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

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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.

Proposed Fishery for the Hudson River and Tributaries

Given the measures of stock status described above, we are proposing a continuation of the Hudson River fishery at this time. This includes a continuation of the restricted fishery in the main-stem Hudson River, a partial closure of the fishery in tributaries, and annual stock monitoring as described in the previous SFMP (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 25^{th} 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.

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

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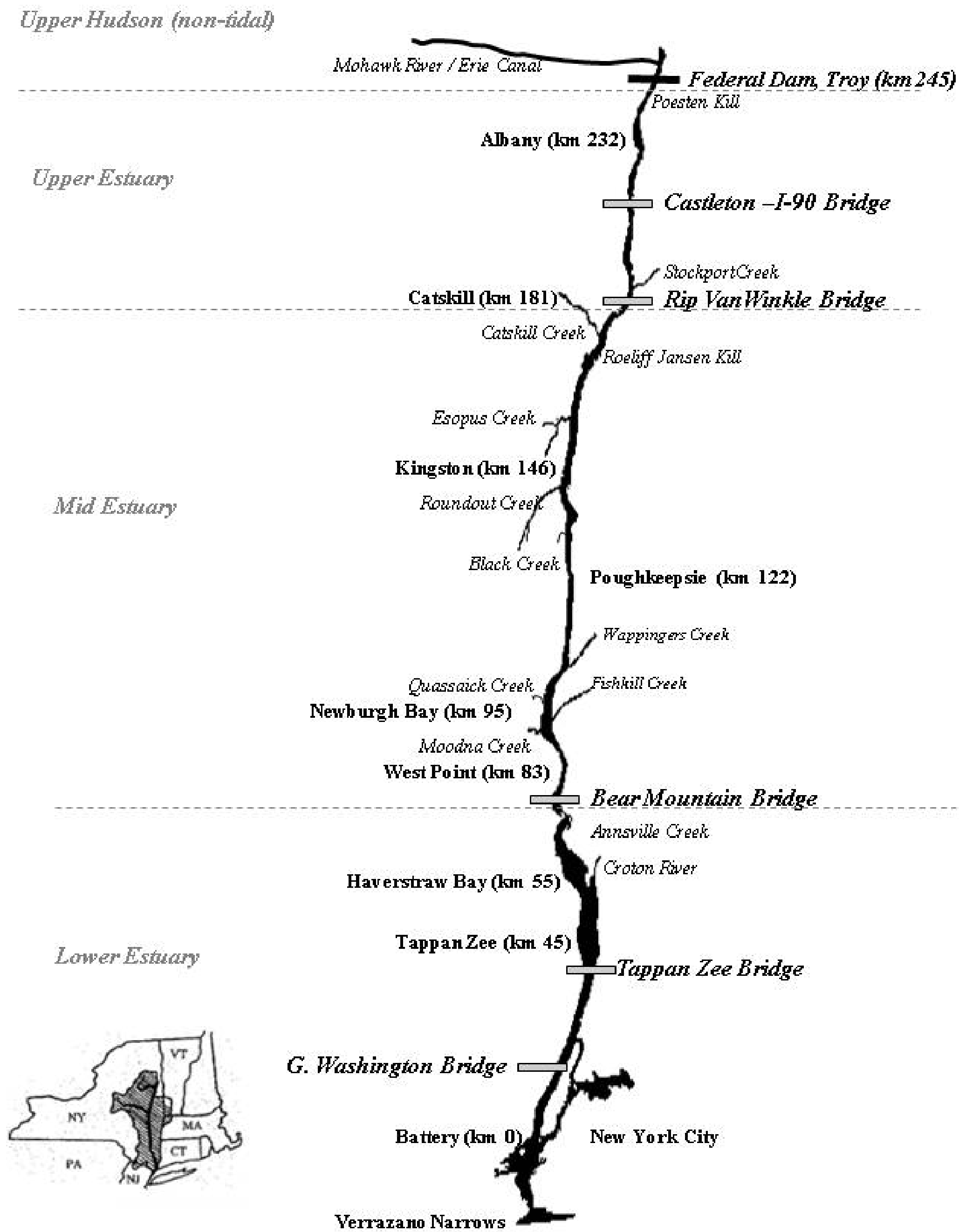


Figure 1. Hudson River Estuary with major spawning tributaries for river herring.

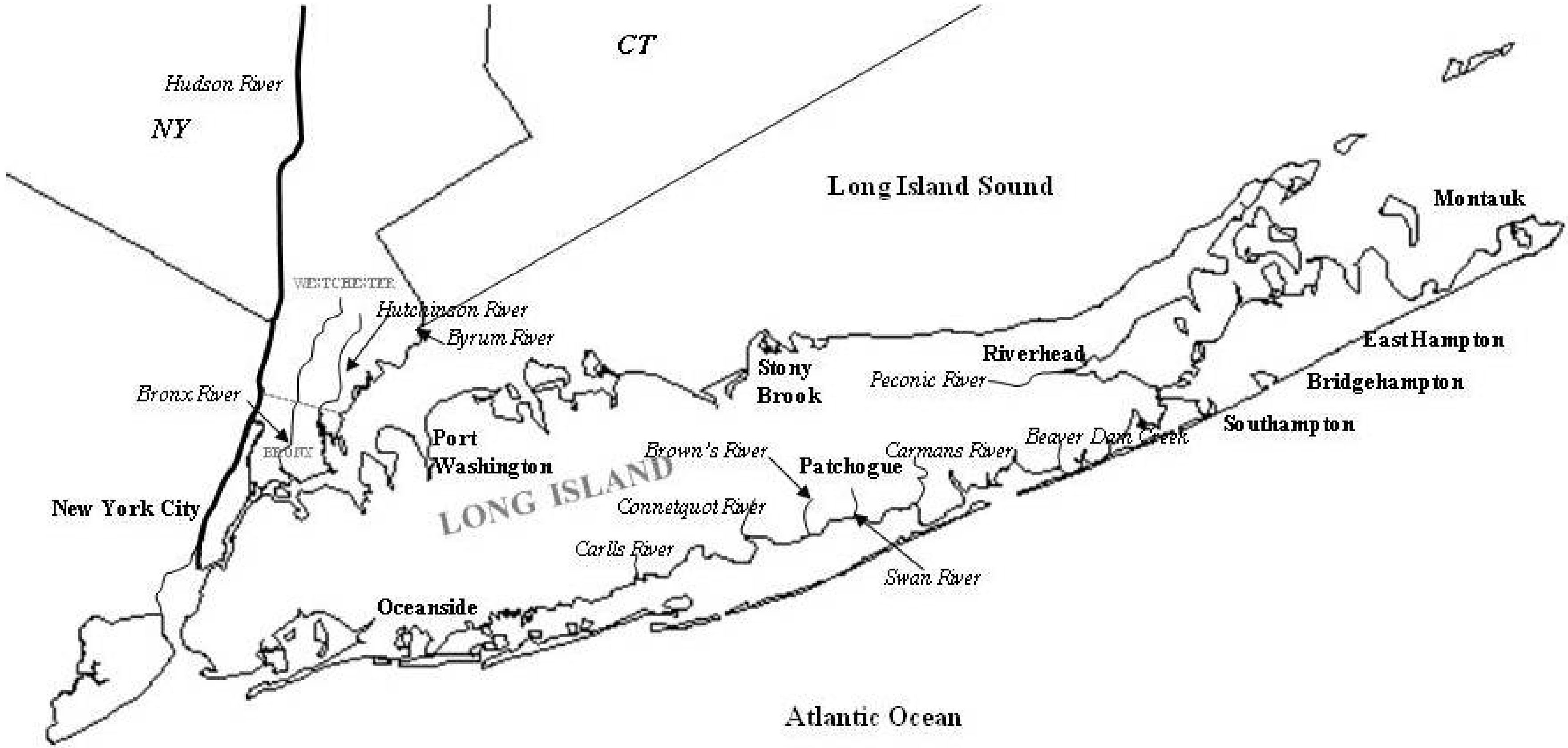


Figure 2. Long Island, Bronx and Westchester Counties, New York, with some river herring (primarily alewife) spawning streams identified.

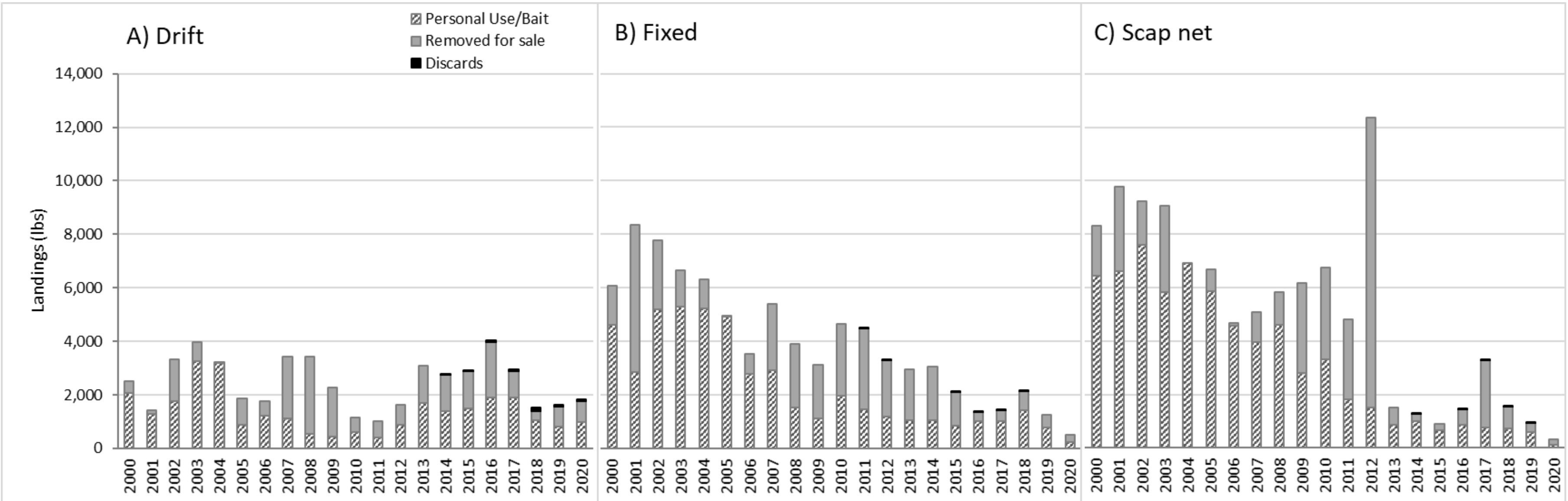


Figure 3. Dispositions of commercially caught river herring as reported in mandatory trip reports.

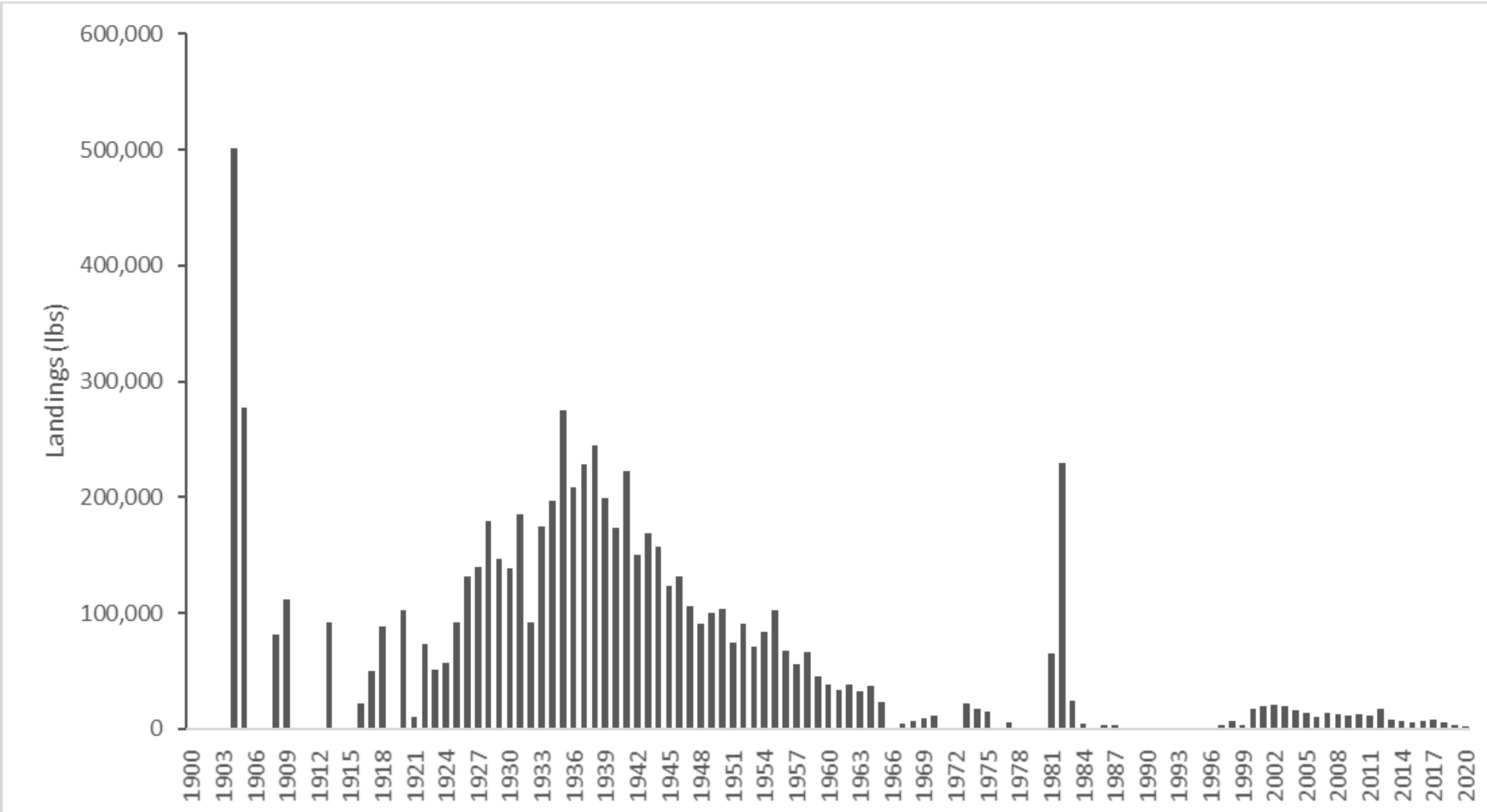


Figure 4. River herring landed in New York waters.

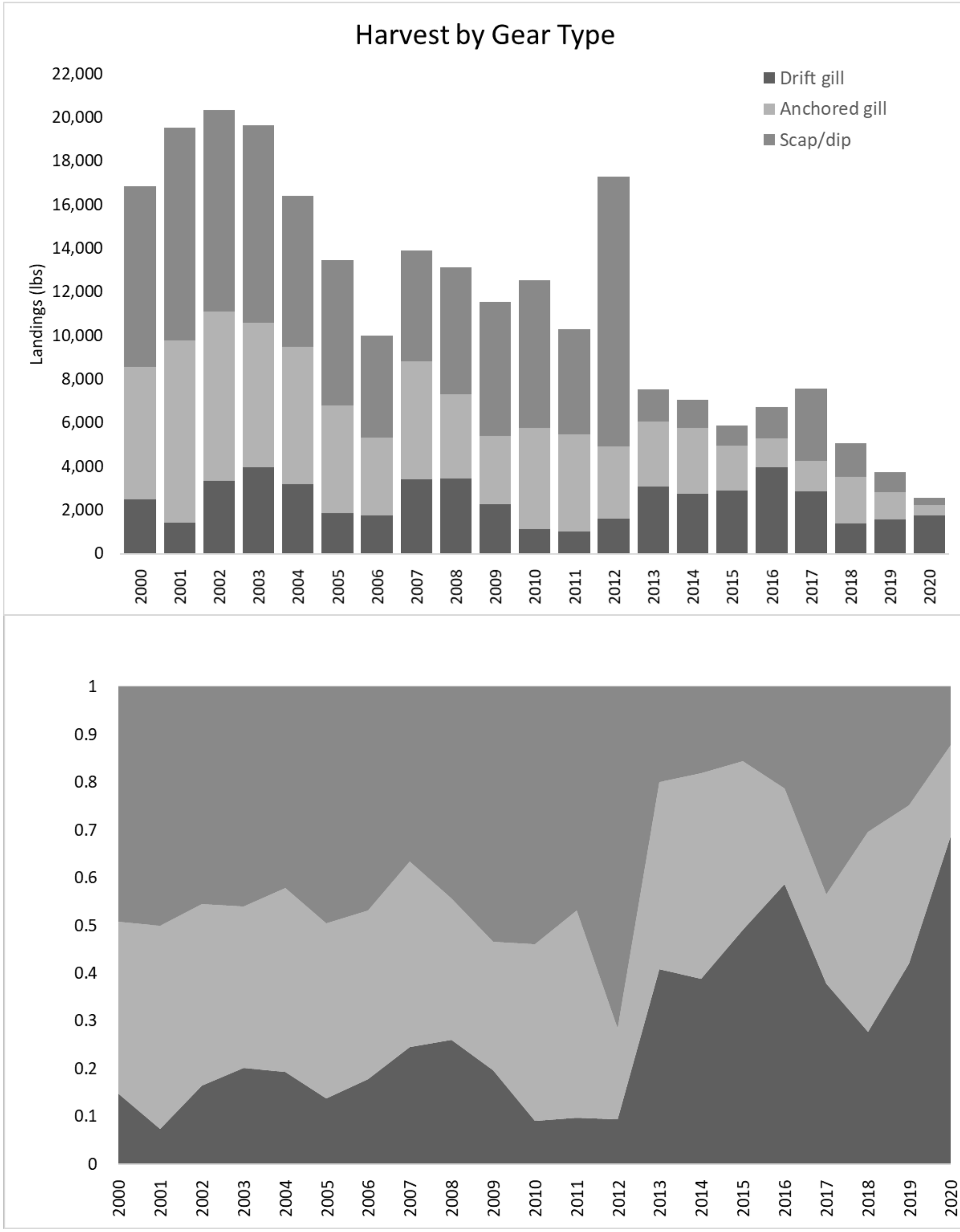


Figure 5. (Top) Annual total landed pounds of river herring separated by gear type. Catch includes targeted river herring trips only. (Bottom) Percent landed by gear type.

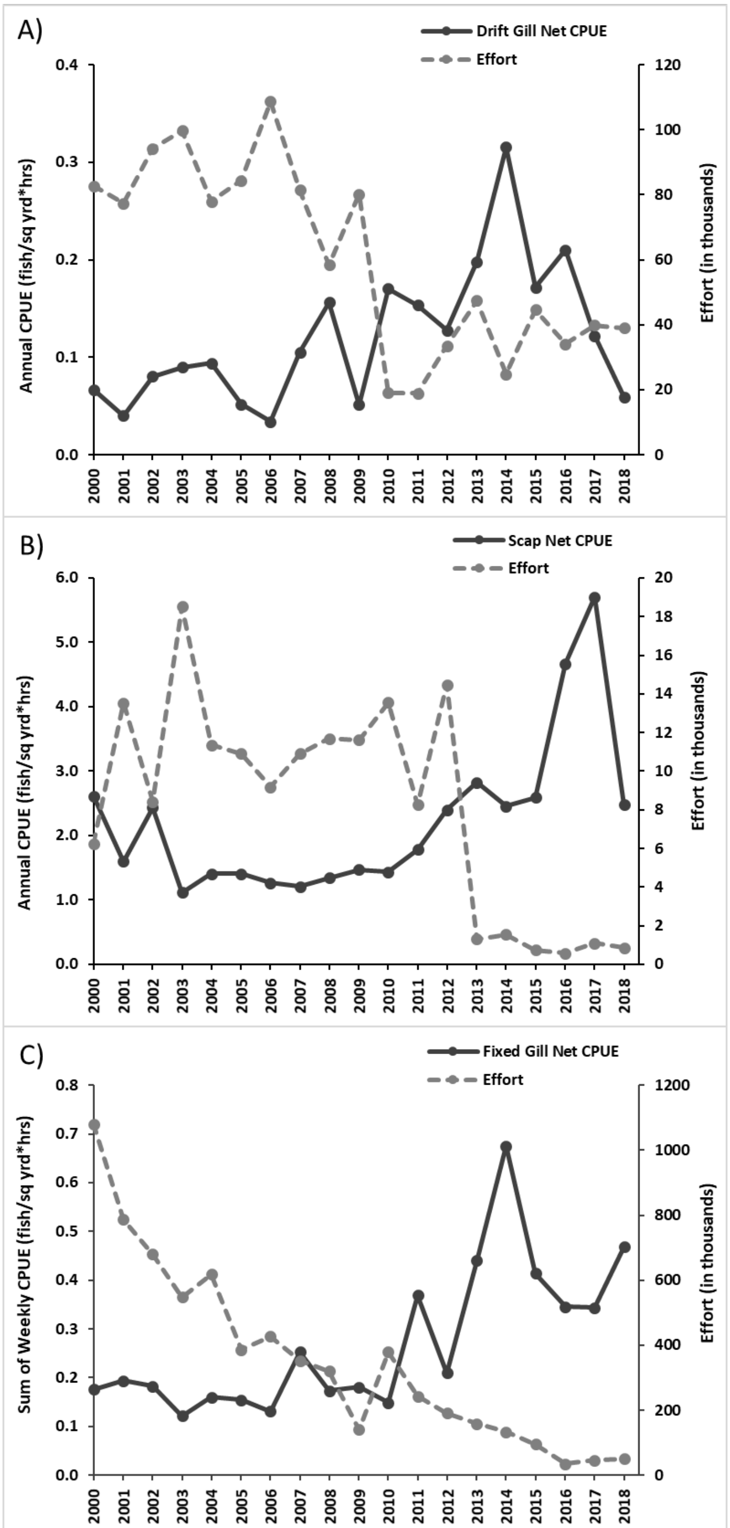


Figure 6. Efforts (sq yd net area * hours) and CPUEs from mandatory commercial reports. A) Drift gill net fishery above rkm 75; CPUE is total catch/total effort. B) Scap net fishery above rkm 75; CPUE is total catch/total effort. C) Fixed gill net fishery below rkm 75; CPUE is the sum of weekly catch/weekly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

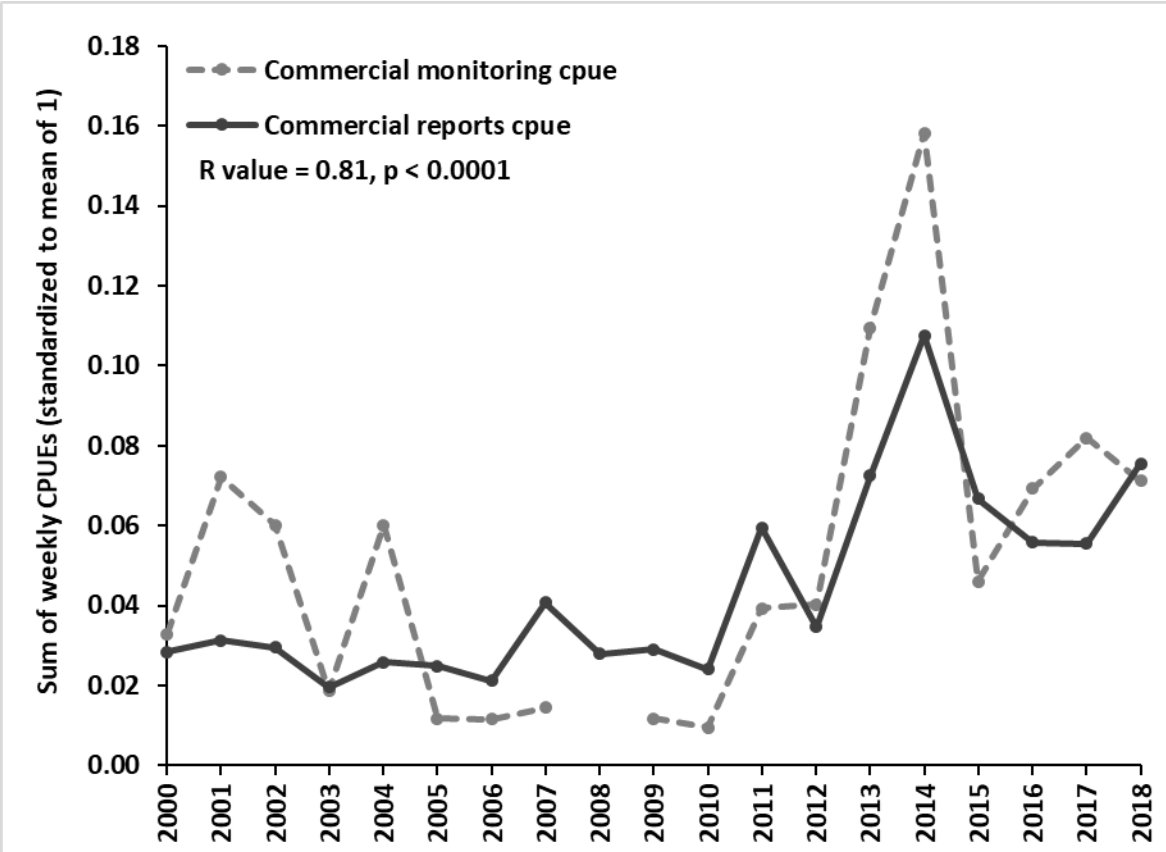


Figure 7. Comparison of the sum of weekly CPUEs calculated from commercial monitoring and mandatory commercial reports of the fixed gill net fishery below the Bear Mountain Bridge (rkm 75).

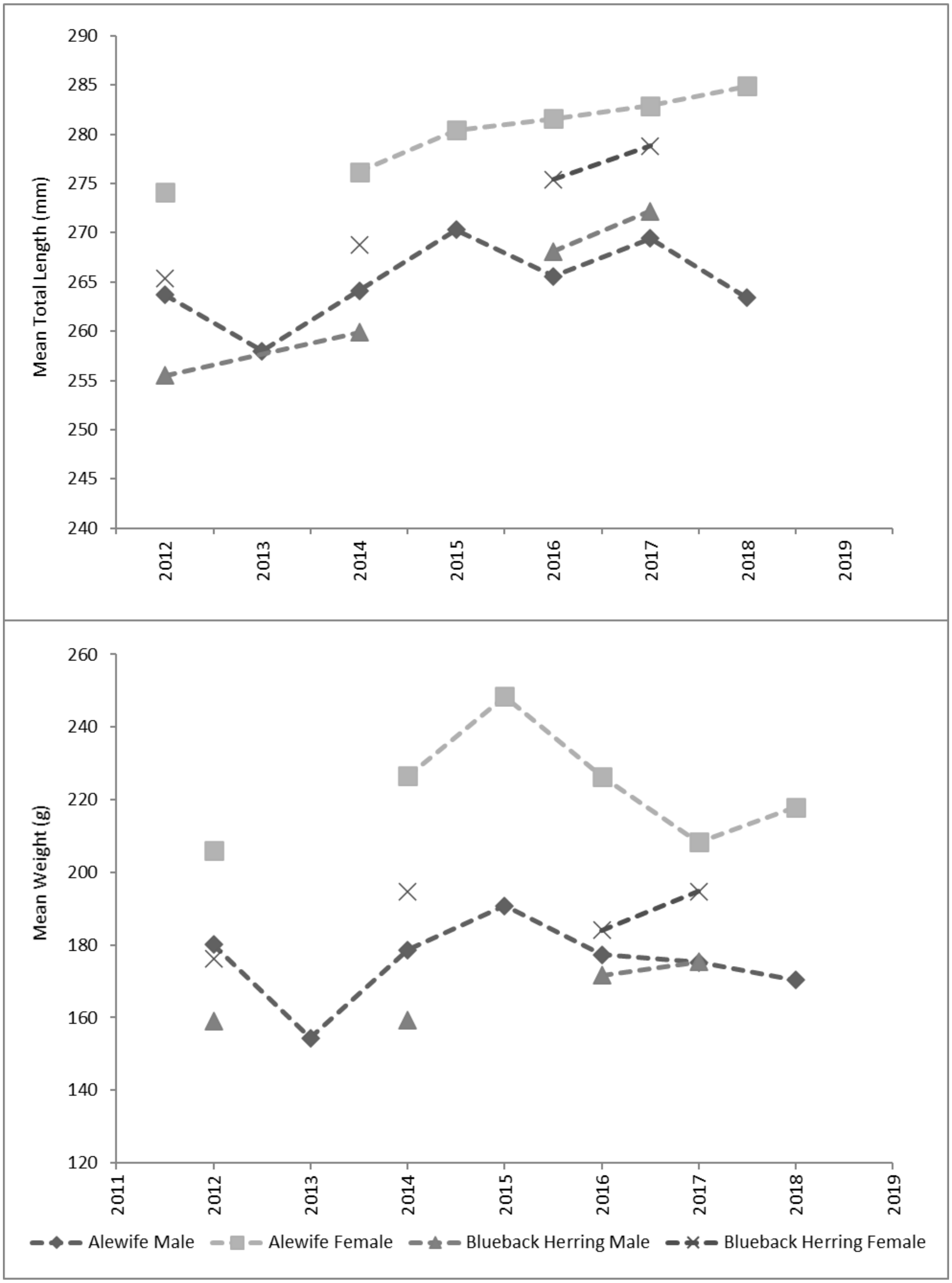


Figure 8. Mean length and weight of river herring collected in fishery dependent sampling in the commercial fishery in the Hudson River. Years omitted when minimum sample size not met to detect a significant change of 5 mm total length.

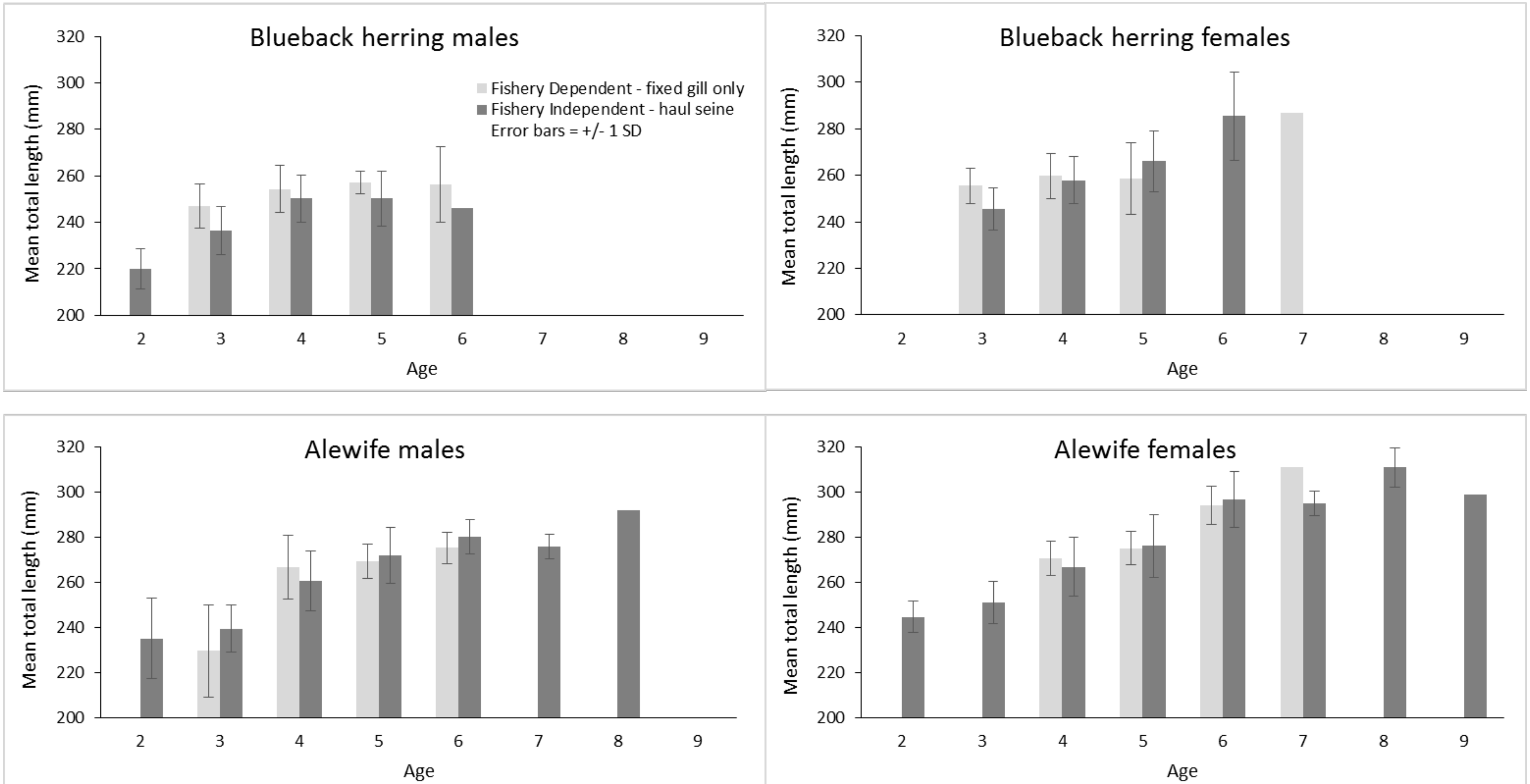


Figure 9. Comparison of length at age of river herring sampled in the lower-river fixed gill net commercial fishery versus the fishery independent survey in 2012.

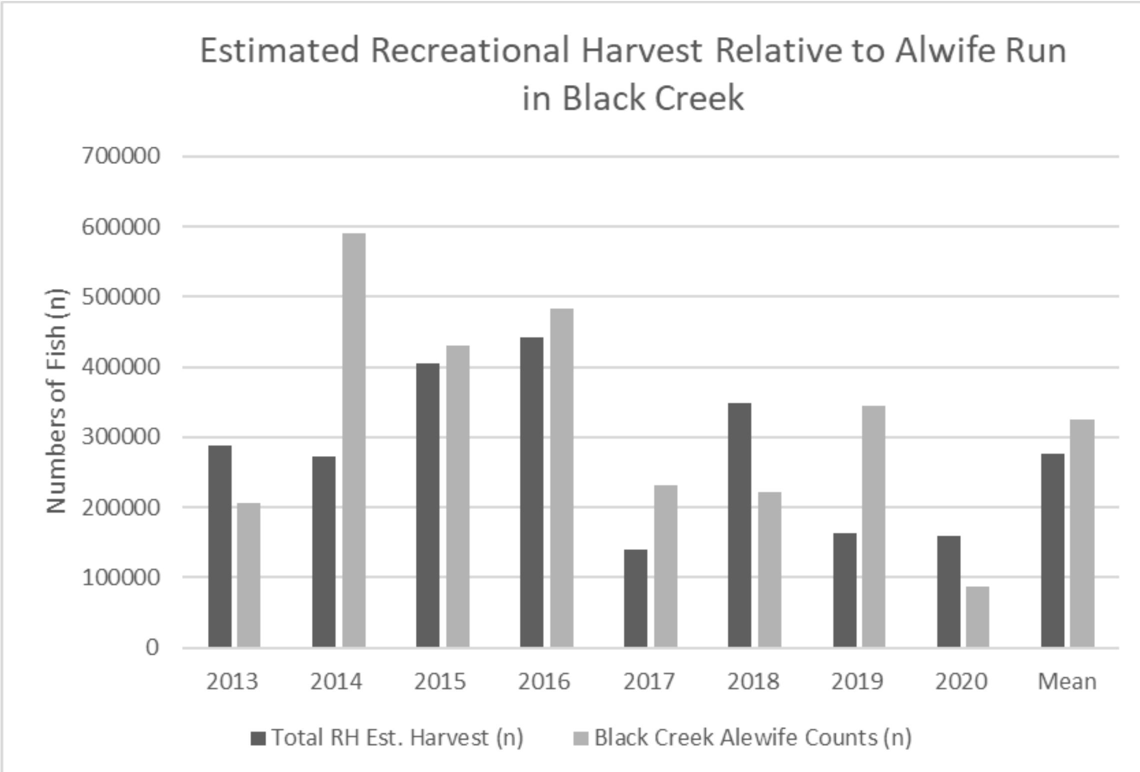


Figure 10. Estimated recreational river herring harvest relative to annual alewife counts in Black Creek, one of 68 tributaries to the Hudson River.

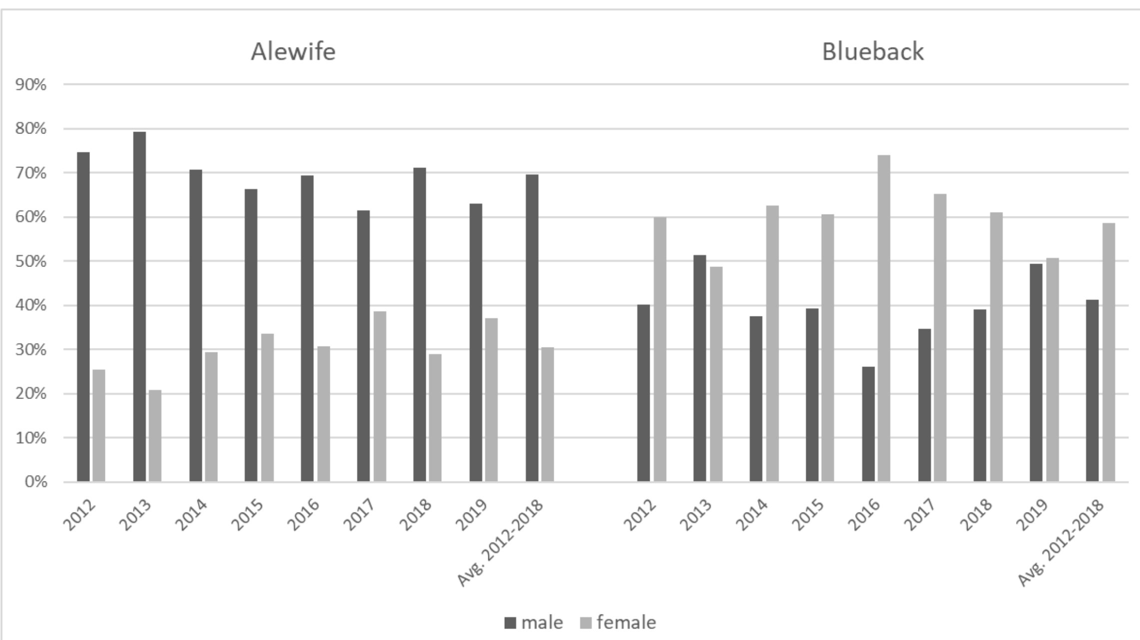


Figure 11. Annual sex ratios from river herring collected during the fisheries independent survey.

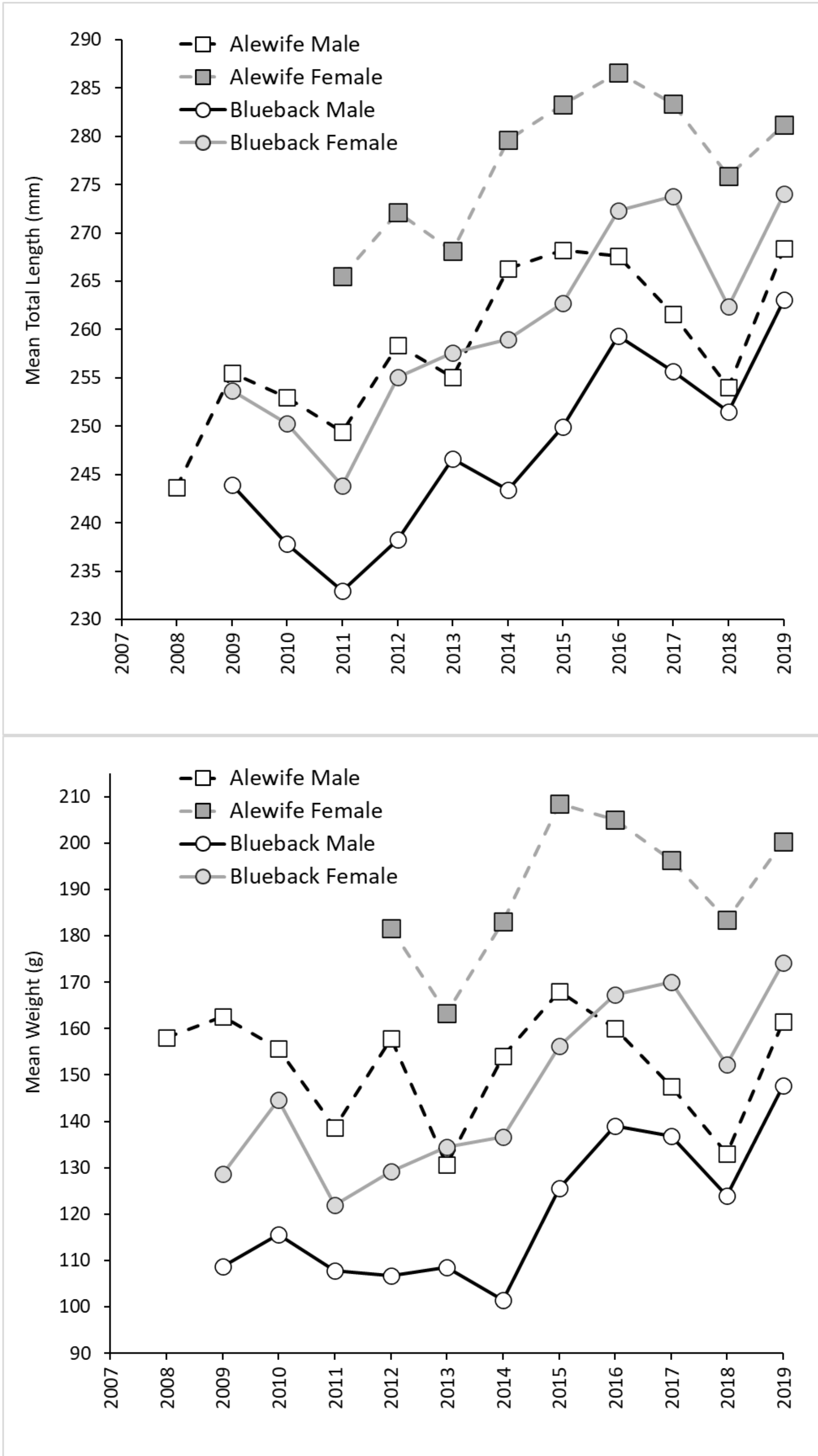


Figure 12. Mean length (top) and weight (bottom) of river herring collected during fishery independent sampling.

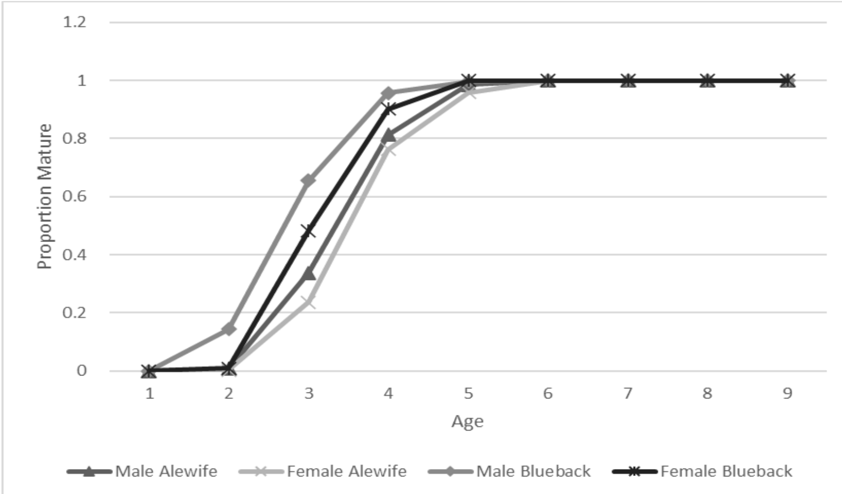


Figure 13. Maturity schedule for alewife and blueback herring derived from 2012-19 age and repeat spawn data.

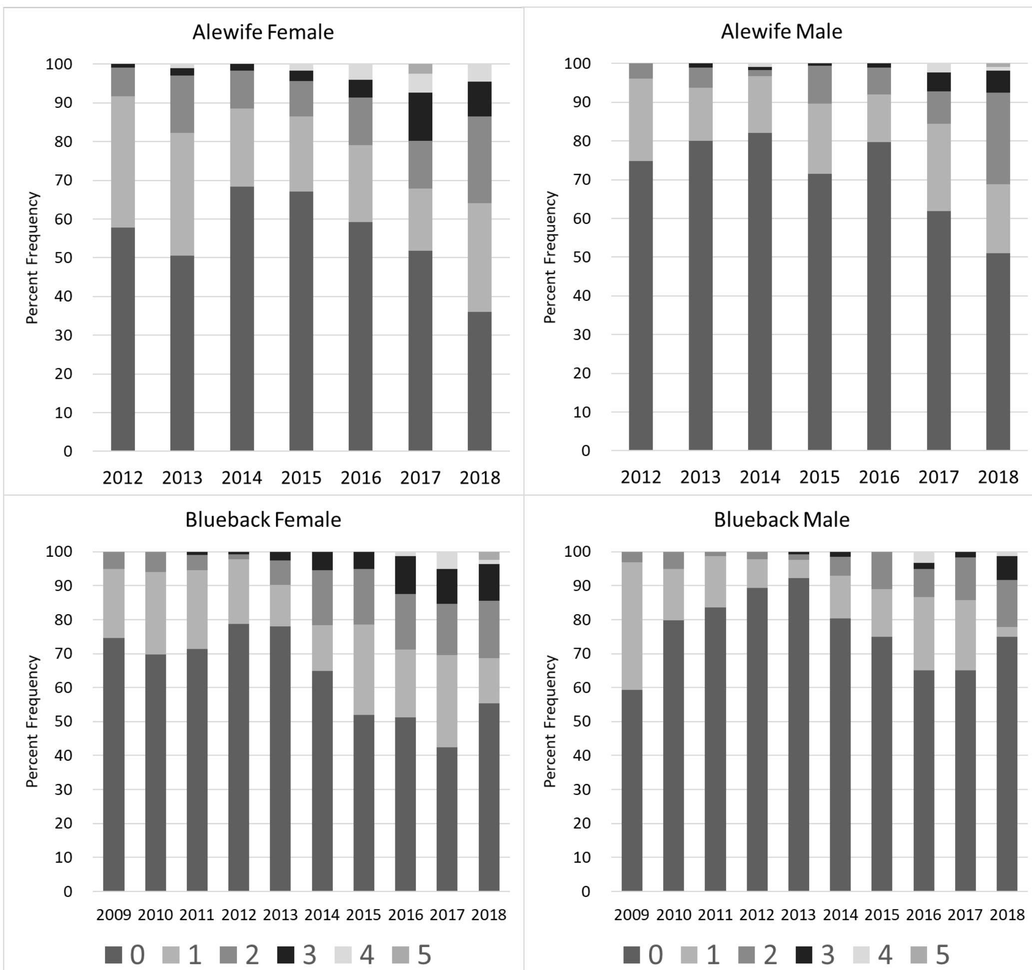


Figure 14. Frequency of repeat spawning occurrence of river herring collected during fisheries independent sampling. Numbers in legend indicate number of repeat spawns

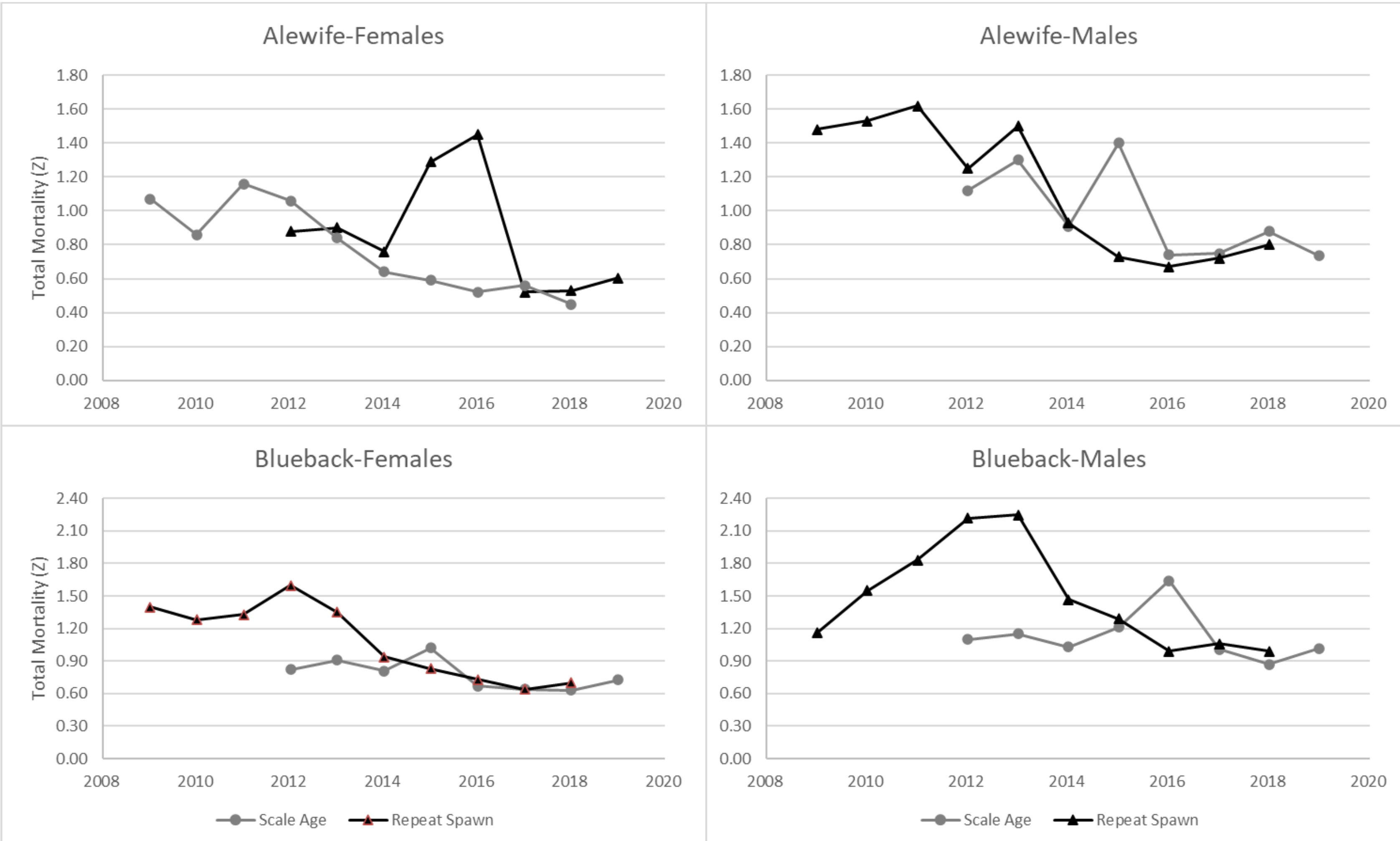


Figure 15. Annual total instantaneous mortality (Z) estimates for river herring collect during fisheries independent sampling.

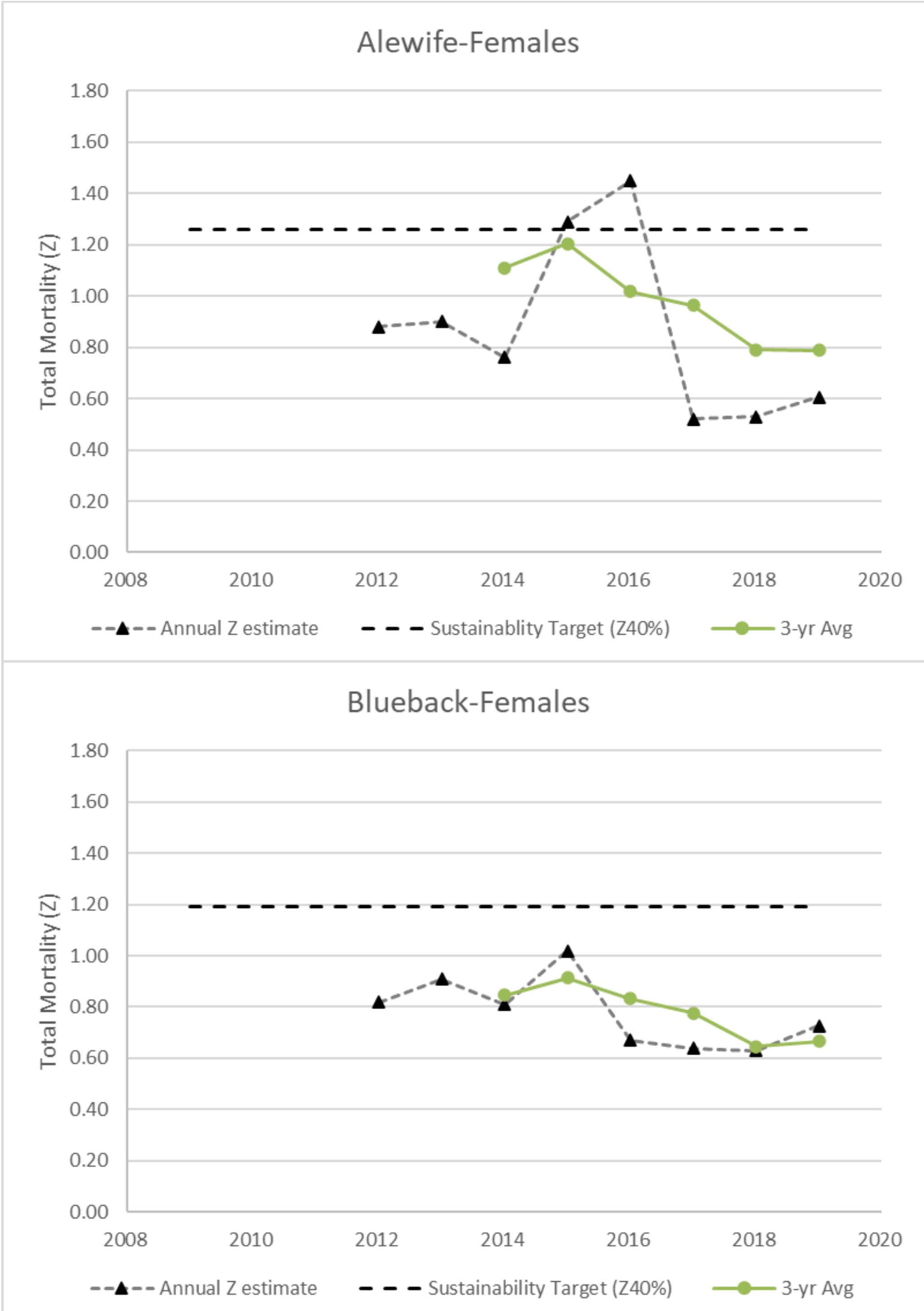


Figure 16. Chapman-Robson instantaneous total mortality (Z) estimates, three-year average Z estimates and respective $Z_{40\%}$ sustainability thresholds for alewife and blueback females.

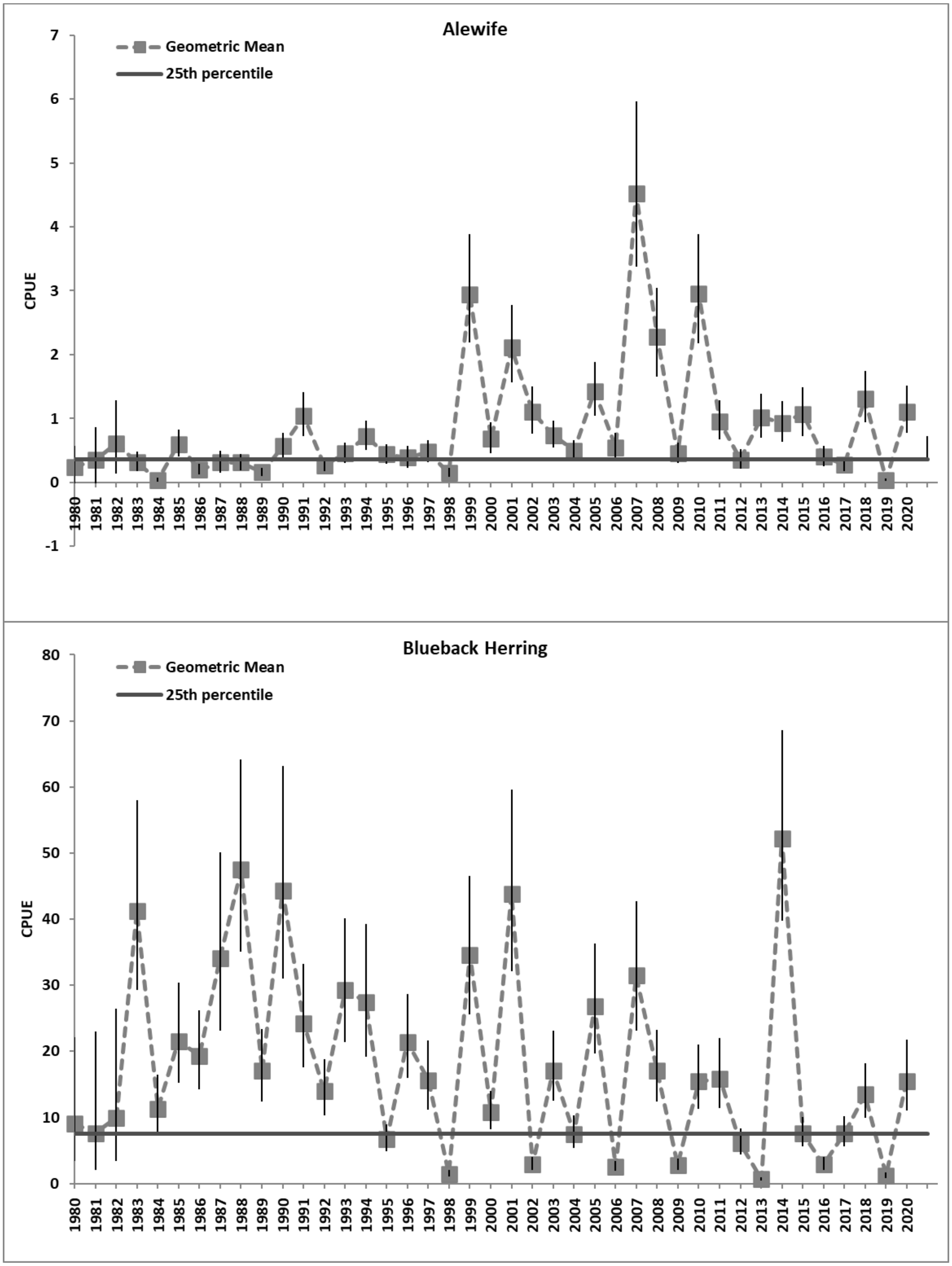


Figure 17. Young-of-year abundance indices for both river herring species.

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.

	Herring Use*							
Year	% 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.

Age	M		Maturity		Weight at 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).

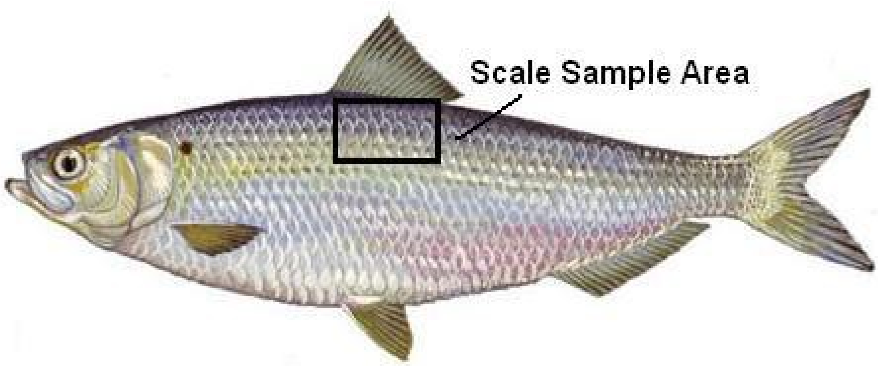
Regulation	2013 to Present	Regulation link
Season	Mar 15 – Jun 15	6 CRR-NY 10.10 (c)(2)
Creel/ catch limits (personal use)	**10 per day per angler or a maximum boat limit of 50 per day for a group of boat anglers (whichever is lower)**	6 CRR-NY 10.10 (c)(2)
Creel/ catch limits (party or charter)	- **10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

9 Appendix 2

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

Sample Collection

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



Structure Processing

Otoliths

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

Scales

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

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

Age Interpretation

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

Otoliths

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

Scales

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

Production Aging

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

Comparison of age and repeat spawning mark assignments among readers are analyzed using a standard precision template developed by NOAA's Northeast Fisheries Science Center. Templates can be found at http://www.nefsc.noaa.gov/fbp/age-prec/. Precision is evaluated by examination of the mean coefficient of variation (CV), percent agreement and the Bowker's test of symmetry. Aging laboratories around the world view a measure of mean CV of 5% or less to be acceptable (Compana 2001).

References

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

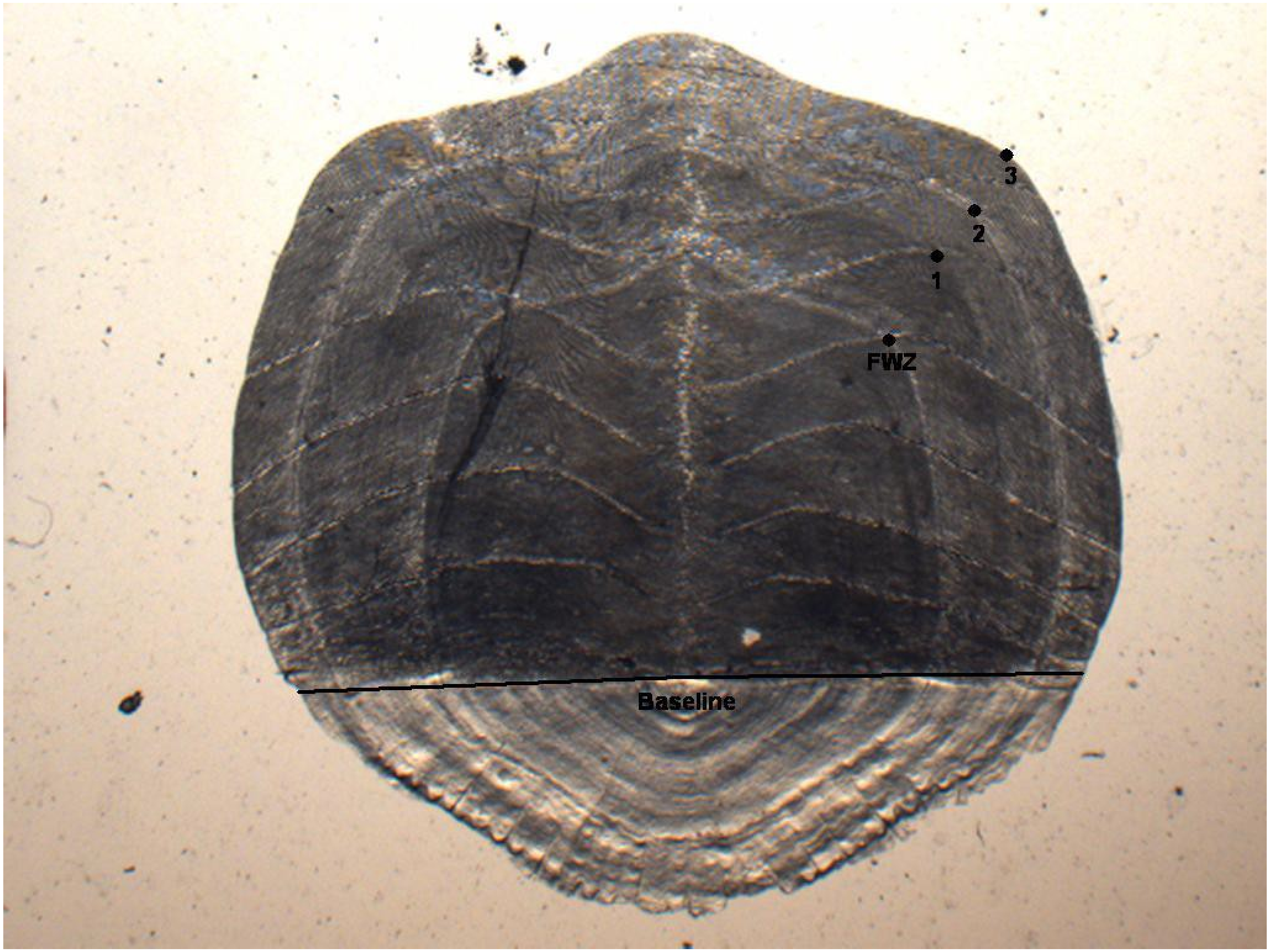


Figure 1. This 3 year old alewife has its baseline, fresh water zone (FWZ) and annuli all marked. Note the straight baseline and large FWZ typical of alewives.

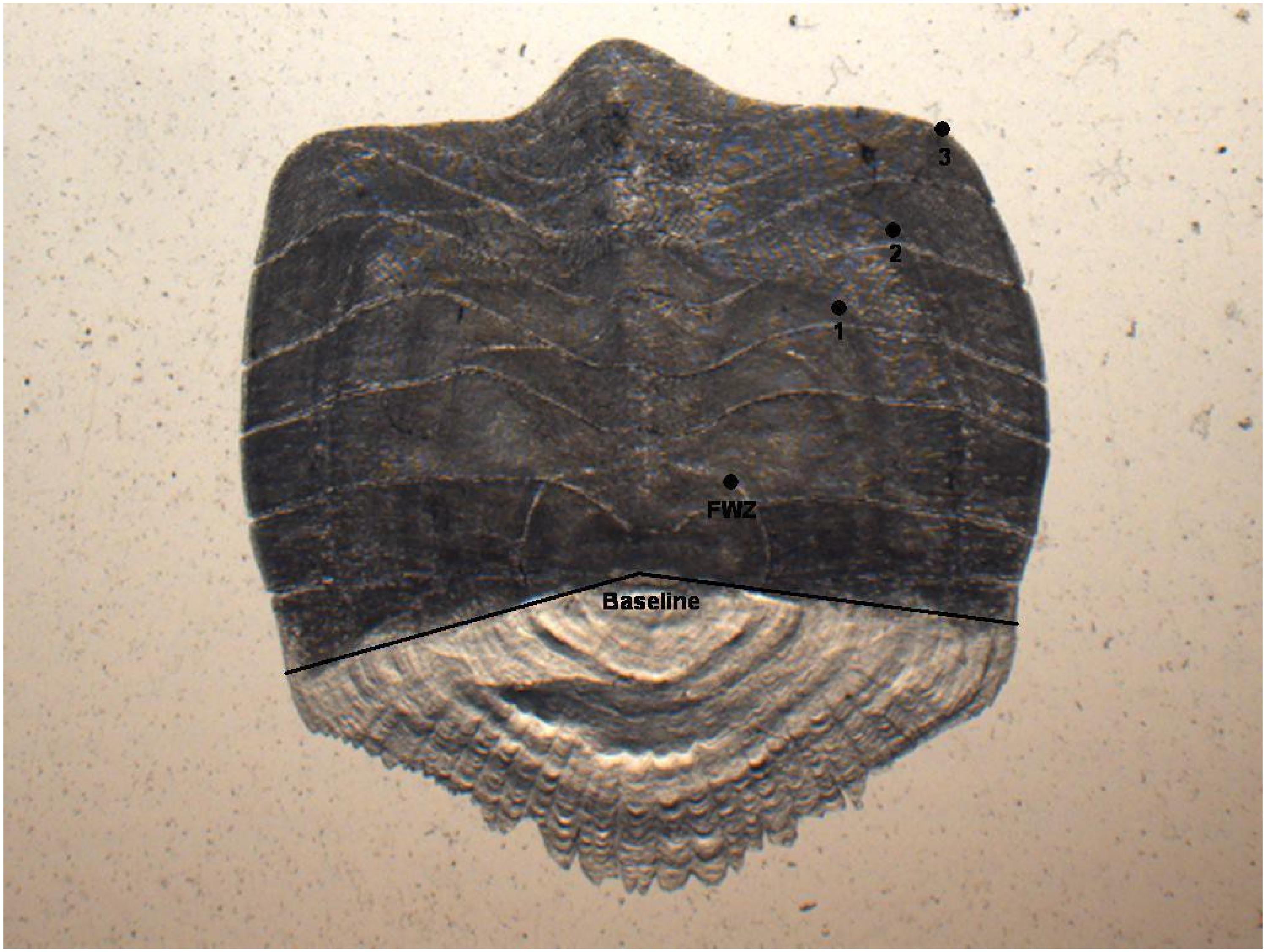


Figure 2. The baseline, fresh water zone (FWZ) and annuli are all marked on this blueback scale. Note the small FWZ and angled baseline typical of bluebacks.

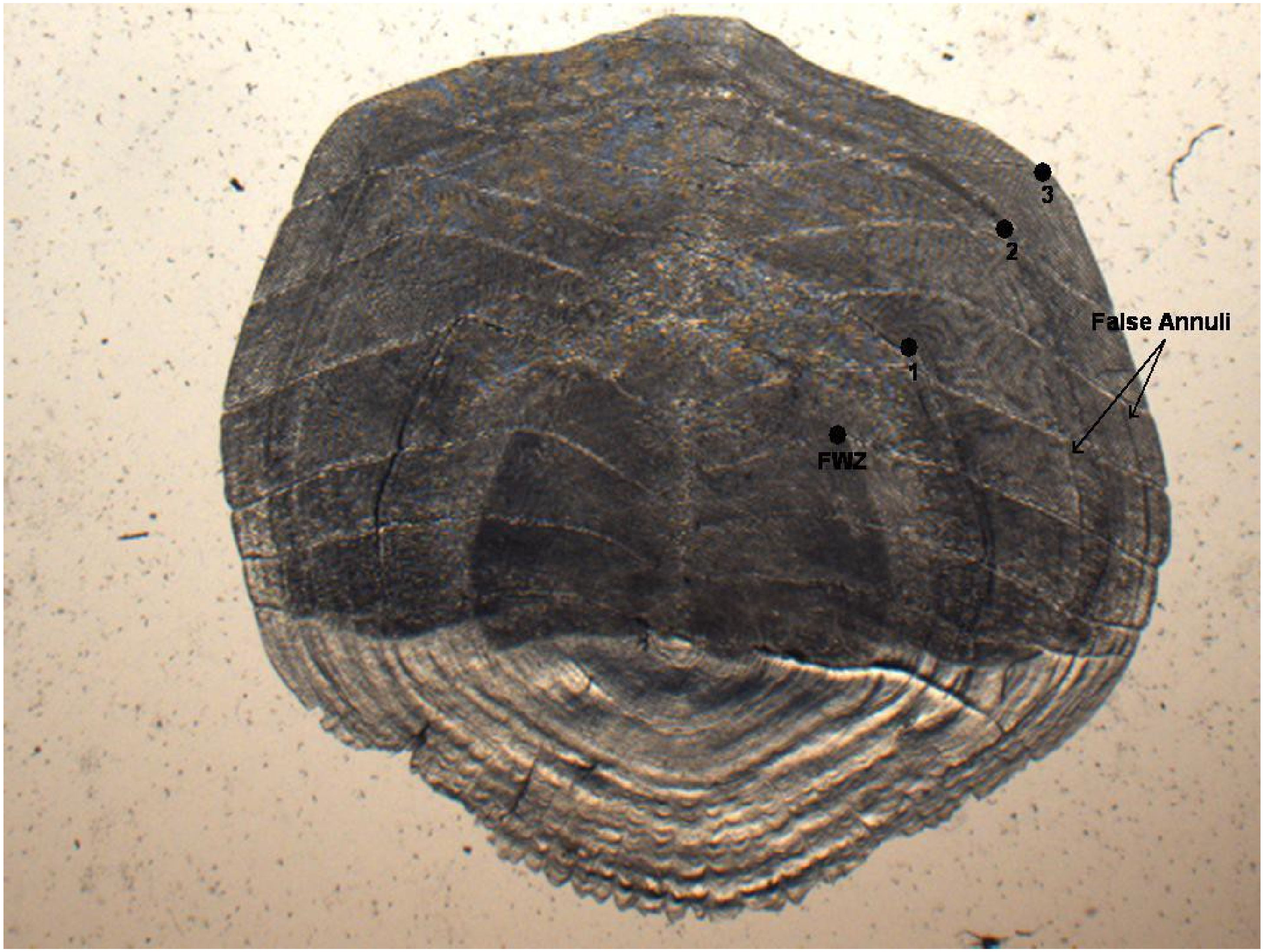


Figure 3. This three year old alewife has two false annuli, one on either side of annulus 2.

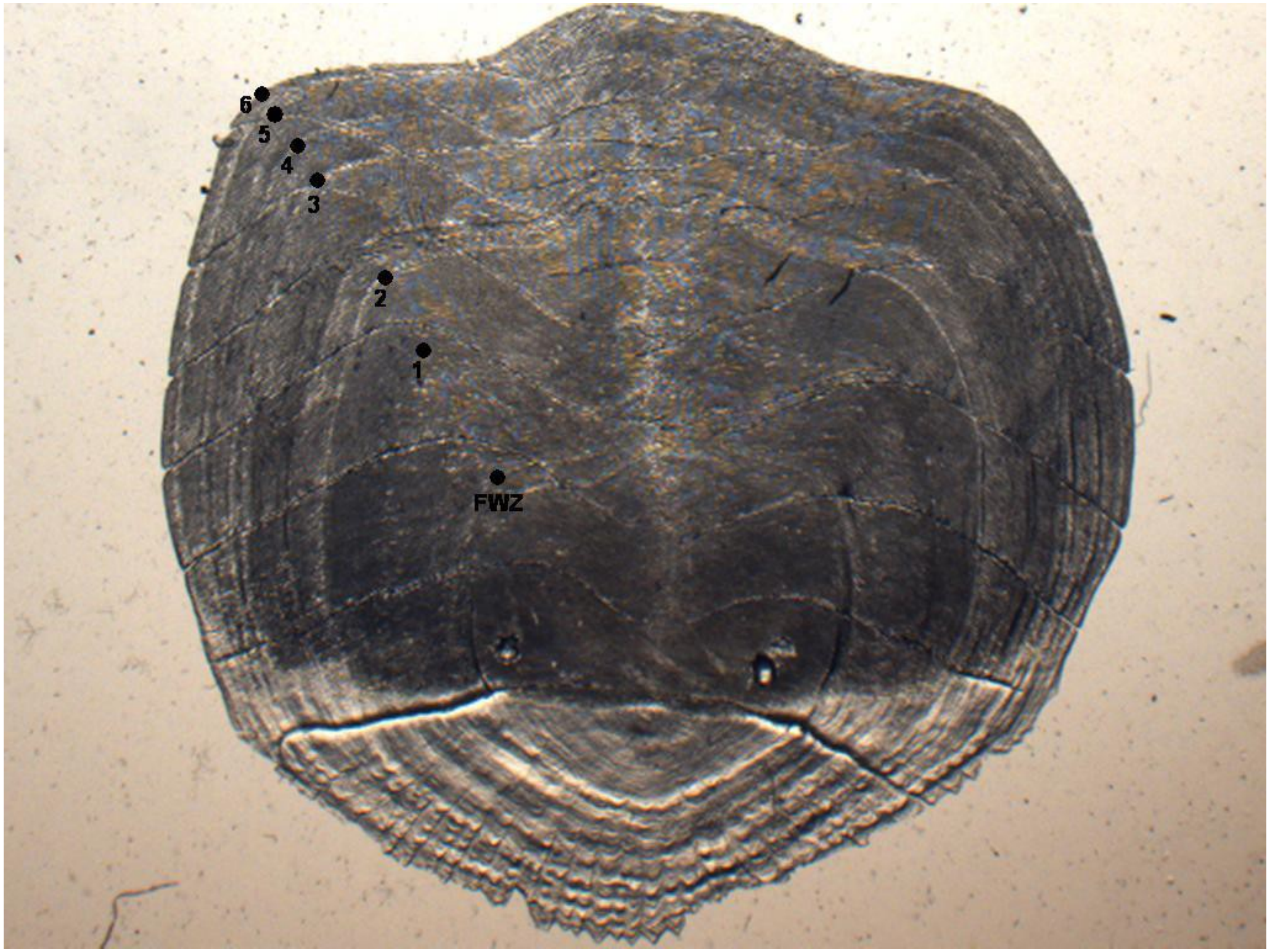


Figure 4. A six year old alewife. Note how weak the first annulus appears compared to the second.

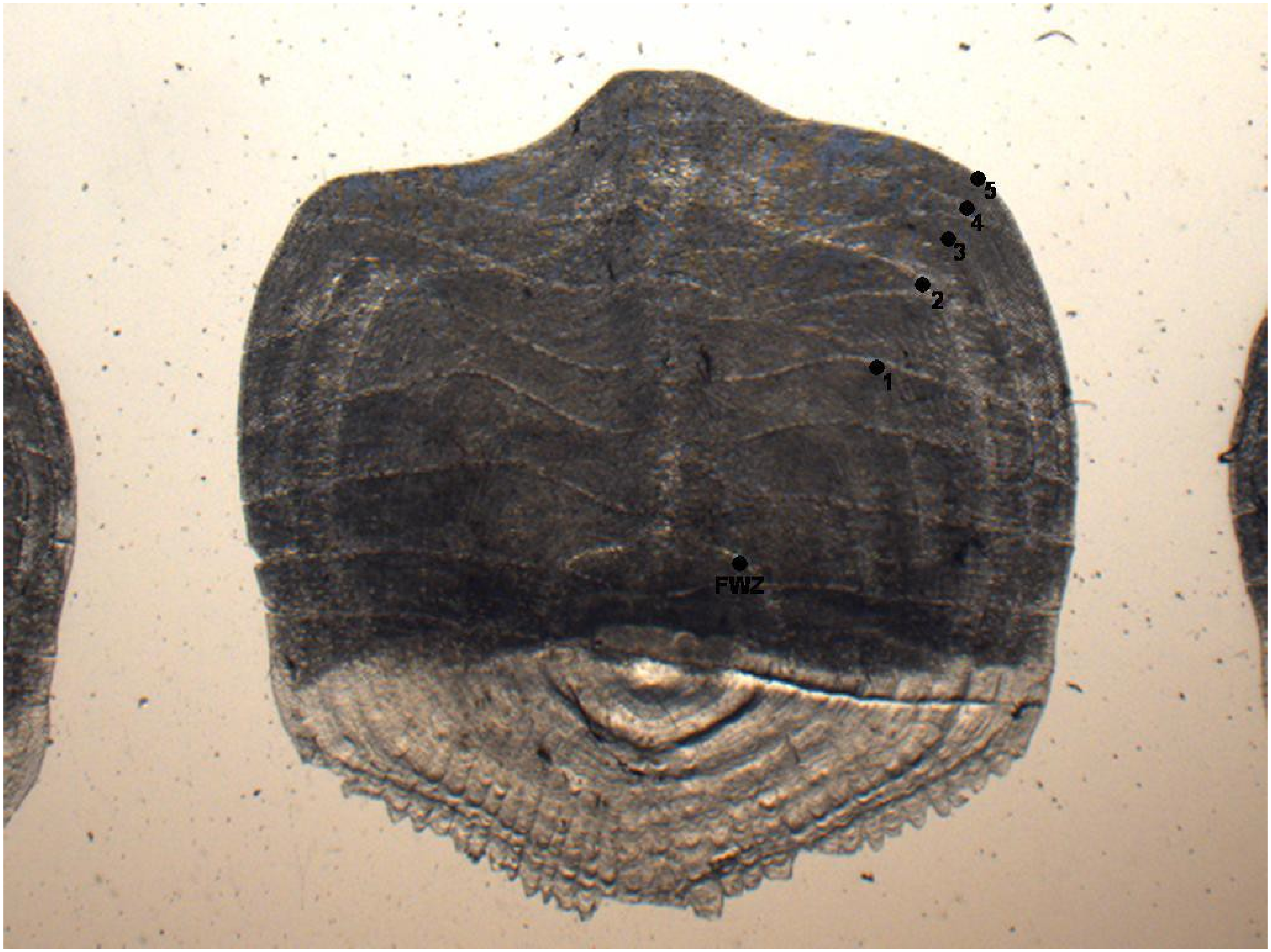


Figure 5. This five year old blueback has the typical strong second annulus.

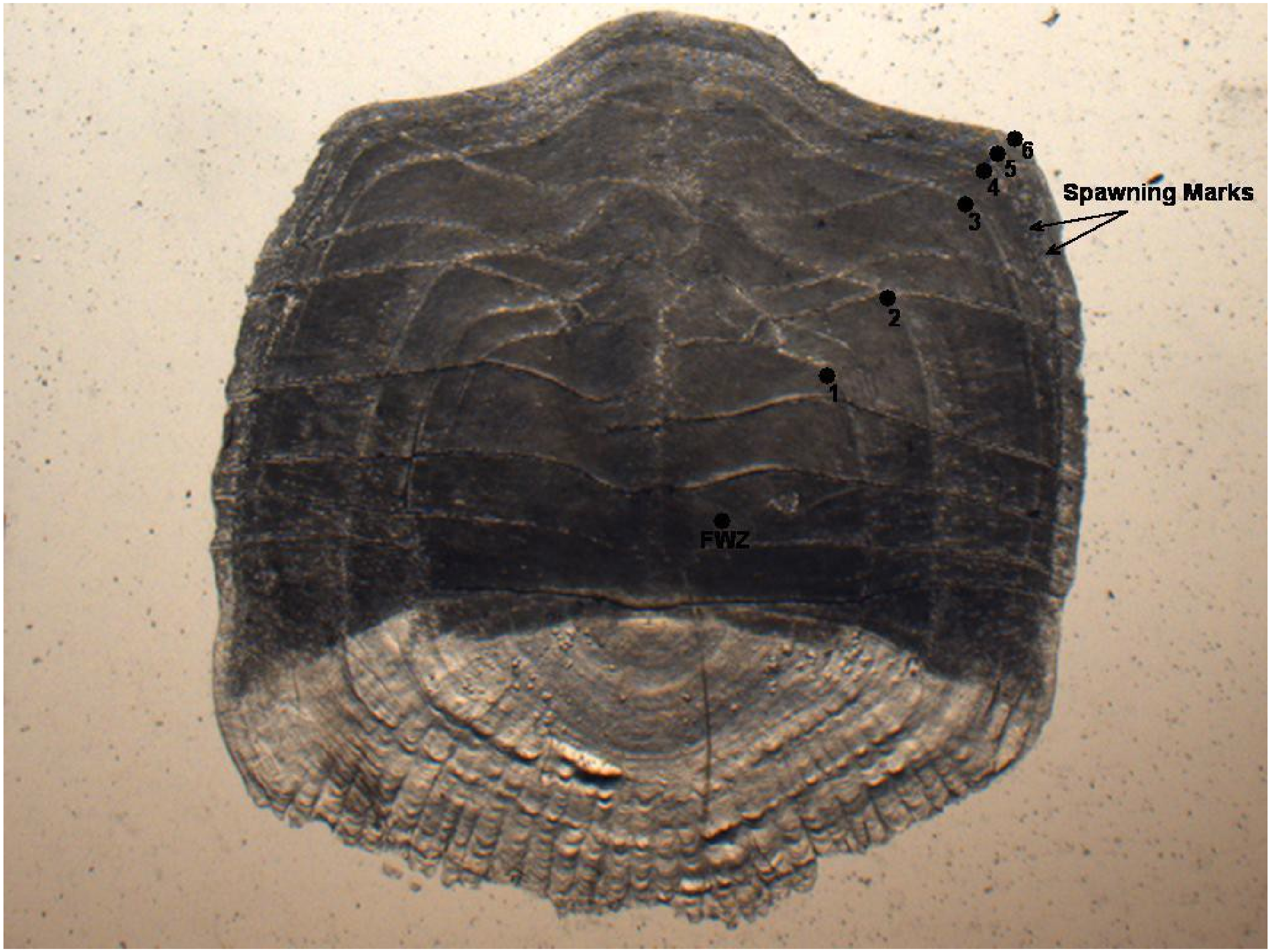


Figure 6. This six year old blueback has spawning marks at its 4th and 5th annuli.