Delaware River
Sustainable Fishing Plan for American Shad

Prepared by:

The Delaware River Basin
Fish & Wildlife Management Cooperative

Delaware Division of Fish and Wildlife • *New Jersey Division of Fish and Wildlife*

Pennsylvania Fish and Boat Commission • *New York Division of Fish & Wildlife, Division of Marine Resources*

U.S. Fish and Wildlife Service • *National Marine Fisheries Service*

and

Liaisons

National Park Service • *The City of Philadelphia Water Department*

Delaware River Basin Commission • *The Nature Conservancy*

For:

The Atlantic States Marine Fisheries Commission
Shad and River Herring Management Board

March 2022

Table of Contents

List of Figures

List of Tables

Executive Summary

The Atlantic States Marine Fisheries Commission's (ASMFC) Amendment 3 to the Interstate Fishery Management Plan for Shad and River Herring requires states to submit Sustainability Plans for continuance of American shad fisheries in their jurisdictional waters. Within the Delaware River Basin, the Delaware River Basin Fish and Wildlife Management Cooperative (Co-op) is responsible for the management of American shad. Previous 10-years management were codified in the original 2012 Sustainable Fisheries Plan (2012 SFP) and subsequent update in 2017 (2017 SFP), both as approved by ASMFC. These plans were based on time-series relative benchmarks for population and fishery measures. The Co-op is seeking renewal of their Sustainable Fishing Plan (SFP) of the Delaware River American shad stock for the next 5-year cycle, 2022 – 2026. The proposed SFP retains all previously defined indices. An additional index was added to this updated plan to monitor total mortality of female American shad in the Delaware River. The total mortality of female American shad is based upon the 2020 ASMFC Stock Assessment (ASMFC 2020) methodology and associated benchmark. The Co-op judge these fisheries as sustainable while avoiding diminishing potential stock reproduction and recruitment as long as all six indices of stock condition remain within the defined benchmarks.

Currently the Delaware River American shad stock is experiencing unsustainable adult female mortality as determined in the 2020 ASMFC Stock Assessment (ASMFC 2020). The 2020 assessment found total mortality, determined by Z estimates, was 1.3 for the Delaware River Basin, which was above the benchmark of 1.07. Juvenile production as measured by juvenile abundance indices (JAI), assessed by seine surveys in both non-tidal and tidal reaches, has varied without trend. Below average production was observed in non-tidal reaches from 1998 to 2002, but excellent year classes were observed in both JAI indices in 1996 and 2007. The 2013 JAI was the highest of the tidal reach time series, and that index has been higher than the 50th percentile of the time series in three of the past five years. The non-tidal JAI has had two years of the past five that were higher than the 50th percentile of the time series. Measures of relative adult abundance at Smithfield Beach were suggestive of declining abundance in early 1990s followed by low but stable levels from 1999 to 2009. The 2020 ASMFC Stock Assessment found no trend in abundance for Smithfield Beach. The Smithfield Beach female CPUE has been above the 50th percentile of the time series for three of the past five years.

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

demarcation line was removed for this updated SFP. For this update SFP, 50% of all commercial catch will be assigned to the mixed stock, and the remaining will be assigned to landings on the Delaware River stock. Landings on the mixed stock were highest in the early 1990s and have been generally declining since that time. Landings on the mixed stock have been below the 50th percentile of the time-series since 2015.

Fishers in New Jersey represent a small directed fishery for American shad; whereas, landings of shad reported to the State of Delaware occur in the spring gill net fishery. Trends of combined landings, representative of the Delaware River stock, have been declining since 1990, with lowest levels observed in the most recent years (2008-2019), with the exception of a high harvest in 2014. The decline is most likely due to gear changes in Delaware's striped bass quota driven fishery and the low number of New Jersey fishers seeking American shad. To reduce mortality on the Delaware River stock, quotas are being proposed for both Delaware and New Jersey and Delaware will also be implementing a gear modification (thicker twine size to 0.52-mm) in the SFP update. The proposed quotas represent a cap on landings set at approximately 33% reduction from the most recent 10-years, excluding 2014 as an anomalous year.

In addition to the Delaware Bay fisheries, a small haul seine fishery (Lewis haul seine) occurs in the Delaware River, some 15 miles above the fall line at Lambertville, NJ. This fishery exists as an eco-tourism venture with nominal harvest of shad. The 2020 ASMFC Stock Assessment found an increasing trend in adult abundance for the Lewis haul seine. Co-op members will continue to annually contract with the Lewis haul seine fishery for characterizing the American shad spring-time spawning migration, as the fishery represents a considerable time-series (1925 – present-day).

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

In addition to harvest and natural mortality, the Co-op investigated other factors that may also impact the Delaware River stock. Flow management in the Delaware River is highly regulated, particularly in the upper portion of the Basin. Co-op members are active in management groups to ensure flow management is protective of American shad spawning and supports nursery habitat. Invasive species, such as northern snakehead, blue catfish, and flathead catfish are recent introductions to the basin that could potentially increase predation on American shad. Possible losses from oceanic commercial fisheries principally, as bycatch, have been difficult to evaluate; but, the Co-op is concerned these offshore fisheries may be having a

negative impact on the Delaware River stock. As part of the American shad restoration program for the Schuylkill and Lehigh rivers, the Pennsylvania Fish and Boat Commission (PFBC) estimates the contribution of otolith-marked hatchery shad to the returning adult spawning populations in both rivers. While evidence suggests these fry stockings substantially support the runs in the Schuylkill and Lehigh rivers, the contribution to the main stem Delaware run above their respective confluences has been minimal. Multiple water intake structures are found in the Delaware River and upper estuary that may be causing mortality on American shad eggs, larvae, and juveniles through impingement and entrainment. The Co-op is actively commenting on water intake projects to improve protections for shad at those facilities. Additional habitat alterations in the basin from dams and other barriers reduces access to spawning and nursery habitat for shad in tributaries to the Delaware River. Co-op members are actively working to support dam removals and improved fish passage in basin tributaries (see DRBFWMC 2021 and DeSalvo et al. 2022).

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

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

- **Non-tidal JAI:** This index is derived from the New Jersey Division of Fish and Wildlife (NJDFW)/Co-op annual fixed station seining in the non-tidal Delaware River main stem at Phillipsburg, Water Gap, and Milford. The non-tidal JAI is standardized with respect to environmental covariates using generalized linear model methodology. The benchmark is based on data from 1988-2007 and 2012-2019. Failure is defined as the occurrence of three out of five years where JAI values fall below a value of 188 (i.e., the 50^{th} percentile of the historical data).

- **Tidal JAI:** This index is derived from the NJDFW annual striped bass seining in the upper estuary. Only those stations from Newbold Island to the Delaware Memorial Bridge are included. The JAI index represents the annual geometric mean of the catch data. A benchmark was based on data from 1987 – 2019. Failure is defined as the occurrence of three out of five years where JAI values fall below a value of 5.81 (i.e., the 50^{th} percentile of the historical data).

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

- **Ratio of Harvest to Smithfield Beach CPUE:** This index is calculated as a ratio of the combined commercial harvest of the Delaware River American shad stock, in pounds, divided by relative abundance of adult female survivors captured at Smithfield Beach (Adult CPUE index) divided by 100. The benchmark is based on data from 1996-2019 and failure is defined as the occurrence of three out of five years where values are above a value of 799 (i.e., the 50th percentile of historical data).

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

It is anticipated that this sustainability plan will reduce mortality on the Delaware River American shad stock while allowing for human use of the resource. The Co-op views this plan having a five-year term beginning with its acceptance by the ASMFC.

Sustainable Fishery Plan for the Delaware River

1. Introduction

In accordance with guidelines provided in Amendment 3 to the Interstate Fishery Management Plan for Shad and River Herring (ASMFC 2010), the Delaware River Basin Fish and Wildlife Management Cooperative (Co-op) had the first American Shad Sustainable Fishing Plan (SFP) accepted by the Atlantic States Marine Fisheries Commission (ASMFC) Policy Board in 2012 (2012 SFP) and an updated plan that was approved by the Board in 2017 (2017 SFP) for management use through 2021. This document (i.e., 2022 SFP) represents a revised SFP for governing management of American shad over the next five-year term, 2022 – 2026, pending final approval by ASMFC. It is submitted jointly by the States of Delaware, New Jersey, and New York, and the Commonwealth of Pennsylvania, for management of American shad in waters of the Delaware River Basin (Figure 1).

The 2017 SFP built upon the progress made during the tenure of the 2012 SFP including adding a mixed stock landings fishery benchmark to address the harvest of out of basin stocks in the lower bay fishery. During 2017 SFP tenure a new genetic sampling program was undertaken to help better inform managers of the stock structure of the lower bay landings and better define stock delineation for the mixed stock fishery benchmark. Additionally, for the 2017 SFP the non-tidal JAI was standardized using a GLM to account for environmental covariates during sampling and the benchmark and associated trigger are now based upon these standardized index values.

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

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

1.1 Request for Fishery

The Co-op desires that the Shad and River Herring Management Board consider this request to approve a Sustainable Fishery Plan for American Shad of the Delaware River Basin. This plan includes a request for approval of both recreational and commercial harvest within the entirety of the main stem Delaware River and its tidal tributaries in the states of Delaware, New Jersey, New York, and Pennsylvania. Accordingly, the Co-op justifies this request based on analysis of historical trends in juvenile and adult relative abundance, and commercial and recreational fishery data.

1.2 Definition of Sustainability

Amendment 3 to the Interstate Fishery Management Plan for Shad and River Herring defines a sustainable fishery as one that will not diminish potential future stock reproduction and recruitment. The Co-op proposes that reproduction and recruitment in the Delaware River American shad stock be measured by two indices of age zero abundance to be augmented with an index of spawning stock abundance, a ratio of landings to that index of spawning stock abundance, and a mixed stock fishery index. Benchmarks have been proposed for all indices to define levels needed to reduce mortality and avoid diminishing potential stock reproduction and recruitment. We will judge fisheries as sustainable if indices of stock condition remain within these benchmarks; otherwise, exceedance will necessitate corrective management actions. In light of the findings of the ASFMC's 2020 Stock Assessment, a female adult mortality index and associated benchmark value and management trigger has also been incorporated into the 2022 SFP.

2. Stock Status

2.1 Previous Assessments

The Delaware River was included in the 1988, 1998, 2007, and 2020 ASMFC coast-wide stock assessments for American shad (Gibson *et al*. 1988; ASMFC 1998, ASMFC 2007, ASMFC 2020). The 1988 Assessment utilized the Shepherd stock-recruitment model to estimate maximum sustainable yield (MSY) and maximum sustainable fishing rates (F_{msy}). That assessment estimated F_{msy} for the Delaware River to be equal to 0.795 with exploitation at MSY at 0.548. The historical fishing rate for the Delaware River stock was estimated to be F = 0.320. The 1998 Assessment utilized the Thompson-Bell yield-per-recruit model to derive an overfishing definition (F_{30}) for American shad. Average fishing mortality from 1992 to 1996 for the Delaware River was estimated at F = 0.17, which includes out-of-basin estimates of harvest, and was considered well below the F_{30} value of F = 0.43. The 2007 assessment found the Delaware River stock of American shad declined through the 1990s and remained at low levels. The cause of the decline was not identified, nor was any explanation postulated for why the stock

remained at low levels since the decline. The 2007 assessment concluded that juvenile production remained stable without any apparent trend, and did not appear to be correlated between adult abundance or returning adults in subsequent years (ASMFC 2007). The stock assessment sub-committee was unable to reach consensus on what could be considered the best scientific benchmark(s) from the available datasets (ASMFC 2007).

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

2.2 Stock Monitoring Programs

2.2.1 Fishery Independent Surveys

2.2.1.1 Juvenile Abundance Surveys

In the tidal Delaware River, NJDFW collected data pertaining to young-of-year (YOY) American shad during their annual striped bass recruitment survey. Since 1980, seining was accomplished using a 100-ft (30.48 m) by 6-ft (1.83 m) bagged seine of 1/4 inch (6.35 mm) delta mesh, during daylight hours. A series of fixed station sites were sampled twice a month from June through November. November sampling was discontinued in 2016. Catches from sites were combined into two general regions. Region 2 represents sites (n = 16) from the Delaware Memorial Bridge, RM 70.9, to the Philadelphia Naval Shipyard, RM 94.4; whereas Region 3 represents sites (n = 8) from just north of the Betsy Ross Bridge, RM 105.8 to Newbold Island, RM 125.4. Data from lower Delaware Bay sites were eliminated where YOY American shad are less likely to be encountered in higher salinity waters. The tidal index is generated using the shad catches from Regions 2 and 3 during the months of August through October and is expressed as a catch per haul geometric mean. In 2015, a QA/QC check was completed on all data sets from the Delaware River resulting in updates to the recruitment indices during the time-series and in 2020 sampling was not completed due to the COVID-19 pandemic.

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

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

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

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

Data standardization model development (i.e., generalized linear model, GLM) improved the precision and accuracy of the Big 3 JAI (2017 SFP). Amendment 3 to the ASMFC to the Interstate Fishery Management Plan for Shad and River Herring requires JAIs to be expressed as geometric means (GM) or area under the curve (AUC; ASMFC 2010), with associated confidence limits. For the 2022 SFP, the non-tidal JAI will continue to be expressed both as a GM and a GLM; however, the benchmark for the non-tidal JAI will be based on the GLM analysis. The Co-op considers the GLM as providing a more robust JAI index than can be indexed by geometric means.

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

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

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

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

Amendment 3 defines recruitment failure as occurring when three consecutive JAI values are lower than 75% of all other values in the data series (ASMFC 2010). To address the recent 2020 ASMFC Stock Assessment report, which indicated that the total mortality of the Delaware River Basin stock of adult American shad is unsustainable and Delaware Basin shad abundance is unknown, benchmark values for JAIs were made more conservative. Recruitment failure is now defined occurring when 3 out of 5 years of JAI values are lower than 50% of all other values in the time-series. The Co-op has adopted this definition for both the non-tidal and tidal JAI benchmarks. These are calculated as the 50^{th} percentile, using the "quantile" function in the R package or "percentile.inc" function in Microsoft Excel spreadsheets. Years to be included in the benchmark calculation were determined by using years where sampling techniques and/or locations were standardized. The non-tidal benchmark includes years 1988 to 2019 and the tidal benchmark includes years 1987 to 2019.

2.2.1.2 Adult Abundance Indices

Co-op members annually monitor the relative abundance of returning spawning adult shad in the Delaware River. Monitoring occurs after the commercial fishery is executed, such that captured shad represent survivors from the fishery. This effort is currently being accomplished at Smithfield Beach (RM 218) as a gill net survey on actively spawning adults and fish passage counts through fishways on the Lehigh and Schuylkill rivers.

2.2.1.2.1 Gill Net Survey

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

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

Observed sex ratios in any given year is dependent on the frequency of gill net mesh sizes deployed. The frequency of stretch mesh sizes used varied among years (Figure 7). The use of 4.5-in and 5.0-in stretch mesh nets tended to be principally deployed in any given year to support broodstock collections. The increased use of the 4.75 inch stretch mesh size in later years (i.e., post 2012) was due to a perceived need to increase the male to female ratio for improved egg viability. Nightly deployment of a single net of 4.0-in stretch mesh was initiated in 2016 targeting small shad observed routinely passing through the 4.5-in gill nets. A 4.0-in, 5.75-in, and 6.0-in stretch mesh nets were not deployed in 2019, however, due to limited shoreline

availability without losing the net due to unfavorable river conditions. Use of large (≥ 5.5-in) stretch mesh sizes were not as commonly deployed as smaller stretch mesh sizes, due to the perceived lack of catch, during later years.

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

Observed annual size distributions of captured shad varied among years for both female and male shad (Figure 9). Female total lengths ranged from 402-mm TL (2018) to 644-mm TL (2003), with median sizes between 516-mm TL (2010) to 571-mm TL (2003). Generally, males are smaller sized than females. Total lengths ranged from 398-mm TL (2005) to 615-mm TL (1996), with median sizes between 468-mm TL (2009) to 454-mm TL (2002).

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

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

Application of annual age-length keys provides for the estimation of mean size-at-age. Annual total catch was parsed by stretch mesh size of capture to account influences associated with gill net selectivity and annual sampling variability of various mesh sizes. Least-square regressions of the time-series demonstrate significantly declining slopes for Age 5 and Age 6 female shad in the 4.5-in to 5.0-in stretch mesh sizes (Figure 11). Inferences of mean size-at-age for catches of

female shad from mesh sizes 5.75-in to 6.0-in are tenuous given infrequent occurrence. Mean size-at-age were not investigated for male shad.

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

In previous SFPs, in an attempt to get a general sense of trends in total instantaneous mortality (Z), historical age data from shad collected at Smithfield Beach were analyzed using a Chapman-Robson bias-corrected mortality estimator described in Smith et al. (2012). Total mortality was calculated for females and combined sexes on an annual basis beginning in 1997. To be consistent with the methods used in the 2012 Benchmark Stock Assessment for River Herring, the age of full recruitment was the age of highest abundance and there had to be at least three ages to be included in the respective analyses (ASMFC 2012). Female Z estimates ranged from 0.81 (2006) to 2.87 (2012).

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

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

Catch-per-unit-effort (CPUE), represented as geometric means (GM), provides relative population trends for spawning adults at Smithfield Beach. Total CPUE (females & males, combined) annual values varied (0.23–3.98 shad/net-hour) among the time-series (Figure 13). Peak abundances were observed prior to 1993 (> 2.0 shad/net-hours); after which CPUE varied 0.23–1.59 shad/net-hours. Refinement of CPUE was accomplished to focus on female catch

only, (Figure 13). The intent was a perceived improved benchmark for assessing trends of available spawning stock. Trends of female-only GM demonstrated similar patterns as the total combined CPUE, with values varying 0.21–1.07 shad/net-hours for the time-series (1996–2019). In recent years, 2016–2019, annual GM values either ranked poorly (2016: 17th; 2019: 23rd) or placed in the top ten (2017: 10th, 2018: 4th) in the time-series.

The utility of Smithfield Beach as a monitoring program for defining sustainability of the Delaware American shad is critical. Yet, the primary purpose as a broodstock source for the PFBC restoration program confounds conclusive statements on observed population biological trends. Should program objectives for the PFBC restoration efforts relax; monitoring objectives need to take priority.

2.2.1.2.2 Adult Fish Passage

Many of the Delaware River tributaries historically contained spawning runs of American shad. Unfortunately, with the development of the lock/canal systems throughout the Delaware River Basin, including the Lehigh and Schuylkill rivers in the early 1800s, shad became extirpated in many of these tributaries. Efforts have been undertaken to restore shad in the Lehigh and Schuylkill rivers by installation of fish ladders and stocking fry through a hatchery program. Fish passage monitoring exists for the Lehigh and Schuylkill rivers, but passage into many other Delaware River tributaries is unknown.

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

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

The lack of relationship between the Lehigh and Schuylkill rivers shad passages suggests shad runs into these rivers are not representative of the Delaware River spawning run. Co-op members agreed that Easton and Fairmount fish passage data was of no utility in assessing/monitoring the shad population within the Delaware River. No attempt was made to document downriver passage from the either river back into the Delaware River.

2.2.1.2.3 Comparison of JAI to adult indices

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

2.2.2 Fishery Dependent Data

2.2.2.1 Commercial Fisheries

Exploitation of the Delaware River American shad stock occurs in several fisheries within the Basin. Commercial harvest is permitted by the States of New Jersey and Delaware. These fisheries occur in tidal waters of Delaware and New Jersey using staked, anchored, or drifting gill nets. Fishers principally harvest shad during the spring spawning migration from late February into May. Fishers in New Jersey represent a small directed fishery for American shad; whereas, landings of shad reported to the State of Delaware occur in the spring gill net fishery, which targets striped bass.

In addition to the Delaware Estuary/Bay fisheries, a small haul seine fishery (Lewis haul seine) occurs in the Delaware River, some 15 miles above the fall line at Lambertville, NJ.

2.2.2.1.1 Lewis Haul Seine

Lewis haul seine: The Lewis haul seine is the only in-river fishery and is located at Lambertville, NJ (RM 148.7). It dates back to the late 1880's, representing a significant time-series of recorded data with catch-per-unit-effort data documented since 1925 (Figure 15). The fishery has evolved from a commercial fishery to an eco-tourism enterprise that resulted in changes to the length of net used. The fishery employed seine nets of different length depending on the water flow and height over the years. Although this may be problematic, the length of the time series still gives a good indication of spawning run strength in the Delaware River (ASMFC 2007). Since 2012, this fishery has been contractually supported by Co-op members ($6,000 annually). Requirements included a minimum of 33 days fishing in the traditional style and time-period (mid-March through June) along with reporting biological data (length, weight, scale sample) for all harvested shad to maintain the integrity of the time-series. Investigation of biological parameters of harvested shad by the Lewis haul seine have not been pursued.

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

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

2.2.2.1.2 New Jersey Commercial Fishery

Fishery Characterization and Regulations: Prior to 1998, the National Marine Fisheries Service (NMFS) estimated American shad landings for the State of New Jersey. In 1999, the NMFS estimates were combined with voluntary logbook data from New Jersey's commercial fishers. These landings data reported by NMFS date from the late 1800s to 2000, while extensive, are thought to be under-reported and considered inaccurate. In 2000, the State of New Jersey instituted limited entry and mandatory reporting for the American shad commercial fishery. American shad landings reported to the State of New Jersey are separated into two reporting regions: Upper Bay/River and Lower Bay. Historically, Gandys Beach (RM 30) was the demarcation for separating the reported landings.

These reporting forms allow insight into the fishery. Records indicate that the shad fishing season started as early as February 15 and ended as late as May 22 with mesh sizes between five and six inches typically being fished. In the past, American shad were primarily landed by drifting gill nets in the Upper Bay/River fishery while staked and anchored gill nets accounted for the majority of shad being landed in the Lower Bay. This distinct separation of gear deployed by general area is not as strong in the recent past as participation in the fishery has declined due to attrition and effort is much less consistent.

Regulations for American shad harvest in New Jersey include a limited entry/limited transferability license system, limitations on the amount and type of gear allowed to be fished, and gill net season and area restrictions enforced through a limited entry permitting system in the lower Delaware Bay. Specifically, these restrictions included gill nets can be deployed from February 1 to December 15, minimum stretch mesh size increases through the season, with 2.75 inches through February 29 and 3.25 inches March 1 to December 15. Net length is also limited to 2,400 feet from Feb 1 to May 15 and 1,200 feet from May 16 to December 15 (Table 1). A haul seine can also be used to harvest American shad from November 1 to April 30. The seine must have a 2.75-inch minimum stretch mesh and maximum length of 420 feet.

Fishery Participation: In New Jersey, as of February, 2022, there were 70 permits issued to allow harvest of American shad. The shad permit allows the holder to fish in any state waters where the commercial harvest of shad is allowed if the permit holder meets all other net requirements for commercial fishing in a particular area. Currently, only 43 of these permits are active (28 commercial and 15 incidental), due to attrition (Table 2). Since harvest reporting

became mandatory in 2000 the number of fishers landing shad in New Jersey has seen a steady decrease. From 2000 through 2006 the number of fishers landing shad averaged in the mid-twenties (range of 21-29). From 2007 through 2009 this number dropped into the mid-teens (range of 14-17), and since 2012 this number has averaged around nine fisherman landing shad in the Delaware Bay (range of 9-13). The number of fishers landing shad in New Jersey is expected to continue to decrease as the current fishers age out of the fishery and interest in the fishery itself continues to decline.

Landings: Harvest of American shad by region in New Jersey has seen a shift from historically being a predominantly Lower Bay fishery (below Gandys Beach) to an Upper Bay/River fishery and a significant decrease due lack of effort and fisher participation. From 1985 through 2000, landings in the Lower Bay averaged 81,013 pounds, while the Upper Bay/River fishery saw average landings of 18,759 pounds of shad. From 2001 through 2016 this trend reversed with Lower Bay landings averaging 11,558 pounds and the Upper Bay/River fishery landing an average of 35,358 pounds of shad. Since 2017 the landings have been relatively evenly split with the Lower Bay averaging 5,612 pounds and the Upper Bay/River fishery averaging 5,160 pounds of shad landed (Figure 16).

Fishing Effort: Effort data for New Jersey's commercial fishery is estimated from CPUE presented in pounds per square foot of netting (Table 3). Overall effort in New Jersey has decreased more than 50 percent since 2005.

Biological Data: Length frequency data (fork length) were collected from American shad caught during fishery independent tagging operations by gill net in lower Delaware Bay (i.e., Reed's Beach, RM 14.8). However, data are comparable to the commercial fishery since similar gill net mesh sizes are used for this program. Fork lengths ranged from 346 mm to 615 mm and have fluctuated without trend over the course of the time series (Table 4). Sex ratios show the fishery is mostly prosecuted for females, with both the Upper Bay/River and Lower Bay fisheries averaging 80% female, but there are years when the percentage of males increased (i.e. 2010, Figure 17). The State of New Jersey obtains and will continue to obtain representative samples of the commercial catch to determine gender, size, and otolith samples for age estimation as required under the ASMFC FMP.

2.2.2.1.3 Delaware Commercial Fishery

Fishery Characterization and Regulations: The Delaware commercial American shad fishery in the Delaware River & Bay occurs during the spring spawning migration from late February through May. Landings are reported to the State of Delaware under a mandatory food fish license and are separated into two general areas of the bay, Upper or Lower Delaware Bay as delineated fisheries occurring above or below Bowers Beach, Delaware. Almost all shad landed are in conjunction with the concurrent striped bass commercial season that begins February 15 and extends through May 31 in the estuary. All landings are by gill net, both anchored (fixed)

and drifted. Anchor nets are used primarily in Delaware Bay; drift nets are used exclusively in the Delaware River by regulation (Table 5). There are no specific regulations that have been adopted to reduce or restrict commercial landings of American shad in the Delaware River & Bay. Regulations governing the striped bass fishery have the greatest impact on the total catch of American shad due to the presence of both species in the river and bay during the spring. Restrictions for the striped bass fishery include a limited entry license system, limitations on the amount and type of gear allowed to be fished, and gill net season and area restrictions. Specifically, these restrictions included no fixed gill nets in the Delaware River north of the southern shore of the Appoquinimink River from January 1 through May 31, and not more than 200' of fixed, anchored, or staked gill net from May 10 through September in the rest of the Delaware Estuary.

Fishery Participation: Delaware has a limited entry license system for the commercial gill net fishery under their food fishing equipment permitting regulations. There is a cap of 119 gill net permits, and no new permits will be issued. Fishers may choose not to renew their permit annually, so the total number actually obtaining a permit will change annually. Fishery participation has been decreasing for multiple years and this trend is expected to continue (Table 6). Many fishers do not land any American shad and many do not fish at all since they were allowed to transfer their individual striped bass quota to other licensed fishers. Furthermore, permits may be passed onto direct descendants or issued to a resident who has completed a commercial fishing apprenticeship program.

Landings: Beginning in 1985, the State of Delaware required mandatory reporting of commercial landings under the provisions enacted by the Delaware General Assembly in 1984. Every fisherman holding a commercial food-fishing license was required to submit a monthly report specifying where he fished, the type and amount of fishing gear deployed, and the pounds landed of each species taken for each day fished. Commercial landings of American shad in Delaware occur in the concurrent striped bass fishery.

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

Fishing Effort: Since 1985, the data on catch, landings, and effort have been collected via logbooks. However, commercial harvesters are only required to report mesh size when landing striped bass. Commercial fishing effort for Delaware is measured using net yards. Net-yards were the yards of net fished on that day the landings occurred. The overall State of Delaware CPUE was high from 1985-1988 and then has been at a consistently less than 0.5 pounds per net yard fish since 1989, with the exception of an increase in CPUE in 2014 (Figure 19). Shad is no longer the target species of the spring gill net fishery. Few shad are harvested in the fishery since the larger mesh sizes used for striped bass allow escapement. To emphasize the decline of effort on American shad within the Delaware Estuary, the Co-op examined effort data from

the State of Delaware, expressed in yards of net fished, from 2003 to 2019 (Figure 20). Effort has generally decreased throughout the time series with effort peaking in the upper bay and river fishery in 2005 and the lower bay fishery in 2007.

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

2.2.2.1.4 Determining Exploitation of the Delaware River American Shad Stock

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

New Jersey gill netters who target shad express concern that their nets catch striped bass in high numbers, yet they are not allowed to land bass; the bass damage their nets and they cut their hands on the spines and gill cover edges, so no additional effort resulting in increased landings is expected in New Jersey. Delaware gill netters report that any attempts to target shad catch large numbers of bass, and if they have already filled their striped bass quota, they cannot land additional striped bass and many will cease fishing. The overall decrease in coastal stocks of American shad may be an additional factor to the decrease in landings of shad.

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

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

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

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

2.2.2.1.5 Commercial Landings on Mixed Stock Fisheries

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

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

A separate study using genetic analysis of microsatellite nuclear DNA was conducted in 2009 and 2010 to determine American shad stock composition (Waldman *et al*. 2014). Although samples were collected in 2009, they were only evaluated for a two-stock composition (Delaware/Hudson) and results were not comparable to the author's 2010 analysis or the more recent collections and analysis by U.S. Fish and Wildlife Service (USFWS), therefore the 2009 data were not considered in the development of this plan. For 2010, stock composition was

determined from American shad collected in Maurice Cove, NJ (RM 21, n = 31) and off Big Stone Beach, DE (n=191, RM 14; Figure 25). Stock composition estimates for 33 baseline populations indicated that 76% of the sampled fish in this study were of non-Delaware River origin (Table 10).

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

The 2012 Sustainable Fishing Plan (SFP) acknowledged the occurrence of fish from other coastal shad stocks in the Delaware Bay harvest. At the time, it was assumed that only fish from the lower Bay had some representation from other coastal stocks, and a demarcation line was drawn across the Bay from the Leipsic River, DE (RM 34) to Gandys Beach, NJ (RM 30), as adopted from the ASMFC 2007 American Shad Stock Assessment, to represent the uppermost extent of which other coastal stocks ascended into Delaware Bay. This demarcation line was derived based on mark-recapture data from the NJDFW tagging program and formed the basis for assigning (i.e., as a proportion) the commercial harvest in the lower Bay to the Delaware River stock. For harvest that occurred in the Bay north of the demarcation line, 100% was considered Delaware River stock. For harvest south of the demarcation line, 39% of harvest was assigned to the Delaware River stock, and the remainder was assigned as mixed stock origin shad.

For the 2017 SFP, the demarcation point on the Delaware shoreline was changed to better reflect how landings are reported in that state and updated tagging data and genetics results from Waldman et al. (2014) were also considered. The demarcation line in the 2017 SFP extended from Gandys Beach, NJ to Bowers Beach, DE (RM 23). Using the recapture proportion from the NJDFW tagging studies, all landings north of the updated demarcation line were considered 100% Delaware River stock. South of the demarcation line, 40% of landings were be

assigned to the Delaware River stock and the remaining 60% of landings assigned to the mixed stock.

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

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

The 2012 SFP did not have a mechanism to limit expansion of the Delaware Bay fisheries on the mixed stocks, but recommended that the feasibility for directly managing the mixed stock harvest be considered in the 2017 SFP. In the 2017 SFP, the Co-op established a benchmark that explicitly managed the harvest on the mixed stock. The benchmark was based on the total pounds landed from the mixed stock, which consists of 60% of the landings south of the demarcation line from Bowers Beach, DE to Gandys Beach, NJ. The benchmark was defined as the 75th percentile of landings from 1985-2015 where 25% of values are higher (47,650 lbs.). The benchmark was updated for 2022 SFP to reflect more recent genetics information (see section 3.1.6).

The Co-op will continue to annually monitor landings in the Delaware Bay to ensure any significant increase in harvest results in increased regulatory control for keeping exploitation at

current levels. Overall, mixed stock landings have been declining since mandatory reporting was enacted by both the States of Delaware and New Jersey (Figure 26).

2.2.2.2 Recreational Fisheries

The recreational fishery for American shad generally occurs from late March through June of each year. The fishery is concentrated in the non-tidal reach from Trenton, New Jersey (RM 133) to Hancock, New York (RM 330). Brandywine Creek supports the only notable recreational American shad fishery in Delaware's portion of the Delaware Estuary. It is a modest fishery that primarily occurs at the first blockage encountered upstream.

Historical participation in the recreational shad fishery has fluctuated but overall, angler effort has declined. Numerous creel surveys have been conducted since the 1960's using various sampling methodology (Marshall 1971; Lupine *et al*. 1980, 1981; Hoopes *et al.* 1983; Miller and Lupine 1987, 1996; NJDFW 1993, 2001; Volstad e*t al.* 2003). Estimates of angler catch and harvest in 2002 (Volstad 2003) were substantially lower than reported by Miller and Lupine (1987, 1996), representing a decline of total catch by 63% and 42% since those surveys in 1986 and 1995, respectively. Similarly, the percent of harvested shad declined from 1986 (49%) to 1995 (20%) and was estimated at 19% in the 2002 survey. Angler catch rates (shad/hr), also varied among the three surveys (0.19 shad/hr, 0.25 shad/hr, 0.13 shad/hr in 1986, 1995, and 2002, respectively) with the lowest catch rate observed during the 2002 study. Inclusion of only those anglers specifically targeting American shad during the 2002 survey however, substantially improved angler catch rate (non-tidal: 0.34 shad/hr; Volstad *et al*. 2003). No comprehensive creel survey of the Delaware River has been accomplished since 2002.

The Marine Recreational Information Program (MRIP) provides characterization of recreational American shad harvest in the Delaware Estuary & Bay. Catch estimates are inconsistent among years and highly imprecise (Table 12). The excessively high (> 50%) percent standard error estimates (PSE) suggest total numbers of shad harvested by recreational anglers are unreliable. Co-op members agree anglers nominally fish for American shad in the Delaware Estuary and Bay; yet, also agree the MRIP data are not representative of any shad harvest in the Delaware Estuary and Bay.

The PFBC, in collaboration with the NPS - Upper Delaware Scenic & Recreational River (UPDE), jointly promoted a voluntary angler diary program (2001–2016) for reporting recreational angler catch (Lorantas and Myers 2003, 2005, 2007; Lorantas *et al*. 2004; Pierce and Myers 2007; Pierce and Myers 2014; NPS unpublished data). The diary program was considered unrepresentative of the Delaware River recreational shad fishery. Essentially, only the licensed guides by UPDE, routinely reported trip/catch information, who were more focused on the tailwater trout fishery than shad. Furthermore, in most years, no information was available from participating anglers in downriver reaches (RM 133–303) below the UPDE, where the recreational shad fishery is principally focused.

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

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

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

Recreational hooking mortality is assumed to be low in the Delaware River. A study by Millard *et al.* 2003 observed a 1.6% recreational hooking mortality of spawning American shad caught in the Hudson River after a five-day holding period. All mortality occurred for fish caught on or after May 6 when water temperatures increased to greater than 12^{o}C. No hooking mortality studies have been conducted in the Delaware River.

There is a critical need for routine comprehensive creel surveys characterizing the recreational American shad fishery in the Delaware River Basin. Potential future surveys need to focus principally on the non-tidal reaches. Since the MRIP program does not include non-tidal reaches, resulting data from that program poorly describes the Delaware River recreational shad fishery. Volstad e*t al.* (2003), represents the most recent comprehensive creel survey (i.e., 2002) accomplished in the non-tidal Delaware River reaches. This study was jointly supported by Co-op members, but funding was on an *ad hoc* basis. It is nearly 20 years out-of-date and likely does not represent present day shad angling behaviors. Alternative available creel data since Volstad *et al.* (2003) is of limited utility and inadequate to describe recreational use and harvest of American shad. Instead, anecdotal angler reports suggest the recreational shad

fishery persists principally as catch-and-release. Furthermore, the presumption tournament shad fishing is of minor consequence to the Delaware River shad population remains unsupported. The lack of reliable, routinely collected data on recreational use and harvest, precludes compilation of more robust stock assessments.

2.2.2.3 In-State Bycatch and Discards

There is little information on bycatch or discards of shad in any commercial fisheries within the Delaware Estuary; except in the Delaware Bay striped bass fishery, which is discussed in detail in Section 2.2.2.1.3. Otherwise, American shad has not been reported as bycatch from other commercial fisheries operating within the Delaware River Basin to either the States of New Jersey or Delaware. Neither state requires the reporting of discarded shad from any commercial fisheries within the Delaware River Basin; thus, no information is available.

2.3 Other Influences on Stock Abundance

In addition to harvest and natural mortality, other factors can also impact American shad populations. The Co-op has identified several such influences: (1) Delaware River flow management, (2) invasive species interactions, (3) potential effects from overfishing and ocean bycatch, (4) impacts of restoration stocking, (5) impingement and entrainment, and (6) habitat alteration.

2.3.1 Delaware River Flow Management

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

Flow management in the Delaware River Basin can have a direct impact on spawning success and juvenile survival of American shad as well as impact other aquatic species in the basin. A Flexible Flow Management Program (FFMP 2017) was developed to direct releases from the New York City reservoirs in the upper basin. The FFMP ensures that minimum releases occur at

each of the reservoirs, provides a mitigated step-down strategy when releases are directed to change dramatically to ensure areas of the river are not inadvertently dewatered, and also provides cold-water releases in the summer months to help protect the trout fishery in the upper basin. Releases from the hydroelectric facilities are also managed to support cold-water fisheries and help protect dewatering events in the respective tributaries as well as the main stem river. The Co-op will continue to work with the many different regulatory bodies in the Basin to ensure continued and improved water management strategies for American shad and other aquatic resources.

2.3.2 Invasive Species Interactions

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

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

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

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

2.3.3 Overfishing and Ocean Bycatch

Excessive losses to directed fishing and bycatch are often implicated as causative factors in fish stock declines. Directed commercial harvest occurs in spawning rivers on adults and until 2005,

in ocean waters. Recreational harvest of American shad generally occurs during spawning migrations. American shad taken while fishing for other species is called bycatch and it can occur in both rivers and the ocean.

Potential impacts of recent directed ocean harvest on American shad are more difficult to identify. Ocean harvest has been poorly quantified. Moreover, limited tagging data suggests that ocean harvest is made up of many Atlantic coast populations. Since the stock of origin is generally not known, it is very difficult to identify losses that are specific to the Delaware River stock. Some sense for relative losses on a coast-wide basis can be obtained from reported landings. The Delaware shad population appeared to decline most precipitously during the early 1990s. Mean annual harvest for states north of North Carolina during the first half of the 1990s was 1,148,893 lbs. per year from ocean waters and 413,510 lbs. from in river fisheries (ASMFC 2007). Reported annual ocean harvest of American shad from outside the 200 mile limit off of Mid-Atlantic and New England states was 310,000 lbs. (Northwest Atlantic Fisheries Organization http://www.nafo.int/about/frames/about.html catch statistics for ocean waters outside of the EEZ). Recent ASMFC shad assessments have drawn conflicting conclusions about impacts of this ocean harvest. ASMFC (1998) concluded that there was no evidence that the ocean harvest was affecting coast-wide stocks. ASMFC (2007) hypothesized that coastal harvest was affecting some stocks including that in the Delaware River. Amendment 1 to the Interstate Fishery Management Plan for Shad and River Herring (ASMFC 1999), began a phase-out of directed harvest of American shad in state coastal waters beginning in 2000. A total ban has been in effect by U.S. Atlantic coastal states since 2005.

2.3.3.1 Incidental Ocean Harvest

Quantification of the impact of bycatch and incidental fisheries on Delaware River American shad remains difficult. Two fishery management plans have identified alternatives to reduce catch of American shad in their Fishery Management Plans (FMP). The Mid Atlantic Fisheries Management Council's (MAFMC) Amendment 14 of the Atlantic Mackerel, Squid and Butterfish FMP (MAFMC 2014) and the New England Fishery Management Council's (NEFMC) Amendment 5 to the Atlantic Herring FMP (NEFMC 2014) both identified shad and river herring as incidental catch in these directed fisheries and acknowledged the need to minimize catch of shad and river herring. Both of these plans, through the amendments identified above and subsequent framework adjustments:

- Implemented more effective monitoring of river herring and shad catch at sea;
- Established catch caps for river herring and shad; and
- Identified catch triggers and closure areas.

The 2020 ASMFC Stock Assessment for American Shad (see section 4.1.4; ASMFC, 2020) provides a detailed assessment of incidental ocean catch following methods described in the most recent River Herring Stock Assessment (ASMFC 2017) which were developed for the FMPs

described above. The entire analysis is not presented here, but key results are summarized below:

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

2.3.4 Impacts of Restoration Stocking

The PFBC has been stocking otolith-marked American shad fry as part of their restoration program for the Delaware River Basin (Table 13). Eggs collected from Delaware River shad have been used in restoration efforts on other rivers, but since 2000, all Delaware River shad fry have been allocated to the Lehigh, and Schuylkill rivers. Occasionally, excess production was stocked back into the Delaware River at Smithfield Beach (2005 to 2008). Egg-take operations on the Delaware River have resulted in the use of an average of 741 adult shad brood fish per year (1996–2019). Eggs from these shad are fertilized and transported to the PFBC's Van Dyke Anadromous Research Station where they are hatched, otolith-marked and stocked in areas above dams where fish passage projects are in place.

The contribution of hatchery-reared fry to the returning population was estimated by interpretation of oxytetracycline daily tagging patterns within the otolith microstructure (Hendricks *et al*. 1991). The total hatchery contribution at Smithfield Beach was low ranging from 0.0 to 7.8% (Table 14), suggesting that hatchery-reared fry are not a significant component of the Smithfield Beach catch. The PFBC restoration program focuses shad fry stockings within the Lehigh and Schuylkill River main stems. Both the Lehigh River (RM 183) and Schuylkill River (RM 92) connect to the Delaware River main stem well downriver of Smithfield Beach (RM 218). Presumably hatchery-stocked shad are returning to their natal river of either tributary. The poor catches of marked shad at Smithfield Beach suggest straying is not a frequent occurrence.

Self-sustaining shad spawning runs in to the Lehigh and Schuylkill rivers originally envisioned (i.e., >100,000 fishes; PFBC 1988) have not materialized after 35 years of restoration efforts. It is the conclusion of PFBC that American shad passage into the Lehigh and Schuylkill rivers is insufficient and inadequate to achieve the original restoration goals. PFBC, in partnership with the Wildlands Conservancy and American Rivers/NOAA Community Grant Program, supported a feasibility study to investigate a suite of engineering options on the Lehigh River. Study findings suggested improvements of shad passage were best accomplished by full dam removal of the Easton and/or Chain dams (KCI Technologies Inc. 2013). To date, the owners have not expressed interest in pursuing dam removal. Yet without annual maintenance fry shad stockings, any future spawning runs into either tributary would most likely be nominal. The PFBC will continue annual shad fry stockings to maintain *status quo* of present-day spawning runs. Yet, Co-op members will continue to investigate alternatives for returning shad to historical spawning ranges.

2.3.5 Impingement and Entrainment

Power generating facilities, refineries, and other industries rely on withdrawal of surface water from the Delaware River and tributaries to cool their industrial processes, with most industrial water withdrawals requiring continuous once-through use of water. This withdrawal results in fish and other aquatic organisms either becoming trapped against the intake screens (impingement) or taken further into the cooling system (entrainment). Both impingement and entrainment can result in the death of fish and other organisms. When fish spawn in spring and early summer in the Delaware River, the resulting eggs and larvae are vulnerable to entrainment; as fish grow larger during the balance of the year, they become susceptible to impingement. Therefore, losses to impingement and entrainment are ongoing throughout the calendar year.

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

2.3.6 Habitat Alteration

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

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

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

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

3. Sustainable Fishery Benchmarks and Management Actions

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

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

3.1 Benchmarks

3.1.1 Female Total Mortality

One of the objectives of Amendment 3 to the Interstate Fishery Management Plan for Shad and River Herring (ASMFC 2010) is to maintain total mortality of stocks at or below stock

assessment benchmarks. The female total mortality Z_{40} benchmark developed for the Delaware River in the 2020 assessment is 1.07 (ASMFC 2020). The three-year average female Z estimate from otoliths in 2017 (1.3) was above the benchmark (1.07), therefore; mortality was determined to be unsustainable. Due to data limitations in 2018, the current three-year average Z is unavailable for this update, however; annual Z estimates since the completion of the assessment indicate a continued need to reduce mortality (Table 15, Figure 12).

3.1.2 Non-tidal JAI index

This JAI is based on annual catch data standardized by environmental covariates using GLM methodology. Only data originating from Phillipsburg, Delaware Water Gap, and Milford Beach are included in the JAI. The benchmark was based on data from years 1988-2019 (Table 16, Figure 27). Failure is defined as the occurrence of three out of five years where JAI values are below the 50th percentile from the reference period (188). Exceeding the benchmark will trigger management action. The period of 1988 to 2019 was selected as these years encompass the years when sampling methodology was consistently applied to all sampling stations included in the JAI calculations; however, no sampling occurred at any non-tidal station between 2008 and 2011 and in 2018. The non-tidal JAI fell below the benchmark most recently between 2013 and 2016.

3.1.3 Tidal JAI index

This JAI is based on annual geometric means of the catch data from stations near Trenton to Delaware Memorial Bridge. The benchmark was based on data from years 1987-2019 (Table 17, Figure 28). Failure is defined as the occurrence of three out of five years where JAI values are below the 50th percentile of the reference period (5.81). Exceeding the benchmark will trigger management action. The period of 1987 to 2019 was selected as these encompass the years when sampling methodology was consistent among stations. The tidal JAI fell below the benchmark most recently in 2012, 2016, and 2019.

3.1.4 Smithfield Beach CPUE Index

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

3.1.5 Ratio of Commercial Harvest to Smithfield Beach Relative Abundance Index

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

3.1.6 Mixed Stock Landings

This index is defined as the total pounds landed from the mixed stock, which consists of 50% of combined commercial landings from Delaware and New Jersey. The index was based on data from 1985-2019 (Table 20, Figure 31). The benchmark is defined as the 25th percentile of the time-series where 75% of values are higher. Failure is defined as the occurrence of 2 consecutive years above a value of 18,505 pounds. Exceeding the benchmark will trigger management action. This index provides additional harvest protections for American shad stocks with origins outside of the Delaware River, some of which have closed commercial fisheries. The pounds landed on the mixed stock has exceeded the benchmark most recently in 2013 and 2014.

3.2 Benchmark Summary

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

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

3.3 Management Actions

There are many restrictions already in place for the commercial fishery that limit participation. These include limited entry, seasons, and gear restrictions throughout the Delaware Bay. During the implementation of the 2017 SFP, indices for the fishery benchmarks were not exceeded for the specified time periods, therefore no management action was taken in response to benchmark exceedance in the 2017 SFP. In response to the mortality benchmark exceedance as identified in the 2020 Stock Assessment, the Co-op will be implementing measures to reduce landings in both the commercial and recreational fisheries.

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

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

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

Commercial Fishery:

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

Recreational Fishery:

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

4. Proposed Time Frame for Implementation

The Co-op proposes that this plan be re-evaluated on a five-year cycle. The tenure for the 2022 SFP is expected to cover the period 2022 through 2026. Thereafter the next planned update should be initiated in 2025. All datasets, with the exception of the mortality benchmark, will be updated annually for assessing the exceeding of any benchmarks requiring immediate management action.

The Co-op views the 2022 SFP as a working document. Over the tenure of the 2022 SFP, Co-op members will continue investigations of recommended actions herein and/or as new opportunities become available. Petitions arising to ASMFC for updating the 2022 SFP may be initiated prior 2025.

5. Future Monitoring Programs

5.1 Fishery Independent

5.1.1 Juvenile Abundance Indices

The tidal beach seine program conducted by NJDFW will continue indefinitely, given its importance to their striped bass monitoring requirements.

The non-tidal seine program will continue through a collaborative effort during the duration of this SFP (2022-2026). The index will be generated from catches from Phillipsburg, Water Gap, and Milford. The inclusion of Trenton and the upper freshwater sites in the East Branch to the index will be reevaluated for the next SFP update. The continuance of this program is dependent on the collaboration among Co-op members ability to commit personnel resources without dedicated budgeted funding.

5.1.2 Adult Stock Monitoring

Spawning stock
The PFBC will continue to fully support the fishery independent survey at Smithfield Beach (gill net survey) for the next five years (2022-2026). The objective is to obtain biological data on the spawning stock as well as an index of relative abundance. Additionally, all caught shad will be strip spawned in support of the PFBC American shad restoration program for the Lehigh and Schuylkill rivers.

Hatchery evaluation
Otoliths of all hatchery-reared American shad larvae stocked by PFBC into the Delaware River Basin are marked with oxytetracycline to distinguish hatchery-reared shad from wild, naturally-produced shad (Hendricks *et al*. 1991). Since 1987, larvae were marked with unique tagging patterns accomplished by multiple marks produced by immersions 3 or 4 days apart. Determinations of origin are interpreted from the presence of florescent tagging patterns in the otolith microstructure. Hatchery contribution is determined for specimens collected in the Schuylkill and Lehigh rivers above the first dam and in the Delaware River at Smithfield Beach. The proportion of hatchery fish present in juvenile or adult population will continue to be monitored as per ASMFC Amendment 3.

5.2 Fishery Dependent

5.2.1 Commercial Fishery

The States of Delaware and New Jersey will conduct fishery dependent surveys as required by ASMFC Amendment 3. Landings will be reported monthly to allow for timely tracking of harvest each year.

5.2.2 Recreational Fishery

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

6. Fishery Management Program

6.1 Commercial Fishery

Delaware: The State of Delaware has no regulations that have been specifically adopted to reduce or restrict the landings of American shad in the Delaware Estuary. However, there will be a monofilament size restriction for anchored gillnets and a landings cap to be implemented

by the 2023 fishing season and there are general regulations that apply to the commercial fishery that limit commercial fishing. Existing regulations affecting the striped bass fishery will remain the same, such as limited entry, limitations on the amount of gear and annual mandatory commercial catch reports. Area and gear restrictions, with the inclusion of the increased monofilament diameter with this SFP, will otherwise remain unchanged (see Section 2.2.2.1.3).

New Jersey: New Jersey waters are open to gill netting for the majority of the year but the current directed commercial fishery for American shad occurs primarily during March through April of each year depending on environmental conditions. New Jersey regulations are listed in Table 1. Limited entry is in place; permits are not gear specific. All permits are currently non-transferable except to immediate family members. New Jersey will be implementing a quota for commercial American shad landings during the implementation of this SFP that will be effective for the 2023 fishing season.

Pennsylvania and New York: Both Pennsylvania and New York do not permit the commercial harvest of American shad within the Delaware River Basin.

6.2 Recreational Fishery

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

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

The Lehigh and Schuylkill rivers represent the two largest tributaries to the Delaware River, draining 3,529.7 km^2 and 4,951.2 km^2, respectively. Both of these tributaries in their entirety are contained within Pennsylvania. Beginning January 1, 2013, regulations were modified to reflect recreational catch and release only and prohibited commercial harvest of American shad.

6.3 Bycatch and Discards

New Jersey and Delaware do not require mandatory reporting of bycatch and discards in their commercial fisheries. In the recreational fishery many anglers are practicing catch-and-release,

there are no plans to regulate this other than with possession limits which are already in place or are planned to be implemented.

7. Data Needs for the Delaware River American Shad Population

To some extent American shad remain an enigma for the Delaware River Basin as well as coast-wide. While current knowledge has provided insight into the returning adult spawning run, YOY production and recreational/commercial exploitation, we essentially have a very limited knowledge of landscape-scale and temporal variation of shad within the Basin similar to other basins along the Atlantic Coast.

To conduct a data rich stock assessment for American shad in the Delaware River Basin, additional data needs for improved stock assessment are described in the 2020 ASMFC American shad Stock Assessment (ASMFC 2020) and items specific to the Delaware River Basin listed in this section.

7.1 Conducting a Basin-wide Creel Survey

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

7.2 Determining Proportion of Mixed Stock Fishery

Tagging and genetics studies have indicated that some portion of the American shad captured in the Delaware Bay are spawning stock from other Atlantic Coast Rivers. Additional robust genetic or tagging studies within the entire expanse of the Bay will better evaluate the extent of mixed stock circulation in the Basin. In addition, better reporting of capture location for the Delaware River/Bay commercial harvest occurs is necessary to better characterize the impact of the fishery on the Delaware River stock as well as stock of other Atlantic Coast rivers.

7.3 Improving Ageing Techniques

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

7.4 Adding Fishery-Independent Monitoring Programs

Reliance of characterizing the adult shad spawning run singularly upon Smithfield Beach as representative of the entire Delaware River Basin is a poor assumption. Sampling on a larger geographic scale is needed to better characterize the variation of spawning adult population in the Basin. Returning spawning adult shad appear to be utilizing the upper Delaware Estuary reaches as spawning grounds, as water quality continues to improve. Without an adult monitoring program in the upper Delaware Estuary, validation of the tidal JAI will remain intangible.

7.5 Characterizing Loss from Non-traditional Fishery Harvest sources

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

8. Literature Cited

ASMFC (Atlantic States Marine Fisheries Commission). 1998. American Shad Stock Assessment. ASMFC, Peer Review Report, Washington, D.C.

ASMFC (Atlantic States Marine Fisheries Commission). 1999. Amendment 1 to the River Herring FMP. Washington, D.C.

ASMFC (Atlantic States Marine Fisheries Commission). 2007. American Shad stock assessment report for peer review. Washington, D.C.

ASMFC (Atlantic States Marine Fisheries Commission). 2010. Amendment 3 to the Interstate Fishery Management Plan for Shad and River Herring (American Shad Management). Atlantic States Marine Fisheries Commission Shad and River Herring Plan Development Team. 158p.

ASMFC (Atlantic States Marine Fisheries Commission). 2012. River Herring Benchmark Stock Assessment, Volume 1. Stock Assessment Report No. 12-02. Arlington, VA, USA.

ASMFC (Atlantic States Marine Fisheries Commission). 2017. River Herring Assessment Update, Volume 1. Arlington, VA, USA.

ASMFC (Atlantic States Marine Fisheries Commission). 2020. American Shad 2020 Stock Assessment Report. Arlington, VA, USA.

Delaware River Basin Fish and Wildlife Management Cooperative (DRBFWMC). 2011. Delaware River sustainable fishing plan for American Shad. Approved by the Atlantic States Marine Fisheries Commission Shad and River Herring Board in February 2012. 67 p.

Delaware River Basin Fish and Wildlife Management Cooperative (DRBFWMC). 2021. American shad habitat plan for the Delaware River. Submitted to the Atlantic States Marine Fisheries Commission as a requirement of Amendment 3 to the Interstate Management Plan for Shad and River Herring, January 7, 2021. 35 pp.

DeSalvo, L. L., M. DeLucia, E. H. Martin, and D. H. Keller. 2022. Delaware River Basin Restoration Roadmap for American Shad, Alewife, and Blueback Herring. The Nature Conservancy's final report to National Fish and Wildlife Foundation (Grant No.: 65162). The Nature Conservancy, Harrisburg, Pennsylvania.

Flexible Flow Management Program (FFMP). 2017, Agreement for a Flexible Flow Management Program signed by the parties to the Amended Decree of the U.S.

Supreme Court in New Jersey v. New York, 347 U.S. 995 (1954). https://dev-webapps.usgs.gov/odrm/home/ffmp/FFMP2017.pdf, last accessed September 23, 2021.

Gibson, M.R., V.A. Crecco, and D.L. Stang. 1988. Stock assessment of American Shad from selected Atlantic coastal rivers. Atlantic States Marine Fisheries Commission, Special Report 15, Washington, D.C.

Hendricks, M.L., T.R. Bender, Jr. and V.A. Mudrak. 1991. Multiple marking of American Shad otoliths with tetracycline antibiotics. North American Journal of Fisheries Management 11:212-219.

Hoopes, R. L., R. A. Lahr, C. W. Billingsley. 1983. Angler use and fish harvest from the upper Delaware River during 1982. Pennsylvania Fish & Boat Commission. 450 Robinson Lane, Bellefonte, PA 18623.

Isel, M. W., and J. S. Odenkirk. 2019. Evaluation of northern snakehead diets in Virginia's tidal rivers and lakes. Pages 83–93 in J. S. Odenkirk and D. C. Chapman, editors. Proceedings of the first international snakehead symposium. American Fisheries Society, Symposium 89, Bethesda, Maryland.

KCI Technologies. 2013. Lehigh River Fish Passage Improvement Feasibility Study. (http://www.fishandboat.com/Fish/Fisheries/Documents/LehighFishPassageFeasibility.pdf)

Lorantas, R. M. and J. L. Myers. 2003. Delaware River and Estuary Angler Log 2001 Summary. Pennsylvania Fish & Boat Commission, 450 Robinson Lane, Bellefonte, PA 18623.

Lorantas, R. M., D. P. Kristine, J. L. Myers. 2004. Delaware River and Estuary Angler Log 2004. Pennsylvania Fish & Boat Commission, 450 Robinson Lane, Bellefonte, PA 18623.

Lorantas, R. M. and J. L. Myers. 2005. Delaware River and Estuary Angler Log 2003. Pennsylvania Fish & Boat Commission, 450 Robinson Lane, Bellefonte, PA 18623.

Lorantas, R. M. and J. L. Myers. 2007. Delaware River and Estuary Angler Log 2004. Pennsylvania Fish & Boat Commission, 450 Robinson Lane, Bellefonte, PA 18623.

Lupine, A.J., J. Buchanan, J. Gall and C. Weilandics, 1980. Delaware River Fisheries Research Project F-38-R-2. 1980 Delaware River American Shad Population Estimate. NJDFW Miscellaneous Report No. 43.

Lupine, A.J., C. Weilandics, and J. Gall. 1981. Delaware River Fisheries Research Project F-38-R-3. 1981 Delaware River American Shad Population Estimate. NJDFW Miscellaneous Report No. 45.

Marshall, R. W., 1971. Shad creel census. Unpublished Data. Pennsylvania Fish & Boat Commission, 450 Robinson Lane, Bellefonte, PA 18623.

Mid-Atlantic Fishery Management Council (MAFMC). 2014. Fisheries of the Northeastern United States; Atlantic Mackerel, Squid, and Butterfish Fisheries; Amendment 14. 79 Fed. Reg. 10029 (February 24, 2014) 50 CFR Part 648.

Millard, M.J., J. Mohler, A. Kahnle, K. Hattala, W. Keller, and A. Cosman. 2003. Mortality associated with catch and release angling of Striped Bass and American Shad in the Hudson River. Final Report. 48p.

Miller, J.P. New Jersey Division of Fish and A.J. Lupine. 1987. Angler utilization and economic survey of the American Shad fishery in the Wildlife. 1993. Delaware River. Fisheries Research Project F-48-R-7, Job I-1, Delaware River American Shad Fishermen's Association. Hellertown, PA. 26p.

Miller, A. and A. Lupine. 1996. Creel survey New Jersey Division of the Fish and Wildlife. 2001. Delaware River American Shad recreational fishery. Shad Angler Logbook Survey. 2000 Survey Data with the Delaware River Shad Fishermen's Association. Hellertown, PA. 32p.

New England Fishery Management Council (NEFMC). 2014. Fisheries of the Northeastern United States; Atlantic Herring Fishery; Amendment 5. 79 Fed. Reg. 8786 (February 13, 2014) 50 CFR Part 648.

New Jersey Division of Fish and Wildlife. 1993. Delaware River Fisheries Research Project F-48-R-7, Job I-1, Delaware River American Shad Population Estimate.

New Jersey Division of Fish and Wildlife. 2001. Delaware River American Shad Angler Logbook Survey. 2000 Survey Data with the Delaware River Shad Fishermen's Association.

PDE (Partnership for the Delaware Estuary). 2017. Technical Report for the Delaware Estuary and Basin 2017. L. Haaf, S. Demberger, D. Kreeger, and E. Baumbach (eds). PDE Report No. 17-07. 379 pages.

PFBC (Pennsylvania Fish and Boat Commission) 1988. Strategic Fishery Management Plan for American Shad Restoration in the Schuylkill and Lehigh river basins. Pennsylvania Fish & Boat Commission, 450 Robinson Lane, Bellefonte, PA 18623.

Pierce, D.J. and J.L. Myers. 2007. Delaware River and Estuary Angler Log 2005 & 2006. Pennsylvania Fish & Boat Commission, 450 Robinson Lane, Bellefonte, PA 18623.

Pierce, D.J. and J.L. Myers. 2014. Delaware River and Estuary Angler Log 2007 through 2011. Pennsylvania Fish & Boat Commission, 450 Robinson Lane, Bellefonte, PA 18623.

Pine, W.E., III, T.J. Kwak, D.S. Waters, and J.A. Rice. 2005. Diet selectivity of introduced flathead catfish in coastal rivers. Transactions of the American Fisheries Society 134:901-909.

Schmitt, J.D., E. M. Hallerman, A. Bunch, Z. Moran, J.A. Emmel and D.J. Orth. 2017. Predation and prey selectivity by nonnative catfish on migrating Alosines in an Atlantic slope estuary. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 9:108-125.

Smith, M.W, A.Y Then, C. Wor, G. Ralph, K.H. Pollock and J.M Hoenig. 2012 Recommendations for Catch-Curve Analysis. North American Journal of Fisheries Management. 32:5, 956-967.

Volstad, J.H., W. Richkus, J. Miller, A. Lupine, and J. Dew. 2003. The Delaware River Creel Survey 2002. Pennsylvania Fish and Boat Commission, Versar Inc. Columbia, Maryland.

Waldman, J., D. Hasselman, P. Bentzen, M. Dadswell, L. Maceda and I. Wirgin. 2014. Genetic mixed-stock analysis of American Shad in two Atlantic Coast fisheries: Delaware Bay, USA, and Inner Bay of Fundy, Canada. North American Journal of Fisheries Management, 34:6, 1190-1198, DOI: 10.1080/02755947.2014.954067.

9. Figures

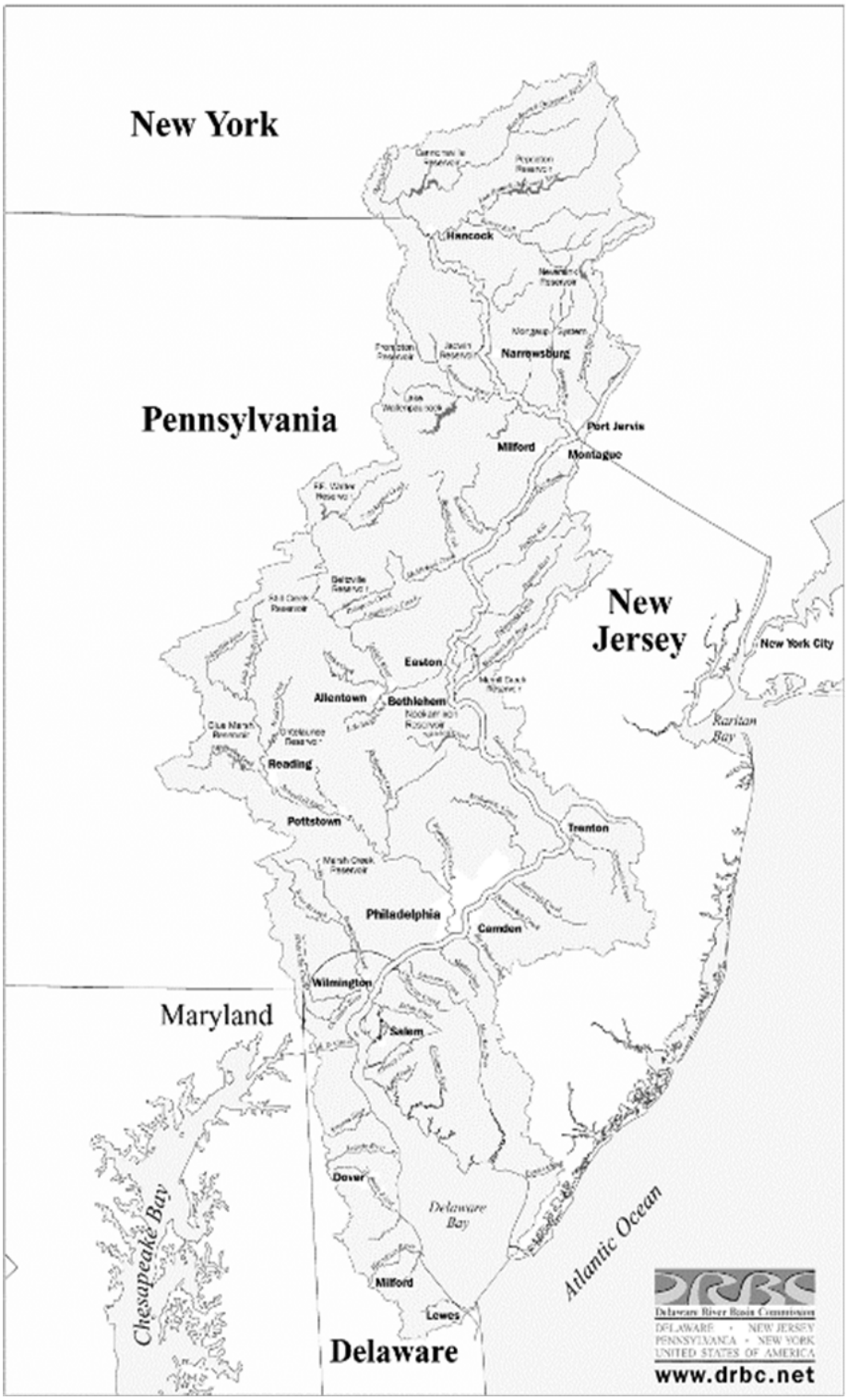

Figure 1. The Delaware River watershed.

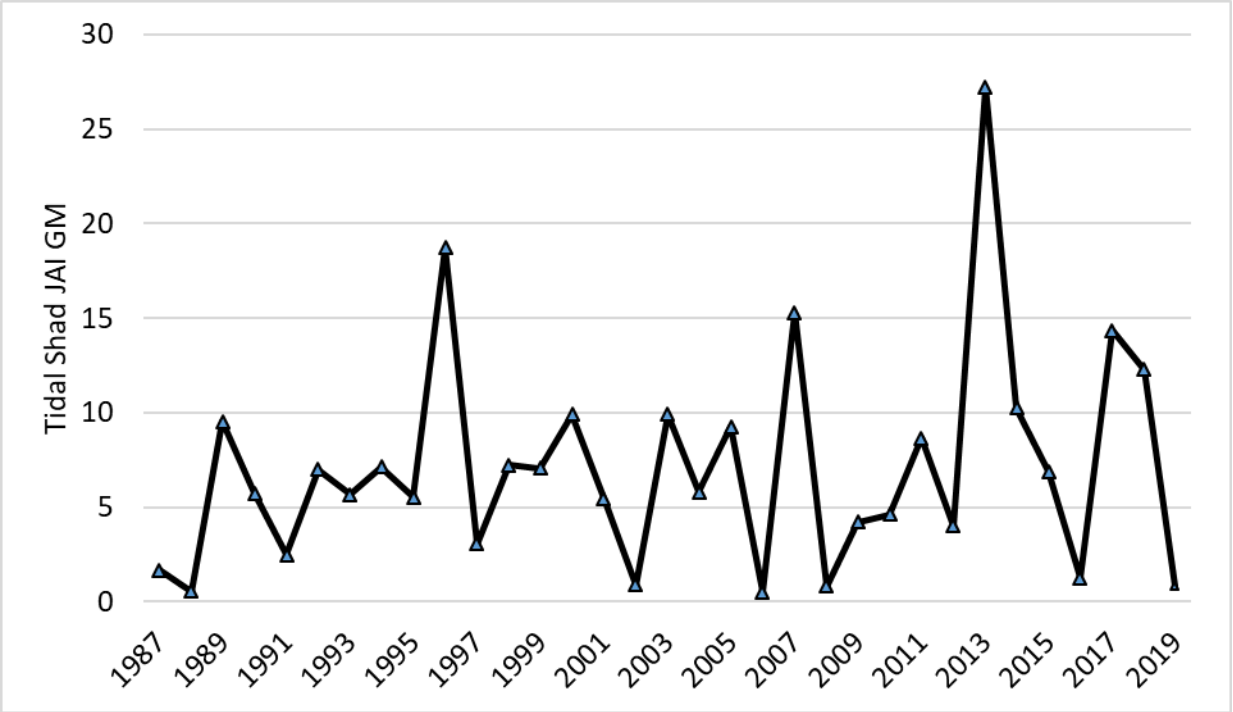

Figure 2. The geometric mean of the juvenile abundance index (JAI) for American shad in the tidal Delaware River.

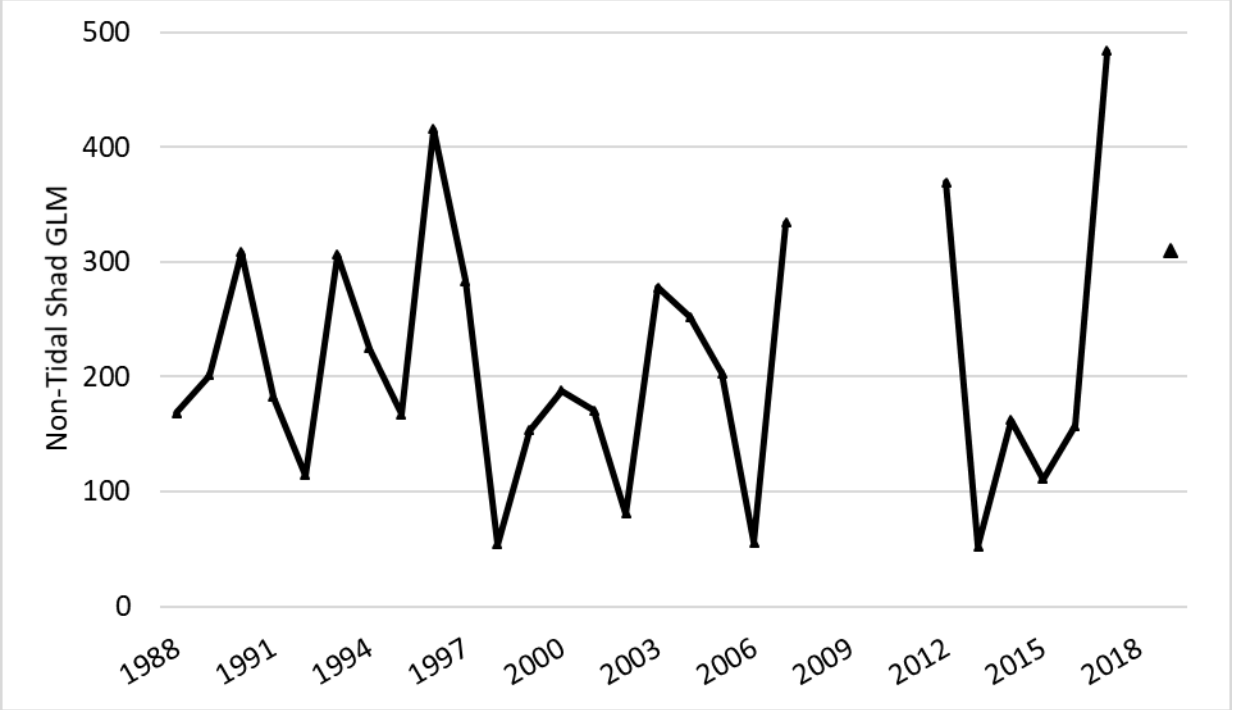

Figure 3. The generalized linear model of the juvenile abundance index (JAI) for American shad in the non-tidal Delaware River at Phillipsburg, Delaware Water Gap, and Milford.

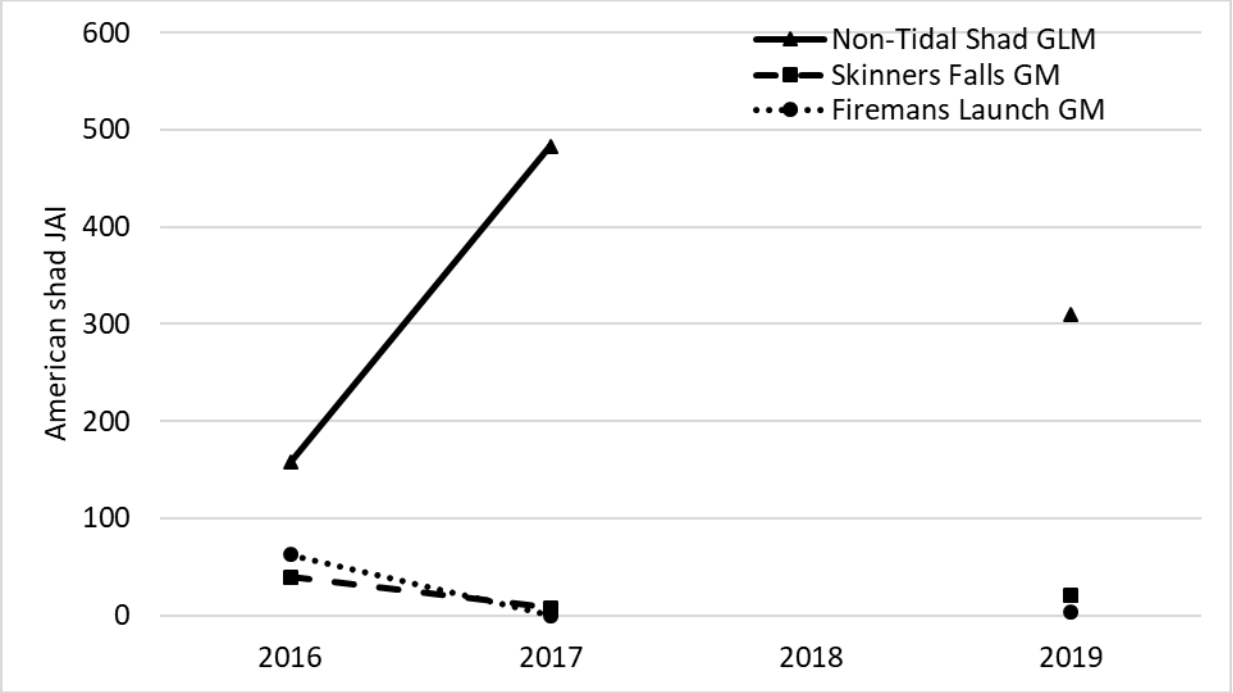

Figure 4. Non-Tidal American shad JAI for the Upper Delaware River (geometric means for Skinner's Falls and Fireman's Launch) compared to the Big 3 sites (generalized linear model for Phillipsburg, Water Gap, Milford).

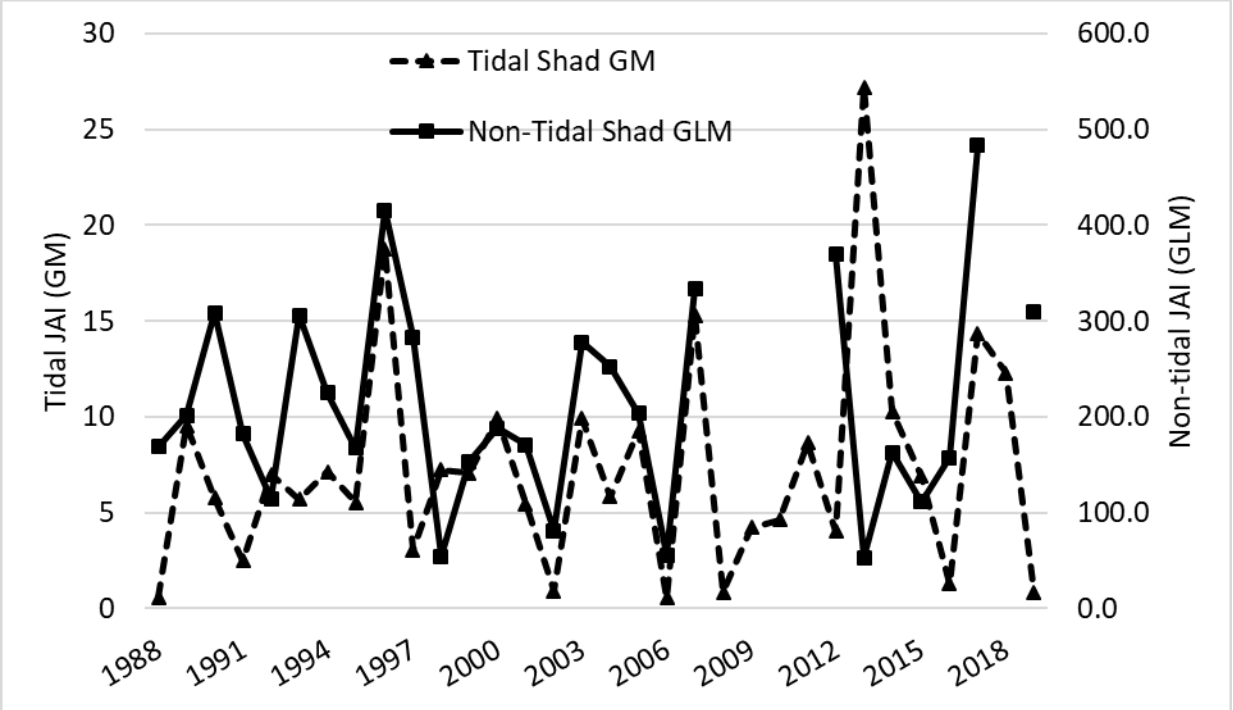

Figure 5. Comparison of the tidal to non-tidal JAI indices for American shad. Note there was no non-tidal sampling from 2008-2011 and 2018.

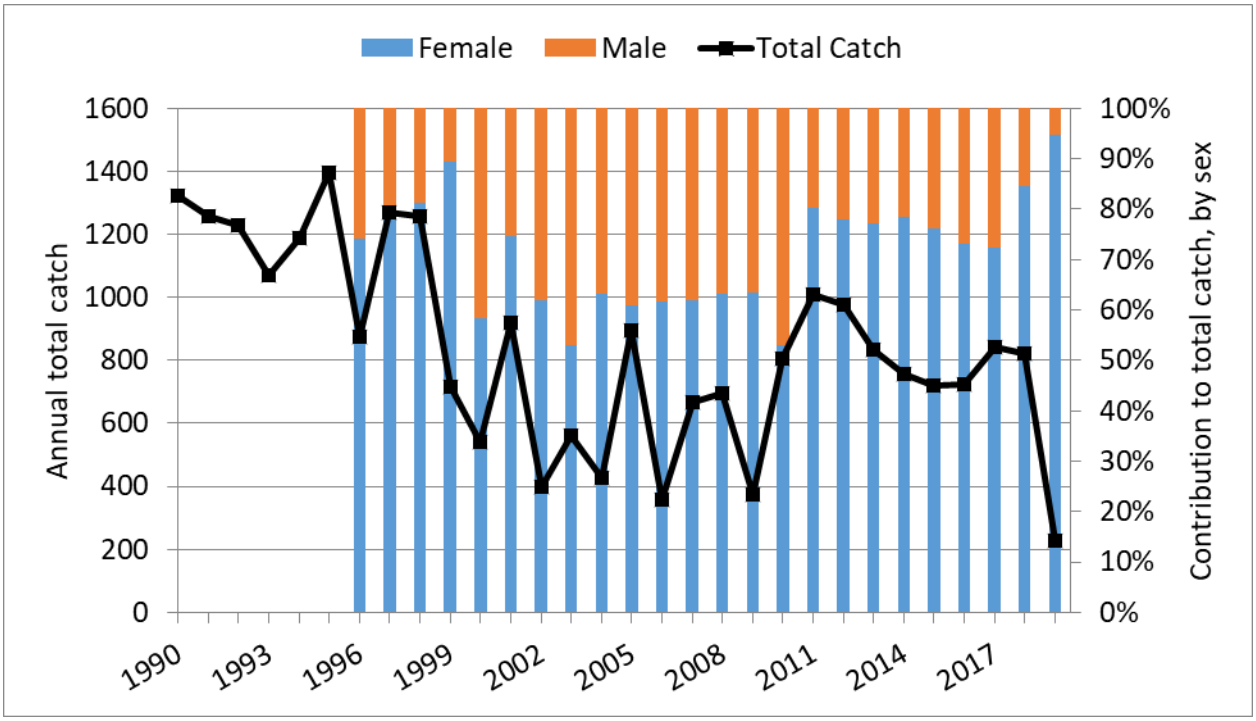

Figure 6. Total catch of American Shad at Smithfield Beach (RM 218), by sex. No biological data were recorded prior to 1996.

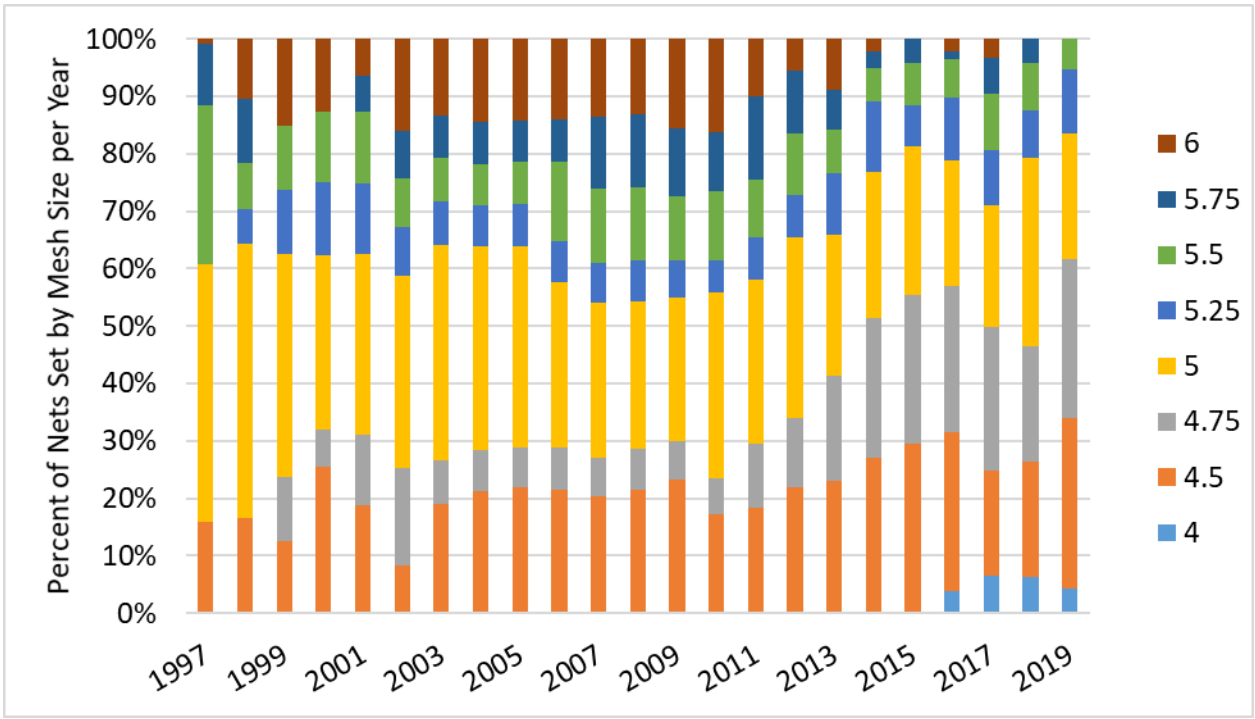

Figure 7. Frequency of gill net stretch mesh sizes deployed for brood stock and monitoring efforts at Smithfield Beach (RM 218).

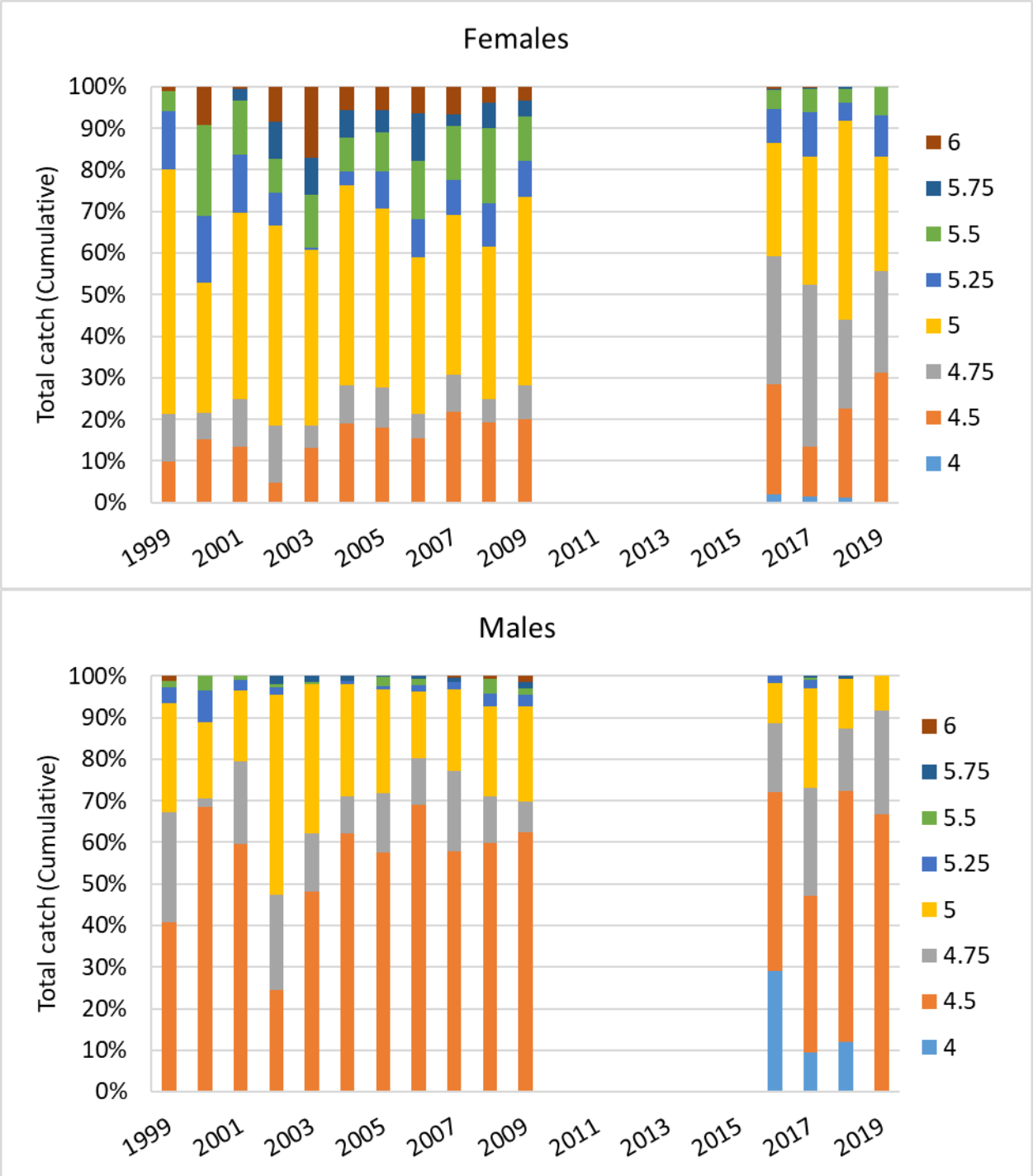

Figure 8. Percent of annual total catch of shad at Smithfield Beach (RM 218) by stretch mesh size (inch) deployed. Catch was not reported by mesh size prior to 1999 and 2010 through 2015.

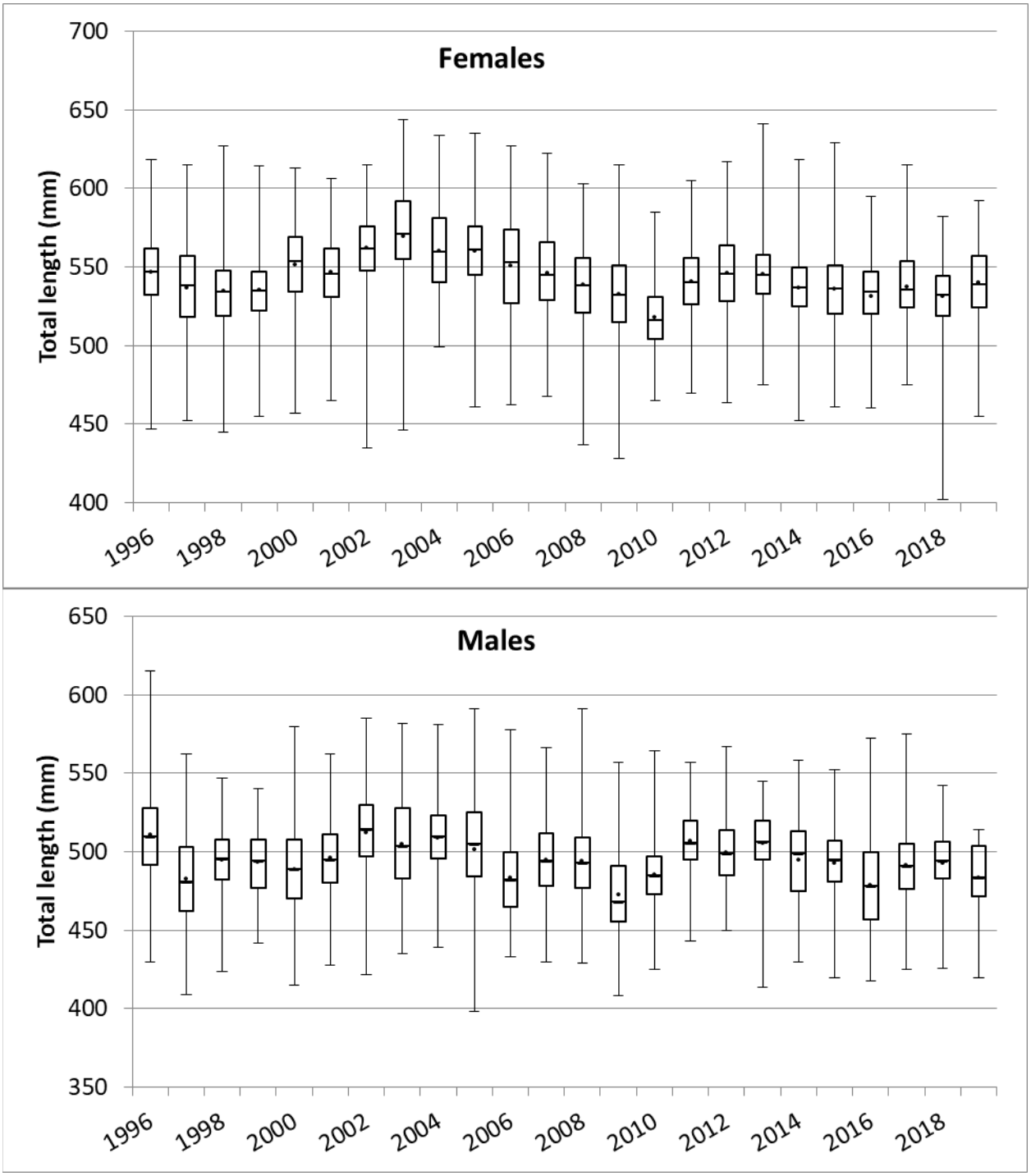

Figure 9. Size distribution of captured American shad at Smithfield Beach (RM 218). The boxes represent the 25 and 75th quartiles, with the whiskers extending to the 10th and 90th percentiles. Median (solid horizontal line) and average (asterisk) are also illustrated.

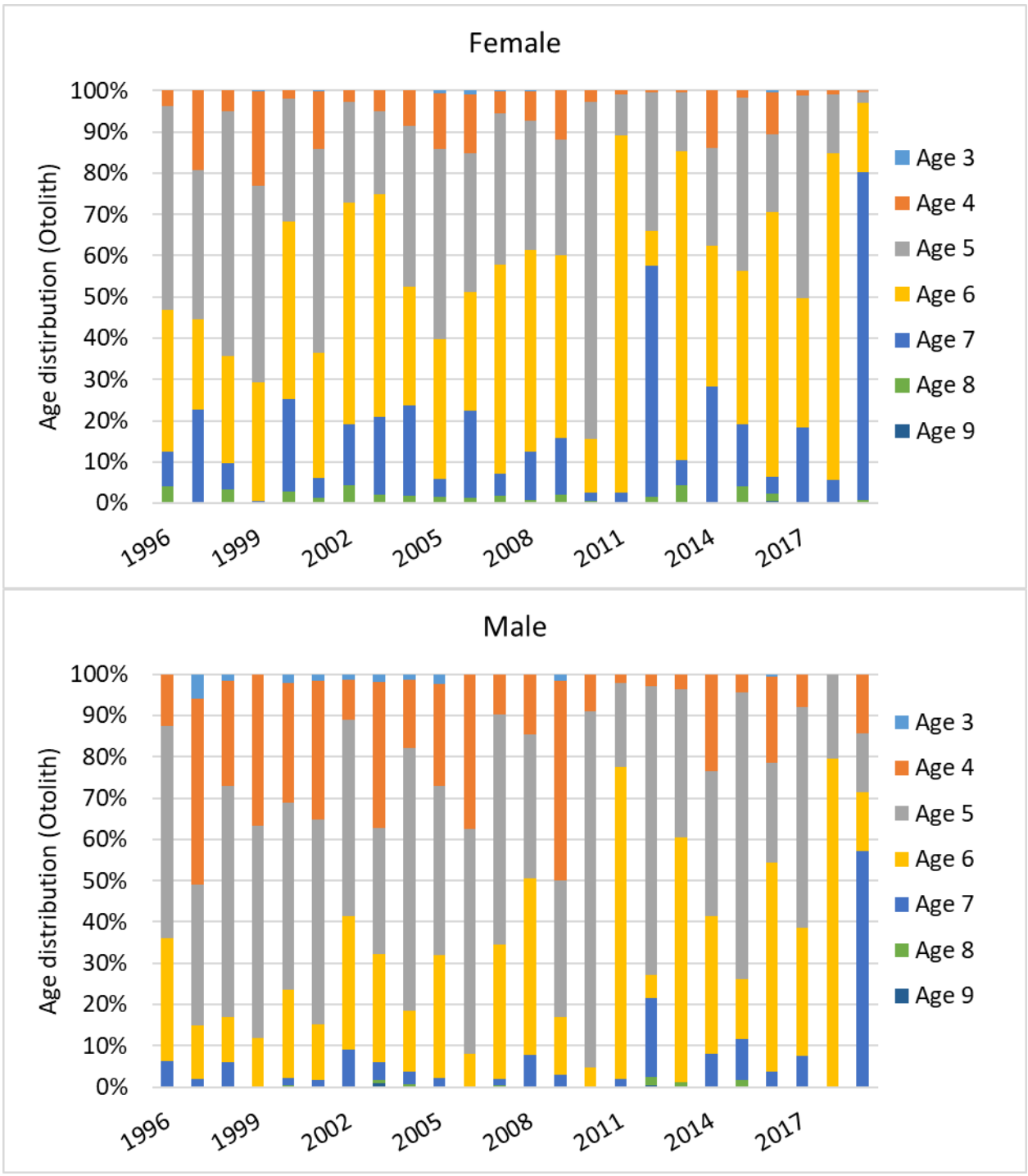

Figure 10. Age distribution by sex for American shad captured at Smithfield Beach as interpreted from otolith microstructures.

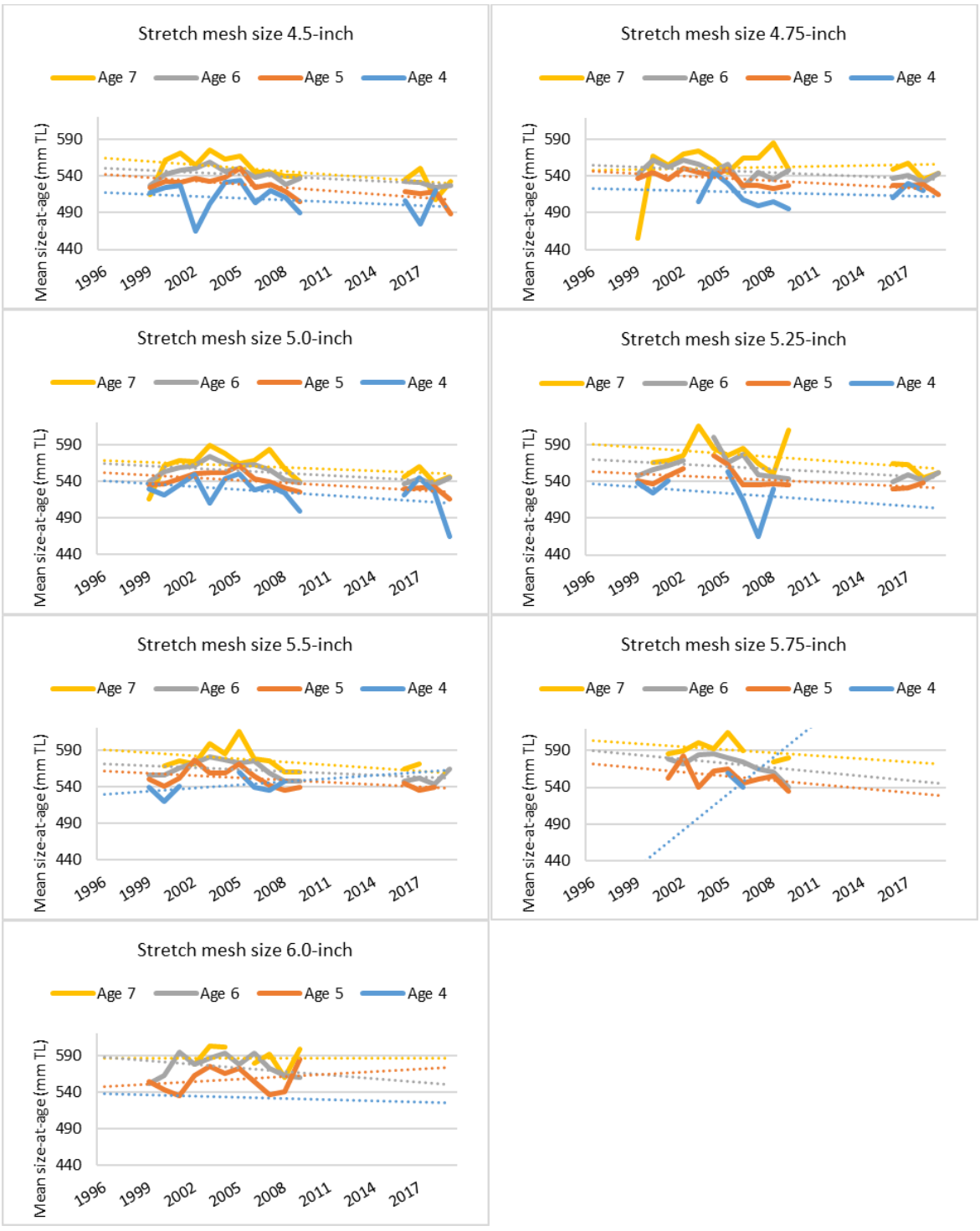

Figure 11. Mean size-at-age (mm TL) for female American Shad collected from Smithfield Beach, by stretch mesh size of capture. Trend lines, as linear least-squares regressions are depicted as dotted lines, for each respective age-class.

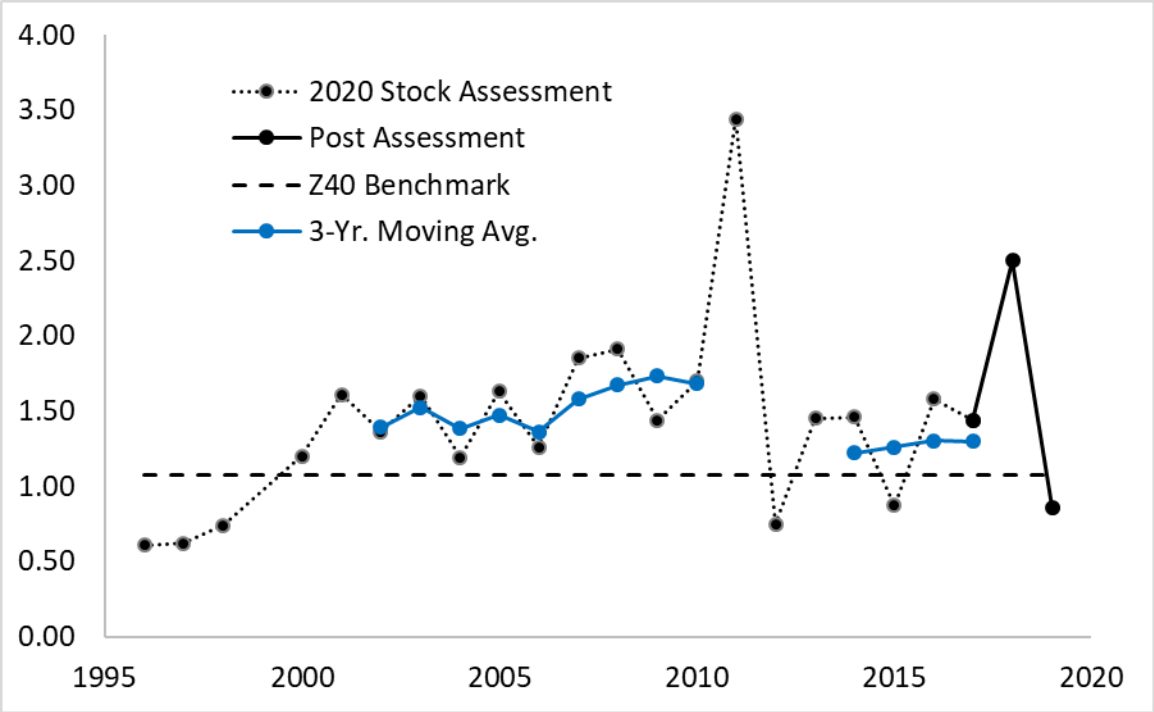

Figure 12. Female American shad total mortality for the Delaware River population.

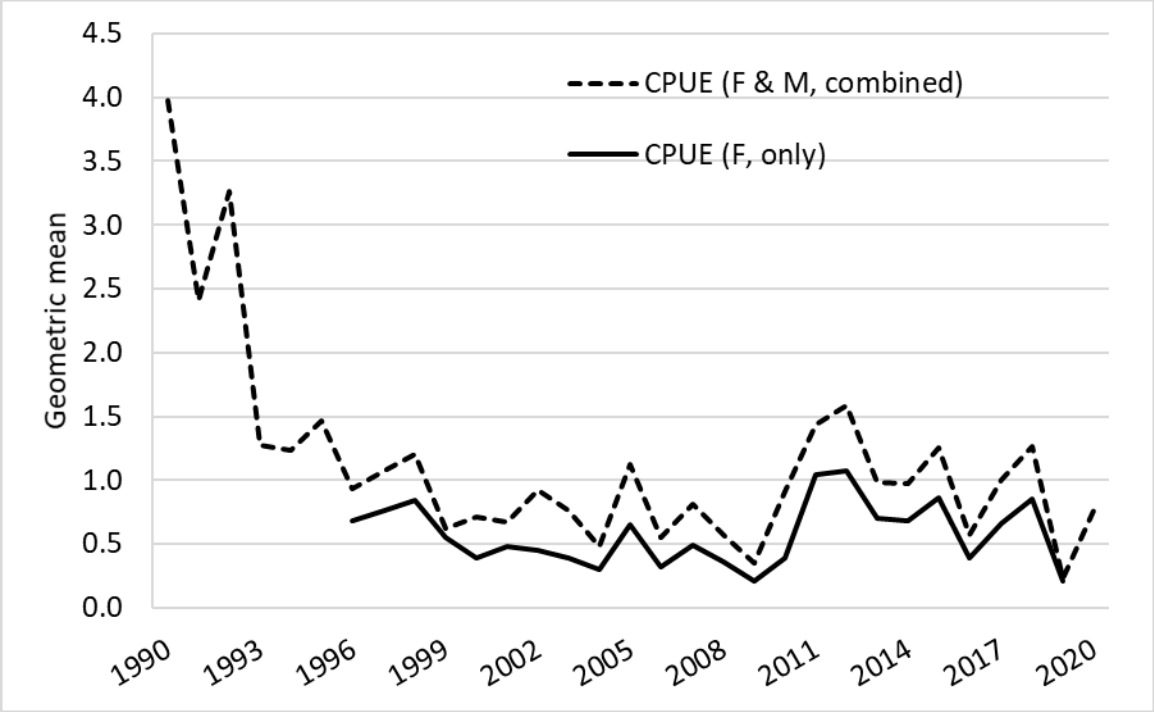

Figure 13. Time-series relative abundance (CPUE) for spawning adult catches at Smithfield Beach (RM 218).

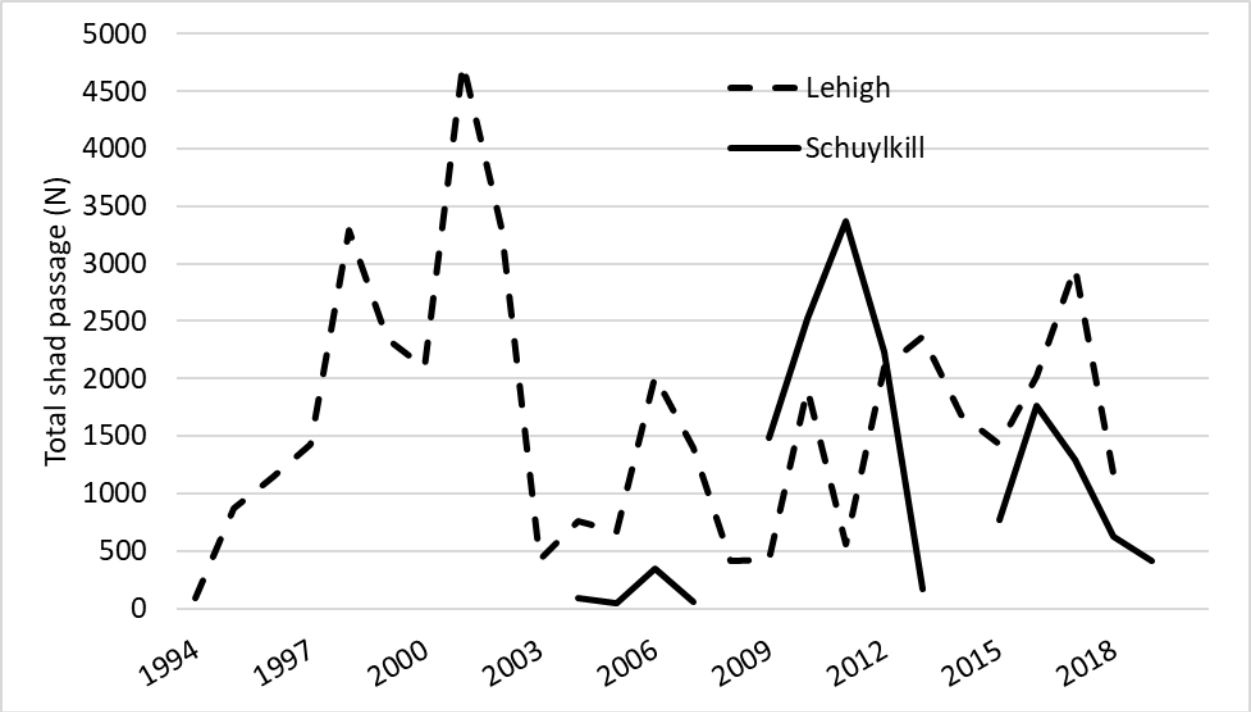

Figure 14. American shad passage in the Schuylkill and Lehigh Rivers.

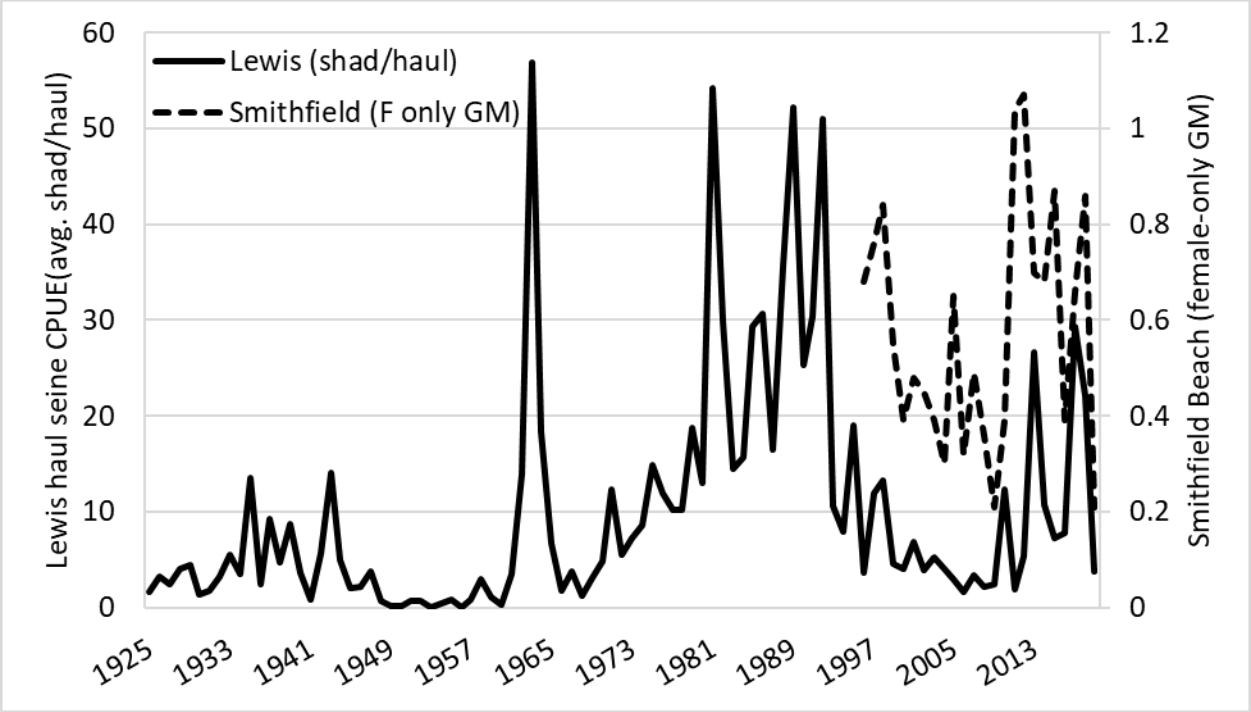

Figure 15. Lewis haul seine CPUE (avg. shad/haul) and Smithfield Beach (female-only geometric mean) indices of relative abundance.

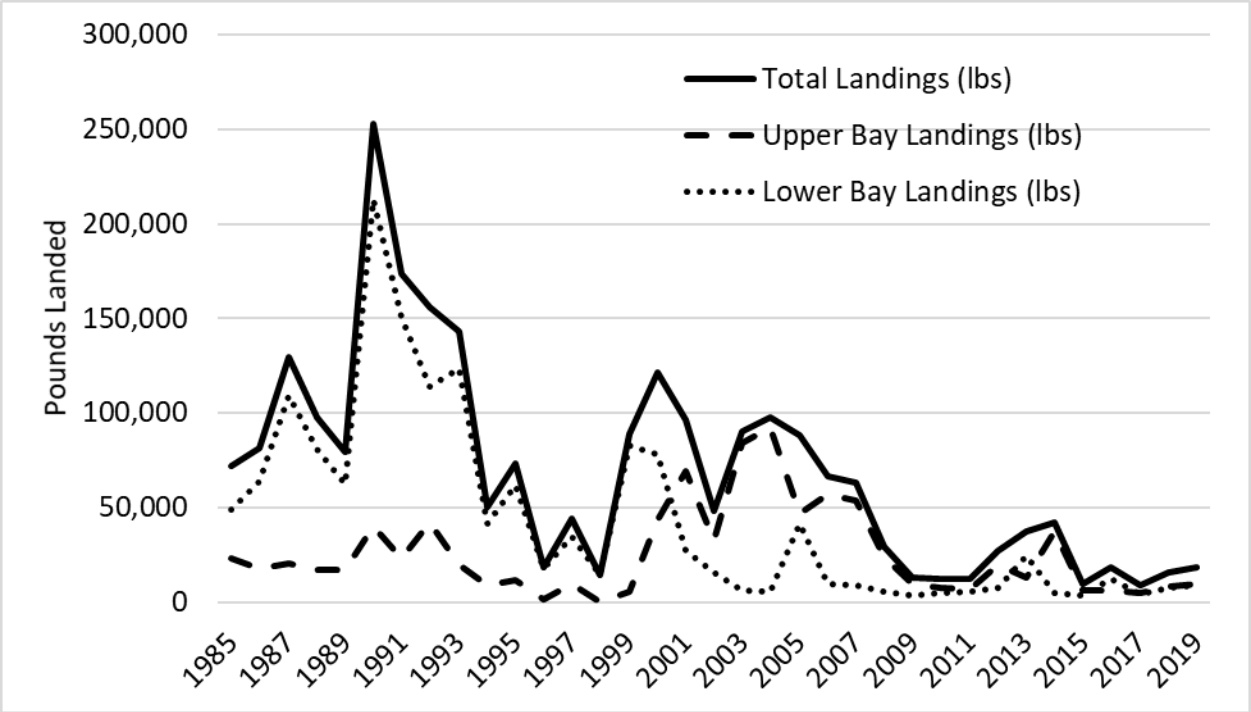

Figure 16. Commercial landings in the state of New Jersey. Upper and lower bay landings are delineated by harvest occurring north and south of Gandys Beach, NJ.

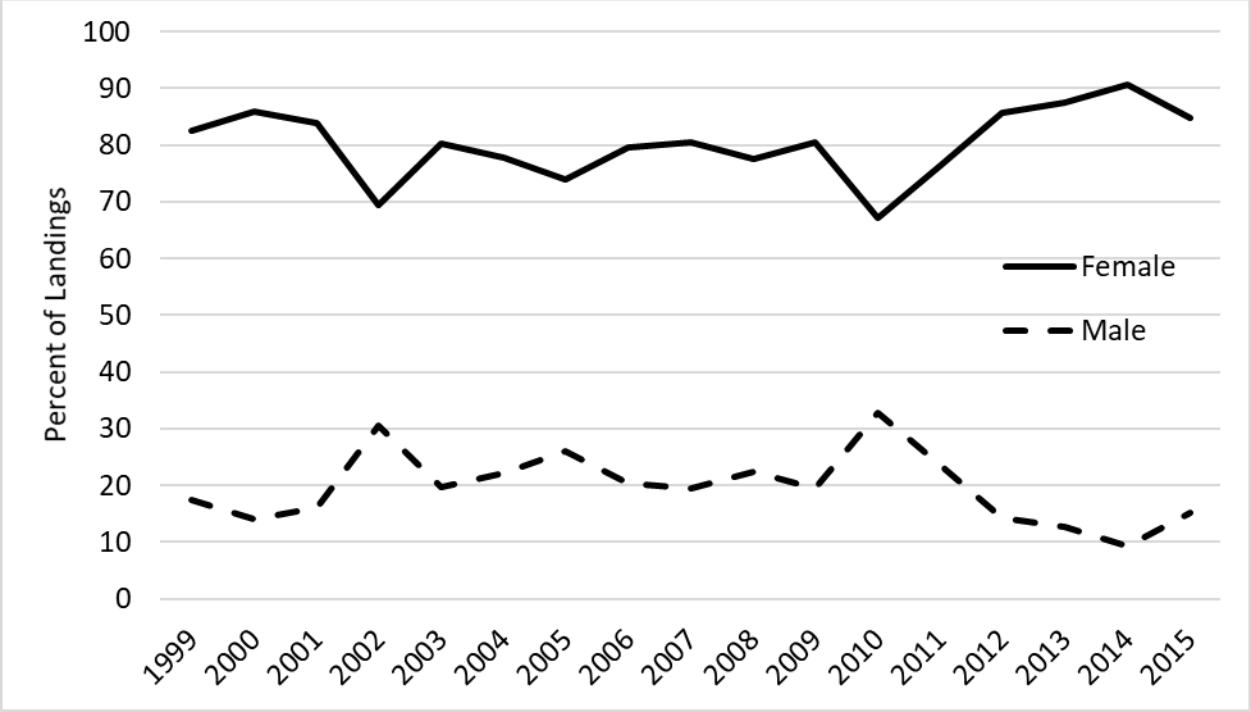

Figure 17. Sex composition of New Jersey's commercial gill net shad landings.

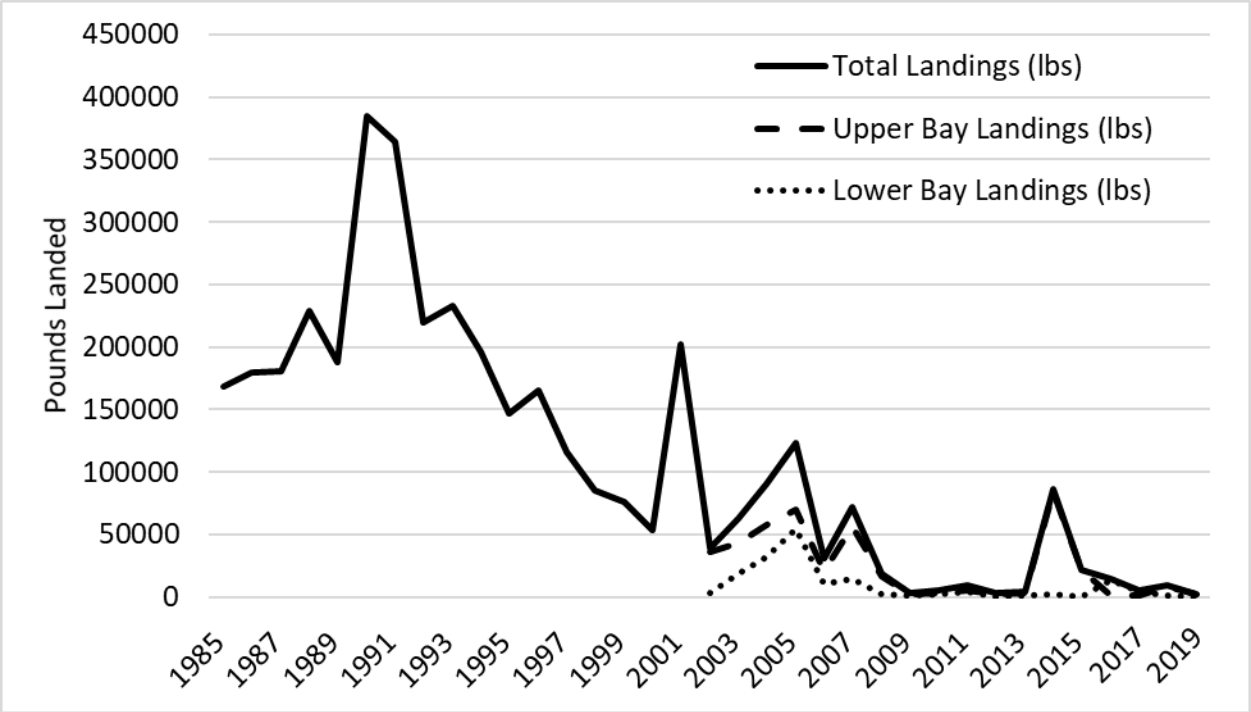

Figure 18. Commercial landings in the state of Delaware. Upper and lower bay landings are delineated by harvest occurring north and south of Bowers Beach, DE. Harvest location was not reported prior to 2002.

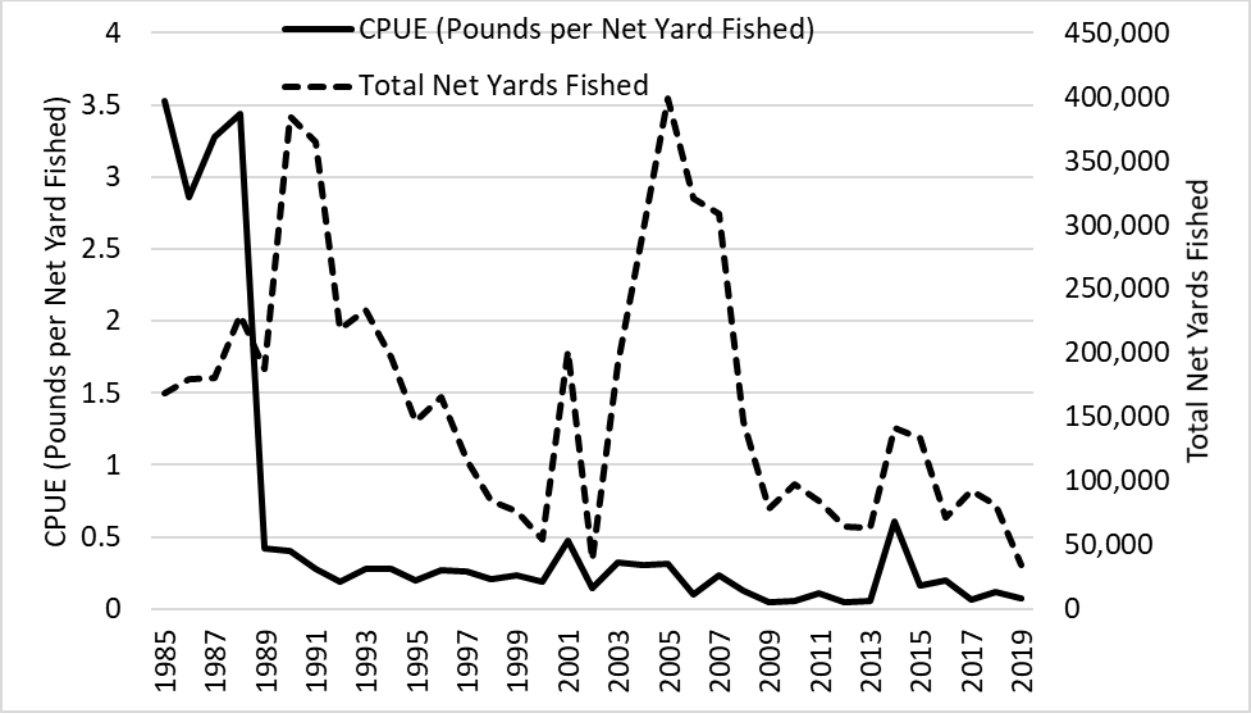

Figure 19. Delaware's catch per unit effort (CPUE) for the American shad commercial fishery.

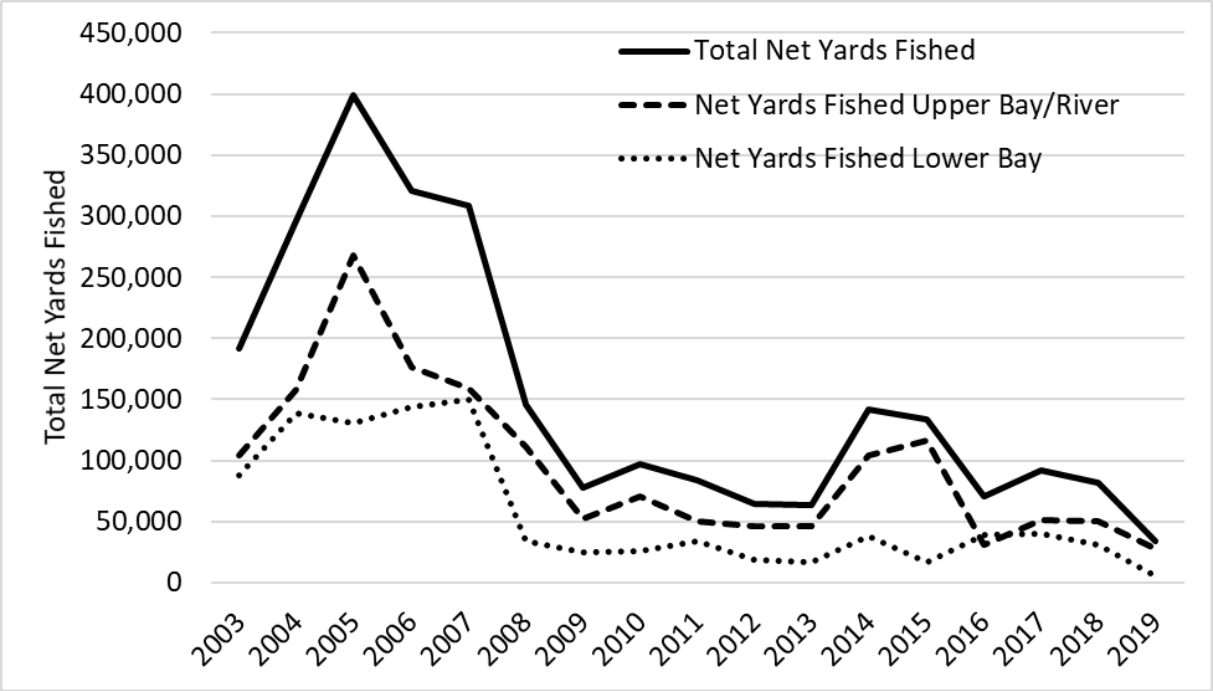

Figure 20. Delaware's gill net effort for the American shad commercial fishery. Upper and lower bay landings are delineated by harvest occurring north and south of Bowers Beach, DE. No collection location information were reported prior to 2002.

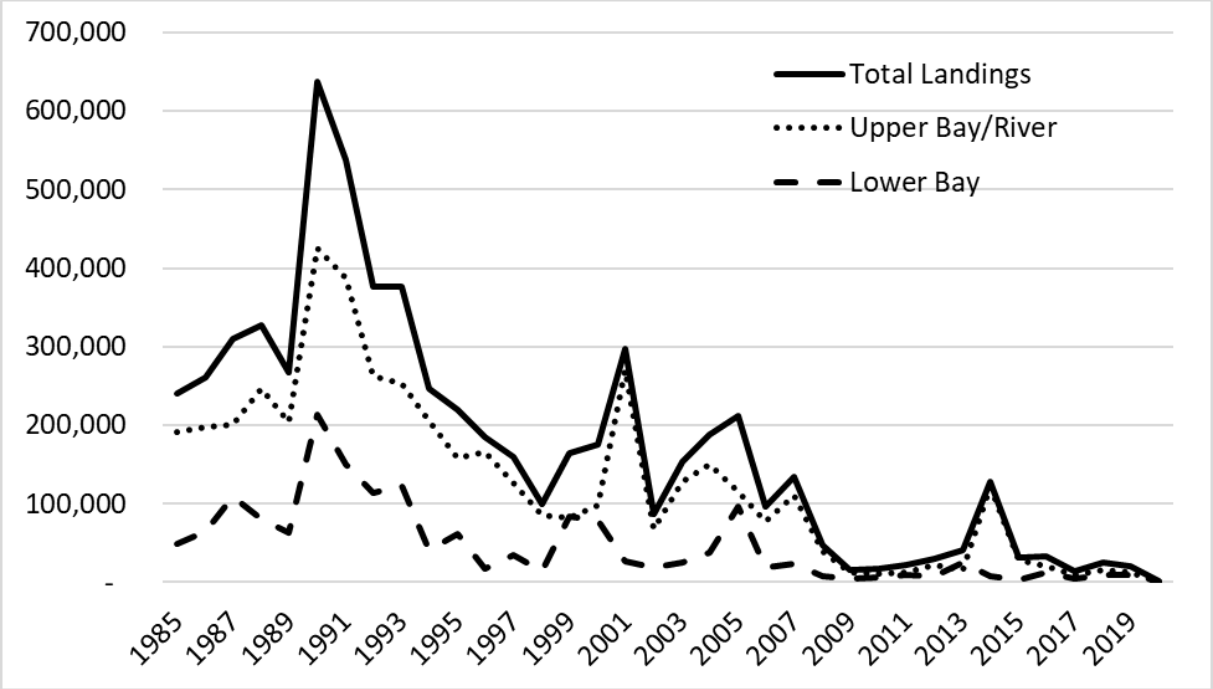

Figure 21. American shad commercial harvest for the states of Delaware and New Jersey, in pounds.

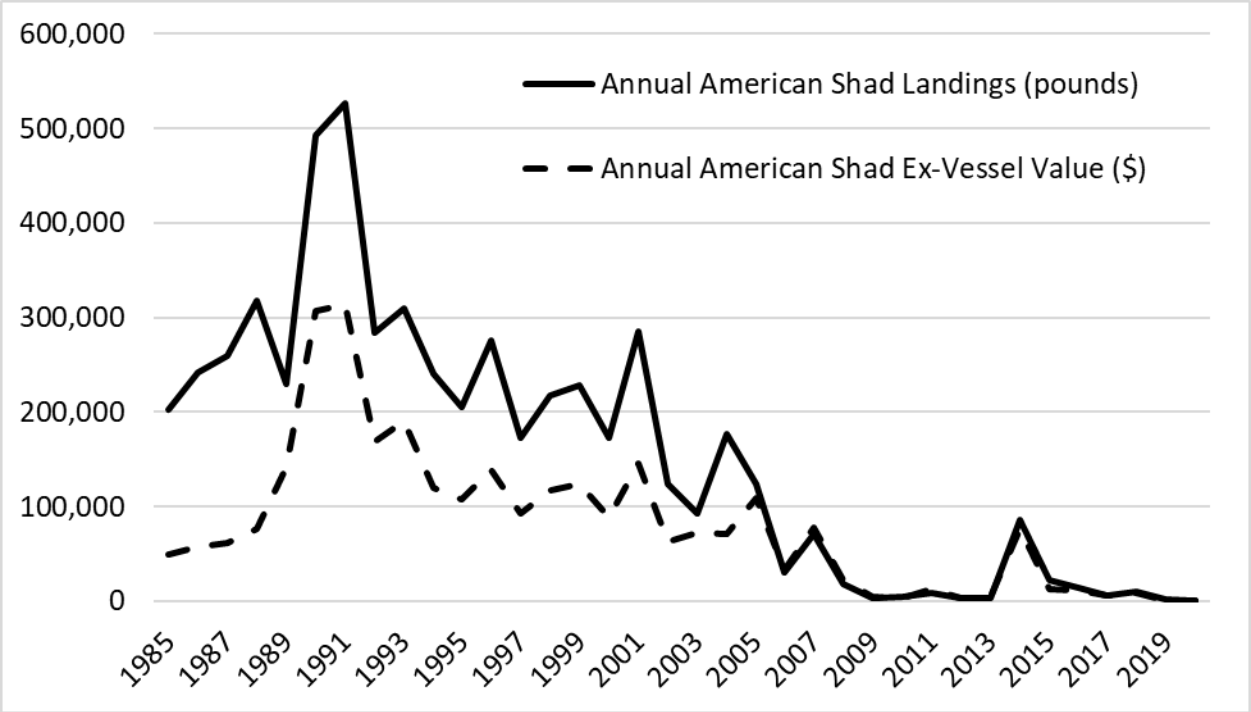

Figure 22. Pounds landed and market value for American shad landed in the State of Delaware.

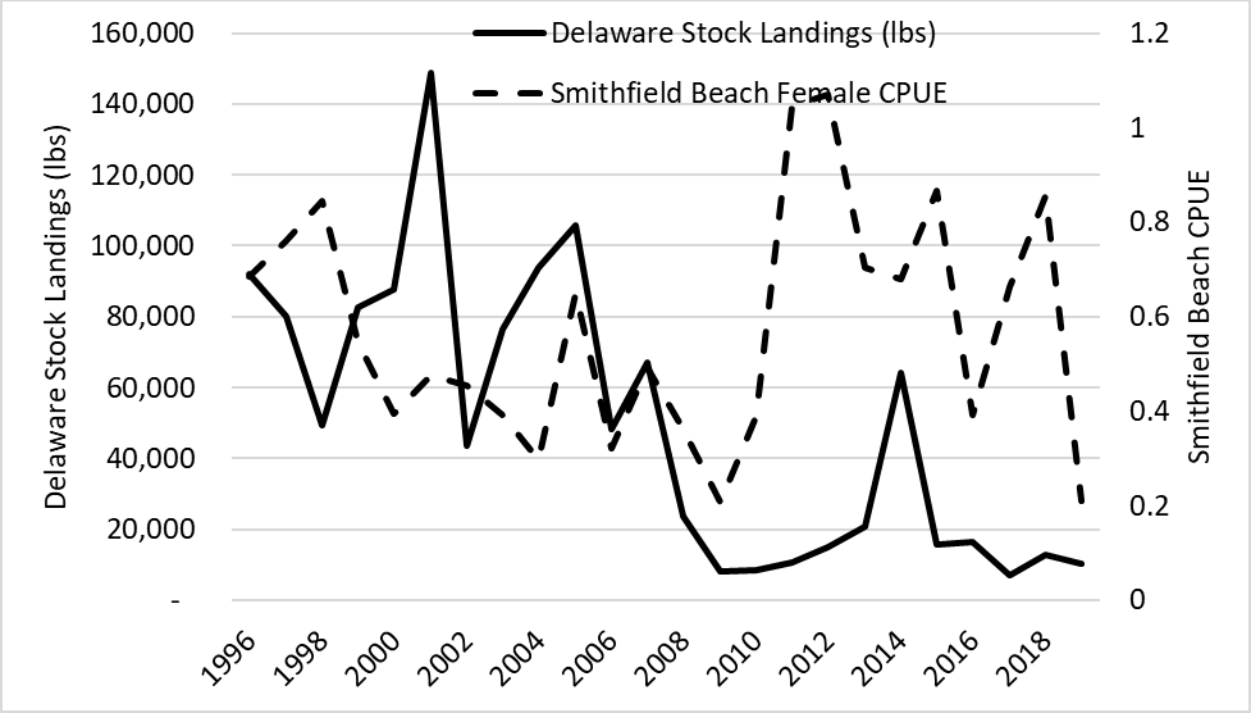

Figure 23. Comparison of trends between Delaware River stock landings and Smithfield Beach female American shad CPUE.

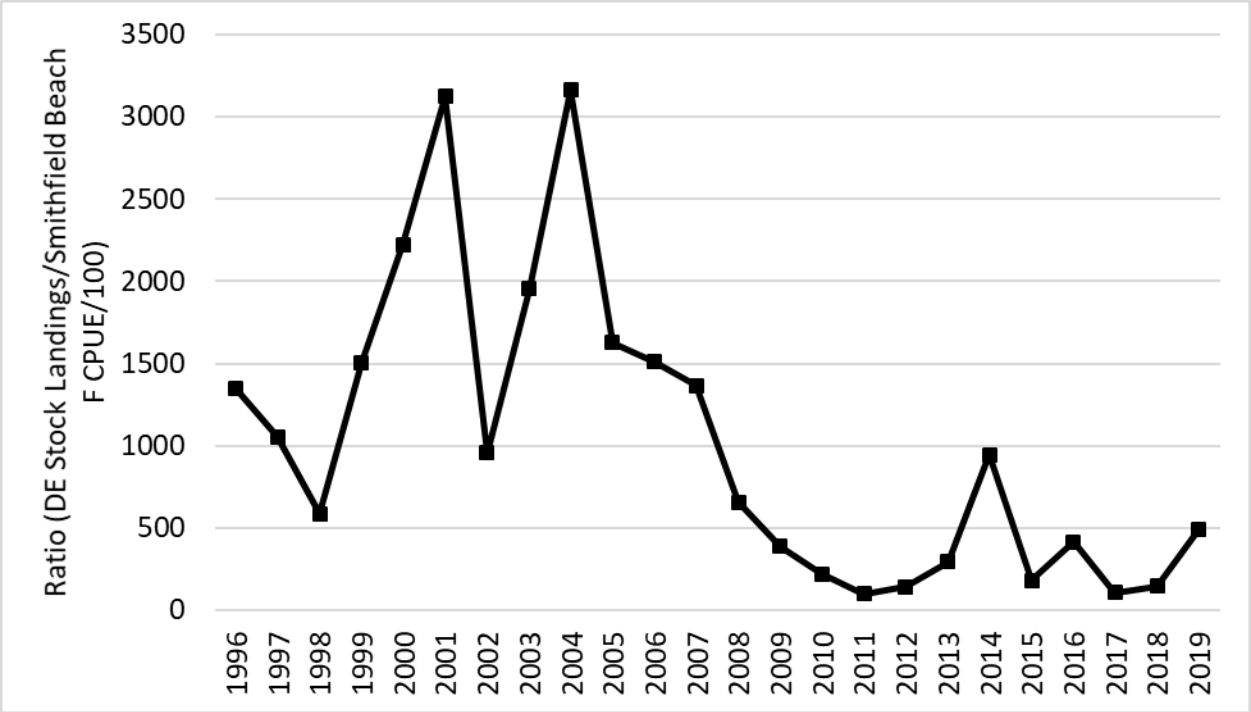

Figure 24. Ratio of Delaware River stock landings divided by Smithfield Beach CPUE (divided by 100).

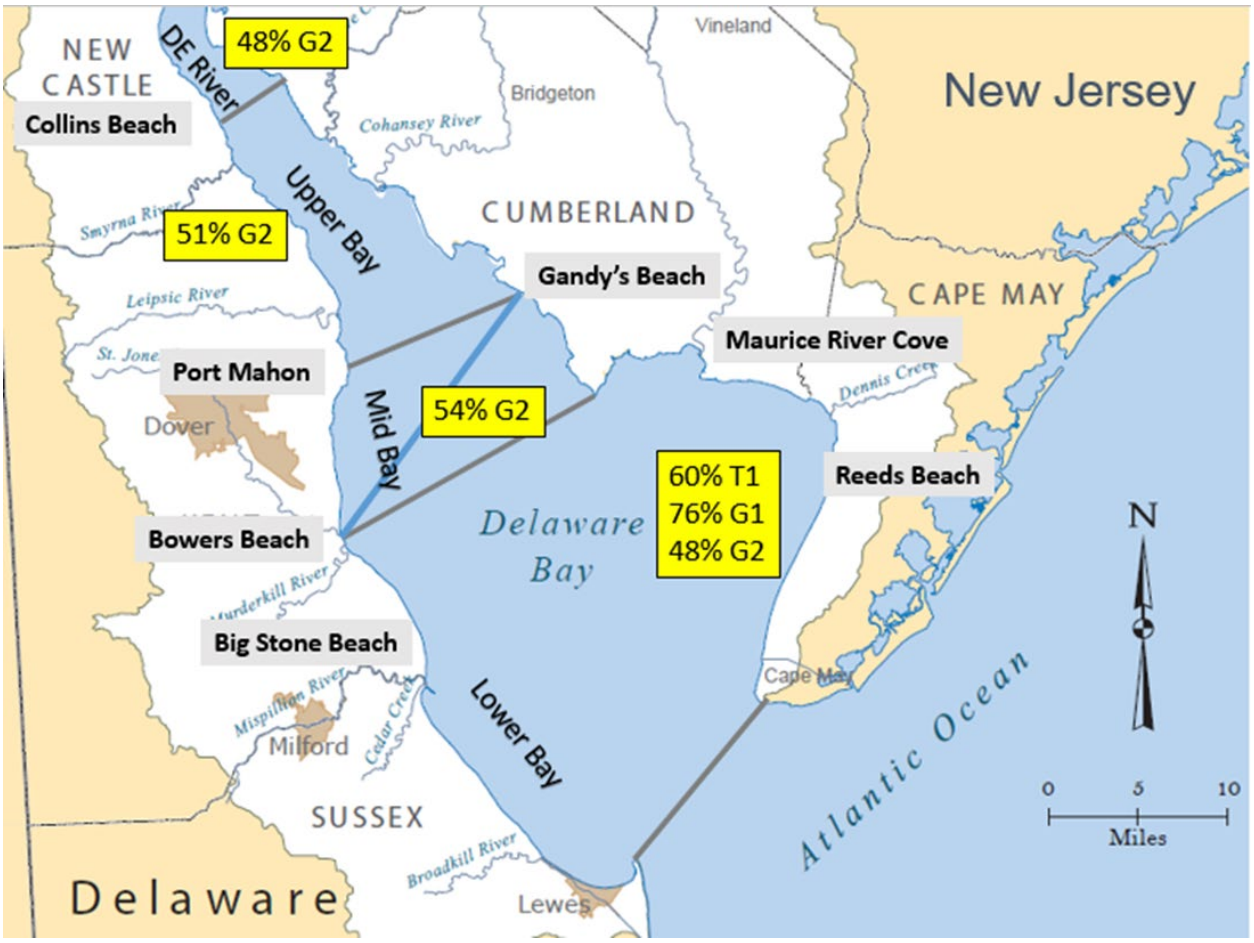

Figure 25. Map of the lower Delaware River and Bay, delineating harvest reporting regions for Delaware (n=4) and New Jersey (n=2, grey lines), demarcation line from 2017 SFP (blue), and proportions of mixed (non-Delaware Bay) stock by region based on study. T1 = New Jersey Tagging Study off Reeds Beach,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

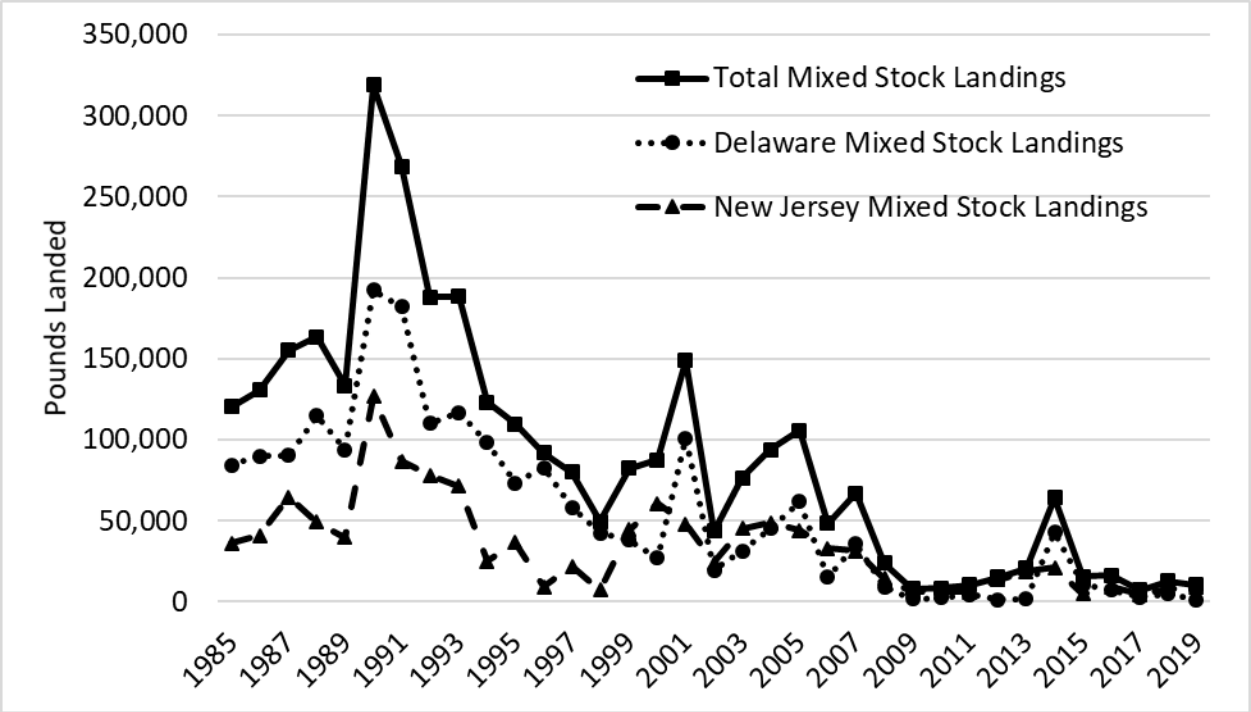

Figure 26. American shad landings (pounds) assigned to the mixed stock fisheries.

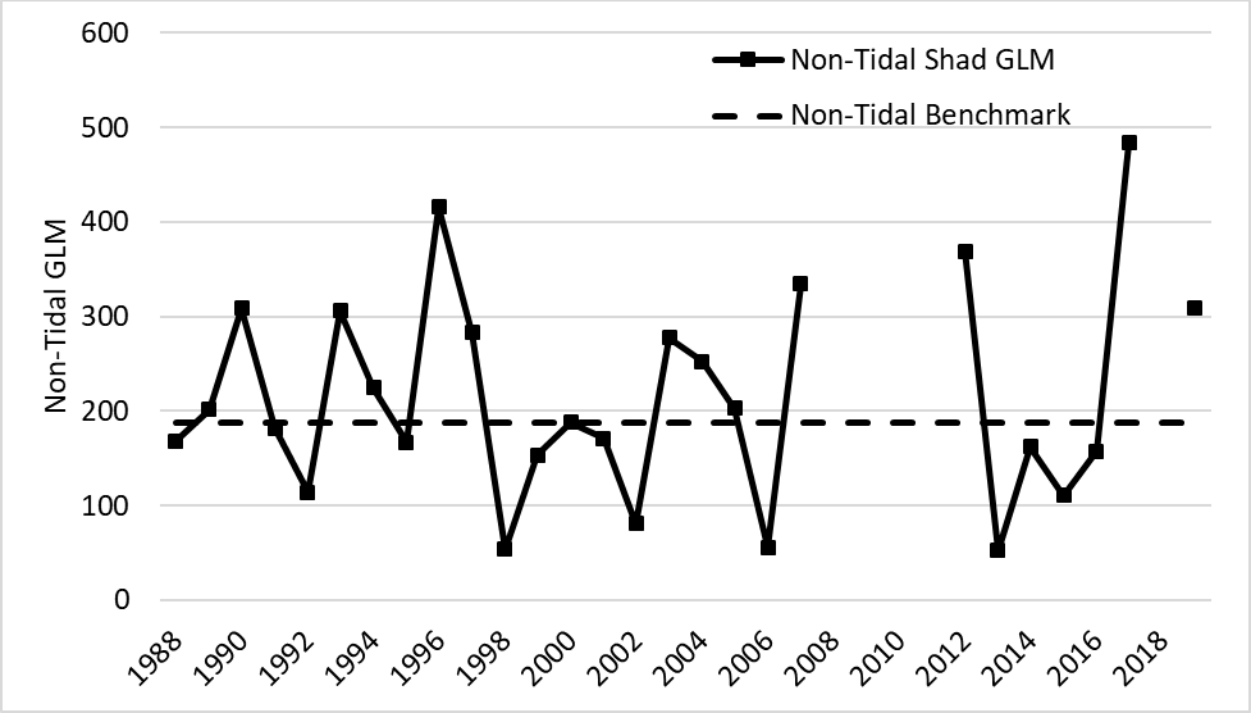

Figure 27. The Delaware River non-tidal American shad JAI (GLM) with a 50th percentile benchmark. Note that the benchmark value may change annually based on updated GLM analysis.

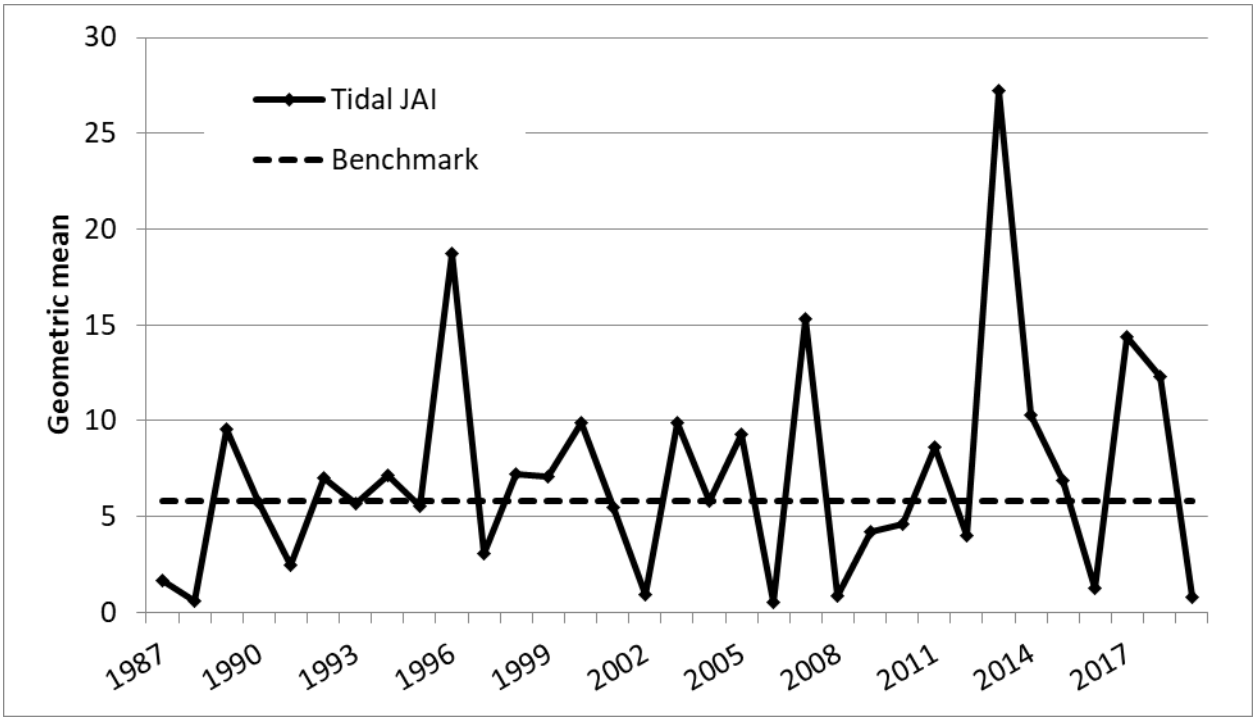

Figure 28. The Delaware River tidal American Shad JAI (GM) with a 50th percentile benchmark. The GM values are based on catches from Region 2 and 3 of the NJDFW tidal seine sites.

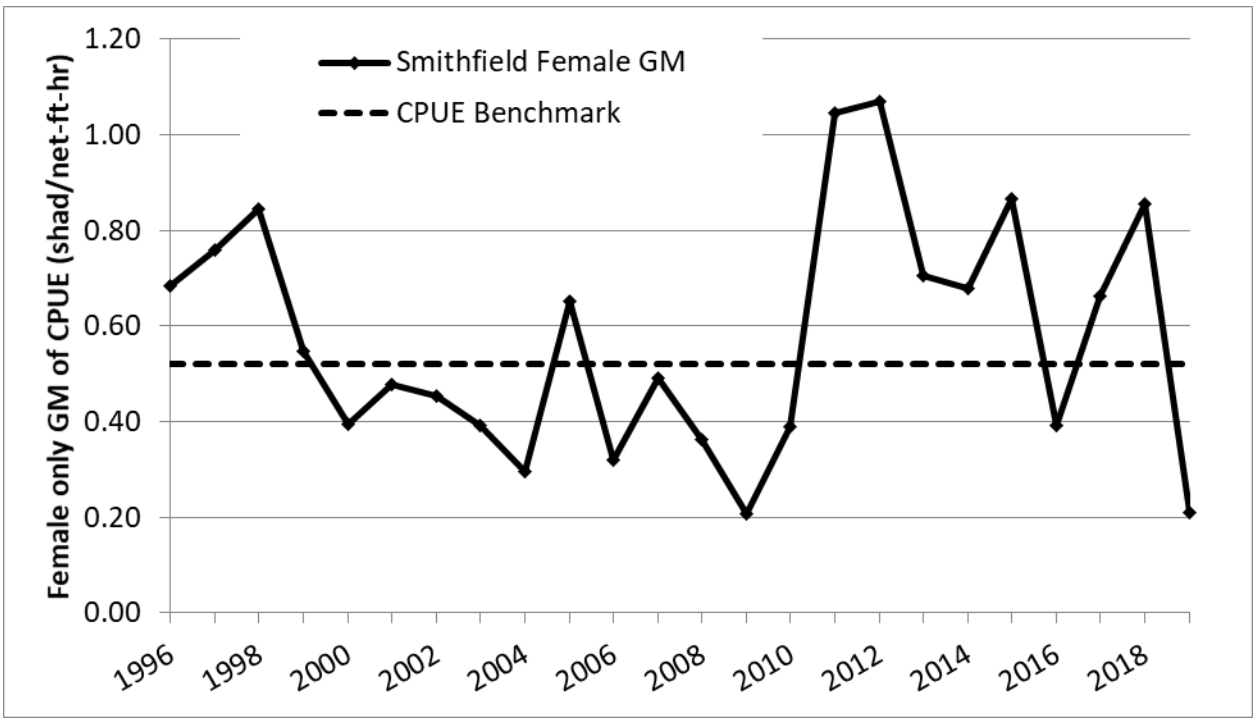

Figure 29. The Delaware River spawning adult female American shad index at Smithfield Beach (RM 218) with a 50th percentile benchmark.

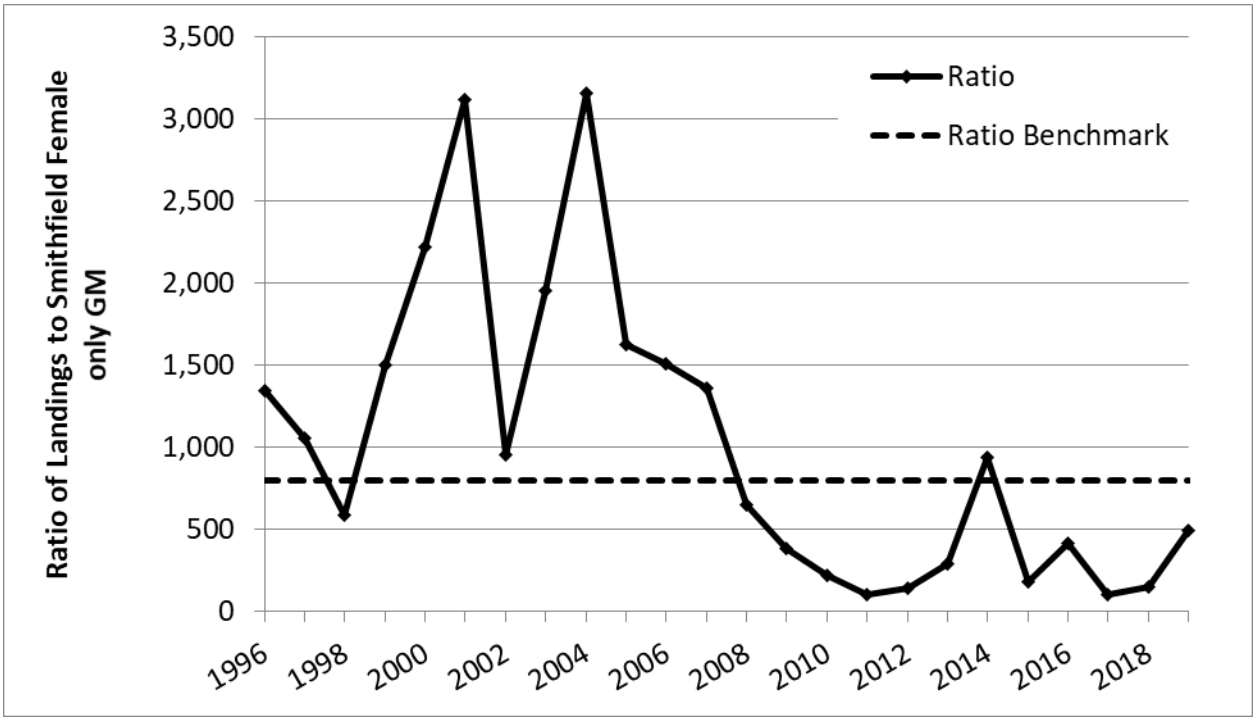

Figure 30. Ratio of Delaware River stock landings divided by Smithfield Beach female shad GM (divided by 100) with a 50th percentile benchmark: 1990-2019.

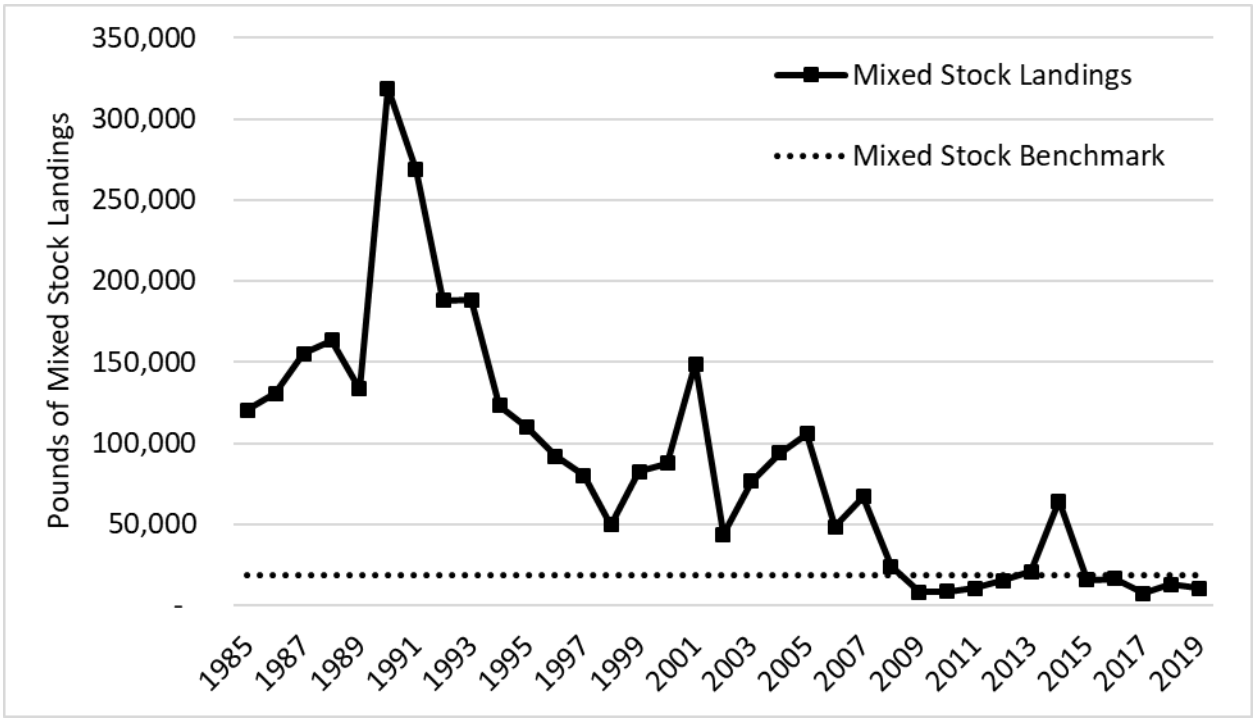

Figure 31. American shad landings in the Delaware Bay from the mixed stock fishery with a 25th percentile benchmark.

10. Tables

Table 1. New Jersey commercial fishing regulations for 2022.

System	Season	Gear Limits	Mandatory Reporting	Other Restrictions
Delaware Bay & River	Gill nets: Feb 1-Dec 15	Stretch mesh min.: 2.75” Feb 1-Feb 29 *3.25” Mar 1-Dec 15 Length: 2400’ Feb 12-May 15 1200’ May 16-Dec 15	YES	Limited entry; gear restrictions in defined areas
	----------	----------		
	Haul Seine: Nov 1-Apr 30	2.75" min. stretch mesh, max length 420'		

*except with special permit

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

Year	Total Permits Issued	Active Permits	Permits Reporting Landings
2000	-	-	28
2001	-	-	29
2002	-	-	21
2003	-	-	24
2004	-	-	24
2005	-	-	24
2006	-	-	25
2007	-	-	17
2008	-	-	14
2009	-	-	16
2012	83	51	11
2013	71	47	13
2014	71	47	11
2015	71	47	9
2016	71	47	9
2017	71	47	12
2018	70	44	11
2019	70	43	9
2020	70	43	4
2021	70	43	4

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

	No. of Fishermen			No. of Man-days			Square Feet of Net			Pounds Harvested			Pounds/Square Foot		
Year	Upper Bay	Lower Bay	Comb.	Upper Bay	Lower Bay	Comb.	Upper Bay	Lower Bay	Comb.	Upper Bay	Lower Bay	Comb.	Upper Bay	Lower Bay	Comb.
2012	8	3	11	44	38	82	1,338,500	117,600	1,456,100	19,923	7,445	27,368	0.016	0.051	0.019
2013	9	4	13	54	55	109	1,369,040	654,000	2,023,040	13,204	24,455	37,659	0.018	0.02	0.019
2014	3	8	11	82	34	116	2,458,400	186,480	2,644,880	37,319	5,059	42,378	0.015	0.027	0.016
2015	7	2	9	52	38	90	1,357,200	256,000	1,613,400	6,013	3,405	9,418	0.004	0.013	0.006
2016	5	4	9	39	84	123	2,401,200	1,208,640	3,609,840	6,222	12,155	18,377	0.003	0.010	0.005
2017	8	4	12	47	56	103	544,300	638,960	1,183,260	4,535	4,197	8,762	0.008	0.007	0.007
2018	7	7	11	62	62	124	692,945	1,288,015	1,980,960	8,012	7,726	15,738	0.012	0.006	0.008
2019	7	6	9	47	69	116	306,825	833,825	1,140,650	9,680	8,619	18,299	0.032	0.010	0.016

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

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

Table 5. Delaware's gill net effort for the American Shad commercial fishery. Upper and lower bay landings are delineated by harvest occurring north and south of Bowers Beach, DE.

Year	No. of Fishermen				No. Vessel Trips				Net Yards Fished				Pounds Harvested				Pounds/Net Yard			
	Upper Bay/River Anchor	Upper Bay/River Drift	Lower Bay Anchor	Lower Bay Drift	Upper Bay/River Anchor	Upper Bay/River Drift	Lower Bay Anchor	Lower Bay Drift	Upper Bay/River Anchor	Upper Bay/River Drift	Lower Bay Anchor	Lower Bay Drift	Upper Bay/River Anchor	Upper Bay/River Drift	Lower Bay Anchor	Lower Bay Drift	Upper Bay/River Anchor	Upper Bay/River Drift	Lower Bay Anchor	Lower Bay Drift
2003	18	12	8	2	271	85	117	4	71,145	32,743	85,100	2,500	38,290	5,161	18,742	118	0.54	0.16	0.22	0.05
2004	19	13	9	3	348	76	186	21	125,140	33,300	121,040	17,400	53,779	4,221	31,242	851	0.43	0.13	0.26	0.05
2005	23	23	4	3	302	270	107	69	138,440	129,900	68,310	62,400	46,377	22,961	35,114	19,113	0.33	0.18	0.51	0.31
2006	26	12	8	7	308	121	154	37	117,325	59,050	107,820	36,400	18,265	2,211	8,814	1,235	0.16	0.04	0.08	0.03
2007	23	17	6	8	270	114	135	67	117,540	41,100	99,275	50700	49,668	7,157	10,402	4,211	0.42	0.17	0.1	0.08
2008	22	15	3	6	212	108	5	49	65,689	45,870	3,800	30,675	13,930	2,137	34	2,232	0.21	0.05	0.01	0.07
2009	19	14	2	6	99	38	5	22	30,352	22,450	5,000	20,200	2,032	404	92	918	0.07	0.02	0.02	0.05
2010	13	12	1	4	85	54	12	24	40,800	30,250	3,050	23,000	1,529	1,694	409	1,387	0.04	0.06	0.13	0.06
2011	17	10	1	5	98	50	13	33	30,830	19,400	5,200	28,600	3,531	1,721	1,159	2,722	0.11	0.09	0.22	0.1
2012	10	7	0	6	63	45	0	28	21,850	24,050	0	18,400	1,216	1,095	0	429	0.06	0.05	0	0.02
2013	10	9	0	3	45	63	0	18	14,900	31,000	0	17,200	778	1,715	0	784	0.05	0.06	0	0.05
2014	11	4	1	5	173	13	1	44	97,435	6,300	1,000	36,800	83,400	299	2	2,093	0.86	0.05	0	0.06
2015	11	4	0	4	143	27	0	20	96,500	20,380	0	17,000	21,091	420	0	254	0.22	0.02	0	0.01
2016	6	6	3	4	41	38	16	34	16,545	14,652	11,300	28,300	4,273	9,342	211	425	0.26	0.64	0.02	0.02
2017	8	4	0	7	76	25	0	74	26,820	24,700	0	40,500	4,430	89	0	1,070	0.17	0	0	0.03
2018	9	3	0	3	92	16	0	34	43,361	7,400	0	31,000	7,491	840	0	1,307	0.17	0.11	0	0.04
2019	7	2	0	3	55	4	0	8	26,860	1,350	0	5,700	2,265	26	0	113	0.08	0.02	0	0.02

Table 6. Number of permits issued to Delaware fishermen and number reporting American shad landings annually.

Year	Total Permits Issued	Active Permits	Permits Reporting Landings
2000	110	84	56
2001	111	75	53
2002	108	72	46
2003	110	70	41
2004	110	66	44
2005	111	67	52
2006	111	63	45
2007	111	59	41
2008	111	56	38
2009	111	60	35
2010	111	56	29
2011	111	56	30
2012	111	59	20
2013	111	54	20
2014	111	52	19
2015	111	51	19
2016	111	20	12
2017	111	48	16
2018	111	44	16
2019	111	45	11

Table 7. The State of Delaware summary of biological data collected on American shad from Delaware and New Jersey commercial fishers.

Year	Number	Mean TL (mm)	Mean WT (lbs)
1999	370	510	4.8
2000	250	506	N/A
2001	250	521	3.5
2002	189	517	N/A
2003	186	528	4.0
2004	37	548	4.6
2005	190	539	4.6
2006	294	523	5.3
2007	245	512	4.9
2008	N/A	N/A	N/A
2009	N/A	N/A	N/A
2010	150	510	N/A
2011	335	534	4.3
2012	432	541	4.2
2013	251	533	3.5
2014	270	473	3.0
2015	299	507	2.8
2016	300	518	2.58
2017	32	504	3.41
2018	223	531	3.68
2019	21	522	3.59

Table 8. American shad tag returns, by year, from fish tagged in New Jersey's Tagging program off Reed's Beach in Delaware Bay.

Year	American Shad Tagged	Recaptures
1995	107	10
1996	294	14
1997	500	36
1998	554	38
1999	753	46
2000	425	32
2001	663	35
2002	273	15
2003	170	7
2004	51	0
2005	220	9
2006	73	2
2007	42	1
2008	0	0
2009	11	1
2010	85	3
2011	17	0
2012	18	0
2013	17	0
2014	18	2
2015	10	1
2016	94	2
2017	10	0
2018	36	1
2019	66	0

Table 9. Recaptures of American Shad tagged in New Jersey's Tagging program off Reed's Beach in Delaware Bay.

Recapture Location	Number of Reports	Percent of Reports
St. Lawrence River, Quebec	1	0.4
New Brunswick, Canada	3	1.2
Shubenacadie River, Nova Scotia	1	0.4
Atlantic Ocean and Rivers, RI	3	1.2
Connecticut River	40	15.9
Hudson River	44	17.5
Atlantic Ocean, NY	3	1.2
Atlantic Ocean, NJ	38	15.1
Delaware Bay/River	101	40.2
Atlantic Ocean, DE	4	1.6
Atlantic Ocean, MD	1	0.4
Atlantic Ocean, VA	1	0.4
Chesapeake Bay and Tribs	7	2.8
Atlantic Ocean and Rivers, NC	2	0.8
Santee River, SC	1	0.4
Unknown Location	1	0.4

Table 10. Assignment of stock origin for American shad collected in the Delaware Bay off Big Stone Beach (n=191) and Maurice River Cove (n=31) in 2010 from 33 baseline rivers (condensed, from Waldman et. al, 2014).

Region of Stock Origin	Percent Assignment
Northern region	12.6
Connecticut River	13.7
Hudson River	34.4
Delaware River	24.2
Chesapeake Bay	9.5
Southeastern region	5.6

Table 11. Assignment of stock origin for American shad collected in the Delaware Bay and River from 2017-2020 (from Bartron and Prasko, 2021). Bay demarcations can be found in Figure 25.

Region	Number Samples Taken	Percent Assigned to Delaware Stock	Percent Assigned to non-Delaware Stock
Smithfield Beach, PA	100	70	30
Lambertville, NJ	246	58	42
Schuylkill River, PA	22	64	36
Delaware River	23	52	48
Upper Bay	73	49	51
Mid-Bay	145	46	54
Lower Bay	343	52	48

Table 12. Marine Recreational Information Program (MRIP) characterization of recreational American shad harvest in the Delaware Estuary and Bay. PSE = Percent Standard Error.

	Recapture Location			
	Delaware		New Jersey	
Year	Total Harvest	PSE	Total Harvest	PSE
1994	13,218	68.8	18,706	101
1995				
1996				
1997			7,380	102.2
1998				
1999	5,601	61.2		
2000				
2001			96,971	94.4
2002				
2003	14,408	103.3		
2004				
2005				
2006				
2007				
2008				
2009				
2010	7,016	103.5	26,050	99.8
2011	16,598	102.1		
2012			32,511	99.7
2013				
2014				
2015				
2016				
2017				
2018				
2019	235	97.9		

Table 13. Number of American shad fry stocked in the Delaware River Basin. Due to COVID-19 social restrictions, PFBC hatchery operations were closed for the 2019 season.

Year	Delaware River	Lehigh River	Schuylkill River
1985		600,000	251,980
1986		549,880	246,400
1987		489,980	194,575
1988		340,400	
1989		2,087,700	316,810
1990		793,000	285,100
1991		793,000	75,000
1992		353,000	3,000
1993		789,600	
1994		642,200	
1995		1,044,000	
1996		993,000	
1997		1,247,000	
1998		948,000	
1999		501,000	410,000
2000		447,900	535,990
2001		675,625	490,901
2002		85,025	2,000
2003		783,013	1,000,448
2004		366,414	521,583
2005	169,802	668,792	545,459
2006	52,782	293,083	253,729
2007	47,587	276,000	540,655
2008	158,151	696,785	486,774
2009		210,584	161,938
2010		347,522	380,000
2011		473,366	643,361
2012		301,112	200,429
2013		402,089	338,084
2014		584,730	439,136
2015		247,649	198,855
2016		236,062	261,940
2017		434,454	361,391
2018		304,362	74,174
2019		0	0

Table 14. Hatchery contribution for adult American shad collected from the Delaware River (Smithfield Beach), the Lehigh River, and the Schuylkill River.

	Smithfield Beach		Lehigh River		Schuylkill River	
Year	N	Percent	N	Percent	N	Percent
1997	88	0.0%	No collections			
1998	234	3.8%	No collections			
1999	208	0.0%	104	91%		
2000	330	3.0%	99	91%		
2001	198	4.0%	103	92%		
2002	378	1.1%	99	89%		
2003	245	7.8%	No collections			
2004	414	1.2%	60	80%		
2005	776	0.5%	13	62%		
2006	350	1.4%	55	73%		
2007	746	2.8%	40	58%	22	92%
2008	667	1.0%	41	51%	28	100%
2009	367	1.1%	27	63%	24	96%
2010	470	0.2%	96	67%	25	100%
2011	409	0.5%	16	56%	22	88%
2012	412	1.0%	62	43%	21	84%
2013	454	0.2%	76	74%	25	84%
2014	488	1.4%	80	59%	25	88%
2015	Not Examined		62	32%	4	100%
2016	Not Examined		103	16%	29	66%
2017	Not Examined		98	14%	25	92%
2018	383	0%	49	8%	22	96%
2019	189	0%	2	50%	18	67%

Table 15. Female American shad total mortality for the Delaware River population.

Year	Z Estimate	SE	# Observations	# Year Classes	3-Yr. Moving Avg.	Z40 Benchmark
1996	0.61	0.11	**27**	3		1.07
1997	0.62	NaN	**20**	**2**		1.07
1998	0.74	0.29	56	3		1.07
2000	1.20	0.42	132	3		1.07
2001	1.61	0.12	200	3		1.07
2002	1.36	0.13	169	4	1.39	1.07
2003	1.60	0.28	219	4	1.52	1.07
2004	1.19	0.66	140	3	1.38	1.07
2005	1.63	1.65	185	4	1.47	1.07
2006	1.26	0.72	109	3	1.36	1.07
2007	1.85	0.28	232	4	1.58	1.07
2008	1.91	0.42	252	3	1.67	1.07
2009	1.44	0.21	139	3	1.73	1.07
2010	1.70	0.09	65	3	1.68	1.07
2011	3.44	NaN	290	**2**		1.07
2012	0.75	1.14	198	4		1.07
2013	1.45	0.62	261	3		1.07
2014	1.46	1.45	247	3	1.22	1.07
2015	0.87	0.18	145	3	1.26	1.07
2016	1.58	0.38	207	4	1.30	1.07
2017	1.44	0.94	144	3	1.30	1.07
2018	2.50	NaN	211	**2**		1.07
2019	0.86	1.70	166	3		1.07

Numbers in red indicate failure to meet requirements for inclusion of annual estimate and included for reference

Table 16. Juvenile non-tidal abundance indices for Delaware River American Shad. Non-tidal sites include Phillipsburg, Delaware Water Gap and Milford Beach. GLM = generalized linear model mean.

Year	Non-Tidal Shad GLM	Non-Tidal Benchmark
1988	168.44	188
1989	201.42	188
1990	308.57	188
1991	182.24	188
1992	114.26	188
1993	306.08	188
1994	224.89	188
1995	167.25	188
1996	415.6	188
1997	283.1	188
1998	53.99	188
1999	153.49	188
2000	187.71	188
2001	170.82	188
2002	80.94	188
2003	277.5	188
2004	252.2	188
2005	203.14	188
2006	55.53	188
2007	334.17	188
2008		188
2009		188
2010		188
2011		188
2012	369.14	188
2013	52.56	188
2014	162.37	188
2015	111	188
2016	157.34	188
2017	483.34	188
2018		188
2019	309.54	188

Table 17. Juvenile tidal abundance indices for Delaware River American Shad. GM = geometric mean.

Year	Tidal Shad GM	Tidal Benchmark
1987	1.68	5.81
1988	0.56	5.81
1989	9.54	5.81
1990	5.74	5.81
1991	2.49	5.81
1992	7	5.81
1993	5.68	5.81
1994	7.13	5.81
1995	5.52	5.81
1996	18.73	5.81
1997	3.05	5.81
1998	7.22	5.81
1999	7.07	5.81
2000	9.89	5.81
2001	5.45	5.81
2002	0.89	5.81
2003	9.9	5.81
2004	5.81	5.81
2005	9.26	5.81
2006	0.53	5.81
2007	15.3	5.81
2008	0.82	5.81
2009	4.21	5.81
2010	4.61	5.81
2011	8.64	5.81
2012	4	5.81
2013	27.22	5.81
2014	10.26	5.81
2015	6.9	5.81
2016	1.26	5.81
2017	14.35	5.81
2018	12.29	5.81
2019	0.79	5.81

Table 18. Delaware River spawning adult female American shad GM of the CPUE at Smithfield Beach (RM 218).

Year	Smithfield Female GM	CPUE Benchmark
1996	0.68	0.52
1997	0.76	0.52
1998	0.84	0.52
1999	0.55	0.52
2000	0.39	0.52
2001	0.48	0.52
2002	0.45	0.52
2003	0.39	0.52
2004	0.30	0.52
2005	0.65	0.52
2006	0.32	0.52
2007	0.49	0.52
2008	0.36	0.52
2009	0.21	0.52
2010	0.39	0.52
2011	1.04	0.52
2012	1.07	0.52
2013	0.70	0.52
2014	0.68	0.52
2015	0.87	0.52
2016	0.39	0.52
2017	0.66	0.52
2018	0.86	0.52
2019	0.21	0.52

Table 19. The Ratio of Delaware Stock landings divided by Smithfield female GM divided by 100.

Year	Delaware Stock Landings	Smithfield Beach GM	Ratio	Ratio Benchmark
1996	92068.5	0.68376	1346.51	799
1997	80157.5	0.75995	1054.78	799
1998	49534	0.84473	586.387	799
1999	82464	0.54728	1506.79	799
2000	87659	0.39406	2224.53	799
2001	148986	0.47733	3121.26	799
2002	43563.5	0.45463	958.217	799
2003	76471	0.39107	1955.43	799
2004	93775.5	0.29667	3160.97	799
2005	105797	0.65064	1626.05	799
2006	48339.5	0.32016	1509.83	799
2007	67133	0.49138	1366.2	799
2008	23686.5	0.36151	655.214	799
2009	8045.5	0.20673	389.178	799
2010	8619.5	0.38993	221.051	799
2011	10593.5	1.04437	101.434	799
2012	15054	1.06901	140.821	799
2013	20695.5	0.70449	293.768	799
2014	64086	0.67922	943.529	799
2015	15591.5	0.86709	179.814	799
2016	16314	0.39202	416.156	799
2017	7160.5	0.66196	108.171	799
2018	12688	0.85628	148.176	799
2019	10351.5	0.20983	493.319	799

Table 20. Total American shad landings (pounds) by state from the Delaware River and Bay assigned to mixed stock fisheries.

Year	Mixed Stock Landings	Mixed Stock Benchmark
1985	120,242	18,505
1986	130,556	18,505
1987	155,091	18,505
1988	163,651	18,505
1989	133,544	18,505
1990	318,984	18,505
1991	268,843	18,505
1992	187,907	18,505
1993	188,215	18,505
1994	123,256	18,505
1995	109,880	18,505
1996	92,069	18,505
1997	80,158	18,505
1998	49,534	18,505
1999	82,464	18,505
2000	87,659	18,505
2001	148,986	18,505
2002	43,564	18,505
2003	76,471	18,505
2004	93,776	18,505
2005	105,797	18,505
2006	48,340	18,505
2007	67,133	18,505
2008	23,687	18,505
2009	8,046	18,505
2010	8,620	18,505
2011	10,594	18,505
2012	15,054	18,505
2013	20,696	18,505
2014	64,086	18,505
2015	15,592	18,505
2016	16,314	18,505
2017	7,161	18,505
2018	12,688	18,505
2019	10,352	18,505