.

These criteria also make the multiple hydroelectric project licenses that expire by 2030 priorities for the MRTC. These include projects on the mainstem Merrimack River and Nashua River where improving efficiency and effectiveness of existing facilities is the focus, as well as projects on the Contoocook and Piscataquog Rivers where no passage facilities currently exist (Table 7). While the Suncook, Soucook, and Contoocook Rivers are not within the Recommended Action, information on Fish Passage and Habitat Access are included below as restoration opportunities are likely to occur within the next decade.

Table 7. Hydroelectric facilities with expiring licenses before 2030; MRTC agencies will actively participate in the licensing processes.

FERC Project - #	Facility Name	Facility Owner	Waterway	License Expiration Date
2790	Lowell	Central Rivers Power	Merrimack River	4/30/2023
3442	Mine Falls	City of Nashua	Nashua River	7/31/2023
3025	Kelley's Falls	Green Mountain Power	Piscataquog River	3/31/2024
3342	Penacook Lower	Briar Hydro Associates	Contoocook River	11/30/2024
3240	Rolfe Canal	Briar Hydro Associates	Contoocook River	11/30/2024
6689	Penacook Upper	Briar Hydro Associates	Contoocook River	11/30/2024
2800	Lawrence	Central Rivers Power	Merrimack River	11/30/2028

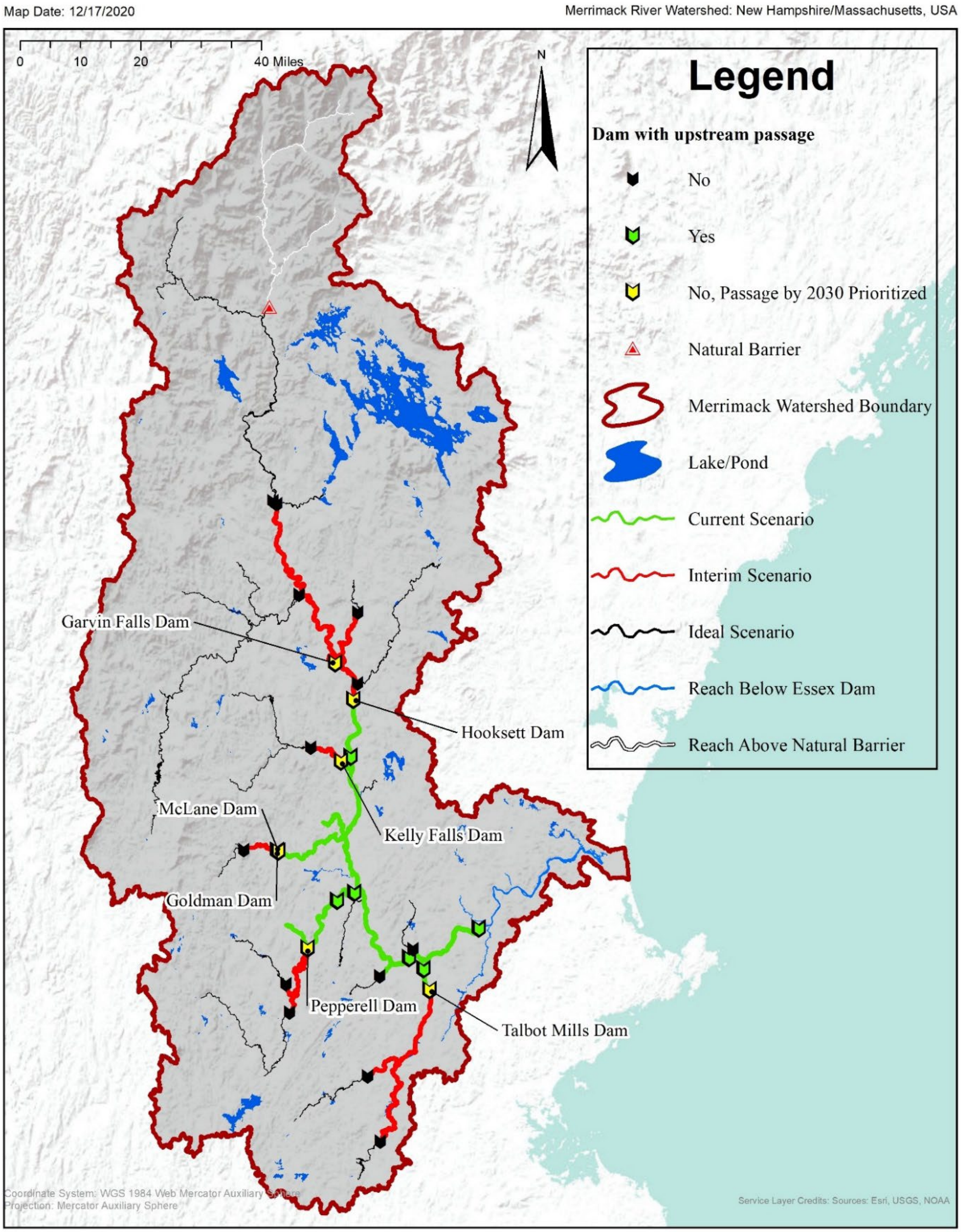

Figure 4. Current and Potential Diadromous Fish Access, Merrimack River Watershed

4.1.2 Fish passage/habitat access mainstem Merrimack River (MA, NH)

The first barrier on the mainstem of the Merrimack River is the Essex Dam, which spans the river at rkm 48.3 approximately 12.9 km above the head of tide. Originally named the Great Stone Dam, the Essex Company finished construction in 1848. At 274.3-meters-long and 10-meters-tall, it was the largest dam in the world at that time. The dam was designed to divert water into two power canals for textile manufacturing. The dam is now used for hydroelectric power generation. The dam impounds a 15.8-km-long, 265.1-hectare reservoir with a storage capacity of roughly 19,900 acre-feet. The original license for the Lawrence Hydroelectric Project was issued by the FERC in 1978 to Lawrence Hydroelectric Associates and Essex Company with an authorized capacity of 16.8 MW. The project was operational by 1981 using two Kaplan turbine units, each rated at 7.4 MW, to generate electricity resulting in an installed capacity of 14.8 MW. The original license included mandatory conditions for the construction and operation of a fish lift and a downstream bypass sluice.

Essex Company is still the licensee, but the project has transferred ownership to Central Rivers Power. Recently the project was upgraded with an automatic crest gate system to better control impoundment levels. In addition, the FERC amended the license to remove the historic canals from the project boundary. The project will begin licensing in 2023, with the original license set to expire in 2028. As the first mainstem barrier, the outcomes of this licensing will determine the future success of diadromous fish restoration in the Merrimack watershed. The MRTC will take an active approach in the licensing process to ensure effective fish passage structures support diadromous fish restoration goals.

The Pawtucket Dam is the second dam on the Merrimack River constructed on Pawtucket Falls at rkm 69.2 in Lowell, MA. Constructed in 1847, the dam originally provided hydropower through the network of associated canals to run America's first large-scale planned industrial city. At 333-meter-long and 4.6-meter-tall, the stone- masonry gravity dam is one of the largest in the Merrimack watershed. The dam impounds the river 37 km upstream, with a surface area of 291.4 hectares and a capacity of 3,960 acre-feet of water storage. The dam was recently upgraded with an automatic crest gate system to better control the impoundment water level. The dam currently diverts water to a main hydroelectric development (E.L. Field Powerhouse) with two Kaplan units (17.3 MW) and four other hydropower developments located in the downtown canals with a myriad of antiquated turbine units. The total project authorized capacity is 24.8 MW. Boott Hydropower, LLC obtained the original license in April of 1983. The project is presently undergoing licensing with the original license set to expire on April 30, 2023. In the draft license application, the Licensee has proposed decommissioning the developments in the downtown canal system. Boott Hydropower, LLC remains the licensee, but ownership of the project has recently transferred from Enel Green Power to Central Rivers Power.

The Pawtucket dam has several fish passage facilities that began operation in 1986: a fish ladder at the north end of the dam, a fish lift at the power station, a downstream bypass in the power canal, a temporary eel trap at the north end of the dam, and fish counting stations at each upstream passage facility. Many of these fish passage measures are ineffective and challenging infrastructure combined with a lack of downstream entrainment prevention for out-migrating fish causes reduced passage, increased migratory delay, and high project-induced mortality. Fish passage improvements are necessary at Lowell to meet the management goals of the MRWCP (MRTC 2021).

The Merrimack River Project consists of three developments on the mainstem, Amoskeag, Hooksett, and Garvin's Falls. The three developments have a combined installed capacity of 29.9 MW. The dams are located along a 33.8-km stretch of the upper Merrimack in New Hampshire's Hillsborough and Merrimack Counties, near Manchester, Hooksett, and Concord respectively. The original license was issued to the Public Service Company of New Hampshire in 1980, and the project was issued a new license in 2007. Central Rivers Power operates the facilities under the current license set to expire in 2047.

Amoskeag Development (Manchester, NH)

Constructed on the site of the historic Amoskeag Falls, Amoskeag Dam impounds the river at rkm 119.1 in Manchester, NH. Originally constructed in the 1830s to provide hydropower for the mills of the Amoskeag Manufacturing Company; the dam was re-built in the 1920s for hydroelectric power generation. The 8.8-meter-tall, 216.4-meter-long dam impounds a 11.3-km reach of the mainstem with a surface area of 193.4 hectares. The powerhouse contains three Francis turbine units with a total installed capacity of 16 MW. Fish passage facilities were put into operation in 1989. The fishway facilities include a pool and weir fish ladder, multiple eel traps, and a downstream bypass system at the powerhouse waste gate. A trap and trucking station is part of the ladder allowing adult fish to be collected for stocking. Because the fish ladder was designed for Atlantic salmon, the effectiveness for other diadromous fish has been poor. However, recent modifications to the ladder have shown promise for alosines. With no entrainment prevention at the powerhouse, safe downstream passage at the development remains a concern.

Hooksett Development (Hooksett, NH)

The Hooksett hydroelectric facility is the fourth dam on the Merrimack River, located north of the town of Hooksett at rkm 132. The 14-meter-high dam comprises two sections: a 103.6-meter stone masonry section on the western half of the river connected to a 76.2-meter concrete section to the east. The dam creates a 8.9-km, 163.9-hectare reservoir. The powerhouse contains a single vertical propeller turbine with 1.6 MW of installed capacity. Hooksett Dam has no upstream fish passage structures. However, a requirement for upstream passage facilities is included in a settlement agreement for the Merrimack Project. Construction of a rock ramp fishway at the western spillway is anticipated the summer of 2022 or 2023. Gate structures next to the powerhouse are used for downstream passage with minimal success. With no entrainment prevention at the powerhouse, safe downstream passage at the development remains a concern.

Garvin's Falls Development (Concord, NH)

Garvin's Falls is the fifth and final dam on the Merrimack mainstem located 8 kilometers upstream of Hooksett at rkm 140. The 5.5-meter-high, 167.6-meter-long dam is made of granite and concrete. The 259-hectare impoundment created by the dam is 12.9-kilometers-long. The two powerhouses each contain two Kaplan/propeller generating units that have a total installed capacity of 12.3 MW. Like Hooksett, there are no anadromous upstream fish passage measures at Garvin's Falls. However, there are seasonal eel traps installed at the development. Provisions for future fishways are contained in the 2007 settlement agreement. A louver-type downstream fish guidance and bypass system is present in the 152.4-meter-long power canal. Since the cessation of the Atlantic salmon program in the Merrimack River, the louver is no longer installed in the power canal, but the bypass system still operates to pass American eel and stocked alosines. With no entrainment prevention at the powerhouse, safe downstream passage at the development remains a concern.

4.1.2.1 Agencies with regulatory authority:
The MRTC, while an ad hoc committee, regularly interacts and completes agreements with dam owners and hydropower operators that are then confirmed by the member agencies. The individual States have their independent authorities related to diadromous fish passage and management The USFWS and NMFS have fishway prescription authority through the Federal Power Act, used in connection with FERC.

4.1.2.2 Goal/Target:
The Merrimack River Watershed Comprehensive Plan (2021) includes goals and objectives that are quantified in terms of the entire population as well as within the river basin's many segmented habitat reaches. Adult population targets are described as targets based on biological data and accessible habitat for the targeted reach described in that plan. Target populations are based on a minimum of 80%-effective upstream passage at all projects.

4.1.2.3 Progress:
The relicensing process for the Essex Dam Project will begin in 2023 and the MRTC expects to achieve modifications to the project that will allow for the goals in the MRWCP and this habitat plan to be met. FERC relicensing is ongoing for the Pawtucket Dam Project and the agencies expect that new upstream and downstream passage measures will be implemented as part of that process with construction occurring between 2024 and 2026. Over the past 5 passage seasons fishway engineers with USFWS and NMFS have worked with the hydropower operators to make improvements to the ladder at the Amoskeag Development, leading to improved passage of alosines at that facility. At the Hooksett Development in New Hampshire, 90% design plans of a rock ramp fishway have been approved by the management agencies. The Licensee and MRTC have agreed on a timeline for providing passage and are currently discussing downstream mitigation measures. Upstream passage at Garvin's Falls will be triggered by passage numbers at Amoskeag and the construction of the Hooksett rock ramp fishway.[2]

4.1.2.4 Timeline:
The MRTC and Boott Hydropower, owner and licensee of the Lowell (Pawtucket Dam) Project, have reached an agreement in principal for upstream and downstream fish passage improvements to meet the goals of the MRWCP. This agreement is also reflected in Boott's final relicensing application currently pending before the FERC. The agreement must still be finalized and then submitted to and approved by FERC as part of its relicensing order. As design plans for a fishway at the Hooksett development have now been approved, MRTC is optimistic upstream passage will be available there by 2024. Currently the first 5 mainstem dams on the Merrimack are owned by one entity, Central Rivers Power, which may make achieving mainstem passage goals more feasible over the next decade.

4.1.3 Fish passage/habitat access Concord River (MA)

The Concord River has three obstacles to fish passage. Near the mouth of the Concord (0.64 km from the confluence with the Merrimack River), is the breached Middlesex Dam. This structure

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[2] Passage of 9,800 American shad or 23,200 river herring at Hooksett OR 19,300 American shad or 45,800 river herring at Amoskeag.

is passable under normal flow conditions, though likely causes delays in migration. Another 1.6 km upstream is the Centennial Island Hydroelectric Project. Volitional passage is provided in the bypass reach via a fish ladder at the north end of the dam. Continuing approximately 4.8 km upstream is the Talbot Mills Dam, the final barrier on the Concord River mainstem. Talbot Mills Dam is a complete barrier to fish passage, except for American eel.[3] Removal of this dam will provide access to 56.3 km (299 hectares) of historical mainstem river habitat for diadromous fish in the upper Concord, and lower Assabet and Sudbury Rivers. The NOAA Fisheries Restoration Center, MADMF, and other partners are actively engaged with the owner of Talbot Mills Dam to remove the dam in the near future.

4.1.3.1 Agencies with regulatory authority:

At Centennial, the Commonwealth of Massachusetts has legal authorities regarding dams and fish passage and the USFWS and NMFS have authority through the Federal Power Act and through FERC for licensed hydropower dam/projects. The Commonwealth of Massachusetts has legal authorities regarding dams and fish passage at Talbot Mills.

4.1.3.2 Goal/Target:

The MRTC has a goal to confirm or improve passage at Middlesex Falls, improve poor up and downstream passage at Centennial Falls, and remove the Talbot Mills Dam.

4.1.3.3 Progress:

Members of the MRTC are planning to confirm passage at the breached Middlesex Falls and identify any further work that may be needed in the next 12 months. At Centennial Island, the MRTC is actively involved with the owner and hopes to implement a small nature-like fishway on river right to replace the poorly functioning existing Denil ladder on river left. The MRTC has also documented severe degradation of the downstream trash rack/fish exclusion structures by the dam and the owner has prioritized their replacement. In 2019 the owners agreed to pursue funding for removal and in early 2022 the Talbot Mills removal effort was chosen as a "Priority Project" by MA Division of Ecological Restoration, bringing additional expertise and funding to the team.

4.1.3.4 Timeline:

The Talbot Mills project is the only effort with a currently defined timeline. The most recent Scope of Work developed among project partners sets an aggressive target date for dam removal in the fall of 2023. While this date may not be met, removal in the next three years seems likely.

4.1.4 Fish passage/habitat access Nashua River (NH, MA)

The Nashua River watershed is the third largest in the Merrimack basin consisting of three distinct reaches. The North Nashua River flows 31 km southeast from the confluence of Whitman River and Philips Brook in Fitchburg, MA where it meets the Nashua River in Lancaster, MA. The South Nashua River flows 8.4 km north from the Wachusett Reservoir Dam outlet where it joins the North Nashua River. From here the Nashua River flows 60.5 km northeast into New Hampshire, where it flows into the Merrimack at rkm 87.7. There are over 1,609 km of rivers and streams in the 138,046-hectare watershed, including several impounded reaches. Because of flow diversion at the Wachusett Reservoir, the Nashua River watershed differs from its historical drainage. There are 178 lakes, ponds, and impoundments in the

[3] American eel have been documented above this dam, indicating that at least some individuals of this species are capable of scaling the dam under certain conditions. It is still a significant impediment for this species.

watershed with a total surface area of 4,351.2 hectares (10,756 acres). Two contiguous ponds in the watershed are identified by NHFG as suitable alewife stocking habitat; Flints Pond (20.2 hectares) and Potanipo Pond (55 hectares). Major tributaries in the watershed include the Quinapoxet, Stillwater, Squannacook, and Nissitissit Rivers.

The first dam on the Nashua River is the Jackson Mills Dam, which impounds the river 2 km upstream from the confluence with the Merrimack in the city of Nashua, NH. The stone masonry gravity dam was constructed in 1920, with the hydropower facility coming into operation in the mid-1980s. The run-of-river facility consists of a 54.9-meter-long dam, 10.1 meter in height including a 2.4-meter-high automatic crest gate. The dam impounds a 16.0-hectare reservoir with negligible usable storage capacity. The installed capacity of the project is 1.0 MW generated by a single propeller turbine in the powerhouse at the north end of the dam. The Exemptee is planning to replace the existing unit with a Kaplan turbine. The project has a license exemption issued in 1984 to the City of Nashua, NH.

As a condition of the license exemption, the Exemptee was required to install fish passage facilities. Both upstream and downstream passage structures are in place, with a Denil fish ladder for upstream passage, and a stainless-steel bypass pipe for fish migrating downstream. Observational evidence and recent site inspections suggest the current fish ladder needs improvements, although no studies have been conducted to confirm. As Jackson Mills is the first dam on the river, effective fish passage is vital for the success of diadromous fish in the Nashua River watershed. The Exemptee has recently agreed to replace the upstream passage facility and install full depth, ¾” exclusion racks to the downstream facility no later than 2030.

The second dam on the Nashua River is the Mine Falls hydroelectric project, located 6.4 km upstream of the Jackson Mills project in Nashua, NH. The hydropower facility is situated at the site of a 19th century dam and gatehouse. The dam once served to divert water, via a gatehouse, to a 10.7-meter-wide hand-dug power canal. The defunct canal flows 4.8 kilometers east, parallel to the Nashua River, to the former site of the Nashua Manufacturing Company textile mill. The dam impounds a 97.9-hectare reservoir with a usable storage capacity of 450 acre-feet. The water is routed through a 106.7-meter power canal to the powerhouse, which contains two Kaplan turbines with an authorized capacity of 3.0 MW. The original license was issued in 1983 to the City of Nashua and will expire in 2023.

Fish passage was prescribed in the original license to be implemented either by 1985 or upon completion of upstream passage facilities at the Pawtucket Dam. The upstream fish passage measure is a fish lift discharging fish into the power canal. While the presence of upstream passage facilities is beneficial, several improvements are needed to improve fish passage and survival. The current downstream bypass system is generally a safer route of passage though studies indicate a poor entrance efficiency. The existing upstream and downstream facilities will require modifications in the new license.

The Pepperell project is the third dam on the Nashua River 14.5 kilometers upstream of the Mine Falls project in Pepperell, MA. The 76.5-meter-long, 7.2-meter-tall Pepperell Paper Company Dam impounds a 5.6-kilometer-long, 119-hectare reservoir and provides water to the powerhouse via a 172.5-meter-long penstock. The project’s three generating units combine for an installed capacity of 2.14 MW. The original 40-year license was issued to the Pepperell Hydro Company, LLC in 2015 and expires in 2055.

Currently there are no upstream fish passage structures, but the license contains numerous conditions (including minimum flow levels) for fish passage resulting from a settlement. The installation of upstream fish passage at Pepperell is required upon passage of 5,000 river herring during two consecutive years at the Mine Falls Project and this trigger may be met in 2022 as more than 5,000 herring were passed in 2021.[4] Downstream protections for alosines are required in the license. Full implementation of these fish passage measures is important as upstream fish passage improves at Mine Falls and Jackson Mills.

4.1.4.1 Agencies with regulatory authority:

Depending on the location of a specific Project, either the State of New Hampshire (Jackson Mills and Mine Falls) or the Commonwealth of Massachusetts (Pepperell) has legal authorities regarding dams and fish passage and the U. S. Fish and Wildlife Service and National Marine Fisheries Service have authority through the Federal Power Act and through FERC for licensed hydropower dam/projects.

4.1.4.2 Goal/Target:

Achieve goals and objectives defined in the MRWCP (2021). An annual minimum run of 58,700 shad is the target for this tributary.

4.1.4.3 Progress:

No shad passage has been documented in the Nashua River to date. Studies have been completed and the agencies are working with the City of Nashua to finalize a timeline for the completion of recommended fish passage improvements at Jackson Falls and Mines Falls.

4.1.4.4 Timeline:

The Exemptee and MRTC have developed a timeline in the revised amendment application, but FERC approval is still pending.

4.1.5 Fish passage/habitat access Souhegan River (NH)

At rkm 99.8 in the town of Merrimack, NH, the Souhegan River enters the Merrimack River from the west. The Souhegan flows 54.4 km from its source at the confluence of the south and west branches near New Ipswich, NH. The Souhegan River and tributaries total 657 river kilometers, draining the 56,980-hectare watershed. There are 42 lakes and ponds with a total surface area of 448 hectares (1,105 acres). Although a few dams have been removed from the lower river, many barriers remain, including four hydroelectric projects in the middle and upper reaches. Wildcat Falls is a natural feature approximately 2.0 miles upstream from the Souhegan mouth. During lower flow conditions, these falls are not considered a barrier for most diadromous fish.

About 22.5 km upstream of the Merrimack confluence, the McLane Dam impounds the Souhegan River. The 5.5-meter-tall, 54.9-meter-long stone masonry spillway was originally built in 1846 and was reconstructed with concrete in 1992. The McLane Dam serves no function and increases the risk of flooding to upstream properties. The dam blocks migration for both resident and diadromous fish.

[4] If the trigger is met in 2022, passage does not need to be implemented until 2026 per the settlement. The Licensee is currently discussing conceptual upstream passage designs with the MRTC.

Immediately downstream of the Route 13 Bridge (0.4 km above the McLane Dam), the Souhegan is impounded by the Goldman Dam. This dam was originally constructed in 1810 and rebuilt in the 1960s. The private trust-owned structure has a spillway of approximately 52.7 meters in length and a low-level outlet at the north end. Like the McLane Dam, Goldman Dam serves no function. Signs of aging, such as undermining of the concrete dam face, are visible. Passage at the McLane and Goldman Dams will open nearly four kilometers of historical diadromous fish habitat on the Souhegan River.

Further upstream, near rkm 32.2, Pine Valley Mills Dam is the third barrier on the Souhegan River. Constructed in 1912, the 61-meter-long, 7-meter-tall stone-masonry dam impounds a 2.8-hectare reservoir. Water is supplied to a turbine in the nearby powerhouse with a capacity of 0.525 MW.

The 40-year license was originally issued to Mr. Winslow H. MacDonald in 1987, and has since been transferred to PVC Commercial Center, LLC. The license will expire in September 2027. The project has a downstream bypass for fish. No upstream passage was required in the original license; however, there is a reservation of authority to require upstream passage at the project if Atlantic salmon were restored to the Souhegan. Upstream fish passage at the two non-hydro dams downstream is needed before migratory fish reach the Pine Valley Project.

4.1.5.1 Agencies with regulatory authority:

The State of New Hampshire has legal authorities regarding dams and fish passage and the USFWS and NMFS have authority through the Federal Power Act and through FERC for the licensed hydropower Pine Valley Dam.

4.1.5.2 Goal/Target:

Achieve goals and objectives defined in the MRTC CP (2021). An annual minimum run of 7,509 shad is the target for this tributary (Table 3).

4.1.5.3 Progress:

A feasibility study was done to evaluate the potential removal of the McLane and Goldman Dams, but the project did not move forward due to a lack of local support. Future attempts to provide fish passage should start by reengaging the town of Milford.

4.1.5.4 Timeline:

There is no developed timeline for actions on the Souhegan River

4.1.6 Fish passage/habitat access Piscataquog River (NH)

The Piscataquog River flows east for 59.5 km from Deering Reservoir in Deering, NH to the Merrimack downstream from the Amoskeag Dam in Manchester, NH at rkm 114.3 Numerous tributaries flow into the Piscataquog, with a combined length of over 624 km, and a drainage area of 56,202 hectares. There are 52 lakes and ponds (including four major impoundments) totaling 818.4 hectares (2,025 acres).

The first dam on the Piscataquog River is the Kelley's Falls Project 3.2 km upstream from the Merrimack confluence. The multi-section concrete gravity dam is 153.3 meter long and 9.4 meters tall, with the spillway comprising 58.5 meters of the total length with a height of 6.4 meters. The dam was constructed in 1916 and impounds a 52.2-hectare reservoir (Namaske Lake) with a storage capacity of 1,350 acre-feet. The powerhouse contains a turbine with a capacity of 0.45 MW. The original license was issued in 1984 with a 40-year term expiring on

March 31, 2024. The licensee is Kelley's Falls, LLC (a subsidiary of Green Mountain Power Corporation). MRTC member agencies are actively involved in the licensing process of this project.

Article 26 of the original license included the condition that the "Licensee shall provide upstream and downstream fish passage facilities within one year after completion of fish passage facilities at the downstream Lowell Project (P-2790)". Lowell's fish passage facilities came online in the mid-1980s. In 1987, the license was amended to require the approved upstream and permanent downstream passage in the second year following an annual upstream passage of 15,000 American shad at Amoskeag Dam. There are no upstream fish passage structures in place at the project; however, MRTC member agencies are seeking upstream fish passage at the project during the current relicensing period. The Licensee uses the existing log sluice as a bypass for stocked anadromous species, American eel, and resident species.

Gregg's Falls Dam is owned by the State of New Hampshire located at rkm 11.3 on the Piscataquog. The earthen-fill and concrete gravity dam is 414.5 meters long and 18.3 meters tall, impounding the 55.4-hectare reservoir known as Glen Lake. Glen Lake has a storage capacity of 3,650 acre-feet. The powerhouse contains two turbines with an installed capacity of 3.48 MW. A license exemption was issued for the project in 1983. Project ownership has changed hands since the original issuance, and the project is now operated by Eagle Creek Renewable Energy, LLC on lease from the State. The project has downstream passage installed for Atlantic salmon.

The third dam on the Piscataquog River is the Hadley Falls Project located at the western end of Glen Lake. The dam is 6.1 meters tall and approximately 91.4 meters in length including a 53.6-meter-long spillway that impounds a 9.7-hectare reservoir. The project is owned by the NH Department of Environmental Services and was operated by Algonquin Power & Utilities Corp with an authorized capacity of 0.25 MW under a license exemption that was issued in 1982. The run-of-river project no longer operates and is in a state of disrepair making it a candidate for decommissioning and removal.

4.1.6.1 Agencies with regulatory authority:

The State of New Hampshire has legal authorities regarding dams and fish passage and the U. S. Fish and Wildlife Service and National Marine Fisheries Service have authority through the Federal Power Act and through FERC for the for licensed hydropower dam/projects.

4.1.6.2 Goal/Target:

Achieve goals and objectives defined in the MRTC CP (2021). An annual minimum run of 20,300 shad is the target for this tributary (Table 2).

4.1.6.3 Progress:

Fish passage improvements are under discussion at Kelley's Falls as part of the relicensing process. The USFWS has reached an agreement with Eagle Creek regarding fish passage improvements at Gregg's Falls. The Hadley Falls Dam is under consideration for removal.

4.1.6.4 Timeline:

Ongoing.

4.1.7 Fish passage/habitat access Suncook River (NH)

There is a series of three dams in close proximity 0.8 km above the confluence with the Merrimack. The lowermost dam is the China Mill Project, a 1.7 MW facility not federally-regulated. The China Mill Dam is the first barrier on the Suncook River. The project does not require a federal license because it began operation prior to the Federal Water Power Act (FWPA, 1920), and is therefore non-jurisdictional under the current FPA. The dam impounds the river and diverts water through a 365.8-meter-long power canal less than a kilometer upstream of the river mouth. The dam is roughly 46 meters in length and is a complete barrier to fish passage.

The other two dams comprise the Webster-Pembroke Project (P-3185). At the upstream end of the project, the Webster Dam forms the Suncook River Reservoir. The reservoir has a surface area of 10.5 hectares and a volume of 147 acre-feet. The partially removed, stone-masonry Pembroke Dam, located on the bypass reach about 549 meters downstream, receives the minimum flow release and spill from the Webster Dam. The run-of-river project was issued a license exemption in 1983 with an authorized capacity of 2.75 MW. There are no fish passage facilities at the project.

The Suncook River watershed is a priority because of the considerable amount of lentic spawning habitat in the river corridor. Although the non-jurisdictional status of the China Mill Project limits engagement, providing fish passage in the lower Suncook remains a priority.

4.1.7.1 Agencies with regulatory authority:
The State of New Hampshire has legal authorities regarding dams and fish passage and the U. S. Fish and Wildlife Service and National Marine Fisheries Service have authority through the Federal Power Act and through FERC for the for licensed hydropower dam/projects.

4.1.7.2 Goal/Target:
Provide upstream and downstream passage at the first three dams on the Suncook River. An annual minimum run of 11,605 shad is the target for this tributary (Table 2).

4.1.7.3 Progress:
Partial removal of the Pembroke Dam was an important step toward making the Suncook River accessible to anadromous species, but access will not be achieved until fish passage is provided at the China Mill Dam.

4.1.7.4 Timeline:
Ongoing.

4.1.8 Fish passage/habitat access Soucook River (NH)
The Soucook River flows 39.6 km south from the confluence of Bumfagen Brook and Gues Meadow Brook in Loudon, NH to the Merrimack at rkm 138.1 downstream from the Garvin's Falls Dam. In addition to the Soucook mainstem, over 230.1 km of tributaries drain the 23,569-hectare watershed. There are 21 lakes and ponds in the watershed with a total surface area of 297.8 hectares (734 acres). With no barriers present until rkm 30.9, the Soucook River is relatively free flowing compared to other rivers in the Merrimack basin, with only a few small dams in the upper watershed. While a smaller river, some reaches of the mainstem are suitable for blueback herring and American shad, but, with the exception of Fox Pond and Rocky Pond in the upper watershed, few contiguous lakes or impoundments offer suitable spawning habitat for alewife. Fish passage improvements made at the upper mainstem Merrimack dams (e.g., Hooksett Dam) will provide access to the Soucook watershed.

4.1.8.1 Agencies with regulatory authority:

The State of New Hampshire has legal authorities regarding dams and fish passage and the U. S. Fish and Wildlife Service and National Marine Fisheries Service have authority through the Federal Power Act and through FERC for the for licensed hydropower dam/projects.

4.1.8.2 Goal/Target:

Provide access to suitable habitat upstream of the Loudon Village Dam. An annual minimum run of 6,397 shad is the target for this tributary (Table 2).

4.1.8.3 Progress:

The Loudon Village Dam is not a hydropower project. Fish passage construction at this site will require outside sources of funding.

4.1.8.4 Timeline:

Ongoing.

4.1.9 Fish passage/habitat access Contoocook River (NH)

Originating from the combined outlet of Mountain Brook Reservoir, Pool Pond, and Contoocook Lake in Jaffrey, NH, the Contoocook River flows 119.1 km northeast to the Merrimack at rkm 161.4 in Penacook, NH. There are over 30 dams on the Contoocook mainstem, including 11 hydropower dams. The first three dams on the Contoocook River support hydropower generation facilities. All three projects are operated by Briar Hydro Associates and owned by Essex Hydro. These projects operate in a run-of-river mode but have a license condition to maintain a minimum flow of 338 cfs. The licensing process began in 2019. None of these dams have upstream fish passage structures for anadromous fish (Penacook Upper Falls Dam has an eel trap and lift).

The first dam on the Contoocook River, Penacook Lower Falls Dam, is located 0.5 kilometers upstream from the Merrimack. The dam is of recent construction compared to others in the Merrimack watershed, with the hydropower facility starting operation in 1983. The project, operated as a run-of-river facility, consists of approximately 213.4-meter-long dam with spillways at each end and a powerhouse at the downstream end of the north shore. The dam impounds a reservoir with a surface area of 3.4 hectares and a 54-acre-foot storage capacity. The authorized capacity of the project is 4.11 MW produced by a Kaplan turbine. At the time of the original license in 1982, upstream fish passage facilities were not required at the project because of numerous downstream dams without fish passage. A modified gate next to the project intake is operated for downstream passage of stocked anadromous fish and American eels.

The original license includes a provision for constructing fish passage structures within three years of the first passage at the next downstream dam – which was Sewall's Falls Dam at the time of licensing – now Garvin's Falls. Each mainstem dam below the Penacook Lower Falls Project will have fish passage facilities within the next decade. The installation of upstream fish passage is an important consideration for the new license issued for this project.

The Penacook Upper Falls Project is the second dam on the Contoocook and is 0.8 kilometers upstream from Penacook Lower Falls. The dam supports a power generation facility that came online in December 1986. The dam is 57 meters long, 4.7 meters tall impounding a 4.5-hectare reservoir with little storage capacity. A Kaplan turbine operates in the powerhouse at the east end of the dam, with an installed capacity of 2.8 MW. Like Penacook Lower Falls, fish passage was not required at the time of construction. However, a condition required fish passage facilities to be installed within one year of the completion of fish passage facilities at all downstream dams.

The installation of upstream fish passage is a necessary condition for the new license (the current license expires in 2024).

Less than a kilometer upstream from Penacook Upper Falls Dam, the Contoocook bifurcates into a shallow and wide main river corridor to the north and the project tailrace to the south. The two watercourses reconnect about a kilometer and a half further upstream. The Rolfe Canal Project, which received an original license in 1984, includes structures on both watercourses. Water is diverted into Rolfe Canal by the 91.4-meter-long, 3-meter-high York Dam. A 1,219-meter-long bypass reach extends below the dam with a license-required minimum flow of 100 cfs. The dam creates a reservoir with a surface area of around 20.2 hectares. The Rolfe Canal headgate structure is 213.4 meters from the bifurcation in the impoundment. Another 914 meters downstream from the headgates is a 39.6-meter-long, 5.2-meter-high granite block dam that feeds a 274.3-meter-long penstock leading to the powerhouse with a Kaplan turbine rated at 4.28 MW. The remainder of the Rolfe Canal has a minimum flow of 5 cfs that passes over the Briar Pipe dam and around the Briar Pipe apartments before discharging into the tailrace of the powerhouse.

As with the two Penacook Falls projects, fish passage facilities were not required initially due to lack of passage at downstream dams with the same provisions at the Penacook projects. Because the Rolfe Canal and Penacook projects have the same licensee (Briar-Hydro Associates) and owner (Essex Hydro), the FERC ordered these projects undergo licensing on the same timeline. Installing fish passage on these three projects is an important for meeting management goals in the watershed. The current license is set to expire on November 30, 2024.

4.1.9.1 Agencies with regulatory authority:

The State of New Hampshire has legal authorities regarding dams and fish passage and the USFWS and NMFS have authority through the Federal Power Act and through FERC for the for licensed hydropower dam/projects.

4.1.9.2 Goal/Target:

Provide upstream and downstream passage at the first three dams on the Contoocook River. An annual minimum run of 94,792 shad is the target for this tributary (Table 2)

4.1.9.3 Progress:

All three projects on the Contoocook River are currently undergoing FERC relicensing.

4.1.9.4 Timeline:

Ongoing.

4.2 Threat: Hydropower Facility Operations

4.2.1 Recommended Action:

There are currently 49 active hydroelectric projects comprising 57 developments (generating powerhouses) with a combined capacity of approximately 140 megawatts (MW) in the Merrimack River Watershed. Twenty-nine developments are exempt from licensing. Twenty-eight developments are operating with a license, ten of which will expire before 2030 (Figure 5). In New Hampshire and Massachusetts, two Licensees operate nearly 30% of the licensed hydroelectric projects: Central Rivers Power, LLC (CRP) and Eagle Creek Renewable Energy, LLC (a subsidiary of Ontario Power Generation). Other Licensees operating multiple dams in the watershed include Green Mountain Power Corporation, the City of Nashua, and Essex Hydro Associates, LLC. All hydropower dams in the Merrimack that have shad passage or are expected to in the near-term operate in run of river, rather than peaking, operation. Some dams in the upper watershed, notably on the Pemigewasset River, occasionally operate in a peak mode however the Merrimack almost always has a dampened but natural hydrograph. Apart from up and downstream passage issues discussed above, regulatory agencies should focus on impoundment management, minimum flow levels, and thermal effects from hydropower facilities.

4.2.2 Agencies with Regulatory Authority:

The States have legal authorities regarding dams and hydropower operation through FERC, Water Quality Certification (401) and Coastal Zone Management Act, as applies. The U. S. Fish and Wildlife Service and National Marine Fisheries Service have authority through the Federal Power Act and the Fish and Wildlife Coordination Act.

4.2.3 Goal/Target:

The state and federal agencies will seek to develop and implement measures to reduce or mitigate any documented impacts of water use (e.g., thermal degradation of habitat) on shad spawning and nursery habitat based upon available information.

4.2.4 Progress:

The FERC relicensing process is underway for the Pawtucket Falls Project (P-2790) and no significant impacts to American shad outside of passage have been discovered or discussed. Six other projects targeted by the MRTC are due for relicensing in the next decade and should be examined for any potential operation

4.2.5 Timeline:

Ongoing.

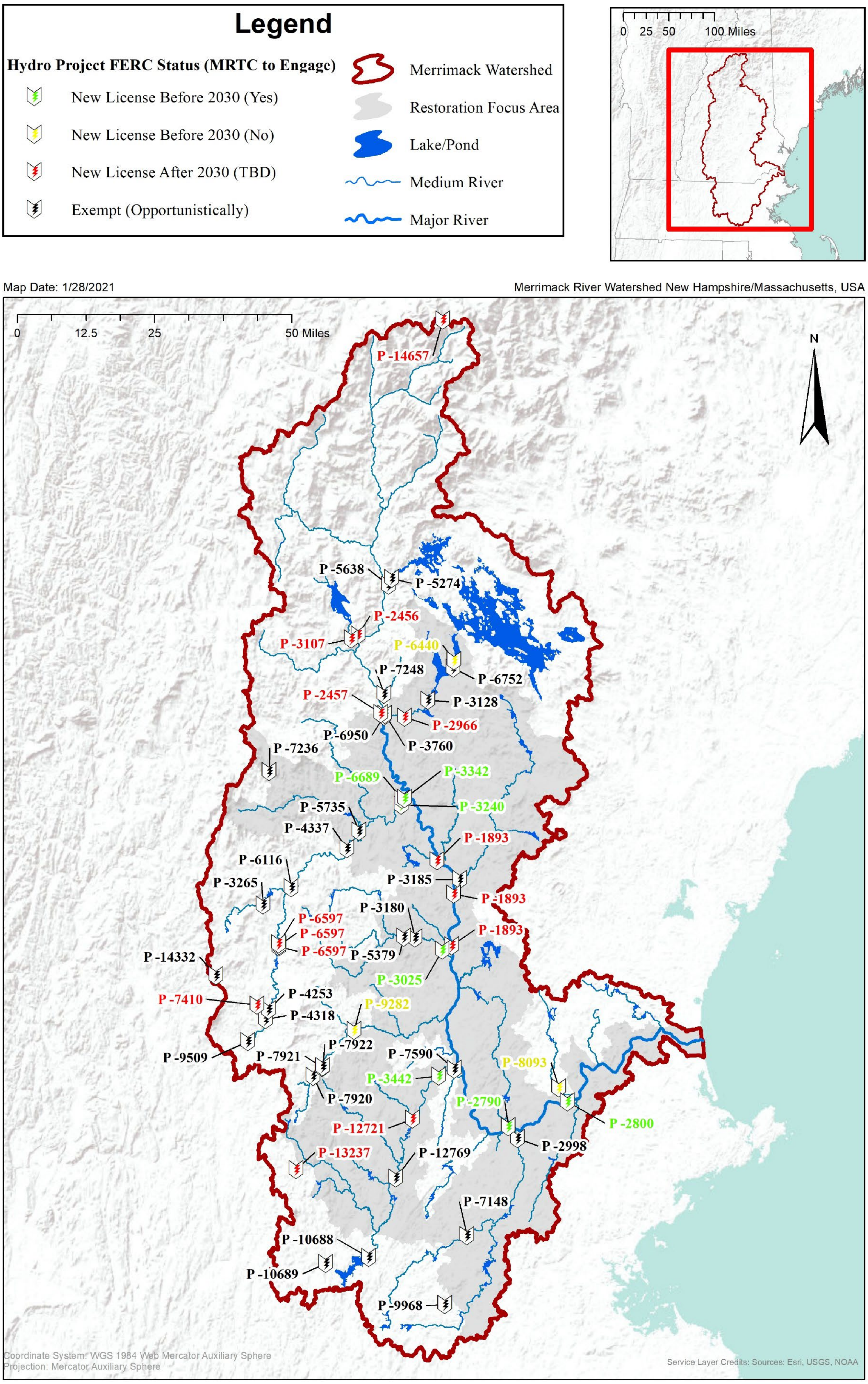

Figure 2. License Status and Distribution of Hydroelectric Projects in the Merrimack River Watershed

4.3 Threat: Water Withdrawal

4.3.1 Recommended Action:

An inventory and assessment of all permitted water withdrawals from the mainstem and targeted tributary shad habitat should be conducted using state agency permit data. At this time, there are water withdrawals for cooling water intake structures permitted by appropriate state and or federal agencies from the mainstem river. The only known large scale withdrawal permit is for the Merrimack Station, in Bow, NH (coal). While other large withdrawal permits have not been discovered, many smaller scale withdrawals are permitted and could have cumulative impacts at low flows. Information on Water Diversion Permits can be found on individual agency websites (e.g., NHDES).

Water withdrawals also occur in tributaries and should also be reviewed for potential impacts to habitat. Details of the type and extent of water withdrawal and subsequent discharge for these plants and others that remain to be collectively examined should be reviewed for potential impacts to American Shad habitat and potential population impacts. Considering climate change and associated changes in precipitation (i.e., timing, magnitude), evapotranspiration, and water withdrawals should be examined, and or managed more closely.

Measures to either prevent or significantly reduce entrainment of eggs, early life stages and juveniles should be considered for commercial river water users.

4.3.2 Agencies with regulatory authority:

Regulatory authority for the withdrawal of water is under State authorities and/or legislation and in some instances the Environmental Protection Agency.

4.3.3 Goal/Target:

The state and federal agencies will seek to develop and implement measures to reduce documented impacts of water withdrawals on early life stages and outmigrants (e.g., entrainment and/or impingement) through available regulatory or other mechanisms.

4.3.4 Progress:

None.

4.3.5 Timeline:

Monitoring of permit reports, permitting and other regulatory oversight by the states and federal agencies as applicable is ongoing.

4.4 Threat: Thermal Discharge

4.4.1 Recommended Action:

An inventory and assessment of all permitted thermal discharges from the mainstem and targeted tributary shad habitat should be conducted using state agency permit data as well as data from the Environmental Protection Agency (EPA) which has responsibility for the National Pollutant Discharge Elimination System (NPDES) and/or its delegation to approved State agencies, to varying levels. Permitted water withdrawals and discharge for cooling water intake structures occur at the Merrimack Station, in Bow, NH (coal).

4.4.2 Agencies with regulatory authority:

The Commonwealth of Massachusetts and the State of New Hampshire have not been delegated authority and work with the EPA to issue NPDES permits.

4.4.3 Goal/Target:

Goals and targets vary among regulatory agencies. A NPDES permit will generally specify an acceptable level of a pollutant or pollutant parameter in a discharge (e.g., water temperature). The permittee may choose which technologies to use to achieve that level. Some permits, however, do contain certain generic 'best management practices'. NPDES permits make sure that a state's mandatory standards for clean water and the federal minimums are being met.

4.4.4 Progress:

Industrial, municipal, and other facilities must obtain permits if their discharges go directly to surface waters since passage of this law in 1972. An inventory of NPDES permitted thermal discharges, remains to be considered as a management task by the fishery agencies relative to American shad and river herring habitat in this basin. The EPA maintains a national website of NPDES permits (https://www.epa.gov/npdes-permits).

4.4.5 Timeline:

The Clean Water Act limits the length of NPDES permits to five years. NPDES permits can be renewed (reissued) at any time after the permit holder applies. In addition, NPDES permits can be administratively extended if the facility reapplies more than 180 days before the permit expires, and EPA or the state regulatory agency, which ever issued the original permit, agrees to extend the permit.

4.5 Threat: Water Quality

4.5.1 Recommended Action:

State and federal agencies should regularly assess water quality monitoring data to ensure water quality does not become impaired and to support recommendations on proposed activities that may affect water quality. Urban runoff, combined sewer overflows (CSOs), dam impacts, heated discharge from power plants, and historical sediment contaminants affect overall water quality in the Merrimack River. Contemporary reports indicate pathogens are the major water quality concern for the river, coming primarily from the combined effects of CSOs and urban runoff. CSOs remain in operation in six communities across the Merrimack watershed; Haverhill, Lawrence, Lowell, and Fitchburg (Nashua River) in Massachusetts, and Nashua, and Manchester in New Hampshire. Some historical pollutants are still a concern today with sediments containing high levels of mercury and other industrial pollutants. Atmospheric deposition of toxics is also a concern, and fish consumption advisories are in effect for much of the lower watershed as a result (Meek and Kennedy 2010). The majority of lotic waters in the historical range of the diadromous species in the Merrimack watershed are Class B or C (USACE 2006).

Physical, chemical, and biological monitoring of water quality should be adequately supported, primarily through existing State agency authorities, by designated agencies, to ensure sufficient temporal and spatial coverage, sampling design, and sampling intensity. Classification standards and data between New Hampshire and Massachusetts should be coordinated and shared along with necessary monitoring measures. Communication between professional fishery agency staff and water quality staff should continue to be strengthened.

4.5.2 Agencies with Regulatory Authority:

The Clean Water Act of 1972 is the foundation for surface water quality protection in the United States. Sections of this Act provide direction on standards to the states. The states of New Hampshire and Massachusetts maintain surface water monitoring programs.

4.5.3 Goal/Target:

Varies by authorizing agency but standards cannot be weaker than federal identified designations. The State of New Hampshire designates the mainstem as Class B. In Massachusetts, the Merrimack River is designated a Class B (inland) water from the NH border to Haverhill at Creek Brook, while the 35.4-km tidal section from Haverhill to the ocean is designated a Class SB (coastal and marine) water. Standards associated with these designations are available on respective state agency (i.e., DEP) web sites.

4.5.4 Progress:

Water quality on the mainstem and tributaries are monitored directly by respective state agencies, federal agencies (e.g., U. S. Geological Survey) non-profit watershed groups, power companies and others. State agency water quality monitoring web sites include: Massachusetts https://www.mass.gov/guides/water-quality-monitoring and for New Hampshire https://www.des.nh.gov/water/rivers-and-lakes/river-and-lake-monitoring. Monitoring data collected by the Merrimack River Watershed Council can be found at https://merrimack.org/science/water-quality-monitoring-program/.

4.5.5 Timeline:

State agency monitoring for standard assessments is ongoing as are other programs including USGS gauge stations with water quality instrumentation.

4.6 Threat: Land Use

4.6.1 Recommended Action:

State, federal, and local governments should continue to support existing protective measures to address poor land use practices that may affect shad habitat either directly or indirectly. These measures may occur at multiple levels of government as noted. Riparian zone vegetation protection and bank protection are examples of concerns that insufficient land use (e.g., agriculture, residential, commercial uses) regulation or enforcement may result in degraded habitat and impact water quality. In some jurisdictions, local Conservation Commissions can enact or expand buffer or "no-disturb zones" adjacent to riverbanks and other wetland resources (e.g., Commonwealth of Massachusetts River Protection Act (1996) and Wetland Protection Act (2014)). States should work in collaboration to develop and support consistent regulations and enforcement measures.

4.6.2 Agencies with Regulatory Authority:

Land use regulatory authority may reside at the local, state and/or federal government level.

4.6.3 Goal/Target:

The codification of rules and adequate enforcement to provide riparian vegetation protection and bank protection/stability and address other potential negatively impacting land use activities will help protect aquatic habitats.

4.6.4 Progress:
Status of existing state and local government rules are not summarized here. Examples of measures that have improved protections for land in Massachusetts include local Conservation Commissions and DEP use of the Rivers Protection Act and Wetlands Protection Act to protect riparian and wetland habitats.

4.6.5 Timeline
Ongoing.

4.7 Threat: Climate Change

4.7.1 Recommended Action:
State and federal agencies should identify data of value in the detection and monitoring for climate change effects on shad habitat and associated shad population dynamics or other responses (e.g., run timing) and whether those changes can successfully be adapted to by those populations. Sources of data (fishway counts, tagging studies) should be evaluated for ongoing value and to help determine whether any modifications may be necessary. Data that would be of value in this effort and are not being regularly collected (e.g., tagging studies) should be identified and developed by the state and federal agencies as determined necessary. In freshwater, the timing, frequency, and magnitude of river discharge should be evaluated at regular intervals (spring run-off, droughts, pulse events) and related to fishery data including, but not limited to, fishway operational schedules, fish movement and behavior data, spawning success, habitat suitability, and juvenile recruitment and outmigration. In the near-shore and marine environment, monitoring, and studies to assess shifts in conditions and habitats (e.g., water temperatures, currents, food sources, predators) should occur at regular intervals. The ASMFC 2020 American Shad Benchmark Stock Assessment and Peer Review provides modeling analyses that shows reduced growth rates and maximum size with increase sea surface temperatures (ASMFC, 2020). Additional work to understand climate change effects in freshwater and estuarine habitats on life history events and/or population level effects should also be examined.

Efforts to improve climate change resiliency should be pursued. Strategies should be developed and implemented to reduce stressors associated with climate change including drought, floods and increasing temperatures. Disaster management, urban planning, and river restoration are some strategies that can help mitigate the impacts of climate change.

4.7.2 Agencies with regulatory authority:
Regulatory authorities for climate change are not clearly in place currently. However, both state and federal resources agencies have recognized the need to incorporate the reality of climate change as physical scientists work to develop future scenarios on effects (e.g., temperature regimes, river discharge, rainfall, snowpack) that may, to varying degrees, affect species occurrence, population viability, and habitat quantity and quality.

4.7.3 Goal/Target:
It will be desirable to understand any trends in population metrics or other parameters, and any linked climate change drivers that may affect population structure, distribution, abundance, and viability. The resource agencies will seek to improve climate change resiliency and reduce other anthropogenic impacts that may exacerbate these impacts. Ultimately the agencies will seek to ensure the full restoration and long-term sustainability of this population given it is not at the extreme end of its distribution range.

4.7.4 Progress:
New or updated federal and state resource plans are required to include climate change.

4.7.5 Timeline:
Ongoing.

4.8 Threat: Invasive Species

4.8.1 Recommended Action:
Invasive aquatic plant species are increasing in occurrences and expanding their range within the Merrimack River watershed, impacting native aquatic species and habitats. Variable milfoil and Asian clam are both found in reaches throughout the Merrimack (Nedeau 2017; NH DES 2020) while variable milfoil, Eurasian milfoil, fanwort, water chestnut, European naiad, and curly leaf pondweed have been identified in the Nashua (NH DES 2020). and water chestnut and Eurasian milfoil are also present in the Concord watershed (CISMA-SUASCO 2022). State agencies and NGOs have been working to monitor the locations and extent of these invasive plants and work with partners on mitigation measures including pulling plants before they go to seed. This highly labor-intensive approach includes federal agency assistance and NGOs. Other invasive organisms not yet present (documented) of potential concern include range expansions of Asian mussel species (e.g., zebra mussel) and other organisms that have demonstrated detrimental impacts when introduced in other aquatic systems (e.g., blue catfish, snakehead).

4.8.2 Agencies with regulatory authority:
State agencies have developed statutes that forbid the importation of known invasive plants and many other non-natives species, with associated fines. Similarly, there are regulations requiring boaters clean all equipment, including fishing gear, live wells, boats and trailers, or be subject to fines. Importation bans for specific species occur at the federal and state level.

4.8.3 Goal/Target:
Measures that can help prevent either the direct or indirect introduction of invasive species should continue to focus on outreach and education. The development and responsible implementation of safe and effective measures to reduce the introduction, rate of spread, and establishment of invasive species should continue to be explored and evaluated.

4.8.4 Progress:
State agencies have increased efforts on education and outreach with boaters and anglers. Partnerships to manage certain areas (pulling of plants) have been developing. Aquatic Nuisance Species funding at the federal level has been increasing in recent years due to the extent of this problem. These funds are used primarily by state agencies and have increased monitoring, assessment, and planning activities. State agencies are also participating in the permitting process to ensure herbicide treatments of aquatic invasive plants do not have negative impacts on spawning and nursery habitat for diadromous fish, including shad.

4.8.5 Timeline:
Ongoing.

5 HABITAT RESTORATION PROGRAM

5.1 Barrier removal and fish passage program

The MRTC maintains a focused barrier removal and fish passage program that is executed by the member agencies depending on jurisdiction. In addition to the seven dams highlighted in Section 4.1, the MRTC and individual member agencies are actively involved in passage improvements and dam removals throughout the watershed.

In 2017, significant restoration work occurred on the Shawsheen River, which enters the Merrimack below the Essex Dam in Lawrence at rkm 44.9. In that year both the Marland Place Dam (ca. 1700s) and the Balmoral Dam (ca. 1920s) were removed, restoring access to miles of habitat inaccessible for centuries. The Ballardvale Dam remains as the last upstream barrier. Because this dam is in the lower half of the watershed, removing or modifying it would provide access to a substantial amount of historical habitat that would greatly benefit river herring and provide some habitat for American shad. The MRTC is also involved in relicensing activities on dams in non-target watersheds within shad's historical extent in the watershed, like the Winnipesaukee River. The agencies and partners will continue work on restoring shad habitat and habitat accessibility, including barrier removal, throughout the greater Merrimack Watershed.

A related task for habitat restoration is the calculation of fishway capacities for existing fishways in the watershed (*see* Barrier Inventory). Currently, the capacities for the existing facilities at the Essex and Pawtucket Dams and those needed to meet the goals for the Barrier to Migration Recommended Action have been calculated. To meet long term restoration goals USFWS and NMFS engineers should calculate capacity for the remaining existing structures in the watershed.

5.2 Hatchery product supplementation and adult transfer programs

Since 2009 the MRTC has maintained an active hatchery supplementation program that has been combined with the transfer of gravid fish from the Essex Dam to upriver mainstem spawning habitats. These efforts are spearheaded by USFWS and NHFGD.

Table 9. Annual shad stocking and transferred numbers, Merrimack River Watershed. Gravid adults collected at the Essex Dam; eggs collected, hatched, and cultured at the Nashua National Fish Hatchery.

Year	Total American Shad Stocked (Larvae)	Total American Shad Transferred (Adults)
2008	-	537
2009	1,299,369	1,051
2010	1,002,360	1,244
2011	2,855,947	966
2012	2,081,711	1,573
2013	4,634,166	1,868
2014	7,828,918	1,970
2015	2,296,061	2,055
2016	1,523,218	2,842
2017	4,832,379	3,235
2018	288,018	1,887
2019	594,597	2,212
2020	0[5]	250
2021		2,811
Grand Total	**29,236,744**	**24,501**

[5] Zero shad fry were stocked in 2020 due to the COVID-19 pandemic. USFWS hatchery staff were not permitted to cross state lines to collect brood stock from Essex Dam

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7 APPENDIX 1: BARRIERS TO HISTORICAL SHAD HABITAT IN THE MERRIMACK RIVER

Dam Name	Purpose	Height (m)	Width (m)	Length (m)	River	State	Town	Distance upstream (km)	Lat	Lon	Upstream Passage
Essex	Hydroelectric	10.0	-	274.3	Merrimack River	MA	Lawrence	48.0	42.7006	-71.1665	Lift
Pawtucket	Hydroelectric	4.6	-	333.0	Merrimack River	MA	Lowell	70.0	42.65257	-71.3224	Lift Vertical Slot
Amoskeag	Hydroelectric	8.8	-	216.4	Merrimack River	NH	Manchester	119.0	43.0021	-71.4719	Half Ice Harbor
Hooksett	Hydroelectric	14.0	-	179.8	Merrimack River	NH	Hooksett	132.0	43.1014	-71.4666	No
Garvin's Falls	Hydroelectric	5.5	-	167.6	Merrimack River	NH	Concord	140.0	43.1655	-71.51	No
Middlesex Falls	None - Breached	-	-	-	Concord River	MA	Lowell	0.6	42.64271	-71.3041	Breach
Centennial Island	Hydroelectric	< 3.0	-	70.0	Concord River	MA	Lowell	2.2	42.6293	-71.2984	Denil
Talbot Mills	None - Relic	3.1	-	38.7	Concord River	MA	North Billerica	7.0	42.59185	-71.2839	No
Assabet Dam	Hydroelectric	4.9	-	128.0	Assabet River (Concord)	MA	Acton	10.5	42.4407	-71.4316	No
Central Street Dam	None known	-	-	-	Sudbury River (Concord)	MA	Framingham	24.1	42.32492	-71.4015	No
Jackson Mills	Hydroelectric	10.1	-	54.9	Nashua River	NH	Nashua	2.0	42.7635	-71.4645	Denil
Mine Falls	Hydroelectric	-	-	-	Nashua River	NH	Nashua	6.4	42.7503	-71.5055	Lift
Pepperell	Hydroelectric	7.2	-	76.5	Nashua River	MA	Pepperell	14.5	42.66694	-71.575	No
Squannacook River Dam	None known	-	-	-	Squannacook River (Nashua)	MA	Groton	0.0	42.60262	-71.6278	No
Ice House Power	Hydroelectric	3.7	-	57.9	Nashua River	MA	Ayer	34.2	42.5528	-71.6189	No
McLane	None - Relic	5.5	-	54.9	Souhegan River	NH	Milford	22.5	42.83606	-71.6455	No
Goldman	None - Relic	-	-	52.7	Souhegan River	NH	Milford	22.9	42.83677	-71.6491	No
Pine Valley	Hydroelectric	7.0	-	61.0	Souhegan River	NH	Wilton	32.2	42.8389	-71.7285	No
Kelley's Falls	Hydroelectric	9.4	-	153.3	Piscataquog River	NH	Manchester	3.2	42.9935	-71.4962	No
Gregg's Falls	Hydroelectric	18.3	-	414.5	Piscataquog River	NH	Goffstown	11.3	43.0169	-71.5686	No
Hadley Falls	Hydroelectric	6.1	-	91.4	Piscataquog River	NH	Goffstown	13.8	43.0185	-71.5979	No
China Mill	Hydroelectric	-	-	46.0	Suncook River	NH	Pembroke	0.7	43.13009	-71.4563	No
Webster Pembroke	Hydroelectric	-	-	-	Suncook River	NH	Suncook	1.4	43.12967	-71.4506	No
Soucook River	None known	-	-	-	Soucook River	NH	Loudon	30.9	43.28646	-71.4685	No
Penacook Lower Falls	Hydroelectric	-	-	213.4	Contoocook River	NH	Boscawen	0.5	43.2852	-71.5952	No

Dam Name	Purpose	Height (m)	Width (m)	Length (m)	River	State	Town	Distance upstream (km)	Lat	Lon	Upstream Passage
Penacook Upper Falls	Hydroelectric	4.7	-	57.0	Contoocook River	NH	Concord	1.3	43.2836	-71.6022	No
Rolfe Canal	Hydroelectric	3.0	-	91.4	Contoocook River	NH	Concord	3.2	43.2725	-71.6045	No
Hopkinton	Hydroelectric	3.4	-	76.2	Contoocook River	NH	Hopkinton	20.5	43.2223	-71.716	No
Hoague-Sprague	Hydroelectric	4.3	-	91.4	Contoocook River	NH	Hopkinton	29.4	43.1904	-71.7481	No
Hopkinton Flood Control Dam	Flood control	23.2	-	240.8	Contoocook River	NH	Hopkinton	29.5	43.18857	-71.7479	No
Franklin Falls	Hydroelectric	-	-	-	Winnipesaukee River	NH	Franklin	0.8	43.4428	-71.6498	No
Stevens Mill Dam	Hydroelectric	6.7	-	24.4	Winnipesaukee River	NH	Franklin	2.3	43.4462	-71.6444	No
Clement Dam	Hydroelectric	5.0	-	36.6	Winnipesaukee River	NH	Tilton	8.3	43.4407	-71.5958	No
Lochmere Dam	Hydroelectric	3.4	-	48.8	Winnipesaukee River	NH	Tilton	16.5	43.4731	-71.534	No
Eastman Falls	Hydroelectric	11.3	-	103.9	Pemigewasset River	NH	Franklin	1.6	43.44757	-71.6585	No
Franklin Falls	Flood control	42.7	-	530.4	Pemigewasset River	NH	Franklin	4.6	43.46757	-71.6609	No
Ayers Island	Hydroelectric	21.9	-	213.1	Pemigewasset River	NH	Bristol	24.8	43.59816	-71.7184	No

Dam Name	Purpose	Owner	Height (m)	Width (m)	Length (m)	Impoundment size (ha)	Water Capacity (acre feet)	River	State	Town	Distance upstream (km)	Lat	Lon	US Passage	FP Capacity	FP Effectiveness	DS Passage	Source
Essex	Hydroelectric	Central Rivers Power	10.0	-	274.3	26.1	19,900	Merrimack River	MA	Lawrence	48.0	42.7006	-71.1665	Lift	Limited[1]	Unknown	Surface bypass	MassGIS
Pawtucket	Hydroelectric	Central Rivers Power	4.6	-	333.0	291.4	3,960	Merrimack River	MA	Lowell	70.0	42.65257	-71.3224	Lift	Limited[2]	30.40%	Surface bypass	MassGIS
Pawtucket														Vertical Slot	Sufficient	75% (herring)		
Amoskeag	Hydroelectric	Central Rivers Power	8.8	-	216.4	193.4	-	Merrimack River	NH	Manchester	119.0	43.0021	-71.4719	Half Ice Harbor	Limited[3]	Poor[4]	Surface bypass	NH GRANIT
Hooksett	Hydroelectric	Central Rivers Power	14.0	-	179.8	163.9	-	Merrimack River	NH	Hooksett	132.0	43.1014	-71.4666	No	N/A	N/A	Surface bypass	NH GRANIT
Garvin's Falls	Hydroelectric	Central Rivers Power	5.5	-	167.6	259.0	-	Merrimack River	NH	Concord	140.0	43.1655	-71.51	No	N/A	N/A	Low level and surface bypass	NH GRANIT
Middlesex Falls	None - Breached	City of Lowell	-	-	-	-	-	Concord River	MA	Lowell	0.6	42.64271	-71.3041	Breach				MassGIS
Centennial Island	Hydroelectric	Centennial Island Hydroelec Co (MA)	< 3.0	-	70.0	-	-	Concord River	MA	Lowell	2.2	42.6293	-71.2984	Denil	Limited[5]	Poor	Surface bypass	MassGIS
Talbot Mills	None - Relic	Private	3.1	-	38.7	-	-	Concord River	MA	North Billerica	7.0	42.59185	-71.2839	No				MassGIS
Assabet Dam	Hydroelectric	Acton Hydro Electric (MA)	4.9	-	128.0	8.1	-	Assabet River (Concord)	MA	Acton	10.5	42.4407	-71.4316	No				MassGIS
Central Street Dam	None known	Private	-	-	-	-	-	Sudbury River (Concord)	MA	Framingham	24.1	42.32492	-71.4015	No				MassGIS
Jackson Mills	Hydroelectric	City Of Nashua , New Hampshire	10.1	-	54.9	16.0	-	Nashua River	NH	Nashua	2.0	42.7635	-71.4645	Denil	Limited[6]	Unknown	Surface bypass	NH GRANIT
Mine Falls	Hydroelectric	City Of Nashua , New Hampshire	-	-	-	97.9	450	Nashua River	NH	Nashua	6.4	42.7503	-71.5055	Lift	Limited	56%(herring) [7]	Surface bypass	NH GRANIT
Pepperell	Hydroelectric	Pepperell Hydro Company, LLC	7.2	-	76.5	119.0	-	Nashua River	MA	Pepperell	14.5	42.66694	-71.575	No			Surface bypass	MassGIS
Squannacook River Dam	None known	Town of Groton, MA	-	-	-	-	-	Squannacook River (Nashua)	MA	Groton	0.0	42.60262	-71.6278	No				MassGIS
Ice House Power	Hydroelectric	Ice House Partners, Inc.	3.7	-	57.9	55.4	-	Nashua River	MA	Ayer	34.2	42.5528	-71.6189	No			Surface bypass	MassGIS
McLane	None - Relic	Private	5.5	-	54.9	-	-	Souhegan River	NH	Milford	22.5	42.83606	-71.6455	No			Surface bypass	NH GRANIT
Goldman	None - Relic	Private	-	-	52.7	-	-	Souhegan River	NH	Milford	22.9	42.83677	-71.6491	No			Surface bypass	NH GRANIT
Pine Valley	Hydroelectric	PVC Commerical Center, LLC.	7.0	-	61.0	2.8	-	Souhegan River	NH	Wilton	32.2	42.8389	-71.7285	No			Surface bypass	NH GRANIT
Kelley's Falls	Hydroelectric	Kelley's Falls, LLC	9.4	-	153.3	52.2	1,350	Piscataquog River	NH	Manchester	3.2	42.9935	-71.4962	No			Surface bypass	NH GRANIT
Gregg's Falls	Hydroelectric	Eagle Creek Renewable Energy, LLC	18.3	-	414.5	55.4	3,650	Piscataquog River	NH	Goffstown	11.3	43.0169	-71.5686	No			Surface bypass	NH GRANIT
Hadley Falls	Hydroelectric	New Hampshire DES	6.1	-	91.4	9.7	-	Piscataquog River	NH	Goffsttown	13.8	43.0185	-71.5979	No			Surface bypass	NH GRANIT
China Mill	Hydroelectric	Essex Power Company	-	-	46.0	-	-	Suncook River	NH	Pembroke	0.7	43.13009	-71.4563	No				NH GRANIT
Webster Pembroke	Hydroelectric	Algonguin Power Income Fund	-	-	-	10.5	147	Suncook River	NH	Suncook	1.4	43.12967	-71.4506	No			Surface bypass	NH GRANIT
Soucook River	None known	Town of Loudon (NH)	-	-	-	-	-	Soucook River	NH	Loudon	30.9	43.28646	-71.4685	No				NH GRANIT
Penacook Lower Falls	Hydroelectric	Briar-Hydro Associates (MA)	-	-	213.4	3.4	54	Contoocook River	NH	Boscawen	0.5	43.2852	-71.5952	No			Surface bypass	NH GRANIT
Penacook Upper Falls	Hydroelectric	Briar-Hydro Associates (MA)	4.7	-	57.0	4.5	-	Contoocook River	NH	Concord	1.3	43.2836	-71.6022	No			Surface bypass	NH GRANIT
Rolfe Canal	Hydroelectric	Briar-Hydro Associates (MA)	3.0	-	91.4	20.2	-	Contoocook River	NH	Concord	3.2	43.2725	-71.6045	No			Surface bypass	NH GRANIT
Hopkinton	Hydroelectric	Hopkinton, Town Of (NH)	3.4	-	76.2	44.5	-	Contoocook River	NH	Hopkinton	20.5	43.2223	-71.716	No			Surface bypass	NH GRANIT
Hoague-Sprague	Hydroelectric	Green Mountain Power Corp (VT)	4.3	-	91.4	0.8	-	Contoocook River	NH	Hopkinton	29.4	43.1904	-71.7481	No				NH GRANIT
Hopkinton Flood Control Dam	Flood control	USACE	23.2	-	240.8	89.0	3,700	Contoocook River	NH	Hopkinton	29.5	43.18857	-71.7479	No				NH GRANIT
Franklin Falls	Hydroelectric	Franklin Falls Hydro Elec Co (NH)	-	-	-	-	-	Winnipesaukee River	NH	Franklin	0.8	43.4428	-71.6498	No			Surface bypass	NH GRANIT
Stevens Mill Dam	Hydroelectric	Franklin Power, LLC.	6.7	-	24.4	0.4	-	Winnipesaukee River	NH	Franklin	2.3	43.4462	-71.6444	No			surface and mid-level bypass	NH GRANIT
Clement Dam	Hydroelectric	Clement Dam Hydroelectric,LLC	5.0	-	36.6	-	-	Winnipesaukee River	NH	Tilton	8.3	43.4407	-71.5958	No			Surface bypass	NH GRANIT
Lochmere Dam	Hydroelectric	New Hampshire Water Resources (NH)	3.4	-	48.8	1725.6	-	Winnipesaukee River	NH	Tilton	16.5	43.4731	-71.534	No			Surface bypass	NH GRANIT
Eastman Falls	Hydroelectric	Hse Hydro Nh Eastman Falls, Llc	11.3	-	103.9	-	-	Pemigewasset River	NH	Franklin	1.6	43.44757	-71.6585	No			Surface bypass	NH GRANIT
Franklin Falls	Flood control	USACE	42.7	-	530.4	180.0	2,800	Pemigewasset River	NH	Franklin	4.6	43.46757	-71.6609	No			Surface bypass	NH GRANIT
Ayers Island	Hydroelectric	Hse Hydro Nh Ayers Island, Llc	21.9	-	213.1	242.8	10,000	Pemigewasset River	NH	Bristol	24.8	43.59816	-71.7184	No			Surface bypass	NH GRANIT

Footnotes

¹ Capacity is limited by the size of the fish lift and operational limitations, especially in low flow years.

² Capacity is limited by poor trap efficiency at the lift and zone of passage conditions in the bypass reach.

³ Calculations should be performed but capacity may be limited by the internal hydraulics of the existing fishway and attraction water system deficiencies.

⁴ FP effectiveness is is unkown but assumed to be poor because FWS criteria are not being met within the fishway for submergence depth and drop per pool.

⁵ Capacity is limited due to this fishway not being constructed as designed per FWS site inspection report.

⁶ Capacity is limited by a poor design that results in a low amount of flow coming out of each entrance, therefore not meeting FWS criteria for attraction flow and submergence depth.

⁷ Upstream studies for river herring were conducted and found to be 56% effective. Given the hydraulics at the entrance (i.e., not meeting submergence depth criteria) and the small volume of water maintained within the fishway entrance channel and holding pool it is assumed that shad passage effectiveness would be less than 56%

NEW YORK STATE OF OPPORTUNITY | Department of Environmental Conservation

Sustainable Fishery Management Plan for New York River Herring Stocks

William W. Eakin
Cornell University in Cooperation with Hudson River Estuary Program

and

Gregg H. Kenney, Carol Hoffman
Division of Marine Resources

February 2022

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. The magnitude of the recreational fishery for river herring is unknown for most years. However, we have estimated recreational harvest from 2007-2020 using data obtained from our Cooperative Angler Program and a statewide creel survey conducted in 2007. Estimated recreational river herring harvest ranged from 85,249 fish in 2007 to 426,098 fish in 2016, with an average of 258,281 herring (~92,981 lbs.) from 2013-2020. To put estimated recreational harvest in context, run counts from Black Creek, a small tributary with approximately 1.8 km of available spawning habitat, averaged 324,698 alewives (~116,891 lbs.) annually during the same time period. Black Creek is just one of the 68 primary tributaries to the Hudson River.

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 15,136 pounds, peaking in 2002 at 20,346 pounds. Following regulation changes in 2013, reported commercial landings declined to roughly 40% (~6,000 lbs/year) of the average from 2000 through 2012.

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 increased steadily from 2000 peaking in 2014 and have been declining to present. Drift gill net effort declined from 2006 to 2010 and has remained relatively stable from 2010 to present. Fixed gill net effort in the lower river has decreased steadily since 2000 while CPUEs increased from 2010 peaking in 2014 followed by a slight decline from 2014 to present; however, recent CPUEs remain well above the mean CPUEs during the time period 2000 to 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. Mean length at age for both species across all ages has 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.

Total instantaneous mortality (Z) estimates derived from age and repeat spawning data have followed similar trends in most years. Mortality estimates for alewives declined from 2012 to 2014. In 2015 and 2016, age-based mortality estimates for female alewives increased dramatically while repeat spawn-based estimates continued to decline. This may be due to a large year class moving through the fishery resulting in over dispersion of older fish and was further compounded by fewer age three and age four fish observed in 2015-2016. Current mortality estimates have declined, returning to pre-2015 levels. Mortality estimates for blueback herring have declined or remained stable since 2012.

Since the previous version of this plan, we developed a total mortality threshold ($Z_{40\%}$) using a modified Thompson-Bell yield per recruit model following the methods described in the most recent American shad benchmark stock assessment (ASMFC 2020). For details on model structure see section 2.5 of the assessment. The resulting $Z_{40\%}$ thresholds are Z=1.26 and Z=1.19 for female alewife and blueback herring, respectively. The final three-year average mortality estimates were 0.55 and 0.67 for female alewife and blueback herring, respectively. Both Z values are below the $Z_{40\%}$ thresholds indicating that adult female mortality is sustainable for both species.

Young-of-year (YOY) production has been measured annually by beach seine since 1980. CPUE of alewife remained low through the late 1990s then increased erratically through 2010 and has remained relatively stable above the benchmark from 2011 to present. CPUE of young of year blueback herring has varied with a very slight downward trend since 1980. Over the past decade, YOY index values have fallen below the 25th percentile only twice for alewives and four times for blueback herring; however, the 2014 blueback 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.

<u>Proposed Fishery for the Hudson River and Tributaries</u>

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 (Eakin et al. 2017). We propose to continue to use the sustainability target for juvenile indices which is defined as three consecutive juvenile index values below the 25th percentile of the time series as well as the new total mortality thresholds developed for this plan which are Z = 1.26 and Z = 1.19 for adult female alewife and blueback herring, respectively. We will monitor, but not set targets for mean length, mean length at age and frequency of repeat spawning 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.

A summary of existing restrictions is 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.

<u>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</u>

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 (Eakin et al. 2017).

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). 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 an updated five-year SFMP for river herring in waters of New York State with additional sustainability targets and thresholds. 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 early 1900. Landings peaked in the early 1900s, again in the 1930s with the final peak in the early 1980s. Landings declined from the mid-1980s to the late 1990s. Since the late 1990s, landings have remained relatively stable with a slight decline in the most recent years. 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 Copper 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 to be installed within the next few years. 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 and Kahnle 2007; 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, Bronx, 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 efforts to understand river herring runs on Long Island since 1995.The 2018 estimated alewife population was 150,000, with 24 identified alewife runs (https://www.arcgis.com/home/webmap/viewer.html?webmap=e6ab78352f2e4076876380e7500567e9&extent=-73.3924,40.6352,-72.7036,40.9549) Several runs of alewives on Long Island had been known to 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 (https://www.arcgis.com/home/webmap/viewer.html?webmap=e6ab78352f2e4076876380e7500567e9&extent=-73.3924,40.6352,-72.7036,40.9549). 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 as well as alewife tagging. These efforts have been undertaken to understand the Long Island coastal streams and to improve the runs that exist there (https://seatuck.org/river-revival/).

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). There have been five years of re-stocking of the Bronx River. In 2021, 250 alewives from the Peconic River were restocked into the Bronx River. Monitoring of this run has recently been updated to include eDNA techniques.

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, Bronx, and Westchester County

Most streams on Long Island and in the Bronx and Westchester Counties 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 riverbed 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) was identified as a suitable location for side channel restoration and in 2018, the creation of a side channel was completed. The site previously consisted of an artificially created tidal embayment that is separated from the main river channel by dredge spoils. Tidal backwaters, such as those previously 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 has improved water quality, provide coarser-grained bed materials, and ultimately create more productive spawning, nursery, and foraging habitat for river herring.

Long Island, Bronx, 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 (Eakin et al. 2017), 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 thirteen locations (Canaan Lake, Brookhaven; Twin Ponds, Centerport; Argyle Lake, Babylon; Udall's Mill Pond, Saddle Rock; and Massapequa Creek, Massapequa; Penataquit Creek, Bay Shore; Grangebel Park, Riverhead; 182nd St Dam, Bronx River, Bronx; Upper Lake, Carmans River; Beaver Lake, Oyster Bay; Yaphank Creek, Wertheim National Wildlife Reserve; Mill Creek, Hubbard County Park; Edwards Avenue Dam, Riverhead); a box culvert modification at Alewife creek, Southampton; and dam removals at Harrison Pond in Smithtown; and at Sunken Meadow Sate Park . Additionally, a dam removal project is expected to begin in 2022 for the Woodhull Dam on Little River in Riverhead to provide additional spawning habitat once barriers have been mitigated. Barrier mitigation remains a priority for several environmental groups and local, state, and federal agencies.

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 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 2021, five states (Maine, New Hampshire, Massachusetts, New York, 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

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 34 fishers annually participates 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 continuing to work 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, 24 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. Since 2013, an average of 143 gill nets and 95 scap nets permits were sold annually. However, according to the required annual reports only 33% of the permitees actively fished during that same time period (Table 3), 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 3).

Commercial Landings and License Reporting

Recorded landings of river herring in New York State began in the early 1900s (Figure 4). 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. 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.

Several peaks in landings occur during the time series (Figure 4). 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.

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 15,136 pounds, peaking in 2002 at 20,346 pounds. Post regulation change in 2013, landings declined to roughly 40% 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. From 2016 to present, an average of 132 pounds of river herring have been reported as discards.

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 fishers. These fishers 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 increased steadily from 2000 peaking in 2014 and have been declining to present. Drift gill net effort declined from 2006 to 2010 and has remained relatively stable from 2010 to present. Due to the opportunistic nature of the upriver fishery (fishers 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 a 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 prohibited in tributaries. Scap net CPUEs declined from 2000 to 2007 but 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, peaking in 2014. 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, lower river fixed gill net 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 as described in the above section.

Data are obtained by observers onboard commercial fishing vessels. Staff 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 185 trips targeting river herring (lower river: 149; mid and upper river: 36) (Table 4). Prior to 2012, these trips were sporadic and sample sizes were low, from zero to 11 trips per year. Since 2012, observer trips have become more consistent but because the number of trips is still relatively low, 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, $p < 0.0001$). 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 further. 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 5). Annual observed landings ranged from 44 to 3,129 fish, with alewives observed more often than blueback herring. The sex ratio of alewives was nearly equal (~ 50:50) in most 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. Power analysis was conducted to determine the minimum sample size required to detect a significant change of 5 mm total length. Sample sizes that did not meet the respective minimum sample size were omitted. There is an increasing trend in total length and no trend in weight for both species. These trends or lack thereof are similar to those 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. In 2012, a subsample of scales collected during on-board monitoring were aged to develop an age-length key. The age-length key was then applied to all unaged samples to assign ages for the commercial fishery. Mean length at age for the 2012 commercial samples was then compared to the mean length at age for fish collected in our fishery independent survey in the same year (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 beginning in 2013 continuing to present.

Table 6 shows the age structure for commercial monitoring samples taken from 2012 to 2019. Mean age for sexes of both species has remained stable or slightly increased, which corresponds with the increase in mean lengths during the same time period and is similar to the trends observed 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 a 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 7). 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 2020, 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 were used for bait ranged from 27% (2007) to 58 % (2013,2015,2018) with a mean of 48%. River herring caught per trip varied from 1.5 to 6.7 while herring purchased per trip ranged from 0.63 to 1.7 (Table 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 from 2007-2020 ranged from 85,249 fish in 2007 to 426,098 fish in 2016 with a mean of 242,713. To put potential recreational herring harvest in context, the average estimated annual recreational harvest from 2013-2020 was 258,281 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 324,698 alewives (roughly 117,000 pounds) annually (Figure 10 and Table 8). Black Creek is only one of the 68 primary tributaries to the Hudson River.

This analysis should be interpreted with caution and viewed 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. 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 alewife into the tributary. The majority of the migration occurs at night similar to observations of other state agencies utilizing fish counters to obtain abundance estimates. Additionally, 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 8. 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 (Figure 10 and Table 8).

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 9). Since 2012, targeted river herring sampling resulted in consistent hauls and increased catches.

Since 2012, alewife catches have been on average 69.6% male and 30.4% 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 may 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 41.3% males and 58.7% 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. 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 model (Ricker 1975). This model uses the annual age and associated lengths 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 for the time period 2012-2018. These provide growth characteristics of each species and were used to inform yield-per-recruit models described below. The resulting growth model outputs are reported in Table 10.

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. Since 2008, mean total length of male alewife has increased to present. Mean total length of female alewife has also steadily increased since 2008. Mean total length of blueback herring has increased for both sexes from 2009 to the present. Mean weights of alewife males have remained stable while females have been increasing. Male blueback herring mean weights were stable from 2009 to 2014 but have increased to present while female blueback herring mean weights have been steadily increasing since 2009.

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 2012-2019 indicate that male alewives begin to spawn at ages three to four and are fully mature by age five while female alewives begin to spawn at ages three to four and fully mature by age six (Figure 13). Blueback herring begin to spawn at ages two to three and the majority reach full maturity by age five (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 more recent literature (Coggins et al. 2013), we have been examining 10 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 (Loesch 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 11 and 12. From 2012 to 2019 during our fisheries independent sampling, we collected 10,032 scales samples from alewives and assigned ages to a stratified random subsample of 1,750 scale samples. Female alewives ranged from age two to ten with zero to five repeat spawn marks and ranged from 68% to 36% virgin fish. 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 2019, we collected 4,250 scale samples from blueback herring and assigned ages to 1,263 of those samples. Female blueback ages ranged from two to nine with zero to five repeat spawn marks. Female bluebacks ranged from 79% to 42% virgin fish. Male bluebacks ranged in age from two to six with zero to three repeat spawn marks and ranged from 92% to 59% virgin fish. Mean age of male and female bluebacks has remained stable since 2012.

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. Since 2012, mean length at age for both species across all ages has been stable. Along with stable 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 suggests a higher survival rate during both post-spawn emigration and during ocean residency (Figure 14).

Based on recommendations in the recent American Shad Benchmark Stock Assessment (ASMFC 2020) and the anticipated recommendation from the upcoming River Herring Benchmark Stock Assessment in 2023, we will be transitioning from scales to otoliths for production aging. During this transition period, we will age paired scales and otoliths over the next few years before transitioning fully to otoliths.

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 13, Figure 15). Mortality estimates derived from age data for alewives declined or remained stable from 2012-2014. In 2015 and 2016, mortality estimates increased dramatically; however, this increase was likely 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 and 2016. In 2017, mortality estimates declined to previous levels and have remained stable to present. 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, recent data suggest the extent of their impact was limited.

Blueback herring age-based mortality estimates remained stable or declined since 2012 (Table 13, Figure 15). In the previous plan, both sexes of blueback herring were comprised of primarily three- and four-year-old fish. Recent data indicates continued expansion of the age structure with increased occurrences of both older fish and increased occurrences of repeat spawning marks (Tables 11 and 12).

Mortality estimates have been derived from repeat spawning data since 2009 and generally followed the same trends as estimates derived from age data. Mortality estimates in recent years remained stable or declined (Table 13, Figure 15).

In most instances, the mortality estimates based on spawning marks were higher than those calculated from ages. 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. However, trends between the two estimation methods follow similar trends and annual estimates are not significantly different ($p=0.63$).

Spawner-per-Recruit (SPR)

Following methods described in Section 2.5.2 of the recent ASMFC American Shad Benchmark Stock Assessment (ASMFC 2020), we used a modified Thompson-Bell spawner-per-recruit model to develop a total mortality ($Z_{40\%}$) sustainability target for female alewife and blueback herring. Model inputs were derived from Hudson specific alewife and blueback herring empirical data such as maturity schedule, weight-at-age and natural mortality (Table 14). The three-year average total mortality estimates for each species will be used to evaluate against the sustainability thresholds.

The resulting $Z_{40\%}$ sustainability thresholds for alewife females is 1.26 and 1.19 for female blueback herring (Table 15 and Figure 16). These are new sustainability thresholds and not included in previous plans.

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. Byron Young's sampling has continued annually since 2011. There have also been additional video monitoring and alewife tagging studies, with estimations of Peconic River run size (https://seatuck.org/volunteer-river-herring-survey/).

3.2.4 Volunteer and Other River Herring Monitoring

The Seatuck Organization, in collaboration with the NYS DEC, Peconic Estuary Partnership, Long Island Sound Study, South Shore Estuary Reserve, and others, runs annual citizens alewife survey (https://seatuck.org/volunteer-river-herring-survey/). The survey incorporates 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 South Shore Estuary Reserve Diadromous Fish Workgroup began a volunteer survey of alewife spawning runs on the south shore of Long Island in 2006, which is now run by the Seatuck Organization, as noted in the paragraph above. The survey is designed to identify alewife spawning in support of diadromous fish restoration projects. The Diadromus Fish Workgroup evaluates current fish passage projects and sets a baseline of known spawning runs. Data are available on the Seatuck organization website (https://seatuck.org/volunteer-river-herring-survey/).Monitoring takes place from March through May. Data indicated that alewife use multiple streams in low numbers. 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 2021, there was an estimated 29,000 fish alewife run in the Peconic River, via visual estimate. The last fish was caught on May 20, 2021 (B. Young, retired, NYS DEC, 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. A video can be viewed on their website at https://www.seatuck.org/index.php/fish-counting

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 2011, and remained 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 14 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 (2027), 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 (Eakin et al. 2017).

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 (Eakin et al. 2017). 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. Sustainability targets will be set using juvenile indices and a new total mortality threshold for female alewife and blueback herring. 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. We will also monitor age structure and frequency of repeat spawning. 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 and Thresholds

Total Mortality

We propose to set new sustainability thresholds for female alewife and blueback herring total mortality (Z) using a modified Thompson-Bell yield per recruit model with Hudson stock specific data from the time period of 2012 through 2018. The three-year average total mortality estimate for each river herring species will be used to evaluate exceedance of the total mortality target. The resulting sustainability thresholds are 1.26 and 1.19 for female alewife and blueback herring, respectively (Figure 16).

Juvenile Indices

We propose a continuation of sustainability targets 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 25th 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 0.36 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 or if total mortality exceeds the thresholds for three consecutive years. Potential management actions may include but are not limited to: area closures, gear restrictions, and permit fee restructuring. Specific management actions for each potential action may include but are not limited to:

Area closures: Prohibit commercial fishing above the Bear Mountain Bridge
Rationale: The majority of spawning occurs above the Bear Mountain Bridge; therefore, closure of this area would reduce harvest of spawning river herring.

Gear restrictions: Eliminate angling as a means for commercial harvest
Rationale: Regulations implemented in 2013 prohibited the use of nets in all tributaries to the Hudson River; however, angling for commercial purposes is still permitted and currently not quantifiable but suspected to be a significant source of harvest. Eliminating this gear would reduce harvest of spawning river herring.

Permit fee restructuring: Permit fees were set in the early 1900s and have not changed to date.
Rationale: Current permit fees allow access to commercial gears at a nominal cost (e.g. .05 cents per net foot for a gill net up to 600 feet). Accounting for inflation, the cost per net foot would be $1.58 per foot today. Permit fee restructuring would dissuade recreational fishers from using commercial gears to avoid the 2013 implementation of the recreational 10 fish creel limit.

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 and/or total mortality is below the total mortality thresholds for three 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, and mean length at age 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 targets and thresholds 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 impact of bycatch in ocean fisheries is largely 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

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

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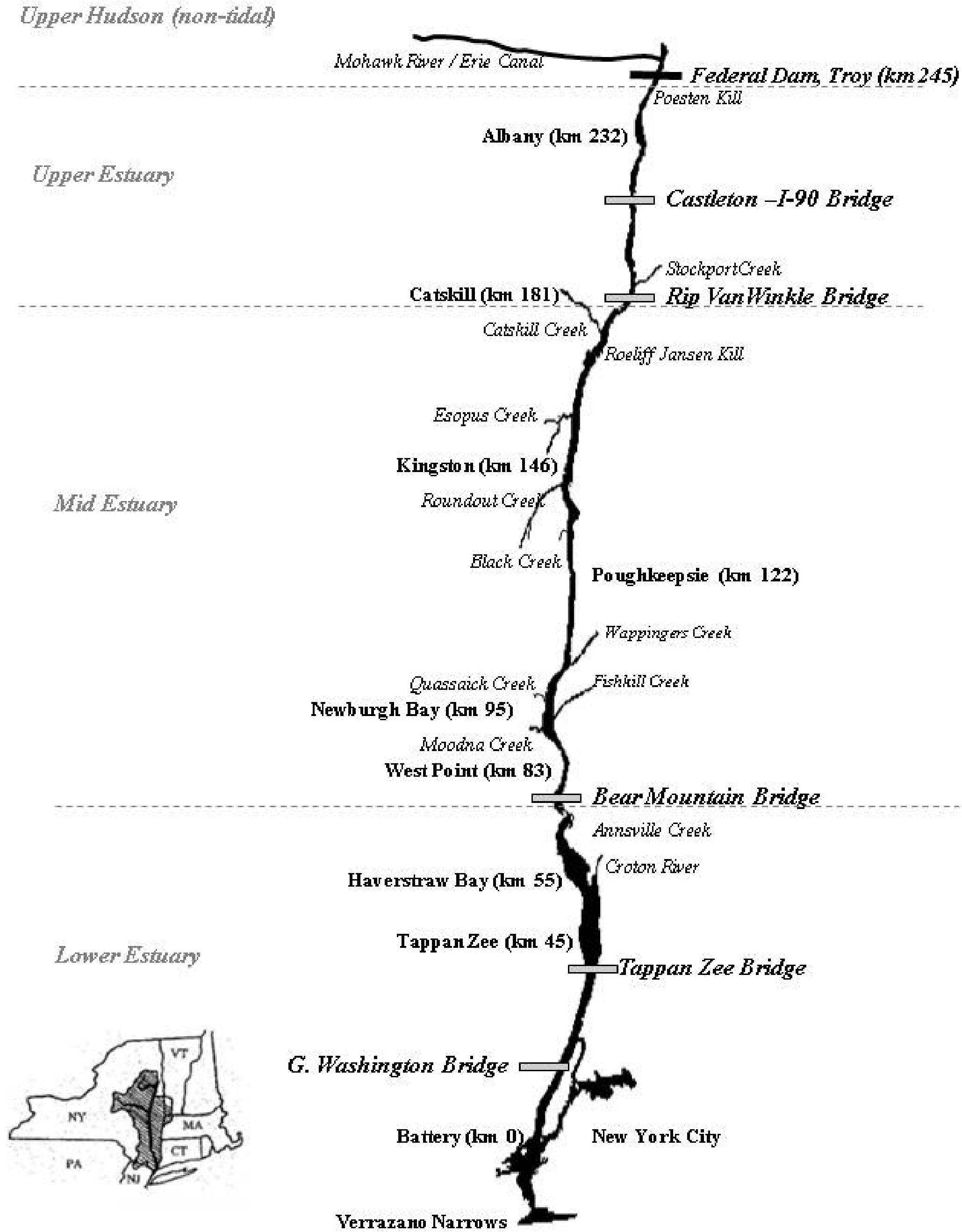


Figure 1. Hudson River Estuary with major spawning tributaries for river herring.

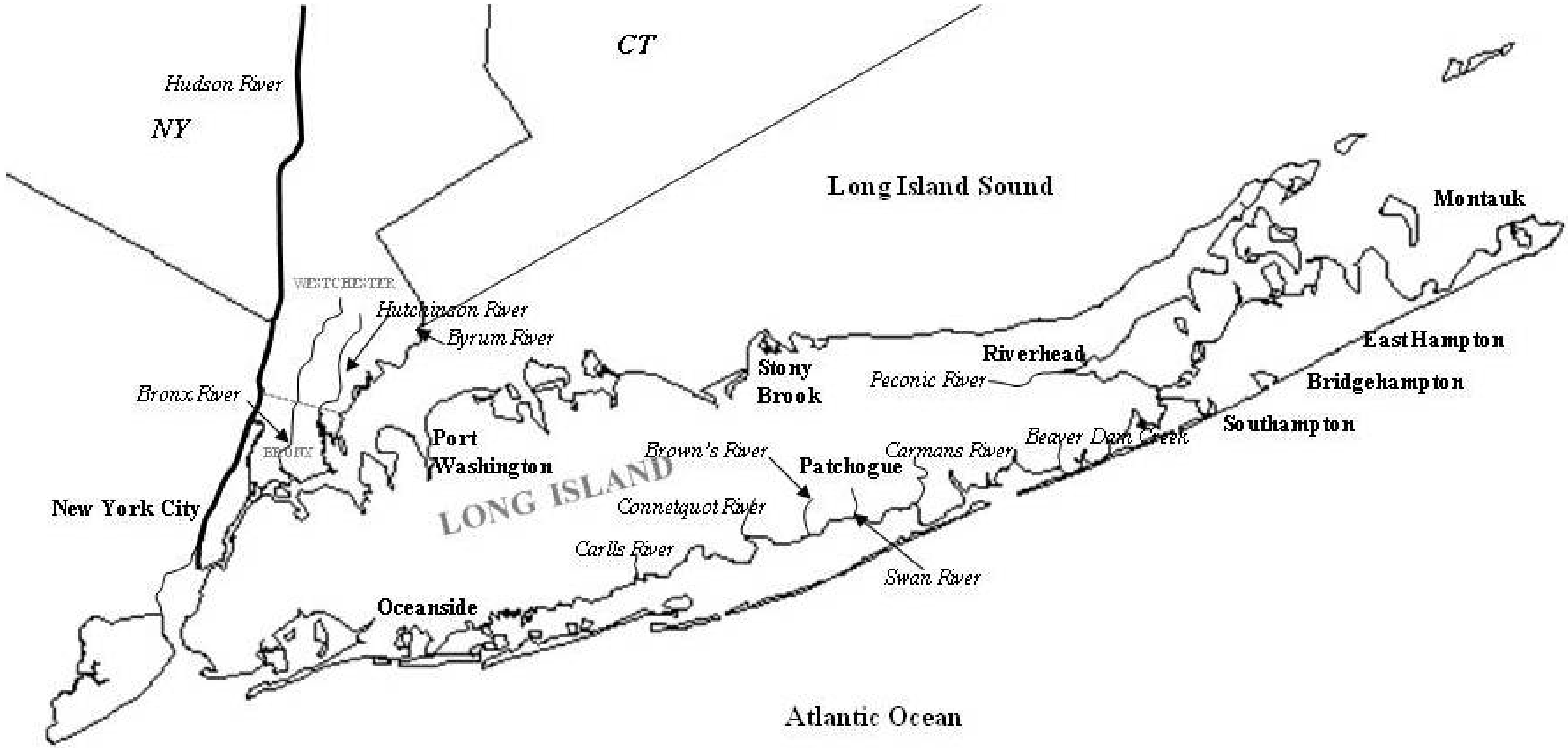


Figure 2. Long Island, Bronx and Westchester Counties, New York, with some river herring (primarily alewife) spawning streams identified.

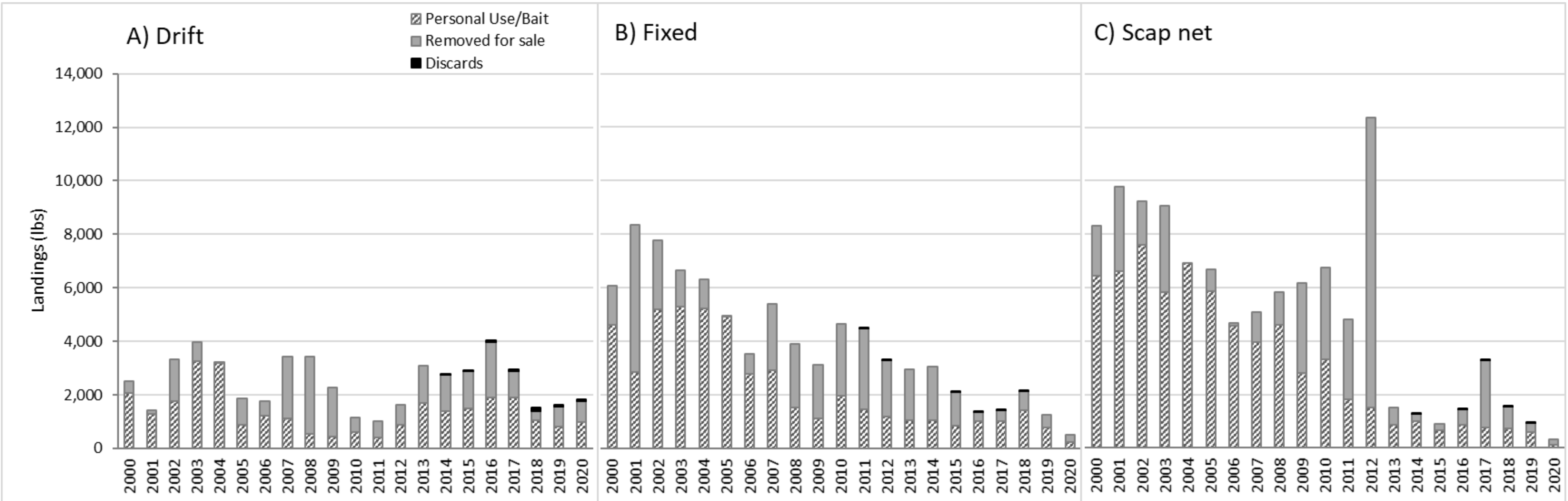


Figure 3. Dispositions of commercially caught river herring as reported in mandatory trip reports.

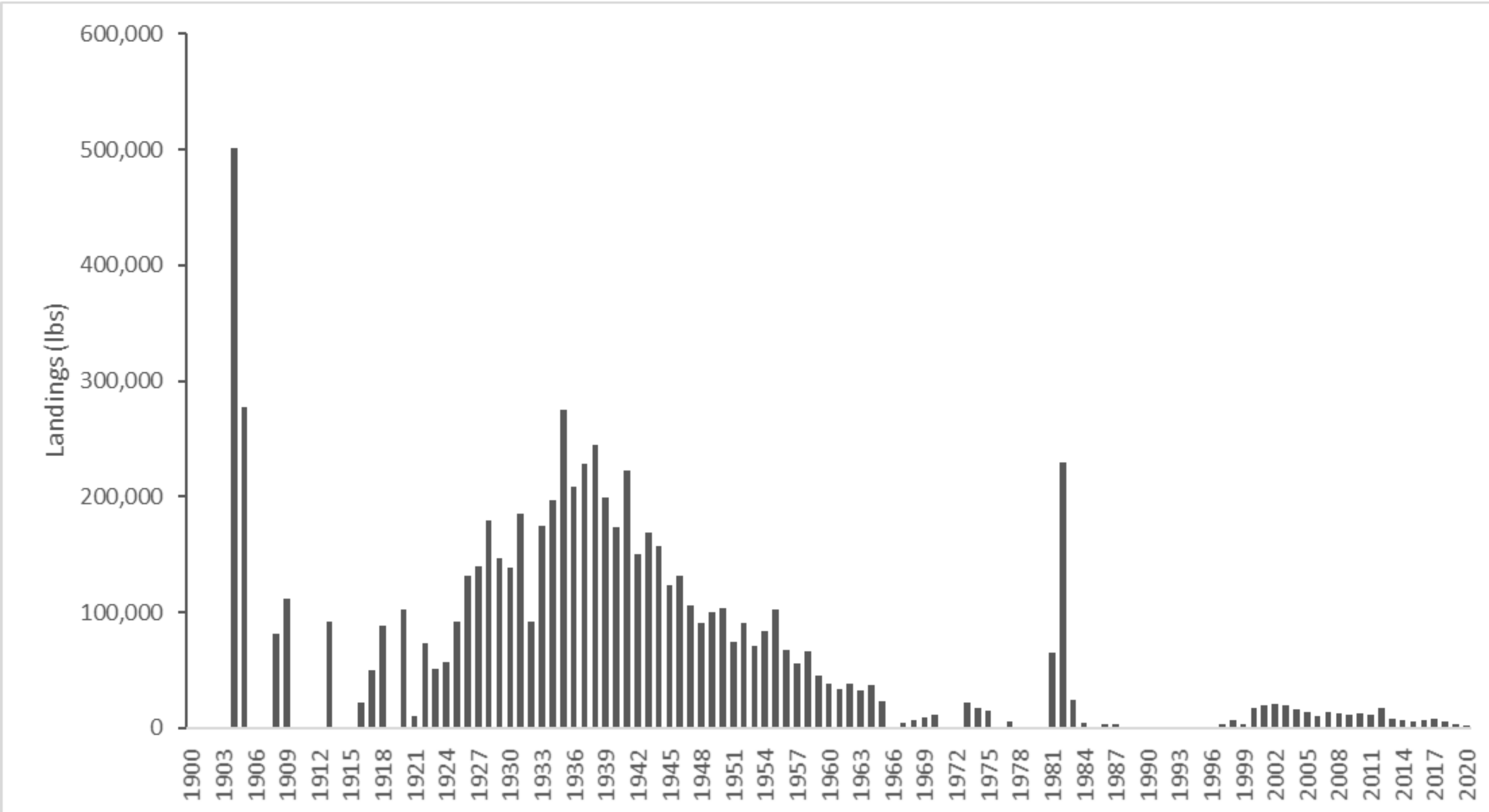


Figure 4. River herring landed in New York waters.

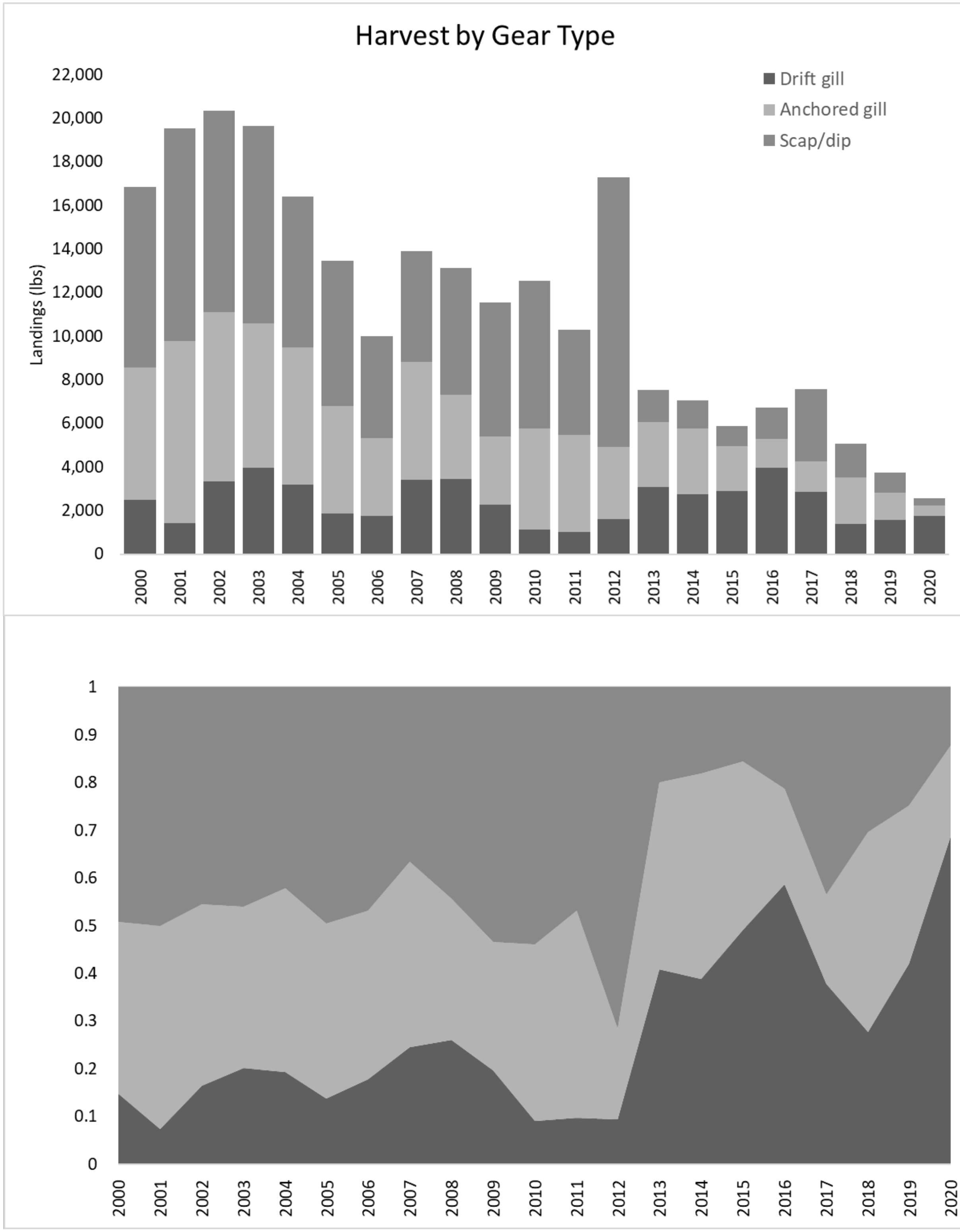


Figure 5. (Top) Annual total landed pounds of river herring separated by gear type. Catch includes targeted river herring trips only. (Bottom) Percent landed by gear type.

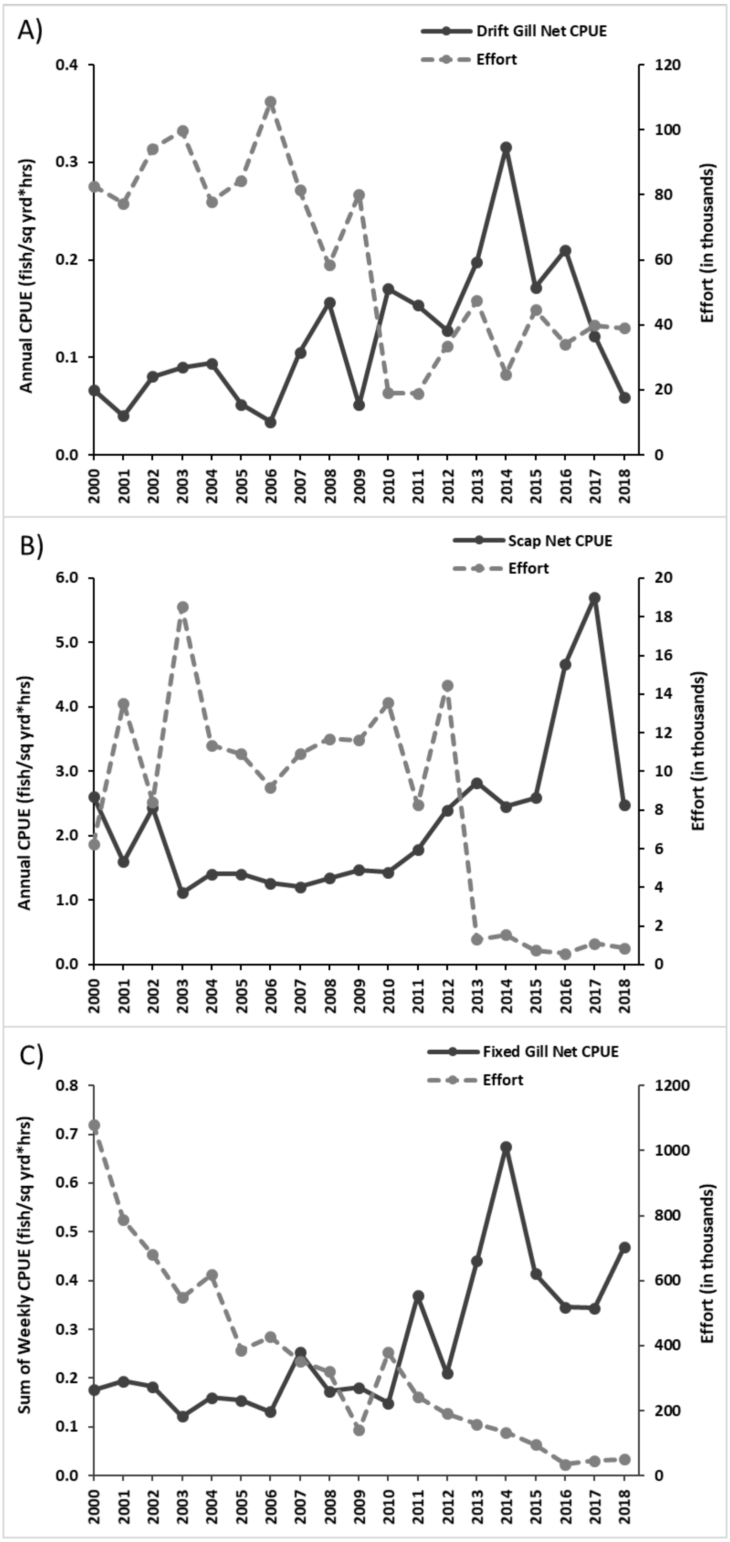


Figure 6. Efforts (sq yd net area * hours) and CPUEs from mandatory commercial reports. A) Drift gill net fishery above rkm 75; CPUE is total catch/total effort. B) Scap net fishery above rkm 75; CPUE is total catch/total effort. C) Fixed gill net fishery below rkm 75; CPUE is the sum of weekly catch/weekly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

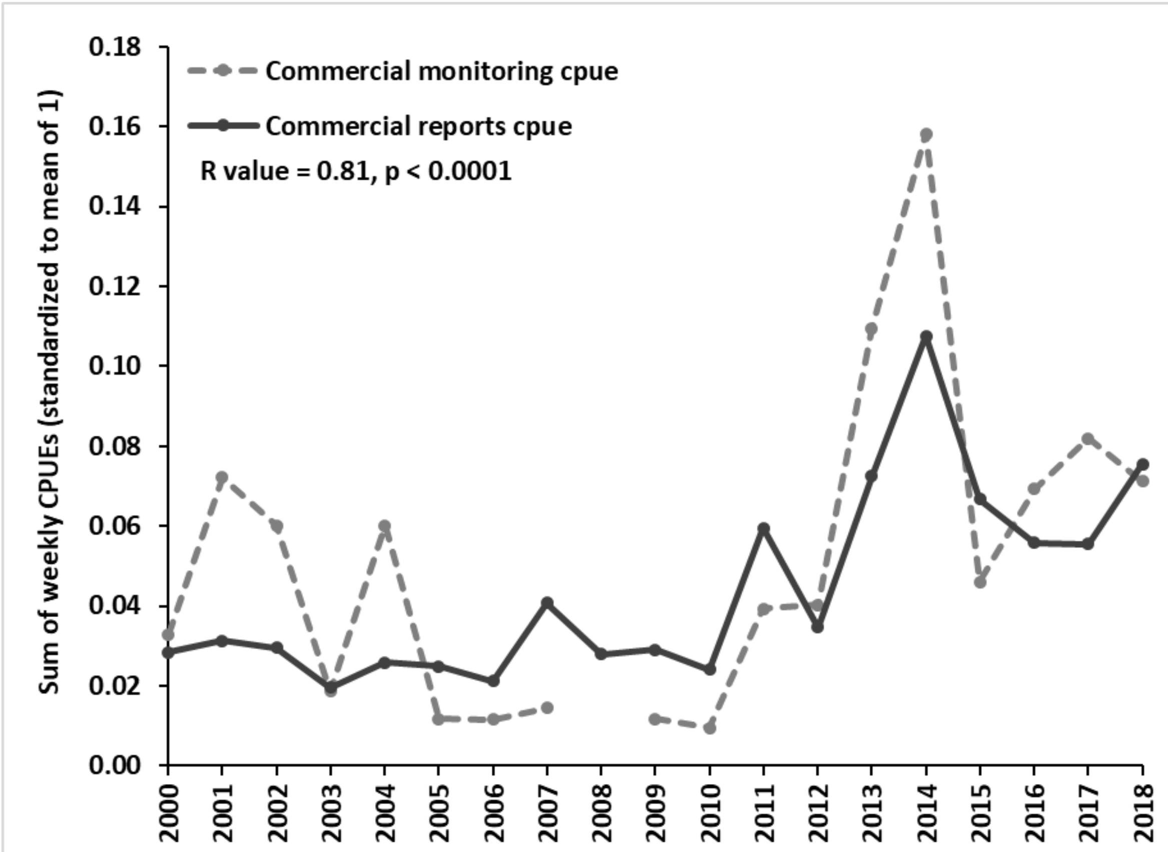


Figure 7. Comparison of the sum of weekly CPUEs calculated from commercial monitoring and mandatory commercial reports of the fixed gill net fishery below the Bear Mountain Bridge (rkm 75).

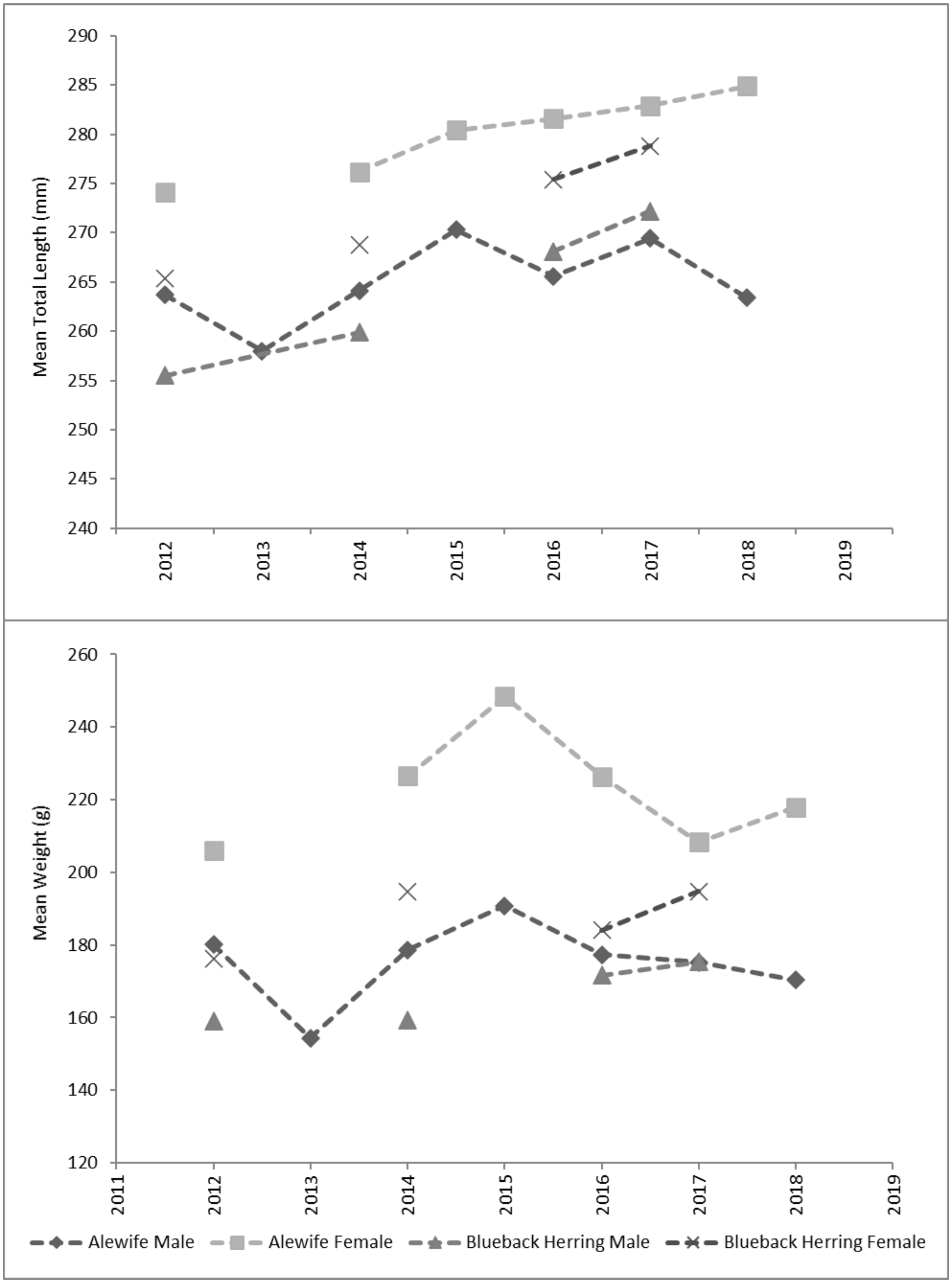


Figure 8. Mean length and weight of river herring collected in fishery dependent sampling in the commercial fishery in the Hudson River. Years omitted when minimum sample size not met to detect a significant change of 5 mm total length.

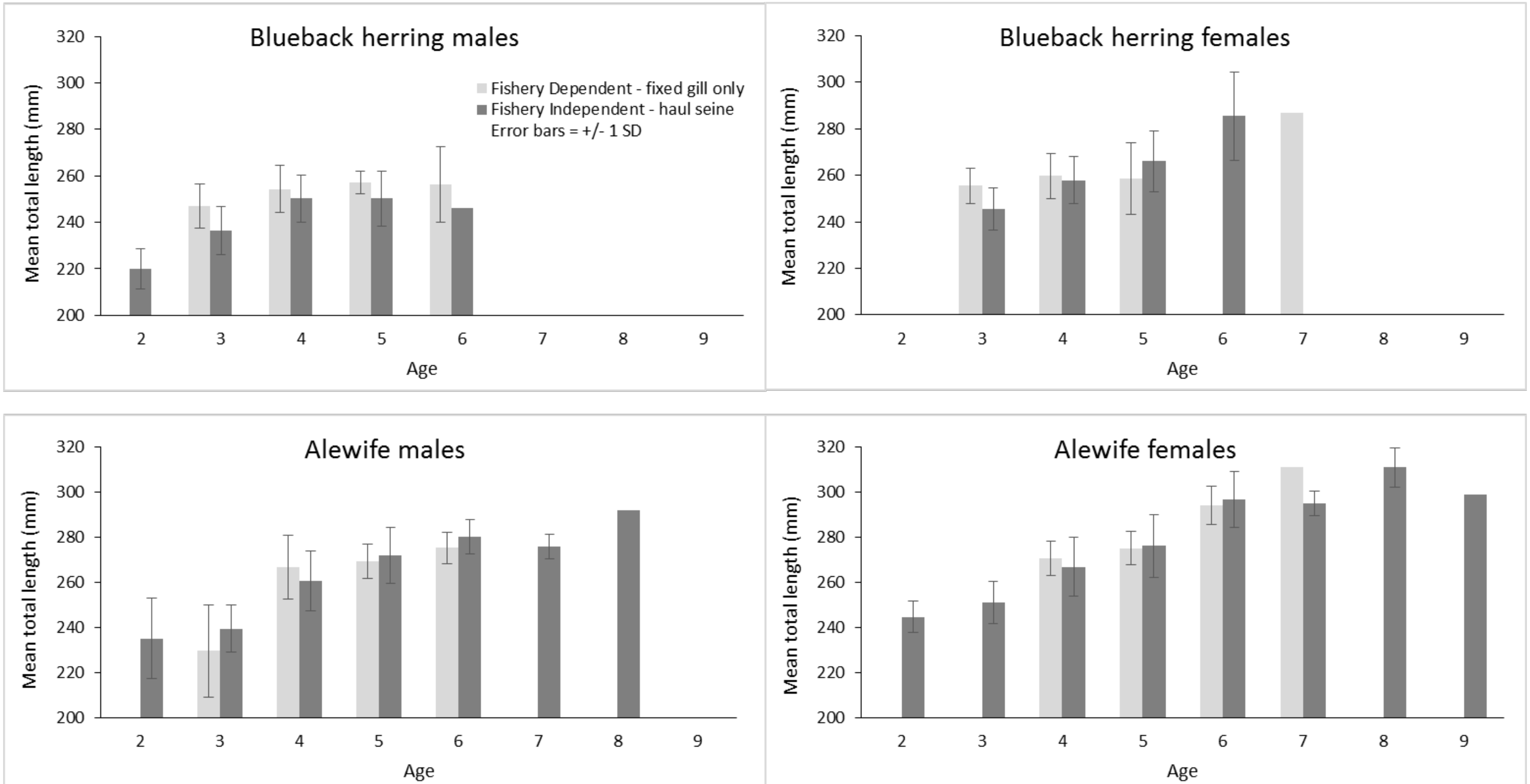


Figure 9. Comparison of length at age of river herring sampled in the lower-river fixed gill net commercial fishery versus the fishery independent survey in 2012.

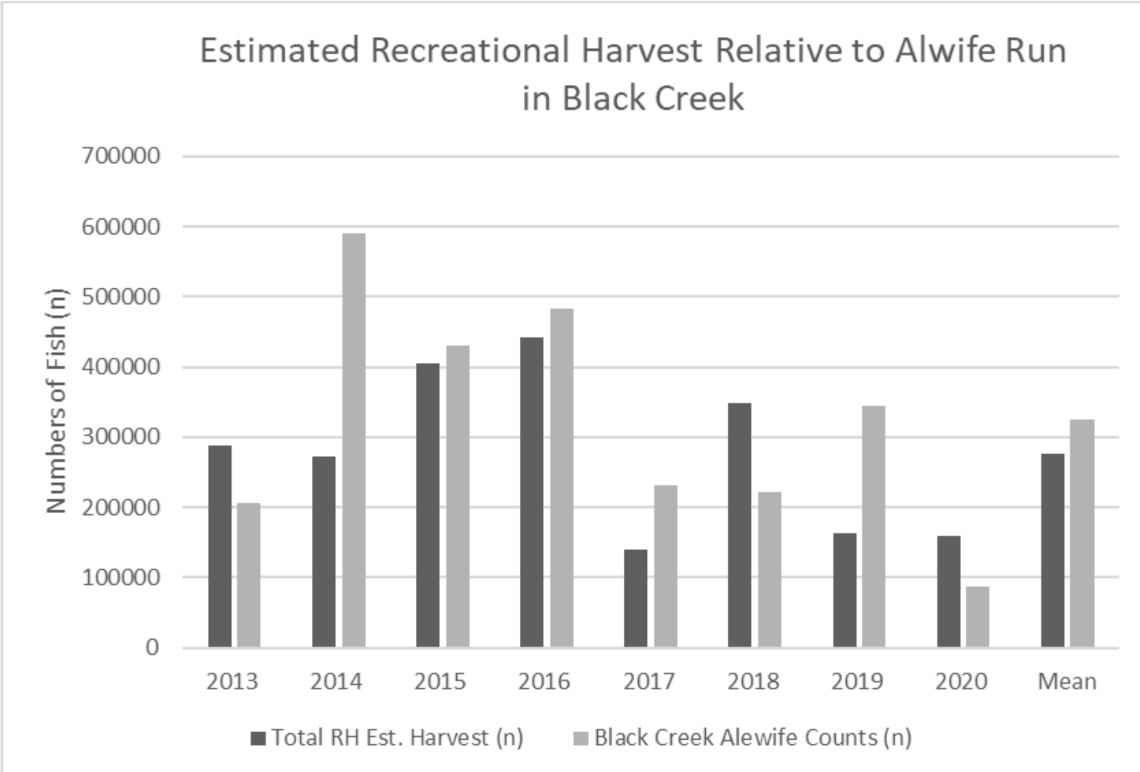


Figure 10. Estimated recreational river herring harvest relative to annual alewife counts in Black Creek, one of 68 tributaries to the Hudson River.

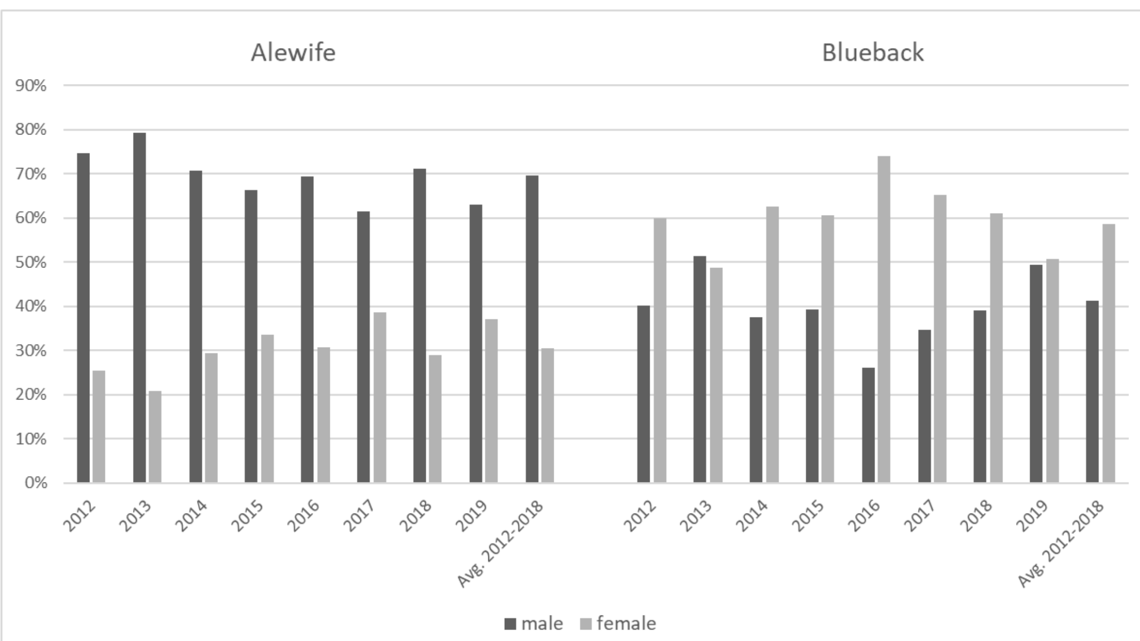


Figure 11. Annual sex ratios from river herring collected during the fisheries independent survey.

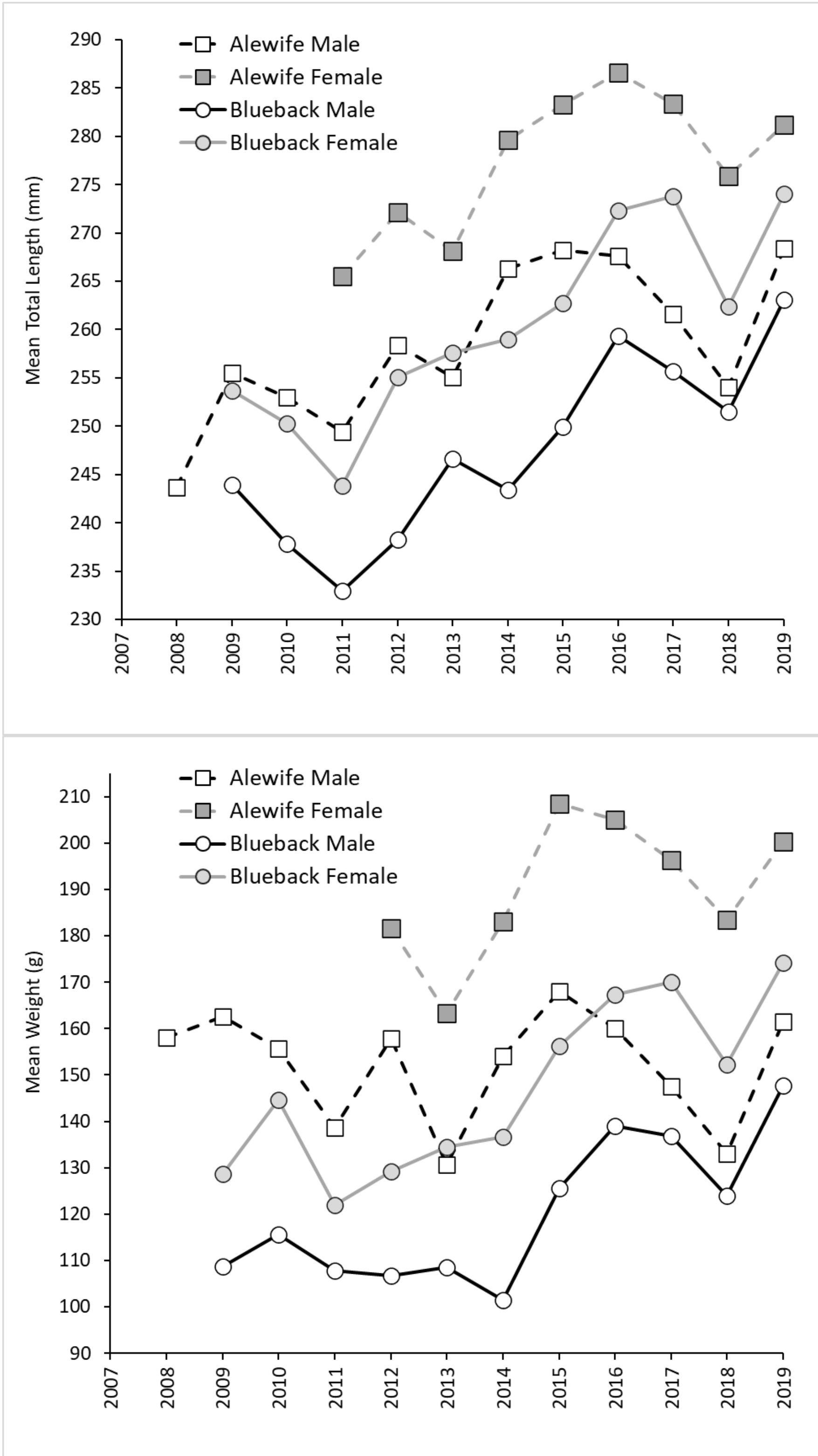


Figure 12. Mean length (top) and weight (bottom) of river herring collected during fishery independent sampling.

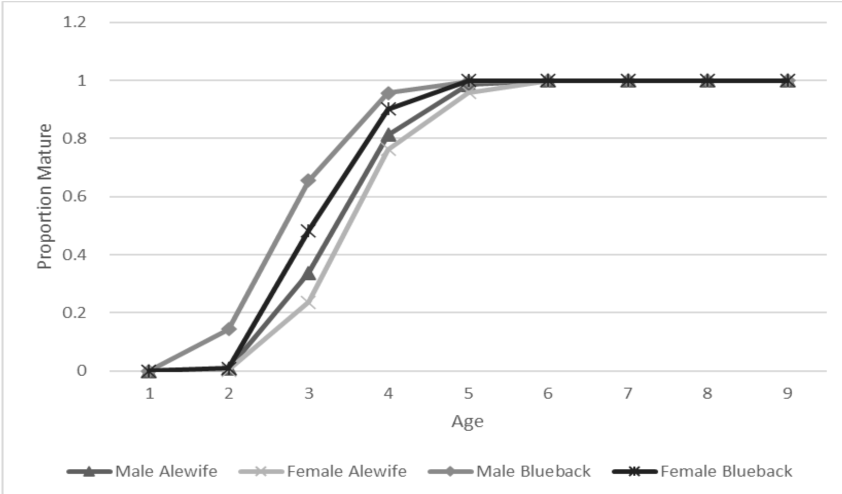


Figure 13. Maturity schedule for alewife and blueback herring derived from 2012-19 age and repeat spawn data.

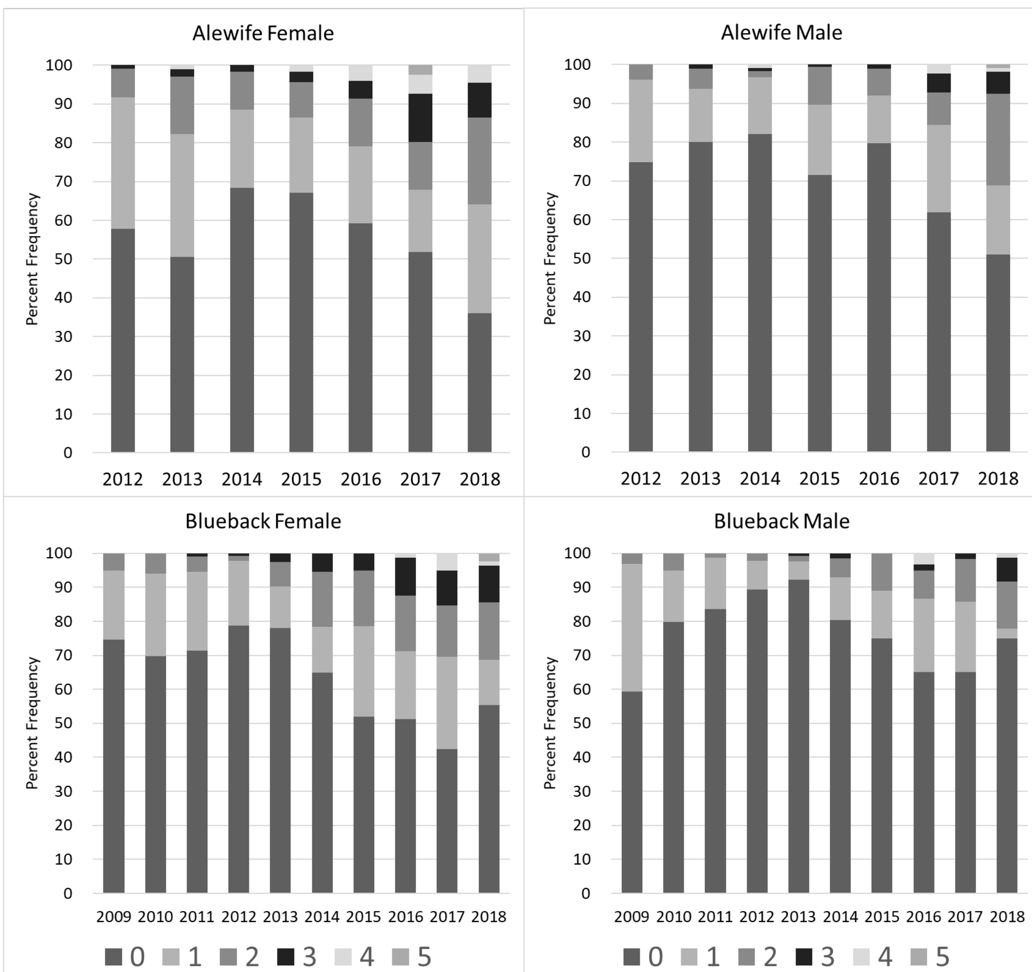


Figure 14. Frequency of repeat spawning occurrence of river herring collected during fisheries independent sampling. Numbers in legend indicate number of repeat spawns

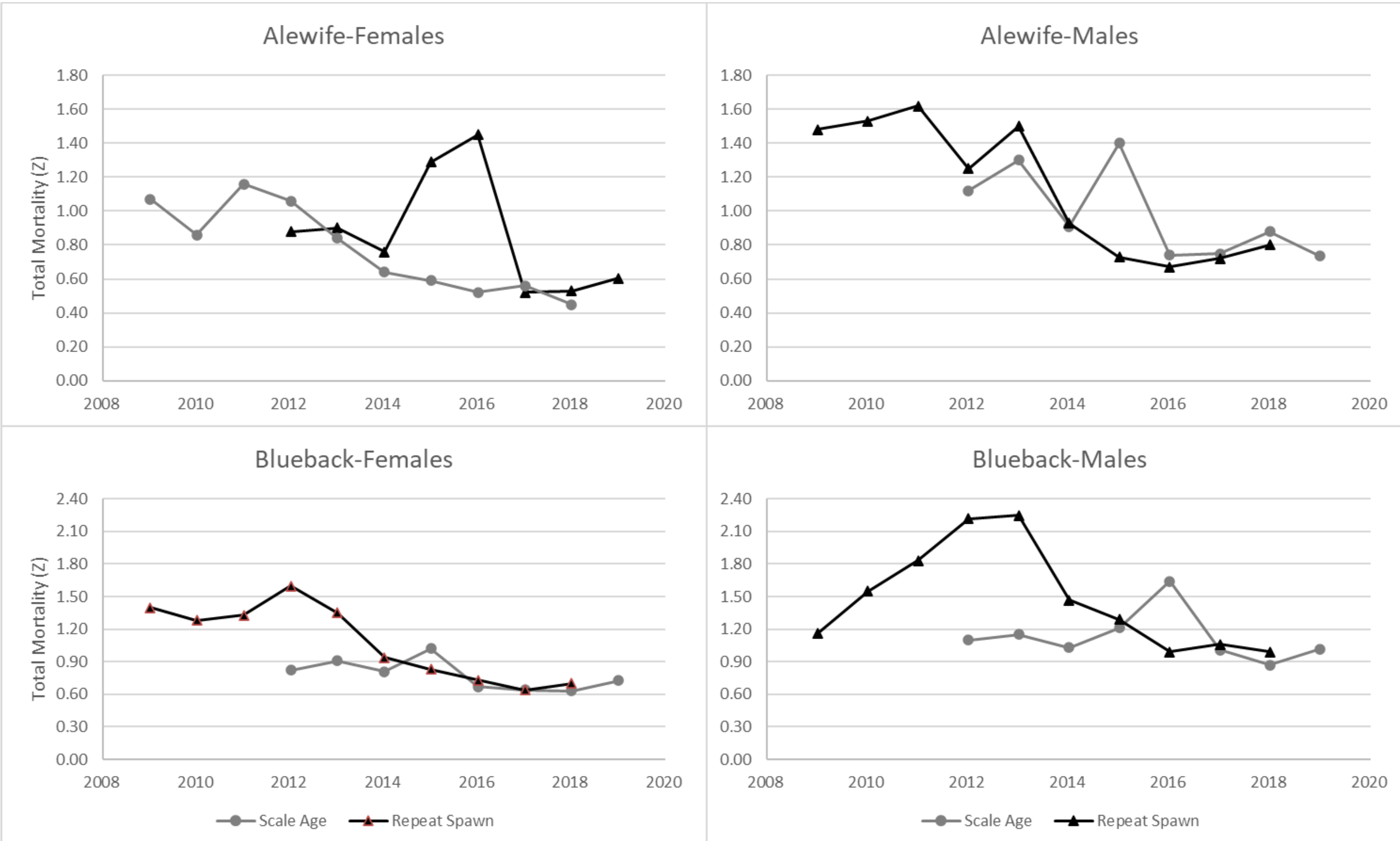


Figure 15. Annual total instantaneous mortality (Z) estimates for river herring collect during fisheries independent sampling.

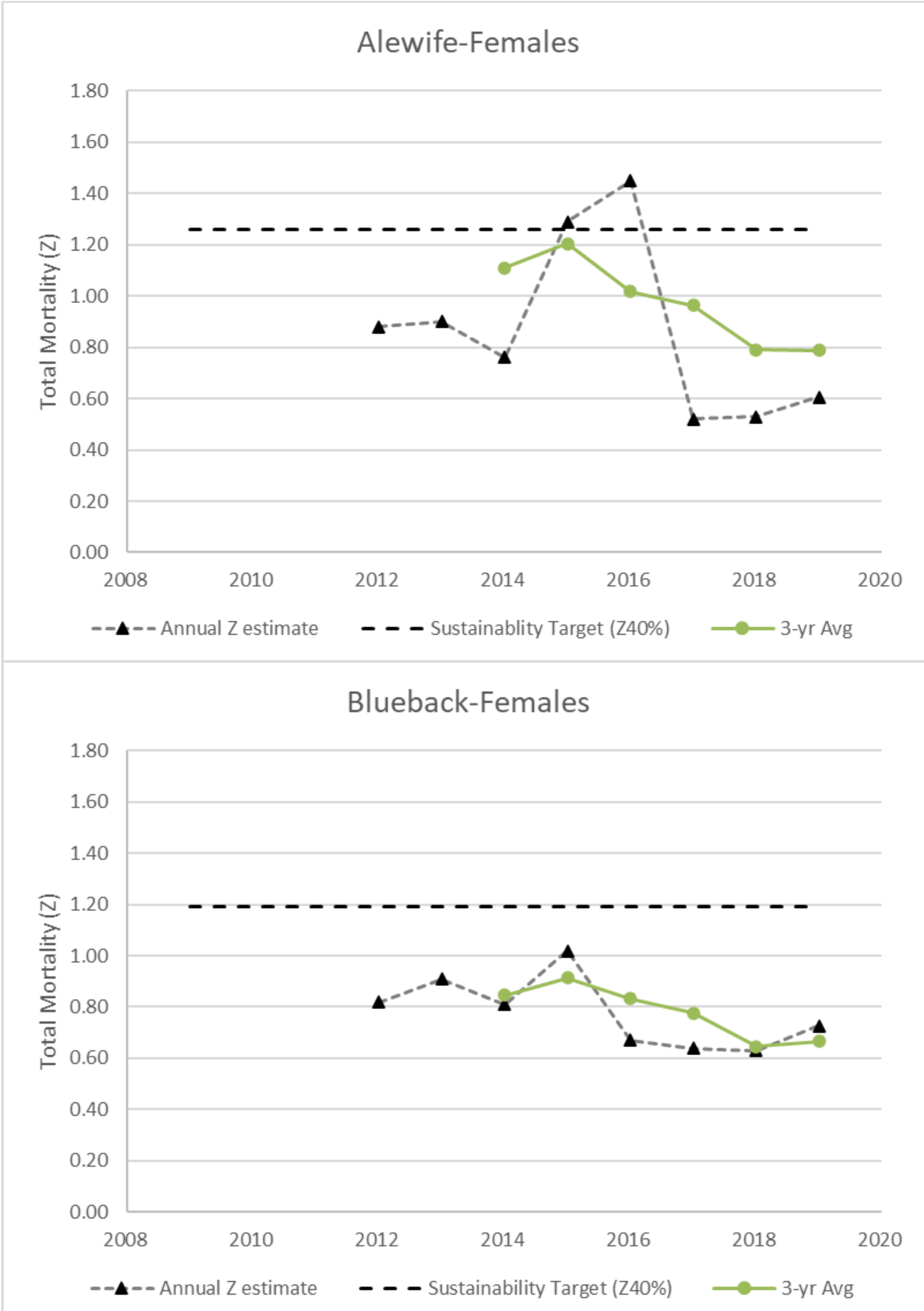


Figure 16. Chapman-Robson instantaneous total mortality (Z) estimates, three-year average Z estimates and respective $Z_{40\%}$ sustainability thresholds for alewife and blueback females.

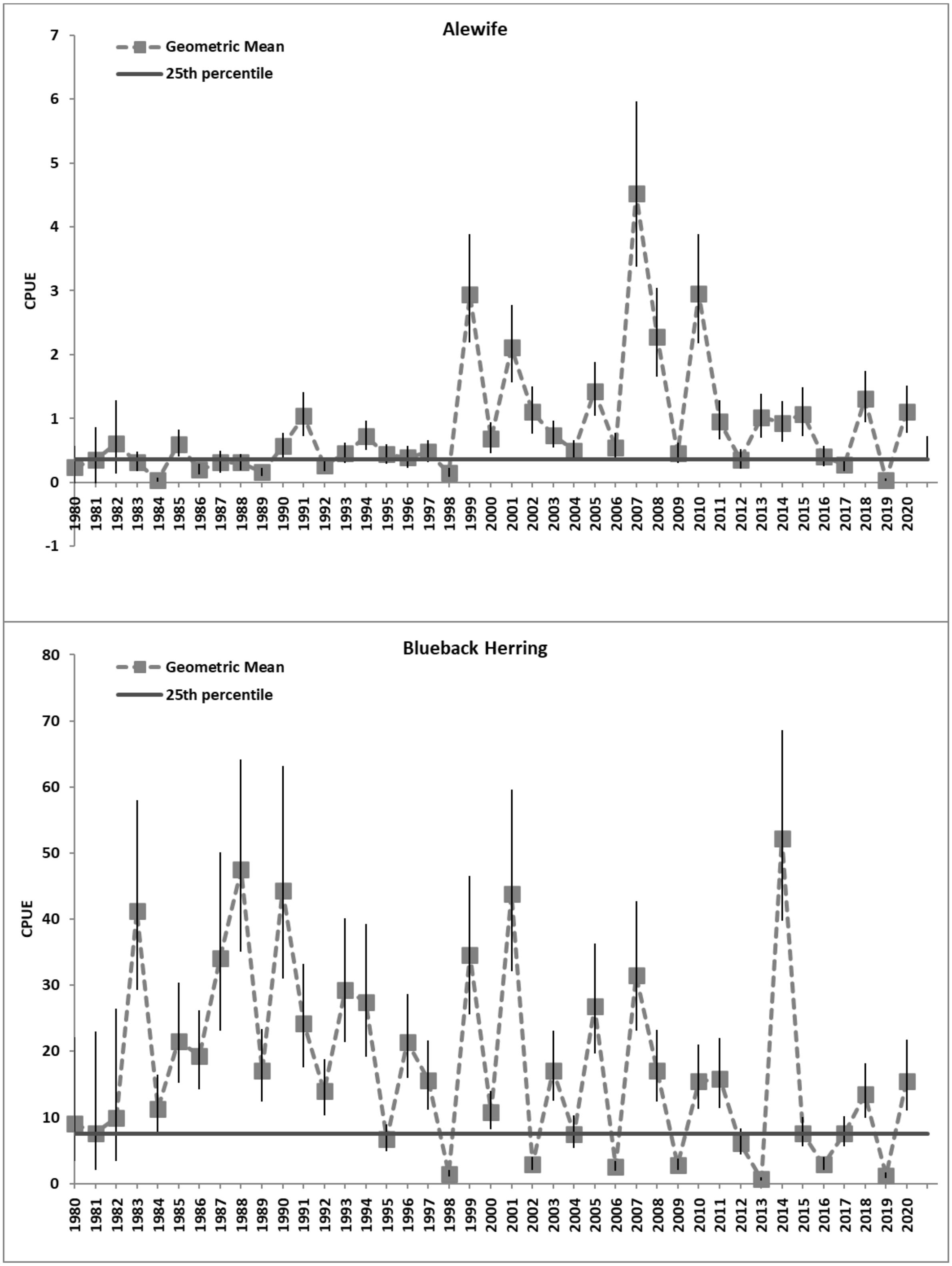


Figure 17. Young-of-year abundance indices for both river herring species.

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 & otoliths	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 Selected total mortality sustainability target $Z_{40\%}$
Young-of-year Indices	1983 to present: NYSDEC YOY survey	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	Both species index variable Alewife increasing Blueback slight decreasing trend Selected conservative sustainability target of 25th percentile

Table 3. 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%
2016	143	0	145	145	92	104	59	41%	25	27%
2017	151	0	153	153	84	87	53	35%	22	26%
2018	137	0	139	139	78	81	50	36%	23	29%
2019	130	0	131	131	66	70	37	28%	14	21%
2020	111	0	111	111	55	58	40	36%	14	25%

Table 4. 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
2016	10	22435.1	842	0.038	0.265	5	1021	152	0.149
2017	13	19991.7	1395	0.070	0.313	10	4820	819	0.170
2018	20	40819.3	2839	0.070	0.272	7	8043	290	0.036
2019	13	18477.8	2839	0.072	0.311	0			
2020	No Sampling-Covid-19								

^Sq yd net area * hours

Table 5. 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%
2016	15	182	257	1	0.41	0.59	224	315	15	0.42	0.58						994	44%	56%	0%
2017	23	401	735	13	0.35	0.65	412	622	25	0.40	0.60						2,208	52%	48%	0%
2018	27	513	920	158	0.36	0.64	541	900	55	0.38	0.62		1	41			3,129	51%	48%	1%
2019	13	243	439	2	0.36	0.64	180	463	1	0.28	0.72						1,328	52%	48%	0%
2020	0	No Sampling-Covid-19																		

Table 6. 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	10	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
2016*		12	47	22	26					107	4.58
2017*		15	30	16	12	7	4			85	4.74
2018*		10	19	30	9	5				73	4.73
2019**		1	14	17	14	4	1	0		51	5.17
2020***											
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	4.57
2015*		14	41	67	18	4	1			146	4.73
2016*		6	52	33	53	14	2			160	5.14
2017*		13	32	24	13	11	11	1		104	5.13
2018*		3	22	36	13	17	18	4	1	114	5.81
2019**		1	14	21	14	9	3	1	0	62	5.46
2020***											
Blueback Male											
2012	2	18	40	11	3					75	3.94
2013*		10	9	4	2					25	3.92
2014*		17	55	25	2					99	4.12
2015*		7	8	17	1					33	4.35
2016*		4	67	13	11					95	4.32
2017*		4	12	32	10					57	4.84
2018*		10	15	7	8	4				44	4.57
2019**		1	7	5	2	1	0			16	4.78
2020***											
Blueback 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
2016*		6	67	39	19	4				135	4.61
2017*			11	11	27	20	4			73	5.93
2018*		10	15	7	8	4				44	4.57
2019**		1	8	9	8	1	0	0		28	5.11
2020***											

* 2013-2018 ages are estimated using the length at age key derived from the fishery independent data from that respective year

** 2019 ages estimated using length at age key derived from fishery independent data from 2016-2019

*** No sampling due to Covid 19

Table 7. Estimated recreational use and take of river herring by Hudson River anglers.

Year	Herring Use* % of all CAP Trips using herring as bait	N bought / trip	N caught / trip	Total RH use/trip	% change in annual CAP SB trips	Estimated Statewide SB trips**	SB trips using herring as bait**	Est. Rec Herring Use (n)
2001						53,988	39,500	93,157**
2005	0.89			2.36		72,568	64,500	152,117**
	Cooperative Angler Program Data							
2006	0.49	1.47	2.57	4.04				
2007	0.27	1.64	1.78	3.42		90,742	24,920	85,249***
2008	0.33	0.81	1.54	2.35	41%	128,393	42,526	99,947***
2009	0.35	0.61	3.68	4.29	7%	97,251	33,884	145,410***
2010	0.52	0.67	4.76	5.42	5%	95,029	49,658	269,385***
2011	0.48	0.71	4.35	5.06	66%	150,952	71,808	363,101***
2012	0.53	1.10	4.76	5.86	-15%	76,797	40,398	236,671***
2013	0.58	1.04	5.23	6.27	-18%	74,023	43,129	270,566***
2014	0.56	0.74	5.30	6.04	-16%	76,039	42,326	255,694***
2015	0.58	0.66	6.04	6.70	12%	101,199	58,486	391,784***
2016	0.54	0.40	4.44	4.84	80%	163,685	88,040	426,098***
2017	0.48	0.43	3.57	4.00	-30%	63,519	30,482	122,055***
2018	0.58	0.62	3.81	4.43	43%	129,506	75,639	335,341***
2019	0.49	0.44	3.20	3.64	-6%	85,627	42,328	153,969***
2020	0.43	0.72	2.59	3.31	-14%	77,752	33,455	110,738***

*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 2020 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 8. Annual daily alewife count data from Black Creek and commercial and estimated recreational river herring harvest.

	Total Counts	Min	Max	Mean	LCI	UCI	n (days)*	Commerical Harvest**	Recreational Harvest***	Total RH Est. Harvest (n)
2013	205,885	25	40,571	4,381	203,681	208,089	47	17,547	270,567	288,113
2014	590,680	294	58,416	18,459	586,104	595,256	32	16,574	255,695	272,269
2015	431,136	26	45,186	13,065	426,992	435,280	33	13,226	391,785	405,010
2016	483,555	2	91,715	8,955	479,133	487,977	54	16,270	426,098	442,368
2017	231,930	12	28,692	7,482	229,576	234,284	31	18,309	122,056	140,365
2018	221,951	20	36,281	5,285	219,223	224,679	44	12,440	335,342	347,781
2019	344,682	14	33,048	5,559	342,765	346,599	58	8,844	153,970	162,814
2020	87,764	0	15,546	1,721	86,764	88,765	51	6,077	153,971	160,048

* Number of days count data were recorded

**Number harvested of combined river herrring species from Hudson River commercial reports

***Estimated harvest numbers of combined river herring species derived from CAP data and 2007 statewide angler survey

Table 9. 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	16	26.06	0.44
2004	0	10	2	0.00	5.00
2005	120	41	13	9.23	3.15
2006	27	3	5	5.40	0.60
2007	53	0	6	8.83	0.00
2008	262	21	15	17.47	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	2149	1304	165	13.02	7.90
2013	4865	4057	120	40.54	33.81
2014	11240	3054	115	97.74	26.56
2015	4328	3030	104	41.62	29.13
2016	4126	1967	152	27.14	12.94
2017	2480	416	95	26.11	4.38
2018	3783	1449	133	28.44	10.89
2019	8368	2307	121	69.16	19.07
2020	No sampling Covid-19				

Table 10. Von Bertalanffy model parameters (Linf, K, t0) and outputs for river herring in the Hudson River.

	Female Alewife	Male Alewife	Female Blueback	Male Blueback
n fish	1172	1197	933	860
Linf	311.4065	292.5934	292.3044	269.466
K	0.4791	0.5333	0.5936	0.7652
t0	-0.1716	-0.1498	-0.1294	-0.06576
Age		**Predicted Total Length**		
0	-53.0	-18.3	26.7	13.2
1	-53.0	133.4	127.7	150.3
2	-53.0	205.0	189.2	214
3	-53.0	238.9	226.5	243.7
4	-53.0	254.9	249.3	257.5
5	-53.0	262.4	263.1	263.9
6	-53.0	266.0	271.5	266.9
7	-53.0	267.7	276.7	268.3
8	-53.0	268.5	279.8	268.9
9	-53.0	268.9	281.7	269.2
10	-53.0	269.0	282.8	269.3

Table 11. Age structure of river herring from fisheries independent sampling.

	Age										
Year	2	3	4	5	6	7	8	9	10	Total	Mean Age
					Alewife Male						
2012	27	385	726	308	91	21	2			1559	4.1
2013		615	782	276	48	15	1			1737	3.9
2014	1	372	933	1233	61	18	29			2647	4.4
2015		105	430	544	203	12	8			1302	4.7
2016	3	192	670	354	462	34				1715	4.7
2017		343	365	168	119	53	18			1067	4.3
2018		406	554	456	104	40	7	2		1569	4.3
2019*		139	757	583	397	80	17			1974	4.8
2020**											
					Alewife Female						
2012	5	76	210	175	32	11	7	2		518	4.4
2013		148	275	84	58	17	12	1		596	4.3
2014		83	537	383	137	75	27	5		1247	4.7
2015		56	179	372	114	30	8			759	4.9
2016		34	254	165	375	110	21	1		960	5.4
2017		61	183	151	101	99	44	7		647	5.2
2018		76	303	194	70	99	94	18	3	857	5.2
2019*		44	447	407	216	132	56	11	2	1314	5.1
2020**											
					Blueback Male						
2012	64	157	89	16	3					329	3.2
2013	34	483	209	44	17					787	3.4
2014	83	308	205	51	1					649	3.4
2015	3	412	168	44	3					630	3.4
2016	2	75	302	25	30					434	4.0
2017	18	41	18	34	5					116	3.7
2018	2	236	161	20	25	12				456	3.7
2019*	1	84	177	72	35	7				374	4.2
2020**											
					BluebackFemale						
2012		152	168	61	4					385	3.8
2013	1	364	203	97	21	1				687	3.7
2014	7	320	274	77	36	9				723	3.8
2015		248	262	162	36	9				716	4.0
2016		19	287	222	207	36	14			786	5.0
2017		68	29	95	47	12	1			252	4.6
2018		208	157	51	71	13	5	5		510	4.1
2019*		78	179	132	91	18	5	2		505	4.6
2020**											

* Numbers at age estimated using 2016-2018 age-length key
** No Sampling Covid-19

Table 12. Repeat spawn data of river herring from fisheries independent sampling.

Year	Repeat spawning marks										
	0	1	2	3	4	5	6	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
2016	51	19	30	12				112	1.03	0.46	0.54
2017	58	11	16	13	3			101	0.93	0.57	0.43
2018	64	13	4	11	6			98	0.80	0.65	0.35
2019*											
2020**											
					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
2016	40	20	18	24	5	2		109	1.45	0.37	0.63
2017	53	14	16	17	13			113	1.32	0.47	0.53
2018	41	10	6	16	14	8		95	1.75	0.43	0.57
2019*											
2020**											
					Blueback 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
2016	39	13	5	1	2			60	0.57	0.65	0.35
2017	41	13	8	1				63	0.51	0.65	0.35
2018	54	2	10	5	1			72	0.57	0.75	0.25
2019*											
2020**											
					Blueback 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
2016	41	16	13	9	1			80	0.91	0.51	0.49
2017	25	16	9	6	3			59	1.08	0.42	0.58
2018	46	11	14	9	1	2		83	0.96	0.55	0.45
2019*											
2020**											

** No sampling Covid-19

*** Repeat spawn data unavailable

Table 13. Instantaneous mortality estimates derived from age and repeat spawn data using a bias-correction Chapman and Robson mortality estimator described in Smith et al. (2012).

	Scale Age												Repeat Spawn											
	Alewife						Blueback						Alewife						Blueback					
	Female			Male			Female			Male			Female			Male			Female			Male		
Year	Z	SE	3-yr Avg	Z	SE	3-yr Avg	Z	SE	3-yr Avg	Z	SE	3-yr Avg	Z	SE	3-yr Avg	Z	SE	3-yr Avg	Z	SE	3-yr Avg	Z	SE	3-yr Avg
2009													1.07	0.22		1.48	0.12		1.40	0.09		1.16	0.41	
2010													0.86	0.01		1.53	0.12		1.28	0.13		1.55	0.12	
2011													1.16	0.09	1.03	1.62	0.21	1.54	1.33	0.10	1.34	1.83	0.13	1.51
2012	0.88	0.19		1.12	0.09		0.82	0.35		1.10	0.22		1.06	0.06	1.03	1.25	0.15	1.47	1.60	0.14	1.40	2.22	0.11	1.87
2013	0.90	0.08		1.30	0.10		0.91	0.13		1.15	0.12		0.84	0.08	1.02	1.50	0.19	1.46	1.35	0.19	1.43	2.25	0.44	2.10
2014	0.76	0.13	0.85	0.91	0.45	1.11	0.81	0.18	0.85	1.03	0.26	1.09	0.64	0.08	0.85	0.93	0.05	1.23	0.94	0.18	1.30	1.47	0.15	1.98
2015	1.29	0.04	0.98	1.40	0.22	1.20	1.02	0.20	0.91	1.21	0.15	1.13	0.59	0.17	0.69	0.73	0.13	1.05	0.83	0.12	1.04	1.29	0.28	1.67
2016	1.45	0.12	1.17	0.74	0.29	1.02	0.67	0.20	0.83	1.64	0.49	1.29	0.52	0.13	0.58	0.67	0.20	0.78	0.73	0.11	0.83	0.99	0.12	1.25
2017	0.52	0.09	1.09	0.75	0.07	0.96	0.64	0.08	0.78	1.01	0.12	1.29	0.56	0.14	0.56	0.72	0.16	0.71	0.64	0.06	0.73	1.06	0.13	1.11
2018	0.53	0.09	0.83	0.88	0.15	0.79	0.63	0.09	0.65	0.87	0.14	1.17	0.45	0.12	0.51	0.80	0.21	0.73	0.70	0.12	0.69	0.99	0.28	1.01
2019	0.61	0.07	0.55	0.74	0.02	0.79	0.73	0.11	0.67	1.02	0.10	0.97	No estimates											

Table 14. Life history data used as inputs to the Thompson-Bell spawning stock biomass per-recruit models.

	M		Maturity		Weight at age	
Age	Alewife	Blueback	Alewife	Blueback	Alewife	Blueback
1	0.59	0.59	0.00	0.00	21.45	22.24
2	0.59	0.59	0.00	0.01	70.03	72.32
3	0.59	0.59	0.24	0.48	122.71	120.96
4	0.59	0.59	0.76	0.90	166.54	156.46
5	0.59	0.59	0.96	1.00	198.75	179.32
6	0.59	0.59	1.00	1.00	220.91	193.14
7	0.59	0.59	1.00	1.00	235.60	201.23
8	0.59	0.59	1.00	1.00	245.12	205.89
9	0.59	0.59	1.00	1.00	251.21	208.54
10	0.59	0.59	1.00	1.00	255.07	210.04

Table 15. Results of biological reference point, Z40% from Thompson-Bell spawning stock biomass per-recruit models.

	M	$Z_{40\%}$
Female Alewife	0.59	1.26
Female Blueback	0.59	1.16

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).

Regulation	2013 to Present	Regulation link
Season	Mar 15 – Jun 15	6 CRR-NY 36.3 (a)
Creel/ catch limits	None	
Commercial Gear (Marine permit)	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	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)
	Seine as commercial gear - No size restrictions below Castleton/I90	6 CRR-NY 36.3 (c)
	Scoop/Dip/Scap net as commercial gear - **10' x 10' maximum**	6 CRR-NY 36.3 (c)
	Fyke/hoop/trap nets as commercial gear - No size restrictions	6 CRR-NY 36.3 (c)
Commercial Gear (Bait license)	Cast Net as bait collection gear - 10 ft maximum diameter	*To find the law* ***click here****, on ENV, find Article 11, click on Title 13, click* ***ECL 11-1315***
Closed areas	No gill nets above I90 - Castleton Bridge	6 CRR-NY 36.3 (2)(ii)
	No nets on Kingston Flats	6 CRR-NY 36.3 (2)(i)
	No nets in any tributary (including Mohawk River)	6 CRR-NY 36.3 (2)(i)
Escapement (no fishing days)	36 hr lift period for **all commercial gears** Friday 6AM – Saturday 6PM	6 CRR-NY 36.3 (4)
Marine Permit Fees (established 1911)	Gill net $0.05/foot	6 CRR-NY 35.1
	Scap net <10 sq ft $1.00	
	Seine $0.05/foot	
	Trap nets $3 to $10	
	Fyke net $1 to $2	
Marine Permit Reporting	**Mandatory daily catch & effort; Vessel Trip Reports (VTRs) due monthly**	6 CRR-NY 36.1 (a)(1)
Transport and sale	- 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	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)

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**
	  ○ **Register with Hudson River Fisheries Unit**
	  ○ **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)

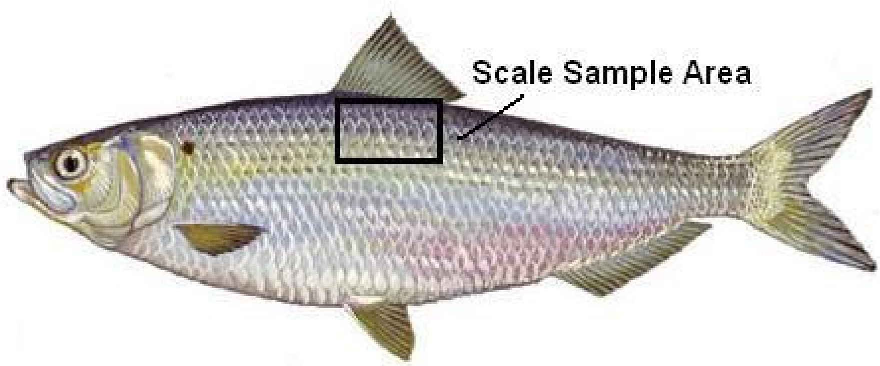
Recreational gear (personal use)	Angling	6 CRR-NY 10.10 (c)(2)
	Seine – not exceeding 36 square feet	6 CRR-NY 10.10 (c)(3)(ii)(e)
	Scap net – - **Not exceeding 16 square feet** - Only one net	6 CRR-NY 10.10 (c)(3)(ii)(d) 6 CRR-NY 10.10 (c)(3)(ii)(b)
	Dip/Scoop – - Not exceeding 14 inches in diameter 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)** ○ **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

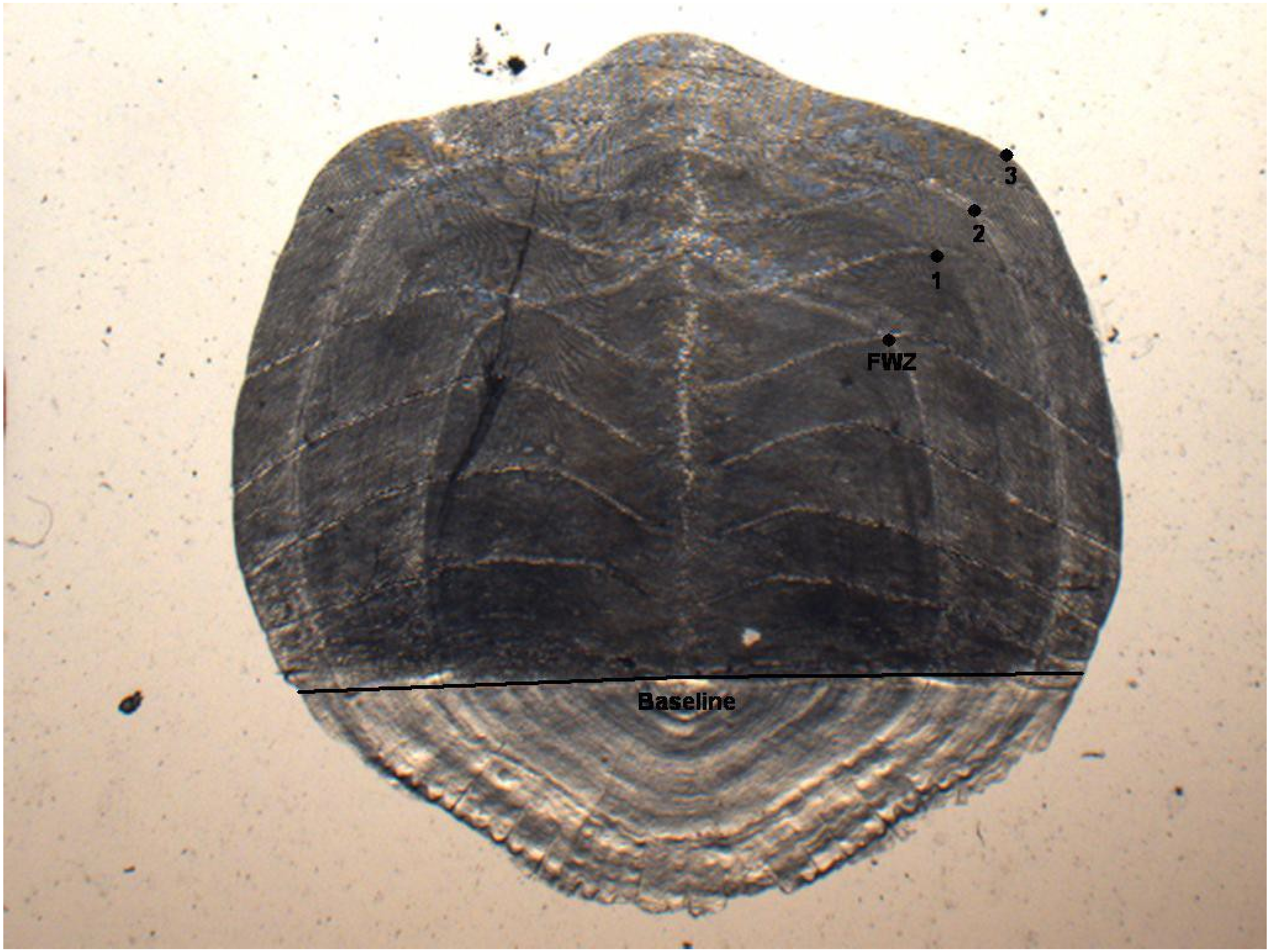


Figure 1. This 3 year old alewife has its baseline, fresh water zone (FWZ) and annuli all marked. Note the straight baseline and large FWZ typical of alewives.

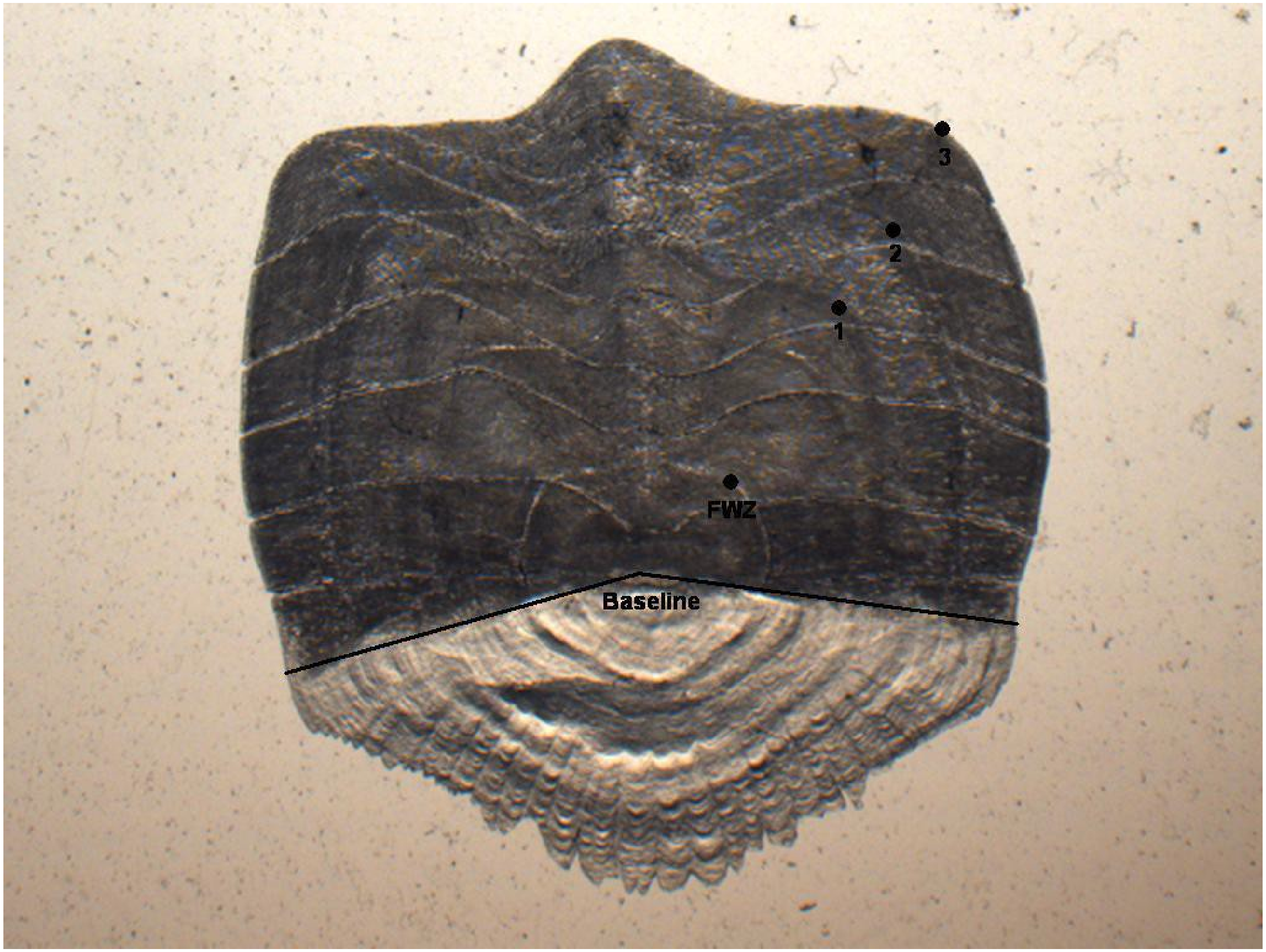


Figure 2. The baseline, fresh water zone (FWZ) and annuli are all marked on this blueback scale. Note the small FWZ and angled baseline typical of bluebacks.

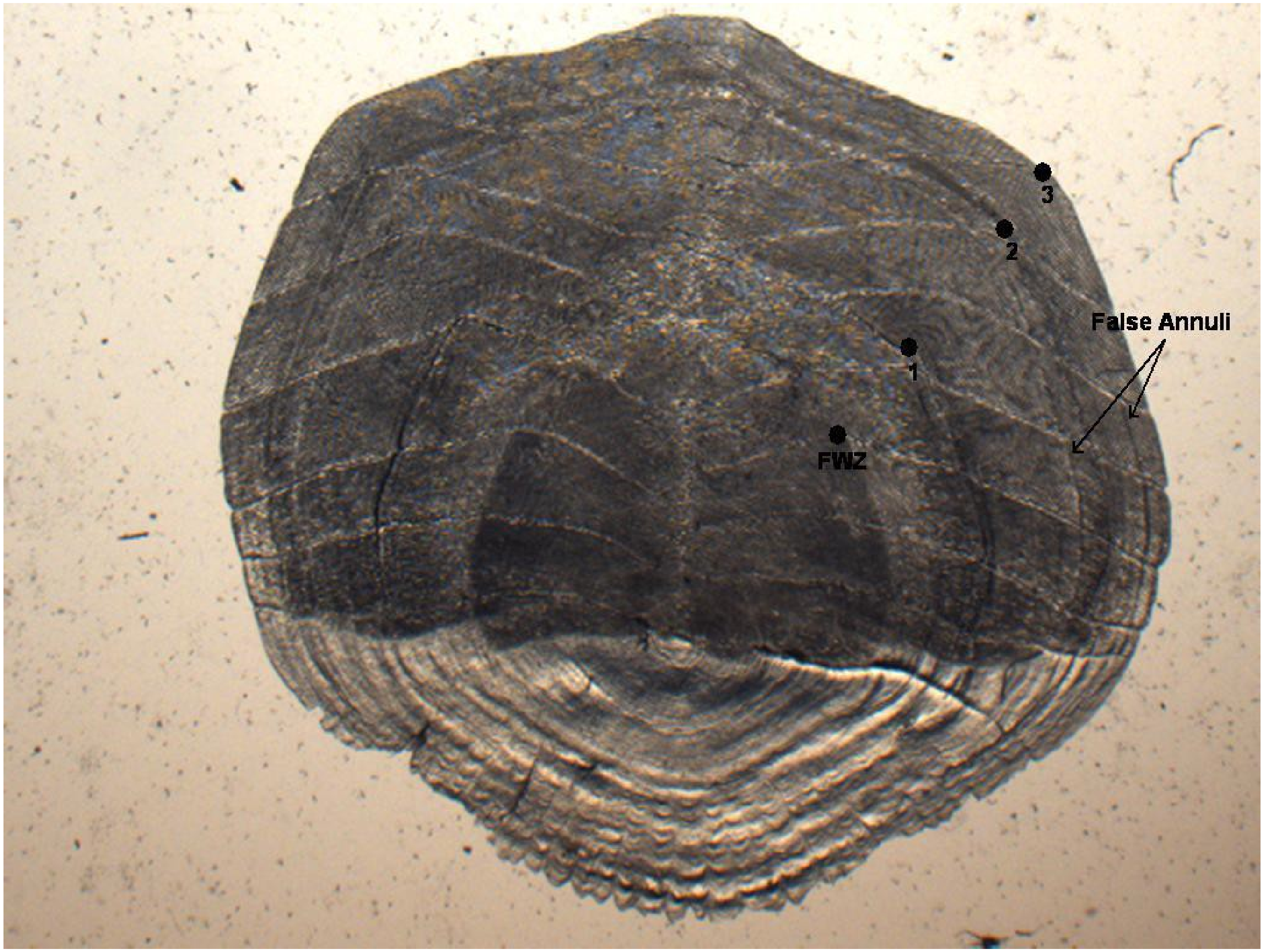


Figure 3. This three year old alewife has two false annuli, one on either side of annulus 2.

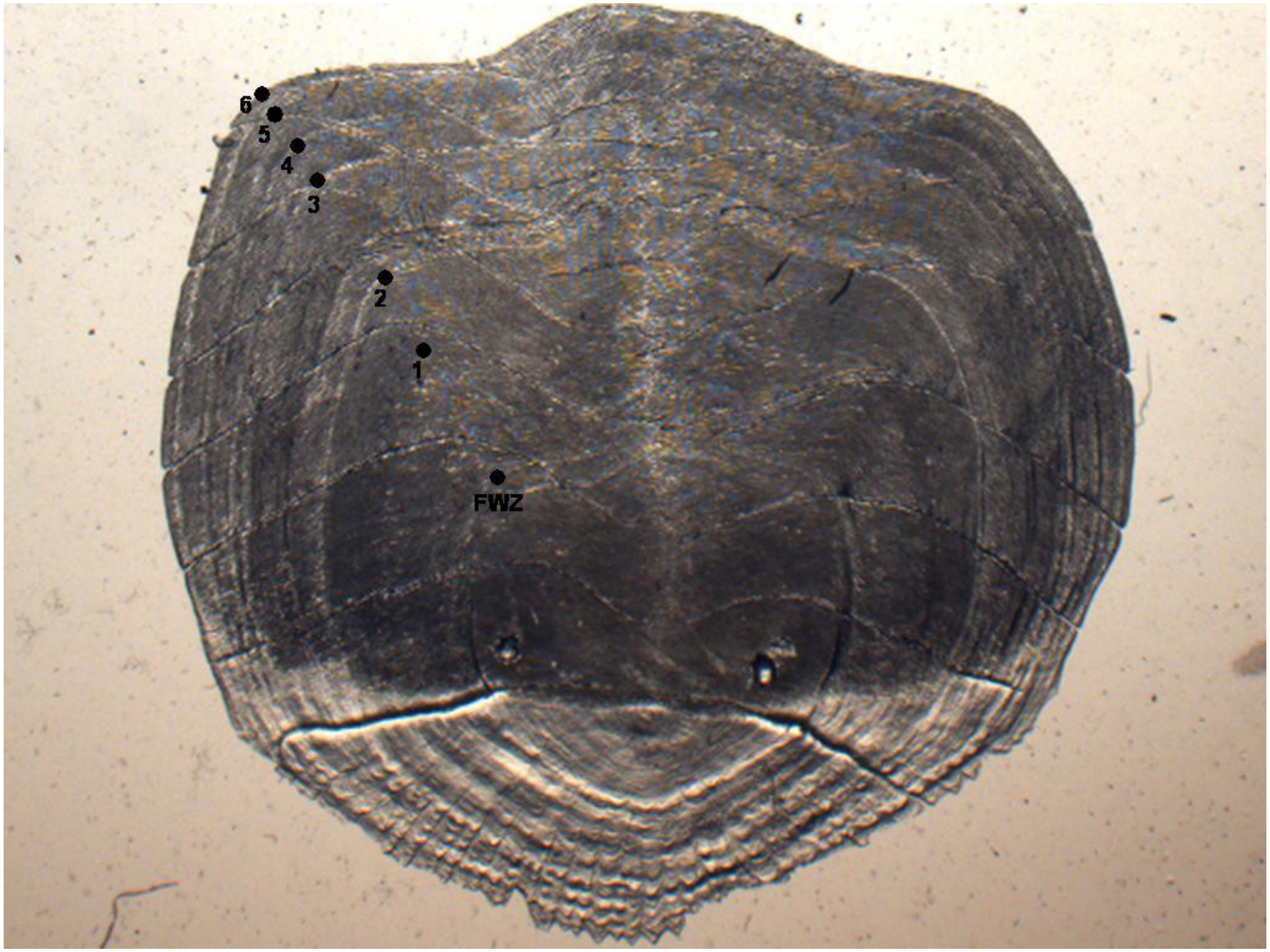


Figure 4. A six year old alewife. Note how weak the first annulus appears compared to the second.

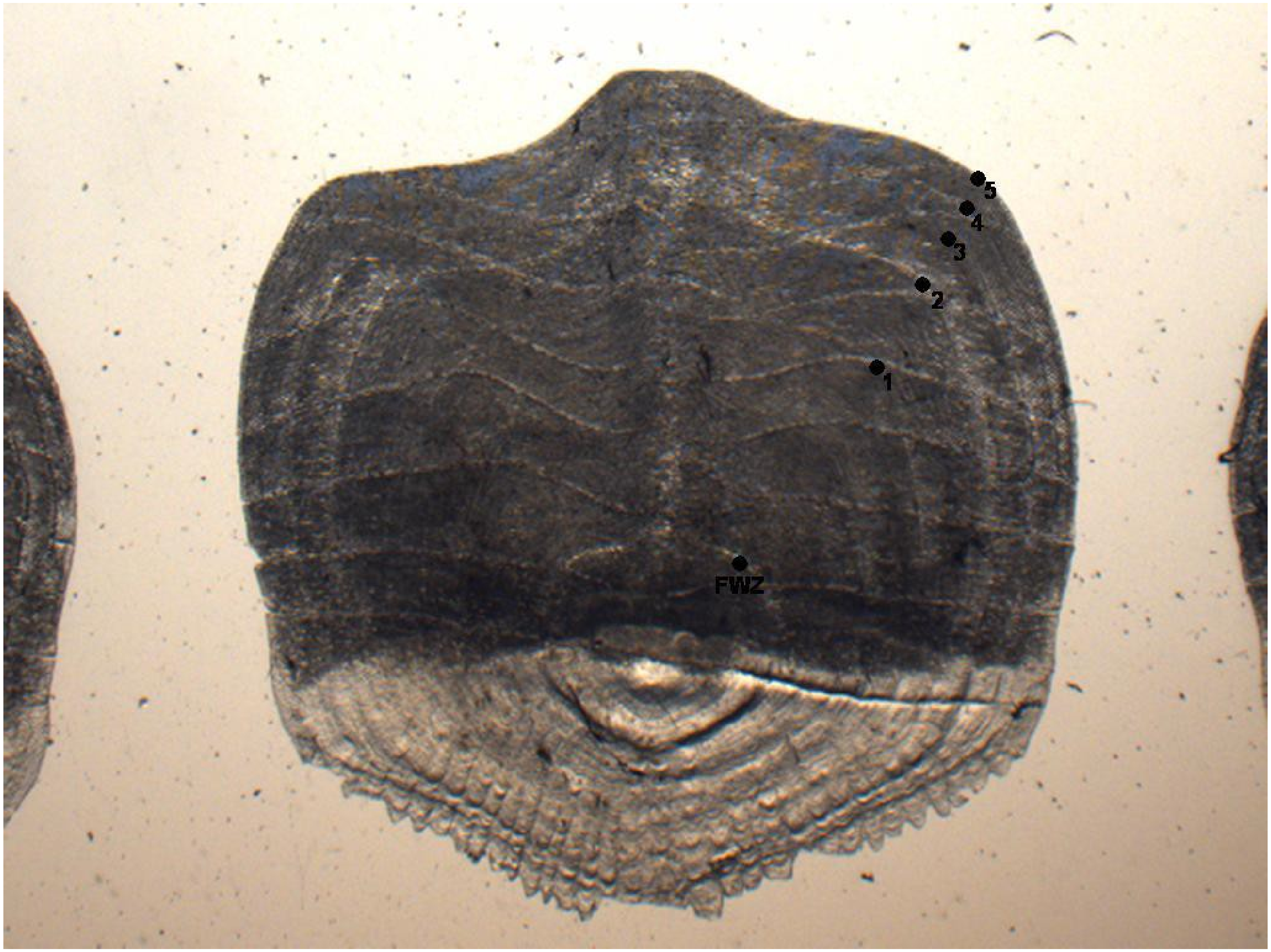


Figure 5. This five year old blueback has the typical strong second annulus.

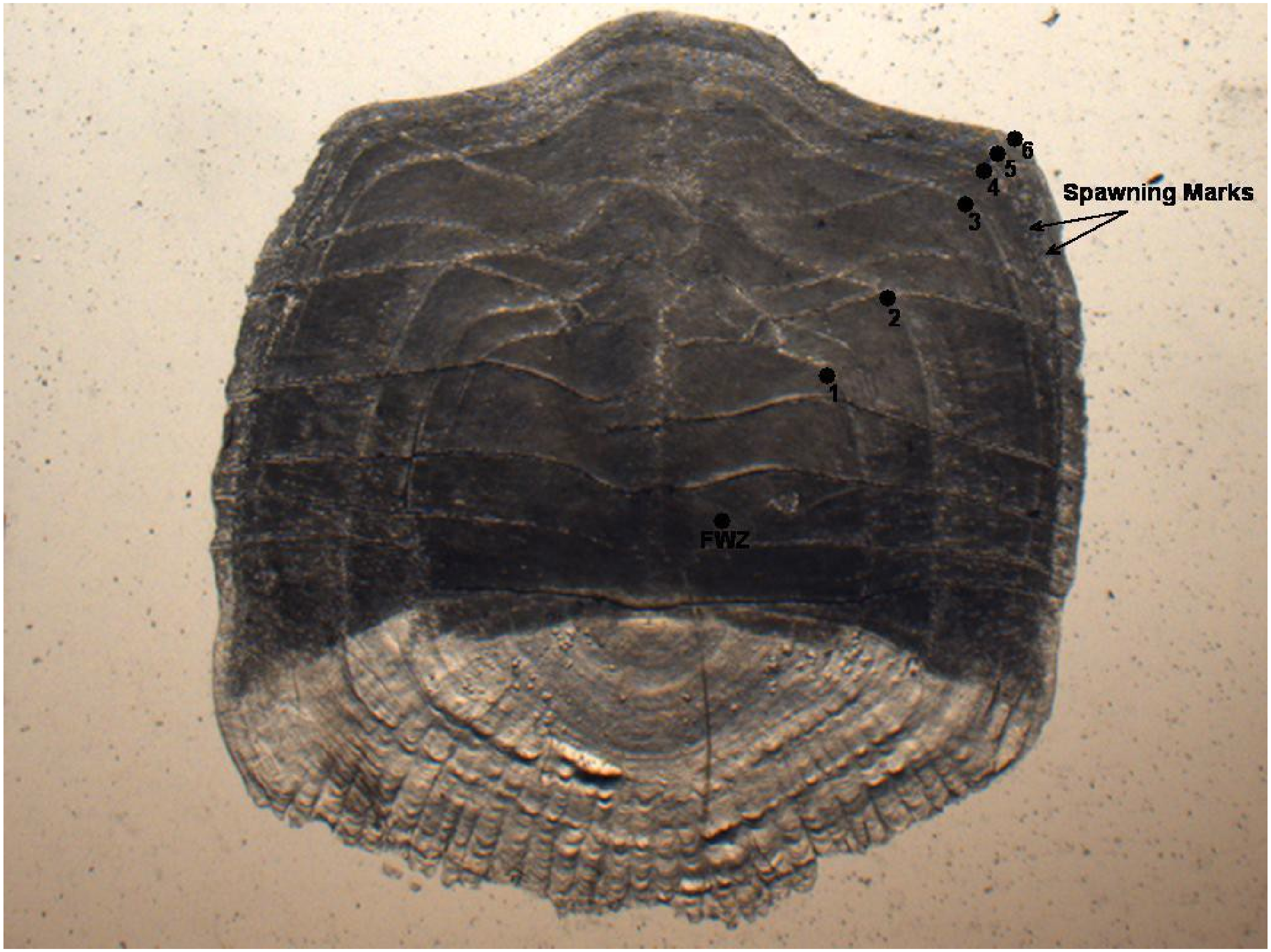


Figure 6. This six year old blueback has spawning marks at its 4th and 5th annuli.

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

March 2022

Table of Contents

List of Figures

List of Tables

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. Previous 10-years management were codified in the original 2012 Sustainable Fisheries Plan (2012 SFP) and subsequent update in 2017 (2017 SFP), both as approved by ASMFC. These plans were based on time-series relative benchmarks for population and fishery measures. The Co-op is seeking renewal of their Sustainable Fishing Plan (SFP) of the Delaware River American shad stock for the next 5-year cycle, 2022 – 2026. The proposed SFP retains all previously defined indices. An additional index was added to this updated plan to monitor total mortality of female American shad in the Delaware River. The total mortality of female American shad is based upon the 2020 ASMFC Stock Assessment (ASMFC 2020) methodology and associated benchmark. The Co-op judge these fisheries as sustainable while avoiding diminishing potential stock reproduction and recruitment as long as all six indices of stock condition remain within the defined benchmarks.

Currently the Delaware River American shad stock is experiencing unsustainable adult female mortality as determined in the 2020 ASMFC Stock Assessment (ASMFC 2020). The 2020 assessment found total mortality, determined by Z estimates, was 1.3 for the Delaware River Basin, which was above the benchmark of 1.07. Juvenile production as measured by juvenile abundance indices (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 the 50th percentile of the time series in three of the past five years. The non-tidal JAI has had two years of the past five that were higher than the 50th percentile of the time series. Measures of relative adult abundance at Smithfield Beach were suggestive of declining abundance in early 1990s followed by low but stable levels from 1999 to 2009. The 2020 ASMFC Stock Assessment found no trend in abundance for Smithfield Beach. The Smithfield Beach female CPUE has been above the 50th percentile of the time series for three of the past five years.

Commercial exploitation of the Delaware River American shad stock is permitted by the States of New Jersey and Delaware within the tidal and estuarine portions of the Basin. Harvest occurs generally during the spring spawning migration from late February into May principally using anchored or drift gill nets. In the 2012 SFP, the Co-op acknowledged that the commercial fishery in the Delaware Bay exploited American shad from mixed stock fisheries, along with Delaware River stock. In the 2017 SFP, the location of the demarcation line was from Bowers Beach, DE to Gandys Beach, NJ with 60% of landings assigned to the mixed stock south of the demarcation line. Additional genetic evaluation of the commercial catch since the 2017 has determined that the mixed stock is exploited throughout the entire fishery and the demarcation line was removed for this updated SFP. For this update SFP, 50% of all commercial catch will be assigned to the mixed stock, and the remaining will be assigned to landings on the Delaware River 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 50th percentile of the time-series since 2015.

Fishers in New Jersey represent a small directed fishery for American shad; whereas, landings of shad reported to the State of Delaware occur in the spring gill net 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 (2008-2019), 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. To reduce mortality on the Delaware River stock, quotas are being proposed for both Delaware and New Jersey and Delaware will also be implementing a gear modification (thicker twine size to 0.52-mm) in the SFP update. The proposed quotas represent a cap on landings set at approximately 33% reduction from the most recent 10-years, excluding 2014 as an anomalous year.

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. The 2020 ASMFC Stock Assessment found an increasing trend in adult abundance for the Lewis haul seine. Co-op members will continue to annually contract with the Lewis haul seine fishery for characterizing the American shad spring-time spawning migration, as the fishery represents a considerable time-series (1925 – present-day).

Historically, a substantial recreational fishery for shad existed in the non-tidal reaches of the Delaware River. Angler participation, effort, harvest, and their behaviors is unknown. Anecdotal reports suggest most shad anglers practice catch-and-release. The mortality associated with catch-and-release of shad in the Delaware River is unknown, but considered to be minimal based on studies in the Hudson River. The recreational creel limit is currently 3 American shad in the Delaware River, bay, and tidal tributaries. To reduce mortality on the Delaware River stock, the creel limit is being proposed to be reduced to 2 American shad in the SFP update.

In addition to harvest and natural mortality, the Co-op investigated other factors that may also impact the Delaware River stock. Flow management in the Delaware River is highly regulated, particularly in the upper portion of the Basin. Co-op members are active in management groups to ensure flow management is protective of American shad spawning and supports nursery habitat. Invasive species, such as northern snakehead, blue catfish, and flathead catfish are recent introductions to the basin that could potentially increase predation on American shad. 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. 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 main stem Delaware run above their respective confluences has been minimal. 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. Additional habitat alterations in the basin from dams and other barriers reduces access to spawning and nursery habitat for shad in tributaries to the Delaware River. Co-op members are actively working to support dam removals and improved fish passage in basin tributaries (see DRBFWMC 2021 and DeSalvo et al. 2022).

The Co-op proposes six benchmarks for sustainability. The benchmarks have been set to respond to any potential decline in stock on increased exploitation. Thus all benchmarks are viewed as conservative measures. Failure to meet the defined benchmark(s) trigger consideration of immediate management action. The severity of the action will be commensurate to the number of benchmarks exceeded. All benchmarks will be reviewed annually as part of the ASMFC Annual Compliance Report submission.

- **Total Mortality:** This index is calculated as the adult female total mortality $Z_{40\%}$ estimate. It is calculated from the three-year average female Z estimate from otoliths from Smithfield Beach. The benchmark is based on data from 2005 – 2017 and failure is defined as the three-year rolling average with values above a value of 1.07 (i.e., $Z_{40\%}$).

- **Non-tidal JAI:** This index is derived from the New Jersey Division of Fish and Wildlife (NJDFW)/Co-op annual fixed station seining in the non-tidal Delaware River main stem at Phillipsburg, Water Gap, and Milford. 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 2012-2019. Failure is defined as the occurrence of three out of five years where JAI values fall below a value of 188 (i.e., the 50^{th} percentile of the historical data).

- **Tidal JAI:** This index is derived from the NJDFW annual striped bass seining in the upper estuary. Only those stations from Newbold 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 – 2019. Failure is defined as the occurrence of three out of five years where JAI values fall below a value of 5.81 (i.e., the 50^{th} percentile of the historical data).

- **Adult CPUE:** This index is based on the annual geometric mean of female CPUE (shad/net-ft-hr) in the PFBC gill net, egg-collection effort at Smithfield Beach. The benchmark was based on sampling from 1996-2019, with failure defined as the occurrence of three out of five years where index values fall below a value of 0.52 (i.e., the 50th percentile of the historical data).

- **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 female survivors captured at Smithfield Beach (Adult CPUE index) divided by 100. The benchmark is based on data from 1996-2019 and failure is defined as the occurrence of three out of five years where values are above a value of 799 (i.e., the 50th percentile of historical data).

- **Mixed Stock Landings:** This index is calculated as the annual landings from the mixed stock fishery. It is calculated as 50% of total commercial shad landings combined reported to the states of Delaware and New Jersey. The benchmark is based on data from 1985 – 2019 and failure is defined as the occurrence of 2 consecutive years with values above a value of 18,505 pounds (i.e., the 25th percentile of historical data).

It is anticipated that this sustainability plan will reduce mortality on 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) had the first American Shad Sustainable Fishing Plan (SFP) accepted by the Atlantic States Marine Fisheries Commission (ASMFC) Policy Board in 2012 (2012 SFP) and an updated plan that was approved by the Board in 2017 (2017 SFP) for management use through 2021. This document (i.e., 2022 SFP) represents a revised SFP for governing management of American shad over the next five-year term, 2022 – 2026, 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 2017 SFP built upon the progress made during the tenure of the 2012 SFP including adding a mixed stock landings fishery benchmark to address the harvest of out of basin stocks in the lower bay fishery. During 2017 SFP tenure a new genetic sampling program was undertaken to help better inform managers of the stock structure of the lower bay landings and better define stock delineation for the mixed stock fishery benchmark. Additionally, for the 2017 SFP the non-tidal JAI was standardized using a GLM to account for environmental covariates during sampling and the benchmark and associated trigger are now based upon these standardized index values.

The 2022 SFP was updated to address the outcome of the ASMFC's 2020 American Shad Benchmark Stock Assessment which found American shad stocks to be depleted coast-wide with adult mortality within the Delaware Basin assessed as unsustainable. With these findings in mind, the Co-op chose to address the benchmark levels and associated triggers for all five of the benchmarks from the 2017 SFP as well as incorporating a new mortality benchmark based upon analyses conducted during the stock assessment. The changes in benchmark levels, management triggers, and the addition of the mortality-based benchmark represents an effort by the Co-op to more conservatively manage the American shad resource within the Delaware Basin in light of the 2020 assessment findings.

Status updates of monitoring programs supporting the 2022 SFP and associated benchmarks will be reported in annual compliance reports to ASMFC. Annual reports are jointly submitted by the Co-op.

1.1 Request for Fishery

The Co-op desires that the Shad and River Herring Management Board consider this request to approve a Sustainable Fishery Plan for American Shad of the Delaware River Basin. This plan includes a request for approval of both recreational and commercial harvest within the entirety of the main stem Delaware River and its tidal tributaries in the states of Delaware, New Jersey, New York, and Pennsylvania. 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, a ratio of landings to that index of spawning stock abundance, and a mixed stock fishery index. Benchmarks have been proposed for all indices to define levels needed to reduce mortality and avoid diminishing potential stock reproduction and recruitment. We will judge fisheries as sustainable if indices of stock condition remain within these benchmarks; otherwise, exceedance will necessitate corrective management actions. In light of the findings of the ASFMC's 2020 Stock Assessment, a female adult mortality index and associated benchmark value and management trigger has also been incorporated into the 2022 SFP.

2. Stock Status

2.1 Previous Assessments

The Delaware River was included in the 1988, 1998, 2007, and 2020 ASMFC coast-wide stock assessments for American shad (Gibson *et al*. 1988; ASMFC 1998, ASMFC 2007, ASMFC 2020). 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 2007 assessment found 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).

The most recent stock assessment was completed in 2020 (ASMFC 2020). The assessment used a modified Thompson-Bell spawning biomass per recruit (SBPR) model and weighted linear regression total mortality estimators to develop a total mortality estimate and Z_{40} threshold for the Delaware Basin. The assessment found that recent female adult mortality in the Delaware Basin (1.3) was above the established Z_{40} threshold of 1.07 (ASMFC 2020). Neither juvenile nor adult abundance could be determined due to conflicting trends in multiple data sets over the time series that were available for analysis.

2.2 Stock Monitoring Programs

2.2.1 Fishery Independent Surveys

2.2.1.1 Juvenile Abundance Surveys

In the tidal Delaware River, NJDFW collected data pertaining to young-of-year (YOY) American 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 from 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 Newbold 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. The tidal index is generated using the shad catches from Regions 2 and 3 during the months of August through October and is expressed as a catch per haul geometric mean. 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 and in 2020 sampling was not completed due to the COVID-19 pandemic.

The tidal JAI increased from 1980 through 1996 and the yearly index values have been highly variable since (Figure 2). Multiple strings of very good year classes followed by poor year classes have been observed through the entire time series with some of the best year classes and some of the worst year classes being observed in the last ten year of the time series. This highly variable nature suggests that year class strength may be more strongly influenced by external/environmental factors beyond adult abundance. This idea is further supported by the lack of correlation between the yearly adult and juvenile indices that are calculated for this SFP.

The tidal JAI will continue to be calculated as a GM of annual catch for the duration of the 2022 SFP.

The NJDFW conducted night-time beach seine sampling (300-ft x 12-ft bagless, knotless ¼-in delta mesh) targeting YOY American shad in the non-tidal Delaware River. Beginning in 1979, only a single site, Byram (RM 157.0), was sampled. Multiple additional sites were added in subsequent years, including Trenton (RM 131.6), Phillipsburg (RM 184.2), Water Gap (RM 210.0) and Milford Beach (RM 246.4), initiated in 1980, 1981, 1983, and 1988, respectively. The non-tidal seining was discontinued following the 2007 season. Justification was based on finding a significant correlation relating the non-tidal and tidal beach seining, suggesting that YOY shad abundance followed similar trends from both seine surveys.

Beginning in 2012, the Co-op reinitiated the NJDFW non-tidal beach seine survey for annual monitoring American shad YOY production. Four sites (Trenton, Phillipsburg, Water Gap, and Milford Beach) were annually surveyed following the original NJDFW protocols. Subsequent evaluation determined that catches from the Trenton fixed station did not significantly contribute to improved index performance (2017 SFP). Consequentially, the non-tidal JAI time-series index (1988-2007, 2012-2019) excluded catches from the Trenton station (2017 SFP). The present-day non-tidal index is composed only of the combined catches from Phillipsburg, Water Gap, and Milford fixed stations (i.e., informally referred to as the Big 3), as representative of the juvenile shad production for the non-tidal Delaware River. Sampling effort, however, remains on-going at all four of the traditional fixed stations.

Data standardization model development (i.e., generalized linear model, GLM) improved the precision and accuracy of the Big 3 JAI (2017 SFP). 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), with associated confidence limits. For the 2022 SFP, the non-tidal JAI will continue to 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 juvenile shad abundance from the non-tidal reaches of the Delaware River were highly variable annually (Figure 3). The top five ranked years in the Big 3 GLM estimates were 1996 (2^{nd}), 2007 (4^{th}), 2012 (3^{rd}), 2017 (1^{st}), and 2019 (5^{th}). The remaining years since 2012 (i.e., 2013 -2016) had GLM values ranging from 52.5-162.4, which were below the time-series average of 214.3. No sampling was accomplished in 2018 due to sustained high river conditions from rainfall, or in 2020 due to the COVID-19 pandemic. The highly variable nature of the non-tidal JAI suggests that environmental conditions strongly influence successful shad production and capture.

The upper Delaware Basin, above Port Jervis, NY (RM 254), represents considerable potential shad juvenile production. Additional fixed-stations were prosecuted with the intent for quantifying juvenile shad production relative to the Big 3. An initial site located at Lackawaxen (RM 277), implemented from 2012 to 2014, was discontinued due excessive submerged aquatic vegetation precluding effective seining. Alternative sites at Skinner's Falls (RM 295) and Fireman's Park (RM 0.5, East Branch Delaware River) were identified based on findings from a one-year synoptic survey conducted by the National Park Service (NPS) in 2015. Seining, following the original NJDFW protocols, for juvenile shad at these two stations were initiated in 2016 and continue to present date. Catches from these two up-basin stations are reported separately as geometric means and have not been incorporated into the Big 3 index.

Interpretation of geometric means of juvenile shad for the upper Delaware Basin remains tenuous, given only three years of data (2016-2017 and 2019) are available. The upper Delaware Basin sampling is not reflective of the Big 3 catches during the few years of sampling (Figure 4). During peak catches in the Big 3 in 2017, no juvenile shad were caught at Fireman's Launch and the Skinner's Falls catch (GM: 8 shad/haul) showed a decline from 2016 (40 shad/haul). River conditions likely influence catchability at the both upper Delaware Basin stations (i.e., river flow tends to collapse the net during deployment and retrieval). Yet, anecdotal observations suggest strong presence of juvenile shad at both stations. Co-op members will maintain sampling effort at these two upper Delaware Basin stations to establish a longer-term time-series for comparability.

The 2012 SFP found significant complimentary trends among the non-tidal and tidal JAIs. These relationships, to some extent, have since deteriorated. Previous relationships relied upon co-occurrences of peak year-classes, specifically 1996 and 2007 (Figure 5). Since 2012, the JAIs tended to demonstrate mismatched time-series peaks (1988-2019; Spearman's Rank: $r = 0.177$; $p = 0.377$). This recent disparity between the two indices suggests regional divergence of year-class production success.

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). To address the recent 2020 ASMFC Stock Assessment report, which indicated that the total mortality of the Delaware River Basin stock of adult American shad is unsustainable and Delaware Basin shad abundance is unknown, benchmark values for JAIs were made more conservative. Recruitment failure is now defined occurring when 3 out of 5 years of JAI values are lower than 50% of all other values in the time-series. The Co-op has adopted this definition for both the non-tidal and tidal JAI benchmarks. These are calculated as the 50th percentile, using the "quantile" function in the R package or "percentile.inc" function in Microsoft Excel spreadsheets. Years to be included in the benchmark calculation were determined by using years where sampling techniques and/or locations were standardized. The non-tidal benchmark includes years 1988 to 2019 and the tidal benchmark includes years 1987 to 2019.

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 is executed, such that captured shad represent survivors from the fishery. This effort is currently being accomplished at Smithfield Beach (RM 218) as a gill net survey on actively spawning adults and fish passage counts through fishways on the Lehigh and Schuylkill rivers.

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 PFBC restoration efforts in the Schuylkill and Lehigh rivers, the largest tributaries to the Delaware River. Night-time gill netting (8 - 20 nets per night, 4.0-in. – 6.0-in. stretch mesh, 200-ft x 6-ft) occurs when the river achieves consistent temperatures 16.0 – 21.0 ^{o}C which is typically the second week of May through the first week of June. The total number of net sets by mesh size per night depends on the previous nights' catch for maximizing female captures. Size selectivity from gill net gear is perceived as minor based on previous assessments (2017 SFP). Occurrences of entanglement can be as frequent as gilled shad. Likely the high rates of capture by entanglement contributes to all sizes of stretch mesh potentially capturing all sizes of shad. Historical collections were initiated in 1990, but biological data (length, weight, scale/otolith structures) were not recorded prior to 1996.

Total catch at Smithfield Beach varied among years (Figure 6). Greatest total numbers of captured shad occurred in 1995 (n = 1,398), with several other early years (i.e., 1990–1994, 1997-1998) in the time-series also having large total catches (> 1,000 individuals). Conversely, low shad catches (< 400 shad) also occurred in multiple years including 2002 (n = 400), 2006 (n = 356), 2009 (n = 372) and 2019 (n = 226). The observed low catch in 2019 was likely influenced by consistent high flows experienced for the duration of the 2019 season that prevented nets from hanging open and required an alternative deployment of directly setting nets adjacent (< 2-m) to the shoreline, rather than more mid-channel. The modified sampling procedure coupled with the high flow conditions likely resulted poor catchability throughout the 2019 season and sampling was likely a poor representation of population abundance.

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 7). The use of 4.5-in and 5.0-in 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. Nightly deployment of a single net of 4.0-in stretch mesh was initiated in 2016 targeting small shad observed routinely passing through the 4.5-in gill nets. A 4.0-in, 5.75-in, and 6.0-in stretch mesh nets were not deployed in 2019, however, due to limited shoreline availability without losing the net due to unfavorable river conditions. Use of large (≥ 5.5-in) stretch mesh sizes were not as commonly deployed as smaller stretch mesh sizes, due to the perceived lack of catch, during later years.

Most of the Smithfield Beach catch occurred in two stretch mesh sizes (Figure 8). The 5.0-in stretch mesh typically captured 27.0% to 58.4% of all females; however, in 2016 and 2017, the 4.75-in stretch mesh net caught the highest percentage (30.2% and 39.0%, respectively) of females in those years. Likely this was related to the increased deployment of the 4.75-in nets in those years. Female shad were routinely caught in all other stretch mesh sizes, but in lesser quantities. The 4.5-in stretch mesh typically captured 24.3% to 69.1% of all males. The 5.0-in and 4.75-in stretch mesh nets also captured some of the male total catch, 8.3% to 48.0% and 2.2% to 26.3%, respectively. The other larger stretch mesh sizes (> 5.25-in stretch mesh) caught few (< 10%) males whereas the use of the 4.0-in stretch mesh successfully captured small-sized males (9.4% to 27.1%) in 2016 to 2018.

Observed annual size distributions of captured shad varied among years for both female and male shad (Figure 9). Female total lengths ranged from 402-mm TL (2018) to 644-mm TL (2003), with median sizes between 516-mm TL (2010) to 571-mm TL (2003). 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 454-mm TL (2002).

The Delaware River American shad spawning population was supported by a few age classes as interpreted from otolith microstructures (Figure 10). Age 5 and Age 6 typically represented the majority (> 70%) of female shad, however, these two ages were not as strongly represented in 1997 (58%), 2004 (68%), 2006 (63%), 2012 (42%), 2014 (58%), and 2019 (19%). Ages 3 and 7, typically contributed less than 1% and 10%, respectively, in any given year, but in the aforementioned years, Age 7 female shad composed a greater portion (22% - 79%) of the observed ages. Ages 8 and 9 female shad were rare (<4%) occurrences. No female shad over Age 9 were observed.

Male shad were principally (>90%) represented by Age 4, Age 5, and Age 6 (Figure 10). Age 5 male shad were commonly represented (30%–86%); whereas, in many years Age 4 or Age 6 shad were prevalent. Young (i.e., Age 2 to 3) and older (i.e., Age 7 to 9 shad) were infrequent (< 10%) occurrences, excepting in 2012 and 2019 when Age 7 shad composed 19% and 57% of the male catch, respectively.

Application of annual age-length keys provides for the estimation of mean size-at-age. Annual total catch was parsed by stretch mesh size of capture to account influences associated with gill net selectivity and annual sampling variability of various mesh sizes. Least-square regressions of the time-series demonstrate significantly declining slopes for Age 5 and Age 6 female shad in the 4.5-in to 5.0-in stretch mesh sizes (Figure 11). Inferences of mean size-at-age for catches of female shad from mesh sizes 5.75-in to 6.0-in are tenuous given infrequent occurrence. Mean size-at-age were not investigated for male shad.

There is some evidence to suggest that female mean size-at-age is declining towards smaller sized shad (Figure 11). These declining trends are likely a shift in the population, given the perceived minor influence of gill net selectivity upon female shad capture. In later years 2011 – 2019, older (i.e., > Age 6), and presumably larger sized female shad, tended to have a greater contribution to the total catch. The observed declining trend is contrary to that assumption. However, error associated with age estimation from otolith microstructure has not been evaluated. Co-op members anticipate developing otolith age estimation protocols over the duration of this Plan. The Co-op recognizes the significance of a declining trend in female mean size-at-age, and will continue to monitor this trend.

In previous SFPs, 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). Female Z estimates ranged from 0.81 (2006) to 2.87 (2012).

The 2022 SFP incorporates analyses from the 2020 Stock Assessment that used a modified Thompson-Bell female spawning stock biomass per recruit (SBPR) model and weighted linear regression total mortality estimators to develop a total mortality estimate and Z_{40} threshold for the Delaware Basin (see sections 2.5 and 2.6; ASMFC 2020). After a thorough analysis of available data, it was determined that female specific ages derived from otoliths collected at Smithfield Beach provided the best quality and quantity of data for assessing adult mortality. Final Z estimates for comparison against per-recruit reference points are provided as running three-year averages to smooth variability of annual estimates from a combination of factors explored through preliminary analysis (e.g., sampling error, recruitment variation) (Figure 12).

The three-year average female estimate from otoliths in 2017 (1.3) was above the benchmark (1.07) and the average standard error for this estimate was 0.49 (ASMFC 2020). There were no female data available from otoliths in 2018 precluding estimation of a three-year average for females in 2019 from this data set.

Catch-per-unit-effort (CPUE), represented as geometric means (GM), provides relative population trends for spawning adults at Smithfield Beach. Total CPUE (females & males, combined) annual values varied (0.23–3.98 shad/net-hour) among the time-series (Figure 13). Peak abundances were observed prior to 1993 (> 2.0 shad/net-hours); after which CPUE varied 0.23–1.59 shad/net-hours. Refinement of CPUE was accomplished to focus on female catch only, (Figure 13). The intent was a perceived improved benchmark for assessing trends of available spawning stock. Trends of female-only GM demonstrated similar patterns as the total combined CPUE, with values varying 0.21–1.07 shad/net-hours for the time-series (1996–2019). In recent years, 2016–2019, annual GM values either ranked poorly (2016: 17th; 2019: 23rd) or placed in the top ten (2017: 10th, 2018: 4th) in the time-series.

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.

2.2.1.2.2 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 stocking fry through a hatchery program. Fish passage monitoring exists for the Lehigh and Schuylkill rivers, but passage into many other Delaware River tributaries is unknown.

The PFBC and Philadelphia Water Department (PWD) maintain an extended monitoring time-series, characterizing total shad passage into the Lehigh River and Schuylkill rivers from the Delaware River (Figure 14). Passage is estimated from video surveillance at the Easton fishway on the Lehigh (RM 0.0) from 1995 to 2012 and at the Fairmount fishway on the Schuylkill (RM 8.4) from 2004 to 2019. After 2012, surveillance was discontinued at the Easton fishway, and was replaced using a predictive regression relationship between total passage and a one-day electrofishing survey developed from concurrent years monitored (1996–2012).

Peak passage years in the Lehigh River were identified for 2002, 1998, 2017, 2000, and 2013 respectively and 2011, 2012, 2016, 2010, and 2009 in the Schuylkill River, representing the top five years with the greatest total passage (Figure 14). No significant correlations (Pearson's: $p > 0.05$) were found between either river total passage to Smithfield Beach (female-only GM).

The lack of relationship between the Lehigh and Schuylkill rivers shad passages suggests shad runs into these rivers are not representative of the Delaware River spawning run. Co-op members agreed that Easton and Fairmount fish passage data 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.

2.2.1.2.3 Comparison of JAI to adult indices

The two previous SFPs (2012 & 2017) attempted to explore any correlations between adult relative abundance and year class strength (juvenile production) in any given year. No obvious correlation or relationship was determined to exist. The lack of a correlation and highly variable nature of the yearly juvenile abundance indices suggests that year class strength may be more strongly influenced by external/environmental factors beyond adult abundance.

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 staked, 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 in the spring gill net fishery, which targets striped bass.

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 (Figure 15). The fishery has evolved from a commercial fishery to an eco-tourism enterprise that resulted in changes to the length of net used. The fishery employed seine nets of different length depending on the water flow and height over the years. Although this may be problematic, the length of the time series still gives a good indication of spawning run strength in the Delaware River (ASMFC 2007). Since 2012, this fishery has been contractually supported by Co-op members ($6,000 annually). Requirements included a minimum of 33 days fishing in the traditional style and time-period (mid-March through June) along with reporting biological data (length, weight, scale sample) for all harvested shad to maintain the integrity of the time-series. Investigation of biological parameters of harvested shad by the Lewis haul seine have not been pursued.

The Lewis haul seine provides an index of the Delaware River American shad adult spawning run. Catches in 1963, 1981, 1989, 1992 and 1988 represent the top five highest recorded abundances of shad, respectively. In recent years, catches observed in 2013 (CPUE = 26.6

shad/haul) and 2017 (CPUE = 29.3 shad/haul) represented high relative abundance, ranking 11th and 9th overall in the 95-year time-series. No significant correlation (Pearson's: $p = 0.116$) was found between the Lewis haul seine (CPUE) and Smithfield Beach (female-only GM). Despite the apparent disparity between these indices, Co-op members will continue contracting with the Lewis haul seine. Reported CPUE by the Lewis haul seine offers insight into shad relative abundance in the lower reaches of the Delaware River that may otherwise not be documented.

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 reporting forms 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 with mesh sizes between five and six inches typically being fished. In the past, American shad were primarily landed by drifting gill nets in the Upper Bay/River fishery while staked and anchored gill nets accounted for the majority of shad being landed in the Lower Bay. This distinct separation of gear deployed by general area is not as strong in the recent past as participation in the fishery has declined due to attrition and effort is much less consistent.

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 1). A haul seine can also be used to harvest American shad from November 1 to April 30. The seine must have a 2.75-inch minimum stretch mesh and maximum length of 420 feet.

Fishery Participation: In New Jersey, as of February, 2022, there were 70 permits issued 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 43 of these permits are active (28 commercial and 15 incidental), due to attrition (Table 2). 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 2012 this number has averaged around nine fisherman landing shad in the Delaware Bay (range of 9-13). The number of fishers landing shad in New Jersey is expected to continue to decrease as the current fishers age out of the fishery and interest in the fishery itself continues to decline.

Landings: Harvest of American shad by region in New Jersey has seen a shift from historically being a predominantly Lower Bay fishery (below Gandys Beach) to an Upper Bay/River fishery and a significant decrease due lack of effort and fisher participation. 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. From 2001 through 2016 this trend reversed with Lower Bay landings averaging 11,558 pounds and the Upper Bay/River fishery landing an average of 35,358 pounds of shad. Since 2017 the landings have been relatively evenly split with the Lower Bay averaging 5,612 pounds and the Upper Bay/River fishery averaging 5,160 pounds of shad landed (Figure 16).

Fishing Effort: Effort data for New Jersey's commercial fishery is estimated from CPUE presented in pounds per square foot of netting (Table 3). Overall effort in New Jersey has decreased more than 50 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). 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 4). 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, Figure 17). 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 two general areas of the bay, Upper or Lower Delaware Bay as delineated fisheries occurring above or below Bowers Beach, Delaware. 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 5). 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 the southern shore of the Appoquinimink River 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 119 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 6). 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: Beginning in 1985, the State of Delaware required mandatory reporting of commercial landings under the provisions enacted by the Delaware General Assembly in 1984. Every fisherman holding a commercial food-fishing license was required to submit a monthly report specifying where he fished, the type and amount of fishing gear deployed, and the pounds landed of each species taken for each day fished. Commercial landings of American shad in Delaware occur in the concurrent striped bass fishery.

Harvest of American shad by region in Delaware was not reported until 2002. Since 2002 landings in the Upper Bay/River have averaged 24,082 pounds while the Lower Bay landings averaged 9,176 pounds annually (Figure 18).

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 was high from 1985-1988 and then has been at a consistently less than 0.5 pounds per net yard fish since 1989, with the exception of an increase in CPUE in 2014 (Figure 19). Shad is no longer the target species of the spring gill net fishery. 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 2003 to 2019 (Figure 20). Effort has generally decreased throughout the time series with effort peaking in the upper bay and river fishery in 2005 and the lower bay fishery in 2007.

Biological Data: Biological data collected by the State of Delaware were gathered from Delaware and New Jersey commercial fisher's landing catches from Delaware Bay. The State of Delaware collects information on length (mm), weight (lbs), and sex from the commercial fisher's landings (Table 7). Scale samples have been collected from these landings, but have not yet been processed for age estimation.

2.2.2.1.4 Determining Exploitation of the Delaware River American Shad Stock

Recent combined commercial landings (1985–2020) from the Upper Delaware Bay and River and Lower Delaware Bay are shown in Figure 21. State landings are considered reliable following the implementation of mandatory reporting in 1985 in Delaware and 2000 in New Jersey. Combined landings for Delaware and New Jersey have declined from a peak of 637,968 pounds in 1990 to a low of 704 pounds in 2020. Landings have been relatively low since 2010, with a peak in 2014 of 128,172 pounds (Figure 21). The main causative factors for the lower landings in the past decade in Delaware include regulatory action (limited entry), attrition in the fisheries, and reportedly low market value of shad, based on Delaware ex-vessel reports ($/lb = 0.75 in 2020; Figure 22), increased mesh size (7" stretch mesh) preferred by Delaware gill netters targeting larger striped bass, and increased abundance of striped bass. Average American shad landings in New Jersey continue to decline as fisherman age out of the fishery and the market for shad continues to wane. The yearly effort and number of fishermen landing American shad from the Delaware Bay New Jersey has declined significantly since the closure of the ocean intercept fishery in 2005.

New Jersey gill netters who target shad express concern 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.

Based on the 2020 Stock Assessment on American shad completed by the Atlantic States Marine Fisheries Commission, the adult total mortality rate of the Delaware River stock is considered unsustainable and there are conflicting trends (no trend and increasing trend) in adult abundance indices.

The Co-op used a ratio of commercial harvest to the geometric mean (GM) of female shad CPUE at Smithfield Beach (landings/GM, scaled by 100) from 1996-2019 to track how landings of the

Delaware River stock are reflected in the upstream adult abundance surveys each year. Total landings of the Delaware River stock were calculated using 50% of the entire commercial landings for each state (see section 2.2.2.1.5 for additional information on determining the proportion and location of Delaware River stock versus mixed coastal stock in the fishery).

A comparison of the landings to gill net GMs of female shad CPUE at Smithfield Beach shows a similar trend between the fishery and a measure of escapement from the upper Delaware until 2009, when lower harvest equated with higher GMs at Smithfield Beach (Figure 23). The ratio of commercial harvest/GM from Smithfield Beach ranged from 389 to 3,161 from 1996-2009 and was in a generally declining trend (Figure 24). From 2010-2019, the ratio ranged from 101 to 944 and remained relatively unchanged during that time period with the exception of an increase in 2014 as a result of high shad commercial landings that year.

2.2.2.1.5 Commercial Landings on Mixed Stock Fisheries

American shad occurring in the Delaware Basin are represented by both Delaware River origin fish as well as fish from multiple other coastal river stocks. The commercial fisheries operating within the Delaware Bay and lower Delaware River of Delaware and New Jersey land shad from the Delaware River stock as well as other coastal stocks and that the fishery directly impacts other coastal shad populations. To determine the proportion that other coastal river stocks are represented in the Delaware Basin landings, tag recaptures and recent genetics studies were considered.

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 conducted at Reed's Beach located in Cape May County, approximately 10 to 15 miles from ocean waters (Figure 25). This program uses drifting gill nets of 5.5-in to 6-in stretch mesh during March through May of each year. In the program, 4,508 American shad were tagged from 1995 to 2020 (Table 8). In recent years sampling yielded few American shad, with fewer than 100 shad tagged annually in the past 15 years. Through 2020, there have been 251 American shad returns reported (5.6% of tagged fish). The tag return data indicate that 60% of shad tagged this portion of Delaware Bay are recaptured outside of the Delaware Basin. Reported recaptures ranged from the Santee River in South Carolina to the St. Lawrence River near Quebec, Canada with the majority of non-Delaware Basin reports coming from Hudson, and Connecticut Rivers (Table 9).

A separate study using genetic analysis of microsatellite nuclear DNA was conducted in 2009 and 2010 to determine American shad stock composition (Waldman *et al*. 2014). Although samples were collected in 2009, they were only evaluated for a two-stock composition (Delaware/Hudson) and results were not comparable to the author's 2010 analysis or the more recent collections and analysis by U.S. Fish and Wildlife Service (USFWS), therefore the 2009 data were not considered in the development of this plan. For 2010, stock composition was determined from American shad collected in Maurice Cove, NJ (RM 21, n = 31) and off Big Stone Beach, DE (n=191, RM 14; Figure 25). Stock composition estimates for 33 baseline populations indicated that 76% of the sampled fish in this study were of non-Delaware River origin (Table 10).

In 2017, the USFWS, in cooperation with Co-op members began collecting tissue samples from American shad caught in the commercial fishery and Co-op member's fishery-independent sampling in the Delaware River Basin to determine stock origin from 2017-2020 (Bartron and Prasko 2021). Genetic analysis was similar to the work reported in Waldman et al. 2014. A total of 14 baseline populations were evaluated from Maine to South Carolina as well as three locations in the Delaware River (Smithfield Beach, Lambertville, and Schuylkill River) and four regions covering the geographic range of the commercial fishery in lower Delaware River and Delaware Bay. These regions were delineated by Lower Bay (south of a line from Bowers Beach, DE to Egg Island Point, NJ), Mid-Bay (south of a line from Port Mahon, DE to Gandys Beach, NJ), Upper Bay (south of a line Collins Beach, DE to Mad Horse Creek, NJ), and Delaware River (all locations north of the Upper Bay region; Figure 25). In the Delaware River samples (n=368), there was some degree of other coastal stocks being represented (30%-42%, Table 11). These assignments were lower than samples collected from the commercial fishery in the lower River and Delaware Bay (Table 11). A total of 584 samples were collected between the four regions of the commercial fishery over the 4-year study. The proportion of fish assigned to a non-Delaware River stock in the fishery from the lower River and Bay ranged from 48% to 54% across the four geographic regions (Table 11).

The 2012 Sustainable Fishing Plan (SFP) acknowledged the occurrence of fish from other coastal shad stocks in the Delaware Bay harvest. At the time, it was assumed that only fish from the lower Bay had some representation from other coastal stocks, and a demarcation line was 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, to represent the uppermost extent of which other coastal stocks ascended into Delaware Bay. This demarcation line was derived based on mark-recapture data from the NJDFW tagging program and formed the basis for assigning (i.e., as a proportion) the commercial harvest in the lower Bay to the 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 demarcation point on the Delaware shoreline was changed to better reflect how landings are reported in that state and updated tagging data and genetics results from Waldman et al. (2014) were also considered. The demarcation line in the 2017 SFP extended from Gandys Beach, NJ to Bowers Beach, DE (RM 23). Using the recapture proportion from the NJDFW tagging studies, all landings north of the updated demarcation line were considered 100% Delaware River stock. South of the demarcation line, 40% of landings were be assigned to the Delaware River stock and the remaining 60% of landings assigned to the mixed stock.

During the development of the 2017 SFP, there was an acknowledgement by the Co-op that additional genetic studies were necessary to evaluate the geographic extent to which the mixed stock was being exploited in the commercial fishery of the Delaware Bay and lower Delaware River in Delaware and New Jersey. In particular, there were uncertainties to the degree to which the mixed stock was exploited in the mid-Bay, upper Bay and lower Delaware River. In the USFWS study (Bartron and Prasko 2021) that sampled all four regions where the commercial fishery is executed, the proportion of the landings that were composed of non-Delaware (mixed stock) origin was similar across all regions, representing about half (50%) of all landings in the Delaware Bay and lower Delaware River. This new study suggests that the entire commercial fishery exploits shad from the mixed stock and of relatively equal proportion across the geographic range of the fishery. This study also suggests that there is not a clear demarcation line in the Delaware Bay to discriminate landings for assigning to the Delaware River stock versus other coastal stocks (mixed stocks). This was the first study to evaluate stock origin from the commercial fishery upstream from the lower Delaware Bay and provides evidence that previous demarcation lines in the Delaware Bay are not appropriate when describing the geographic extent of the impacts of the existing commercial fishery on shad of mixed stock origin. For this reason, the Co-op is recommending removal of any in-basin demarcation lines for the commercial fishery in Delaware and New Jersey.

The Co-op is sensitive to the potential impacts on East Coast shad stocks from the commercial fishery in the Delaware Bay and lower Delaware River. With the improved data available for the development of the 2022 SFP, the Co-op is modifying its assignment procedure for proportioning landings to the mixed stock. Moving forward, 50% of all commercial landings in Delaware and New Jersey from the Delaware Bay and lower Delaware River will be assigned to the mixed stock fishery.

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. In the 2017 SFP, the Co-op established a benchmark that explicitly managed the harvest on the mixed stock. The benchmark was based on the total pounds landed from the mixed stock, which consists of 60% of the landings south of the demarcation line from Bowers Beach, DE to Gandys Beach, NJ. The benchmark was defined as the 75th percentile of landings from 1985-2015 where 25% of values are higher (47,650 lbs.). The benchmark was updated for 2022 SFP to reflect more recent genetics information (see section 3.1.6).

The Co-op will continue to annually monitor landings in the Delaware Bay to ensure any significant increase in harvest results in increased regulatory control for keeping exploitation at current levels. Overall, mixed stock landings have been declining since mandatory reporting was enacted by both the States of Delaware and New Jersey (Figure 26).

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). Brandywine Creek supports the only notable recreational American shad fishery in Delaware's portion of the Delaware Estuary. It is a modest fishery that primarily occurs at the first blockage encountered upstream.

Historical participation in the recreational shad fishery has fluctuated but overall, angler effort has declined. 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). 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 12). The excessively high (> 50%) percent standard error estimates (PSE) suggest 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 NPS - Upper Delaware Scenic & Recreational River (UPDE), 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). The diary program was considered unrepresentative of the Delaware River recreational shad fishery. Essentially, only the licensed guides by UPDE, routinely reported trip/catch information, who were more focused on the tailwater trout fishery than shad. Furthermore, in most years, no information was available from participating anglers in downriver reaches (RM 133–303) below the UPDE, where the recreational shad fishery is principally focused.

The Delaware River Shad Fisherman's Association (DRSFA) represents the single largest club specifically focused on the Delaware River American shad. It is unknown the extent that DRSFA members release or harvest shad catches. The DRSFA also promotes an angler log, but these records have not been made available to Co-op members. Statements concerning American shad restoration and conservation are described on DRSFA's website (https://www.drsfa.org/).

Historically, annual shad tournaments within the Delaware River have been organized by various enthusiasts and clubs over the past several decades. Permitting and catch reporting by tournament organizers is required by the basin states; yet, available information regarding shad tournaments is inconsistent. Present-day, tournament shad fishing is best represented by the annual Bi-state Shad Fishing Contest, launched in 2011. This tournament draws exceptional angler participation offering large monetary prize rewards among various categories. Participating anglers in the Bi-state tournament typically focus shad fishing in the middle and lower reaches of the Delaware River. Other award-centric tournaments also occur during the springtime shad run, but generally tend towards fewer participants and remain localized to a specific reach.

Shad tournaments typically remain harvest-oriented for determining participant success (i.e., largest shad, etc.) and assignment of any accolades. Annual estimation of total harvest by tournament participation is unknown. Tournament organizers, however, generally maintain up-to-date on-line leaderboards, allowing participants to real-time check if caught shad can place; otherwise, anglers are able to catch-and-release shad, rather than culling harvested fish. Quantification of any reduction of overall tournament harvesting of shad related to this practice is unknown.

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^{o}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 20 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 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. Furthermore, the presumption tournament shad fishing is of minor consequence to the Delaware River shad population remains unsupported. The lack of reliable, routinely collected data on recreational use and harvest, precludes compilation of more robust stock assessments.

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; except in 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) Delaware River flow management, (2) invasive species interactions, (3) potential effects from overfishing and ocean bycatch, (4) impacts of restoration stocking, (5) impingement and entrainment, and (6) habitat alteration.

2.3.1 Delaware River Flow Management

The Delaware River is an important source of drinking water, industrial water supply, power generation, and supports fishing and other recreational uses. The river also supports a diverse suite of aquatic life, including many fish species, such as American shad. Water flow is highly regulated in the Delaware River Basin and management is designed to support the many dependent users of the resource. Flow releases from the upper Basin, at the Cannonsville, Pepacton, and Neversink reservoirs, are managed by New York City as part of their city's water supply system, and releases are designed to achieve flow targets on the Delaware River at Montague. Hydroelectric projects, such as those in the Mongaup River and at Lake Wallenpaupack also influence river flows in the Delaware River and their respective tributaries. Other basin reservoirs, including Jadwin, Prompton, F.E. Walter, Beltzville, Blue Marsh, Nockamixon, Merrill Creek can also be used to help achieve flow targets in the Delaware River at Trenton, which help manage the location of the salt front in the estuary and provide flood control.

Flow management in the Delaware River Basin can have a direct impact on spawning success and juvenile survival of American shad as well as impact other aquatic species in the basin. A Flexible Flow Management Program (FFMP 2017) was developed to direct releases from the New York City reservoirs in the upper basin. The FFMP ensures that minimum releases occur at each of the reservoirs, provides a mitigated step-down strategy when releases are directed to change dramatically to ensure areas of the river are not inadvertently dewatered, and also provides cold-water releases in the summer months to help protect the trout fishery in the upper basin. Releases from the hydroelectric facilities are also managed to support cold-water fisheries and help protect dewatering events in the respective tributaries as well as the main stem river. The Co-op will continue to work with the many different regulatory bodies in the Basin to ensure continued and improved water management strategies for American shad and other aquatic resources.

2.3.2 Invasive Species Interactions

Several aquatic invasive fish species are becoming more established in the Delaware River system that could have negative impacts on the American shad population. Northern snakehead (*Channa argus*), flathead catfish (*Pylodictis olivaris*), and blue catfish (*Ictalurus furcatus*) are larger predatory species that have been documented or could potentially prey on adult and juvenile American shad.

Northern snakehead were first reported from the Delaware River Basin in the Schuylkill River in 2004 and have recently spread as far as the New York portion of the watershed (https://nas.er.usgs.gov/queries/factsheet.aspx?speciesid=2265, last accessed September 22, 2021) Although large northern snakehead could potentially predate adult American shad, that has not been documented in the literature. Predation on juvenile shad has also not been documented, but is more likely to occur. Juvenile alewife and blueback herring have been documented in the gut contents of northern snakehead in Virginia rivers (Isel and Odenkirk 2019).

Flathead catfish were first documented in the Schuylkill River system, in the Blue Marsh Reservoir, as early as 1997 (https://nas.er.usgs.gov/viewer/omap.aspx?SpeciesID=750, last accessed September 22, 2021). The species is prevalent in the Schuylkill River system and has been reported from the main stem as far north as Narrowsburg Pool in New York. Flathead catfish have been known to prey on both juvenile and adult American shad and selectively target shad during the spring spawning migration (Pine et al. 2005, Schmitt et al. 2017).

Blue catfish, a more recent invader to the Delaware River Basin, were first reported from the Christina River in 2013 and are currently only found in the lower river. Blue catfish can reach a large size and are also known to prey on American shad, but likely not as selectively as flathead catfish (Schmitt et al. 2017)

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.

2.3.3.1 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.

The 2020 ASMFC Stock Assessment for American Shad (see section 4.1.4; ASMFC, 2020) provides a detailed assessment of incidental ocean catch following methods described in the most recent River Herring Stock Assessment (ASMFC 2017) which were developed for the FMPs described above. The entire analysis is not presented here, but key results are summarized below:

- From 1989-2017, the total annual incidental catch of American shad ranged from 42 – 262 metric tons, averaging 64 metric tons since 2010.
- Catches of American shad were greater in New England than in the mid-Atlantic, though the contribution of each region varied among years.
- American shad catches occurred primarily in large-mesh gill nets, small-mesh bottom trawls and paired midwater trawls. The contribution of each gear type varied by year.
- The majority of catch in small-mesh bottom trawls and large-mesh gill nets is discarded. Most catch from midwater trawls is retained.
- The size distribution of observed American shad varied by gear.
  - Bottom trawl. Range: 10-77cm. Mode: 26cm.
  - Gill nets. Range: 14-76cm. Mode: 47cm.
  - Midwater trawl. Range: 13-51cm. Mode: 25cm.
- Catch estimates represent total catch (retained + discarded) of American shad in U.S. oceanic and state waters. Catch estimates can be attributed to a specific fishing fleet but cannot be attributed to a specific fishery because species managed through multiple fishery management plans are often caught on one fishing event.
- Stock determination of incidental catch has not been conducted.

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 13). 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 to 2008). Egg-take operations on the Delaware River have resulted in the use of an average of 741 adult shad brood fish per year (1996–2019). 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 14), 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 hatchery-stocked shad are returning to their natal river of either tributary. The poor catches of marked shad at Smithfield Beach suggest straying is not a frequent occurrence.

Self-sustaining shad spawning runs in to the Lehigh and Schuylkill rivers originally envisioned (i.e., >100,000 fishes; PFBC 1988) have not materialized after 35 years of restoration efforts. It is the conclusion of PFBC that American shad passage into the Lehigh and Schuylkill rivers is insufficient and inadequate to achieve the original restoration goals. 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 on the Lehigh River. 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). To date, the owners have not expressed interest in pursuing dam removal. Yet without annual maintenance fry shad stockings, any future spawning runs into either tributary would most likely be nominal. The PFBC will continue annual shad fry stockings to maintain *status quo* of present-day spawning runs. Yet, Co-op members will continue to investigate alternatives for returning shad to historical spawning ranges.

2.3.5 Impingement and Entrainment

Power generating facilities, refineries, and other industries rely on withdrawal of surface water from the Delaware River and tributaries to cool their industrial processes, with most industrial water withdrawals requiring continuous once-through use of water. This withdrawal results in fish and other aquatic organisms either becoming trapped against the intake screens (impingement) or taken further into the cooling system (entrainment). Both impingement and entrainment can result in the death of fish and other organisms. 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 impingement and entrainment are ongoing throughout the calendar year.

There are several large water intake systems at energy projects on in the Delaware River Basin. In recent years, some coal-fired plants have closed or been converted to more efficient energy generating stations. Although impingement and entrainment impacts to fish populations, including American shad, are thought to be significant at the remaining facilities, additional assessment of current operations and impacts need to be evaluated for intake systems in the Basin.

2.3.6 Habitat Alteration

Although American shad and other migratory fish have access to the entire main stem river and far up into its headwaters, issues with water quality and access to spawning and nursery habitat in the tributaries are still being addressed. Dam construction and pollution starting in the 1800s had a significant impact on the shad population in the Delaware Basin. Although main stem dams no longer exist and significant water quality improvements have occurred since the

1940s, habitat alteration continues to influence American shad populations. Over 1,500 dams still exist in the Delaware River Basin that preclude access to spawning and nursery habitat for American shad (DRBFWMC 2021). The Nature Conservancy has recently released a report to prioritize dams for removal or fish passage to benefit American shad and river herring in the Delaware River Basin (DeSalvo et al. 2022). Dam removals have occurred in the Basin and are several more are planned in the near future, improving access to historic habitats.

American eel weirs are still operational in the upper Delaware River Basin and can impact upstream and downstream migration of American shad. The impact to migration is thought to be minimal, but historically, it was recognized that the downstream traps on the eel weirs may cause mortality on juvenile American shad migrating downstream.

The Delaware River watershed spans nearly 13,000 square miles in the mid-Atlantic region and the Delaware River and tributaries provide drinking water to over 5% of the U.S. population. The watershed has a range of habitats ranging from heavily forested areas to highly urbanized areas. The landscape in the watershed has changed through time, with a 10% increase in developed land and decrease of 2% for forested land from the period of 1996-2010 (PDE 2017). The loss of forested habitat and increase in development likely has impacts on the water quality and water quantity in the Delaware River basin and may impact on American shad reproduction and juvenile survival, although those impacts have not been quantified.

3. Sustainable Fishery Benchmarks and Management Actions

The Co-op proposes a series of relative indices for monitoring trends in the American shad population in the Delaware River Basin. The benchmarks were derived to allow the existing fishery to continue. The benchmarks have been set to respond to any potential decline in stock. Thus all benchmarks are viewed as conservative measures. The benchmark measures for maintaining sustainability are in order of their importance as follows:

1. Female Total Mortality
2. Non-tidal juvenile abundance index (JAI)
3. Tidal juvenile abundance index (JAI)
4. Smithfield Beach female adult catch-per-unit-effort (CPUE) survey
5. Commercial harvest to Smithfield Beach relative abundance ratio
6. Mixed stock landings

3.1 Benchmarks

3.1.1 Female Total Mortality

One of the objectives of Amendment 3 to the Interstate Fishery Management Plan for Shad and River Herring (ASMFC 2010) is to maintain total mortality of stocks at or below stock assessment benchmarks. The female total mortality Z_{40} benchmark developed for the Delaware River in the 2020 assessment is 1.07 (ASMFC 2020). The three-year average female Z estimate from otoliths in 2017 (1.3) was above the benchmark (1.07), therefore; mortality was determined to be unsustainable. Due to data limitations in 2018, the current three-year average Z is unavailable for this update, however; annual Z estimates since the completion of the assessment indicate a continued need to reduce mortality (Table 15, Figure 12).

3.1.2 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 1988-2019 (Table 16, Figure 27). Failure is defined as the occurrence of three out of five years where JAI values are below the 50th percentile from the reference period (188). Exceeding the benchmark will trigger management action. The period of 1988 to 2019 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 and in 2018. The non-tidal JAI fell below the benchmark most recently between 2013 and 2016.

3.1.3 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 1987-2019 (Table 17, Figure 28). Failure is defined as the occurrence of three out of five years where JAI values are below the 50th percentile of the reference period (5.81). Exceeding the benchmark will trigger management action. The period of 1987 to 2019 was selected as these encompass the years when sampling methodology was consistent among stations. The tidal JAI fell below the benchmark most recently in 2012, 2016, and 2019.

3.1.4 Smithfield Beach CPUE Index

This index is based on the annual GM of the CPUE (shad/net-ft-hr) of female shad in the PFBC egg-collection effort at Smithfield Beach and represents the data series where sex information was available from 1996 through 2019 (Table 18, Figure 29). This index represents a fishery-independent measure of the spawning run success as survivors after the fishery. Failure is defined as the occurrence of three out of five years where GM values are below the 50th percentile of the reference period (0.52). Exceeding the benchmark will trigger management action. The GM fell below the benchmark most recently in 2010, 2016, and 2019.

3.1.5 Ratio of Commercial Harvest to Smithfield Beach Relative Abundance Index

This index is defined as the ratio of the total Delaware River stock landed by commercial fishers as reported to the States of New Jersey and Delaware divided by the survivors after the fishery as indexed by the Smithfield Beach gill net female shad GM divided by 100. It is based on data from 1996-2019 (Table 19, Figure 30). Failure is defined as the occurrence of three out of five years where ratio values are higher than the 50th percentile of the reference period (799). Exceeding the benchmark will trigger management action. The ratio estimate exceeded the benchmark most recently in 2014.

3.1.6 Mixed Stock Landings

This index is defined as the total pounds landed from the mixed stock, which consists of 50% of combined commercial landings from Delaware and New Jersey. The index was based on data from 1985-2019 (Table 20, Figure 31). 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 2 consecutive years above a value of 18,505 pounds. 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. The pounds landed on the mixed stock has exceeded the benchmark most recently in 2013 and 2014.

3.2 Benchmark Summary

Index	2022 Benchmark Value	Years of Index for Benchmark	Benchmark Level	Management Trigger	Benchmark Change from 2017
Female Total Mortality	1.07	1996-2019	$Z_{40\%}$	Three year rolling average above benchmark	This is a new Benchmark
Non-Tidal JAI (GLM)	188*	1988-2019	50th percentile	3 out of 5 years below benchmark	Benchmark previously was ~145.9, raised from 25th to 50th percentile, management trigger changed from 3 consecutive years, data from 2015-2019 added
Tidal JAI (GM)	5.81	1987-2019	50th percentile	3 out of 5 years below benchmark	Benchmark previously was 4.00, raised from 25th to 50th percentile, management trigger changed from 3 consecutive years, data from 2015-2019 added
Smithfield Beach Female CPUE (GM) Index	0.52	1996-2019	50th percentile	3 out of 5 years below benchmark	Benchmark previously was 37.5, raised from 25th to 50th percentile, management trigger changed from 3 consecutive years, females only considered, data from 2015-2019 added
Ratio of Comm. Harvest to Smithfield Beach	799	1996-2019	50th percentile	3 out of 5 years above benchmark	Benchmark was previously 36.5, delineation and proportion of Delaware River Stock harvest changed (see Mixed Stock Landings), lowered from 85th to 50th percentile, management trigger changed from 3 consecutive years, data from 2015-2019 added
Mixed Stock Landings	18,505	1985-2019	25th percentile	2 consecutive years above benchmark	Benchmark was previously 47,650 lbs, lowered from 75th to 25th percentile, demarcation line removed, proportion assigned to mixed stock is 50% of all landings, data from 2015-2019 added

*This value may change slightly each year based on re-analysis of data using the GLM.

3.3 Management Actions

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. During the implementation of the 2017 SFP, indices for the fishery benchmarks were not exceeded for the specified time periods, therefore no management action was taken in response to benchmark exceedance in the 2017 SFP. In response to the mortality benchmark exceedance as identified in the 2020 Stock Assessment, the Co-op will be implementing measures to reduce landings in both the commercial and recreational fisheries.

Immediate action will be taken to reduce shad landings by approximately 33% in the commercial fisheries of Delaware and New Jersey. Delaware will require a minimum monofilament diameter size of 0.52 mm for all anchored gillnets with stretch mesh of four inches or larger. Delaware will also implement a landings cap of 7,772 pounds annually, which if exceeded, will require management action as directed by the Co-op Policy Committee the following season. Delaware also plans to implement more detailed reporting on gear and fishing location and conduct on-board sampling of the fishery. New Jersey will be implementing an annual quota of 17,251 pounds that will be tracked weekly the first year following exceedance, and will allow for in-season closure of the fishery once the quota is achieved. Any quota exceedance will be deducted pound-for-pound from the following season's quota.

Immediate action will be taken to reduce recreational landings by reducing the creel limit for American shad from three to two fish per day, basin-wide. Within the Lehigh and Schuylkill (above I-95 bridge) rivers, the American shad fishery will remain as catch-and-release.

The Co-op will review the benchmarks of the SFP annually and if benchmark(s) are exceeded, the Policy Committee will meet and recommend specific management action to be taken immediately that is commensurate with the level of benchmark(s) exceedance from the list below:

Commercial Fishery:

- Reduce commercial fishery landings through implementing one or more of the following:
    - gear restrictions
    - area restrictions
    - seasonal restrictions
    - escapement periods
    - trip limits
    - quota with in-season closure in Delaware
    - reduced quotas in Delaware and New Jersey
- Closure of the commercial fishery
- Other measures to be determined

Recreational Fishery:

- Reduce recreational fishery landings through implementing one or more of the following:
    - creel limit reduction to 1 fish per day
    - recreational catch and release only
    - seasonal closures
    - area closures
    - gear restrictions
- Closure of the recreational fishery
- Other measures to be determined

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 2022 SFP is expected to cover the period 2022 through 2026. Thereafter the next planned update should be initiated in 2025. All datasets, with the exception of the mortality benchmark, will be updated annually for assessing the exceeding of any benchmarks requiring immediate management action.

The Co-op views the 2022 SFP as a working document. Over the tenure of the 2022 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 2022 SFP may be initiated prior 2025.

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 (2022-2026). 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 the next five years (2022-2026). 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.

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 will be reported monthly to allow for timely tracking of harvest each year.

5.2.2 Recreational Fishery

A comprehensive angler use and harvest survey on the Delaware River is cost prohibitive due to the extensive area to be covered. The Co-op will attempt to pursue financial support for a comprehensive creel survey in order to better document angler use and harvest in the Basin. Monitoring recreational landings, catch and effort is mandated by ASMFC in Amendment 3.

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 will be a monofilament size restriction for anchored gillnets and a landings cap to be implemented by the 2023 fishing season and there are general regulations that apply to the commercial fishery that limit commercial fishing. Existing regulations 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, with the inclusion of the increased monofilament diameter with this SFP, will otherwise remain unchanged (see Section 2.2.2.1.3).

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 1. Limited entry is in place; permits are not gear specific. All permits are currently non-transferable except to immediate family members. New Jersey will be implementing a quota for commercial American shad landings during the implementation of this SFP that will be effective for the 2023 fishing season.

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 currently impose a three shad daily possession limit with no size limit or closed season. Within the tidal portion of the Delaware River, Bay, and their tributaries, New Jersey imposes a six shad daily possession limit, with a maximum of three American shad, with no size limit or closed season. The State of Delaware continues with a ten fish/day, combined American and hickory shad, with no size limit or closed season. Little effort is expended by recreational anglers for American shad in Delaware waters with no reported harvest.

With the implementation of this SFP, recreational daily possession limits specifically for American shad will be reduced to two fish per day across all basin states by the 2023 fishing season.

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.

6.3 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 or are planned to be implemented.

7. Data Needs for 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 needs for improved stock assessment are described in the 2020 ASMFC American shad Stock Assessment (ASMFC 2020) and items specific to the Delaware River Basin listed in this section.

7.1 Conducting a Basin-wide Creel Survey

The recreational fishery has not been assessed by creel survey in the Delaware River Basin since 2002. An updated basin-wide creel survey is necessary to better understand the recreational fishery and its impact on stock status. Post-release mortality assessment for recreational catch and release fisheries is also a data need for improved stock assessment.

7.2 Determining 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. Additional robust genetic or tagging studies within the entire expanse of the Bay will better evaluate the extent of mixed stock circulation in the Basin. 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.

7.3 Improving Ageing Techniques

Based on the recommendations from the 2020 Stock Assessment, otoliths are the preferred aging structure. Currently, the Delaware River Fish and Wildlife Cooperative Unit Aging Subcommittee (DRFWCUAS) is developing a new aging otolith aging protocol incorporating recommendations in the recent stock assessment.

7.4 Adding Fishery-Independent Monitoring Programs

Reliance of characterizing the adult shad spawning run singularly 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.

7.5 Characterizing Loss from Non-traditional Fishery Harvest sources

Losses of shad from the Delaware River population beyond either recreational or commercial harvest occur. Additional assessment of impingement and entrainment from various water should be undertaken. Flow management regimes in the Basin should be reviewed to determine impacts to American shad reproduction and survival.

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9. Figures

Figure 1. The Delaware River watershed.

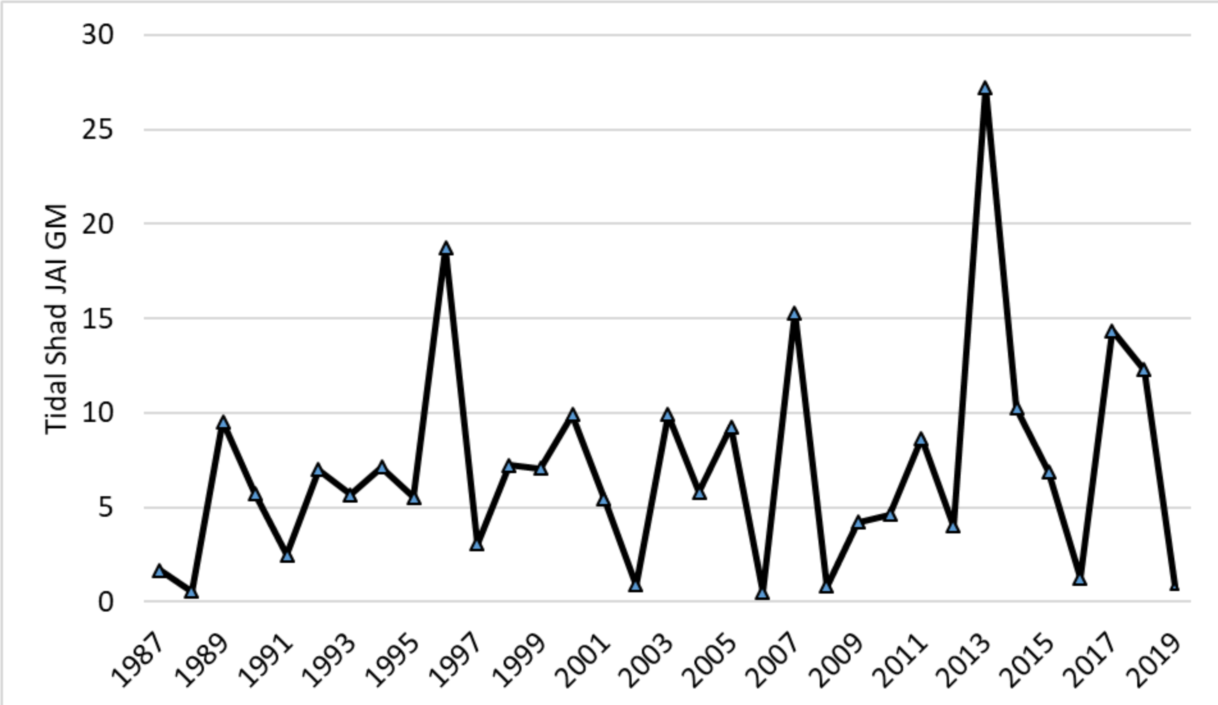


Figure 2. The geometric mean of the juvenile abundance index (JAI) for American shad in the tidal Delaware River.

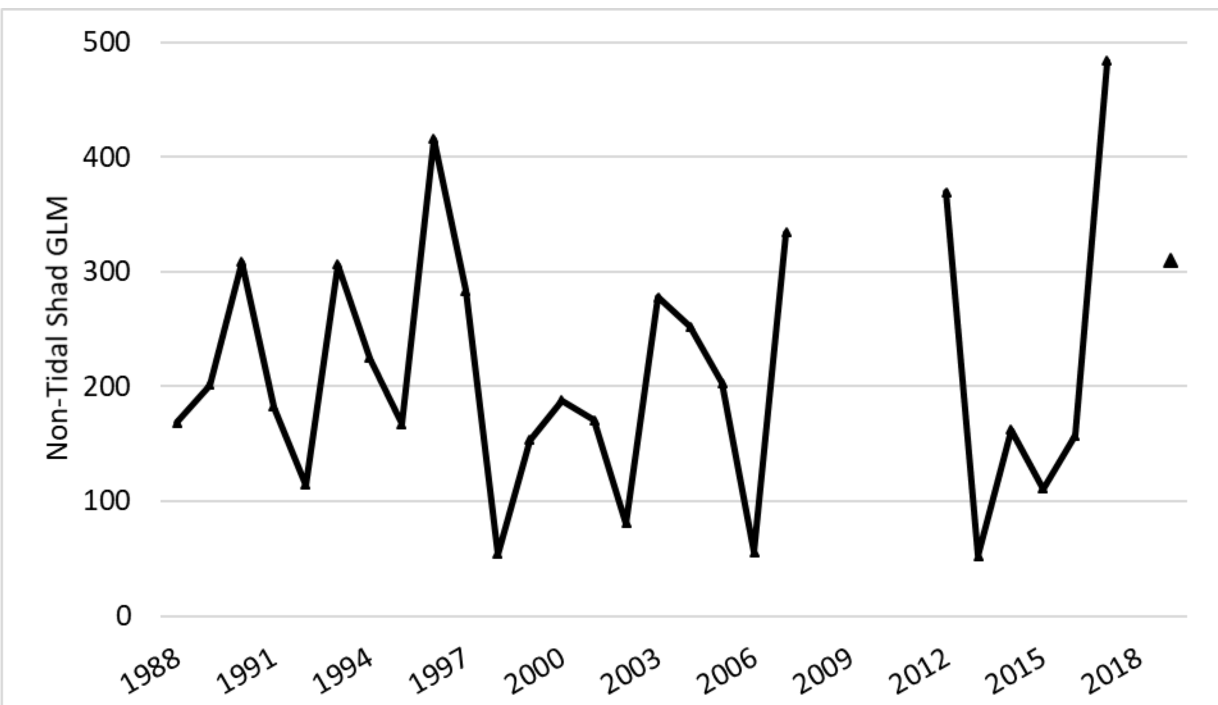


Figure 3. The generalized linear model of the juvenile abundance index (JAI) for American shad in the non-tidal Delaware River at Phillipsburg, Delaware Water Gap, and Milford.

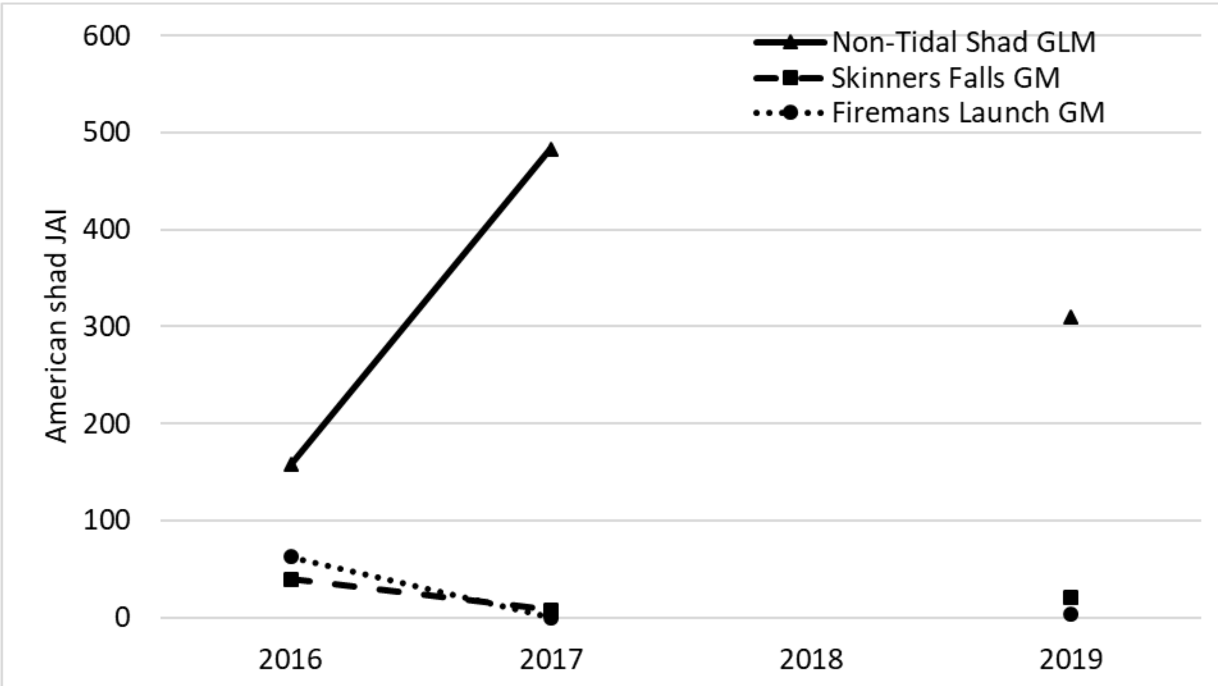


Figure 4. Non-Tidal American shad JAI for the Upper Delaware River (geometric means for Skinner's Falls and Fireman's Launch) compared to the Big 3 sites (generalized linear model for Phillipsburg, Water Gap, Milford).

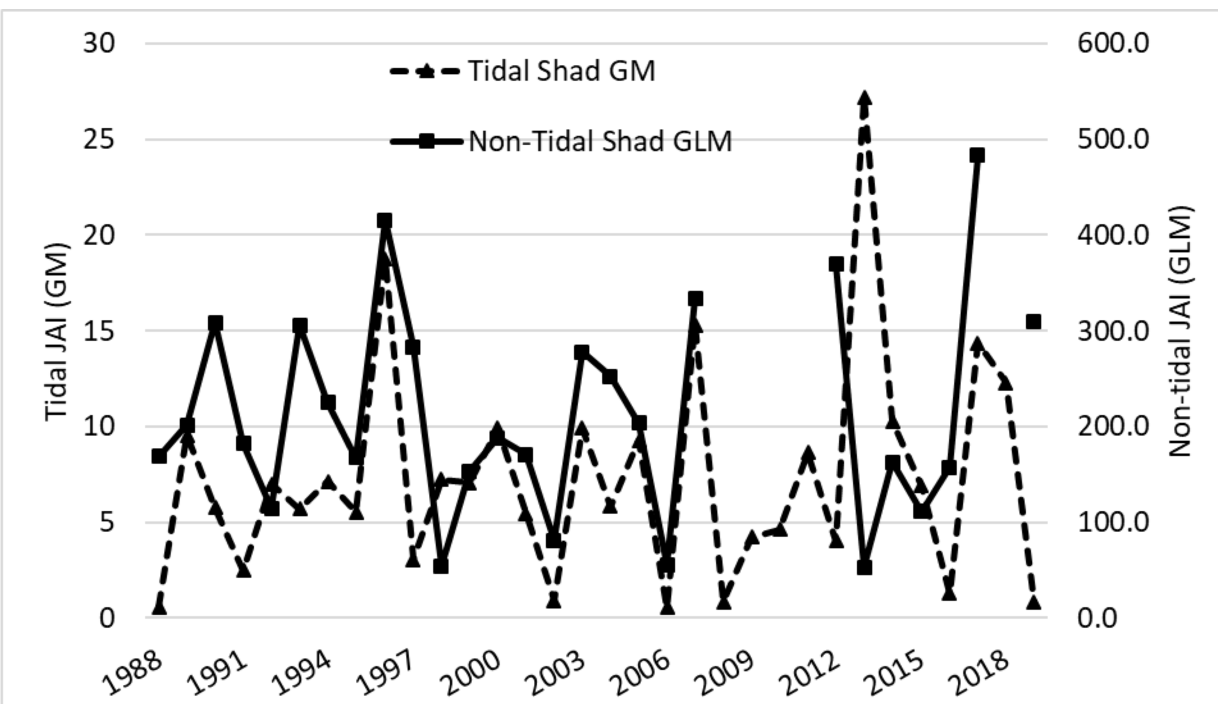


Figure 5. Comparison of the tidal to non-tidal JAI indices for American shad. Note there was no non-tidal sampling from 2008-2011 and 2018.

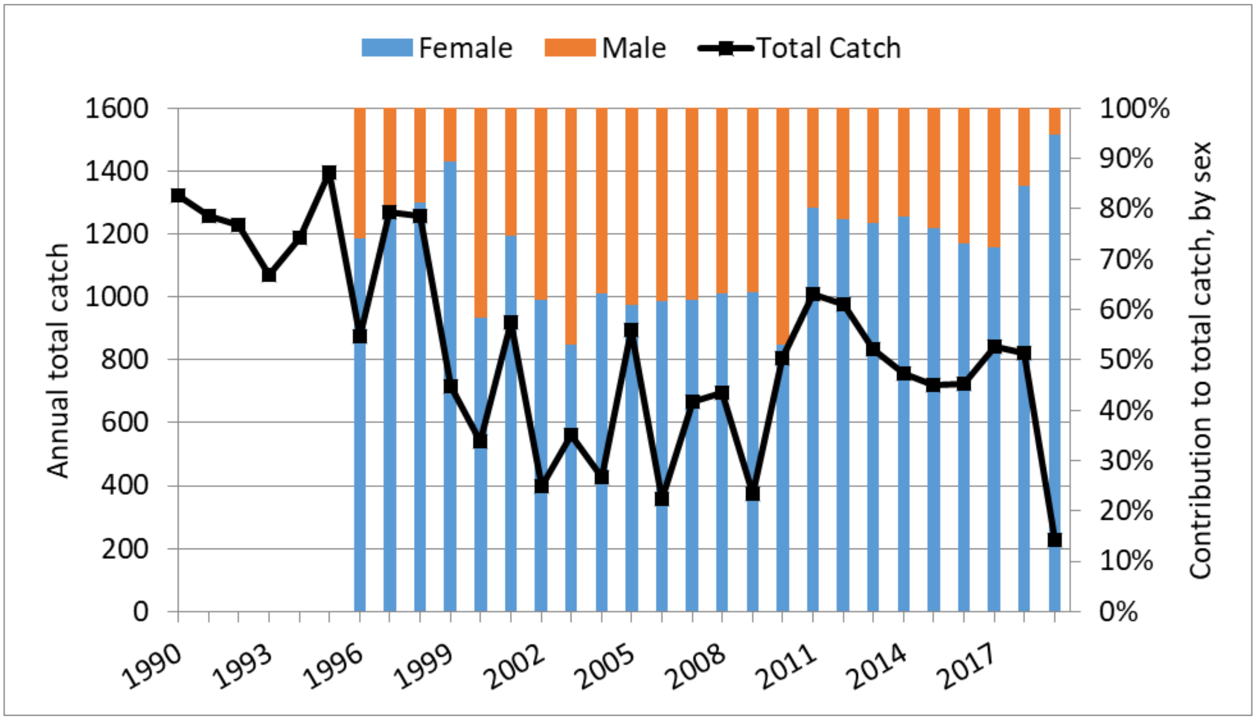


Figure 6. Total catch of American Shad at Smithfield Beach (RM 218), by sex. No biological data were recorded prior to 1996.

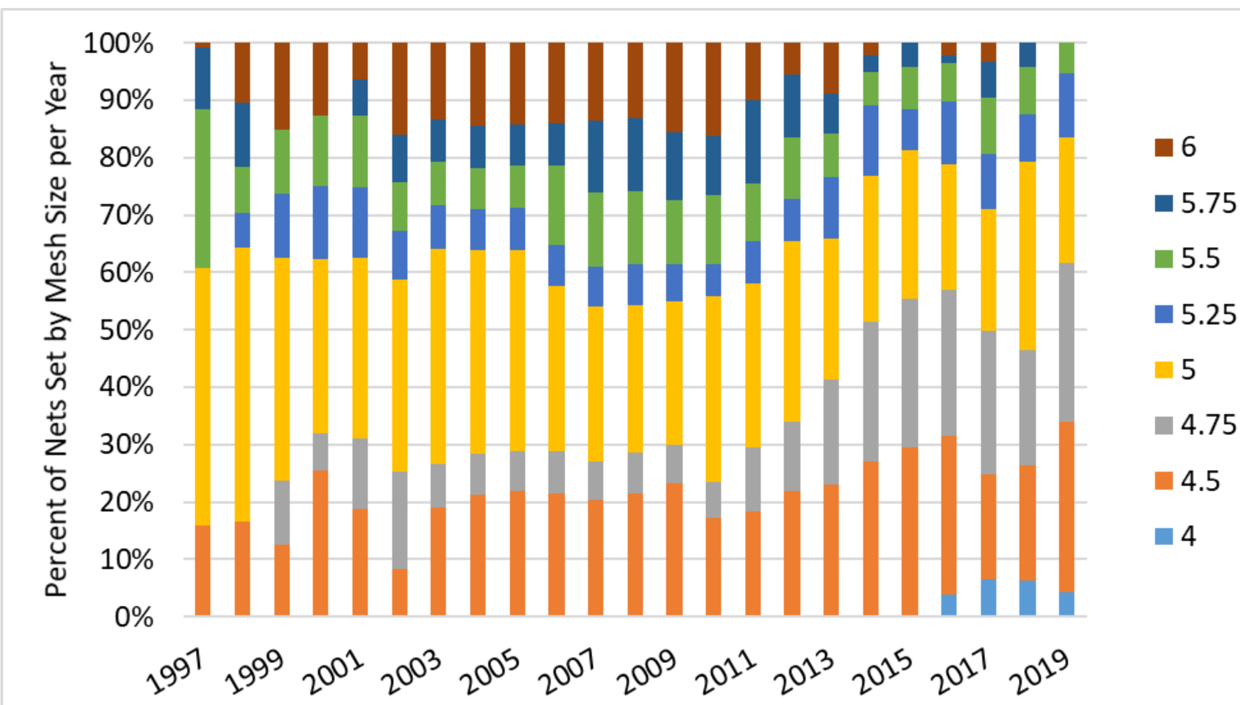
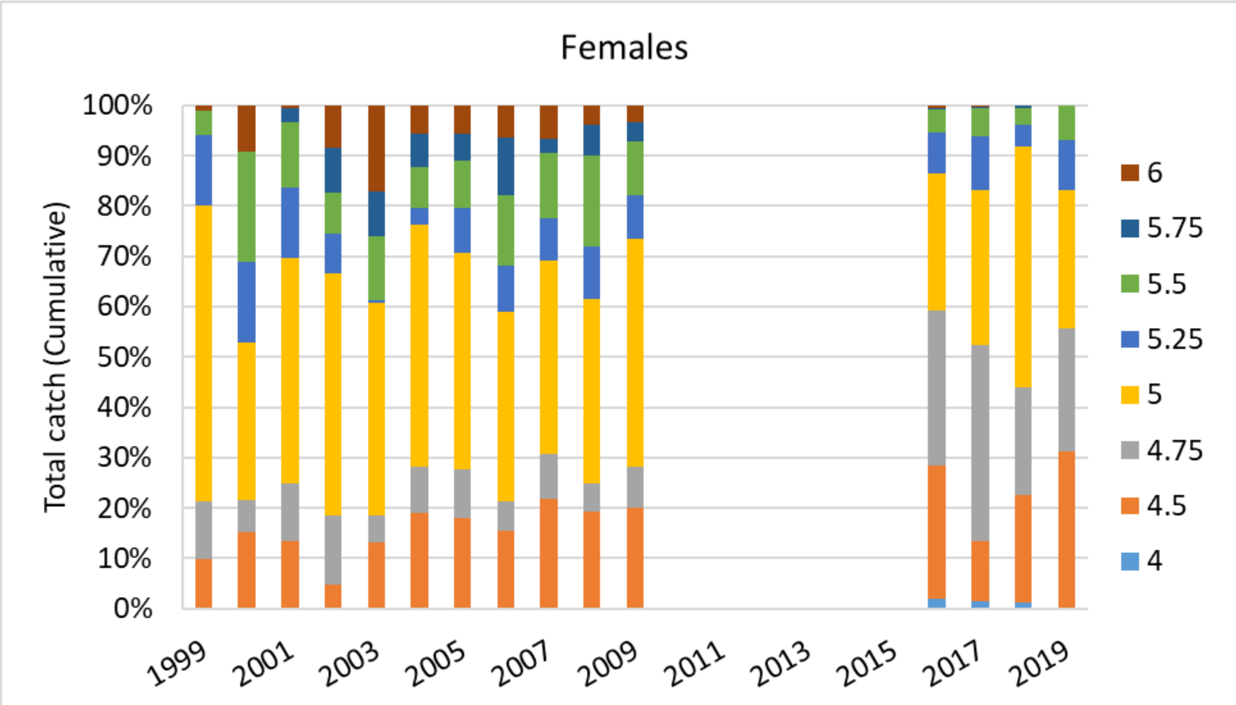


Figure 7. Frequency of gill net stretch mesh sizes deployed for brood stock and monitoring efforts at Smithfield Beach (RM 218).



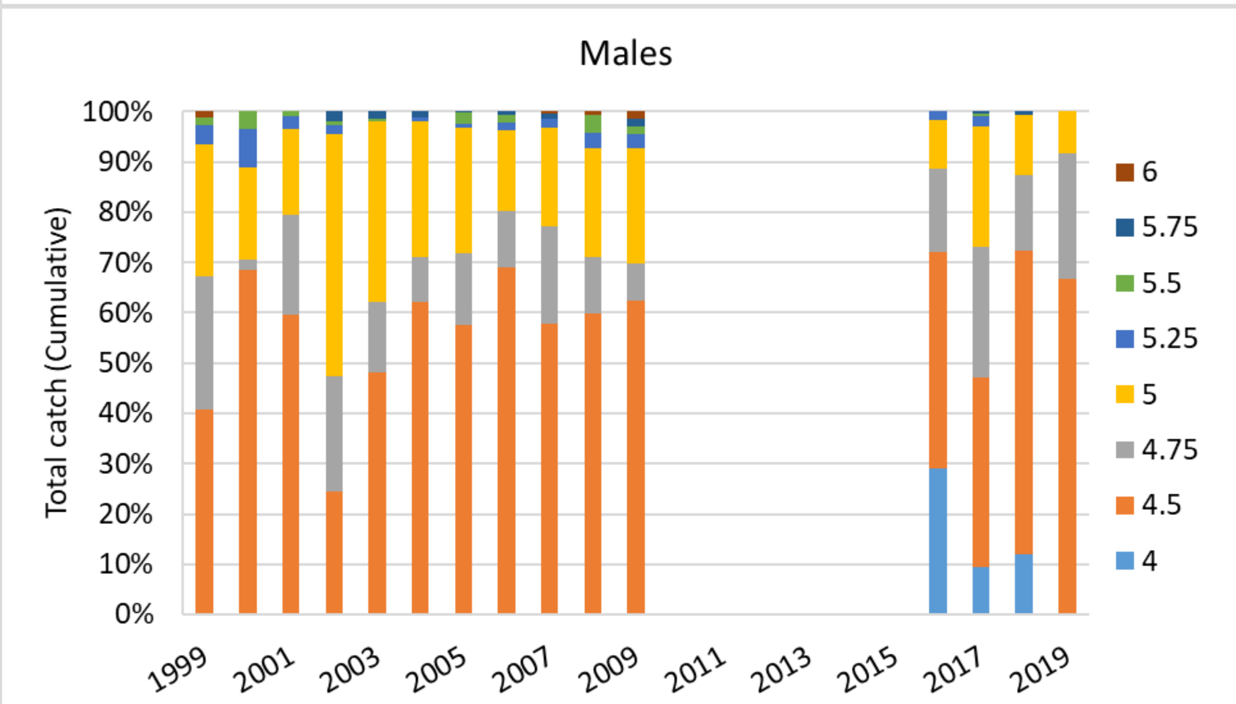


Figure 8. Percent of annual total catch of shad at Smithfield Beach (RM 218) by stretch mesh size (inch) deployed. Catch was not reported by mesh size prior to 1999 and 2010 through 2015.

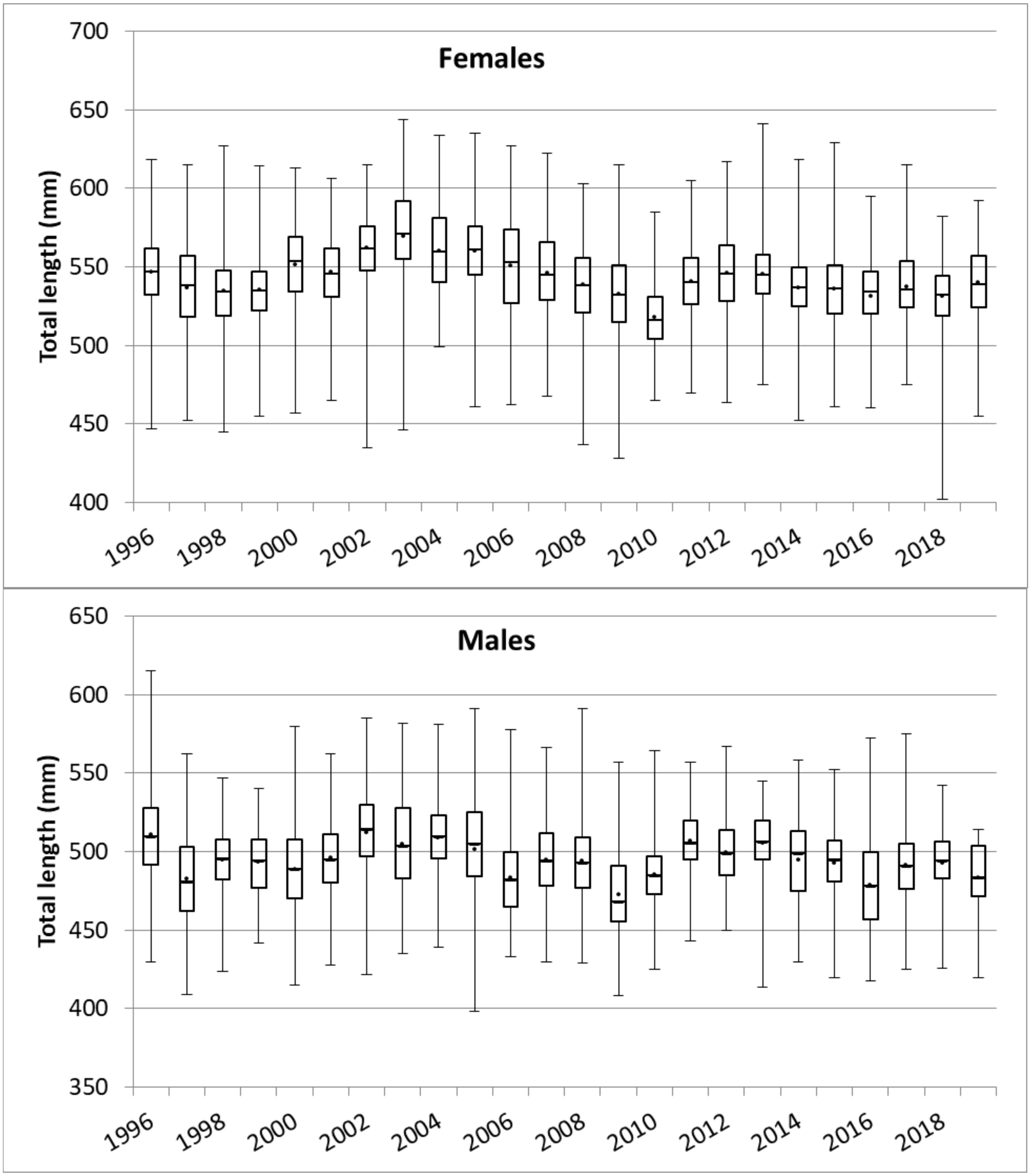


Figure 9. Size distribution of captured American shad at Smithfield Beach (RM 218). The boxes represent the 25 and 75th quartiles, with the whiskers extending to the 10th and 90th percentiles. Median (solid horizontal line) and average (asterisk) are also illustrated.

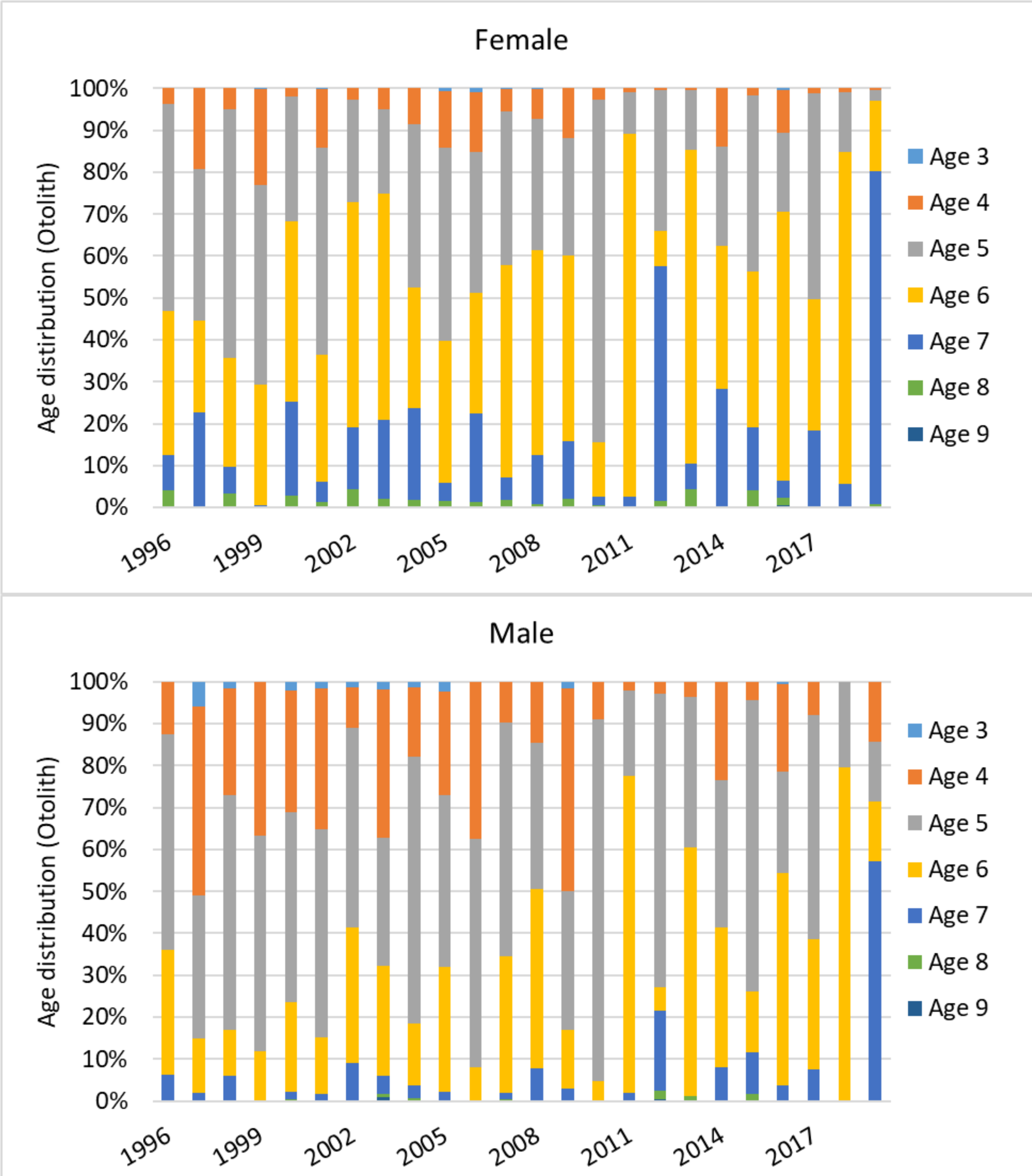


Figure 10. Age distribution by sex for American shad captured at Smithfield Beach as interpreted from otolith microstructures.

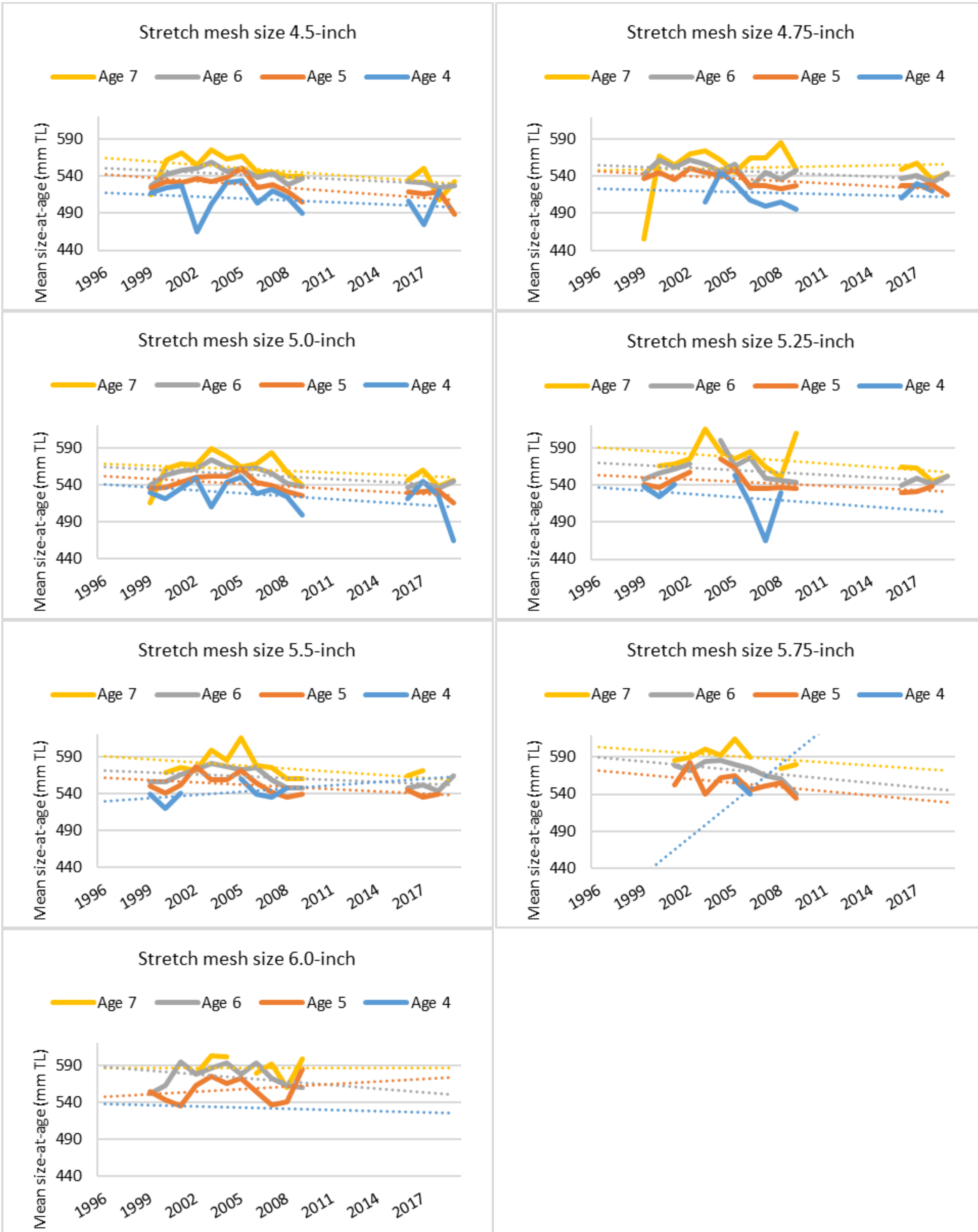


Figure 11. Mean size-at-age (mm TL) for female American Shad collected from Smithfield Beach, by stretch mesh size of capture. Trend lines, as linear least-squares regressions are depicted as dotted lines, for each respective age-class.

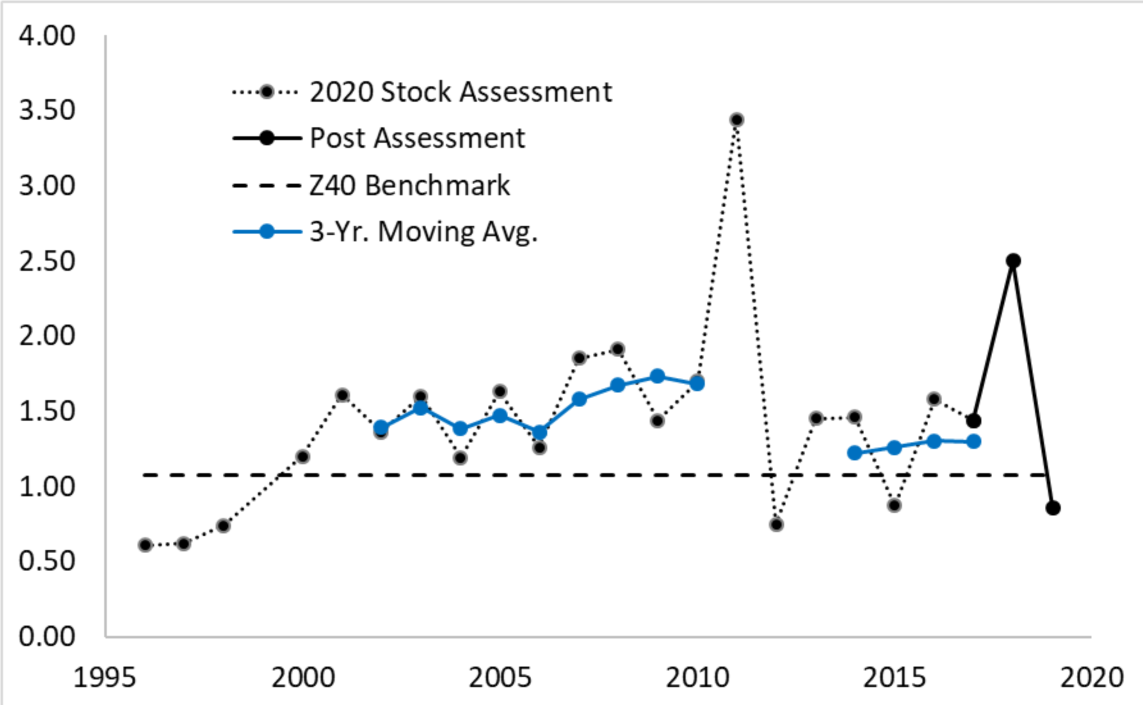


Figure 12. Female American shad total mortality for the Delaware River population.

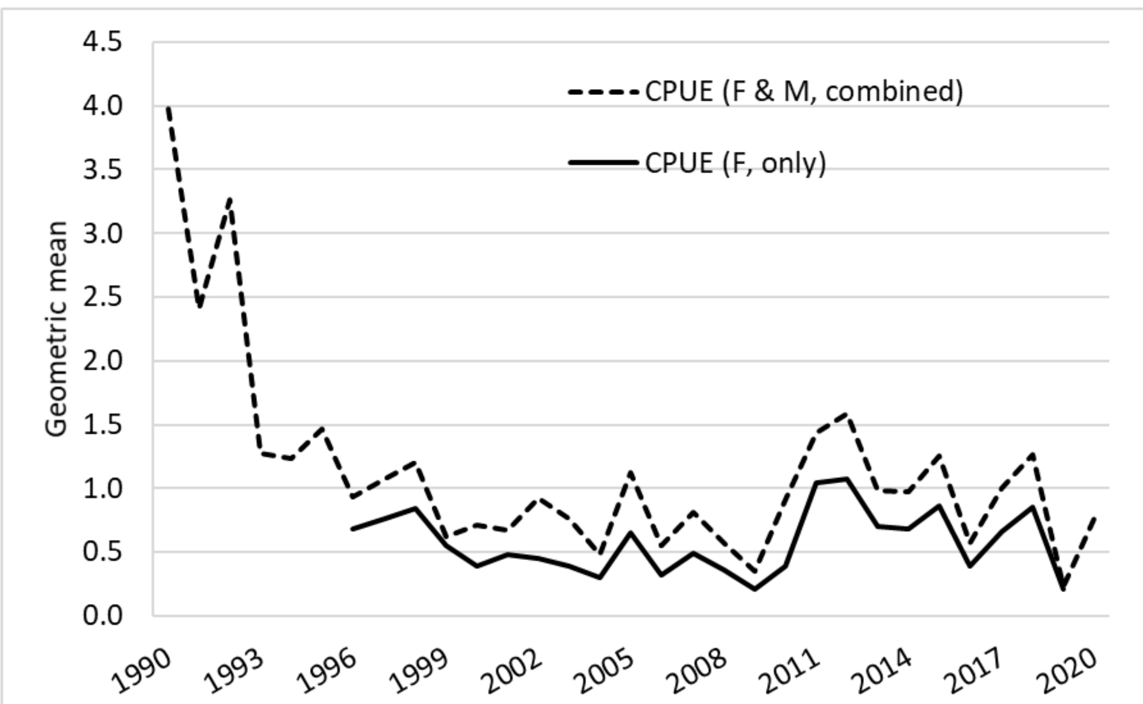


Figure 13. Time-series relative abundance (CPUE) for spawning adult catches at Smithfield Beach (RM 218).

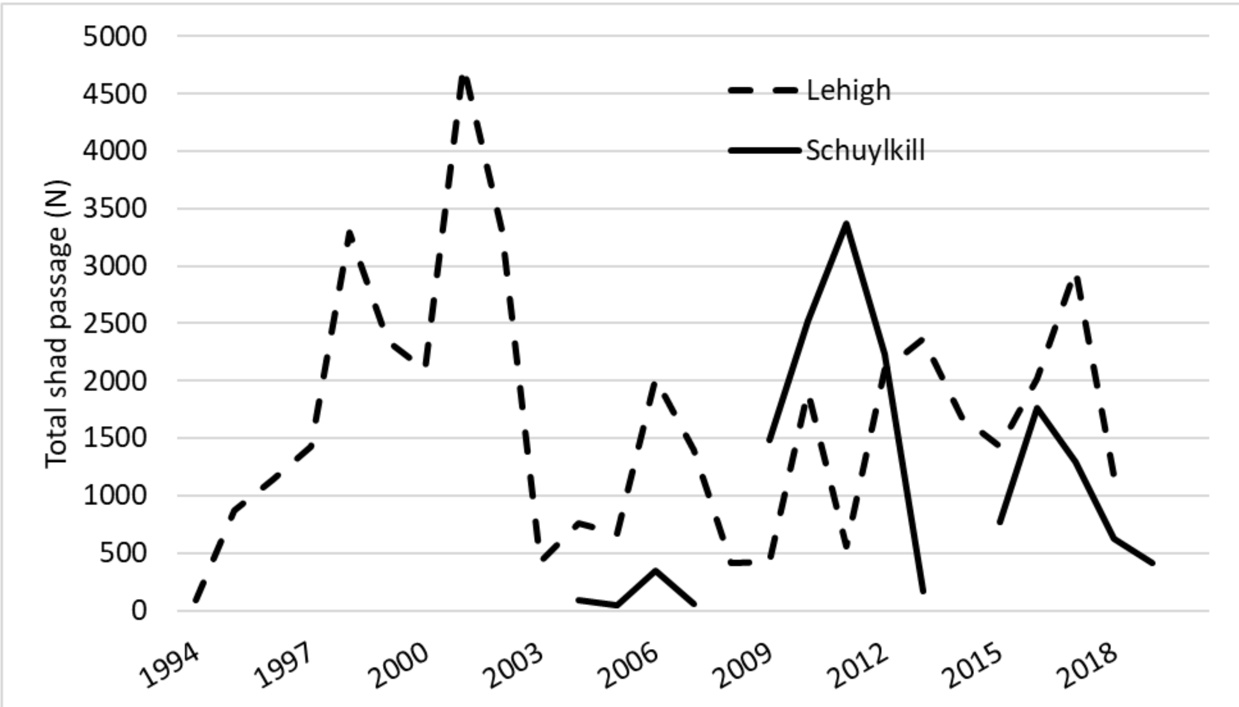


Figure 14. American shad passage in the Schuylkill and Lehigh Rivers.

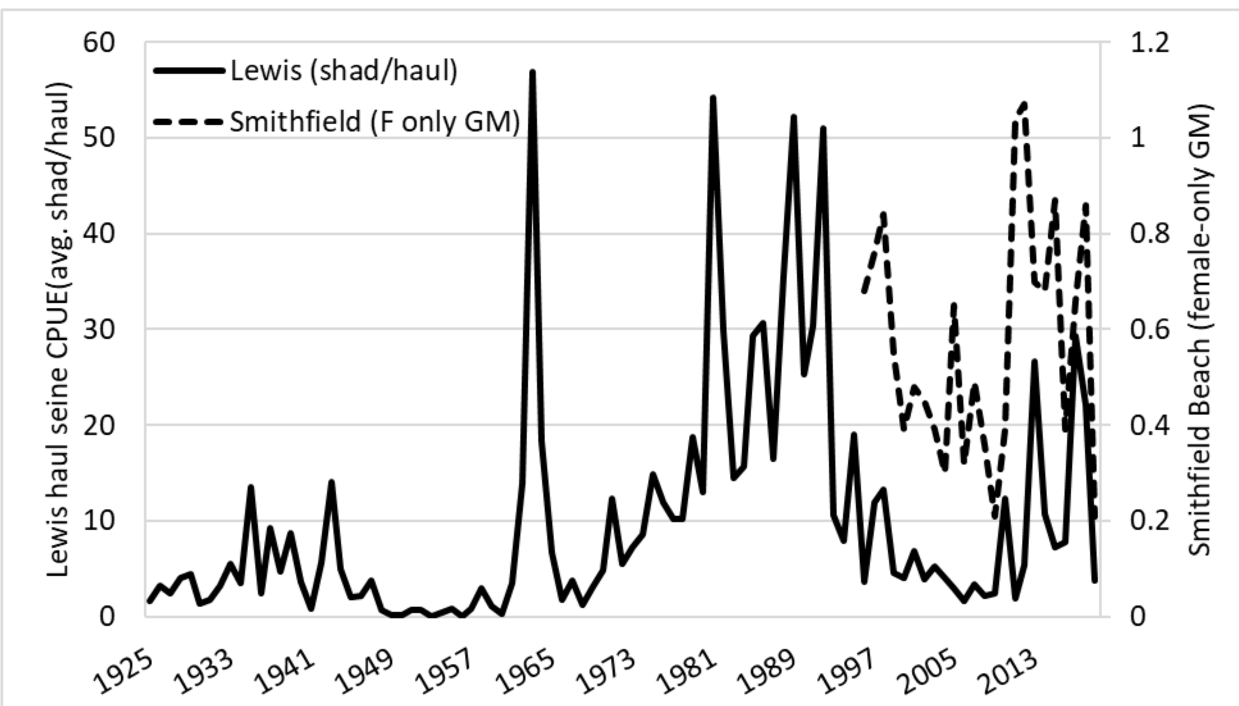


Figure 15. Lewis haul seine CPUE (avg. shad/haul) and Smithfield Beach (female-only geometric mean) indices of relative abundance.

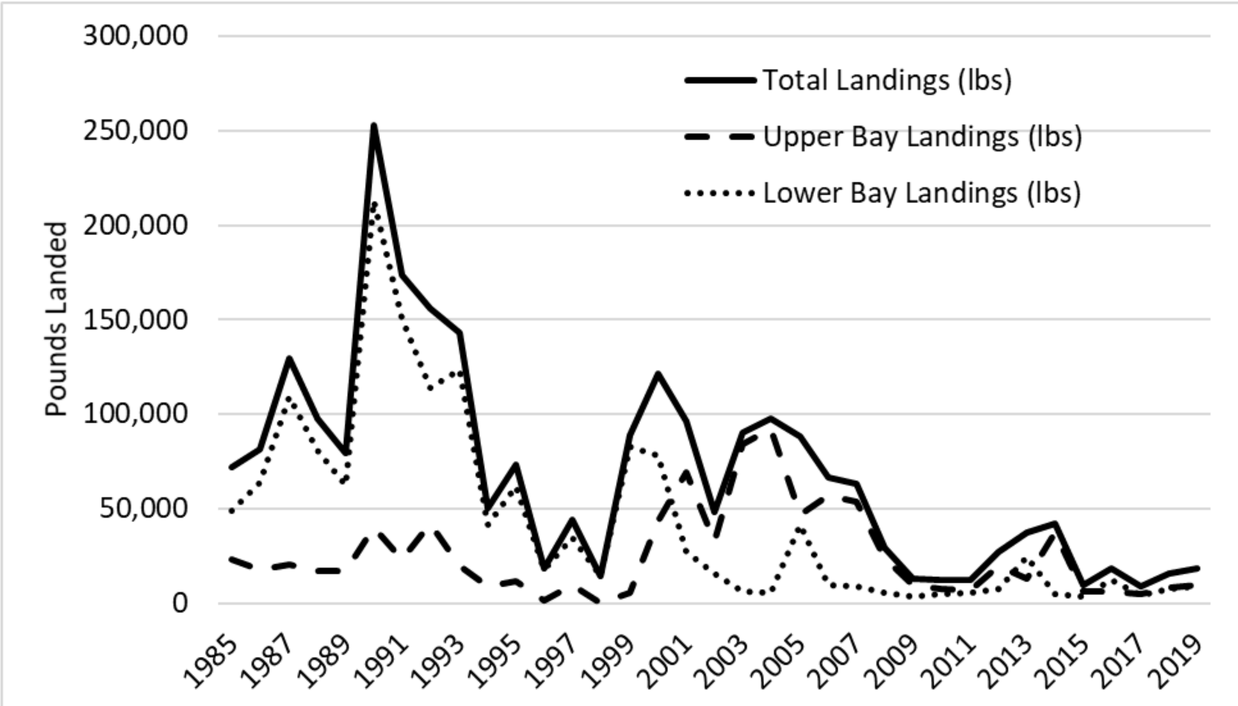


Figure 16. Commercial landings in the state of New Jersey. Upper and lower bay landings are delineated by harvest occurring north and south of Gandys Beach, NJ.

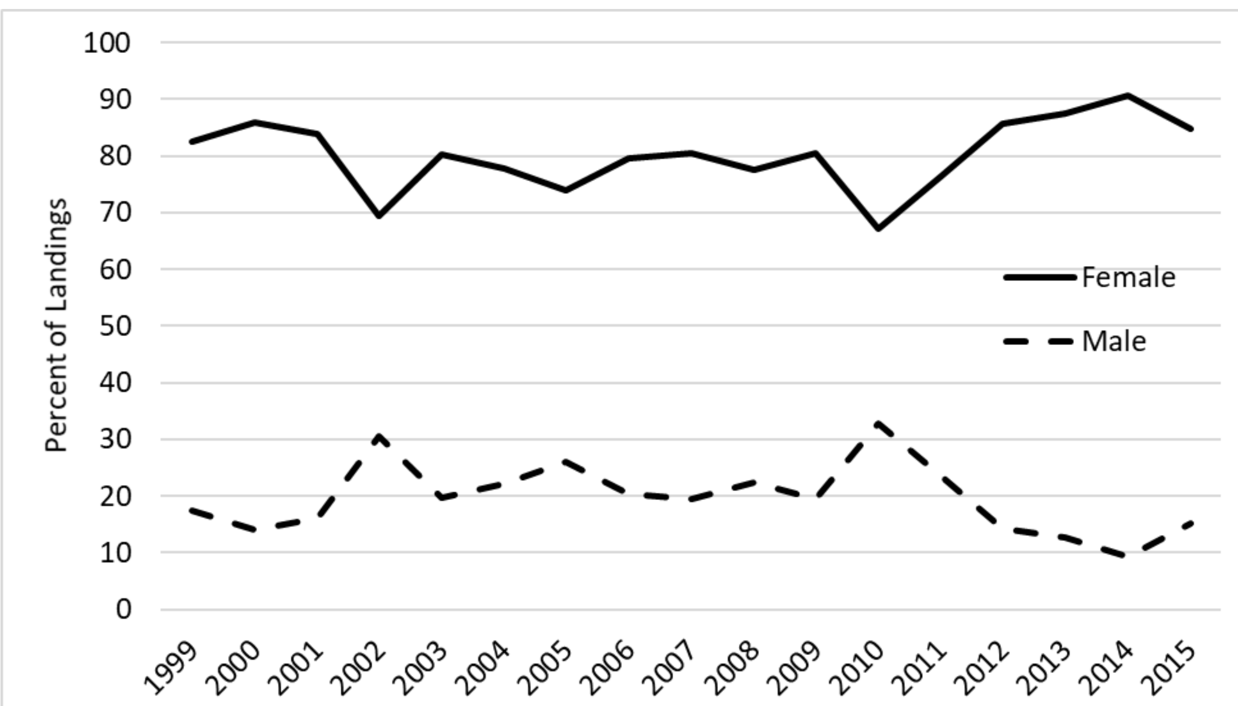


Figure 17. Sex composition of New Jersey's commercial gill net shad landings.

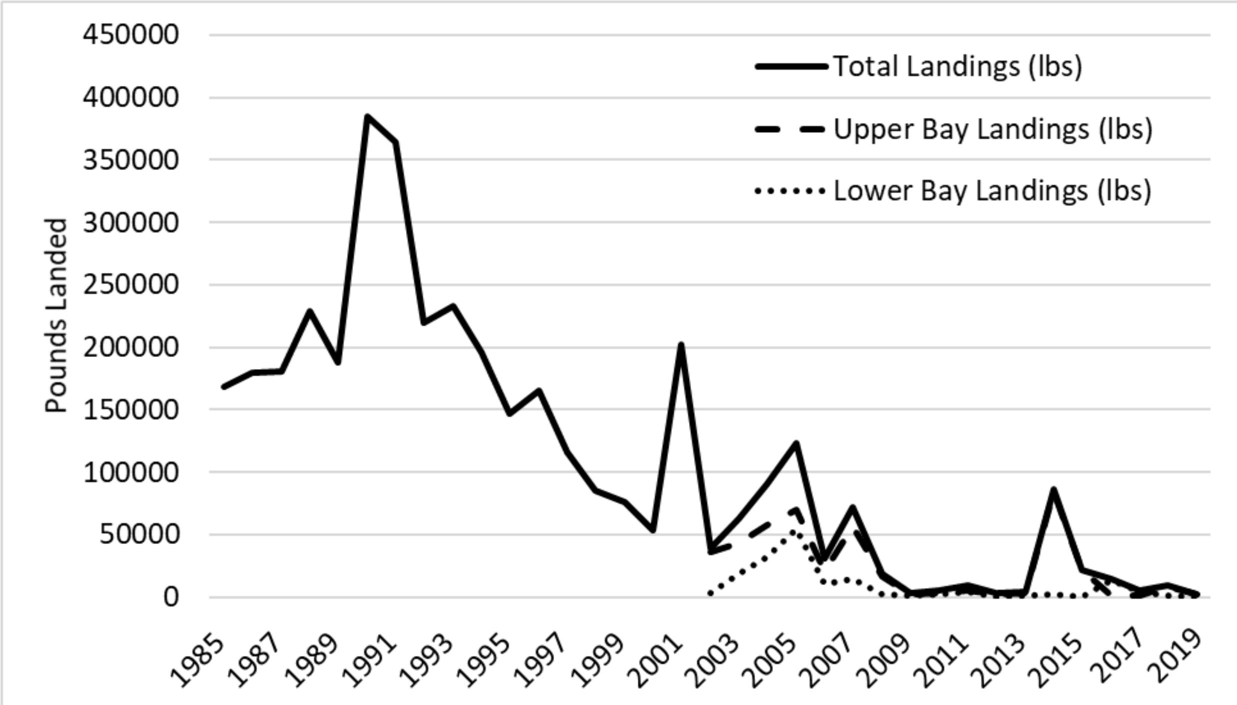


Figure 18. Commercial landings in the state of Delaware. Upper and lower bay landings are delineated by harvest occurring north and south of Bowers Beach, DE. Harvest location was not reported prior to 2002.

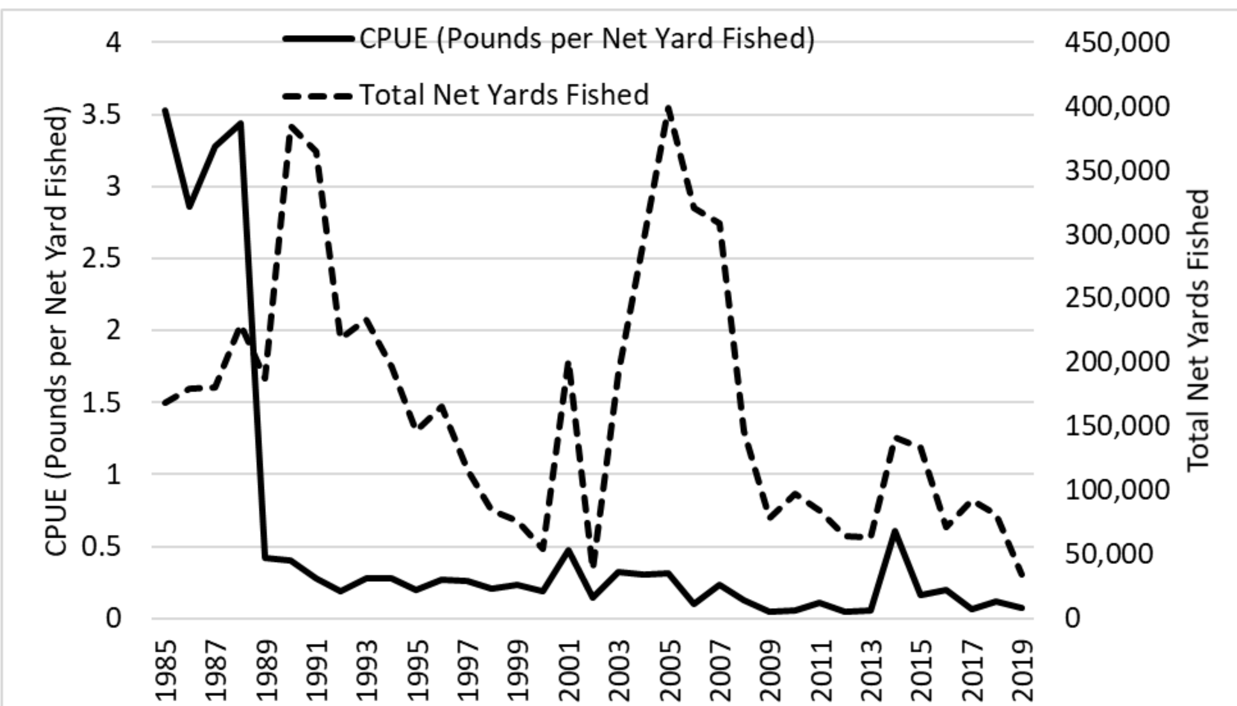


Figure 19. Delaware’s catch per unit effort (CPUE) for the American shad commercial fishery.

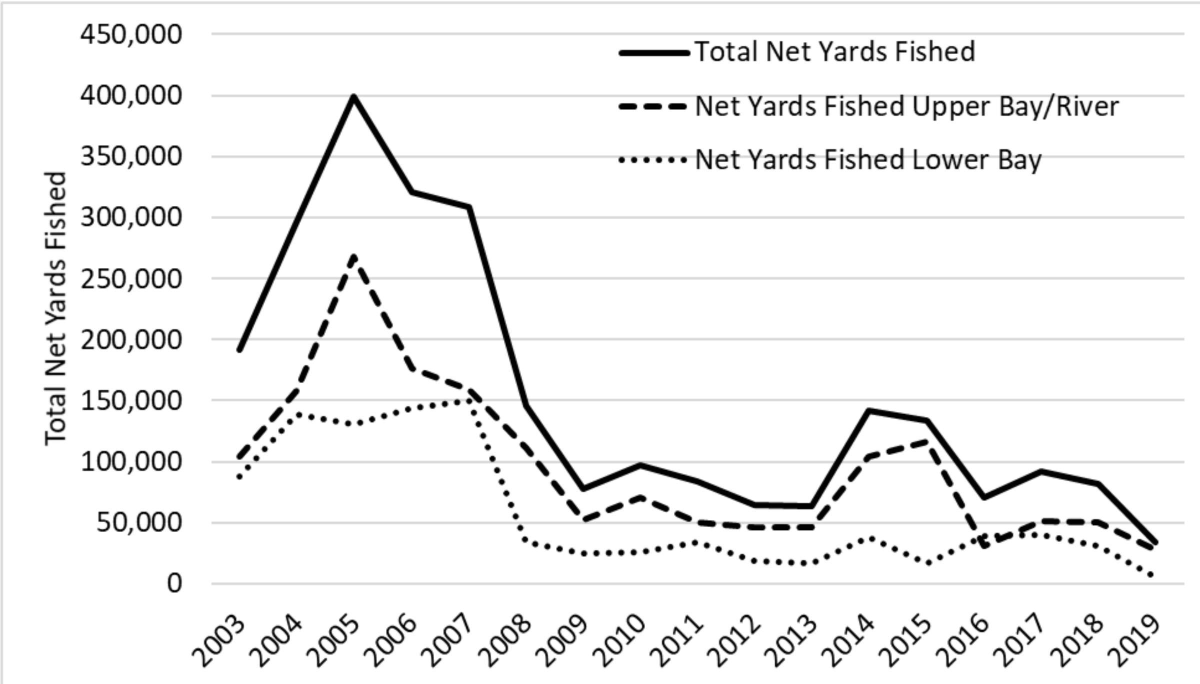


Figure 20. Delaware's gill net effort for the American shad commercial fishery. Upper and lower bay landings are delineated by harvest occurring north and south of Bowers Beach, DE. No collection location information were reported prior to 2002.

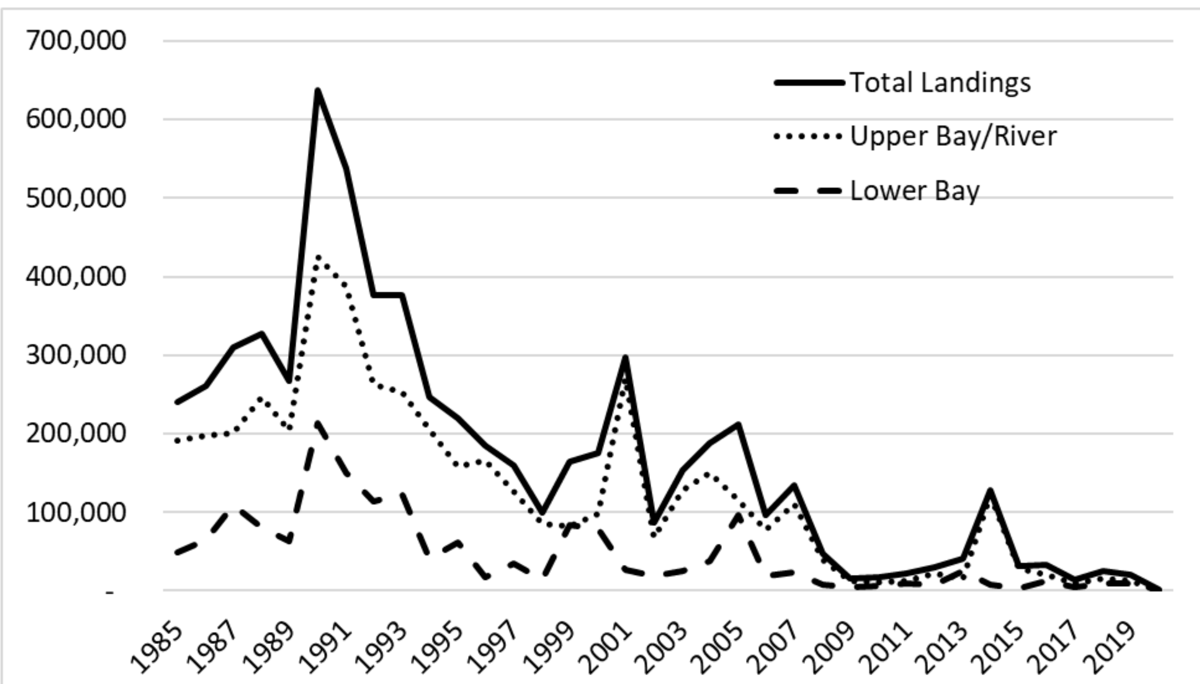


Figure 21. American shad commercial harvest for the states of Delaware and New Jersey, in pounds.

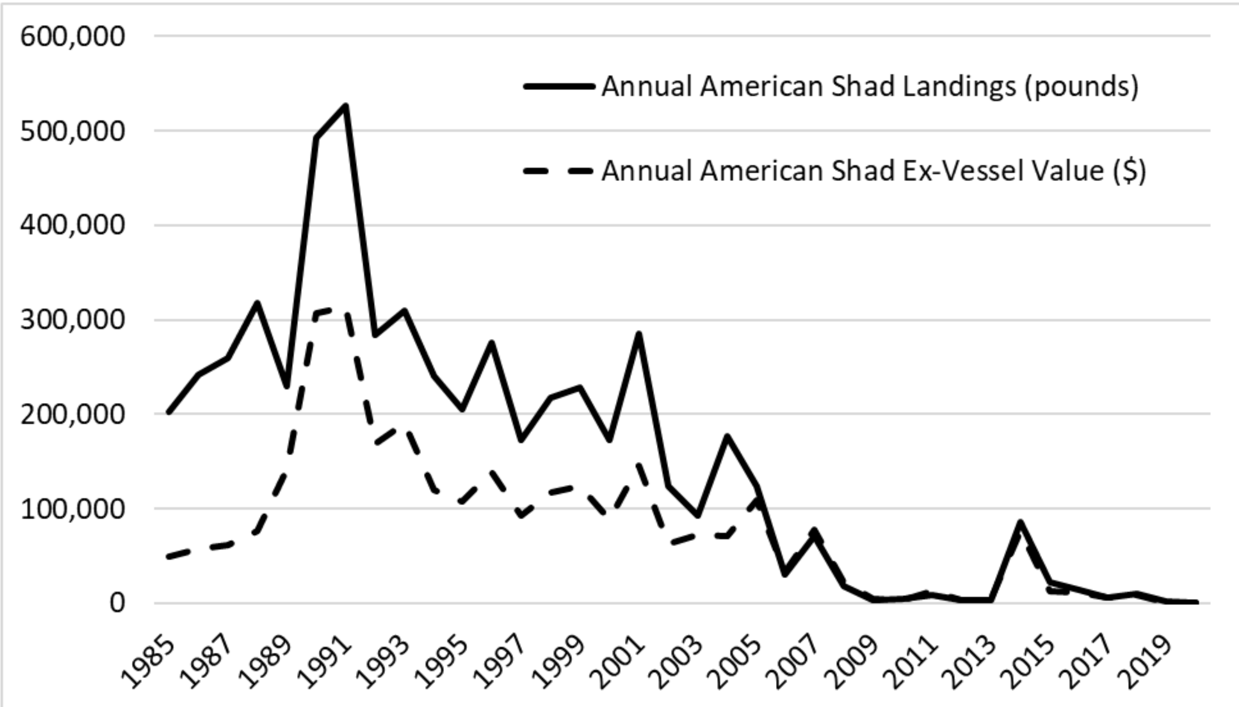


Figure 22. Pounds landed and market value for American shad landed in the State of Delaware.

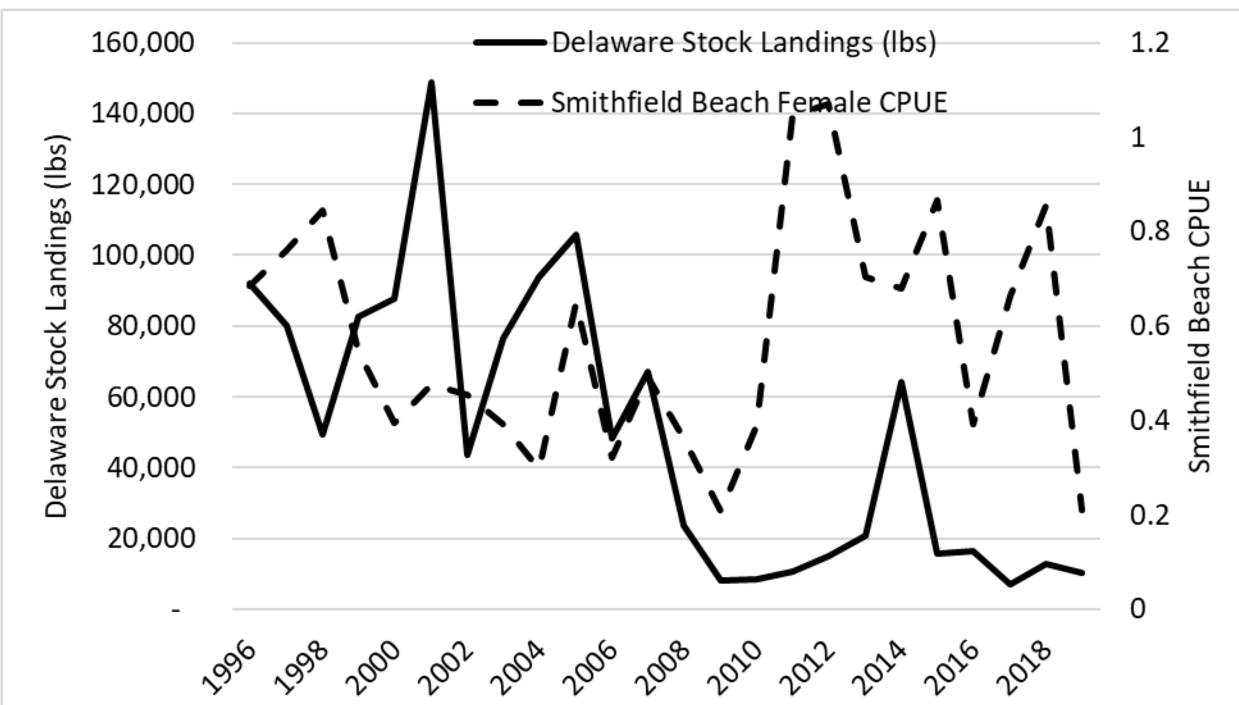


Figure 23. Comparison of trends between Delaware River stock landings and Smithfield Beach female American shad CPUE.

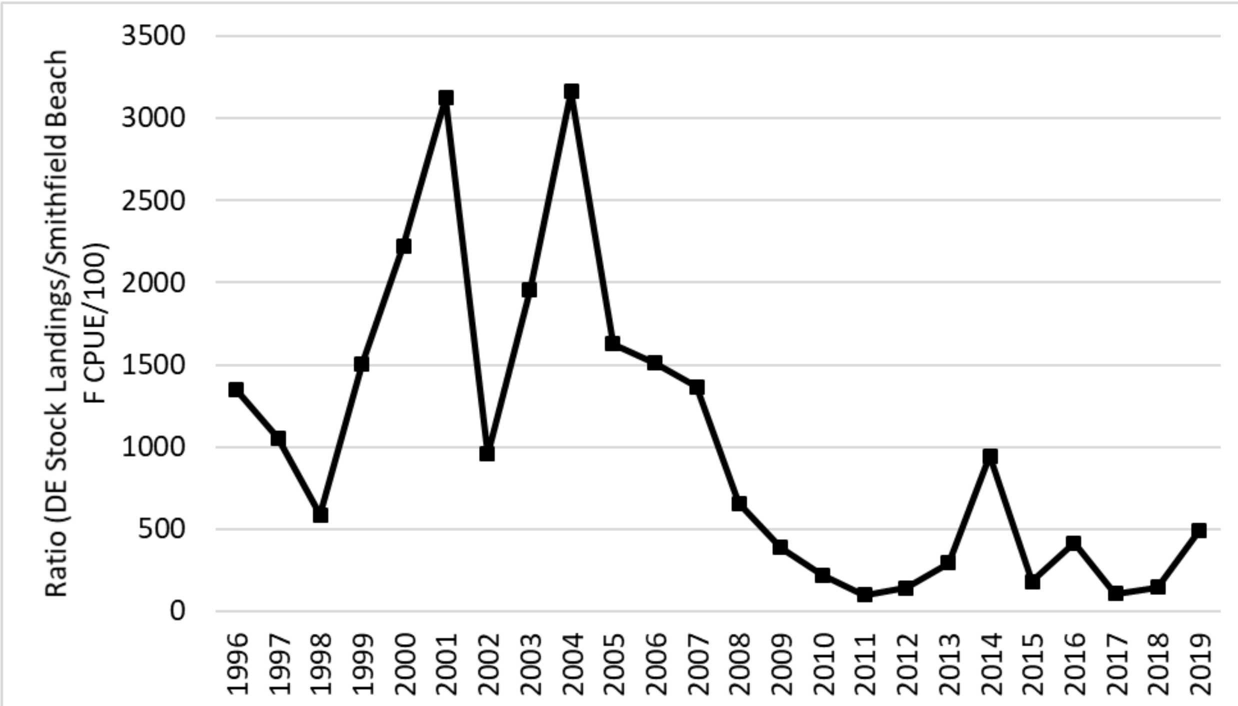


Figure 24. Ratio of Delaware River stock landings divided by Smithfield Beach CPUE (divided by 100).

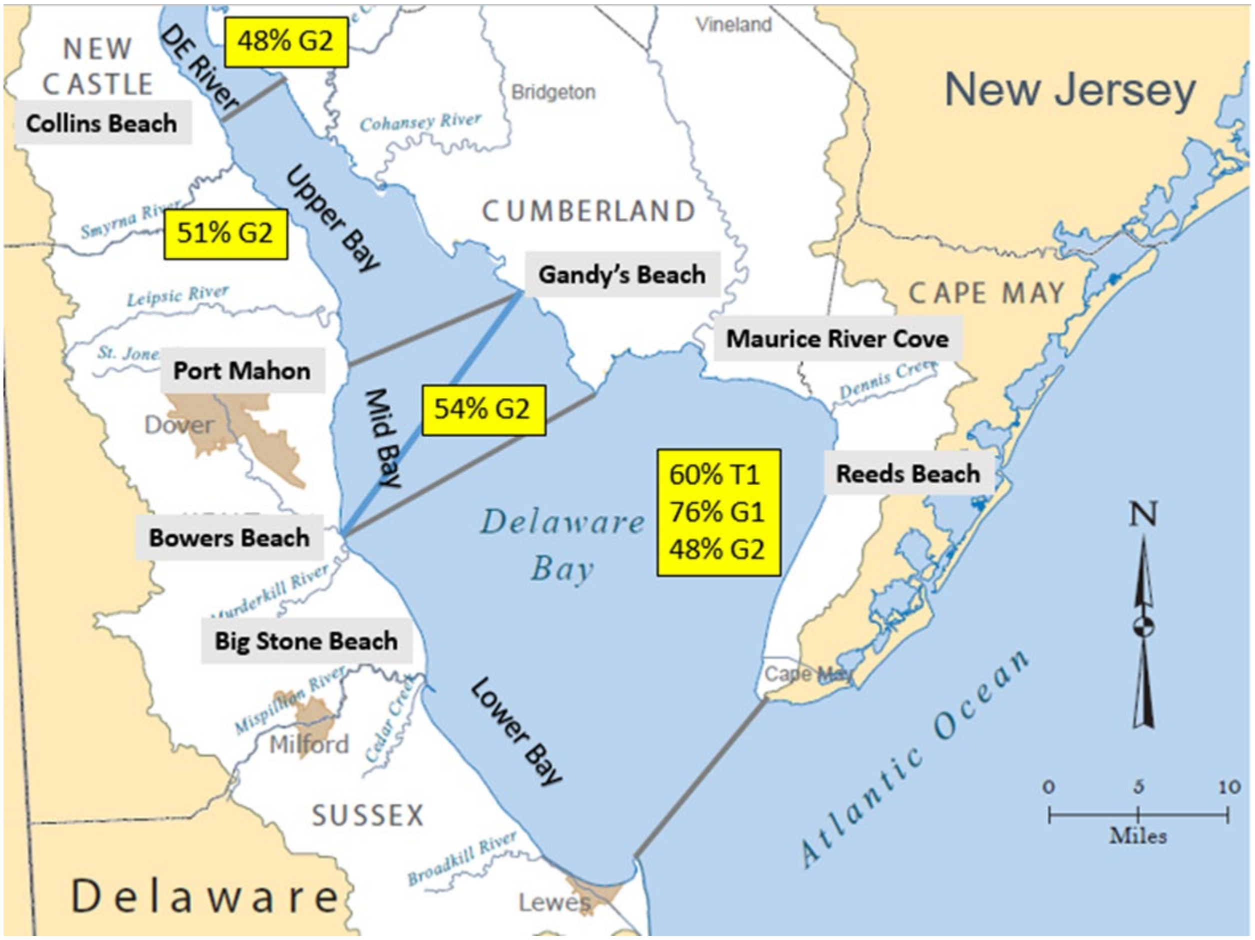


Figure 25. Map of the lower Delaware River and Bay, delineating harvest reporting regions for Delaware (n=4) and New Jersey (n=2, grey lines), demarcation line from 2017 SFP (blue), and proportions of mixed (non-Delaware Bay) stock by region based on study. T1 = New Jersey Tagging Study off Reeds Beach, NJ 1995-2020; G1 = Waldman et. al 2014 genetics study off Big Stone Beach, DE and Maurice River Cove, NJ 2010; G2 = U.S. Fish and Wildlife Service genetics study from 2017-2020, various locations sampled from the commercial fishery.

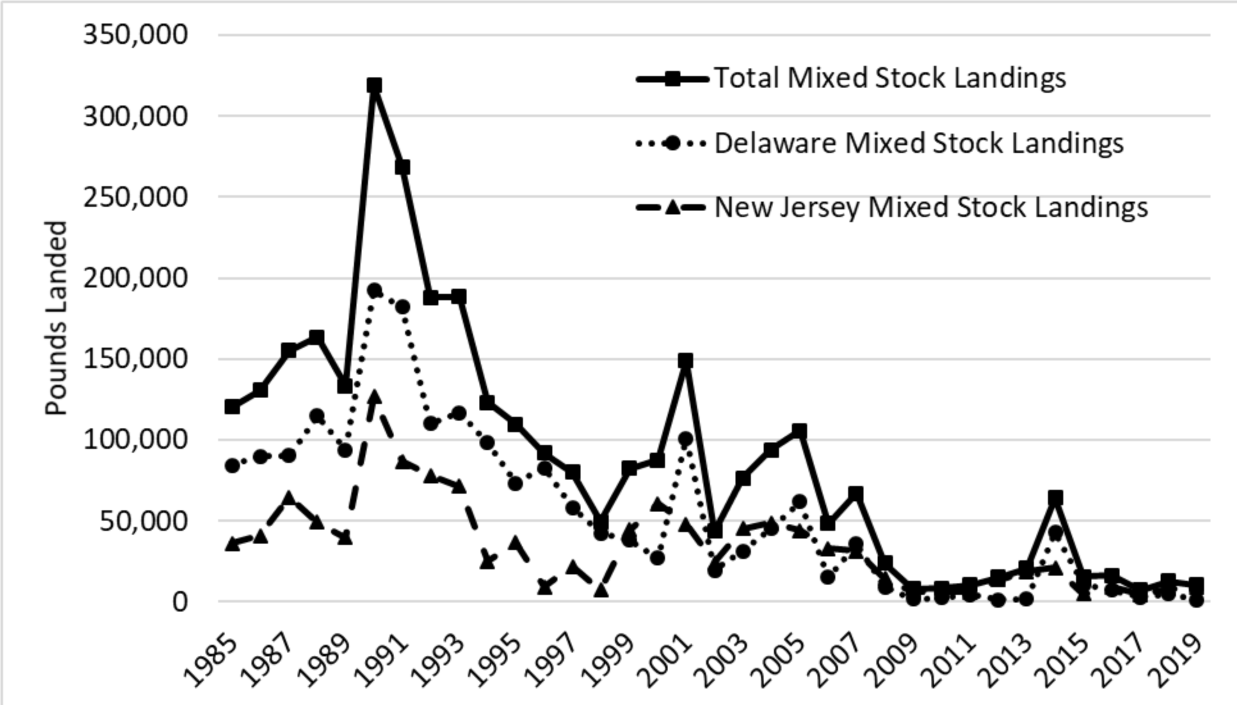


Figure 26. American shad landings (pounds) assigned to the mixed stock fisheries.

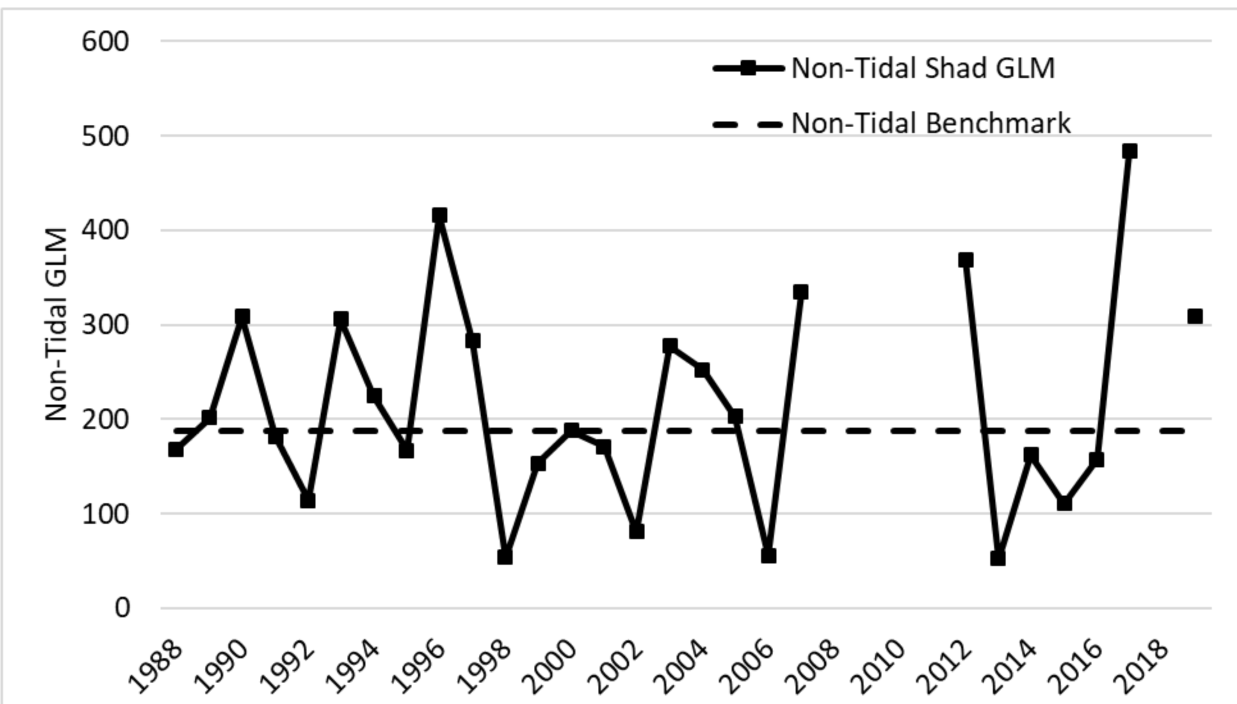


Figure 27. The Delaware River non-tidal American shad JAI (GLM) with a 50th percentile benchmark. Note that the benchmark value may change annually based on updated GLM analysis.

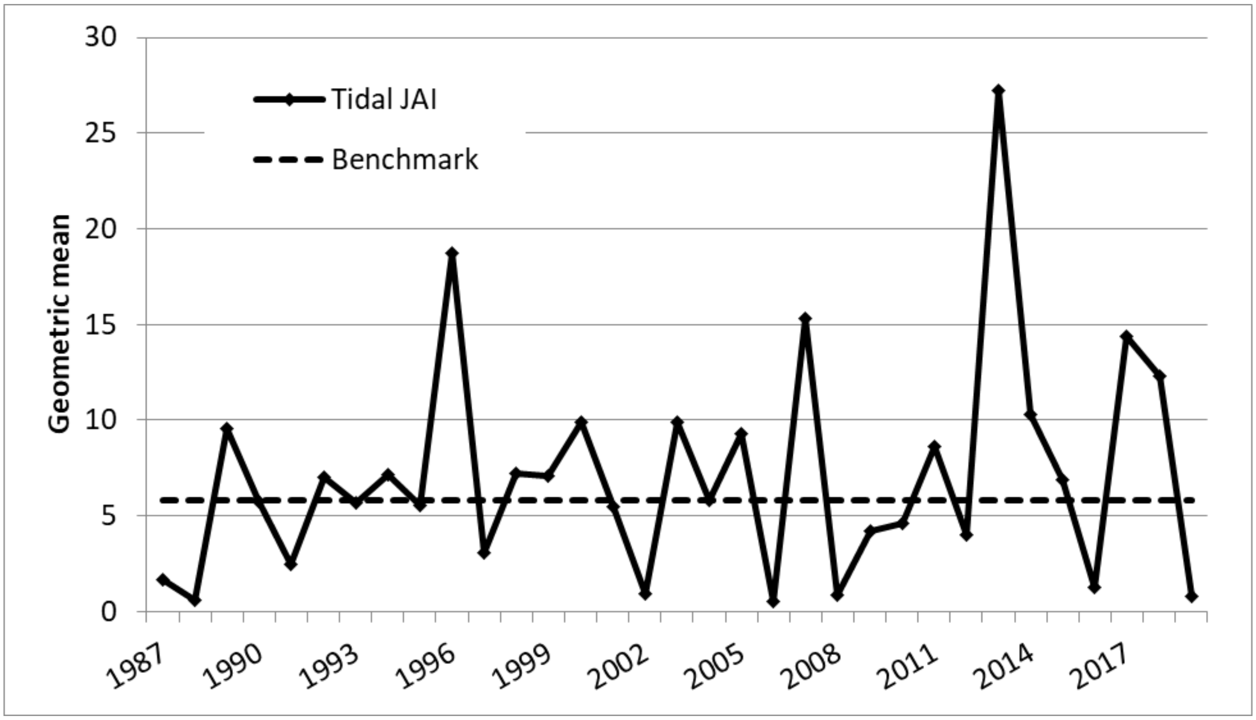


Figure 28. The Delaware River tidal American Shad JAI (GM) with a 50th percentile benchmark. The GM values are based on catches from Region 2 and 3 of the NJDFW tidal seine sites.

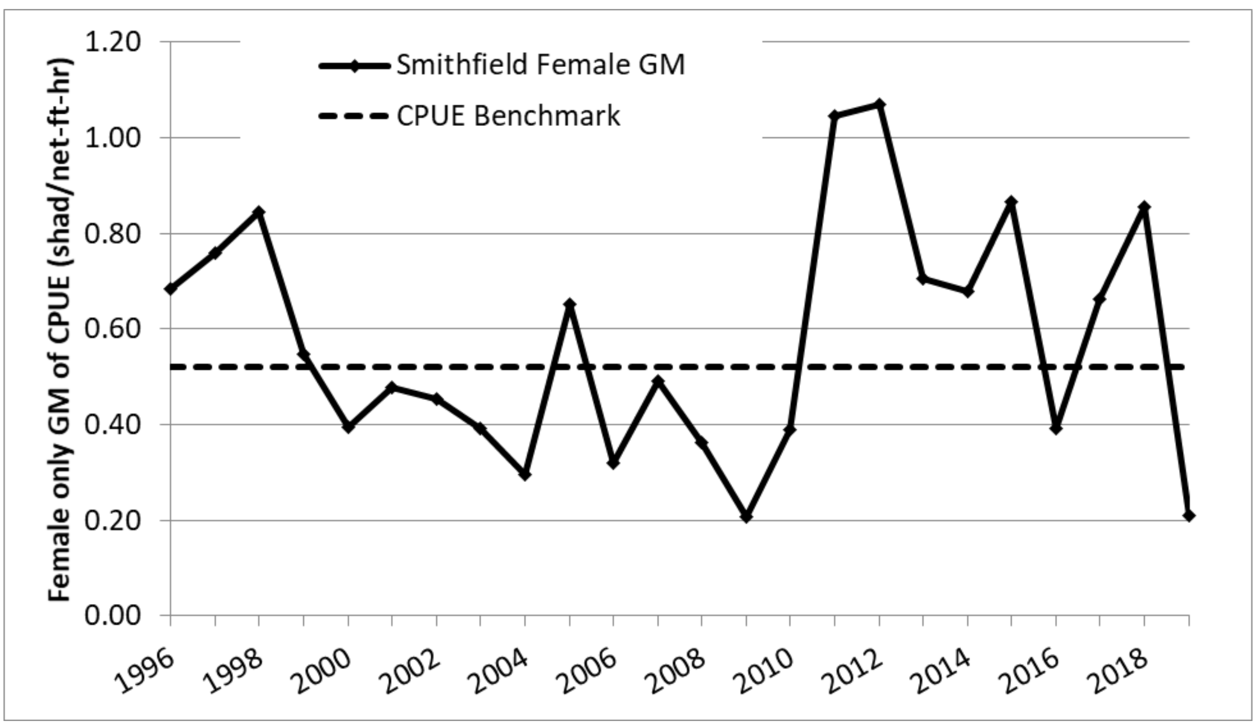


Figure 29. The Delaware River spawning adult female American shad index at Smithfield Beach (RM 218) with a 50th percentile benchmark.

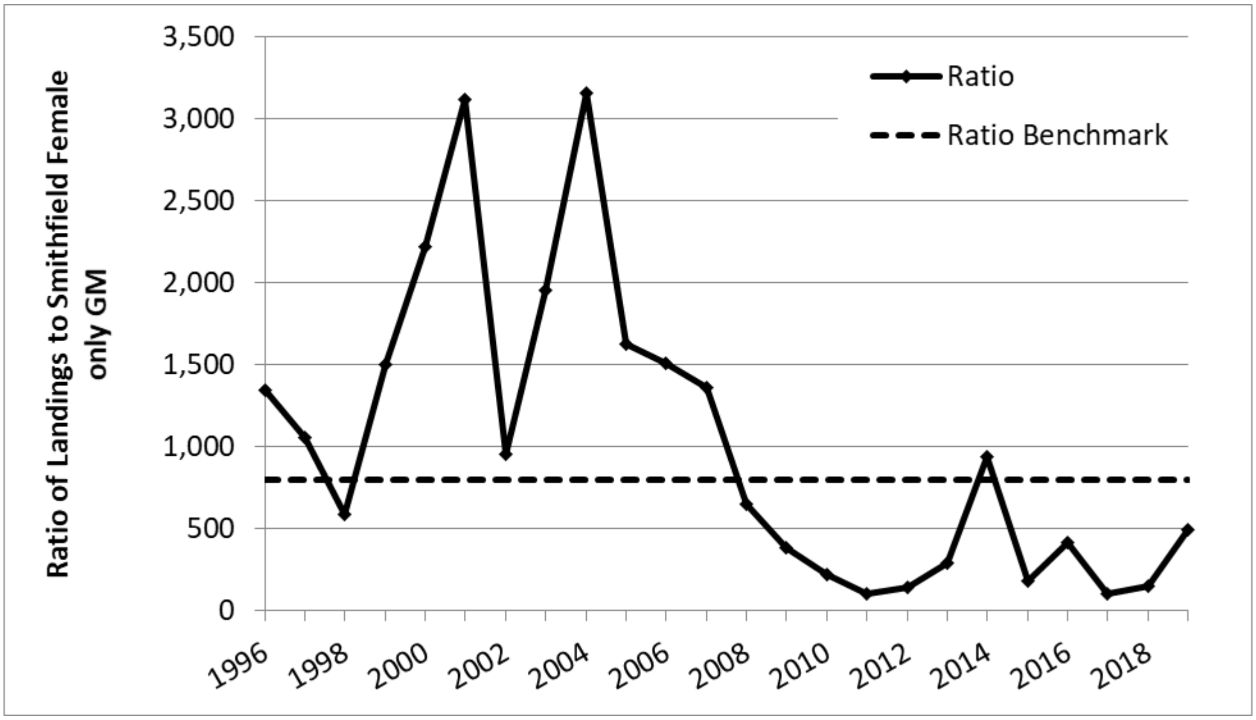


Figure 30. Ratio of Delaware River stock landings divided by Smithfield Beach female shad GM (divided by 100) with a 50th percentile benchmark: 1990-2019.

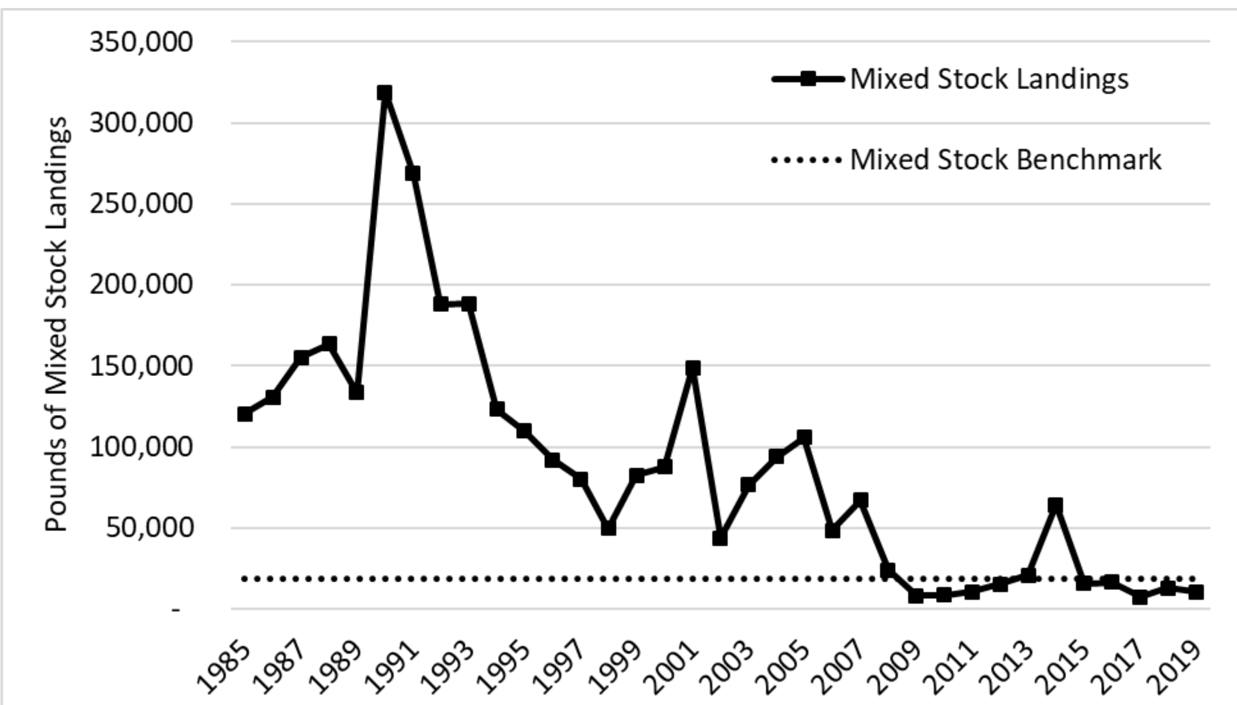


Figure 31. American shad landings in the Delaware Bay from the mixed stock fishery with a 25th percentile benchmark.

10. Tables

Table 1. New Jersey commercial fishing regulations for 2022.

System	Season	Gear Limits	Mandatory Reporting	Other Restrictions
Delaware Bay & River	Gill nets: Feb 1-Dec 15	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	YES	Limited entry; gear restrictions in defined areas
	-----------------	-------------------------------		
	Haul Seine: Nov 1-Apr 30	2.75" min. stretch mesh, max length 420'		

*except with special permit

Table 2. Number of permits issued to New Jersey fishermen and number reporting landings annually in the Delaware Bay 2000-2021.

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	71	47	13
2014	71	47	11
2015	71	47	9
2016	71	47	9
2017	71	47	12
2018	70	44	11
2019	70	43	9
2020	70	43	4
2021	70	43	4

Table 3. New Jersey's gill net effort data for the American shad commercial fishery.

	No. of Fishermen			No. of Man-days			Square Feet of Net			Pounds Harvested			Pounds/Square Foot		
Year	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	0.02	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
2016	5	4	9	39	84	123	2,401,200	1,208,640	3,609,840	6,222	12,155	18,377	0.003	0.010	0.005
2017	8	4	12	47	56	103	544,300	638,960	1,183,260	4,535	4,197	8,762	0.008	0.007	0.007
2018	7	7	11	62	62	124	692,945	1,288,015	1,980,960	8,012	7,726	15,738	0.012	0.006	0.008
2019	7	6	9	47	69	116	306,825	833,825	1,140,650	9,680	8,619	18,299	0.032	0.010	0.016

Table 4. Mean Fork length (mm) of American shad captured in New Jersey's tagging gill net surveys.

Year	Number	Male	Female	Sexes Combined	Range	Std. Dev.	Stretch Mesh (inches)
1995	107			483.7	405-605	30.8	5.5-6.0
1996	294			467.7	384-567	33.6	4.5-6.0
1997	500			448.4	346-600	34.1	5.0-6.0
1998	554			460.4	383-605	28.5	5.0-6.0
1999	753			465.1	375-563	26.2	5.0-5.75
2000	425			455.9	382-547	25.2	5.0-6.0
2001	663			474.1	396-615	29.6	5.0-6.0
2002	273	452.8	483.1	476.8	375-573	32.9	5.0-6.0
2003	170	451.4	477.4	472.2	401-538	27.1	5.0-6.0
2004	51	447.5	497.4	489.6	414-575	38.7	5.0-6.5
2005	220	445.2	477.5	470.6	402-586	36.7	5.0-6.5
2006	73	453.6	484	480.3	406-584	37.3	5.5
2007	42	444.5	478.2	476.6	426-571	32.9	5.5-6.5
2008	0						
2009	11	423.3	477.9	455	387-523	46	5.0-6.0
2010	85	430.9	457.9	447.1	366-518	32.3	5.0-6.0
2011	17	444.71	489.58	473.05	425-538	34	5.0-6.0
2012	18	435.67	485.67	477.33	459-515	26.7	5.0-6.0
2013	17		481.32	481.32	443-507	16.7	5.5-6.0
2014	18	444.25	485.77	476.11	395-525	33.6	5.5-6.0
2015	10	457	481.2	469.1	437-500	11	5.5-6.0
2016	94	466.6	473.5	472.8	409-529	23	5.5-6.0
2017	10	427	476	461.3	412-510	32.6	5.5-6.0
2018	36	440	469.4	467.4	414-518	27.3	5.0-6.0
2019	66	465.3	465.8	467.4	401-551	28.9	5-5.5

Table 5. 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	0.1	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	0.1
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	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	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	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	0.01
2016	6	6	3	4	41	38	16	34	16,545	14,652	11,300	28,300	4,273	9,342	211	425	0.26	0.64	0.02	0.02
2017	8	4	0	7	76	25	0	74	26,820	24,700	0	40,500	4,430	89	0	1,070	0.17	0	0	0.03
2018	9	3	0	3	92	16	0	34	43,361	7,400	0	31,000	7,491	840	0	1,307	0.17	0.11	0	0.04
2019	7	2	0	3	55	4	0	8	26,860	1,350	0	5,700	2,265	26	0	113	0.08	0.02	0	0.02

Table 6. 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
2016	111	20	12
2017	111	48	16
2018	111	44	16
2019	111	45	11

Table 7. The State of Delaware summary of biological data collected on American shad from Delaware and New Jersey commercial fishers.

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
2016	300	518	2.58
2017	32	504	3.41
2018	223	531	3.68
2019	21	522	3.59

Table 8. American shad tag returns, by year, from fish tagged in New Jersey's Tagging program off Reed's Beach in Delaware Bay.

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
2016	94	2
2017	10	0
2018	36	1
2019	66	0

Table 9. Recaptures of American Shad tagged in New Jersey's Tagging program off Reed's Beach in 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	15.9
Hudson River	44	17.5
Atlantic Ocean, NY	3	1.2
Atlantic Ocean, NJ	38	15.1
Delaware Bay/River	101	40.2
Atlantic Ocean, DE	4	1.6
Atlantic Ocean, MD	1	0.4
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
Unknown Location	1	0.4

Table 10. Assignment of stock origin for American shad collected in the Delaware Bay off Big Stone Beach (n=191) and Maurice River Cove (n=31) in 2010 from 33 baseline rivers (condensed, from Waldman et. al, 2014).

Region of Stock Origin	Percent Assignment
Northern region	12.6
Connecticut River	13.7
Hudson River	34.4
Delaware River	24.2
Chesapeake Bay	9.5
Southeastern region	5.6

Table 11. Assignment of stock origin for American shad collected in the Delaware Bay and River from 2017-2020 (from Bartron and Prasko, 2021). Bay demarcations can be found in Figure 25.

Region	Number Samples Taken	Percent Assigned to Delaware Stock	Percent Assigned to non-Delaware Stock
Smithfield Beach, PA	100	70	30
Lambertville, NJ	246	58	42
Schuylkill River, PA	22	64	36
Delaware River	23	52	48
Upper Bay	73	49	51
Mid-Bay	145	46	54
Lower Bay	343	52	48

Table 12. Marine Recreational Information Program (MRIP) characterization of recreational American shad harvest in the Delaware Estuary and Bay. PSE = Percent Standard Error.

	Recapture Location			
	Delaware		New Jersey	
Year	Total Harvest	PSE	Total Harvest	PSE
1994	13,218	68.8	18,706	101
1995				
1996				
1997			7,380	102.2
1998				
1999	5,601	61.2		
2000				
2001			96,971	94.4
2002				
2003	14,408	103.3		
2004				
2005				
2006				
2007				
2008				
2009				
2010	7,016	103.5	26,050	99.8
2011	16,598	102.1		
2012			32,511	99.7
2013				
2014				
2015				
2016				
2017				
2018				
2019	235	97.9		

Table 13. Number of American shad fry stocked in the Delaware River Basin. Due to COVID-19 social restrictions, PFBC hatchery operations were closed for the 2019 season.

Year	Delaware River	Lehigh River	Schuylkill River
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
2016		236,062	261,940
2017		434,454	361,391
2018		304,362	74,174
2019		0	0

Table 14. Hatchery contribution for adult American shad collected from the Delaware River (Smithfield Beach), the Lehigh River, and the Schuylkill River.

	Smithfield Beach		Lehigh River		Schuylkill River	
Year	N	Percent	N	Percent	N	Percent
1997	88	0.0%	No collections			
1998	234	3.8%	No collections			
1999	208	0.0%	104	91%		
2000	330	3.0%	99	91%		
2001	198	4.0%	103	92%		
2002	378	1.1%	99	89%		
2003	245	7.8%	No collections			
2004	414	1.2%	60	80%		
2005	776	0.5%	13	62%		
2006	350	1.4%	55	73%		
2007	746	2.8%	40	58%	22	92%
2008	667	1.0%	41	51%	28	100%
2009	367	1.1%	27	63%	24	96%
2010	470	0.2%	96	67%	25	100%
2011	409	0.5%	16	56%	22	88%
2012	412	1.0%	62	43%	21	84%
2013	454	0.2%	76	74%	25	84%
2014	488	1.4%	80	59%	25	88%
2015	Not Examined		62	32%	4	100%
2016	Not Examined		103	16%	29	66%
2017	Not Examined		98	14%	25	92%
2018	383	0%	49	8%	22	96%
2019	189	0%	2	50%	18	67%

Table 15. Female American shad total mortality for the Delaware River population.

Year	Z Estimate	SE	# Observations	# Year Classes	3-Yr. Moving Avg.	Z40 Benchmark
1996	0.61	0.11	**27**	3		1.07
1997	0.62	NaN	**20**	**2**		1.07
1998	0.74	0.29	56	3		1.07
2000	1.20	0.42	132	3		1.07
2001	1.61	0.12	200	3		1.07
2002	1.36	0.13	169	4	1.39	1.07
2003	1.60	0.28	219	4	1.52	1.07
2004	1.19	0.66	140	3	1.38	1.07
2005	1.63	1.65	185	4	1.47	1.07
2006	1.26	0.72	109	3	1.36	1.07
2007	1.85	0.28	232	4	1.58	1.07
2008	1.91	0.42	252	3	1.67	1.07
2009	1.44	0.21	139	3	1.73	1.07
2010	1.70	0.09	65	3	1.68	1.07
2011	3.44	NaN	290	**2**		1.07
2012	0.75	1.14	198	4		1.07
2013	1.45	0.62	261	3		1.07
2014	1.46	1.45	247	3	1.22	1.07
2015	0.87	0.18	145	3	1.26	1.07
2016	1.58	0.38	207	4	1.30	1.07
2017	1.44	0.94	144	3	1.30	1.07
2018	2.50	NaN	211	**2**		1.07
2019	0.86	1.70	166	3		1.07

Numbers in red indicate failure to meet requirements for inclusion of annual estimate and included for reference

Table 16. Juvenile non-tidal abundance indices for Delaware River American Shad. Non-tidal sites include Phillipsburg, Delaware Water Gap and Milford Beach. GLM = generalized linear model mean.

Year	Non-Tidal Shad GLM	Non-Tidal Benchmark
1988	168.44	188
1989	201.42	188
1990	308.57	188
1991	182.24	188
1992	114.26	188
1993	306.08	188
1994	224.89	188
1995	167.25	188
1996	415.6	188
1997	283.1	188
1998	53.99	188
1999	153.49	188
2000	187.71	188
2001	170.82	188
2002	80.94	188
2003	277.5	188
2004	252.2	188
2005	203.14	188
2006	55.53	188
2007	334.17	188
2008		188
2009		188
2010		188
2011		188
2012	369.14	188
2013	52.56	188
2014	162.37	188
2015	111	188
2016	157.34	188
2017	483.34	188
2018		188
2019	309.54	188

Table 17. Juvenile tidal abundance indices for Delaware River American Shad. GM = geometric mean.

Year	Tidal Shad GM	Tidal Benchmark
1987	1.68	5.81
1988	0.56	5.81
1989	9.54	5.81
1990	5.74	5.81
1991	2.49	5.81
1992	7	5.81
1993	5.68	5.81
1994	7.13	5.81
1995	5.52	5.81
1996	18.73	5.81
1997	3.05	5.81
1998	7.22	5.81
1999	7.07	5.81
2000	9.89	5.81
2001	5.45	5.81
2002	0.89	5.81
2003	9.9	5.81
2004	5.81	5.81
2005	9.26	5.81
2006	0.53	5.81
2007	15.3	5.81
2008	0.82	5.81
2009	4.21	5.81
2010	4.61	5.81
2011	8.64	5.81
2012	4	5.81
2013	27.22	5.81
2014	10.26	5.81
2015	6.9	5.81
2016	1.26	5.81
2017	14.35	5.81
2018	12.29	5.81
2019	0.79	5.81

Table 18. Delaware River spawning adult female American shad GM of the CPUE at Smithfield Beach (RM 218).

Year	Smithfield Female GM	CPUE Benchmark
1996	0.68	0.52
1997	0.76	0.52
1998	0.84	0.52
1999	0.55	0.52
2000	0.39	0.52
2001	0.48	0.52
2002	0.45	0.52
2003	0.39	0.52
2004	0.30	0.52
2005	0.65	0.52
2006	0.32	0.52
2007	0.49	0.52
2008	0.36	0.52
2009	0.21	0.52
2010	0.39	0.52
2011	1.04	0.52
2012	1.07	0.52
2013	0.70	0.52
2014	0.68	0.52
2015	0.87	0.52
2016	0.39	0.52
2017	0.66	0.52
2018	0.86	0.52
2019	0.21	0.52

Table 19. The Ratio of Delaware Stock landings divided by Smithfield female GM divided by 100.

Year	Delaware Stock Landings	Smithfield Beach GM	Ratio	Ratio Benchmark
1996	92068.5	0.68376	1346.51	799
1997	80157.5	0.75995	1054.78	799
1998	49534	0.84473	586.387	799
1999	82464	0.54728	1506.79	799
2000	87659	0.39406	2224.53	799
2001	148986	0.47733	3121.26	799
2002	43563.5	0.45463	958.217	799
2003	76471	0.39107	1955.43	799
2004	93775.5	0.29667	3160.97	799
2005	105797	0.65064	1626.05	799
2006	48339.5	0.32016	1509.83	799
2007	67133	0.49138	1366.2	799
2008	23686.5	0.36151	655.214	799
2009	8045.5	0.20673	389.178	799
2010	8619.5	0.38993	221.051	799
2011	10593.5	1.04437	101.434	799
2012	15054	1.06901	140.821	799
2013	20695.5	0.70449	293.768	799
2014	64086	0.67922	943.529	799
2015	15591.5	0.86709	179.814	799
2016	16314	0.39202	416.156	799
2017	7160.5	0.66196	108.171	799
2018	12688	0.85628	148.176	799
2019	10351.5	0.20983	493.319	799

Table 20. Total American shad landings (pounds) by state from the Delaware River and Bay assigned to mixed stock fisheries.

Year	Mixed Stock Landings	Mixed Stock Benchmark
1985	120,242	18,505
1986	130,556	18,505
1987	155,091	18,505
1988	163,651	18,505
1989	133,544	18,505
1990	318,984	18,505
1991	268,843	18,505
1992	187,907	18,505
1993	188,215	18,505
1994	123,256	18,505
1995	109,880	18,505
1996	92,069	18,505
1997	80,158	18,505
1998	49,534	18,505
1999	82,464	18,505
2000	87,659	18,505
2001	148,986	18,505
2002	43,564	18,505
2003	76,471	18,505
2004	93,776	18,505
2005	105,797	18,505
2006	48,340	18,505
2007	67,133	18,505
2008	23,687	18,505
2009	8,046	18,505
2010	8,620	18,505
2011	10,594	18,505
2012	15,054	18,505
2013	20,696	18,505
2014	64,086	18,505
2015	15,592	18,505
2016	16,314	18,505
2017	7,161	18,505
2018	12,688	18,505
2019	10,352	18,505

Atlantic States Marine Fisheries Commission

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MEMORANDUM

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

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

DATE: **April 15, 2022**

SUBJECT: **TC Recommendations on updates to state habitat and fishery management plans**

The Shad and River Herring Technical Committee (TC) met via conference call and webinar on February 3 and April 8, 2022, to achieve two objectives:

1. Review State Sustainable Fishery Management Plans (SFMPs) and Shad Habitat Plans
2. Develop TC recommendations on each proposal for Board consideration

The TC recommends approval of all proposals, with the inclusion of some requested revisions. Summaries of each state's proposed changes and TC recommendations are included below.

Connecticut River Atlantic Salmon Commission (CRASC) Habitat Plan Update

Ken Sprankle presented the final draft of the updated American Shad Habitat Plan for the Connecticut River that incorporated updates from the CRASC American Shad Management Plan from 2017 and the Fish Passage Performance Addendum from 2020. The most notable threats determined by the plan are fish passage, habitat impacts from hydropower flow, an expansion of invasive *Hydrilla*, and impacts from human development. The TC recommended minor formatting changes and noted for future versions to consider requiring states to report more specific water quality parameters that cause degradation.

Merrimack River Habitat Plan for American Shad

Ben Gahagan presented the final American Shad Habitat Plan for the Merrimack River. The plan outlines numerous threats, including hydropower operations, water withdrawal, thermal discharge, water quality, and land use. However, the most significant threat is barriers to fish passage. The plan identifies seven target dams for a mix of passage improvements and removals, as well as many others that will undergo the Federal Energy Regulatory Commission (FERC) re-licensing process, and contains strategies to make significant improvements to fish passage by 2030. The TC recommended including language to define the passage standards that Massachusetts is using, which is an upstream efficiency of 80%.

New York SFMP 2022 Update

Wes Eakin presented the updated NY SFMP for River Herring, which proposed maintaining status quo for the fishery management program: a continuation of the restricted fishery in the Hudson River and moratorium in all other state waters. The main change to the SFMP is the inclusion of a new sustainability threshold for female total mortality, $Z_{40\%}$. The $Z_{40\%}$ mortality threshold was chosen as a more conservative threshold based on literature review. The stock status update showed erratic young-of-year indices but no recruitment failure, and the mortality estimates were either stable or decreasing and remained below the new sustainability target. The proposed sustainability thresholds are two consecutive years above the $Z_{40\%}$ mortality threshold or three consecutive years of recruitment failure,

M22-46

which is defined as recruitment below the 25th percentile (based on recruitment from 1983-2015), and each would trigger management actions.

Delaware River Basin Cooperative SFMP for American Shad

Sheila Eyler presented the updated DE COOP SFMP for American shad, which proposed a continuation of the commercial and recreational fisheries within the jurisdiction with new benchmarks to act as more conservative management triggers. The new metrics were developed in response to the 2020 Benchmark Stock Assessment, which indicated an unsustainable mortality rate for the Delaware River stock.

The SFMP includes six benchmarks to inform management and potentially trigger action, one of which is new to this update. The new benchmark is *Female Total Mortality*, which is calculated as a three year rolling average, and will trigger management if it exceeds 1.07. The remaining five benchmarks have been updated to a more conservative level since the last SFMP.

Non-tidal and Tidal JAIs: Benchmarks are increased from 25th percentile to 50th and changed the trigger from three consecutive years below the benchmark to any three out of five years.

Smithfield Beach CPUE: The index is changed to only consider females, the benchmark is increased from 25th to 50th percentile, and the trigger is changed from three consecutive years below the benchmark to any three out of five years below the benchmark.

Ratio of Commercial Harvest to Smithfield Beach: Benchmark is decreased from 85th to 50th percentile, and the trigger is changed from three consecutive years above the benchmark to any three out of five years below the benchmark.

Mixed Stock Landings: In response to new genetic information, the demarcation line in the Delaware River to separate Delaware River stock and mixed stock was removed and 50% of all landings attributed to mixed stock. The benchmark was reduced from the 75th percentile to the 25th, and the trigger is two consecutive years above the benchmark.

The DE COOP will hold annual meetings to evaluate any triggers that were activated in the previous year and decide on management actions accordingly. The benchmarks are set to be implemented immediately, but management actions will be implemented in 2023 in order to avoid imposing new management during the fishing season.

Atlantic States Marine Fisheries Commission

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MEMORANDUM

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

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

DATE: **April 15, 2022**

SUBJECT: **Technical Committee Report on American Shad Passage Prioritization**

Background

American shad stocks on the Atlantic Coast are considered at "all time low levels of abundance" based upon stock assessments completed for American shad in 2007 and 2020. These assessments demonstrate that despite significant fishery restrictions implemented under the Commission's Fishery Management Plan (FMP) for Shad and River Herring, many stocks are not showing detectable improvements.

The 2020 American Shad Stock Assessment and Peer Review Report (Assessment Report) examined shad habitat and migration barriers, and fish passage performance as of 2018 provided by Shad and River Herring Technical Committee (TC) members. Using standardized data and simulation modelling, the analysis determined that overall, dams completely or partly block nearly 40% of the total historical American Shad habitat.

In May 2021, at the TC's recommendation, the Board tasked the TC with prioritizing systems for shad recovery and developing an inventory of available data that would support development of fish passage criteria. The TC recommends that actions to reduce the negative effects of barriers and poor fish passage measures for both up and downstream migration of shad are necessary to provide increased opportunities for population recovery. Specifically, where dam removal is not possible, fish passage performance standards should be developed based on available data, fish passage modeling tools, and fish passage expertise. If the required information to develop performance standards are not available, it should be collected and/or developed for such purposes and applications.

TC Task Development

To respond to the Board task assigned in May 2021, the TC formed a task group to develop information and draft recommendations for TC review. The steps taken in the development of this task are summarized below:

- A query of FERC projects in the relicensing process or planned for relicensing was completed for the years 2020 to 2030 on East Coast river systems. Under the Federal Power Act, the USFWS and NOAA have Section 18 Fish Passage Prescription Authority, a legal tool to have FERC direct hydroproject owners to implement and evaluate passage and protection measures.
    - In addition, FERC licensed hydropower project must also obtain a Water Quality Certificate (WQC) as defined by the Federal Clean Water Act. The WQC is often

M22-47

delegated by the Environmental Protection Agency (EPA) to individual State Government agencies (i.e., Massachusetts Department of Environmental Protection) or may in some case be handled by the EPA. In either case, the WQC may include specific fish passage conditions, such as passage performance standards, providing another mechanism for the States to assert their role in cooperative passage performance standards with sister state and federal agencies.
    - As the management agencies responsible for the public's fishery resources, deference is given to the agencies in the eyes of FERC, in comparison to applicant positions on these topics.
- A total of 158 FERC projects were identified from Maine to Florida based only on FERC license status/schedule.
- The TC Task Group developed a questionnaire for members to address the Board's charges:
    1) Does the system have an existing recovery plan?
    2) Does the system have existing performance standards?
    3) Does the system have existing upstream fish passage?
    4) Does the system have existing downstream fish passage?
    5) Is alosine passage needed?
    6) Any issue(s) for existing passage structures/operations?
    7) Priority?
    8) Comments
- Filtering on a TC member's designation as a "priority", noting shad as primary, the FERC project list was reduced to 34 projects (Table 1).

Results and Recommendations

For each of the projects identified as priorities, the TC recommends that the relevant state and federal agencies determine the extent to which their existing Shad Restoration or Management Plan(s) are current and relevant for information to best address upstream and downstream passage for specific goals and/or objectives. The following items should be considered for each priority project:

- If existing plan information is determined to be outdated or does not suitably address fish passage, the plan should be updated with state and federal participation with staff familiar with both Section 18 Authorities and Water Quality Certificates. Another option may be a plan addendum specific to fish passage.
- When existing plans include the commonly stated and undefined language such as "safe, timely, and effective" passage measures, steps to develop specific passage performance criteria should be discussed and developed by the agencies.
- Fish passage performance criteria development should rely on a diverse set of information for supporting rationale including but not limited to, plan goals and objectives, status and trends of population(s), existing passage information, references to other plans with passage performance criteria, research and other supporting information including the 2020 Benchmark Stock Assessment, and passage/fish

population modeling. It is the growing body of information that makes this rationale compelling for the need for better passage performance, not any single element[1].

- Performance targets should address rates of passage success that include; percent passage success for fish arriving at a project area, a time component to address delay as part of passage success, and survival rates with project passage.
- Plans should be submitted to FERC for status as Comprehensive Management Plans, requiring FERC licensee's to address these plans. One criteria for FERC consideration as a CMP is providing a public comment period.
- Development of a Fish Passage Performance Addendum to an existing Plan may be a preferred option to incorporate appropriate passage performance measures. In all instances, the document(s) should be submitted to FERC as a Comprehensive Management Plan.
- A plan that defines habitat-based area adult production, among river segments (dams), is useful for this purpose in plan goals and objectives that address, 1) fisheries, 2) ecological benefits (adults and juveniles), and 3) population (e.g., resilience, repeat spawner component).

Table 1. Summary totals for identified priority FERC Projects by state with questionnaire responses

State	# of Priority Projects	Existing Recovery Plan?	Passage Performance Standards?	U/S Passage in System?	D/S passage in system?	Is Alosine Passage Needed?	Any Issues for Existing Passage structure/ops?
Maine	8	Yes = 8	Attempting = 2 No = 6	Yes =5 No = 3	Yes = 8	Better passage = 3 Yes = 3	Yes = 7
New Hampshire	10	Yes = 7 No = 3	Yes = 7 No = 3	Yes = 3 No = 7	Yes = 3 No = 7	Yes = 10	Yes = 3
Massachusetts	3	Yes = 3	Yes = 3	Yes = 3	Yes = 3	Yes = 3	Yes = 3
Rhode Island	1	Yes = 1	Yes = 1	No = 1	No = 1	Yes = 1	No = 1
Connecticut	4	Yes = 4	No = 4	No = 4	No = 4	Yes = 4	No = 4
New York	4	Unk = 4	Unk = 4	Unk = 4	Yes = 3 Unk = 1	Unk = 4	Yes = 4
Pennsylvania	2	Yes = 2	Yes = 1 No = 1	Yes = 2	No = 2	Yes = 2	Yes = 1 No = 1
Virginia	1	Unk = 1	Unk = 1	Yes = 1	Yes = 1	Yes = 1	Yes = 1
Georgia	1	Yes = 1	No = 1	No = 1	No = 1	Yes = 1	Unk = 1
Total	34	Yes = 26 No = 3 Unk. = 5	Yes = 12 No = 15 Unk. = 5 Attempting = 2	Yes = 14 No = 16 Unk. = 4	Yes = 18 No = 15 Unk. = 1	Yes/better = 26 Unk. = 4	Yes = 19 No = 6 Unk. = 1

[1] The Connecticut River Atlantic Salmon Commission's Connecticut River American Shad Management Plan (2017) and its Fish Passage Performance Addendum (2020), help to illustrate the approaches noted here and includes the questions and responses of its public review before submittal to FERC.

Table 2. River basin locations of priority FERC projects by state

State	Priority Projects	River Systems [Tributary and/or Main Stem (#))
Maine	8	Kennebec; Androscoggin (3); Little Androscoggin, Androscoggin; Penobscot; Saco.
New Hampshire	10	Salmon Falls (3); Nashua, Merrimack; Contoocook, Merrimack (3); Piscataquog, Merrimack; Connecticut; Ashuelot, Connecticut.
Massachusetts	3	Merrimack.
Rhode Island	1	Connecticut (2).
Connecticut	4	Quinebaug (2); Moosup, Quinebaug; Housatonic.
New York	4	East; Mohawk, Hudson (3).
Pennsylvania	2	Susquehanna (2).
Virginia	1	Appomattox.
Georgia	1	Savannah.

DRAFT FOR BOARD REVIEW

REVIEW OF THE ATLANTIC STATES MARINE FISHERIES COMMISSION FISHERY MANAGEMENT PLAN FOR SHAD AND RIVER HERRING *(Alosa spp.)* FOR THE 2020 FISHING YEAR

Shad & River Herring Plan Review Team

James Boyle, Atlantic States Marine Fisheries Commission (Chair)

Michael Brown, Maine Department of Marine Resources

Mike Dionne, New Hampshire Fish and Game Department

Brian Neilan, New Jersey Division of Fish and Wildlife

Jim Page, Georgia Department of Natural Resources

May 2022

DRAFT FOR BOARD REVIEW

REVIEW OF THE ASMFC FISHERY MANAGEMENT PLAN FOR SHAD AND RIVER HERRING *(Alosa spp.)*

I. Status of the Fishery Management Plan

Date of FMP Approval:	October 1985
Amendments:	Amendment 1 (April 1999) Amendment 2 (August 2009) Amendment 3 (February 2010)
Addenda:	Technical Addendum #1 (February 2000) Addendum I (August 2002)
Management Unit:	Migratory stocks of American shad, hickory shad, alewife, and blueback herring from Maine through Florida
States With Declared Interest:	Maine through Florida, including the Potomac River Fisheries Commission (PRFC) and the District of Columbia
Active Boards/Committees:	Shad & River Herring Management Board, Advisory Panel, Technical Committee, Stock Assessment Subcommittee, Plan Review Team, Plan Development Team

The 1985 Fishery Management Plan (FMP) for Shad and River Herring was one of the first FMPs developed by the ASMFC. Amendment 1 was initiated in 1994 to require and recommend specific monitoring programs to inform future stock assessments—it was implemented in October 1998. A Technical Addendum to Amendment 1 was approved in 1999 to correct technical errors.

The Shad and River Herring Management Board (Board) initiated Addendum I in February 2002 to change the conditions for marking hatchery-reared alosines; clarify the definition and intent of *de minimis* status for the American shad fishery; and modify and clarify the fishery-independent and dependent monitoring requirements. These measures went into effect on January 1, 2003.

In May 2009, the Board approved Amendment 2 to restrict the harvest of river herring (blueback herring and alewife) due to observed declines in abundance. The Amendment prohibited commercial and recreational river herring harvest in state waters beginning January 1, 2012, unless a state or jurisdiction has a sustainable fishery management plan (SFMP) reviewed by the Technical Committee and approved by the Board. The Amendment defines a sustainable fishery as "a commercial and/or recreational fishery that will not diminish the potential future stock reproduction and recruitment." Catch and release only fisheries may be maintained in any river system without an SFMP. SFMPs have been approved by the Management Board for Maine, New Hampshire, Massachusetts, New York, and South Carolina (Table 1). Amendment 2 also required states to implement fishery-dependent and independent monitoring programs.

In February 2010, the Board approved Amendment 3 in response to the 2007 American shad stock assessment, which found most American shad stocks at all-time lows. The Amendment requires similar management and monitoring for shad as developed in Amendment 2 (for river herring). Specifically, Amendment 3 prohibits shad commercial and recreational harvest in state waters beginning January 1, 2013, unless a state or jurisdiction has a SFMP reviewed by the Technical Committee and approved by the Board. The Amendment defines a sustainable fishery as "a commercial and/or recreational fishery that will not diminish the potential future stock reproduction and recruitment." Catch and release only fisheries may be maintained in any river system without an SFMP. SFMPs have been approved by the Board for Massachusetts, Connecticut, the Delaware River Basin Fish Cooperative (on behalf of New York, Delaware, New Jersey, and Pennsylvania), PRFC, North Carolina, South Carolina, Georgia, and Florida (Table 1). All states and jurisdictions are also required to identify local significant threats to American shad critical habitat and develop a plan for mitigation and restoration. All states and jurisdictions habitat plans have been accepted and approved.

Table 1. States/jurisdictions with approved sustainable fishery management plans (SFMPs) for river herring or shad. Includes year of original Board approval and approved updates[1].

State	River Herring SFMP	Shad SFMP
Maine	Approved (2010, 2017, 2020)	Approved (2020)
New Hampshire	Approved (2011, 2015, 2020)	
Massachusetts	Approved (2016)	Approved (2012, 2019)
Connecticut		Approved (2012, 2017)
Rhode Island		
Pennsylvania		Approved* (2012, 2017, 2020)
New York	Approved (2011, 2017)	Approved* (2012, 2017, 2020)
New Jersey		Approved* (2012, 2017, 2020)
Delaware		Approved* (2012, 2017, 2020)
PRFC		Approved (2012, 2017)
Maryland		
Virginia		
North Carolina		Approved (2012, 2017, 2020)
South Carolina	Approved (2010, 2017, 2020)	Approved (2011, 2017, 2020)
Georgia		Approved (2012, 2017, 2020)
Florida		Approved (2011, 2017, 2020)

*The Delaware River Basin Fish and Wildlife Management Co-op has a Shad SFMP, though Delaware and New Jersey are only states that have commercial fisheries. All states have recreational measures, with limited to no catch in the upper Delaware River (New York & Pennsylvania).

[1] SFMPs must be updated and re-approved by the Board every five years.

II. Status of the Stocks

While the FMP addresses four species: two river herrings (blueback herring and alewife) and two shads (American shad and hickory shad)—these are collectively referred to as shad and river herring, or SRH.

The most recent American Shad Benchmark Stock Assessment (ASMFC 2020) indicates American shad remain depleted on a coastwide basis. Multiple factors, such as overfishing, inadequate fish passage at dams, predation, pollution, water withdrawals, channelization of rivers, changing ocean conditions, and climate change are likely responsible for shad decline from historic abundance levels. Additionally, the assessment finds that shad recovery is limited by restricted access to spawning habitat. Current barriers partly or completely block 40% of historic shad spawning habitat, which may equate to a loss of more than a third of spawning adults.

Of the 23 river-specific stocks of American shad for which sufficient information was available, adult mortality was determined to be unsustainable for three stocks (Connecticut, Delaware, and Potomac) and sustainable for five stocks (Hudson, Rappahannock, York, Albemarle Sound, and Neuse). The terms “sustainable” and “unsustainable” were used instead of “not overfishing” and “overfishing” because fishing mortality cannot be separated from other components contributing to total mortality. The assessment was only able to determine abundance status for two stocks: abundance for the Hudson is depleted, and abundance for the Albemarle Sound is not overfished. For the Hudson and coastwide metapopulation, the “depleted” determination was used instead of “overfished” because the impact of fishing on American shad stocks cannot be separated from the impacts of all other factors responsible for changes in abundance.

The status of 15 additional stocks could not be determined due to data limitations, so trends in YOY and adult abundance were provided for information on abundance changes since the 2005 closure of the ocean-intercept fishery. For YOY indices, two systems experienced increasing trends while one system experienced a decreasing trend since 2005. All other systems experienced either no trend (eight systems), conflicting trends among indices (one system), or had no data (11 systems). For adult indices, four systems experienced increasing trends while no systems experienced decreasing trends since 2005. All other systems experienced either no trend (11 systems), conflicting trends among indices (seven systems), or had no data (one system). Trend analyses also indicate a continued lack of consistent increasing trends in coastwide metapopulation abundance since 2005.

Taken in total, American shad stocks do not appear to be recovering. The assessment concluded that current restoration actions need to be reviewed and new efforts need to be identified and applied. Because multiple factors are likely responsible for shad decline, the recovery of American shad will need to address multiple factors including improved monitoring, anthropogenic habitat alterations, predation by non-native predators, and exploitation by fisheries. There are no coastwide reference points for American shad. There is no stock assessment available for hickory shad.

The most recent *River Herring Benchmark Assessment Report* (ASMFC 2012) indicated that of the 24 river herring stocks for which sufficient data were available to make a conclusion, 23 were depleted relative to historic levels and one was increasing. The status of 28 additional stocks could not be determined because the time-series of available data was too short.

Estimates of coastwide abundance and fishing mortality could not be developed because of the lack of adequate data. The "depleted" determination was used instead of "overfished" because of the many factors that have contributed to the declining abundance of river herring, which include not just directed and incidental fishing, but likely also habitat issues (including dam passage, water quality, and water quantity), predation, and climate change. There are no coastwide reference points.

The river herring stock assessment was updated in 2017 (ASMFC 2017) with additional data from 2011-2015, and concluded that river herring remain depleted at near historic lows on a coastwide basis. Total mortality estimates over the final three years of the data time series (2013-2015) were generally high and exceed region-specific reference points for some rivers. However, some river systems showed positive signs of improvement. Total mortality estimates for 2 rivers fell below region-specific reference points during the final three years of the data time series. No total mortality estimates were below reference points at the end of the 2012 stock assessment data time series. Of the 54 stocks with available data, 16 experienced increasing abundance trends, 2 experienced decreasing abundance trends, 8 experienced stable abundance and 10 experienced no discernable trend in abundance over the final 10 years of the time series (2006-2015). The next river herring stock assessment is expected to be completed in 2023.

III. Status of the Fisheries

Shad and river herring formerly supported the largest and most important commercial and recreational fisheries throughout their range. Historically fishing took place in rivers (both freshwater and saltwater), estuaries, tributaries, and the ocean. Although recreational harvest data are scarce, today most harvest is believed to come from the commercial industry. Commercial landings for these species have declined dramatically from historic highs. Details on each fishery are provided below.

AMERICAN SHAD:

Total commercial landings throughout the 1950s fluctuated around eight million lbs, then declined to just over two million lbs in 1976. A period of moderate increase occurred through the mid-1980s, followed by further declines through the remainder of the time series. Since the closure of the ocean intercept fishery in 2005, landings have been substantially lower, falling below one million lbs. Since 2015, landings have remained below half a million lbs.

The total non-confidential commercial landings (directed and bycatch) reported in compliance reports from individual states and jurisdictions in 2020 were 407,179 lbs, representing a 49% increase from landings in 2019 (273,450 lbs) (Table 2). Bycatch landings accounted for approximately 25% of the total commercial landings of American shad in 2020. Landings from North Carolina, South Carolina, and Georgia accounted for 43.9%, 36.5%, and 12.4% of the directed coastwide commercial fishery removals in 2020, respectively. The remainder of the directed landings came from Connecticut and Delaware. Maryland commercial fishermen are permitted a bycatch allowance of two fish per day of dead American shad for personal use, provided that shad are captured by gear legally deployed for the capture of other fish species; no sale is permitted. Landings from Virginia, District of Columbia, and PRFC are attributed to limited bycatch allowances for American Shad.

Substantial recreational shad fisheries occur on the Connecticut (CT and MA), Delaware (NY, PA NJ, and DE), Susquehanna (MD), Santee and Cooper (SC), and St. Johns (FL) Rivers. Shad recreational fisheries are also pursued on several other rivers in Massachusetts, District of Columbia, Virginia, North Carolina, South Carolina, and Georgia. Though shad are recreationally targeted in these locations, many fisheries are catch and release only. Hook and line shad catch levels are not well understood; actual harvest and/or effort is only estimated by a few states through annual creel surveys (e.g. Maryland, North Carolina, Georgia, and Florida). Harvest may only amount to a small portion of total catch (landings and discards), but hooking mortality could increase total recreational fishery removals substantially.

Since 2009, recreational harvest data from the Marine Recreational Information Program (MRIP) are generally not provided for American shad due to high proportional standard errors (PSEs). This is a result of the MRIP survey design, which focuses on active fishing sites along coastal and estuarine areas and is unsuitable for capturing inland harvest. However, North Carolina, South Carolina, and Florida reported American shad recreational harvest estimates for 2020 (Table 3).

HICKORY SHAD:
In 2020, North Carolina, South Carolina, and Georgia reported directed commercial hickory shad landings; Rhode Island, New York, Virginia, and North Carolina reported bycatch landings. North Carolina accounts for a vast majority of directed landings, contributing 87% of the total. Coastwide commercial and bycatch landings in 2020 totaled 92,023 lbs, representing a 36% decrease from 2019 landings (143,851 lbs) (Table 2). Virginia and North Carolina reported recreational harvest of 876 lbs and 20,967 lbs, respectively.

RIVER HERRING (BLUEBACK HERRING/ALEWIFE COMBINED):
Commercial landings of river herring declined 95% from over 13 million lbs in 1985 to about 733 thousand lbs in 2005. Recent commercial landings continue to increase, despite the closure of the ocean-intercept fishery in 2005 and North Carolina implementing a no-harvest provision for commercial and recreational fisheries of river herring in coastal waters of the state in 2007. In 2020, the coastwide directed commercial river herring landings reported in state compliance reports were 1.88 million lbs, a 25% decrease from 2019 (2.5 million lbs). Bycatch landings in 2020 totaled 24,806 lbs, a 97% decrease from the 2019 total of 720,111 lbs (Table 2). Confidential data preclude reporting commercial landings by state. New Hampshire and South Carolina provided estimates of recreational river herring harvest in 2020; recreational harvest estimates for Maine and Massachusetts are produced by MRIP but highly uncertain (Table 3).

Table 2. Shad and river herring total commercial fishery removals (directed landings and bycatch[1], in lbs) provided by states, jurisdictions and NOAA Fisheries for 2020.

	River Herring	American Shad	Hickory Shad
Maine		C	C
New Hampshire		0	0
Massachusetts		9	0
Rhode Island		0	5,362
Connecticut		21,414	0
New York		1,150	C
New Jersey		337	0
Pennsylvania		0	0
Delaware		387	0
Maryland		0	0
D.C.		0	0
PRFC		17,019	0
Virginia		3,378	1,234
North Carolina		213,724	75,182
South Carolina		111,848	C
Georgia		37,913	9,661
Florida		0	0
Total Directed	1,879,029	306,465	C
Total Bycatch	24,806	100,714	C
Total	**1,903,835**	**407,179**	**92,023**

*All values for river herring by state are not shown due to confidential data. Confidential values for American shad and hickory shad are indicated by "C."

Table 3. Recreational harvest information for river herring and American shad in 2020 from MRIP and state compliance reports.

State	River Herring Harvest	American Shad Harvest	Source of Estimates
Maine	119 fish		MRIP*
New Hampshire	26,887 fish (13,443.5 lbs)		APAIS and mandatory-reporting for net and pot fishing
Massachusetts	19,236 fish		MRIP*
North Carolina		4,621 fish (10,546 lbs)	Recreational creel surveys on the Roanoke, Tar, Neuse, and Cape Fear rivers
South Carolina	2,688 fish (1,137 lbs)		There were restrictions from COVID-19 on Fishery-Dependent Monitoring that prohibited fieldwork after March 19th, 2020.
Florida		177 fish (212kg)	Access point creel survey on St. Johns River

*MRIP estimate considered highly uncertain. Maine data has a PSE of 104.5 and Massachusetts 64.9. Spatial coverage of MRIP sampling may not align with recreational harvest areas for shad. In Maine, only 3 shad were

[1] Available information on shad and river herring bycatch varies widely by state. Estimates may not capture all bycatch removals occurring in state waters.

sampled in 2018 and fewer than 56 shad have been sampled since 1996. In Massachusetts, the estimate is based on one caught fish.

IV. Status of Research and Monitoring

Amendment 2 (2009) and Amendment 3 (2010), required fishery-independent and fishery-dependent monitoring programs for select rivers. Juvenile abundance index (JAI) surveys, annual spawning stock surveys (Table 4), and hatchery evaluations are required for specified states and jurisdictions. States are required to calculate mortality and/or survival estimates, and monitor and report data relative to landings, catch, effort, and bycatch. States must submit annual reports including all monitoring and management program requirements on or before July 1 of each year.

In addition to the mandatory monitoring requirements stipulated under Amendments 2 and 3, some states and jurisdictions continue important voluntary research initiatives for these species. For example, Massachusetts, Pennsylvania, Delaware, Maryland, District of Columbia, North Carolina, South Carolina, and the United States Fish and Wildlife Service (USFWS) are actively involved in shad restoration using hatchery-cultured fry and fingerlings. All hatchery fish are marked with oxytetracycline marks on otoliths to allow future distinction from wild fish. During 2020, several jurisdictions reared American shad, stocking a total of 14,688,667 American shad, an increase of 23% from the 11,964,361 shad stocked in 2019 (Table 5). In addition 1,268,795 river herring (both alewife and blueback) larvae were stocked in Harrison Lake, part of the James River system, in 2020.

V. Status of Management Measures

All state programs must implement commercial and recreational management measures or an alternative program approved by the Management Board (Table 1). The current status of each state's compliance with these measures is provided in the Shad and River Herring Plan Review Team Report (Table 6).

Amendment 2 (2009) prohibits river herring commercial and recreational harvest in state waters beginning January 1, 2012, unless a state or jurisdiction submits a sustainable fishery management plan and receives approval from the Board. Amendment 3 (2010) also requires the development of a SFMP for any jurisdiction maintaining a shad commercial or recreational fishery after January 1, 2013 (with the exception of catch and release recreational fisheries). States are required to update SFMPs every five years. In 2017, states reviewed their SFMPs and made changes based on fishery performance or observations (e.g., revised sustainability targets) where necessary. At a minimum, states updated data for their commercial and/or recreational fisheries and recommended the current sustainability measures be carried forward in the next plan. To date the Board has reviewed and approved updated SFMPs for all states, with the updated Massachusetts SFMP for shad being approved in February 2019.

Under Amendments 2 and 3 to the FMP, states may implement, with Board approval, alternative management programs for river herring and shad that differ from those required by the FMP. States and jurisdictions must demonstrate that the proposed management program will not contribute to overfishing of the resource or inhibit restoration of the resource. The Management Board can approve a proposed alternative management program if the state or jurisdiction can show to the Management Board's satisfaction that the alternative proposal will have the same conservation value as the measures contained in the FMP. In August 2020, the Board approved alternative management plans for recreational fishery regulations in South Carolina, Georgia, and Florida.

Table 4. American shad and river herring passage counts at select rivers along the Atlantic coast in 2020.

State/River	Shad	River Herring
Maine		
Androscoggin	23	*
Saco	5,417	34,571
Kennebec	180	143,240
Sebasticook	109	2,847,095
Penobscot	11,233	2,074,324
St. Croix	2	611,907
New Hampshire		
Cocheco		3,832
Exeter		17
Oyster		4,655
Lamprey		56,632
Winnicut		
Massachusetts		
Merrimack	52,239	87,150
Rhode Island		
Pawcatuck	248	
Gilbert Stuart		125,196
Nonquit		94,851
Buckeye Brook		153,933
Connecticut River		
Holyoke Dam	362,244	
Pennsylvania		
Schuylkill (Fairmont Dam)	0	*
Pennsylvania/Maryland/Delaware		
Susquehanna (Conowingo)	6,413	0
Susquehanna (Holtwood)	*	*
Susquehanna (Safe Harbor)	*	*
Susquehanna (York Haven)	*	*
South Carolina		
St. Stephen Dam	275,660	15,323
Total 2020	696,556	1,188,067
Total 2019	437,853	6,543,632
Total 2018	642,688	9,404,020
Total 2017	761,386	5,876,375
Total 2016	540,917	5,514,890

*Count not completed due to impacts from COVID-19 pandemic.

Table 5. Stocking of Hatchery-Cultured Alosine Larvae (Fry) in State Waters, 2020.

State	American Shad	River Herring
Maine		
Androscoggin River	0	0
New Hampshire		
Lamprey River	0	*
Massachusetts*		
Merrimack River	0	0
Nashua River	0	0
Rhode Island		
Pawcatuck River	1,661,728	0
Pawtuxet River	0	0
Pennsylvania		
Susquehanna River	0	0
Lehigh River	0	0
Schuykill River	0	0
Delaware		
Nanticoke River	0	0
Maryland		
Choptank River	0	0
District of Columbia/PRFC**		
Potomac River	0	0
Virginia		
James River	0	0
North Carolina		
Neuse River	0	0
Roanoke River	0	0
South Carolina		
Santee	13,026,939	0
Edisto River	0	0
Wateree River	0	0
Georgia		
Altamaha River	0	0
Oconee River	0	0
Total	**14,688,667**	**0**

*In Maine and Massachusetts river herring of wild origin are stocked as adult pre-spawning individuals through trap and transfer programs. Similarly, New Hampshire stocked river herring are adults of wild origin. These are not counted toward the total because they are not of hatchery origin.

**Numbers of fry stocked from combined efforts of PRFC, DC, and MD.

VI. Prioritized Research Needs

Due to the large number of research recommendations identified during stock assessments of these alosine species, only research recommendations identified as high priority are presented below. Recommendations are categorized by the expected time frame necessary to complete the recommendation (short term vs. long term). See the most recent benchmark stock assessment of each species (2020 for American shad, 2012 for blueback herring and alewife) for additional important research recommendations.

AMERICAN SHAD

Short Term

- Otoliths should be collected as the preferred age structure. If collection of otoliths presents perceived impact to conservation of the stock, an annual subsample of paired otolith and scales (at least 100 samples if possible) should be collected to quantify error between structures.
- Error between structures, if scales are the primary age structure collected, and for spawn mark count estimates (either between multiple readers or within reader) should be quantified on an annual basis. A mean coefficient of variation (CV) of 5% and detection of no systematic bias should serve as targets for comparisons.
- Two readers should determine consensus ages and spawn mark counts based on improvements in ageing error in the Delaware system when consensus-based estimates were part of the ageing protocol.

Long Term

- Develop a centralized repository for agencies to submit and store genetic sampling data for future analysis. The Atlantic sturgeon repository at the United States Geological Survey (USGS) Leetown Science Center should serve as an example.
- Collect genetic samples from young-of-year (YOY) and returning mature adults during spawning runs for future analysis of baseline genetic population structure and site fidelity/straying rates. These data will help define stock structure, identify stock composition from genetic sampling of American shad catch in mixed-stock fisheries, and provide information on recolonization capabilities in defunct American shad systems.
- Conduct annual stock composition sampling through existing and new observer programs from all mixed-stock fisheries (bycatch and directed). Potential methods include tagging (conventional external tags or acoustic tags) of discarded catch and genetic sampling of retained and discarded catch. Mortality rates of juvenile fish in all systems remain unknown and improvement in advice from future stock assessments is not possible without this monitoring. Known fisheries include the Delaware Bay mixed-stock fishery and all fisheries operating in the Atlantic Ocean (U.S. and Canada) that encounter American shad (see Section 4.1.4 in the stock assessment report).
- Implement fishery-independent YOY and spawning run surveys in all systems with open fisheries. Surveys should collect catch rates, length, individual weight, sex (spawning runs), and age (spawning runs) data at a minimum to allow for assessment of stocks with legal harvest. Require these surveys be in operation in systems with requested fisheries before opening fisheries.
- Conduct complete in-river catch monitoring in all systems with open fisheries. Monitoring programs should collect total catch, effort, size, individual weight, and age data at a

minimum. Require these surveys be in operation in systems with requested fisheries before opening fisheries.
- Conduct maturity studies designed to accommodate the unique challenges American shad reproductive behavior (i.e., segregating by maturity status during spawning runs) poses on traditional monitoring programs. This information will also improve understanding of selectivity by in-river fisheries and monitoring programs.
- Conduct fish passage research at barriers with adults for both upstream and downstream migration and movements and with juveniles for downstream as discussed in Section 1.1.9.5 of the stock assessment report.

RIVER HERRING

Short Term
- Analyze the consequences of interactions between the offshore bycatch fishery and population trends in the rivers.
- Continue genetic analyses to determine population stock structure along the coast and enable determination of river origin of incidental catch in non-targeted ocean fisheries.
- Continue to assess current ageing techniques for river herring, using known-age fish, scales, otoliths, and spawning marks.
- Improve reporting of harvest by waterbody and gear.
- Develop and implement monitoring protocols and analyses to determine river herring population responses and targets for rivers undergoing restoration (dam removals, fishways, supplemental stocking, etc.).
- Explore the sources of and provide better estimates of incidental catch in order to reduce uncertainty in incidental catch estimates.

Long Term
- Encourage studies to quantify and improve fish passage efficiency and support the implementation of standard practices.
- Determine and quantify which stocks are impacted by mixed stock fisheries (including bycatch fisheries). Methods to be considered could include otolith microchemistry, oxytetracycline otolith marking, genetic analysis, and/or tagging.
- Validate [better estimate] the different values of natural mortality (M) for river herring stocks and improve methods for calculating M.
- Conduct biannual ageing workshops to maintain consistency and accuracy in ageing fish sampled in state programs.
- Investigate the relation between juvenile river herring production and subsequent year class strength, with emphasis on the validity of juvenile abundance indices, rates and sources of immature mortality, migratory behavior of juveniles, and life history requirements.
- Expand observer and port sampling coverage to quantify additional sources of mortality for alosine species, including bait fisheries, as well as rates of incidental catch in other fisheries.

VII. Status of Implementation of FMP Requirements

In accordance with the Shad and River Herring Fishery Management Plan, the states are required to submit an annual compliance report by July 1st of each year. The Plan Review Team

(PRT) reviewed all state reports for compliance with the mandatory measures in Amendments 2 (River Herring) and 3 (American shad). Table 6 provides important information on each state's fisheries, monitoring programs, and compliance issues pertaining to the 2019 fishing year. Table 7 summarizes state reports of protected species interactions.

De Minimis Status

A state can request *de minimis* status if commercial landings of river herring or shad are less than 1% of the coastwide commercial total. *De minimis* status exempts the state from the sub-sampling requirements for commercial and recreational catch for biological data. The following states have met the requirements and requested continued *de minimis* status in 2019:

- Maine (American shad)
- New Hampshire (American shad and river herring)
- Massachusetts (American shad)
- Georgia (river herring)
- Florida (American shad and river herring)

State Compliance

All states with a declared interest in shad and river herring management have submitted annual compliance reports. Virginia has also submitted a separate American shad bycatch report in accordance with the provisions of their limited bycatch program.

Most states have regulations in place that meet the intent of the requirements of the Interstate Fisheries Management Plan for Shad and River Herring. The PRT notes the following compliance issues encountered in their review of the state reports:

1. Several states did not report on all monitoring requirements listed under Amendments 2 and 3 (see Table 6). The primary reason for these omissions was the Covid-19 pandemic, which prevented states from conducting the required surveys.
2. South Carolina did not provide a copy or link to their current fishery regulations.
3. South Carolina, DC, and PRFC did not provide a section for law enforcement reporting.
4. New Hampshire and Connecticut did not include a section for hickory shad reporting.

VIII. PRT Recommendations

After a thorough review of the state reports, **the PRT recommends approval of the state compliance reports for the 2020 fishing year and *de minimis* requests**. In order to further streamline the compliance review process, the PRT also recommends moving section VIII B, which provides the results of hickory shad monitoring, to the appendices. This change would allow states that conduct hickory shad monitoring a place to share the results, while removing optional data from the main body of the compliance report.

Table 6. Summary of PRT Review of 2019 State Compliance Reports.

STATE	2020 FISHERY AND MONITORING HIGHLIGHTS	UNREPORTED INFORMATION AND COMPLIANCE ISSUES
MAINE	COVID-19 prevented normal operation and sampling for the month of May at the Brunswick fishway on the Androscoggin River.	Due to Covid-19 closure on Androscoggin river, no spawning stock survey or calculation of mortality and/or survival estimate was conducted. Additionally, due to the small run count on the Saco river, no mortality/survival estimate was measured to reduce sampling mortality
NEW HAMPSHIRE		Did not include a section for hickory shad reporting.
MASSACHUSETTS	In 2020, no shad were transferred to trucks for transport or removed for biological sampling and agency studies due to disruptions in operations resulting from COVID-19.	No JAI program; requirement for American shad to develop one in the Merrimack River. No mortality/survival estimates for shad or river herring due to Covid-19.
RHODE ISLAND		Samples were taken for mortality/survival estimates for river herring but mortality rates have not been updated since 2015.
CONNECTICUT		Shad: As a result of the Covid-19 pandemic, in accordance with the 2020 Holyoke fishway contingency plan, all trapping and biological sampling of American Shad were halted for the duration of the 2020 fish passage season preventing the completion of the annual spawning stock survey and drastically reduced in effort because of CT DEEP Covid-19 travel and working restrictions. Insufficient data was collected in 2020 and an abundance index could not be generated. Also no recreational FD monitoring for lack of funds and staff, so appendix has no information as well. Aside from monitoring, the progress on habitat recommendations were not ready at the time of the report, and there was no hickory shad section. River Herring: Due to COVID-19 restrictions fishery independent sampling could not be completed or effort was reduced to a point that insufficient data could be collected to generate the required indices. Did not include a section for hickory shad reporting.
NEW YORK		American shad: Calculation of mortality rates and annual spawning stock survey not completed due to COVID-19 restrictions. River herring: Spawning stock assessment, monitoring of recreational landings, and mortality estimates were not completed in 2020 due to funding and COVID-19 constraints.
NEW JERSEY	Only the January cruise of the Ocean trawl was completed in 2020 due to COVID-19. Other FI monitoring not completed.	Did not include summary of regulatory or monitoring changes for the following year. Did not report on progress in implementing habitat recommendations.
PENNSYLVANIA		No monitoring for shad or river herring because there was no sampling in 2020 due to Covid-19.

Table 6. Summary of PRT Review of 2019 State Compliance Reports.

STATE	2020 FISHERY AND MONITORING HIGHLIGHTS	UNREPORTED INFORMATION AND COMPLIANCE ISSUES
DELAWARE BASIN COOP		American shad: No recreational monitoring since 2002. Shad and river herring: Almost all monitoring was not completed due to Covid-19.
DELAWARE		Spawning stock survey for American and hickory shad not completed due to Covid-19.
MARYLAND	Fish passage mortality was lower than previous years because the Conowingo Dam East Fish Lift operated for only four days (May 12-15) in 2020. The initiation of fish passage operations was delayed due to the COVID-19 pandemic. Fish passage was suspended after May 15, 2020 to prevent upstream spread of Northern Snakehead.	
D.C.		American shad: COVID-19 work restrictions prevented the completion of a substantial amount of require fishery independent monitoring including a spawning stock survey, calculation of mortality/survival estimates, and a hatchery evaluation. River herring: COVID-19 work restriction prevented the completion of required fishery independent monitoring in 2020. Only an abbreviated JAI seine survey was conducted. No spawning stock survey, adult biological data, or mortality/survival estimates are available for 2020. Did not provide a section for law enforcement reporting.
PRFC	No hatchery evaluation was conducted because Covid-19 prevented any broodstock collections.	American shad: COVID-19 work restrictions prevented the completion of a substantial amount of required fishery independent monitoring including a spawning stock survey and calculation of mortality/survival. Did not provide a section for law enforcement reporting.
VIRGINIA	In 2020, the James River staked gillnet (river mile 10) was discontinued due to contractor health and logistical reasons. Sampling on the James River was conducted using two anchor gill nets, each 300 ft (~92 m) at river mile 36 (37° 11.0' N, 76° 42.3' W). No significant changes occurred in the York or Rappahannock rivers.	
NORTH CAROLINA		During 2020, sampling was impacted from mid-February through May due to the COVID pandemic. Sampling did not occur for the following projects with respect to American shad: North Carolina Division of Marine Fisheries (NCDMF) Albemarle Sound, Pamlico Sound and Rivers Independent Gill Net Surveys; Recreational Creel Surveys (all systems); and North Carolina Wildlife Resources Commission (NCWRC) Spawning Area Surveys (all systems). Sampling did not occur for the following projects with respect to river herring (blueback and alewife): North Carolina

Table 6. Summary of PRT Review of 2019 State Compliance Reports.

STATE	2020 FISHERY AND MONITORING HIGHLIGHTS	UNREPORTED INFORMATION AND COMPLIANCE ISSUES
		Division of Marine Fisheries (NCDMF) Albemarle Sound Independent Gill Net Survey; and North Carolina Wildlife Resources Commission (NCWRC) Spawning Area Surveys (all systems). Sampling for these programs is expected to resume in 2021.
SOUTH CAROLINA		The 2020 sampling season was preempted and cut short due to a mandatory "work from home order" from the SC Governor in response to the Covid-19 outbreak in the state. The result prohibited project biologists from performing any fieldwork for Shad or Herring after March 19th, 2020. Did not provide a section for law enforcement reporting and did not provide a copy or link to current fishery regulations.
GEORGIA	American shad: In June 2020, the Shad TC voted to approve GA's recommendation to change the management benchmark for the Savannah River from data utilizing the commercial drift-net CPUE to a fishery-independent CPUE generated from electrofishing data collected annually between February and June at the New Savannah Bluff Lock and Dam (NSBLD). This change resulted from the ongoing decline and recent absence of commercial drift-net effort in the Savannah River. This change will provide managers with a more stable and consistent dataset by which to make management decisions. Additionally, GA plans to cease conducting the juvenile seine survey in the Savannah River in 2021. This effort continues to be significantly impacted almost annually by high water levels and is considered a supplemental effort since the SCDNR conducts the juvenile electrofishing survey used in the SFMP by fishery managers. The GADNR did not conduct creel sampling on the Altamaha River in 2020 due to COVID and will not conduct creel sampling in 2021 due to internal restructuring but is planning to resume the creel survey in 2022. Hickory shad: Creel surveys on the Altamaha River were cancelled in 2020 due to COVID and will not be conducted in 2021 due to internal restructuring but are planned to resume in 2022.	
FLORIDA	2020 was the 4th year below the St. Johns River E-fish index sustainability threshold, triggering management.	

Table 7. Reported protected species interactions (sturgeon species) in shad or river herring fisheries in 2019. Only the states listed below reported interactions.

Jurisdiction	Atlantic sturgeon		Shortnose sturgeon		Unclassified		Total by State	
	Catch	Mortalities	Catch	Mortalities	Catch	Mortalities	Catch	Mortalities
RI	*						Unavailable*	Unavailable*
CT					29	0	29	0
NJ	**	**	**	**	**	**	**	**
PRFC	2	0					2	0
VA	7	0					7	0
NC	3	0					3	0
SC	2	0					2	0
GA	25	0	5	0			30	0
Total by Species	39	0	5	0	29	0	**73**	**0**

*Rhode Island reports NOAA NEFOP and ASM data, which is available after the compliance report submission deadline. Therefore, their data lags by one year. Rhode Island reported 9 sturgeon caught in their waters in 2019.

**In 2020 gill netters in New Jersey coastal waters reported discarding 2,921 lbs of sturgeon.

Atlantic States Marine Fisheries Commission

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703.842.0740 • 703.842.0741 (fax) • www.asmfc.org

MEMORANDUM

April 15, 2022

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

From: **Tina Berger, Director of Communications**

RE: **Advisory Panel Nomination**

Please find attached a nomination to the Shad and River Herring Advisory Panel – Deborah Wilson, who has been involved in Maine fisheries and fisheries management for the past 40 years.

Please review this nomination for action at the next Board meeting.

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

Enc.

cc: Emilie Franke

M22-45

SHAD & RIVER HERRING ADVISORY PANEL

Bolded names await approval by the Shad & River Herring Management Board

April 15, 2022

Maine

River Herring:

Deborah Wilson (conservation)
374 Bayview Road
Nobleboro, ME 04555
Phone: (207)380-6997
Deb.wilson1028@gmail.com

Mike Thalhauser (comm)
Alewife Harvesters of Maine
13 Atlantic Avenue
Stonington, ME 04681
207.367.2708
mthalhauser@coastalfisheries.org
Appt. Confirmed 10/30/19

Shad:

Vacancy - shad rec

New Hampshire

Shad & River Herring:

Eric Roach (rec)
54A Foggs Lane
Seabrook, NH 03874
Phone: 603.502.0928
Eroach1970@gmail.com
Appt Confirmed 2/4/21

Massachusetts

Shad & River Herring:

Mark Amorello (rec)
P.O. Box 235
Pembroke, MA 02359
Phone: 781.831.2123
markamorello@yahoo.com
Appt. Confirmed 10/30/19

River Herring:

Vacancy

Connecticut

Shad & River Herring:

2 Vacancies

New York

Shad & River Herring:

Byron Young
53 Highview Lane
Ridge, NY 11961
Phone: (631) 821-9623
Cell: (631) 294-9612
Fax: (631) 821-9623
Email: youngb53@optimum.net
Appt. Confirmed 5/5/08
Chair from 1/09- 1/11
Confirmed interest in March 2019

New Jersey

Shad:

Vacancy – recreational

Shad & River Herring:

Jeff Kaelin (comm. trawl and purse seine)
Director of Sustainability and Government Relations
Lund's Fisheries, Inc.
997 Ocean Drive
Cape May, NJ 08204
Phone: 207.266.0440
jkaelin@lundsfish.com
Appt Confirmed 8/20/09
Confirmed interest in March 2019

Pennsylvania

Vacancy

Delaware

Shad & River Herring:

Dr. Edward Hale
Delaware Sea Grant
23 Gosling Drive
Lewes, DE 19958
Phone: 302.470.3380
Ehale@udel.edu
Appt Confirmed 2/4/21

SHAD & RIVER HERRING ADVISORY PANEL

Bolded names await approval by the Shad & River Herring Management Board

April 15, 2022

Maryland
Shad & River Herring:
Vacancy - recreational

Virginia
Shad & River Herring:
Vacancy

Shad:
Vacancy

North Carolina
River Herring:
Louis Ray Brown, Jr. (rec)
212 Walnut Creek Drive
Goldsboro, NC 27534
Phone (day): (919) 778-9404
Phone (eve): (919) 778-9792
FAX: (919) 778-1197
Email: lrbrown@nc.rr.com
Appt. Confirmed 5/5/08; 8/18
Confirmed interest in March 2019

Vacancy – commercial

South Carolina
Shad:
Thomas M. Rowe, Jr. (rec)
4625 Flounder Lake Drive
Meggett, SC 29449
Phone: 843-908-0247
FAX: 843-549-7575
Email: thomasmrowe@hotmail.com
Appt Confirmed 8/3/10
Confirmed interest in Sept 2017

Vacancy – commercial net

Georgia
River Herring:
Fulton Love (dealer)
6817 Basin Road
Savannah, GA 31419
Phone: (912)925-3616
FAX: (912)925-1900
Appt. Confirmed 10/30/95
Appt. Reconfirmed 9/8/99; 3/19/08
No response to Sept 2017 or March 2019 inquiry regarding continuing interest in serving on AP

Florida
Shad & River Herring:
2 vacancies

Potomac River Fisheries Commission
River Herring:
Kevin L. Gladhill (rec)
21370 Mount Lena Road
Boonsboro, MD 21713
Phone (day): (301)988-6697
Phone (eve): (301)714-1074
Email: KLGladhill@myactv.net
Appt. Confirmed 5/5/08
No response to Sept 2017 or March 2019 inquiry regarding continuing interest in serving on AP

Vacancy – commercial pound net

District of Columbia
Shad:
Joe Fletcher (rec)
1445 Pathfinder Lane
McLean, VA 22101
Phone (day): (202)244-0461
Appt. Confirmed 10/30/95
Appt. Reconfirmed 9/15/99
Appt. Reconfirmed 4/21/08
No response to Sept 2017 inquiry regarding continuing interest in serving on AP

Nontraditional Stakeholders
Chair, Pam Lyons Gromen (fisheries conservation) (1/11)
Executive Director
Wild Oceans
1793 Sandy Court
Springboro, Ohio 45066
Phone: 240.405.6931
Email: plgromen@wildoceans.org
Appt. Confirmed 5/5/08
Confirmed interest in March 2019

ATLANTIC STATES MARINE FISHERIES COMMISSION

Advisory Panel Nomination Form

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

Form submitted by: Deborah B Wilson
State: Maine
(your name)

Name of Nominee: Deborah B Wilson

Address: 374 Bayview Road

City, State, Zip: Nobleboro, ME 04555

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

Phone (day): 207-380-6997 Phone (evening): same

FAX: ______ Email: deb.wilson1028@gmail.com

FOR ALL NOMINEES:

1. Please list, in order of preference, the Advisory Panel for which you are nominating the above person.

   1. Shad and River Herring
   2. ______
   3. ______
   4. ______

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

   yes______ no x

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

yes ___x___ no________

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

________________ ________________

Alewife Harvesters of Maine ________________

________________ ________________

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

________________ ________________

________________ ________________

________________ ________________

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

________________ ________________

________________ ________________

________________ ________________

FOR COMMERCIAL FISHERMEN:

1. How many years has the nominee been the commercial fishing business? ________ years

2. Is the nominee employed only in commercial fishing? yes________ no________

3. What is the predominant gear type used by the nominee?________________

4. What is the predominant geographic area fished by the nominee (i.e., inshore, offshore)?________________

FOR CHARTER/HEADBOAT CAPTAINS:

1. How long has the nominee been employed in the charter/headboat business? ________ years

2. Is the nominee employed only in the charter/headboat industry? yes ________ no________

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

   ____

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

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

____

FOR RECREATIONAL FISHERMEN:

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

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

   If "yes," please explain.

____

____

____

FOR SEAFOOD PROCESSORS & DEALERS:

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

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

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

____

____

____

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

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

____

FOR OTHER INTERESTED PARTIES:

1. How long has the nominee been interested in fishing and/or fisheries management? 40 years
2. Is the nominee employed in the fishing business or the field of fisheries management?
   yes _____ no x

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

   Fishway Construction

Town Alewife Harvest Management

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

Pertinent to this position, I have been involved with Maine fisheries and fisheries management for the past 40 years. During the past 20 years, my principal work has been with River Herring. Here is a list of jobs and activities relevant to m participation on the Shad and River Herring Advisory Panel.

- I directed all facets of the Damariscotta Mills Fish Ladder Restoration from its inception in 2007 to its completior in 2017. Specifically, I worked with Curtis Orvis, Fishway Engineer for the US Fish and Wildlife Service, to implement his re-design of the Damariscotta Mills Fish Ladder into a pool and weir fishway. I then managed the construction of the new structure over a ten-year period with my husband, Mark Becker. In addition, I worked with a neighborhood group and wrote grants to raise all funds needed for the construction.

- In 2020 and 2021, my husband and I managed the construction of the new Bristol Mills Fish Ladder. Again, we worked with Curtis Orvis to implement his design for a new pool and weir fish ladder. This project differed from Damariscotta Mills, where the new fishway largely followed the course of the original fishway, with the addition o a plunge pool. Both projects were aimed at the passage of River Herring.

- I served on the ASMFC Advisory Panel for Shad and River Herring during the Amendment 2 process through 2019.

- I served as a Nobleboro Town Selectperson for six years, from 2008 – 2013. One role of a Nobleboro Selectperson is to oversee the alewife fishery, which I was already significantly involved with as the director of the Damariscotta Mills Fish Ladder Restoration.

- Following my two terms as selectperson, I have served on the 3-member Fish Committee for the Towns of Nobleboro and Newcastle (that jointly hold the rights to the alewife fishery at Damariscotta Mills) and I continue to serve in that capacity. The Fish Committee oversees the alewife harvest and makes decisions regarding harvesting equipment and harvesting practices.

Nominee Signature: ______________________ Date: 1/11/2022

Name: Deborah B Wilson
(please print)

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

____
State Director

____
State Legislator

____
Governor's Appointee

Signed on behalf of State Delegation