Stock Assessment Report No. 12-02

of the

Atlantic States Marine Fisheries Commission

River Herring Benchmark Stock Assessment Volume II

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Working towards healthy, self-sustaining populations for all Atlantic coast fish species or successful restoration well in progress by the year 2015

PREFACE

The 2012 Benchmark Stock Assessment of River Herring occurred through an Atlantic States Marine Fisheries Commission (ASMFC) external peer review process. ASMFC organized and held Data Workshops on October 27-28, 2009 and August 23-26, 2010. Assessment Workshops were held on February 28 – March 2, 2011 and August 8 – 10, 2011. Participants of the Data and Assessment Workshops included the ASMFC River Herring Stock Assessment Subcommittee and Technical Committee, as well as invited individuals from state and federal partners. ASMFC coordinated a Peer Review Workshop from March 14 – 15, 2012. Participants included members of the River Herring Stock Assessment Subcommittee and a Review Panel consisting of four reviewers appointed by ASMFC.

This 2012 River Herring Benchmark Stock Assessment Report is divided into two volumes due to its length.

Volume I includes:

Section A – Terms of Reference and Advisory Report of the Peer Review Panel
PDF pages 4 – 37
The Advisory Report provides an summary of the stock assessment results supported by the Review Panel. The Terms of Reference Report provides a detailed evaluation of how each Terms of Reference was addressed by the Stock Assessment Subcommittee. Individual reviewer reports are also available upon request from the ASMFC.

Section B – Technical Committee Response to Peer Review Report
PDF Page 38
A report from the Technical Committee to the Management Board which clarifies the purpose and use of the Stock Assessment Report's estimates of incidental catch of river herring in response to the Review Panel Report.

Section C – 2012 River Herring Stock Assessment Report for Peer Review (Coastwide)
PDF Pages 39 – 388
This report describes the background information, data used, and analysis for the assessment submitted by the Technical Committee to the Review Panel. It contains a coastwide analysis and comparison of river herring populations.

Volume II includes:

Section D – 2012 River Herring Stock Assessment Report for Peer Review (Maine through Florida)
This report describes the background information, data used, and analysis for the assessment submitted by the Technical Committee to the Review Panel. This volume contains a detailed description and summary of river herring populations by jurisdiction or watershed unit.

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5 Status of River Herring Stocks in Maine

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Executive Summary
John Pory made one of the first written accounts of river herring (alewife and blueback herring) abundance in New England in 1622 (Watts 2003). John Josellyn (1674) further documented accounts of river herring in Maine, then still part of Massachusetts, when describing harvest by two fishermen using stone weirs. Watts (2003) provides verbatim copies of historical documents regarding the importance of river herring in New England back to the 17^{th} century. These texts provide a rich history of the utilization of river herring throughout New England. These documents provide a background for many of the management and social issues related to managing river herring in New England today.

Maine retains some of the last healthy runs of river herring in New England. Maine's directed commercial fisheries are self-sustaining and operate under fisheries management plans cooperatively developed between the municipalities that own rights to harvest the river herring resources and the State of Maine. Reported landings of Maine river herring have declined from historical levels in the 1950s. The reasons for the decline in river herring stocks are not clear. Habitat loss, poor fish passage, predation, directed fisheries, and bycatch in ocean fisheries all affect Maine river herring populations. There remains the need to better understand the impact of these activities and develop management measures that insure river herring populations continue to thrive throughout their range.

5.1 INTRODUCTION

The alewife and blueback herring are two of eleven species of anadromous fish found in Maine. Anadromous fish spend most of their life at sea and return to freshwater to spawn. The majority of adults return as first-time spawners at ages four and five. River herring have supported important municipal commercial fisheries since colonial times. Prior to the construction of dams on the larger river systems, inland towns such as Clinton and Newport on the Sebasticook River, 80 miles inland, had exclusive rights to harvest river herring. Currently, 38 municipalities maintain exclusive rights to harvest river herring. The Atlantic States Marine Fisheries Commission approved fisheries management plans for 22 municipalities that will fish in 2011. The harvester sells the majority of the harvest as lobster bait, though a small percentage of the landings are smoked and utilized for human consumption.

Alewives historically occurred in all major and minor coastal watersheds in the state (Watts 2003). Watts attributes the earliest declines in these populations to dam construction and industrial pollution, which rendered many waters unsuitable for their migration into freshwater spawning and nursery habitats. Protection of spawning populations of alewives began as early as the 1700s. Fish passage requirements at hydroelectric dams, a fishway construction program by the state, and restoration efforts in Maine over the past 30 years have significantly increased the amount of spawning habitat available to alewives.

5.2 MANAGEMENT UNIT DEFINITION

Municipal boundaries are the units used to manage Maine's river herring resources in inland waters. River herring resources that migrate inland, beyond the immediate coastal waters of the state, are property of the municipality. The Maine Department of Marine Resources (DMR) and respective municipality cooperatively manage river herring resource within the management unit. The coastal area outside municipal boundaries is closed to all commercial fishing for river herring by state law.

5.3 REGULATORY HISTORY

5.3.1 Regulation History

As early as 1706, the Town of Middleborough, Massachusetts, passed laws restricting the harvest to those planting corn (Watts 2003). The number of fish allotted for harvest was in direct proportion to the amount of corn a person planted for the season. Those not planting corn were not allotted fish for that year. These early conservations measures indicate the important role river herring held during the colonial period. Through the years several laws were passed, the most significant were those related to upstream passage at the numerous mill dams that existed during that time. Upstream fish passage laws began as early as 1735 in Massachusetts. From this point forward, many of the regulations dealt with partitioning the resource among user groups and fishing methods used to harvest fish. Many of these regulations and traditional uses of the resource continue today.

Beginning in 1960 and running through 1987 the State of Maine recommended a one day closed period per week to allow river herring escapement to spawning grounds. Most municipalities, though not all, instituted the one closed day per week. From 1988-1994 the state required that all municipalities have two closed days or conservation equivalent to ensure spawning escapement. In 1995, the state required three closed days of conservation equivalent.

5.3.2 Current Regulations

The Department of Marine Resources, along with municipalities granted the rights to harvest river herring resources, cooperatively manage these municipal fisheries. Each town must submit an annual harvesting plan to DMR for approval that includes a three-day per week escapement period or biological equivalent to insure conservation of the resource. In some instances, an escapement number is calculated and the harvester passes a specific number upstream to meet escapement goals. River herring runs not controlled by a municipality and not approved as sustainable by the ASMFC River Herring and American Shad Management Board are closed.

Each run and harvest location is unique, either in seasonality, fish composition, or harvesting limitations. Some run specific management plans require continuous escapement and are more restrictive than the three day closed period. Others have closed periods shorter than the three-day requirement, but require an escapement number, irrespective of the number harvested during the season. Maine increased the weekly fishing closure from a 24-hour closure in the 1960s to 48-hour closure beginning in 1988. The closed period increased to 72-hours beginning in 1995 to protect spawning fish (Figure 5.1). Most towns operate a weir at one location on each stream and law prohibits fishing at any other location on the stream. The state landings program compiles in-river landings of river herring from mandatory reports provided by the municipality under each municipal harvest plan or they lose exclusive fishing rights.

The state will permit twenty-two municipalities to fish for river herring in 2011. The river specific management plans require the remaining municipalities to close their runs for conservation and not harvest. There are several reasons for these state/municipal imposed restrictions on the fishery. Many municipalities voluntarily restrict harvest to increase the numbers of fish that return in subsequent years. Some of these runs are large, but have the potential to become even larger. The commercial fishery does not exploit the estimated 1.5 – 2.0 million river herring that return to the East Machias River annually.

Recreational fishermen are allowed to fish for river herring year-round. The limit is 25 fish per day and gear is restricted to dip net and hook-and-line. Recreational fishermen may not fish in waters, or in waters upstream, of a municipality that owns fishing rights. Recreational fishermen are not required to report their catch. The MRFSS and MRIP programs do sample some of these fishermen based on results queried from the database. Recreational fishing for river herring in Maine limited and landings are low.

5.3.3 Alewife Fishing Rights (Alewife and Blueback Herring)

The commissioner is authorized to develop, manage, or lease alewife fishing rights as follows.

1) Alewife rights: The commissioner shall grant the right, exclusive or otherwise, to take alewives to any municipality entitled to those rights on January 1, 1974 and may grant the right to take alewives to any other municipality provided:

A. Any municipality that has had the right to take alewives, exclusive or otherwise, or is granted that right by the commissioner, shall take action through its legislative body and file a copy of this action with the commissioner prior to April 20th or lose that right for the remaining part of that year.

B. Municipal rights in existence on January 1, 1974 which are not exercised for three consecutive years shall lapse.

C. At its annual meeting the municipality may determine by vote:

(1) Whether alewife fishing will be operated by the municipality through the municipal officers or a committee.

(2) Whether the municipal rights to take alewives will be sold by the municipal officers or committee.

D. Harvesting plans shall be developed as follows.

(1) Any municipality engaged in harvesting alewives shall submit a written harvesting plan to the commissioner prior to April 20th of each calendar year. All harvesting plans shall set forth in detail the exact conditions under which alewives may be taken, all in accordance with good conservation practices.

(2) The commissioner, after consultation with the appropriate municipal officers, shall approve or modify the harvesting plan as he deems necessary for the conservation of alewives and other anadromous fish, and shall file a copy of the approved plan with the clerk of the municipality.

Limitations. The following limitations apply to any grant:

A. It shall be unlawful to take alewives from 6 a.m. each Saturday morning until 6 a.m. Sunday morning. Municipalities which make other provisions for escape of spawning alewives, which are approved by the commissioner, shall be exempt from this limit.

B. It shall be unlawful for any municipality or purchaser or lessee of the municipal right to take alewives in any manner except as provided in the approved alewife harvesting plan.

Closed period in rivers and streams not under lease agreement. In any river or stream not managed under a lease agreement, there is a 72-hour closed period on the taking of alewives and obstruction of the watercourse to allow the free passage of fish from 6 a.m. on Thursday to 6 a.m. the following Sunday.

5.4 ASSESSMENT HISTORY

Maine has not conducted a formal coast wide assessment of its river herring resources. The length of Maine's coastline and number of watersheds that support river herring make a coast wide assessment difficult. Each water body supporting a river herring run is a separate spawning stock with adults homing to natal spawning and rearing locations.

River herring assessments are limited to fish passage counts at fishways or commercial landings from municipal fisheries. Ratios of escapement to returns 4-5 years later provided data to increase or decrease harvest rates. Crecco (1990) conducted the most recent ASMFC assessment for the Damariscotta fishery. Crecco determined that the Damariscotta River alewife fishery was severely over fished. Commercial exploitation rates for the fishery ranged from 90 to 98 percent. After this assessment, the Town of Damariscotta closed the fishery for 8 years to rebuild the run.

The Damariscotta river herring run is the most studied run in Maine. Its proximity to the coast and size of the run provide large numbers of study fish for researchers. Historically the commercial catches of alewives were large compared to most Maine alewife runs. Numerous studies investigated the sex ratio of river herring returns to the fishway, parent-progeny relationships, and efficiency of the fishway for male and female alewives.

Walton's (1987) research investigating the parent-progeny relationship of alewives entering the lake to spawn. His research indicates that the number of spawning females and numbers juvenile emigrants are asymptotically related. Despite the annual variability in estimated egg deposition the numbers of juveniles produced remained relatively constant throughout the eight year study. His conclusion is that the ability of Maine's lakes to produce alewives is finite and that year class strength is established prior to juvenile emigration from spawning habitats

5.5 STOCK SPECIFIC LIFE HISTORY

5.5.1 Alewife

Adults enter rivers from early May to early June and swim upstream into lakes, ponds, and dead water habitats to spawn. The temperature range for spawning is 12.8-15.5 °C. Each female produces 60,000-100,000 eggs, depending upon the size of the individual fish. The majority of the surviving spent adults then make their way downstream shortly after spawning. Early spawners can be seen migrating seaward and passing later run spawners that are still migrating upriver. Eggs, which are about 1.3 mm in diameter, hatch in about three days at 22 °C and six days at 15.5 °C. The seaward migration of young generally occurs from mid July through early December at a size range of 32-152 mm. Size at emigration depends upon the availability of feed in the lakes, the total numbers of young produced in a particular watershed, and the length of time the fish remain in the freshwater environment.

There are populations of dwarf anadromous alewives found in eastern Maine. These runs were located in ponds in the Bagaduce River. Two of these runs no longer exist. Walker Pond still has a population of dwarf alewives and their life history does vary from those of typical anadromous alewives in that the juveniles remain in nursery habitat for 16 months compare to the typical 4 months (Walton & Smith 1974).

Little is known about the life history of either alewife or blueback herring after they migrate to sea. Trawl survey data indicate that one and two year olds inhabit the coastal waters of Maine in the spring and fall. Abundance, species composition, and number at length change annually. Survey trawls at most of the 90 survey locations capture one or both of these species (Sherman 2001).

5.5.2 Blueback Herring

There is little stock specific life history data available for individual stocks of blueback herring. In Maine, stocks of blueback herring spawn in the main stem rivers and larger tributaries. Spawning occurs in late May through June dependant on water temperature. The commercial alewife fishery does capture some blueback herring but the number is low. The occurrence of blueback herring does increase toward the end of the alewife-fishing season.

Once the young-of the-year leave the rivers they over winter near the coast. After the first winter, little information about their migratory or feeding behavior is available. Blueback herring spawning requirements differ slightly from those of the alewife. They spawn in the main stem sections of rivers and streams and do not ascend into ponds or lakes. Blueback herring spawn from Nova Scotia to northern Florida, but are most numerous in warmer waters from Chesapeake Bay south. Females usually reach

100% maturity by age 5 and produce 60,000-103,000 eggs, whereas males generally mature at an earlier age (ages 3-4) and smaller size than females.

5.5.3 Growth

The growth of juvenile alewives is dependent on the nursery and rearing habitat they occupy. Juveniles resulting from stocking pre-spawn alewives, during the same day but at different locations, exhibit different growth rates. This depends largely on the trophic level of the pond and other environmental factors. Juveniles from eutrophic or mesotrophic lakes grow larger than those from oligotrophic lakes within the same watershed.

Dow (1973) indicated growth of adult alewives from cold water estuaries were smaller that those found on warmer water estuaries. Investigations by Roundsefell & Stringer (1943) reported considerable inter-site variation in the size of adult anadromous alewives from different locations in Maine. This is not substantiated by research conducted by Walton & Smith (1974) who reported similar growth parameters and no significant differences in length at age for 21 coastal watersheds in Maine.

The total lengths of adult alewives returning to spawn in the Androscoggin and Sebasticook rivers range from 260 to 330 millimeters. Based on scale analysis, the ages of these returns are 3 to 7 year old. The Maine – New Hampshire Trawl Survey captures alewives much smaller than the adults captured during the annual spawning runs. The majority of these alewives are young-of-the-year and consistent with length frequencies of juvenile river herring leaving nursery habitats in the spring. The trawl survey captures a small number of alewives in the 150 to 200 mm range. These fish are assumed 2-year-olds, but this has not been confirmed through scale aging techniques (Figure 5.2).

There is little data on the growth of blueback herring in Maine. Field staff samples few adults during the annual spawning run. The few samples that do occur are limited to individuals captured at the fishway on the Sebasticook River or while sampling commercial alewife runs. The Maine – New Hampshire trawl survey does capture blueback herring during the spring and fall inshore trawl surveys (Figure 5.3)

During the past four years, data collected at the Brunswick Fishway indicate that the mean total lengths of alewives ascending the fishway are declining (Figure 5.4). Alewives are not as large as alewives captured in commercial catches of years past, but trends in mean length are heavily influenced by year class strength. The Sebasticook alewives show no trend for the same period (Figure 5.5). The downward trends in mean lengths observed in some states are not apparent in Maine data for these two rivers for the past four years.

5.5.4 Fecundity

For both species, age at sexual maturity is primarily ages 4-5 in the northern portion of their ranges. Fecundity increases with size and age. Alewife produce 60,000-103,000 eggs per season and blueback herring produce a similar amount, 60,000 to 100,000 eggs per season. Fecundity of individual fish correlates positively to length and age. Older fish are more fecund than younger fish.

5.6 HABITAT DESCRIPTIONS

Habitat requirements for spawning populations of river herring in Maine are specific to each species. Overlap observed in spawning populations of river herring in states to the south do not appear to occur in Maine. Alewife spawning occurs in ponded habitats or slow section of river systems. In contrast, blueback herring spawn in the main channels of tidal fresh water rivers, and inland streams and rivers. Blueback herring spawn in fast water below locations where commercial alewife fisheries occur. Access to specific habitat types, flows, or substrate, do not appear more important than access to the suite of habitat types generally found in typical coastal river for blueback herring or lakes and ponds for alewife.

The effects of habitat loss are noted on the St. Croix River in eastern Maine (Figure 5.6). In 1995, the Maine Legislature passed a law resulting in unilateral closure of the Woodland Dam and Grand Falls fishways to upstream passage of spawning alewives into spawning habitat. This closure was opposed by state and Canadian fishery agencies. The alewife run in the St. Croix River has since collapsed. Canadian fisheries agencies do stock 2,000 fish annually but the return rate is only 0.26 percent of historic levels.

Restoration of alewives in the St. Croix River was initiated by Maine in 1965 when Denil fishways were installed at the Woodland dam (2nd dam) and the Grand Falls dam (3rd dam). A fishway had previously been installed in the Vanceboro dam at the outlet of Spednic Lake in 1963 on the New Brunswick side of the river. A poorly functioning fishway on the New Brunswick shore that was operational at the Milltown dam (1st dam) in the 1960's and 1970's was replaced in 1981 with a more efficient Pool and Chute fishway. The alewife run increased dramatically four years after the Milltown fishway became fully functional in 1982 and peaked at 2.6 million fish in 1987. Coincident with the increase in the alewife population, the smallmouth bass fishery in Spednic Lake declined. Following complaints of poor smallmouth bass fishing from local guides and sporting camps at Spednic Lake in Washington County, the IF&W undertook a cooperative study with the New Brunswick Department of Natural Resources. Although it was not possible to establish that the increase in the alewife run impacted the smallmouth bass fishery, it was postulated that the large influx of alewives through the Vanceboro Dam, coupled with a lake drawdown of 9-14 feet, may have resulted in loss of young fry bass habitat (Maine Rivers 2006). This also may have increased competition for food and habitat which lead to poor bass fry survival over several successive years (Maine Rivers 2006). In response to the smallmouth bass decline, the St. Croix River Fisheries Steering Committee agreed to block the Vanceboro fishway during the alewife run and requested that Georgia Pacific Company revise its water management plan on the St. Croix watershed in order to minimize the impacts of water drawdown on young bass. Georgia Pacific agreed and closed the Vanceboro fishway beginning in 1988, which has resulted in the collapse of the alewife run in the St. Croix River.

In an effort to reach a compromise, the St. Croix River Fisheries Steering Committee drafted a Memorandum of Understanding that would allow for the controlled escapement of up to 90,000 alewives through the Grand Falls fishway into the waters below West Grand Lake and Spednic Lake. A bill was introduced in the Maine Legislature in 2001 (L.D. 365) that would allow the Woodland and Grand Falls fishways to reopen but the bill was defeated. The Maine signatories did not sign or implement the Memorandum of Understanding. The alewife run in the St. Croix River reached a new low in 2002. Canadian fisheries staff counted only 900 alewives at the Milltown fishway. The Canadian Department of Fisheries and Oceans transported 807 of the 900 alewives to the Woodland headpond in an effort to save the run from extinction.

5.7 RESTORATION PROGRAMS

The goal of Maine's river herring restoration activities is to provide access to all habitats that historically supported river herring. Many of these habitats are well inland of the coastal rivers that support the current river herring runs. Access to much of this habitat is still blocked by dams without upstream fish passage and other impediments. The resource agencies are making progress by installing upstream and downstream fish passage facilities, especially on the Sebasticook River and smaller coastal watersheds. A well established trap and truck program maintains historic runs that do not have upstream passage until resource agencies achieve permanent passage.

The number of river alewife stocked varies based on available habitat and access to broodstock. The annual stocking goal of the restoration projects range from 120,000 to 500,000 fish, with most stocked in the Androscoggin and Sebasticook watersheds. These locations do not have upstream passage and require transport of spawning fish around existing barriers. This changed in 2009 with the removal of an existing hydropower dam and upstream passage on all dams on the main stem of the Sebasticook. In 2009 stocking numbers dropped by 150,000 fish. During the 2010 stocking season Maine fisheries staff targeted 63 spawning habitats into which 323,180 pre-spawn river herring would be released.

Starting in 2010 the DMR began restoring river herring to the Penobscot River, Maine's largest river. The trap and transfer program introduced 21,556 pre-spawn river herring from the Kennebec River into three habitats (Chemo, Perch, and Mattamiscontis Ponds) in the Penobscot drainage. This trap and transfer program will continue until sufficient returns to the Penobscot permit transfers of fish from sources within the Penobscot basin.

5.7.1 Restoration Objective(s) and/or Targets

Dam construction during the last century isolated many of the inland waters currently stocked with alewives. The historical significance of anadromous fish to these waters was eventually lost, and freshwater fish communities, especially recreationally important game fish, began dominating these habitats. In the 1980s, DMR began restoration of historical spawning habitats for anadromous fish in inland waters. Establishing a baseline for alewife introduction was important to fisheries managers that provide fishing opportunities for salmon, trout, and bass.
The interim restoration-stocking target for inland spawning habitats is six fish per surface acre for inland lakes and ponds locations stocked by truck. The State of Maine established this stocking rate during a 10-year study conducted by MDMR, Maine Department of Environmental Protection and Maine Inland Fisheries and Wildlife (Kircheis 2002). The goal of the study was to quantify the effects of a spawning population of alewife on the resident fish species and zooplankton community within inland waters. A stocking rate of six fish per surface acre of lake or pond habitat showed no negative effects for growth rates of resident fresh water fish species. The DMR observes this stocking rate for all truck-stocked locations. It is important to note that the initial stocking rate for this study was arbitrary and the stocking density could perhaps be higher and still not demonstrate significant in any negative impacts to resident fish species.

The state manages coastal runs for free passage and does not restrict these waters to the six fish per acre limit. All fishways that provide upstream passage for alewives are free passage, even those that provide access to habitats once stocked by truck. The management goals for these locations are return rates of 235 fish per acre with 35 fish per acre escapement into spawning habitat.

The DMR management program for alewives initially focused on providing, or improving, fish passage on smaller coastal drainages. Since 1969, DMR has installed 17 fishways and maintains 19 others from Cumberland County to Washington County. It also assists in the operation and maintenance of 12 non-hydro dams owned by other public entities. With the advent of better water quality in the larger river systems, DMR has actively sought installation of fish passage in hydroelectric dams licensed by the Federal Energy Regulatory Commission.

The DMR is actively involved in the restoration of anadromous fish to the Androscoggin and Kennebec Rivers. Since 1983 the DMR has operated the vertical slot fishway in the Brunswick dam located at the head-of-tide on the Androscoggin River. The construction of fish lifts at the next two up-stream dams, Pejepscot and Worumbo, allows passage of anadromous fish to Lewiston Falls. The majority of alewife habitat is located in the lakes and ponds in the Sabattus and Little Androscoggin rivers. These ponds are not currently accessible due to FERC licensed hydropower dams without upstream fish passage. The DMR has transported alewives to ponds in these two drainages annually since 1983. The number stocked fluctuates widely over the years and relates to the amount and location of habitat stocked in previous years (Figure 5.7).

The DMR implemented a restoration plan for alewives in the Kennebec River watershed above Augusta in 1986 because of an Agreement with the majority of hydroelectric dam owners in the watershed. The plan called for the stocking of alewives in the program's initial years to build up the population size, with eventual fish passage later. This Agreement was modified in 1998 and incorporated into the Kennebec River Settlement Accord, which resulted in the removal of the Edwards Dam in 1999, continued funding for the anadromous fish restoration program, and established new dates for fish passage. The alewife restoration program in the Kennebec River focuses on stocking lakes and ponds in the Sebasticook River watershed and Seven Mile Stream drainage. DMR has mainly stocked warm water lakes due to concerns of Maine Department of Inland Fisheries and Wildlife (IF&W) biologists that the restoration of alewives to cold water lakes might result in competition with smelt, an important forage species for landlocked salmon and brown trout. Results of a ten-year cooperative study in Lake George from 1987 through 1996, involving IF&W, DMR, and the Department of Environmental Protection (DEP),showed that the stocking of six alewives per surface acre of lake habitat had no negative impact on inland fisheries or water quality (Kircheis et al, 2002). Based on these findings, DMR and IF&W staffs recommended the initiation of the restoration of alewives in additional lakes in the Sebasticook drainage.

Fish passage on the Saco River became available in 1993 when Central Maine Power built fish passage facilities at the Cataract dam located at head-of-tide (dam and passage facilities now owned and operated by Florida Power and Light). The amount of habitat for alewives is limited in the Saco River drainage, but a remnant of the former run continues as the result of a trap and truck effort to the Skelton Dam headpond by the dam's owners. Passage became available at Skelton in 2002 with the installation of an inclined fish lift by Florida Power and Light.

5.7.2 Hatchery Evaluation

There are no hatcheries in Maine raising juvenile river herring for current restoration programs. The high costs of developing and supporting a long-term hatchery program prevent the state from exploring a hatchery program as an option for restoring river herring runs in Maine.

5.7.3 Fish Passage efficiency

The goal for fish passage efficiency at hydropower dams is 100 percent depending on environmental conditions. In reality, many of the upstream fish passage facilities are well below this goal. Upstream efficiency studies are routinely part of FERC licensing requirements and conducted with oversight from the state resource agencies. River herring passage efficiency at state or town owned coastal fishways or those leading into lakes and ponds are not routinely assessed.

5.7.4 Trap and transport

State resource agencies use trap and transport to maintain or rebuild extirpated runs along the Maine coast. Trap and transport also provides passage around dams without fishways and enhances runs with poor upstream passage. The trap and transfer programs stock 400,000 to 500,000 fish annually into spawning habitats that do not have upstream fish passage.

5.8 AGE

The maximum age for alewife and blueback herring in Maine is nine years (Libby 1980, Walton 1983). These ages are from river herring captured in commercial fisheries conducted in the 1970s and 1980s. Walton and Libby used ageing techniques developed by Marcy 1969, Rothschild 1963, and Norden 1967. Fish aged more recently, 2000 through 2008, do not appear to attain these older ages. As of 2000 fisheries staff now refers to Cating (1950), Marcy (1969), and Rothschild (1963) to determine the age of returning river herring. The method developed by Cating for American shad, may not be suitable for river herring. Maine does not have known age fish used to validate scale ages using Cating's method.

5.9 FISHERY DESCRIPTIONS

The predominant Maine river herring fisheries are directed fisheries located at head-of-tide or above. The municipality that owns the fishing rights and the State of Maine manages these fisheries cooperatively. Traditionally the town owning the rights leases the rights to individual fishermen or hires fishermen to harvest the run for the town.

Fisherman in coastal waters fish for river herring using seines, weirs, gill nets or fish traps. The numbers of commercial fishermen using these gears to target river herring are increasing. The number of active bait gillnet fishermen over the past ten years is 26 individuals. Mesh size restrictions and 24-hour tending regulations at some locations limit fishing effort. There are now five fish traps and three weirs fished in Maine coastal waters. These traps operate continuously, targeting a number of species for bait and other commercial species (squid, Atlantic mackerel, and butterfish). River herring catches in these operations are high and are predominantly juveniles. The trap locations are not located near migratory routes of spawning river herring except for one trap in Cape Elizabeth and a weir in Perry.

Frequently fishermen deploy stop and purse seines to capture bait for the commercial lobster fishery. Stop and purse seine fishermen are opportunistic, intercepting fish when they are located near shore. The target catch includes several species of fish used for bait including river herring. This is one of a number of fisheries directing effort toward targeting juvenile river herring along the Maine coast.

5.9.1 Commercial fisheries

The commercial harvesters are not required to collect biological data from the commercial catches. There is mandatory reporting of annual landings for each commercial fishery operated by a municipality. Funding and personnel limitations do not allow state resource management agencies an opportunity to collect this information. In 2008, MDMR asked all commercial fishermen to voluntarily collect scale samples from the commercial catches to determine the age structure of fish returning to spawn. The majority of commercial fishermen did collect these samples, but there were some fishermen who did not participate. These data are in the Maine Sustainable Harvest Plan provided to the American shad and River Herring Technical Committee. During the preparation of this plan, additional age data from the 1942 report "Restoration and Management of the New England Alewife Fisheries with Special Reference to Maine" by Rounsfell and Stringer (1943) were discovered.
Libby (1982) sampled the commercial alewife fishery at Damariscotta Lake in 1980 and found that the mean total lengths of alewives during that year for both sexes were larger than those observed today at the Brunswick and Sebasticook river fishways (Tables 5.1, 5.2, and 5.3).

The municipal river herring fisheries conducted in Maine rivers are site specific and all of the commercial runs are unique. The harvest methods and local control of these fisheries make comparing the runs difficult. Four municipal commercial runs dominate the commercial landings for the State of Maine. These fisheries occur on small coastal river systems, some with limited spawning and nursery habitat. Despite the unique character of the runs in Maine, commercial catches have declined compared to historical levels of harvest (Figure 5.8)

Damariscotta Lake

The Damariscotta fishery is one of the most studied in Maine. A 150-meter stone pool and chute fishway passes river herring into spawning habitat. The elevation of the 1,781-hectare lake is 16 meters above mean high tide. The efficiency of this fishway varies and it ability to pass larger female river herring was studied by Libby (1981). He concluded the male to female ratio of the commercial catch at the base of the fishway, compared to the ratio of alewives entering the lake favored males and directly relates to the efficiency of the fishway and its length. The ratios of males to females entering the lake were as high a 4:1 during the run.

The commercial fishery occurs at the base of the fishway. Unobstructed upstream passage is available to migrating fish throughout the run. Harvesters trap fish in a side channel that provides supplemental attraction water at the base of the fishway. The commercial fishery operates four days a week throughout the run. The number of fish entering the lake are counted during a ten minute period each hour and expanded to the hours of operation (Figure 5.9)

Damariscotta closed the alewife fishery for eight years after Crecco's assessment of fishing pressure and its affect on the run. The fishery reopened opened in 2001 with limited harvest. Spawning escapement into Damariscotta Lake remains a primary objective of the municipality that manages the fishery.

A recent assessment of the fishway by the U.S. Fish & Wildlife Service indicates the need to modify and/or repair four sections of the fishway. The slope, water velocities, and water depth in some areas of the fishway delay upstream passage. The fishway was built in 1803 and modified several times over the last 200 years. Improving and maintaining escapement into the lake is critical to maintaining the run. Unfortunately, the stone pool and chute fishway is sensitive to water level fluctuations. Abnormal high or low water prevents alewives, especially female alewives, from successfully ascending the fishway.

St. George River

The St. George River fishery is located at head-of-tide in the St. George River. An extensive weir system closes the river to all upstream passage. Harvesters hold live river herring in a trap at the head of the weir prior to sale. The weir operates five days a week and is open 2 days a week to allow upstream passage for spawning fish. Spawning escapement is not monitored, but assumed to be two fifths of the annual run. Due to the expanse of the weir, environmental conditions, especially river flows during the spring, affect the harvest. The weir frequently lifts off bottom and breached due to accumulated debris on the weir mesh.

The St. George run remains one of the most intensively fished runs in Maine (Figure 5.10). Seven ponds within the watershed provide spawning and nursery habitat. The amount of habitat available to alewife increased in 2003 with the construction of a rock ramp fishway at Sennebec Lake. Restoration efforts in the watershed continue. The DMR plans to construct upstream passage into several lakes and ponds in the watershed in the future.

Union River

The Town of Ellsworth maintains the Union River fishery by stocking adult alewives above the hydropower dam at head-of-tide. There is no free passage or upstream fish passage facility required at this hydropower station. The FERC license requires transporting river herring around the dam by Pennsylvania Power and Light, the dam owners. Two lakes support this commercial fishery. The annual stocking rate (from 2011 forward) is 150,000 fish from the commercial run, during the harvest. The Union River is one of three commercially harvested resources with known escapement numbers.

The fishery on the Union River is relatively new and provides a large number of alewives for commercial use, primarily lobster bait (Figure 5.11). The Union River fishery is unique because of known escapement rates. The town can manipulate these rates and correlated them directly to harvest. As with most other directed alewife fisheries in Maine, water flows influence the number of fish that are available to commercial harvesters. This was evident in 2005 when extreme high flows prevented alewives from reaching commercial fishing locations and destroyed commercial fishing gear.

Orland River

The Orland River fishery operates four days a week, allowing a three-day escapement period per week (Figure 5.12). Two Alaska Step Pass fishways provide upstream fish passage. The fishery occurs at head of tide and like most river herring fisheries, high water and fluctuations in flows affect run timing and strength. There is a series of lakes that support the Orland River alewife run, as well as a small blueback herring run.

Ocean, Coastal, and In-river Fisheries

There is little directed effort for river herring in main stem rivers below head of tide but increasing pressure in the coastal zone to catch river herring as bait for the Maine lobster fishery. There are increasing stop seine and trap nets set to target a variety of herring species for lobster bait. These fisheries are opportunistic and not permitted within the municipal boundaries of towns that own river herring harvest rights. These fisheries are required to report landings if they have a permit to harvest Atlantic herring and after January 1, 2011 must purchase a Pelagic License to fish for river herring and meet mandatory reporting requirements. For many years the NMFS and State of Maine landings program attempted to record commercial river herring landings in the Atlantic herring fishery and bait gillnet fishery. However, the State of Maine did not require mandatory reporting for these fisheries prior to 2002 (Tables 5.4, 5.5, 5.6).

5.9.2 Bycatch Losses

The data collected to determine bycatch losses come from Vessel Trip Reports (VTR) required for all federally permitted fishing vessels. The weight of bycatch is often estimated by fishermen and not an accurate weight or number. There is no means to verify these catch weights or determine the amount of under-reporting or misidentification of species reported.

River herring bycatch occurs in all small mesh fisheries conducted along Maine's coast. Bycatch by weight inside Maine territorial waters among the small mesh otter trawl fisheries is low, based on sea-sample data collected from these fisheries in past years and time of year when these fisheries occur (Tables 5.7 and 5.8). These fisheries target whiting and northern shrimp during the fall and winter respectively. Bycatch is limited to juvenile fish and is small compared to the catch numbers of the target species. The mid-water trawls do catch river herring, though there is not enough observer coverage to determine how much, or where, this bycatch occurs. This is a current concern to many researchers trying to rebuild stocks of Alosines.

5.9.3 Recreational Fisheries

The recreational catch of river herring in Maine is low. There are no surveys or mandatory reporting required of recreation fishermen. The MRIP survey does indicate that recreational fishermen fishing for river herring were interviewed fishing for river herring in Maine. Recreations catches were low with high PSE values.

5.10 FISHERY-INDEPENDENT SURVEYS

5.10.1 Adult Catch Data

Fishery independent adult catch data is limited to biological data collected at two state operated fishways and the Maine-New Hampshire Inshore Trawl Survey. State fisheries personnel collect biological samples throughout the run on the Androscoggin and Sebasticook rivers. Data include weight-length, species composition, scale samples, and gonad weights. In addition to biological data, staff collects run counts, trap and transfer numbers, and species community data are collected. Samplers separate species of river herring and sample them separately. Limited data are collected at additional locations to assess changes made to upstream passage facilities. These changes typically occur at fishways that lead to upstream spawning and nursery habitats. Collection of adult catch data occurs for one or two years depending on initial catch data and the need to acquire additional data to assess these changes.

The Maine-New Hampshire Inshore Trawl Survey provides data from the near shore coastal areas of Maine and New Hampshire to the Massachusetts boarder. The trawl survey occurs semi-annually in the spring and in the fall. The survey samples 90 stations randomized over towable bottom within five survey strata.

5.10.2 Age Composition

Collection of age data occurs at fish passage facilities on the Androscoggin and Sebasticook rivers. Data collection started at the newly constructed Lockwood fishway on the main stem Kennebec River in 2005. Staff collects a limited number of samples annually throughout the duration of these river herring runs.

5.10.3 Androscoggin River

Androscoggin River alewife age data exists for most years from 1983 through 2010. The anadromous fish restoration program on the Androscoggin River began in 1983 when Central Maine Power Company constructed upstream fish passage at the head-of-tide. The age structure of returning adult alewives does not appear to change significantly between years. Data collected during the early years of the restoration project are similar to data collected for the past three-year period (Table 5.9).

There is no commercial fishery conducted in the Androscoggin River except occasional gill net fishing below the head of tide. However, there are a number of hydropower dams between head-of-tide and spawning and nursery habitat. Three hydropower dams exist on the main stem Androscoggin River and four on the Little Androscoggin River. The role these hydropower stations have on the age structure is unknown, though assumed to significantly impact survival of downstream adult migration.

5.10.4 Sebasticook River

The Sebasticook River is a major tributary to the Kennebec River that historically produced large runs of anadromous fish. Removal of Edwards' Dam at the head-of-tide in Augusta, Maine, in 1999, opened several miles of river to free passage for all anadromous fish species. After removal of Edwards, the Ft. Halifax Dam, located on the Sebasticook River, became an obstacle to upstream passage. Trap and transfer operations moved from Edwards Dam to Ft. Halifax. For a short period, an intense river herring fishery existed below the Ft. Halifax Dam. The fishery peaked in 2005 with several thousand fish harvested, but much of this harvest was unrecorded. The affect of this harvest is apparent in the ages of alewife sampled in 2003 (Table 5.10)

Biological sampling began at Ft. Halifax in 2000. Like the Androscoggin biological data collection, these biological data are a mix of several different stocks of alewives that use the Sebasticook River to access spawning habitat upstream. When fisheries staff collects biological samples, the stock of origin is unknown. These data do provide a reasonable estimate of some biological parameters but may not be representative of a particular run or stock. The dam owner removed Fort Halifax dam in 2008 instead of building a fishway. The Benton Falls hydropower dam located 6 miles upstream of the Fort Halifax site is now the first barrier on the river. There is fish passage at Benton and Burnham that provide upstream passage into a number of spawning habitats.

5.10.5 Juvenile Catch Data

The State of Maine conducts an annual juvenile alosine survey for six Maine rivers including Merrymeeting Bay. This survey samples for all juvenile alosines managed by the state resource agencies. The survey began in 1979, covering 17 fixed stations as well as data from a separate juvenile striped bass survey designed to assess the numbers of juvenile striped bass in the lower Kennebec River. The Juvenile Alosine Survey for the Kennebec/Androscoggin estuary monitors the abundance of juvenile alosines at 14 permanent sampling sites. Four sites are on the upper Kennebec River, three on the Androscoggin River, four on Merrymeeting Bay, one each on the Cathance, Abadagasset, and Eastern rivers. These sites are in the tidal freshwater portion of the estuary. Since 1994, MDMR added six additional sites in the lower salinity-stratified portion of the Kennebec River.

The sampling protocol for all stations is similar to that used in the juvenile shad-sampling program on the Connecticut River. Field staff samples each site once every other week from July to the end of September. The goal is to sample each site six times during the season. Field staff collects samples with a beach seine within three hours of high slack water. The seine is made of 6.35 mm stretch mesh nylon, measures 17 m long and 1.8m deep with a 1.8 m x 1.8 m bag at its center. One person holds an end of the seine stationary at the land/water interface, and the boat operator tows the opposite end perpendicular to shore. After the net fully extends, the boat operator tows the seine in an upriver arc and pulls the net ashore. The net samples an area of approximately 220 m^2. Staff sort and process the catch in the field.

The number of adult blueback herring spawning in Maine rivers is difficult to assess. These fish are limited to the main stems of rivers below the first upstream obstruction, typically a dam. Although some dams do have upstream passage facilities, blueback herring are reluctant to use these passages. Blueback herring rarely use the Brunswick fishway, though fishway staff observes large numbers of blueback herring spawning directly below the fishway in the tailrace.

The survey does not do as good a job of indicting the spawning success of alewife. Little if any spawning occurs in Merrymeeting Bay or the lower portion of Maine tidal rivers. Alewives are likely captured in the bay as they rest and feed along their downstream migration routes. A number of environmental factors may influence number of alewives in the bay at a given time. High water levels that facilitate downstream passage and colder water temperatures, believed to trigger downstream migration, may increase the number of juveniles in the bay at a given time.

5.11 ASSESSMENT APPROACH(S) AND RESULTS

Little formal assessment of any of Maine's river herring resources have occurred during the past several decades. Crecco and Gibson (1990) did conduct a formal assessment of the Damariscotta Lake run and indicated that the run was severely over fished. Crecco used the Shepherd Stock Recruitment model to estimate maximum sustainable yield, annual fishing rate at MSY, and project harvest levels that would cause collapse of the fishery. Crecco concluded that the Damariscotta run was harvested at levels that indicated stock recruitment failure was apparent.

Maine and ASMFC fisheries staff completed a comprehensive, though less detailed, assessment of several Maine river herring runs in 2010 to meet the Amendment 2 to the American Shad and River Herring Plan. These analyzes used a number of biological datasets, harvest rates, and escapement rates to estimate population size and composition for each commercial and some non-commercial river herring runs in Maine. For most commercial fisheries the biological datasets are short, beginning in 2008 through the present. Reported harvest and estimated escapement provide a longer time series of data, many runs having data through the 1950s.

5.11.1 Spawning Stock

Data from adult fisheries independent surveys indicate that the number and weights of alewife are trending upward or are stable for the past several years (Figures 5.13 and 5.14). The trends of blueback herring in the survey indicate variable catch numbers and catch weights during the past several years with no apparent trend (Figures 5.15 and 5.16).

5.11.2 Trends in Age

Analysis of river herring scale samples collected from the Androscoggin and Sebasticook rivers indicates that returning fish are 4-6 years old. The numbers of river herring older than six years represent a small proportion of the adults sampled. This is an apparent shift in the age structure for all Maine river herring runs, commercial and non-commercial from the mid 1980s, but similar to length data collected in the 1940s. Scale samples collected from 15 commercial fisheries in 2008 had few river herring over 6 years of age. While commercial catches in the 1980s commonly had fish as old as 8 years of age.

5.11.3 Juvenile Stock

Results of the annual juvenile alosine survey indicate that annual production of alewife and blueback herring within the sample area and migration timing through the sites vary widely year-to-year (Tables

5.11 and 5.12; Figures 5.17 and 5.18). Prior to 1992, the number of blueback herring captured were low and sporadic, occurring only occasionally during the sample season. The survey time series for both species does indicate a stable or slightly increasing population. The juvenile survey results are a better indication of annual blueback herring spawning success.

5.12 BENCHMARKS

There are no previous benchmarks established for the Maine river herring fisheries other than Crecco's estimation of Z (3.22), u (0.891), and F (2.20) for the Damariscotta fishery in the 1970s. Estimates of Z for most of the river herring fisheries are not as high as the value Crecco observed in the 1970s.

5.12.1 Total Mortality

Prior to 2008, limited biological data was collected from the Maine municipal river herring fisheries. Researchers collected data during studies conducted at Damariscotta Lake in the late 1970s. Currently DMR staff collects age data on the Androscoggin and Sebasticook rivers during monitoring of upstream fish passage. These data calculate the total mortality (Z) for alewife runs from these rivers, with total mortality calculated separately by sex for each year and river system.

Since the inception of Amendment 2 in 2008, commercial river herring fisherman began collecting scale samples from catches of river herring returning to natal rivers to spawn. These samples provide a basis to estimate total mortality of the runs fished in Maine. Fisherman continue to collect scale samples under the direction of the DMR.

Several methods to estimate Z were explored, including Catch Curve, Heinecke, and Chapman-Robson. Each of these has advantages when working with limited data sets. The Catch Curve was most restrictive, needing a number of age-classes in order to conduct the analysis. The Chapman-Robson method address biases present in the Catch Curve analysis.

Age data analyzed from scale samples collected since the inception of the Sebasticook River run reflect, in part, the high fishing pressure exerted on this population from 2002 through 2005 (Figure 5.19, Figure 5.20) Fishing regulations allowed unrestricted access to these fisheries resources. DMR assumed management of this resource from the Department of Inland Fisheries and Wildlife in 2007. Commercial fishing started in 2009 on the Sebasticook River after fishing rights transferred to the Town of Benton. The annual mortality estimates for males and females differ. The reasons for these differences are not clear. The Sebasticook River is a source of broodstock for a number of restoration projects east of the Kennebec River. The Sebasticook River run ranges between 1.5 and 2.5 million fish annually.

The age data presented in this analysis are from scale samples collected at the Brunswick Fishway since it opened in 1983. Much of the raw data are no longer available for analysis, but any data available contributed in calculating the Z-estimates (Figures 5.21 and 5.22). Trend lines fitted to the male Z-estimates were flat for the years data were available and the Z-estimates for females indicated a slight downward trend. The Androscoggin River alewife run is small compared to the Sebasticook Run. The yearly run averages 46,000 individuals. There is not a commercial fishery on the Androscoggin River, except a limited gill net fishery in the lower river below the dam.

Z-estimates calculated using the Beverton-Holt model were compared to the Catch-Curve, Heinke, and Chapman-Robson models. The Beverton-Holt trends were the same for the Androscoggin and Sebasticook rivers, however, they indicated an increasing Z-estimates for both sexes of alewives for the period 2000 – 2101 (Figures 5.23 and 5.24).

Starting in 2008, DMR requested that commercial harvesters collect scale samples from commercial and non-commercial river herring runs along the Maine coast. Harvesters collected scale samples from 15 runs. Fishing is active on some runs, while others are closed for conservation or were not fished within the past five years. The DMR asked harvesters to collect samples from 25 fish every week during the duration of the run. Most harvesters fishing commercial runs were able to provide the number of scale samples requested. Commercial harvesters also volunteered to provide coverage at locations that are temporarily closed or have been closed for several years. The number of scale samples collected from runs that are temporarily closed, or closed for more than five years, were typically less than the number requested (Table 5.13).

Calculation of total mortality estimates occurred for all runs regardless of the number of samples collected. All sample locations that had corresponding sex data are included in the combined Z-estimates in each figure. Heinke and Chapman-Robson methods were used to obtain Z-estimates. We used these methods because of the limitations of the number of age data classes that the Catch-Curve method requires for the analysis (Figures 5.25, 5.26, 5.27, and 5.28).

5.13 CONCLUSIONS AND RECOMMENDATIONS

Maine commercial river herring landings are down when compared to levels of reported harvest in the 1950s though commercial river herring landings are not an accurate measure of Maine's current river herring stocks. The majority of the river herring fisheries in Maine are closed to directed commercial harvest as a conservation measure. River herring in nine of the state's ten largest rivers are not exploited by commercial fishermen above the head-of-tide. Limited numbers of gill net fishermen fish below the head of tide and report low landings due to current gill net regulations. The DMR does not assess these populations, but expects that they are larger than all directed commercial landings combined.

The directed commercial fisheries at some locations have declined but the causes for the declining landings are not clear. These declines are likely the cause of a number of factors including bycatch, habitat degradation, predation, and lack of adequate upstream and downstream fish passage. Some of the same trends appear at locations where the stock is not commercially fished does not occur. Several directed fisheries continue to maintain self-sustaining fisheries for river specific stocks.

Bycatch of juvenile river herring in coastal waters appears to have increased during the past several years. This increase in catch is a combination of directed river herring in the coastal areas and bycatch in other small mesh fisheries inside and outside three-miles of Maine's coast. Bycatch and directed river herring landings are self-reported and may not accurately reflect the number river herring captured or discarded. In 2011, a commercial fishing license is required for anyone who fishes for any pelagic species using any gear type. This license will create a database of small mesh gear fisherman for a proposed bycatch sampling program in Maine coastal waters. The bycatch sampling program will focus on Alosines, alewife, blueback herring, and American shad captured as bycatch in the Atlantic herring, Atlantic Mackerel, and Atlantic menhaden fishery.

The DMR maintains a number of non-commercial runs through stocking while the state resource agencies pursue upstream and downstream passage into historic spawning habitats. None of the directed fisheries are stocked with spawning fish and all are expected to maintain self-sustaining populations. Management of directed river herring fisheries in Maine incorporate management actions to conserve populations of spawning fish through gear restrictions, closed seasons, and fishing area closures. These management actions are enforced though the Maine Marine Patrol and law enforcement action at the local level. Management plans exist for all municipally owned directed fisheries, each approved by DMR.

During the 2010 fishing season fisheries staff monitored the majority of the direct fisheries and collected biological data from these runs. These data provide information for a comprehensive stock assessment for runs that are actively fish and affected by directed fishing effort. Biological data collection is difficult because of the geographic area over which these fisheries occur, the number of fishing locations and limited personnel resources. Increased sampling is important to effectively manage the existing resources and assess the effectiveness of current management actions.

The limited data that are available indicate that the current population of river herring in Maine is stable at current level or in some instances increasing. Mortality estimates for the Androscoggin and Sebasticook rivers are lower than those calculated by Crecco in the 1980s. Juvenile index survey data indicate increasing populations of blueback and alewife in Merrymeeting Bay. Analysis of mean length and weight data indicate variable trends in weights and lengths at those locations where sampling does occur.

5.13.1 Recommendations

1. Increase sampling of stock specific runs that support directed commercial fisheries.
2. Increase upstream and downstream fish passage into historical spawning and nursery habitats.
3. Quantify bycatch of river herring in ocean fisheries, especially within three miles of the coast.

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Table 5.1 Mean Total Lengths of Fishery Dependent Catches at the Damariscotta Fishway

Date	Number Sampled	Mean Total Length (mm)			
		Males	SE	Females	SE
5/6/1980	50	305.5	1.7	316.2	2.2
5/8/1980	50	300.4	1.8	316.6	1.6
5/12/1980	50	305.2	1.7	310.2	2.0
5/14/1980	50	304.1	1.6	315.4	2.3
5/16/1980	37	304.4	1.6	312.9	2.2
5/18/1980	50	301.6	1.8	308.5	1.6
5/20/1980	50	299.9	1.5	311.0	1.4
5/22/1980	50	302.0	1.4	309.0	1.8
5/24/1980	50	292.7	1.8	302.0	1.7
5/26/1980	50	299.3	1.5	308.3	1.8
5/28/1980	50	296.3	1.7	305.9	2.5
5/30/1980	50	295.7	1.7	304.2	1.8
6/1/1980	45	298.0	1.9	307.7	2.2
6/3/1980	44	293.4	2.2	307.2	2.3
6/5/1980	35	299.0	2.7	305.3	2.4

Table 5.2 Mean Total Lengths of Fishery Independent Catches at the Brunswick Fishway.

Date	Number Sampled	Mean Total Length (mm)			
		Males	SE	Females	SE
5/13/2008	50	268.1		287.1	
5/17/2008	50	270.6		281.4	
5/21/2008	50	256.0		267.7	
6/4/2008	50	267.9		279.0	

Table 5.3 Mean Total Lengths of Fishery Independent Catches at the Sebasticook Fishway.

Date	Number Sampled	Mean Total Length (mm)			
		Males	SE	Females	SE
5/9/2007	100	282.1		290.2	
5/13/2007	100	267.5		280.9	
5/14/2007	100	277.2		281.5	
5/16/2007	100	278.9		282.6	
5/21/2007	100	276.6		287.4	
5/24/2007	100	273.8		278.6	
5/26/2007	100	265.3		274.4	
5/28/2007	100	271.7		277.8	
6/6/2007	98	255.3		266.2	

Table 5.4 Combined Direct and Non-Direct Ocean, Coastal, In-River Alewife Harvest.

Ocean / Coastal Commercial Harvest (Kg)

	Gill net			Weir			Pound/Trap net		
	N	Total weight	Mean weight	N	Total weight	Mean weight	N	Total weight	Mean weight
2002	22	1,886.9	85.8	1.0	4.5	10.0		0	
2003	22	2,753.8	125.2		0.0		2	23	11.3
2004	30	5,599.4	186.6	1.0	9,922.5	9,922.5	5	68	13.5
2005	32	1,193.9	37.3	12.0	1,579.5	131.6		0	
2006	20	591.3	29.6	1.0	9,450.0	9,450.0	30	3,771	125.7
2007	30	253.6	8.5	1.0	0.0	0.0	1	3	3.2
2008	56	66.2	1.2		0.0		20	3,464	173.2
2009	37	616.5	16.7		0.0		36	4,526	125.7
2010*									

*preliminary data

	Unknown Gear Type			Other Gear(cast net, dip net)			Total		
	N	Total weight	Mean weight	N	Total weight	Mean weight	N	Total weight	Mean weight
2002		9			0.0			1,900	
2003		149			0.0			2,925	
2004		106		6.0	249.8	92.5		15,945	
2005		35			0.0			2,808	
2006		62		14.0	252.9	40.1		14,127	
2007		81			0.0			4,349	
2008		0		33.0	5,724.0	173.5		9,254	
2009		0		1.0	315.0	700.0		5,457	
2010*									

*preliminary data

Table 5.5 Direct and Non-Direct Ocean / Coastal Blueback Herring Harvest.

Blueback Herring Ocean / Coastal Commercial Harvest (Kg)

	Gill net			Weir			Pound/Trap net		
	N	Total weight	Mean weight	N	Total weight	Mean weight	N	Total weight	Mean weight
2002	22.0	0	0	5	450	90	5	275	55
2003	22.0	203	9				30	1,024	34
2004	30.0	135	5				12	464	39
2005	32.0	101	3				20	662	33
2006	20.0	149	7				16	640	40
2007	30.0	596	20	6	262	44	23	3,066	133
2008	56.0	2,091	37	3	1,329	443	18	195	11
2009	37.0	435	12	2	124	62	38	6,590	173
2010*							26	11,764	452

	Otter Trawl			Other Gear(cast net, dip net)			Total		
	N	Total weight	Mean weight	N	Total weight	Mean weight	N	Total weight	Mean weight
2002	3	203	68		295			1,220	
2003		0						1,226	
2004		0						5,099	
2005		0						764	
2006	3	2,093	698		2,109			4,974	
2007								80,018	
2008								7,983	
2009								15,822	
2010*								11,912	

*preliminary data

Table 5.6 Bait Gill Net Permit Holders and Active Participants.

Bait Gill Net Fishery

	Permit Holders	Active Permits	Number of Nets	Sq. Yards of Net	Hours Fished
2002	92	22	unknown	unknown	unlimited
2003	340	22	unknown	unknown	unlimited
2004	286	30	unknown	unknown	unlimited
2005	284	32	unknown	unknown	unlimited
2006	258	20	unknown	unknown	unlimited
2007	299	30	unknown	unknown	unlimited
2008	370	56	unknown	unknown	unlimited
2009	378	37	unknown	unknown	unlimited
2010	428	-	unknown	unknown	unlimited

Table 5.7 Alewife Bycatch Maine Otter Trawl Fisheries.

Alewife Bycatch in Otter Trawl Fisheries (VTR data)			
Year	Total Effort Effort (hours fished)	Total Catch Reported (Kg)	CPUE hours fished
2002	52	9	0.2
2003	200	150	0.7
2004	228	107	0.5
2005	195	35	0.2
2006	242	62	0.3
2007	305	81	0.3
2008	108	41	0.4
2009	165	41	0.2
2010*	136	24	0.2

* Preliminary data

Table 5.8 Blueback Herring Bycatch Maine Otter Trawl Fisheries.

Blueback Herring Bycatch in Otter Trawl Fisheries (VTR data)			
Year	Total Effort (hours fished)	Total Catch Reported (Kg)	CPUE (hours fished)
2002	3	293	250.0
2003	-	-	-
2004	-	-	-
2005	3	1	0.8
2006	6	2,093	775.0
2007	-	-	-
2008	-	-	-
2009	-	-	-
2010*	-	-	-

*Preliminary data

Table 5.9 Alewife Age Structure from Samples Collected at the Brunswick Fishway.

	Androscoggin River - Brunswick Fishway											
	2010		2009		2008		1995		1994		1993	
	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females
Age 3	30	10	6	3	38	10	3	2	0	0	33	6
Age 4	61	38	51	29	58	35	36	38	48	45	19	12
Age 5	18	17	52	34	26	21	6	26	25	20	14	7
Age 6	2	4	15	6	5	7	0	11	1	2	4	7
Age 7	0	0	1	3	0	0	0	0	0	1	1	1

Table 5.10 Alewife Age Structure from Samples Collected at the Ft. Halifax and Benton Fishways.

Sebasticook River - Benton and Ft. Halifax Fishways

	2010		2009		2008		2003		2002		2001	
	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females
Age 3	10	8	2	0	4	0	42	34	21	15	6	0
Age 4	19	32	42	27	21	15	20	26	65	53	65	44
Age 5	10	13	10	26	15	10	8	11	29	28	21	10
Age 6	0	2	1	0	0	2	0	0	6	4	3	2
Age 7	0	0	0	0	0	0	0	0	0	0	2	0

Table 5.11 Juvenile Alosine Survey - Alewife.

Alewife

			Arithmetic Mean		Geometric Mean		
Year	**Sample Size**	**Total Catch**	**Mean**	**SE**	**Mean**	**LCI**	**UCI**
1979	9	197	21.89	14.05	4.51	0.64	17.50
1980	27	338	12.52	6.56	1.64	0.48	3.70
1981	31	153	4.94	2.95	0.74	0.17	1.59
1982	20	137	6.85	5.72	0.90	0.12	2.22
1983	70	5309	75.84	39.97	3.18	1.53	5.91
1984	65	696	10.71	5.31	0.94	0.40	1.70
1985	58	287	4.95	2.38	0.89	0.40	1.55
1986	74	404	5.46	1.52	1.43	0.84	2.21
1987	79	1294	16.38	5.38	2.33	1.33	3.74
1988	112	2200	19.64	8.47	2.11	1.33	3.16
1989	103	1741	16.90	4.40	2.46	1.51	3.76
1990	100	2047	20.47	9.07	1.57	0.90	2.49
1991	86	3979	46.27	27.32	2.40	1.34	3.94
1992	79	3123	39.53	15.05	2.85	1.57	4.78
1993	76	1386	18.24	6.12	2.16	1.17	3.60
1994	93	667	7.17	1.70	1.80	1.16	2.63
1995	110	3351	30.46	8.54	4.43	2.89	6.56
1996	89	1150	12.92	4.37	1.38	0.75	2.22
1997	110	1754	15.95	5.50	1.79	1.10	2.72
1998	112	1565	13.97	9.45	1.04	0.60	1.60
1999	108	4325	40.05	13.96	2.44	1.44	3.87
2000	111	20885	188.15	53.83	5.64	3.30	9.25
2001	129	2344	18.17	5.36	1.47	0.88	2.24
2002	127	1430	11.26	2.94	1.75	1.14	2.54
2003	114	4664	40.91	16.29	2.34	1.42	3.62
2004	105	2769	26.37	7.71	3.45	2.18	5.22
2005	112	1238	11.05	3.45	1.17	0.67	1.82
2006	110	3795	34.50	11.83	1.88	1.06	3.03
2007	113	1211	10.72	3.41	1.24	0.72	1.92
2008	96	1,304	13.58	4.57	1.31	0.73	2.09
2009	111	847	7.63	2.08	1.38	0.86	2.05

Table 5.12 Juvenile Alosine Survey – Blueback Herring

Blueback Herring

			Arithmetic		Geometric		
Year	**Sample Size**	**Total Catch**	**Mean**	**SE**	**Mean**	**LCI**	**UCI**
1979	9	0	0.00	0.00	0.00	0.00	0.00
1980	27	1	0.04	0.04	0.01	-0.02	0.03
1981	31	31	1.00	0.50	0.08	-0.06	0.25
1982	20	0	0.00	0.00	0.00	0.00	0.00
1983	70	0	0.00	0.00	0.00	0.00	0.00
1984	65	0	0.00	0.00	0.00	0.00	0.00
1985	58	0	0.00	0.00	0.00	0.00	0.00
1986	74	0	0.00	0.00	0.00	0.00	0.00
1987	79	25	0.32	0.26	0.05	-0.02	0.13
1988	112	13	0.12	0.10	0.03	-0.02	0.08
1989	103	9	0.09	0.07	0.03	-0.01	0.07
1990	100	4	0.04	0.03	0.02	-0.01	0.05
1991	86	0	0.00	0.00	0.00	0.00	0.00
1992	79	1079	13.66	7.48	0.58	0.20	1.09
1993	76	47	0.62	0.62	0.05	-0.05	0.16
1994	98	289	2.95	1.32	0.38	0.15	0.66
1995	110	1402	12.75	3.18	1.99	1.23	3.01
1996	93	620	6.67	5.93	0.30	0.09	0.55
1997	110	598	5.44	3.79	0.49	0.24	0.79
1998	112	562	5.02	2.07	0.69	0.38	1.08
1999	108	982	9.09	3.50	0.73	0.35	1.21
2000	111	1086	9.78	9.46	0.15	-0.01	0.32
2001	129	273	2.12	0.90	0.30	0.13	0.50
2002	127	1489	11.72	4.22	1.00	0.56	1.56
2003	114	1697	14.89	7.79	0.90	0.47	1.44
2004	105	3020	28.76	8.33	1.69	0.91	2.80
2005	112	1526	13.63	5.71	0.65	0.29	1.11
2006	110	2541	23.10	14.86	0.68	0.30	1.16
2007	113	1218	10.78	7.80	0.48	0.21	0.82
2008	96	244	2.54	1.31	0.40	0.18	0.67
2009	111	66	0.69	0.37	0.15	0.05	0.27

Table 5.13 Alewife Run Locations Where Commercial Harvesters Collected Scales for Aging in 2008 vs. 2010.

Run Location (East - West)	Commercial Fishery	2008	2010
Saco River	N		X
Presumpscot River	N		X
Winnegance Lake	Y		X
Dresden Mills	Y	X	X
Sewall Pond	N	X	X
Nequassett Lake	y	X	X
Androscoggin	N	X	X
Vassalboro	Y		X
Benton	Y		X
Sheepscot River	Y		X
Dryer River	Y		X
Damariscotta River	Y		X
Medomak River	N		X
Warren	Y		X
Souadabscook River	N		X
Orland	Y		X
Union River	Y		X
Mount Desert Island	N		X
Grist Mill Stream	Y	X	X
Flanders Stream	Y	X	
Patten Pond	Y	X	X
Card Mill Stream	N	X	
Gouldsboro	Y	X	X
Cherryfield	Y		X
East Machias	Y		X
Dennysville	N		X
Pembroke	Y		X
Perry	Y		X

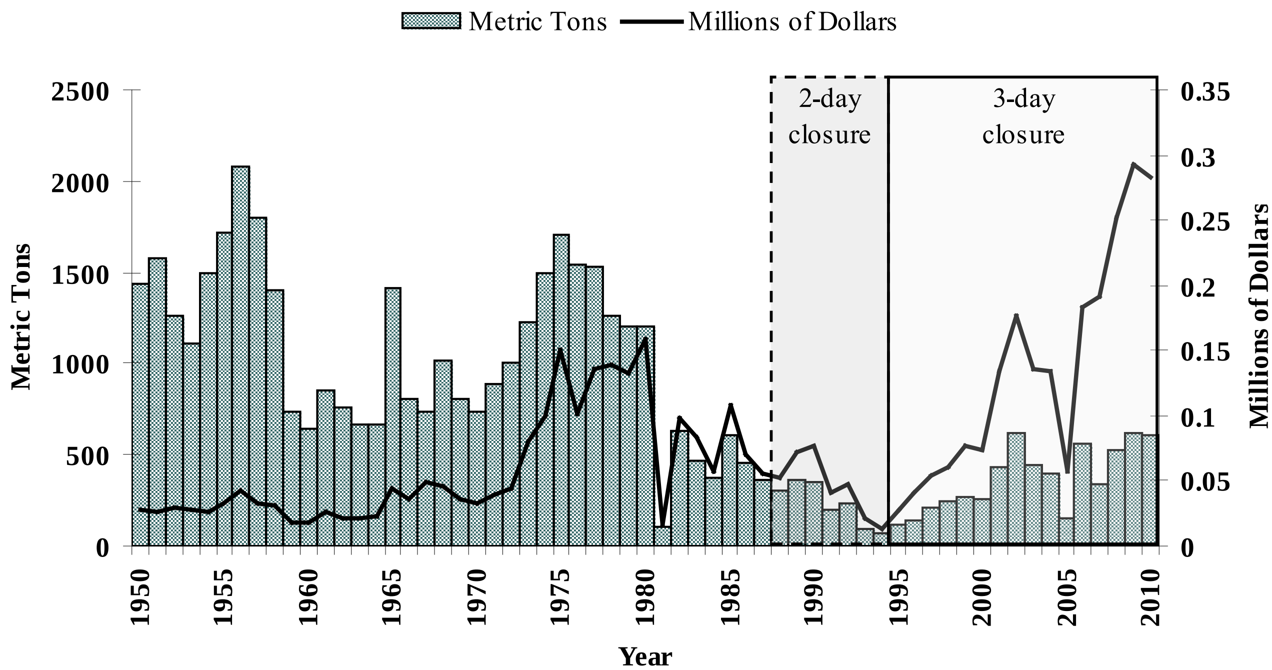

Figure 5.1 State of Maine Alewife Landings.

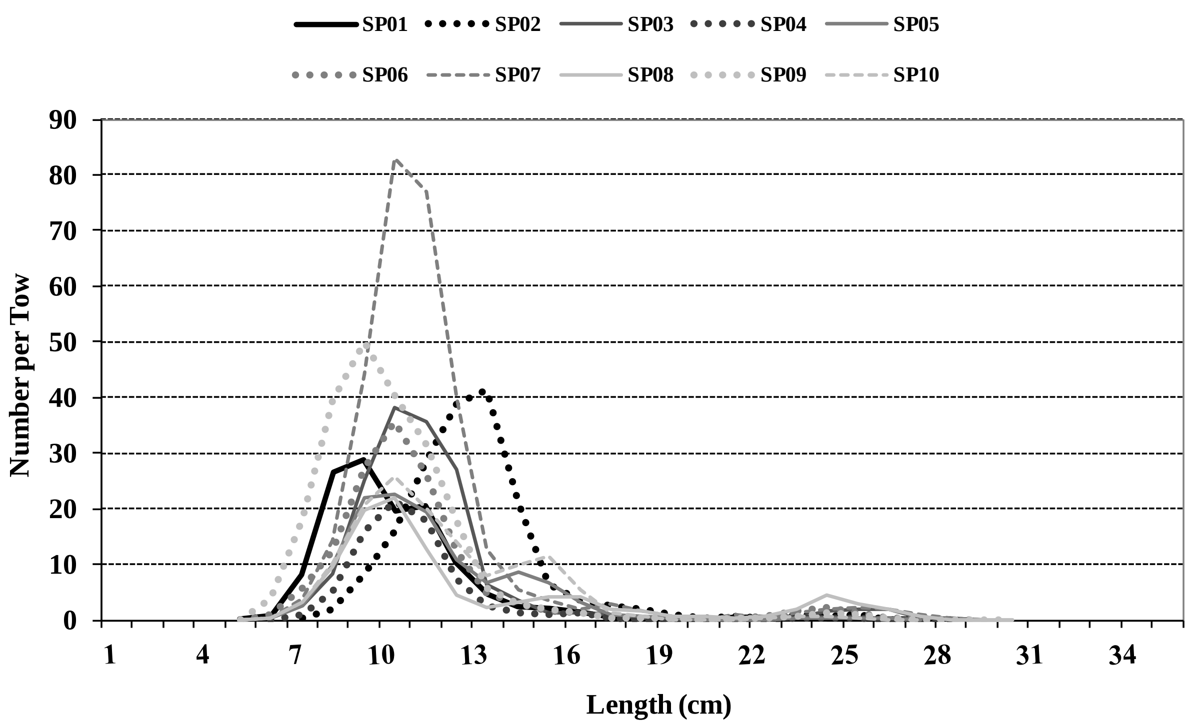

Figure 5.2 Length Frequency of Alewife Captured During the 2001 – 2010 Spring Inshore Trawl Survey.

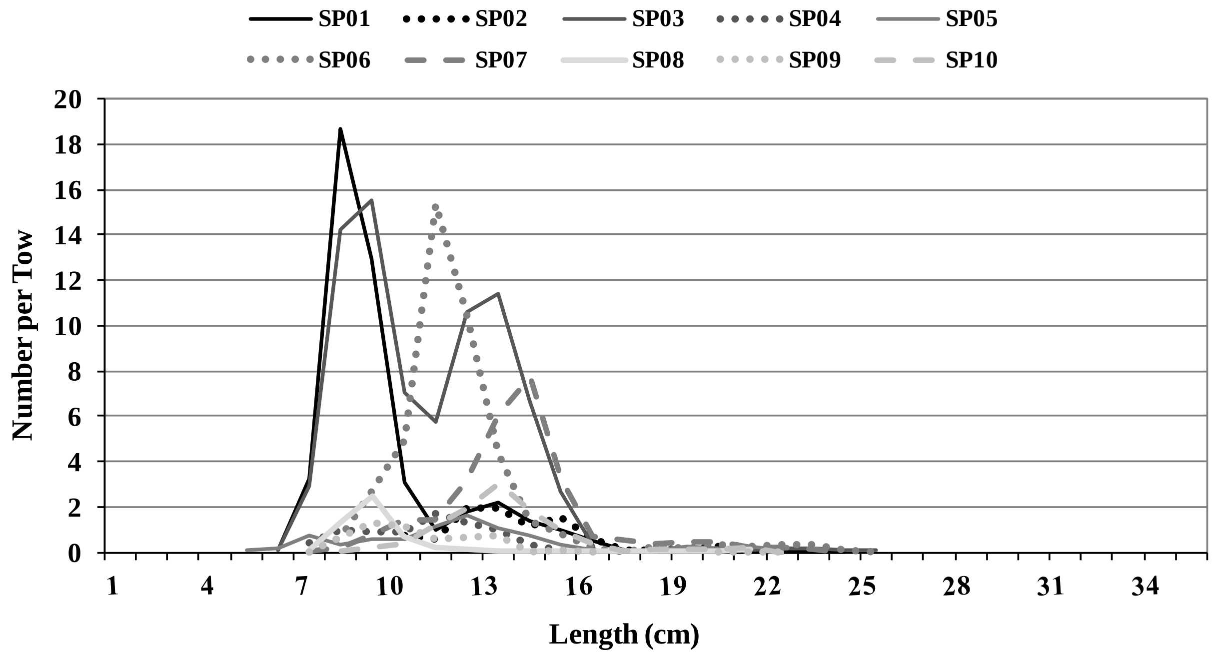

Figure 5.3 Length Frequency of Blueback Herring Captured During the 2001 – 2010 Maine-New Hampshire Spring Trawl Survey.

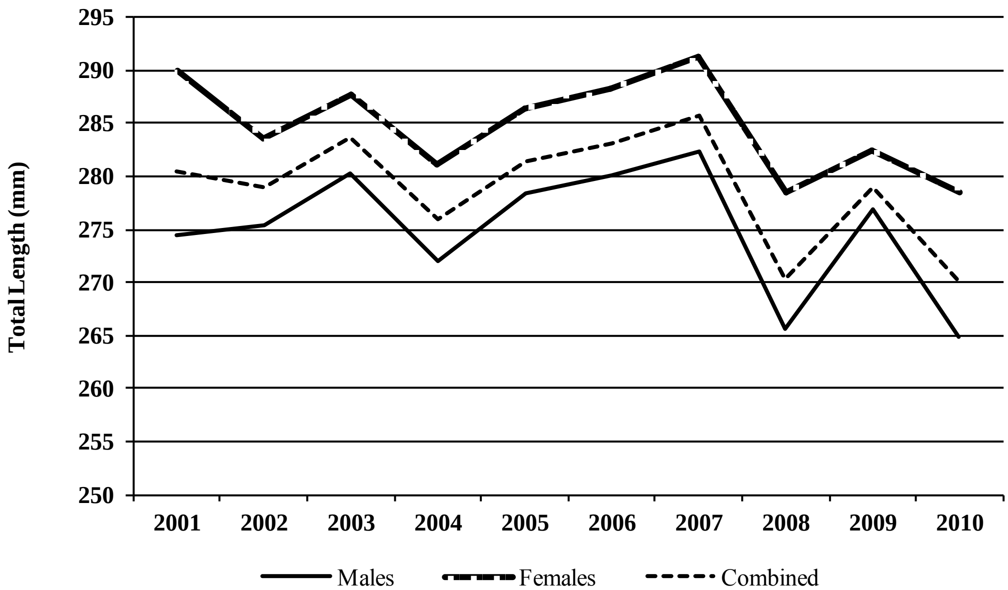

Figure 5.4 Mean Total Lengths of Alewives Sampled at the Brunswick Fishway.

Figure 5.5 Mean Total Lengths of Alewives Sampled at the Sebasticook Fishway.

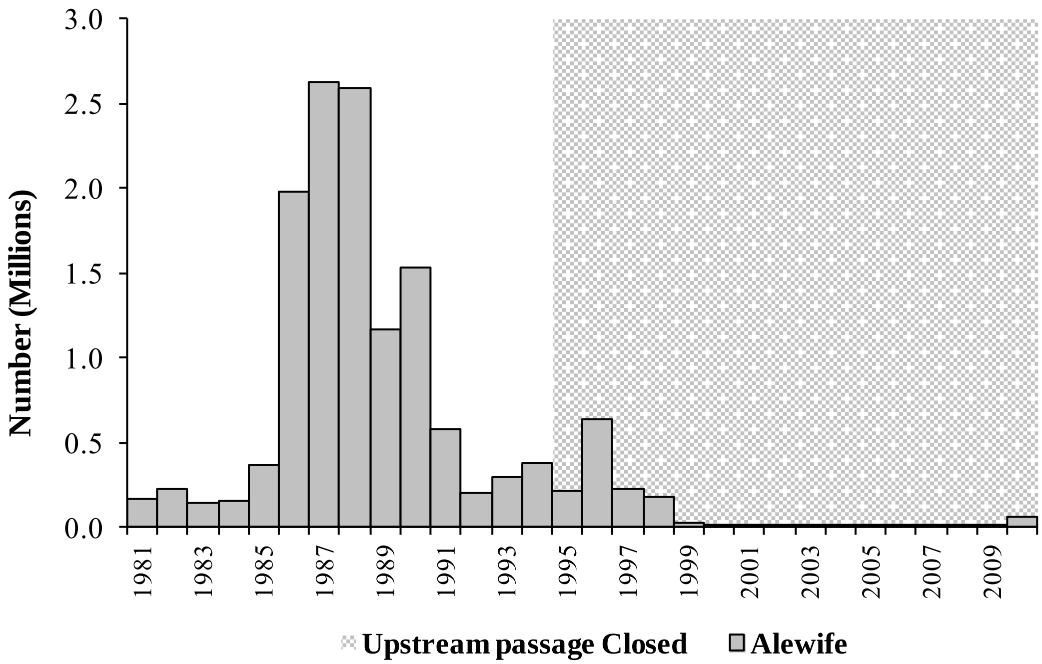

Figure 5.6 Number of river herring counted at Milltown Fishway on the St. Croix River from 1981-2010.

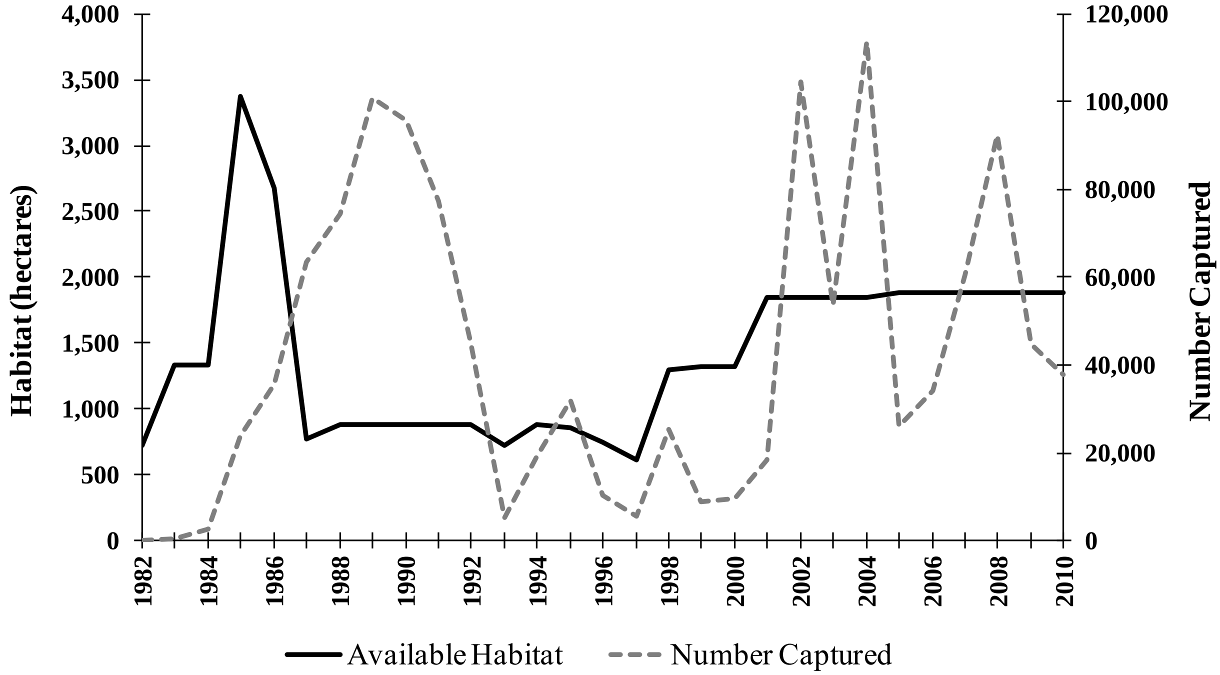

Figure 5.7 Adult River Herring Run Size and Habitat Availability - Androscoggin River Watershed, 1982-2010.

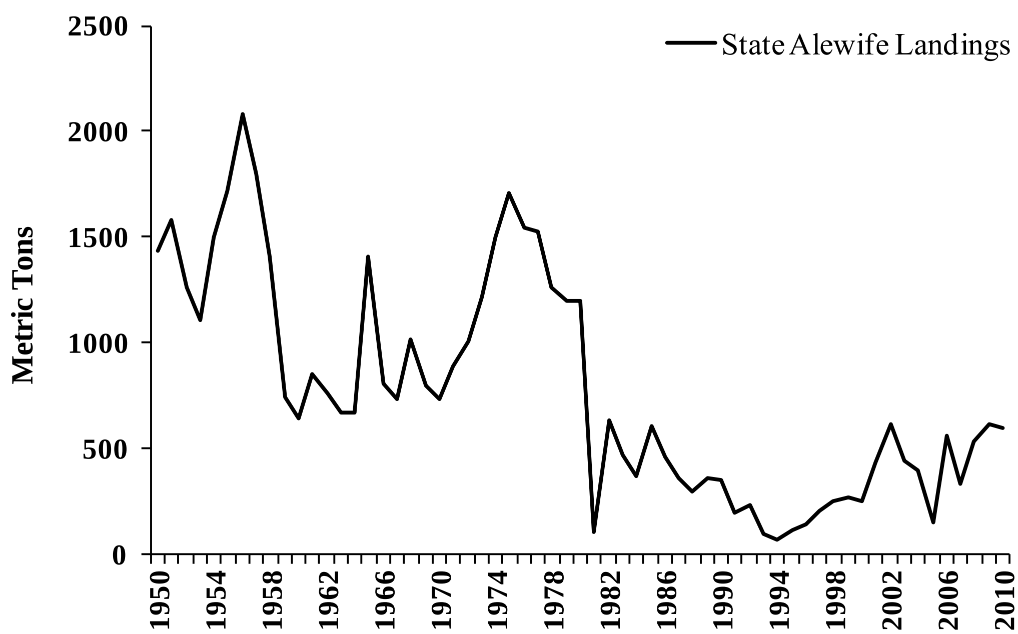

Figure 5.8 Maine Commercial Alewife Harvest.

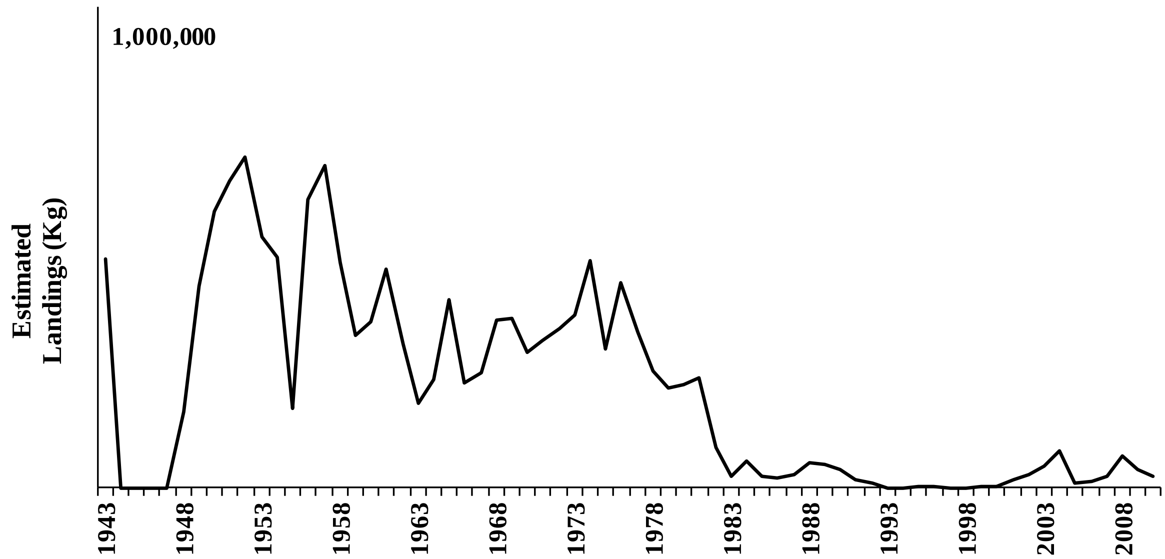

Figure 5.9 Damariscotta Lake Alewife Harvest – Commercial Catches

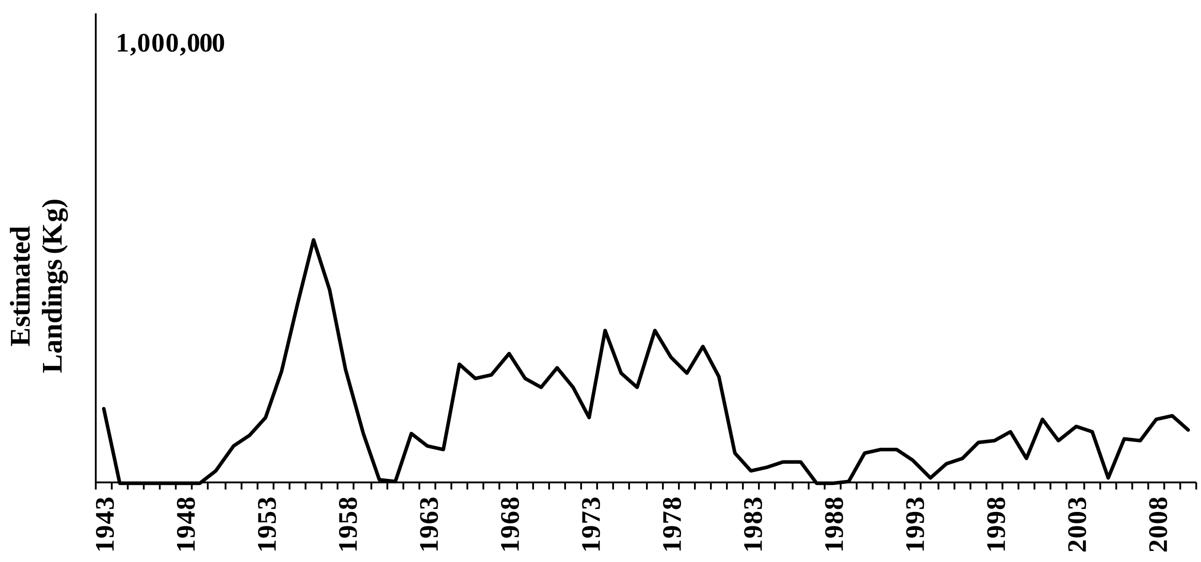

Figure 5.10 St. George Commercial Alewife Harvest

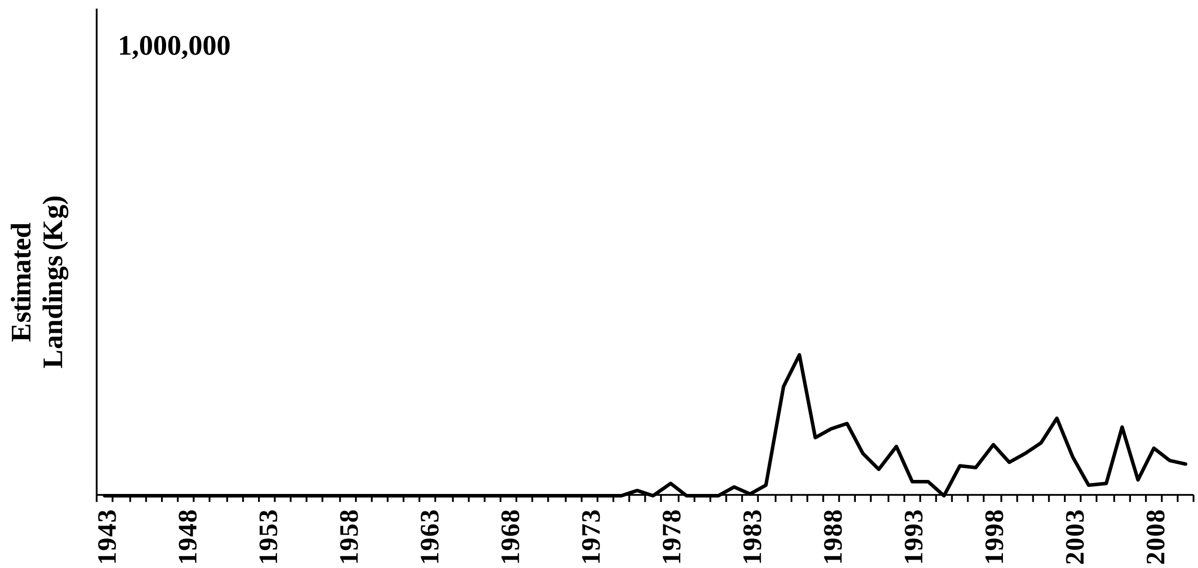

Figure 5.11 Union River Alewife Harvest

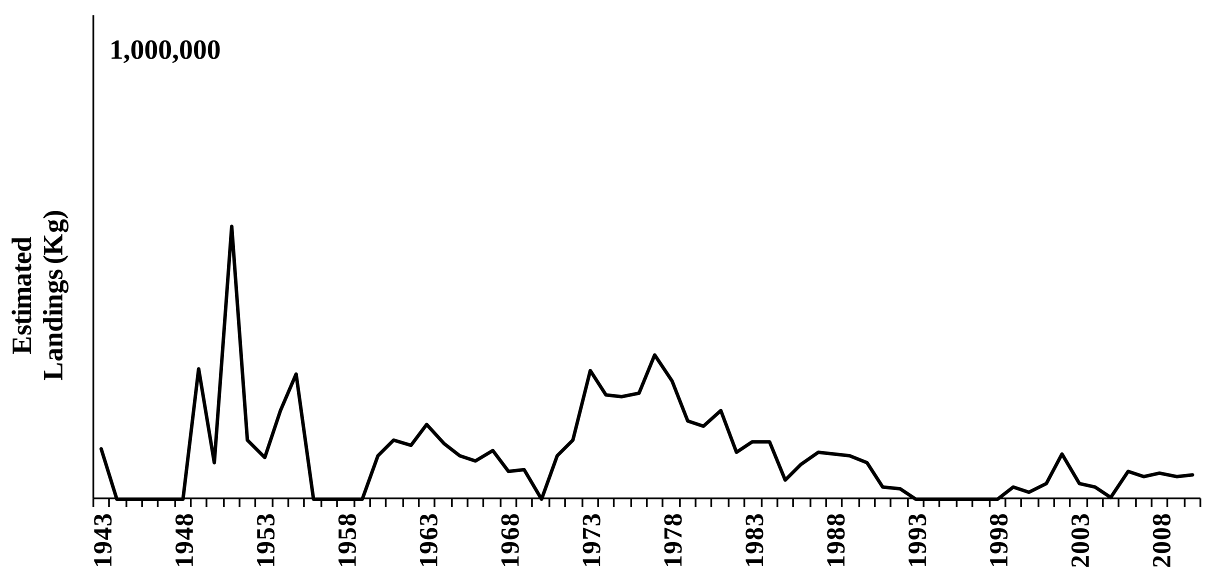

Figure 5.12 Orland Commercial Alewife Harvest

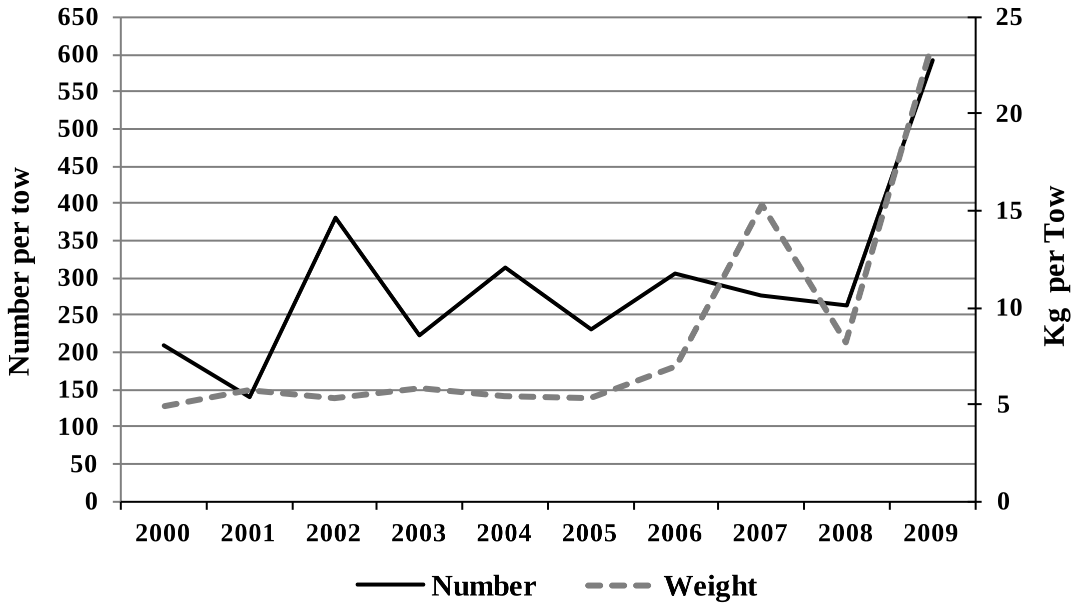

Figure 5.13 Total Number and Weight of Alewife Captured During the Fall Maine-New Hampshire Trawl Survey.

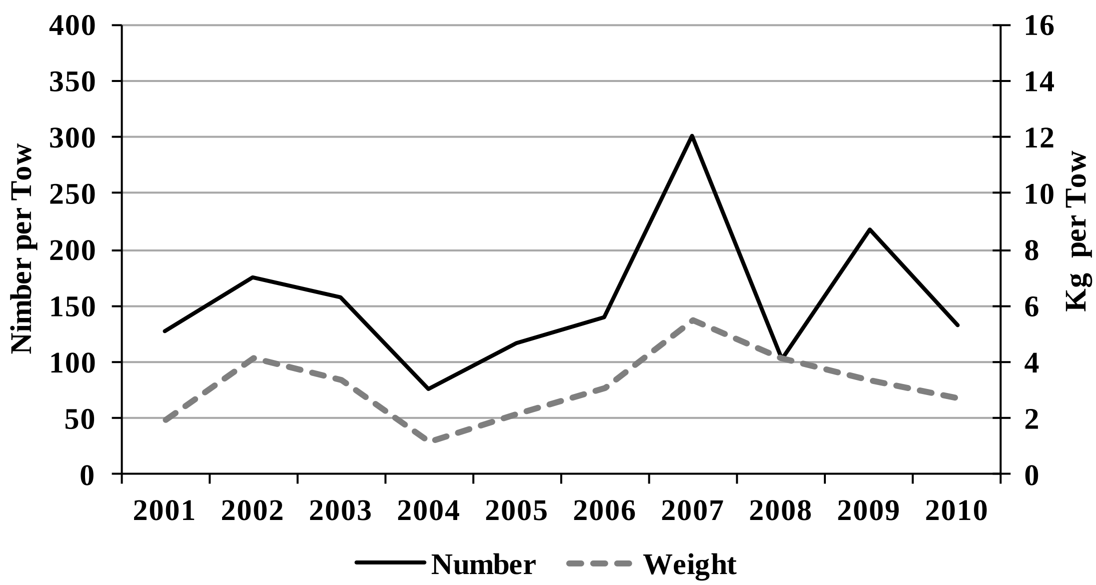

Figure 5.14 Total Number and Weight of Alewife Captured During the Spring Maine-New Hampshire Trawl Survey.

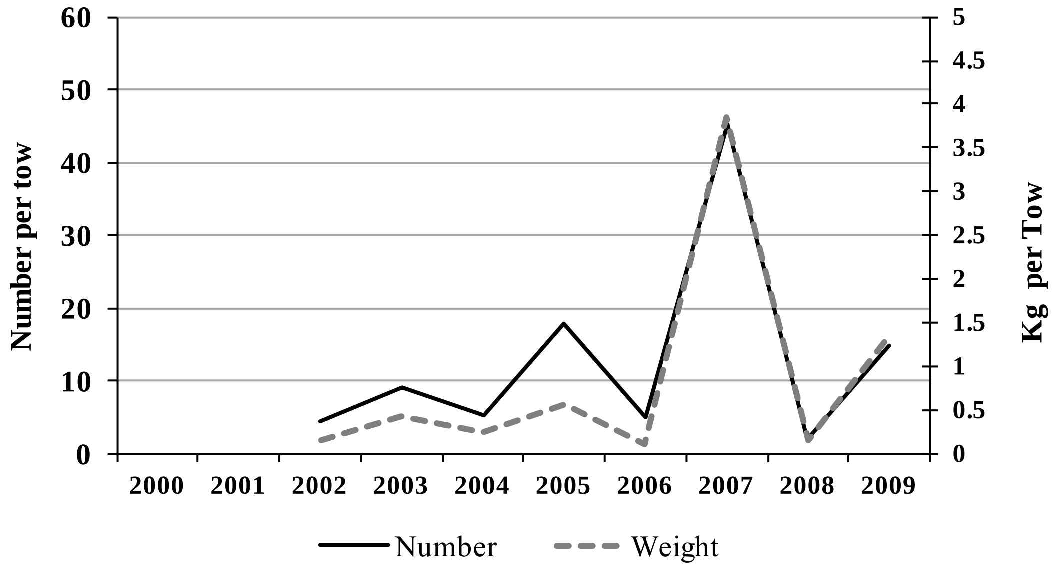

Figure 5.15 Total Number and Weight of Blueback Herring Captured During the Fall Maine-New Hampshire Trawl Survey.

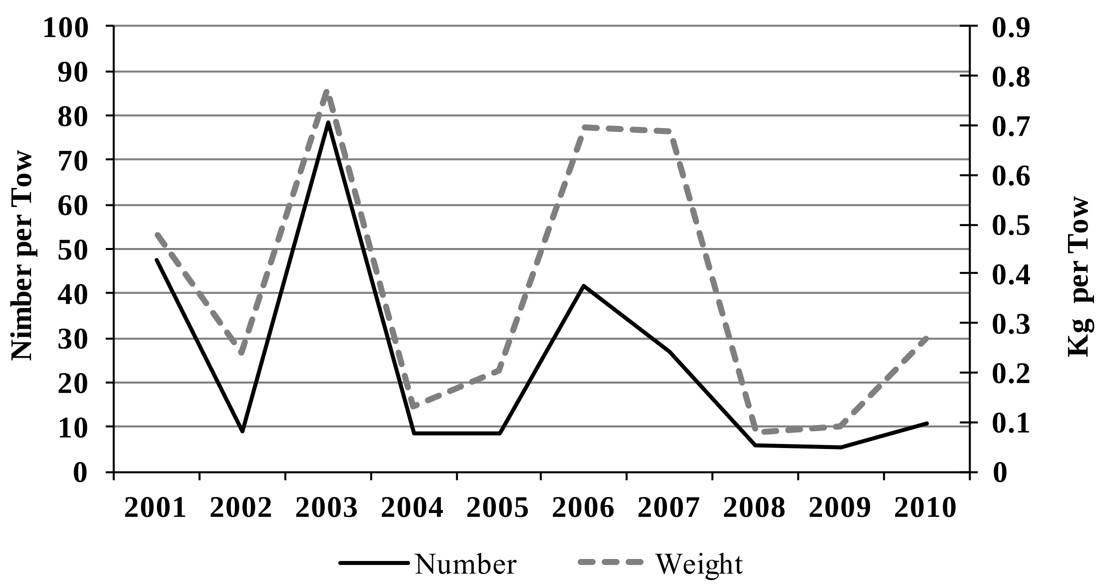

Figure 5.16 Total Number and Weight of Blueback Herring Captured During the Spring Maine-New Hampshire Trawl Survey.

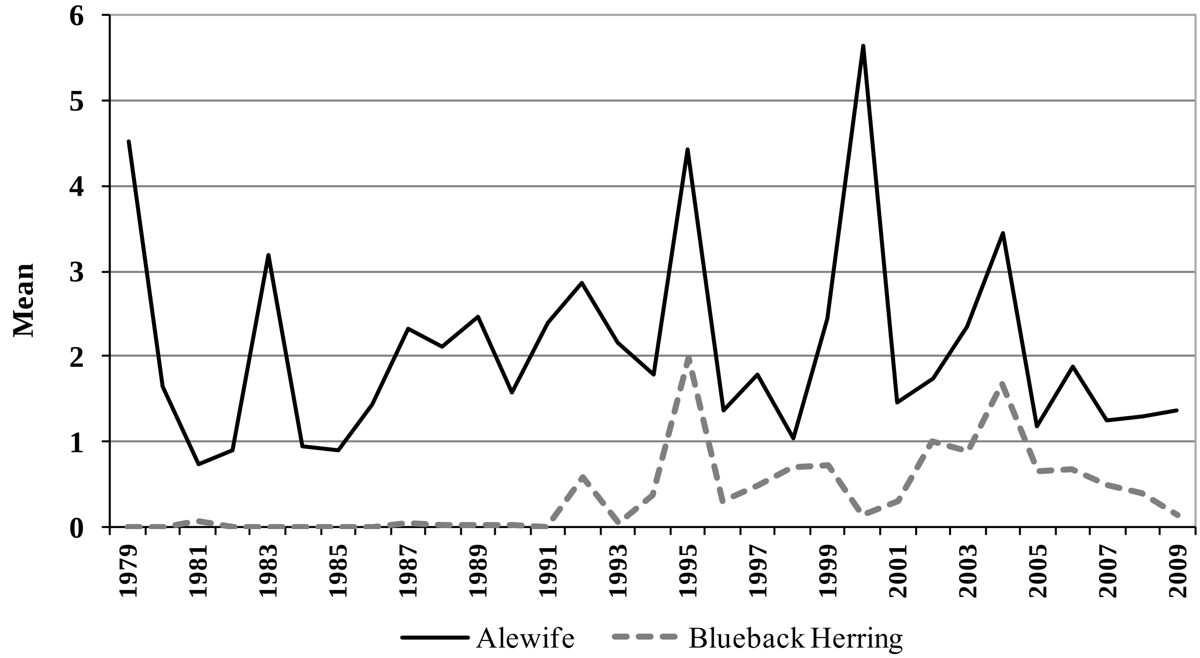

Figure 5.17 Geometric Means for Merrymeeting Bay – Alewife and Blueback Herring

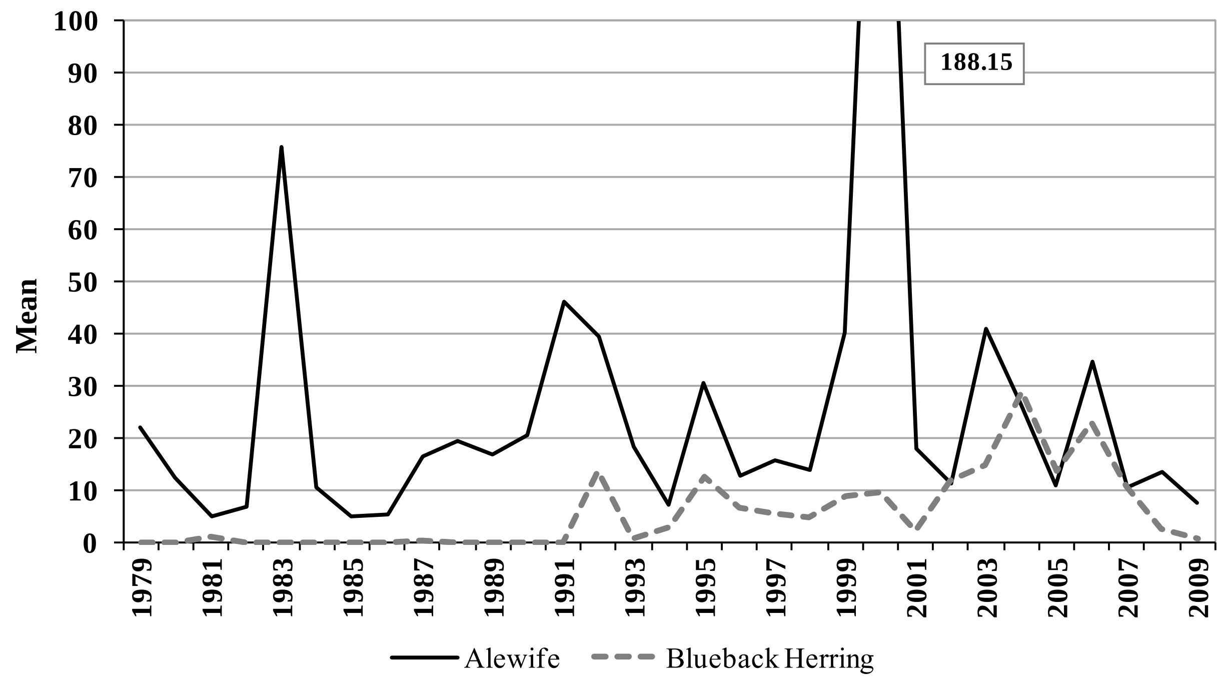

Figure 5.18 Arithmetic Means for Merrymeeting Bay – Alewife and Blueback Herring.

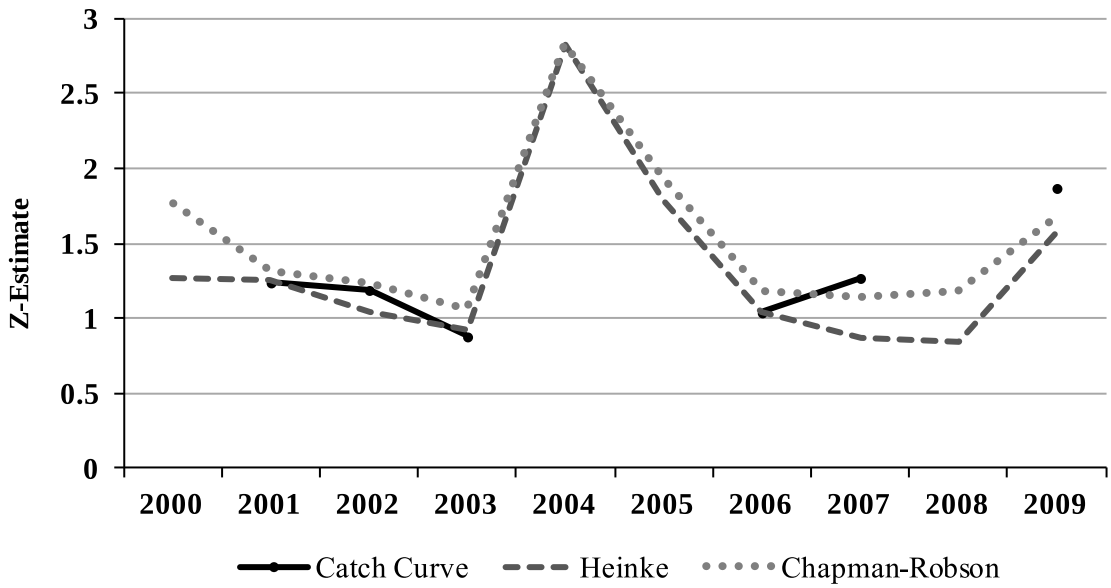

Figure 5.19 Male Alewife Z Estimates for the Sebasticook River at Ft. Halifax and Benton Falls.

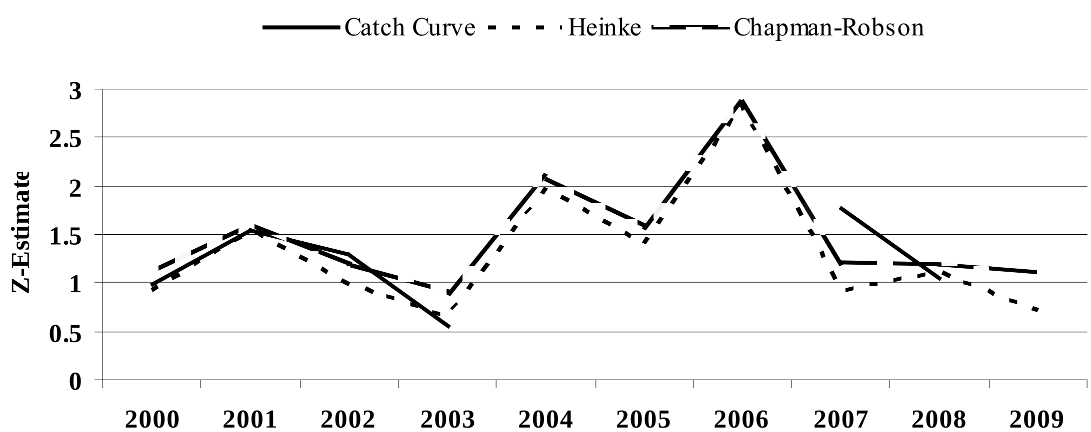

Figure 5.20 Female Alewife Z Estimates for the Sebasticook River at Ft. Halifax and Benton Falls.

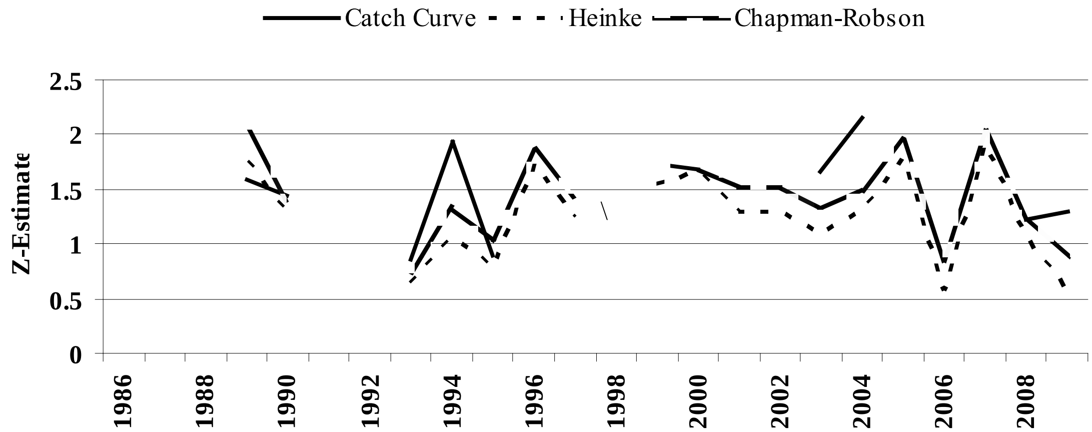

Figure 5.21 Male Alewife Z Estimates for the Androscoggin River at the Brunswick Fishway.

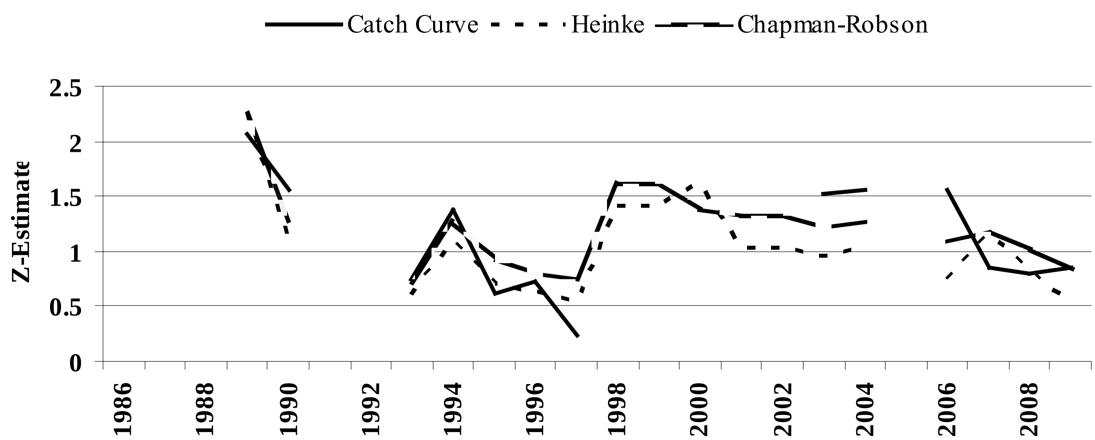

Figure 5.22 Female Alewife Z Estimates for the Androscoggin River at the Brunswick Fishway.

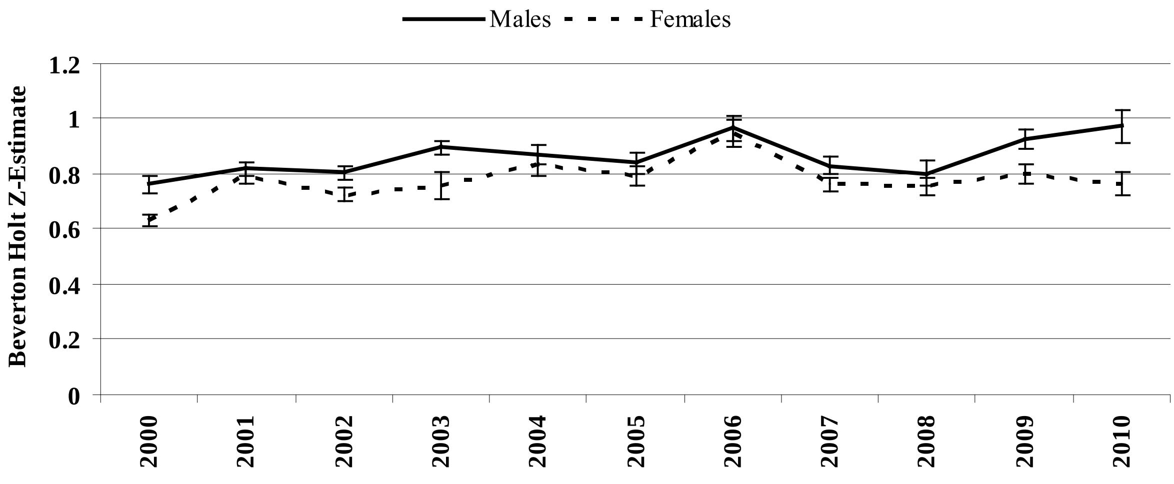

Figure 5.23 Male and Female Alewife Z Estimates for the Sebasticook River using Beverton-Holt.

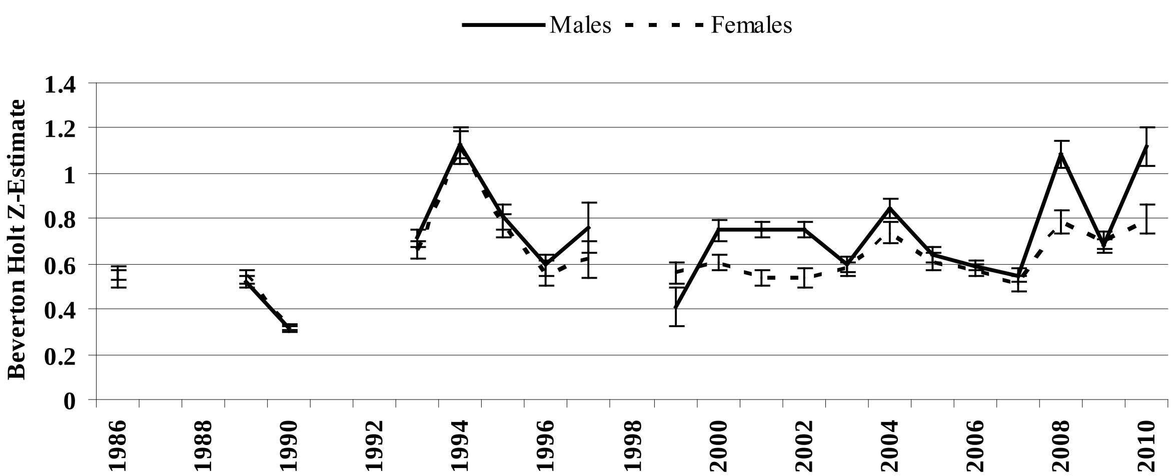

Figure 5.24 Male and Female Alewife Z-Estimates for the Androscoggin River using Beverton-Holt

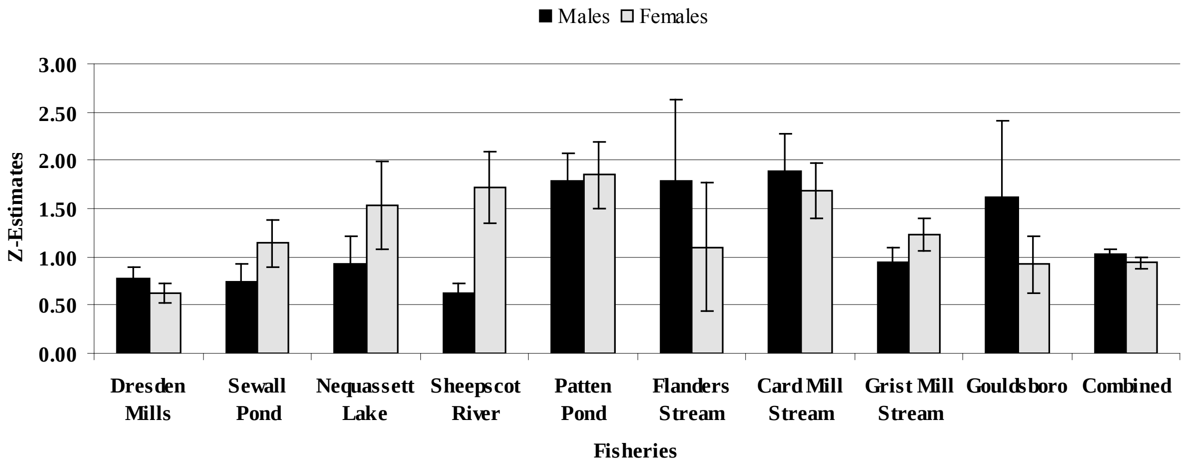

Figure 5.25 Male and female Z-estimates (Heinke) of Alewife Captured at Nine Commercial and Non-Commercial Runs in 2008.

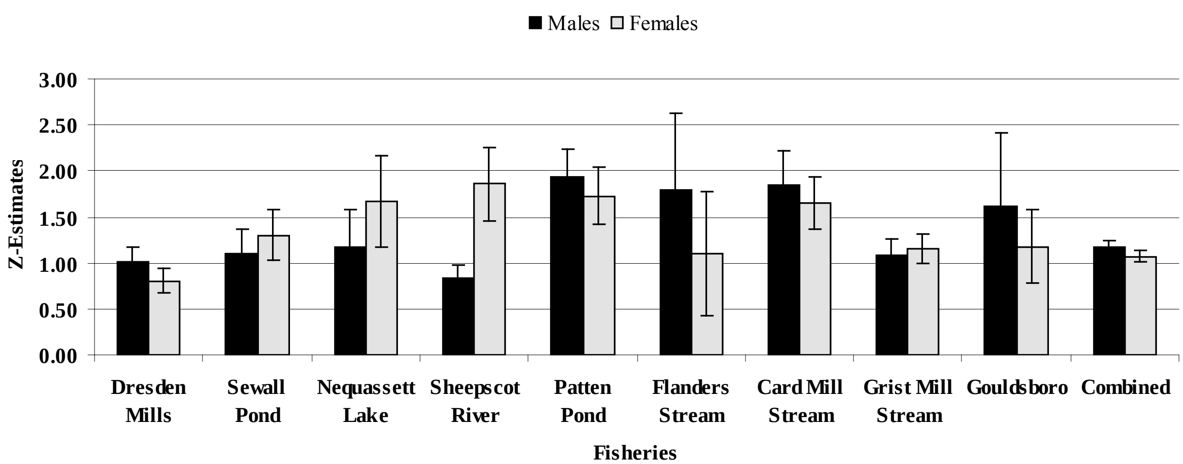

Figure 5.26 Male and female Z-estimates (Chapman-Robson) of Alewife Captured at Nine Commercial and Non-Commercial Runs in 2008.

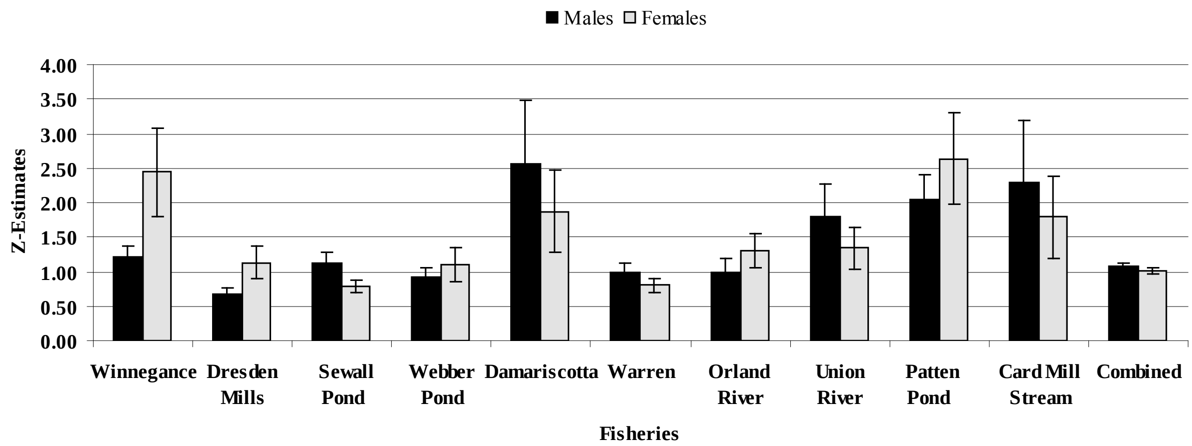

Figure 5.27 Male and female Z-estimates (Heinke) of Alewife Captured at Ten Commercial and Non-Commercial Runs in 2009.

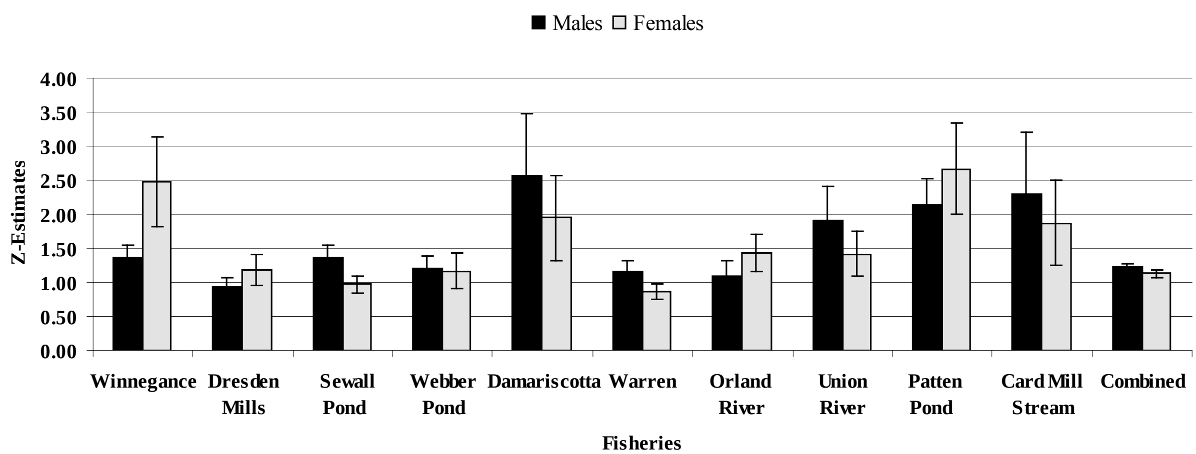

Figure 5.28 Male and female Z-estimates (Chapman-Robson) of Alewife Captured at Ten Commercial and Non-Commercial Runs in 2009.

6. Status of River Herring Stocks in New Hampshire Rivers

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6.1. INTRODUCTION

New Hampshire's coastal rivers once supported abundant runs of anadromous fish including river herring (alewife and blueback herring) (Table 6.1; Figure 6.1), American shad, and Atlantic salmon (Jackson 1944). These and other diadromous species have been denied access to historical freshwater spawning habitat since the construction of milldams as early as the 1600s but more dramatically during the nineteenth century textile boom in most New Hampshire coastal rivers (Figure 6.2). Barriers eliminated American shad and Atlantic salmon populations, but river herring only declined in numbers because they utilized small areas of freshwater at the base of dams during spring runoffs for spawning.

Restoration of diadromous fish populations in New Hampshire began with construction of fishways in the late 1950s and continued through the early 1970s by the New Hampshire Fish and Game Department (NHFGD) in the Exeter, Lamprey, Winnicut, Oyster, and Cocheco rivers in the Great Bay Estuary (Figure 6.3, 6.4, 6.5, 6.6, and 6.7) and the Taylor River in the Hampton-Seabrook Estuary (Figure 6.8). These fishways re-opened acres of freshwater spawning and nursery habitat for river herring, American shad, and other diadromous fish.

6.2. MANAGEMENT UNIT DEFINITION

NHFGD manages the river herring populations within state waters. Primarily river herring are intercepted for biological sampling and enumerated at Department owned fish ladders at the head-of-tide dams for management purposes. Individual river herring spawning runs in the Exeter (Squamscott), Lamprey, Winnicut, Oyster, Cocheco, and Taylor Rivers were evaluated independently in this report as units of the State's river herring stock.

6.2.1. Exeter/Squamscott River

The Exeter River drains an area of 326 square km in southern New Hampshire (Figure 6.3). The river flows east and north from the Town of Chester to the Town of Exeter. It empties into Great Bay northeast of Exeter. The head-of-tide occurs at the Town of Exeter and the saltwater portion of the river is called the Squamscott River.

The two lowermost dams on the main stem Exeter River are the Great Dam in Exeter at river kilometer (rkm) 13.5 and the Pickpocket Dam at rkm 26.9 (each 4.6 km high). The next barrier above Pickpocket Dam is a set of natural falls at rkm 38.1. NHFGD constructed upstream fish passage facilities (Denil fishways) on both dams from 1969 to 1971 for anadromous fish, funded in part by the U.S. Fish and Wildlife Service (USFWS). Fish ladder improvements occurred in 1994 and 1999 and a fish trap was constructed at the upriver end of the Great Dam fish ladder. There are no downstream fish passage facilities on either dam so emigrating adults and juveniles pass over the spillway when river flows allow. There are approximately one hundred meters of fresh water that occurs between head-of-tide and the Great Dam caused by an elevated ledge that prevents saltwater incursion. River herring have been observed below the Great Dam and have the ability to spawn in this area. Most spawning and rearing habitat occurs above the dam. Periodic water quality monitoring has recorded declines in dissolved oxygen

(DO) between the two dams for some years since 1995 (Smith *et al.* 2005; Langan 1995).

6.2.2. Lamprey River

The Lamprey River flows 97 km through southern New Hampshire to the Town of Newmarket where it becomes tidal and enters the Great Bay estuary just north of the mouth of the Squamscott River. The Lamprey River watershed is shown in Figure 6.4. The Macallen Dam, located at rkm 3.8 in Newmarket, is the lowermost head-of-tide dam (8.2 m high) on the Lamprey River. Fish passage on this river is a Denil fish ladder constructed from 1969 to 1970 for anadromous fish by NHFGD, funded in part by the USFWS. The Wiswall Dam is located 4.8 km above the Macallen Dam and currently does not have fish passage. It has a 3.4 m spillway and is an effective barrier to upstream movement of river herring and other diadromous species. A fish passage system is designed and construction was completed in 2011. There are no downstream passage facilities at the Macallen Dam and emigrating juveniles and adults must pass over the spillway. Fish kills have not been observed below the first dam suggesting that adults and juveniles emigrate with limited mortality.

6.2.3. Winnicut River

The Winnicut River drains a watershed of 36.8 square km in southeast New Hampshire (Figure 6.5). It originates in the town of North Hampton and flows north through Greenland where it empties into Great Bay. The last remaining dam on the main stem of the river, located at the head-of-tide at approximately 1.6 rkm, was removed in 2009. A run-of-river fish passage structure was constructed in 2011 to enhance passage of river herring through the constriction of the river caused by the Route 33 Highway Bridge approximately 100 feet above the former dam.

6.2.4. Oyster River

The Oyster River drains a watershed of 27.5 km through southeast New Hampshire (Figure 6.6). It begins in Barrington and flows southeast to Lee, then flows east-southeast through Durham where it empties into Little Bay. The first dam exists at the head of tide just west of NH Route 108 at approximately rkm 5. The spillway length is 42.7 m and a height of 3 m. A Denil fish ladder was constructed at this dam around 1975. The next barrier to fish passage is a dam at about rkm 7.6.

6.2.5. Cocheco River

The Cocheco River flows 48 km southeast through southern New Hampshire to Dover where it joins the Salmon Falls River to form the Piscataqua River (Figure 6.7). The lowermost dam (4.6 m high, built on a natural ledge for a total height of 8 – 10 m) on the Cocheco River is within the City of Dover at the head of tide, at rkm 6.1. A Denil fish ladder was constructed at the dam in 1969 to 1970 for anadromous fish by NHFGD, funded in part by the USFWS. The next barrier is a set of natural falls located at rkm 10.6.

The City of Dover currently owns the dam and leases the attached hydroelectric facility to Southern New Hampshire Hydroelectric Development Corporation (SNHHDC). The Federal Energy Regulatory Commission (FERC) requires SNHHDC to provide downstream fish passage and utilize a grating system to prevent small fish from passing through the turbines. The downstream passage system is a PVC tube emptying in a plunge pool below the dam. This system successfully passes emigrating diadromous species when operating efficiently. Emigrating juvenile and adult river herring must either pass over the dam if flows allow, travel through the downstream migration tube, or move through the turbines at the hydroelectric facility if they can pass through the grating system.

6.2.6.Taylor River

The Taylor River is located in southeastern New Hampshire and is about 17.1 km long (Figure 6.8). The river begins on the border between Hampton Falls and Kensington, New Hampshire. It flows north, east, then southeast through Hampton Falls where it meets tide water at Interstate 95. The lowermost 6.4 km of the river forms the boundary between Hampton and Hampton Falls. The first dam is located at rkm 3.2. There is a Denil fish ladder at this head-of-tide dam that was constructed in the late 1960s. The next dam is a barrier to further fish passage and is located at rkm 5.1.

6.3. REGULATORY HISTORY

The regulatory history of river herring in New Hampshire state waters (inland and 0-3 miles) began in 1967. With the establishment of a permit and reporting requirement for residents or nonresidents utilizing a seine, net, or weir for the taking of river herring. In 1987, the taking of river herring in state waters on Wednesdays by any method was prohibited. New regulations were instituted in 2005 closing a large section of tidal waters in the Taylor River and restricting harvest days in the Squamscott River in Exeter. The new regulations were intended to allow more river herring returns to the Exeter and Taylor river fishways.

The current regulations are:

Fis 603.01 River Herring.

(a) No person shall take river herring, alewives (*Alosa pseudoharengus*) and bluebacks (*Alosa aestivalis*) from the waters of the state, by any method, between sunrise Wednesday and sunrise Thursday of any week.

(b) Any trap or weir used during the period specified in paragraph (a) above, shall be constructed so as to allow total escapement of all river herring.

(c) Any river herring taken by any method during the period specified in paragraph (a) shall be immediately released back into the waters from which it was taken.

Fis 604.03 Taylor River. The Taylor River from the railroad bridge to the head of tide dam in Hampton shall be closed to the taking river herring by netting of any method.

Fis 604.04 Squamscott River.

(a) During April, May and June the taking of river herring in the Squamscott River and its tributaries from the Rt. 108 Bridge to the Great Dam in Exeter shall be subject to the following:

(1) Open to the taking of river herring by netting of any method only on Saturdays and Mondays;

(2) The daily limit shall be one tote per person. “Tote” means a fish box or container measuring 31.5"x 18" x 11.5"; and

(3) The tote shall have the harvester’s coastal harvest permit number plainly visible on the outside of the tote.

6.4. ASSESSMENT HISTORY

New Hampshire has not conducted a formal river herring stock assessment nor been included in past coastwide stock assessments.

6.5. GENERAL LIFE HISTORY

Both alewives and blueback herring are found in the coastal rivers and streams of New Hampshire. Alewives spawn from late-April to late-May when water temperatures have reached a minimum of 9^0 C. Blueback herring typically spawn from early-May until the end of June when temperatures have reached 16^0 C. Typically alewives spawn in the slack water areas of rivers and impoundments while blueback herring prefer faster moving water in rivers and streams. After utilizing the freshwater as nursery habitat during summer months, the juveniles typically emigrate to the ocean from late-August through October. The majority of returning adult river herring are between the ages of 3 and 5 years old.

6.5.1. Growth

From 1990 to 2008, the NHFGD has collected length, sex, species, and age data from fish ladders during the spring spawning migrations (see section 3.10) in coastal river systems. Von Bertalanffy growth curves for total length at age for male and female river herring are presented in Figure 6.10.

6.6. HABITAT DESCRIPTIONS

As stated in Atlantic States Marine Fisheries Commission's Amendment 1 of the Interstate Fishery Management Plan for Shad and River Herring (ASMFC 1999), habitats used by alosines include spawning sites and nursery areas in coastal rivers, which are primarily freshwater portions of rivers and their associated bays and estuaries. In addition to spawning and nursery areas, adult habitats also consist of the near shore ocean. These habitats are distributed along the East Coast from the Bay of Fundy, Canada to Florida. Use of these habitats by migratory alosines may increase or diminish as the size of the population changes.

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

Cocheco River

The Cocheco River flows 48 km southeast through southern New Hampshire to Dover where it joins the Salmon Falls River to form the Piscataqua River. The Piscataqua River flows approximately 20 km to the sea. The Cocheco River drains a watershed of 479 square km. The lowermost dam (4.6m high, built on a natural ledge for a total height of 8-10 m) on the Cocheco River is within the City of Dover, at rkm 6.1. This dam impounds an area of 20 acres. A Denil fish ladder which provides access to approximately 49 acres of potential spawning habitat was constructed at the dam in 1969 to 1970 for anadromous fish by NHFGD, the owner also maintains a downstream migration structure which was replaced for increased efficiency in 2010. The downstream passage system is a PVC tube emptying in a plunge pool below the dam, which successfully passes emigrating diadromous species when operating efficiently. The next barrier is a set of natural falls located at rkm 10.6. During normal flow conditions river herring can ascend this natural falls and continue migrating upriver a distance of 1.3 km to the Watson Dam in Dover, NH. There is no fish ladder at this dam, but a downstream migration pipe is provided by the hydroelectric facility. Currently there are no concerns with the passage efficiency of the existing fish ladder or the water quality throughout the spawning and emigration season in the Cocheco River. No spawning activity has been observed below the dam.

Lamprey River

The Lamprey River flows 97 km through southern New Hampshire to the Town of Newmarket where it becomes tidal and enters the Great Bay Estuary just north of the mouth of the Exeter River. The mouth of the Lamprey River in Great Bay is approximately 27 km inland from the Atlantic coast. The Lamprey River watershed drains an area of 549 square km. It is the largest watershed that empties directly into The Great Bay. The Macallen Dam, located at rkm 3.8 in Newmarket, is the lowermost head-of-tide dam (8.2 m high) on the Lamprey River. A Denil fish ladder constructed from 1969 to 1970 for anadromous fish by NHFGD allows access to 120 acres of potential spawning habitat. The Wiswall Dam is located 4.8 km upstream of the Macallen Dam and currently does not have fish passage. It has a 3.4 m spillway and is an effective barrier to upstream movement of river herring. A fish passage system is being designed and construction is anticipated to occur within the next five years. This would provide access to another 69 km of river habitat in the main stem and tributaries. There are no downstream passage facilities at the Macallen Dam and emigrating juveniles and adults must pass over the spillway. Fish kills have not been observed below the first dam suggesting that adults emigrate with limited mortality.

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

Oyster River

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

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

Squamscott/Exeter River

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

The Exeter River is the only river monitored by the NHFGD that has available fresh water spawning habitat located below the fishway. The Exeter River is also the only coastal river with upstream fish passage available on the first two dams providing access to the greatest amount of spawning habitat on the New Hampshire coast. NHFGD constructed upstream fish passage facilities (Denil fishways) on both dams from 1969 to 1971 for anadromous fish. Fish ladder improvements occurred in 1994 and 1999 at the Great Dam fishway. A fish trap was constructed at the upriver end of the fish ladder. In addition, improvements were made in the vicinity of the ladder entrance to enhance attraction flow during normal river flow conditions. Despite the recent work to improve fish passage efficiency of the fish ladder at Great Dam, the vast majority of river herring choose to spawn below the fish ladder in an approximately 0.50 acre area of fresh water that occurs between head-of-tide and the Great Dam caused by an elevated ledge that prevents saltwater incursion. River herring gather in very large numbers below the Great Dam and spawning has been observed. These observations combined with relatively high levels of documented harvest occurring each year below the first dam and the inefficiency of the fish ladder in passing river herring indicates that escapement to spawn in this river is much higher than measured by the number of river herring passing up river through the fish ladder.

There are no downstream fish passage facilities on either dam so emigrating adults and juveniles pass over the spillway when river flows allow. There are no hydroelectric operations at either fishway, however, at the Great Dam there is a condominium complex that utilizes a small amount of water from the penstock for cooling of their heating and air conditioning system. This minimal flow through the penstock does not have an impact on emigrating river herring. In addition, poor water quality has been documented in the critical nursery habitat above Great Dam. Periodic water quality monitoring has recorded low levels of dissolved oxygen (DO) between the two dams in some years since 1995 (Smith et al. 2005; Langan 1995).

Other Rivers Within the Great Bay Estuary:

There are three other major rivers in the Great Bay Estuary that are not monitored regularly by NHFGD staff. They are the Winnicut, Bellamy and Salmon Falls Rivers. The rivers range in length from 14.6 km for the Winnicut to 61 km for the Salmon Falls. Watershed sizes range from approximately 855 square km for the Salmon Falls to 45.3 square km for the Winnicut River.

The Winnicut River flows directly into Great Bay in Greenland, NH. The NHFGD operated a Canada step weir fish passage from approximately 1957 until 2009 on the Winnicut. During the summer of 2009 the fish ladder and associated NHFGD owned dam were removed to restore anadromous fish habitat. The dam removal drained a 34 acre impoundment and the Winnicut River became the only major tributary to Great Bay with no man-made barriers along its entire length.

The Bellamy River enters the Great Bay Estuary at Little Bay in Dover, NH. A partially breached timber crib dam at the head-of-tide at rkm 6.9 was removed to restore anadromous fish habitat in 2004. Since the removal NHFGD staff have observed large numbers of river herring below the next dam approximately 0.6 km upstream.

The Salmon Falls River joins the Cocheco River to form the Piscataqua River within the Great Bay Estuary. The head-of-tide dam is located at approximately rkm 6.7. A Denil fish ladder has been operated at this dam since 2002. The Salmon Falls River is a border river between the states of Maine and New Hampshire and the fish ladder and associated hydroelectric facility are on the Maine side in the town of South Berwick. The hydroelectric operator is responsible for operation and maintenance of the fish ladder with technical guidance by both NHFGD and Maine Division of Marine Resources. The Denil fish ladder at the head-of-tide dam provides river herring access to a 58 acre impoundment.

6.6.1.Habitat Quality

Dams and natural barriers restrict potential available spawning and nursery habitat in New Hampshire coastal rivers for river herring. Anthropogenic changes to these river systems can further affect habitat (e.g., increased development, increased impervious surfaces, and increased water withdrawals). These may have affected all six river systems, but their effects are the most dramatic in the Exeter and Taylor Rivers. Currently, several New Hampshire state agencies are working with the Town of Exeter on instream flows and water withdrawal for water resources. These factors have affected the downstream emigration of both adult and juvenile river herring with both barrier concerns and water quality issues. These issues came to New Hampshire's attention when low DO levels were monitored in 1995 by the Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET) that indicated low levels of dissolved oxygen between two and five mg per liter in impoundment reaches of the Exeter River (Rich Langan, unpublished data).

6.6.2.Habitat Loss

Once dams are built (with fish passage) or removed, habitat for the two species of river herring can change composition. Therefore habitat loss for one species may benefit the other depending upon whether an impoundment has been developed or a riverine system has been restored. As impoundments degrade due to anthropogenic reasons and become more eutrophic over time habitat continues to be lost.

6.6.3.Habitat Alterations

Fish passage over dams continues to be a problem in New Hampshire where 3,074 active dams have been recorded throughout the state with less than 30 known fish passage systems. New Hampshire Fish and Game has been working with the Department of Environmental Services (DES), and other state and federal agencies to address dam removal projects through the New Hampshire River Restoration Program (RRTF). To date there have been 12 dams completely removed and two partially breached under the RRTF program since 2001, seven of which have benefitted diadromous species. The DES continues to work with municipalities with in-stream flow rules for water withdrawals for municipal use.

6.7. RESTORATION PROGRAMS

Restoration activities for river herring in New Hampshire river systems have included constructing and improving upstream passage facilities at dams; stocking of adult fish into historic and viable spawning reaches; removing dams; and improving water quality in spawning and rearing reaches. From 1984 to 2010 approximately 66,000 adult river herring have been stocked in coastal rivers of New Hampshire (Table 6.2). The transfers that occurred were either in-basin transfers to increase spawning habitat or out-of-basin transfers to help supplement spawning runs in rivers with lower return numbers.

Restoration of diadromous fish populations began with construction of fishways from the late 1950s to the early 1970s by the NHFGD in the Cocheco, Exeter, Oyster, Lamprey, Taylor, and Winnicut rivers. These fishways re-opened acres of freshwater spawning and nursery habitat for river herring, American shad, and other diadromous fish. Since that time, modifications have been made to the Exeter River fish ladder to improve the effectiveness at passing alosines and a holding trap was constructed to facilitate monitoring of spawning fish through enumeration and collection of biological data. The last remaining dam on the main stem of the Winnicut River was removed by the NHFGD and DES in 2009.

6.7.1.Restoration Objective

The restoration target for New Hampshire's river herring is to return rivers populations to levels of abundance that will enable the full utilization of available and/or historical spawning habitat.

6.7.2.Fish Passage Efficiency

New Hampshire has not conducted specific fish passage efficiency studies on the seven fish ladders in coastal rivers.

6.8. AGE

The maximum age for alewife and blueback herring in New Hampshire has been recorded at nine years. Biological samples consisting of length measurements, sex and species determination, and scale samples, used for age determination, are collected from river herring at most fishways annually. Prior to 2009, the biological sampling target for river herring was to obtain three separate samples, one sample taken at each division of the spawning run (beginning, middle, end). Each individual sample attempted to gather approximately 150 length measurements (total length in millimeters) and sex determinations. Scale samples were taken from approximately 50 fish per sample when available. Years in which the target sampling level were reached, resulted in 450 randomly selected sex/length determinations as well as 150 scales for determination of age, sex, and species for each river. Beginning in 2009, scale samples are taken by grouping river herring by species and sex into one centimeter increments (Bins). The returning river herring are sampled throughout the spawning run, in an attempt to obtain a target sampling level of five fish within each bin for each sex and each species.

All alosine scale samples are cleaned, mounted between glass slides, and aged using an overhead scale projector via methods described by Marcy (1969). Prior to 2009, scale samples were also used for species determination for river herring (i.e. alewife or blueback herring) using methods described by MacLellan et al. (1981). Two or more readers independently aged all scales. Beginning in 2009, the bin sampling method controlled the distribution of species in the scale samples; therefore a field species determination of all individuals was incorporated into the 150 random length samples taken during the beginning, middle, and end of the run to determine species distribution within each river.

6.9. FISHERY DESCRIPTIONS

Historically, river herring have been the most prevalent anadromous fishes harvested in New Hampshire and sold as food, fertilizer, bait for commercial or recreational fisheries, and even the scales were utilized for the production of artificial pearls. More recently river herring fisheries have utilized the harvest as bait for commercial and recreational fisheries solely. New Hampshire monitors in-state river herring fisheries through the Coastal Harvest Reporting Program and the National Marine Fisheries Service monitors commercial landings of river herring in New Hampshire through either vessel trip reports or dealer reports from federally permitted vessels or dealers. However, due to the large volume herring fisheries, there is likely an incomplete accounting of river herring as part of the bycatch in the herring fishery.

6.9.1.Commercial Fisheries

In 1896 reported river herring catches totaled 293,671 pounds for New Hampshire streams (Bigelow and Schroeder 1953). Most of the current New Hampshire commercial landings of river herring are from vessels fishing in the EEZ. Landings peaked in 1977 at 210,000 pounds and have dropped ever since (Table 6.3; Figure 6.9). The river herring caught in ocean waters were most likely of mixed stock origin. The very limited harvest of river herring in state waters is primarily for personal use such as lobster or recreational fishing bait. These landings are primarily made through netting activities of state-permitted coastal netters. All individuals participating in netting of river herring with the state are required to annually submit reports of both fishing effort and harvest weight or numbers of river herring taken. The following is a description of the river herring fishery.

Cocheco River

The river herring fishery in the Cocheco River is very sporadic with very few fish harvested over the course of the last several years. Total annual in-river harvest has ranged from zero fish to approximately 550 fish. Harvesters typically fish with cast nets, dip nets, or gill nets. The Cocheco River is closed to fishing from the fish ladder at the lowermost dam to the Washington Street Bridge approximately 200 m downstream. Most of the river herring harvest occurs from the downstream side of the Washington Street Bridge to a distance approximately 0.50 km downstream. In addition, there is a popular striped bass fishery that occurs along this stretch of river. Recreational anglers "snag" river herring to be used as live striped bass bait.

Lamprey River

The river herring harvest at the Lamprey River in recent years has been very low, usually less than 2,000 fish per year. The fishing activity is very sporadic. Landings are reported using a variety of methods including: cast net, gill net, dip net, and weir. Primarily the harvest occurs from approximately 70 m downstream of Macallen Dam to a distance of 0.50 km downstream. There is one weir fisherman that maintains his netting permit but has not fished his weir since 2003. It is worth noting that each spring there is a very popular striped bass fishery that occurs within 0.33 km downstream of Macallen Dam. Striped bass anglers "snag" river herring to use as live bait.

Oyster River

There is typically very little river herring harvest that occurs in the Oyster River, usually less than 800 fish per year. The limited harvest that occurs is via dip net, cast net, or gill net. The Oyster River has very few locations where capturing river herring can be done efficiently. Due to this, harvest can occur sporadically anywhere along the tidal portion of the river.

Squamscott/Exeter River

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

In 2005, following a number of years of increased harvest in the Squamscott/Exeter River, NHFGD implemented major changes to rules for river herring and shad in this river in order to reduce the harvest levels. These changes included implementing a one tote harvest limit per day and increasing the escapement days from one day per week to 5 days per week. Harvest levels since 2005 have been reduced by at least 50% of the levels observed between 1998 and 2003 (Table 6.3) and estimates of instantaneous mortality from 2006 to 2009 have been some of the lowest in the time series.

Other Rivers Within the Great Bay Estuary:

The Bellamy, Winnicut, and Salmon Falls Rivers have a very sporadic harvest ranging from 0 fish to as many as 2,548 fish at the Salmon Falls in 1999. The combined harvest from all three rivers ranges from as few as 111 fish in 1992 to 3,127 in 1999. Like many other New Hampshire coastal rivers it is very difficult to capture river herring efficiently at these locations so harvest can occur anywhere along the tidal portion. However, in the Bellamy River some harvest does occur within the fresh water reach of the river just above the head-of-tide. Typically gill nets, cast nets, and dip nets are used to harvest river herring at these locations.

6.9.2. Recreational Fisheries

There is a very limited recreational fishery for river herring at head-of-tide dams on some of New Hampshire's coastal rivers. This recreational fishery mainly occurs on the Squamscott, Cocheco, and Lamprey Rivers. Harvesters catch river herring with various forms of nets, traps, or snagging with hook and line for the purpose of striped bass bait.

6.9.3. Bycatch

Bycatch of river herring likely occurs in commercial fisheries targeting other species. At this time New Hampshire does not evaluate the number of river herring that are caught as bycatch from commercial fisheries within the EEZ landing in New Hampshire. Sea sampling surveys conducted by the NHFGD in the mid-1990s showed river herring bycatch comprised less than 5% of the total catch.

6.10. FISHERY-INDEPENDENT SURVEYS

Two fishery-independent surveys are conducted in New Hampshire to monitor river herring. Each spring or early summer (April through June) NHFGD operates seven fish ladders along coastal rivers to enumerate and monitor migrating diadromous species, described below. In addition to monitoring adult migration of river herring, NHFGD conducts a seine survey in the Great Bay and Hampton-Seabrook estuaries for juvenile finfish that provides an index of relative abundance for a variety of species including alewives and blueback herring.

6.10.1. Adult Catch Data

Seven fish ladders on six coastal New Hampshire rivers (Cocheco, Exeter, Lamprey, Oyster, Winnicut, and Taylor rivers) are operated from early April to mid-July, to allow for the passage of American shad, river herring, and other diadromous fish to historical spawning and nursery areas. The number of fish passing through the fishways are either enumerated by hand or estimated by the use of Smith-Root Model 1101 electronic fish counters. Counts recorded by the electronic fish counters are adjusted by daily calibration counts consisting of a minimum of ten one-minute counts. During daily visits, fish ladders and electronic counting devices are examined to assure of proper operation.

6.10.2. Juvenile Catch Data

A beach seine survey is conducted annually on a monthly basis from June to November at 15 fixed stations in New Hampshire's estuaries. Four of these stations are located in the Hampton-Seabrook Estuary and 11 are located in the Great Bay Estuary. Within the Great Bay Estuary, three stations are located in Little Harbor, three stations are located in the middle to upper Piscataqua River, and five stations are located in Little Bay/Great Bay area.

Beach seine hauls are conducted by boat using a 30.5 m long by 1.8 m high bag seine with 6.4 mm mesh deployed 10 - 15 m from the beach. A single seine haul is made at each station during the months of June through November. Seine hauls are all conducted during daylight hours and constrained to the period of approximately two hours before to two hours after low tide. Seines are set into the current and, at most stations, in water depths less than six feet to prevent the foot rope of the net from coming off the bottom. With each seine haul, surface salinity (ppt) and temperature (^{o}C) are measured and substrate type at the station is observed and recorded.

All fish captured are identified to the lowest possible taxon (species level is the target) and enumerated. All finfish captured are measured, total length to the nearest millimeter up to a maximum of 25 individuals per species per seine haul sample. The primary species of interest are winter flounder, rainbow smelt, river herring, American shad, and Atlantic silverside. In addition, if the following invertebrate species of special interest are captured, they are identified and enumerated: rock crab, Jonah crab, green crab, horseshoe crab, American lobster, and Asian shore crab.

An annual index of relative abundance is determined using the geometric mean catch-per-seine-haul. This relative annual index can be used to determine successful occurrence of river herring spawning activity between years. However, due to the estuary-wide design and limited sampling rate in close proximity to monitored rivers during times of peak juvenile river herring emigration in the late summer/fall months these indices should be used conservatively.

6.11. ASSESSMENT APPROACHES AND RESULTS

6.11.1. Trends in Run Size

The Cocheco and Lamprey Rivers generally have the highest number of returning river herring each spring. Returns to these rivers have exceeded 40,000 fish on several occasions (Table 6.1). The Oyster River spawning population has been declining since the early 1990s. The run has decreased from 157,000 fish in 1992 to approximately 17,000 fish in 2007. The Winnicut River monitored spawning run has been generally increasing since 1998; 219 river herring in 1998 and 8,300 river herring in 2008. The Winnicut River Dam and associated fish ladder were removed in 2009. Monitoring of the spawning run in the Winnicut River was hindered in 2010, but a run-of-river fish passage structure is anticipated to be constructed in 2011, allowing the continuation of monitoring the spawning run. The Exeter and Taylor Rivers have declining river runs as well. In recent years the Taylor has less than 1,000 fish returning annually, while the Exeter River monitored spawning returns are less than 600 fish each year.

Fish ladder counts in some rivers should be classified as minimum estimates of spawning river herring. For example, large numbers of blueback herring are often observed below the ladders in the Lamprey, Cocheco, and Exeter Rivers in late May but do not ascend the ladders. Several factors may be contributing to the overall decline in river herring return numbers. High flows before and during the runs in recent years may have influenced the decline in returns in monitored rivers. The passage inefficiency of fish ladders created by unusually high river flow levels, in turn reduces the annual return enumerations in those years. An example of strong control by environmental conditions occurred in 2005, 2006, and 2007 when New Hampshire coastal rivers experienced flood conditions that reached "100 year flood" levels in 2006 and 2007. During years where persistent high river velocity exists in all coastal rivers in the state, many river herring are unable to reach or successfully ascend the fish ladders monitored by the Department. In 2005, above average precipitation levels later in the spawning run reduced blueback returns specifically, which for runs comprised largely of bluebacks, such as the Oyster River, resulted in lowered total annual run sizes. The passage inefficiency of fish ladders created by unusually high river flow levels, in turn reduces the annual return enumerations in those years. Other factors affecting returns include; poor water quality affecting survival of young-of-the-year (low DO during summer months, downstream passage problems, water withdrawals by the local municipalities, and drought conditions in some years).

6.11.2. Trends in Length

Total lengths for river herring monitored in New Hampshire coastal rivers ranged from 200 mm to 370 mm in all rivers combined (Tables 6.4, 6.5, and 6.6). The mean length of males varied annually (Tables 6.7, 6.8, and 6.9; Figure 6.11), ranging from 247 mm to 292 mm. Mean length of females ranged from 263 mm to 306 mm. In general, fish returning to the Oyster River had the shortest mean lengths while those returning to the Lamprey River had the longest. This is likely due to the predominance of blueback herring returning to the Oyster River while alewives dominate the monitored spawning runs in the Lamprey River. In most years there are slightly higher percentages of males returning then females.

6.11.3. Trends in Age

The river herring returning to the New Hampshire coastal fish ladders ranged in age from three to nine years old. The majority of alewife returns ranged from age four to six and blueback herring from age three to five (Tables 6.10, 6.11, and 6.12; Figure 6.12). Species were not determined during ageing of scales in 1990.

6.11.4. Trends in Length at Age

Mean total length at age of river herring returning to New Hampshire coastal rivers has decreased over time since 1992 (Figures 6.13 and 6.14). Tables 6.13, 6.14, and 6.15 show river specific river herring mean length at age information. Reasons may be degrading impoundments affecting early growth, various environmental factors such as droughts or floods that have affected either immigration or emigration pathways affecting river specific populations as a whole, selective predation, or other stressors that affect growth potential.

6.11.5. Trends in Repeat Spawning

The percentages of repeat spawning fish are determined by the presence or absence of spawning checks observed during the ageing process of collected river herring scales (Tables 6.16, 6.17, and 6.18). River herring were determined to have repeated spawning up to four times in New Hampshire rivers, with the percentage of single year repeat spawning fish as high as 45% in some years.

6.11.6. Juvenile Abundance

The highest relative abundance for juvenile blueback herring as measured by the geometric mean catch per seine haul, occurred in 1999 when nearly 12,000 were captured (Table 6.19). Peaks in relative abundance for alewives occurred in 2002, 2003, and in 2006. The indices, in general, are very low for juvenile alewives. In contrast, blueback herring are one of the more commonly captured species at some stations in certain years.

6.11.7. Total Mortality

The methods used to evaluate total mortality were: Chapman-Robson, Heinecke, and Catch Curve analysis. The analysis calculated total instantaneous mortality (Z) rates and standard errors using ages from spawning river herring returning to the fishways on the Cocheco, Lamprey, Oyster, Winnicut, and Exeter rivers (Table 6.20; Figure 6.15). The catch curve analysis was the most restrictive and did not calculate mortality at times due to the small span of age classes in some rivers and/or years. However, the Chapman-Robson and Heinecke method addressed these biases if sample size included more than one age and the fish aged were greater than the determined fully recruitment age. Both the Chapman-Robson and Heinecke Z estimates essentially followed the same trend pattern over the time series for each river evaluated.

The Cocheco River has both species that utilized the fish ladder. Mortality estimates indicate peak mortality in the early 1990's then generally stabilizing from the late 1990's to the mid-2000's within ranges between 0.5 and 1.5. An increase in mortality started in 2005 for male alewives female alewives have experienced a decreasing trend since 2006. Male blueback herring mortality rates in the Cocheco River remained relatively stable since 2000 however female blueback herring mortality rates declined dramatically between 2003 and 2007 but appear to experiencing an upward trend again in 2008.

The Lamprey River primarily has alewives that negotiate the fish ladder. Very few blueback herring have been sampled from the exit of the fish ladder; they primarily spawn below the dam, therefore are not included in the analysis for the mortality rate in the Lamprey River. The mortality estimates for the alewives range from approximately 0.5 to 2.0. Both sexes follow the general mortality trend but not necessarily within the same year.

The Exeter River has both species that utilize the fish ladder however there is available spawning freshwater habitat below the dam that is utilized by river herring. Issues affecting total mortality may include downstream fish passage of juvenile and post spawned adults inhibited by water withdrawals and low flows coupled with low summer dissolved oxygen levels in impoundments above the dams. Despite the recent work to improve fish passage efficiency of the fish ladder at Great Dam, the vast majority of river herring choose to spawn below the fish ladder in an approximately 0.50 acre area of fresh water that occurs between head-of-tide and the Great Dam caused by an elevated ledge that prevents saltwater incursion. River herring gather in very large numbers below the Great Dam and spawning has been observed. These observations combined with relatively high levels of documented harvest occurring each year below the first dam and the inefficiency of the fish ladder in passing river herring indicates that escapement to spawn in this river is much higher than measured by the number of river herring passing up river through the fish ladder. This lowers the confidence of mortality rates for the Exeter River calculated using passage numbers. However, mortality estimates ranged from 0.01 to 1.7 between the two species and sexes throughout the years and appear to be on a general decline. Fishing by nets on pre-spawned adults may have contributed to a higher mortality prior to 2005 when regulations were imposed to restrict harvest.

The Winnicut River fish ladder was a Canadian step-weir design which was not effective for passing river herring however renovations in 1997 and 2002 allowed more successful passage by river herring. As a result sampling has been more consistent since 1998 but sample size has been low in some years (Table 6.1) which may affect the reliability of mortality estimates. The mortality estimates have ranged from approximately 0.2 to 2.4 since 1998, however the mortality trend is erratic for male and females between the two species. Along with the lack of confidence in mortality estimates due to low sample size, other mortality issues could be due to emigration escapement issues and fluctuations in a developing population as it reaches river carrying capacity.

The Oyster River fish ladder primarily passes blueback herring and very little alewives. The few alewives have not been included within the mortality estimates. The mortality estimates have ranged from 0.24 to greater than 2.0 between 1992 and 2008. Both sexes have experienced similar trends in mortality but not necessarily within the same years. The dissolved oxygen within the Oyster River impoundment has been recently recorded to have levels below 5 mg/l, again likely affecting adult recruitment.

Sampling has been too erratic in the Taylor River to calculate a mortality estimate with any measure of confidence due to the design of the fish ladder and level of sampling.

6.12. BENCHMARKS

No benchmarks were recommended for New Hampshire. Refer to Section 2.10 for benchmark analysis.

6.13. CONCLUSIONS AND RECOMMENDATIONS

New Hampshire rivers were severely impacted over the past several centuries, negatively affecting anadromous species. Dams, fishing, and poor water quality are among the many obstacles that river herring have faced. Restoration efforts should continue with focus on the following strategies for New Hampshire coastal rivers targeted for restoration:

1. Continue efforts to monitor and improve water quality.
2. Continue transfers of spawning adult river herring from donor rivers to increase available spawning habitat and augment declining runs in other rivers.
3. Continue work to install upstream and downstream fish passage or remove dams in coastal rivers.
4. Continue to monitor returns of spawning adult river herring to fish ladders.
5. Efforts should be made to identify and reduce all sources of mortality whether during ocean residency or in-river.

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Table 6.1 Numbers of river herring returning to fishways on coastal New Hampshire rivers.

Year	Cocheco River	Exeter River	Oyster River	Lamprey River	Taylor River	Winnicut River	Annual Total
1972				*2,528*		*+*	*2,528*
1973				*1,380*		*+*	*1,380*
1974				*1,627*		*+*	*1,627*
1975		*2639*		*2,882*		*+*	*5,521*
1976	*9500*		*11777*	*3,951*	*450000*	*+*	*475,228*
1977	*29500*		*359*	*11,256*		*2,700++*	*43,815*
1978	*1925*	*205*	*419*	*20,461*	*168256*	*3,229++*	*194,495*
1979	**586**	**186**	**496**	**23,747**	375,302	3,410	*403,727*
1980	**7,713**	**2,516**	**2,921**	**26,512**	205,420	4,393	*249,475*
1981	**6,559**	15,626	**5,099**	**50,226**	94,060	2,316	*173,886*
1982	**4,129**	542	6,563	66,189	126,182	2,500	*206,105*
1983	**968**	**1**	**8,866**	**54,546**	151,100	**+**	*215,481*
1984	**477**		5,179	40,213	45,600	+	*91,469*
1985	**974**		**4,116**	54,365	108,201	**+**	*167,656*
1986	**2,612**	**1,125**	93,024	46,623	117,000	**1,000++**	*261,384*
1987	**3557**	220	57,745	45,895	63,514	**+**	*170,931*
1988	**3915**		73,866	31,897	30,297	**+**	*139,975*
1989	18,455		38,925	26,149	41,395	**+**	*124,924*
1990	**31,697**		154,588	25,457	27,210	**+**	*238,952*
1991	**25,753**	**313**	151,975	29,871	46,392	**+**	*254,304*
1992	72,491	537	157,024	16,511	49,108	**+**	*295,671*
1993	**40,372**	**278**	73,788	25,289	84,859	**+**	*224,586*
1994	33,140	*****	91,974	14,119	42,164	**+**	*181,397*
1995	79,385	**592**	82,895	15,904	14,757	**+**	*193,533*
1996	*32,767*	*248*	*82,362*	*11,200*	*10,113*	*+*	*136,690*
1997	*31,182*	*1,302*	*57,920*	*22,236*	*20,420*	*+*	*133,060*
1998	*25,277*	*392*	*85,116*	*15,947*	*11,979*	*219*	*138,930*
1999	*16,679*	*2,821*	*88,063*	*20,067*	*25,197*	*305*	*153,132*
2000	*30,938*	*533*	*70,873*	*25,678*	*44,010*	*528*	*172,560*
2001	*46,590*	*6,703*	*66,989*	*39,330*	*7,065*	*1,118*	*167,795*
2002	*62,472*	*3,341*	*58,179*	*58,065*	*5,829*	*7,041*	*194,927*
2003	*71,199*	*71*	*51,536*	*64,486*	*1,397*	*5,427*	*194,116*
2004	*47,934*	*83*	*52,934*	*66,333*	*1,055*	*8,044*	*176,383*
2005	*16,446*	*66*	*12,882*	*40,026*	*233*	*2,703*	*72,356*
2006	*4,318*	*16*	*6,035*	*23,471*	*147*	*822*	*34,809*
2007	*15,815*	*40*	*17,421*	*55,225*	*217***	*7,543*	*96,261*
2008	*30,686*	*168*	*20,780*	*36,247*	*976*	*8,359*	*97,214*
2009	*36,165*	*513*	*11,661*	*42,425*	*****	*4,974*	*95,737*
2010	*32,654*	*69*	*19,006*	*33,327*	*675*	*576*	*86,307*

= High confidence in estimates
= Medium confidence in estimates
= Low confidence in estimates
= The data was not reviewed; no data sheets could be found
= Not yet reviewed

*- *Due to damage to the fish trap, fishway became a swim through operation*
** - *Due to fish counter malfunction there was up to two weeks where passing fish were not enumerated.*
*** - *Fishway was operated but not monitored due to staffing constraints.*
+ - *Fishway unable to pass fish until modifications in 1997.*
++ - *Fish netted below and hand passed over Winnicut River dam.*

Table 6.2 Numbers of river herring stocked in coastal New Hampshire rivers from 1984 - 2010.

Year	Cocheco River System	Winnicut River	Exeter River	Lamprey River System	Salmon Falls River
1984	5,000				
1985	500				
1986	2,000				
1987	2,125				
1988	2,000				
1989					
1990	2,000				
1991	1,700				
1992	1,300				
1993					
1994	365[a]			320[a]	220
1995	1,400[a]		125	3,230[b]	250
1996	750[a]			2,100[a]	200
1997	950[a]			2,000[a]	300
1998	1,000[a]	300		1,975[a]	240
1999	990[a]	200		2,020[a]	200
2000	1,000[a]	430		2,020[a]	320
2001	1,000[a]			2,000[a]	200
2002	1,000[a]			1,900[a]	
2003	1,100[a]			2,000[a]	
2004	1,050[a]		100	2,000[b]	
2005	1,000[a]		200	2,000[b]	
2006	1,000[a]		40	200[b]	
2007	900[a]		175	2,000[b]	
2008	1,000[a]		250	2,000[b]	
2009	500[a]		250	750[b]	
2010	1,000[a]			750[b]	

[a] - In-river transfer.
[b] - Combination of in-river and out-of-basin transfers.

Table 6.3 Reported ocean commercial landings (kg) of river herring in New Hampshire from the NMFS, 1957-2009.

Year	Species*	Metric Tons	Pounds	$
1957	River Herring	34	75,000	750
1958	River Herring	27.2	60,000	600
1959	River Herring	36.3	80,000	800
1960	River Herring	43.1	95,000	1,000
1961	River Herring	45.4	100,000	1,000
1962	River Herring	56.7	125,000	1,250
1963	River Herring	68	150,000	1,500
1964	River Herring	34	75,000	1,125
1965	River Herring	56.7	125,000	1,875
1966	River Herring	34	75,000	1,125
1967	River Herring	29.5	65,000	1,650
1968	River Herring	18.4	40,600	1,043
1969	River Herring	17	37,500	1,081
1970	River Herring	14.1	31,000	930
1971	River Herring	11.3	25,000	750
1972	River Herring	10.9	24,000	800
1973	River Herring	9.8	21,500	944
1977	River Herring	95.3	210,000	7,518
1978	River Herring	74.8	165,000	8,200
1982	River Herring	51.9	114,500	7,400
1983	River Herring	52.3	115,216	10,730
1984	River Herring	40.8	90,000	6,300
1985	River Herring	27.8	61,300	7,128
1986	River Herring	12.2	26,990	2,275
1987	River Herring	8.9	19,550	2,346
1988	River Herring	5.5	12,087	5,440
1989	River Herring	5.1	11,200	5,478
1992	River Herring	4.4	9,802	4,900
1993	River Herring	1.2	2,676	576
1998	River Herring	11.8	25,994	3,795
2008	River Herring	3.7	8,137	1,839
2009	River Herring	4.3	9,443	1,761
GRAND TOTAL		946.4	2,086,495	93,909

Table 6.4 Length frequency of river herring returning to New Hampshire rivers, 1994-2010.

Length (cm)	Cocheco River – Combined Species																
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	1	0	2	0	0	1	0	0	0	0	0	0	5	0	0
23	3	0	1	11	5	0	3	2	19	1	3	0	0	1	14	5	8
24	15	1	2	63	19	4	25	0	39	15	6	0	8	19	28	12	23
25	16	4	10	83	43	24	49	23	43	34	20	10	23	50	55	32	67
26	44	18	22	97	105	75	90	56	54	71	55	30	31	86	99	75	73
27	35	29	39	60	132	98	115	120	58	125	94	58	34	111	103	139	74
28	17	45	50	39	97	125	55	123	76	120	88	62	59	103	87	110	77
29	9	30	53	40	40	79	52	69	75	60	86	97	70	48	41	63	67
30	2	11	30	33	13	47	43	48	64	16	60	62	49	18	19	13	46
31	1	1	14	19	12	0	18	13	20	10	26	20	14	12	3	5	11
32	0	1	2	6	5	3	5	3	5	2	7	6	10	6	0	2	2
33	0	0	0	1	1	2	0	0	0	0	5	2	2	2	0	0	0
34	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0
35	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	142	140	224	452	475	458	455	458	453	454	450	347	300	457	454	456	450

Table 6.4 Continued.

Length (cm)	Exeter River– Combined Species																
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	2	0	3	0	1	0	0	0	0	0	0	0	0	0
23	0	0	0	42	2	4	0	0	0	0	0	2	0	1	2	0	0
24	0	1	0	233	22	11	4	0	6	1	0	0	0	3	7	3	4
25	0	11	0	251	66	50	21	11	18	1	1	4	0	6	21	11	11
26	0	27	0	158	86	120	65	66	31	2	11	9	1	7	37	45	14
27	0	43	2	164	95	120	73	124	37	14	29	24	2	7	55	129	8
28	0	38	11	126	69	62	61	129	36	27	19	15	7	9	29	99	5
29	0	19	6	67	33	24	24	91	25	15	13	15	4	4	12	38	3
30	0	6	2	24	7	6	8	26	6	4	3	4	1	1	2	9	2
31	0	1	0	5	4	2	2	5	1	1	2	1	0	1	2	2	1
32	0	1	1	1	0	1	1	1	0	2	0	1	1	0	1	0	0
33	0	0	0	1	2	0	0	0	0	0	0	2	0	1	0	0	0
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	*	147	22	1075	386	403	259	454	160	67	78	77	16	40	168	336	48

*- *Due to damage to fish trap, fishway became a swim through operation*

Table 6.4 Continued.

Length (cm)	Lamprey River– Combined Species																
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
20	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
24	1	1	0	2	3	2	6	0	0	0	6	1	4	20	5	2	23
25	12	1	3	11	18	21	36	7	5	31	19	2	13	31	40	13	56
26	18	15	13	37	50	66	72	31	20	54	49	21	18	27	90	35	66
27	48	32	14	45	71	100	128	78	37	54	100	49	18	44	128	99	29
28	31	43	38	35	80	97	150	113	68	91	88	98	47	70	80	144	42
29	19	31	33	56	58	99	92	118	107	78	59	94	78	66	60	100	62
30	9	12	17	60	34	45	79	71	103	77	65	83	79	60	26	37	53
31	1	5	8	47	18	13	30	25	79	39	46	32	52	48	18	13	24
32	2	2	1	9	6	7	11	7	30	19	11	16	16	30	3	5	12
33	0	0	0	2	1	3	3	2	7	4	6	6	6	12	3	1	1
34	0	0	0	0	0	0	0	0	2	1	4	0	1	2	0	2	1
35	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	141	142	127	304	339	453	608	452	459	449	453	402	333	411	453	451	369

Figure 6.4 Continued.

Length (cm)	Oyster River– Combined Species																
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	1	1	3	0	1	0	1	7	8	1	11	0	0
23	7	0	3	11	15	4	4	1	15	0	5	17	49	31	98	13	8
24	19	0	12	72	46	20	33	6	123	42	31	40	136	98	99	91	71
25	28	27	29	74	91	105	78	41	86	107	85	63	106	106	83	120	171
26	24	43	46	113	137	147	112	116	75	136	133	90	53	126	87	46	126
27	23	33	24	93	109	111	111	130	96	87	110	71	49	62	49	19	60
28	20	16	17	62	60	52	69	98	46	40	53	44	26	20	22	7	17
29	13	10	1	16	38	11	30	42	29	28	28	11	19	7	2	3	3
30	4	14	1	4	5	2	6	12	3	6	5	0	2	2	2	0	0
31	0	1	0	3	3	0	0	3	0	1	1	0	0	0	0	0	1
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	138	150	133	448	506	453	446	449	474	447	452	343	448	453	453	299	457

Table 6.4 Continued.

Length (cm)	Winnicut River– Combined Species																
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
20	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
21	0	0	0	0	0	0	2	0	0	0	0	7	2	0	0	0	0
22	0	0	0	0	0	2	26	0	2	1	1	26	5	7	6	3	0
23	0	0	0	0	3	6	87	6	25	32	13	74	30	35	29	47	0
24	0	0	0	0	23	36	98	50	109	138	59	65	31	75	64	91	0
25	0	0	0	0	26	70	107	119	145	127	116	64	16	135	98	98	0
26	0	0	0	0	16	64	62	126	90	99	149	46	14	106	128	88	0
27	0	0	0	0	6	26	43	91	49	37	80	38	11	52	75	62	0
28	0	0	0	0	3	9	17	57	22	7	29	19	6	18	37	42	0
29	0	0	0	0	1	2	7	13	7	2	5	4	7	8	15	18	0
30	0	0	0	0	1	2	1	2	3	1	0	0	1	7	3	0	0
31	0	0	0	0	0	1	0	0	1	0	1	0	0	0	0	3	0
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	*0	*0	*0	*0	79	218	450	464	453	444	453	343	124	443	457	452	0

**- Fishway unable to pass fish.*

Table 6.4 Continued.

Length (cm)	Taylor River– Combined Species																
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	7	14	2	0	1	0	4	0	0	0	4	0	0
24	0	0	0	0	35	29	6	0	0	0	20	1	0	0	3	0	0
25	0	0	0	0	33	45	58	0	0	0	19	8	0	0	0	0	0
26	0	0	0	0	16	49	70	0	3	0	12	3	0	3	0	0	0
27	0	0	0	0	18	25	66	0	7	0	8	2	0	5	0	0	0
28	0	0	0	0	9	11	33	0	7	0	10	0	0	3	0	0	0
29	0	0	0	0	5	3	8	0	8	0	6	0	0	4	0	0	0
30	0	0	0	0	1	1	3	0	0	0	1	0	0	2	0	0	0
31	0	0	0	0	1	1	1	0	0	0	0	0	0	1	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	*0	*0	*0	*0	125	181	247	0	26	0	80	14	0	18	7	0	0

** data not available for selected year*

Table 6.5 Length frequency of alewife river herring returning to New Hampshire rivers, 1994-2010.

Length (cm)	Cocheco River - Alewife																
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	4	1	0	3	0	0	0	0	0	0	0	0	0	1	1	3	7
25	8	1	3	11	0	2	1	0	1	2	0	1	3	0	3	9	20
26	27	2	15	9	10	4	11	3	7	4	3	6	5	2	15	14	24
27	37	11	22	9	27	20	25	20	10	29	14	16	5	13	26	21	18
28	26	34	33	8	44	29	26	30	22	36	20	27	13	27	26	18	16
29	10	41	47	7	15	37	18	34	21	25	28	28	22	21	17	17	7
30	5	17	39	11	9	10	18	19	21	8	21	24	18	12	8	5	3
31	2	4	25	8	5	6	7	8	7	4	13	10	8	8	2	1	0
32	0	1	3	2	3	2	0	3	3	3	2	7	1	4	0	0	0
33	0	0	1	2	2	1	0	0	1	0	0	1	2	3	0	0	0
34	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	119	112	190	70	115	111	106	117	93	111	102	120	77	92	98	88	96

Table 6.5 Continued.

Length (cm)	Exeter River - Alewife																
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	1	0	3	0	0	0	0	0	1	0	1	0	0	0
24	0	0	0	1	1	2	0	0	0	0	0	1	0	0	1	1	2
25	0	0	0	7	5	3	3	0	0	0	0	2	0	4	7	3	8
26	0	11	0	14	8	13	9	1	6	1	0	4	1	9	27	20	5
27	0	27	2	19	18	41	29	6	11	7	10	14	2	7	33	73	5
28	0	48	8	29	33	20	29	18	19	16	15	17	1	9	43	131	3
29	0	24	5	21	18	15	17	20	11	20	12	16	7	6	18	58	2
30	0	11	3	14	5	6	6	10	5	5	3	4	4	2	3	17	0
31	0	5	1	3	4	2	1	1	0	3	3	2	0	1	1	4	1
32	0	1	1	1	0	0	0	0	0	1	1	0	0	0	1	0	0
33	0	0	0	1	0	0	0	0	0	1	0	1	1	1	0	0	0
34	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	*	127	20	111	92	105	94	56	52	54	44	64	16	40	134	307	26

*- *Due to damage to fish trap, fishway became a swim through operation*

Table 6.5 Continued.

Length (cm)	Lamprey River - Alewife																
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	1	1	0	0	0	0	0	0	0	0	2	0	0	2
25	9	2	2	1	6	6	5	0	1	2	6	1	5	5	5	1	6
26	12	1	8	9	22	8	17	5	3	20	13	4	9	7	17	6	14
27	30	22	12	11	27	27	30	12	12	13	22	9	11	10	39	24	10
28	47	32	25	10	30	35	36	39	18	22	37	24	6	18	24	45	3
29	25	36	41	13	28	27	47	40	28	26	32	38	23	27	31	32	1
30	12	14	24	30	16	22	27	30	35	28	19	24	31	30	13	26	0
31	4	8	10	14	5	11	23	12	23	12	23	20	24	18	9	7	1
32	1	3	5	4	0	3	7	6	12	13	5	4	9	11	5	3	0
33	1	1	1	1	0	1	2	1	5	3	3	3	4	9	0	1	0
34	0	0	0	0	0	0	1	0	2	0	2	1	0	3	0	0	0
35	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	141	119	128	94	135	141	195	145	139	140	162	128	122	140	143	145	37

Table 6.5 Continued.

Length (cm)	Oyster River - Alewife																
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
25	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	5	16
26	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	6	13
27	0	1	2	0	0	0	0	0	0	0	0	0	0	0	1	2	15
28	0	3	2	0	0	0	0	0	0	0	2	0	0	0	1	0	5
29	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	1	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	8	5	0	0	0	0	0	1	0	3	0	0	0	4	15	54

Table 6.5 Continued.

Length (cm)	Winnicut River - Alewife																
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	1	8	1	1	0	1	0
23	0	0	0	0	0	1	1	0	0	0	0	16	5	8	3	3	0
24	0	0	0	0	1	4	8	8	5	11	4	21	7	19	8	15	0
25	0	0	0	0	0	17	4	19	21	17	11	14	5	25	14	17	0
26	0	0	0	0	1	21	3	25	23	24	34	16	1	40	37	18	0
27	0	0	0	0	2	11	3	21	17	11	29	17	3	24	37	27	0
28	0	0	0	0	1	10	2	11	6	6	9	5	3	9	21	14	0
29	0	0	0	0	0	2	0	3	5	1	4	2	3	7	9	17	0
30	0	0	0	0	0	1	0	0	1	0	0	0	3	3	4	2	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	2	0
32	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	*0	*0	*0	*0	5	67	21	87	79	70	92	100	32	139	134	116	0

**- Fishway unable to pass fish.*

Table 6.5 Continued.

Length (cm)	Taylor River - Alewife																
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
26	0	0	0	0	2	0	0	0	0	0	0	0	0	2	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0
29	0	0	0	0	1	0	0	0	0	0	0	0	0	5	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	*0	*0	*0	*0	3	0	0	0	0	0	1	0	0	19	0	0	0

** data not available for selected year*

Table 6.6 Length frequency of blueback river herring returning to New Hampshire rivers, 1994-2010.

Length (cm)	Cocheco River - Blueback																
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	1	0	0	2	0	0	0	0	3	0	0	0	0	0	3	1	7
24	4	0	0	8	3	0	2	0	10	0	0	0	1	1	7	0	10
25	10	0	8	18	15	0	6	1	14	7	0	0	0	17	9	0	26
26	1	8	5	20	14	9	9	5	7	11	7	3	2	18	13	0	8
27	4	8	14	10	15	16	4	8	6	5	7	2	1	21	8	0	1
28	2	4	8	10	6	4	2	11	7	2	1	0	2	5	7	1	0
29	1	3	4	5	1	0	2	0	5	0	2	0	2	5	1	0	0
30	0	2	3	1	0	0	0	0	1	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	23	25	42	75	54	29	25	25	53	25	17	5	8	67	48	2	53

Table 6.6 Continued.

Length (cm)	Exeter River - Blueback																
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	2	0	0	0	0	0	0	0	0	1	0	0
24	0	0	0	22	2	0	0	0	0	0	0	0	0	0	2	1	0
25	0	5	0	40	23	3	0	0	0	1	0	0	0	0	4	2	1
26	0	11	0	34	31	15	1	9	0	0	3	0	0	0	3	2	0
27	0	9	0	27	16	22	0	26	1	0	6	0	0	0	0	1	0
28	0	14	0	25	4	7	1	20	0	0	4	0	0	0	0	0	0
29	0	12	1	11	3	2	0	16	1	0	0	0	0	0	1	0	0
30	0	7	1	1	0	0	1	13	0	0	0	0	0	0	0	0	0
31	0	1	0	1	0	0	0	1	0	0	0	0	0	0	1	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	*0	61	2	161	80	51	3	85	2	1	13	0	0	0	12	6	1

*- *Due to damage to fish trap, fishway became a swim through operation*

Table 6.6 Continued.

Length (cm)	Lamprey River - Blueback																
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	3
25	0	0	0	1	0	7	0	0	0	0	0	0	0	2	0	0	18
26	0	0	0	0	0	7	0	0	0	2	0	0	0	2	0	0	10
27	0	2	0	0	0	2	0	0	0	1	0	0	1	5	0	1	1
28	0	3	0	0	0	3	0	0	0	0	0	0	0	2	0	0	0
29	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	13	0	2	0	19	0	0	0	3	0	0	2	11	0	1	32

Table 6.6 Continued.

Length (cm)	Oyster River - Blueback																
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
22	0	0	0	0	0	0	0	0	0	0	0	4	1	0	0	0	0
23	4	0	2	2	0	1	0	0	1	0	0	1	8	3	16	0	8
24	15	1	5	15	8	4	5	1	11	5	5	20	23	30	43	13	66
25	30	10	23	24	16	13	17	6	43	23	19	11	38	35	25	33	153
26	28	39	37	36	34	39	30	25	21	53	30	28	25	45	29	22	112
27	24	32	31	35	33	44	51	48	30	32	39	22	11	37	20	10	44
28	18	16	25	15	35	34	21	41	21	15	23	31	19	20	9	7	12
29	20	10	4	15	17	8	17	14	11	15	9	9	13	8	2	1	3
30	8	8	0	5	6	2	2	8	2	5	3	0	2	1	0	0	0
31	0	3	1	1	2	0	0	1	1	1	0	0	1	0	0	0	0
32	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	147	120	128	150	151	145	143	144	141	149	128	126	141	179	145	86	398

Table 6.6 Continued.

Length (cm)	Winnicut River - Blueback																
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
20	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	4	0	0	0	0	0	2	0	0	0	0
23	0	0	0	0	1	3	17	0	1	3	1	4	12	4	0	3	0
24	0	0	0	0	13	8	28	2	9	15	5	16	16	4	3	0	0
25	0	0	0	0	27	16	40	14	29	21	13	10	16	6	1	12	0
26	0	0	0	0	18	24	28	12	14	21	9	10	15	7	6	15	0
27	0	0	0	0	9	13	21	15	8	14	10	5	4	3	4	2	0
28	0	0	0	0	2	3	14	10	5	2	6	6	4	5	1	1	0
29	0	0	0	0	2	2	3	5	2	1	0	1	3	0	1	0	0
30	0	0	0	0	1	0	2	1	0	0	0	0	0	1	0	0	0
31	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	*0	*0	*0	*0	74	69	157	59	68	77	44	52	73	30	16	33	0

**- Fishway unable to pass fish.*

Table 6.6 Continued.

Length (cm)	Taylor River - Blueback																
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	2	3	0	0	0	0	1	0	0	0	2	0	0
24	0	0	0	0	21	12	2	0	1	0	8	0	0	0	4	0	0
25	0	0	0	0	35	11	8	0	0	0	19	6	0	0	1	0	0
26	0	0	0	0	22	18	28	0	1	0	13	5	0	0	0	0	0
27	0	0	0	0	16	12	29	0	3	0	9	3	0	0	0	0	0
28	0	0	0	0	10	5	19	0	11	0	9	0	0	0	0	0	0
29	0	0	0	0	4	3	9	0	11	0	4	0	0	0	0	0	0
30	0	0	0	0	4	2	2	0	3	0	3	0	0	0	0	0	0
31	0	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	*0	*0	*0	*0	115	67	97	0	30	0	67	14	0	0	7	0	0

** data not available for selected year*

Table 6.7 Percent of male and female river herring, mean total length (mm), and total sampled river herring during spawning returns to the first dam on the Cocheco, Exeter, Oyster, Lamprey, Taylor, and Winnicut rivers, New Hampshire, 1994-2010.

	Cocheco River– Combined Species					Exeter River– Combined Species					Oyster River– Combined Species				
	%		Mean Length		Total	%		Mean Length		Total	%		Mean Length		Total
Year	Male	Female	Male	Female	N	Male	Female	Male	Female	N	Male	Female	Male	Female	N
1994	56.5	44.5	274	274	462	*	*	*	*	*	63.2	36.8	262	277	450
1995	48.8	51.2	279	287	450	66.5	33.5	271	284	520	53.0	47.0	264	277	450
1996	50.7	49.3	282	290	402	54.8	45.2	278	284	221	61.4	38.6	258	270	446
1997	63.7	36.3	267	278	452	59.2	40.8	262	266	1075	60.7	39.3	261	272	448
1998	52.4	47.6	271	280	475	64.5	35.5	268	278	386	48.2	51.8	261	273	506
1999	52.4	47.6	277	288	458	65.8	34.2	267	278	403	57.4	42.6	261	273	453
2000	61.5	38.5	272	285	455	66.0	34.0	273	280	259	59.0	41.0	263	277	446
2001	54.1	45.9	278	286	458	59.7	40.3	277	288	454	60.8	39.2	269	283	449
2002	59.6	40.4	273	287	453	63.1	36.9	272	282	160	69.0	31.0	259	270	474
2003	49.3	50.7	275	280	454	62.7	37.3	283	291	67	51.7	48.3	260	272	447
2004	42.4	57.6	282	288	450	57.7	42.3	277	286	78	58.0	42.0	263	275	452
2005	50.4	49.6	285	294	347	66.2	33.8	278	289	77	60.5	39.5	257	273	343
2006	60.0	40.0	281	295	300	43.8	56.2	281	295	16	79.1	20.9	251	273	448
2007	62.8	37.2	272	285	457	60.0	40.0	268	283	40	64.7	35.3	254	267	453
2008	59.0	41.0	266	279	454	58.3	41.7	268	278	168	65.8	34.2	248	263	453
2009	58.3	41.7	273	282	456	56.3	43.8	276	283	336	76.6	23.4	251	265	299
2010	66.7	33.3	275	278	450	60.4	39.6	263	277	48	66.3	33.7	256	266	457

**-Sampling did not occur.*

Table 6.7 Continued.

	Lamprey River– Combined Species					Taylor River– Combined Species					Winnicut River– Combined Species				
	%		Mean Length		Total	%		Mean Length		Total	%		Mean Length		Total
Year	Male	Female	Male	Female	N	Male	Female	Male	Female	N	Male	Female	Male	Female	N
1994	51.9	48.1	274	281	447	*	*	*	*	*	*	*	*	*	*
1995	52.6	47.4	279	293	450	*	*	*	*	*	*	*	*	*	*
1996	51.0	49.0	281	294	398	*	*	*	*	*	*	*	*	*	*
1997	46.7	53.3	284	297	304	*	*	*	*	*	*	*	*	*	*
1998	56.3	43.7	279	289	339	70.4	29.6	253	274	125	84.8	15.2	254	271	79
1999	52.3	47.7	279	289	453	61.9	38.1	253	269	181	82.6	17.4	257	271	218
2000	52.3	47.7	279	290	608	44.9	55.1	261	274	247	79.8	20.2	248	265	450
2001	58.2	41.8	286	294	452	*	*	*	*	*	71.8	28.2	262	273	464
2002	58.2	41.8	292	306	459	38.5	61.5	269	288	26	73.7	26.3	255	265	453
2003	57.2	42.8	284	296	449	*	*	*	*	*	85.4	14.6	253	264	444
2004	53.0	47.0	285	290	453	63.8	36.2	255	275	80	79.0	21.0	260	269	453
2005	57.2	42.8	290	298	402	71.4	28.6	256	263	14	78.4	21.6	247	266	343
2006	55.3	44.7	289	303	333	*	*	*	*	*	89.5	10.5	251	264	124
2007	59.6	40.4	282	303	411	61.1	38.9	287	279	18	88.0	12.0	257	270	443
2008	47.5	52.5	274	283	453	*	*	*	*	*	81.4	18.6	259	274	457
2009	60.3	39.7	282	291	451	*	*	*	*	*	82.1	17.9	256	277	452
2010	60.7	39.3	272	296	369	*	*	*	*	*	*	*	*	*	*

**-Sampling did not occur.*

Table 6.8 Percent of male and female alewife river herring, mean total length (mm), and total sampled river herring during spawning returns to the first dam on the Cocheco, Exeter, Oyster, Lamprey, Taylor, and Winnicut rivers, New Hampshire, 1994-2010.

	Cocheco River - Alewife					Exeter River - Alewife					Oyster River - Alewife				
	%		Mean Length		Total	%		Mean Length		Total	%		Mean Length		Total
Year	Male	Female	Male	Female	N	Male	Female	Male	Female	N	Male	Female	Male	Female	N
1994	58.0%	42.0%	268	274	119	*	*	*	*	*	+	+	+	+	0
1995	50.9%	49.1%	282	289	112	64.6%	35.4%	277	288	127	50.0%	50.0%	261	270	8
1996	52.1%	47.9%	283	293	190	60.0%	40.0%	283	296	20	80.0%	20.0%	267	283	5
1997	75.7%	24.3%	276	291	70	64.9%	35.1%	275	286	111	+	+	+	+	0
1998	53.0%	47.0%	277	287	115	58.7%	41.3%	276	279	92	+	+	+	+	0
1999	52.3%	47.7%	280	290	111	64.8%	35.2%	272	277	105	+	+	+	+	0
2000	56.6%	43.4%	279	287	106	71.3%	28.7%	275	283	94	+	+	+	+	0
2001	45.3%	54.7%	280	292	117	71.4%	28.6%	283	291	56	+	+	+	+	0
2002	61.3%	38.7%	284	293	93	63.5%	36.5%	277	284	52	100.0%	0.0%	290	0	1
2003	39.6%	60.4%	279	284	111	61.1%	38.9%	283	293	54	+	+	+	+	0
2004	44.1%	55.9%	286	292	102	63.6%	36.4%	279	293	44	33.3%	66.7%	281	284	3
2005	48.3%	51.7%	283	294	120	65.6%	34.4%	277	289	64	+	+	+	+	0
2006	64.9%	35.1%	284	296	77	43.8%	56.3%	281	295	16	+	+	+	+	0
2007	49.5%	49.5%	283	295	93	60.0%	40.0%	268	283	40	+	+	+	+	0
2008	58.2%	41.8%	273	281	98	60.4%	39.6%	269	280	134	75.0%	25.0%	271	268	4
2009	51.1%	48.9%	271	283	184	58.3%	41.7%	276	283	307	68.8%	31.3%	259	269	16
2010	48.6%	51.4%	283	294	72	50.0%	50.0%	265	280	32	72.7%	27.3%	256	282	22

**-Sampling did not occur.*

+-Sampling occurred but no alewife encountered in run.

Table 6.8 Continued.

	Lamprey River - Alewife					Taylor River - Alewife					Winnicut River - Alewife				
	%		Mean Length		Total	%		Mean Length		Total	%		Mean Length		Total
Year	Male	Female	Male	Female	N	Male	Female	Male	Female	N	Male	Female	Male	Female	N
1994	55.3%	44.7%	274	284	141	*	*	*	*	*	*	*	*	*	*
1995	46.2%	53.8%	278	292	119	*	*	*	*	*	*	*	*	*	*
1996	51.6%	48.4%	283	293	128	*	*	*	*	*	*	*	*	*	*
1997	51.1%	48.9%	286	294	94	*	*	*	*	*	*	*	*	*	*
1998	58.5%	41.5%	275	285	135	66.7%	33.3%	260	286	3	80.0%	20.0%	261	267	5
1999	48.9%	51.1%	277	290	141	+	+	+	+	0	77.6%	22.4%	259	272	67
2000	52.3%	47.7%	282	291	195	+	+	+	+	0	66.7%	33.3%	245	264	21
2001	56.6%	43.4%	287	293	145	*	*	*	*	*	73.6%	26.4%	259	268	87
2002	59.7%	40.3%	290	305	139	+	+	+	+	0	83.5%	16.5%	259	276	79
2003	64.3%	35.7%	285	296	140	*	*	*	*	*	88.6%	11.4%	255	272	70
2004	53.1%	46.9%	283	292	162	100.0%	0.0%	251	0	1	77.2%	22.8%	263	269	92
2005	53.1%	46.9%	287	297	128	+	+	+	+	0	81.0%	19.0%	245	265	100
2006	50.0%	50.0%	285	301	122	*	*	*	*	*	93.8%	6.3%	254	279	32
2007	59.3%	40.7%	285	307	140	57.9%	42.1%	287	281	19	84.2%	15.8%	258	273	139
2008	42.7%	57.3%	276	285	143	+	+	+	+	0	79.9%	20.1%	264	273	134
2009	54.8%	45.2%	282	291	197	*	*	*	*	*	66.9%	33.1%	260	277	166
2010	45.7%	54.3%	279	294	81	*	*	*	*	*	*	*	*	*	*

**-Sampling did not occur.*

+-Sampling occurred but no alewife encountered in run.

Table 6.9 Percent of male and female blueback river herring, mean total length (mm), and total sampled river herring during spawning returns to the first dam on the Cocheco, Exeter, Oyster, Lamprey, Taylor, and Winnicut rivers, New Hampshire, 1994-2010.

	Cocheco River - Blueback					Exeter River - Blueback					Oyster River - Blueback				
	%		Mean Length		Total	%		Mean Length		Total	%		Mean Length		Total
Year	Male	Female	Male	Female	N	Male	Female	Male	Female	N	Male	Female	Male	Female	N
1994	69.6%	30.4%	251	259	23	*	*	*	*	*	68.0%	32.0%	260	276	147
1995	24.0%	76.0%	269	274	25	67.2%	32.8%	272	292	61	52.5%	47.5%	266	277	120
1996	50.0%	50.0%	265	277	42	100.0%	0.0%	294		2	57.0%	43.0%	260	269	128
1997	58.7%	41.3%	257	268	75	85.7%	14.3%	260	272	161	66.7%	33.3%	261	275	150
1998	59.3%	40.7%	258	267	54	77.5%	22.5%	257	277	80	47.0%	53.0%	264	275	151
1999	65.5%	34.5%	265	270	29	72.5%	27.5%	263	274	51	57.2%	42.8%	263	274	145
2000	76.0%	24.0%	258	271	25	100.0%	0.0%	278		3	62.2%	37.8%	263	277	143
2001	52.0%	48.0%	267	273	25	55.3%	44.7%	272	288	85	58.3%	40.3%	268	282	144
2002	71.7%	28.3%	255	267	53	50.0%	50.0%	266	286	2	73.8%	26.2%	260	271	141
2003	52.0%	48.0%	256	265	25	100.0%	0.0%	249		1	56.4%	43.6%	261	273	149
2004	41.2%	58.8%	263	273	17	69.2%	30.8%	268	274	13	59.4%	40.6%	263	273	128
2005	80.0%	20.0%	262	263	5	+	+	+	+	0	61.9%	37.3%	255	276	126
2006	62.5%	37.5%	263	282	8	+	+	+	+	0	74.5%	24.1%	254	277	141
2007	70.1%	29.9%	260	269	67	+	+	+	+	0	59.2%	40.8%	254	267	179
2008	64.6%	35.4%	250	272	48	58.3%	41.7%	248	271	12	71.0%	29.0%	247	261	145
2009	50.0%	50.0%	234	282	2	100.0%	0.0%	255		6	66.4%	33.6%	253	267	119
2010	79.2%	20.8%	252	249	53	100.0%	0.0%	259		1	66.1%	33.9%	256	264	398

**-Sampling did not occur.*

+-Sampling occurred but no blueback encountered in run.

Table 6.9 Continued.

	Lamprey River - Blueback					Taylor River - Blueback					Winnicut River - Blueback				
	%		Mean Length		Total	%		Mean Length		Total	%		Mean Length		Total
Year	Male	Female	Male	Female	N	Male	Female	Male	Female	N	Male	Female	Male	Female	N
1994	+	+	+	+	0	*	*	*	*	*	*	*	*	*	*
1995	38.5%	61.5%	288	292	13	*	*	*	*	*	*	*	*	*	*
1996	+	+	+	+	0	*	*	*	*	*	*	*	*	*	*
1997	0.0%	100.0%		282	2	*	*	*	*	*	*	*	*	*	*
1998	+	+	+	+	0	73.0%	27.0%	253	271	115	85.1%	14.9%	254	271	74
1999	47.4%	52.6%	253	265	19	67.2%	32.8%	253	272	67	88.4%	11.6%	256	267	69
2000	+	+	+	+	0	48.5%	51.5%	262	274	97	72.0%	28.0%	249	265	157
2001	+	+	+	+	0	*	*	*	*	*	78.0%	22.0%	262	279	59
2002	+	+	+	+	0	33.3%	66.7%	268	288	30	75.0%	25.0%	253	263	68
2003	100.0%	0.0%	264		3	*	*	*	*	*	85.7%	14.3%	254	258	77
2004	+	+	+	+	0	58.2%	41.8%	254	273	67	79.5%	20.5%	256	269	44
2005	+	+	+	+	0	71.4%	28.6%	256	263	14	80.8%	19.2%	249	267	52
2006	100.0%	0.0%	256		2	*	*	*	*	*	84.9%	15.1%	247	257	73
2007	63.6%	36.4%	262	271	11	+	+	+	+	0	83.3%	16.7%	254	266	30
2008	+	+	+	+	0	100.0%	0.0%	239		7	87.5%	12.5%	260	278	16
2009	75.0%	25.0%	255	251	4	*	*	*	*	*	65.1%	34.9%	252	265	43
2010	90.6%	9.4%	256	268	32	*	*	*	*	*	*	*	*	*	*

**-Sampling did not occur.*

+-Sampling occurred but no blueback encountered in run.

Table 6.10 Number-at-age of river herring collected from the coastal rivers of New Hampshire, 1994-2010.

Cocheco River– Combined Species																	
Age	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
3	69	19	45	45	29	6	61	20	17	6	1	2	0	0	6	13	5
4	61	74	78	49	65	62	36	61	54	89	15	29	13	31	27	75	13
5	10	42	63	34	50	47	27	43	45	29	69	47	21	55	57	48	28
6	0	2	35	14	15	20	7	9	24	7	26	46	25	54	44	42	19
7+	0	0	2	3	10	5	0	9	6	5	8	1	26	19	12	8	7
Total	140	137	223	145	169	140	131	142	146	136	119	125	85	159	146	186	72

Exeter River– Combined Species																	
Age	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
3	*	70	6	82	69	23	53	8	2	2	0	2	0	3	21	3	6
4	*	94	11	112	44	88	37	45	15	30	6	25	1	9	62	147	17
5	*	17	5	52	37	38	5	47	27	14	31	26	6	15	44	119	12
6	*	4	0	22	16	7	2	31	10	6	18	8	4	11	16	39	3
7+	*	0	0	4	6	0	0	10	0	3	2	3	5	2	3	5	0
Total	*	185	22	272	172	156	97	141	54	55	57	64	16	40	146	313	38

Oyster River– Combined Species																	
Age	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
3	65	33	32	64	36	44	61	21	12	32	20	22	6	9	46	33	29
4	48	68	61	50	58	84	56	48	54	62	17	38	46	71	48	64	23
5	23	25	37	28	44	15	25	39	37	43	69	45	46	68	38	22	32
6	4	2	3	7	11	2	1	24	28	7	21	20	32	22	11	13	10
7+	0	0	0	1	2	0	0	10	11	5	4	0	9	9	6	3	6
Total	140	128	133	150	151	145	143	142	142	149	131	125	139	179	149	135	100

Table 6.10 Continued.

Lamprey River– Combined Species																	
Age	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
3	48	26	26	15	18	15	50	11	3	8	7	0	3	2	9	6	10
4	68	74	60	18	30	44	68	49	28	53	26	25	13	21	25	44	21
5	19	31	35	35	46	53	44	52	39	41	63	55	42	42	52	79	27
6	5	1	5	24	31	35	26	26	42	17	45	44	36	54	37	60	25
7+	1	0	0	4	10	13	7	7	27	24	21	4	30	32	20	12	9
Total	141	132	126	96	135	160	195	145	139	143	162	128	124	151	143	201	92

Taylor River– Combined Species																	
Age	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
3	*	*	*	*	49	48	31	*	1	*	22	1	*	0	3	*	*
4	*	*	*	*	33	10	47	*	1	*	19	13	*	1	4	*	*
5	*	*	*	*	24	4	14	*	6	*	15	0	*	10	0	*	*
6	*	*	*	*	6	5	5	*	16	*	7	0	*	6	0	*	*
7+	*	*	*	*	6	0	0	*	6	*	5	0	*	2	0	*	*
Total	*	*	*	*	118	67	97	*	30	*	68	14	*	19	7	*	*

Winnicut River– Combined Species																	
Age	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
3	*	*	*	*	45	44	60	42	29	36	3	48	9	5	5	30	*
4	*	*	*	*	24	69	70	64	61	88	58	52	41	56	29	65	*
5	*	*	*	*	4	19	30	25	30	21	66	38	34	60	71	40	*
6	*	*	*	*	4	4	16	14	21	2	7	13	16	32	37	49	*
7+	*	*	*	*	2	0	2	1	6	0	2	1	5	16	8	25	*
Total	*	*	*	*	79	136	178	146	147	147	136	152	105	169	150	209	*

** data not available for selected year*

Table 6.11 Number-at-age of alewife river herring collected from the coastal rivers of New Hampshire, 1994-2010.

Cocheco River - Alewife																	
Age	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
3	52	10	37	18	11	1	48	14	3	4	1	2	0	0	0	13	5
4	57	60	61	15	38	45	26	52	29	72	10	28	9	7	18	74	13
5	10	40	51	23	42	40	25	36	33	26	57	43	19	29	37	48	28
6	0	2	31	12	14	20	7	7	22	5	26	46	25	39	33	41	19
7+	0	0	1	2	10	5	0	8	6	4	8	1	24	18	10	8	7
Total	119	112	181	70	115	111	106	117	93	111	102	120	77	93	98	184	72

Exeter River – Alewife																	
Age	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
3	*	44	5	24	20	12	52	2	2	1	0	2	0	3	17	0	4
4	*	68	11	55	23	51	36	16	14	30	2	25	1	9	57	146	15
5	*	11	4	21	30	35	4	29	26	14	23	26	6	15	44	118	11
6	*	1	0	7	14	7	2	8	10	6	17	8	4	11	14	39	2
7+	*	0	0	4	5	0	0	1	0	3	2	3	5	2	2	4	0
Total	*	124	20	111	92	105	94	56	52	54	44	64	16	40	134	307	32

Oyster River – Alewife																	
Age	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
3	0	3	1	0	0	0	0	0	0	0	0	0	0	0	1	3	2
4	0	5	3	0	0	0	0	0	0	0	0	0	0	0	0	6	13
5	0	0	1	0	0	0	0	0	1	0	2	0	0	0	2	2	3
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
7+	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	3	2
Total	0	8	5	0	0	0	0	0	1	0	3	0	0	0	4	16	22

Table 6.11 Continued.

Lamprey River – Alewife																	
Age	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
3	48	25	26	15	18	3	50	11	3	8	7	0	2	0	9	4	9
4	68	65	60	17	30	38	68	49	28	53	26	25	13	19	25	44	16
5	19	28	35	35	46	52	44	52	39	38	63	55	41	38	52	78	25
6	5	1	5	23	31	35	26	26	42	17	45	44	36	52	37	59	24
7+	1	0	0	4	10	13	7	7	27	24	21	4	30	31	20	12	7
Total	141	119	126	94	135	141	195	145	139	140	162	128	122	140	143	197	81

Taylor River – Alewife																	
Age	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
3	*	*	*	*	0	0	0	*	0	*	0	0	*	0	0	*	*
4	*	*	*	*	2	0	0	*	0	*	0	0	*	1	0	*	*
5	*	*	*	*	0	0	0	*	0	*	1	0	*	10	0	*	*
6	*	*	*	*	0	0	0	*	0	*	0	0	*	6	0	*	*
7+	*	*	*	*	1	0	0	*	0	*	0	0	*	2	0	*	*
Total	*	*	*	*	3	0	0	*	0	*	1	0	*	19	0	*	*

Winnicut River – Alewife																	
Age	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
3	*	*	*	*	1	12	9	28	18	20	2	34	4	5	3	21	*
4	*	*	*	*	3	38	7	41	23	40	36	31	9	45	24	35	*
5	*	*	*	*	0	13	2	9	18	9	47	24	9	51	66	37	*
6	*	*	*	*	1	4	2	9	15	1	5	10	7	24	33	49	*
7+	*	*	*	*	0	0	1	0	5	0	2	1	3	14	8	24	*
Total	*	*	*	*	5	67	21	87	79	70	92	100	32	139	134	166	*

** data not available for selected year*

Table 6.12 Number-at-age of blueback river herring collected from the coastal rivers of New Hampshire, 1994-2010.

Cocheco River - Blueback																	
Age	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
3	17	9	8	27	18	5	13	6	14	2	0	0	0	0	6	0	0
4	4	14	17	34	27	17	10	9	25	17	5	1	4	24	9	1	0
5	0	2	12	11	8	7	2	7	12	3	12	4	2	27	20	0	0
6	0	0	4	2	1	0	0	2	2	2	0	0	0	15	11	1	0
7+	0	0	1	1	0	0	0	1	0	1	0	0	2	1	2	0	0
Total	21	25	42	75	54	29	25	25	53	25	17	5	8	67	48	2	0

Exeter River – Blueback																	
Age	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
3	*	26	1	58	49	11	1	6	0	1	0	0	0	0	4	3	2
4	*	26	0	57	21	37	1	29	1	0	4	0	0	0	5	1	2
5	*	6	1	31	7	3	1	18	1	0	8	0	0	0	0	1	1
6	*	3	0	15	2	0	0	23	0	0	1	0	0	0	2	0	1
7+	*	0	0	0	1	0	0	9	0	0	0	0	0	0	1	1	0
Total	*	61	2	161	80	51	3	85	2	1	13	0	0	0	12	6	6

Oyster River – Blueback																	
Age	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
3	65	30	31	64	36	44	61	21	12	32	20	22	6	9	45	30	27
4	48	63	58	50	58	84	56	49	54	62	17	39	48	71	48	58	10
5	23	25	36	28	44	15	25	39	36	43	67	45	46	68	36	20	29
6	4	2	3	7	11	2	1	25	28	7	21	20	32	22	11	11	8
7+	0	0	0	1	2	0	0	10	11	5	3	0	9	9	5	0	4
Total	140	120	128	150	151	145	143	144	141	149	128	126	141	179	145	119	78

Table 6.12 Continued.

Lamprey River – Blueback																	
Age	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
3	0	1	0	0	0	12	0	0	0	0	0	0	1	2	0	2	1
4	0	9	0	1	0	6	0	0	0	0	0	0	0	2	0	0	5
5	0	3	0	0	0	1	0	0	0	3	0	0	1	4	0	1	2
6	0	0	0	1	0	0	0	0	0	0	0	0	0	2	0	1	1
7+	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2
Total	0	13	0	2	0	19	0	0	0	3	0	0	2	11	0	4	11

Taylor River – Blueback																	
Age	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
3	*	*	*	*	49	48	31	*	1	*	22	1	*	0	3	*	*
4	*	*	*	*	31	10	47	*	1	*	19	13	*	0	4	*	*
5	*	*	*	*	24	4	14	*	6	*	14	0	*	0	0	*	*
6	*	*	*	*	6	5	5	*	16	*	7	0	*	0	0	*	*
7+	*	*	*	*	5	0	0	*	6	*	5	0	*	0	0	*	*
Total	*	*	*	*	115	67	97	*	30	*	67	14	*	0	7	*	*

Winnicut River – Blueback																	
Age	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
3	*	*	*	*	44	32	51	14	11	16	1	14	5	0	2	9	*
4	*	*	*	*	21	31	63	23	38	48	22	21	32	11	5	30	*
5	*	*	*	*	4	6	28	16	12	12	19	14	25	9	5	3	*
6	*	*	*	*	3	0	14	5	6	1	2	3	9	8	4	0	*
7+	*	*	*	*	2	0	1	1	1	0	0	0	2	2	0	1	*
Total	*	*	*	*	74	69	157	59	68	77	44	52	73	30	16	43	*

** data not available for selected year*

Table 6.13 Mean total length-at-age (TL, mm) of river herring returning to New Hampshire rivers, 1992-2010.

Cocheco River– Combined Species																			
Mean Length (mm) at Age																			
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Age																			
3	280	249	260	268	272	253	258	258	268	271	248	262	266	258			236	249	255
4	284	267	273	282	282	262	269	273	277	280	266	274	274	273	265	261	257	266	273
5	314	284	292	290	292	286	280	284	295	288	284	285	282	284	280	268	271	281	293
6	322	300		307	296	305	293	294	304	292	300	294	300	300	291	285	277	292	297
7+	328				311	309	314	314		309	306	305	311	315	298	312	290	312	306

Exeter River– Combined Species																			
Mean Length (mm) at Age																			
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Age																			
3	274		*	271	285	253	257	259	270	272	266	252		236		245	252	250	253
4	283	264	*	283	285	268	270	269	283	274	273	283	271	272	273	261	270	275	265
5	290	279	*	296	300	282	280	279	293	285	281	289	277	283	284	271	279	280	285
6	302	298	*	317		289	288	297	306	287	287	295	288	301	285	289	282	286	290
7+	292	319	*			315	312			287		314	311	322	300	306	310	291	

Oyster River– Combined Species																			
Mean Length (mm) at Age																			
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Age																			
3	267	242	253	262	257	255	254	258	261	260	250	254	249	241	235	243	238	249	250
4	277	264	273	270	265	267	269	269	271	271	252	261	264	256	245	250	248	255	260
5	288	278	288	283	269	280	278	281	280	276	268	275	270	272	258	264	262	269	269
6	303	289	293	308	274	292	293	296	281	281	276	286	276	280	277	271	273	275	274
7+	318					318	307			287	284	298	290		291	288	281	286	282

Table 6.13 Continued.

Lamprey River– Combined Species Mean Length (mm) at Age																			
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Age																			
3	283		269	274	278	263	261	253	273	272	262	264	259		247	247	261	250	254
4	293	274	279	285	287	274	266	268	281	282	279	276	271	273	261	268	269	272	261
5	302	283	292	297	296	296	281	281	295	292	294	288	284	290	285	279	277	285	288
6	320	301	308	314	300	305	292	296	304	299	304	298	294	301	302	299	287	295	303
7+	321		329			316	304	312	312	306	311	319	313	324	310	313	305	307	309

Taylor River– Combined Species Mean Length (mm) at Age																			
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Age																			
3	*	251	*	*	*	*	246	253	263	*	236	*	247	253	*		241	*	*
4	*	265	*	*	*	*	255	266	267	*	266	*	258	258	*	264	238	*	*
5	*	279	*	*	*	*	272	282	274	*	275	*	267		*	276		*	*
6	*	295	*	*	*	*	284	294	291	*	284	*	281		*	295		*	*
7+	*	309	*	*	*	*	296			*	291	*	296		*	308		*	*

Winnicut River– Combined Species Mean Length (mm) at Age																			
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Age																			
3	*	*	*	*	*	*	249	250	239	254	250	247	232	233	229	239	235	237	*
4	*	*	*	*	*	*	260	261	253	262	252	256	258	248	242	247	254	254	*
5	*	*	*	*	*	*	271	273	269	272	266	269	266	268	252	258	263	265	*
6	*	*	*	*	*	*	285	289	274	281	272	280	274	268	275	270	278	279	*
7+	*	*	*	*	*	*	303		289	268	291		277	263	281	292	287	289	*

**data not available for selected year*

Table 6.14 Mean total length-at-age (TL, mm) of alewife river herring returning to New Hampshire rivers, 1992-2010.

Cocheco River - Alewife																			
Mean Length (mm) at Age																			
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Age																			
3	285	249	263	272	274	261	267	250	273	274	262	265	266	258				249	255
4	288	271	273	283	286	262	273	276	280	281	275	277	279	273	266	273	262	266	273
5	316	291	292	290	296	289	281	287	297	291	288	287	284	286	281	276	276	281	293
6	322	302		307	298	308	294	294	304	297	301	306	300	300	291	288	280	292	297
7+	328				325	305	314	314		313	306	312	311	315	299	314	294	312	306

Exeter River-Alewife																			
Mean Length (mm) at Age																			
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Age																			
3	279		*	274	284	261	260	258	270	282	266	255		236		245	255		256
4	284	262	*	283	285	276	275	270	283	280	274	283	276	272	273	261	272	276	265
5	292	282	*	296	302	292	280	280	292	287	281	289	279	283	284	271	279	280	284
6	304	302	*	305		299	289	297	306	289	287	294	289	301	284	289	282	286	304
7+		329	*			315	307			298		314	311	322	300	306	308	297	

Oyster River - Alewife																			
Mean Length (mm) at Age																			
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Age																			
3	272			262	278												231	250	276
4	281			268	269													255	257
5	298				266						290		284				274	264	258
6	297																	261	276
7+	324												281				303	286	278

Table 6.14 Continued.

Lamprey River - Alewife																			
Mean Length (mm) at Age																			
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Age																			
3	283		269	274	278	263	261	249	273	272	262	264	259		250		261	252	254
4	293	274	279	284	287	275	266	268	281	282	279	276	271	273	261	269	269	272	260
5	302	282	292	297	296	296	281	281	295	292	294	290	284	290	286	280	277	285	290
6	320	301	308	314	300	305	292	296	304	299	304	298	294	301	302	300	287	295	304
7+	321		329			316	304	312	312	306	311	319	313	324	310	314	305	307	322

Taylor River - Alewife																			
Mean Length (mm) at Age																			
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Age																			
3	*	256	*	*	*	*				*		*			*			*	*
4	*	260	*	*	*	*	260			*		*			*	264		*	*
5	*	279	*	*	*	*				*		*	251		*	276		*	*
6	*		*	*	*	*				*		*			*	295		*	*
7+	*		*	*	*	*	286			*		*			*	308		*	*

Winnicut River - Alewife																			
Mean Length (mm) at Age																			
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Age																			
3	*	*	*	*	*	*	244	249	240	254	251	248	234	231	227	239	233	234	*
4	*	*	*	*	*	*	263	259	252	261	254	259	260	247	243	248	254	250	*
5	*	*	*	*	*	*		273	264	270	265	269	266	268	251	258	263	265	*
6	*	*	*	*	*	*	277	288	276	278	271	290	277	269	284	271	278	279	*
7+	*	*	*	*	*	*			282		294		276	263	281	292	286	290	*

**data not available for selected year*

Table 6.15 Mean total length-at-age (TL, mm) of blueback river herring returning to New Hampshire rivers, 1992-2010.

Cocheco River – Blueback																			
Mean Length (mm) at Age																			
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Age																			
3	273		252	264	262	248	252	260	252	262	245	255					236		
4	277	263	268	275	266	262	264	267	268	273	256	260	264	258	262	257	247	234	
5	299	277		294	276	282	274	270	278	270	273	261	271	263	274	259	262		
6	322	292			282	288	287			277	290	266				277	268	282	
7+					297	318				280		277			286	292	272		

Exeter River – Blueback																			
Mean Length (mm) at Age																			
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Age																			
3	264		*	267	292	249	255	261	255	268		249					239	250	244
4	276	268	*	281		260	265	267	282	271	266		268				254	251	264
5	283	277	*	294	295	276	278	271	298	281	286		270					260	301
6	297	292	*	321		284	279			287			275				276		262
7+	292	308	*				334			286							312	270	

Oyster River – Blueback																			
Mean Length (mm) at Age																			
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Age																			
3	267	242	253	262	256	255	254	258	261	260	250	254	249	241	234	243	238	248	248
4	276	264	273	270	265	267	269	269	271	270	252	261	264	256	245	250	248	255	264
5	287	278	288	283	269	280	278	281	280	276	268	275	269	272	258	264	261	269	270
6	304	290	293	308	274	292	293	296	281	281	276	286	276	280	277	271	273	277	273
7+	316					318	306			287	284	298	292		291	288	276		284

Table 6.15 Continued.

Lamprey River – Blueback Mean Length (mm) at Age																			
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Age																			
3				279				254							241	247		245	257
4	280			287		253		270								262			262
5		288		304				250				264			271	267		258	265
6						312										279		269	263
7+																272			260

Taylor River – Blueback Mean Length (mm) at Age																			
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Age																			
3	*	248	*	*	*	*	246	252	263	*	236	*	247	253	*		241	*	*
4	*	264	*	*	*	*	255	266	267	*	266	*	258	258	*		238	*	*
5	*	279	*	*	*	*	272	282	274	*	275	*	268		*			*	*
6	*	295	*	*	*	*	284	294	291	*	284	*	281		*			*	*
7+	*	309	*	*	*	*	298			*	290	*	296		*			*	*

Winnicut River – Blueback Mean Length (mm) at Age																			
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Age																			
3	*	*	*	*	*	*	249	250	239	255	247	245	230	239	230		239	245	*
4	*	*	*	*	*	*	260	262	253	263	251	254	256	249	242	241	256	259	*
5	*	*	*	*	*	*	271	274	269	273	267	268	264	270	252	254	266	262	*
6	*	*	*	*	*	*	287		274	285	274	270	267	266	269	270	276		*
7+	*	*	*	*	*	*	303		296	268	276				281	292		287	*

**data not available for selected year*

Table 6.16 Distribution of repeat spawning frequency of river herring returning to New Hampshire rivers, from scale samples aged between 2000 and 2010.

	Cocheco River - Combined Species					
Year	% r0	% r1	% r2	% r3	% r4	Total N
2000	66%	15%	18%	1%	0%	131
2001	57%	33%	6%	2%	1%	142
2002	63%	25%	12%	0%	0%	146
2003	71%	16%	10%	3%	0%	136
2004	34%	45%	18%	3%	0%	119
2005	47%	29%	18%	6%	0%	125
2006	53%	24%	13%	8%	2%	85
2007	69%	17%	9%	4%	1%	160
2008	68%	26%	6%	0%	0%	146
2009	78%	21%	1%	0%	0%	90
2010	35%	35%	29%	1%	0%	72

	Exeter River - Combined Species					
Year	% r0	% r1	% r2	% r3	% r4	Total N
2000	90%	8%	2%	0%	0%	97
2001	48%	33%	16%	3%	0%	141
2002	80%	13%	7%	0%	0%	54
2003	62%	25%	13%	0%	0%	55
2004	58%	26%	14%	2%	0%	57
2005	78%	16%	3%	3%	0%	64
2006	63%	31%	6%	0%	0%	16
2007	83%	15%	3%	0%	0%	40
2008	90%	8%	2%	1%	0%	146
2009	88%	11%	1%	0%	0%	314
2010	76%	21%	0%	3%	0%	38

	Oyster River - Combined Species					
Year	% r0	% r1	% r2	% r3	% r4	Total N
2000	66%	26%	7%	2%	0%	145
2001	36%	42%	16%	5%	1%	146
2002	63%	17%	15%	4%	0%	142
2003	49%	32%	16%	3%	0%	149
2004	32%	25%	34%	8%	1%	131
2005	50%	35%	14%	1%	0%	126
2006	57%	24%	13%	6%	0%	141
2007	62%	28%	7%	3%	0%	179
2008	72%	17%	7%	3%	0%	149
2009	59%	35%	6%	0%	0%	101
2010	53%	24%	18%	5%	0%	100

Table 6.16 Continued.

	Lamprey River - Combined Species					
Year	% r0	% r1	% r2	% r3	% r4	Total N
2000	54%	26%	17%	3%	1%	195
2001	41%	45%	10%	3%	0%	145
2002	37%	29%	29%	5%	0%	139
2003	48%	27%	20%	6%	0%	143
2004	45%	27%	20%	7%	1%	162
2005	48%	36%	14%	2%	0%	128
2006	41%	34%	19%	6%	0%	124
2007	43%	27%	22%	6%	2%	151
2008	67%	20%	8%	3%	1%	143
2009	50%	40%	9%	1%	0%	146
2010	36%	39%	20%	5%	0%	92

	Taylor River - Combined Species					
Year	% r0	% r1	% r2	% r3	% r4	Total N
2000	69%	28%	2%	1%	0%	97
2001	*	*	*	*	*	*
2002	7%	40%	47%	7%	0%	30
2003	*	*	*	*	*	*
2004	71%	15%	10%	4%	0%	68
2005	93%	7%	0%	0%	0%	14
2006	*	*	*	*	*	*
2007	68%	26%	5%	0%	0%	19
2008	100%	0%	0%	0%	0%	7
2009	*	*	*	*	*	*
2010	*	*	*	*	*	*

	Winnicut River - Combined Species					
Year	% r0	% r1	% r2	% r3	% r4	Total N
2000	77%	11%	9%	3%	0%	179
2001	57%	33%	9%	1%	0%	146
2002	67%	12%	18%	3%	0%	147
2003	63%	34%	3%	0%	0%	147
2004	36%	44%	18%	1%	0%	136
2005	66%	24%	9%	1%	0%	152
2006	70%	24%	4%	3%	0%	105
2007	38%	40%	14%	7%	1%	169
2008	36%	33%	26%	3%	1%	150
2009	54%	23%	16%	6%	0%	149
2010	*	*	*	*	*	*

**-Sampling did not occur.*

+-Sampling occurred but no alewife encountered in run.

Table 6.17 Distribution of repeat spawning frequency of alewife river herring returning to New Hampshire rivers, from scale samples aged between 2000 and 2010.

	Cocheco River - Alewife					
Year	% r0	% r1	% r2	% r3	% r4	Total N
2000	68%	11%	20%	1%	0%	106
2001	56%	34%	6%	3%	1%	117
2002	54%	33%	13%	0%	0%	93
2003	69%	17%	12%	2%	0%	111
2004	30%	46%	20%	4%	0%	102
2005	46%	29%	18%	7%	0%	120
2006	49%	25%	14%	9%	3%	77
2007	69%	15%	8%	8%	1%	93
2008	70%	27%	3%	0%	0%	98
2009	78%	20%	1%	0%	0%	88
2010	35%	35%	29%	1%	0%	72

	Exeter River - Alewife					
Year	% r0	% r1	% r2	% r3	% r4	Total N
2000	89%	9%	2%	0%	0%	94
2001	63%	36%	2%	0%	0%	56
2002	81%	13%	6%	0%	0%	52
2003	61%	26%	13%	0%	0%	54
2004	64%	23%	11%	2%	0%	44
2005	78%	16%	3%	3%	0%	64
2006	63%	31%	6%	0%	0%	16
2007	83%	15%	3%	0%	0%	40
2008	91%	8%	1%	0%	0%	134
2009	88%	11%	1%	0%	0%	307
2010	81%	19%	0%	0%	0%	32

	Oyster River - Alewife					
Year	% r0	% r1	% r2	% r3	% r4	Total N
2000						+
2001						+
2002	0%	100%	0%	0%	0%	1
2003						+
2004	100%	0%	0%	0%	0%	3
2005						+
2006						+
2007						+
2008	50%	25%	0%	25%	0%	4
2009	40%	33%	27%	0%	0%	15
2010	73%	14%	5%	9%	0%	22

**-Sampling did not occur.*

+-Sampling occurred but no alewife encountered in run.

Table 6.17 Continued.

	Lamprey River - Alewife					
Year	% r0	% r1	% r2	% r3	% r4	Total N
2000	54%	26%	17%	3%	1%	195
2001	41%	45%	10%	3%	0%	145
2002	37%	29%	29%	5%	0%	139
2003	49%	26%	19%	6%	0%	140
2004	45%	27%	20%	7%	1%	162
2005	48%	36%	14%	2%	0%	128
2006	40%	34%	20%	6%	0%	122
2007	43%	26%	22%	6%	2%	140
2008	67%	20%	8%	3%	1%	143
2009	50%	41%	8%	1%	0%	145
2010	37%	38%	20%	5%	0%	81

	Taylor River - Alewife					
Year	% r0	% r1	% r2	% r3	% r4	Total N
2000						+
2001	*	*	*	*	*	*
2002						+
2003	*	*	*	*	*	*
2004	100%	0%	0%	0%	0%	1
2005						+
2006	*	*	*	*	*	*
2007	68%	26%	5%	0%	0%	19
2008						+
2009	*	*	*	*	*	*
2010	*	*	*	*	*	*

	Winnicut River - Alewife					
Year	% r0	% r1	% r2	% r3	% r4	Total N
2000	76%	0%	19%	5%	0%	21
2001	55%	36%	7%	2%	0%	87
2002	59%	13%	22%	5%	0%	79
2003	64%	31%	4%	0%	0%	70
2004	34%	45%	20%	2%	0%	92
2005	60%	28%	11%	1%	0%	100
2006	63%	31%	0%	6%	0%	32
2007	38%	40%	14%	8%	0%	139
2008	35%	34%	26%	4%	1%	134
2009	45%	27%	21%	8%	0%	116
2010	*	*	*	*	*	*

**-Sampling did not occur.*

+-Sampling occurred but no alewife encountered in run.

Table 6.18 Distribution of repeat spawning frequency of blueback river herring returning to New Hampshire rivers, from scale samples aged between 2000 and 2010.

	Cocheco River - Blueback					
Year	% r0	% r1	% r2	% r3	% r4	Total N
2000	56%	32%	12%	0%	0%	25
2001	60%	28%	8%	0%	4%	25
2002	79%	11%	9%	0%	0%	53
2003	76%	12%	4%	8%	0%	25
2004	59%	35%	6%	0%	0%	17
2005	80%	20%	0%	0%	0%	5
2006	88%	13%	0%	0%	0%	8
2007	69%	19%	12%	0%	0%	67
2008	63%	25%	13%	0%	0%	48
2009	50%	50%	0%	0%	0%	2
2010						+

	Exeter River - Blueback					
Year	% r0	% r1	% r2	% r3	% r4	Total N
2000	100%	0%	0%	0%	0%	3
2001	39%	32%	25%	5%	0%	85
2002	50%	0%	50%	0%	0%	2
2003	100%	0%	0%	0%	0%	1
2004	38%	38%	23%	0%	0%	13
2005						+
2006						+
2007						+
2008	75%	0%	17%	8%	0%	12
2009	50%	50%	0%	0%	0%	6
2010	50%	33%	0%	17%	0%	6

	Oyster River - Blueback					
Year	% r0	% r1	% r2	% r3	% r4	Total N
2000	65%	26%	7%	2%	0%	143
2001	35%	43%	15%	6%	1%	144
2002	64%	16%	16%	4%	0%	141
2003	49%	32%	16%	3%	0%	149
2004	30%	26%	34%	9%	1%	128
2005	50%	35%	14%	1%	0%	126
2006	57%	24%	13%	6%	0%	141
2007	62%	28%	7%	3%	0%	179
2008	72%	17%	8%	3%	0%	145
2009	63%	35%	2%	0%	0%	86
2010	47%	27%	22%	4%	0%	78

**-Sampling did not occur.*

+-Sampling occurred but no blueback encountered in run.

Table 6.18 Continued.

	Lamprey River - Blueback					
Year	% r0	% r1	% r2	% r3	% r4	Total N
2000						+
2001						+
2002						+
2003	0%	33%	67%	0%	0%	3
2004						+
2005						+
2006	100%	0%	0%	0%	0%	2
2007	45%	36%	18%	0%	0%	11
2008						+
2009	0%	0%	100%	0%	0%	1
2010	27%	45%	18%	9%	0%	11

	Taylor River - Blueback					
Year	% r0	% r1	% r2	% r3	% r4	Total N
2000	69%	28%	2%	1%	0%	97
2001	*	*	*	*	*	*
2002	7%	40%	47%	7%	0%	30
2003	*	*	*	*	*	*
2004	70%	15%	10%	4%	0%	67
2005	93%	7%	0%	0%	0%	14
2006	*	*	*	*	*	*
2007						+
2008	100%	0%	0%	0%	0%	7
2009	*	*	*	*	*	*
2010	*	*	*	*	*	*

	Winnicut River - Blueback					
Year	% r0	% r1	% r2	% r3	% r4	Total N
2000	76%	13%	8%	3%	0%	157
2001	59%	29%	12%	0%	0%	59
2002	76%	10%	13%	0%	0%	68
2003	61%	36%	3%	0%	0%	77
2004	41%	43%	16%	0%	0%	44
2005	79%	17%	4%	0%	0%	52
2006	73%	21%	5%	1%	0%	73
2007	40%	40%	13%	3%	3%	30
2008	44%	31%	25%	0%	0%	16
2009	88%	12%	0%	0%	0%	33
2010	*	*	*	*	*	*

**-Sampling did not occur.*

+-Sampling occurred but no blueback encountered in run.

Table 6.19 Annual juvenile abundance index of river herring seined in Great Bay Estuary, New Hampshire, 1997-2010.

Year	Alewife Catch	Alewife Arithmetic Mean	Alewife Geometric Mean	Blueback Catch	Blueback Arithmetic Mean	Blueback Geometric Mean
1997	16	0.18	0.07	295	3.31	0.49
1998	14	0.16	0.04	1821	20.23	0.66
1999	660	7.33	0.27	11838	131.53	0.97
2000	71	0.79	0.26	5092	56.58	0.74
2001	119	1.24	0.13	1476	15.38	0.88
2002	164	1.82	0.34	261	2.90	0.26
2003	899	9.99	0.32	1812	20.13	0.76
2004	35	0.39	0.14	124	1.38	0.22
2005	29	0.32	0.11	2146	23.84	0.35
2006	1471	16.34	0.32	432	4.80	0.42
2007	203	2.26	0.21	1503	16.70	0.50
2008	39	0.43	0.15	37	0.41	0.13
2009	32	0.36	0.10	182	2.02	0.20
2010	14	0.16	0.08	79	0.88	0.17

Table 6.20 Estimates of total instantaneous mortality (Z) with standard errors for river herring in coastal New Hampshire rivers, using Chapman-Robson, Heinecke, and catch curve methods based on age, separated by species and sex, 1990-2010.

Cocheco River			Chapman-Robson		Heinecke		Catch Curve	
Species	Sex	Year	Z estimate	SE	Z estimate	SE	Z estimate	SE
Alewives	Male	1992	0.84	0.138	0.57	0.093	0.44	0.184
Alewives	Male	1993	1.49	0.233	1.25	0.191	*	*
Alewives	Male	1994	2.30	0.468	2.22	0.446	*	*
Alewives	Male	1995	1.19	0.176	0.89	0.128	1.70	0.748
Alewives	Male	1996	0.84	0.103	0.63	0.075	0.39	0.019
Alewives	Male	1997	1.22	0.260	1.14	0.240	1.07	0.017
Alewives	Male	1998	1.87	0.370	2.14	0.441	1.35	0.782
Alewives	Male	1999	0.82	0.112	0.64	0.086	1.02	0.357
Alewives	Male	2000	0.84	0.111	0.76	0.101	0.73	0.138
Alewives	Male	2001	1.03	0.159	0.83	0.126	1.05	0.455
Alewives	Male	2002	0.71	0.099	0.49	0.068	0.83	0.155
Alewives	Male	2003	0.95	0.152	0.74	0.117	0.93	0.276
Alewives	Male	2004	1.28	0.217	1.05	0.174	1.11	0.146
Alewives	Male	2005	1.06	0.183	0.72	0.121	1.47	0.786
Alewives	Male	2006	1.85	0.514	1.73	0.475	*	*
Alewives	Male	2007	1.19	0.258	1.39	0.306	0.75	0.834
Alewives	Male	2008	1.82	0.402	1.69	0.364	*	*
Alewives	Male	2009	0.86	0.097	0.72	0.080	0.96	0.269
Alewives	Male	2010	1.00	0.208	0.82	0.169	1.01	0.288
Alewives	Female	1992	1.95	0.520	1.85	0.486	*	*
Alewives	Female	1993	1.49	0.262	1.27	0.216	*	*
Alewives	Female	1994	1.76	0.365	1.61	0.327	*	*
Alewives	Female	1995	1.19	0.176	0.89	0.128	1.70	0.748
Alewives	Female	1996	1.24	0.196	0.97	0.151	1.67	0.639
Alewives	Female	1997	**	**	**	**	**	**
Alewives	Female	1998	0.55	0.081	0.36	0.054	0.46	0.132
Alewives	Female	1999	1.06	0.188	1.07	0.190	0.87	0.206
Alewives	Female	2000	0.62	0.093	0.43	0.064	0.40	0.201
Alewives	Female	2001	0.76	0.103	0.61	0.082	0.56	0.149
Alewives	Female	2002	0.95	0.187	0.69	0.134	0.77	0.305
Alewives	Female	2003	1.33	0.177	1.47	0.199	1.01	0.169
Alewives	Female	2004	1.02	0.150	0.94	0.136	1.11	0.166
Alewives	Female	2006	1.14	0.283	0.94	0.231	1.20	0.342
Alewives	Female	2007	1.02	0.186	1.01	0.184	0.97	0.107
Alewives	Female	2008	0.96	0.169	0.78	0.136	0.67	0.070
Alewives	Female	2009	0.65	0.071	0.44	0.048	0.49	0.224
Alewives	Female	2010	0.88	0.168	0.66	0.125	0.51	0.103
Blueback	Male	1992	1.56	0.430	1.67	0.469	1.28	0.340
Blueback	Male	1993	2.60	0.667	2.56	0.653	*	*
Blueback	Male	1994	2.01	0.634	1.95	0.606	*	*
Blueback	Male	1996	0.94	0.251	0.92	0.245	0.55	0.317
Blueback	Male	1997	1.79	0.400	1.65	0.361	*	*
Blueback	Male	1998	1.39	0.344	1.15	0.279	*	*
Blueback	Male	1999	1.56	0.430	1.39	0.375	*	*
Blueback	Male	2000	1.03	0.247	0.75	0.175	1.15	0.536

Table 6.20 Continued.

Cocheco River			Chapman-Robson		Heinecke		Catch Curve	
Species	Sex	Year	Z estimate	Species	Sex	Year	Z estimate	Species
Blueback	Male	2001	0.98	0.417	1.10	0.471	0.69	0.400
Blueback	Male	2002	1.13	0.233	0.96	0.195	1.04	0.200
Blueback	Male	2003	0.98	0.308	1.30	0.420	0.62	0.360
Blueback	Male	2004	**	**	**	**	**	**
Blueback	Male	2005	**	**	**	**	**	**
Blueback	Male	2006	1.10	0.516	0.92	0.424	*	*
Blueback	Male	2007	1.34	0.255	1.16	0.217	1.55	0.376
Blueback	Male	2008	1.30	0.338	1.22	0.316	1.24	0.083
Blueback	Male	2009	**	**	**	**	**	**
Blueback	Male	2010	**	**	**	**	**	**
Blueback	Female	1992	1.47	0.483	1.30	0.420	*	*
Blueback	Female	1993	1.73	0.364	1.58	0.324	*	*
Blueback	Female	1994	1.39	0.567	1.25	0.505	*	*
Blueback	Female	1995	1.87	0.623	1.79	0.589	*	*
Blueback	Female	1996	1.47	0.483	1.70	0.579	1.10	0.634
Blueback	Female	1997	0.96	0.213	0.89	0.197	0.88	0.053
Blueback	Female	1998	1.61	0.434	1.73	0.475	1.32	0.362
Blueback	Female	1999	1.20	0.452	0.98	0.361	*	*
Blueback	Female	2000	0.81	0.340	0.69	0.289	0.55	0.083
Blueback	Female	2001	1.03	0.340	0.92	0.300	0.90	0.117
Blueback	Female	2002	1.39	0.416	1.18	0.346	*	*
Blueback	Female	2003	1.32	0.410	1.39	0.433	1.10	0.234
Blueback	Female	2004	**	**	**	**	**	**
Blueback	Female	2005	**	**	**	**	**	**
Blueback	Female	2006	**	**	**	**	**	**
Blueback	Female	2007	0.75	0.172	0.60	0.136	0.20	0.222
Blueback	Female	2008	0.98	0.255	0.69	0.177	1.04	0.523
Blueback	Female	2009	**	**	**	**	**	**
Blueback	Female	2010	**	**	**	**	**	**

Table 6.20 Continued.

Lamprey River			Chapman-Robson		Heinecke		Catch Curve	
Species	Sex	Year	Z estimate	SE	Z estimate	SE	Z estimate	SE
Alewives	Male	1990	1.61	0.596	1.50	0.550	*	*
Alewives	Male	1991	**	**	**	**	**	**
Alewives	Male	1992	1.23	0.182	1.24	0.184	1.05	0.247
Alewives	Male	1993	1.95	0.290	1.81	0.264	*	*
Alewives	Male	1994	1.74	0.284	1.67	0.271	1.83	0.143
Alewives	Male	1995	1.88	0.344	1.74	0.312	*	*
Alewives	Male	1996	1.25	0.182	1.08	0.156	1.23	0.220
Alewives	Male	1997	1.10	0.207	0.87	0.161	1.10	0.350
Alewives	Male	1998	1.05	0.156	0.85	0.125	0.86	0.174
Alewives	Male	1999	0.73	0.092	0.50	0.062	0.70	0.229
Alewives	Male	2000	0.84	0.100	0.71	0.083	0.81	0.158
Alewives	Male	2001	0.71	0.084	0.51	0.060	0.85	0.157
Alewives	Male	2002	1.41	0.248	1.15	0.198	*	*
Alewives	Male	2003	0.69	0.077	0.57	0.063	0.39	0.155
Alewives	Male	2004	0.86	0.110	0.68	0.086	0.81	0.107
Alewives	Male	2005	1.10	0.162	0.75	0.108	1.65	0.859
Alewives	Male	2006	0.83	0.121	0.65	0.094	0.92	0.164
Alewives	Male	2007	1.13	0.187	1.07	0.176	1.02	0.411
Alewives	Male	2008	1.73	0.364	1.76	0.370	1.59	0.117
Alewives	Male	2009	1.09	0.128	0.86	0.099	1.02	0.301
Alewives	Male	2010	1.05	0.219	0.73	0.150	1.28	0.644
Alewives	Female	1990	**	**	**	**	**	**
Alewives	Female	1991	**	**	**	**	**	**
Alewives	Female	1992	1.08	0.171	0.89	0.139	0.94	0.183
Alewives	Female	1993	1.56	0.244	1.35	0.205	*	*
Alewives	Female	1994	1.10	0.172	1.03	0.161	1.11	0.070
Alewives	Female	1995	1.20	0.173	0.90	0.126	1.73	0.757
Alewives	Female	1996	1.07	0.164	0.76	0.113	1.26	0.600
Alewives	Female	1997	1.06	0.199	0.79	0.147	1.07	0.417
Alewives	Female	1998	0.86	0.144	0.64	0.106	0.82	0.189
Alewives	Female	1999	0.85	0.113	0.66	0.087	0.79	0.110
Alewives	Female	2000	0.76	0.093	0.56	0.068	0.66	0.146
Alewives	Female	2001	1.28	0.217	1.05	0.174	1.63	0.540
Alewives	Female	2002	0.71	0.103	0.48	0.068	0.90	0.430
Alewives	Female	2003	0.57	0.082	0.43	0.061	0.47	0.142
Alewives	Female	2004	0.85	0.110	0.66	0.084	0.75	0.141
Alewives	Female	2005	1.01	0.147	0.77	0.110	1.10	0.485
Alewives	Female	2006	0.87	0.142	0.64	0.104	0.50	0.112
Alewives	Female	2007	1.02	0.165	0.90	0.144	1.08	0.103
Alewives	Female	2008	0.87	0.113	0.81	0.105	0.86	0.246
Alewives	Female	2009	0.95	0.118	0.62	0.076	0.84	0.465
Alewives	Female	2010	1.39	0.344	1.15	0.279	*	*

Table 6.20 Continued.

Oyster River			Chapman-Robson		Heinecke		Catch Curve	
species	sex	year	estimate	SE	estimate	SE	estimate	SE
Blueback	Male	1992	0.67	0.080	0.48	0.056	0.41	0.080
Blueback	Male	1993	2.04	0.349	1.93	0.323	*	*
Blueback	Male	1994	1.01	0.109	0.82	0.087	1.30	0.281
Blueback	Male	1995	1.51	0.242	1.29	0.201	*	*
Blueback	Male	1996	1.17	0.175	0.92	0.134	1.35	0.487
Blueback	Male	1997	0.79	0.081	0.58	0.059	0.78	0.200
Blueback	Male	1998	0.64	0.077	0.41	0.049	0.47	0.234
Blueback	Male	1999	2.11	0.351	2.01	0.327	*	*
Blueback	Male	2000	0.93	0.103	0.64	0.069	0.72	0.341
Blueback	Male	2001	0.77	0.094	0.58	0.071	0.73	0.214
Blueback	Male	2002	0.73	0.078	0.60	0.063	0.53	0.066
Blueback	Male	2003	1.14	0.149	0.92	0.118	1.34	0.260
Blueback	Male	2004	1.59	0.255	1.47	0.232	1.81	0.287
Blueback	Male	2005	0.99	0.137	0.71	0.096	0.88	0.374
Blueback	Male	2006	0.83	0.086	0.61	0.062	1.19	0.455
Blueback	Male	2007	0.89	0.093	0.70	0.073	0.93	0.165
Blueback	Male	2008	0.67	0.067	0.51	0.051	0.72	0.114
Blueback	Male	2009	1.21	0.173	1.30	0.188	0.80	0.542
Blueback	Male	2010	0.62	0.101	0.57	0.093	0.51	0.119
Blueback	Female	1992	0.60	0.091	0.76	0.116	0.47	0.169
Blueback	Female	1993	1.64	0.257	1.45	0.221	*	*
Blueback	Female	1994	1.01	0.180	0.75	0.132	0.90	0.329
Blueback	Female	1995	1.29	0.210	1.12	0.180	1.34	0.263
Blueback	Female	1996	1.19	0.185	0.91	0.137	1.67	0.707
Blueback	Female	1997	0.69	0.100	0.51	0.073	0.77	0.126
Blueback	Female	1998	0.97	0.122	0.79	0.098	1.01	0.126
Blueback	Female	1999	1.61	0.256	1.59	0.252	1.49	0.057
Blueback	Female	2000	1.10	0.195	0.78	0.136	1.47	0.714
Blueback	Female	2001	0.89	0.158	0.75	0.132	0.47	0.128
Blueback	Female	2002	0.63	0.107	0.41	0.068	0.43	0.193
Blueback	Female	2003	0.79	0.113	0.58	0.082	0.66	0.171
Blueback	Female	2004	1.34	0.219	1.20	0.194	1.35	0.202
Blueback	Female	2005	1.22	0.214	0.90	0.154	*	*
Blueback	Female	2006	0.76	0.136	0.50	0.088	0.24	0.094
Blueback	Female	2007	1.22	0.181	1.22	0.182	0.90	0.283
Blueback	Female	2008	0.80	0.134	0.59	0.098	0.91	0.274
Blueback	Female	2009	1.01	0.180	0.75	0.132	0.90	0.329
Blueback	Female	2010	1.33	0.280	1.31	0.276	1.13	0.121

Table 6.20 Continued.

Winnicut River			Chapman-Robson		Heinecke		Catch Curve	
species	sex	year	estimate	SE	estimate	SE	estimate	SE
Alewives	Male	1998	1.1	0.667	1.1	0.667	*	*
Alewives	Male	1999	1.47	0.25	1.41	0.239	1.37	0.009
Alewives	Male	2000	0.89	0.247	0.85	0.233	0.76	0.183
Alewives	Male	2001	1.25	0.197	1.34	0.213	0.87	0.501
Alewives	Male	2002	0.7	0.102	0.58	0.083	0.74	0.242
Alewives	Male	2003	1.95	0.346	1.82	0.316	*	*
Alewives	Male	2004	2.37	0.47	2.30	0.450	*	*
Alewives	Male	2005	0.69	0.079	0.48	0.054	0.86	0.182
Alewives	Male	2006	0.62	0.124	0.42	0.084	0.36	0.092
Alewives	Male	2007	1.00	0.123	0.94	0.115	0.90	0.013
Alewives	Male	2008	1.16	0.134	1.00	0.113	1.12	0.246
Alewives	Male	2009	1.45	0.249	1.29	0.219	1.68	0.357
Alewives	Female	1999	0.89	0.247	0.69	0.189	0.63	0.167
Alewives	Female	2000	0.61	0.251	0.69	0.289	0.33	0.190
Alewives	Female	2001	0.69	0.147	0.57	0.121	0.45	0.110
Alewives	Female	2002	0.75	0.244	0.69	0.224	0.59	0.144
Alewives	Female	2003	0.92	0.359	0.85	0.330	0.69	<0.001
Alewives	Female	2004	1.28	0.366	1.54	0.454	0.85	0.892
Alewives	Female	2005	1.16	0.355	0.88	0.261	*	*
Alewives	Female	2007	0.73	0.18	0.53	0.130	0.65	0.150
Alewives	Female	2008	0.86	0.186	0.83	0.179	0.67	0.158
Alewives	Female	2009	0.99	0.179	0.93	0.168	0.60	0.259
Blueback	Male	1998	1.12	0.149	1.05	0.139	1.03	0.164
Blueback	Male	1999	0.98	0.131	0.71	0.093	0.82	0.326
Blueback	Male	2000	1.06	0.134	1.02	0.128	1.19	0.238
Blueback	Male	2001	1.06	0.193	0.93	0.168	1.06	0.130
Blueback	Male	2002	1.22	0.196	1.22	0.195	1.14	0.024
Blueback	Male	2003	1.71	0.27	1.63	0.254	1.86	0.197
Blueback	Male	2004	1.16	0.211	0.82	0.144	*	*
Blueback	Male	2005	1.27	0.251	1.17	0.230	1.15	0.059
Blueback	Male	2006	0.87	0.118	0.66	0.088	0.90	0.160
Blueback	Male	2007	0.69	0.141	0.51	0.103	0.69	0.299
Blueback	Male	2008	1.39	0.567	1.25	0.505	*	*
Blueback	Male	2009	2.35	0.656	2.30	0.636	*	*
Blueback	Female	1998	0.63	0.226	0.69	0.250	0.35	0.268
Blueback	Female	1999	**	**	**	**	**	**
Blueback	Female	2000	0.94	0.161	0.72	0.121	0.67	0.166
Blueback	Female	2001	1.30	0.464	1.10	0.385	*	*
Blueback	Female	2002	0.85	0.242	0.77	0.220	0.42	0.245
Blueback	Female	2003	1.39	0.474	1.20	0.404	*	*
Blueback	Female	2004	1.25	0.546	1.10	0.471	*	*
Blueback	Female	2005	2.08	0.875	2.08	0.875	*	*
Blueback	Female	2006	1.25	0.546	1.10	0.471	*	*
Blueback	Female	2007	0.69	0.354	0.69	0.354	0.20	0.172
Blueback	Female	2008	**	**	**	**	**	**
Blueback	Female	2009	1.67	0.501	1.95	0.606	0.71	0.615

Table 6.20 Continued.

Exeter River***		Chapman-Robson		Heinecke		Catch Curve	
Species	Year	Z estimate	SE	Z estimate	SE	Z estimate	SE
River Herring	1991	1.02	0.113	0.92	0.100	1.05	0.066
River Herring	1992	1.01	0.091	0.85	0.076	1.19	0.223
River Herring	1993	1.37	0.162	1.24	0.145	1.35	0.152
River Herring	1994	No Sampling					
River Herring	1995	1.72	0.180	1.70	0.178	1.58	0.076
River Herring	1996	1.39	0.375	1.16	0.307	*	*
River Herring	1997	1.01	0.077	0.89	0.067	1.09	0.157
River Herring	1998	0.64	0.050	0.51	0.040	0.59	0.093
River Herring	1999	1.26	0.116	1.07	0.097	1.27	0.261
River Herring	2000	1.03	0.110	0.79	0.082	1.18	0.212
River Herring	2001	0.98	0.109	0.76	0.083	1.28	0.282
River Herring	2002	1.53	0.276	1.31	0.231	*	*
River Herring	2003	0.91	0.129	0.83	0.118	0.78	0.020
River Herring	2004	1.19	0.176	0.94	0.136	1.37	0.477
River Herring	2005	1.27	0.224	1.21	0.212	1.08	0.057
River Herring	2006	0.69	0.183	0.51	0.133	0.09	0.181
River Herring	2007	0.99	0.195	0.77	0.149	1.05	0.321
River Herring	2008	0.89	0.083	0.69	0.062	1.13	0.159
River Herring	2009	0.90	0.053	0.65	0.037	1.13	0.290
River Herring	2010	1.00	0.185	0.76	0.137	0.87	0.300

**- No Z estimate due to less than three ages to assess.*
***- No Z estimates due to extremely low sample size, no species differentiation, or ages below fully recruited age.*
****- Due to low sample size Z estimates were not conducted between species or sex.*

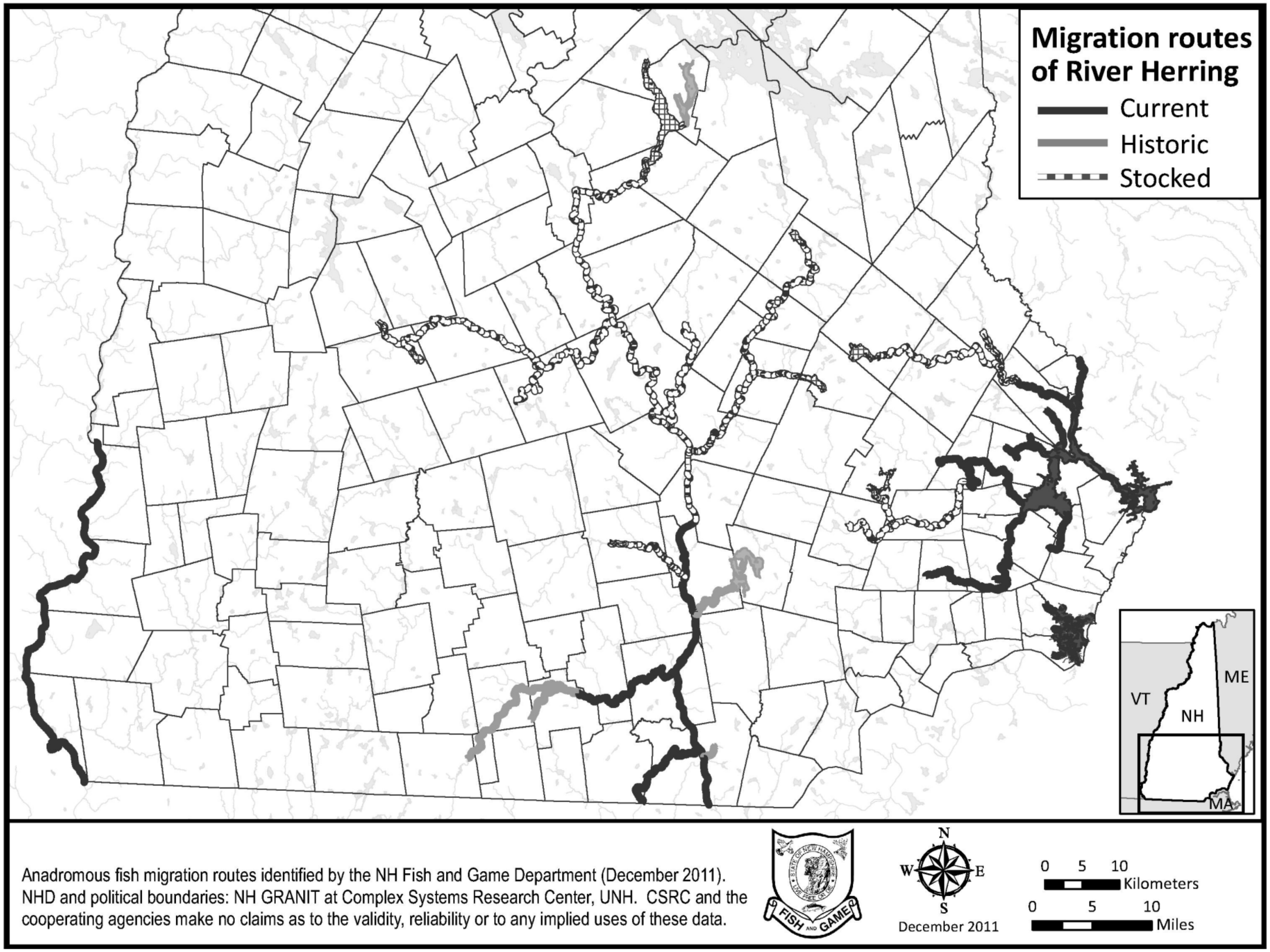


Figure 6.1 Map of New Hampshire's river herring migration routes (historic, current and stocked fish).

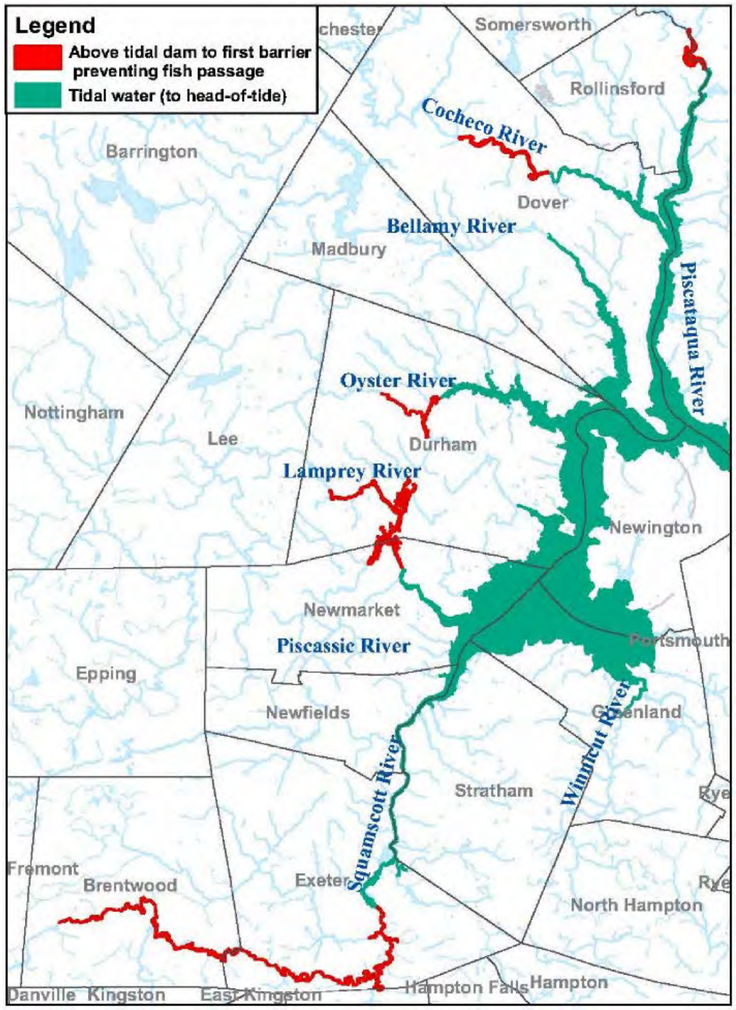


Figure 6.2 Great Bay Estuary rivers with fish passage and available anadromous spawning and rearing habitat.

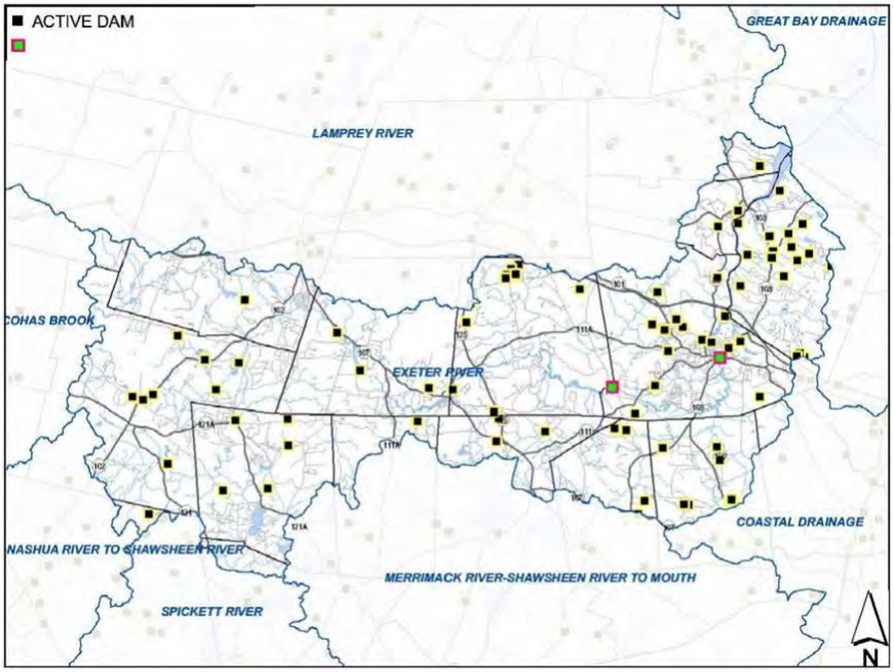


Figure 6.3 Exeter River watershed dams and fish passage, Great Bay Estuary, New Hampshire.

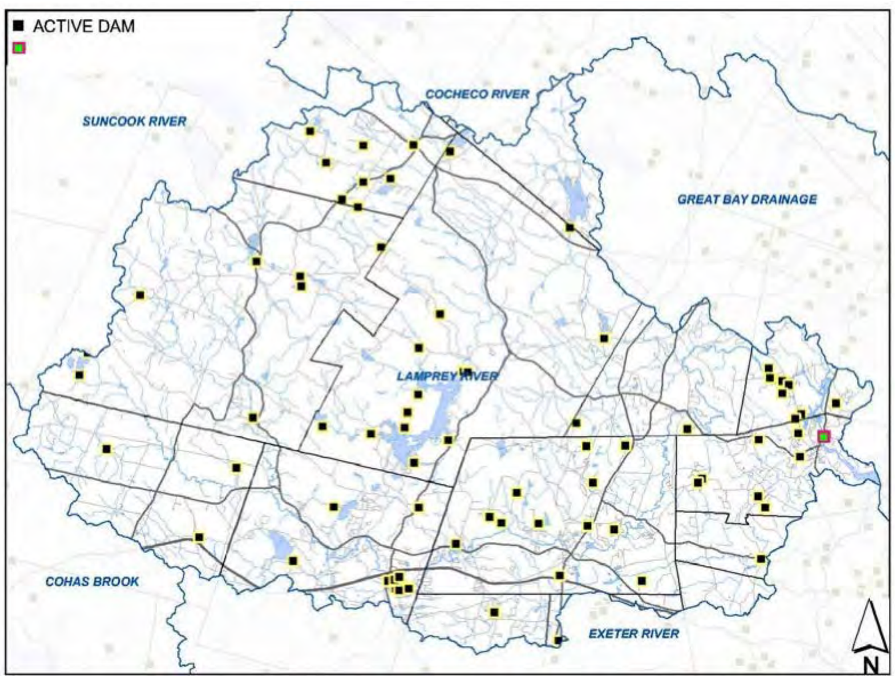


Figure 6.4 Lamprey River watershed dams and fish passage, Great Bay Estuary, New Hampshire.

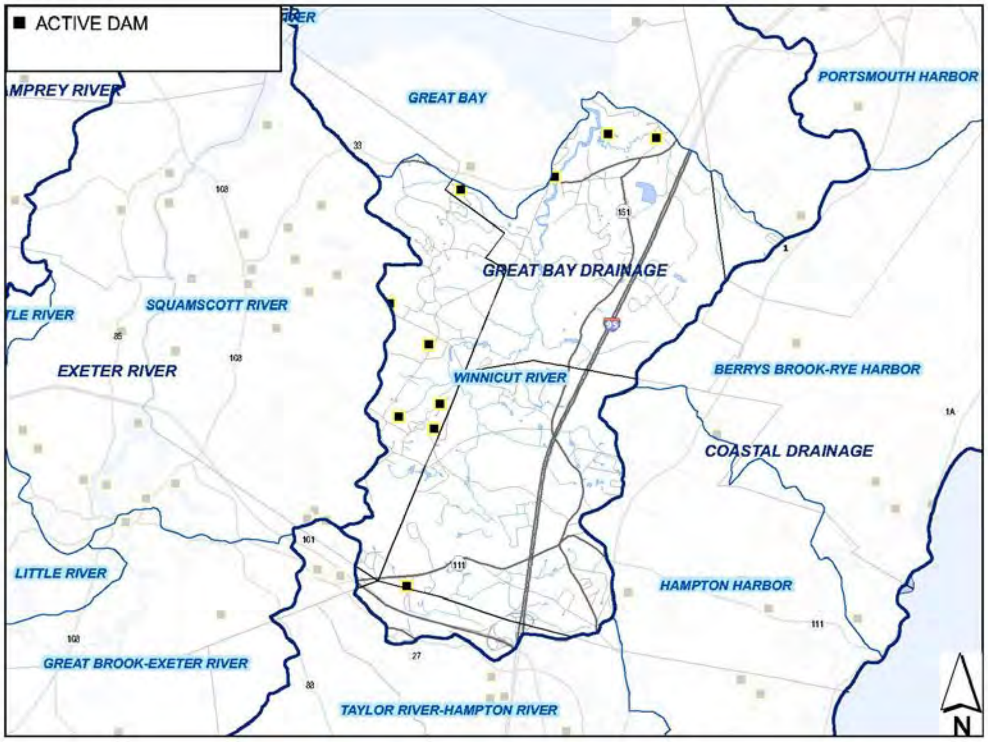


Figure 6.5 Winnicut River watershed dams and fish passage, Great Bay Estuary, New Hampshire.

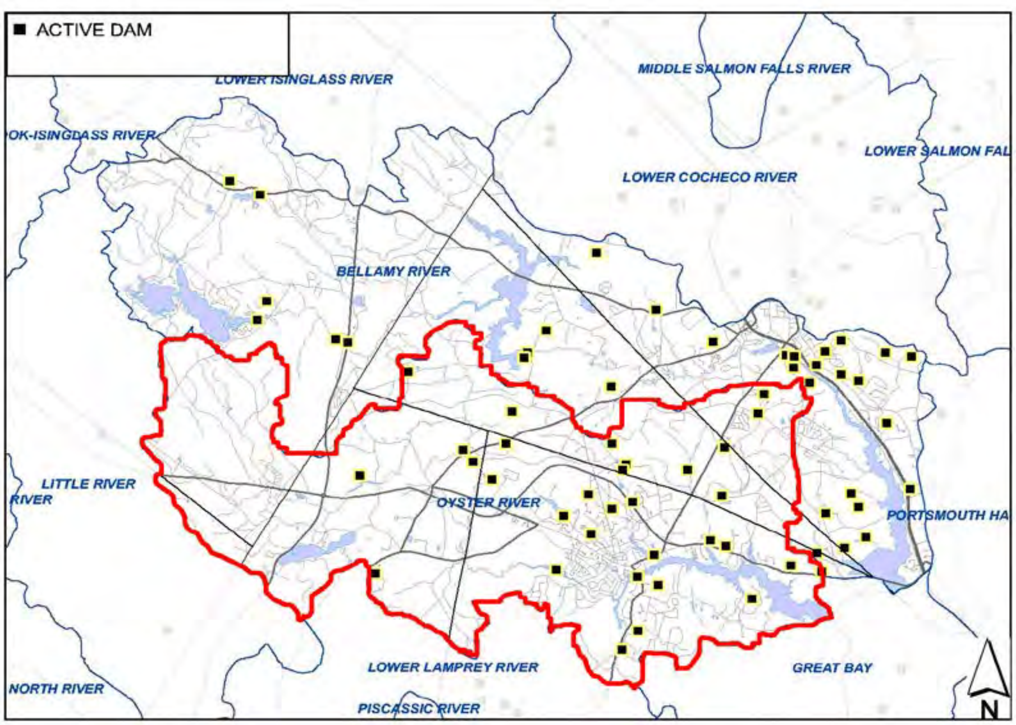


Figure 6.6 Oyster River watershed dams and fish passage, Great Bay Estuary, New Hampshire.

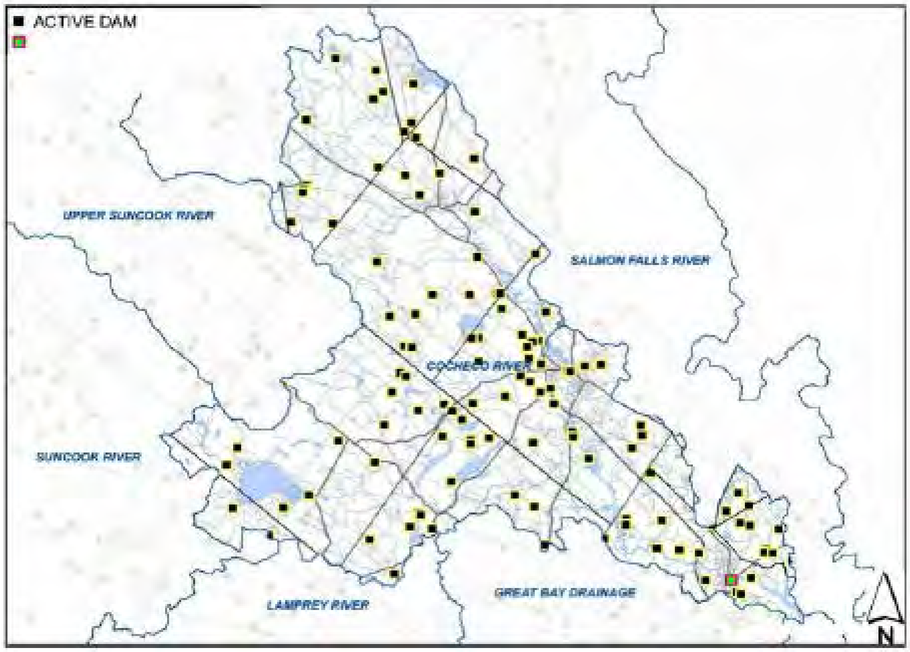


Figure 6.7 Cocheco River watershed dams and fish passage, Great Bay Estuary, New Hampshire.

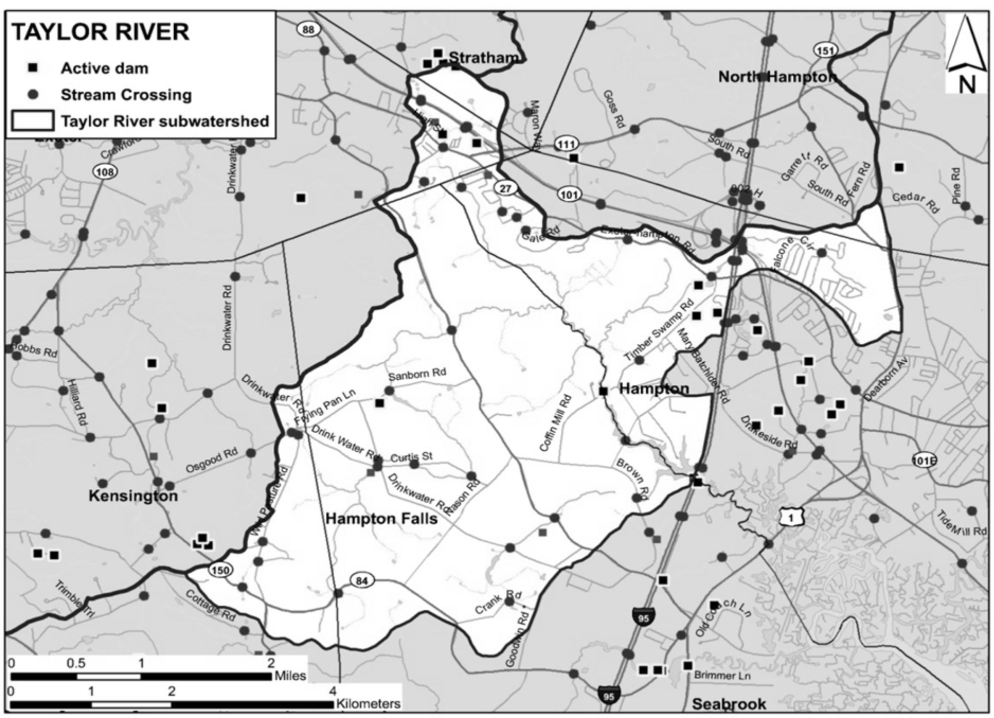


Figure 6.8 Taylor River watershed dams and fish passage, Hampton-Seabrook Estuary, New Hampshire.

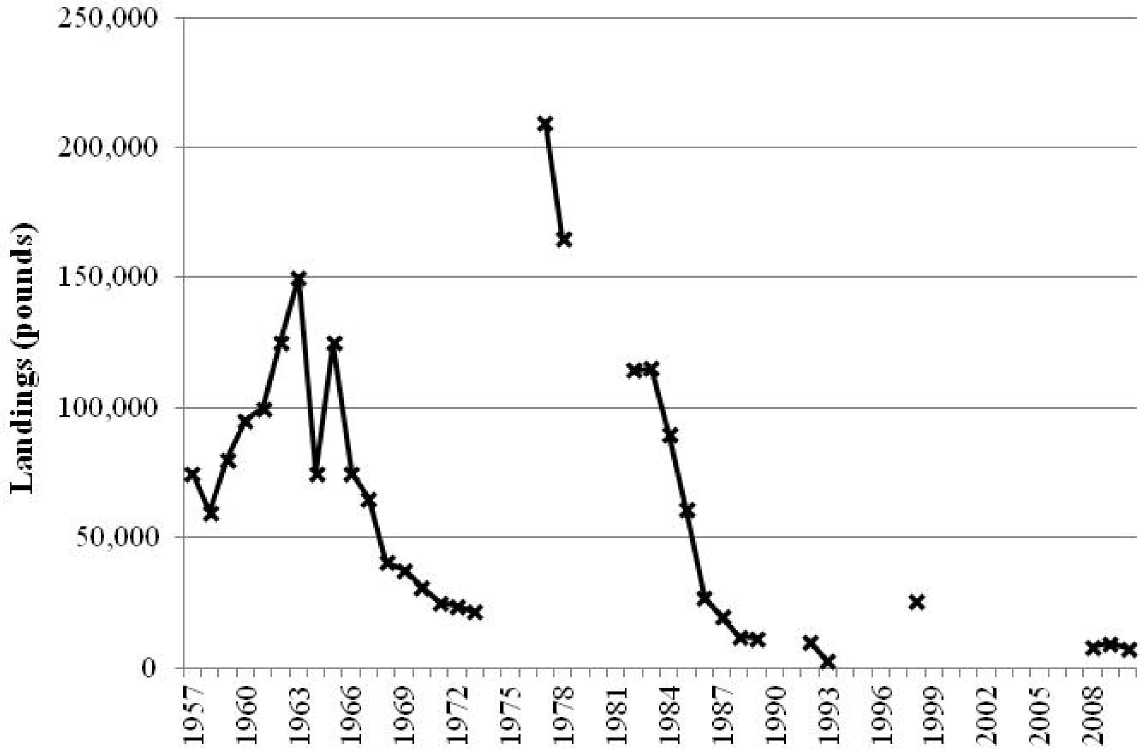


Figure 6.9 Commercial landings (in pounds) of river herring in New Hampshire.

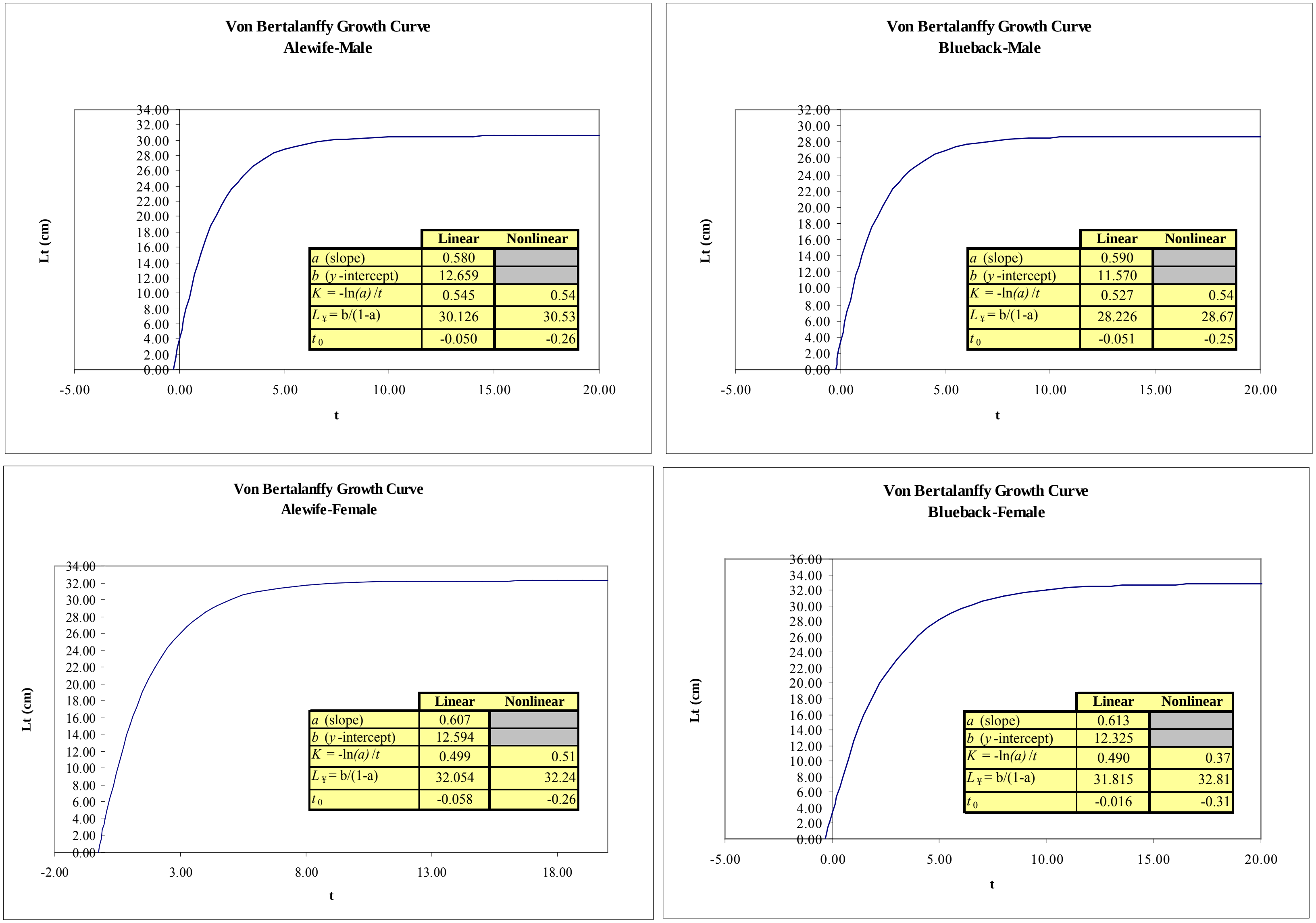
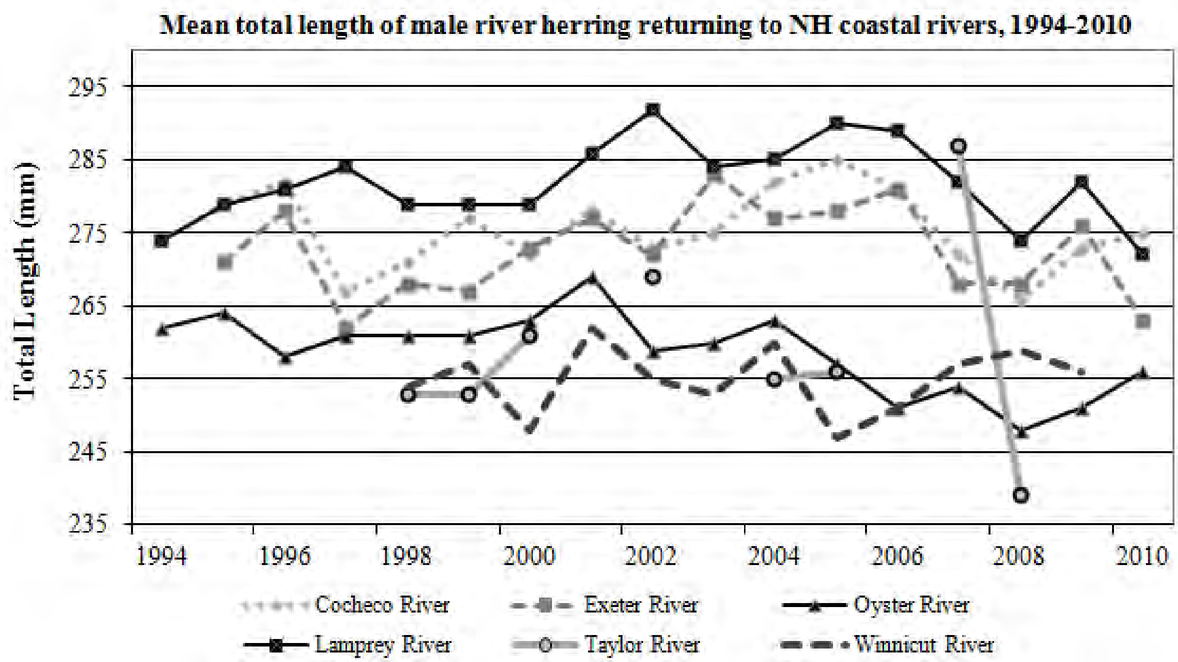


Figure 6.10 Von Bertalanffy growth curves for male and female river herring from New Hampshire rivers.



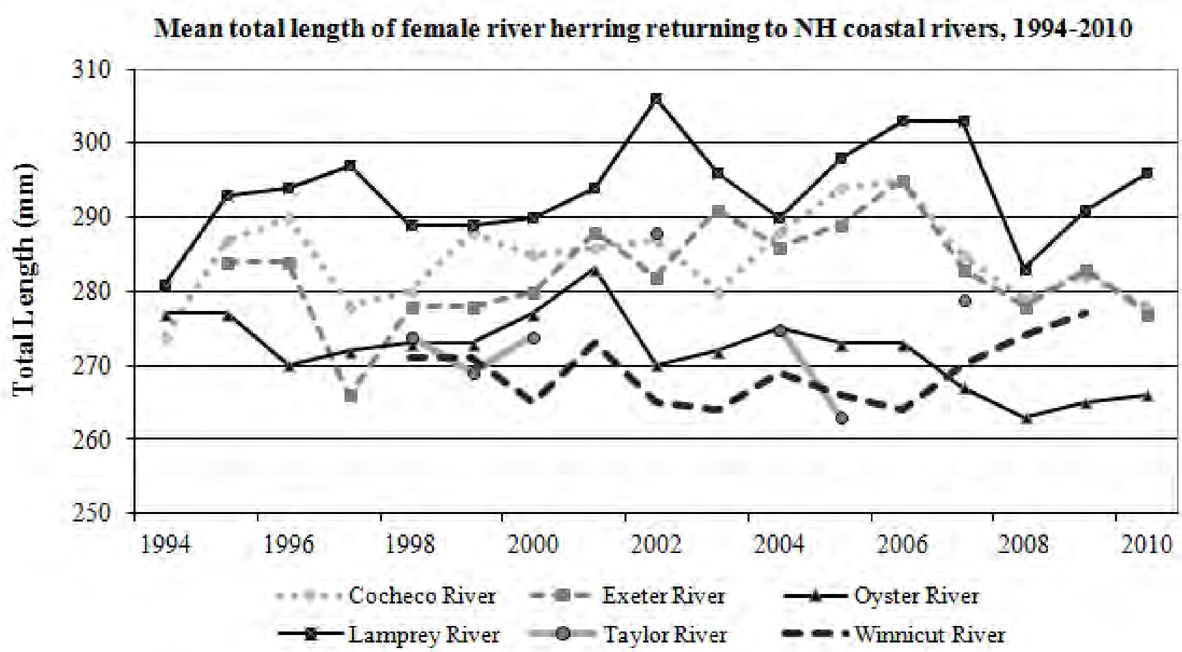


Figure 6.11 Mean total length (mm) of male and female river herring returning to the coastal rivers of New Hampshire, 1994-2010.

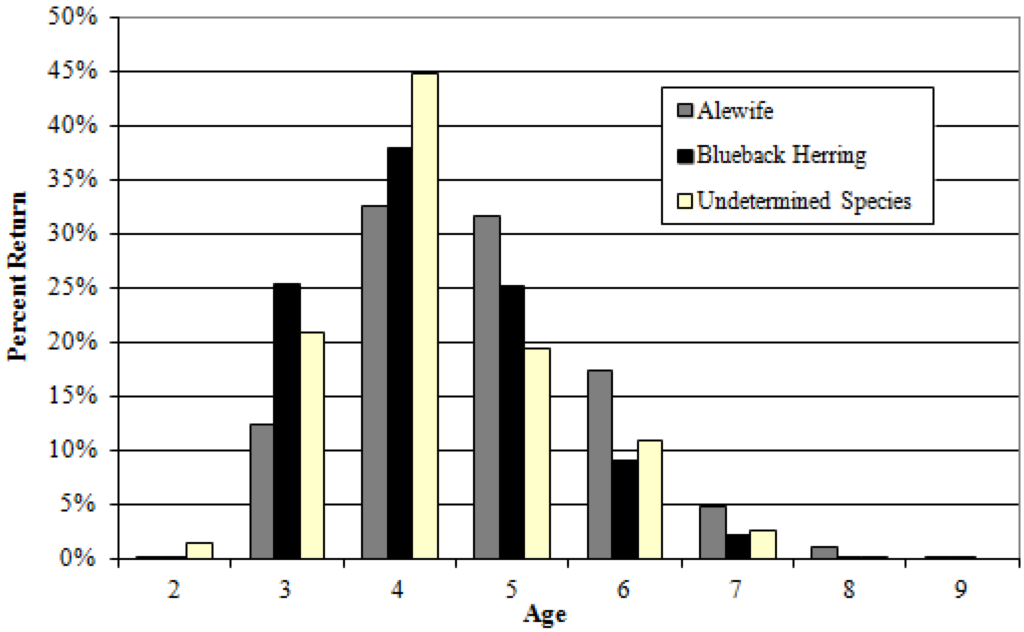


Figure 6.12 Percent of river herring returning at age to New Hampshire coastal rivers, 1990-2010.

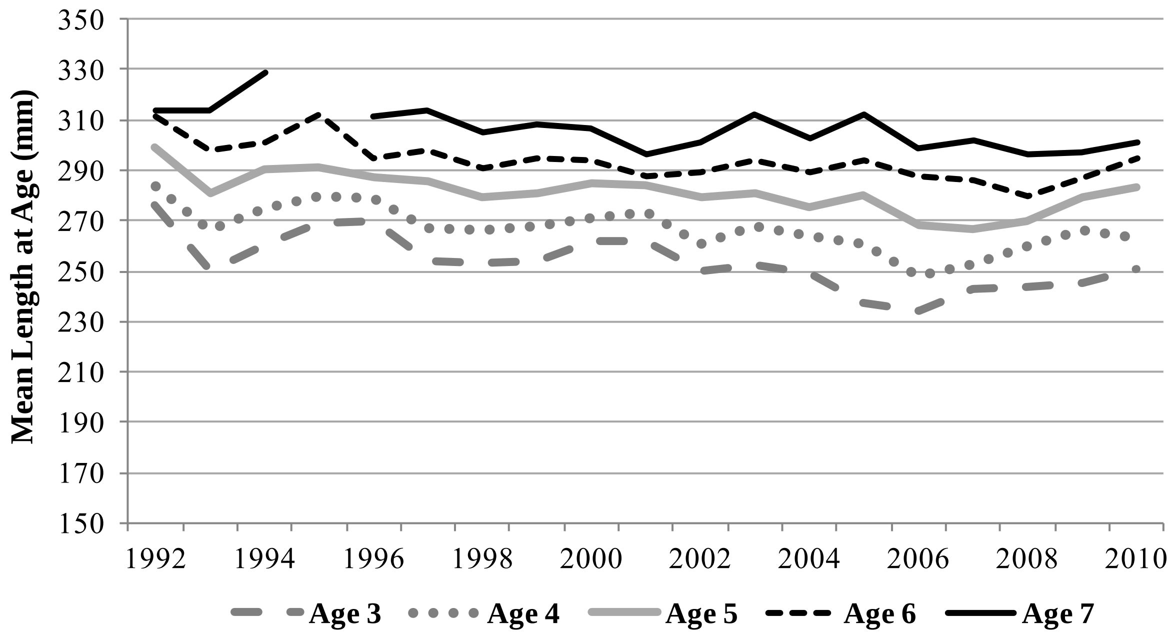


Figure 6.13 Mean length at age for river herring returns to New Hampshire coastal rivers, 1992 - 2010.

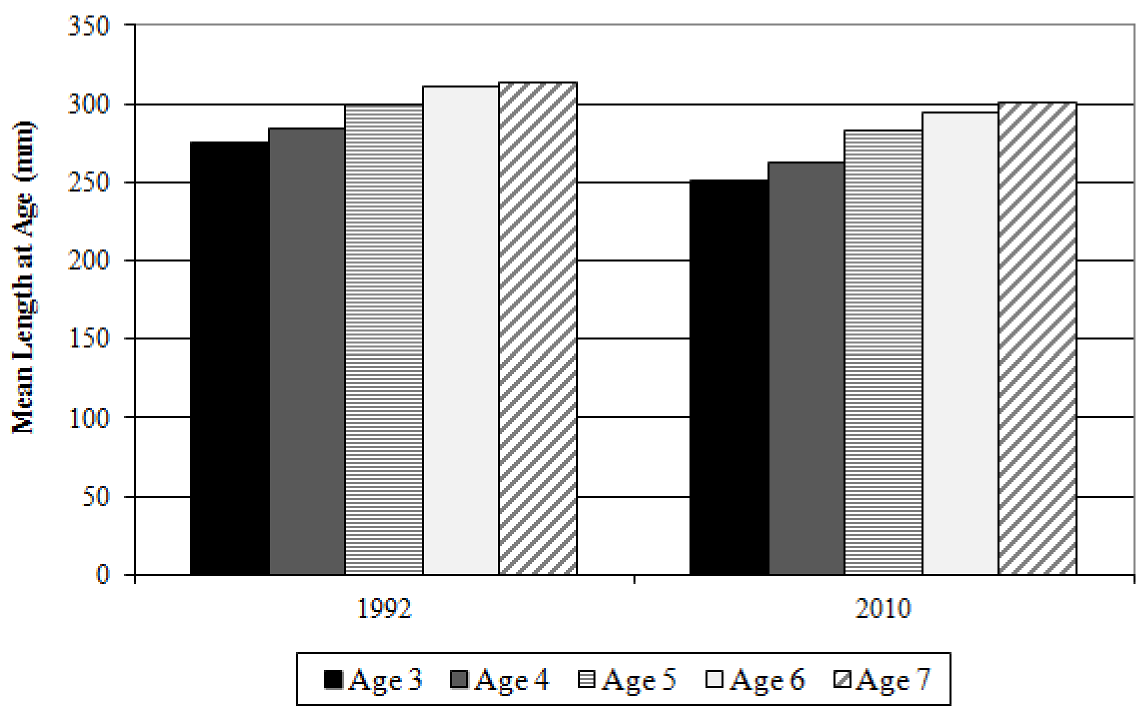


Figure 6.14 Mean length at age differences between 1992 and 2010 of river herring returning to New Hampshire coastal rivers.

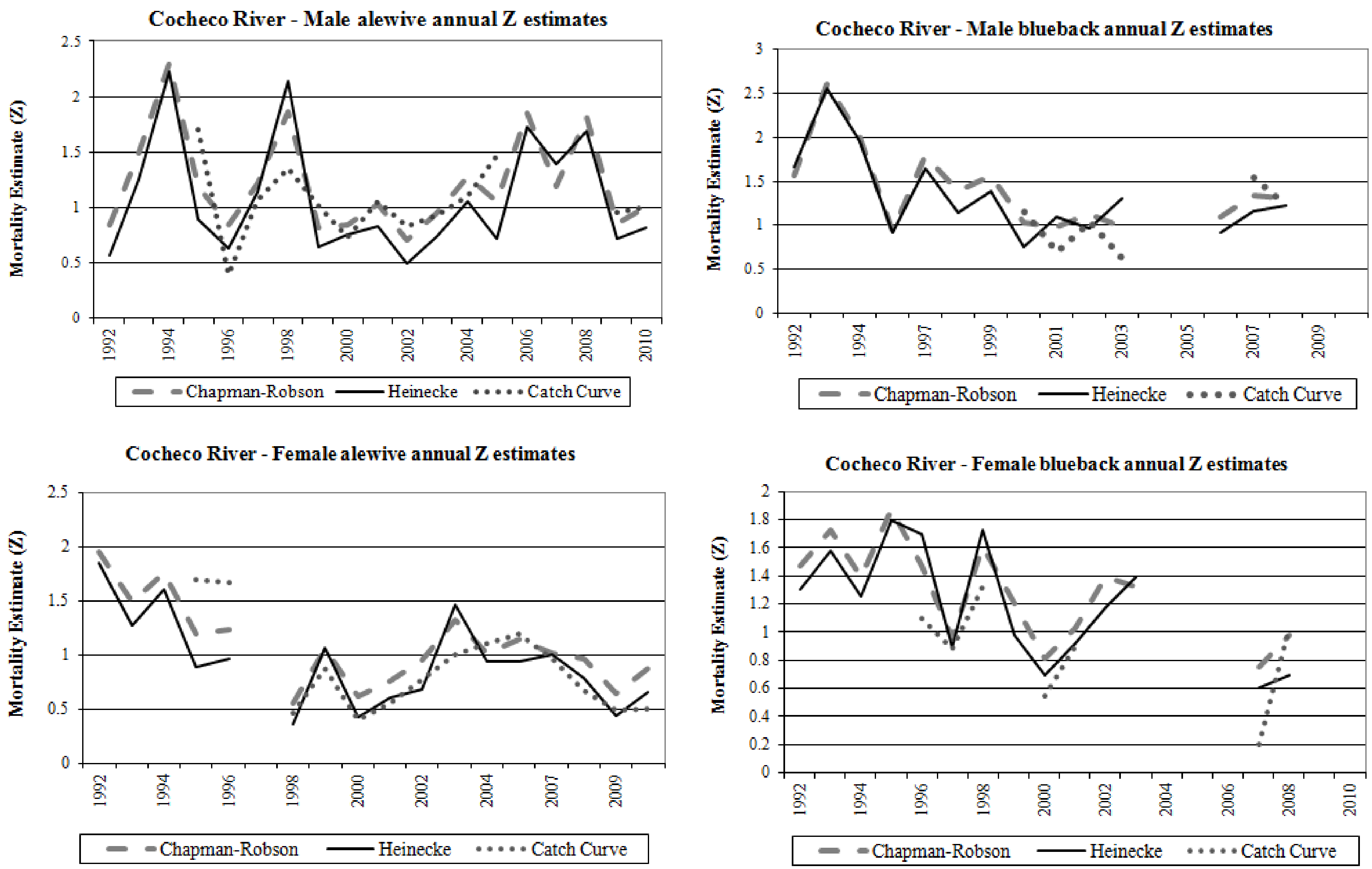


Figure 6.15 Estimates of total instantaneous mortality (Z) for river herring in coastal New Hampshire rivers, using Chapman-Robson, Heinecke, and catch curve methods based on age, separated by species and sex, 1990-2010.

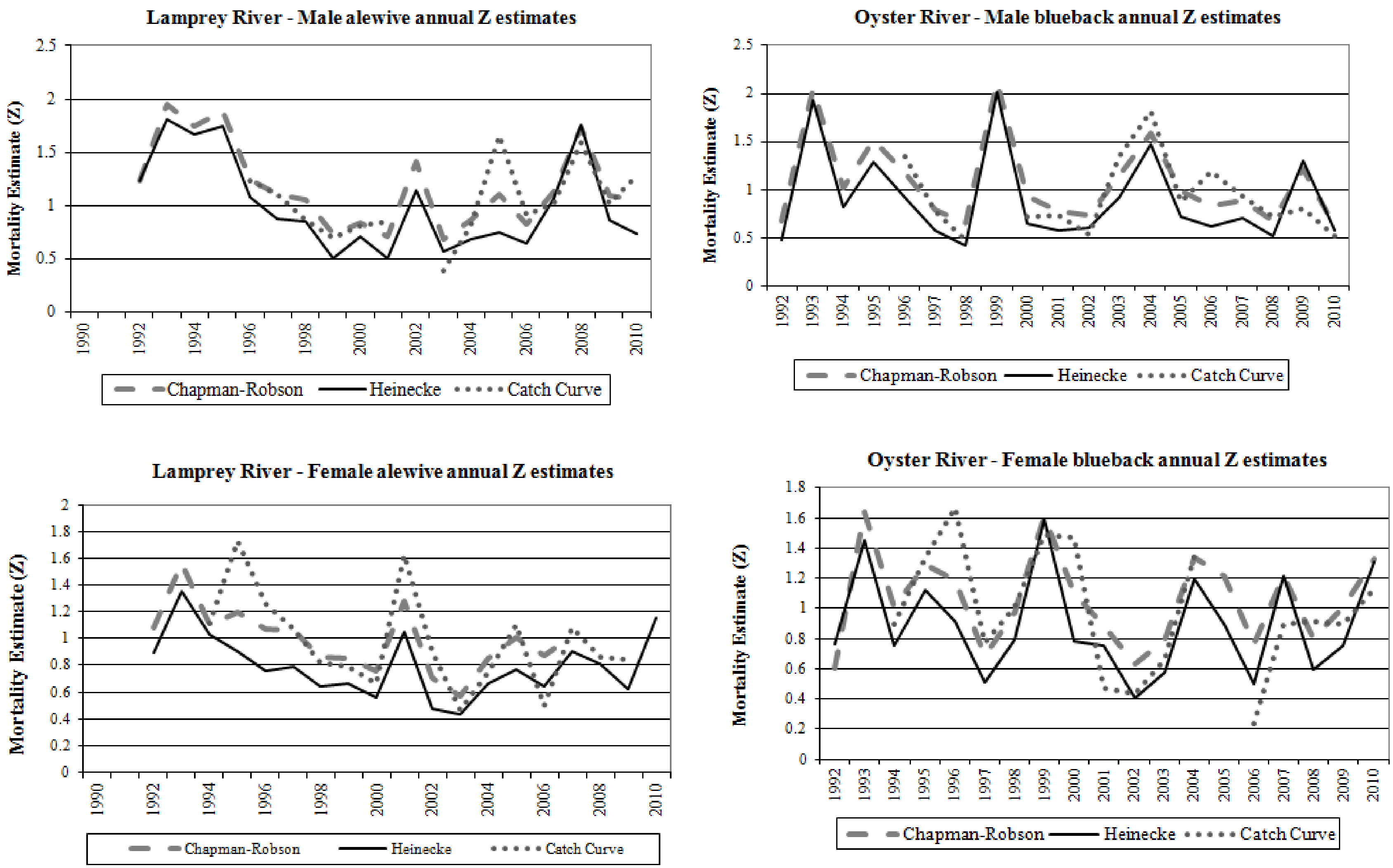


Figure 6.14 Continued.

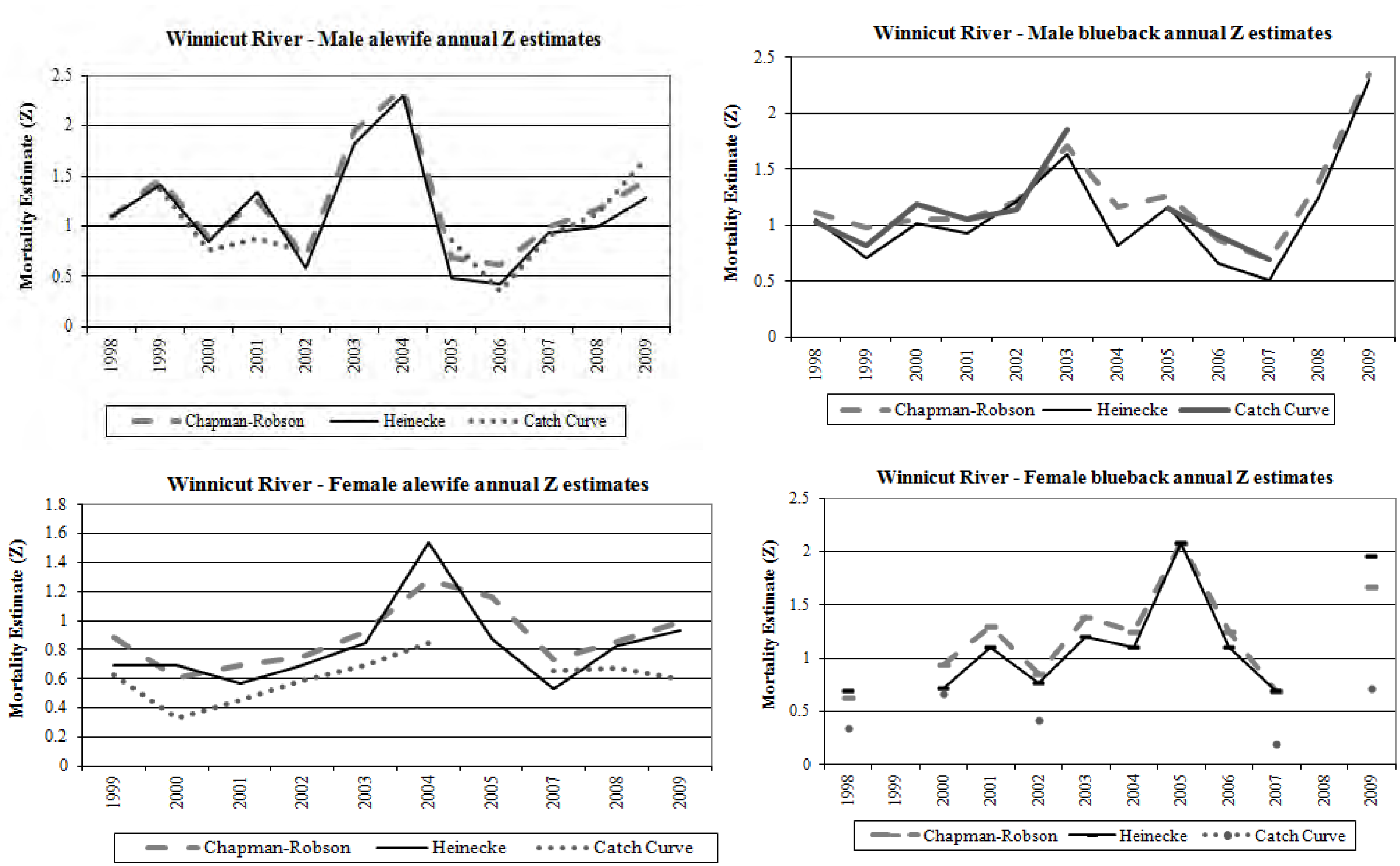
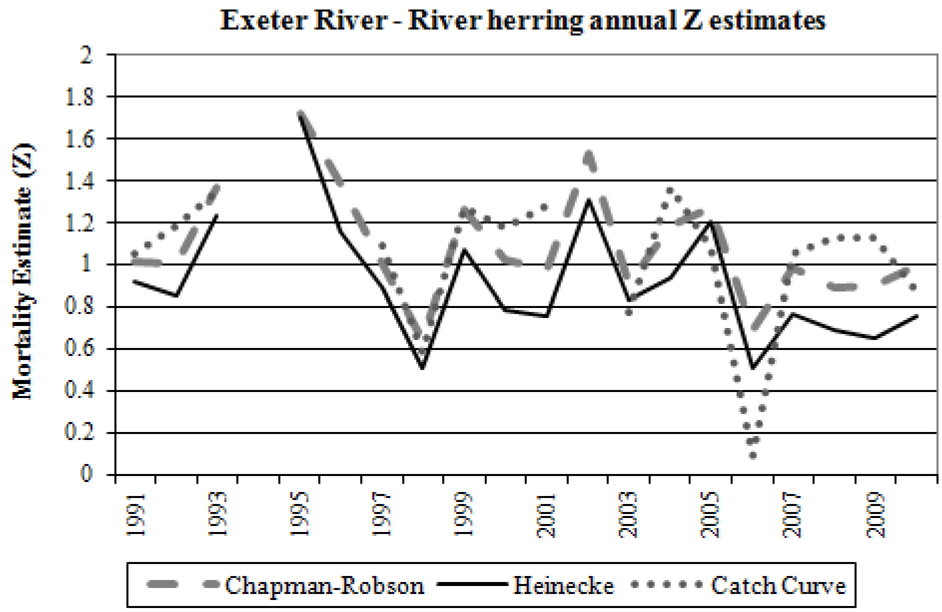


Figure 6.14 Continued.



**Due to low sample size Z estimates were not conducted between species or sex.*

Figure 6.14 Continued

7. Status of River Herring Stocks in Massachusetts Rivers

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Executive Summary

Run count data for three (Parker, Monument and Mattapoisett Rivers) of the five rivers used to estimate trends in passage and total run size indicated a precipitous decline in alewife abundance after 2000. Such a decline was not observed in the Nemasket River, but average passage count after 2004 (587,000 fish) was about half of the average run size prior to 2004 (1.04 million fish). Abundance has slowly increased in each river since about 2006-2008.

A decline in the Monument River run size of blueback herring was not observed until after 2004 and total run size remains low. Size data from the Monument River and Stony Brook indicated that the average total lengths of alewife and blueback herring have declined over time. Herring in the Monument River are currently about 20-27 mm smaller than herring sampled during 1984-1987. The average age of alewife and blueback herring in the Monument River has declined over time. The maximum age of both species is 1-2 years less than the maximum ages observed during 1985-1987. The proportions of alewives that were repeat spawners in the Monument River declined in recent years by 64% or more compared to data from 1986-1987. In other rivers, proportions of repeated spawners as high as 0.54 (Charles River) were observed, but most estimates were below 0.21 in recent years. Similar reductions in proportions of repeat spawners were observed for blueback herring in the Monument River. Results from the statistical catch-at-age model, and estimates of total instantaneous mortality from age, repeat spawner, and length data showed that the total mortality of alewife in the Monument River during the late 1990s increased by at least 20% compared to the earlier part of the time series.

7.1. INTRODUCTION

In Massachusetts, more than 100 coastal rivers and streams are home to the anadromous alewife (*Alosa pseudoharengus*) and blueback (*Alosa aestivalis*) herring. Known colloquially as “river herring”, these fishes are ecologically-important because they are forage for many marine and freshwater fish predators such as striped bass (*Morone saxatilis*), cod (*Gadus morhua*), and yellow perch (*Perca flavescens*) as well as birds (Loesch, 1987). In addition, they are a key link in the transfer of nutrients from freshwater to marine systems and vice versa (Mullen et al., 1986). River herring provide recreational and cultural benefits to citizens who value them for food and bait.

In recent years, river herring abundance in several runs throughout Massachusetts have declined to historical low levels. The declines prompted the Massachusetts Division of Marine Fisheries (DMF) to establish in 2005 a three-year moratorium on the sale and harvest of river herring throughout state. In addition, the National Marine Fisheries Service has listed blueback herring and alewife as “species of concern”. This report summarizes historical and current data on abundance, population characteristics, and mortality of river herring for the determination of the status of the stocks.

7.2. MANAGEMENT UNIT DEFINITION

Herring runs in Massachusetts are managed directly by DMF or by local town governments with DMF oversight.

7.3. FISHERY REGULATIONS

Currently, the Commonwealth of Massachusetts is in the sixth year of a harvest moratorium for river herring. Beginning in 2005, the moratorium was scheduled to expire on January 1, 2009, but lack of recovery prompted an extension of the moratorium through 2011. The Massachusetts Marine Fisheries Advisory Commission approved in November of 2008 the following regulations on the Harvest, Possession and Sale of River Herring in the Commonwealth, 322-CMR Section 6:17:

(1) Purpose. 322 CMR 6.00 is promulgated to establish consistent state management of river herring fisheries.

(2) Definitions.
(a) "River Herring" means those species of fish known as alewives (Alosa pseudoharengus) and bluebacks (Alosa aestivalis).
(b) "Batch" means all fish in any separate container.
(c) "Container" means any box, tote, bag, bucket or other receptacle containing loose fish which may be separated from the entire load or shipment.

(3) Taking and Possession of River Herring in Waters under the Jurisdiction of the Commonwealth. It shall be unlawful for any person to harvest, possess or sell river herring in the Commonwealth or in the waters under the jurisdiction of the Commonwealth.

(4) Exceptions. The Director may authorize the harvest and possession of river herring from a particular spawning run for personal use based on documentation that the spawning run from which herring are harvested is not depleted.

(5) Tolerance for bait fisheries. No person shall possess any batch of fish where more than 5% of the total is comprised of river herring species by count.

(6) Expiration. These measures shall expire on January 1, 2012.

7.4. ASSESSMENT HISTORY

No assessments of river herring populations in Massachusetts were conducted prior to the present effort that used 2004-2010 data. Three major efforts have been made by the Division of Marine Fisheries (and predecessor agency) to survey the presence and status of river herring runs and in the last century (Belding 1921; Reback et al. 1972; and Reback et al. 2004-5). These surveys provide valuable information on the presence of runs, fish passage, and fisheries, but did not attempt to quantify population abundance.

7.5. GENERAL LIFE HISTORY

Both blueback herring and alewives are found in many coastal stream systems in Massachusetts. While both species are capable of spawning in a variety of freshwater environments in Massachusetts, bluebacks spawn in more riverine areas, while alewives tend to spawn in more lacustrine (ponds and lakes) areas. Alewives begin to spawn in late March to mid-May when water temperature reach about 10.5^{o}C , but they have been observed in Massachusetts streams as early as February and, in one instance, January. Bluebacks begin to spawn later in the spring (late April through June) when water temperatures reach about 13.9°C. Blueback eggs are semi-buoyant and tend to drift with the current while alewife eggs will remain in contact with the substrate. After utilizing the freshwater habitat for a nursery area for most of the summer, juvenile herring begin their migration to the ocean in July. Peak migration occurs in September on Cape Cod (Kosa and Mather, 2001; Yako et al., 2002) and it continues through December. Once in the marine environment, river herring feed on zooplankton such as microcrustaceans, fish eggs and fish larvae (Munroe, 2002). Maturity occurs between 3 to 5 years of age and the fish return to their natal streams utilizing their olfactory sense to guide them to home waters.

7.6. HABITAT DESCRIPTIONS

With over 100 river herring runs in Massachusetts there is a wide range of habitat types used by anadromous alewife and blueback herring. Many habitats have been altered from natural states by watershed development and dam construction. The typical alewife run has a corridor of migratory habitat that transitions from intertidal to freshwater river and leads to a freshwater pond used for spawning and nursery habitat. Other habitats used by alewife include man-made ponds, large reservoirs, brackish tidal ponds, and main stem rivers. Blueback herring can use the same habitat types as alewife but show a tendency to favor lotic environments. The Division of Marine Fisheries has an ongoing investigation to assess the suitability of river herring spawning and nursery habitats (Chase 2010) that will contribute additional information on water quality and habitat requirements.

7.7. RESTORATION PROGRAMS

Massachusetts' statutes direct the Division of Marine Fisheries to work with Towns to sustain river herring runs, manage fisheries and provide fish passage. The Division of Marine Fisheries has maintained a fishway crew since 1934. This ongoing program has focused on sustaining and restoring passageways for adult river herring migration and juvenile herring emigration. The present program continues this tradition with additional efforts aimed at collaborative projects, spawning and nursery habitat restoration and other diadromous fish species.

7.8. AGE

Age samples have been recorded in the Monument River since 1980. Outside of the Monument River few efforts have been made to age river herring in Massachusetts until the present assessment for 2004-2010. All available river herring age data in Massachusetts are summarized in the following sections.

7.9. FISHERIES DESCRIPTIONS

7.9.1. Commercial Fishery

Historically, river herring were one of the most valuable anadromous fishes harvested commercially in Massachusetts and sold as food or commercial bait (Belding, 1921). Prior to the 1950s, annual landings were 2.26 million kilograms (5 million pound) or less (Appendix Table 7.1; Figure 7.1). Landings increased dramatically during the late 50s-early 60s (peak: 14.96 million kilograms or 33 million pounds in 1958) as foreign fleets, using purse seines, exploited herring on Georges Bank. By the early-1980s, after the establishment of the exclusive economic zone, river herring landings were only a very small fraction of the historical highs and most harvest occurred using dipnets and beach seines. Regulation of harvest limits in 1989 (25 fish/day) by the Commonwealth of Massachusetts restricted landings further and by 1994, there was little river herring sold commercially at fish houses. Since 2005, there has been a moratorium on the possession and sale of river herring in Massachusetts.

The landings data reported by NMFS are underestimated because of poor or no record-keeping of harvest by towns with herring runs. Since the 1980s, DMF has collected annual harvest data from the towns of Middleboro, Bournedale, and Mattapoisett with herring runs on the Nemasket River, Monument River and Mattapoisett River, respectively (Figure 7.2).

7.9.2. Bycatch in Commercial Fisheries

The issue of river herring bycatch is receiving a lot of attention at this time. Bycatch of river herring does occur in commercial fisheries that are targeting other species. Quantification of this take is difficult to estimate and efforts are being made to improve monitoring and reporting of this source of mortality. The commercial mid-water trawl, pair trawls and purse seine fisheries for Atlantic herring are becoming a point of focus. Cieri et al. (2008) reported that bycatch of river herring from the Atlantic herring fishery ranged from 171,973 pounds to 1.68 million pounds during 2005-2007. Periodic reports of by-catch are also received from the long fin and short fin squid, whiting, and northern shrimp fisheries as well as menhaden bait fisheries. Reports are often anecdotal and not well documented. In addition small numbers of illegal harvest (poaching) are usually reported to the Environmental Police each spring. These types of losses contribute to the total mortality of alewife and blueback herring but the actual extent and amount is poorly known at this time. In the Atlantic herring fishery, only 5% of the total landings are allowed to contain river herring as bycatch. In response to these bycatch issues, in 2008, DMF initiated a comprehensive monitoring program for river herring bycatch in the Atlantic herring fishery.

7.9.3. Recreational Fishery

Historically, there have been few reports of river herring being taken by recreational anglers for food. More often, river herring were taken for bait. The Marine Recreational Fisheries Statistics Survey (MRFSS) estimates of the numbers of river herring harvested and released by anglers in Massachusetts are very imprecise and show little trend (Appendix Table 7.2). Since spring of 2005, there has been no recreational (bait) fishery for alewife and/or blueback herring allowed in the Commonwealth of Massachusetts.

7.9.4. Subsistence Fishery

The only subsistence river herring fishery currently conducted within Massachusetts is under a Memorandum of Understanding (MOU) between the Commonwealth and the federally recognized Mashpee Wampanoag Indian Tribe on Cape Cod. This understanding recognizes the Tribe's aboriginal fishing rights and allows harvesting of river herring by Tribal members which is regulated by the Tribe pursuant to the Tribe's regulatory authority. Reported harvests are provided to DMF and harvest ranges from about 1,200 fish to 3,500 fish per year, with removals coming from several rivers.

7.9.5. Stocking Efforts

DMF conducts a trap and transport stocking program for alewife and blueback herring. The three major objectives are to: 1) maintain and enhance existing populations, 2) restore historically important populations and 3) create new populations where feasible. Stocking of gravid river herring where river access has been provided or improved is generally conducted for three or more consecutive years per system. Prior to the moratorium the program transported between 30,000 and 50,000 fish per year into ten to fifteen different systems. Since the moratorium, effort has been reduced to protect donor populations and approximately 20,000 fish per year have been deposited into five to ten systems. Many of the recent efforts have been with-in system, moving fish upstream past multiple obstructions to the headwater spawning habitat.

7.10. FISHERIES-INDEPENDENT MONITORING

Data on alewife and blueback herring in Massachusetts come from mostly historical and/or current work conducted by DMF, University of Massachusetts and federal scientists, and local citizen groups interested in protecting river herring resources. Figure 7.3 shows the rivers and locations for which fisheries-independent data are available. In this document, "passage" estimates are considered herring counts that, when added to the harvest estimates, do not produce the total amount of herring in the river system because the count location is situated above viable spawning habitat of river herring (e.g., Nemasket River). "Escapement" estimates are considered herring counts that, when added to harvest estimates, produce the total amount of river herring in the system because the harvest and count locations are situated close to the river mouth (e.g., Monument River).

All data are summarized by species and river in Appendix Table 7.3. Data for this assessment were stringently reviewed to provide the most reliable, scientifically-valid estimates of passage or total run size and population characteristics. Therefore, not all data summarized in Appendix Table 7.3 were used. The following gives a brief description of data available:

Acushnet River (New Bedford) - Since 2005, DMF has conducted a census of river herring entering the spawning ground using a fish trap. Simultaneous estimation of passage by using an electronic counter began in 2008, and video counting was attempted in 2008. DMF has also collected biological samples from dead fish, but samples were collected at -random and sample sizes were too small to use in this assessment.

Agawam River (Wareham) - The town of Wareham has been estimating combined passage using an electronic counter since 2006. Biological data are available from only 1991.

Back River (Weymouth) - The town of Weymouth's herring warden provides a "relative" passage estimate from his daily observations of run activity. No statistically-valid design is used. In 2007, DMF began characterizing the alewife population under an NOAA Anadromous Fish Conservation Act grant. DMF collected biological data on size structure, sex composition, age structure, length-weight relationships and length-at-age relationships of spawning populations (see Monument River below).

Bound Brook (Scituate) - The North and South Rivers Watershed Association began passage counts using visual estimation in 2010. No statistical design was used. There are no biological data.

Charles River (Boston) - The University of Massachusetts with assistance of DMF conducted video counts in 2008 and 2009. Biological data are available from 1985 and 1993.

Connecticut River (Holyoke) - Fishlift counts have been made at the Holyoke Dam since 1967 for blueback herring by the US Fish and Wildlife Service. The numbers are used by the State of Connecticut in their river herring assessment; therefore, the information is not discussed herein to avoid duplication of effort.

Coonamessett River (Falmouth) - Falmouth Department of Natural Resources has been estimating passage using visual estimation since 2005. There are no biological data available.

*Herring Brook, First (*Scituate) - The North and South Rivers Watershed Association conducted passage counts using visual estimation in 2005-2006. No statistical design was used. There are no biological data available.

Herring Brook, Second (Norwell) - The North and South Rivers Watershed Association conducted passage counts using visual estimation in 2005-2006. No statistical design was used. There are no biological data available.

Herring Brook, Third (Norwell/Hanover) - The North and South Rivers Watershed Association conducted passage counts using visual estimation in 2003, and 2005-2006. No statistical design was used. There are no biological data available.

Herring River (Wellfleet) - The Association to Preserve Cape Cod has been estimating passage numbers using visual counting since 2007. There are no biological data available.

Herring River (Harwich) - The Association to Preserve Cape Cod has been estimating passage numbers using visual counting since 2007. There are no biological data available.

Ipswich River (Ipswich) - The Ipswich Watershed Association has been estimating passage using visual counting since 2000. They've attempted to use the statistical design of Rideout et al. (1979) but prior to 2005, effort was not sufficient to provide reliable estimates. In 2006-2008, DMF also made census counts by using a fishtrap. There are no biological data available.

Jones River (Kingston) - The Jones River Watershed Association has been conducting passage counts using visual estimation since 2005. There are no biological data available.

Little River (Gloucester) - Massachusetts Audubon made passage counts using visual estimation during 2000-2002, 2005, and 2009. There are no biological data available.

Marston-Mills River (Marston-Mills) - Starting in 2007, a local watershed group provides visual counts of combined herring passage at Mill Pond dam in the Marston-Mills River. They use a stratified random design. There are no historical or current data on population characteristics.

Mattapoisett River (Mattapoisett) - Since 1988, Alewives Anonymous has provided passage counts of alewife using an electronic fish counter. Harvest data are also provided. In 1995, 2006 and 2007, DMF collected biological data on size structure, sex composition, age structure, length-weight relationships and length-at-age relationships of spawning populations (see Monument River below).

Merrimack River (Lawrence) - The only data available are the number of herring lifted at the Essex and Pawtucket Dam fishlifts since 1983. Data are provided by the US Fish and Wildlife Service.

Monument River (Bournedale) - DMF has been scientifically monitoring the abundance, sex composition, length structure, age composition and removals of alewife and blueback herring in the Monument River since the early 1980s (Churchill, 1981; O'Hara, 1980; Brady, 1987a, b). Prior to 1985, abundance was estimated by using visual counts following the statistical design of Rideout et al. (1979). Since 1985, escapement has been estimated by using a Smith-Root electronic fish counter that is calibrated daily. Fish entering the system are sampled approximately weekly by using a dipnet. Fish samples are processed for length, sex, and age composition. All scales are aged using the criteria of Rothschild (1963), Marcy (1969) and Kornegay (1977), and repeat spawners are identified. Fish samples are used to apportion abundance into species- and sex-specific estimates (Brady, 1987). DMF often uses herring from this river as donor stock to other river systems. All numbers transported are added to harvest recorded by the Bournedale fish warden to get total number of removals. Scale ages are only available for 1984-1987, 1993, and 1995-present. Since the counting location is not far above the catchment basin where herring are removed, and both are close to the river mouth, the total run size is estimated by adding escapement counts to removal numbers.

Mystic River (Boston) - Since 2004, DMF has characterized the alewife and blueback populations under an NOAA Anadromous Fish Conservation Act grant. DMF has collected biological data on size structure, sex composition, age structure, length-weight relationships and length-at-age relationships of spawning populations (see Monument River above). There are no estimates of run size available.

Nemasket River (Middleboro) - Since 1996, the town of Middleboro has provided visual counts of alewife passage at the fishway off Wareham Street (river mile 7.5). The statistical design of Rideout et al. (1979) is used. Since 2004, DMF has characterized the alewife and blueback populations under an NOAA Anadromous Fish Conservation Act grant. DMF has collected biological data on size structure, sex composition, age structure, length-weight relationships and length-at-age relationships of spawning populations (see Monument River above).

Parker River (Newbury) - Students and researchers at the University of Massachusetts, Amherst conducted several studies during the 1970s that provide information on juvenile and adult population characteristics, abundance and migration of alewives (Beltz, 1975; Cohen, 1976; Cole et al., 1976; Cole et al., 1978; Huber, 1974; Jimenez, 1978; Libey, 1976; Mayo, 1974; Rideout et al., 1979). Since 1997, the Parker River Clean Water Association has been estimating passage numbers at the first dam using visual counting and the statistical design of Rideout et al. (1979). Due to high flood waters of 2005 and 2006, a weir failed, making it difficult for alewives to pass. Passage counts since 2005 are probably biased. There are no current data on population characteristics.

Pilgrim Lake (Orleans) - The Association to Preserve Cape Cod has provided abundance estimates of alewife passage using visual counting and a stratified random design since 2008.

Quashnet River (Falmouth/Mashpee) - In 2004, DMF characterized the alewife population under an NOAA Anadromous Fish Conservation Act grant. DMF collected biological data on size structure, sex composition, age structure, length-weight relationships and length-at-age relationships of spawning populations (see Monument River above). There are no estimates of passage numbers available.

Sippican River (Wareham) - Alewives Anonymous made electronic census counts of alewife passage in 1995-2002 and 2006. There are no biological data available.

South River (Marshfield) - The North and South Rivers Watershed Association conducted passage counts using visual estimation in 2006, 2008 and 2010. No statistical design was used. There are no biological data available.

Stony Brook (Brewster) - The Association to Preserve Cape Cod has provided estimates of alewife passage numbers at the lower Mill Pond dam using visual counting and a stratified random design since 2007. In 2004, DMF characterized the alewife population under an NOAA Anadromous Fish Conservation Act grant. DMF collected biological data on size structure, sex composition, age structure, length-weight relationships and length-at-age relationships of spawning populations (see Monument River above). Mr. George A. Kurlycheck, a Middle School teacher in Harwich, collected average size data on alewife (sexes combined) from 1978-2001.

Town Brook (Plymouth) - Since 2004, DMF has characterized the alewife and blueback populations under an NOAA Anadromous Fish Conservation Act grant. DMF has collected biological data on size structure, sex composition, age structure, length-weight relationships and length-at-age relationships of spawning populations (see Monument River above). The town of Plymouth, University of Massachusetts, and DMF have made visual counts since 2008 and video counts were made in 2008 and 2009.

*Town River (*Bridgewater) - The town of Bridgewater has made combined electronic passage counts of river herring (species combined) since 2000. There are no biological data available.

Trunk River (Falmouth) - Falmouth Department of Natural Resources has been estimating passage since 2008. No statistical design is used. There are no biological data available.

Wankinco River (Wareham) - The town of Wareham has made combined electronic passage counts since 2007. There are no biological data available.

7.10.1. Trends in Run Size

The river estimates of passage counts and total run size used in this assessment came from the Mattapoisett River, Monument River, Nemasket River, Parker River, and Town River (Appendix Table 7.4; Figure 7.4). Some river estimates were deemed unusable because 1) lack of statistical design (e.g., Back River), 2) non-reflectance of natural abundance trends (e.g., Merrimack River), or 3) shortness of time series (e.g., Marston-Mills River, Stony Brook, and Town Brook).

Matttapoisett River

Alewife - Passage estimates of alewife showed increasing trends in numbers from 22,000 fish in 1988 to 130,000 fish in 2000 (Appendix Table 7.4; Figure 7.4). Passage estimates dropped precipitously through 2004 to 5,385 fish. Passage size has increased gradually to 12,319 fish in 2010.

Monument River

Alewife - A fluctuating, but increasing trend in total run size was evident from 1980 to 2000, peaking at about 597,937 fish (Appendix Table 7.4; Figure 7.4). Thereafter, it dropped precipitously through 2002 to 182,031 fish, and then continued to decline through 2006 to the lowest level observed in the time series (52,472 fish). Alewife abundance has increased gradually since 2007 to an average of about 119,354 fish. (Appendix Table 7.4; Figure 7.3.4).

Blueback - Total run size was highest during 1980-1991, averaging about 64,800 fish. Abundance was lower on average (41,000 fish) during 1992-2002 and it began to decline in 2003 to 8,140 fish in 2007 (Appendix Table 7.4; Figure 7.4). Abundance increased to 18,532 and 30,356 fish in 2008 and 2009, respectively, but dropped to 9,358 fish in 2010.

Nemasket River

Alewife - Passage numbers of alewife have fluctuated considerably since 1996 (Appendix Table 7.4; Figure 7.4). Passage numbers averaged 910,000 fish prior to 2002, but following the peak (1.9 million fish) in 2003, numbers declined through 2005 to 401,000 fish. Since 2008, numbers have increased to 791,150 fish on average.

Parker River

Alewife - Passage counts of alewives fluctuated considerably during the 1970s, peaking at 38,163 fish in 1973 and then declining to an average of 11,256 fish between 1976-1978. Passage counts were as high as 7,894 fish in 2000, exceeding the 1977 estimate of 6,654 fish, but declined to low levels by 2005 (Appendix Table 7.3; Figure 7.4). Since 2008, passage numbers have increased slightly.

Town River

Alewife/Blueback - Passage numbers of alewife and blueback herring (combined) have fluctuated considerably since 2000 (Appendix Table 7.4; Figure 7.4). Passage numbers were as high 310,000 fish in 2003. In most years, however, passage numbers averaged only 39,373 fish.

A simple population model was fitted to the alewife counts for the Mattapoisett River, Monument River and Nemasket River to estimate the net "reproductive" rates:

$$N_t = N_0 \cdot R^t$$

where N_t is the count at time t, N_0 is estimated initial population size, and R is the net "reproductive" rate. R can be used as an indication that the population has remained stable over time (R=1), has increased (R>1), or has declined (R<1).

The equation was linearized using natural-log transformation:

$$\ln(N_t) = \ln(N_0) + \ln(R) \cdot t$$

To simultaneously estimate the parameters for periods of three different trends in counts, a piecewise regression approach was used. The linear model was fitted separately to data from three periods, but models were linked so that the ending year for the first and second periods were also the intercept for the second and third periods:

$$\ln(N_{1,t}) = \ln(N_{1,0}) + \ln(R_1) \cdot t \quad \text{for } t < C_1$$

$$\ln(N_{2,t}) = \ln(N_{1,0}) + C_1 \cdot (\ln(R_1) - \ln(R_2)) + \ln(R_2) \cdot t \quad \text{for } t \geq C_1 \text{ and } t < C_2$$

$$\ln(N_{3,t}) = \ln(N_{1,0}) + C_1 \cdot (\ln(R_1) - \ln(R_2)) + C_2 \cdot (\ln(R_2) - \ln(R_3)) \cdot t \quad \text{for } t \geq C_2$$

where C_1 and C_2 are the common years of change and other values are as described above. For this three period model, six parameters $ln(N_{1,0})$, $ln(R_1)$, $ln(R_2)$, $ln(R_3)$, C_1 and C_2 were estimated using least-squares.

Matttapoisett River

Alewife - The common times of change (C_1 and C_2) were estimated to be 13.4 (year 2000.4) and 18.1 (year 2005.1), and the estimated net "reproductive" rates was 1.12, 0.50, and 1.20 for the first, second and third periods, respectively. Passage counts in this river increased by 12% per year, on average, during 1988-2000, declined by 50% per year, on average, through 2005 and increased by 20% per year, on average, after 2005 (Figure 7.5). The high r-square value (0.95) indicated excellent model fit.

Monument River

Alewife - The common times of change (C_1 and C_2) were estimated as 21.2 (year 2000.2) and 26.8 (year 2005.8), and the estimated net "reproductive" rates were 1.08, 0.69, and 1.22 for the first, second, and third periods, respectively. Total counts in this river increased by 8% per year, on average, during 1988-2000, declined by 27% per year, on average, through 2005, and increased by 22% per year, on average, from 2006-2010 (Figure 7.5). The high r-square value (0.80) indicated good model fit.

Nemasket River

Alewife - The common times of change (C_1 and C_2) were estimated as 7.1 (year 2002.1) and 9.8 (year 2004.8), and the estimated net "reproductive" rates were 1.02, 0.73, and 1.14 for the first, second and third periods, respectively (Figure 7.5). Passage counts in this river increased by 2% per year, on average, during 1996-2002, declined by 26% per year, on average, through 2004, and increased by 14% per year, on average, from 2005-2010. The low r-square value (0.48) indicated poor model fit.

7.10.2. Trends in Size Structure

Raw length frequencies available for each river, species and sex are shown in Appendix Tables 7.5 and 7.6, and summary statistics for the length distributions are shown in Appendix Tables 7.7 and 7.8. Males of each species are smaller in length than females of the same species, and blueback herring are smaller in length than alewives. Comparison of average sizes among rivers showed that alewives collected in the Monument River, Mystic River, Quashnet River, Stony Brook, and Town Brook were about 10-30 mm smaller than alewives collected in the Back, Mattapoisett, and Nemasket rivers (Appendix Tables 7.7 and

7.8). Mean total length of both species and sexes from the Monument River declined from 1984 through the mid-1990s (Appendix Table 7.8; Figure 7.6). Female and male alewives and blueback herring sampled during 2004-2010 were about 20-27 mm smaller, on average, than alewives and blueback herring of the same sex sampled during 1984-1987 (Appendix Table 7.8). Mean total length of alewife (sexes combined) in Stony Brook showed a similar decline over time (Figure 7.6).

7.10.3. Trends in Age

Any available age data regardless of the length of the time series were used in this assessment. Raw data are presented in Appendix Tables 7.9 and 7.10. Mean age is presented in Appendix Table 7.11.

Agawam River

Alewife - Age samples (n=71 for females; n=86 for males) were available from 1991. The youngest and oldest alewives observed on the run were ages 3 and 7, respectively, for females and ages 3 and 6, respectively, for males (Appendix Table 7.9; Figure 7.7). Mean ages for female and male alewife in 1991 were 4.6 and 4.3 years, respectively (Appendix Table 7.11).

Blueback - Age samples (n=6 for females; n=7 for males) were available from 1991. These sample sizes were too small to provide accurate observation on the youngest and oldest ages of blueback herring in the run. Mean ages for female and male blueback herring in 1991 were not calculated due to small sample sizes (Appendix Table 7.11).

Back River

Alewife - Age samples (n=210 for females; n=228 for males) were available from 2007 for alewife only. The youngest and oldest alewives observed in the run were ages 3 and 8, respectively, for females and ages 3 and 7, respectively, for males (Appendix Table 7.9; Figure 7.7). Mean ages for female and male alewife in 2007 were 4.2 and 4.0 years, respectively (Appendix Table 7.11).

Charles River

Blueback - Age samples were available from 1985 and 1993. The youngest and oldest alewives observed in the run were ages 3 and 10, respectively, for females and ages 2 and 7, respectively, for males (Appendix Table 7.9; Figure 7.8). Mean ages for female and male alewife were 5.2 and 4.4 years in 1985, respectively, and 4.8 and 4.0 in 1993 (Appendix Table 7.11).

Mattapoisett River

Alewife - Age samples were available from 1995 and 2006. The youngest and oldest alewives observed in the run were ages 3 and 7, respectively, for females and 3 and 6, respectively, for males (Appendix Table 7.9; Figure 7.7). Mean ages for female and male alewife were 4.8 and 4.4, respectively, in 1995 and 3.9 and 3.7 years, respectively, in 2006 (Appendix Table 7.11) indicating a possible decline between the two years.

Monument River

Alewife - The earliest time series (1985-1987) of age composition data come from Brady (1987a). The youngest and oldest individuals observed in the run during 1985-1987 were age 3 and 8 for females, and age 3 and 7 for males, respectively (Appendix Table 7.10; Figure 7.9). Ages 4-5 were the most abundant age-classes in the spawning run. From 1993-2006, the youngest and oldest individuals observed on the run were generally age 3 and 6 for both sexes, respectively, although older ages were observed infrequently. Ages 7 and 8 were observed in larger samples from 2007-2010. Ages 4 and 5 were the most abundant age-classes. Comparison of the age compositions between 1984-1987 and later years indicated that the maximum age of male and female alewife has decreased by one to two years. Comparison of mean ages during 1985-1987 to mean ages during 1993-2010 indicated a decline in mean age over time (Appendix Table 7.11; Figure 7.10).

Blueback - The earliest time series (1985-1987) of age composition data come from Brady (1987b). The youngest and oldest individuals of both sexes observed in the run during 1985-1987 were age 3 and 7, respectively (Appendix Table 7.10; Figure 7.11). Ages 4-5 were the most abundant age-classes in the spawning run. From 1993-2010, the youngest and oldest individuals observed on the run were age 3 and 6, respectively, for both sexes, except in 1997 and 2008. Ages 4 and 5 were the most abundant age-classes. Comparison of the age compositions over time indicated that the maximum age of male and female alewife has decreased by one to two years. Comparison of mean ages during 1985-1987 to mean ages during 1993-2010 indicated a decline in mean age over time (Appendix Table 7.11; Figure 7.10).

Mystic River

Alewife -Age compositions of both sexes of alewife from 2004-2010 were comprised of ages 2-7 with peak numbers occurring mostly at ages 4 and 5 (Appendix Table 7.9; Figure 7.12). Mean age ranged from 3.9 to 4.7 years for females and from 3.5 to 4.3 years for males (Appendix Table 7.11).

Blueback - Age samples for blueback herring were available from 2005-2010. The youngest and oldest individuals of both sexes observed in the run were age 3 and 8, respectively (Appendix Table 7.9; Figure 7.12). Ages 4 and 5 were the most abundant age-classes. Mean age ranged from 3.4 to 4.4 years for females and from 3.2 to 3.8 years for males (Appendix Table 7.11).

Nemasket River

Alewife - The youngest and oldest individuals of both sexes observed in the run during 2004-2010 were age 3 and 8, respectively (Appendix Table 7.9; Figure 7.13). Ages 4-5 were the most abundant age-classes. Mean age ranged from 4.2 to 5.3 years for females, and from 4.0 to 4.9 years for males (Appendix Table 7.11).

Parker River

Alewife - The earliest time series (1971-1978) of age composition data come from studies of alewife by Cole et al. (1976), Cole et al. (1978), and Mayo (1974). The youngest and oldest alewives of both sexes observed in the run were age 3 and 9, respectively. Ages 4-6 were the most abundant age-classes in the spawning run, although ages 7-8 were common (Figure 7.14). Average age from 1971-1978 ranged from 4.3 to 6.0 years for females, and from 4.0 to 5.7 for males (Appendix Table 7.11).

Quashnet River

Alewife - During 2004, the youngest and oldest individuals observed in the run were age 3 and 5 for both sexes, respectively (Appendix Table 7.9; Figure 7.7). Age 4 was the most abundant age-class. Mean ages for female and male alewife in 2004 were 4.3 and 3.9 years, respectively (Appendix Table 7.11).

Blueback - No description of the age composition is made because only 8 individuals were aged (Appendix Table 7.9).

Stony Brook

Alewife - During 2004, the youngest and oldest individuals observed in the run were age 3 and 7 for females, and age 3 and 6 for males, respectively (Appendix Table 7.9; Figure 7.7). Ages 4-5 were the most abundant age-classes. Mean ages for female and male alewife in 2004 were 4.5 and 4.1, respectively (Appendix Table 7.11).

Town Brook

Alewife - The youngest and oldest individuals observed in the run during 2004-2010 were age 3 and 8 for females and age 3 and 7 for males, respectively (Appendix Table 7.9; Figure 7.13). Age 4 was the most abundant age-class for both sexes. Mean age ranged from 4.0 to 4.9 years for females and from 3.8 to 4.6 years for males (Appendix Table 7.11).

Blueback - No description of the age composition is made because only 9 were aged (Appendix Table 7.9).

7.10.4. Trends in Mean Length-At-Age

Mean length-at-age data for alewife and blueback herring from the Monument River were plotted by sex and year to determine if changes in growth have occurred over time (Figure 7.15). Unfortunately, data from 1984-1987 were not available for historical comparison. Although variable, mean length-at-age of alewife for ages 3-5 of both sexes declined in the mid-1990s and increased through 2003. Since 2004, mean length-at-age has been variable without trends. Mean length-at-age for blueback herring has varied without trend.

7.10.5. Trends in Proportions of Repeat Spawners

The frequencies of new and repeat spawners determined by reading spawning checks on scales are listed in Appendix Table 7.12 and 13 by species, river, sex and year. The proportions that repeat spawners comprised the total samples are given in Table 7.1.

Agawam River

Alewife - The proportion of repeat spawners for female and male alewife in 1991 was 0.11 and 0.10, respectively (Table 7.1).

Blueback - The proportions of repeat spawners for female and male blueback herring were not calculated due to small sample size (Table 7.1).

Back River

Alewife - The proportion of repeat spawners for both sexes was 0.11 in 2007 (Table 7.1).

Charles River

Blueback - The proportions of repeat spawners for female blueback herring were 0.54 in 1985 and 0.44 in 1993. For males, the proportions were 0.49 in 1985 and 0.25 in 1993 (Table 7.1). Data for both sexes indicate a possible decline in the fraction of repeat spawners.

Mattapoisett River

Alewife - The proportions of repeat spawners for female alewife were 0.33 in 1995 and 0.04 in 2007. For males, the proportions were 0.19 in 1995 and 0.03 in 2007 (Table 7.1). Data for both sexes indicate a possible decline in the fraction of repeat spawners.

Monument River

Alewife - The earliest time series (1986-1987) of repeat spawner data come from Brady (1987a). During 1986-1987, the estimated proportions of repeat spawners for females ranged from 0.44 to 0.45, and those for males ranged from 0.39 to 0.41 (Table 7.1). From 1993-2010, proportions of repeat spawners ranged from 0.01-0.41, but most were $\leq$0.29. Since 2003, the proportions of repeat spawners have been $\leq$0.19.

Blueback - The earliest time series (1986-1987) of repeat spawner data come from Brady (1987b). During 1986-1987, the estimated proportions of repeat spawners for females ranged from 0.38 to 0.39, and those for males ranged from 0.20 to 0.22 (Table 7.1). From 1993-2010, proportions of repeat spawners ranged from 0.00-0.27, but most were $\leq$0.20. Since 2003, the proportions of repeat spawners have been $\leq$0.14.

Mystic River

Alewife - The estimated proportions of repeat spawners for females varied widely without trend (0.00

in 2006 to 0.36 in 2004) (Table 7.1). However, the proportions of repeat spawners for males remained consistent at 0.3-0.32 in 2004-2005, but declined to <0.21 during 2006-2010.

Blueback - The estimated proportions of repeat spawners for female and male blueback herring varied without trend (range: 0.03 in 2005 to 0.36 in 2008 for females; 0.06 in 2005 to 0.27 in 2008 for males) (Table 7.1).

Nemasket River

Alewife - The estimated proportions of repeat spawners for females and males were high in 2004 (0.43 for females; 0.44 for males) but declined thereafter to ≤0.30 for females and ≤0.29 for males (Table 7.1).

Quashnet River

Alewife - The estimated proportions of repeat spawners for both sexes were ≤0.07 in 2004 (Table 7.1).

Blueback – No estimates of proportions of repeat spawners were produced because of low sample sizes (Table 7.1).

Stony Brook

Alewife - The estimated proportions of repeat spawners for both sexes were ≤0.21 in 2004 (Table 7.1).

Town Brook

Alewife - The estimated proportions of repeat spawners for female and male alewife were low (≤0.17) prior to 2007, but increased above 0.17 thereafter (Table 7.1).

Blueback - No estimates of proportions of repeat spawners were produced because of low sample sizes (Table 7.1).

7.10.6. Trends in Total Instantaneous Mortality Rates

7.10.7. Age and repeat spawner data

The Chapman-Robson survival estimator (Chapman and Robson, 1960; Murphy, 1997) was applied to the annual age- and repeat-spawner frequency data to generate estimates of survival rate (S) for each species, sex and year. Total instantaneous mortality rate (Z) was estimated by the natural-log transformation of S. For age data, the first age-at-full recruitment was the age with the highest frequency. For repeat spawner data, the new spawners (0) were assumed fully-recruited. Only Z estimates made from data with three or more age-classes (including first fully-recruited age) were deemed valid. All methods were programmed in *R*.

7.10.8. Length data

The Beverton-Holt (BH) length-based Z estimator (Beverton and Holt, 1957) was applied to all available length data. The equation for Z is

$$Z = \frac{K(L_\infty - \bar{L})}{\bar{L} - L_c}$$

where K and L_8 are the growth and asymptotic length, respectively, for a von Bertalanffy growth equation, Lc is the length-at-first capture (smallest size of the youngest age at which animals are fully-vulnerable to fishery and sampling gear) and L bar is the mean length of fish ≥Lc. The population is assumed to be in equilibrium after any change in mortality. K and L_8 were estimated from mean length-at-age data available in Mayo (1974; back-calculated mean lengths) for alewife and in Collette and Klein-

MacPhee (2002) for blueback herring. The standard von Bertalanffy growth equation was fitted to the growth data, but L_8 was fixed to the maximum observed length in each study to ensure that it was not underestimated due to incomplete sampling of the population. Estimates of L_8 , K, and Lc are given in Table 7.2.

If the population is not in equilibrium, the Z estimates will be biased. To deal with this situation, an alternative Beverton-Holt estimator that accounts for non-equilibrium conditions (Gedamke and Hoenig, 2006) was also applied to the length data. In this method, a Z is estimated for each period of mortality change along with the year of that change using maximum likelihood. Akaike's Information Criterion (AIC) values are compared to determine the model structure that best describes variability in the length data. The same input parameters as the equilibrium method are required. The non-equilibrium method was programmed in *R* and the function *optim* was used to find the parameters that minimized the negative log-likelihood. This method was applied to data only from the Monument River because of the shortness of the time series for other rivers.

Estimates of Z from the age, repeat spawner (rps), and length data by species and sex are given in Appendix Table 7.14 and are plotted in Figures 7.16-7.19. Although Z estimates were made for alewife and blueback herring from several rivers, long time series of Z estimates from which change could be detected were available only from the Monument River. The resulting estimates of Z from the Gedamke and Hoenig (2006) method and years in which mortality changed for the Monument River are presented in Table 7.3. Estimates for each river are summarized below:

Agawam River

Alewife - Z estimates for females in 1991 ranged from 0.71 (BH) to 0.96 (age), while those for males ranged from 0.91 (BH) to 1.18 (age) (Appendix Table 7.14; Figure 7.17).

Blueback - Z estimates for females in 1991 ranged from 0.81 (age) to 0.86 (BH). The valid single estimate of Z for males was 1.31 (BH) (Appendix Table 7.14; Figure 7.16). There were no valid estimates from repeat spawner data.

Back River

Alewife - Z estimates for females in 2007 ranged from 0.66 (BH) to 1.99 (rps), while those for males ranged from 0.77 (BH) to 1.64 (age) (Appendix Table 7.14; Figure 7.16).

Charles River

Blueback - Z estimates for females in 1985 ranged from 0.47 (BH) to 0.67 (age), while those for males ranged from 0.67 (BH) to 0.96 (age) (Appendix Table 7.14; Figure 7.17). In 1993, Z estimates for females ranged from 0.7 (BH) to 1.19 (age), while those for males ranged from 1.05 (age) to 1.38 (BH) (Appendix Table 7.14; Figure 7.17).

Mattapoisett River

Alewife - Z estimates for females in 1995 ranged from 0.54 (BH) to 0.72 (age). During 2006-2007, Z estimates ranged from 0.7 (BH) to 1.1 (age); no estimates were available from rps data (Appendix Table 7.14; Figure 7.16). For males, Z estimates in 1995 ranged from 0.73 (BH) to 0.94 (age). During 2006-2007, BH Z estimates ranged from 0.89-1.22 and are the only ones available (Appendix Table 7.14; Figure 7.16).

Monument River

Alewife - For 1985-1987, Z estimates from age and rps frequency data ranged from 0.76 (age data) to 1.04 rps for females and from 0.84 to 1.12 (age) for males (Appendix Table 7.14; Figure 7.18). For 1993-2010, Z estimates from age and rps frequency data ranged from 0.87 (age) to 2.53 (rps) for females and from 1.02 (age) to 2.82 (rps). Estimates of Z from repeat spawner data tended to be higher than estimates derived from age data. Comparison of Z estimates from age and repeat spawner data showed an increase in total mortality over time series for both sexes, although estimates for female alewife from age data showed a slight decline in Z after 2000.

An increasing trend in total instantaneous mortality was also observed in the BH Z estimates for both sexes (Appendix Table 7.14; Figure 7.18). Z values for 1984-1987 were about half of those estimated for the same time period using age and rps data. As the year of the time series increased, mortality approached levels estimated using age and repeat spawner data. Comparison of AIC values from the GH method indicated that the best model for female alewife assumed two mortality changes (1989 and 2004) over the time series (Table 7.3). For male alewife, the best model assumed mortality changed once (1988). For female alewife, Z was estimated to be 0.45 prior to 1989, 1.09 during 1989-2003, and 1.56 after 2004. For male alewife, Z was estimated to be 0.57 prior to 1988, and 1.49 thereafter.

Blueback - For 1985-1987, Z estimates from age and rps frequency data ranged from 0.98 (age) to 1.49 (age) for females and from 1.06 (age) to 1.64 (rps) for males (Appendix Table 7.14; Figure 7.19) For 1993-2010, Z estimates from age and rps frequency data ranged from 0.75 (age) to 1.54 (age) for females and from 0.76 (age) to 1.73 (rps) for males. Estimates of Z from repeat spawner data tended to be higher than estimates derived from age data. Comparison of Z estimates from age and repeat spawner data showed no trend in total mortality over time series for both sexes.

An increasing trend in total instantaneous mortality was observed in the BH Z estimates for both sexes (Appendix Table 7.14; Figure 7.19). Some Z values for 1984-1987 were about half of those estimated for the same time period using age and rps data. As the year of the time series increased, mortality approached and exceeded levels estimated using age data. Comparison of AIC values from the GH method indicated that the best model assumed mortality changed twice (female: 1989 and 2005; male: 1985 and 1995) over the time series (Table 7.3). For female blueback, estimates of Z were 0.58 prior to 1989, 1.27 during 1989-2004, and 2.10 thereafter. For males, estimates of Z were 0.66 prior to 1985, 1.08 during 1985-1994, and 1.85 thereafter.

Mystic River

Alewife - Z estimates for females during 2004-2010 ranged from 0.96 (age) to 2.58 (BH) (Appendix Table 7.14; Figure 7.16). For males, Z estimates during 2004-2010 ranged from 0.88 (age) to 3.96 (BH) (Appendix Table 7.14; Figure 7.16).

Blueback - Z estimates for females during 2004-2010 ranged from 0.86 (age) to 2.41 (rps) (Appendix Table 7.9; Figure 7.17). For males, Z estimates during 2004-2010 ranged from 1.26 (age) to 2.46 (BH) (Appendix Table 7.14; Figure 7.17).

Nemasket River

Alewife - Z estimates for females during 2004-2010 ranged from 0.51 (BH) to 2.35 (rps) (Appendix Table 7.14; Figure 7.16). For males, Z estimates during 2004-2010 ranged from 0.54 (BH) to 2.21 (rps) (Appendix Table 7.14; Figure 7.16).

Quashnet River

Alewife - Only one Z for each sex was available. For 2004, Z (BH) was 1.10 for females and 1.46 for males (Appendix Table 7.14; Figure 7.16).

Blueback - Only one Z for each sex was available. For 2004, Z (BH) was 1.01 for females and 2.96 for males (Appendix Table 7.14; Figure 7.17).

Stony Brook

Alewife - Z estimates for females during 2004-2010 ranged from 0.90 (BH) to 1.96 (age) (Appendix Table 7.14; Figure 7.16). For males, Z estimates during 2004-2010 ranged from 1.14 (BH) to 1.30 (age).

Town Brook

<u>Alewife</u> - Z estimates for females during 2004-2010 ranged from 0.84 (age) to 1.87 (rps) (Appendix Table 7.14; Figure 7.16). For males, Z estimates during 2004-2010 ranged from 0.87 (age) to 1.87 (rps).

<u>Blueback</u> - The Z estimate in 2005 for male blueback herring was 1.20 (Figure 7.17). No estimates were made for females because of low sample sizes (Appendix Table 7.14).

Increasing trends in total mortality over time were evident for Monument River alewife using the three types of data (e.g., age, repeated spawner frequency, and length data), but similar trends were evident using the length data only for blueback. It is difficult to conclude if total mortality of river herring increased in the other rivers as well due to the shortness of the time series of data and variability in the Z estimates among rivers.

7.10.9. Trends in Age-1 Indices of Relative Abundance

Relative indices of age-1 abundance for alewife and blueback herring from the DMF trawl survey are shown in Figure 7.20 for areas north and south of Cape Cod. Indices of relative abundance of alewife fluctuated without trends during 1978-2010 and were generally lower south of Cape Cod.

7.11. ASSESSMENT APPROACHES AND RESULTS

A forward-projecting age-structured statistical catch-at-age (SCA) model for the Monument River alewife stock was constructed and is used to estimate age-3 abundance and natural mortality rates during 1980-2010 from total in-river catches, escapement counts, and escapement age composition.

7.11.1. Model Structure

The structure of the population model is aged-based and projects the population numbers-at-age by sex s forward through time given model estimates of age-3 numbers and natural mortality rates and field estimates of proportion mature-at-age. The population numbers-at-age ($N_{s,d,y,a}$) matrix has dimensions s x d x y x A-2, where s is number of sexes (2), d is the number of maturity phases (2), y is the number of years and A is the oldest age group (age 8+). The number of year classes in the model was 6, representing ages 3 through 8+.

The cohort dynamics of the model is a hybrid of the Gaspereau River model in Gibson and Myers (2003a). The model incorporates the *immature* and *mature* phases by sex of the alewife's life history and assumes the year begins at the start of spawning. Mature individuals of each age move into the Monument River where they are intercepted and removed for harvest, and escapement counts are made upriver of the catchment basin. Biological samples for length, sex, and age are collected from escapement fish. The model allows natural mortality values to be specified for each year, age, sex and maturity phase or allows natural mortality to be estimated for each sex, two periods over the time series, or combinations of the two. If the estimation of natural mortality is chosen, then the resulting estimates are interpreted as including all remaining mortality aside from natural mortality (e.g., bycatch mortality).

Given the above dynamics, population numbers-at-age by sex and maturity phases are calculated through time by using cohort survival models (Table 7.4). Number of age-3 alewife at the beginning of spawning season (R_y) are directly estimated in the model and these estimates are partitioned into sex-specific (s) (1=female; 2=male) and maturity phase (d)(1=immature; 2=mature) estimates of age-3 abundance ($N_{s,d,y,3}$) using the proportion female (f) and mature proportions-at-age (p_a)(derived outside of the model). Number of age-3 alewife (R_y) in the population is modeled as a log-normal deviation (independent and identically distributed normal random variables with zero mean and constant variance and are constrained to sum to zero over all years) from average abundance (R bar). This formulation differs from the original Gibson and Meyers model which linked recruitment via a Beverton-Holt equation.

The initial population abundance-at-age for ages 4-8+ in 1980 for each sex and maturity phase ($N_{s,d,1980,a}$) is calculated by assuming a static stock (Table 7.4). *M* is the natural mortality rate in 1980 for sex *s*, maturity phase *d*, and age *a*, and *u* is the exploitation rate which is assumed known (calculated from catch/(catch+escapement)).

Population abundance-at-age for ages 4-7 ($N_{s,d,y,a}$) and the plus-group ($N_{s,d,y,8+}$) are calculated in the remaining years by using similar cohort equations (Table 7.4). The program was designed to accept user-inputted *M* values specified by year, sex, and age or to allow estimation of *M* by sex (2 estimates), two periods (2 estimates), and sex and two periods (4 estimates). The estimates of *M* were applied to both immature and mature fish. If *M* is estimated, then the parameter represents "all mortality other than in-river fishing".

The annual proportions of fish mature at each age and sex were calculated from repeat-spawner frequency data collected in the Monument River. Due to the small sample sizes of repeat-spawner data and missing data in some years, the averages of proportions mature-at-age from all years were used. The resulting proportions-at-age for each sex were:

	Age					
Sex	3	4	5	6	7	8+
Female	0.102	0.729	0.983	1	1	1
Male	0.275	0.86	0.993	1	1	1

Total removals of alewife are one set of data from which age-3 abundances and natural mortality rates are estimated. Total removals in numbers include harvested fish and fish taken for transplant to other rivers. The equation for removals-at-age is given in Table 7.4 and it requires estimates of annual numbers of mature fish at each sex and age and exploitation rates (assumed known). All predictions are stored in an array of dimensions *s* x *y* x *A-2*. Predicted catch-at-age data are then compared to the observed total catch through the predicted total removals equation.

Escapement counts and age structure are the second set of data from which age-3 abundances and natural mortality are estimated. Count data were available from 1980-1981, 1984-1987, and 1990-2010. Escapement age data were available only from years 1985-1987, 1993, and 1995-2010. A multiple regression model that predicts well total abundance in the Monument River from lagged autumn monthly cumulative rainfall data was used to fill-in missing escapement data for 1982, 1983, 1988 and 1989 after subtracting removal estimates from the prediction. The equation for escapement numbers-at-age is given in Table 7.4 and it requires estimates of annual numbers of mature fish at each sex/age and exploitation rates. All predictions are stored in an array of dimensions *s* x *y* x *A-2*. Estimated escapement-at-age values are then compared to the observed total escapement and to proportions of escapement numbers-at-age through the predicted total escapement and age composition equations.

Female spawning stock biomass (SSB) is calculated from mature female numbers that escaped harvest and mean weight-at-age for mature females (Table 7.4). Calculated mean weights-at-age are provided in Appendix Table 7.15. Fishing mortality rates were calculated from the calculated exploitation rates assuming a Type I fishery.

For total removals and escapement numbers, lognormal errors are assumed and the generalized concentrated likelihood ($-L_l$)(Parma 2002; Deriso et al. 2007) was calculated (Table 7.5). CV_y is the coefficient of variation for the observed removal or escapement numbers in year *y*, n_C and n_E are the number of years, nd λ_C and λ_E are the relative weights (Parma 2002; Deriso et al., 2007).

For escapement age composition data, a multinomial error likelihood ($-L_p$) is assumed ($n_{y.s}$ is the effective number of fish of sex s aged in year y and $P_{s,y,a}$ is the observed proportions of escapement numbers-at-age)(Table 7.5). Effective sample size is estimated using iterative procedures of McAllister and Ianelli (1997). The formula for the average effective sample size is provided in Table 7.5. The average effective sample size is applied, re-calculated and re-substituted until the average effective sample size stabilizes under equal weighting of all likelihood components.

The total log-likelihood ($-L_I$–L_p) is used by the autodifferentiation routine in AD Model Builder to search for the "best" age-3 abundance and "natural" mortality parameters that minimize the total log-likelihood. AD Model Builder allows the minimization process to occur in phases. During each phase, a subset of parameters is held fixed and minimization is done over another subset of parameters until eventually all parameters have been included. Average age-3 abundance is minimized in phase 1, abundance deviations are minimized in phase 2, and, if estimated, "natural" mortality is minimized in phase 3.

Model fit for all components was checked by using standardized residual plots and root mean square errors. Equations for standardized residuals (r) for log-normal (total removals and escapement) and multinomial (age composition) errors are given in Table 7.6 (n is the total number of total removals or escapement values). For escapement age composition data, standardized residuals required the average effective sample size for each sex. Equations for root mean square error (RMSE) are given in Table 7.6.

7.12. BENCHMARKS

Fishing mortality and female spawning stock biomass reference points for management were derived using three analytical approaches. First, yield-per-recruit (YPR) analyses were conducted to derive $F_{0.10}$ (F where slope between two adjacent YPR values is 10% of the slope at the origin) and F_{max} (F at maximum yield) reference values. Second, spawning biomass-per-recruit (SPR) analysis was conducted to derive the $F_{40\%}$ and $F_{20\%}$ reference points (fishing mortality rates that reduces the spawning biomass to 40% and 20% of the maximum unfished biomass, respectively). Third, recruitment and spawning stock biomass estimates in conjunction with SPR and YPR (production model method in Gibson and Myers, 2003b) were used to derive values for F_{med} (level of fishing mortality where recruitment has been sufficient to balance losses to fishing mortality in half the observed years), F_{col} (the fishing mortality that drives the population to extinction), F_{msy} (the fishing rates that produces maximum sustainable yield), SSB_{msy} (the spawning stock biomass at MSY), and $SSB_{20\%}$ (minimum threshold biomass).

The YPR and SPR analyses follow the model adapted by Gibson and Myers (2003c) for alewife and the equations are shown in Table 7.7. Here, a is the age of the fish, p_a is the proportion mature at that age, $M_{m,a}$ and $M_{i,a}$ are the instantaneous natural mortality rates for mature and immature fish of age a, and w_a is the female weight at age. Since a plus group was used in the model, one additional SS_a (SS_9) was calculated to match the maximum observed age in Massachusetts (9: observed in Parker River) for female alewife.

YPR and SPR were calculated for a set of Fs that ranged from 0 to 5 with 0.01 increment. F_{max} was found by selecting the fishing mortality where YPR_F takes its largest value, and $F_{0.10}$ was found by selecting the fishing mortality where the marginal gain in yield was 10% that at F=0. The $SPR_{x\%}$ reference points were found by selecting the fishing mortality rate where SPR_F was x% that of $SPR_{F=0}$. Only data from 1990 were used to calculate SPR and YPR values in order to develop historical estimates of reference points before the decline in abundance and changes in age structure.

F_{med} was calculated by finding the fishing mortality rate that produced a SPR replacement line with a slope that equals the median survival ratio (median of R_y/SSB_{y-3}) from the recruitment-spawner biomass estimates.

The remaining quantities were produced using a production model based on the Beverton-Holt spawner-recruit model. A Beverton-Holt spawner-recruit model (Table 7.7) was fit externally to the age-3 recruitment numbers (R_y) and corresponding spawning stocking biomass (SSB_{y-3}). Here, a is the slope at the origin of the spawner-recruit relationship (the maximum rate at which spawners can produce recruits at low population sizes) and R_0 is the asymptotic recruitment level which is the carrying capacity expressed as the number of fish that survive to age-3 (Gibson and Myers 2003b & c). The BH equation was fitted to the recruitment-spawner data using non-linear least-squares regression. Only estimates of recruitment from 1986-2009 and SSB from 1983-2006 are used to estimate the S-R relationship to eliminate the influence and possible bias of the static stock abundance estimates during the first year (1980) and the slight retrospective bias near the terminal (see below).

For a given level of F, the equilibrium spawning biomass (SSB*), corresponding number of recruits, and equilibrium yield is calculated by using the BH a and R_0 parameters (Table 7.7). F_{msy} is found by finding the fishing mortality rate that produces the maximum C* and SSB_{msy} is the value of SSB* corresponding to this fishing mortality rate. F_{col} is the value of F where $1/SPR_F = a$. The minimum threshold biomass ($SSB_{20\%}$) was calculated as 20% of the equilibrium female spawner biomass in the absence of fishing.

7.12.1. Base Configuration and Results

Initial runs of the model were conducted to examine the impact of different structures (i.e., M by sex, M by period, and M by sex and period) for the estimation of M. Iterations of effective sample sizes and adjustments of CVs for the total escapement and catch series were made for each model run. To pick a "best" model, two sets of analyses were run. For the models that estimated sex-specific, and sex- and period-specific Ms, each was balanced by changing the CVs and effective sample sizes. For each set of fixed CVs and effective sample sizes, the structure of M estimation was changed to the alternate M structures. AIC values were then compared to determine the "best" model. The run in which M was estimated for two time periods (1980-1999, 2000-2010) was deemed "best" and was selected as the base run.

Comparison of model outputs revealed an imbalance between the total escapement numbers and escapement age composition (escapement data were not predicted well after 2000), indicating possible conflict between the two sources of data. Since we believe that the total escapement numbers have less error than the age composition data, the likelihood contribution of the latter was downweighted by 75%.

The female sex proportion (f) used in the base model run was 0.5. Adjustments of CVs for the total escapement and catch series to obtain an RMSE value near 1.00 were 0.10 and 0.169, respectively. The average effective samples sizes for female and male catch age composition were set to 35 and 54, respectively, based on the original non-downweighted model results.

Resulting contributions to total likelihood are listed in Table 7.8. The converged total likelihood was 545.48. In total, 34 parameters were estimated in the model. The resulting estimates of recruitment and natural mortality are given in Table 7.9. Graphs depicting the observed and predicted values for total removals and total escapement numbers, and standardized residuals are shown in Figure 7.21. Plots of observed and predicted catch age composition (proportions) and bubble plots of standardized residuals for each sex, year, and age are shown in Figures 7.22 and 7.23. The model fit the observed total catch and total escapement (Figure 7.21) well, but the fit to the escapement age composition was poor in several cases (Figures 7.22 and 7.23). This was due to the downweighting of the escapement age composition data. Based on coefficients of variation, many estimates were precise (CVs$\leq$0.20) (Table 7.9).

The abundance estimates of the Monument River alewife by sex, maturity state, year and age are given in Appendix Table 7.16. Prior to 1989, alewife total abundance (3+) was low and average about 285,000 fish (Figure 7.24). Although variable, total abundance increased to 1.37 million fish by 2000. Total abundance declined steadily to 156,366 fish by 2005. Since 2006, total abundance has averaged only 238,000 fish (Appendix Table 7.16). Age-3 abundance followed similar patterns as total abundance (Table 7.9). Age-3 numbers were low prior to 1989 (average = 163,000 fish), increased and peaked at about 852,000 fish in 1995 (1992 year-class), declined to 191,366fish in 1998, increased to its peak of 982,282 fish in 2000, and declined to its second lowest level of 80,672 fish by 2005 (2002 year-class). Since 2006, age-3 numbers have averaged about 168,000 fish.

7.12.2. μ and F Mortality Rates

Exploitation rates (μ) for alewife in the Monument River before the 2005 moratorium ranged as high as 0.40 in 1980 to as low as 0.04 in 2000 (Table 7.10). Exploitation steadily declined over the time series. Since the moratorium, exploitation rates have been zero. Corresponding fishing mortality (F) rates are listed in Table 7.10. F was highest during the early 1980s and averaged 0.34 per year. It steadily declined over the time series and averaged 0.13 from 2001-2004.

7.12.3. Natural Mortality

The period estimates of "natural" mortality, which includes all other sources of mortality not accounted for, were 0.74 for 1980-1999 and 1.20 for 2000-2010, indicating that mortality increased by 62% after 1999 (Table 7.9).

7.12.4. Spawning Stock Biomass

Estimates of female spawning stock biomass (SSB) for alewife by age are provided in Appendix Table 7.17. Prior to 1989, female SSB (3+) was low and averaged about 8,265 kilograms (Figure 7.25). Although variable, female SSB increased steadily to 37 thousand kilograms by 1996 and remained high but variable through 2001. Female SSB declined steadily from about 16 thousand kilograms in 2002 to its lowest value of about 4,807 kilograms in 2006. Since 2007, female SSB has averaged only 6,833 kilograms.

7.12.5. Retrospective Analysis

Small retrospective bias was evident in estimates of age-3 abundance, "natural" mortality estimates, female SSB, and total population abundance. There was a consistent underestimation of the terminal year values of age-3 numbers, female SSB and total population abundance, but a consistent overestimation of "natural" mortality values in the second period (Figure 7.26).

7.12.6. Reference Points

The fit of the Beverton-Holt stock-recruitment equation to the age-3 abundance and female SSB is shown in Figure 7.27. A plot of the residuals indicated reasonable model fit (Figure 7.27). The estimates of a and R_0 are 31.52 (SE=17.31) and 524,896 fish (SE=345,995), respectively. Both estimates were imprecise (CVs >0.5). Reference points generated from YPR, SPR and the production model are shown in Table 7.11. For YPR analysis, the fishing mortality rate that maximized the yield-per-recruit, F_{max}, was greater than 5, and $F_{0.1}$ was 1.06 (Figure 7.28). The fishing mortality that reduced the female spawning biomass to 40% and 20% of the level without fishing was 0.55 and 1.08, respectively.

From the spawner-recruit data, F_{med} was estimated to be 0.73. From the production model, the fishing mortality rate that produces maximum sustainable yield, F_{msy}, was 0.49 and corresponding spawning stock bass, SSB_{msy}, was 22,251 kilograms. SSB_{msy} was higher than the 20% of the equilibrium spawner biomass, $SSB_{20\%}$ (14,496 kilograms) (Table 7.11). Current female spawning stock biomass (8,256 kilograms) is 37% of SSB_{msy}. The fishing mortality rate that drives the population to extinction, F_{col}, was 1.14. The relationships between the reference points from the production model are shown with the SR data in Figure 7.29. The estimates of F_{msy} and F_{col} are considerably lower than those estimated for alewife (F_{msy}>1.0; F_{col} >1.82) in three Canadian rivers by Gibson and Myers (2003b). The in-river fishing mortality rates exceeded only F_{msy} in the beginning of the time series (Table 7.10).

The reference points based on the overall S-R relationship may be over-estimating the alewife's current ability to respond to changes in mortality. Examination of period-specific S-R points revealed that, since 1998, the number of fish surviving to age-3 has dropped but has remained constant at about 200,000 fish regardless of the level of female spawning stock biomass (Figure 7.30). This suggests that the reference points for alewives in its current survival regime may be lower.

7.12.7. Sensitivity Analyses

Sensitivity analyses were conducted to determine the influence of assumed-known input values on the resulting estimates of age-3 abundance, female SSB, natural mortality rates, and total population abundance. The sensitivity of the base model output to changes in the female sex ratio, CVs of total removals and escapement numbers, average effective sample size, and the ratio used to downweight the escapement age composition were examined. The following changes in input parameters were made:

Female sex ratio	±0.1
CVs and effective sample sizes	±20%
Downweight Ratio	±0.1

For changes in female sex ratio, the CVs and effective sample sizes were re-balanced before downweighting.

Changing the female sex ratio by ±0.1 had little impact on the estimates of age-3 abundance, natural mortality or total population abundance (Appendix Figure 7.1). The ±0.1 change had the biggest impact on female SSB (Appendix Figure 7.1). On average, female SSB increased by 224% with a 0.1 increase in the sex ratio, while female SSB decreased by 104% with a 0.1 decrease in the sex ratio (Appendix Figure 7.1).

Changing the CVs of the total removals and escapement numbers by ±20% had little impact on the estimates of age-3 abundance, natural mortality, female SSB or total population abundance (Appendix Figure 7.2).

Changing the average effective sample sizes had variable impacts on the estimates of age-3 abundance, natural mortality, female SSB or total population abundance. Increasing the average effective sample sizes by 20% increased and decreased specific values of the age-3 estimates between -19 and +44%, while decreasing the average effective sample size by -20% increased and decreased specific values of the age-3 estimates between -51 and +30% (Appendix Figure 7.3). Changes in female SSB (range: -3.0 to 5%), total abundance (range: -5.0 to 4.0%), and natural mortality estimates (range: -0.6 to 1.9%) were less dramatic (Appendix Figure 7.3).

Changing the downweight ratio had also variable impacts on the estimates of age-3 abundance, natural mortality, female SSB or total population abundance. Increasing the downweight ratio by 0.1 increased and decreased specific values of the age-3 estimates between -32 and +101%, while decreasing the downweight ratio by 0.1 increased and decreased specific values of the age-3 estimates between -99 and +48% (Appendix Figure 7.4). Changes in female SSB (range: -10.0 to 8%), total abundance (range: -11.0 to 21.0%), and natural mortality estimates (range: -2.0 to 7.0%) were less dramatic (Appendix Figure 7.4).

7.12.8. Comparison of Total Instantaneous Mortality Estimates

Total instantaneous mortality estimates (Z) were derived by adding the annual F values (Table 7.10) to the respective period estimates of "natural" mortality. These values were compared to Z estimates derived using the Chapman-Robson survival estimator on age data (see *Trends in Total Instantaneous Mortality*). In addition, Z reference points (i.e., Z_{col} and $Z_{20\%}$) were calculated by adding the "natural" mortality estimate for 1980-1999 to the F reference points presented in Table 7.11. Comparison of the Z estimates showed that the Z estimate derived in this model were comparable to the Z derived using the Chapman-Robson estimator on age data for female and male alewife (Figure 7.31). The Chapman-Robson-based estimates showed increased mortality starting in the mid-1990s, while the SCA model, due to the model configuration, showed increased mortality after 1999. Except for two estimates of male alewife Z, most Z estimates were well below the Z reference points. This indicates that, although there was an increase in total mortality, the increase was not high enough to collapse the stock of alewife in the Monument River.

7.13. CONCLUSIONS AND RECOMMENDATIONS

The following is a short list of many potential causes of the changes in abundance, population characteristics and dynamics of alewife and blueback herring in Massachusetts acting singly or synergistically:

Environmental Changes - Changes in weather as a result of climate change can impact many aspects of the alewife and blueback life stages. Changes in rainfall patterns could affect the food production in the nursery areas and cause higher mortality of juveniles as competition for limited zooplankton resources is believed a major factor affecting survival and growth of juveniles (Walton 1983). Such changes can cause shifts in the carrying capacity of a nursery ground and ultimately affect recruitment. Support for a change in carrying capacity is evident in the stock-recruitment data for Monument River alewife (Figure 7.30). Since 1998, the number of fish surviving to age-3 dropped but has remained constant at about 200,000 fish regardless of the level of female spawning stock biomass (Figure 7.30). This suggests that survival declined and a plot of the number of age-3 fish divided by the corresponding female spawning stock biomass shows that this occurred through the mid-2000s (Figure 7.32).

Another potential impact of changes in rainfall is on the migration patterns of juvenile herring. It is believed that drops in temperature and rainfall events cue juveniles to move out of Massachusetts river systems in fall (Kosa and Mather, 2001; Yako et al., 2002). Decreases in rainfall during their peak migration in fall may inhibit migration and increase potential mortality. To investigate whether trends in abundance of Monument River alewife may be correlated with rainfall, we regressed total alewife abundance against monthly cumulative rainfall from July through December lagged 3, 4, 5 and 6 years in the past (abundance in the run is comprised mostly of ages 4, 5 and 6). Stepwise multiple regression was used to select the significant monthly data that best predicted the total abundance. Results are shown in Figure 7.33and suggest that the survival of ages 4 and 5 fish when they were juveniles is positively dependent on rainfall during the fall months of September, November and December.

Predation - It is possible that the increase in total mortality observed after 1999 and decrease in size of herring over time are the result of selective predation by increasing populations of striped bass (*Morone saxatilis*), cormorants (*Phalacrocorax auritus*), spiny dogfish *(Squalus acanthias*), and seals (*Phoca vitulina*). Striped bass, in particular, may have impacted river herring as strong, negative correlations (Spearman rho) between average sizes of female and male alewife and blueback herring from the Monument River and striped bass coast-wide abundance are evident (Figure 7.34).

Bycatch in Fisheries - It is indeed possible that bycatch in several fisheries off Massachusetts fishery may be impacting river herring stocks since fisheries like the Atlantic herring fishery began in the late 1990s and total mortality iwas shown to increase during that time at least in the Monument River. However, river-specific impacts are impossible to assess at this time because there is no information on river-stock composition from the bycatch.

Legal Bait Harvesting and Poaching - Although not well quantified, anecdotally, there was a tremendous increase in unreported harvest of river herring both legally and illegally from the spawning runs primarily for use as bait in the recreational striped bass fishery. This occurred 6-7 years prior to the moratorium in concurrence with the rebuilding of the striped bass stocks.

Watershed Alterations - Many rivers in Massachusetts continue to be severely degraded by water withdrawals, transport of wastewater out of the watershed, and loss of water inputs due to development within the watershed. Such conditions affect the passage and spawning of adults and survival of young.

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Table 7.1 Proportion of repeat spawners in alewife and blueback herring samples by sex, river and year. *=not calculated due to small sample size.

Alewife

Female

River	1986	1987	1991	1993	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Agawam			0.11																	
Back																	0.11			
Mattapoisett					0.33											0.04				
Monument	0.45	0.44		0.20	0.08	0.18	0.29	0.41	0.11	0.08	0.14	0.29	0.12	0.01	0.08	0.16	0.08	0.15	0.13	0.13
Mystic														0.36	0.08	0.00	0.13	0.25	0.29	0.15
Nemasket														0.43	0.29	0.10	0.13	0.22	0.30	0.23
Quashnet														0.07						
Stony														0.21						
Town														0.14	0.18	0.08	0.17	0.29	0.31	0.21

Male

River	1986	1987	1991	1993	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Agawam			0.10																	
Back																	0.11			
Mattapoisett					0.19											0.03				
Monument	0.39	0.41		0.23	0.05	0.24	0.22	0.29	0.12	0.10	0.18	0.31	0.19	0.07	0.04	0.05	0.06	0.13	0.10	0.07
Mystic														0.32	0.30	0.00	0.07	0.16	0.21	0.14
Nemasket														0.44	0.29	0.10	0.12	0.20	0.17	0.16
Quashnet														0.05						
Stony														0.12						
Town														0.17	0.12	0.04	0.23	0.32	0.32	0.17

Blueback

Female

River	1985	1986	1987	1991	1993	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Agawam				*																	
Charles	0.54				0.44																
Monument		0.38	0.39		0.18	0.11	0.06	0.17	0.00	0.20	0.00	0.00	0.08	0.03	0.08	0.05	0.14	0.01	0.06	0.05	0.01
Mystic																0.03	0.16	0.15	0.36	0.12	0.15
Quashnet															*						
Town																*					

Male

River	1985	1986	1987	1991	1993	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Agawam				*																	
Charles	0.49				0.25																
Monument		0.22	0.20		0.13	0.06	0.17	0.00	0.27	0.10	0.00	0.02	0.14	0.03	0.02	0.08	0.14	0.06	0.06	0.04	0.01
Mystic																0.06	0.21	0.18	0.27	0.13	0.13
Quashnet															*						
Town																*					

Table 7.2 Von Bertalanffy growth parameters and L_c for alewife and blueback herring by sex.

Species	Sex	L_{oo} (mm TL)	K	L_c(mm TL)
Alewife	Female	355	0.41	240
	Male	340	0.45	235
Blueback	Female	330	0.41	230
	Male	320	0.39	220

Table 7.3 Results of the non-equilbirum estimation of Zs following Gedamke and Hoenig (2006) for Monument River alewife and blueback herring.

Female Alewife

Parameter	Estimate	SE	t
Z1	0.45	0.031	14.52***
Z2	1.09	0.054	20.18***
Z3	1.56	0.117	13.33***
Y1	1988.7	0.404	14.13***
Y2	2003.6	0.957	21.51***
SD	40.29	5.699	7.07**
AIC	221.8		

Male Alewife

Parameter	Estimate	SE	t
Z1	0.57	0.055	10.36***
Z2	1.49	0.07	21.28***
Y1	1988	0.401	15.03***
SD	46.62	6.598	7.06***
AIC	225.1		

Female Blueback

Parameter	Estimate	SE	t
Z1	0.58	0.045	12.88***
Z2	1.27	0.087	14.60***
Z3	2.1	0.269	7.81***
Y1	1988.7	0.545	10.55***
Y2	2005.1	0.897	24.59***
SD	28.34	4.003	7.08***
AIC	204.3		

Male Blueback

Parameter	Estimate	SE	t
Z1	0.66	0.06	11.78***
Z2	1.08	0.09	11.49***
Z3	1.85	0.13	14.34***
Y1	1985.40	0.56	4.31***
Y2	1995.10	0.72	16.80***
SD	28.03	4.00	7.00***
AIC	181.10		

Table 7.4 Population dynamics equations used in the alewife SCA model.

Population Model	Symbol	Equation
Age-3 numbers	$\hat{R}_y$	$\hat{R}_y = \hat{\bar{R}} \cdot \exp^{\hat{e}_y}$
Sex-specific age-3 numbers	$\hat{N}_{s,d,y,3}$	Female Immature: $\hat{N}_{1,1,y,3} = \hat{R}_y \cdot f \cdot (1 - p_{1,y,3})$ Female Mature: $\hat{N}_{1,2,y,3} = \hat{R}_y \cdot f \cdot p_{1,y,3}$ Male Immature: $\hat{N}_{2,1,y,3} = \hat{R}_y \cdot (1 - f) \cdot (1 - p_{2,y,3})$ Male Mature: $\hat{N}_{2,2,y,3} = \hat{R}_y \cdot (1 - f) \cdot p_{2,y,3}$
1980 abundance-at-age (4-8+)	$\hat{N}_{s,d,1980,a}$	Immature: $\hat{N}_{s,1,1980,a} = \hat{N}_{s,1,1980,a-1} \cdot \exp^{-M_{s,1,1980,a-1}} \cdot (1 - p_{s,1980,a})$ Mature: $\hat{N}_{s,2,1980,a} = \hat{N}_{s,2,1980,a-1} \cdot (1 - u_{1980}) \cdot \exp^{-M_{s,2,1980,a-1}} +$ $\hat{N}_{s,1,1980,a-1} \cdot \exp^{-M_{s,1,1980,a-1}} \cdot p_{s,1980,a}$
Abundance-at-age (4-7)	$\hat{N}_{s,d,y,a}$	Immature: $\hat{N}_{s,1,y,a} = \hat{N}_{s,1,y-1,a-1} \cdot \exp^{-M_{s,1,y-1,a-1}} \cdot (1 - p_{s,y,a})$ Mature: $\hat{N}_{s,2,y,a} = \hat{N}_{s,2,y-1,a-1} \cdot (1 - u_{y-1}) \cdot \exp^{-M_{s,2,y-1,a-1}} +$ $\hat{N}_{s,1,y-1,a-1} \cdot \exp^{-M_{s,1,y-1,a-1}} \cdot p_{s,y,a}$
Plus-group abundance-at-age	$\hat{N}_{s,d,y,8+}$	Immature: $\hat{N}_{s,1,y,8+} = \hat{N}_{s,1,y-1,a-1} \cdot \exp^{-M_{s,1,y-1,a-1}} \cdot (1 - p_{s,y,a}) +$ $\hat{N}_{s,1,y-1,8+} \cdot \exp^{-M_{s,1,y-1,8+}} \cdot (1 - p_{s,y,a})$ Mature: $\hat{N}_{s,2,y,8+} = \hat{N}_{s,2,y-1,a-1} \cdot (1 - u_{y-1}) \cdot \exp^{-M_{s,2,y-1,a-1}} +$ $\hat{N}_{s,1,y-1,a-1} \cdot \exp^{-M_{s,1,y-1,a-1}} \cdot p_{s,y,a} +$ $\hat{N}_{s,2,y-1,8+} \cdot (1 - u_{y-1}) \cdot \exp^{-M_{s,2,y-1,8+}}$
Predicted removals-at-age	$\hat{C}_{s,y,a}$	$\hat{C}_{s,y,a} = \hat{N}_{s,2,y,a} u_y$
Predicted total removals	$\hat{C}_y$	$\hat{C}_y = \sum_s \sum_a \hat{C}_{s,y,a}$
Predicted escapement-at-age	$\hat{E}_{s,y,a}$	$\hat{E}_{s,y,a} = \hat{N}_{s,2,y,a} (1 - u_y)$
Predicted total escapement	$\hat{E}_y$	$\hat{E}_y = \sum_s \sum_a \hat{E}_{s,y,a}$
Predicted escapement age composition	$\hat{P}_{s,y,a}$	$\hat{P}_{s,y,a} = \frac{\hat{E}_{s,y,a}}{\sum_a \hat{E}_{s,y,a}}$
Female spawning stock biomass	SSB_y	$SSB_y = \sum_a \hat{N}_{1,2,y,a} \cdot (1 - u_y) \cdot w_{1,2,y,a}$
Fishing mortality	$\hat{F}_y$	$\hat{F}_y = -\log_e (1 - u_y)$

Table 7.5 Likelihood functions for removals and escapement data.

Negative Log-Likelihood	Symbol	Equation
Lognormal total removals and escapement	$-L_l$	$$-L_l = 0.5*(n_C + n_E)*\ln\left(\frac{RSS_C + RSS_E}{n_C + n_E}\right)$$ where $$RSS_C = \lambda_C \sum_y \left(\frac{\log_e(C_y + 1e^{-5}) - \log_e(\hat{C}_y + 1e^{-5})}{CV_{c,y}}\right)^2$$ $$RSS_E = \lambda_E \sum_y \left(\frac{\log_e(E_y + 1e^{-5}) - \log_e(\hat{E}_y + 1e^{-5})}{CV_{E,y}}\right)^2$$
Multinomial escapement age composition	$-L_p$	$$-L_p = \lambda_p \sum_y \sum_s -n_{s,y} \sum_a (P_{s,y,a} + 1e^{-5}) \cdot \ln(\hat{P}_{s,y,a} + 1e^{-5})$$ where λ_p is a user-defined weighting factor.
Effective sample size	$\hat{\bar{n}}_s$	$$\hat{\bar{n}}_s = \frac{\sum_y \hat{n}_{s,y}}{d_{s,y}}$$ where $$\hat{n}_{s,y} = \frac{\sum_a \hat{P}_{s,y,a}(1 - \hat{P}_{s,y,a})}{\sum_a (P_{s,y,a} - \hat{P}_{s,y,a})^2}$$ and $\hat{P}_{s,y,a}$ is the predicted proportion-at-age a in year y for sex s from the escapement numbers, $P_{s,y,a}$ is the observed proportion-at-age, and $d_{s,y}$ is the number of years of data for escapement series.

Table 7.6 Diagnostic functions for removals and escapement data.

Diagnostics	Symbol	Equation
Standardized residuals (lognormal)	$r_{C,y}$ or $r_{E,y}$	$r_{C,y} = \frac{\log_e(C_y + 1e^{-5}) - \log_e(\hat{C}_y + 1e^{-5})}{\sqrt{\log_e(CV_y^2 - 1)}}$ $r_{E,y} = \frac{\log_e(E_y - 1e^{-5}) - \log_e(\hat{E}_y + 1e^{-5})}{\sqrt{\log_e(CV_y^2 + 1)}}$
Standardized residuals (age composition)	$r_{s,y,a}$	$r_{s,y,a} = \frac{P_{s,y,a} - \hat{P}_{s,y,a}}{\sqrt{\frac{\hat{P}_{s,y,a}(1-\hat{P}_{s,y,a})}{\hat{\bar{n}}_s}}}$
Root mean square error	$RMSE$	Total removals $RMSE_C = \sqrt{\frac{\sum_y r_{C,y}^2}{n}}$ Total escapement $RMSE_E = \sqrt{\frac{\sum_y r_{E,y}^2}{n}}$

Table 7.7 Reference points equations used in the alewife SCA model.

Reference Point Calculations	Symbol	Equation
Yield-Per-Recruit (kg)	YPR_F	$YPR_F = \sum_{a=3}^{\max a} SS_a w_a (1 - e^{-F})$ where SS_a is given by: $SS_3 = p_3$ $SS_4 = SS_3 e^{-M_{m,3}-F} + (1-p_3)e^{-M_{i,3}} p_4$ $SS_5 = SS_4 e^{-M_{m,4}-F} + (1-p_3)(1-p_4)e^{-M_{i,3}-M_{i,4}} p_5$ $SS_6 = SS_5 e^{-M_{m,5}-F} + (1-p_3)(1-p_4)(1-p_5)e^{-M_{i,3}-M_{i,4}-M_{i,5}} p_6$ $SS_7 = SS_6 e^{-M_{m,6}-F} + (1-p_3)(1-p_4)(1-p_5)(1-p_6)e^{-M_{i,3}-M_{i,4}-M_{i,5}-M_{i,6}} p_7$ $SS_8 = SS_7 e^{-M_{m,7}-F} + (1-p_3)(1-p_4)(1-p_5)(1-p_6)(1-p_7)e^{-M_{i,3}-M_{i,4}-M_{i,5}-M_{i,6}-M_{i,7}} p_8$ and for the plus-group, one additional SS_a was calculated to match the maximum observed age in Massachusetts (9: observed in Parker River) for female alewife: $SS_9 = SS_8 e^{-M_{m,8}-F} + (1-p_3)(1-p_4)(1-p_5)(1-p_6)(1-p_7)(1-p_8)e^{-M_{i,3}-M_{i,4}-M_{i,5}-M_{i,6}-M_{i,7}-M_{i,8}} p_8$
Spawning Biomass-Per-Recruit Analysis (kg)	SPR_F	$SPR_F = \sum_{a=3}^{\max a} SS_a w_a e^{-F}$
Beverton-Holt S-R Equation (linearized)	BH	$\log_e(\hat{R}_y) = \log_e(\hat{a}) + \log_e(SSB_{y-3}) - \log_e(1 + \hat{a}SSB_{y-3}/\hat{R}_0) + \varepsilon$
Equilibrium spawning stock biomass, recruits and catch	SSB^*, R^* and C^*	$SSB^* = \frac{(\hat{a}SPR_F - 1)\hat{R}_0}{\hat{a}}$ $R^* = \frac{\hat{a}SSB^*}{1 + (\hat{a}SSB^*/\hat{R}_0)}$ $C^* = R^* \cdot YPR_F$
Minimum threshold SSB	$SSB_{20\%}$	$SSB_{20\%} = 0.2\frac{(\hat{a}SPR_{F=0} - 1)\hat{R}_0}{\hat{a}}$

Table 7.8 Likelihood components with respective contributions in base model run.

Likelihood Components

	Weight	RSS
Total Escapement	1	30.88
Total Catch	1	29.13
Escape Age Comps	0.25	2181.91
Total Likelihood		545.48
Number of Estimates		34.00
AIC		1158.96
Catch RMSE	1.00479	
Escape. RMSE	1.0051	

Table 7.9 Parameter estimates and associated standard deviations of base model configuration.

Year	Age-3 Numbers	SD	CV
1980	151,525	15,256	0.10
1981	181,290	48,937	0.27
1982	153,641	65,610	0.43
1983	276,750	48,382	0.17
1984	204,357	39,220	0.19
1985	154,736	29,794	0.19
1986	153,730	36,109	0.23
1987	163,244	51,014	0.31
1988	26,069	54,276	2.08
1989	45,116	69,680	1.54
1990	491,425	94,485	0.19
1991	476,495	98,893	0.21
1992	267,682	62,475	0.23
1993	98,248	36,861	0.38
1994	490,500	75,680	0.15
1995	852,025	126,104	0.15
1996	417,516	84,026	0.20
1997	362,490	69,363	0.19
1998	191,388	49,077	0.26
1999	680,316	96,786	0.14
2000	982,282	161,324	0.16
2001	309,716	68,136	0.22
2002	214,402	43,117	0.20
2003	257,673	40,081	0.16
2004	151,535	30,030	0.20
2005	80,672	19,425	0.24
2006	128,376	25,613	0.20
2007	167,345	33,405	0.20
2008	260,970	47,625	0.18
2009	135,324	41,070	0.30
2010	148,128	55,198	0.37

Period	M	SD	CV
1980-1999	0.737	0.055	0.075
2000-2010	1.205	0.064	0.053

Table 7.10 In-river exploitation rates (μ) and equivalent fishing mortality rates for the Monument River.

Year	μ	F
1980	0.41	0.52
1981	0.20	0.22
1982	0.40	0.51
1983	0.40	0.51
1984	0.29	0.35
1985	0.21	0.23
1986	0.14	0.16
1987	0.22	0.25
1988	0.19	0.21
1989	0.19	0.21
1990	0.33	0.39
1991	0.14	0.15
1992	0.19	0.22
1993	0.18	0.20
1994	0.28	0.33
1995	0.13	0.14
1996	0.15	0.16
1997	0.17	0.19
1998	0.20	0.22
1999	0.25	0.29
2000	0.04	0.04
2001	0.07	0.07
2002	0.19	0.21
2003	0.09	0.10
2004	0.13	0.14
2005	0.01	0.01
2006	0.00	0.00
2007	0.00	0.00
2008	0.00	0.00
2009	0.00	0.00
2010	0.00	0.00

Table 7.11 Reference points derived from YPR, SPR and production model methods.

Method	Basis	Estimate
Yield Per Recruit	F0.1	1.06
	Fmax	5
Spawner Per Recruit	F40%	0.55
	F20%	1.08
	Fmed	0.73
Production Model	Fcol	1.14
	Fmsy	0.49
	SSBmsy	22251
	SSB20%	14496

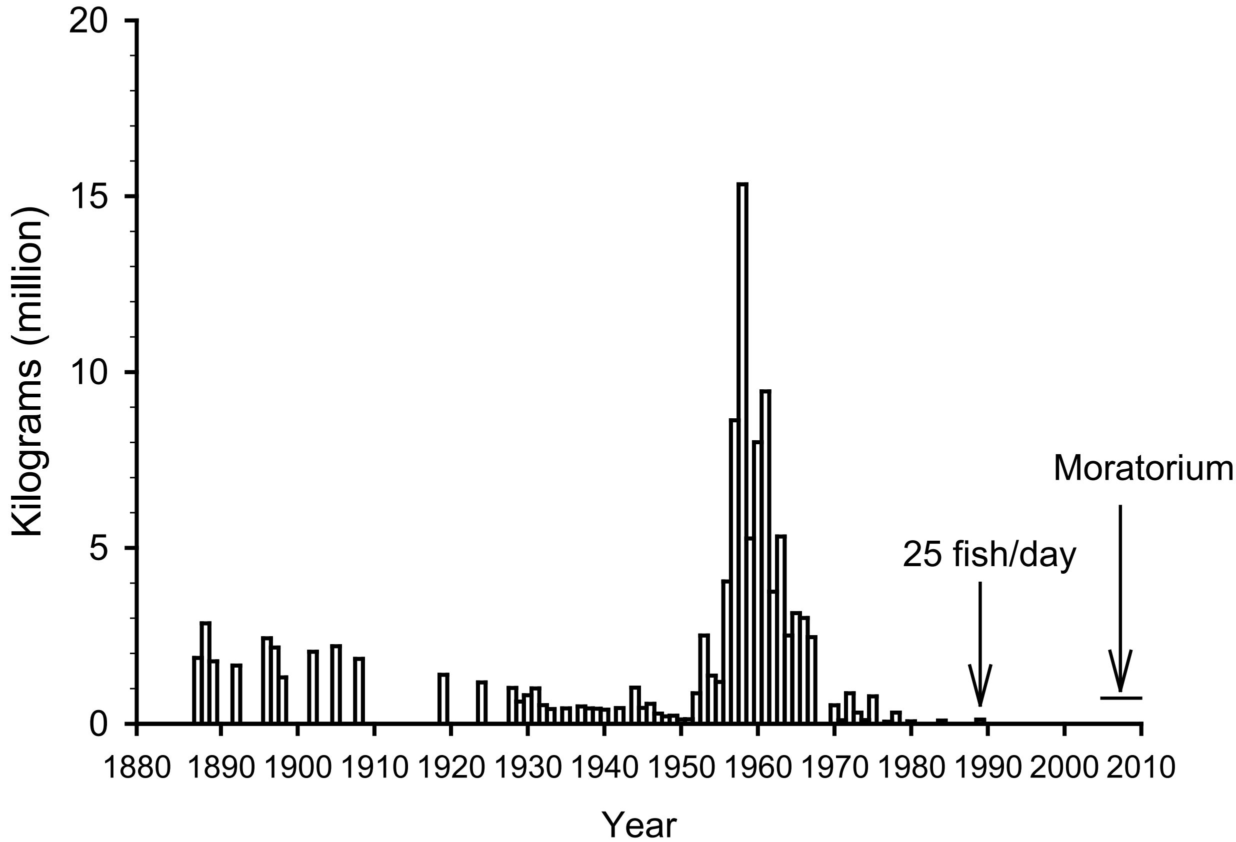


Figure 7.1 Massachusetts commercial landings of river herring, 1887-2010.

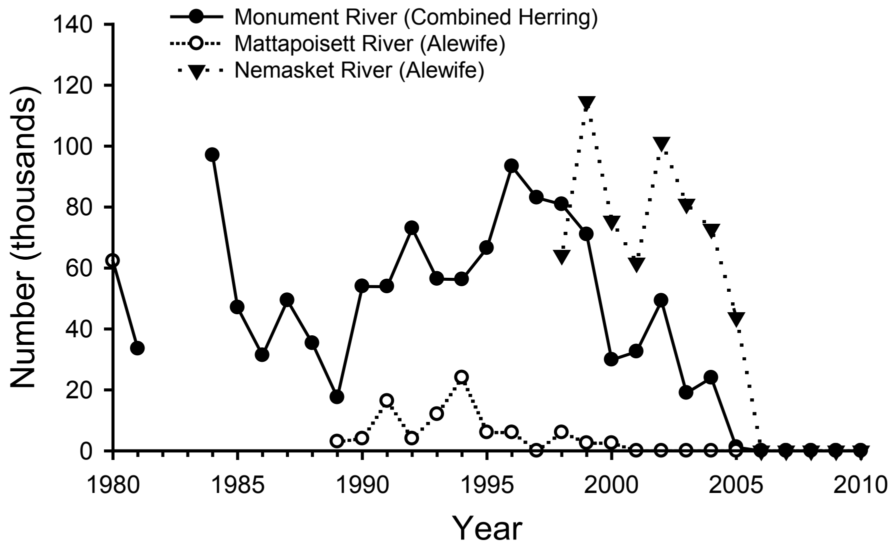


Figure 7.2 Number of fish removed (for bait, stocking, or scientific samples) from three Massachusetts rivers, 1980-2010.

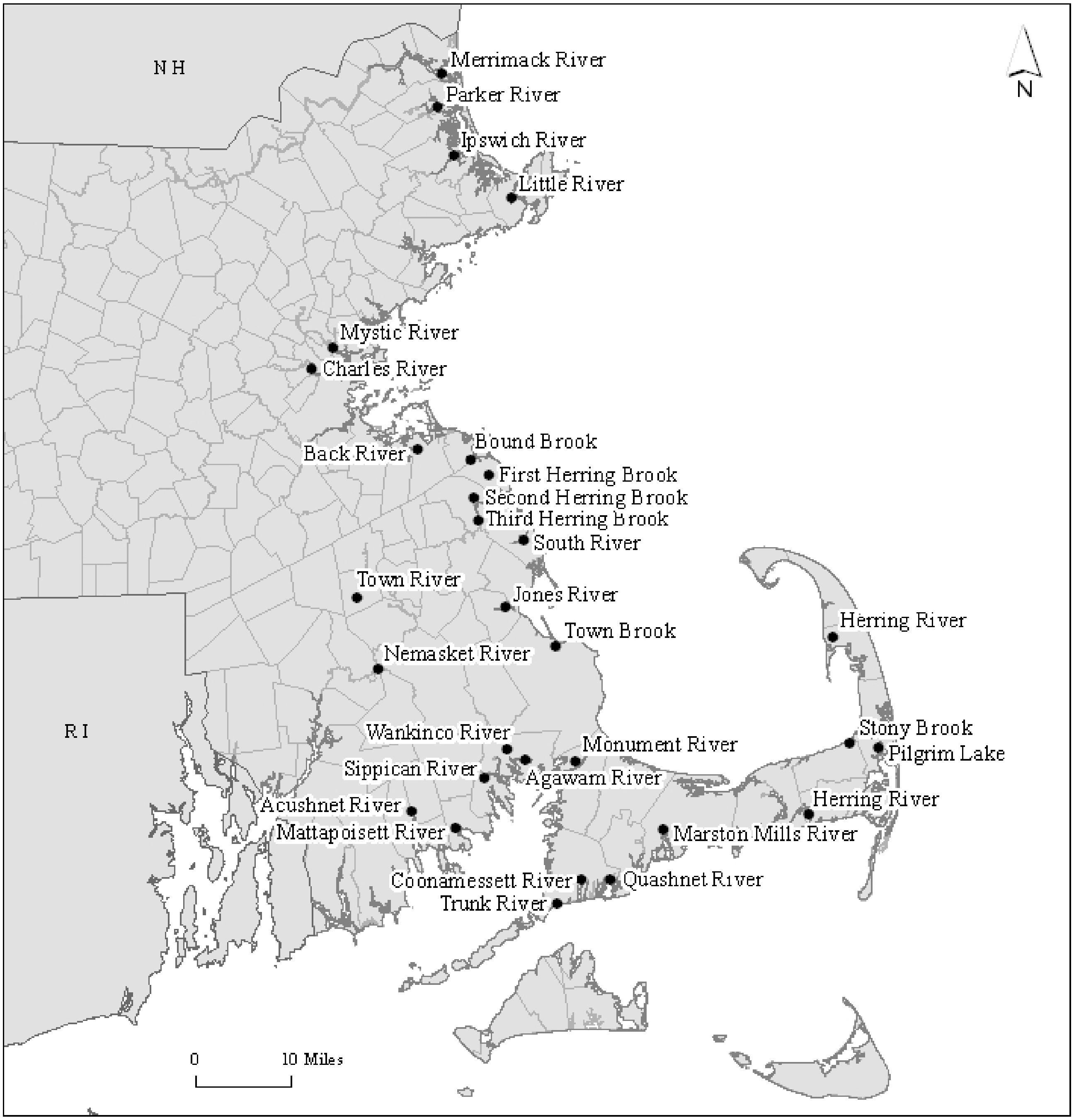


Figure 7.3 Massachusetts rivers for which historical and/or current data on river herring are available.

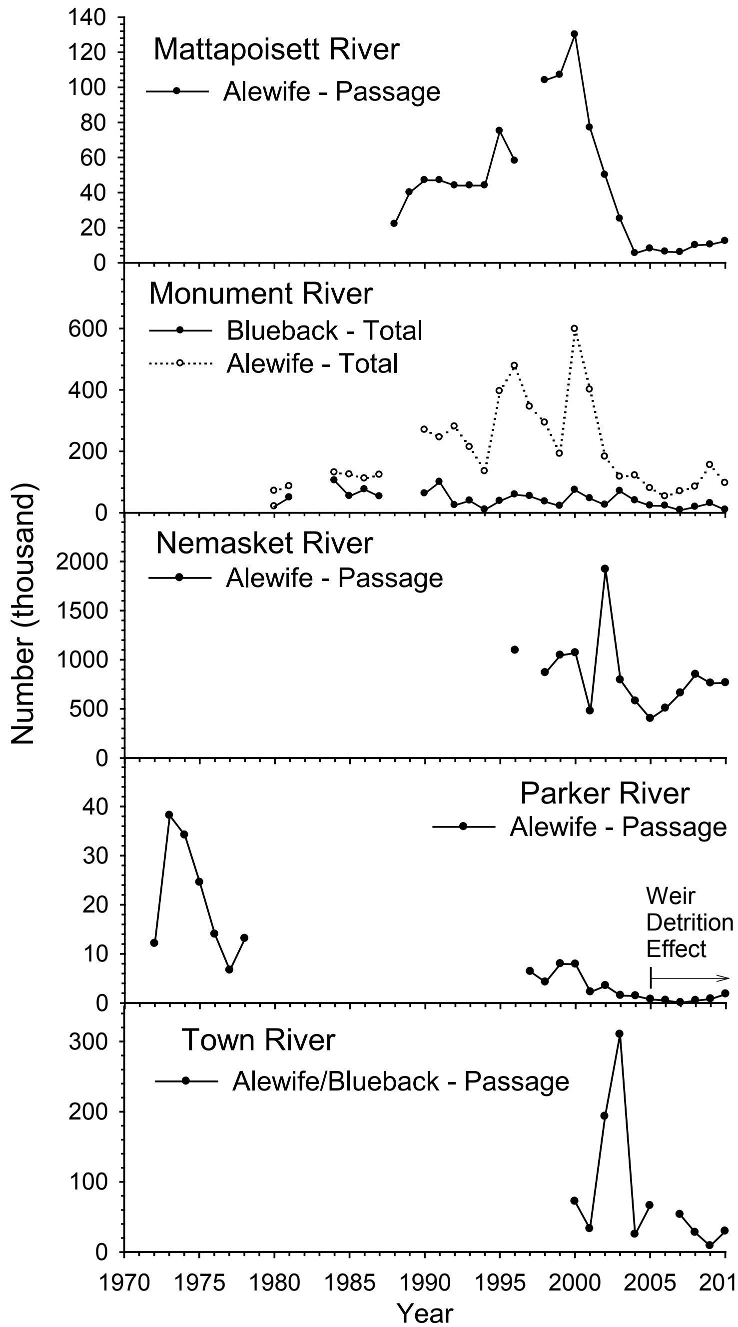


Figure 7.4 Passage and total run size counts for alewife and blueback herring in five Massachusetts Rivers.

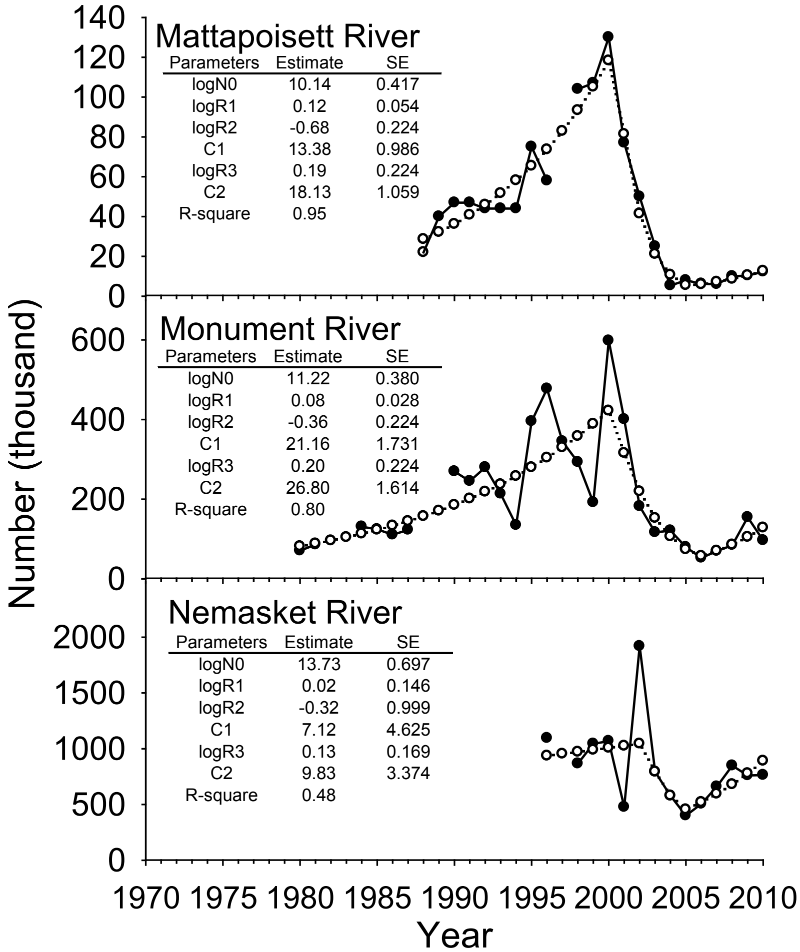


Figure 7.5 Observed (solid) and predicted (hollow) passage or total run size counts for alewife and blueback herring in the Mattapoisett, Monument and Nemasket rivers.

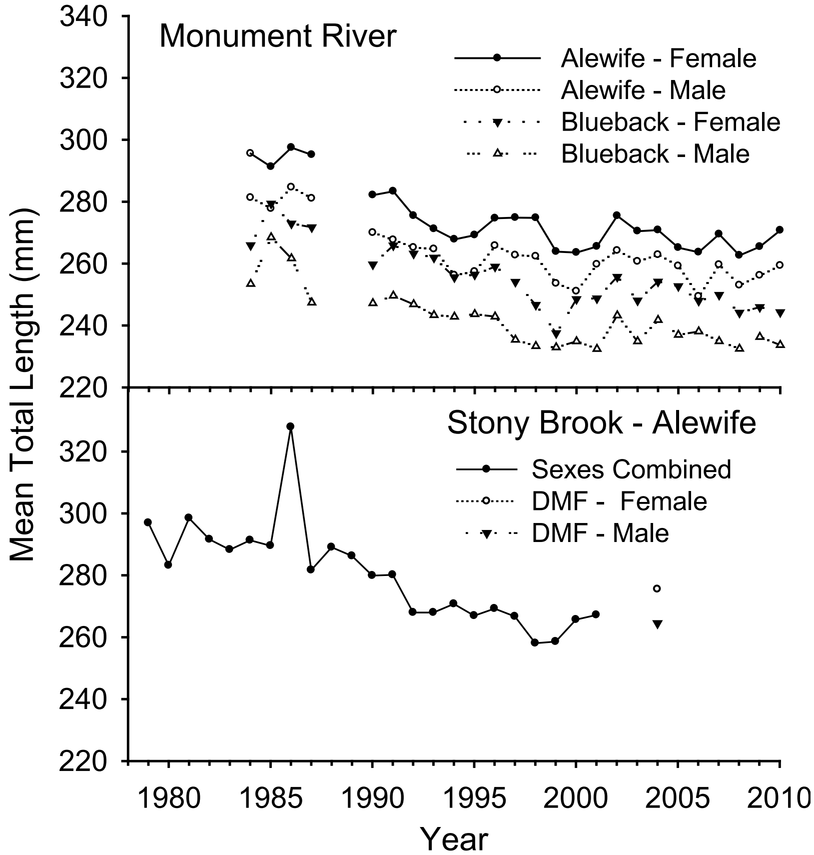


Figure 7.6 Mean total lengths of alewife and blueback herring in the Monument River and Stony Brook, 1978-2010.

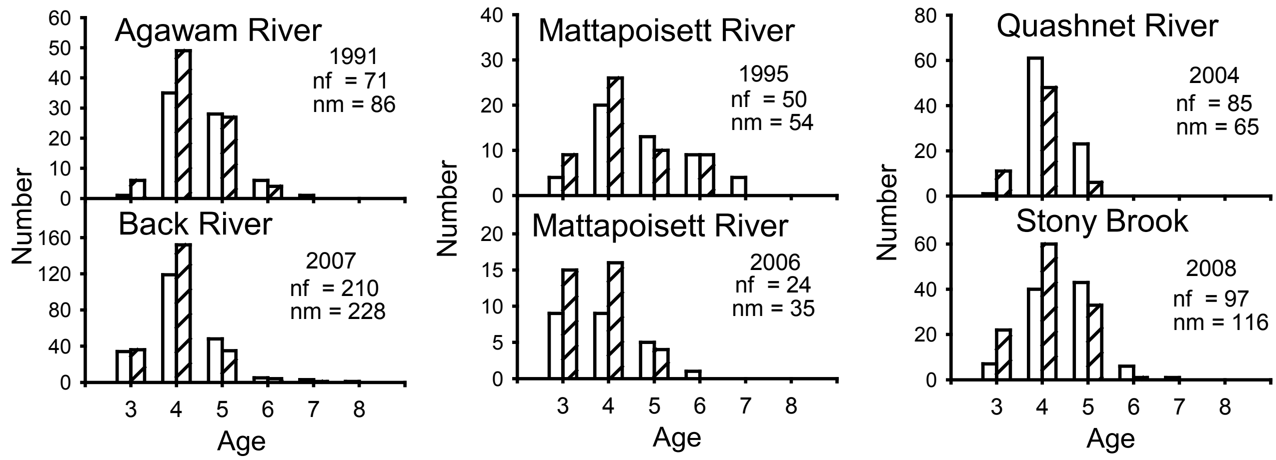


Figure 7.7 Age structure of alewife by sex (female: hollow bars; male: hash marks) in several Massachusetts rivers from intermittent sampling, 2004-2010. nf is female sample size and nm is male sample size

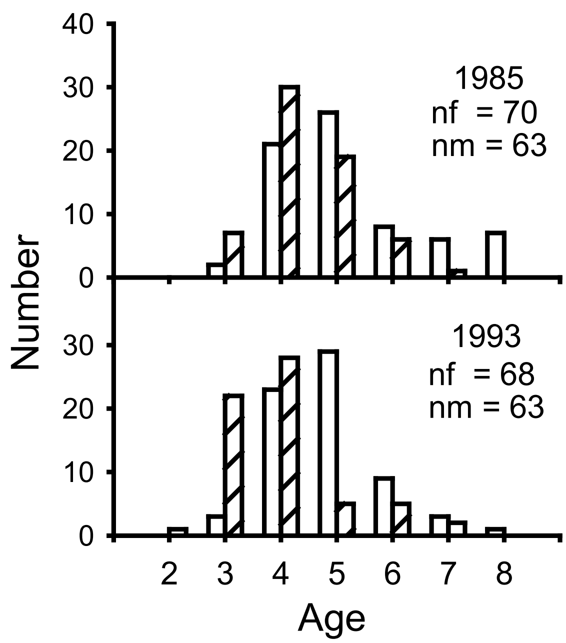


Figure 7.8 Age structure of Charles River blueback herring by sex (female: hollow bars; male: hash marks), 1985 and 1993. *nf* is female sample size and *nm* is male sample size.

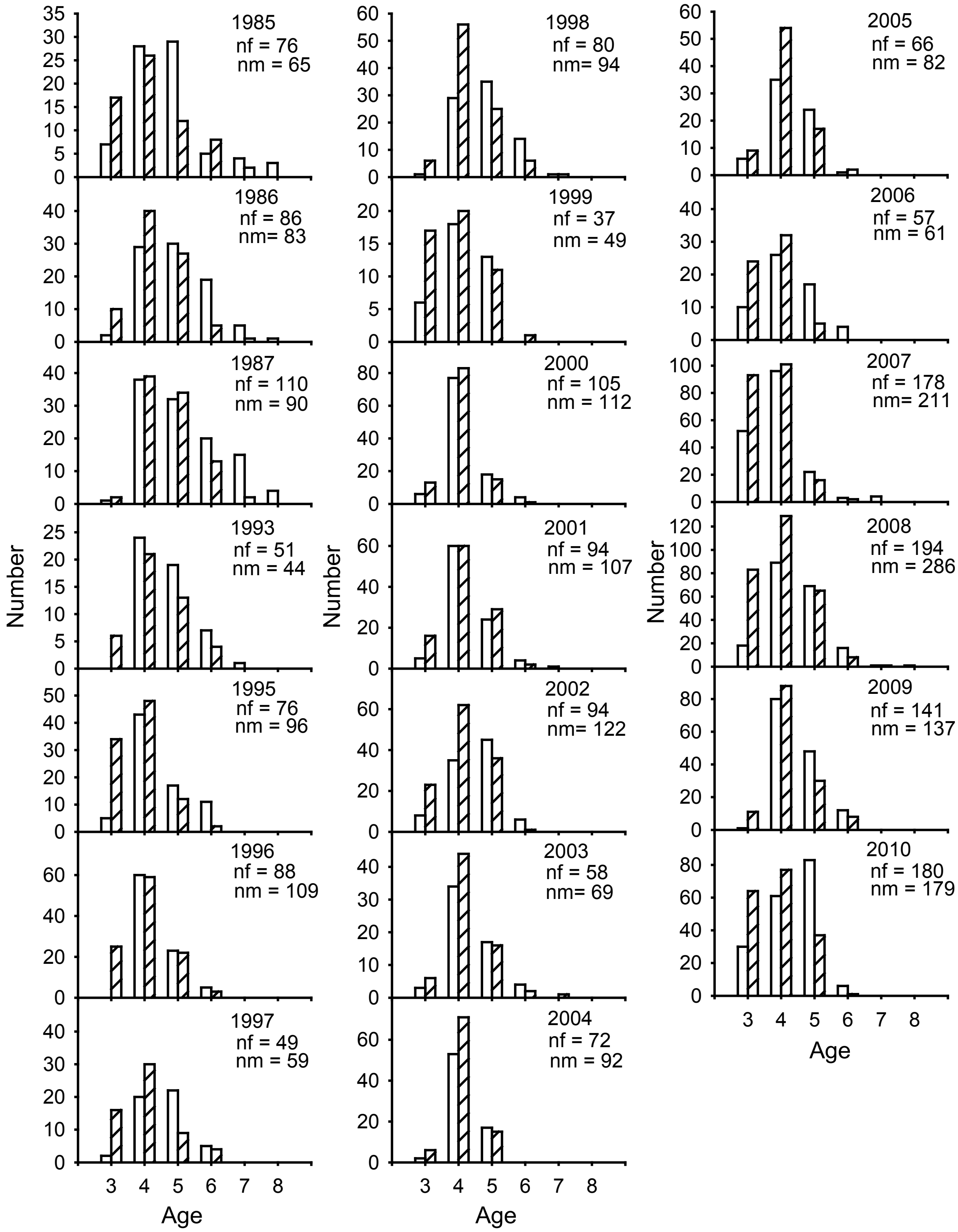


Figure 7.9 Age structure of Monument River alewife by sex (female: hollow bars; male: hash marks), 1985 –2010. nf is female sample size and nm is male sample size.

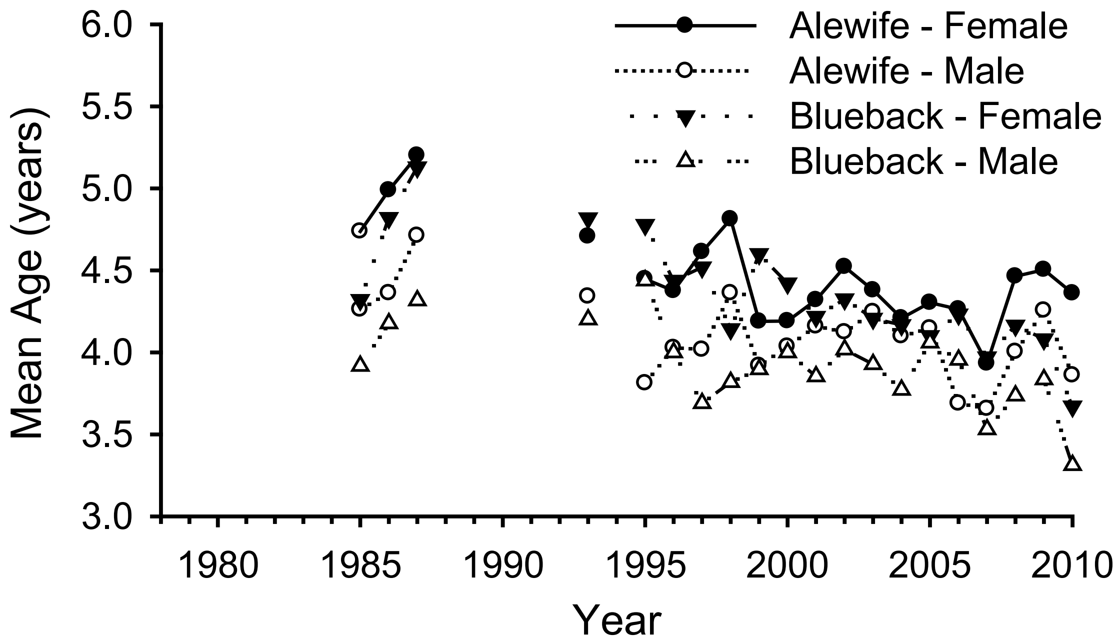


Figure 7.10 Mean age of Monument River alewife and blueback herring by sex, 1985-2010.

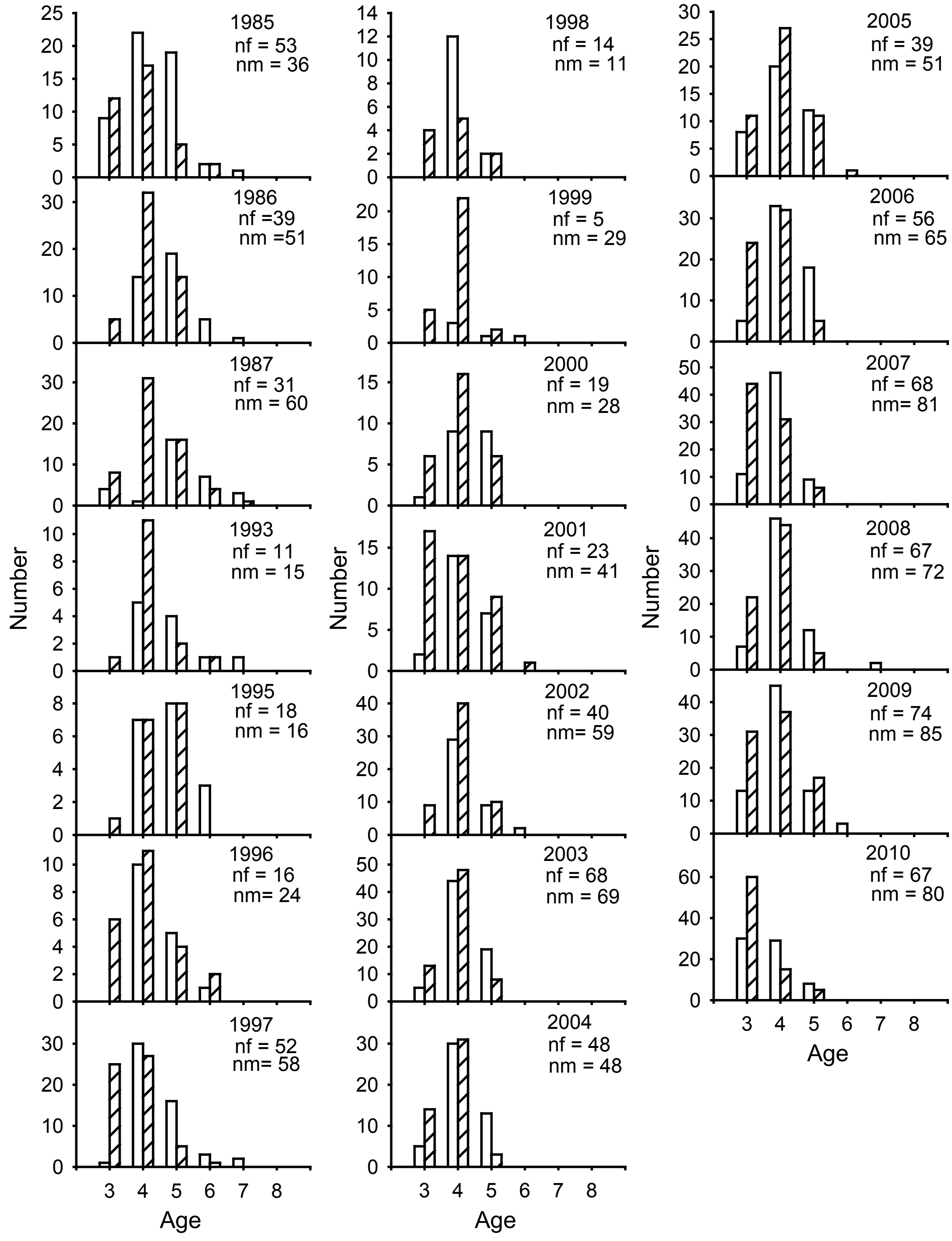


Figure 7.11 Age structure of Monument River blueback herring by sex (female: hollow bars; male: hash marks) determined from sampling, 1985-2010. nf is female sample size and nm is male sample size.

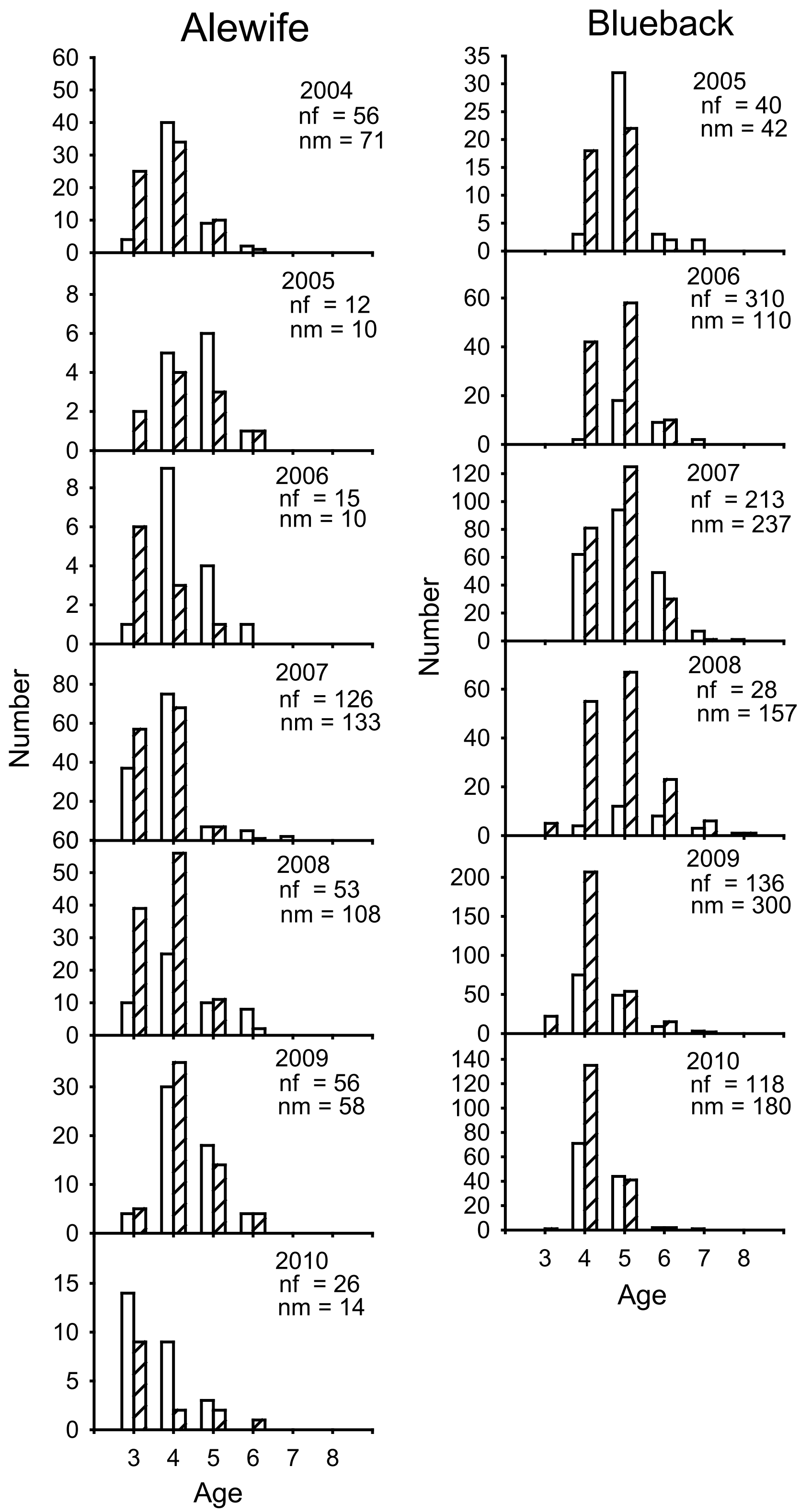


Figure 7.12. Age structure of Mystic River alewife and blueback herring by sex (female: hollow bars; male: hash marks), 2004-2010. nf is female sample size and nm is male sample size.

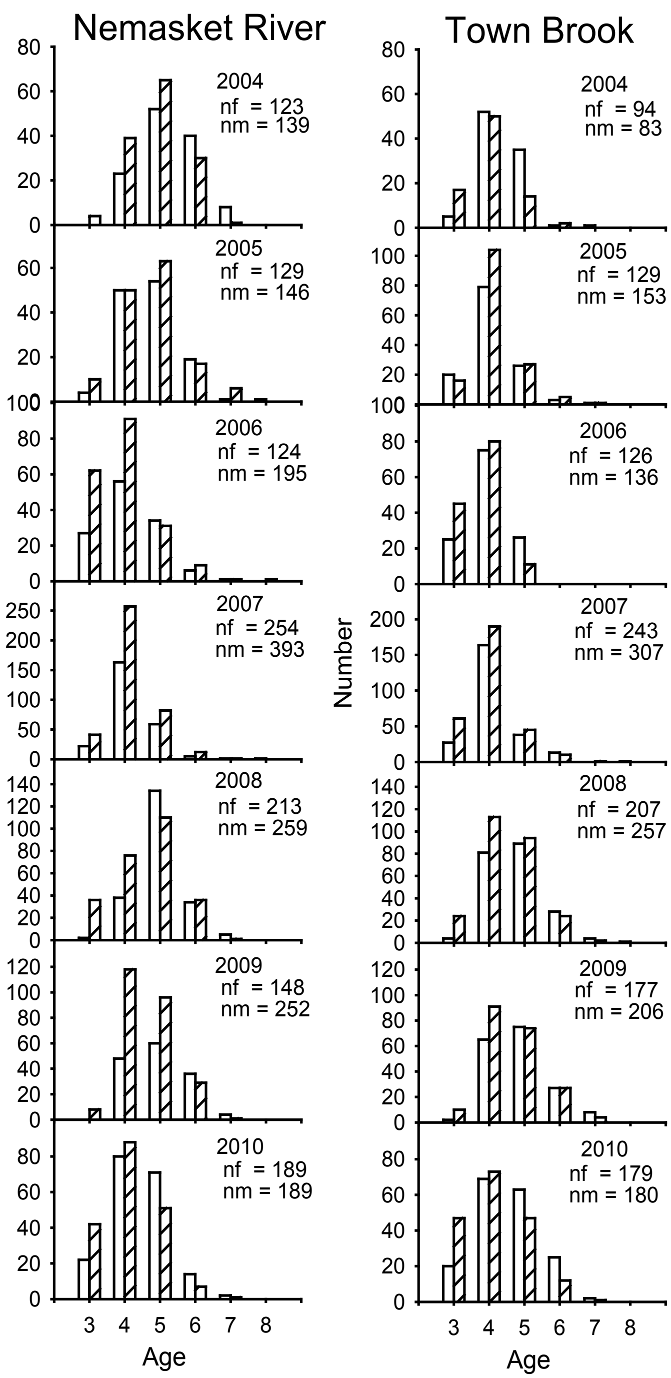


Figure 7.13. Age structure of Nemasket River and Town Brook alewife by sex (female: hollow bars; male: hash marks), 2004-2010. nf is female sample size and nm is male sample size.

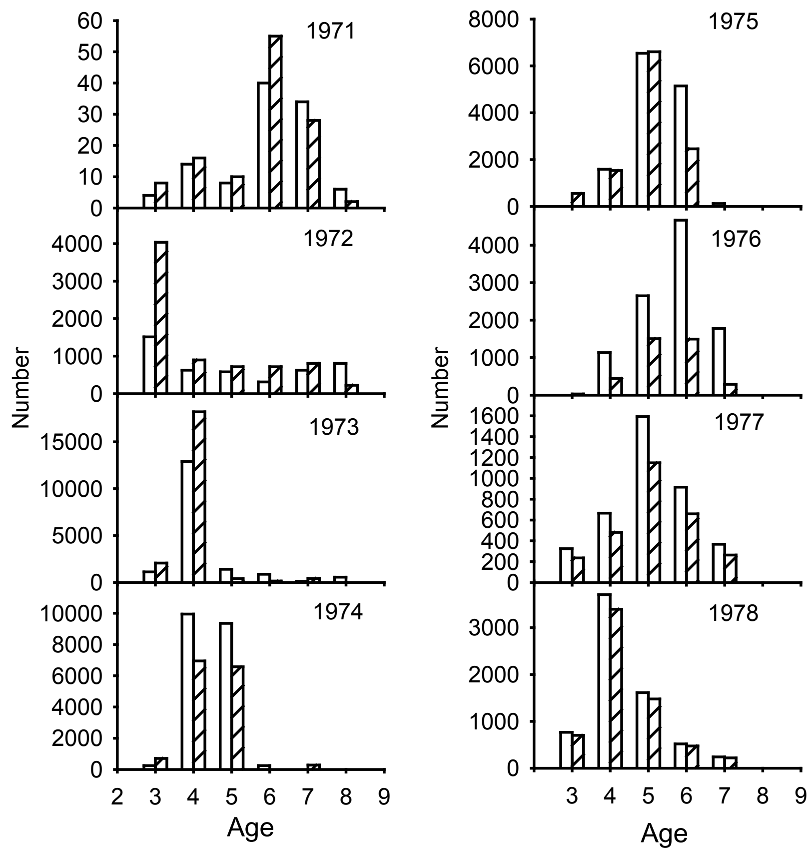


Figure 7.14 Age structure of Parker River alewife by sex, 1971-1978. The age structure of the total run for each year is shown (expanded from samples) except 1971 (female: hollow bars; male: hash marks)

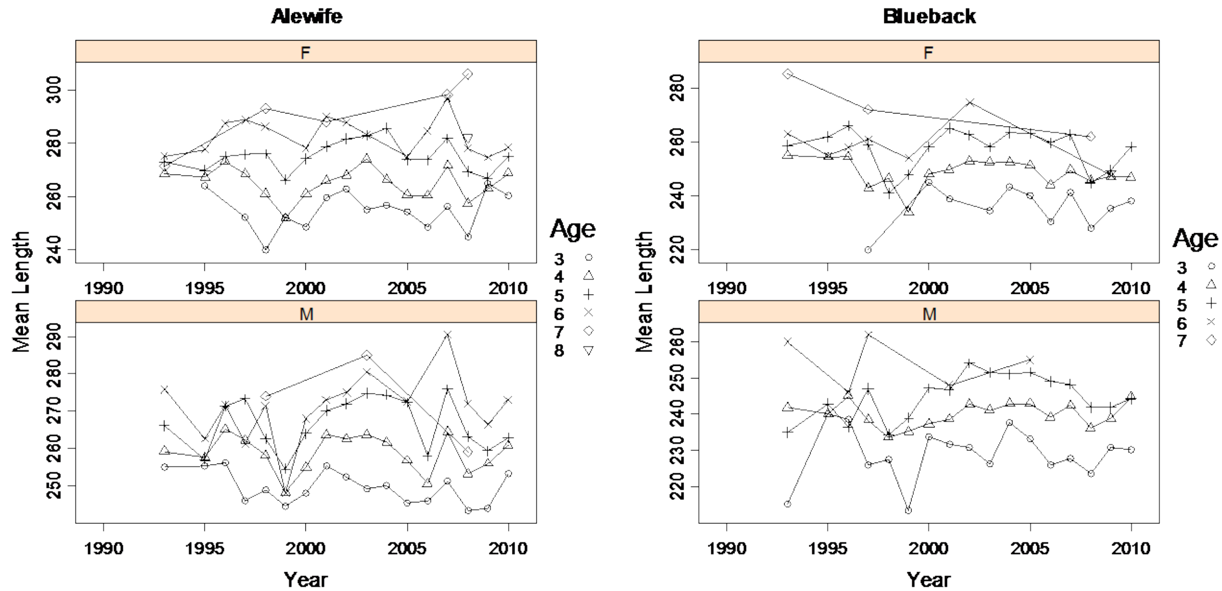


Figure 7.15 Mean length-at-age of alewife and blueback herring by year and sex for the Monument River, 1990-2010.

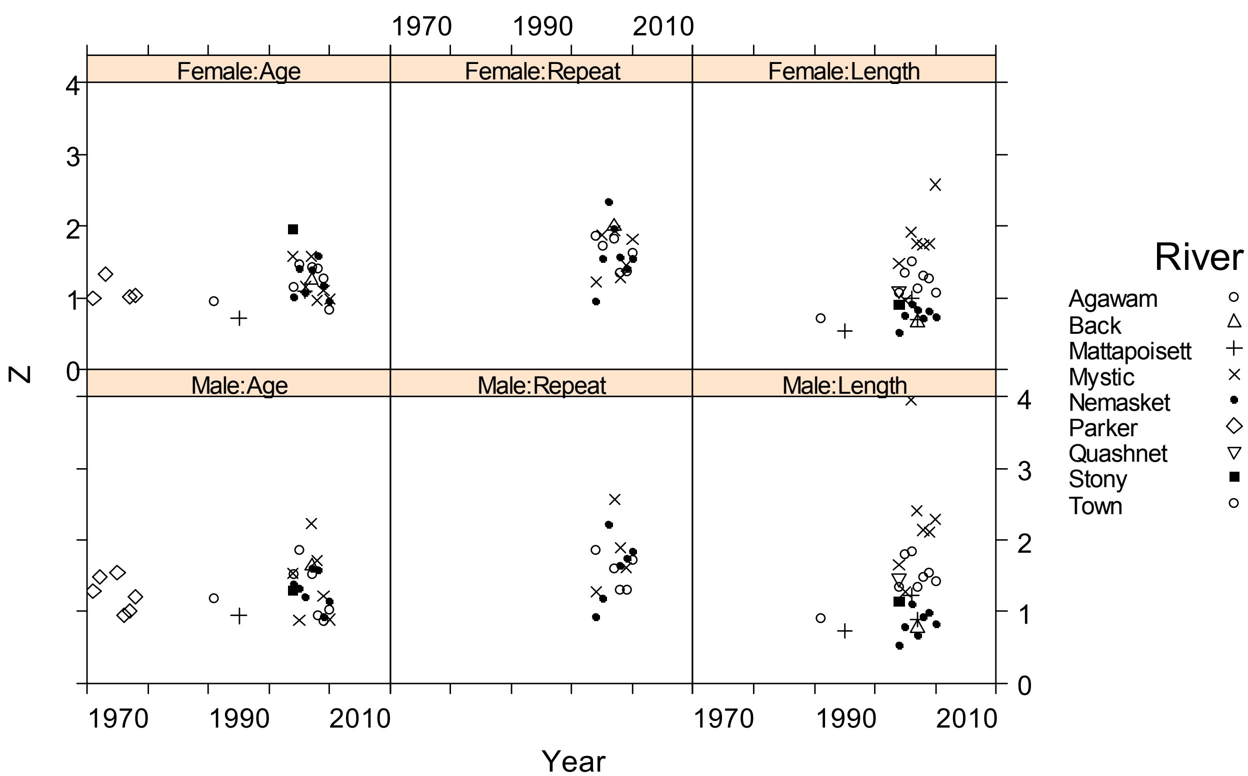


Figure 7.16. Estimates of instantaneous total mortality from age, repeat spawner and length data for alewife in Massachusetts rivers, 1971-2010. The Chapman-Robson survival estimator was applied to age and repeat spawner frequency data, and the Beverton-Holt estimator was applied to length data.

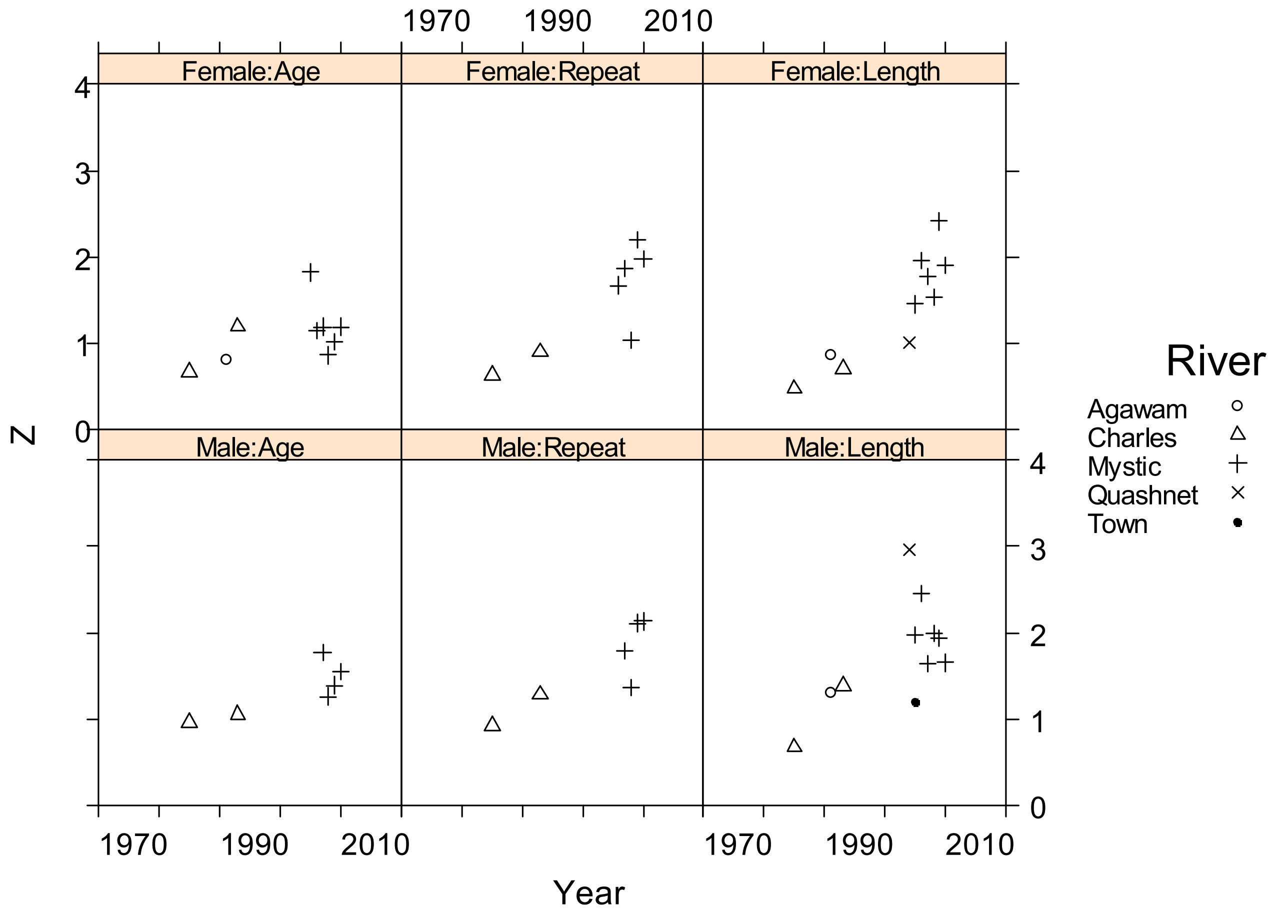


Figure 7.17 Estimates of total instantaneous mortality (Z) from age, repeat spawner, and length data for blueback herring in several Massachusetts rivers, 1985-2010. The Chapman-Robson survival estimator was applied to age and repeat spawner frequency data, and the Beverton-Holt (BH) estimator was applied to length data.

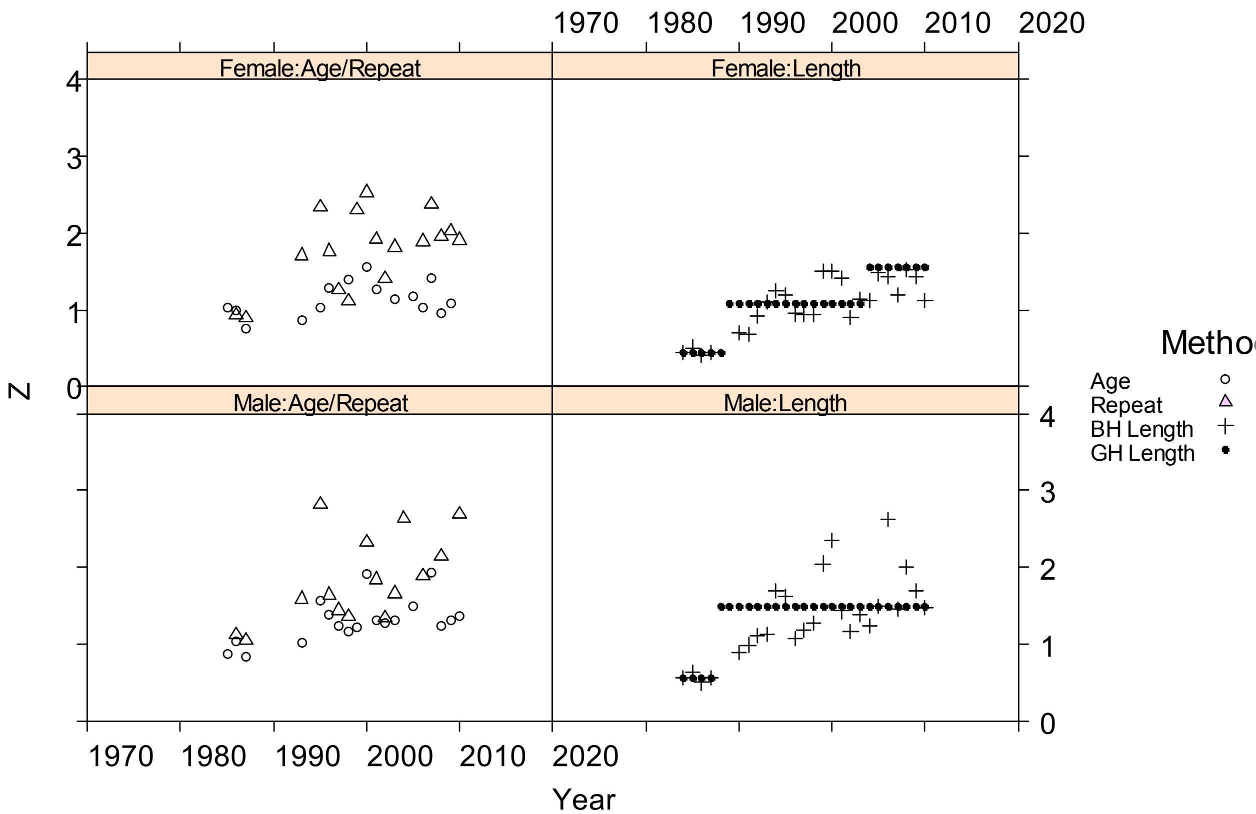


Figure 7.18 Estimates of total instantaneous mortality (Z) from age, repeat spawner, and length data for alewife in the Monument River, 1984-2010. The Chapman-Robson survival estimator was applied to age and repeat spawner frequency data, and the Beverton-Holt (BH) and Gedamke-Hoenig (GH) length-based mortality estimators were applied to length data.

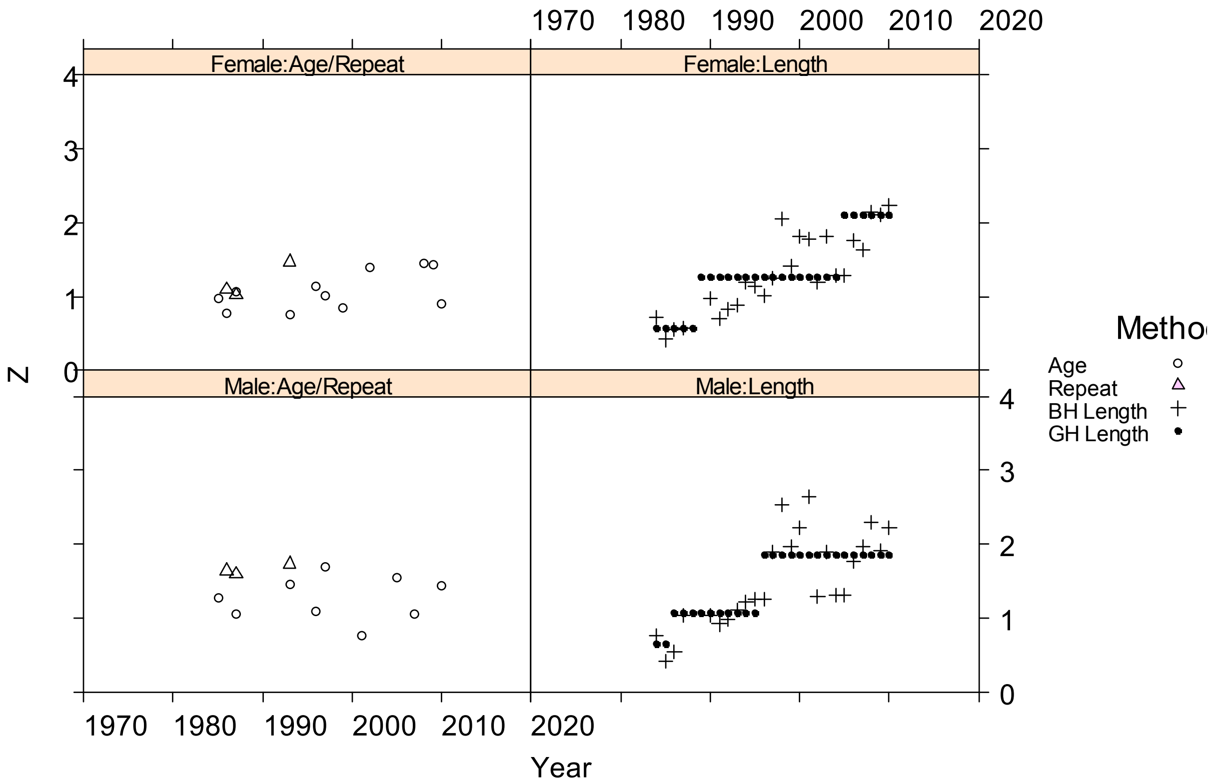


Figure 7.19 Estimates of total instantaneous mortality (Z) from age, repeat spawner, and length data for blueback herring in the Monument River, 1984-2010. The Chapman-Robson survival estimator was applied to age and repeat spawner frequency data, and the Beverton-Holt (BH) and Gedamke-Hoenig (GH) length-based mortality estimators were applied to length data.

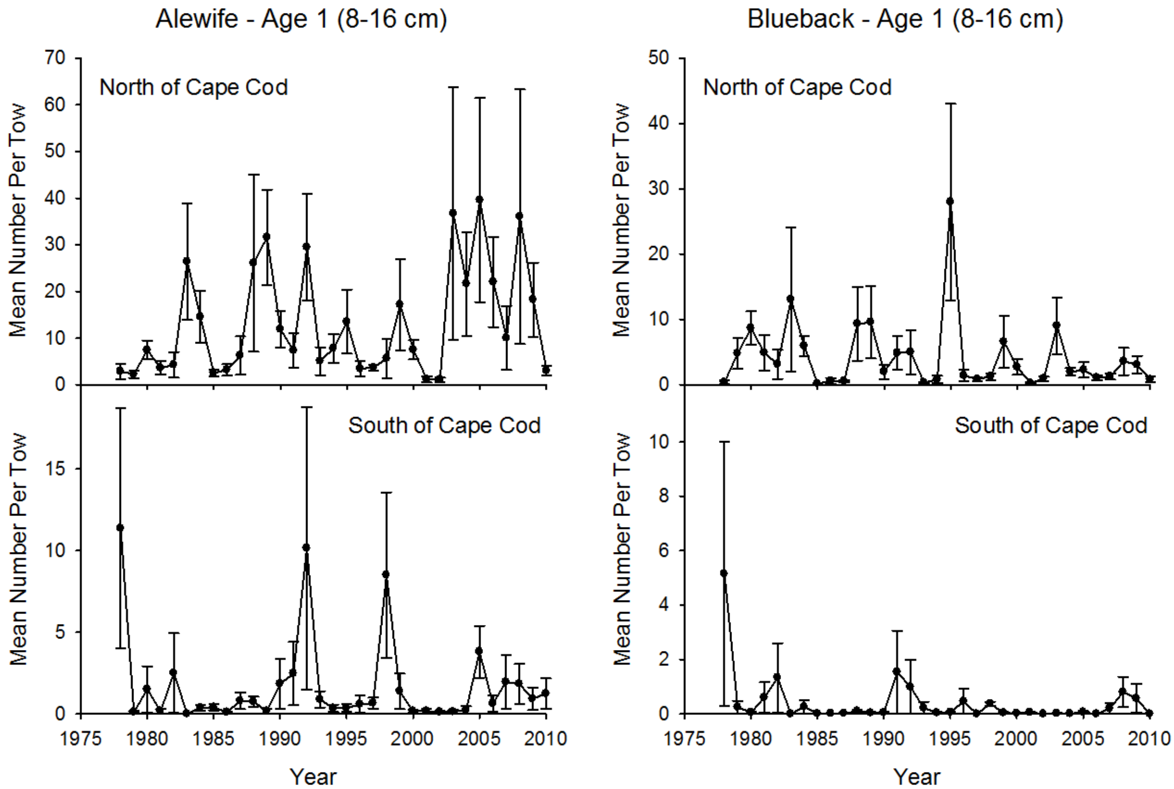


Figure 7.20 Indices of relative abundance (stratified mean number per tow) for age-1 alewife and blueback herring north and south of Cape Cod from the spring Massachusetts inshore bottom trawl survey, 1978-2010. Whiskers are +/-1 standard error.

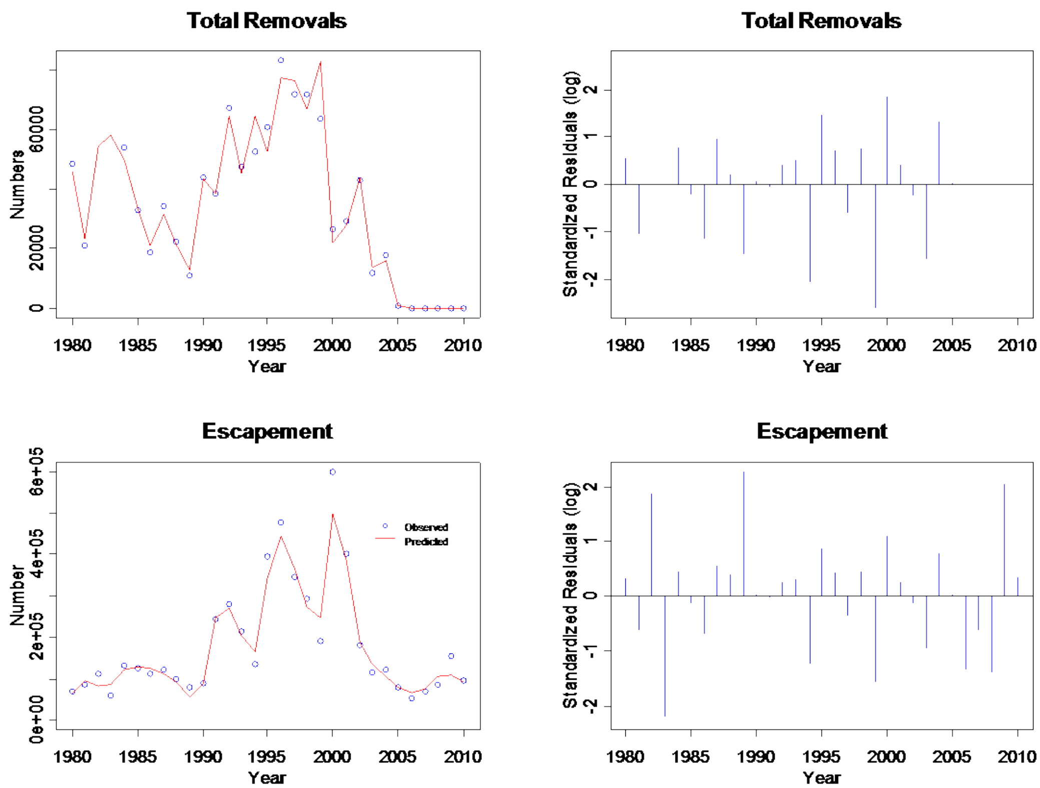


Figure 7.21 Comparison of observed and predicted total removals and escapement numbers and standardized residuals for Monument River alewife.

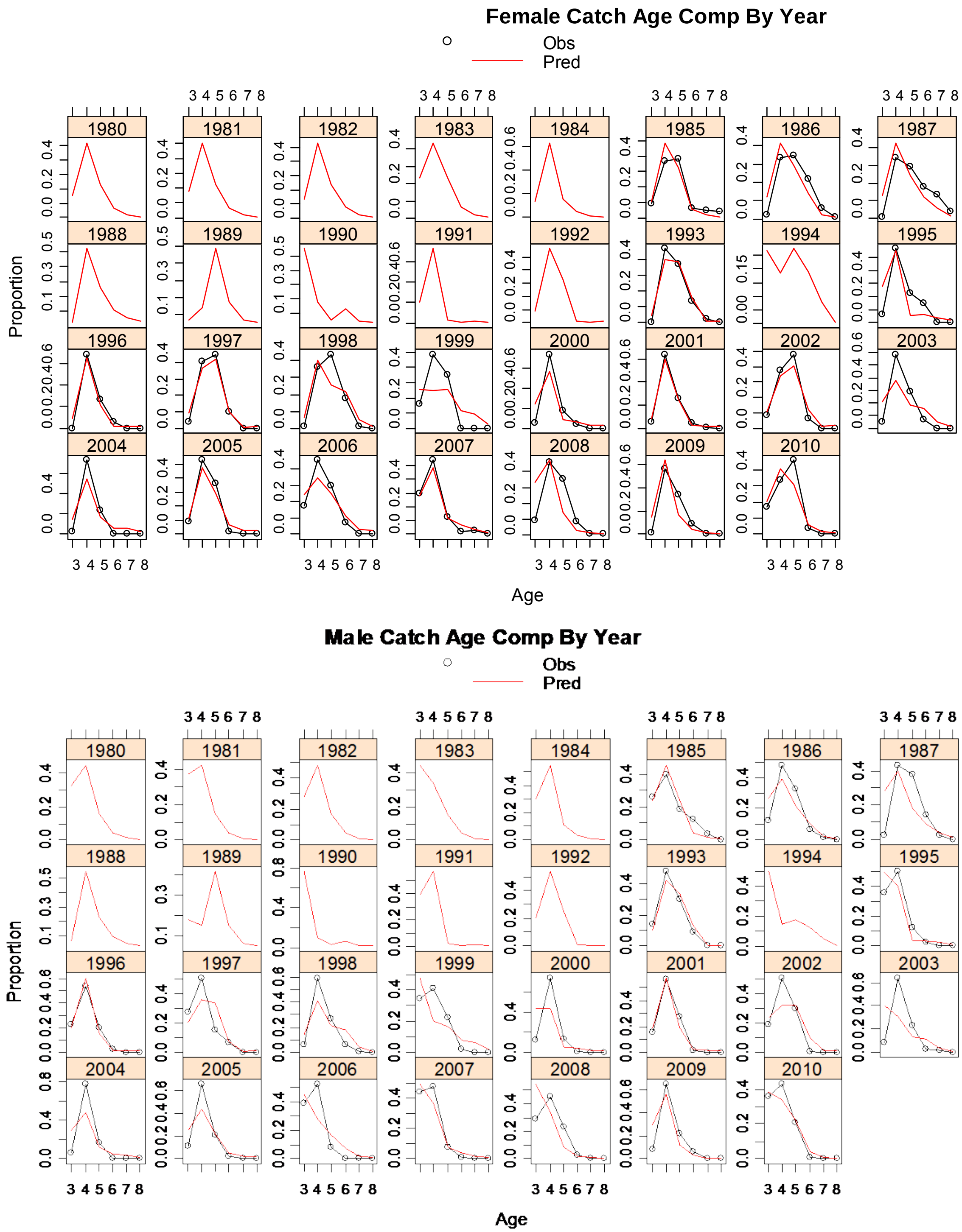
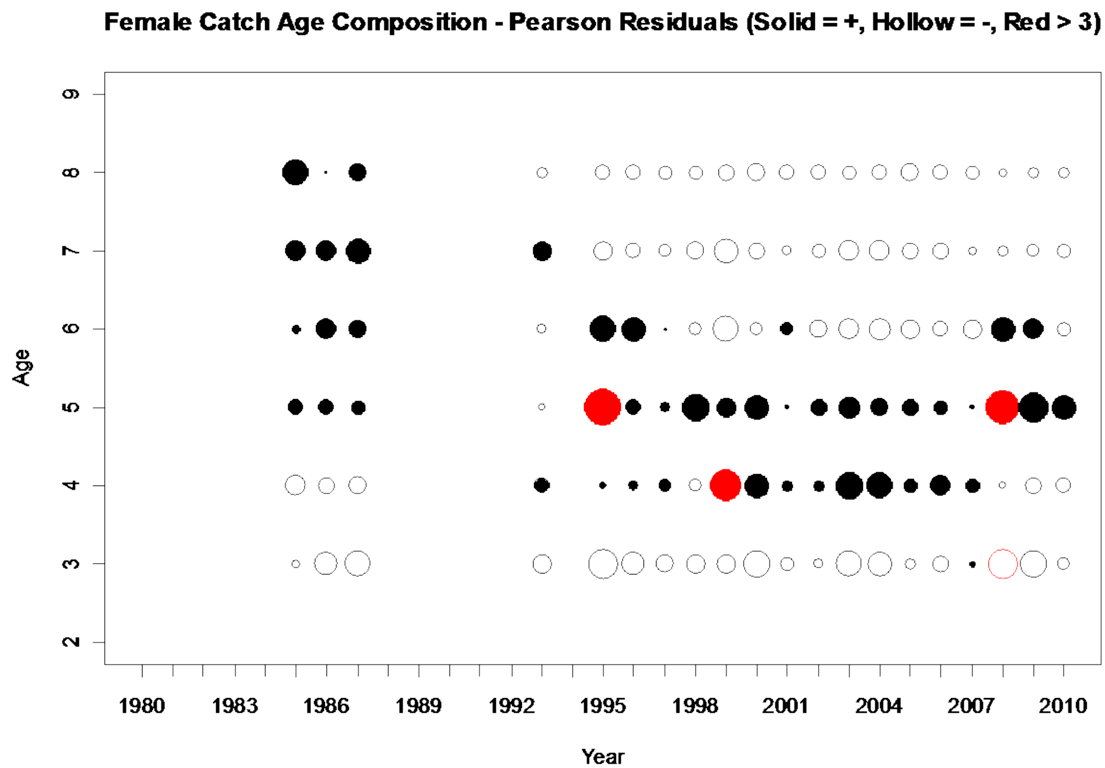


Figure 7.22 Observed and predicted escapement age composition (proportions) for Monument River alewife by sex, age, and year.



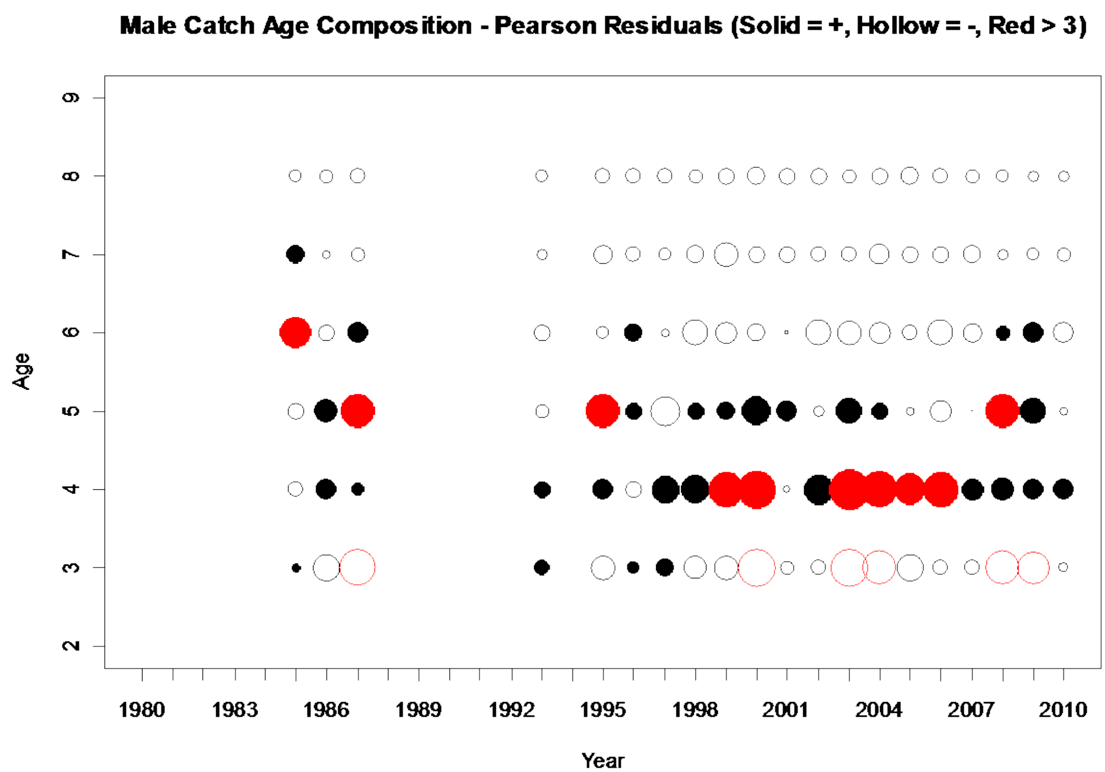


Figure 7.23 Bubble plots of standardized residuals of catch age composition by sex, year, and age for Monument River.

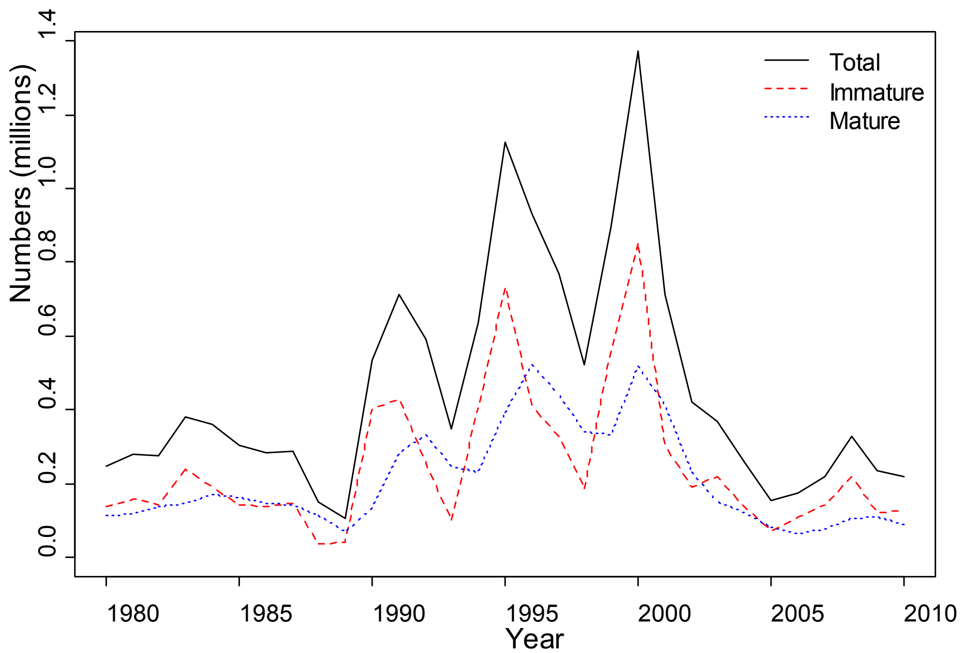


Figure 7.24 Population abundance estimates for the Monument River alewife stock.

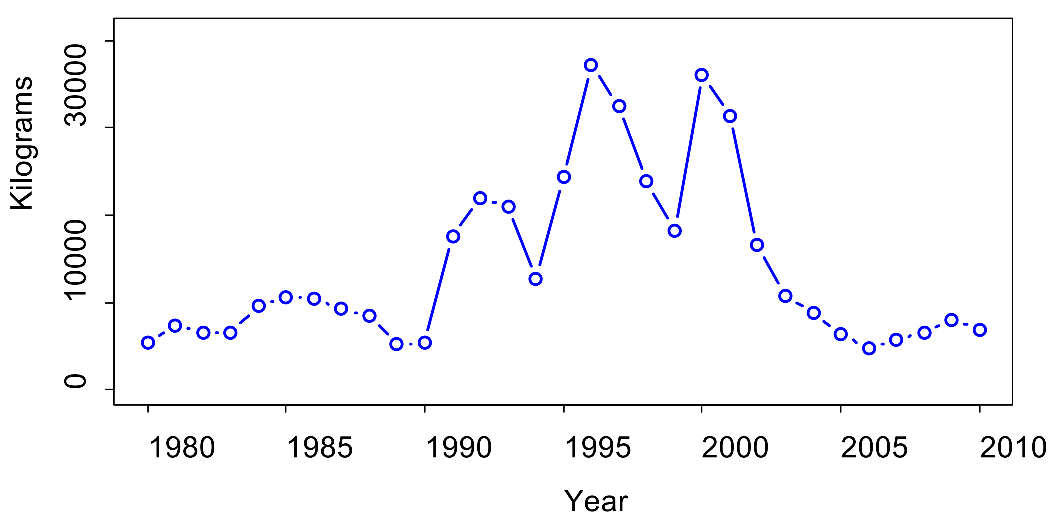


Figure 7.25 Estimates of female spawning stock biomass (kilograms) for Monument River alewife.

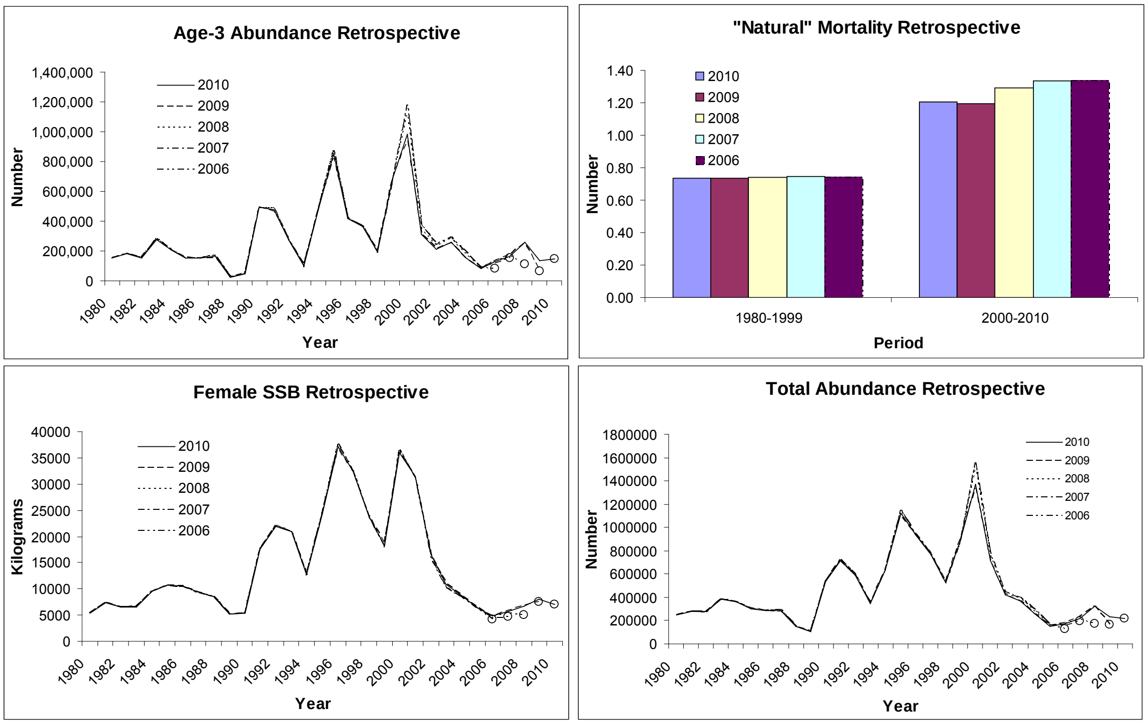


Figure 7.26 Retrospective analyses for age-3 abundance, "natural" mortality, and female spawning stock biomass, and total population abundance estimates for the Monument River.

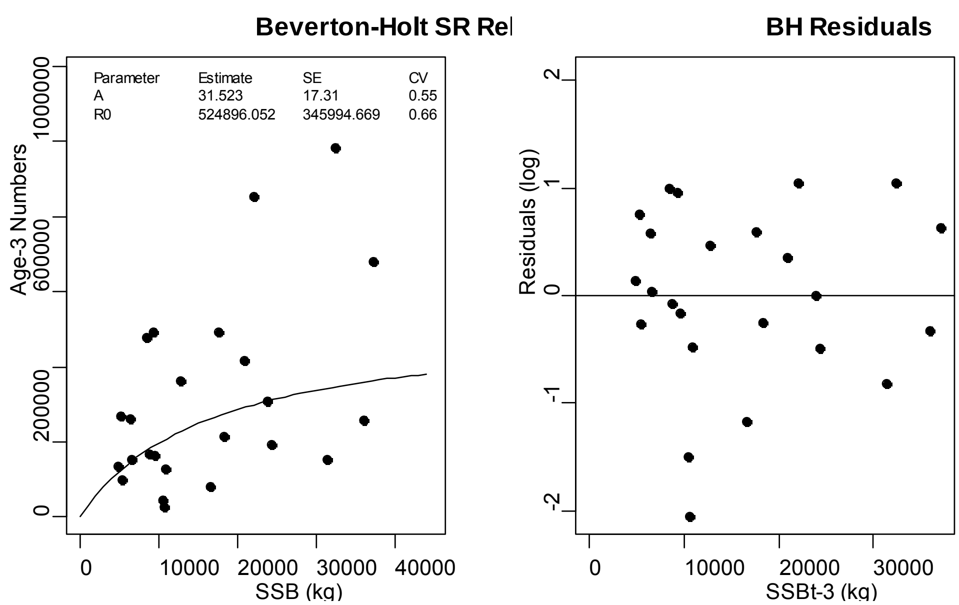


Figure 7.27 Beverton-Holt stock-recruitment relationship for the Monument River alewife. Estimates of a and R_0 are provided in the first graph, and residuals are shown in the second graph.

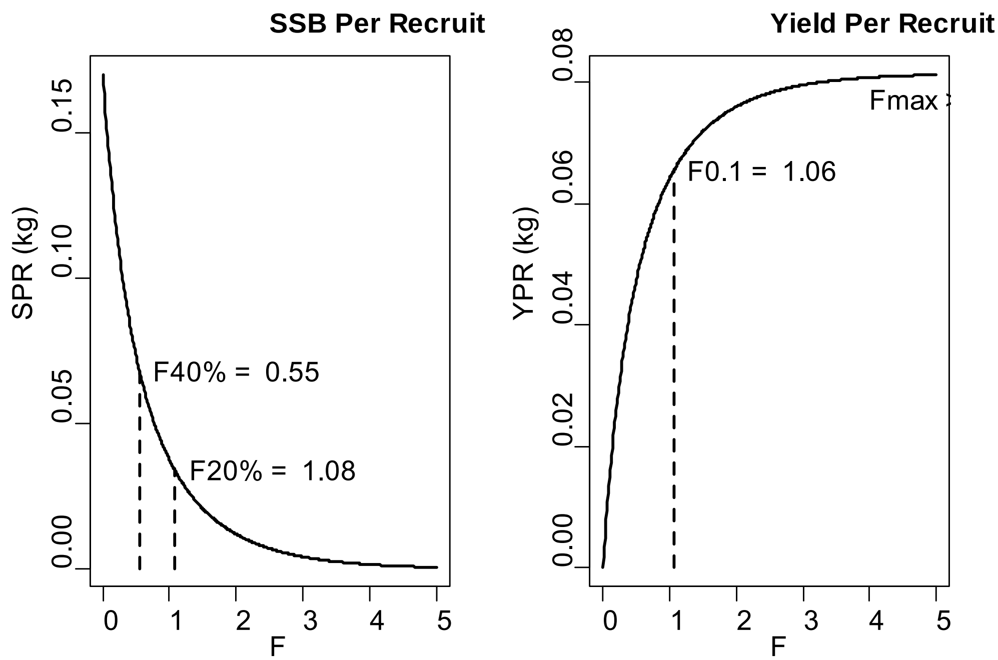


Figure 7.28 Results of spawning biomass-per-recruit and yield-per-recruit and analyses for Monument River alewife.

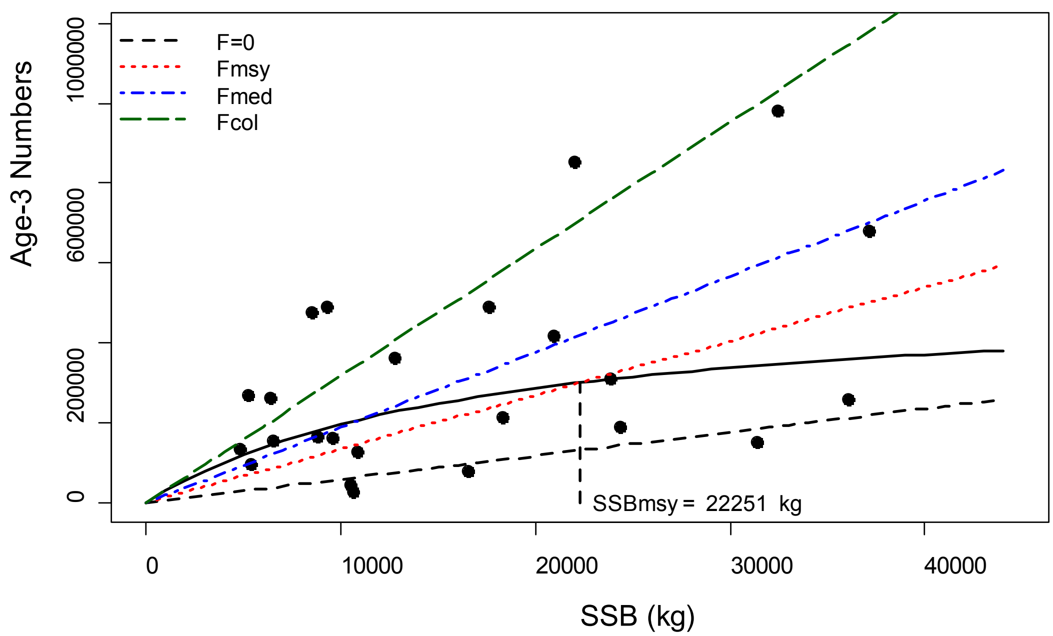


Figure 7.29 Production model reference points for Monument River alewife.

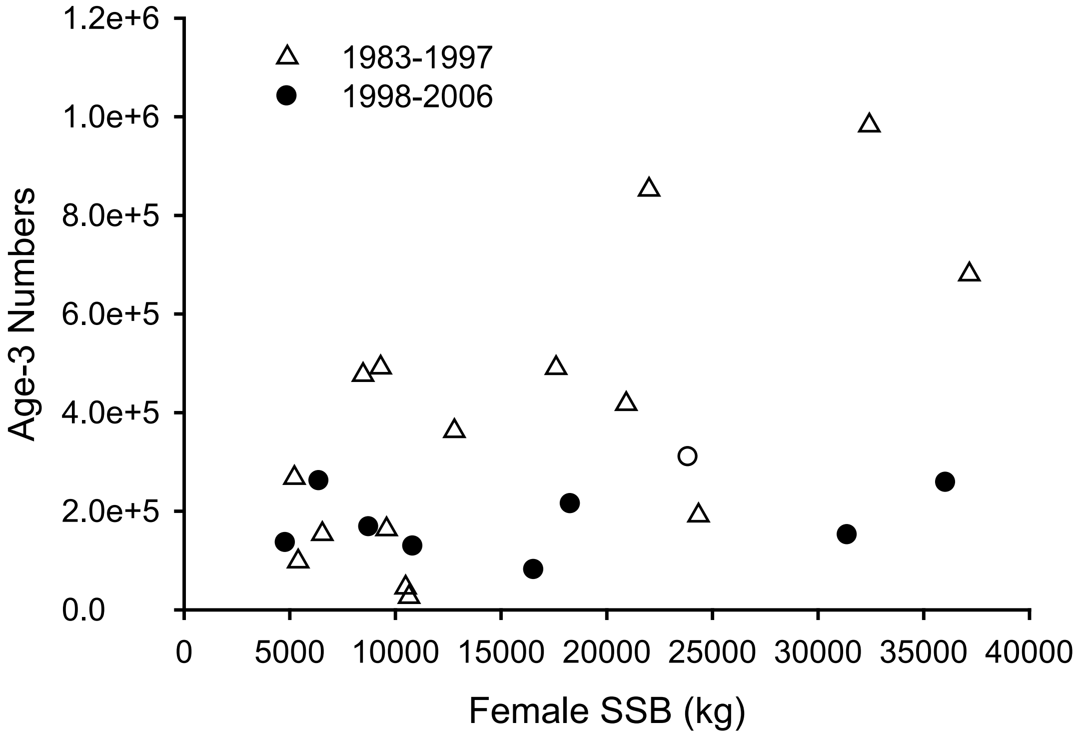


Figure 7.30 Plot of S-R data for Monument River alewife with year-classes symbolized by time periods (1983-1997 and 1998-2006).

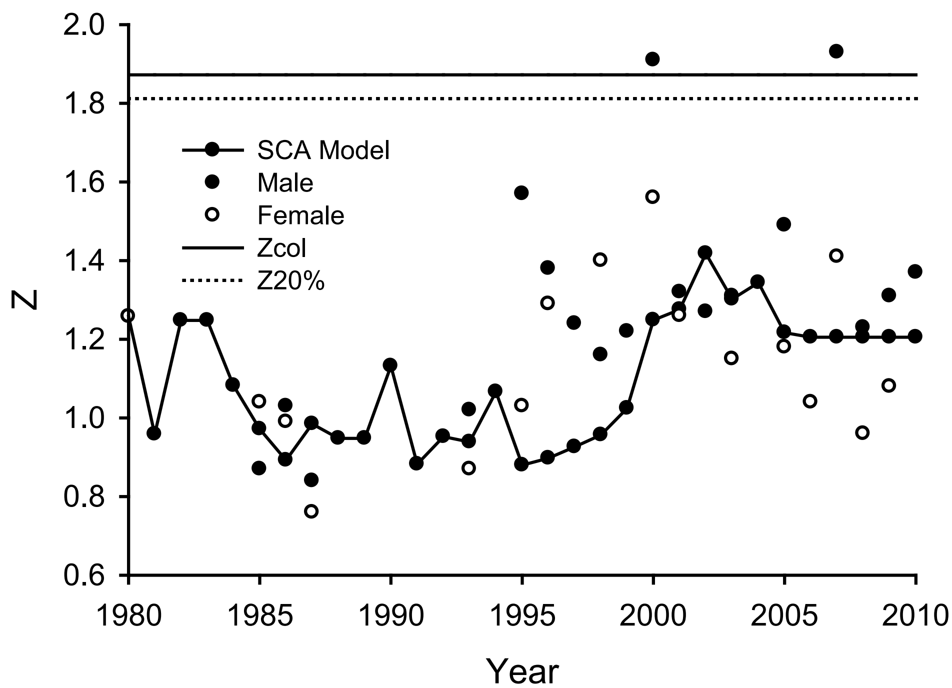


Figure 7.31 Comparison of Z estimates derived from the SCA model and those derived from raw age data using the Chapman-Robson survival estimator for Monument River alewife. Also, shown are the Z reference points (Zcol and Z20%).

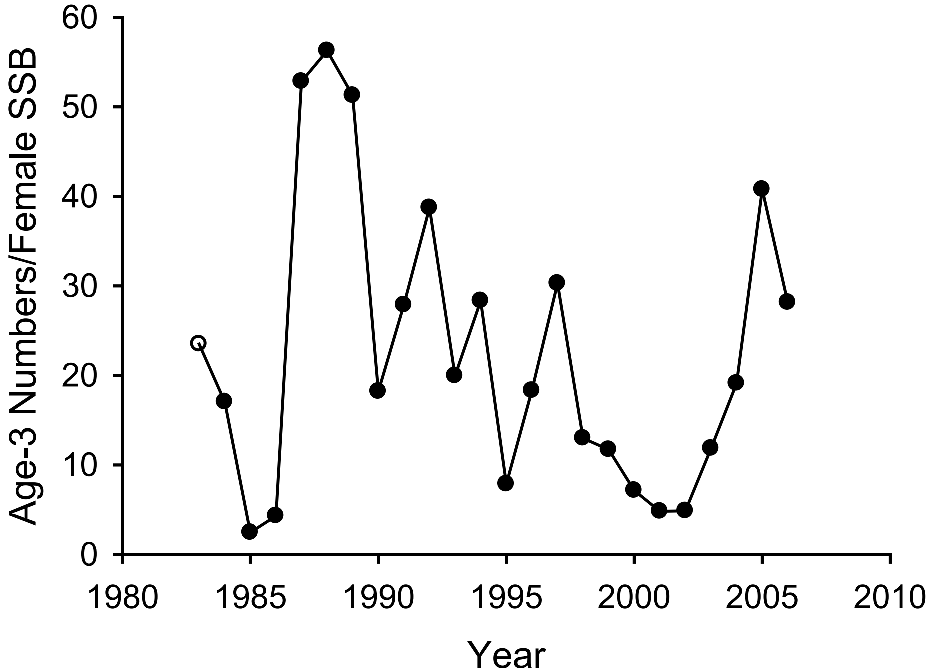


Figure 7.32 Plot of survival ratios (age-3 numbers divided by female SSB) for Monument River alewife.

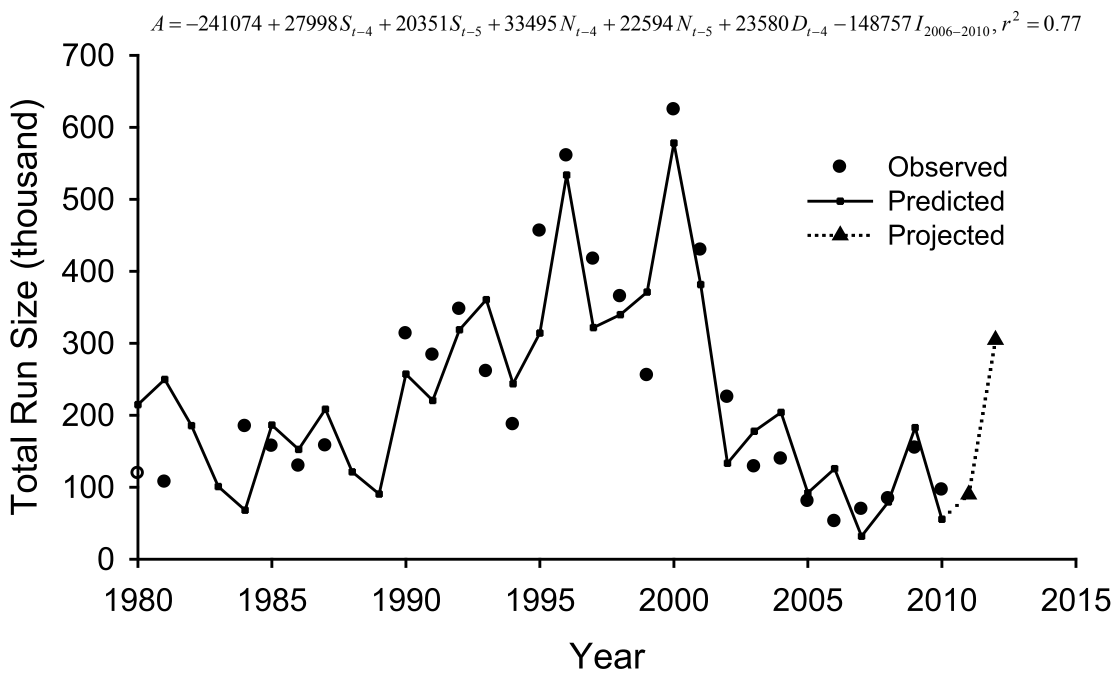


Figure 7.33 Prediction of Monument River alewife total abundance using monthly cumulative rainfall from Onset, Massachusetts lagged 4 and 5 years.

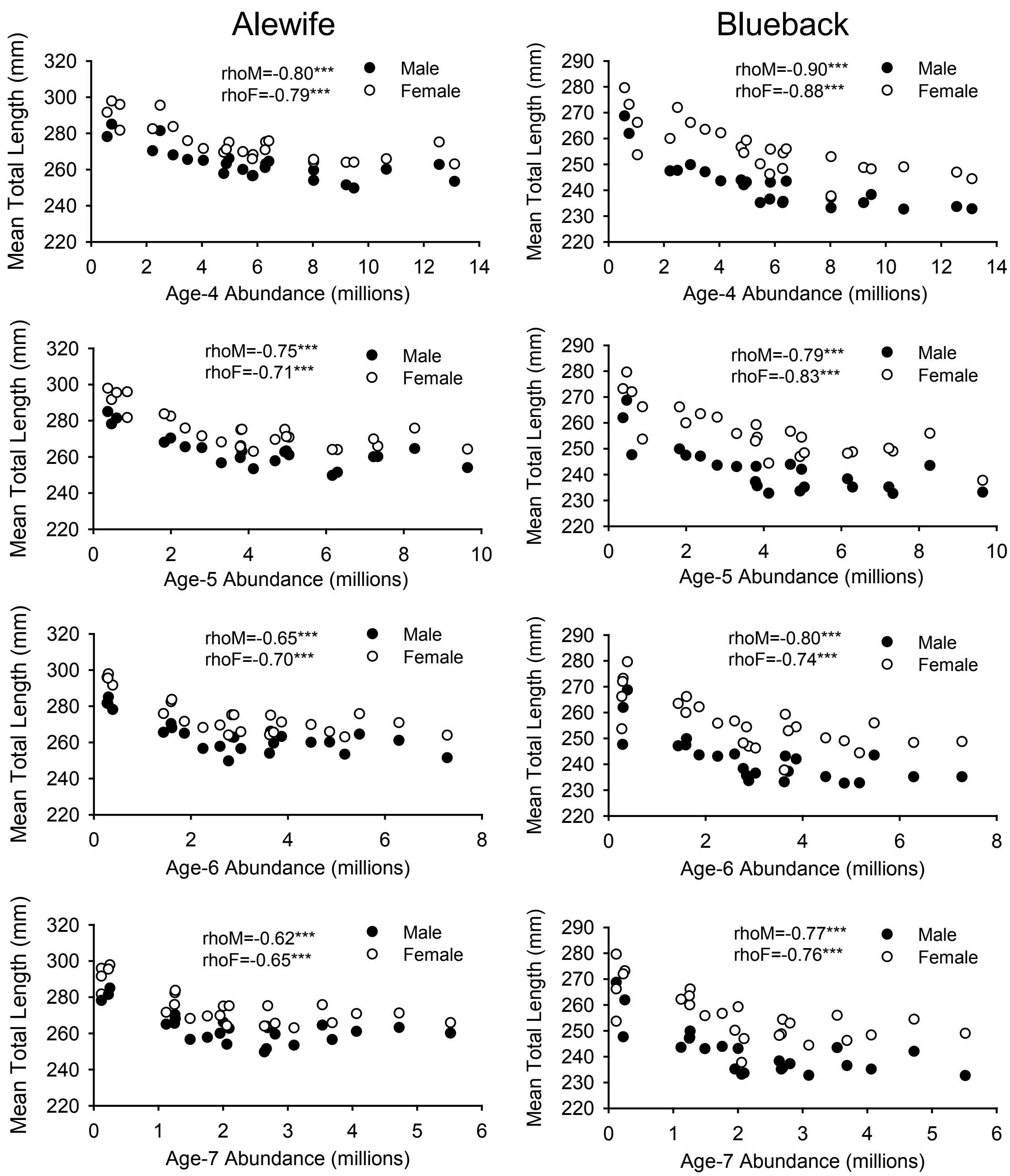


Figure 7.34 Mean length for male and female alewife and blueback herring from the Monument River versus striped bass coastwide abundance for ages 4-7 lagged one year.

Appendix Table 7.1. Commercial landings (pounds) of river herring in Massachusetts by gear type, 1887-2007. Source: National Marine Fisheries Service and ASMFC (1985).

Commercial Landings											
Year	Dip Net	Purse Seine	Float Trap	Fyke Net	Gillnet	Beach Seine	Lift Net	Trawls	Pound Net	Unknown Gear	Total
1887										4,130,000	4,130,000
1888										6,292,000	6,292,000
1889										3,911,000	3,911,000
1890										-	-
1891										-	-
1892										3,651,000	3,651,000
1893										-	-
1894										-	-
1895										-	-
1896										5,356,000	5,356,000
1897										4,779,000	4,779,000
1898										2,900,000	2,900,000
1899										-	-
1900										-	-
1901										-	-
1902										4,517,000	4,517,000
1903										-	-
1904										-	-
1905										4,861,000	4,861,000
1906										-	-
1907										-	-
1908										4,062,000	4,062,000
1909										-	-
1910										-	-
1911										-	-
1912										-	-
1913										-	-
1914										-	-
1915										-	-
1916										-	-
1917										-	-
1918										-	-
1919										3,064,000	3,064,000
1920										-	-

Appendix Table 7.1 cont.

Commercial Landings

Year	Dip Net	Purse Seine	Float Trap	Fyke Net	Gillnet	Beach Seine	Lift Net	Trawls	Pound Net	Unknown Gear	Total
1921										-	-
1922										-	-
1923										-	-
1924										2,593,000	2,593,000
1925										-	-
1926										-	-
1927										-	-
1928										2,248,000	2,248,000
1929										1,386,000	1,386,000
1930										1,790,000	1,790,000
1931										2,212,000	2,212,000
1932										1,164,000	1,164,000
1933										923,000	923,000
1934										-	-
1935										959,000	959,000
1936										-	-
1937										1,086,000	1,086,000
1938										958,000	958,000
1939										946,000	946,000
1940										879,000	879,000
1941										-	-
1942										984,000	984,000
1943										-	-
1944										2,266,000	2,266,000
1945										988,000	988,000
1946										1,249,000	1,249,000
1947										633,000	633,000
1948										468,000	468,000
1949										502,000	502,000
1950	0	25,100	300	0	0	244,500	0	0	0	0	269,900
1951	0	42,300	3,700	0	0	230,000	0	0	0	0	276,000
1952	0	87,000	12,700	0	0	1,804,000	0	500	0	500	1,904,700
1953	0	4,538,200	240,100	0	0	751,600	0	4,800	0	0	5,534,700
1954	0	2,843,000	54,000	0	0	119,500	0	3,700	0	0	3,020,200
1955	0	1,869,800	75,600	0	400	675,300	0	0	0	0	2,621,100

Appendix Table 7.1 cont.

						Commercial Landings					
Year	Dip Net	Purse Seine	Float Trap	Fyke Net	Gillnet	Beach Seine	Lift Net	Trawls	Pound Net	Unknown Gear	Total
1956	0	8,752,500	77,000	0	0	92,000	0	0	0	0	8,921,500
1957	14,800	16,439,200	54,000	0	0	140,000	0	2,379,100	0	0	19,027,100
1958	16,200	32,482,400	106,800	0	0	1,167,000	0	42,300	0	0	33,814,700
1959	30,000	9,729,400	27,500	0	0	1,711,200	0	105,700	14,200	0	11,618,000
1960	0	16,151,300	26,900	0	0	1,387,900	0	0	85,000	0	17,651,100
1961	0	19,107,600	0	0	0	1,230,600	500,000	0	0	0	20,838,200
1962	0	6,123,200	0	0	0	2,150,000	0	2,500	0	0	8,275,700
1963	40,000	10,882,200	0	0	0	798,300	0	13,000	1,600	0	11,735,100
1964	339,900	3,998,600	0	0	0	1,190,300	0	0	0	0	5,528,800
1965	66,200	6,332,200	0	0	0	532,900	0	0	4,000	0	6,935,300
1966	90,100	6,106,400	0	0	0	436,700	0	0	0	0	6,633,200
1967	95,000	5,105,800	3,100	0	0	228,000	0	0	0	0	5,431,900
1968	14,200	0	0	0	0	102,500	0	0	0	0	116,700
1969	0	0	0	0	0	100,000	0	0	0	0	100,000
1970	0	813,600	0	0	0	100,000	0	242,700	0	0	1,156,300
1971	0	44,600	500	0	0	143,200	0	34,000	0	0	222,300
1972	38,800	1,171,700	700	0	0	128,500	0	567,700	0	0	1,907,400
1973	32,500	518,200	7,400	0	0	106,000	0	31,300	0	0	695,400
1974	175,300	0	2,500	0	0	0	0	50,700	0	0	228,500
1975	37,800	1,631,900	17,200	0	0	30,000	0	0	0	0	1,716,900
1976	6,400	0	0	0	0	38,500	0	0	0	0	44,900
1977	0	18,000	1,500	0	0	50,000	0	62300	0	0	131,800
1978	0	619,700	0	0	0	81,000	0	600	0	0	701,300
1979	0	0	0	0	0	52,000	0	300	0	0	52,300
1980	45,000	0	0	0	0	99,000	0	0	0	0	144,000
1981	36,300	0	0	0	0	47,700	0	0	0	0	84,000
1982	28,000	0	0	0	0	25,500	0	0	0	0	53,500
1983	13,000	0	0	0	0	80,000	0	100	0	0	93,100
1984	37,700	110,800	0	500	0	45,000	0	100	0	0	194,100
1985	35,200	0	0	400	0	11,000	0	0	0	0	46,600
1986	23,900	0	0	0	0	8,500	0	0	0	0	32,400
1987	24,000	0	0	0	0	8,500	0	0	0	0	32,500
1988	35,580	0	0	0	0	7,000	0	0	0	0	42,580
1989	14,200	237,500	0	0	0	4,000	0	0	0	0	255,700
1990	18,200	0	0	0	0	2,500	0	0	0	0	20,700

Appendix Table 7.1 cont.

						Commercial Landings					
Year	Dip Net	Purse Seine	Float Trap	Fyke Net	Gillnet	Beach Seine	Lift Net	Trawls	Pound Net	Unknown Gear	Total
1991	17,800	0	0	0	0	2,500	0	0	0	0	20,300
1992	16,200	0	0	0	0	2,500	0	0	0	0	18,700
1993	16,400	0	0	0	0	2,500	0	0	0	0	18,900
1994	0	0	0	0	0	0	0	0	0	0	0
1995	0	0	0	0	0	0	0	0	0	0	0
1996	0	0	0	0	0	0	0	0	0	0	0
1997	0	0	0	0	0	0	0	180	0	0	180
1998	0	0	0	0	0	0	0	0	0	0	0
1999	0	0	0	0	0	0	0	0	0	0	0
2000	0	0	0	0	0	0	0	0	0	0	0
2001	0	0	0	0	0	0	0	0	0	0	0
2002	0	0	0	0	0	0	0	0	0	0	0
2003	0	0	0	0	0	0	0	0	0	0	0
2004	0	0	0	0	0	0	0	0	89	0	89
2005	0	0	0	0	0	0	0	0	0	0	0
2006	0	0	0	0	0	0	0	0	0	0	0
2007	0	0	0	0	0	0	0	0	0	0	0
2008	0	0	0	0	0	0	0	0	0	0	0
2009	0	0	0	0	0	0	0	0	0	0	0
2010	0	0	0	0	0	0	0	0	0	0	0

Appendix Table 7.2. Marine Recreational Fisheries Statistics Survey estimates of numbers and associated statistics of river herring (alewife and blueback) harvested and released in Massachusetts by the recreational anglers.

	Alewife							Blueback					
Year	Total Catch	SE	Releases	SE	Harvest	SE	Year	Total Catch	SE	Releases	SE	Harvest	SE
1982							1982						
1983	81	81	81	81	0	0	1983						
1984							1984						
1985							1985						
1986	32,506	20424	0	0	32,506	20424	1986	804	804	0	0	804	804
1987							1987	83,281	66,261	20,163	20,163	63,118	63,118
1988							1988						
1989							1989	639	295	0	0	639	295
1990							1990	5,632	3,274	5,632	3,274	0	0
1991							1991	562	413	0	0	562	413
1992	9,411	9411	0	0	9,411	9411	1992						
1993							1993	5,707	2,219	1,182	1,182	4,525	1,878
1994							1994	1,246	747	0	0	1,246	747
1995							1995	352	350	0	0	352	350
1996							1996	5,504	3,904	0	0	5,504	3,904
1997							1997	9,496	6,440	0	0	9,496	6,440
1998							1998	739	739	739	739	0	0
1999							1999						
2000							2000						
2001	2,124	1651	0	0	2,124	1651	2001						
2002							2002						
2003							2003	75,752	41,962	19,392	13,837	56,360	39,614
2004	237,564	85369	0	0	237,564	85369	2004						
2005							2005	11,657	11,657	0	0	11,657	11,657
2006							2006						
2007							2007	1,191	1,191	1,191	1,191	0	0
2008							2008	18,543	15,360	18,543	15,360	0	0
2009							2009						

Appendix Table 7.3. Summary of time series of fisheries-independent data for river herring in Massachusetts.

Run	Species	Enumeration Method	Counts	Length Data	Weight Data	Sex Data	Age Data	Repeat Spawn Data	Source	Comments
Acushnet River	Alewife/ Blueback	Trap (2005 - present) Electronic (2008 - present) Video (2008)	Total and combined escapement (2005 - present)	Alewife (2005-2010) Blueback (2008-2009)	Alewife (2005-2010) Blueback (2008-2009)	Alewife (2005-2010) Blueback (2008-2009)	Alewife (2005-2010) Blueback (2008-2009)	Alewife (2005-2010) Blueback (2008-2009)	MADMF CSBB USGS	Census
Agawam River	Alewife/ Blueback	Electronic	Combined Passage (2006 - present)	1991	1991	1991	1991	1991	Wareham MADMF CSBB	
Back River (Combined)	Alewife/ Blueback	Visual Video (2008-2009)	Combined Passage 1977-78; 1984, 1986 - present	Alewife 2007	Alewife 2007	Alewife 2007	Alewife 2007	Alewife 2007	Weymouth MADMF UMASS	No statistical design (Visual counts)
Bound Brook	Alewife	Visual	Passage (2010)	None	None	None	None	None	NSRWA	No statistical design
Charles River	Blueback herring	Video (2008-2009	Combined Passage (2008-2009)	1985; 1993	1985; 1993	1985; 1993	1985; 1993	1985; 1993	MADMF UMASS	
Connecticut River (Holyoke)	Blueback	Fishlift/ Video	Total and combined Passage (1967 - present)	None	None	None	None	None	USFWS	Census
Coonamessett River	Alewife/ Blueback	Visual	Combined Passage (2005 - present)	None	None	None	None	None	Falmouth DNR	
1st Herring Brook	Alewife	Visual	Passage (2005 - 2006)	None	None	None	None	None	NSRWA	No statistical design
2nd Herring Brook	Alewife	Visual	Passage (2005 - 2006)	None	None	None	None	None	NSRWA	No statistical design
3rd Herring Brook	Alewife/ Blueback	Visual	Combined Passage (2003, 2005 - 2006)	None	None	None	None	None	NSRWA	No statistical design
Herring Brook	Alewife/ Blueback	Visual	Combined Passage (2010)	None	None	None	None	None	NSRWA	No statistical design
Herring River (Wellfleet)	Alewife/ Blueback	Visual	Combined Passage (2007 - present)	None	None	None	None	None	MADMF APCC	Stratified random design
Herring River (Harwich)	Alewife/ Blueback	Visual	Combined Passage (2007 - present)	None	None	None	None	None	APCC	Stratified random design
Ipswich River	Alewife/ Blueback	Visual Trap	Combined Passage (2000 - present) Total combined Passage. (2006 - 2008)	None	None	None	None	None	IRWA MADMF	No statistical design prior to 2005 Census (trap)
Jones River	Alewife/ Blueback	Visual	Combined Passage (2005 - present)	None	None	None	None	None	JRWA	
Little River	Alewife/ Blueback	Visual	Combined Passage (2000-2002; 2005; 2009)	None	None	None	None	None	MA Audubon	Counts to be continued under 8 Towns and the Bay
Marston Mills River	Alewife/ Blueback	Visual	Combined Passage 2006 - present	None	None	None	None	None	Watershed Association	Stratified random design

Appendix Table 7.3 cont.

Run	Species	Enumeration Method	Counts	Length Data	Weight Data	Sex Data	Age Data	Repeat Spawn Data	Source	Comments
Mattapoisett River	Alewife	Electronic counter	Combined Passage (1987 - 2010)	1995; 2006 - 2007	1995; 2006 - 2007	1995; 2006 - 2007	1995; 2006 - 2007	1995; 2006 - 2007	AA MADMF	
Merrimack River	Alewife/ Blueback	Fishlift/ Video	Combined Passage (1983 - Present)	None	None	None	None	None	USFWS	High water affected counts from 2005-2007
Monument River	Alewife/ Blueback	Electronic Visual Video (2008-2009)	Total and combined escapement: 1980-81; 1984-1987; 1990 - present	Both spp.: 1984 - 1987, 1990 - 2010	Both spp.: 1984 - 1987, 1993, 1995 - 2010	Both spp.: 1984 - 1987, 1990 - 2010	Both spp.: 1984 - 1987, 1993, 1995 - 2010	Both spp.: 1984 - 1987, 1993, 1995 - 2010	MADMF UMASS (video)	Census
Mystic River	Alewife/ Blueback	None*	None*	Alewife (2004-2010) Blueback (2005-2010)	Alewife (2004-2010) Blueback (2005-2010)	Alewife (2004-2010) Blueback (2005-2010)	Alewife (2004-2010) Blueback (2005-2010)	Alewife (2004-2010) Blueback (2005-2010)	MADMF	Future site for fish counting using electronic counter
Nemasket River	Alewife	Visual	Passage 1996; 1998 - present	1996, 2000, 2004 - 2010	1996, 2000, 2004 - 2010	1996, 2000, 2004 - 2010	1996, 2000, 2004 - 2010	1996, 2000, 2004 - 2010	MLHFC MADMF	No statistical design
Parker River	Alewife	Visual	Passage (1972 - 1978; 2000 - Present)	1971-1972	None	1971-1978	1971-1978	None	Mayo (1974), UMASS PRCWA	Detrition of weir affected counts in 2006-2007
Pilgrim Lake	Alewife	Visual	Combined Passage (2007 - present)	None	None	None	None	None	APCC	Stratified random design
Quashnet River	Alewife/ Blueback	None	None	Both sp.: 2004	Both sp.: 2004	Both sp.: 2004	Both sp.: 2004	Both sp.: 2004	MADMF	
Sippican River	Alewife	Electronic Counter	Combined Passage (1995-2002; 2006)	None	None	None	None	None	AA MADMF	Counter not installed from 2003-2005 & 2007 (high water) 2008 & 2009 (counter was used to replace failed counter on Matt. River; 2010 (plans to replace existing ladder)
South River	Alewife/ Blueback	Visual	Combined Passage (2006, 2008, 2010)	None	None	None	None	None	NSRWA	No statistical design
Stony Brook	Alewife/ Blueback	Visual	Combined Passage 2007 - present	Alewife (2004)	Alewife (2004)	Alewife (2004)	Alewife (2004)	Alewife (2004)	MADMF APCC	Stratified random design
Town Brook	Alewife/ Blueback	Visual (2008 - present) Video (2008 - 2009)	Combined Passage (2008 - present)	Alewife (2004-2010) Blueback (2004)	Alewife (2004-2010) Blueback (2004)	Alewife (2004-2010) Blueback (2004)	Alewife (2004-2010) Blueback (2004)	Alewife (2004-2010) Blueback (2004)	MADMF Plymouth UMASS	No statistical design
Town River	Alewife/ Blueback	Electronic Counter	Combined Passage (2000 - present)	None	None	None	None	None	Bridgewater	
Trunk River	Alewife	Visual	Escapement (2009, 2010)	None	None	None	None	None	Falmouth	No statistical design
Wankinco River	Alewife/ Blueback	Electronic Counter	Combined Passage (2007 - present)	None	None	None	None	None	Wareham MADMF CSBB	
Ocean North of Cape Cod	Alewife/ Blueback	Trawl Survey	Age-1 Relative Abund: 1978-2010	Both sp.: 1978-2010	Agreggate for both spp.: 1978 - 2010	None	None	None	MADMF	
Ocean South of Cape Cod	Alewife/ Blueback	Trawl Survey	Age-1 Relative Abund: 1978-2010	Both sp.: 1978-2010	Agreggate for both spp.: 1978 - 2010	None	None	None	MADMF	

Appendix Table 7.4. Passage, total and removal numbers of river herring from select Massachusetts rivers.

Mattapoisett River

	Alewife	
Year	Passage	Removals
1972		
1973		
1974		
1975		
1976		
1977		
1978		
1979		
1980		
1981		
1982		
1983		
1984		
1985		
1986		
1987		
1988	22,000	0
1989	40,000	3,000
1990	47,000	3,960
1991	47,000	16,320
1992	44,000	3,960
1993	44,000	12,000
1994	44,000	24,000
1995	75,000	6,000
1996	58,000	6,000
1997		
1998	104,000	6,000
1999	107,000	2,500
2000	130,000	2,500
2001	77,000	0
2002	50,000	0
2003	25,000	0
2004	5,385	0
2005	8,000	0
2006	6,270	0
2007	6,011	0
2008	9,987	0
2009	10,356	0
2010	12,319	0

Monument River

	Blueback	Alewife	Combined
Year	Total Count	Total Count	Removals
1972			
1973			
1974			
1975			
1976			
1977			
1978			
1979			
1980	20,357	70,736	62,280
1981	49,483	85,796	33,480
1982			
1983			
1984	104,645	130,709	97,000
1985	53,715	124,316	47,000
1986	75,734	110,803	31,320
1987	52,686	122,935	49,350
1988			35,280
1989			17,520
1990	62,397	269,502	53,950
1991	99,646	245,151	53,880
1992	24,017	280,001	73,002
1993	39,117	213,249	56,380
1994	9,665	134,590	56,210
1995	37,912	395,201	66,513
1996	59,008	477,432	93,339
1997	53,855	345,074	83,045
1998	36,210	292,970	80,881
1999	21,754	191,516	70,973
2000	73,902	597,937	29,859
2001	46,478	400,422	32,552
2002	25,530	182,031	49,211
2003	70,181	116,718	18,990
2004	39,602	121,184	23,954
2005	22,944	79,483	1,192
2006	22,192	52,472	0
2007	8,140	69,385	0
2008	18,532	84,196	0
2009	30,536	154,532	0
2010	9,358	96,355	0

Nemasket River

	Alewife	
Year	Passage	Removals
1972		
1973		
1974		
1975		
1976		
1977		
1978		
1979		
1980		
1981		
1982		
1983		
1984		
1985		
1986		
1987		
1988		
1989		
1990		
1991		
1992		
1993		
1994		
1995		
1996	1,094,860	
1997		
1998	866,538	64,200
1999	1,043,906	114,632
2000	1,069,000	75,426
2001	476,779	61,668
2002	1,919,000	101,302
2003	793,000	80,971
2004	578,000	72,763
2005	401,000	43,741
2006	505,000	0
2007	659,880	0
2008	848,848	0
2009	760,717	0
2010	763,884	0

Appendix Table 7.4 cont.

Year	Parker River Combined Passage	Marston-Mills Combined Passage	Stony Brook Combined Passage	Agawam Combined Passage	Wankinco Combined Passage	Sippican Combined Passage	Town River Combined Passage	Pilgrim Lake Alewife Passage	Herring R. (Harwich) Combined Passage	Herring R. (Wellfleet) Combined Passage
1972	12,097									
1973	38,163									
1974	34,163									
1975	24,539									
1976	13,998									
1977	6,654									
1978	13,116									
1979										
1980										
1981										
1982										
1983										
1984										
1985										
1986										
1987										
1988										
1989										
1990										
1991										
1992										
1993										
1994										
1995						326				
1996						680				
1997	6,396					610				
1998	4,242					671				
1999	7,965									
2000	7,894					959	72,000			
2001	2,244					558	33,000			
2002	3,500					359	193,069			
2003	1,500						310,000			
2004	1,447						25,000			
2005	747						65,826			
2006	500			53,173		89				
2007	60	13,996	30,252	100,473	2,788		53,315			
2008	485		33,383	30,429	8,246		27,783	1,525		
2009	800		19,197	36,354	6,539		8,596	906	23,537	31,589
2010	1,800		71,026	30,057	10,665		29,465			

Parker River: Detrition of stream weirs affected 2006-2007

Appendix Table 7.5. Length frequencies of alewife and blueback herring from various rivers by sex and year. Length intervals are 10-mm total length bins with the label equal to the lower limit of the bin.

Alewife

Back River

	2004		2005		2006		2007		2008		2009		2010	
TL mm	M	F	M	F	M	F	M	F	M	F	M	F	M	F
190														
200														
210														
220														
230														
240							1	5						
250							19	16						
260							59	57						
270							78	64						
280							54	48						
290							15	15						
300							2	5						
310														
320								1						
330														
340														
Total	0	0	0	0	0	0	228	211	0	0	0	0	0	0

Mattapoisett River

	1995		2004		2005		2006		2007		2008		2009		2010	
TL mm	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
190																
200																
210																
220									1							
230																
240	1						3									
250	4						11	2	1	2						
260	12	5					14	9	6	3						
270	19	8					3	7	3	4						
280	7	6					2	4	3	8						
290	8	18					2	2		5						
300	2	7								1						
310	1	6								1						
320																
330																
340																
Total	54	50	0	0	0	0	35	24	14	24	0	0	0	0	0	0

Mystic River

	2004		2005		2006		2007		2008		2009		2010	
TL mm	M	F	M	F	M	F	M	F	M	F	M	F	M	F
190														
200														
210	1				6				1					
220	7			1	3		6	2	1	1	2			
230	16	8	2		3	2	29	6	21	7	6	3	1	
240	10	6			9	7	44	28	28	8	13	8	7	8
250	12	8	3	2	1	5	35	36	25	11	27	22	2	10
260	12	15	2	2	2	7	10	26	28	14	13	15	2	7
270	9	15	2	4		7	12	21	3	9	1	12	2	
280	3	4		2		1	3	10	1			4		
290	1							3		2				
300			1	1				2		1		1		1
310														
320														
330														
340														
Total	71	56	10	12	24	29	139	134	108	53	62	65	14	26

Nemasket River

	2004		2005		2006		2007		2008		2009		2010	
TL mm	M	F	M	F	M	F	M	F	M	F	M	F	M	F
190														
200														
210							1							
220									1					
230			1		1								1	
240	1		6	2	19	1	1		14		4	1	2	
250	10	1	25	7	51	9	21	15	47	9	74	7	29	8
260	20	9	30	21	59	35	84	51	76	17	106	30	81	27
270	23	16	40	40	40	43	131	76	64	66	77	72	96	62
280	35	31	19	25	18	19	96	67	39	67	40	51	51	78
290	34	28	17	19	6	14	45	29	17	33	11	23	15	45
300	14	29	9	10	2	2	14	14	1	15	1	6	1	5
310	2	11		6	1	4		2		5		1		6
320		2					1	1		1				
330														
340														
Total	139	127	147	130	197	127	394	255	259	213	313	191	276	231

Appendix Table 7.5 cont.

Alewife

Quashnet River

	2004		2005		2006		2007		2008		2009		2010	
TL mm	M	F	M	F	M	F	M	F	M	F	M	F	M	F
190														
200														
210														
220														
230	2	1												
240	11	2												
250	20	13												
260	18	21												
270	11	26												
280	4	20												
290		4												
300														
310														
320														
330														
340														
Total	66	87	0	0	0	0	0	0	0	0	0	0	0	0

Stony Brook

	2004		2005		2006		2007		2008		2009		2010	
TL mm	M	F	M	F	M	F	M	F	M	F	M	F	M	F
190														
200														
210														
220														
230	2	1												
240	14	3												
250	23	6												
260	34	12												
270	30	36												
280	13	24												
290	1	14												
300		1												
310														
320														
330														
340														
Total	117	97	0	0	0	0	0	0	0	0	0	0	0	0

Town Brook

	2004		2005		2006		2007		2008		2009		2010	
TL mm	M	F	M	F	M	F	M	F	M	F	M	F	M	F
190														
200														
210	1								1					
220	1		3	1	5				3	1	1			
230	5	2	8	3	10	4	9	2	10	3	13	1	6	1
240	12	1	33	9	27	12	43	6	43	16	35	14	45	4
250	16	12	62	32	50	23	74	32	83	35	82	42	85	25
260	25	20	30	44	34	46	108	78	70	74	70	56	85	64
270	22	40	14	31	11	36	60	73	31	49	37	63	44	79
280	3	16	4	13		5	15	40	12	20	7	22	9	38
290		3		9		2		14	4	6		11	3	14
300		1		1			1			3		3		2
310													1	
320								1						
330														
340														
Total	85	95	154	143	137	128	310	246	257	207	245	212	278	227

Agawam

	1991	
TL mm	M	F
190		
200		
210		
220		
230		
240	6	
250	13	1
260	23	8
270	23	18
280	14	25
290	6	13
300	1	5
310		1
320		
330		
340		
Total	86	71

Appendix Table 7.5 cont.

Blueback

Mystic River

	2004		2005		2006		2007		2008		2009		2010	
TL mm	M	F	M	F	M	F	M	F	M	F	M	F	M	F
190					1				3					
200			2		1		2		6		8			
210					17		1		8		21		3	
220			14	2	41		36	8	43	4	49	3	37	1
230			22	11	37	5	97	50	50	4	145	37	112	25
240			14	13	28	16	70	64	28	5	87	74	105	43
250			5	18	3	8	31	60	14	10	19	29	27	38
260			2	13	1	3	5	25	3	5	1	6	3	10
270				3		1	1	7	2					1
280								3						
290														
300														
310				5										
320														
330														
340														
Total	0	0	59	65	129	33	243	217	157	28	330	149	287	118

Quashnet River

	2004		2005		2006		2007		2008		2009		2010	
TL mm	M	F	M	F	M	F	M	F	M	F	M	F	M	F
190														
200														
210														
220	2													
230	2													
240	1													
250		2												
260		1												
270														
280														
290														
300														
310														
320														
330														
340														
Total	5	3	0	0	0	0	0	0	0	0	0	0	0	0

Town Brook

	2004		2005		2006		2007		2008		2009		2010	
TL mm	M	F	M	F	M	F	M	F	M	F	M	F	M	F
190														
200														
210														
220														
230			3	1										
240			2											
250			1											
260		1	1											
270														
280														
290														
300														
310														
320														
330														
340														
Total	0	1	7	1	0	0	0	0	0	0	0	0	0	0

	Agawam		Charles				Nemasket	
	1991		1985		1993		2004	
TL mm	M	F	M	F	M	F	M	F
190								
200					3			
210					10	3		
220	2				16	1	1	
230	2	1	3		7	5	1	
240			16	2	8	4		
250	1		19	10	7	9		
260	2	3	16	20	5	16		
270		2	8	11	4	15		
280			1	14	1	9		
290						2		
300				7		4		
310				3				
320				1				
330				1				
340				1				
Total	7	6	63	70	61	68	2	0

Appendix Table 7.6. Length frequencies of alewife and blueback herring by sex and year from the Monument River. Length bins are +/- 2.5 mm total length around the midpoint shown.

Alewife Male

Total Length (mm)	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
205																											
210																											
215																											
220																											
225											1			1			1								1	1	
230		1									2	1		4		1	3	1					2	1	7	2	
235							2		2		7	2		2	1	9	10	2	2	1	2	2	3	3	20	3	1
240							1	2	2	4	10	2	3	10	4	12	14	2	4	1	4	4	7	14	37	11	15
245	1	2	1				4	12	2	1	12	11	10	11	4	13	24	6	6	3	3	5	10	18	39	9	25
250	1	2		3			9	16	6	3	26	20	8	20	15	22	19	15	5	6	9	10	15	24	47	25	32
255	4	4	2	2			9	22	8	14	16	24	16	22	16	28	27	21	19	7	15	15	15	32	34	42	38
260	5	6	3	3			9	26	18	11	22	25	29	18	12	23	12	18	27	5	13	16	6	38	36	28	51
265	8	9	8	11			14	21	14	15	20	24	46	31	15	13	15	23	16	9	16	12	3	40	24	16	50
270	11	6	7	8			17	25	20	12	8	10	38	33	13	5	4	12	20	8	13	10		22	22	12	26
275	14	7	4	11			26	33	8	8	7	3	27	19	8	2	3	10	15	2	13	3		13	11	6	15
280		14	8	15			14	25	6	6	4	1	8	10	8	3			12	3	4	3		12	5	2	5
285	10	10	14	17			5	8	4	4	4		7	9	2			2	7		2	1		2	3		3
290	16	9	5	9			8	6	3	1			4	6	2						1					1	2
295	14	4	16	7			3	7					1	1	1							1		1			
300	8	2	8	5			3	2																			1
305	2	1	3	4																							
310	2	6		3																							
315			3	1																							
320			1																								
325																											
330																											
Total	96	83	83	99			124	205	93	79	139	123	197	197	101	131	132	112	133	45	95	82	61	220	286	158	264

Alewife Female

Total Length (mm)	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
205																											
210																											
215																											
220																			1								
225																											
230											2						2										
235																2	2	1					1		9		
240							1			1	1	1	1		1	3	4	2				1	3	2	5	2	2
245							1				6	2		6	3		4	7		2		0	1	6	13	3	4
250							1	3	1	3	11	3	2	3	1	9	5	7	3	3	2	10	8	12	20	6	3
255							6	5	6	5	10	10	3	7	10	11	16	10	7	1	6	8	8	14	27	22	11
260		3		1			4	6	8	11	15	14	16	13	5	13	17	12	5	1	12	8	8	20	23	28	29
265	3	2	4	2			8	12	12	10	14	15	19	16	9	11	20	15	7	8	12	9	10	26	22	32	37
270	4	3	2				10	18	14	16	15	11	23	25	11	9	18	16	17	10	12	14	3	29	34	29	30
275	6	5	3	9			12	17	16	21	16	10	15	30	11	10	16	13	15	7	8	7	5	35	12	18	36
280	10	13	9	18			20	18	14	14	14	12	23	25	9	7	10	5	23	7	5	6	6	14	17	11	39
285	11	12	5	22			23	13	9	7	8	9	18	23	10	2	3	8	13	3	8	3	1	15	7	6	17
290	14	14	10	7			22	19	8	3	4	3	5	14	7			1	10	1	4		2	3	2		5
295	18	20	13	9			10	19	4	1	4		7	5	7	1		1	5	1	2		2	4	1		1
300	20	13	5	13			9	13	4		1	1	4	5	4	1		1	2		1			4	1		2
305	17	8	11	8			3	8			1	1	1	2	2										1		
310	11	7	12	5			4	7																1	0		
315	11	3	5	12				2	1																		
320	1	1	3	6			1	1																			
325	1		1	4																							
330			1																								
335			2	1																							
340			1	1																							
Total	127	104	87	118			135	161	97	92	122	92	137	174	90	79	117	99	108	44	72	66	58	185	194	157	216

Appendix Table 7.6 cont.

Blueback Male

Total Length (mm)	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
200																									1		
205							1									1								1			
210														0		1				2		1		2	4	2	5
215							1		1	2	1		1	9		4		1		5	2	1	4	8	12	3	4
220	2			3			7	1		2		1		14	2		3	4	2	3	2	4	7	12	8	10	9
225	7			1			5	2	1		1	1	1	16	2	3	6	8	3	9	3	3	6	10	9	14	18
230	14		1	9			5	3		2	2	3	2	21	1	5	6	13	7	10	6	8	11	13	12	19	18
235	20		2	11			8	1	3		2	1	4	14	4	1	7	7	9	15	14	9	16	12	12	24	13
240	13	2	2	13			12	8	5	6	5	5	7	13		7	9	3	10	11	7	7	13	12	11	14	8
245		3	3	5			11	9	1	2	5	4	11	12	2	9	3	6	13	13	8	9	2	12	2	4	2
250	13	2	3	6			14	14	3	6	3	3	5	8	1		2	1	11	4	5	7	5		1	2	3
255	8	2	5	4			23	11	3		1	1	2	8				1	11	4	1	1	1				
260	15	3	6	1			15	9	3	2	2	1	1	7			1		3		1	1					
265	17	3	9	4			9	3	1		1	1	1	2					1		1						
270	7	8	10	3			3	2		1																	
275	5	4	8	3			1	1																			
280		2	2	3					1			1															
285	5	2																									
290	6	3		3						1																	
295	4																										
300		1																									
305	2	1																									
310																											
315																											
320																											
325																											
330																											
Total	138	36	51	69			115	64	22	24	23	22	35	124	12	31	37	44	70	76	50	51	65	82	71	92	80

Blueback Female

Total Length (mm)	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
205																											
210																											
215																						1					
220	1							1						1		1									1	1	1
225														1		1				1		1	2		4		
230	2						1				3			3				2		3	1	1	4	1	1	3	4
235	2						1	1			1			7			1	1	3	10			6	5	11	7	10
240	4		1	3			1	1			1		2	8	5		5	7	1	6	5	3	6	8	11	14	20
245				1			10	4	2	1	5	5	2	17	7		4	5	6	11	7	4	14	17	18	24	10
250	5	2	1	2			6	4	2	1		3	1	16	2	1	4	3	7	10	10	11	5	13	11	14	8
255	13	3	4	2			11	11	2	3	2	4	4	8	3	1	3	5	8	21	7	5	4	9	4	12	6
260	13	4	3	3			11	6	1	3	6	3	3	6	1		2	1	7	4	7	8	8	8	2	2	4
265	17	3	4	3			11	4	1	2	3	2	3	13				2	5	3	5	3	2	6	4	3	4
270	17	4	8	2			9	10	2		1	4	2	7			1	1	3		5	3	3				
275	8	8	5	3			7	6	1	2	2		3	8					1	1	1		2	1			
280	7	8	7	4			2	6	2	0	1			3				1	2		1			1			
285		3	6	5				3	1	1				2													
290	5	9	1	4			1	3			1																
295	3	7	2	2				1																			
300	2	3	1	1				2																			
305	1																										
310	1																										
315		1																									
320																											
325																											
330																											
Total	101	55	43	35			71	63	14	13	26	21	20	100	18	4	20	28	43	70	49	40	56	69	67	80	67

Appendix Table 7.7. Sample size (n), mean, and standard deviation (SD) of total length distributions of alewife and blueback herrings by sex collected in nine rivers , 1985-2010.

Alewife - Females

	Agawam			Back			Mattapoisett			Mystic			Nemasket			Quashnet			Stony Brook			Town Brook		
	n	Mean Length	SD	n	Mean Length	SD	n	Mean Length	SD	n	Mean Length	SD	n	Mean Length	SD	n	Mean Length	SD	n	Mean Length	SD	n	Mean Length	SD
1991	71	282.2	11.88																					
1995							50	289.4	14.52															
2004										56	260.9	14.57	127	291.5	14.36	87	270.9	11.96	97	275.5	12.53	95	271.0	12.11
2005										12	270.7	18.69	130	280.4	15.22							143	265.9	13.67
2006							24	273.4	10.61	23	257.9	13.51	127	275.3	13.66							128	263.6	11.10
2007				211	283.9	12.69	24	282.6	13.73	134	260.3	15.83	255	278.1	12.41							246	270.2	12.18
2008										53	257.9	16.01	213	282.1	12.51							207	266.7	13.00
2009										65	260.5	13.12	191	278.3	11.33							212	268.1	12.74
2010										26	255.7	12.16	231	281.4	11.67							227	271.5	11.22

Alewife - Males

	Agawam			Back			Mattapoisett			Mystic			Nemasket			Quashnet			Stony Brook			Town Brook		
	n	Mean Length	SD	n	Mean Length	SD	n	Mean Length	SD	n	Mean Length	SD	n	Mean Length	SD	n	Mean Length	SD	n	Mean Length	SD	n	Mean Length	SD
1991	86	269.8	13.63																					
1995							54	274.9	13.94															
2004										71	250.6	18.00	141	282.6	15.15	66	259.8	11.59	117	264.4	12.56	85	259.1	14.25
2005										10	262.2	20.21	147	273.0	16.16							154	255.1	11.17
2006							35	263.1	11.51	16	237.0	13.37	197	265.1	13.35							137	253.8	11.44
2007				228	273.7	11.00	14	266.6	15.78	139	248.9	13.16	395	276.6	12.84							310	261.2	11.75
2008										108	250.9	12.03	259	269.1	13.03							257	258.5	12.79
2009										62	251.8	10.88	313	268.1	11.06							245	258.6	11.33
2010										14	252.3	11.71	276	272.1	10.67							278	260.1	11.49

Blueback - Females

	Agawam			Charles			Mystic			Nemasket			Quashnet			Town Brook		
	n	Mean Length	SD	n	Mean Length	SD	n	Mean Length	SD	n	Mean Length	SD	n	Mean Length	SD	n	Mean Length	SD
1985				70	276.8	20.58												
1991	6	262.3	16.71															
1993				68	264.1	20.18												
2004													3	259.0	4.359	1	261.0	NA
2005							61	251.5	14.31							1	232.0	NA
2006							38	242.8	13.99									
2007							217	248.0	11.77									
2008							28	247.4	12.70									
2009							150	244.2	7.76									
2010							118	247.6	9.48									

Blueback - Males

	Agawam			Charles			Mystic			Nemasket			Quashnet			Town Brook		
	n	Mean Length	SD	n	Mean Length	SD	n	Mean Length	SD	n	Mean Length	SD	n	Mean Length	SD	n	Mean Length	SD
1985				63	256.7	11.81												
1991	7	242.9	17.61															
1993				61	235.8	20.30												
2004										2	232.5	6.36	5	231.6	5.413			
2005							58	236.1	10.59							7	244.43	9.981
2006							131	230.6	11.20									
2007							243	239.0	10.04									
2008							157	233.4	14.05									
2009							333	234.7	10.42									
2010							287	238.9	8.74									

Appendix Table 7.8. Sample size (n), mean, and standard deviation (SD) of total length distributions of alewife and blueback herrings by sex collected in the Monument River, 1984-2010.

Monument River

	Alewife							Blueback Herring					
	Female			Male				Female			Male		
Year	n	Mean Length	SD	n	Mean Length	SD	Year	n	Mean Length	SD	n	Mean Length	SD
1984	127	295.6	13.17	96	281.3	14.85	1984	101	265.9	16.17	138	253.4	20.45
1985	104	291.3	12.80	83	277.8	16.72	1985	55	279.4	14.59	36	268.5	16.29
1986	87	297.5	16.51	83	284.6	15.34	1986	43	272.9	12.87	51	261.7	12.44
1987	118	295.1	16.30	99	281.1	14.25	1987	35	271.7	17.32	69	247.4	18.00
1988							1988						
1989							1989						
1990	135	282.1	14.27	124	270.0	13.87	1990	71	259.7	11.65	115	247.2	14.19
1991	161	283.4	15.49	205	267.6	13.34	1991	63	265.9	16.00	64	249.6	11.17
1992	97	275.5	12.54	93	265.2	11.69	1992	14	263.2	13.67	22	246.8	14.35
1993	92	271.2	10.36	79	264.7	11.28	1993	13	261.9	11.09	24	243.3	17.24
1994	122	267.8	14.55	139	256.2	12.65	1994	26	255.6	15.90	23	242.8	11.66
1995	92	269.2	12.45	123	257.4	8.99	1995	21	256.4	9.24	22	243.6	13.64
1996	137	274.6	11.95	197	265.8	10.48	1996	20	259.0	11.19	35	242.9	9.57
1997	174	274.9	12.77	197	262.7	13.97	1997	100	254.1	14.40	124	235.4	13.24
1998	90	274.8	15.27	101	262.3	12.42	1998	18	246.7	6.18	12	233.3	9.85
1999	79	263.9	12.78	131	253.5	10.44	1999	4	237.5	17.56	31	232.9	12.23
2000	117	263.5	12.02	132	251.1	10.58	2000	20	248.5	8.75	37	234.9	9.17
2001	99	265.5	13.01	112	259.7	10.22	2001	28	248.8	11.83	44	232.4	8.92
2002	108	275.4	12.72	133	264.2	11.62	2002	43	255.7	11.10	70	243.2	10.36
2003	44	270.5	11.35	45	260.7	10.80	2003	70	248.1	10.01	76	234.9	11.04
2004	72	270.8	11.59	95	262.4	11.17	2004	49	254.8	10.71	50	242.9	10.07
2005	66	265.1	10.73	82	259.2	11.17	2005	40	251.9	11.82	51	242.4	10.72
2006	58	263.7	14.04	61	249.4	7.89	2006	56	247.9	12.31	65	238.0	9.51
2007	185	269.1	12.88	220	259.4	11.41	2007	69	250.3	10.04	82	235.0	10.55
2008	194	262.6	13.75	286	253.0	12.23	2008	67	244.1	9.52	72	232.5	10.78
2009	157	265.5	9.54	158	256.2	10.23	2009	80	246.0	8.07	92	236.3	8.47
2010	216	270.7	10.70	264	259.4	10.84	2010	67	244.3	9.66	80	233.7	9.20

Appendix Table 7.9 Age composition of alewife and blueback herring from Massachusetts rivers, 2004-2010.

Alewife

Back River

	Female							Male						
Age	2004	2005	2006	2007	2008	2009	2010	2004	2005	2006	2007	2008	2009	2010
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	34	0	0	0	0	0	0	36	0	0	0
4	0	0	0	119	0	0	0	0	0	0	152	0	0	0
5	0	0	0	48	0	0	0	0	0	0	35	0	0	0
6	0	0	0	5	0	0	0	0	0	0	4	0	0	0
7	0	0	0	3	0	0	0	0	0	0	1	0	0	0
8	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	210	0	0	0	0	0	0	228	0	0	0

Quashnet River

	Female							Male						
Age	2004	2005	2006	2007	2008	2009	2010	2004	2005	2006	2007	2008	2009	2010
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	1	0	0	0	0	0	0	11	0	0	0	0	0	0
4	61	0	0	0	0	0	0	48	0	0	0	0	0	0
5	23	0	0	0	0	0	0	6	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	85	0	0	0	0	0	0	65	0	0	0	0	0	0

Mattapoisett River

	Female								Male							
Age	1995	2004	2005	2006	2007	2008	2009	2010	1995	2004	2005	2006	2007	2008	2009	2010
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	4	0	0	9	0	0	0	0	9	0	0	15	0	0	0	0
4	20	0	0	9	0	0	0	0	26	0	0	16	0	0	0	0
5	13	0	0	5	0	0	0	0	10	0	0	4	0	0	0	0
6	9	0	0	1	0	0	0	0	9	0	0	0	0	0	0	0
7	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	50	0	0	24	0	0	0	0	54	0	0	35	0	0	0	0

Stony Brook

	Female							Male						
Age	2004	2005	2006	2007	2008	2009	2010	2004	2005	2006	2007	2008	2009	2010
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	7	0	0	0	0	0	0	22	0	0	0	0	0	0
4	40	0	0	0	0	0	0	60	0	0	0	0	0	0
5	43	0	0	0	0	0	0	33	0	0	0	0	0	0
6	6	0	0	0	0	0	0	1	0	0	0	0	0	0
7	1	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	97	0	0	0	0	0	0	116	0	0	0	0	0	0

Mystic River

	Female							Male						
Age	2004	2005	2006	2007	2008	2009	2010	2004	2005	2006	2007	2008	2009	2010
2	1	0	0	0	0	0	0	1	0	0	0	0	0	0
3	4	0	1	37	10	4	14	25	2	6	57	39	5	9
4	40	5	9	75	25	30	9	34	4	3	68	56	35	2
5	9	6	4	7	10	18	3	10	3	1	7	11	14	2
6	2	1	1	5	8	4	0	1	1	0	1	2	4	1
7	0	0	0	2	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	56	12	15	126	53	56	26	71	10	10	133	108	58	14

Town Brook

	Female							Male						
Age	2004	2005	2006	2007	2008	2009	2010	2004	2005	2006	2007	2008	2009	2010
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	5	20	25	27	4	2	20	17	16	45	61	24	10	47
4	52	79	75	164	81	65	69	50	104	80	190	113	91	73
5	35	26	26	38	89	75	63	14	27	11	45	94	74	47
6	1	3	0	13	28	27	25	2	5	0	10	24	27	12
7	1	1	0	0	4	8	2	0	1	0	1	2	4	1
8	0	0	0	1	1	0	0	0	0	0	0	0	0	0
Total	94	129	126	243	207	177	179	83	153	136	307	257	206	180

Nemasket River

	Female							Male						
Age	2004	2005	2006	2007	2008	2009	2010	2004	2005	2006	2007	2008	2009	2010
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	4	27	22	2	0	22	4	10	62	41	36	8	42
4	23	50	56	163	38	48	80	39	50	91	257	76	118	88
5	52	54	34	59	134	60	71	65	63	31	82	110	96	51
6	40	19	6	5	34	36	14	30	17	9	12	36	29	7
7	8	1	1	1	5	4	2	1	6	1	1	1	1	1
8	0	1	0	1	0	0	0	0	0	1	0	0	0	0
Total	123	129	124	251	213	148	189	139	146	195	393	259	252	189

Agawam

	Female	Male
Age	1991	1991
2	0	
3	1	6
4	35	49
5	28	27
6	6	4
7	1	0
8	0	0
Total	71	86

Appendix Table 7.9 cont.

Blueback

Mystic River

Age	Female 2004	2005	2006	2007	2008	2009	2010	Male 2004	2005	2006	2007	2008	2009	2010
2	0	0	0	0	0	0	0	0	0	0	0	5	22	1
3	0	3	2	62	4	75	71	0	18	42	81	55	207	135
4	0	32	18	94	12	49	44	0	22	58	125	67	54	41
5	0	3	9	49	8	9	2	0	2	10	30	23	15	2
6	0	2	2	7	3	3	1	0	0	0	1	6	2	0
7	0	0	0	1	1	0	0	0	0	0	0	1	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	0	40	31	213	28	136	118	0	42	110	237	157	300	180

Town Brook

Age	Female 2004	2005	2006	2007	2008	2009	2010	Male 2004	2005	2006	2007	2008	2009	2010
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	2	0	0	0	0	0
4	1	1	0	0	0	0	0	0	4	0	0	0	0	0
5	0	0	0	0	0	0	0	0	1	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	1	1	0	0	0	0	0	0	7	0	0	0	0	0

Quashnet River

Age	Female 2004	2005	2006	2007	2008	2009	2010	Male 2004	2005	2006	2007	2008	2009	2010
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	3	0	0	0	0	0	0
4	2	0	0	0	0	0	0	2	0	0	0	0	0	0
5	1	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	3	0	0	0	0	0	0	5	0	0	0	0	0	0

Agawam

Age	Female 1991	Male 1991
2	0	0
3	0	1
4	3	2
5	2	2
6	1	2
7	0	0
8	0	0
Total	6	7

Charles

Age	Female 1985	1993	Male 1985	1993
2	0	0	0	1
3	2	3	7	22
4	21	23	30	28
5	26	29	19	5
6	8	9	6	5
7	6	3	1	2
8+	7	1	0	0
Total		68		63

Appendix Table 7.10. Age composition of alewife and blueback herring from the Monument River, 1985-2010.

Alewife

Female

Age	1985	1986	1987	1993	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	7	2	1	0	5	0	2	1	6	6	5	8	3	2	6	10	52	18	1	30
4	28	29	38	24	43	60	20	29	18	77	60	35	34	53	35	26	97	89	80	61
5	29	30	32	19	17	23	22	35	13	18	24	45	17	17	24	17	22	69	48	83
6	5	19	20	7	11	5	5	14	0	4	4	6	4	0	1	4	3	16	12	6
7	4	5	15	1	0	0	0	1	0	0	1	0	0	0	0	0	4	1	0	0
8	3	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Total	76	86	110	51	76	88	49	80	37	105	94	94	58	72	66	57	178	194	141	180

Male

Age	1985	1986	1987	1993	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	17	10	2	6	34	25	16	6	17	13	16	23	6	6	9	24	93	83	11	64
4	26	40	39	21	48	59	30	56	20	83	60	62	44	71	54	32	100	129	88	77
5	12	27	34	13	12	22	9	25	11	15	29	36	16	15	17	5	16	65	30	37
6	8	5	13	4	2	3	4	6	1	1	2	1	2	0	2	0	2	8	8	1
7	2	1	2	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	65	83	90	44	96	109	59	94	49	112	107	122	69	92	82	61	211	286	137	179

Blueback

Female

Age	1985	1986	1987	1993	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	9	0	4	0	0	0	1	0	0	1	2	0	5	5	11	5	11	7	13	30
4	22	14	1	5	7	10	30	12	3	9	14	29	44	30	14	33	48	46	45	29
5	19	19	16	4	8	5	16	2	1	9	7	9	19	13	14	18	9	12	13	8
6	2	5	7	1	3	1	3	0	1	0	0	2	0	0	0	0	0	0	3	0
7	1	1	3	1	0	0	2	0	0	0	0	0	0	0	0	0	0	2	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	53	39	31	11	18	16	52	14	5	19	23	40	68	48	39	56	68	67	74	67

Male

Age	1985	1986	1987	1993	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
3	12	5	8	1	1	6	25	4	5	6	17	9	13	14	8	14	44	22	31	60
4	17	32	31	11	7	11	27	5	22	16	14	40	48	31	33	40	31	44	37	15
5	5	14	16	2	8	4	5	2	2	6	9	10	8	3	9	11	6	5	17	5
6	2	0	4	1	0	2	1	0	0	0	1	0	0	0	1	0	0	0	0	0
7	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	36	51	60	15	16	24	58	11	29	28	41	59	69	48	51	65	81	72	85	80

Appendix Table 7.11. Average age (years) of alewife and blueback herring collected by sex, river and year. *=not calculated due to small sample size.

Alewife

Female

River	1971	1972	1973	1974	1975	1976	1977	1978	1985	1986	1987	1991	1993	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Agawam	-	-	-	-	-	-	-	-	-	-	-	4.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Back	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.2	-	-	-
Mattapoisett	-	-	-	-	-	-	-	-	-	-	-	-	-	4.8	-	-	-	-	-	-	-	-	-	-	3.9	-	-	-	-
Monument	-	-	-	-	-	-	-	-	4.7	5.0	5.2	-	4.7	4.4	4.4	4.6	4.8	4.2	4.2	4.3	4.5	4.4	4.2	4.3	4.3	3.9	4.5	4.5	4.4
Mystic	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.1	4.7	4.4	3.9	4.3	4.4	3.6
Nemasket	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.3	4.8	4.2	4.4	5.0	5.0	4.4
Parker	6.0	5.2	4.3	4.5	5.3	5.7	5.1	4.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Quashnet	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.3	-	-	-	-	-	-
Stony Brook	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.5	-	-	-	-	-	-
Town Brook	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.4	4.3	4.0	4.2	4.8	4.9	4.6

Male

River	1971	1972	1973	1974	1975	1976	1977	1978	1985	1986	1987	1991	1993	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Agawam	-	-	-	-	-	-	-	-	-	-	-	4.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Back	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.0	-	-	-
Mattapoisett	-	-	-	-	-	-	-	-	-	-	-	-	-	4.4	-	-	-	-	-	-	-	-	-	-	3.7	-	-	-	-
Monument	-	-	-	-	-	-	-	-	4.3	4.4	4.7	-	4.3	3.8	4.0	4.0	4.4	3.9	4.0	4.2	4.1	4.2	4.1	4.1	3.7	3.7	4.0	4.3	3.9
Mystic	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.8	4.3	3.5	3.6	3.8	4.3	3.6
Nemasket	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.9	4.7	4.0	4.1	4.6	4.6	4.1
Parker	5.7	4.2	4.0	4.5	5.0	5.4	5.1	4.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Quashnet	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.9	-	-	-	-	-	-
Stony Brook	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.1	-	-	-	-	-	-
Town Brook	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.0	4.0	3.8	4.0	4.5	4.6	4.2

Blueback

Female

River	1971	1972	1973	1974	1975	1976	1977	1978	1985	1986	1987	1991	1993	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Agawam	-	-	-	-	-	-	-	-	-	-	-	4.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Charles	-	-	-	-	-	-	-	-	5.2	-	-	-	4.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Monument	-	-	-	-	-	-	-	-	4.3	4.8	5.1	-	4.8	4.8	4.4	4.5	4.1	4.6	4.4	4.2	4.3	4.2	4.2	4.1	4.2	4.0	4.2	4.1	3.7
Mystic	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.1	4.4	4.0	4.5	3.6	3.4
Quashnet	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-
Town Brook	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-	-

Male

River	1971	1972	1973	1974	1975	1976	1977	1978	1985	1986	1987	1991	1993	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Agawam	-	-	-	-	-	-	-	-	-	-	-	4.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Charles	-	-	-	-	-	-	-	-	4.4	-	-	-	4.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Monument	-	-	-	-	-	-	-	-	3.9	4.2	4.3	-	4.2	4.4	4.0	3.7	3.8	3.9	4.0	3.9	4.0	3.9	3.8	4.1	4.0	3.5	3.7	3.8	3.3
Mystic	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.5	3.7	3.8	3.8	3.2	3.3
Quashnet	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-
Town Brook	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-	-

Appendix Table 7.12. Repeat spawner frequencies for alewife and blueback herring by river, sex and year. 0 = new spawner, 1=second-time spawner, 2= third-time spawner, etc.

Alewife

Back River

	Female							Male						
RPS	2004	2005	2006	2007	2008	2009	2010	2004	2005	2006	2007	2008	2009	2010
0	0	0	0	186	0	0	0	0	0	0	202	0	0	0
1	0	0	0	16	0	0	0	0	0	0	23	0	0	0
2	0	0	0	7	0	0	0	0	0	0	3	0	0	0
3	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	210	0	0	0	0	0	0	228	0	0	0

Quashnet River

	Female							Male						
RPS	2004	2005	2006	2007	2008	2009	2010	2004	2005	2006	2007	2008	2009	2010
0	79	0	0	0	0	0	0	62	0	0	0	0	0	0
1	6	0	0	0	0	0	0	3	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	85	0	0					65	0	0				

Mattapoisett River

	Female								Male							
RPS	1995	2004	2005	2006	2007	2008	2009	2010	1995	2004	2005	2006	2007	2008	2009	2010
0	33	0	0	23	0	0	0	0	44	0	0	34	0	0	0	0
1	14	0	0	1	0	0	0	0	9	0	0	1	0	0	0	0
2	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total		0	0	24	0	0	0	0		0	0	35	0	0	0	0

Stony Brook

		Female							Male						
RPS		2004	2005	2006	2007	2008	2009	2010	2004	2005	2006	2007	2008	2009	2010
0		77	0	0	0	0	0	0	102	0	0	0	0	0	0
1		17	0	0	0	0	0	0	13	0	0	0	0	0	0
2		2	0	0	0	0	0	0	1	0	0	0	0	0	0
3		1	0	0	0	0	0	0	0	0	0	0	0	0	0
Total		97	0	0	0	0	0	0	116	0	0	0	0	0	0

Mystic River

	Female							Male						
RPS	2004	2005	2006	2007	2008	2009	2010	2004	2005	2006	2007	2008	2009	2010
0	36	11	15	110	40	40	22	48	7	10	125	91	46	12
1	18	0	0	12	7	14	3	19	3	0	7	16	10	2
2	1	1	0	3	5	2	1	4	0	0	2	0	2	0
3	1	0	0	1	1	0	0	0	0	0	0	1	0	0
Total	56	12	15	126	53	56	26	71	10	10	134	108	58	14

Town Brook

	Female							Male						
RPS	2004	2005	2006	2007	2008	2009	2010	2004	2005	2006	2007	2008	2009	2010
0	81	110	116	202	146	122	142	69	134	130	237	174	140	150
1	11	18	10	37	50	50	30	13	17	6	64	70	58	21
2	0	2	0	3	11	5	7	1	2	0	6	13	6	9
3	2	0	0	1	0	0	0	0	0	0	0	0	2	0
Total	94	130	126	243	207	177	179	83	153	136	307	257	206	180

Nemasket River

	Female							Male						
RPS	2004	2005	2006	2007	2008	2009	2010	2004	2005	2006	2007	2008	2009	2010
0	70	98	112	218	167	103	146	78	104	176	347	207	208	159
1	31	24	11	30	37	42	35	34	30	15	47	43	38	25
2	21	5	1	3	8	3	8	24	8	3	0	9	4	5
3	1	2	0	1	1	0	0	3	4	1	0	0	2	0
Total	123	129	124	252	213	148	189	139	146	195	394	259	252	189

Agawam

	Fem	Male
RPS	1991	1991
0	63	77
1	6	9
2	2	0
3	0	0
Total	71	86

Appendix Table 7.12 cont.

Blueback

Mystic River

	Females							Males						
RPS	2004	2005	2006	2007	2008	2009	2010	2004	2005	2006	2007	2008	2009	2010
0	0	36	26	180	18	120	100	0	33	87	195	114	262	156
1	0	0	3	27	6	15	17	0	2	23	37	34	37	22
2	0	1	2	6	3	1	1	0	0	0	5	7	2	1
3	0	0	0	0	1	0	0	0	0	0	0	2	0	0
Total	0	37	31	213	28	136	118	0	35	110	237	157	301	179

Quashnet River

	Females							Males						
RPS	2004	2005	2006	2007	2008	2009	2010	2004	2005	2006	2007	2008	2009	2010
0	3	0	0	0	0	0	0	5	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	3	0	0	0	0	0	0	5	0	0	0	0	0	0

Town Brook

	Females							Males						
RPS	2004	2005	2006	2007	2008	2009	2010	2004	2005	2006	2007	2008	2009	2010
0	1	1	0	0	0	0	0	0	7	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	1	1	0	0	0	0	0	0	7	0	0	0	0	0

Agawam

	Fem	Male
RPS	1991	1991
0	6	7
1	0	0
2	0	0
3	0	0
Total	6	7

Charles

	Female		Male	
RPS	1985	1993	1985	1993
0	32	37	32	47
1	18	18	21	10
2	10	11	10	4
3	3	0	0	2
4	7	0	0	0
Total	70	66	63	63

Appendix Table 7.13. Repeat spawner frequencies for alewife and blueback herring from the Monument River by sex and year. 0 = new spawner, 1=second-time spawner, 2= third-time spawner, etc.

Alewife

Female

RPS	1986	1987	1993	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
0	47	62	41	70	72	35	47	33	97	81	67	51	71	61	49	163	165	122	156
1	25	26	9	4	14	9	28	4	7	10	24	3	1	5	8	12	26	17	17
2	12	17	1	2	2	5	5	0	1	3	3	4	0	0	1	3	3	2	7
3	2	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	86	110	51	76	88	49	80	37	105	94	94	58	72	66	58	178	194	141	180

Male

RPS	1986	1987	1993	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
0	51	53	34	91	83	46	67	43	101	88	84	56	87	79	58	198	250	123	167
1	24	27	9	4	26	8	22	6	10	18	34	10	5	3	3	13	34	14	11
2	8	9	1	1	0	5	5	0	1	1	3	3	1	0	0	0	2	0	1
3	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Total	83	90	44	96	109	59	94	49	112	107	122	69	93	82	61	211	286	137	179

Blueback

Female

RPS	1986	1987	1993	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
0	24	19	9	16	15	43	14	4	19	23	37	66	46	37	48	67	63	70	66
1	12	7	1	2	1	9	0	1	0	0	3	2	2	2	8	1	4	4	1
2	2	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	39	31	11	18	16	52	14	5	19	23	40	68	48	39	56	68	67	74	67

Male

RPS	1986	1987	1993	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
0	40	48	13	15	20	58	8	26	28	40	51	67	45	48	56	76	68	82	79
1	10	9	1	1	4	0	3	3	0	1	8	2	3	3	9	5	4	3	1
2	1	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	51	60	15	16	24	58	11	29	28	41	59	69	48	51	65	81	72	85	80

Appendix Table 7.14. Yearly estimates of instantaneous total mortality (Z) from age-repeat spawner frequency and length data for alewives and blueback herring from Massachusetts Rivers by sex.

Alewife

Females

Chapman-Robson Z Estimates (Age Data)

Year	Agawam	Back	Mattapoisett	Monument	Mystic	Nemasket	Parker	Stony	Town
1971							1.00		
1972									
1973							1.33		
1974									
1975									
1976									
1977							1.01		
1978							1.03		
1979									
1980									
1981									
1982									
1983									
1984									
1985				1.04					
1986				0.99					
1987				0.76					
1988									
1989									
1990									
1991	0.96								
1992									
1993				0.87					
1994									
1995			0.72	1.03					
1996				1.29					
1997									
1998				1.4					
1999									
2000				1.56					
2001				1.26					
2002									
2003				1.15					
2004					1.58	1.02		1.96	1.16
2005				1.18		1.41			1.47
2006			1.1	1.04	1.15	1.08			
2007		1.24		1.42	1.57	1.39			1.44
2008				0.96	0.96	1.59			1.41
2009				1.08	1.1	1.18			1.26
2010					0.98	0.95			0.84

Chapman-Robson Z Estimates (Repeat Spawning)

Year	Back	Mattapoisett	Monument	Mystic	Nemasket	Stony	Town
1971							
1972							
1973							
1974							
1975							
1976							
1977							
1978							
1979							
1980							
1981							
1982							
1983							
1984							
1985							
1986			0.93				
1987			0.9				
1988							
1989							
1990							
1991							
1992							
1993			1.714				
1994							
1995			2.34				
1996			1.76				
1997			1.26				
1998			1.12				
1999			2.3				
2000			2.53				
2001			1.92				
2002			1.41				
2003			1.82				
2004				1.22	0.96		1.87
2005				1.87	1.55		1.73
2006			1.89		2.35		
2007	1.99		2.38	1.94	1.97		1.83
2008			1.95	1.28	1.56		1.35
2009			2.03	1.45	1.4		1.37
2010			1.91	1.81	1.54		1.62

Appendix Table 7.14 cont.

Beverton-Holt Equlibrium Z Estimates

Year	Agawam	Back	Mattapoisett	Monument	Mystic	Nemasket	Quashnet	Stony	Town
1971									
1972									
1973									
1974									
1975									
1976									
1977									
1978									
1979									
1980									
1981									
1982									
1983									
1984				0.44					
1985				0.51					
1986				0.41					
1987				0.44					
1988									
1989									
1990				0.71					
1991	0.71			0.68					
1992				0.92					
1993				1.10					
1994				1.25					
1995			0.54	1.20					
1996				0.95					
1997				0.94					
1998				0.94					
1999				1.50					
2000				1.50					
2001				1.42					
2002				0.90					
2003				1.14					
2004				1.13	1.48	0.51	1.10	0.90	1.08
2005				1.48	0.96	0.76			1.35
2006			1.00	1.43	1.92	0.91			1.51
2007		0.66	0.70	1.19	1.76	0.83			1.14
2008				1.53	1.74	0.71			1.31
2009				1.43	1.76	0.81			1.26
2010				1.12	2.58	0.73			1.08

Appendix Table 7.14 cont.

Alewife
Males

Chapman-Robson Z Estimates (Age Data)

Year	Agawam	Back	Mattapoisett	Monument	Mystic	Nemasket	Parker	Stony	Town
1971							1.29		
1972							1.49		
1973									
1974									
1975							1.54		
1976							0.95		
1977							1.01		
1978							1.21		
1979									
1980									
1981									
1982									
1983									
1984									
1985				0.87					
1986				1.03					
1987				0.84					
1988									
1989									
1990									
1991	1.18								
1992									
1993				1.02					
1994									
1995			0.94	1.57					
1996				1.38					
1997				1.24					
1998				1.16					
1999				1.22					
2000				1.91					
2001				1.32					
2002				1.28					
2003				1.31					
2004					1.54	1.38		1.3	1.53
2005				1.48	0.88	1.32			1.48
2006					1.03	1.21			
2007		1.64		1.93	2.23	1.6			1.53
2008				1.23	1.71	1.58			0.94
2009				1.31	1.21	0.93			0.87
2010				1.37	0.89	1.15			1.02

Chapman-Robson Z Estimates (Repeat Spawning)

Year	Back	Monument	Mystic	Nemasket	Stony	Town
1971						
1972						
1973						
1974						
1975						
1976						
1977						
1978						
1979						
1980						
1981						
1982						
1983						
1984						
1985						
1986		1.12				
1987		1.05				
1988						
1989						
1990						
1991						
1992						
1993		1.59				
1994						
1995		2.82				
1996		1.64				
1997		1.44				
1998		1.36				
1999						
2000		2.33				
2001		1.84				
2002		1.34				
2003		1.66				
2004		2.64	1.28	0.92		1.87
2005				1.18		
2006		1.89		2.21		
2007			2.57			1.61
2008		2.14	1.89	1.65		1.3
2009			1.62	1.75		1.31
2010		2.69		1.85		1.72

Appendix Table 7.14 cont.

				Beverton-Holt Equlibrium Z Estimates					
Year	Agawam	Back	Mattapoisett	Monument	Mystic	Nemasket	Quashnet	Stony	Town
1971									
1972									
1973									
1974									
1975									
1976									
1977									
1978									
1979									
1980									
1981									
1982									
1983									
1984				0.57					
1985				0.63					
1986				0.50					
1987				0.57					
1988									
1989									
1990				0.89					
1991	0.91			0.99					
1992				1.11					
1993				1.13					
1994				1.70					
1995			0.73	1.62					
1996				1.08					
1997				1.19					
1998				1.27					
1999				2.05					
2000				2.35					
2001				1.43					
2002				1.16					
2003				1.38					
2004				1.24	1.65	0.54	1.46	1.14	1.34
2005				1.49	1.28	0.79			1.81
2006			1.22	2.62	3.96	1.11			1.84
2007		0.77	0.89	1.46	2.40	0.67			1.34
2008				2.00	2.14	0.93			1.49
2009				1.70	2.11	0.98			1.54
2010				1.48	2.28	0.82			1.43

Appendix Table 7.14 cont.

Blueback

Females

Chapman-Robson Z Estimates (Age Data)

Year	Agawam	Charles	Monument	Mystic
1971				
1972				
1973				
1974				
1975				
1976				
1977				
1978				
1979				
1980				
1981				
1982				
1983				
1984				
1985		0.67	0.98	
1986			1.49	
1987			1.07	
1988				
1989				
1990				
1991	0.81			
1992				
1993		1.19	0.75	
1994				
1995				
1996			1.15	
1997			1.02	
1998				
1999			0.85	
2000				
2001				
2002			1.39	
2003				
2004				
2005				1.82
2006				1.15
2007				1.19
2008			1.54	0.86
2009			1.43	1.02
2010			0.90	1.19

Chapman-Robson Z Estimates (Repeat Spawning)

Year	Charles	Monument	Mystic
1971			
1972			
1973			
1974			
1975			
1976			
1977			
1978			
1979			
1980			
1981			
1982			
1983			
1984			
1985	0.63		
1986		1.1	
1987		1.02	
1988			
1989			
1990			
1991			
1992			
1993	0.9	1.47	
1994			
1995			
1996			
1997			
1998			
1999			
2000			
2001			
2002			
2003			
2004			
2005			
2006			1.67
2007			1.86
2008			1.03
2009			2.19
2010			1.97

Beverton-Holt Equlibrium Z Estimates

Year	Agawam	Charles	Monument	Mystic	Quashnet
1971					
1972					
1973					
1974					
1975					
1976					
1977					
1978					
1979					
1980					
1981					
1982					
1983					
1984			0.72		
1985		0.47	0.42		
1986			0.55		
1987			0.57		
1988					
1989					
1990			0.97		
1991	0.86		0.71		
1992			0.83		
1993		0.7	0.88		
1994			1.19		
1995			1.14		
1996			1.01		
1997			1.25		
1998			2.05		
1999			1.41		
2000			1.81		
2001			1.78		
2002			1.19		
2003			1.82		
2004			1.29		1.01
2005			1.28	1.45	
2006			1.76	1.96	
2007			1.63	1.78	
2008			2.15	1.53	
2009			2.11	2.41	
2010			2.23	1.90	

Appendix Table 7.14 cont.

Blueback
Males

Chapman-Robson Z Estimates (Age Data)

Year	Charles	Monument	Mystic	Town
1971				
1972				
1973				
1974				
1975				
1976				
1977				
1978				
1979				
1980				
1981				
1982				
1983				
1984				
1985	0.96	1.27		
1986				
1987		1.06		
1988				
1989				
1990				
1991				
1992				
1993	1.05	1.45		
1994				
1995				
1996		1.1		
1997		1.72		
1998				
1999				
2000				
2001		0.76		
2002				
2003				
2004				
2005		1.54		
2006				
2007		1.05	1.77	
2008			1.26	
2009			1.39	
2010		1.43	1.55	

Chapman-Robson Z Estimates (Repeat Spawning)

Year	Charles	Monument	Mystic	Town
1971				
1972				
1973				
1974				
1975				
1976				
1977				
1978				
1979				
1980				
1981				
1982				
1983				
1984				
1985	0.92			
1986		1.64		
1987		1.6		
1988				
1989				
1990				
1991				
1992				
1993	1.28	1.73		
1994				
1995				
1996				
1997				
1998				
1999				
2000				
2001				
2002				
2003				
2004				
2005				
2006				
2007			1.79	
2008			1.36	
2009			2.11	
2010			2.13	

Beverton-Holt Equlibrium Z Estimates

Year	Agawam	Charles	Monument	Mystic	Quashnet	Town
1971						
1972						
1973						
1974						
1975						
1976						
1977						
1978						
1979						
1980						
1981						
1982						
1983						
1984			0.77			
1985		0.67	0.41			
1986			0.54			
1987			1.03			
1988						
1989						
1990			1.03			
1991	1.31		0.92			
1992			0.98			
1993		1.38	1.11			
1994			1.22			
1995			1.26			
1996			1.25			
1997			1.90			
1998			2.53			
1999			1.96			
2000			2.23			
2001			2.65			
2002			1.29			
2003			1.89			
2004			1.31		2.96	
2005			1.31	1.98		1.20
2006			1.77	2.46		
2007			1.96	1.64		
2008			2.30	1.99		
2009			1.91	1.93		
2010			2.23	1.65		

Appendix Table 7.15. Mean weights-at-age for female Monument River alewife. Data in highlighted cells were estimated from years with data.

	Age					
Year	3	4	5	6	7	8
1980	0.155	0.175	0.197	0.217	0.236	0.256
1981	0.155	0.175	0.197	0.217	0.236	0.256
1982	0.155	0.175	0.197	0.217	0.236	0.256
1983	0.155	0.175	0.197	0.217	0.236	0.256
1984	0.155	0.175	0.197	0.217	0.236	0.256
1985	0.155	0.175	0.197	0.217	0.236	0.256
1986	0.155	0.175	0.197	0.217	0.236	0.256
1987	0.155	0.175	0.197	0.217	0.236	0.256
1988	0.155	0.175	0.197	0.217	0.236	0.256
1989	0.155	0.175	0.197	0.217	0.236	0.256
1990	0.155	0.175	0.197	0.217	0.236	0.256
1991	0.155	0.175	0.197	0.217	0.236	0.256
1992	0.155	0.175	0.197	0.217	0.236	0.256
1993	0.155	0.212	0.223	0.228	0.225	0.256
1994	0.155	0.175	0.197	0.217	0.236	0.256
1995	0.172	0.177	0.170	0.206	0.236	0.256
1996	0.155	0.185	0.198	0.218	0.236	0.256
1997	0.146	0.181	0.207	0.216	0.236	0.256
1998	0.122	0.165	0.197	0.223	0.240	0.256
1999	0.160	0.156	0.177	0.217	0.236	0.256
2000	0.154	0.177	0.200	0.202	0.236	0.256
2001	0.161	0.174	0.200	0.224	0.200	0.256
2002	0.167	0.183	0.207	0.223	0.236	0.256
2003	0.157	0.186	0.201	0.214	0.236	0.256
2004	0.167	0.181	0.221	0.217	0.236	0.256
2005	0.161	0.171	0.194	0.206	0.236	0.256
2006	0.149	0.169	0.196	0.224	0.236	0.256
2007	0.158	0.188	0.216	0.255	0.254	0.256
2008	0.144	0.165	0.190	0.211	0.254	0.256
2009	0.154	0.174	0.181	0.195	0.236	0.256
2010	0.163	0.179	0.198	0.216	0.236	0.256

Appendix Table 7.16. Estimates of population abundance of Monument River alewife by sex, maturity state, year, and age.

Female Immature

		Age					
Year	Total	3	4	5	6	7	8
1980	76,931	68,035	8,824	72	0	0	0
1981	90,296	81,399	8,824	72	0	0	0
1982	79,614	68,985	10,558	72	0	0	0
1983	133,295	124,261	8,948	86	0	0	0
1984	107,946	91,756	16,117	73	0	0	0
1985	81,509	69,476	11,901	131	0	0	0
1986	78,133	69,025	9,011	97	0	0	0
1987	82,323	73,297	8,953	73	0	0	0
1988	21,285	11,705	9,507	73	0	0	0
1989	21,853	20,257	1,518	77	0	0	0
1990	223,290	220,650	2,627	12	0	0	0
1991	242,587	213,946	28,619	21	0	0	0
1992	148,172	120,189	27,750	233	0	0	0
1993	59,928	44,113	15,589	226	0	0	0
1994	226,083	220,234	5,722	127	0	0	0
1995	411,171	382,559	28,565	47	0	0	0
1996	237,317	187,465	49,620	232	0	0	0
1997	187,477	162,758	24,315	404	0	0	0
1998	107,241	85,933	21,110	198	0	0	0
1999	316,780	305,462	11,146	172	0	0	0
2000	480,755	441,045	39,620	91	0	0	0
2001	175,099	139,062	35,835	202	0	0	0
2002	107,748	96,267	11,299	183	0	0	0
2003	123,574	115,695	7,822	58	0	0	0
2004	77,479	68,039	9,400	40	0	0	0
2005	41,798	36,222	5,528	48	0	0	0
2006	60,612	57,641	2,943	28	0	0	0
2007	79,836	75,138	4,683	15	0	0	0
2008	123,305	117,176	6,105	24	0	0	0
2009	70,312	60,760	9,521	31	0	0	0
2010	71,495	66,509	4,937	49	0	0	0

Female Mature

		Age					
Year	Total	3	4	5	6	7	8
1980	49,705	7,728	25,935	11,524	3,310	941	267
1981	51,299	9,246	25,935	11,524	3,310	941	344
1982	60,106	7,836	31,949	14,103	4,456	1,270	493
1983	60,446	14,114	26,320	14,142	4,084	1,280	506
1984	75,387	10,422	47,409	11,768	4,102	1,173	513
1985	73,074	7,892	35,547	23,651	4,023	1,390	571
1986	65,413	7,840	27,229	19,059	9,018	1,523	743
1987	63,501	8,325	27,296	15,398	7,857	3,696	929
1988	54,876	1,330	28,684	14,411	5,788	2,936	1,728
1989	32,167	2,301	4,599	15,593	5,622	2,244	1,808
1990	45,352	25,063	7,960	2,497	6,082	2,179	1,571
1991	117,158	24,301	85,071	3,804	811	1,962	1,210
1992	150,270	13,652	84,707	48,678	1,585	336	1,313
1993	118,108	5,011	47,204	45,747	18,898	612	636
1994	94,055	25,016	17,352	25,801	18,005	7,393	488
1995	155,441	43,453	85,457	8,668	8,947	6,201	2,714
1996	232,725	21,293	151,507	48,895	3,619	3,712	3,699
1997	202,228	18,487	74,089	85,111	20,045	1,475	3,021
1998	158,294	9,761	64,111	40,790	33,910	7,941	1,781
1999	135,524	34,696	33,733	34,564	15,767	13,029	3,735
2000	210,668	50,096	119,038	17,358	12,495	5,662	6,020
2001	184,371	15,796	110,778	45,848	5,010	3,587	3,353
2002	103,476	10,935	34,809	41,520	12,873	1,400	1,939
2003	62,645	13,141	23,691	11,766	10,117	3,120	809
2004	52,388	7,728	28,864	8,753	3,220	2,754	1,069
2005	35,438	4,114	16,888	10,302	2,296	840	998
2006	26,610	6,547	9,136	6,634	3,068	680	545
2007	29,987	8,535	14,561	3,607	1,998	920	367
2008	40,108	13,310	18,982	5,746	1,086	599	386
2009	46,344	6,902	29,601	7,490	1,730	326	295
2010	37,545	7,555	15,349	11,681	2,255	519	186

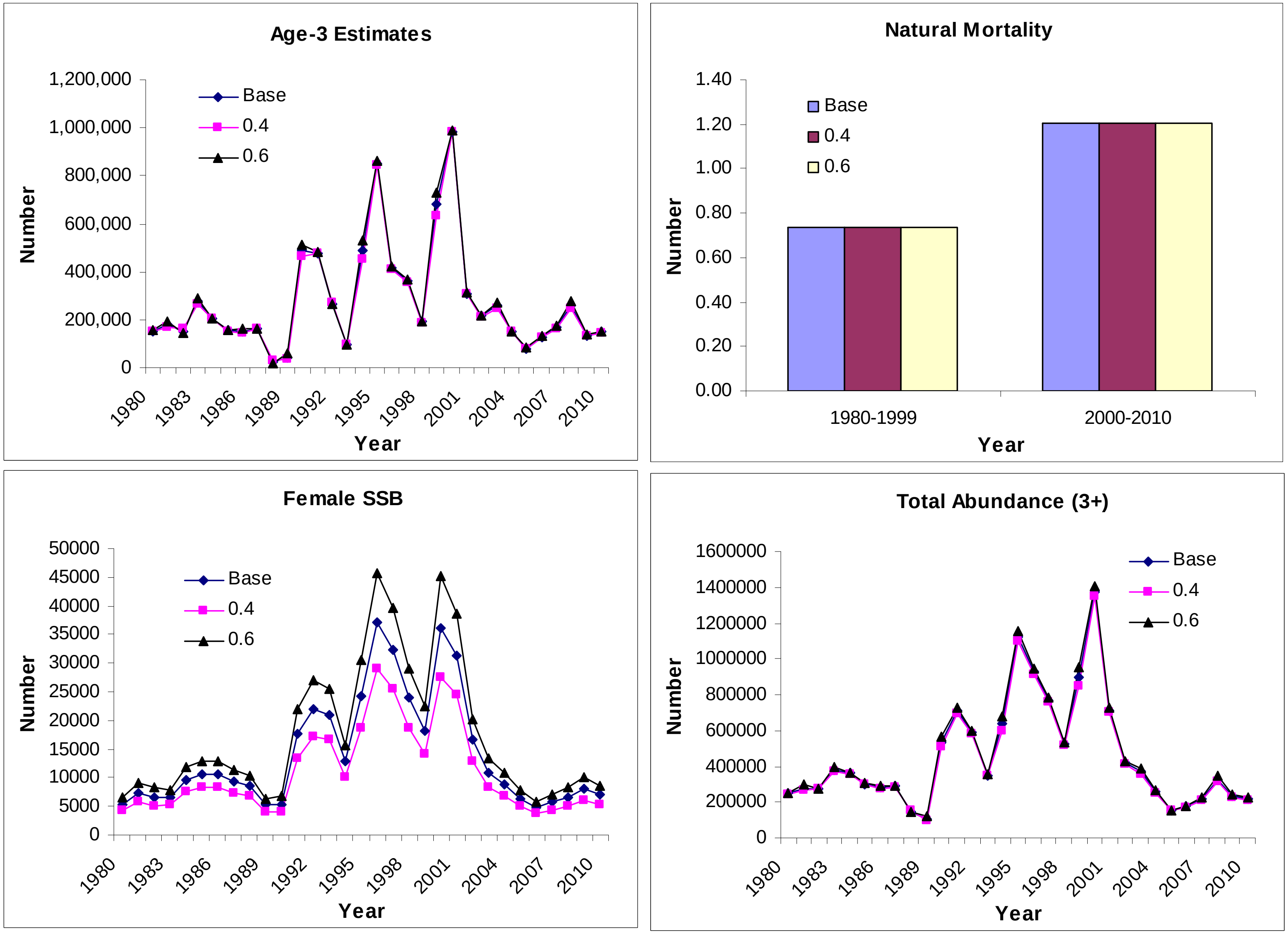
Appendix Table 7.16 cont.

	Male Immature								Male Mature							Population
			Age								Age					
Year	Total	3	4	5	6	7	8	Year	Total	3	4	5	6	7	8	Total
1980	58,621	54,928	3,680	12	0	0	0	1980	63,060	20,835	28,531	9,860	2,809	798	227	247,321
1981	69,411	65,718	3,680	12	0	0	0	1981	67,217	24,927	28,531	9,860	2,809	798	291	277,217
1982	60,111	55,695	4,403	12	0	0	0	1982	75,722	21,126	36,615	12,697	3,789	1,078	418	275,629
1983	104,069	100,322	3,732	15	0	0	0	1983	84,821	38,053	28,991	12,607	3,652	1,088	430	381,746
1984	80,814	74,079	6,722	13	0	0	0	1984	95,531	28,099	52,221	10,099	3,627	1,049	436	356,658
1985	61,078	56,092	4,964	23	0	0	0	1985	87,346	21,276	40,015	20,894	3,429	1,229	503	300,819
1986	59,502	55,727	3,758	17	0	0	0	1986	79,669	21,138	31,144	17,511	7,922	1,298	656	282,315
1987	62,923	59,176	3,734	13	0	0	0	1987	79,827	22,446	31,600	14,549	7,184	3,247	801	289,473
1988	13,427	9,450	3,965	13	0	0	0	1988	59,548	3,584	32,744	13,581	5,442	2,684	1,512	149,926
1989	17,001	16,355	633	13	0	0	0	1989	35,069	6,203	5,279	14,578	5,271	2,110	1,627	108,117
1990	179,240	178,142	1,096	2	0	0	0	1990	88,205	67,571	9,137	2,348	5,658	2,043	1,449	538,871
1991	184,669	172,729	11,937	4	0	0	0	1991	167,815	65,518	95,119	3,468	758	1,825	1,126	708,950
1992	108,649	97,035	11,574	40	0	0	0	1992	183,041	36,806	98,217	45,046	1,437	314	1,222	587,364
1993	42,155	35,615	6,502	39	0	0	0	1993	129,612	13,509	54,145	43,406	17,404	555	593	347,521
1994	180,214	177,806	2,386	22	0	0	0	1994	135,918	67,444	19,944	24,273	17,000	6,809	449	636,252
1995	320,781	308,859	11,914	8	0	0	0	1995	238,295	117,153	96,415	8,003	8,370	5,855	2,500	1,122,143
1996	172,085	151,350	20,695	40	0	0	0	1996	289,071	57,408	175,735	45,665	3,324	3,473	3,466	926,305
1997	141,614	131,403	10,141	69	0	0	0	1997	239,842	49,842	85,701	81,479	18,636	1,355	2,829	766,905
1998	78,217	69,378	8,805	34	0	0	0	1998	180,268	26,316	73,831	38,770	32,311	7,382	1,658	520,966
1999	251,292	246,614	4,649	29	0	0	0	1999	195,562	93,543	38,667	32,551	14,912	12,414	3,473	897,706
2000	372,617	356,077	16,525	16	0	0	0	2000	309,023	135,064	135,100	16,095	11,704	5,355	5,705	1,367,280
2001	127,253	112,272	14,946	35	0	0	0	2001	228,030	42,586	130,583	43,702	4,625	3,360	3,175	714,567
2002	82,465	77,721	4,713	31	0	0	0	2002	126,615	29,480	40,850	40,943	12,223	1,292	1,826	422,162
2003	96,679	93,407	3,262	10	0	0	0	2003	87,568	35,430	27,185	11,303	9,932	2,962	756	372,499
2004	58,859	54,931	3,921	7	0	0	0	2004	69,727	20,836	33,727	8,370	3,079	2,703	1,012	261,181
2005	31,558	29,244	2,306	8	0	0	0	2005	44,620	11,092	19,601	9,968	2,186	804	969	156,366
2006	47,769	46,536	1,227	5	0	0	0	2006	39,105	17,652	10,828	6,495	2,957	648	525	177,759
2007	62,619	60,663	1,953	3	0	0	0	2007	47,100	23,010	17,291	3,612	1,949	886	352	223,452
2008	97,152	94,602	2,546	4	0	0	0	2008	66,229	35,883	22,540	5,766	1,084	584	371	330,778
2009	53,031	49,055	3,971	5	0	0	0	2009	63,615	18,607	35,151	7,516	1,730	325	286	237,310
2010	55,764	53,696	2,059	8	0	0	0	2010	53,273	20,368	18,227	11,721	2,255	519	183	222,093

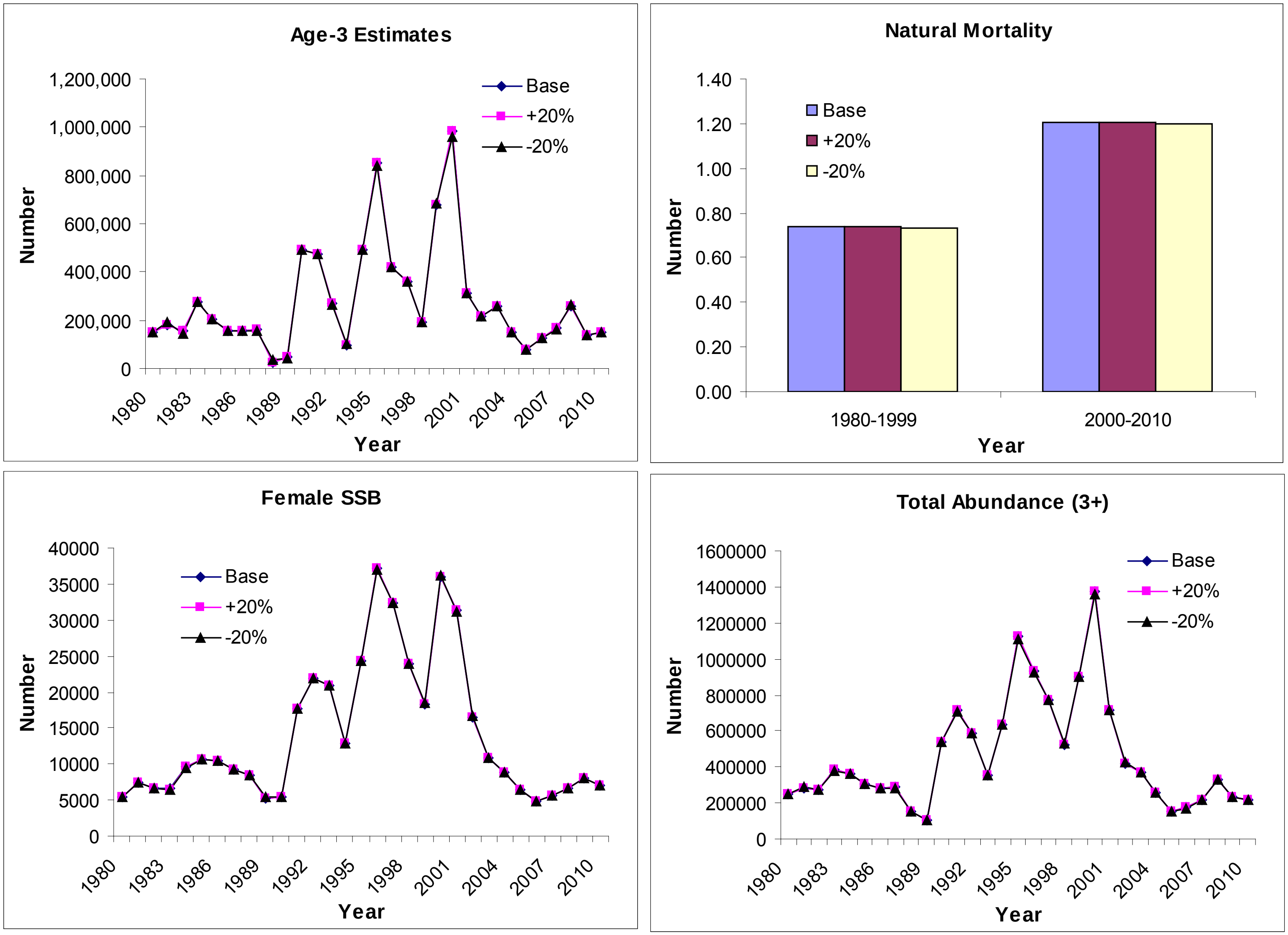
Appendix Table 7.17. Estimates of female spawning stock biomass (kilograms) for the Monument River alewife.

		Age					
Year	Total	3	4	5	6	7	8
1980	5,355	711	2,696	1,348	427	132	41
1981	7,432	1,149	3,639	1,820	576	178	71
1982	6,586	729	3,355	1,667	580	180	76
1983	6,538	1,313	2,764	1,672	532	181	78
1984	9,580	1,144	5,875	1,642	630	196	93
1985	10,641	968	4,921	3,686	691	260	116
1986	10,482	1,041	4,080	3,215	1,676	308	163
1987	9,302	1,007	3,729	2,368	1,331	681	186
1988	8,469	167	4,066	2,300	1,017	561	358
1989	5,221	289	652	2,488	988	429	375
1990	5,395	2,618	939	332	889	347	271
1991	17,602	3,258	12,875	648	152	400	268
1992	22,005	1,706	11,953	7,733	277	64	271
1993	20,921	635	8,180	8,339	3,522	112	133
1994	12,790	2,790	2,185	3,658	2,812	1,256	90
1995	24,337	6,479	13,112	1,277	1,598	1,269	602
1996	37,157	2,811	23,875	8,246	672	746	807
1997	32,428	2,234	11,100	14,582	3,584	288	640
1998	23,865	956	8,492	6,451	6,070	1,530	366
1999	18,295	4,165	3,948	4,590	2,567	2,307	717
2000	36,055	7,387	20,173	3,324	2,416	1,279	1,476
2001	31,399	2,370	17,967	8,547	1,046	669	800
2002	16,562	1,476	5,149	6,947	2,321	267	401
2003	10,842	1,873	4,000	2,147	1,965	668	188
2004	8,759	1,117	4,547	1,684	608	566	238
2005	6,401	655	2,855	1,976	468	196	252
2006	4,807	976	1,544	1,300	687	161	139
2007	5,702	1,348	2,738	779	509	234	94
2008	6,620	1,917	3,132	1,092	229	152	99
2009	8,059	1,063	5,151	1,356	337	77	76
2010	6,949	1,231	2,748	2,313	487	122	48

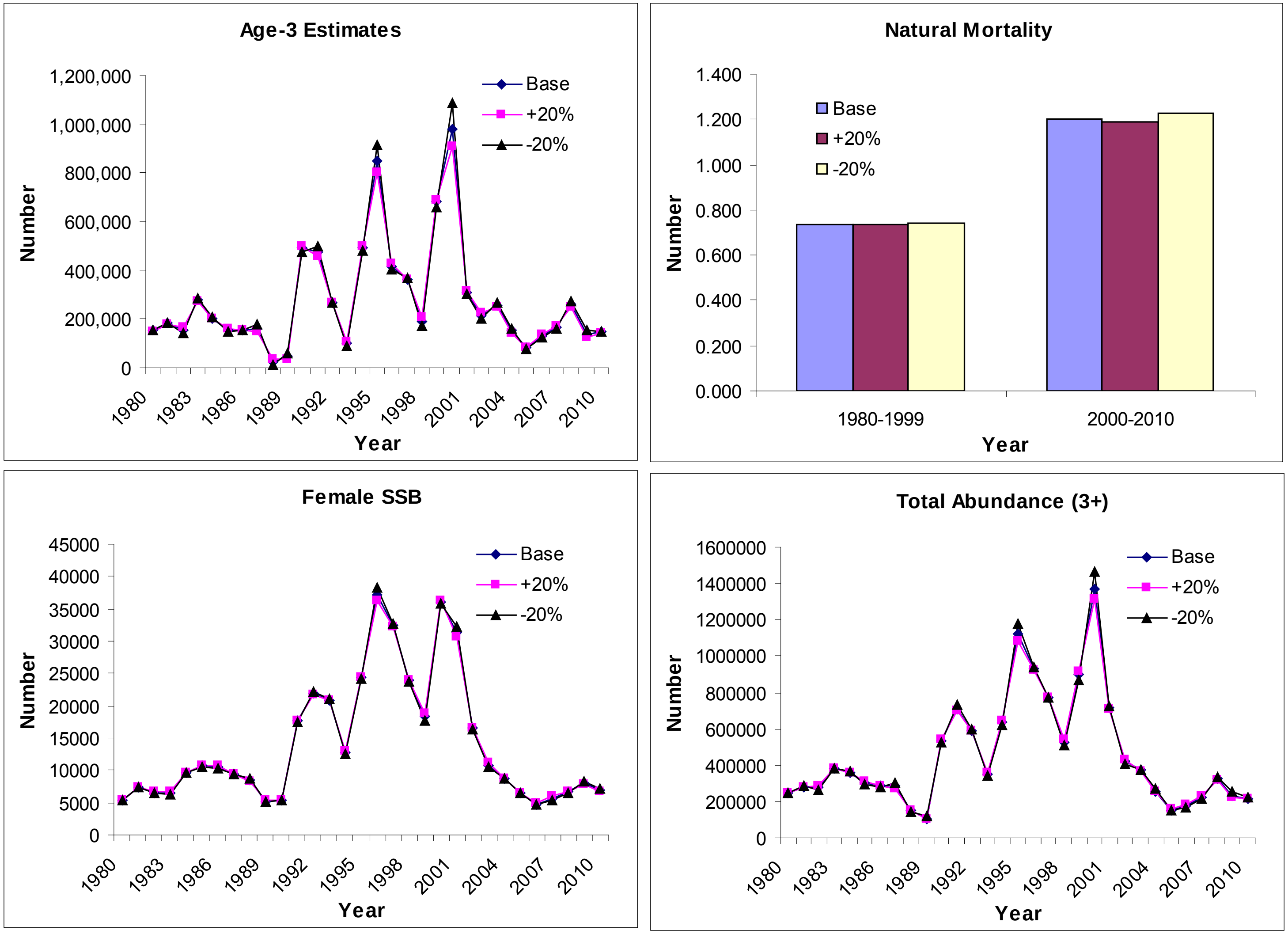
Appendix Figure 7.1 Sensitivity analysis of input female sex ratio on SCA model output.



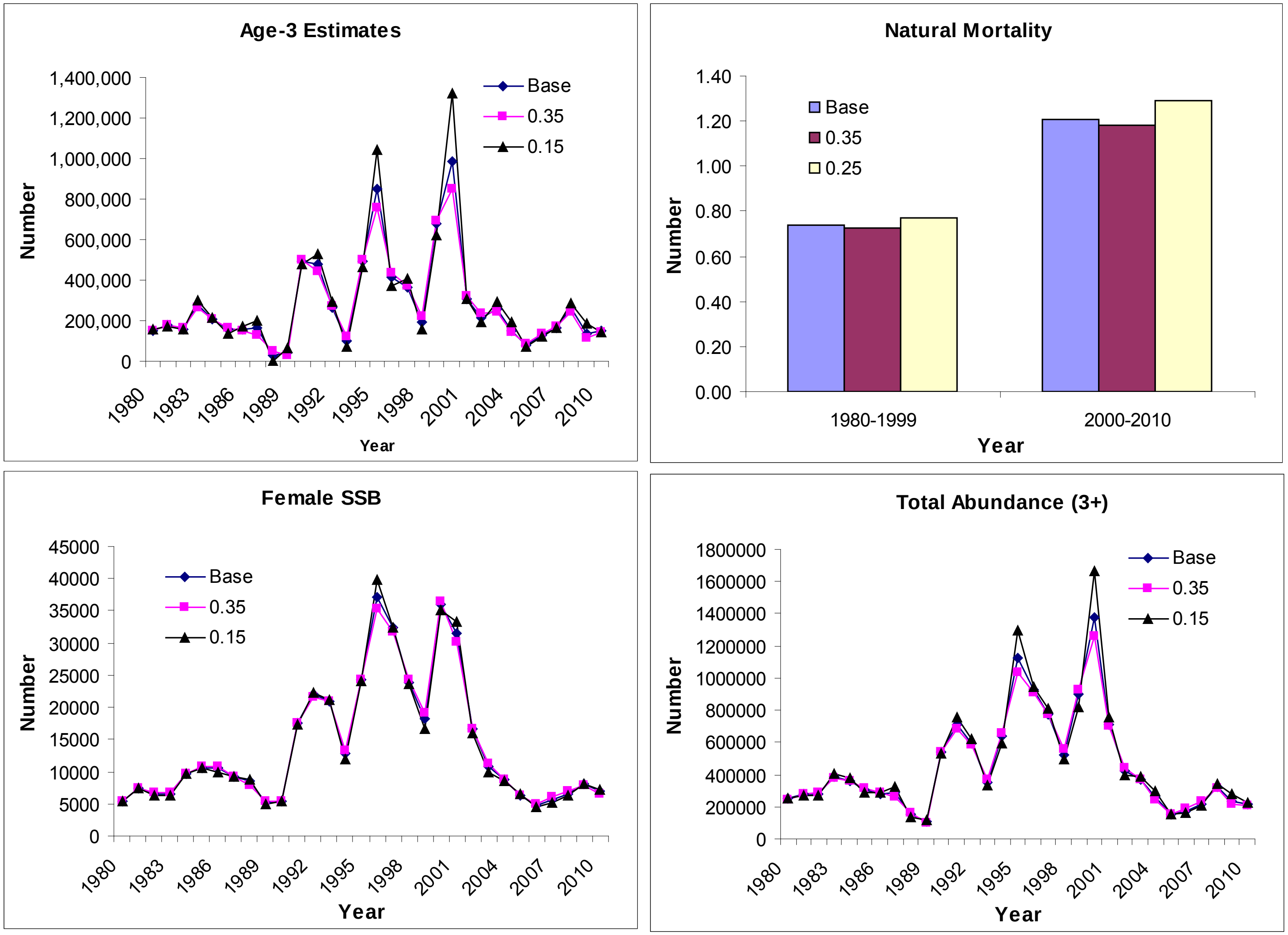
Appendix Figure 7.2. Sensitivity analysis of changing CVs of total removals and escapement numbers by ±20% on SCA model output.



Appendix Figure 7.3. Sensitivity analysis of changing average effective sample sizes by ±20% on SCA model output.



Appendix Figure 7.4. Sensitivity analysis of changing the downweight ratio of the age composition data by ±0.1 on SCA model output.



8. Status of Rhode Island River Herring Stocks

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Executive Summary

Since 2000, the Gilbert Stuart river herring spawning stock size drastically decreased each year from 290,814 to a low of 7,776 fish in 2005. Likewise, Nonquit run size decreased from 185,524 fish in 2000 to a low of 25,417 in 2004. In addition, mortality rates (Z) for both sites approached 4.0, and percentage of repeat spawners decreased to less than ten percent. Due to these factors, Rhode Island imposed a statewide closure in 2006, on the harvest of river herring (alewives and bluebacks) in fresh and marine waters. During this same time period neighboring states Massachusetts and Connecticut also imposed river herring closures. Since the closure in March 2006, Rhode Island run sizes have increased, but are still well below the estimated run sizes (1999-2001) recorded prior to the decline. Likewise mortality rates and percentage of repeat spawners have shown some improvement.

8.1. INTRODUCTION

In Rhode Island, the Division of Fish and Wildlife currently manages 21 river herring runs and operates and maintains 19 fishways on 12 of the systems. These systems include small brooks and streams to large rivers and impoundments. Since the 1960s, the Division of Fish and Wildlife has worked toward restoring anadromous fish to Rhode Island. These efforts include partnering with various organizations on anadromous habitat restoration projects, conducting anadromous fish stocking, monitoring anadromous fish populations throughout the state, providing seasonal adjustments and maintenance to existing fishways, and setting harvest regulations.

The two Rhode Island systems with the most complete quantitative data sets on river herring are the Gilbert Stuart and Nonquit. Available data include spawning stock size, length at age, mortality rates, proportion of repeat spawning and juvenile abundance indices. Gilbert Stuart has an Alaskan steeppass fishway which provides access to 68 acres of nursery and spawning habitat. Gilbert Stuart Pond empties into the Narrow River and discharges into the Atlantic Ocean (Figure 8.1). River herring at Gilbert Stuart have been monitored by the Division of Fish and Wildlife since 1980. Nonquit has a Denil fishway which provides access to 202 acres of nursery and spawning habitat. Nonquit Pond spills into Almy Brook which joins the Sakonnet River and empties into the Atlantic Ocean (Figure 8.2). Nonquit River herring stocks have been monitored since 1999.

In addition, to assessing the status of the Gilbert Stuart and Nonquit stocks, this report will summarize spawning stock size results from Buckeye Brook, JAI results from the Pawcatuck River seine survey, and river herring data collected from three marine fishery-independent surveys.

8.2. MANAGEMENT UNIT DEFINITION

The Rhode Island Department of Environmental Management (RIDEM) has management authority over river herring (alewives and bluebacks) occurring in the state's fresh and marine waters [RI Gen. Laws 20-1-2].

8.3. REGULATORY HISTORY

Currently there is a moratorium on harvest of river herring (alewives and bluebacks) in Rhode Island's fresh and marine waters (RIDFW Reg. Part II; RIMF Reg. Part 7.20). Due to drastic declines in spawning stock size beginning in 2001, Rhode Island passed regulations in March 2006 for the complete closure. Prior to 1998, the freshwater daily river herring limit was 12 fish per day and closed Sunday, Monday, and Tuesday. There were no regulations for marine waters. In 1998 the daily freshwater limit was increased to 24 fish per day with the same closed days, and then decreased to 12 fish per day in 2005. The 2006 closure marked the first time there were reciprocal regulations for Rhode Island marine and fresh waters. The marine and freshwater closure continued through 2011 and is planned for 2012. Table 8.1 summarizes current and past Rhode Island river herring regulations.

8.4. ASSESSMENT HISTORY

The last formal assessment was prepared by Crecco and Gibson in 1990. The Rhode Island system assessed in the report was the Annaquatucket River which in the 1970s had a spawning stock size over 300,000 (Durbin 1979). At the time of the assessment, the status of the river herring population was partially exploited with no trend in stock condition. Even with stocking efforts over the last ten years, the Annaquatucket river herring stock is currently severely depleted and considered a small remnant run. Currently, only presence/absence data are recorded, therefore this system will not be covered in this report.

8.5. STOCK-SPECIFIC LIFE HISTORY

Gilbert Stuart and Nonquit river herring stocks are iteroparous and predominately alewives. Between 2000 and 2005, weekly species identification results showed Rhode Island's spring returns were 100% alewives. Since 2005, species identification at both sites has been over 95% alewives. Gilbert Stuart river herring were used as Rhode Island's main broodstock source between 1966 and 1978 to stock into the Annaquatucket, Hunt, and Pawcatuck rivers. Gilbert Stuart was again used as a broodstock source between 1999 and 2004, and sparingly in years following due to the drastic declines in run size in 2004. Both the Gilbert Stuart and Nonquit systems were stock between 1990 and 1993 with alewife broodstock from Massachusetts systems.

8.6. HABITAT DESCRIPTION

Gilbert Stuart has an Alaskan steeppass fishway which provides access to 68 acres of nursery and spawning habitat. Gilbert Stuart Pond empties into the Narrow River and discharges into the Atlantic Ocean (Figure 8.1). Nonquit has a Denil fishway which provides access to 202 acres of nursery and spawning habitat. Nonquit Pond spills into Almy Brook which joins the Sakonnet River and empties into the Atlantic Ocean (Figure 8.2). Buckeye Brook is a natural free flowing system that provides access to 91 acres of spawning habitat in Warwick and Spring Green Ponds. Buckeye Brook empties into Narragansett Bay. The Pawcatuck River is a riverine system and currently has two Denil fishways which provide access to miles of riverine habitat, Watchaug Pond (573 acres), and Chapman Pond (164 acres). In addition to a river herring run, the Pawcatuck River is also managed for American shad.

8.7. RESTORATION PROGRAMS

8.7.1. Recovery Target

The state of Rhode Island has informally adopted a recovery target of greater than 50% of the spawning stock size estimated by Gibson (1984). Target goals for spawning stock size at Buckeye Brook, Gilbert Stuart and Nonquit are shown in Table 8.3. The estimates are calculated based on habitat size and are used as indicators to predict the spawning stock size potential of restored habitat or strength of existing runs.

8.7.2. Restoration Objectives

The Rhode Island Division of Fish and Wildlife is partnering with many government agencies, NGO's, and private entities on a wide variety of anadromous habitat restoration projects throughout the state. Projects include constructing new fishways, culvert modifications, and dam removals to enhance spawning and nursery habitat. Sixteen fish passage projects are proposed, currently being implemented, or recently completed on the Blackstone, Ten Mile, Pawtuxet, Pawcatuck and Woonasquatucket rivers (Edwards 2010; Erkan 2002). A critical component of these restoration efforts is the reintroduction of spawning broodstock to restored systems, which is discussed in section 1.7.3.

8.7.3. Stocking Efforts

Stocking has been very important to Rhode Island's river herring restoration efforts (Table 8.2). Each year trap and transport is conducted utilizing out-of-state and in-state broodstock sources to supplement existing runs or restore extirpated systems that have been restored. Gilbert Stuart was Rhode Island's only broodstock source for river herring between 1966 and 1972, and today is still an important source. Nonquit has not been utilized as a broodstock source, but was considered in 2001, prior to the drastic decrease in spawning stock size. Between 1990 and 1993, both Gilbert Stuart and Nonquit received supplemental stockings from the Agwam and Bourne rivers located in Massachusetts. Since 2001 it has become increasingly difficult to obtain available out-of state and in-state broodstock sources, due to the declines in river herring run sizes.

8.7.4. Fish Passage

The Alaskan steeppass at Gilbert Stuart has been the primary survey site for monitoring adult river herring since 1981. The eight foot obstruction at the Gilbert Stuart Birthplace, is a dam with various water control structures serving the historic grist mill (Erkan 2002). In 2000, the fishway passed over 290,000 fish and in recent years estimates of one thousand fish per hour have been observed (Edwards 2010). The Denil fishway at Nonquit has been the primary survey site for monitoring adult river herring since 1999. The seven foot obstruction is owned by the City of Newport Water Company and the impoundment is used as a secondary water supply (Erkan 2002). In 1999, the fishway passed over 230,000 fish (Edwards 2010). Buckeye Brook is a free-flowing system and river herring migrate to Warwick Pond without obstruction. The connection between Warwick Pond and Spring Green Pond passes through the T.F Green Airport property. Recently, T.F Green Airport completed modifications to enhance river herring access to Spring Green Pond.

8.8. AGE

Scale samples collected from Rhode Island Division of Fish and Wildlife's anadromous fish sampling projects at Gilbert Stuart and Nonquit were pressed between glass slides and analyzed by techniques described in Rothschild (1963) and Marcy (1969). The age of each fish and number of spawning marks were recorded. Regenerated scales are not considered reliable for ageing. Two groups have carried out most of the ageing work for river herring. Biologists from both groups have worked together to ensure consistency of methodology in the collection, processing, and age determination of scale samples. Approximately 150 scale samples are collected throughout the spring run at Gilbert Stuart and Nonquit. For both sites, the typical ages for males are 3 and 4, and females are typically ages 4 and 5 (Tables 8.6, 8.7, 8.11 and 8.12. Age-two males and age seven females were the minimum and maximum ages observed over the past five years.

8.9. FISHERIES-DEPENDENT MONITORING

8.9.1. Commercial Fisheries

Rhode Island commercial landings are shown in Table 8.14 (NMFS, Fisheries Statistics Division, Silver Spring, MD, personal communication). The river herring fishery was an inshore fishery and landings occurred throughout the late 1800's in New England waters (NMFS 1989). Oviatt et al. (2003) estimated over 1,100,000 kg ww of alewives were landed at Rhode Island ports in 1880, which is a substantial increase compared with the reported Rhode Island river herring commercial landings of zero in 1960 (NMFS 2010). The majority of the river herring landings between 1950 and 1980 were from seine hauls and trap net fisheries. The trap net fishery was the predominate source of landings throughout the 1990's. The reported landings have been zero or negligible since 1987. In March 2006, Rhode Island passed the moratorium on the harvest of river herring (alewives and blueback herring) in marine and freshwaters of the state.

8.9.2. Recreational Fisheries

No recreational data are available.

8.9.3. Bycatch Estimates

Bycatch is known to take place in the Atlantic herring bait fisheries, however no bycatch data is available.

8.9.4. Subsistence Fishery

No subsistence fishery data is available.

8.9.5. Characterization of Other Losses

No data is available.

8.10. FISHERIES-INDEPENDENT MONITORING

8.10.1. Spawning Stock Surveys

Each spring river herring spawning stock size is estimated using electronic fish counters or direct count methods on several Rhode Island river systems. The anadromous life history of river herring allows for a unique sampling and monitoring opportunity when they return to their native freshwater systems to spawn. In addition to estimating run sizes, a representative sample of river herring from Gilbert Stuart and Nonquit were sampled for biological data. River herring were sampled and measured for length, weight, and scale samples taken for age analysis. Approximately 50 alewives were sampled three times throughout each spring migration. Gilbert Stuart has a break in the biological data time series between 1993 and 2000; however spawning stock size was estimated during those years. Mortality rates (Z) are estimated by a percentage of repeat spawners method (Crecco and Gibson 1988).

Gilbert Stuart

The Division has estimated spawning stock size since 1981 using electronic fish counters or direct count methods. River herring were sampled for biological data during two time periods. The first sampling period was between 1980 and 1992, and the second from 2000 to present. The break in the biological data time series between 1993 and 1999 was due to changes in staff, but spawning stock size estimates were continued during this time period.

Nonquit

The Division has estimated spawning stock size at Nonquit since 1999 using a solar operated electronic fish counter. The only known data, which included run size estimates, were collected in 1976 and reported as 80,000 fish (Lynch 1976). River herring were sampled for biological data since 2000, except for in 2010 when river herring were unable to be captured after numerous attempts.

Buckeye Brook

The Buckeye Brook Coalition and Division partnered in 2003 to initiate a direct count program utilizing volunteers (Puriton 2000; Stevenson 1997). River herring have not been sampled for biological data, nor have JAI’s been performed at Buckeye Brook.

Pawcatuck River

A fishway trap is installed and operated each spring to monitor American shad returns. The increased number of river herring compared to American shad and high water volume make utilizing the fishway trap unfeasible for estimating river herring run size. Direct count techniques have failed, due to visibility and electronic counters are not efficient at the site. Since 2006, in addition to observations (presence/absence) the Division has initiated a four factor ranking system in which personnel estimate the number of herring in the trap and fishway each day the trap is checked for American shad. This procedure should assist in estimating the Pawcatuck River run size in the future.

Annaquatucket River and remaining RI herring runs

At other Rhode Island river herring systems, the Division conducts periodic qualitative analysis which consists of determining the presence and absence of adult and juvenile river herring. Methods include random net surveys, visual observations and electrofishing to determine spawning success. The Annaquatucket River experienced a complete collapse during the 1990's which may have resulted from other factors unrelated to the factors responsible for the recent decline.

8.10.2. Ocean Trawl Survey Indices

The Marine Division of Rhode Island Fish and Wildlife conducts a trawl survey, a Narragansett Bay seine survey, and coastal pond seine survey. The marine surveys are conducted in Narragansett Bay, Block Island Sound and surrounding coastal ponds. All three surveys collect river herring numbers and length frequency data.

Trawl Survey

The methodology used in the allocation of sampling stations employs both random and fixed station allocation. Fixed station allocation began in 1988 in Rhode Island and Block Island Sounds. This was based on the frequency of replicate stations selected per depth stratum since 1979. With the addition of the Narragansett Bay monthly segment which started in 1990, an allocation system of 13 fixed stations was employed. Sampling stations were established by dividing Narragansett Bay into a grid of cells. The seasonal trawl survey is conducted in the spring and fall of each year. Usually 42 stations are sampled each season; however this number has ranged from 26 to 72 over the survey time series. The stations sampled in Narragansett Bay during the seasonal segment are a combination of fixed and random sites. Thirteen fixed during the monthly portion and 26, (14 of which are randomly selected) during the seasonal portion. The random sites are randomly selected from a predefined grid. All stations sampled in Rhode Island and Block Island Sounds are fixed.

Depth Stratum Identification:

Area	Stratum	Area nm2	Depth Range (m)
Narragansett Bay	1	15.50	<=6.09
	2	51.00	>=6.09
Rhode Island Sound	3	0.25	<=9.14
	4	2.25	9.14 – 18.28
	5	13.5	18.28 – 27.43
	6	9.75	>=27.43
Block Island Sound	7	3.50	<=9.14
	8	10.50	9.14 – 18.28
	9	11.50	18.28 – 27.43
	10	12.25	27.43 – 36.57
	11	4.00	>=36.57

At each station, an otter trawl equipped with a ¼ inch liner is towed for twenty minutes covering .83 nautical miles. Data on wind direction and speed, sea condition, air temperature and cloud cover as well as surface and bottom water temperatures, are recorded at each station. Catch is sorted by species. Length (cm/mm) is recorded for all finfish, skates, squid, scallops, lobster, blue crabs and horseshoe crabs. Similarly, weights (gm/kg) and number are recorded for each species (Lynch 2007). The survey is a random / fixed stratified trawl survey that operates throughout state waters. Adults and juveniles are collected.

Narragansett Bay Seine Survey

Since 1988, eighteen stations have been sampled monthly from June through October. The survey is a fixed station seine survey using a 200ft seine net that samples throughout Narragansett Bay. Predominately juveniles are collected (McNamee 2010).

Coastal Pond Seine Survey

Since 1992, twelve stations have been sampled monthly from May through November. The survey is a fixed station seine survey using a 160 ft seine net that takes place in Rhode Island's coastal ponds. The majority of the samples collected are juveniles but occasionally adults are captured and reported with the length frequency data (Lake 2009).

8.10.3. Juvenile Abundance Indices

Gilbert Stuart

Between 1988 and 1996 a trapnet was installed during the fall to capture juveniles exiting the freshwater impoundment. The trapnet was connected to the exit of the Alaskan steeppass fishway, therefore trapped fish endured high velocities of water. Due to high juvenile mortality the JAI was discontinued in 1996. During the 2007 season a different style trapnet, which prevents juvenile mortality was utilized. This weir based trap located 200 yards below the fishway allows trapped out-migrating juveniles a safe holding pen. The trap is set for one hour and juveniles are enumerated and length measurements are collected.

Nonquit

Since 2001 a trapnet was installed weekly each fall in the Denil fishway. The trap is placed in slots located at the front of the turning pool, and juveniles are captured as they exit the freshwater impoundment and held in the turning pool.

Pawcatuck River

Seine survey conducted weekly each fall since 1988 at five fixed stations in the lower Pawcatuck River (O'Brien 1986). Majority of the samples collected are juveniles but occasionally age one river herring are captured and reported with the length frequency data.

Remaining Rhode Island Runs

Periodic qualitative analysis which consists of determining the presence and absence of adult and juvenile river herring is selected Rhode Island systems. Methods include random net surveys, visual observations and electrofishing to determine spawning success.

8.11. ASSESSMENT APPROACHES AND RESULTS

8.11.1. Trends in Spawning Stock Size

Rhode Island river herring spawning stock sizes drastically decreased from 2000 to 2004. Since the statewide closure in 2006, the run sizes have increased but are still well below the run sizes estimated between 1999 and 2002 (Table 8.15; Figure 8.7).

Gilbert Stuart

Between 1998 and 2001, the Gilbert Stuart stock displayed a stable trend and passed over one million herring. The annual mean spawning stock size during this period was 266,853. After 2001, the run declined to a low of 7,776 in 2005 (Table 8.15; Figure 8.7). Since the closure in 2006, the spawning stock size has increased but was still substantially below the annual mean for the 1998 through 2001 time frame. The Gilbert Stuart run size has been below the predicted target population size of 64,000 since 2003, until the 2010 river herring run size was estimated at 110,000 (Table 8.3).

Nonquit

When the current time series began in 1999 the run size was estimated at 230,853 fish (Table 8.15; Figure 8.7. After 1999, the run size declined to a low of 25,417 fish in 2004. As with Gilbert Stuart, the Nonquit run size drastically decreased between 2002 and 2005. Since the closure in 2006, the spawning stock size has increased but was still substantially below 1999 returns, with the exception of 2008 when the run size reached 224,000. The Nonquit run size was below the predicted target population size of 138,000 each year since 2000, with the exception of 2008 (Table 8.3).

8.11.2. Trends in Length

Annual mean fork length results were less for both males and females for river herring sampled at Gilbert Stuart between 2000 and 2010, as compared with results from fish sampled between 1980 and 1992 (Tables 8.4 and 8.5; Figure 8.3). The last mean lengths reported for Nonquit were in 1976 and since 2000 the Nonquit mean lengths were below those previously reported (Lynch 1976, Tables 8.9 and 8.10; Figure 8.5).

8.11.3. Trends in Age

Pooled age data (1980-1992) at Gilbert Stuart showed fifteen percent of the river herring sampled was ages 6, 7 or 8 (Gibson 1992). Annual mean age for both males and females has decreased since 1980 (Figure 8.4). Age data from 2003 to present show no age 8 river herring and a decrease in percentages of 6 and 7 year olds sampled at Gilbert Stuart. Tables 8.6 and 8.7show number and percent at age for males and females sampled at Gilbert Stuart. Tables 8.11 and 8.12 show the number and percent at age for males and females sampled at Nonquit. Mean age for males and females in the Nonquit has remained stable from 2000 to present (Figure 8.6).

8.11.4. Trends in Length at Age

River herring from Gilbert Stuart and Nonquit have displayed a decrease in length at age over time (Table 8.4). Since 2000, the mean length at ages recorded for Gilbert Stuart, were consistently lower for all age classes than reported in 1992 (Gibson 1992). Mean fork length at age for males and females at Gilbert Stuart is shown in Tables 8.4 and 8.5. Age results at Nonquit show the same decrease in percentages of 6 and 7 year olds sampled as compared from fish sampled at Gilbert Stuart between 1984 and 1992. Mean fork length at age for males and females at Nonquit is shown in Tables 8.9 and 8.10.

8.11.5. Trends in Proportion of Repeat Spawners

Percent repeat spawning at Gilbert Stuart and Nonquit has decreased since 2000. Historical percentages for Nonquit were lacking, but historic percentages were available for Gilbert Stuart. Pooled estimates (1983-1992) resulted in a repeat spawning value of 42 % (Gibson 1992). The five year average (2003-2007) for Gilbert Stuart and Nonquit was 8.9% and 6.8%, respectively. Since the closure in 2006 the percentage of repeat spawners has increased at both locations, but compared to the historic data (1984-1992) the percentage of repeat spawning has drastically decreased for both sites (Figure 8.9). The three year average (2008-2010) for Gilbert Stuart and Nonquit following the closure were 12.5% and 17.9%, respectively.

8.11.6. Total Mortality (Z) Estimates

The instantaneous mortality (Z) rates were calculated using the repeat spawning method (Crecco and Gibson 1988). Results are presented in Figure 8.10. Mortality rates substantially increased between 2003 and 2005. Both sites displayed the highest mortality rates in 2004 with Z values estimated at 3.9 for Gilbert Stuart and 4.1 for Nonquit. Historical mortality rate data for Nonquit was lacking, but historic data was available for Gilbert Stuart. Pooled estimates (1984-1992) utilizing the repeat spawning method resulted in a Z value of 1.2 (Gibson 1992). Both Gilbert Stuart and Nonquit mortality rates have increased over time. With the exception of 2008, Nonquit Z values are higher than the values estimated between 1983 and 1992 at Gilbert Stuart (Gibson 1992). The higher mortality rates observed at Nonquit over Gilbert Stuart may be a direct result of Nonquit not having any harvest regulations prior to 2004 because of the marine and freshwater boundaries located at the primary fishing site.

8.11.7. Trends in Juvenile Abundance

Relative abundance indices in juveniles from the trawl survey are shown in Figure 8.8, and expressed in mean number per tow. Length frequency results are shown in Table 8.16 (Olszewski 2010). The trawl survey river herring indices decreased beginning in 2002 and have increased slightly in recent years. The timing of this decrease coincides with the drastic decline in RI river herring spawning stock sizes. Relative abundance indices of juveniles from the Narragansett Bay Seine Survey are shown in Figure 8.8, and expressed in mean number per seine haul. Length frequency results are shown in Table 8.17 (McNamee 2010). Relative abundance indices of juveniles from the Coastal Pond Seine Survey are shown in Figure 8.8, and expressed in mean number per seine haul. Majority of the samples collected are juveniles but occasionally adults are captured and reported with the length frequency data (Table 8.18) (Lake 2009). Relative abundance indices for juveniles in the Gilbert Stuart River are shown in Table 8.19, and expressed in mean number per one hour trap set. Relative abundance indices for juveniles in the Nonquit River are shown in Table 8.19, and expressed in mean number per one hour trap set. The juvenile abundance indices from the Gilbert Stuart and Nonquit trap showed no correlation with the spawning stock size estimates for either system. Relative abundance indices for juveniles in the Pawcatuck River are shown in Table 8.20, and expressed in mean number per seine haul. The Pawcatuck River seine survey abundance indices for river herring have decreased since 2004 and have remained low over the past several years.

8.12. BENCHMARKS

The state of Rhode Island has informally adopted a recovery target for river herring run sizes of greater than 50% of the predicted spawning stock sizes based on available habitat, estimated by Gibson (1984). Target goals for spawning stock size at Buckeye Brook (39,461), Gilbert Stuart (32,150) and Nonquit (69,124) are shown in Table 8.3. In addition, Rhode Island has informally adopted a Z benchmark value of less than 2.5 using the percentage of repeat spawner technique (Crecco and Gibson 1988) and a percentage of repeat spawning benchmark of greater than 10 percent.

8.13. CONCLUSIONS AND RECOMMENDATIONS

Since 2001, Rhode Island river herring stocks experienced sharp declines in spawning stock size, causing Rhode Island to impose a statewide closure in 2006 to the harvest of river herring in fresh and marine waters. Between 2000 and 2005, the Gilbert Stuart run size decreased from 290,814 to 7,776 and the Nonquit run size decreased from 230,853 to 25,417 (Figure 8.7). During the same time period, neighboring states Massachusetts and Connecticut also imposed closures. In addition to decreases in spawning stock size, Rhode Island river herring stocks displayed increases in mortality rates (Z), decreases in percentage of repeat spawners, and truncated age structures. Prior to the closure, the Rhode Island freshwater daily river herring limit was twelve fish per day and closed Sunday, Monday, and Tuesday with no marine regulations in place.

Recent results show there has been some improvement since the closure, but current run sizes are still well below the estimated run sizes (1999-2001) recorded prior to the decline (Table 8.15). Over the last three years the Gilbert Stuart average run size increased from 14,965 (2004-2006) to 67,921 and Nonquit run size increased from 47,504 (2004-2006) to 104,288. Likewise mortality rates (Z) and percentage of repeat spawners has shown some improvement (Figures 8.9 and 8.10).

The decrease in river herring run sizes between 2002 and 2005 warranted drastic regulatory changes in which the Rhode Island moratorium was imposed in March 2006. The moratorium is still in place and will continue through 2012. Reasons for the drastic declines in Rhode Island river herring run sizes may be related to a combination of factors which may have affected river herring stocks prior to the closure. Some theories include degradation of spawning and nursery habitat, an increase in predator populations, and overfishing. Degradation of spawning habitat could be the result of changes in water quality in the freshwater systems affecting egg development or juvenile mortality. Predator population increases in certain sportfish and bird species, may have been affecting river herring stocks. Overfishing may have been a result of an increase in the in-river fishery, an unregulated marine fishery in Rhode Island marine waters prior to 2006, or an ocean by-catch fishery intercepting Rhode Island river herring stocks during seasonal migrations.

In summary, Rhode Island's best available results are from river herring data collected at Gilbert Stuart and Nonquit. The Buckeye Brook spawning stock size estimates, Pawcatuck River JAI data, and results from the marine surveys are additional valued data sets. The Division's goal is to estimate spawning stock size (quantitative methods), determine biological characteristics, and conduct JAI's for Gilbert Stuart, Nonquit, Pawcatuck River, and Buckeye Brook river herring stocks in the future and compare with results from the marine surveys. Gilbert Stuart and Nonquit have the best available quantitative data sets and the longest run size time series. In the past the Division has used the results from these two systems to gauge river herring stocks throughout the state and make recommendations for regulatory changes. The JAI time series is short for both systems, but if continued could provide useful information in the future. The Buckeye Brook spawning stock size estimates are available, but the time series is short. River herring have not been sampled for biological data and no JAI's have been conducted. The Pawcatuck River spawning stock size estimates are still being developed, therefore not included in this report. Sampling for biological characteristics has occurred but is incomplete therefore not included. Pawcatuck River seine survey is available and there is a long time series, but there are not any accurate spawning stock size estimates available to compare with. The seine survey is used for American shad monitoring and therefore the river herring results were included in this report. Marine trawl and seine surveys offer long time series which provide catch indices and length frequency data. Results may be useful for tuning other models or indexing the broader river herring populations in state waters (mixed-ocean stocks). In addition, the Division will conduct various qualitative assessments at remaining river herring runs throughout the state.

Future monitoring recommendations include:

1) Mandatory- Continue spawning stock size monitoring at Gilbert Stuart, Nonquit and Buckeye Brook to extend the existing time series and evaluate the stock status. Continue sampling river herring for biological data at Gilbert Stuart, Nonquit, and Pawcatuck River to determine age composition, growth rates, percent repeat spawning, and mortality rates. Continue JAI survey at Gilbert Stuart, Nonquit, and the Pawcatuck River to extend the existing time series.

2) Recommended- Initiate JAI survey and adult biological sampling at Buckeye Brook. Continue modifying the four-factor system to estimate the Pawcatuck River herring run size. Continue collecting river herring data from the three marine surveys. Continue monitoring success of stocking program by various sampling methods to determine spawning success.

3) Desired- As new river systems are restored and river herring populations become established, set up monitoring projects to determine spawning stock size, biological characteristics, and juvenile abundance indices.

Towards a river herring restoration goal and stock recovery, the Rhode Island Division of Fish and Wildlife will continue to monitor runs throughout the state, transplant adult broodstock into extirpated or restored systems, work with partners on numerous fish passage projects, and represent the state at regional meetings.

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Table 8.1 Rhode Island river herring regulation change summary.

Year	Regulation Change
Prior to 1998	12 fish bag limit per person per day
1998	Part II freshwater regulations – Increased bag limit to 24 fish per person per day
2002	Part II freshwater regulations – Changed the freshwater/saltwater boundary at Nonquit pond
2004	Part II freshwater regulations – Closed Prince Pond to harvest and reduced bag limit to 12 fish per person per day in Hardig and Buckeye Brook
2005	Part II freshwater regulations – Reduced bag limit to 12 fish per person per day statewide
2006	Part II RI freshwater regulations – Imposed moratorium in all fresh water systems; Part 7.20 RI marine regulations – Imposed moratorium in all state marine waters

Table 8.2 Alewife broodstock stocking summary.

Date	Location Stocked	Number	Date	Location Stocked	Number
4/12/2001	Bellville	2,500	4/28/2004	Wordon's Pond	1,000
4/12/2001	Echo Lake	2,500	4/28/2004	Wesquage	400
4/24/2001	Prince Pond	600	4/20/2005	Brickyard Pond	1,000
4/25/2001	Crossmills, Charlestown	1,200	4/20/2005	Echo Lake	660
5/2/2001	Warwick Pond, Warwick	1,000	4/21/2005	Belleville	1,660
5/4/2001	Crossmills, Charlestown	1,100	4/18/2005	Prince Pond	200
5/4/2001	Hamilton Reservoir	1,100	4/19/2005	Factory Pond	1,000
4/9/2002	Echo Lake	2,500	4/22/2005	Crossmills, Charlestown	600
4/11/2002	Bellville	2,500	4/25/2005	Wesquage	450
4/16/2002	Crossmills, Charlestown	600	4/26/2005	Turner Reservoir	1,000
4/17/2002	Chapmans	1,000	4/13/2006	Echo Lake	500
4/17/2002	Crossmills, Charlestown	1,500	4/13/2006	Brickyard Pond	500
4/18/2002	Prince Pond	1,000	4/14/2006	Factory Pond	1,000
4/19/2002	Turner Reservoir	1,500	4/18/2006	Belleville	700
4/22/2002	Watchaug Pond	250	4/21/2006	Indian Lake	1,000
4/23/2002	Wesquage	500	4/28/2006	Crossmills, Charlestown	350
4/23/2002	Wordon's Pond	500	4/28/2006	Wesquage	350
4/26/2002	Turner Reservoir	1,500	4/17/2007	Echo Lake	300
5/1/2002	Wesquage	600	4/17/2007	Brickyard Pond	300
4/15/2003	Turner Reservoir	1,200	4/23/2007	Indian Lake	1,400
4/17/2003	Turner Reservoir	2,250	4/24/2007	Kickemuit	200
4/16/2003	Echo Lake	2,500	4/24/2007	Kickemuit	100
4/22/2003	Factory Pond	2,500	4/15/2008	Indian Lake	1,000
4/24/2003	Belleville	2,500	4/18/2008	Kickemuit	350
4/28/2003	Wesquage	1,000	4/21/2008	Woonasquatucket	600
4/29/2003	Prince Pond	700	4/22/2008	Echo Lake	700
5/1/2003	Chapmans	200	4/22/2008	Brickyard Pond	300
5/6/2003	Crossmills, Charlestown	800	4/23/2008	Turner Reservoir	1,000
5/8/2003	Warwick Pond, Warwick	750	5/5/2008	Woonasquatucket	600
4/15/2004	Turner Reservoir	1,500	5/7/2008	Blackstone	500
4/20/2004	Turner Reservoir	1,500	2008	Omega-volunteers lifting	3,000
4/13/2004	Echo Lake	2,300	4/15/2009	Indian Lake	1,000
4/13/2004	Prince Pond	200	4/17/2009	Echo Lake	500
4/15/2004	Belleville	2,500	4/17/2009	Brickyard Pond	500
4/20/2004	Indian Lake	2,500	4/22/2009	Turner Reservoir	1,000
4/21/2004	Warwick Pond, Warwick	750	2009	Omega-volunteers lifting	800
4/22/2004	Crossmills, Charlestown	750	4/14/2010	Indian Lake	1,000
4/23/2004	Crossmills, Charlestown	500	4/15/2010	Turner Reservoir	1,000
4/23/2004	Factory Pond	1,500	4/16/2010	Kickemuit	1,000

Table 8.3 River herring spawning stock size estimates based on habitat size (Gibson 1984).

Location	Estimated Spawning Stock Size	Actual 2004-2007 Mean Spawning Stock Size	Actual 2008-2010 Mean Spawning Stock Size
Gilbert Stuart			
Habitat Size			
68 acres	64,306	20,440	67,921
Nonquit			
Habitat Size			
202 acres	138,248	50,473	104,288
Buckeye Brook			
Habitat Size			
91 acres	78,923	12,933	24,875

Table 8.4 Mean fork length (mm) at age for female river herring sampled at Gilbert Stuart.

	Mean Fork Length-at-Age							
Year	2	3	4	5	6	7	N	Annual Mean FL
1984	221.8	165.7	292.3	309.7	321.4	333	138	265.7
1985	232.4	271.3	296.9	307.3	323	334.5	35	266.5
1986			302.8	304.5	320.4	326.3	74	273.3
1987								
1988	240	269	284	311	317	331	81	260.2
1989		273	286	299	318	324	115	256.3
1990			286	293	308		17	259.6
1991	Data Not Available						42	250.0
1992		259.9	271.9	302.6	311.4	320	Not Available	249.1
1993								
1994								
1995								
1996								
1997								
1998								
1999								
2000		229.8	241.4	245.5	260.0		58	242.2
2001	224.5	233.3	241.6	244.4	252.0		47	251.8
2002		237.7	246.8	249.0	260.5		42	255.9
2003		242.0	250.8	255.3	263.3		29	254.7
2004		215	237	242	257		66	231.6
2005		212	233	251	241		82	239.0
2006		227	237	255	262		32	243.0
2007			239	244	278		39	242.3
2008			228	244	254	270	43	240.4
2009			233	239	237		30	234.5
2010		207	226	237	242		24	231.9

Table 8.5 Mean fork length (mm) at age for male river herring sampled at Gilbert Stuart.

Year	Mean Fork Length-at-Age						N	Annual Mean FL
	2	3	4	5	6	7		
1984	224.2	264.9	287.4	297.6			75	251.5
1985	224.4	260.9	279.4	295	305.3		41	252.3
1986		261	287.3	292	301.5		43	256.2
1987								
1988	238	262	278	299	310		122	236.0
1989		263	278	288	317	318	111	250.9
1990			283	291			15	252.2
1991	Data Not Available						89	231.9
1992	239.5	251.3	268.1	291.3	302.5		Not Available	226.6
1993								
1994								
1995								
1996								
1997								
1998								
1999								
2000		220.9	235.1	231.3			43	232.3
2001		231.0	246.5	254.1	253.3		101	241.2
2002	222.8	230.1	238.1	244.2			99	234.3
2003		231.7	241.2	248.1	245		75	239.5
2004	206	219	233	240			53	224.6
2005	211	215	232	233			42	224.9
2006	209	221	224	241	245		100	225.8
2007		220	227	234			110	225.8
2008		216	227	236	237		94	225.8
2009	201	208	227	235	226		67	228.9
2010	216	221	226	231			85	223.8

Table 8.6 Number and percent at age for female river herring sampled at Gilbert Stuart.

Year	Number-at-Age						Total	Mean Age	Percent-at-Age					
	2	3	4	5	6	7			2	3	4	5	6	7
1984		12	70	40	15	1	138	4.4	0.0%	8.7%	50.7%	29.0%	10.9%	0.7%
1985		6	17	4	6	2	35	4.5	0.0%	17.1%	48.6%	11.4%	17.1%	5.7%
1986			13	35	18	7	73	5.3	0.0%	0.0%	17.8%	47.9%	24.7%	9.6%
1987														
1988	1	27	9	22	17	5	81	4.5	1.2%	33.3%	11.1%	27.2%	21.0%	6.2%
1989		6	60	39	7	2	114	4.5	0.0%	5.3%	52.6%	34.2%	6.1%	1.8%
1990			8	9			17	4.5	0.0%	0.0%	47.1%	52.9%	0.0%	0.0%
1991														
1992														
1993														
1994														
1995														
1996														
1997														
1998														
1999														
2000		5	34	17	2		58	4.3	0.0%	8.6%	58.6%	29.3%	3.4%	0.0%
2001		1	11	32	3		47	4.8	0.0%	2.1%	23.4%	68.1%	6.4%	0.0%
2002		11	13	14	4		42	4.3	0.0%	26.2%	31.0%	33.3%	9.5%	0.0%
2003		1	17	7	4		29	4.5	0.0%	3.4%	58.6%	24.1%	13.8%	0.0%
2004		11	37	17	1		66	4.1	0.0%	16.7%	56.1%	25.8%	1.5%	0.0%
2005		19	9	18	36		82	4.9	0.0%	23.2%	11.0%	22.0%	43.9%	0.0%
2006		9	7	10	6		32	4.4	0.0%	28.1%	21.9%	31.3%	18.8%	0.0%
2007			30	8	1		39	4.3	0.0%	0.0%	76.9%	20.5%	2.6%	0.0%
2008			16	23	3	1	43	4.7	0.0%	0.0%	37.2%	53.5%	7.0%	2.3%
2009			16	13	1		30	4.5	0.0%	0.0%	53.3%	43.3%	3.3%	0.0%
2010		1	10	12	1		24	4.5	0.0%	4.2%	41.7%	50.0%	4.2%	0.0%

Table 8.7 Number and percent at age for male river herring sampled at Gilbert Stuart.

Year	Number-at-Age						Total	Mean Age	Percent-at-Age					
	2	3	4	5	6	7			2	3	4	5	6	7
1984	3	17	41	14			75	3.1	4.0%	22.7%	54.7%	18.7%	0.0%	0.0%
1985		17	9	12	3		41	4.0	0.0%	41.5%	22.0%	58.5%	7.3%	0.0%
1986		2	6	24	11		43	5.0	0.0%	4.7%	14.0%	55.8%	25.6%	0.0%
1987														
1988	2	90	13	10	7		122	3.4	1.6%	73.8%	10.7%	8.2%	5.7%	0.0%
1989		16	70	22	1	2	111	3.3	0.0%	14.4%	63.1%	19.8%	0.9%	1.8%
1990			2	10	3		15	5.1	0.0%	0.0%	13.3%	66.7%	20.0%	0.0%
1991														
1992														
1993														
1994														
1995														
1996														
1997														
1998														
1999														
2000		7	30	6			43	4.0	0.0%	16.3%	69.8%	14.0%	0.0%	0.0%
2001	2	16	52	30	1		101	4.1	2.0%	15.8%	51.5%	29.7%	1.0%	0.0%
2002	4	49	33	13			99	3.6	4.0%	49.5%	33.3%	13.1%	0.0%	0.0%
2003		20	45	9	1		75	3.9	0.0%	26.7%	60.0%	12.0%	1.3%	0.0%
2004	7	20	22	4			53	3.4	13.2%	37.7%	41.5%	7.5%	0.0%	0.0%
2005	2	8	6	26			42	3.9	4.8%	19.0%	14.3%	61.9%	0.0%	0.0%
2006	3	28	52	16	1		100	3.8	3.0%	28.0%	52.0%	16.0%	1.0%	0.0%
2007		28	71	11			110	3.9	25.5%	64.5%	10.0%	10.0%	0.0%	0.0%
2008		26	44	23	1		94	4.0	0.0%	27.7%	46.8%	24.5%	1.1%	0.0%
2009	1	4	42	19	1		67	4.2	1.5%	6.0%	62.7%	28.4%	1.5%	0.0%
2010	5	30	42	8			85	3.6	5.9%	35.3%	49.4%	9.4%	0.0%	0.0%

Table 8.8 Summary of Gilbert Stuart river herring data between 1980 and 2010.

Year	Population Size	N Sampled	Sex Ratio (% Female)	Mean Age (Male)	Mean Age (Female)	Mean Length (Male)	Mean Length (Female)	Percent Repeat Spawner
1980	54,042		58.9	4.93	5.09	261.0	272.0	
1981	64,297		42.6	4.71	4.98	252.9	265.8	
1982	88,194		24.0	4.50	4.97	255.8	272.0	
1983	68,919		57.8	4.26	4.62	244.2	264.0	
1984	52,873	213	64.8	3.13	4.46	251.5	265.7	22.0
1985	56,224	76	46.0	4.02	4.45	252.3	266.5	28.9
1986	51,986	107	43.9	5.02	5.26	256.2	273.3	66.7
1987	50,893			4.16	5.29	275.8	304.4	66.7
1988	74,324	203	39.9	3.43	4.52	236.0	260.2	32.5
1989	89,577	226	50.9	3.33	4.46	250.9	256.3	28.3
1990	11,009	32	53.1	5.07	4.53	252.2	259.6	50.0
1991	21,540	131	32.1	3.37	3.97	231.9	250.0	23.3
1992	32,384			3.52	4.56	226.6	249.1	26.3
1999	259,336							
2000	290,814	101	57.4	3.98	4.28	232.3	242.2	18.8
2001	254,948	148	31.8	4.12	4.79	313.5	251.8	20.3
2002	152,056	141	29.8	3.56	4.26	234.3	255.9	17.0
2003	67,172	104	27.9	3.88	4.48	239.5	254.7	7.7
2004	16,960	119	55.5	3.43	4.12	224.6	231.6	8.4
2005	7,776	124	66.1	3.90	4.87	224.9	239.0	5.0
2006	21,600	132	24.2	3.84	4.41	225.8	243.0	15.9
2007	36,864	149	26.2	3.86	4.26	225.8	242.3	7.4
2008	58,640	137	31.4	3.99	4.74	225.8	240.4	19.9
2009	34,835	97	30.9	4.22	4.50	228.9	234.5	10.3
2010	110,287	109	22.0	3.62	4.54	223.8	231.9	7.3

Table 8.9 Mean fork length (mm) at age for female river herring sampled at Nonquit.

Year	Mean Fork Length-at-Age						N	Annual Mean FL
	2	3	4	5	6	7		
2000		227.2	237.8	244.2	244.8		66	239
2001		238.5	246.0	250.8	256.5		79	248
2002		237.7	246.8	249.0	260.5		71	248
2003		242.0	250.8	255.3	263.3		79	252.3
2004		228.0	245.9	256.4	260.7		54	234.6
2005		219	228	237	243		92	230.9
2006			221	234	237		46	231.2
2007		228	242	244	253		55	242.1
2008		227	235	241	244		64	238.9
2009		222	230	241	244	248	61	235.9
2010	No Data Available: No Sampling Done							

Table 8.10 Mean fork length (mm) at age for male river herring sampled at Nonquit.

Year	Mean Fork Length-at-Age						N	Annual Mean FL
	2	3	4	5	6	7		
2000		226.6	233.1	241.7			77	231
2001	223.5	233.6	240.0	243.4	251.0		76	238
2002	223.8	233.8	237.8	241.8			74	235
2003		233.2	241.4	246.1			64	238.6
2004		234.7	240.6	244.5			74	224.7
2005	208	214	232	229			50	221.8
2006	210	220	222	236	242		97	221.8
2007		221	230	235	234		85	229.1
2008		215	223	228	236		85	223.5
2009		217	225	230	237	232	74	226.1
2010	No Data Available: No Sampling Done							

Table 8.11 Number and percent at age for female river herring sampled at Nonquit.

	Number-at-Age								Percent-at-Age					
Year	2	3	4	5	6	7	Total	Mean Age	2	3	4	5	6	7
2000		9	39	13	5		66	4.21	0.0%	13.6%	59.1%	19.7%	7.6%	0.0%
2001		6	42	25	6		79	4.39	0.0%	7.6%	53.2%	31.6%	7.6%	0.0%
2002		7	33	25	6		71	4.42	0.0%	9.9%	46.5%	35.2%	8.5%	0.0%
2003		1	33	37	8		79	4.66	0.0%	1.3%	41.8%	46.8%	10.1%	0.0%
2004		2	33	16	3		54	4.37	0.0%	3.7%	61.1%	29.6%	5.6%	0.0%
2005		12	14	32	34		92	4.96	0.0%	13.0%	15.2%	34.8%	37.0%	0.0%
2006		12	25	9			46	3.93	0.0%	26.1%	54.3%	19.6%	0.0%	0.0%
2007		2	41	10	2		55	4.22	0.0%	3.6%	74.5%	18.2%	3.6%	0.0%
2008		2	18	32	12		64	4.84	0.0%	3.1%	28.1%	50.0%	18.8%	0.0%
2009		3	25	25	6	2	61	4.66	0.0%	4.9%	41.0%	41.0%	9.8%	3.3%
2010	No Data Available: No Sampling Done													

Table 8.12 Number and percent at age for male river herring sampled at Nonquit.

	Number-at-Age								Percent-at-Age					
Year	2	3	4	5	6	7	Total	Mean Age	2	3	4	5	6	7
2000		31	39	7			77	3.69	0.0%	40.3%	50.6%	9.1%	0.0%	0.0%
2001	2	21	44	8	1		76	3.80	2.6%	27.6%	57.9%	10.5%	1.3%	0.0%
2002	6	32	31	5			74	3.47	8.1%	43.2%	41.9%	6.8%	0.0%	0.0%
2003		22	33	9			64	3.80	34.4%	51.6%	51.6%	14.1%	0.0%	0.0%
2004		27	41	6			74	3.72	36.5%	55.4%	55.4%	8.1%	0.0%	0.0%
2005	5	9	6	30			50	4.22	10.0%	18.0%	12.0%	60.0%	0.0%	0.0%
2006	2	50	37	7	1		97	3.54	2.1%	51.5%	38.1%	7.2%	1.0%	0.0%
2007		13	58	11	3		85	4.05	0.0%	15.3%	68.2%	12.9%	3.5%	0.0%
2008		13	50	17	5		85	4.16	0.0%	15.3%	58.8%	20.0%	5.9%	0.0%
2009		8	40	23	2	1	74	4.30	0.0%	10.8%	54.1%	31.1%	2.7%	1.4%
2010	No Data Available: No Sampling Done													

Table 8.13 Summary of Nonquit river herring data sampled from 2000-2010.

Year	Population Size	N Sampled	Sex Ratio (% Female)	Mean Age (Male)	Mean Age (Female)	Mean Length (Male)	Mean Length (Female)	Percent Repeat Spawner
2000	185,524	143	46.2	3.69	4.21	231	239	14.0
2001	129,518	155	51.0	3.80	4.39	238	248	10.3
2002	97,444	145	49.0	3.47	4.42	235	248	9.0
2003	74,998	143	55.2	3.80	4.66	238.6	252.3	15.4
2004	25,417	128	42.2	3.72	4.37	224.7	234.6	4.7
2005	42,192	142	64.8	4.22	4.96	221.8	230.9	6.4
2006	74,902	143	32.2	3.54	3.93	221.8	231.2	2.1
2007	59,380	140	39.3	4.05	4.22	229.1	242.1	5.3
2008	224,506	149	43.0	4.16	4.84	223.5	238.9	18.8
2009	49,841	135	45.2	4.30	4.66	226.1	235.9	17.0
2010	38,516			No Data	Available			

Table 8.14. NMFS reported river herring commercial landings (1950-2010).

Year	Haul seines	Pound net	Fyke & Hoop nets	Trawl	Hand Lines	Fish Pots	Total (pounds)	Total (kg)
1950	157,000	155,100					312,100	141,542
1951	104,300	801,500					905,800	410,794
1952	163,000	17,300		600			180,900	82,041
1953	184,300	31,300		700			216,300	98,095
1954	13,400	3,200		400			17,000	7,710
1955	2,400	43,700					46,100	20,907
1956	54,500						54,500	24,717
1957	29,300						29,300	13,288
1958		11,400					11,400	5,170
1959	301,300		39,300				340,600	154,467
1960							0	0
1961							0	0
1962							0	0
1963	112,000	17,300					129,300	58,639
1964	140,000						140,000	63,492
1965	210,000						210,000	95,238
1966	189,000	3,500					192,500	87,302
1967	175,000	10,500					185,500	84,127
1968	168,000	22,000					190,000	86,168
1969	196,000	18,900					214,900	97,460
1970	102,200	23,800		17,600			143,600	65,125
1971	52,500			100			52,600	23,855
1972	34,000						34,000	15,420
1973	15,100						15,100	6,848
1974	34,000	2,000			100		36,100	16,372
1975	35,500	6,000					41,500	18,821
1976	31,200	2,800					34,000	15,420
1977	32,500	2,800					35,300	16,009
1978	24,000	2,200					26,200	11,882
1979	5,500	6,200					11,700	5,306
1980	5,000	2,400					7,400	3,356
1981							0	0
1982		4,800					4,800	2,177
1983		6,100					6,100	2,766
1984		900					900	408
1985		400					400	181
1986							0	0
1987		2,600					2,600	1,179
1988							0	0
1989							0	0
1990							0	0
1991							0	0
1992							0	0
1993							0	0
1994							0	0
1995				400		3	403	183
1996		750					750	340
1997							0	0
1998							0	0
1999							0	0
2000				574			574	260
2001							0	0
2002				12			12	5
2003	*Moratorium After 2002*							

Table 8.15 Spawning stock size estimates for river herring at Gilbert Stuart, Nonquit and Buckeye Brook.

Gilbert Stuart			Nonquit			Buckeye Brook	
Year	Alewives		Year	Alewives		Year	Alewives
1981	64,297						
1982	88,194						
1983	68,919						
1984	17,337						
1985	16,492						
1986	48,011						
1987	50,893						
1988	74,324						
1989	89,577						
1990	11,009						
1991	21,540						
1992	32,384						
1993	21,754						
1994	43,342						
1995	95,331						
1996	70,904						
1997	122,720						
1998	262,315						
1999	259,336		1999	230,853			
2000	290,814		2000	185,524			
2001	254,948		2001	129,518			
2002	152,056		2002	97,444			
2003	67,172		2003	74,998		2003	38,949
2004	15,376		2004	25,417		2004	5,010
2005	7,776		2005	42,192		2005	18,707
2006	21,744		2006	74,902		2006	9,428
2007	36,864		2007	59,380		2007	18,587
2008	58,640		2008	224,506		2008	34,629
2009	34,835		2009	49,841		2009	31,697
2010	110,287		2010	38,516		2010	8,299

Table 8.16 Seasonal trawl survey length frequency data collected for river herring (1996-2010).

Length	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
2			1												1
3	11		9	11		1								1	
4	114	3	7	19	14	19		49	46	7	1		36	119	20
5	243	7	24	36	29	51		197		2	66		33	48	57
6	122	6	3	65	97	7	4	59			4		1	1	5
7	12	7		54	20	1	1	10			1			2	9
8	6	8		16	3	1								3	13
9	2	6		1	4										5
10	1	1		1									1		2
11				2		1									
12			1												
13															
14															
15		1													
16															
17															
18															
19															
20															
21		6													
22		17													
23	1	29													
24	3	27													
25	4	8													
26		5													

Table 8.17 Narragansett Bay seine survey length frequency data collected for river herring (2008-2010).

Length (mm)	2008	2009	2010	Total
31		2		2
32		2		2
33		1		1
35	5			5
37		1		1
38			1	1
40	6	1	1	8
41		2	3	5
42		4	2	6
43		1	4	5
44		2	4	6
45	2	2	5	9
46		2	3	5
47		1	1	2
48		6	6	12
49		1	6	7
50	12	2	10	24
51		1	10	11
52		3	13	16
53			4	4
54		3	7	10
55	21	7	9	37
56		1	9	10
57		2	5	7
58		1	5	6
59		2		2
60	43	3	12	58
61		6	3	9
62		2	2	4
63		2		2
64		3	4	7
65	51	9	3	63
66		8	1	9
67		3	3	6
68		13	1	14
69		5		5
70	31	10	1	42
71		8		8
72		5		5
73		1		1
74		3		3
75	18	4		22
77			1	1
78		1		1
80	9	1		10
82			1	1
85	6			6
90	4			4
91			1	1
95	10			10
100	16	4		20
103		1		1
104		1		1
105	7	2		9
106		1		1
108		1		1
109		1		1
110	11	1		12
115	7			7
120	3			3
130	3			3
135	1			1
Total	266	149	141	556

Table 8.18 Coastal pond length frequency data collected for river herring (1996-2010).

Length	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
2			1												1
3	11		9	11		1								1	
4	114	3	7	19	14	19		49	46	7	1		36	119	20
5	243	7	24	36	29	51		197		2	66		33	48	57
6	122	6	3	65	97	7	4	59			4		1	1	5
7	12	7		54	20	1	1	10			1			2	9
8	6	8		16	3	1								3	13
9	2	6		1	4										5
10	1	1		1									1		2
11				2		1									
12			1												
13															
14															
15		1													
16															
17															
18															
19															
20															
21		6													
22		17													
23	1	29													
24	3	27													
25	4	8													
26		5													

Table 8.19 Gilbert Stuart and Nonquit juvenile river herring mean catch rates.

Gilbert Stuart	Catch/Hr	SE
1988	112.07	46.81
1989	79.13	40.26
1990	152.25	71.34
1991	163.30	59.50
1992	343.30	125.30
2007	94.90	86.50
2008	97.25	75.54
2009	6.60	4.47
2010	10.89	6.79
Nonquit	Catch/Hr	SE
2001	161.25	83.40
2002	66.57	7.90
2003	415.04	242.58
2004	2,110.33	1,906.33
2005	887.91	451.73
2006	62.39	40.80
2007	110.15	71.49
2008	2,219.58	1,954.64
2009	40.67	9.59
2010	31.87	25.57

Table 8.20 Pawcatuck River JAI results for river herring (1993-2010).

Year	Number of Hauls	Number of Fish	Geometric Mean YOY	LL 95%CL	UL 95%CL	Zero Hauls	Arithmetic Mean	SE
1993	35	520	0.37	-0.05	0.97	28	7.09	1.23
1994	25	43	0.31	-0.07	0.85	22	1.72	1.34
1995	30	240	0.90	0.14	2.17	23	8.00	4.21
1996	30	145	0.31	-0.08	0.87	26	4.83	4.60
1997	40	5	0.08	-0.02	0.18	35	0.13	0.09
1998	55	1122	1.51	0.63	2.87	36	20.40	12.57
1999	45	10	0.18	0.05	0.32	38	0.43	0.09
2000	65	527	2.03	1.20	3.17	27	8.11	1.01
2001	65	35	0.21	0.06	0.39	56	0.54	0.23
2002	50	500	2.34	1.30	3.86	19	19.61	10.47
2003	54	226	0.67	0.24	1.24	41	4.19	2.13
2004	60	533	1.43	0.68	2.50	37	8.88	4.09
2005	57	27	0.08	-0.04	0.22	54	0.47	0.44
2006	67	184	0.27	0.03	0.55	60	2.75	2.02
2007	70	186	0.30	0.05	0.61	62	2.66	1.44
2008	60	10	0.08	-0.01	0.17	56	0.17	0.11
2009	60	0	0.00	0.00	0.00	60	0	0
2010	55	17	0.15	0.03	0.28	48	0.31	0.15

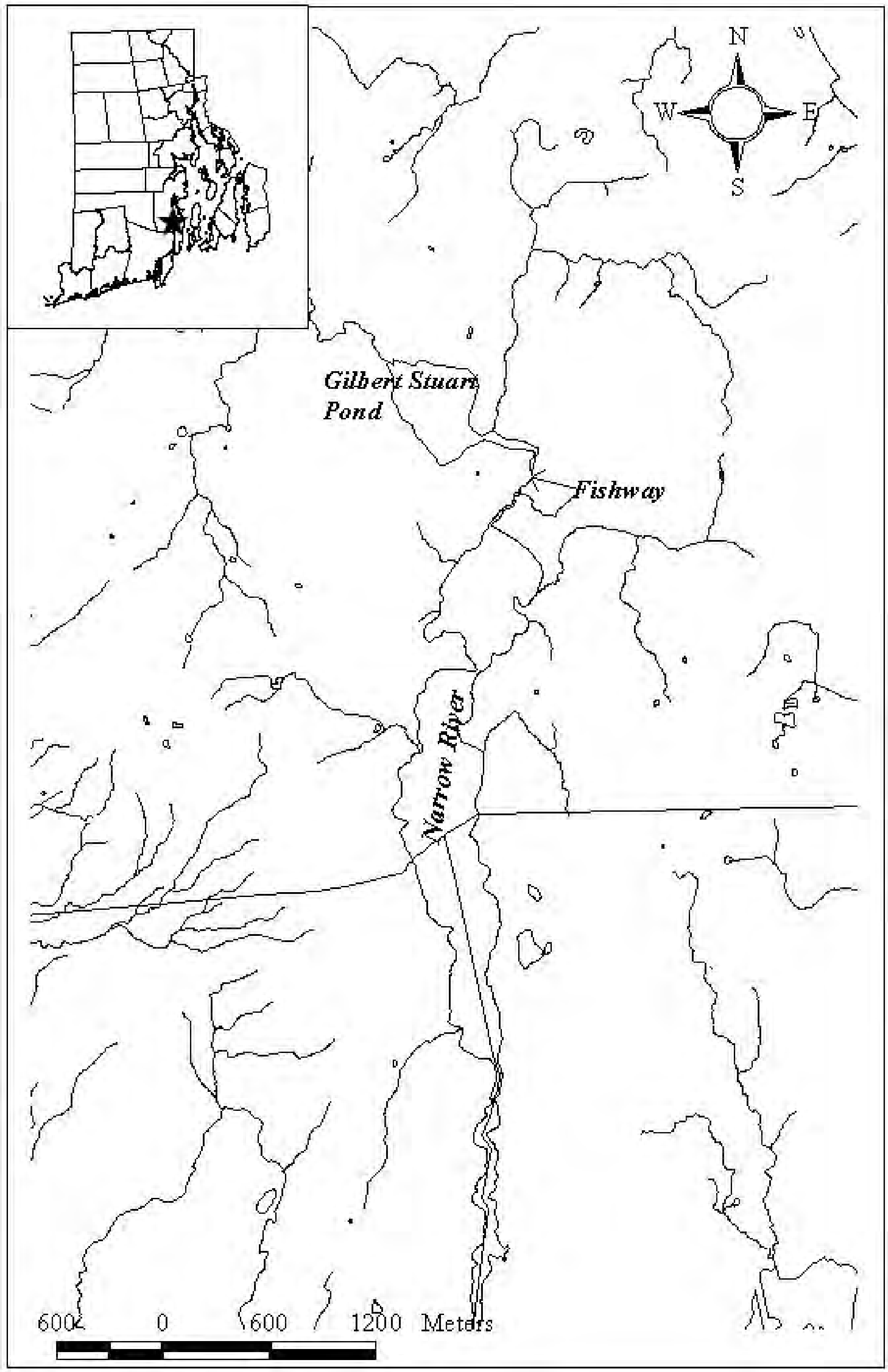

Figure 8.1 Gilbert Stuart Fishway, North Kingstown, Rhode Island

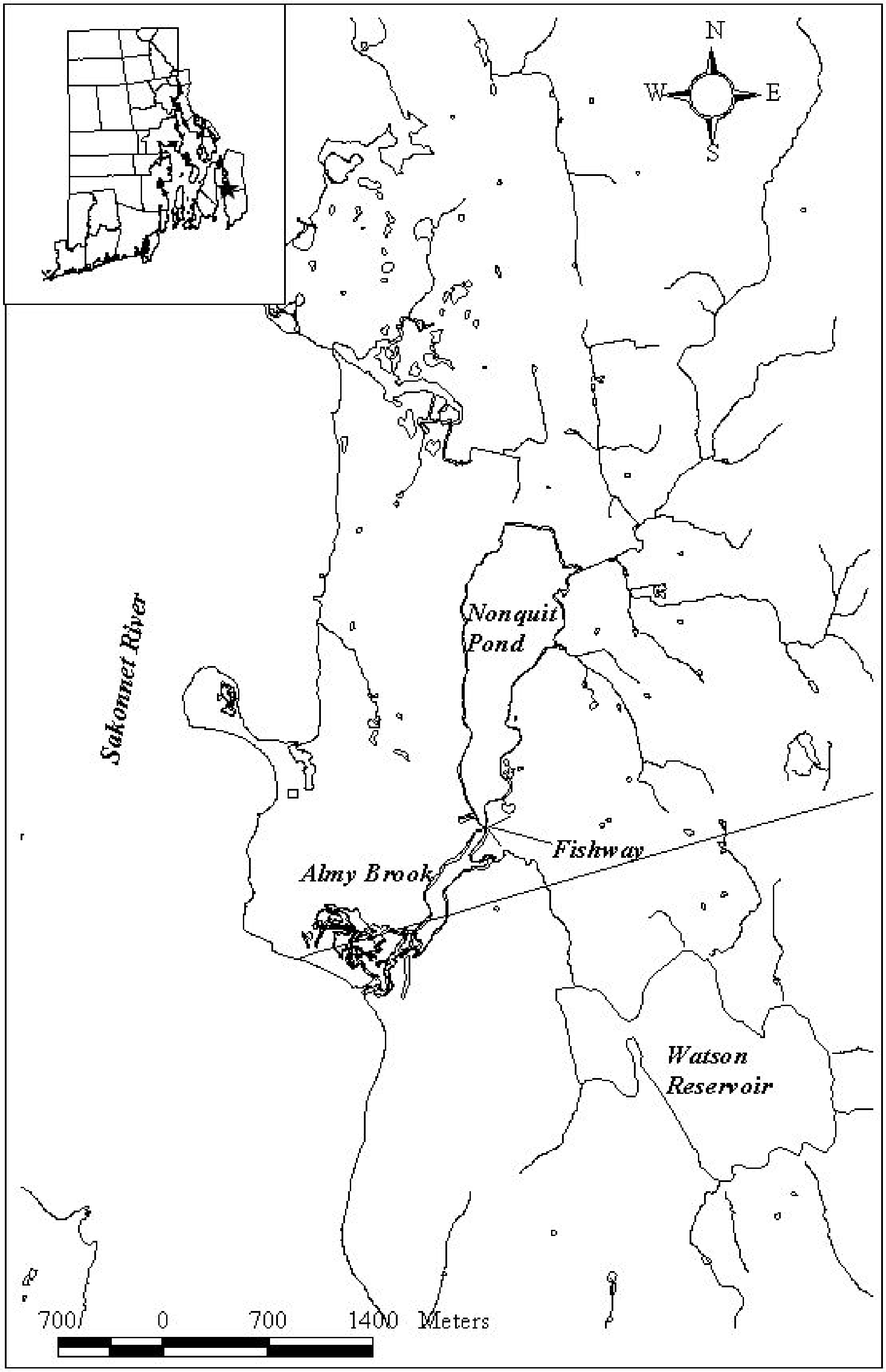

Figure 8.2 Nonquit Fishway, Tiverton, Rhode Island

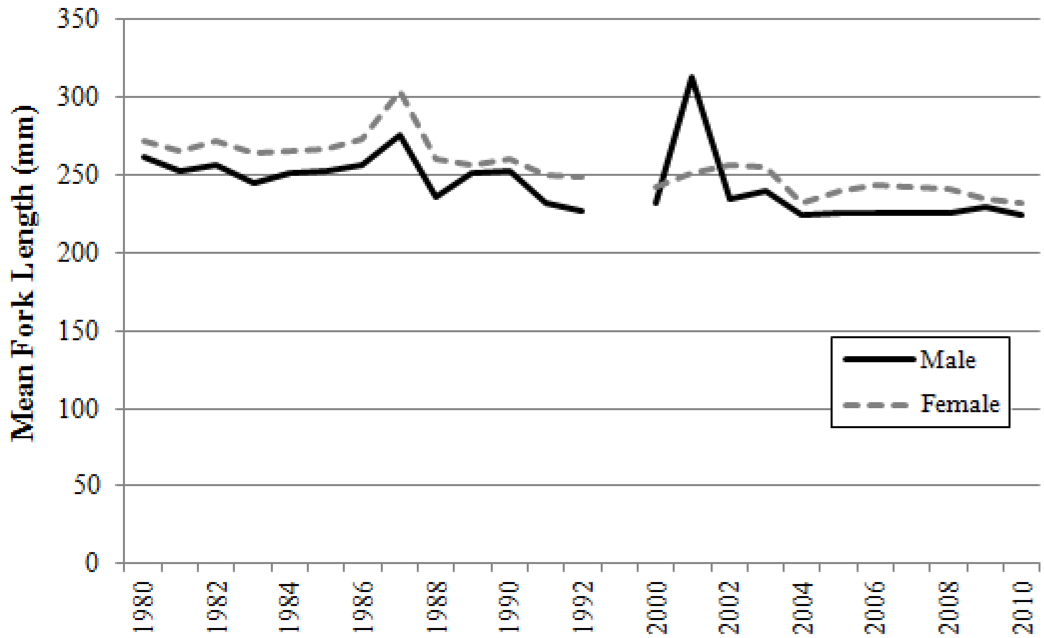

Figure 8.3 Annual mean fork length (mm) for river herring sampled at Gilbert Stuart.

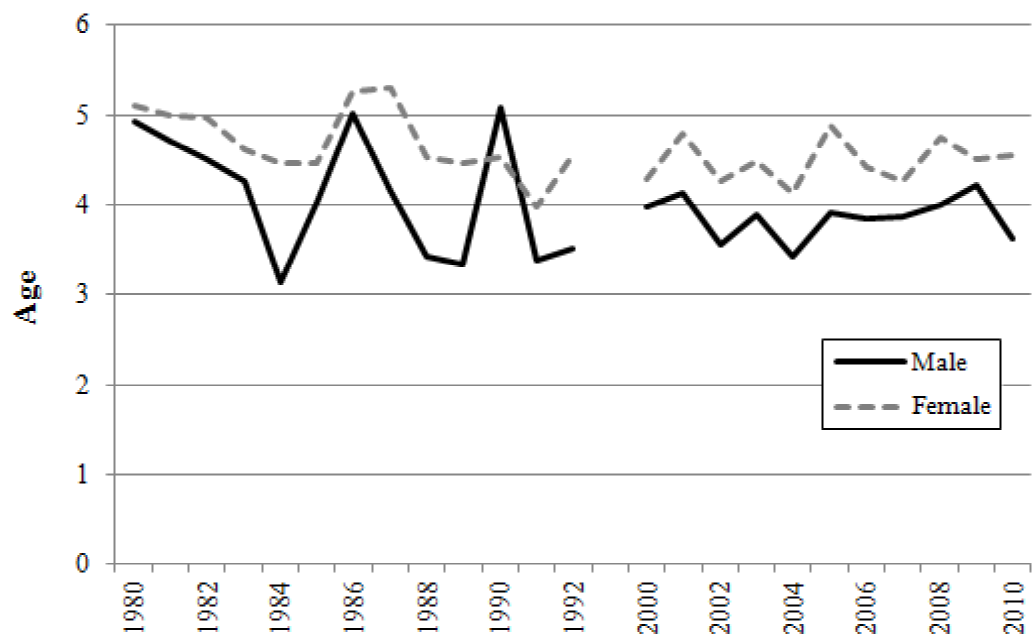

Figure 8.4 Annual mean age for river herring sampled at Gilbert Stuart.

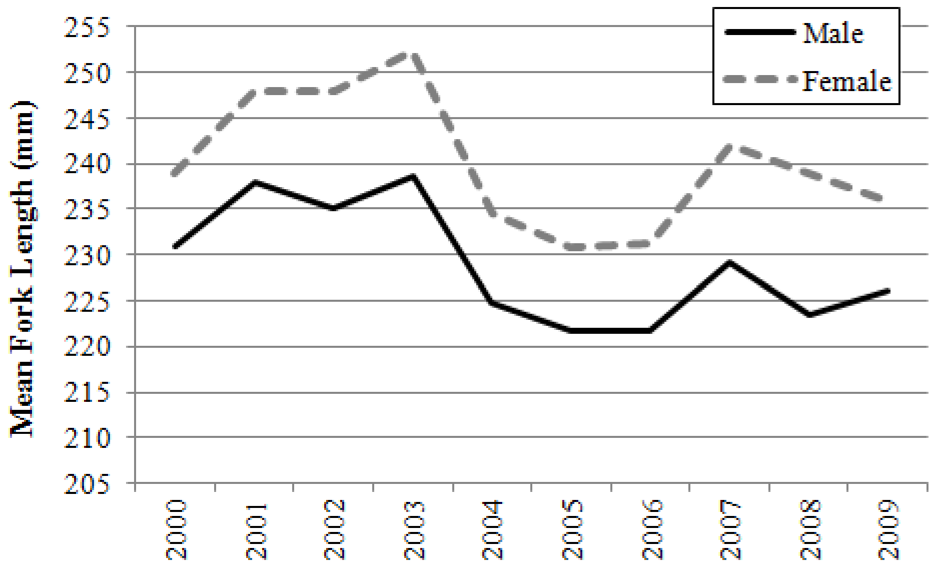

Figure 8.5 Annual mean fork length (mm) for river herring sampled at Nonquit.

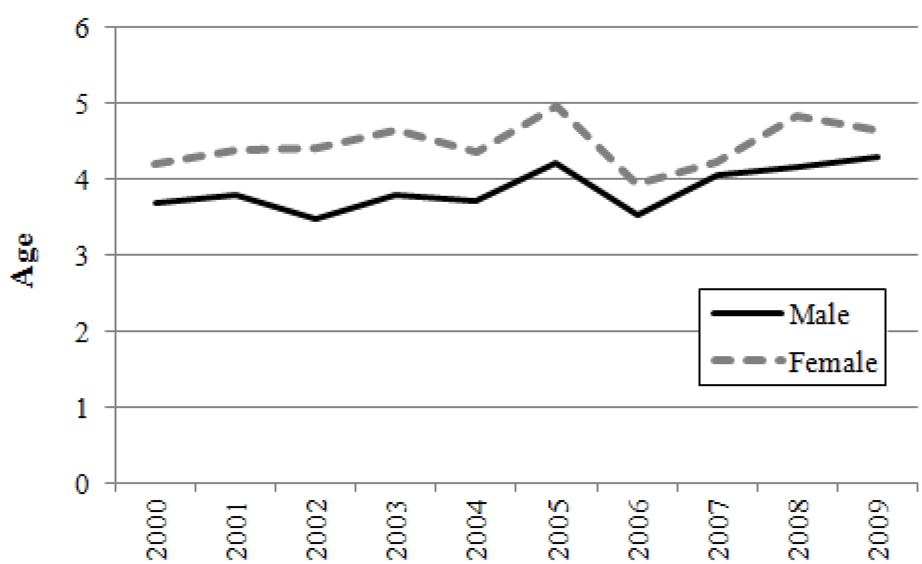

Figure 8.6 Annual mean age for river herring sampled at Nonquit.

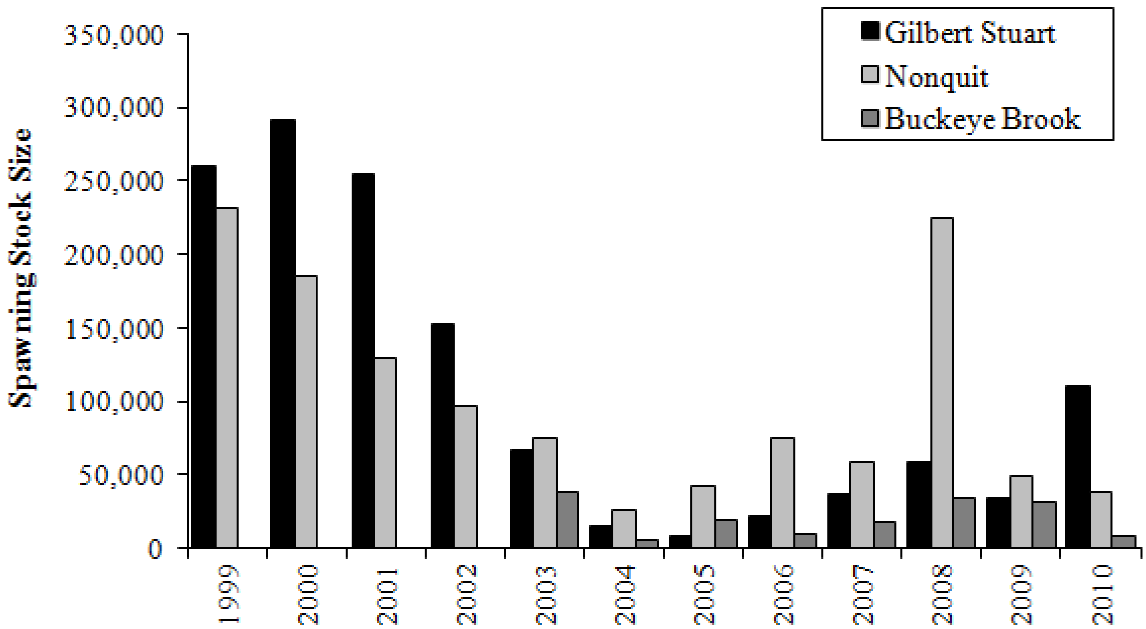

Figure 8.7 Spawning stock size estimates for Gilbert Stuart, Nonquit and Buckeye Brook.

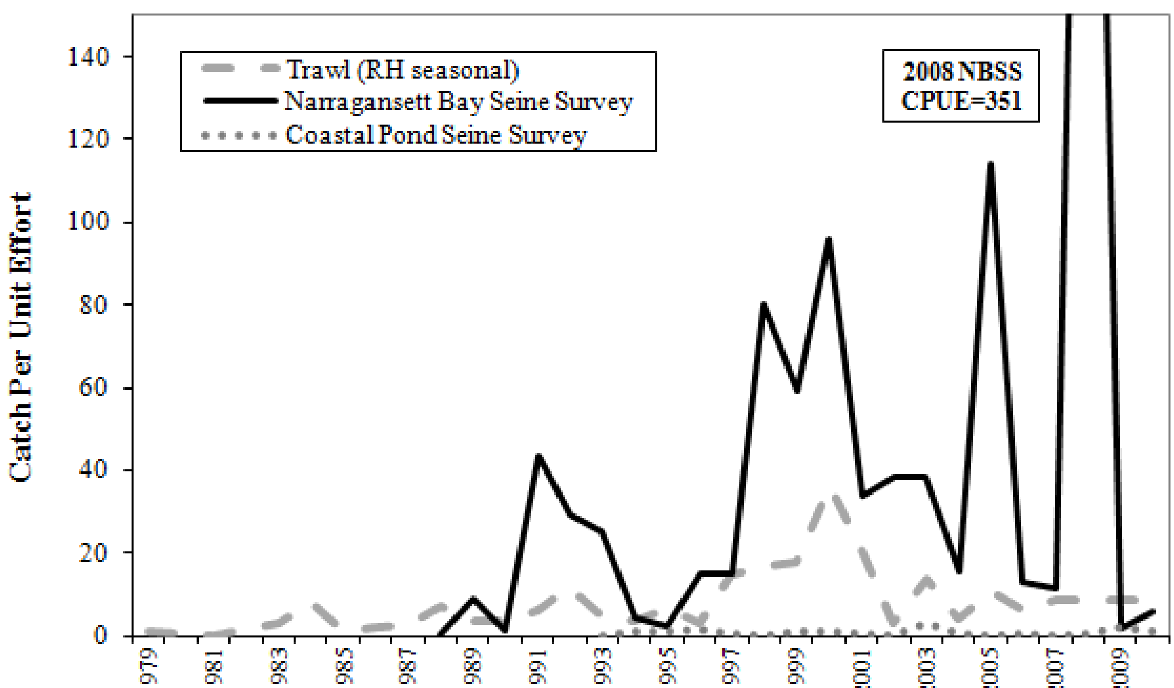

Figure 8.8 Marine Survey Indices-Annual mean river herring catch per tow or seine haul (arithmetic mean)

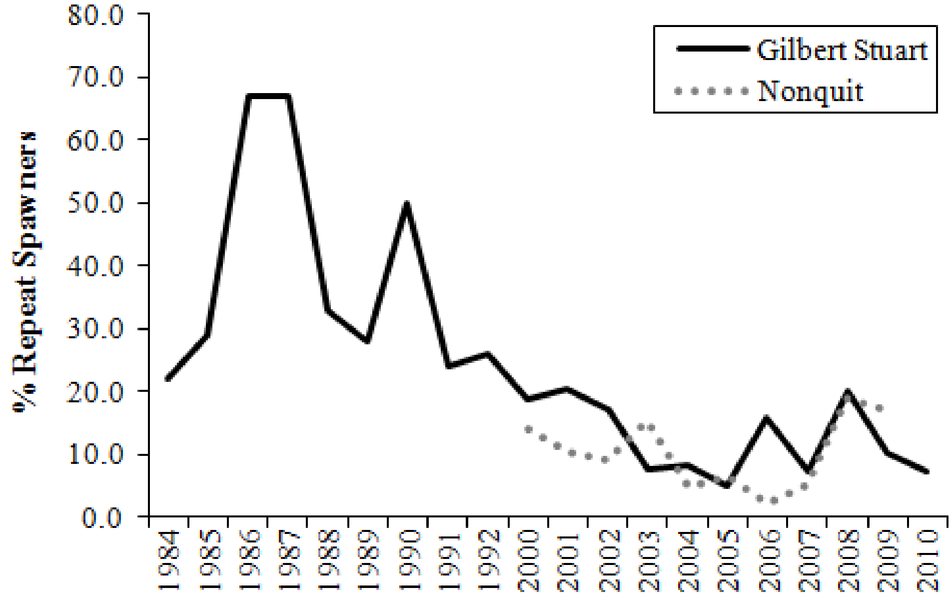

Figure 8.9 Percent repeat spawning for river herring sampled at Gilbert Stuart and Nonquit.

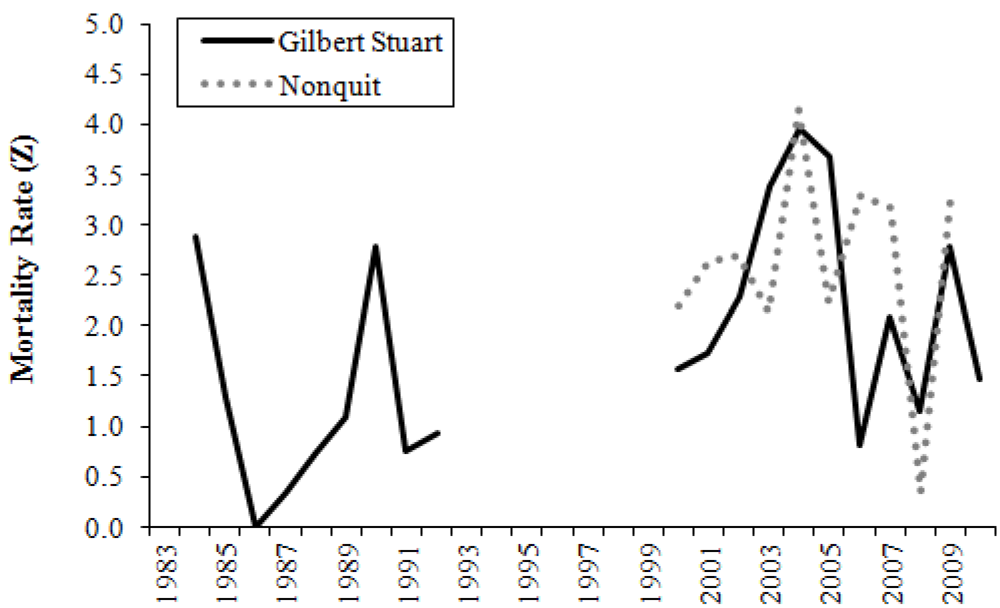

Figure 8.10 Total Mortality Rate (Z) for river herring sampled at Gilbert Stuart and Nonquit.

9. Status of River Herring in Connecticut

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Executive Summary

A moratorium on the take of anadromous river herring in Connecticut state waters has been in effect since 2002. Blueback herring (*Alosa aestivalis*) fish-lift counts and run size estimates in the Connecticut River have remained at low levels from 1995 through 2010 and have continued to stay at low levels in the decade following the statewide moratorium. Connecticut River blueback juvenile production (mean catch/seine haul) has remained relatively low from 1998 through 2009. In 2010 the juvenile index was unexpectedly strong, with the fourth highest CPUE in the time series (1979-2010). Alewife (*Alosa pseudoharengus*) abundance has not been monitored directly in the Connecticut River. Alewife and blueback relative abundance of mixed stock age 1+, (mean catch/tow) are documented by the Long Island Sound Trawl Survey (LISTS). Passage counts of adult river herring are collected within several Connecticut tributaries by the Inland Fisheries Division (IFD).

Historically, when river herring fisheries were prominent, harvest was a small contributor to total commercial fisheries landings in the State. Total age aggregate (ages 3+) fishing mortality (FT) estimates on blueback herring, based on the ratio of Sound-wide landings to stock size, were generally highest from 1981 to 1985, but fishing mortality rates never exceeded 0.07 from 1981 to 2001. Because of the alarming drop in blueback herring counted at the Connecticut River Holyoke Lift since 1995, a state-wide moratorium to blueback and alewife harvest was enacted in Connecticut waters from 2002 to present. Despite the State-wide landings closure, adult blueback stock size in the upper River has shown no sign of recovery. However, the emergence of the very strong 2010 blueback year-class, when only 92 adults were passed at the Holyoke fish-lift, suggests the possibility of a differential build-up of blueback production within the lower (< 80 km) River. Alewife counts at Bride Lake in East Lyme Connecticut have fluctuated since 2003 and produced the highest counts of adult alewives in 2010 and 2011.

9.1. INTRODUCTION

Connecticut has numerous river herring runs, but little long term data collection exists to track stock status. The annual Connecticut River adult blueback herring (*Alosa aestivalis*) counts at the Holyoke Fishlift has remained low through 2010 despite a State-wide moratorium of migratory river herring harvest from 2002 to the present (Table 9.1). Juvenile indices for blueback herring have been monitored annually throughout the River since 1979 (Benway 2011). Juvenile production was high and relatively stable from 1979 to about 1997, but juvenile indices dropped thereafter by 50 to 95% through 2009. The blueback juvenile index (mean number/seine haul) of 11.72 in 2009 was the lowest in the time series. Prior to 1986, nearly a half million pre-spawned adult blueback herring were passed annually at the Holyoke Dam fish lift (river km 140), but lift numbers declined steadily after 1995 to where only 76 adult blueback herring were passed at the Holyoke lift in 2010 (Table 9.1).

The blueback herring congener, the alewife (*Alosa pseudoharengus*), spawns mainly from mid March to mid May in coastal tributaries and mostly within the lower (< river km 80) Connecticut River (Loesch 1987). Alewife are not thought to ascend as far as the Holyoke fish lift (Gephard and McMenemy 2004), thus, there is no time series of adult alewife in the Connecticut River. Alewife relative abundance (mean catch/tow) has been monitored based on a Sound-wide trawl surveys from 1984-2010 (Gottschall and Pacileo 2011) and from fish-lift counts and visual estimates from several coastal streams (DEEP unpub., Gephard et al.2008). Unlike the pronounced blueback decline in the Connecticut River, relative abundance of alewife State-wide has either remained stable or has shown some increases in recent years.

The Connecticut Department of Energy and Environmental Protection (DEEP) has conducted analysis on Connecticut River blueback herring to examine the effects of fishing and predation on the recent blueback stock decline. Since blueback herring have exhibited a much greater decline than alewife since 1996 there is now an increasing body of evidence to suggest that enhanced predation by striped bass (*Morone saxatilis*) in the Connecticut River has played a major role in the decline in Connecticut river blueback herring stock size (Savoy and Crecco 2004; Crecco and Benway 2010; Davis et al.2009)

9.2. MANAGEMENT UNIT DEFINITION

The demarcation line between the marine and inland district occurs at the I-95 Baldwin Bridge crossing the lower Connecticut River. The moratorium for river herring is in effect for all state waters. Long Island Sound is jointly managed by Connecticut and New York State.

9.3. REGULATORY HISTORY

Connecticut has three major rivers (Connecticut, Housatonic and Thames) and several smaller rivers and coastal streams (Figure 9.1). The bulk of Connecticut river herring fisheries occurred in the Connecticut River (Blake and Smith 1984). Fisheries in designated Inland waters are under the regulatory jurisdiction of DEEP Inland Fish Division (IFD).

Haul seine was the primary gear for commercial river herring fisheries in the Connecticut River. There was a natural attrition to these fisheries and they phased out in the 1980s (Table 9.2). From 2002 to present there has been a state wide moratorium on the commercial and recreational take of anadromous blueback herring and alewife. Under emergency declaration authority of section 26-102 of the Connecticut General Statutes, the commercial or recreation taking of migratory alewives and blueback herring is prohibited from all marine waters and most inland waters (with exceptions) until March 31, 2012. This prohibition is determined on an annual basis.

Prior to the moratorium, the recreational limit for both inland and marine waters was 25 blueback herring or alewife, in aggregate, per person per day. Land locked alewives from specific lakes may be taken recreationally by angling and scoop net. For areas identified, the recreational creel limit is 25 fish for personal use purposes. Commercial fishing is not allowed in those bodies of water.

Massachusetts regulations to prevent the over harvest of Connecticut River anadromous fish date back to the late 18th century as construction of canals and dams created impediments to migration. During canal construction laws were passed to regulate fishing near the dam in South Hadley (Thomas, 1801).

During the early 19th century, Connecticut regulations applied penalties for preventing fish migration. Laws were enacted prohibiting constructing a dam unless there was a proper opening for fish to pass during April through June. Obstructions created to catch fish near a dam in the river during spring migration, would result in a fine. Rest days prohibited seining and scoop netting in the Shetucket River below the junction with the Quinebaug (Thames River Watershed) during designated nights in the spring Friday. Seining was also prohibited at the mouth of Housatonic River during the spring (Goodrick *et al.* 1821). No weirs or other obstructions, were allowed across Bride Brook outlet in East Lyme, between sunset on Saturday and sunrise on the following Friday from late March early May (Connecticut General Assembly, 1900).

In the mid 20th century, Connecticut state statutes identified specific coves within the Connecticut River prohibiting the use of seines and fyke nets during spring anadromous spawning runs.

9.4. ASSESSMENT HISTORY

The most recent coastwide river herring stock assessment (ASMFC 1990) indicated that adult blueback herring (*Alosa aestivalis*) in the Connecticut River remained relatively stable from 1971 to 1989. The most recent fishing mortality (F) estimates on Connecticut River blueback herring, based on catch curves (F = Z – 1.0), was 0.34 which was 75% below the F_{msy} threshold level of 1.40. The 1990 assessment (ASMFC 1990) concluded that the blueback herring stock in the Connecticut River was partially exploited and not overfished. More recent juvenile and adult abundance estimates in the River (Savoy and Crecco 2004) have exhibited a severe and persistent decline, especially after 1992. Prior to 1986, nearly a half million pre-spawned adult blueback herring were passed annually at the Holyoke Dam fish lift (river km 140), but lift numbers declined steadily after 1995 to where only 76 adult blueback herring were passed at the Holyoke lift in 2010 (Table 9.1). Juvenile indices for blueback herring have been monitored annually throughout the River since 1979 (Benway 2011). Juvenile production was high and relatively stable from 1978 to about 1997, but juvenile indices dropped thereafter by 50 to 70%. The preliminary blueback juvenile index (mean number/seine haul) of 11.72 in 2009 represented the lowest arithmetic mean cpue value in the time series (Table 9.3). The blueback herring congener, the alewife (*Alosa pseudoharengus*), spawns from mid March to mid May in coastal tributaries and within the lower (< river km 40) Connecticut River (Loesch 1987). Alewife are seldom passed at the Holyoke fish lift, thus, there is no long-term (1981-2010) time series of adult alewife counts in the Connecticut River. Alewife abundance indices are available for age 1+ to adult from the LIS trawl surveys, (Gottschall and Pacileo 2011) and fishlift counts from coastal streams (Gephard et al 2010). Numbers of alewives have either remained stable or have shown some increase (Table 9.1).

9.5. STOCK SPECIFIC LIFE HISTORY

9.5.1. Growth

There is no consistent time series of length data available for adults by stock. Data provided include the Long Island Sound Trawl Survey which is comprised of river herring from a variety of rivers and streams immature fish and some adults. Length frequencies (cm, FL) of all fin fishes including blueback herring and alewife have been monitored annually from 1989 to 2010 (Tables 9.4 and 9.5).The Connecticut Department of Energy and Environmental Protection (DEEP) Inland Fisheries Division (IFD) has provided lengths obtained during sample collections at several streams as well as length data from graduate student research studies (Tables 9.6 and 9.7).

Bluebacks enter the mainstem and tributaries in April and the spawning run continues until mid-July. Blueback herring preferred spawning sites with fast-flowing water and the associated hard substrate. Blueback selected fast moving waters and avoided slow flowing tributaries (Loesch and Lund 1977).

9.5.2. Reproduction

Blueback herring have an extended spawning season in Connecticut waters. Loesch (1968), detected blueback herring in Connecticut in mid-April when water temperatures were around 8 degrees C. The highest abundance near spawning areas occurred during the latter half of June and early July. Blueback herring choose spawning sites with swift flow and hard substrate and avoided and shallow areas. Parts of the spawning season for the alewife and blueback herring overlap, the two species were observed spatially isolated by selecting different spawning sites.

In an examination of alewife spawning behavior in Bride Lake from 1966-1969, alewives immigrated in March when water temperatures were 4 or 5 deg C and alewives stopped entering the Lake in early June when water temperatures were 19-20 degrees. Alewives were observed on the spawning grounds for 3-82 days (Kissil 1974).

9.5.3. Maturity

Connecticut River river herring males achieve maturity at age 4, and most females at age 5 (Jones et al. 1978).

9.5.4. Fecundity

Variation in estimated egg counts for individual blueback herring ranged from 45,800 (238-mm fish) to 349,700 (310-mm fish). Ovary weights and the total number of eggs in unspawned and spawned fish increased with fish length through the 296-305mm interval (Loesch and Lund 1977).

9.6. HABITAT DESCRIPTION

The Connecticut River is the largest river in New England and flows 410 miles from the Canadian border to Long Island Sound (Figure 9.2). Once referred to as “New England’s most beautifully landscaped sewer”, the Connecticut River has had a long history of environmental and water quality problems. Several decades have passed since the Clean Water Act was initiated and since that time there have been great improvements to the water quality of the river. The biggest impact to river herring habitat was the construction of dams.

9.6.1. Spawning and Nursery Habitat

Loesch and Lund (1977) noted that spawning adult blueback herring were found in the lower Connecticut River in mid-April when water temperatures were as low as 4.7°C, but spawning did not occur until several weeks later in mid-May when the water temperature had risen. Spawning temperatures for alewife were between 7-11 °C in the lower CT River (Marcy et al. 1976a). Alewife choose slower moving waters in Bride Lake (Kissil 1974) and Higganum and Mill Creeks (CT River). Blueback herring selected fast moving waters in the upper Salmon River and Roaring Brook (Loesch and Lund 1977). In areas where alewife and blueback herring spawn in the same general habitat (Loesch 1987), alewife generally spawn along the bank, eddies or deep pools. Blueback herring will typically select the main stream flow for spawning (Loesch and Lund 1977). Kissil (1974) found that alewife spawning in Bride Lake, Connecticut spent 3 to 82 days on the spawning grounds. Blueback herring select fast moving waters in the upper Salmon River and Roaring Brook (Loesch and Lund 1977).

A recent examination of alewife juvenile migration at Bride Lake showed that more than 80% of juveniles migrated out in 3 pulses lasting 1 or 2 days. Emigration was associated with precipitation, decreases in water temperature and increases in flows (Gahagan et. al 2010). Historically, Bride Brook provided an important route for one of the largest migration runs in coastal streams of alewife. However, registered ground water diversions from nearby public water supply wells contribute to dry stream conditions in the brook just downstream of Bride Lake, significantly decreasing the viability of alewife breeding ground. Examples are documented in 1999 (CTDEP 2000).

9.6.2. Habitat Water Quality

The Connecticut River, once famously referred to as "New England's most beautifully landscaped sewer," has a long history of poor water quality due to heavy industrial expansion of textiles, heavy metal processing, logging and sewage. Natural disasters such as hurricanes, droughts and flooding events have also had large impacts on the water quality of the river. Connecticut has also been progressive in the development of water quality management following some the dismal times of heavily polluted waters. An example is the development of Connecticut's Clean Water Act (1967), which was 5 years ahead of the Federal Clean Water Act of 1972.

From the 1800s to the late 1960s, untreated or minimally treated waste discharges from population centers and industries caused serious water quality problems. During the mid 1960's, high levels of fecal coliform bacteria were found in the river. Industrial discharge of untreated waste from paper, chemical, metal, plating, dyeing and other industries created serious water quality problems. Concentrations of dissolved oxygen in an area below the Holyoke Dam were nearly zero during the mid 1960s and early 1970s.

Legislative interest in water pollution dates back as far as 1887 when the Connecticut General Assembly authorized the formation of a sewer study commission to investigate sewage disposal. The commission report in 1889 recommended the State find ways to stop further pollution. A Legislative study commission was created in 1913 to investigate factory wastes and, again, in 1921 to investigate solutions to eliminate pollution. In 1925 laws were enacted to create a State Water Commission, but the commission had few resources and a lack of direct regulatory authority. By the mid 1960s, water quality conditions were so poor that public outcry and governmental interest were sparked and started the process towards change.

Many of the good trends in water quality which include downward trends in total phosphorus, total nitrogen, bacteria and upward trends in pH and DO can be attributed to improvements in wastewater treatment following the Federal Clean Water Act of 1972. Downward trends in sulfate concentrations likely are attributable to reductions in sulfur dioxide emissions mandated by the Clean Air Act of 1970. Current and future water quality challenges for the Connecticut River include reducing nitrogen loads from point and nonpoint sources, reducing bacteria and other contaminant concentrations in urban storm water runoff, and separating storm water and sanitary sewers at some locations to prevent combined sewer overflows (Mullaney, J.R. 2004).

9.6.3. Habitat Alterations

Connecticut River

One of the most significant impacts to anadromous fish habitat in the Connecticut River was the construction of dams beginning in the 18th century. The Connecticut River was the first river in the country to be improved by canals, with the construction of locks at South Hadley Falls in 1795, which enabled traffic on the Connecticut River to move past the 40 foot falls at South Hadley. Shad and salmon stocks began to show signs of depletion after the construction of Turners Falls Dam in 1798. A timber dam constructed at South Hadley falls was completed in 1849, although a smaller version of a dam was built during construction of the canals and was maintained and enlarged 3 to 4 times with a wing dam in place until the construction of the timber dam in 1849 (Kirtland, 1897). The dams caused an immediate decline in the American shad population and even though river herring is not specifically mentioned, one would assume the same effect on river herring. South Hadley Falls and Turners Falls in the Connecticut River are places with bedrock falls which were also places more favorable for dam construction.

The first type of fish passage at Holyoke, was added in 1873 and was unsuccessful at passing shad. In 1900 the present form of the dam was constructed and in 1940 a second attempt was made to construct a fishway, which was also unsuccessful. In 1949 the Holyoke Water Power Company was granted a license to construct a new power plant. A stipulation was for the power company to build fish passage. The finished product was completed in 1952, but was ineffective and replaced by a fish elevator in 1955 (Henry 1976). Daily counts of American shad lifted have been made annually from 1955 to 2005 (Watson 1970; Moffit et al 1982; Leggett et al 2004). Major technological improvements in the Holyoke lift have been made in 1969, 1975 and 1976 (Henry 1976) which resulted in increased annual passage rates (mean number/lift day) of American shad. After 1976 no further improvements in the fish lift were made until 2005. Improvements in 2005 include new tailrace lift tower, bucket and hoist, new spillway lift tower, bucket and hoist, redesigned spillway entrance gallery and crower, a wider exit flume,a new shad trap and truck facility, a new counting room and second counting window (MADFW 2009).

The Enfield Dam was constructed around 1829 to avoid the rapids and to divert water to the Windsor Locks Canal. The dam was a wooden crib structure nearly 1,500 feet in length. The low-head dam was often submerged during high flows in the spring. The presence of the dam caused mirgratory delays and became an obstruction during low flows. The dam fell into disrepair in the late 1970's and is now breached in many areas (Leggett *et al.* 2004).

Thames River

The Greeneville Dam was built on the Thames River in 1829 to provide grists and paper mills with water (US Census Office 1880). Norwich Public utilities completed construction of a fishlift elevator in 1996 to pass fish above the dam.

Housatonic River

The first dam (Derby) of the Housatonic River was completed in 1868 and took three years to come to completion (Leffel 1874). The Stevenson Dam, bordering Monroe and oxford, is the largest of the five Connecticut Light & Power hydroelectric dams on the Housatonic River. Connecticut Light and Power operates 5 hydroelectric plants on the river in Connecticut. Falls Village, Culls Bridge, Shepaug, and Stevenson dams are traditional pond and release facilities which generate power to meet peak power demands. Rocky River is a pump storage facility which takes water from the Housatonic River, pumps it up a pipe and stores it in Candlewood Lake, the state's largest man-made lake (HVA 1999).

Bride Lake

Historically, Bride Brook provided an important route for one of the largest migration runs in coastal streams of alewife. However, registered ground water diversions from nearby public water supply wells contribute to dry stream conditions in the brook just downstream of Bride Lake, significantly decreasing the viability of alewife breeding ground. Examples are documented in 1999 (CTDEP 2000). Recent replacement of an entrance culvert coincides with increases in adult alewife entering the lake over the past 2 years (Table 9.1).

9.6.4. Habitat Loss

In the 1700s, Connecticut River American shad and herring were so abundant that those who consumed shad were looked down upon. The river falls were great places for fishing. Shad and herring were barreled salted and exported (Judd 1905). According to Judd (1905), during this era before dam construction it was not necessary to regulate fisheries. The first dam at South Hadley around 1795 and the dam at Turners Falls heavily affected fish. Fewer fish were caught after 1800. Accounts of fisheries at the falls, after the Revolution were described as the best fishing in springtime and shad were caught in seines and with scoop nets below the falls. Boats fished near the falls and collected shad by scoop net and could collect several thousand fish in a day. Shad were so abundant that is was said that oars would strike the fish while paddling across the river. (Judd 1905).

9.7. RESTORATION

9.7.1. Objective/Target

DEEP Inland Fisheries Division (IFD, is responsible for the enhancement and restoration of diadromous fish in Connecticut. River herring and shad are transplanted from donor streams to streams that were known to historically have river herring (Gephard et. al 2010). IFD also assists and coordinates fish passage projects throughout the state.

The Connecticut River watershed spans across 4 states and includes Connecticut, Massachusetts, New Hampshire and Vermont. The Connecticut River Anadromous Fish Restoration Program is a cooperative interjurisdictional management effort that began in 1967. In 1983 an interstate compact relating to the restoration of Atlantic salmon and diadromous fish was created including the four states located in the Connecticut River watershed, the U.S. Fish and Wildlife Service and the National Marine Fisheries Service (Public Law 98-138). While the initial focus of the compact was Atlantic salmon, the Connecticut River Atlantic Salmon Commission (CRASC) has since included focus on anadromous fish recovery and restoration. Goals outlined in the CRASC River herring management plan include increasing passage through upstream barriers, maximizing outmigrating juvenile survival and enhancing and restoring habitat in the Connecticut River Basin (CRASC, 2003).

Program participants are structured into a technical committee and a policy committee. The program participants are responsible for development of projects and activities to enhance the American shad resource system and to restore Atlantic salmon to the Basin.

9.7.2. Stock Definition

Most of the fisheries post dam construction occurred in the Connecticut River. The Holyoke Dam Fish Lift counts are the only long term proxy for adult blueback herring abundance in the river.

9.7.3. Stocking Efforts

Restoration and Enhancement projects are conducted by IFD. As part of restoration activities, river herring are collected from donor streams and then released in areas that once had river herring or have low numbers.

9.7.4. Hatchery Evaluation

There have been no hatchery efforts for river herring restoration in Connecticut.

9.7.5. Passage Efficiency

Passage efficiencies are unknown.

9.8. AGE

Age structure for Connecticut River herring is unavailable. There were a small number of fish sampled for scales in 2010 but no other data is available.

During 1966 and 1967 scales were collected from Alewives in the Connecticut River and Bride Brook. Scales from blueback herring were collected from the Connecticut and Thames Rivers. Alewives reached a maximum age of 8 years, while blueback herring reached seven years. Bride Brook alewives were 5 and 6. Blueback males were age 3, 47% and 50% age 4. Females were 75% age 4 and 16% at age 5 (Marcy 1969).

9.9. FISHERIES DESCRIPTIONS

9.9.1. Commercial Fishery

A moratorium since 2002 has been in effect on the commercial and recreational harvest of river herring in all Connecticut waters. Haul seine, otter trawl and commercial gill-net fisheries have harvested blueback and alewife mainly during spring (March-May) from Long Island Sound (LIS) and its tributaries (Table 9.2). Otter trawl fisheries licensed by the State have occasionally harvested blueback herring and alewives in LIS and from the EEZ during all months. Beginning in 1975, all lobster pot and otter trawl fishermen licensed by the State were required to report their monthly finfish (by species) and lobster landings by logbook. From 1981 to 1995, all haul seine and gillnet commercial fishermen licensed in Connecticut were also required to report their annual landings and fishing effort (number of days fished) to the State by September of following year. After 1995, all gillnet and haul seine fishermen were required to report their landings in the monthly logbook system. Due to the problems in identifying blueback herring from alewife, commercial landings of both species from 1981 to 2001 are referred to as “river herring”. Since there is no sampling of commercial landings in Connecticut, length frequency and species composition are not available.

River herring contributed a low percentage to total commercial finfish landings and landings of all species including shellfish in Connecticut. River herring were harvested primarily by haul seine (90-95%) with 2-6% harvested by gillnet (Table 9.2). Commercial fishing for river herring occurred primarily in the Connecticut River and was used primarily for lobster bait and bait for game fishing. During the 1950’s they were used as industrial fish, being reduced to fish meal. Two peak periods in the recorded historical landings occurred from 1892-1908 and 1950-1955. During these periods annual landings exceeded 500,000 pounds. A record landing of 1.94 million pounds occurred in 1950 (Blake and Smith 1984). Landings have generally remained at less than 100,000 pounds since 1960. The majority of the river herring landings from the ocean in the mid 1980s to the mid 1990s were taken within Long Island Sound with a little over 20% occurring in the Atlantic Ocean and from Block Island Sound. Landings in the 1990s dwindled to a few thousand pounds except for 1995 and 2000 (Figure 9.3).

Although commercial fishermen on the Connecticut River have reported their annual catches to the State of Connecticut since 1890 this information may not be informative to determine fluctuations in abundance. The License data was not a measure of effort since a record of when a license was issued did not indicate what proportion of the season the gear was fished (in early years). While increases in fishing effort a likely reason for increases in reported landings effects of improved statistical reporting procedures and effects of improved water quality could also be a factor. Without definitive CPUE or survey indices, it is impossible to determine relative resource abundances prior to the late 1970’s. (Smith *et.al* 1989).

9.9.2. Recreational Fishery

There was a recreational fishery for river herring in the Connecticut River prior to the moratorium, but the magnitude of the recreational harvest has never been estimated (Savoy and Crecco 2004). There are no reported landings data on recreational river herring fisheries in Connecticut. There was a directed recreational fishery in the Connecticut River system for use of live bait in the striped bass fishery in the river and for marine fisheries in Long Island Sound. River herring are productive bait for recreational anglers fishing for striped bass and bluefish. However, they are not thought to be a large target of recreational fishing effort (Blake and Smith 1984). Anecdotal evidence from recreational fishermen suggests that adult blueback herring have been harvested in tributaries and from the main stem after 1995 mainly as bait to catch large (> 70 cm) striped bass in the River during April and May. Since blueback herring stock size remained low from 2003 to 2010 (Table 9.1) during the harvest moratorium, the recreational landings of blueback herring before 2003 are believed to be inconsequential.

9.9.3. Bycatch Estimates

There have been no reports of bycatch in logbooks from Connecticut commercial fishermen which document monthly catches. There is potential for significant ocean bycatch losses of blueback herring and alewife from Connecticut waters and elsewhere associated primarily with the Atlantic herring (*Clupea harengus*) and Atlantic mackerel (*Scomber scombrus*) fisheries. Harrington *et al.* (2005) reported that in the Atlantic herring fishery, 530 mt of alewife were landed or discarded in 2000 and 361 mt of alewife lost in 2003. The Atlantic herring fishery lands annually more than 2800 mt of Atlantic herring so there is the clear potential for significant bycatch losses to all river herring stocks along the Atlantic coast (Herring Alliance 2007). Harrington et al (2005) reported that alewife comprised almost 95% of the river herring discarded in the Atlantic herring (*Clupea harengus*) trawl fishery in 2000 and 2003, whereas blueback herring comprised 99% of the river herring discards in the Atlantic mackerel trawl fishery in 2001. Results from the NEFSC Fisheries Observer Program (Kritzer and Black 2007) showed that of the two river herring species taken together as ocean bycatch between 1989 and 2006, alewife on average comprised 62.4% and blueback herring made up 37.6%. More recently, Lessard et al (2011) reported that alewife and blueback herring were both found in about the same frequency in Northwest Atlantic fisheries from 2000-2008. If the recent (1996-2010) emergence of very large ocean discard fisheries has severely eroded blueback herring productivity in the Connecticut River and elsewhere after 1997, it should have also negatively impacted alewife abundance in a similar manner since the ocean migration routes of both alosines overlap temporally and spatially (Neves 1981). These landing and discards from the Atlantic herring and Atlantic mackerel fisheries were not used directly in our estimates of fishing mortality for blueback herring since there is currently no time series (1981 to 2010) of these ocean landings and discards separated by stock or river system.

9.9.4. Subsistence Fishery

A small amount of subsistence fishing was thought to have existed but has never been quantified

9.9.5. Characterization of Other Losses

None documented.

9.10. FISHERIES INDEPENDENT MONITORING

9.10.1. Juvenile Surveys

A long (1979-2010) time series of juvenile relative abundance indices (mean catch/seine haul) for blueback herring has been established in the Connecticut River (Table 9.3). The average juvenile indices (JI) were expressed by both the arithmetic and geometric mean catch per seine haul from stations located between Essex, CT (river km10) and Holyoke, MA (river km 140) (Marcy 1976; Benway 2011) (Figure 9.1). Each year this beach seine survey has been conducted weekly during the months of July through

October. One seine haul is made at each station using a 30.5m bag seine (Marcy 1976, Crecco et al. 1981). Although some juvenile alewife remain in the lower River throughout summer and fall when the juvenile seine survey is conducted (Crecco et al. 1981) they are seldom taken in the seine survey. Loesh (1987) reported juvenile alewife are distributed mainly in deeper (> 5 m) water and are less susceptible than juvenile blueback herring and shad to the beach seine.

9.10.2. Spawning Stock Surveys

Relative abundance (geometric mean number) of blueback herring and alewife has also been monitored annually in Long Island Sound (LIS) since spring 1984 by the CTDEP LIS multi-species trawl survey (Table 9.8). Length frequencies (cm, FL) of all fin fishes including blueback herring and alewife have been monitored annually from 1989 to 2010 (Table 9.8). The trawl survey employs a Sound-wide stratified random design with four depth strata and three bottom substrate types. Forty stations are usually sampled monthly during spring (April-June) and fall (September-October) for a total of 200 samples each year. Most (90%) of the trawl strata from the CTDEP trawl survey are located in the central (west of the Connecticut River) and western basins of LIS. Since age 0 and 1 blueback herring and alewife were sampled more often from spring (April to June) surveys. Marcy (1969) suggested that many juveniles (age 1+) spend their first winter close to the mouth of their natal river due to their presence in the lower portion of the Connecticut River in early spring. An aggregated (all sizes) abundance index for both species was expressed as the geometric mean number/tow from spring, 1984 to 2010 (Table 9.8). The time series (1989-2010) of juvenile relative abundance for both blueback herring and alewives were expressed annually as mean catch/tow of fish. A time series (1989-2010) of adult blueback and alewife from the Sound-wide trawl surveys was considered unreliable since sample sizes of adult (> 25 cm) river herring were too small (N < 25) in most years (Table 9.8). Spring fishway counts are also made annually on adult blueback herring and alewife from several coastal rivers and streams off LIS from 2002 to 2010 (Gephard et al 2010) including Bride Brook, Thames River and Farmington River (CT River tributary) (Table 9.1; Figure 9.5).

9.11. ASSESSMENT APPROACHES AND RESULTS

9.11.1. Trends in Run Size

The Holyoke lift is the only long term source of blueback herring counts. More than 630,000 blueback herring were counted at the fish lift in 1985. However, since the mid-1990's the number counted at the lift has decreased to less than 1,000 fish being passed on an annual basis since 2004 (Table 9.1; Figure 9.4). A shorter time series of alewife abundance show fluctuation in the numbers of fish entering Bride Lake (Table 9.1). The LISTS survey has mixed age classes and does not really show a definitive trend in abundance. LISTS collections of river herring are a mixture from of different stocks from several rivers and streams.

Unlike American shad, there is no direct Connecticut River population estimate for adult blueback herring. Prior to 1996, the total number of adult blueback herring passed annually at the Holyoke Dam fish lift (river km 140) (Savoy and Crecco 2004) was assumed to be an informative index of river-wide stock size (Table 9.1; Figure 9.4). The Holyoke fish passage facility began operation in 1955 and daily counts of adult American shad and blueback herring have been made annually from 1955 to 2010 (Watson 1970; Moffit et al 1982; Leggett et al 2004). No adult alewife have been counted at the Holyoke fish lift because alewife spawn mainly in the lower (< river km 80) River (Marcy 1969). When lift numbers of adult blueback herring fell below 1,000 fish per year from 2004 to 2010, it became increasingly evident that recent annual counts at Holyoke overstated the recent decline in river-wide stock abundance. If the annual Holyoke lift counts were taken as a river-wide index, the passage of 84 to145 blueback herring per year from 2004 to 2010 would suggest that the river-wide stock had declined by 99.99% since about 1990 (Table 9.1; Figure 9.4). It is unlikely that a 99.99% drop in stock since 1990 could have produced measurable juvenile production as indicated from 2004 to 2010 (Table 9.3). The use of annual blueback lift data to monitor river-wide trends in abundance became even less reasonable in 2010, when a large 2010 juvenile index emerged when only 92 adult blueback herring were passed at the Holyoke fish lift (Table 9.3).

Additional lines of evidence also suggest that such a severe drop in Holyoke lift data, particularly after 2001, overstates the magnitude of the river-wide stock decline. First, recent (2005-2008) studies of adult blueback herring relative abundance monitored below Holyoke (Davis et al 2009) revealed catch rates of around 140 adult blueback herring / hr based on electrofishing in Wethersfield Cove (river km 76.5) and at the mouth of the Farmington River (river km 91), but blueback herring catch rates near Holyoke, MA were always 3 to 5 times lower. This indicated that relatively large numbers of adult blueback herring still remained in the lower Connecticut River from 2005 to 2008. Finally, recent (2002-2008) spring surveys of pre-spawned blueback herring from 32 tributaries along the River (Ellis 2008) from Essex, CT (river km 10) to the Massachusetts border (Suffield, CT, river km 111) (Figure 9.1) revealed that adult blueback herring counts generally dropped in all tributaries from 2002 to 2008, but a much more pronounced drop occurred from northern tributaries (> river km 80) located near the Massachusetts border. These findings taken together suggest that adult blueback herring migrating north of Hartford, CT after 2002 experienced much greater mortality than blueback herring that spawn in tributaries closer to the River mouth. Given that the risk of blueback mortality appears to be confined to upriver areas, the Holyoke lift counts of blueback herring, particularly after 1997, greatly exaggerate the River-wide decline of blueback herring.

9.11.2. Trends in Size Structure

Length frequencies are presented from Age 1+ river herring collected from spring and fall surveys in Long Island Sound since 1989 and from IFD fishway monitoring (Tables 9.4, 9.5, 9.6, and 9.7).

9.11.3. Trends in Age Composition

There are no long term data sets available on age structure of river herring.

9.11.4. Trends in Proportion of Repeat Spawner

The current proportion of river herring repeat spawners is unknown

9.11.5. Trends in Z

Without an accepted population estimate, lack of current age structure data, repeat spawning rates, and no directed commercial or recreational fisheries in Connecticut, an estimate of total mortality has not been calculated.

9.11.6. Fishing Mortality

There are no directed commercial fisheries in Connecticut.

9.11.7. Trends in Age – 1 Indices of Relative Abundance

A long (1978-2010) time series of juvenile relative abundance indices (mean catch/seine haul) for blueback herring and American shad has been established in the Connecticut River (Table 9.3). The average juvenile indices (JI) were expressed by both the arithmetic and geometric mean catch per seine haul from stations located between Essex, CT (river km10) and Holyoke, MA (river km 140) (Marcy 1976; Benway 2008). Each year this beach seine survey has been conducted weekly during the months of July through October. One seine haul is made at each station using a 30.5m bag seine (Marcy 1976, Crecco et al. 1981). Juvenile production was high and relatively stable from 1978 to about 1997, but juvenile indices dropped thereafter by 50 to 70%. Blueback juvenile production (mean catch/seine haul) in the River also remained relatively low from 1998 through 2009, but the juvenile index in 2010 was unexpectedly strong, being the highest in the time series since 1994.

9.11.8. Potential Sources of Increased Mortality

While unknown sources of mortality to river herring exist but have not been directly identified magnitude determined, there are sources within the Connecticut River that have been examined.

Striped bass abundance in Connecticut waters and along the Atlantic coast has risen since 1995 to record high levels (ASMFC 2007) coincident with the recent failure of blueback herring in the Connecticut River. Striped bass grow rapidly to a large size (>70 cm) that can easily prey on adult blueback herring, are highly piscivorous on herring-like prey (Hartman 1993), and are efficient diurnal and nocturnal predators (Nelson *et al.*2005). Unlike many other marine finfish predators, adult (> 70 cm) striped bass have the ability to move into freshwater and have been sampled in large and increasing numbers well above the salt wedge in the Connecticut River since 1993 (Savoy 1995; Davis et al. 2009). If the striped bass predation adequately accounts for the recent collapse in blueback herring stock size in the upper Connecticut River, we would expect that: 1) large (> 70 cm) striped bass are present in LIS and the Connecticut River during spring and prey heavily on adult blueback herring; and 2) a large (> 150,000 fish) and growing striped bass population has been documented in the upper River from April to June when adult blueback herring are spawning.

Striped bass relative abundance (mean catch/tow) has been monitored annually throughout Long Island Sound (LIS) from 1984 to 2010 by the CTDEP multispecies trawl survey (Gottschall and Pacileo 2011) (Table 9.9). Since striped bass are sampled more consistently during spring (April-June) cruises, we used the spring time series of striped bass relative abundance. A second time series (1981-2010) of striped bass relative abundance (mean recreational catch/trip) was based on annual Connecticut recreational striped bass catch (harvested and released fish) and effort (directed trips) estimates (Table 9.9) from annual MRFSS surveys (Crecco 2008). Finally, an abundance index (mean catch / electro-fishing day) of 70 cm+ stripers (Table 9.9) was monitored annually by electro-fishing in the River near Windsor CT (river km 103) from 1993 to 2004 (Savoy 2005).

To estimate striped bass population size in the Connecticut River during spring, Savoy (1995) conducted a mark-recapture study in 1994. Striped bass were captured mainly with electrofishing gear from April through June 1994 throughout the lower Connecticut River (Old Saybrook to Windsor, CT). A total of 346 striped bass from the Connecticut River were captured, measured to total length (cm) and tagged with internal anchor tags (Table 9.9). Since no commercial fishing is permitted for striped bass in Connecticut waters, tag recoveries were from recreational fishermen. Striped bass population size (N) in the River was estimated by the Petersen equation. Because the vast majority of recaptures (93%) and striped bass catches (C) in the River occur from April through June, the population estimate discussed herein mainly reflected the 1994 spring population abundance of striped bass. The tag reporting rate by the recreational fishery was assumed to be 60% based on tagging studies of striped bass in Chesapeake Bay (Rugolo et al. 1994a). The combined effects of tag loss, tag-induced mortality, and migration of tagged stripers from the river were assumed to be 50%. As a result, the number of tagged stripers (Mk) in this study was reduced by 50% (Savoy 1995).

Although there may be statistical evidence in support of the Predation Hypothesis, additional empirical support such as dietary studies of striped bass in the River is essential to clearly establish a causal link among striped bass abundance, their consumption of adult blueback herring and the resulting decline in blueback herring stock size. Comprehensive striped bass food habits studies conducted in the River from April to June, 2005 to 2007 (Davis et al. 2009). Dietary analyses and subsequent bioenergetics modeling of striped bass predator-prey effects on shad and river herring in the River are not yet complete. Davis has allowed us the opportunity to summarize his 2005-2008 dietary results in the context of testing the Predation Hypothesis. Davis et al. (2009) has sampled striped bass by electro-fishing and angling weekly from five stations located between Wethersfield, CT (river km 76) and the base of the Holyoke Dam, Holyoke MA (river km 140) (Figure 9.1). A total of 126 bass, ranging in size from 30 to 112 cm (TL), were examined for food habits in 2005, another 331 bass within the same size range in 2006 and 245 bass of the same size range in 2007. His dietary results based on the total stomach samples (N = 702) were expressed as percentage frequency of occurrence of river herring and percentage weight (gm) of river herring in the stomachs.

9.12. BENCHMARKS

There are no benchmarks established for Connecticut's river herring fisheries.

9.13. CONCLUSIONS AND RECOMMENDATIONS

Blueback herring and alewife undergo extensive Atlantic coast migrations (Neves 1981), so both alosines are susceptible to ocean intercept and bycatch fisheries. Alewife stocks appear to be more stable since 1996 during which the blueback herring stock in the Connecticut River has fallen by more than 90% since 1996. If excessive ocean bycatch is the major factor behind the blueback stock collapse, the composition of the alosine bycatch losses in the ocean would have to strongly favor blueback herring. There is the potential for significant ocean bycatch losses of both blueback herring and alewife associated primarily from the Atlantic herring (*Clupea harengus*) and Atlantic mackerel (*Scomber scombrus*) trawl fisheries located offshore and in the Gulf of Maine. Recently, Cieri et al. (2008) estimated the total annual bycatch (pounds converted to mt) of river herring (both species combined) from the Atlantic herring fishery from 2005 to 2007. They reported river herring bycatch losses of 127 mt in 2005, 77mt in 2006 and 771mt in 2007. Harrington et al. (2005) reported that alewife dominated the bycatch in 2000 and 2003. They indicated that 530 mt of alewife were landed or discarded in 2000 and 361 mt of alewife lost in 2003 as compared to only 29 mt of blueback herring in 2000 and 20 mt in 2003. These coast-wide blueback losses are minor since they (29 and 20 mt) are equivalent to only about 5% of the total cumulative blueback losses (454 mt) since 1981 in the Connecticut River. Kritzer and Black (2007) summarized blueback and alewife bycatch levels from the Observer Program for the Atlantic herring and mackerel fisheries from 1989-2006. Kritzer and Black (2007) reported blueback herring bycatch levels of less than 1.5% from the mackerel fishery rather than the 46.4% that was reported by Harrington et al. (2005) in the 2002 mackerel fishery. Kritzer and Black (2007) also revealed that blueback herring comprised on average about 79% of the alosine bycatch in the mackerel fishery and 38% in the Atlantic herring fishery from 1989 to 2006. More recently, Lessard et al. (2011) reported that blueback herring and alewife were found in at-sea catches in the Northwest Atlantic at about the same frequencies from 2000 to 2008. Lessard et al. (2011) found that the annual average (2000-2008) at-sea catch of blueback herring was 687 mt, whereas alewife comprised 1,092 mt annually. Results from these at-sea catch and bycatch studies reveal that alewife and blueback are both taken at about the same frequencies. Thus, recent ocean landings of river herring do not strongly favor blueback herring and thus would not account for the differential trends in blueback and alewife abundance in Connecticut waters.

Enhanced predation by striped bass provides the best explanation for the recent collapse of blueback herring in the Connecticut River. Statistical evidence consists of a significant inverse relationship between several striped bass relative indices from the Connecticut River and LIS from and the decline of adult blueback herring in the River (Savoy and Crecco 2004).

It is widely recognized that statistical evidence (regression and production models) alone does not demonstrate causality, but recent empirical evidence is wholly consistent with predation involving striped bass. Due to the success of striped bass management, striped bass abundance has risen steadily to record levels in mid and north Atlantic coastal waters from 1993 to 2007 (ASMFC 2008). The striped bass is regarded as a voracious finfish predator from the Mid and North Atlantic on menhaden, gizzard shad, American shad and river herring (Walter and Austin 2003; Nelson et al. 2005; Rudershausen et al. 2005). The results of striped bass tagging in the River (Savoy 1995) revealed a spring (April -June) 1994 population size in the Connecticut River of 407,300 striped bass (95% CI: 269,400 to 604,100 fish). Striped bass in the River ranged in size (TL) from 18 cm to 118 cm. Striped bass are known to consume finfish prey up to 60% of their own body length (Manooch 1973). Results from recent (2005-2007) striped bass food habit studies are consistent with this hypothesis (Davis et al. 2009). In this study (Davis et al. 2009), adult herring, most likely blueback herring, were identified most often (20-50%) as food items in striped bass between 40 and 90 cm. The 1994 striped bass stock size in the River of moderate to large-size fish (40-90 cm) was 289,000 (Savoy 1995). Since all striped bass abundance estimates within the River and LIS increased about 5 fold since 1994, it is reasonable to infer that bass population size in the Connecticut River rose from about 289,000 fish in 1994 to about 1,445,000 fish in 2010. These abundance data from 1994 to 2010 suggest that a sufficient number of large (> 70 cm) striped bass were available in the River during spring to have caused a measurable reduction in blueback herring stock size. Moreover, during the spawning migration, adult blueback herring like shad and alewife, have an enormous urge to reach their upriver spawning grounds (Leggett et al. 2004; Fay et. al 1983). This innate drive to spawn may hamper the predator avoidance capability of adult blueback herring, rendering them more susceptible to striped bass predation during the migration and spawning phase of their life history. Lower predation risk perhaps occurs on sub-adult alosines in the ocean due to their greater capacity to adopt tactics (i.e. schooling, spatial stratification) that may serve to minimize or impede contact with finfish predators. Finally, striped bass food habits studies recently conducted in the Connecticut River (Davis et al. 2009) indicated that moderate to large (40 - 90 cm) striped bass fed extensively on adult blueback herring. The results from this recent dietary study are consistent with the theoretical expectations of predation. The severe decline in the Connecticut River blueback stock size after 1995 is likely due to enhanced predation effects by striped bass.

The management implications and long-term prognosis for Connecticut River blueback herring following enhanced striped bass predation are challenging and somewhat ambiguous. On the plus side, blueback juvenile production in the River has only fallen on average by 50 to 75% since 1998 (Benway 2011) despite a 91% decline in adult stock size. Moreover, the emergence of a strong 2010 year-class of blueback herring certainly gives reason for guarded optimism for future stock size. Like American shad (Leggett 1976; Crecco and Savoy 1987: Lorda and Crecco 1987), the blueback stock-recruitment relationship was approximated by a dome-shaped Ricker function, indicating a high level of resilience and potential adaptation to additional sources of mortality. Although overall predation mortality (Mp) from 1996 to 2010 on adult blueback herring has often exceed our F_{msy} thresholds, the impact of enhanced predation may be buffered to some extent if the risk of striped bass predation is more severe on adult blueback herring in the upper Connecticut River. Several lines of evidence support this hypothesis. First, there has been a 99.99% drop in the number of adult blueback herring passed annually upriver at the Holyoke fish lift from the mid 1980's to 2010, whereas the River-wide stock fell by around 91%, suggesting that higher blueback mortality is operating from upriver areas. Second, recent (2005-2007) studies of adult blueback relative abundance in the River (Davis et al. 2009) revealed catch rates (catch/electro-fishing hr.) of adult blueback herring were four times higher from downriver sites at Wethersfield Cove (river km 76) and at the mouth of the Farmington River (river km 91) than from upriver sited located at Enfield CT (river km 110) and below the Holyoke Dam, indicating that adult blueback abundance is higher in the lower Connecticut River from 2005 to 2007. Moreover, Davis et al. (2009) also reported that the highest catch rates of large (> 70 cm TL) striped bass usually occurred in the upper River below the Holyoke Dam. Third, mean annual river-wide indices of juvenile blueback herring (Benway 2008) ranged from 15.8 to 317.7 fish /seine haul from 2004 to 2010 (Table 9.1) when less than 93 adult blueback herring (sexes combined) had been lifted annually at Holyoke. Since it is highly unlikely that a 99.99% drop in river-wide adult stock since the late 1980's, representing less than 93 fish, could have produced river-wide juvenile indices (JI) of 15.8 to 317.7 fish/seine haul, reproductive effort in the lower river appears to be sufficient to produce occasional dominant year-classes such as in 1997 (287.6 fish/seine haul) and 2010 (317.7 fish seine haul). Finally, recent (2002-2008) spring surveys of pre-spawned blueback herring from 32 tributaries along the River (Ellis 2008) from Essex, CT (river km10) to the Massachusetts border (Suffield CT, river km 111) (Figure 9.1) revealed that adult blueback herring counts generally dropped in all tributaries from 2002 to 2008, but that the rate of decline was much more pronounced from northern tributaries located near the Massachusetts border. These findings taken together suggest that adult blueback herring migrating north of Hartford, CT experience much greater risk of predation than blueback herring that spawn in tributaries closer to the River mouth. The presence of a heightened risk of predatory mortality by striped bass on upriver blueback herring would account for the severe drop (99.99%) in blueback herring lifted annually at the Holyoke Dam after 2001. Selective predation mortality on upriver blueback herring might serve to stabilize future egg production at current levels in the lower River, and may allow the blueback herring population to eventually re-colonize the upper River if predation mortality should decline in the future.

On the negative side, depensatory density-dependent mortality brought about by predation should make stock rebuilding of Connecticut River blueback herring via management measures an exceedingly difficult task. As indicated by Spencer and Collie (1997), fish stocks that are subject to moderate to severe depensatory predatory mortality, often undergo a sudden and persistent drop in stock abundance over time even in the presence of a moratorium to harvest. Under severe depensatory predation by striped bass, Connecticut River blueback herring stock size is expected to remain low and unresponsive to favorable climatic events and to further fishery management restrictions as long as striped bass abundance remains high in the River. The prospect that the abundance of large (> 70 cm) striped bass will decline in the near future seems remote. Results from and the most recent striped bass stock assessment (Nelson 2009; Durell et al. 2009) found that, through strict conservation, Atlantic coast striped bass have recently become larger and much older (ages 15+). Given this recent extension of the size and age structure of coastal striped bass, the predation risk on adult blueback herring will likely continue at high levels for the foreseeable future.

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Table 9.1 River Herring passage counts at various fishways. Holyoke=CT River, Rainbow=Farmington River (CTR Trib.), Greeneville Dam=Thames River, Bride Brook=Bride Lake

Year	Fishway	BBH	Fishway	ALW	BBH	Fishway	ALW	BBH	Fishway	ALW	TOTAL BBH	TOTAL ALW
1966									Bride Brook	184,151		184,151
1967									Bride Brook	140,203		140,203
1975	Holyoke	1,625									1,625	
1976	Holyoke	4,745	Rainbow		5						4,750	
1977	Holyoke	32,932	Rainbow		5						32,937	
1978	Holyoke	34,953	Rainbow	1	11						34,964	1
1979	Holyoke	39,461	Rainbow	3	5						39,466	3
1980	Holyoke	198,000	Rainbow	3	15						198,015	3
1981	Holyoke	419,733	Rainbow		6						419,739	
1982	Holyoke	586,808	Rainbow	6	13						586,821	6
1983	Holyoke	454,242	Rainbow	3	57						454,299	3
1984	Holyoke	482,954	Rainbow	1	37						482,991	1
1985	Holyoke	630,000	Rainbow		19						630,019	
1986	Holyoke	517,521	Rainbow	14	56						517,577	14
1987	Holyoke	356,846	Rainbow	3	34						356,880	3
1988	Holyoke	343,363	Rainbow		16						343,379	
1989	Holyoke	286,259	Rainbow		52						286,311	
1990	Holyoke	392,157	Rainbow		49						392,206	
1991	Holyoke	412,380	Rainbow		55						412,435	
1992	Holyoke	312,863	Rainbow		25						312,888	
1993	Holyoke	103,447	Rainbow	4	14						103,461	4
1994	Holyoke	31,766	Rainbow	2	102						31,868	2
1995	Holyoke	112,070	Rainbow	3	503						112,573	3
1996	Holyoke	55,040	Rainbow	5	1,254	Greeneville	129				56,294	134
1997	Holyoke	63,945	Rainbow	3	672	Greeneville	142				64,617	145
1998	Holyoke	11,146	Rainbow	2	498	Greeneville	337				11,644	339
1999	Holyoke	2,699	Rainbow	25	35	Greeneville	3,722				2,734	3,747
2000	Holyoke	9,537	Rainbow	5	1	Greeneville	480				9,538	485
2001	Holyoke	10,603	Rainbow	52	52	Greeneville	702	13			10,668	754
2002	Holyoke	1,939	Rainbow	71	37	Greeneville	2,288	808			2,784	2,359
2003	Holyoke	1,392	Rainbow	54	63	Greeneville	335	137	Bride Brook	117,158	1,592	117,547
2004	Holyoke	145	Rainbow	19	38	Greeneville	329	464	Bride Brook	81,350	647	81,698
2005	Holyoke	534	Rainbow	1	4	Greeneville	592	29	Bride Brook	68,757	567	69,350
2006	Holyoke	21	Rainbow			Greeneville	2,412	187	Bride Brook	129,114	208	131,526
2007	Holyoke	75	Rainbow			Greeneville	2,422	14	Bride Brook	66,975	89	69,397
2008	Holyoke	84	Rainbow	4	5	Greeneville	535	216	Bride Brook	73,268	305	73,807
2009	Holyoke	40	Rainbow			Greeneville	190	2	Bride Brook	74,774	42	74,964
2010	Holyoke	76	Rainbow	8	15	Greeneville	156	5	Bride Brook	164,149	96	164,313
2011	Holyoke	138	Rainbow			Greeneville	248	9	Bride Brook	196,996	147	197,244

Table 9.2 River herring NMFS landings by gear for Connecticut from NMFS Commercial Fisheries Statistics. DN=Dip Nets, Common, ENGU=Entangling Nets (Gill) UNSP, FHN=Fyke and Hoop nets, Fish, GNDO=Gill Nets, Drift, other, GNDS=Gill Nets, Drift, Shad, GNO=Gill Nets, Other, GNS=Gill Nets, Salmon, GN=Gill Nets, Stake, HSB=Haul Seine, Beach, LHO=Lines Hand, Other, NC=Not Coded, OTBF= Otter Trawl Bottom, Fish, PU=Pots, Unclassified, PNO=Pound Nets, Other, TU=Trawls, unspecified, PNF=Pound Nets, Fish.

Year	DN	EN	FHN	GNDO	GNDS	GNO	GNS	GN	HSB	LHO	NC	OTBF	PU	PNO	TU	PNF	Total
1950			600	200					1,947,100								1,947,900
1951				7,000					482,900								489,900
1952		100							758,100					1,300	302,000		1,061,500
1953				4,200					328,500				100		7,500		340,300
1954				2,000					970,700								972,700
1955				600					889,700								890,300
1956	1,000		1,200	37,000					40,200								79,400
1957				600					62,600						100		63,300
1958	2,400								7,100								9,500
1959	2,400		1,100						4,000						300		7,800
1960	2,400		1,000	12,000					2,600						2,000		20,000
1961	1,800					1,000			200						3,000		6,000
1962	6,000						7,000		6,000								19,000
1963	2,000								1,400								3,400
1964	600								12,700			1,500					14,800
1965	2,400								16,700			5,000					24,100
1966	2,900			100					1,600			2,000					6,600
1967	2,900			16,000					2,300			2,200					23,400
1968	3,600								23,300			5,900					32,800
1969	2,100			600					6,900			1,000					10,600
1970	15,400			400					13,900			92,600					122,300
1971	5,800			4,900					12,400			1,900					25,000
1972	7,600		1,400	1,900		400			11,500								22,800
1973			1,800	2,000	3,000	4,000			3,500								14,300
1974	13,600			2,900					500								17,000
1975			1,200	4,000					20,000								25,200
1976	1,600			4,200					61,100	200							67,100
1977			100						61,200								61,300
1978	500			900					37,400	1,000							39,800

Table 9.2 Continued

Year	DN	EN	FHN	GNDO	GNDS	GNO	GNS	GN	HSB	LHO	NC	OTBF	PU	PNO	TU	PNF	Total
1979				2,200					59,000	500		1,000					62,700
1980				1,100					54,000			0					55,100
1981				3,200					49,200	0							52,700
1982	400			2,000					39,300	0		100					41,800
1983	500			2,100					34,700			200					37,500
1984				1,200					30,700			500					32,400
1985	3,400			1,100					33,600			800					38,900
1986				7,700					32,200	200							40,100
1987	500		900	900					19,000			100					21,400
1988	1,100			200					100	300		400					2,100
1989	200			300					500			600					1,600
1990			150	800						200							1,150
1991			200	800						200							1,200
1992	300		300	2,300					300								3,200
1993				1,090						1,350							2,440
1994											2,000						2,000
1995											14,044						14,044
1996				184				68									252
1997																	0
1998																	0
1999												102,060					102,060
2000								700				74,990				2,295	77,985
2001								20									20

Table 9.3 Annual blueback herring juvenile abundance index for the Connecticut River expressed as arithmetic and geometric mean catch per unit effort, 1979-2010.

Year	Arithmetic Mean	Geometric Mean	Hauls	# BBH
1979	111.7	21.54	67	7,483
1980	221.6	26.75	81	17,951
1981	127.8	11.49	93	11,888
1982	65.62	6.09	82	5,381
1983	380.5	16.47	95	36,150
1984	395.4	11.57	71	28,073
1985	229.8	18.23	77	17,697
1986	159.6	13.61	90	14,360
1987	265.4	21.58	94	24,952
1988	317	17.04	93	29,481
1989	137	7.52	96	13,148
1990	251	14.41	96	24,097
1991	157	11.36	108	16,954
1992	161.9	9.87	107	17,319
1993	129.1	14.43	99	12,784
1994	112.5	13.92	103	11,592
1995	80.36	5.03	104	8,357
1996	49.25	5.91	96	4,728
1997	264.7	9.66	112	29,648
1998	50.93	4.39	108	5,500
1999	95.33	5.57	96	9,152
2000	32.49	4.17	98	3,184
2001	58.22	3.83	90	5,240
2002	69.09	3.95	97	6,702
2003	52.51	5.88	87	4,568
2004	19.63	2.36	97	1,904
2005	63.11	4.1	93	5,869
2006	46.6	3.5	96	4,474
2007	96.44	6.61	97	9,355
2008	18.94	2.2	86	1,629
2009	11.72	1.77	97	1,137
2010	317.7	12.82	103	32,722

Table 9.4. Blueback herring length frequencies, spring and fall, 1 cm intervals, 1989-2010 (Gottschall and Pacileo 2011). From 1989 - 1990, lengths were recorded from the first three tows of each day; since 1991, lengths have been recorded from every tow.

Spring																						
Length	**89**	**90**	**91**	**92**	**93**	**94**	**95**	**96**	**97**	**98**	**99**	**00**	**01**	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**08**	**10**
6	0	0	0	0	0	0	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	2	0	2	7	2	0	0	2	0	4	1	0	3	2	1	0	0	1	0	4
8	0	0	3	0	2	76	20	4	0	5	0	10	7	12	7	9	8	1	0	8	0	1
9	0	0	2	0	3	114	11	5	21	15	0	14	5	9	23	23	14	8	1	11	7	4
10	0	0	5	10	7	74	9	19	45	45	0	18	2	9	26	47	6	23	9	14	19	19
11	0	0	3	4	9	41	9	10	258	48	0	28	1	6	11	39	10	2	3	12	25	38
12	3	0	5	0	2	9	5	3	4	16	0	18	2	3	4	20	12	0	5	2	27	8
13	0	0	0	4	0	13	5	2	0	2	0	12	1	1	1	12	3	1	3	4	17	10
14	0	0	0	15	0	5	3	1	1	1	0	3	0	0	0	0	7	0	1	1	5	4
15	0	0	1	27	1	3	4	7	0	0	1	2	0	4	0	0	8	1	2	2	9	1
16	0	0	0	65	0	8	3	7	0	3	5	1	1	1	4	4	13	2	23	1	30	4
17	0	0	1	11	3	9	1	10	4	0	5	3	10	7	4	4	11	2	37	7	64	2
18	0	1	0	2	0	3	0	4	2	0	0	5	15	2	3	3	1	2	7	3	49	1
19	0	0	0	0	1	2	4	3	2	0	0	0	3	0	0	3	2	1	3	2	17	2
20	0	0	0	4	0	1	1	0	0	0	0	2	1	1	0	0	5	2	0	1	2	0
21	2	1	2	0	0	1	1	3	0	0	0	1	3	0	0	3	2	3	2	0	1	1
22	1	0	0	1	0	3	0	4	0	1	0	3	0	0	1	0	1	0	1	1	0	1
23	0	0	3	2	0	3	2	3	1	0	0	5	0	1	0	1	0	0	1	1	0	1
24	0	1	2	0	0	0	0	2	0	0	0	3	0	0	0	0	0	0	2	0	0	1
25	0	0	0	1	0	1	1	1	0	0	0	1	0	0	2	0	0	1	1	0	0	0
26	0	0	0	1	0	0	1	0	0	0	0	1	0	0	0	3	0	0	0	0	0	0
27	0	0	0	0	0	0	0	2	0	0	0	2	0	0	0	0	0	0	0	0	0	0
Total	6	3	29	147	30	373	83	90	338	140	11	136	52	56	89	173	104	49	101	71	272	102

Table 9.4. Continued.

Fall																						
Length	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
5	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-
6	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	-
7	0	0	0	0	0	0	5	0	2	0	0	0	0	0	0	1	0	0	0	0	0	-
8	0	0	0	0	0	0	33	0	2	0	0	0	0	0	0	0	0	0	1	0	0	-
9	0	0	0	0	0	0	21	3	2	2	1	0	0	0	0	0	0	0	1	0	2	-
10	0	0	0	0	0	1	3	0	8	1	0	1	0	0	0	0	0	0	0	0	0	-
11	0	0	0	0	3	13	4	0	3	0	0	0	0	0	0	0	0	0	0	0	0	-
12	0	0	3	9	8	227	14	0	12	1	1	0	7	0	0	2	0	0	0	0	0	-
13	38	1	4	11	24	225	48	0	117	18	0	0	36	2	0	15	2	2	0	0	0	-
14	77	0	1	6	18	247	40	1	111	28	1	0	117	7	0	17	3	8	1	1	3	-
15	24	0	0	1	20	94	3	3	34	16	0	3	52	3	4	6	2	4	14	2	5	-
16	0	0	0	0	2	14	0	0	0	5	2	1	10	0	4	0	0	0	31	0	2	-
17	0	0	0	0	0	2	0	0	0	1	1	2	2	0	1	0	0	0	7	0	1	-
18	1	0	0	0	0	1	0	0	0	0	0	1	3	0	0	0	0	0	0	0	5	-
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-
20	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	-
21	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	-
22	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-
24	0	1	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	-
25	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-
Total	140	2	9	27	76	827	172	7	292	72	8	8	227	12	9	42	8	14	55	3	18	0

Table 9.5 Alewife length frequencies, spring and fall, 1 cm intervals, 1989–2010 (Gottschall and Pacileo 2010). From 1989 - 1990, lengths were recorded from the first three tows of each day; since 1991, lengths have been recorded from every tow.

Spring																						
Length	**89**	**90**	**91**	**92**	**93**	**94**	**95**	**96**	**97**	**98**	**99**	**00**	**01**	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**08**	**10**
6	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
7	0	0	0	0	2	0	0	0	0	0	0	4	0	0	1	0	1	0	0	4	0	2
8	0	0	0	0	18	3	3	0	0	0	2	9	16	0	3	1	2	0	0	4	1	10
9	0	0	2	0	15	9	6	1	6	0	6	21	32	1	18	6	16	0	0	4	6	10
10	0	0	0	1	11	19	18	2	22	7	6	28	23	5	32	55	32	0	8	5	11	23
11	0	0	5	4	10	44	11	2	64	11	20	52	14	6	27	87	26	29	13	32	10	9
12	6	0	4	7	6	83	17	8	127	12	32	43	5	29	25	100	55	44	34	131	17	6
13	1	0	4	4	47	122	48	16	63	44	42	99	4	70	11	83	61	15	38	193	24	12
14	0	0	9	7	77	172	35	26	69	61	56	234	7	139	28	63	37	9	37	178	51	6
15	3	0	8	5	68	140	54	32	56	51	120	334	6	157	25	33	50	49	85	86	101	8
16	2	0	8	5	84	159	38	86	44	50	144	320	4	86	26	31	74	25	128	46	106	7
17	5	4	4	16	63	108	32	203	28	34	330	85	5	82	21	33	73	78	161	47	142	5
18	4	4	9	8	59	81	7	254	32	22	136	15	4	15	19	18	71	93	182	25	196	2
19	6	7	7	2	37	33	7	180	9	11	99	20	3	6	26	42	59	86	122	49	215	7
20	3	1	7	2	27	24	10	161	17	17	82	22	9	17	13	30	26	76	105	38	137	7
21	1	0	3	1	13	17	14	107	34	22	72	27	12	28	22	50	21	40	71	21	53	18
22	4	2	8	2	10	26	12	103	48	18	47	41	18	46	25	48	18	18	41	14	29	22
23	5	1	8	6	3	12	12	76	44	16	47	90	36	63	40	36	7	5	28	16	13	12
24	7	0	3	2	1	12	7	34	28	14	21	58	45	49	42	13	6	1	10	7	14	4
25	3	2	1	0	3	5	2	9	9	2	11	11	23	12	29	11	3	1	3	0	11	2
26	1	0	1	2	1	5	1	3	1	2	2	1	5	7	17	5	2	0	2	0	1	0
27	2	0	1	0	0	1	0	0	0	0	0	1	2	1	2	2	1	0	0	0	0	0
28	1	0	0	0	1	1	0	0	0	1	0	0	0	1	0	2	1	0	0	1	0	0
29	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	56	21	93	74	556	1,076	334	1,304	701	395	1,275	1,515	274	820	452	749	642	569	1,068	901	1,138	172

Table 9.5 Continued

	Fall																					
Length	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
6	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	-
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-
8	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	1	0	0	1	0	-
9	0	0	0	0	3	1	0	0	1	0	0	1	6	1	1	0	1	0	3	2	0	-
10	0	0	0	0	5	1	4	1	1	0	1	4	23	0	7	1	7	0	8	2	1	-
11	0	0	0	0	27	30	5	5	6	1	3	5	59	0	33	6	14	0	22	1	2	-
12	0	0	0	1	120	82	9	25	12	9	6	9	86	4	64	7	8	0	44	0	2	-
13	0	0	3	0	88	84	14	21	21	7	9	17	72	0	4	12	17	0	87	5	10	-
14	0	0	2	4	16	36	11	30	31	0	11	10	23	3	3	16	15	0	134	14	10	-
15	0	0	1	8	21	31	0	9	53	0	5	8	24	3	5	28	15	2	118	4	8	-
16	3	0	3	10	53	14	4	1	110	1	25	2	36	17	20	30	12	4	31	0	1	-
17	2	0	0	12	25	33	1	2	194	4	34	0	27	8	19	12	3	0	8	3	1	-
18	3	0	0	9	13	24	1	1	62	3	11	1	5	0	0	1	5	0	6	0	1	-
19	0	0	0	2	1	11	0	0	0	1	4	1	0	1	0	0	0	0	7	1	0	-
20	0	0	0	0	0	2	0	0	0	0	2	0	0	0	0	0	0	0	0	0	1	-
21	0	0	0	0	3	1	1	0	0	1	2	0	0	0	0	0	0	0	0	0	0	-
22	0	1	0	0	2	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	-
23	0	0	0	0	0	1	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	-
24	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-
25	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-
27	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	-
Total	8	1	9	46	377	354	50	95	492	27	117	58	364	38	156	113	98	6	468	33	37	-

Table 9.6 Connecticut River, mainstem and tributary, blueback herring adult length frequencies, 2005-2010.

TL mm	2005	2006	2007	2008	2010
<220	2	32	1		
220-224	7	114	7		
225-229	7	201	19		
230-234	6	250	30	5	2
235-239	18	239	65	8	3
240-244	26	169	125	6	4
245-249	35	99	182	5	1
250-254	46	68	278	4	3
255-259	59	62	221	11	3
260-264	62	48	148	6	3
265-269	76	44	85	3	3
270-274	57	40	48	2	5
275-279	58	42	31	1	2
280-284	36	37	32	1	3
285-289	23	34	24	2	1
290-294	20	23	19		
295-299	5	13	7	1	1
300-304	8	3	2		
> 305	4	5	2		

Table 9.7 Bride Lake adult Alewife Length frequencies, 2008-2010.

TL mm	2008	2009	2010
<230		4	
230-234		16	
235-239	1	39	7
240-244	2	36	11
245-249	6	81	15
250-254	8	75	15
255-259	10	75	15
260-264	11	63	17
265-269	4	47	15
270-274	7	32	15
275-279	5	15	15
280-284	1	10	5
285-289		6	3
300-304		1	
290-294	2		2

Table 9.8 The geometric mean count per tow was calculated using April-June data for spring and September-October for fall. An asterisk next to the species indicates that the season is a better estimate than the fall index (Simpson et al. 1991).

Year	SP ALW*	FA ALW	SP BBH	FA BBH*
1984	0.43	0.42	5.42	0.38
1985	0.1	0.01	0.3	0.16
1986	0.66	0.05	0.34	0.07
1987	1	0.04	0.14	0.13
1988	0.47	0.19	0.03	0.53
1989	0.72	0.16	0.05	0.34
1990	0.54	0.11	0.08	0.1
1991	0.39	0.07	0.11	0.04
1992	0.39	0.19	0.2	0.08
1993	0.84	0.4	0.08	0.11
1994	1.83	0.66	0.55	0.93
1995	0.96	0.16	0.29	0.27
1996	2.18	0.24	0.28	0.05
1997	1.44	1.23	0.25	0.75
1998	1.11	0.11	0.15	0.16
1999	1.89	0.42	0.02	0.06
2000	1.53	0.25	0.37	0.06
2001	0.75	0.55	0.19	0.2
2002	0.95	0.22	0.15	0.06
2003	1.14	0.58	0.27	0.1
2004	1.86	0.26	0.46	0.09
2005	1.3	0.43	0.33	0.06
2006	0.78	0.05	0.13	0.15
2007	1.62	0.95	0.29	0.24
2008	1.32	0.42	0.21	0.05
2009	1.04	0.18	0.43	0.09
2010	1.29	-	0.37	-

Table 9.9 Time series of large (71 cm+) striped bass (STB River) relative abundance (Mean catch/Electrofish river) in the River, striped bass Sound-wide index (STB LIS, Mean catch/Hour) from CT DEP spring trawl survey (stripls) and striped bass CPUE (Striprec, catch/private boat trip) from the Connecticut recreational fishery (MRFSS).

Year	STB River	STB LIS	STB MRFSS
1981			0.61
1982			0.91
1983			0.75
1984		0.02	0.92
1985		0	0.89
1986		0	1.51
1987		0.05	1.15
1988		0.04	1.36
1989		0.06	1.83
1990		0.16	2.19
1991		0.15	2.15
1992		0.22	2.38
1993	0.01	0.27	2.84
1994	0.04	0.3	3.94
1995	0.01	0.59	5.4
1996	0.09	0.63	7.58
1997	0.14	0.85	5.98
1998	0.11	0.97	7.59
1999	0.06	1.1	5.55
2000	0.2	0.84	6.93
2001	0.13	0.61	8.12
2002	0.11	1.3	6.43
2003	0.16	0.87	6.41
2004	0.2	0.56	8.31
2005		1.17	13.48
2006		0.61	14.05
2007		1.02	13.95
2008		0.57	14
2009		0.6	11.34
2010		0.4	6.68

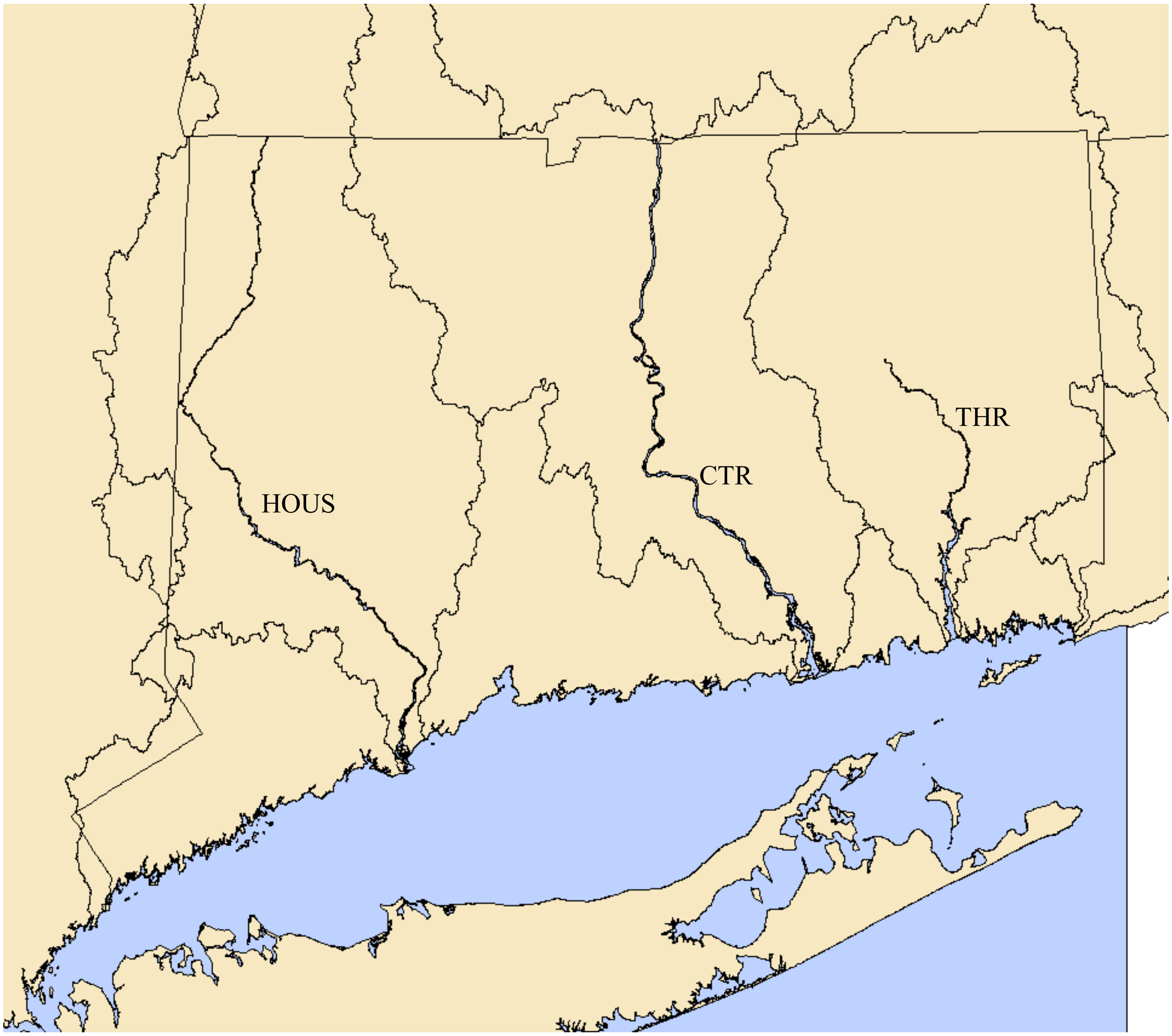

Figure 9.1 Map of Connecticut, Housatonic and Thames Rivers and Long Island Sound.

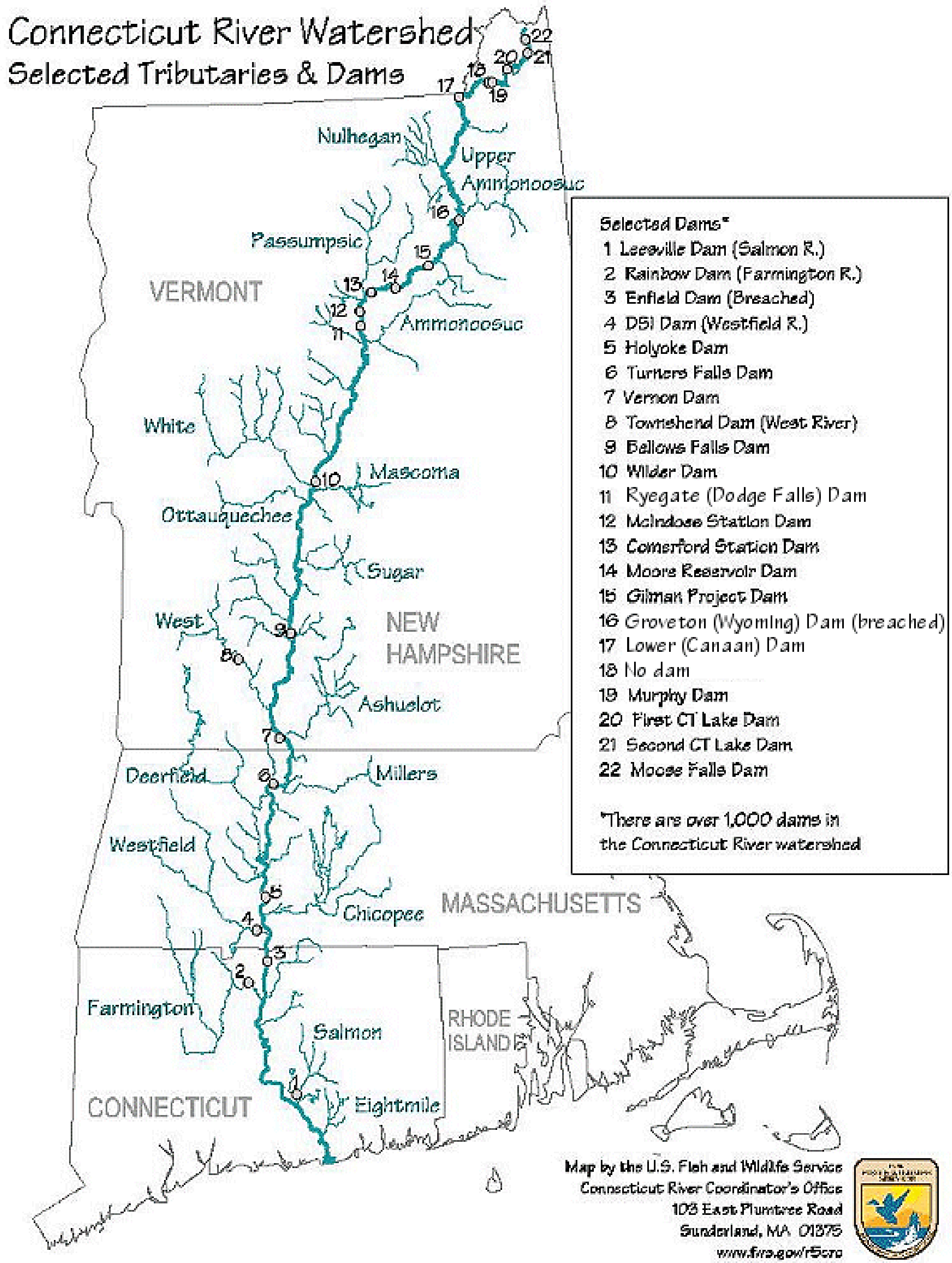

Figure 9.2 Connecticut River tributary and dam locations. Map is by the U.S. Fish and Wildlife Service.

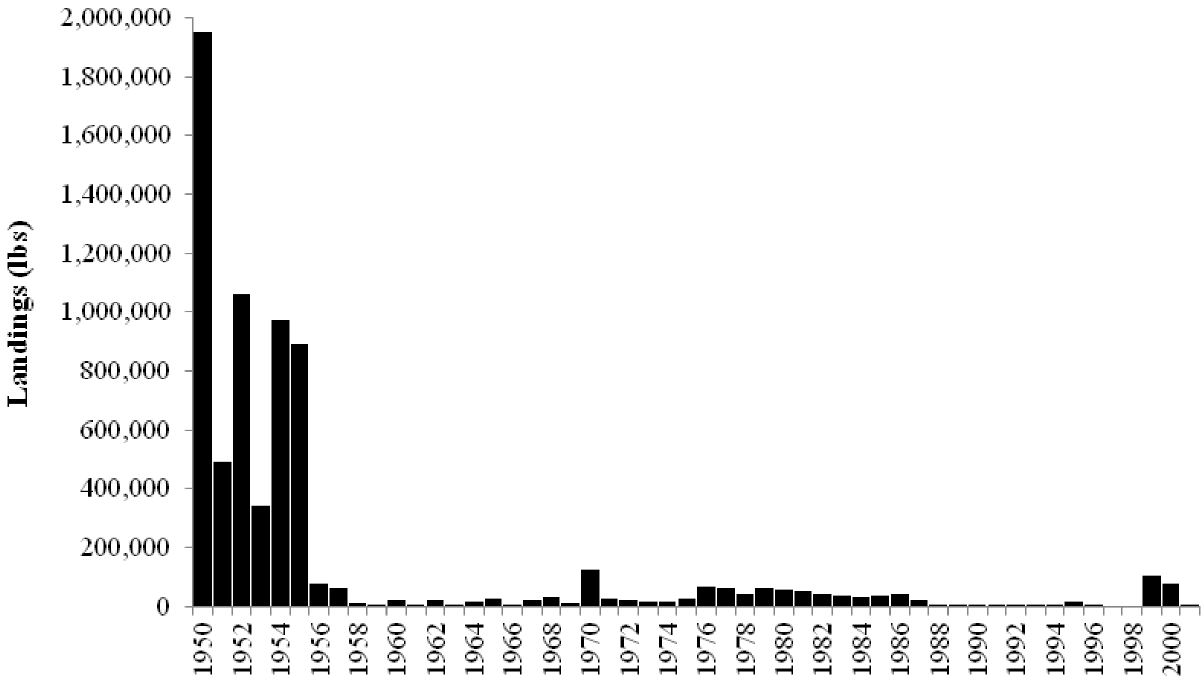

Figure 9.3 NMFS Commercial landings (lbs.) 1950-2001.

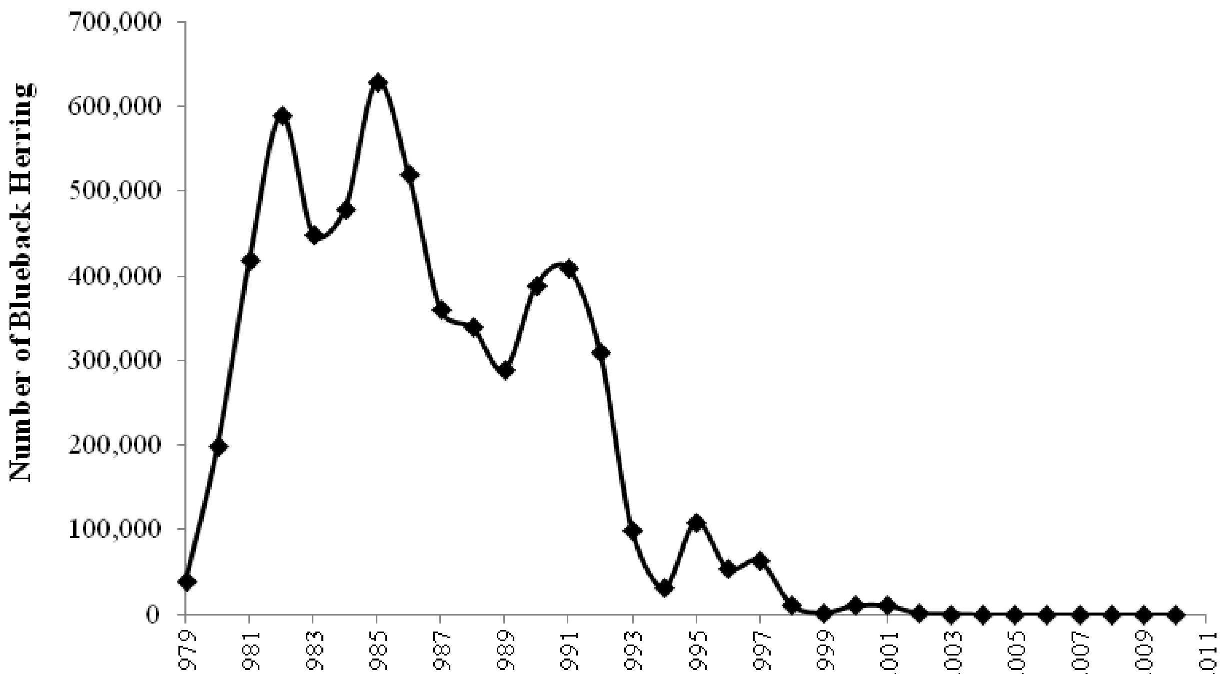

Figure 9.4 Number of blueback herring lifted at the Holyoke Dam, 1979-2010.

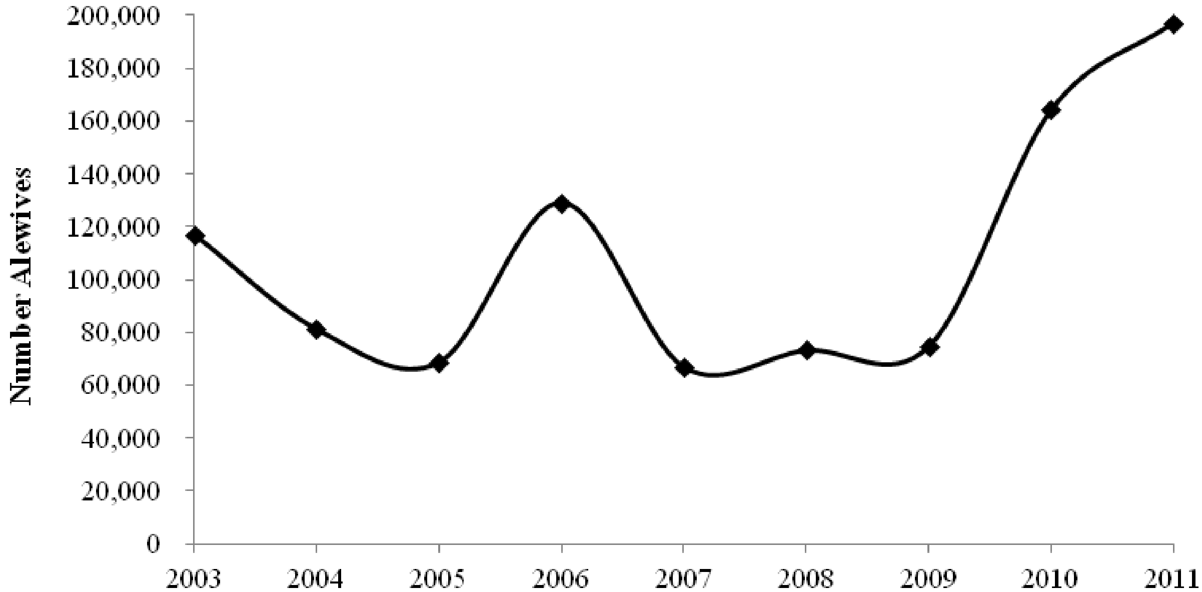

Figure 9.5 Number of Alewives passed at Bride Brook fishway, 2003-2010.

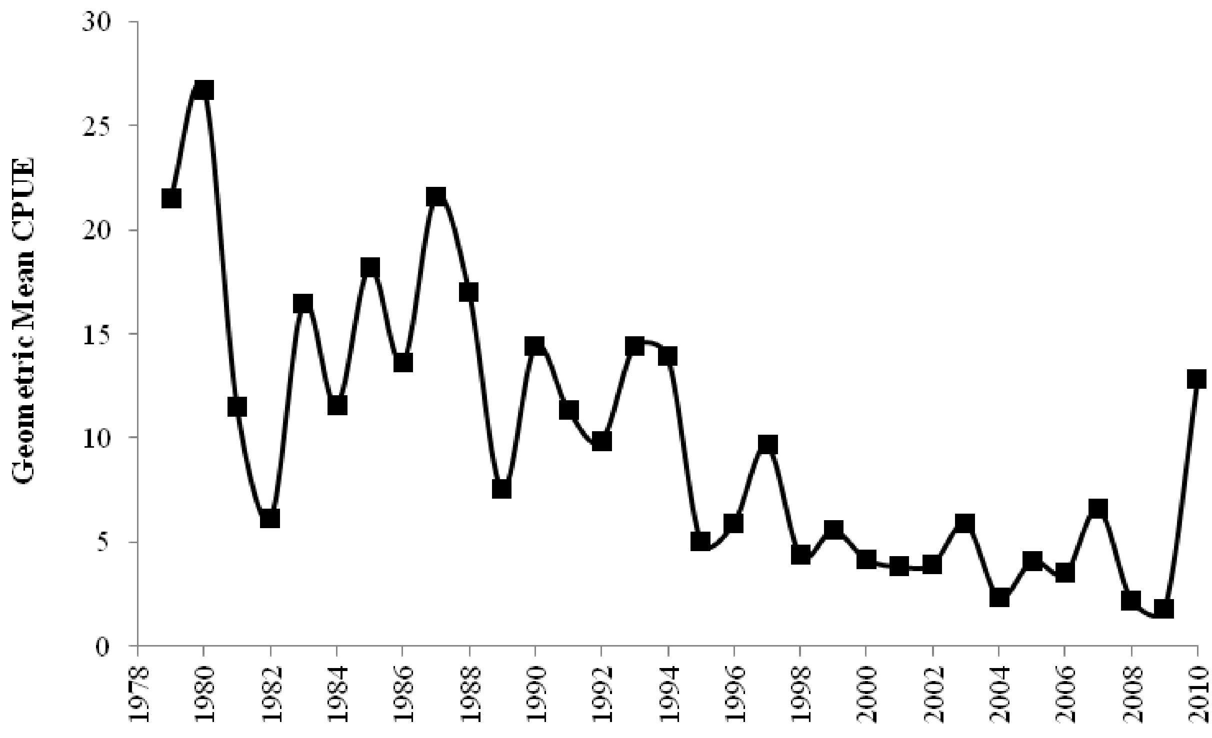

Figure 9.6 Juvenile blueback herring seine survey annual geometric mean catch per unit effort, 1979-2010.

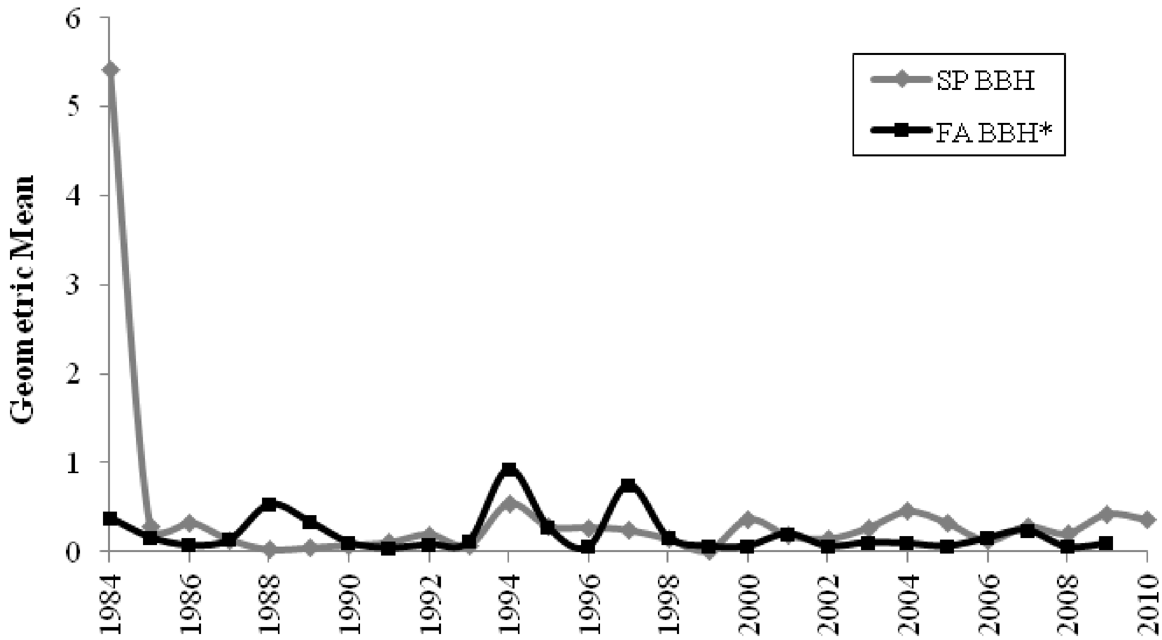

Figure 9.7 Age 1+ blueback herring indices from the Long Island Sound Trawl Survey, 1984-2010. SPBBH= Spring Blueback Herring; FABBH = Fall Blueback Herring.

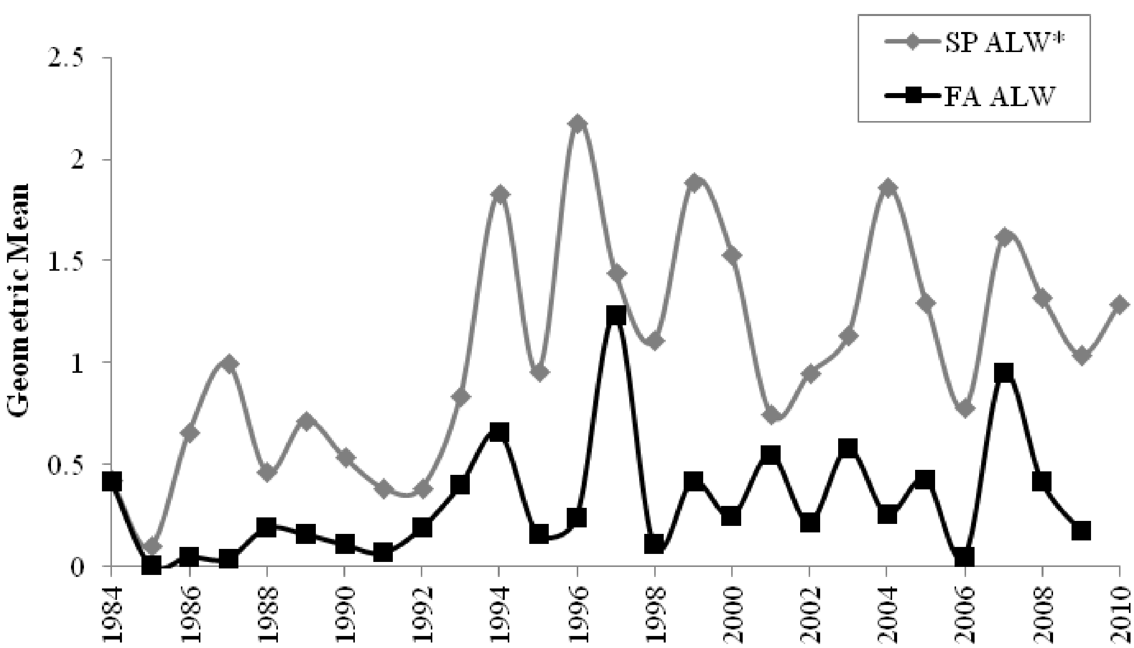

Figure 9.8 Age 1+ alewife indices from the Long Island Sound Trawl Survey, 1984-2010. SP ALE" = Spring Alewife; "FA ALE" = Fall Alewife.

10 Status of New York River Herring Stocks

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Executive Summary

Blueback herring and alewife are known to occur and spawn in New York State in the Hudson River and tributaries, many streams on Long Island and, we suspect, smaller streams in other counties bordering the Long Island Sound and New York Harbor. Data on stock status are only available for the Hudson River and tributaries. Commercial and recreational fisheries exploit the spawning populations of river herring in the Hudson River and tributaries. Most harvested herring are used as bait in the recreational striped bass fishery. Commercial harvest data are available since the early 1900s. Landings peaked in the early 1900s and in the 1930s and then declined through the 1980s. Annual commercial harvest has remained below 50,000 river herring since the early 1990s. Intermittent creel surveys indicate substantial and increasing recreational harvest of river herring. Recreational harvest in 2007 was 240,000 fish. River herring loss to bycatch in ocean commercial fisheries remains largely unknown but is suspected to be significant. We have collected fishery dependent CPUE data since 2,000. CPUE in anchored gill nets fished in the main stem river slightly declined from 2000 to 2006 then steadily increased to the present. Largest river herring in fishery independent surveys of the spawning stock were collected in the 1930s. Size of both blueback herring and alewife has declined over the last 30 years. We used length-age keys developed by Maine, Massachusetts, and Maryland to estimate annual age structure. Observed and estimated age at length of Hudson River fish varied substantially among state keys suggesting differential growth or aging technique among states. Annual mean age since the late 1980s has remained stable in blueback herring and female alewife, but declined in male alewife. Mortality estimates varied substantially depending on model used and model assumptions and therefore actual total mortality on the Hudson stocks remains unknown. However, we should emphasize that mortality on stocks must have been high in the last 30 years to have so consistently reduced mean size and presumably mean age. Young of year production has been measured annually by beach seine since 1980. CPUE of alewife remained low through the late 1990s and has since increased erratically. CPUE of young of year blueback herring has varied with a very slight downward trend since 1980. Stock size is currently low and stable. Because stock indicators are in disagreement (some increasing while others are decreasing), we felt a reduced commercial and recreational fishery was warranted rather than a complete closure.

10.1 INTRODUCTION

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

Written records of the Hudson's river herring fishery were over-shadowed by the shad fishery. Records for herring begin in the early 1900s and follow a path of increased landing through the years of WWII followed by a quick dramatic decline to the mid 1960s. Since then harvest remained relatively low. Just as for American shad, factors, other than fishing, contributed to keeping the population low: habitat destruction (filling of shallow water spawning habitat) and water quality problems associated with pollution, creating dissolved oxygen blocks in major portions of the river (Albany and New York City).

In this chapter, we summarize the history and characteristics of the Hudson stock of river herring, provide abundance trends, describe possible benchmarks, and make recommendations for the stock.

10.2 DEFINITION OF MANAGEMENT UNIT

The management unit of river herring stocks in New York State comprises three sub-units. The largest consists of the Hudson River Estuary, its tributaries, and throughout the stock's range on the Atlantic coast. The Hudson River management area is defined as the area from the Verrazano Narrows in New York City to the Federal Dam at Troy NY, including numerous tributary streams. The Hudson River Estuary is tidal its entire length of 246 km from the Battery (tip of Manhattan Island) in New York City to the Federal Dam at Troy (Figure 10.1). The second sub-unit is made up of all streams that occur on Long Island that empty into all surrounding waters; and streams in the Bronx and southern Westchester Counties (Figure 10.2) that empty into the East River and Long Island Sound. A listing of most all of the streams in these areas are in Appendix Table A. The third sub-unit is the Delaware River north of Port Jervis NY, a shared water body with the state of Pennsylvania. River herring have not been documented to occur in this section of the Delaware and will not be discussed in this chapter. Ocean range of the New York river herring along the Atlantic coast is from the Bay of Fundy, Canada and Gulf of Maine south to waters off Virginia (NAI 2008).

10.3 REGULATORY HISTORY

During the 19th century, regulating fisheries within New York waters was the sole responsibility of the state. In 1868, in response to an apparent decline in American shad, the New York State legislature implemented fishing net restrictions, an escapement (net free) period and a season to control fishing on the Hudson. It is likely that these restrictions (season and net use) also affected the take of river herring, as all three Alosines (American shad [*Alosa sapidissima*], alewife and blueback herring) occurred in the river at the same time. Some variant of these 19th century rules still exist to the present.

Take of river herring in New York remained relatively unregulated. Most restrictions concern the use of gear to take fish, with no limits on take for either recreational or commercial use. Current (2010) regulations pertaining to the commercial and recreational take of alewife and blueback herring in NY waters are listed in Appendix Table B. New York's Sustainable Fishery Plan for river herring, not yet approved (change if SFP approved) by the Atlantic State Marine Fisheries Commission (ASMFC), outlines proposed regulatory changes to be implemented by 2012 to meet the sustainable fishery definition in Amendment 2 to the ASMFC Shad and River Herring Fishery Management Plan.

10.4 ASSESSMENT HISTORY

The first ASMFC assessment of the coast-wide river herring stocks occurred in 1990 (Crecco and Gibson 1990). New York stocks were not included in this analysis.

10.5 STOCK SPECIFIC LIFE HISTORY

<u>Hudson River and tributaries</u>

Hudson River alewife, blueback herring and American shad are spring spawners. Alewives are the first of the herring to enter the estuary, arriving as early as mid-March with continued spawning through early May. Blueback herring prefer slightly warmer temperatures and arrive a bit later, usually in April. Adults of both species initially enter the Hudson tributaries, but also spawn in the shallow waters of the main stem Hudson. Alewife prefer to spawn over gravel, sand and stone in back water and eddies whereas bluebacks tend to spawn in fast moving water over a hard bottom. Herring spawn in the entire freshwater portion of the Hudson and its tributaries up to the first impassible barrier for approximately six to ten weeks. Fish enter the tributaries to spawn when water temperatures reach approximately 10.5C (Hattala et al. 2011). Once spawning ends, most fish quickly return to ocean waters.

A portion of the Hudson's blueback herring stock are known to move as far inland as Rome NY (439 km inland), via the Erie Canal and Mohawk River. Blueback herring access the canal via the Troy Lock and the Waterford flight (series of locks into the Mohawk river/Erie Canal, see description in Section 6). The canal system opens in New York on or about May 1st. Because of this late opening, most alewives are already spawning. Many blueback have yet to spawn and congregate below the lock at Troy to move into the canal system.

Long Island, Bronx and Westchester Counties

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

Not much is known about runs in the Bronx and Westchester County streams.

10.5.1 Growth

From 1975 to present, the New York State Department of Environmental Conservation (NYSDEC) collected data on length, weight, and scale samples for age analysis during a variety of sampling programs (see monitoring program descriptions below). A blueback herring study, conducted in 1989 and 1990, collected data on length and scales for aging from fish in the upper Hudson Estuary and the Mohawk River, a major tributary of the Hudson. Additional length and age data for both species came from the 1936 Biological Survey of the lower Hudson River watershed (Greeley 1937) and a 1999-2001 state-contracted survey conducted by Normandeau Associates, Inc. (NAI 2008) on the Hudson River and its tributaries. Aging techniques varied among studies: the 1989-90 study used Cating's (1954) technique, developed for aging American shad scales. NAI (2008) developed their own aging criteria after noting many discrepancies on annuli placement compared to the Cating shad technique. It is not known what criteria Greeley used to age the fish from the 1936 Biological Survey. The large difference in size at "age" is evident from the different time periods (Figure 10.3 and Figure 10.4).

Until age determination methods can be resolved, no growth curves are presented for this report. See the Age section below which explains further analysis on this issue.

10.5.2 Reproduction

Spawning begins in the Hudson Estuary in April for alewife when water temperatures reach 10-11C. It continues through early May; blueback spawn when water temperatures reach about 14C and cease spawning by early June (Smith 1985). The rate of post-spawning mortality is unknown for either species.

10.5.3 Maturity schedule

We did not estimate a maturity schedule as age is currently unknown.

10.5.4 Fecundity

Limburg and Blackburn (2008) performed a fecundity and condition analysis for blueback herring collected during a large river herring study conducted by the Normandeau Associates, Inc. (NAI 2008) from 1999 to 2001. NAI collected fish from the lower Hudson River's Tappan Zee (km 40) to Lock 17 at Little Falls in the Mohawk River (km 382). A total of 169 females and 75 males were examined.

The blueback herring of the Hudson and Mohawk Rivers embark on a long and complex spawning run. Condition, measured as a Gonadosomatic Index (GSI), levels decreased in both males (30%) and females (26%) as fish stayed longer and swam further up river. Feeding was documented in blueback herring and likely supplemented energy loss due to migration. Total fecundity varied with "age" (as determined from otoliths by Limburg and Blackburn) and ranged from 3,993 to 177,948 for "green" (ripe) fish. Estimated egg standing crop was 98,870 eggs (256 mm length-standardization of "green" fish). This number is low compared to other similar estimates from Canada, the Connecticut and Altamaha Rivers. The identification of multiple size modes of eggs indicate batch spawning in blueback herring, similar to that seen in American shad (Olney and McBride 2003).
Limburg and Blackburn (2008) also stated that fecundity was positively related to fish aged three to six, with wide confidence intervals. However, a lack of relationship with length was most likely the result of the selectivity of the gill net sampling gear. It is also possible that some ages derived from otoliths were not correct since accuracy of ageing river herring by otoliths has not been verified.

10.6 HABITAT DESCRIPTION

10.6.1 Spawning and Nursery Habitat

Hudson River: The sandy, gravelly shallow water areas in the freshwater portion of the Hudson River Estuary, from Kingston (km 144) to Troy (km 256) (Figure 10.1) are used as spawning habitat, along with many of the Hudson's tributaries. The nursery area includes this area and extends south to Newburgh Bay (km 90), encompassing the freshwater portion of the Estuary. The estuary is tidal to Troy.

Estuary tributaries: The estuarine portion of the Hudson River is considered a "drowned" river valley in that the valley slopes quickly into the river with steep gradient. Many of the tributaries are tidal for a short distance (usually about a kilometer) ending at a natural or man-made barrier, often built on a natural barrier. Schmidt and Cooper (1996) catalogued approximately 62 tributaries for the presence or absence of barriers to migratory fish. They found that only one had no barrier for migratory fish, 31 were blocked (either partially or completely) by natural barriers, and the remaining 30 had artificial barriers, dams or culverts, that reduced or eliminated access for fish.

Tributaries: Mohawk River: The Hudson River's first barrier occurs at the Troy Dam at river kilometer 246. The confluence of the Mohawk River, the Hudson's largest tributary, is 2 km north of the Troy Dam. Cohoes Falls, a large scenic waterfall of 20 m is the first natural barrier on the Mohawk just upriver of the confluence with the Hudson. Access into the Mohawk system was created through the Waterford Flight – a series of five locks and dams, built as part of the Erie Canal to circumvent the falls. The canal lock and dam system was built in 1825, to connect the Hudson to central New York and Lakes Ontario and Erie. The New York State Canal Corporation, under the NYS Thruway Authority, is responsible for the operation and maintenance of the canal system. The Canal parallels and/or is part of the Mohawk River for the river's entire length to Rome, NY, a distance of 183 km. Rome is at the dividing point between the Hudson and Great Lakes drainages. The canal continues on through central New York to Syracuse (to Lake Ontario) and Buffalo (Lake Erie). A series of permanent and seasonal pools make up the canal where it intertwines with the Mohawk River. Permanent pools created from hydro-power dams are found in the Waterford section. Temporary pools are created each year in early spring by removable dams (series of gates) that increase water levels to 4.3m while the canal is in operation (May through November). During the winter months, the river is returned to its natural state of riffles and pools. Dredging is often used to maintain the canal at the navigational depth. The natural river bottom is comprised of some exposed bedrock, cobble and gravel with some finer sandy sediment.

Blueback herring began colonizing the Mohawk River in the 1930s (Greeley 1935). They were found as far west as Rome by 1978 (Owens et al 1998). By 1982, they migrated into Oneida Lake in the Great Lakes drainage. The number of herring using the Mohawk increased through the 1990s, but since 2000 herring have rarely occurred in the upper end of the Mohawk. Blueback herring presence in the Mohawk River can be viewed from two perspectives. One perspective is that they are an exotic invasive species, present only due to the locks of the Erie Canal that provide upstream passage into the system. However, once blueback herring were established, they became important forage for local sport fish populations. Spawning in the Mohawk River, can occur as far inland as Rome (J. Hasse, NYSDEC retired, personal communication).

Long Island: Long Island streams are primarily freshwater tidal streams over sandy bottoms. Both head ponds and kettle lakes have sandy substrate typical throughout Long Island.

Bronx and Westchester Counties: Very little is known about the spawning habitat that may remain in these streams.

10.6.2 Habitat Water Quality

Hudson River: The Hudson has a very long history of abuse by pollution. New York City Dept. of Environmental Protection recognized pollution, primarily sewage, as a growing problem as early as 1909. By the 1930s over a billion gallons a day of untreated sewage were dumped in the harbor.

New York City was not the only source of sewage. Most major towns and cities along the Hudson added their share. It was so prevalent that the Hudson was often referred to as an open sewer. Biological demand created by the sewage created oxygen blocks that occurred seasonally (generally mid to late summer) in some sections of the river. One of the best known blocks occurred near Albany in the northern section of the tidal estuary in the 1950s through the 1970s. This block often developed in late spring and remained through the summer months. It essentially cut off the upper 40 km of the Hudson Estuary and the Mohawk River for use as spawning and nursery habitat. A second oxygen block also occurred in the lower river in the vicinity of New York City in late summer. This block could potentially have affected emigrating age zero river herring. This summer oxygen-restricted area occurred for decades until 1989 when a major improvement in a sewage treatment plant came on line in upper Manhattan. It took decades but water quality in general has greatly improved in both areas since the implementation of the Clean Water Act in the 1970s reducing sewage loading to the river.

There are other persistent chemical pollutants in the Hudson's legacy. The best known and most pervasive chemical is PCB (polychlorinated biphenyl) contamination that remains today. The major source of the chemical is an area approximately 76 km north of the Troy Dam, where General Electric discharged up to 1.3 million pounds of PCB's into the river for over 25 years beginning in the 1940s. The EPA declared 322 km of the Hudson below Hudson Falls and Fort Edward, NY, a Superfund site in the 1970s. The removal of the contaminated sediments is the center of a controversial dredging clean-up project. Phase 2, the removal of the majority of contaminated sediments, began in May 2011.

Because of the contamination of fish flesh, the NYSDEC under recommendation from the NY Dept. of Health closed many of the Hudson's fisheries in 1976. Herring remain one of the few species that are allowed to be taken commercially as they accumulate very low levels of contaminants while in the river. A whole host of other environmental contaminants have been found in the Hudson and its fish (PAHs, some metals etc.) but are minor in scale to the level of PCBs. Research is ongoing to try to determine effects of chemicals on fish.

10.6.3 Habitat Loss

Hudson River: Much spawning and nursery habitat was lost in the upper half of the tidal Hudson due to dredge and fill operations to maintain the river's shipping channel to Albany. Most of this loss occurred between the turn of the 19th century (NYDOS 1990) and continued through the first half of the 20th century. Preliminary estimates are that approximately 57% of the shallow water habitat (1,821 hectares or 4,500 acres) north of Hudson (km 190) was lost to filling (Miller and Ladd 2004). Work is in progress to map the entire bottom of the Hudson River. Data from this project will be used to quantify existing spawning and nursery habitat. While most of this dredge and fill loss affected American shad, it is suspected that river herring were also affected as they spawn along the shallow water beaches in the river.

Very little, or no, habitat has been lost due to dam construction. The first major dam was constructed in 1826 at Rkm 256, Troy NY. Prior to the dam, the first natural barrier occurred at Glens Falls, 32 km above the Troy Dam. The construction of the dam is not known to have reduced spawning or nursery habitat.

Long Island: Most all streams on Long Island were impacted as human use expanded. Many streams were blocked off with dams to create head ponds, initially used to contain water for irrigation purposes. The dams remain, with only a few with passage facilities. Many streams were also impacted by the construction of highways, with installations of culverts or other water diversions which impact immigrating fish.

Two success stories include the installation of permanent fish passage on two of Long Island major streams. The first project was on the Carman's River in the South Shore Estuary. This project was the result of advocacy and cooperation by environmental groups and local, state and federal agencies. A similar private effort occurred on the Peconic River within the Peconic Bays Estuary where a rock ramp was installed in 2010 allowing free passage of alewife past the first dam on this river. Local citizens, towns and universities also monitor spring alewife runs on several Long Island streams.
Bronx and Westchester Counties: Streams in southern Bronx and Westchester Counties run through extremely urbanized and /or industrialized areas. Most all streams have been greatly impacted by loss of vegetated riparian cover, submerged aquatic vegetation, natural shoreline and dams.

10.6.4 Habitat Alteration

The introduction of zebra mussels in the Hudson in 1991, and their subsequent explosive growth in the river, quickly caused pervasive changes in the phytoplankton (80% drop) and micro- and macro-zooplankton (76% and 50% drop respectively) communities (Caraco et al. 1997). Water clarity improved dramatically (up by 45%) and shallow water zoobenthos increased by 10%. Given these massive changes, (Strayer et al. 2004) explored potential effects of zebra mussel impact on young-of-year (yoy) fish species. Most telling was a decrease in observed growth rate and abundance of yoy fishes, including both alewife and blueback herring. It is not yet clear how this constraint affects annual survival and subsequent recruitment.

Recently Dr. D. Strayer (personal communication) discovered that some portions of the zooplankton community have recovered to pre-invasion levels. How this may be affecting young fish has yet to be determined.

10.7 RESTORATION PROGRAMS

Only one very small restoration program was conducted on the Bronx River by the New York City Parks Department, the Connecticut Dept. of Environmental Protection, Inland Fisheries Division, and the Bronx River Alliance. In cooperation with the state of Connecticut, adult alewives were moved from Bride's Brook near East Lyme CT to the Bronx River in 2006 and 2008. The CT stream was selected for brood stock collection as it is the geographically closest known alewife run that empties into Long Island Sound. Subsequent sampling in 2009 and 2010 indicated that some alewife have returned to the river. See:

10.8 AGE

Hudson River herring scale samples are removed from an area approximately one inch below the dorsal fin and placed in an individually identified envelope. In the laboratory, scale impressions are made on cellulose acetate slides. Scale impressions are examined with a microfiche reader. Generally two independent age and repeat spawn mark determinations are made by different investigators and agreement on age and repeats are sought for each fish. A third independent reader resolved differences. If differences could not be resolved the sample was not used.

Our first attempt to age scales used the method developed by Marcy (1969). We do not know how Greeley (1937) determined ages he reported for river herring. We can only assume he based the ages on techniques for other fish species caught during the survey. The NYSDEC samples from the 1989-1990 data used the method Cating (1954) developed for American shad. NAI (2008) developed its own aging technique. They began with Cating's (1954) and Marcy's (1969) technique, then noted differences in the structure of the scale, and developed their own technique for aging herring. It is not clear if the aging technique for the NAI data is similar to that used to age other data presented in this report. Repeat spawn mark data should be comparable in that repeat marks are relatively easier to distinguish than pre-spawn annuli.

Many scale samples from NYSDEC surveys remain un-aged. As an alternative, and for a very general picture of potential age structure, we estimated annual age structure using length at age keys from datasets provided by Maine, Massachusetts, and Maryland for alewife and Massachusetts and Maryland for blueback herring. Results are discussed below in Section 10.1 Spawning Stock Surveys. Age data from scales will be reported when a technique is selected and aging is complete. Some repeat spawn data are also reported. Maximum age that the Hudson River herring stock can attain is unknown. Jessop (B. Jessop DFO retired, personal communication) reported a maximum age of 12 for both alewife and blueback herring for the St. John's River in New Brunswick.

10.9 FISHERY DESCRIPTION

Fisheries for river herring in New York State waters occur in the Hudson River Estuary and tributaries, some streams on Long Island, and as bycatch in commercial fisheries in Marine waters around Long Island. The herring taken in the bycatch ocean fishery are of unknown mixed stock origin. Current (2010) commercial fishing restrictions for NY waters are listed in Appendix Table B.

10.9.1 Fishery Dependent - Commercial

Hudson River fishery

Anecdotal reports indicate that herring played a small part in the historical commercial fishing industry in the Hudson River. The present commercial fishery in the Hudson River exploits the spawning migration of both alewife and blueback herring. The primary use of commercially caught herring in recent years has been for bait in the recreational fishery for striped bass. The herring fishery occurs from March into early June annually, although some fishers report catching herring as late as July.

Marine permits are required of fishers to use seines or scap nets greater than 36 ft^2, dip or scoop nets exceeding 14 in. in diameter, and all gill nets. Marine permit holders are required to report effort and harvest annually to the Department. Many marine permit holders are recreational anglers taking river herring for personal use as bait or food. Current regulations allow open access to all Hudson River Marine commercial fishing permits. The fee structure is a remnant of regulations put in place in 1911 and has not been changed in the past 100 years. The minimal permit costs ($1 and above) are attractive to recreational anglers who use commercial net gears, as well as to commercial fishers.

Over the last ten years, a mean of 260 gill net and 260 scap net permits were sole annually. According to the required annual reports, however, only 36% of the permitees actively catch and report fish. The fixed gill net fishery occurs from km 40 to km 70 (Piermont to Bear BMB, Figure 10.1). In this stretch, the river is fairly wide (up to 5.5 km) with wide, deepwater (~ six to eight m) shoals bordering the channel. Fishers use particular locations within this section away from the main shipping channel. Over the past ten years 22 active fishers participated in the fixed gear fishery (Table 10.1). Nets deployed range in size from 3.7 to 182.9 m (12 to 600 ft). Upriver of the BMB two types of gill net fisheries occur from km 90 to km 217 (Newburgh Bay to Castleton) – a moveable "fixed" and a mobile drift fisheries. The river is much narrower (1.6 to 2 km wide) for this entire length. The past ten year average of participants is 35 fishers in the drift gill net fishery and 26 participate in mobile fixed gear fishery. Drift gill nets range in size from 7.6 to 182.9 m (25 to 600 ft); moveable fixed gears are generally less than 30m (100 ft). The other major gear used in the river herring fishery are scap nets (also known as lift and/or dip nets) that are fished in the tributaries. The scap/lift net fishery occurs from km 70 to km 228 (Peekskill to Bethlehem) in the major river herring spawning tributaries including Catskill Creek, Esopus Creek, Rondout Creek, Wappingers Creek, Moodna Creek, Annsville Creek, and many other tributaries. Scap/lift nets range in size from 0.2 to 121.9 m^2 (0.5 to 400ft^2). About 66 fishers participate in this fishery (Table 10.1).

Mixed stock ocean fisheries

We are not aware of any directed fishery for river herring in NY ocean waters. However, some river herring taken in the commercial ocean bycatch are landed. Fisheries involved in such landings are poorly documented.

10.9.2 Commercial Landings and License Reporting

Total reported New York commercial landings for river herring are summarized in Table 10.2 and include all herring caught in all gears for each year. Several slightly different time series of data are reported. From 1904 to 1975, New York's Conservation Department and Sheppard (1976) reported the historic landings annually; source(s) (river or ocean) of the data were not identified. National Marine Fisheries Service (NMFS) reported landings annually from 1950 to the present, also with several gaps during the 1990s. NMFS data are also not segregated into river or ocean source(s). It is unknown why only one species of river herring is identified for portions of the NMFS data series, alewife for 1950 to 1989, then blueback herring for 2000 to 2007. It is unlikely that only one species was caught. From 1995 to the present, NYSDEC has summarized Hudson River landings from mandatory state catch reports for Hudson River commercial fishing licenses. The Hudson River data also includes fishing effort information. Full compliance for the Hudson River reporting occurred in 2000. All Hudson River data are sent to NMFS and Atlantic Coast Cooperative Statistics Program (ACCSP) for incorporation in the national databases.

Because of the discrepancies among the data series and the lack of information to assign the landings to a specific water body source, only the highest value from all the series (Sheppard, Conservation Dept, NMFS and NYSDEC) is used to avoid double counting of statewide landings. Data will be revised if the differences can be reconciled.

Several peaks occur in the river herring landings for New York (Figure 10.5). The first peak occurred in the early 1900s followed by a lull (with some gaps) until the period prior to, during, and after World War II when landings peaked a second time. By the 1950s landings were in a serious decline. A few unusual peaks occurred in the NMFS data series. In 1966, 1.9 million kg were landed, followed by a series of years of low landings with another peak in 1982 (Table 10.2, the 1966 value is omitted on Figure 10.5). Since the 1980s, landings have been low, with some data gaps until about 1995. Another small peak in herring landings occurred in 2002, but has declined since then.

River herring are captured in many gear types and sizes. In this document we describe current trends in the Hudson River stock using that portion of the Hudson River fishery that specifically targets river herring unless otherwise stated. Data for the targeted spring fishery include scap/lift nets and fixed and drift gill nets with a stretch mesh less than 3.75 in. Monofilament gill nets, 2.5 inch stretch mesh, are the primary gear used, although some larger mesh sizes are occasionally reported. Other gears reporting herring include shad gill nets (herring entangled are kept) and a seine. Landings for the targeted fishery are summarized in Table 10.3.

10.9.3 Commercial Discards

Hudson River fishery discard rate

From 1996 to 2010, river herring were not reported as discards on any mandatory reports targeting herring (Table 10.4). However, our commercial fisheries monitoring data (See program description below) suggests otherwise. Since 1995, we have observed a 0.12% rate of discard in the anchored gill net fishery. Reasons for discards are unspecified.

Mixed stock ocean fisheries:

Level of discard and discard rate is unknown.

10.9.4 Commercial Catch Rates

10.9.4.1 Hudson River Catch Rates - Mandatory reports

Relative abundance of river herring is tracked through catch per unit effort (CPUE) statistics of fish taken from the targeted river herring commercial fishery in the Estuary. All commercial fishers annually fill out mandatory reports. Data reported include catch, discards, gear, effort, and fishing location for each trip. Data within week are summarized as total catch divided by total effort, separately by gear type: fixed gill nets by location (above and below the Bear Mountain Bridge), drift gill nets, and scap nets. CPUE is calculated as the number of fish caught per unit effort (square yards of net x hours fished). Weeks of the year used for all calculations of CPUE are inclusive of weeks 11 through 25, mid March through June of each year.

Annual means are summarized in two ways. Above the Bear Mountain Bridge (BMB) and within the spawning reach, annual CPUE is calculated as total catch/total effort. Below the BMB (km 75) and thus below the spawning reach, annual CPUE is calculated as an annual sum of weekly CPUE. Here, nets capture fish moving through to reach upriver spawning locations and run size is determined by number (density) of spawners each week as well as duration (number of weeks) of the run. The sum of weekly CPUE mimics area under the curve calculations where sampling occurs in succeeding time periods. The downside of using reported CPUE to monitor relative abundance is that results can be influenced by inter-annual, location, and inter-gear differences in reporting rate.

We use the CPUE of the fixed gear fishery below the BMB for estimating relative abundance because effort expended by the fishery below this bridge is much greater (~70% of fixed gill net effort) than in the river above this point (remaining 30%). Fixed gear below the bridge is always fished in the lower Hudson (rkm 40 to 75) in relatively the same location each year, is passive in nature, and intercepts fish that pass by. A summary of the past 16 years of weekly CPUE data for the lower river fixed gill nets support this passive nature- CPUE peaks in mid April (week 16, Table 10.5, Figure 10.6) then declines through the remainder of the season.

We do not consider the CPUE of gears fished above the BMB and within the spawning reach as reliable an annual abundance indicator as that from fixed gill nets below the bridge. Upriver gears catch fish that are either staging (getting ready to spawn) or moving into areas to spawn and gears are generally not employed until fish are present. The gears include drift gill nets, scap nets and some fixed gill nets. The CPUE for these gears is variable, rises as herring arrive in the spawning reach and then remains relatively stable throughout the period that herring are present (Figure 10.6).

Annual effort and catch data: Total effort for all gears, except drift gill nets, has been slowly declining since 2000 (Table 10.3, Figure 10.7). Total catch of all gears peaked in 2002, declined, then peaked again in 2007 and has been slowly declining to the present (Figure 10.7). For individual gears, effort in the fixed gill nets below BMB far exceeds all of the other gears fished further up river (Figure 10.8). Effort for the fixed gill net above BMB and the drift gill nets has been variable, but slightly increasing for drift nets. Effort for scap nets has remained fairly stable over all years (Figure 10.8). In contrast, total catch has been highest the scap net gear, fished in the Hudson's tributaries, averaging about 47% of the total catch (Figure 10.9).

Annual CPUE: As stated above annual CPUE is calculated differently for the two component fisheries in the river. We only use the data since 2000, as this is when mandatory reporting was enforced. The fixed gill nets below BMB operate as an intercept fishery, capturing fish on their emigration into the river. CPUE for this gear declined slightly from 2000 to about 2006 then has slowly increased since then (Table 10.6, Figure 10.10). In the spawning reach, the drift gill net and fixed gill net CPUE was variable, but stable until 2004, declined to 2006 and then has increased to the present. This supports the trend of the fixed lower gill net fishery although the effort expended above BMB is much lower. Scap net gear is also fished in the spawning reach, including tributaries when fish are abundant. Scap net CPUE declined slightly from 2000 through 2003, and has since remained relatively stable (Figure 10.11).

10.9.5 Hudson River Commercial Monitoring Program

Catch rates

Up until the mid-1990s, the NYSDEC's commercial fishery monitoring program was directed at the American shad gill net fishery, a culturally historic and economically important fishery. We attempted to increase monitoring of the river herring fishery due to the increase in demand for bait for the recreational striped bass fishery. We began to monitor the river herring fishery on a restricted basis in 1996, limited by available manpower and the ability to connect with the fishers. Monitoring focuses on the lower river fixed gill net fishery as it is a better measure of annual trends (see section above).

Scap net, drift gill net and fixed gill nets above the BMB, comprise a substantial portion of the targeted river herring fishery, but most of these gears are monitored infrequently. Data from this portion of the fishery would be helpful in understanding fishing methods, timing, and use of catch.

Data are obtained by direct observation onboard fishing vessels. Fishers are contacted through the fishing season to obtain rides onboard the fishing vessels. Observers record data on numbers of fish caught, gear type and size, fishing time and location. Scale samples, lengths and weights are taken from a subsample of the fisher's catch. CPUE is calculated as the number of fish collected per square yards of net multiplied by hours fished, the same method used for summarizing mandatory report data.

Since 1996, a total of 66 trips have been made targeting river herring fisheries (53 fixed below BMB, 5 drift gillnet and 8 fixed gill net above BMB). Most all (80%) of these trips are from the fixed gill net fishery below the BMB. Trips are sporadically distributed over all years (Table 10.7). As sample size is low, CPUE was not deemed to be useful.

Hudson River Commercial Monitoring Size and Age structure

Although the CPUE from the fishery monitoring program is not useful, samples of the catch do provide data on the fished portion of the stocks. Commercial fixed gill net fishers use several mesh sizes to target herring. These include 4.4, 6.4 and 7.0 cm (1 ¾, 2 ½, and 2 ¾ inch) stretch mesh nets. Catch composition includes fish caught in all meshes. For a size analysis comparison among years, we subset the data to include only fish caught in similar gears each year; these include gill nets of the larger two mesh sizes.

Alewives were observed as often as blueback herring (Table 10.8). The species fluctuation each year may be the result of when the samples occurred (early or late in the run). The sex ratio of alewife was nearly equal (~ 50:50) in most all of the years; the proportion of blueback females observed was usually higher than males.

Sample size was relatively low each year, ranging from 40 to 185 fish from 2001 to 2010 (Table 10.9 and Table 10.10). Alewife ranged in size from 230 to 319 TL, with the exception of 2004 when two fish over 370 mm TL were caught (Table 10.9). Blueback herring fell within the same size range as alewife. From 2001 to 2010, a slight decline was observed in both mean total length (mm) and weight of for both alewife and blueback herring (Table 10.10, Figure 10.12& Figure 10.13).

Age data for samples collected during the commercial monitoring program are yet to be analyzed.

10.9.5.1 Mixed Stock and Ocean Fishery Catch Rates

Proportion of Hudson River herring caught as ocean fishery by-catch is unknown.

10.9.6 Fishery Dependent – Recreational

Hudson River and tributaries: The recreational river herring fishery exists throughout the main-stem Hudson River, and its tributaries including those in the tidal section and above Troy Dam (Mohawk River). Herring are sought from shore and boat by angling (jigging) and multiple net gears (see Appendix B). Recreational anglers commonly utilize commercial gears because of the low license cost. Boat fishers utilize all allowable gears while shore fishers predominantly use scap/lift nets, or angling (jigging). Recreational herring fishers use their catch as food (smoking/pickling), and as bait. The recreational herring fishery is driven primarily by the striped bass bait industry.

The magnitude of the recreational fishery is unknown for most years. NYSDEC contracted with Normandeau Associates, Inc. to conduct creel surveys on the Hudson River in 2001 and 2005 (NAI 2003 and 2007). Estimated catch in 2001 was 34,777 fish with a 35.2% retention rate (Table 10.11). When the 2001 data were analyzed, NAI found that the total catch and harvest of herring was underestimated due to the angler interview methods. In the 2001 survey, herring caught by fishers targeting striped bass were only considered incidental catch, and not always included in herring total catch and harvest data. Fishers were actually targeting herring and striped bass simultaneously. Corrections were made to the interview process for the 2005 survey. Estimated catch increased substantially in 2005 to 152,117 herring; retention rate increased to 75.1% (Table 10.12). Although some fish are reported as released we consider these mortalities due to the herring's fragile nature.

NYSDEC estimated river herring use in the striped bass fishery in 2007 with data from its Cooperative Angler Program (CAP) and a New York State-wide Angler Survey (SWAS) data. The CAP is designed to gather data from recreational striped bass anglers through voluntary trip reports. Volunteer anglers log information for each striped bass fishing trip including fishing time, location, bait use, and fish caught, including length, and weight, and bycatch. The volunteer anglers were asked to provide specific information about their herring bait use. We used the SWAS data on the total number of striped bass trips times the CAP average percent of trips using bait times the 2007 CAP herring use per angler day to obtain an 2007 estimate of 241,318 (Table 10.12).

The use of herring as bait has increased substantially over the three estimates (2001, 2005, and 2007).

They also demonstrate the magnitude of use and the potential impact this bait fishery can have on the Hudson River herring population.

Long Island: Alewife are caught in many of the small streams on Long Island. No creel data are available but anecdotal information (B. Young, NYSDEC retired, personal communication) suggests that harvest is rising in the more easily accessible streams. Herring taken are used for personal consumption as well as for bait.

The town of East Hampton, on Long Island's east end, has local ordinances in place to prevent fishing during the alewife spawning runs.

10.9.7 Fishery Dependent - Bycatch

River herring occur as bycatch in many fisheries along the Atlantic coast from North Carolina up to the Gulf of Maine and are in the known migratory range of the Hudson stock. This bycatch is mostly un-documented but has the potential to harvest Hudson and many other stocks along the coast. In some years, bycatch of river herring in the Atlantic herring fishery can be equal to, or exceed the total of all in-river landings (Cieri et al. 2008).

10.10 FISHERY INDEPENDENT SURVEYS

10.10.1 Spawning Stock Surveys

Several surveys have sampled the alewife and blueback herring spawning stocks, or production, portion of the population. These are the fish which have escaped from coastal and in-river commercial fisheries. Spawning stock data for river herring in the Hudson River is available from several sources: a New York Conservation Department historical report, a variety of NYSDEC surveys, and a large scale survey contracted to Normandeau Associates, Inc. (NAI 2008).

10.10.2 New York State surveys

The New York State Conservation Department, predecessor of the current NYSDEC, conducted a biological survey of all state natural resources during the 1930s. The Hudson watershed was sampled in 1936 (Greeley 1937). Number, mean length, and weight for both sexes of blueback herring ('summer' herring) and alewife were reported; sample size is very small.

NYSDEC river herring data are from several surveys. The longest dataset (1975-2000) is from an annual survey of chemical contaminants in fish that targeted multiple species within the Hudson River estuary (Table 10.13). Sample size varied among years. In most years, length data were recorded for a sub sample of the total collected. The NYSDEC also conducted a short, two year survey in 1989 and 1990, to examine the population characteristics of blueback herring in the Hudson and the Mohawk River, the Hudson's largest tributary.

From 1985 to the present, the NYSDEC Hudson River Fisheries Unit (HRFU) has conducted an annual American shad and striped bass spawning stock survey. One component of this survey uses electro-fishing gear to collect large numbers of striped bass for tagging; herring are incidental catch. The major gear used for the spawning stock survey is a 154 m or 305 m haul seine, fished at beaches located throughout the spawning area for shad and striped bass. The 10.2 cm stretch mesh in these nets was specifically designed to catch shad and striped bass, but to let smaller river herring escape. However, some large (> 280mm) herring were occasionally caught in these gears. Sampling occurs between Hudson River km 145 and km 232 from late April through early June.

In 1987, the HRFU added a component to the shad and striped bass spawning stock survey to try and target adult river herring. From 1987 to 1990, two small mesh (9.5 mm) beach seines (30.5 and 61m) were occasionally used with little success. In 1998, we specifically designed a small haul seine (91 m) with an appropriate mesh size (5.1 cm) to target herring. It was designed on the same principle as the larger haul seine for shad and bass to be able to capture all sizes of herring present with the least amount of size, and age, bias (Kahnle et al. 1988). We have used this gear from 1999 to the present. Sampling occurs during the shad and bass survey within the area described above, using the same field crew. Generally, the herring seine is deployed between sets of the larger seine used for shad and bass.

For the spawning stock description, we only use the least size-biased gears from the NYSDEC surveys: electro-fishing gear, the beach seine (61m) and the herring haul seine (91m). As sample size varied among years, all data were combined to characterize size and weight composition of the spawning population. Mean total length and weight data are summarized for adults only, >=170mm TL.

10.10.3 Normandeau (State contracted) Survey

During the period when we were trying to target river herring in our own sampling programs, we also contracted Normandeau Associates Incorporated (NAI 2008) in 1999 through 2001 to survey river herring throughout the Hudson River and its tributaries, including the Mohawk River. The primary study objective was to determine the best method available to easily characterize the spawning stock over a broad geographic area. Over the three year period, many combinations of gear were tried in the various sampling areas (Hudson, tributaries and Mohawk). The most prevalent gear used was gill nets chosen for their mobility and need for small field crews. Scap and cast nets were predominantly used in the tributaries.

A number of difficulties were identified. Not all gears worked equally well both temporally and spatially in the different sampling areas (Hudson, small tributaries and Mohawk). Data from the NAI study were limited by the high selectivity of the gill net gears, inconsistent use of different gill net mesh sizes among years, and lack of comparability of gear uses in the Hudson (gill nets) to that used in the tributaries (angling, scap or cast nets). No one gear could capture both species well, as well as both sexes and sizes of fish in relatively unbiased proportions. Data are presented but should be interpreted with caution due to the selectivity issues that could not be adjusted for. Sample size varied greatly between areas, attributed to gear used (Table 10.14). Alewives were caught primarily in the tributaries using scap/lift nets, biased heavily to males; fewer alewives were caught by gill nets in the main river. No alewives were found to use the Mohawk. Blueback herring were primarily caught in the main stem Hudson River followed by Mohawk River; few were caught in the estuary tributaries, especially in 2000 and 2001 (Table 10.14). It is not clear if this was attributed to gear or actual effort expended in the different areas.

NAI (2008) also developed its own aging technique. They began with the aging technique of Cating (1954) developed for American shad, then noted differences in the structure of the scale, and developed their own technique for aging herring. It is not clear if the aging technique for the NAI data is similar to that used to age other data presented in this report therefore comparisons should be made with caution. Repeat spawn mark data *should* be comparable in that repeat marks are relatively easier to distinguish then pre-spawn annuli.

10.10.4 Size and Age Distribution

All river herring collected were identified by species, sex, and most all were weighed, measured, and sampled for scales for aging. Size of alewife dropped noticeable after 1990 when compared to samples collected from 1975 through 1987 (Table 10.15, Figure 10.12). From 1990 to the present, size of alewives has continued to decline at a slow rate. The same pattern of decline in size also occurred for blueback herring (Table 10.15, Figure 10.13). The length-frequency data indicate the same declining trends (Table 10.16 and Table 10.17). Length data from the NAI survey was similar for all years (1999-2001) and areas most likely the result of collection by size biased gear (Figure 10.14).

Modal length in the 1970s of both species and sexes was higher than those collected within the last few years (Table 10.16and Table 10.17). An interesting note is the presence of immature (< 170 mm TL) alewife and blueback herring in some years. It is not known why these fish are in the spawning area but they may be following the adults in an attempt to join the coastal migratory stock.

Limited age data are available for the alewife and blueback herring spawning stocks. For alewife, NAI (2008) data are presented in Table 10.18, combined for all gears and areas sampled. No adjustments have been made for gear selectivity. Age data *should be interpreted with caution* (see Age section) and is presented here for information only. Although age data may be in question, the use of repeat spawn marks may be less so as they are more easily identified than annuli. Up to five repeat spawn marks were found on some scales, the data indicated that less than 40% of males were repeat spawners in 1999, dropping to 4% in 2000, then rising in 2001 to 12% (Table 10.18). A similar pattern in repeat percent occurred when data are separated by sampling area (Table 10.19). For female alewives, repeat spawning was relatively high (75%) in 1999, but it then dropped to 15% for 2000, increasing slightly to 35% 2001 (Table 10.18). These kinds of changes seem unrealistic given that several age classes participate in spawning. Only the appearance of a very strong year class could produce such variation in frequency of repeat spawn and the age estimates did not indicate the presence of such a year class (Table 10.18).

Blueback herring age / repeat spawn data are available from two studies: 1989-1990 (NYSDEC) and 1999-2001(NAI 2008, Table 10.20). As for alewife above, blueback herring age data from the NAI (2008) survey *should be interpreted with caution* (see Age section above). Herring from the NYSDEC study were ages two through seven for males and three through seven for females (Table 10.20). These young ages also reflected a relatively low percentage of repeat spawning each year: 35% in 1989 and 21% in 1990 for males and 25% (1989) and 21% (1990) for females. Ten years later, NAI (2008) reported similar percent of repeat spawning of 21% and 23 % for males and females in 1999. However, in 2000 and 2001 this percentage dropped dramatically to 6% then 12 % for males and 14 and 13% for females (Table 10.20). This inter-annual difference remained when data from the Hudson and Mohawk were summarized separately (Table 10.19). However, estimates were consistently lower in the Mohawk River than in the Hudson River. Low repeat spawn values for the Mohawk were most likely due to higher mortality caused by passage problems both upstream into the Mohawk through the locks, and downstream through several hydro-power plants as well as locks.

NYSDEC spawning stock survey

As discussed above (see Section 8 Age) most all scale samples from NYSDEC survey remain un-aged. As an alternative, and for a very general picture of potential age structure, we estimated annual age structure using length at age keys from datasets provided by Maine, Massachusetts, and Maryland for alewife and Massachusetts and Maryland for blueback herring.

Alewife: Age estimates using length-age keys generated from the three state datasets differed from each other, (Table 10.21, Figure 10.15). In general, the ME key resulted in the youngest ages, followed by older ages from MA, then MD. Ages from two through eight or nine were present in the spawning stock. Peak age varied with key used and by sex; most fish were ages three or four for males and four or five for females. Mean age was youngest using the ME key, older from the MA, and oldest for MD age key (Figure 10.16). Mean age for males was older in 1990, 2001 and 2003, then dropped and remained relatively stable (within state estimation method) for 2005 through 2010. Mean age for females was slightly lower in 2008 and 2009 but by 2010 returned to the same level as estimated for 2001 and 2003 (Figure 10.16).

Blueback herring: Age estimates using length-age keys from MA and MD (Table 10.22) differed from ages assigned by NY (Table 10.20) for the 1989-1990 samples and from each other for most years (Figure 10.17). In general, keys from MD and MA were mostly in agreement for male blueback herring in most years, but MA aged females slightly older (Figure 10.17). Estimated ages from two through eight were present in the spawning stock. Most fish were ages three, four, and five. Mean age remained relatively stable among years within method for 1989 to 1992, then declined to a slightly lower level in 2009 and 2010 (Figure 10.18).

Given current uncertainty about aging methods and age of Hudson River alewife and blueback herring, we suggest that available estimates should only be used for a general discussion of age structure and for trends within estimate method. We do not feel that age estimates should be used to monitor changes in stock status or to set benchmarks until aging methods can be verified.

10.10.5 Volunteer and Other river herring monitoring

River herring spawn in New York over a wide range of habitat including tributaries of Long Island and the Hudson and Mohawk Rivers. NYSDEC's HRFU and the Environmental Defense's South Shore Estuary Reserve Diadromous Fish Workgroup (SSER) have begun to incorporate citizen volunteers into the collection of data on temporal variation of and physical characteristics associated with spawning in tributaries. These data were not provided by the fishery dependent and independent sample programs discussed above. These programs also bring public awareness to environmentally important issues.

The SSER began a volunteer survey of alewife spawning runs on the south shore of Long Island in 2006. Data were available from 2006 through 2008. The survey was designed to identify alewife spawning in support of diadromous fish restoration projects. It evaluated recent fish passage projects (i.e. Carmans River fish ladder) and set a baseline of known population runs. Data were available for 2006 through 2008. Monitoring occurred on six to nine targeted streams annually, with volunteer participation ranging from 24 to 68 individuals. Monitoring took place from March through May. Alewife were seen as early as March 5 (2006) and late as May 31 (2008). Data indicate that alewife use multiple streams in low numbers. It is not clear whether some streams (Howells Creek, Carlls River, Connetquot River, and Brown's River) supports a spawning population since total sightings were very low. The Carmans and Swan Rivers showed the most alewife activity and likely support yearly spawning migrations. The first permanent fish ladder on Long Island was installed in 2008 on the Carmans River. Information gathered during this study will aid in future construction of additional fish passage (Kritzer et al. 2007a, 2007b and Hughes and O'Reilly 2008).

In addition to the SSER, other interested individuals have also monitored Long Island runs (see Appendix Table 10.A). Anecdotal data provides valuable information on tracking existing in-stream conditions, whether streams hold active or suspected runs, interaction with human land uses and suggestions for improvement (L. Penney, Town of East Hampton, personal communication).

NYSDEC also started a similar river herring volunteer monitoring program in 2008 for tributaries of the Hudson River Estuary. We designed this project to gather presence–absence and temporal information about river herring spawning runs from the lower, middle and upper tributaries of the Estuary. A total of 11 tributaries were monitored by 63 volunteer in the first year. Monitoring took place from April through mid June. Data are currently being summarized.

10.10.6 Young-of-the-Year Abundance

Since 1980, the NYSDEC has obtained an annual measure of relative abundance of young-of-the-year (yoy) alewife and blueback herring in the Hudson River Estuary. Although the program was designed to sample yoy American shad, it also provides data on the two river herring species; blueback herring appear more commonly than alewife. In the first four years of the program, sampling occurred river-wide (rkm 0-252), bi-weekly from August through October, beginning after the peak in yoy abundance occurred. The sampling program was altered in 1984 to concentrate in the freshwater middle and upper portions of the Estuary (km 88-225), the major nursery area for young herring. Timing of samples was changed to begin in late June or early July and continues biweekly through late October each year. Gear is a 30.5 m by 3.1 m beach seine of 4 mm stretch mesh. Collections are made during the day at approximately 28 standard sites in preferred yoy herring habitat. Catch per unit effort is expressed as annual geometric and arithmetic means of number of fish per seine haul for annual weeks 26 through 42 (July through October), the period encompassing the major peak of use in the middle and upper estuary.

Other indices are available from the Hudson River generating (HRG) companies Long River Monitoring Program (ASA 2008). The HRG sampling program includes a river-wide beach seine survey and an off shore fall shoal survey (sampling open water areas over the channel and shoals). The HRG beach seine survey (BSS) randomly samples beaches in thirteen river segments spread out the entire 246 km of the Hudson River. Sampling is more highly concentrated in the brackish water portion of the Hudson, as the survey was designed to sample for young of the year striped bass. The BSS began in August for most years of the survey (1974 through 1997), but is now similar in timing to NYSDEC survey running from July through October. The seine used is similar to the NYSDEC YOY program, except that the stretch mesh size is slightly larger (9.5 mm rather than 4 mm. The fall shoals survey (FSS) uses a beam trawl and samples the same river reaches as the BSS however it samples at night in the open water (channel sections) of the river.

CHGE et al. (1999) indicated that neither the BSS nor the FSS samples herring well as herring tend to move on and off shore on a dial cycle. Bluebacks tend to move offshore at night and distribute themselves near the surface of the water; alewives tend to move on shore at night. The "best" herring indices were calculated from FSS samples because the channel stratum represents a larger fraction of the total river habitat than the shore zone. Data for the HRG surveys are available to 2009.

From 1980 to 1998, the NYSDEC geometric mean YOY annual index for alewife was low, with only one year (1991) over one fish per haul. Since 1998, the index has increased erratically (Table 10.23 and Figure 10.19). The HRG survey data indicate that yoy abundance was higher in the 1970s, remained at low levels in the 1980 but then began an erratic high-low cycling since 1998.

From 1980 through 1994, the NYSDEC geometric mean YOY annual index for blueback herring averaged about 24 fish per haul, with only one year (1981) dropping below 10 fish per haul (Table 10.24, Figure 10.20). After 1994, the mean dropped to around 17 fish per haul, and then began the same high-low pattern observed for alewife. The HRG survey data indicate that yoy blueback abundance was also higher in the 1970s and has declined erratically since then to the present.

The underlying reason for the wide variation in yoy river herring indices is not clear. The same erratic trend that occurs since 1998 is also evident for American shad (Hattala and Kahnle 2007). The trend in all three alosines may indicate a change in overall stability in the system.

10.10.7 Entrainment and Impingement Estimates

A river-wide ichthyoplankton survey occurs annually in the Hudson River Estuary, conducted by consultants under contract with the Hudson River Generating companies. In order better define impacts of the once-through cooling systems on fish, estimates of mortality on various ichthyoplankton life stages were calculated using two models, the Empirical Transport Model and the Conditional Entrainment Mortality Rate (CEMR) model. Detailed methodology for both models can be found in CHG&E et al. (1999).

Estimates of mortality are expressed as conditional entrainment and impingement mortality rates, or the percent reduction in a year-class that would be due to mortality from entrainment and or impingement through once-through cooling water systems if no other causes of mortality operated. Losses for the

Hudson River Estuary can occur at one major office complex air conditioning unit, two nuclear power plants, one waste-fuel power plant, and five fossil-fuel power plants located throughout the Hudson Valley above New York City. CEMR at these facilities combined has ranged from 9 to 42 percent for alewife and 8 to 41 percent for blueback herring during the period 1974 to 1997 (Table 10.25). Estimates have not been made for years since 1997.

10.11 ASSESSMENT APPROACH AND RESULTS

We used an index based approach to assessing status of river herring in the Hudson River. Although data were available to set a benchmark for fishing or total mortality using a biomass per recruit approach, we judged that available techniques for measuring stock specific mortality rates were not adequate (See Sections 10.1.3 and 11.5). Moreover, approaches using loss estimates to the stock required information on stock specific ocean losses and these data were not available.

10.11.1 Trends in Run Size

As described above in section 9.3.2.1 Hudson River catch rates, annual CPUE is calculated differently for the two component fisheries in the river. The gear of choice for an abundance index is the fixed gill nets below the Bear Mountain Bridge. This gear operates as an intercept fishery, capturing fish on their emigration into the river before they reach their spawning areas. We only use data from 2000 to 2010, when mandatory reporting was enforced. CPUE for this gear declined slightly from 2000 to about 2006 then has slowly increased since then (Figure 10.10). For all years, 2000 to 2010, the trend is increasing, but the rate of change is not significant.

10.11.2 Trends in size structure

To examine trend in size, only annual samples greater than 34 fish were used in the trend analysis. The minimum sample size was determined using the method described by Lynch and Kim (2010) using a desired CV of 0.15.

Fishery dependent sample size was relatively low each year, plus sexes were combined, limiting the usefulness of these data. For alewives only five of the 10 years (2001 to 2010) were used in the trend analysis; the decline in total length for alewives was significant (slope = -2.12, R^2 = 0.84, P = 0.030). Alewife weight and blueback herring total length and weight were also in decline, but the trend was not significant (Table 10.26).

Fishery independent samples from the spawning stock survey were collected over a long time period from 1989 or 1990 to 2010. However, many of the annual samples were small, limiting the useful data to four to eight years from the time series to base the trend analysis on (Table 10.15 and Table 10.26).

Significant declining trends in mean total length occurred for male alewife (slope = -0.94, R^2 = 0.62, p = 0.021, Table 10.26) and female blueback herring (slope = -0.99, R^2=0.73, p=0.029, Table 10.26). Mean total length for female alewife and male blueback herring declined, but the trend was not significant. Also not significant was the decline in mean weight for both sexes of blueback herring and male alewife. Mean weight for female alewife increased, however the times series for the trend only included four years.

10.11.3 Trends in Age composition

As described above in Section 8, many scale samples from NYSDEC surveys remain un-aged pending development of a dependable aging technique. The alternative we used was to estimate age using length at age keys from datasets provided by Maine, Massachusetts, and Maryland. Annual estimated age structures resulted in some similarities, but also major differences causing us to only use the data in general terms as in describing trends. For this we used mean age from the resulting age structure (Figure 10.16 and Figure 10.18).

For alewife males, eight years of data were available, 1990 and seven years from 2001 to 2010. The resulting trend in mean age was significant if the 1990 data were included, but was not significant if only 2001 to 2010 were used (Table 10.26). The mean age trend for female alewife and both sexes of blueback herring was declining but not significant (Table 10.26).

10.11.4 Trends in Proportion of Repeat Spawners

Five years of repeat spawn data are available, (1989-90 and 1999-2001). Since only one year of recent data are available within the last ten years, no analysis has been done.

10.11.5 Trends in Total instantaneous mortality

The variation in annual age structure, generated by the ME, MA and MD length-age keys, translated into a wide variation in estimates of total mortality when age-based (catch curve and Chapman-Robson) estimation methods were used. Trends in the mortality rates varied among species, sexes and methods (Figure 10.21 and Figure 10.22). This difficulty in estimating ages precluded the use of age-based mortality estimators.

As an alternative, we tried the Beverton-Holt length-based method (Gedamke and Hoenig 2006) using growth parameters for length from the 1936 data described above. However, the "length-based" is a misnomer in that some input parameters are based on length at age. We indicated above (Section 8) that the techniques for aging fish vary among coastal states and for the various studies conducted on the Hudson. It is not clear if the ages from the 1936 study are correct. In addition, since the definition of length at full recruitment (Lc) given by Nelson et al. (2010) seemed arbitrary we estimated total mortality using the Nelson et al. (2010) input and two additional Lc values. Results from the length based method were also influenced by L_∞. Finally, this method is based on the assumption that the stock is in equilibrium. Given the changes observed over the past twenty years, we know that this is not true.

The resulting "length" based total mortality estimates for alewife of both sexes varied tremendously within and among years depending on assumed model inputs (Figure 10.23). Estimates increased until 2006, after which a decline occurred to 2010. An even greater variation occurred for blueback herring (Figure 10.24) with a series of relatively low values in 1989 through 1992 with very high peaks in recent years. Sample size in most years was poor (N=<34) with only five to eight data point for trend analysis spread out over 21 years. Given this demonstrated sensitivity to model inputs and the lack of equilibrium in the stock, we suggest that total mortality of the Hudson's river herring stocks remains unknown. However, we should emphasize that mortality on stocks must have been high in the last 30 years to have so consistently reduced mean size and presumably mean age. We feel that these estimates of total mortality should not be used as a benchmark measure should a mortality benchmark be developed for the coastal stocks.

10.11.6 Trends in Age 0 Indices of Relative Abundance

Alewife: The Hudson River stock of alewife has been erratically increasing over the entire times series. The trend is positive and significant (slope = 0.06, R^2 = 0.33, P = 0.001, Table 10.26) for the entire time series and post-zebras mussel invasion (1992 to the present). The HRG surveys indicate the same trend for the beach seine survey, although the increasing trend is only significant for the time period after 1992. The offshore fall shoal survey data varies without trend.

Blueback herring: Unlike alewife, data for bluebacks indicate a decreasing, non-significant trend for the NYSDEC data, but a significant decreasing trend for the HRG beach seine survey and fall shoal survey (Table 10.26).

10.12 BENCHMARKS

Stock assessments often set benchmarks for juvenile production and characteristics of the adult stock to prevent over-fishing. Setting mortality benchmarks for the Hudson River stocks has been problematic. In the sections above we raised issues and uncertainties associated with calculating current total mortality estimates. If we can resolve uncertainties about aging methods and estimate methodology mortality rates may be useful in the future. Until then we choose to use other stock indicators.

10.12.1 Juvenile Indices

In New York's Sustainable Fishery Plan, we proposed to set a target for juvenile indices using data from the time period of 1984 through 2010 for both species (see section 10.3). However, we will use a more conservative definition of juvenile recruitment failure than described in section 3.1.1.2 of Amendment 2 to the ASMFC Interstate Fisheries Management Plan for Shad and River herring (ASMFC 2009). Amendment 2's definition is that recruitment failure occurs when three consecutive juvenile index values are lower than 90 % of all the values obtained in the base period. We will use a 75% cut off level. The 75% level for alewife is 0.35 (instead of 0.19) and 11.14 (instead of 2.86) for blueback herring.

The fishery will close system-wide if recruitment failure, defined as three consecutive years below the recruitment failure limit, occurs in either species and will remain closed until we see three consecutive years of recruitment greater than the target values.

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

10.12.2 Mean Length

Mean total length reflects age structure of the populations and thus some combination of recruitment and level of total mortality. Mean total lengths of both river herring species in the Hudson River system have declined over the last 20 years and the means are now the lowest of the time series. Since this has been a persistent change in the face of stable recruitment, we suggest that the reduction in length has been caused by excessive mortality of adults within the river and during their ocean residency (bycatch). The bycatch fishery is a large unknown and not solely controlled by New York State to effect a change. Current annual reproduction now relies on a few returning year classes making the populations vulnerable to impacts of poor environmental conditions during the spawning and nursery seasons. We propose to monitor mean total lengths during the fishery.

10.12.3 Catch per Unit Effort in Report Commercial

We suggest that CPUE values of the reported harvest reflect general trends in abundance. However, annual values can be influenced by changes in reporting rate and thus we do not feel that CPUE should be used as a target. Rather, we will follow changes within gear types and fisheries for general trends.

10.12.4 Age structure and Total mortality

We will monitor age structure, frequency of repeat spawning, and total mortality (Z) if we can resolve uncertainties about aging methods and estimate methodology discussed above. Fish for these parameters will be collected by haul seine that target river herring in the spawning stock as discussed above. We recently received special state funding that will allow us to expand our spring stock sampling and field a crew that will specifically target river herring.

10.13 CONCLUSIONS AND RECOMMENDATIONS

Over the last 30 years, the Hudson River stocks of alewife and blueback herring have shown consistent declines in mean total length and weight of mature fish. Similar trends occur in the both the fishery dependent and independent data (Table 10.26). The river herring stock is much reduced from historic levels. The upsurge in herring use as bait for striped bass has placed herring in a tenuous position. With this continuing demand, declining size, and assumed increasing mortality, careful management is needed.

Recruitment has become extremely variable since the mid-1990s for both species. Some decline is occurring for yoy blueback herring and, counter-intuitively, an increasing trend for yoy alewife in all surveys since 1992. It is not clear if the trend in alewife is the result of a change in distribution as the result of zebra mussels affecting food sources for young fish; alewife could now be using inshore areas for feeding making them more vulnerable to being caught by beach seines.

Runs on Long Island remain relatively small and easily disturbed from development pressure.

River herring stocks are a shared resource along their entire migratory range, from North Carolina to Maine and Canada. As long as fisheries continue to operate in coastal waters, decisions on the fishery, and the direction it will take, are also a shared process.

Recommendations:

- Restrict directed recreational and commercial fisheries that could potentially affect New York stocks to curtail further decline. Fishery restrictions have been proposed in New York's Sustainable Fishing Plan for the Hudson River and its tributaries. River herring fishing will be closed on Long Island and the Bronx and south shore of Westchester County due to lack of data on stock condition.

- Identify and control bycatch from fisheries outside of New York such as the Atlantic herring and mackerel fisheries and inshore small mesh fisheries.

- Hudson River and tributaries: Continue fishery independent young of year and spawning stock surveys; and fishery dependent monitoring: CPUE and biological characteristics of catch.

- Long Island, Bronx and south shore of Westchester County: Encourage development of monitoring programs for selected runs.

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Table 10.1 Number of permits sold to take river herring in the Hudson River Estuary, New York, along with reported actual use by fishers calculated from mandatory reports.

	Gill nets: shad& herring, gill											Scap/lift net					
	Permits Sale				Reports received		Actual use of permit to take river herring					Permit Sale		Reports received		Actual use	
Year	N-fishers purchasing permit	N-s&h sold	N-gn sold	N-total gn licenses sold	N-gill nets from reports*	%gill nets from reports*	N-drift reported herring	N-fixed below BMB^	N-fixed above BMB^	Total gill net	% of total gill net permits sold	N-fishers purchasing permit	N permit sold	N-scap nets from reports*	%scap nets from reports*	Total scap net	% Scap net permits sold
1995	112	47	75	122	67	55%	1	3	1	5	4%	2	2	2		2	100%
1996	134	54	88	142	71	50%	1	2	2	5	4%	2	2	2		2	100%
1997	112	45	74	119	107	90%	7	9	6	22	20%	35	35	35		24	69%
1998	140	65	119	184	110	60%	16	11	10	37	26%	46	46	46		33	72%
1999	145	77	68	181	121	67%	15	16	11	42	29%	31	31	31		20	65%
2000	223	108	123	231	146	63%	33	21	18	72	32%	443	448	231	52%	124	28%
2001	190	97	95	192	149	78%	33	20	20	73	38%	345	360	217	60%	127	37%
2002	232	141	120	261	164	63%	38	25	29	92	40%	296	338	177	52%	113	38%
2003	238	144	106	250	183	73%	42	22	35	99	42%	246	278	182	65%	115	47%
2004	275	160	127	287	195	68%	41	26	25	92	33%	259	291	177	61%	106	41%
2005	255	162	111	273	199	73%	31	22	19	72	28%	228	255	157	62%	80	35%
2006	290	179	129	308	218	71%	43	24	32	99	34%	247	273	149	55%	87	35%
2007	290	178	130	308	210	68%	40	27	28	95	33%	216	244	142	58%	75	35%
2008	277	173	119	292	187	64%	36	19	26	81	29%	198	219	137	63%	85	43%
2009	254	159	108	267	185	69%	34	19	26	79	31%	184	199	137	69%	78	42%
2010**	181	0	185	185	129	70%	19	19	27	65	36%	173	190	107	56%	66	38%

*Includes used and unused licenses
** reporting numbers as of 3/14/2011
~refers to below or above the Bear Mountain Bridge (River mile 46)

Table 10.2 New York River river herring landings- all numbers are in kg, unless indicated otherwise.

						nal Marine Fisheries Service (		ACCSP	
				Hudson River ONlLY				New York State	
Year	River herring	Sheppard [a]	Dept. historic annual reports [b]	NYSDEC license reports-kg [c]	NYSDEC license reports (N)[d]	Species	Kg	Species	Kg
1904	227,653		227,653						
1905	125,860		125,860						
1906									
1907									
1908	36,870		36,870						
1909	50,546		50,546						
1910									
1911									
1912									
1913	41,847	41,847	41,847						
1914									
1915									
1916	9,880		9,880						
1917	22,670	22,670	22,670						
1918	40,054	40,054	40,054						
1919									
1920	46,240		46,240						
1921	4,927		4,927						
1922	33,338	33,338	33,338						
1923	23,039		23,039						
1924	25,705		25,705						
1925	41,853	41,853	41,853						
1926	59,717		59,717						
1927	63,603		63,603						
1928	81,184		81,184						
1929	66,663	66,663	66,663						
1930	62,881	62,881	62,881						
1931	84,311	84,311	84,311						
1932	41,510	41,510	41,510						
1933	79,436	79,436	79,436						
1934	89,369	89,369	89,369						
1935	124,580	124,580	124,580						
1936	94,560	94,560	94,560						
1937	103,451	103,451	103,451						
1938	111,013	111,013	111,013						
1939	90,258	90,258	90,258						
1940	78,748	78,748	78,748						
1941	101,231	101,231	101,231						
1942	68,292		68,292						
1943	76,751	76,751	76,751						
1944	71,570	71,570	71,570						
1945	56,123	56,123	56,123						
1946	59,611	59,611	59,611						
1947	48,210	48,210	48,210						
1948	41,072	41,072	41,072						
1949	45,295		45,295						
1950	47,080		46,879			Alewife	47,080		
1951	33,959		31,320			Alewife	33,959		
1952	40,996	40,179	40,179			Alewife	40,996		
1953	32,122	32,122	32,122			Alewife	25,969		
1954	37,909					Alewife	37,909		
1955	46,308	5,630	5,630			Alewife	46,308		
1956	30,828	30,828	30,828			Alewife	30,781		
1957	25,560	25,469	25,469			Alewife	25,560		

						ional Marine Fisheries Service (w		ACCSP	
				Hudson River ONlLY				New York State	
Year	River herring	Sheppard [a]	historic annual reports [b]	license reports-kg [c]	license reports (N)[d]	Species	Kg	Species	Kg
1958	30,009	30,009	30,009			Alewife	30,009		
1959	20,702	20,702	20,702			Alewife	20,702		
1960	17,343	17,343	17,343			Alewife	17,343		
1961	15,345	15,345	15,345			Alewife	15,345		
1962	17,343	17,343	17,343			Alewife	17,343		
1963	14,664	14,664	14,664			Alewife	14,664		
1964	16,798	16,798	16,798			Alewife	16,798		
1965	10,714	10,714	136			Alewife	10,714		
1966	1,901,352	11,123				Alewife	1,901,352		
1967	1,998	1,998	159			Alewife	1,998		
1968	3,178	3,178	160			Alewife	3,178		
1969	4,177	4,177	68			Alewife	4,177		
1970	4,994	4,268	16			Alewife	4,994		
1971	31		31						
1972	182		46			Alewife	182		
1973	9,806	908	114			Alewife	9,806		
1974	7,673	7,673	2			Alewife	6,992		
1975	6,946		227			Alewife	6,946		
1976	681					Alewife	681		
1977	2,724					Alewife	2,724		
1978	318					Alewife	318		
1979	454					Alewife	454		
1980	409					Alewife	409		
1981	29,465					Alewife	29,465		
1982	104,057					Alewife	104,057		
1983	11,214					Alewife	11,214		
1984	1,907					Alewife	1,907		
1985	68					Alewife	68		
1986	1,317					Alewife	1,317		
1987	1,255					Alewife	1,255		
1988	45					Alewife	45		
1989	227					Alewife	227		
1990									
1991									
1992									
1993									
1994	24,867							All potential[e]	24,867
1995	23,453			232	1,163			All potential[e]	23,072
1996	37,568			257	1,187			All potential[e]	37,311
1997	32,879			1,436	7,241			All potential[e]	31,443
1998	43,006			2,834	14,241	Alewife	2,234	All potential[e]	37,938
1999	37,482			1,506	7,553		0	All potential[e]	35,976
2000	34,350			7,648	38,613	Herring, Blueback	222	All potential[e]	26,480
2001	21,043			8,920	43,668	Herring, Blueback	1,467	All potential[e]	10,656
2002	23,706			9,229	46,269	Herring, Blueback	215	All potential[e]	14,415
2003	33,082			8,910	44,811	Herring, Blueback	9,284	All potential[e]	24,171
2004	20,079			7,455	37,816	Herring, Blueback	6,553	All potential[e]	5,629
2005	11,036			6,128	31,948	Herring, Blueback	2,627	All potential[e]	1,235
2006	13,634			4,541	25,144	Herring, Blueback	5,029	All potential[e]	7,375
2007	18,034			6,306	35,953	Herring, Blueback	13,699	All potential[e]	11,728
2008	11,924			5,963	35,612	Herring, Blueback	11,183	All potential[e]	5,961
2009	10,323			5,367	32,700	Herring, Blueback	5,396	All potential[e]	4,956
2010[f]	5,160			5,160	32,824				

a- Sheppard 1976; b-NYSDEC Annual Reports - Historic annual reports; c- NYSDEC License Reports - Mandatory commercial permit reporting system: pounds and/or numbers estimated; d- Total landings include river herring caught in all gears over the entire season; e- All potential river herring species: blueback herring, alewife, "herrings", and river herring; f- NYSDEC reported landings as of 3/14/2011

Table 10.3 Total trips, effort (number of square yards * hours fished), and catch (in numbers) data from commercial fishery reports targeting river herring for major gear types; fixed gill nets, drift gill nets, and scap/lift nets. (Mandatory reporting period 2000 - 2010)

	Annual Sum of Commercial Reports Characteristics*														
	Fixed - below BMB**			Fixed - above BMB			Drift			Scap/Lift			Total		
Year	N - trips	Effort	Catch	N - trips	Effort	Catch	N - trips	Effort	Catch	N - trips	Effort	Catch	N - trips	Effort	Catch
1995	20	46733	238	0	0	-	0	0	-	0	0	-	20	46733	238
1996	37	46019	287	10	4844	435	5	644	15	0	0	-	52	51508	737
1997	68	80536	1,418	8	633	173	34	13272	272	54	219	1,462	164	94661	3,325
1998	111	517417	3,140	36	49217	1,279	67	20173	573	129	2324	4,876	343	589130	9,868
1999	158	349636	4,103	51	22483	796	72	5707	495	133	1357	1,354	414	379183	6,748
2000	255	1227756	12,076	75	54458	1,405	195	82513	5,470	633	6158	16,297	1158	1370885	35,248
2001	250	1063837	16,085	102	15470	2,259	175	79430	3,092	811	13368	21,517	1338	1172105	42,953
2002	271	728095	13,951	132	25896	3,535	242	93703	7,469	816	8427	20,514	1461	856120	45,469
2003	239	585221	9,307	215	61625	5,567	295	100755	9,012	747	18459	20,680	1496	766059	44,566
2004	267	636288	11,669	141	49250	2,735	262	78557	7,304	627	11281	15,922	1297	775375	37,630
2005	203	458419	9,184	123	62446	2,283	239	85307	4,326	586	10848	15,213	1151	617020	31,006
2006	240	466444	4,435	194	141143	4,267	227	118354	4,058	549	9140	11,557	1210	735083	24,317
2007	268	381864	7,344	211	75290	6,340	219	95800	8,786	545	10909	13,201	1243	563863	35,671
2008	243	351670	5,731	148	44589	4,792	166	62323	9,152	652	11671	15,722	1209	470253	35,397
2009	213	145114	2,811	154	27282	5,715	178	261213	6,267	704	11440	17,058	1249	445050	31,851
2010***	211	200063	4,697	133	23841	6,431	89	14521	2,515	605	12988	17,610	1038	251413	31,253

*mesh less than 3.75 in stretch and julian weeks 11 to 25
**Bear Mountain Bridge, River mile 46
**NYSDEC commercial report data as of 3/14/2011

Table 10.4 Landings and discards (Number), of river herring from Hudson River commercial fisheries mandatory reports documenting river herring and observed data from the NYSDEC commercial fishery monitoring program.

	Commercial Reporting *										Commercial Monitoring				
	Gill net reports					Scap net reports					Gill net trip observations				
Year	N-Trips	Landings- N	Discards	Catch	% discard	N-Trips	Landings- N	Discards	Catch	% discard	N-Trips	Landings- N	Discards	Catch	% Discard
1981											53	27	16	43	37.2%
1982											66	15	17	32	53.1%
1983											55	10	11	21	52.4%
1984											64	3	4	7	57.1%
1985											0	0	0	0	0.0%
1986											62	3	13	16	81.3%
1987											55	0	7	7	100.0%
1988											53	1	2	3	66.7%
1989											0	0	0	0	0.0%
1990											23	0	2	2	100.0%
1991											22	1	1	2	50.0%
1992											41	6	8	14	57.1%
1993											9	0	1	1	100.0%
1994											9	1	1	2	50.0%
1995	269	613	-	613	0%	2	550	-	550	0%	15	1	1	2	50.0%
1996	425	737	-	737	0%	2	279	-	279	0%	24	50	0	50	0.0%
1997	630	3263	-	3263	0%	175	3978	-	3978	0%	26	207	2	209	1.0%
1998	804	7628	-	7628	0%	208	6101	-	6101	0%	22	120	0	120	0.0%
1999	752	6084	-	6084	0%	146	1463	-	1463	0%	40	419	2	421	0.5%
2000	916	19475	-	19475	0%	703	19132	-	19132	0%	38	552	0	552	0.0%
2001	841	21634	-	21634	0%	823	21765	-	21765	0%	40	1356	1	1357	0.1%
2002	1017	25170	-	25170	0%	832	21099	-	21099	0%	20	1327	3	1330	0.2%
2003	1083	24131	-	24131	0%	747	20680	-	20680	0%	10	170	2	172	1.2%
2004	994	21812	-	21812	0%	630	15966	-	15966	0%	26	1900	5	1905	0.3%
2005	886	16071	-	16071	0%	602	15803	-	15803	0%	22	636	6	642	0.9%
2006	950	13316	-	13316	0%	567	11778	-	11778	0%	17	249	1	250	0.4%
2007	986	22742	-	22742	0%	545	13201	-	13201	0%	10	335	1	336	0.3%
2008	837	19802	-	19802	0%	660	15810	-	15810	0%	6	44	1	45	2.2%
2009	714	14865	-	14865	0%	707	17077	-	17077	0%	9	468	0	468	0.0%
2010**	525	14877	-	14877	0%	616	17800	-	17800	0%	2	233	0	233	0.0%

*River herring landings from all commercial gears and weeks
**NYSDEC commercial report data as of 3/14/2011
- discards not reported

Table 10.5 Weekly CPUE and annual sum of weekly CPUE's from the commercial fisheries reports targeting river herring using fixed gill nets below the Bear Mountain Bridge (km75) (Mandatory reporting period 2000 - 2010)

	March			April				May				June				
Year	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Sum of weeks
1995				0.006	0.014	0.019	0.025				0.000	0.000	0.000	0.000	0.000	0.064
1996					0.013	0.026	0.013		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.052
1997			0.036	0.020	0.033	0.039	0.014	0.058	0.049	0.027	0.001		0.020	0.000	0.000	0.297
1998	0.028	0.016	0.004	0.003	0.005	0.015	0.009	0.020	0.037	0.000	0.090	0.002	0.000	0.003	0.000	0.230
1999		0.001	0.004	0.018	0.012	0.016	0.015	0.011	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.082
2000	0.038	0.001	0.007	0.007	0.005	0.022	0.011	0.024	0.012	0.008	0.008	0.005	0.007	0.000	0.000	0.155
2001	0.002	0.002	0.006	0.018	0.031	0.026	0.027	0.017	0.020	0.004	0.002	0.001	0.025	0.000	0.000	0.179
2002	0.006	0.012	0.018	0.026	0.034	0.017	0.016	0.012	0.009	0.020	0.007	0.005	0.000	0.001	0.000	0.182
2003	0.005	0.005	0.009	0.013	0.019	0.021	0.021	0.009	0.006	0.000	0.014	0.000	0.000	0.000	0.000	0.122
2004	0.004	0.012	0.010	0.019	0.022	0.028	0.016	0.024	0.013	0.000	0.007	0.000	0.000	0.000	0.000	0.156
2005	0.004	0.004	0.000	0.015	0.020	0.038	0.026	0.022	0.016	0.001	0.000	0.000	0.005	0.000	0.000	0.150
2006	0.018	0.011	0.004	0.009	0.009	0.017	0.023	0.007	0.004	0.006	0.000	0.000	0.004	0.004	0.008	0.123
2007	0.010	0.004	0.017	0.017	0.028	0.046	0.033	0.009	0.006	0.007	0.000	0.001	0.002	0.002	0.067	0.251
2008	0.051	0.001	0.002	0.020	0.024	0.024	0.012	0.008	0.007	0.009	0.012	0.000	0.000	0.000	0.000	0.168
2009	0.018	0.003	0.014	0.020	0.040	0.050	0.026	0.010	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.183
2010**		0.013	0.011	0.053	0.054	0.046	0.048	0.023	0.006	0.004	0.048	0.007	0.000	0.007	0.000	0.320

*CPUE: Catch per unit effort= Catch / Sq. Yards x Hours fished
** NYSDEC commercial report data as of 3/14/2011

Table 10.6 Annual Catch per Unit Effort (CPUE) of river herring in the commercial fishery in the Hudson River. Fixed gill net below BMB calculated as "area under curve" or sum of weekly CPUE; all other gear CPUE calcuclated as weighted mean- total catch/ total effort.

	Sum of weekly CPUE	Weighted mean		
Year	Fixed GN belowBMB	Drift GN	Fixed GN above BMB	Scap
1996	0.052	0.023	0.090	
1997	0.297	0.020	0.273	6.661
1998	0.230	0.028	0.026	2.098
1999	0.082	0.087	0.035	0.998
2000	0.155	0.066	0.026	2.647
2001	0.179	0.039	0.146	1.610
2002	0.182	0.080	0.137	2.434
2003	0.122	0.089	0.090	1.120
2004	0.156	0.093	0.056	1.411
2005	0.150	0.051	0.037	1.402
2006	0.123	0.034	0.030	1.264
2007	0.251	0.092	0.084	1.210
2008	0.168	0.147	0.107	1.347
2009	0.183	0.024	0.209	1.491
2010	0.320	0.173	0.270	1.356

Table 10.7 Observed total effort and catch (N) for all gill net gears, and a subset of effort, catch, and weekly trip distribution for the fixed gill nets below the Bear Mountain Bridge during the Hudson River commercial monitoring program.

				Fixed gill nets below BMB								
		All gears combined				Number of trips per week of the year						
Year	N - trips	Effort*	Catch	Effort*	Catch	13	14	15	16	17	18	Total
1996	1	91	43									
1997	5	6831	208	6831	208	0	0	1	4	0	0	5
1998	0											
1999	4	11372	421	11372	421	0	0	0	2	2	0	4
2000	6	15810	552	15650	545	0	0	0	2	1	2	5
2001	7	26689	1221	26689	1221	1	2	1	0	3	0	7
2002	8	32222	1328	32222	1328	0	1	2	2	3	0	8
2003	2	4800	171	4800	171	0	1	1	0	0	0	2
2004	13	41164	1904	41164	1826	0	2	4	4	1	0	11
2005	5	9600	456	9600	428	0	0	0	1	0	0	1
2006	4	5969	247	5591	246	0	0	0	0	2	0	2
2007	6	30544	335	25778	299	0	1	1	1	0	1	4
2008	1	0	44									
2009	3	19267	468	19267	468	0	0	2	1	0	0	3
2010	1	4327	192	4327	192	0	0	0	0	1	0	1
Total	66											53

Table 10.8 Catch composition of on-board observations and dock-side sub samples of the commercial fishery. Most all data from below BMB.

On-board observations on commercial trips*																			
	Alewife					Blueback herring					Unidentified "river herring"								
	Number			Sex ratio		Number			Sex ratio		Number			Sex ratio		Total	Percent		
Year	Male	Female	Unknown	M	F	Male	Female	Unknown	M	F	Male	Female	Unknown	M	F	reported	Alewife	Blueback	Unknown
1996								43								43	0%	100%	0%
1997	5	25	178	0.17	0.83											208	100%	0%	0%
1998			114													114	100%	0%	0%
1999			73										348			421	17%	0%	83%
2000	19	18		0.51	0.49	3	32	480	0.09	0.91						552	7%	93%	0%
2001	192	178	851	0.52	0.48											1221	100%	0%	0%
2002			43			19	41	1225	0.32	0.68						1328	3%	97%	0%
2003			171													171	100%	0%	0%
2004	124	168	8	0.42	0.58	5	6		0.45	0.55	500	796	297	0.39	0.61	1904	16%	1%	84%
2005			428										28			456	94%	0%	6%
2006			1					246								247	0%	100%	0%
2007			14					53					268			335	4%	16%	80%
2008											44			1.00	0.00	44	0%	0%	100%
2009	187	179	4	0.51	0.49	37	61		0.38	0.62						468	79%	21%	0%
2010	80	42	2	0.66	0.34	33	70	6	0.32	0.68						233	53%	47%	0%

Table 10.9 Length frequency of river herring collected during commercial fishery monitoring trips is the Hudson River Estuary.

	Alewife										Blueback herring									
Total length (mm)	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
<200																				
200-209																				
210-219																				
220-229																				
230-239									1	1		1				1				1
240-249	3		2	4			2		13	14		8	9		1	3	3		3	8
250-259	6	3	3	17	1		7		31	13		22	12		4	5	10		29	15
260-269	15	3	7	28	8		3		51	6		29	21		11	8	3		30	7
270-279	33		15	41	7				23	5		30	6		4	3	4		10	6
280-289	22	2	7	25	2				4	1		16	4							1
290-299	3		4	12			1		1			4	1				1			
300-309			1	1	2				1			2	1							
310-319			1																	
320-329																				
330-339																				
340-349																				
350-359																				
360-369																				
370-379				2																
380-389				1																
390-399																				
>399																				
Total	82	8	40	131	20		13		125	40		112	54		20	20	21		72	38

Table 10.10 Mean total length and weight of river herring collected during commercial fishery monitoring trips is the Hudson River Estuary.

	Alewife - Male										Blueback herring - Male									
	TL					Weight					TL					Weight				
Year	N	Max	Min	Mean	STD	N	Max	Min	Mean	STD	N	Max	Min	Mean	STD	N	Max	Min	Mean	STD
2001	40	240	298	270.5	10.8	50	146	263	192.8	22.9										
2002	7	250	280	261.0	10.9	7	158	236	179.4	26.8	52	239	297	260.9	11.9	53	100	280	189.8	28.0
2003	20	244	285	266.4	11.6	20	118	232	178.9	27.3										
2004	58	243	374	266.7	18.3	58	110	260	189.7	28.8	31	243	285	258.5	11.3	31	120	220	173.9	23.5
2005	10	262	300	273.5	11.5	10	150	300	192.0	42.1	10	244	269	259.6	7.3	10	140	210	187.0	20.0
2006						0					10	239	271	253.4	11.0	10	130	195	169.5	22.9
2007	7	247	259	254.4	4.9	7	120	180	162.9	24.3	11	240	258	251.5	4.8	11	140	180	156.4	12.1
2008						0														
2009	59	239	277	258.0	8.7	59	134	230	170.0	19.3	37	243	274	257.8	6.5	36	148	200	169.2	12.7
2010	20	237	272	253.2	11.0	7	132	176	154.9	14.8	18	238	271	253.9	8.9	7	134	172	152.4	12.2
	Alewife - Female										Blueback herring - Female									
2001	41	245	291	275.4	9.5	51	138	289	217.0	33.6										
2002	1	286	286	286.0	0.0	1	222	222	222.0		60	249	306	274.0	12.4	60	140	280	211.2	30.0
2003	20	261	310	282.8	12.7	20	166	330	219.7	38.9										
2004	73	256	381	281.5	19.2	73	150	280	218.2	29.6	23	245	309	268.0	13.8	23	110	280	190.6	30.1
2005	10	256	305	271.4	13.9	10	130	300	196.0	46.2	10	259	276	267.7	6.5	10	180	220	205.0	11.8
2006						0					10	255	272	264.5	6.1	10	165	210	194.5	16.2
2007	2	263	268	265.5	3.5	2	180	200	190.0	14.1	10	248	292	267.9	12.3	10	160	240	193.0	25.8
2008						0														
2009	62	240	290	266.0	9.7	61	130	292	199.9	29.1	35	247	276	263.0	7.1	35	152	220	180.8	16.8
2010	20	243	282	255.8	11.0	8	152	186	162.5	11.2	20	244	288	262.0	11.6	10	152	230	179.2	24.4
	Alewife - all fish										Blueback herring - All fish									
2001	82	240	298	273.0	10.4	102	138	289	205.1	31.0										
2002	8	250	286	264.1	13.4	8	158	236	184.8	29.0	112	239	306	267.9	13.8	113	100	280	201.2	30.9
2003	40	244	310	274.6	14.6	40	118	330	199.3	39.1										
2004	131	243	381	274.9	20.1	131	110	280	205.6	32.4	54	243	309	262.5	13.2	54	110	280	181.0	27.5
2005	20	256	305	272.4	12.5	20	130	300	194.0	43.1	20	244	276	263.6	7.9	20	140	220	196.0	18.5
2006						0					20	239	272	259.0	10.4	20	130	210	182.0	23.2
2007	13	241	290	258.4	12.0	13	120	220	169.2	29.0	21	240	292	259.3	12.3	21	140	240	173.8	26.9
2008						0														
2009	125	239	300	262.4	10.4	124	130	292	185.4	28.6	72	243	276	260.3	7.3	71	148	220	174.9	15.9
2010	40	237	282	254.5	10.9	15	132	186	158.9	13.1	38	238	288	258.2	11.1	17	134	230	168.2	24.0

Table 10.11 Creel survey data for river herring caught in the recreational fishery in the Hudson River Estuary, 2001 and 2005.

					Striped Bass fishery		
Year	Boat	Shore	Total	Retention rate	Trips	% bait use	Herring/trip
*2001 Mar 16- Jun 30					53988	85.6%	
Catch (N)	31203	3574	34777				
Harvest (N)	10189	2045	12234	35.2%			
*2005 Mar 16 - Jun 17					72568	88.9%	2.36
Catch (N)	134142	17975	152117				
Harvest (N)	98068	16243	114311	75.1%			

*NAI 2003, NAI 2007

Table 10.12 Estimated herring use in the striped bass fishery based on data gathered through NAI creel surveys and NYSDEC Cooperative Angler Program.

	Herring Use*							
Year	% of all CAP Trips using herring as bait	N-SB Trips using RH	N bought / trip	N caught / trip	Total RH use/trip	Estimated SB trips**	Trips using herring as bait**	Estimated Herring Use
2001						53,988	39,500	93,157
2005	89%					72,568	64,500	152,117
	Cooperative Angler Program Data							
2006	93%	263	1.47	2.57	4.04			
2007	70%	331	1.66	1.80	3.46	90,742	69,700	241,318
2008	71%	445	0.86	1.64	2.50			
2009	77%	492	0.63	3.80	4.43			
2010	74%	527	0.67	4.80	5.48			

*Data from NYSDEC - HRFU Cooperative Angler Program (unpublished data)
**Creel survey data: NAI 2003, NAI 2007; 2007 data from NYSDEC statewide angler survey
***Estimate calculated from overall average Herring/trip (CAP) and Estimated SB trips (DEC SWAS)

Table 10.13 Total number of river herring (> 170mm) caught in NYSDEC fishery independent sampling gears in the Hudson River NY.

	Number of river herring caught by gear									
	Spawning stock survey									
	Beach Seines		Haul Seines			Electrofishing				
Year	30.5m (9.5mm)*	61.0 m (9.5mm)	152 m (10.1 cm)	304 m (10.1 cm)	91.4 m (5.1 cm)	Hudson-Mohawk study	Contaminant sampling	Mohawk sampling	Striped bass tagging	Total
1975							4			4
1976							3			3
1977							2			2
1978										
1979							99			99
1980							5			5
1981							7			7
1982							7			7
1983							4			4
1984							33			33
1985							40			40
1986				144						144
1987		113		3						116
1988			7	1						8
1989						633				633
1990	6	7	1			596			123	733
1991			2						39	41
1992							36		282	318
1993									54	54
1994										
1995									2	2
1996			1						1	2
1997									10	10
1998							34		40	74
1999							5		55	60
2000										
2001					432				95	527
2002										
2003					421					421
2004					10					10
2005					164					164
2006					30					30
2007					53					53
2008					283					283
2009					692			96		788
2010					330				149	479

*Mesh size

Table 10.14 Catch composition of river herring caught during the 1999-2001 survey* in the Hudson River and its tributaries, including the Mohawk River.

		Alewife			Blueback Herring			Total**		
Year	Geographic Region	Female	Male	Total	Female	Male	Total	Female	Male	Total
1999	Hudson River	195	89	335	187	56	262	382	145	597
	Hudson River Above Troy	22	31	57	22	13	37	44	44	94
	Hudson River Tributaries	136	1612	1758	84	272	358	220	1884	2116
	Mohawk River				2739	3988	7083	2739	3988	7083
	Total	353	1732	2150	3032	4329	7740	3385	6061	9890
2000	Hudson River	664	602	1317	1134	600	1784	1798	1202	3101
	Hudson River Above Troy	21	6	27	120	56	183	141	62	210
	Hudson River Tributaries	171	3046	3246	18	56	75	189	3102	3321
	Mohawk River				636	678	1372	636	678	1372
	Total	856	3654	4590	1908	1390	3414	2764	5044	8004
2001	Hudson River	554	607	1213	1312	1051	2471	1866	1658	3684
	Hudson River Above Troy	9	6	15	134	75	213	143	81	228
	Hudson River Tributaries	286	1880	2185	27	16	44	313	1896	2229
	Mohawk River				1172	1086	2379	1172	1086	2379
	Total	849	2493	3413	2645	2228	5107	3494	4721	8520
TOTAL ALL YEARS		2058	7879	10153	7585	7947	16261	9643	15826	26414

* NAI 2008, Vol. 1, Table 10.5.1
** Total includes herring of undetermined sex

Table 10.15 Mean total length and weight of river herring collected during spawning stock sampling* in the Hudson River Estuary

	Alewife - Male										Blueback herring - Male									
	TL					Weight					TL					Weight				
Year	N	Max	Min	Mean	STD	N	Max	Min	Mean	STD	N	Max	Min	Mean	STD	N	Max	Min	Mean	STD
1936	8	291	270	282.9	7.8	6	227	184	210.3	16.6	4	290	310	299.0	8.5	4	255	213	244.5	21.3
1975																				
1976																				
1977																				
1978																				
1979																				
1980	1	298	298	298.0		1	249	249	249.0											
1981	2	291	272	281.5	13.4	2	216	179	197.4	26.2	1	284	284	284.0		1	194	194	194.0	
1982											2	290	268	278.9	15.3	2	219	184	201.7	24.5
1983																				
1984	1	267	267	267.0		1	168	168	168.0		16	282	231	259.9	16.6	16	213	132	160.0	26.1
1985	7	312	249	286.4	22.7	7	281	145	220.7	49.0	11	304	245	271.0	18.0	11	231	136	172.6	30.7
1986																				
1987	26	302	266	279.2	8.9	22	260	160	217.3	35.3	21	294	243	268.0	14.0	10	310	140	205.0	42.5
1988																				
1989											316	285	219	256.1	9.0	316	204	75	136.0	15.9
1990	89	296	239	267.5	14.9	87	270	100	178.2	35.7	345	287	195	246.5	15.1	340	225	70	121.3	26.8
1991	17	290	234	265.0	15.7	16	200	100	147.5	30.7	6	262	225	246.5	15.0	6	180	100	128.3	28.6
1992	12	286	236	269.7	15.3	12	220	110	176.7	29.6	124	295	215	249.6	15.6	111	260	80	140.0	37.3
1993	17	299	246	268.2	13.8	14	205	120	159.6	18.5	1	243	243	243.0		1	130	130	130.0	
1994																				
1995	1	252	252	252.0		1	140	140	140.0											
1996																				
1997	2	287	230	258.5	40.3	2	200	120	160.0	56.6										
1998	33	277	237	255.9	9.9	33	180	120	145.2	19.4	24	271	219	242.3	11.3	24	170	100	121.9	18.6
1999	7	261	228	245.6	12.8	6	140	50	73.3	34.4	24	286	225	253.1	18.5	22	220	50	136.5	41.1
2000																				
2001	399	300	210	262.7	13.2						2	267	235	251.0	22.6					
2002																				
2003	265	305	222	262.9	13.7	166	220	50	148.7	38.6	4	267	240	254.0	14.5	4	180	100	130.0	34.6
2004											6	263	234	246.2	11.9	1	240	240	240.0	
2005	96	280	231	252.0	10.2	88	200	80	143.2	30.0	21	266	228	246.4	10.8	16	220	80	108.8	36.5
2006	16	260	220	238.4	8.3	12	180	80	114.6	24.8	2	256	249	252.5	4.9	2	140	120	130.0	14.1
2007	47	290	219	251.6	12.6	47	220	80	140.6	30.7										
2008	202	285	215	243.7	12.1	188	260	60	158.0	38.3	13	253	226	236.6	7.6	13	180	120	130.8	19.3
2009	460	290	214	255.5	10.8	221	220	80	162.6	27.6	108	268	197	243.9	13.7	54	200	60	108.8	35.1
2010	272	295	221	253.0	13.2	115	250	80	155.7	31.6	62	265	202	237.8	12.1	46	180	70	115.6	23.7

Table 10.15 Continued.

	Alewife - Female										Blueback herring - Female									
	TL					Weight					TL					Weight				
Year	N	Max	Min	Mean	STD	N	Max	Min	Mean	STD	N	Max	Min	Mean	STD	N	Max	Min	Mean	STD
1936	9	324	288	302.7	12.3	8	340	198	241.3	43.9	4	266	321	294.0	22.5	4	369	206	279.2	67.6
1975																				
1976											2	330	330	330.0	0.0					
1977																				
1978																				
1979																				
1980	1	315	315	315.0		1	318	318	318.0											
1981	1	292	292	292.0		1	222	222	222.0		1	289	289	289.0		1	228	228	227.6	
1982	1	310	310	310.0		1	275	275	275.0		2	300	286	292.8	10.2	2	253	213	232.6	28.1
1983																				
1984	1	264	264	264.0		1	222	222	222.0		12	300	251	274.8	15.7	12	327	145	212.3	50.5
1985	3	320	312	316.7	4.2	3	295	272	281.3	12.1	10	329	267	284.1	18.0	10	295	159	198.2	38.7
1986																				
1987	28	353	276	302.6	14.8	26	410	200	268.1	55.9	36	340	235	283.7	21.4	24	400	120	242.1	59.6
1988																				
1989											317	305	228	265.9	10.6	316	275	100	159.6	22.9
1990	7	327	255	284.7	22.8	7	310	180	218.6	54.9	283	314	228	263.5	16.5	279	280	88	163.7	37.3
1991	5	290	266	273.2	9.7	5	210	150	172.0	23.9	11	286	241	261.2	14.9	10	220	100	145.0	46.5
1992	24	306	240	273.6	19.7	24	290	120	186.3	47.9	147	324	228	271.3	21.3	128	380	100	182.6	52.5
1993	5	300	258	278.4	16.6	5	220	150	178.0	30.3	1	255	255	255.0		1	160	160	160.0	
1994																				
1995	1	274	274	274.0		1	200	200	200.0											
1996											1	290	290	290.0						
1997	8	310	262	280.5	15.4	8	240	140	185.0	31.6										
1998	6	292	251	266.2	13.7	6	240	160	173.3	32.7	7	286	236	254.9	16.3	7	220	120	151.4	36.7
1999	4	283	258	271.0	10.9	4	220	40	106.3	79.1	21	314	225	275.1	18.8	20	260	100	181.5	36.2
2000																				
2001	123	304	229	272.4	12.9						3	280	257	267.3	11.7					
2002																				
2003	139	310	172	272.0	18.3	85	280	100	161.4	40.3	3	283	252	268.7	15.6	2	120	120	120.0	0.0
2004											4	268	242	252.0	11.4					
2005	16	291	235	263.0	16.2	13	180	80	123.1	31.5	16	263	231	245.0	9.3	13	120	70	98.5	18.2
2006	10	283	239	255.3	12.6	8	280	80	155.6	60.8	1	245	245	245.0		1	160	160	160.0	
2007	5	273	240	257.8	12.2	5	180	120	148.0	22.8										
2008	55	305	225	264.5	18.3	55	380	120	208.4	53.2	8	260	227	245.8	10.4	8	200	120	148.8	24.7
2009	85	300	230	267.6	12.1	41	280	140	205.9	32.0	112	275	206	253.7	9.0	54	160	70	128.6	18.6
2010	87	325	237	271.0	18.4	73	300	110	193.3	45.0	50	276	215	250.3	11.5	44	210	100	144.6	25.1

Table 10.15 Continued.

	Alewife - All fish										Blueback herring - All fish									
	TL					Weight					TL					Weight				
Year	N	Max	Min	Mean	STD	N	Max	Min	Mean	STD	N	Max	Min	Mean	STD	N	Max	Min	Mean	STD
1936	17	324	270	293.4	14.3	14	340	184	228.0	37.4	8	266	321	296.5	16.0	8	369	206	261.9	50.0
1975											4	279	259	266.5	9.6	4	200	168	186.3	13.5
1976											3	330	279	313.0	29.4					
1977	2	308	281	294.7	19.3	2	280	200	240.3	56.6										
1978																				
1979	69	315	245	280.6	17.3	69	380	160	252.1	53.8	30	307	256	276.1	12.8	30	255	113	177.5	37.8
1980	4	315	280	299.0	14.8	4	318	198	258.2	49.4	1	276	276	276.0		1	194	194	194.0	
1981	5	293	272	284.2	10.7	5	222	175	201.1	22.2	2	289	284	286.5	3.5	2	228	194	210.8	23.8
1982	3	310	284	300.7	14.5	3	275	213	253.4	35.0	4	300	268	285.8	13.3	4	253	184	217.2	28.0
1983	1	277	277	277.0		1	211	211	211.0		3	278	239	257.0	19.7	3	208	151	188.8	32.8
1984	5	310	263	278.1	20.2	5	222	110	161.8	44.0	28	300	231	266.3	17.6	28	327	132	182.4	46.0
1985	19	320	246	290.0	23.0	19	295	122	232.0	53.3	21	329	245	277.2	18.8	21	295	136	184.8	36.3
1986																				
1987	54	353	266	291.4	17.0	48	410	160	244.8	53.6	59	340	235	278.3	20.2	36	400	120	234.4	57.5
1988																				
1989											633	305	219	261.0	11.0	632	275	75	147.8	23.0
1990	102	327	239	269.1	16.2	97	310	100	181.3	38.1	630	314	195	254.2	17.9	621	280	70	140.6	38.4
1991	22	290	234	266.9	14.8	21	210	100	153.3	30.6	17	286	225	256.0	16.1	16	220	100	138.8	40.5
1992	38	306	236	272.6	17.8	38	290	110	182.5	41.4	280	324	215	261.5	21.6	247	380	80	162.6	50.4
1993	37	303	233	270.8	16.5	22	220	100	163.0	26.5	17	313	213	277.1	26.2	2	160	130	145.0	21.2
1994																				
1995	2	274	252	263.0	15.6	2	200	140	170.0	42.4										
1996											1	290	290	290.0						
1997	10	310	230	276.1	21.3	10	240	120	180.0	35.3										
1998	39	292	237	257.5	11.0	39	240	120	149.5	23.7	35	286	219	245.2	13.6	35	220	87	127.5	27.0
1999	12	283	228	254.1	16.7	11	220	40	93.2	56.8	48	314	225	264.7	21.5	44	260	50	159.4	44.1
2000																				
2001	522	304	210	265.0	13.8						5	280	235	260.8	16.6					
2002																				
2003	414	310	172	266.0	16.0	260	280	50	152.9	39.3	7	283	240	260.3	15.7	6	180	100	126.7	27.3
2004											10	268	234	248.5	11.5	1	240	240	240.0	
2005	120	291	231	253.6	11.7	107	200	80	138.9	30.9	41	270	228	246.1	11.0	31	220	70	105.8	29.5
2006	27	310	220	247.3	17.8	21	320	80	140.0	61.1	3	256	245	250.0	5.6	3	160	120	140.0	20.0
2007	53	290	219	252.2	12.4	53	220	80	140.6	30.2										
2008	262	305	215	248.3	16.1	247	380	60	169.7	47.0	21	260	226	240.1	9.6	21	200	120	137.6	22.8
2009	565	300	214	257.5	11.7	281	280	80	169.9	31.6	223	275	197	248.8	12.5	111	200	60	118.5	29.6
2010	363	325	221	257.3	16.5	191	300	80	170.3	41.4	116	276	202	243.4	13.2	93	210	70	129.4	27.9

*fish 170 mm or greater; collected using electrofishing, herring haul seine, and beach seine gears

Table 10.16 Length frequency of Hudson River alewife collected using fishery independent gear (electrofishing, herring haul seine and beach seine).

Males																																				
TL	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
<100																																				
100-109																																				
110-119																																				
120-129																																				
130-139																																				
140-149																													1							
150-159																																				
160-169																																				
170-179																																				
180-189																																				
190-199																																				
200-209																																				
210-219																											3						1	1	2	
220-229																									1		6		2			1	2	18	6	4
230-239																1	1	1					1	1	2		11		9		13	8	2	62	25	36
240-249											1					13	3	1	1					9	1		31		37		18	6	13	60	77	69
250-259																16			4		1			11	2		78		48		41		18	39	186	80
260-269										1	1		2			14	6	2	4					9	1		142		69		20	1	10	16	127	50
270-279							1						14			24	3	4	5					3			100		71		3			4	32	26
280-289											1		7			18	3	4	1				1				23		27		1			2	4	6
290-299						1	1				1		2			3	1		2								4		1				1		1	1
300-309											2		1														1		1							
310-319											1																									
320-329																																				
330-339																																				
340-349																																				
350-359																																				
>360																																				
TOTAL	0	0	0	0	0	1	2	0	0	1	7	0	26	0	0	89	17	12	17	0	1	0	2	33	7	0	399	0	266	0	96	16	47	202	460	272

Table 10.16 Continued.

Females																																				
TL	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
<100																																				
100-109																																				
110-119																																				
120-129																																				
130-139																																				
140-149																																				
150-159																																				
160-169																																				
170-179																													1							
180-189																																				
190-199																																				
200-209																													1							
210-219																																				
220-229																											1							2		
230-239																											1		1		2	1		2	2	3
240-249																		4									2		6		1	2	1	9	2	8
250-259																1		2	1					1	1		13		20		4	4	2	8	17	11
260-269										1						1	2	4	1				1	4	1		32		27		3	2	1	11	26	16
270-279													2			1	2	2			1		4		1		37		33		5		1	11	28	22
280-289																2		7	2						1		27		34			1		8	6	14
290-299							1						10			1	1	2					2	1			7		7		1			2	3	7
300-309													8					3	1								3		8					2	1	4
310-319						1		1			2		6										1						1							1
320-329											1		1			1																				1
330-339																																				
340-349																																				
350-359													1																							
>360																																				
TOTAL	0	0	0	0	0	1	1	1	0	1	3	0	28	0	0	7	5	24	5	0	1	0	8	6	4	0	123	0	139	0	16	10	5	55	85	87

Table 10.16 Continued.

Combined sexes																																				
TL	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
<100																									1					1						
100-109																														3						1
110-119																									3					3						4
120-129																									2					2						1
130-139																														2						
140-149																													1							
150-159																												5								
160-169																																				
170-179																													1							
180-189																																				
190-199																																				
200-209																													1							
210-219																											3						1	1	2	
220-229																									1		7		2			1	2	20	6	4
230-239																1	1	1	1				1	1	2		12		11		15	9	2	65	27	40
240-249					2						2					14	3	5	3					9	2		33		44		21	8	14	71	80	77
250-259					5						1					18		2	5		1			12	3		91		69		50	4	21	47	211	91
260-269					10					3	1		2			15	8	6	6				1	13	2		174		98		23	3	11	28	162	68
270-279					10		2		1		1		16			26	5	7	11		1		4	3	1		137		108		9		1	15	62	49
280-289			1		16			1		1	3		7			21	3	12	5				1		1		50		62		1	1		11	10	20
290-299					16	1	3				2		12			6	2	2	4				2	1			11		8		1		1	2	4	8
300-309			1		6	1		1			4		9					3	2								4		9					2	1	4
310-319					4	1		1			4		6										1						1			1				1
320-329											1		1			1																				1
330-339																																				
340-349																																				
350-359													1																							
>360																																				
TOTAL	0	0	2	0	69	3	5	3	1	4	19	0	54	0	0	102	22	38	37	0	2	0	10	39	18	0	522	5	415	11	120	27	53	262	565	369

Table 10.17 Length frequency of Hudson River blueback herring collected using fishery independent gear (electrofishing, herring haul seine and beach seine).

Males																																				
TL	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
<100																																				
100-109																																				
110-119																																				
120-129																																				
130-139																																				
140-149																																				
150-159																																				
160-169																																				
170-179																																				
180-189																																				
190-199																1																			1	
200-209																1																			5	1
210-219															1	5		4						1											2	2
220-229															1	22	1	8							2						1			2	3	9
230-239										1					4	100	1	20						9	3		1			3	6			7	16	23
240-249										4	1		2		62	93		28	1					9	6				2	1	4	1		3	39	13
250-259										4	1		4		144	47	3	34						3	3					1	8	1		1	35	13
260-269								1		2	6		4		81	43	1	16						1	5		1		2	1	2				7	1
270-279										1			5		19	27		10						1	2											
280-289							1			4	1		5		4	6		2							3											
290-299													1					2																		
300-309											2																									
310-319																																				
320-329																																				
330-339																																				
340-349																																				
350-359																																				
>360																																				
TOTAL	0	0	0	0	0	0	1	1	0	16	11	0	21	0	316	345	6	124	1	0	0	0	0	24	24	0	2	0	4	6	21	2	0	13	108	62

Table 10.17 Continued.

Females																																				
TL	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
<100																																				
100-109																																				
110-119																																				
120-129																																				
130-139																																				
140-149																																				
150-159																																				
160-169																																				
170-179																																				
180-189																																				
190-199																																				
200-209																																			1	
210-219																																				1
220-229															1	2		2							1									1		
230-239													1			15		6						1							5			1	1	7
240-249															8	47	2	11						2						2	5	1		2	32	14
250-259										2			4		67	56	3	27	1					2	3		1		1	1	5			3	47	17
260-269										4	2		5		135	49	2	25						1	2		1			1	1			1	28	8
270-279										1	2		5		81	70	2	25							6				1						3	3
280-289							1	1		3	4		3		13	27	2	19						1	4		1		1							
290-299										1	1		9		8	14		17				1			4											
300-309								1		1			6		4	2		6																		
310-319													2			1		5							1											
320-329											1							4																		
330-339		2																																		
340-349													1																							
350-359																																				
>360																																				
TOTAL	0	2	0	0	0	0	1	2	0	12	10	0	36	0	317	283	11	147	1	0	0	1	0	7	21	0	3	0	3	4	16	1	0	8	112	50

Table 10.17 Continued.

Combined sexes																																				
TL	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
<100																	7	4											15	4		4				
100-109																	1													8						
110-119																10														13						1
120-129																48																				2
130-139																13																				
140-149																																				1
150-159																																				
160-169																																				
170-179																																				
180-189																																				
190-199																1																			1	
200-209																1																			6	1
210-219															1	5		4	1					1											2	3
220-229															2	24	1	10						1	3						1			3	4	9
230-239									1	1			1		4	115	1	26						10	3		1			3	13			8	17	31
240-249										4	1		2		70	140	2	40	1					12	6				2	3	9	2		5	71	29
250-259	2				2				1	6	1		8		211	103	6	64	2					5	6		1		1	2	13	1		4	84	31
260-269	1				9			1		6	8		9		216	92	3	43	3					3	7		2		2	2	4			1	35	9
270-279	1	1			10	1			1	2	2		11		100	98	2	36	1					1	8				1		1				3	3
280-289					4		2	1		7	5		8		17	34	2	23	2					1	10		1		1							
290-299					2					1	1		10		8	14		19	3			1			4											
300-309					3			1		1	2		7		4	2		6	3																	
310-319													2			1		5	1						1											
320-329											1							4																		
330-339		2																																		
340-349													1																							
350-359																																				
>360																																				
TOTAL	4	3	0	0	30	1	2	3	3	28	21	0	59	0	633	701	18	280	17	0	0	1	0	34	48	0	5	0	7	31	41	3	0	21	223	120

Table 10.18 Age structure and repeat spawn percent of alewife from spawning stock sampling in the Hudson River Estuary.

		Age											%
Year	Repeats	2	3	4	5	6	7	8	9	10	Total	% virgin	repeat
NYSDEC 1936 (Greeley 1937)													
Male													
1936		2	6	1	2						11		
Female													
1936			4	6	3						13		
NAI 1999-2001 (NAI 2008)													
Male													
1999	0		16	107	169	45	3				340		
	1			1	70	81	11				163		
	2				1	23	15	5			44		
	3						5	4			9		
	4							1			1		
	Total		16	108	240	149	34	10			557	61.0	39.0
2000	0		2	179	311	226	95	9	1		823		
	1				1	7	5	2			15		
	2						9	6	3		18		
	3										0		
	4									1	1		
	5									1	1		
	Total		2	179	312	233	109	17	4	2	858	95.9	4.1
2001	0	14	212	177	74	3					480		
	1			19	31	6					56		
	2					5	1	1			7		
	3										0		
	4						1				1		
	5							1			1		
	Total	14	212	196	105	14	2	2			545	88.1	11.9
Female													
1999	0		1	5	8	8	3				25		
	1				18	22	5	2			47		
	2					11	7	2			20		
	3						5	2			7		
	4							1			1		
	Total		1	5	26	41	20	7			100	25.0	75.0
2000	0			15	186	170	78	24	8	1	482		
	1				1	6	11	10	2		30		
	2					1	11	19	13	2	46		
	3						1	5	2	2	10		
	4								2		2		
	Total			15	187	177	101	58	27	5	570	84.6	15.4
2001	0				17	80	13				110		
	1				1	18	23	1	1		44		
	2					1	2	7			10		
	3							2	1	1	4		
	4								1		1		
	Total				18	99	38	10	3	1	169	65.1	34.9
Male													
2009	0										229		
	1	Not complete, age technique differences need resolving, see text.									65		
	2										12		
	Total										306	74.8	25.2
Female													
2009	0										70		
	1	Not complete, age technique differences need resolving, see text.									41		
	2										9		
	3										1		
	Total										121	57.85	42.15

Table10.19 Percent repeat spawners estimates of river herring caught during 1999 to 2001NAI (2008) spawning stock survey.

Year	Percent repeat		Percent repeat	
	Female	Male	Female	Male
	Alewife - Hudson River		Alewife - Hudson River tributaries	
1999	73.1	39.0	73.6	38.0
2000	16.0	3.5	15.9	4.3
2001	34.9	28.1	na	na
	Blueback Herring- Hudson River		Blueback Herring- Mohawk River	
1999	41.3	27.8	17.7	13.7
2000	22.8	9.2	3.5	4.5
2001	24.6	14.7	4.9	9.2

* Data from Table 10.5-2, Vol.1, NAI 2008

Table 10.20 Age structure and repeat spawn percent of blueback herring from spawning stock sampling in the Hudson River Estuary and the Mohawk River.

		Age													%	%	Mean
Year	Repeats	2	3	4	5	6	7	8	9	10	11	12	13	Total	virgin	repeat	age
NYSDEC 1936 (Greeley 1937)																	
Male																	
1936				1	2	1								4			5.00
Female																	
1936			4	15	13	4								36			4.47
NYSDEC 1989-1990*																	
Male																	
1989	0		43	122	22									187			
	1		1	42	40									83			
	2				12	5	1							18			
	Total		44	164	74	5	1							288	64.9	35.1	4.1
1990	0	8	143	72	12									235			
	1			28	17	1								46			
	2				12	6								18			
	Total	8	143	100	41	7								299	78.6	21.4	3.7
Female																	
1989	0		31	160	33									224			
	1			22	41	3								66			
	2				3	4								7			
	Total		31	182	77	7	0							297	75.4	24.6	4.2
1990	0		6	86	93	14	1							200			
	1				9	34	1							44			
	2					4	6							10			
	Total		6	86	102	52	8							254	78.7	21.3	4.9
NAI 1999-2001 (NAI 2008)																	
Male																	
1999	0	23	143	261	189	69	7	3						695			
	1			24	45	33	5	2						109			
	2				16	24	15	1						56			
	3					5	13	3	1					22			
	4							2						2			
	Total	23	143	285	250	131	40	11	1					884	78.6	21.4	4.6
2000	0		57	351	234	84	13	1						740			
	1			3	18	8	5	1						35			
	2				1	2	6	1						10			
	3						2	1	1					4			
	4							1						1			
	Total	0	57	354	253	94	26	5	1					790	93.7	6.3	4.6
2001	0		15	169	163	72	9	1						429			
	1				13	24	10	1						48			
	2					1	4	3						8			
	3							1						1			
	Total	0	15	169	176	97	23	6						486	88.3	11.7	4.9
Female																	
1999	0	1	39	207	248	127	26	4						652			
	1			16	45	38	12	1						112			
	2				19	19	16	2						56			
	3					5	8	8	1					22			
	4						1	1	2					4			
	Total	1	39	223	312	189	63	16	3					846	77.1	22.9	5.1
2000	0		21	230	319	167	28	1		1				767			
	1			1	16	18	17	12						64			
	2				1	10	3	7	3	1				25			
	3					2		7	10	4		1		24			
	4							1	3	1				5			
	5								1			1		2			
	6									1				1			
	Total	0	21	231	336	197	48	28	17	8	0	2	0	888	86.4	13.6	5.3
2001	0		4	66	130	158	22	5						385			
	1				4	16	20	4	1					45			
	2				1	2	2	2	1					8			
	3							1	2					3			
	4													0			
	5													0			
	6												1	1			
	Total	0	4	66	135	176	44	12	4	0	0	0	1	442	87.1	12.9	5.6
Male																	
2009	0														38		
	1	Not complete, age technique differences need resolving, see text.													24		
	2														2		
	Total														64	59.4	40.6
Female																	
2009	0														44		
	1	Not complete, age technique differences need resolving, see text.													12		
	2														3		
	Total														59	74.8	25.2

Table 10.21 Age structure of Hudson River spawning alewife estimated from length age keys from ME, MA and MD.

Year	Estimated age									Total	Mean age
	2	3	4	5	6	7	8	9	10		
					Male - ME						
1990	0.1	18.1	49.5	18.9	2.3	0.1				89	4.06
2001	0.6	84.3	241.2	64.2	5.7	0.1				396	3.98
2002											
2003	0.3	61.5	153.5	45.3	4.4	0.1				265	3.97
2004											
2005	0.3	36.3	52.6	6.5	0.3	0.0				96	3.69
2006											
2007	0.1	17.9	24.7	3.1	0.2	0.0				46	3.68
2008	0.3	116.1	76.0	8.2	0.3	0.0				201	3.46
2009	1.3	146.8	267.9	39.9	2.0	0.0				458	3.77
2010	0.6	105.9	140.8	23.2	1.5	0.0				272	3.70
					Female - ME						
1990											
2001		13.3	79.7	25.7	3.0	0.3				122	4.16
2002											
2003		16.8	86.0	29.4	4.4	0.5				137	4.17
2004											
2005											
2006											
2007											
2008		10.6	31.9	9.3	1.1	0.1				53	4.02
2009		12.0	57.8	14.1	1.0	0.2				85	4.05
2010		13.5	52.3	18.2	2.6	0.4				87	4.13
					Male - MA						
1990		14.5	45.1	23.9	5.2	0.3				89	4.23
2001	0.6	73.1	221.5	88.1	15.2	0.6				399	4.12
2002											
2003	0.1	51.2	142.3	59.9	11.0	0.5				265	4.12
2004											
2005		31.5	51.4	11.6	1.4	0.0				96	3.82
2006											
2007	0.2	16.2	24.2	5.5	0.8	0.0				47	3.80
2008	0.6	99.7	84.9	14.9	1.8	0.0				202	3.59
2009	0.5	128.3	256.5	66.2	8.5	0.2				460	3.90
2010	0.1	91.2	139.0	36.3	5.2	0.1				272	3.84
					Female - MA						
1990											
2001	0.0	11.4	62.9	39.3	8.4	0.9	0.0			123	4.39
2002											
2003	0.0	13.5	66.3	43.7	11.6	1.8	0.0			137	4.43
2004											
2005											
2006											
2007											
2008	0.0	10.2	28.0	13.3	3.0	0.4	0.0			55	4.19
2009	0.0	10.8	48.1	21.8	3.8	0.3	0.0			85	4.23
2010	0.1	11.2	41.6	25.1	7.3	1.3	0.4			87	4.39
					Male - MD						
1990		8.7	31.8	30.9	14.8	2.5	0.2			89	4.67
2001		43.5	164.8	139.6	45.5	5.3	0.4			399	4.51
2002											
2003		31.4	106.6	89.8	33.0	3.8	0.3			265	4.52
2004											
2005		21.8	49.4	20.7	3.9	0.2	0.0			96	4.08
2006											
2007		11.5	23.9	9.4	1.8	0.4	0.0			47	4.06
2008		80.1	90.5	26.6	4.3	0.4	0.0			202	3.78
2009		83.5	233.5	116.5	24.5	1.8	0.1			460	4.19
2010		65.0	129.9	60.8	14.6	1.5	0.1			272	4.11
					Female - MD						
1990											
2001		4.9	48.8	47.8	17.6	3.5	0.5	0.0		123	4.74
2002											
2003		6.7	52.0	49.4	21.9	5.8	1.2	0.1		137	4.80
2004											
2005											
2006											
2007											
2008		6.9	23.5	17.1	5.8	1.4	0.2	0.0		55	4.49
2009		5.1	41.9	29.0	7.5	1.2	0.2	0.0		85	4.51
2010		6.7	34.0	28.4	12.6	3.9	1.2	0.2		87	4.74

Table 10.22 Age structure of Hudson River spawning blueback herring estimated from length age keys from MA and MD.

	Estimated age										
Year	2	3	4	5	6	7	8	9	10	Total	Mean age
					Male - MA						
1989	0.2	32.6	147.1	101.3	28.4	4.7	1.7			316	4.46
1990	1.9	102.6	147.7	66.0	20.4	5.4	0.9			345	4.06
1991											
1992	0.8	29.5	52.5	28.6	8.2	2.0	0.3			122	4.18
2009	2.8	28.3	51.5	21.7	3.2	0.3	0.1			108	3.96
2010	0.9	25.1	26.8	8.2	0.9	0.1	0.0			62	3.74
					Female - MA						
1989		10.4	125.5	149.0	24.1	6.9	0.7	0.4		317	4.67
1990		29.9	111.5	110.5	22.3	7.7	0.4	0.7		283	4.54
1991											
1992		10.7	51.6	54.8	14.0	7.8	1.1	7.0		147	4.92
2009		14.3	62.8	29.7	3.9	0.2				111	4.22
2010		10.7	26.1	11.6	1.5	0.1				50	4.09
					Male - MD						
1989		31.3	148.6	103.5	28.2	3.8	0.4	0.1		316	4.45
1990		98.7	152.3	65.8	21.9	3.7	0.5	0.1		343	4.07
1991											
1992		27.2	56.2	28.5	9.4	2.3	0.4	0.1		124	4.23
2009		24.8	53.2	20.6	3.1	0.2	0.0	0.0		102	4.03
2010		22.7	29.8	7.5	0.9	0.1	0.0	0.0		61	3.78
					Female - MD						
1989		14.2	165.6	100.2	29.9	6.2	0.9	0.1		317	4.53
1990		25.3	135.8	84.0	29.7	7.0	1.0	0.1		283	4.51
1991											
1992		9.2	55.9	41.8	23.5	10.5	4.2	1.6	0.3	147	4.94
2009		15.0	72.9	19.0	3.4	0.8	0.0			111	4.12
2010		8.0	31.1	9.4	1.3	0.3	0.0			50	4.10

Table 10.23 NYSDEC young of the year indices for alewife collected in the Hudson River Estuary. FSS and BSS are Hudson River Generating company survey indices.

Year	Number of hauls	Number of zero hauls	Number collected	UCI	LCI	Geometric Mean	Arithmetic Mean	Arith. Mean SE	FSS	FSS-SE	BSS	BSS-SE
1974											2.92	0.44
1975											2.47	0.40
1976											2.40	0.63
1977											4.18	0.61
1978											5.49	0.97
1979									0.20	0.08	1.35	0.23
1980	20	17	11	0.60	0.00	0.25	0.55	0.32	0.69	0.35	0.50	0.16
1981	21	19	16	0.63	0.00	0.23	0.76	0.53	0.63	0.21	4.15	0.94
1982	23	15	39	1.28	0.14	0.61	1.70	0.83	0.28	0.08	0.79	0.24
1983	125	101	146	0.54	0.19	0.35	1.17	0.34	0.19	0.07	1.79	0.27
1984	124	118	9	0.08	0.01	0.04	0.07	0.04	0.21	0.13	0.49	0.14
1985	177	127	463	0.83	0.40	0.60	2.62	0.78	0.93	0.41	0.74	0.17
1986	185	156	94	0.29	0.12	0.20	0.51	0.15	0.26	0.08	0.83	0.51
1987	95	76	121	0.53	0.15	0.33	1.27	0.56	0.52	0.27	0.65	0.12
1988	190	156	232	0.46	0.19	0.32	1.22	0.35	0.27	0.13	0.42	0.09
1989	212	184	74	0.23	0.10	0.16	0.35	0.08	0.23	0.07	0.16	0.04
1990	202	146	544	0.78	0.39	0.57	2.69	0.84	0.35	0.14	1.05	0.17
1991	240	162	2651	1.41	0.72	1.04	11.05	4.20	0.33	0.12	3.47	0.57
1992	245	199	175	0.37	0.18	0.27	0.71	0.16	0.17	0.08	0.30	0.12
1993	205	155	354	0.62	0.30	0.45	1.73	0.45	0.23	0.08	0.54	0.16
1994	217	151	768	0.97	0.51	0.72	3.54	1.05	0.12	0.06	1.40	0.34
1995	238	189	425	0.60	0.29	0.44	1.79	0.42	0.11	0.03	1.14	0.35
1996	187	149	606	0.57	0.23	0.39	3.24	1.71	0.49	0.15	0.10	0.04
1997	210	164	450	0.66	0.31	0.48	2.14	0.61	0.32	0.10	2.26	0.44
1998	219	194	88	0.23	0.09	0.15	0.40	0.12	0.03	0.02	0.21	0.15
1999	239	109	6151	3.88	2.19	2.94	25.74	6.70	0.70	0.17	4.53	1.07
2000	241	182	1182	0.94	0.46	0.68	4.90	1.32	0.20	0.08	0.60	0.32
2001	227	120	2801	2.77	1.56	2.11	12.34	2.43	0.87	0.72	2.73	0.78
2002	219	146	2092	1.50	0.76	1.10	9.55	3.15	0.02	0.01	0.58	0.10
2003	244	166	791	0.97	0.54	0.74	3.24	0.89	0.29	0.12	3.39	0.90
2004	229	167	410	0.66	0.35	0.50	1.79	0.49	0.10	0.04	1.27	0.36
2005	234	136	2388	1.89	1.04	1.43	10.21	2.59	0.34	0.09	5.29	1.23
2006	211	159	925	0.77	0.37	0.55	4.38	2.20	0.04	0.02	0.80	0.44
2007	221	81	7202	5.96	3.38	4.52	32.59	6.42	1.87	1.14	6.69	2.00
2008	203	99	3226	3.05	1.66	2.28	15.89	4.03	0.80	0.54	3.89	1.00
2009	232	185	439	0.62	0.30	0.45	1.89	0.41	0.04	0.03	1.37	0.47
2010	238	112	5177	3.86	2.17	2.92	21.75	4.35				

Table 10.24 NYSDEC young of the year indices for blueback herring collected in the Hudson River Estuary. FSS and BSS are Hudson River Generating company survey indices.

Year	Number of hauls	Number collected	Number of zero hauls	UCI	LCI	Geometric Mean	Arithmetic Mean	Arith. Mean SE	FSS	FSS-SE	BSS	BSS-SE
1974											23.51	3.39
1975											69.66	9.49
1976											155.55	23.84
1977											219.37	26.38
1978											229.19	44.49
1979									3.70	0.75	54.45	8.32
1980	20	4	1042	29.01	4.65	12.02	52.10	19.69	2.61	0.75	100.84	53.80
1981	21	9	4051	22.60	1.83	7.18	192.90	149.19	21.20	5.86	181.93	72.90
1982	23	6	2040	31.17	4.30	12.06	88.70	36.03	10.33	2.06	121.72	31.43
1983	125	13	19865	55.87	27.62	39.34	158.92	24.54	6.08	1.07	190.86	41.85
1984	124	33	10395	16.60	7.54	11.26	83.83	22.46	20.39	3.67	22.66	5.41
1985	177	37	42351	30.42	14.95	21.39	239.27	72.54	17.42	4.58	18.82	3.90
1986	185	31	21769	23.18	12.56	17.11	117.67	27.62	6.48	1.38	14.10	4.41
1987	95	12	15646	53.11	23.20	35.19	164.69	33.31	25.61	12.36	69.80	15.69
1988	190	19	51845	61.28	33.16	45.13	272.87	69.76	26.69	4.30	47.41	14.02
1989	212	46	29577	23.35	12.36	17.04	139.51	24.42	16.83	5.41	35.88	8.09
1990	202	32	87146	63.21	31.01	44.33	431.42	73.43	29.69	10.64	97.85	13.97
1991	240	44	77748	33.25	17.61	24.25	323.95	78.58	12.65	4.47	47.44	11.06
1992	245	56	51507	18.76	10.32	13.95	210.23	55.49	15.52	3.87	31.10	6.53
1993	205	35	35054	40.06	21.33	29.28	171.00	22.80	7.72	1.59	35.28	5.52
1994	217	51	81399	39.22	19.16	27.47	375.11	64.13	5.77	1.90	88.84	13.78
1995	238	81	18979	8.96	4.90	6.67	79.74	21.06	1.27	0.42	38.18	23.30
1996	187	25	24168	28.63	15.92	21.39	129.24	26.41	50.16	15.89	36.71	17.55
1997	210	56	27028	21.62	11.18	15.60	128.70	21.53	7.30	1.43	162.11	35.44
1998	219	141	2705	1.99	1.02	1.45	12.35	2.83	0.03	0.03	1.28	0.31
1999	239	35	69957	46.53	25.64	34.58	292.71	68.45	2.07	0.78	58.67	17.79
2000	241	53	15850	14.03	8.25	10.79	65.77	11.92	2.68	1.16	25.98	14.98
2001	227	23	81578	59.63	32.16	43.84	359.37	78.83	5.85	5.00	57.61	11.40
2002	219	117	8390	3.98	2.04	2.89	38.31	9.96	0.80	0.55	12.63	5.77
2003	244	68	28769	23.17	12.55	17.10	117.91	13.57	5.92	1.89	119.20	27.39
2004	229	84	18830	10.27	5.43	7.52	82.23	17.72	1.52	0.35	49.56	11.71
2005	234	45	41731	36.34	19.70	26.80	178.34	23.83	2.33	1.05	65.86	20.09
2006	211	98	4661	3.39	1.87	2.55	22.09	6.45	0.53	0.15	8.28	3.44
2007	221	32	42230	43.93	23.77	32.36	191.09	23.27	5.24	0.91	71.60	9.05
2008	203	45	35679	23.28	12.39	17.03	175.76	70.19	5.56	1.35	39.99	8.85
2009	232	114	5466	3.74	2.04	2.80	23.56	4.39	0.87	0.25	3.88	1.14
2010	238	56	35725	20.86	11.13	15.29	150.11	24.07				

Table 10.25 Annual estimates of alewife and blueback herring American shad conditional entrainment and impingement mortality rates from water withdrawals* at power generating and other cooling systems on the Hudson River. (CHGE et al. 1999)

	Alewife			Blueback herring		
Year	Entrainment	Impingement	Total	Entrainment	Impingement	Total
1974	27.19	1.44	28.63	27.19	0.36	27.55
1975	40.67	1.44	42.11	40.67	0.36	41.03
1976	31.10	1.44	32.54	31.10	0.36	31.46
1977	32.99	1.44	34.43	32.99	0.36	33.35
1978	27.50	1.44	28.94	27.50	0.36	27.86
1979	27.42	1.44	28.86	27.42	0.36	27.78
1980	24.71	1.44	26.15	24.71	0.36	25.07
1981	11.98	1.44	13.42	11.98	0.36	12.34
1982	9.74	1.44	11.18	9.74	0.36	10.10
1983	21.22	1.44	22.66	21.22	0.36	21.58
1984	24.80	1.44	26.24	24.80	0.36	25.16
1985	14.68	1.59	16.27	14.68	0.40	15.08
1986	10.09	1.89	11.98	10.09	0.70	10.79
1987	32.36	1.40	33.76	32.36	0.30	32.66
1988	24.12	1.10	25.22	24.12	0.20	24.32
1989	32.67	1.20	33.87	32.67	0.20	32.87
1990	29.65	1.44	31.09	29.65	0.36	30.01
1991	21.63	1.44	23.07	21.63	0.36	21.99
1992	39.45	1.44	40.89	39.45	0.36	39.81
1993	11.24	1.44	12.68	11.24	0.36	11.60
1994	17.03	1.44	18.47	17.03	0.36	17.39
1995	14.34	1.44	15.78	14.34	0.36	14.70
1996	7.69	1.44	9.13	7.69	0.36	8.05
1997	22.36	1.44	23.80	22.36	0.36	22.72

*For Bowline Point, Indian Point, Roseton, Danskammer, Lovett, Empire State Plaza, Albany Steam Station, Westchester Resco

Table 10.26 Trends in fishery dependent and fishery independent sampling data for river herring in the Hudson River Estuary. **Bolded value = significant trend**

Source data		Year Range	DOF	Slope	R-Square	P	Trend over year range
Fishery dependent							
	CPUE - fixed gill net below BMB	2000-2010	11	0.01	0.29	0.090	Increasing
	CPUE - drift gill net	2000-2010	11	0.01	0.16	0.217	Increasing
	CPUE - fixed gill net	2000-2010	11	0.01	0.27	0.098	Increasing
	CPUE - scap/lift net	2003-2010	8	0.02	0.20	0.270	No trend
	Mean TL - alewife - all	**2001-2010**	**5**	**-2.12**	**0.84**	**0.030**	**Decreasing**
	Mean Wt - alewife - all		4	-2.50	0.81	0.099	Decreasing
	Mean TL - blueback herring- all	2002-2010	4	-1.01	0.87	0.066	Decreasing
	Mean Wt - blueback herring- all		3	-3.27	0.73	0.345	Decreasing
Fishery independent- Adult alewife - annual n > 34							
	Mean TL - male	**1990-2010**	**8**	**-0.94**	**0.62**	**0.021**	**Decreasing**
	Mean TL - female	2001-2010	5	-0.50	0.35	0.290	Decreasing
	Mean Wt - male	1990-2010	7	-1.13	0.37	0.150	Decreasing
	Mean Wt - female	2003-2010	4	5.86	0.71	0.157	Increasing
Fishery independent- Adult blueback herring - annual n > 34							
	Mean TL - male	1989-2010	5	-0.53	0.69	0.082	Decreasing
	Mean TL - female	**1987-2010**	**6**	**-0.99**	**0.73**	**0.029**	**Decreasing**
	Mean Wt - male	1989-2010	5	-1.01	0.64	0.102	Decreasing
	Mean Wt - female	1989-2010	5	-1.55	0.64	0.101	Decreasing
Fishery independent- Mean age - Alewife Male							
	Estimated mean age ME	1990-2010	8	**-0.02**	**0.58**	**0.027**	**Decreasing**
	Estimated mean age MA			**-0.03**	**0.61**	**0.021**	**Decreasing**
	Estimated mean age MD			**-0.04**	**0.63**	**0.019**	**Decreasing**
	Estimated mean age ME	2001-2010	7	-0.04	0.50	0.076	Decreasing
	Estimated mean age MA			-0.04	0.50	0.074	Decreasing
	Estimated mean age MD			0.06	0.52	0.067	Decreasing
Fishery independent- Mean age - Alewife Female							
	Estimated mean age ME	2001-2010	5	-0.01	0.44	0.225	Decreasing
	Estimated mean age MA			-0.01	0.29	0.353	Decreasing
	Estimated mean age MD			-0.02	0.30	0.336	Decreasing
Fishery independent- Mean age - Blueback herring Male							
	Estimated mean age MA			-0.02	0.67	0.089	Decreasing
	Estimated mean age MD			-0.03	0.76	0.053	Decreasing
Fishery independent- Mean age - Blueback herring Female							
	Estimated mean age MA			-0.02	0.62	0.109	Decreasing
	Estimated mean age MD			-0.03	0.67	0.090	Decreasing
Fishery independent- young of the year alewife							
	NYSDEC geometric mean	1980-2010		**0.06**	**0.33**	**0.001**	**Increasing**
		1992-2010		**0.08**	**0.25**	**0.028**	**Increasing**
	HRG Beach seine survey	1974-2009		0.01	0.01	0.656	No trend
		1992-2009		**0.19**	**0.26**	**0.032**	**Increasing**
	HRG Fall shoals survey	1979-2009		0.00	0.01	0.647	No trend
		1992-2009		0.03	0.09	0.222	No trend
Fishery independent- young of the year blueback herring							
	NYSDEC geometric mean	1980-2010		-0.26	0.03	0.336	Slight decrease
		1992-2010		-0.34	0.02	0.528	Slight decrease
	HRG Beach seine survey	1974-2009		**-2.63**	**0.20**	**0.006**	**Decreasing**
		1992-2009		-1.02	0.017	0.602	Slight decrease
	HRG Fall shoals survey	1979-2009		**-0.46**	**0.14**	**0.041**	**Decreasing**
		1992-2009		-0.76	0.13	0.148	Slight decrease

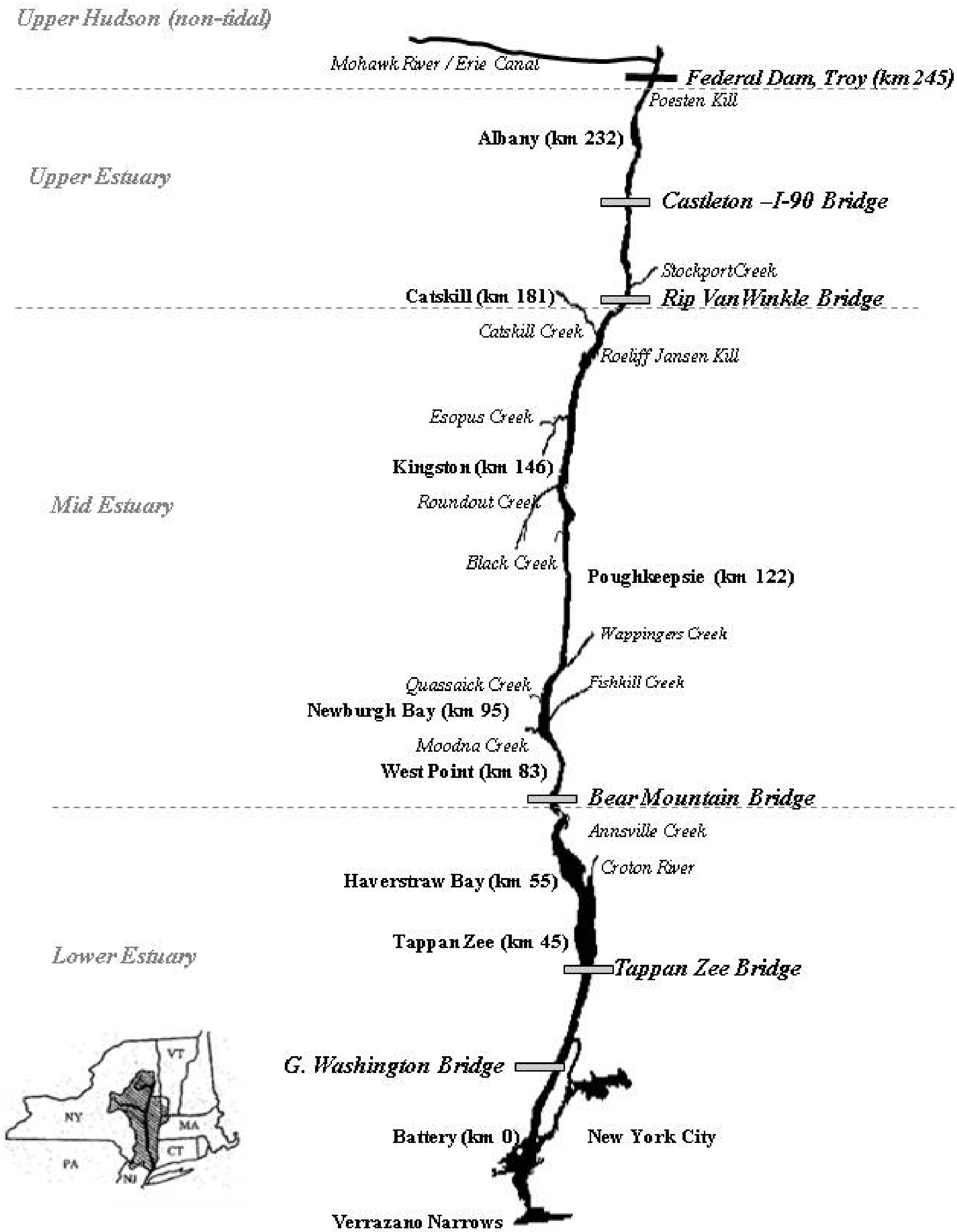


Figure10.1 Hudson River Estuary, New York, with major river herring spawning tributaries (see Appendix Table A for list of streams.

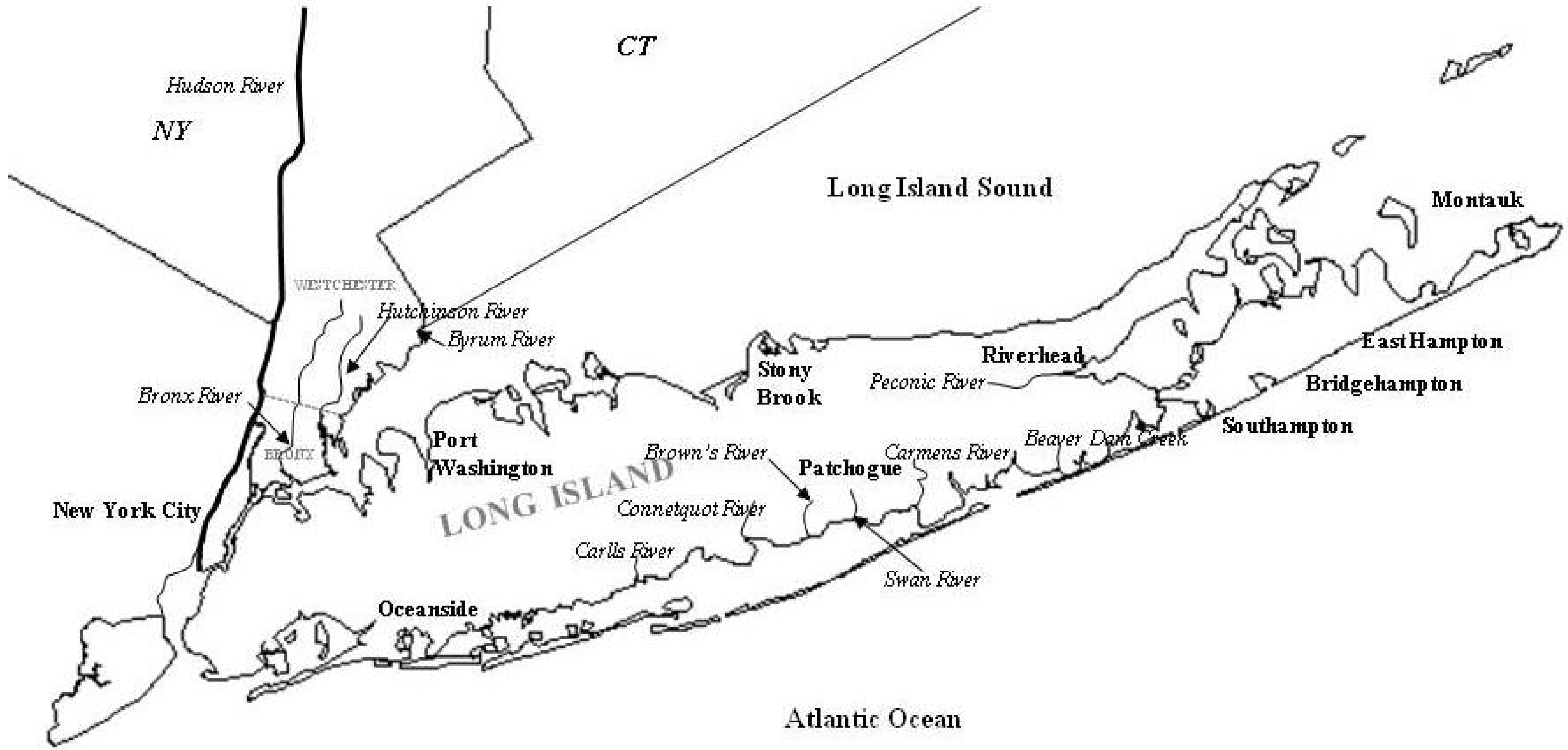


Figure 10.2 Major streams on Long Island, Bronx and Westchester County; some with identified river herring spawning runs. (See Appendix Table A for list of streams.

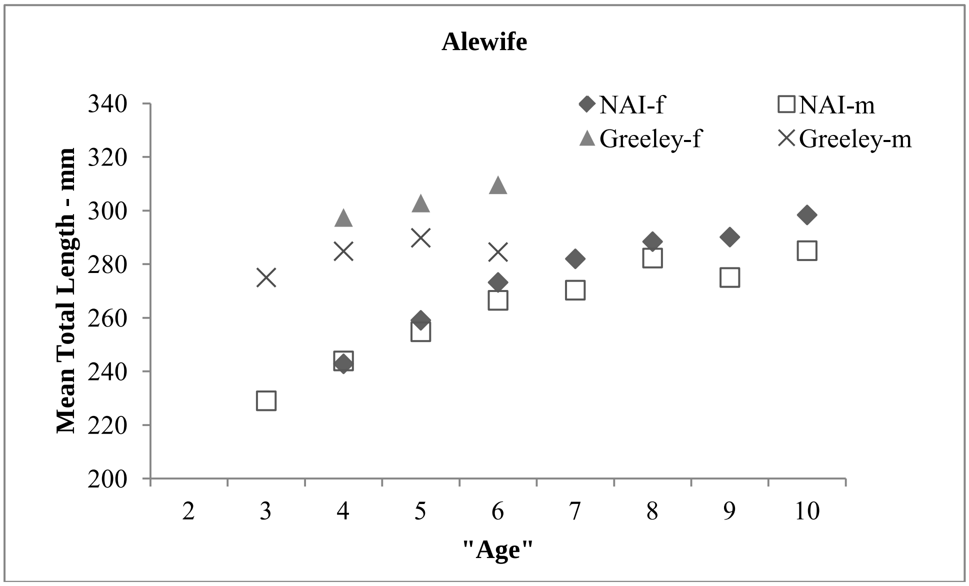


Figure 10.3 Mean length at “age” for alewife in the Hudson River Estuary, NY. “Age” data are uncertain, see text.

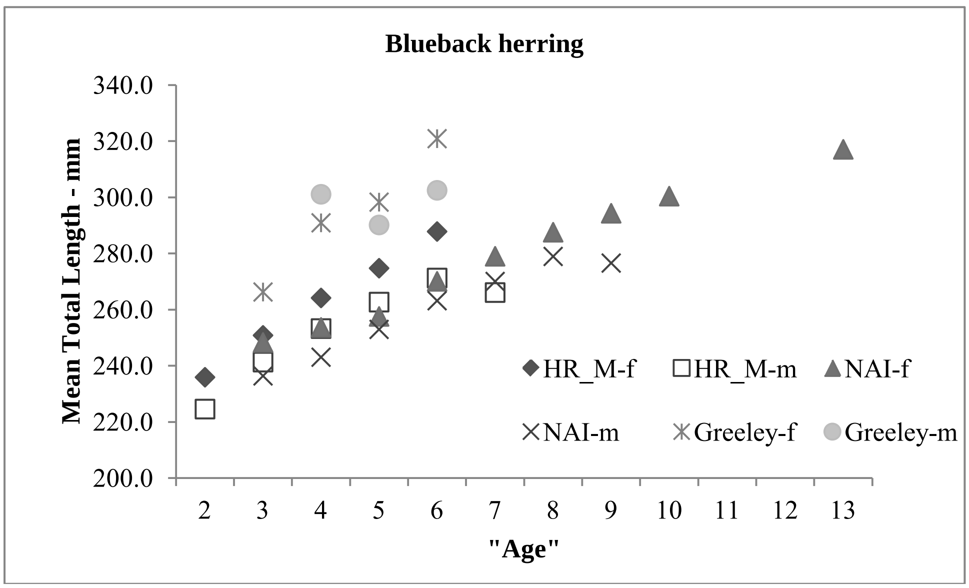


Figure 10.4 Mean length at “age” for blueback herring in the Hudson River Estuary, NY. “Age” data are uncertain, see text.

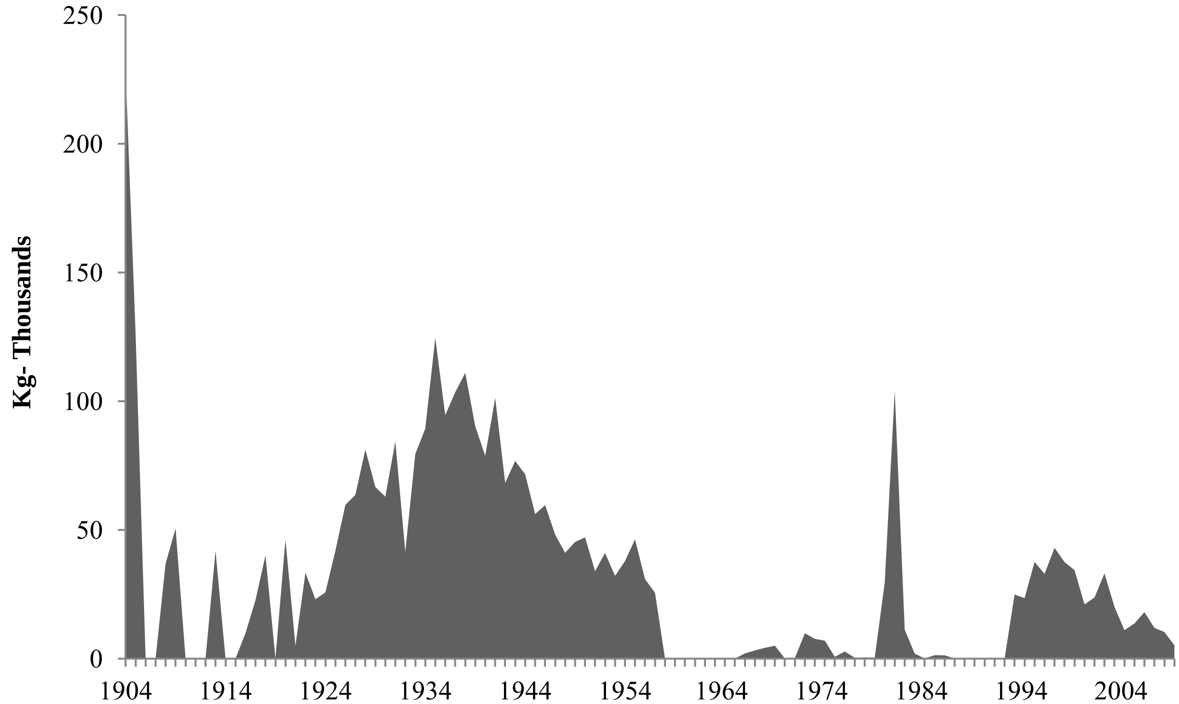


Figure 10.5. Historic commercial fishery landings of New York river herring, 1904-2010. (1966 data point not included - see text).

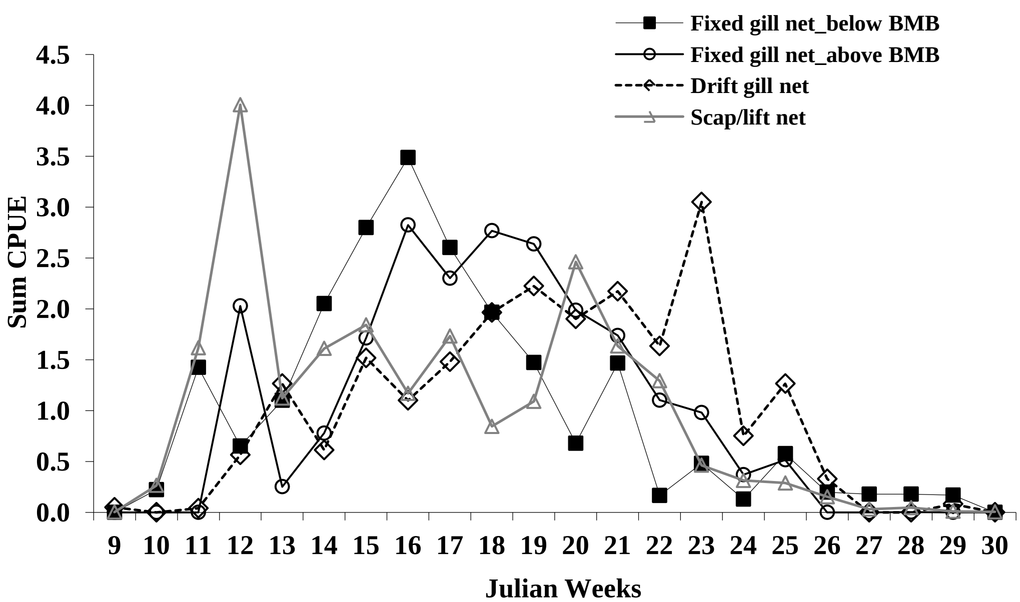


Figure 10.6 Overall trend in weekly CPUE of the various gear types, based on 1995 through 2010 data, to illustrate timing of the targeted spring river herring fishery in the Hudson River.

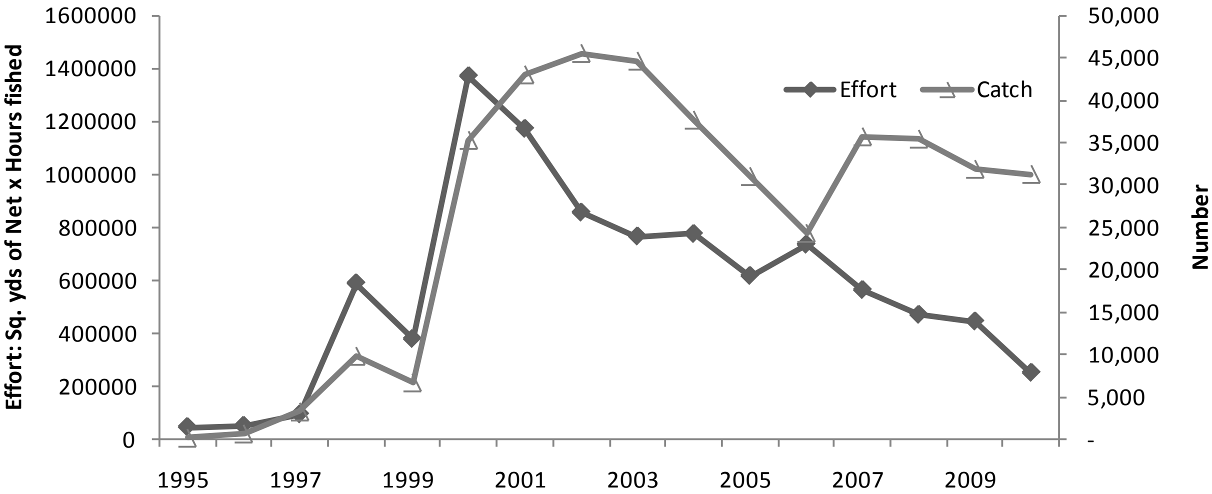


Figure 10.7 Total effort and catch of in the Hudson River commercial river herring fishery, summarized from mandatory reports.

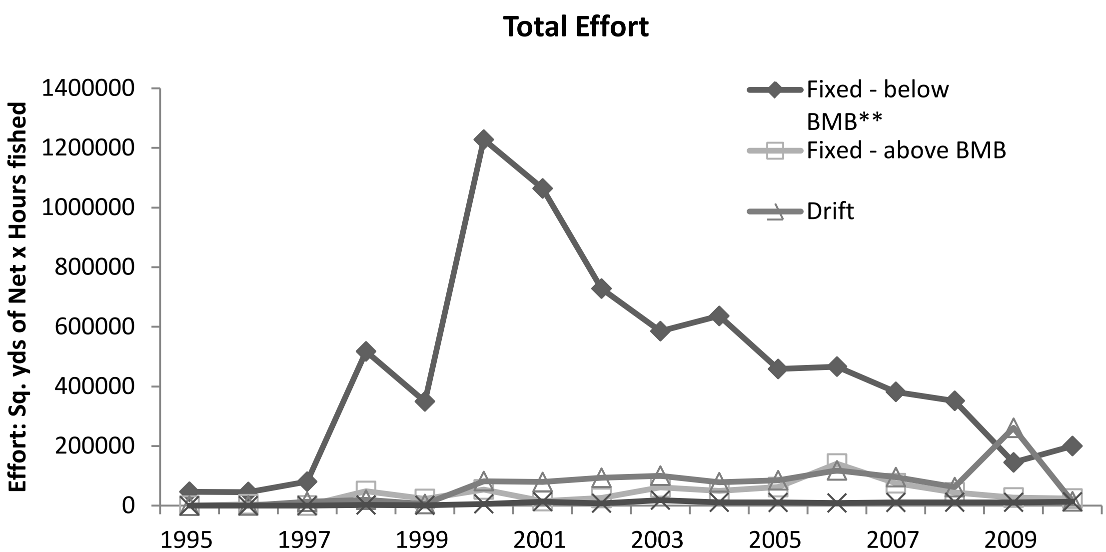


Figure 10.8 Total effort (square yards of net x hours fished), by gear, expended in the Hudson River commercial fishery for river herring.

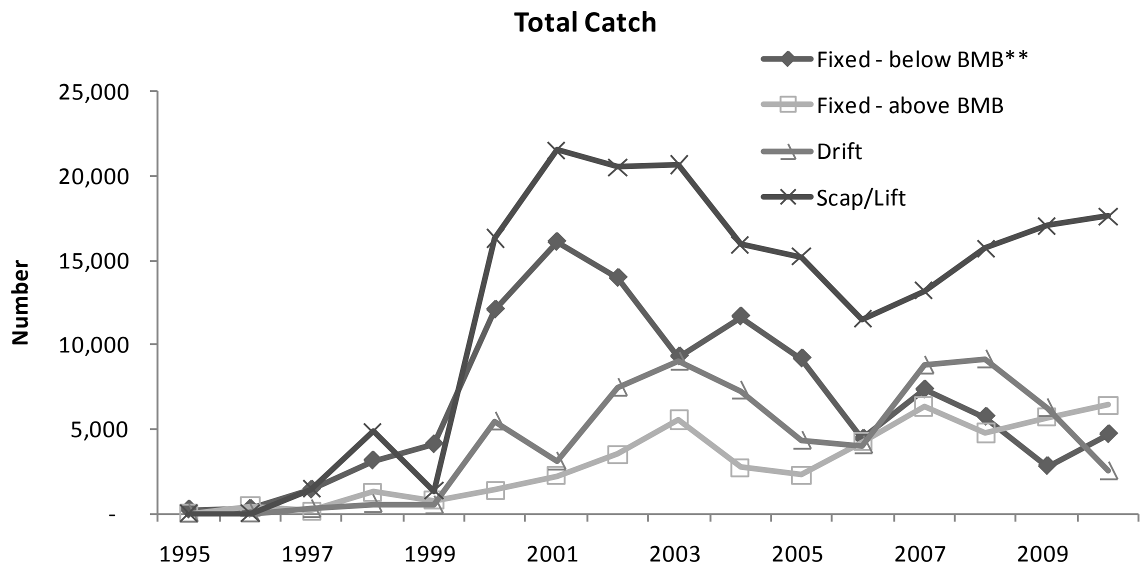


Figure 10.9 Total catch, by gear, of river herring in the Hudson River commercial fishery.

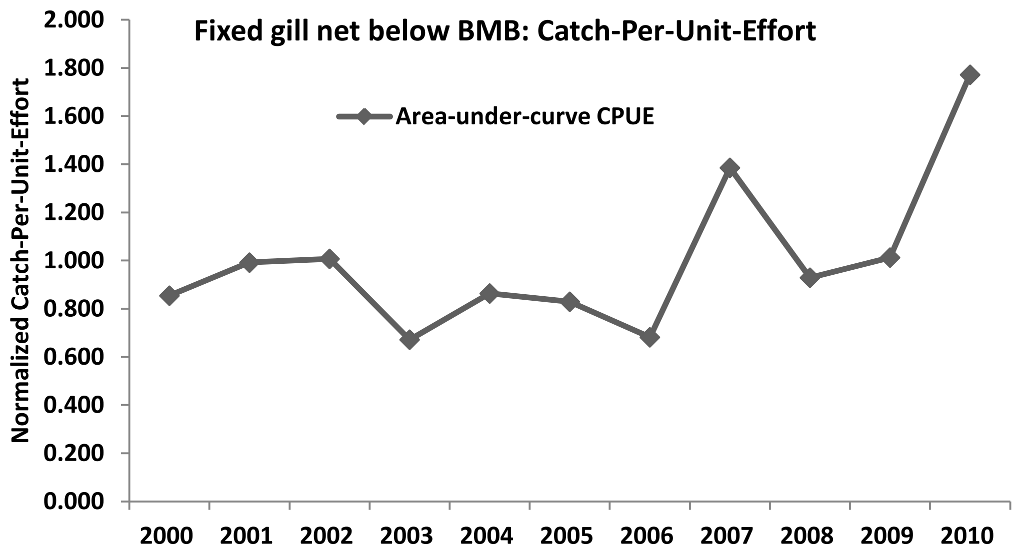


Figure 10.10 Catch-per-unit-effort calculated as weekly sum of CPUE (area under curve) for fixed gill nets below the Bear Mountain Bridge.

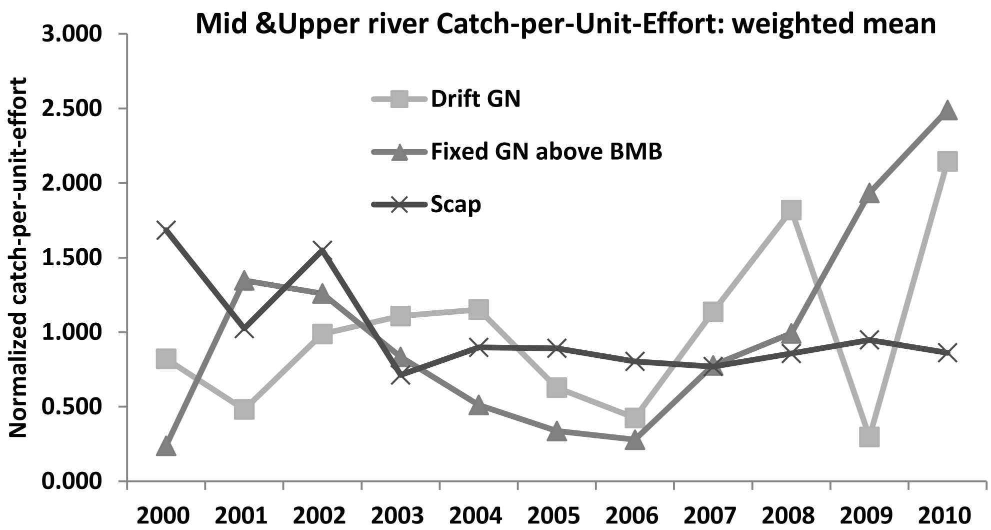


Figure 10.11 Catch-per-unit-effort calculated as total catch/total effort for fixed gill nets above the Bear Mountain Bridge, drift gill nets and scap nets.

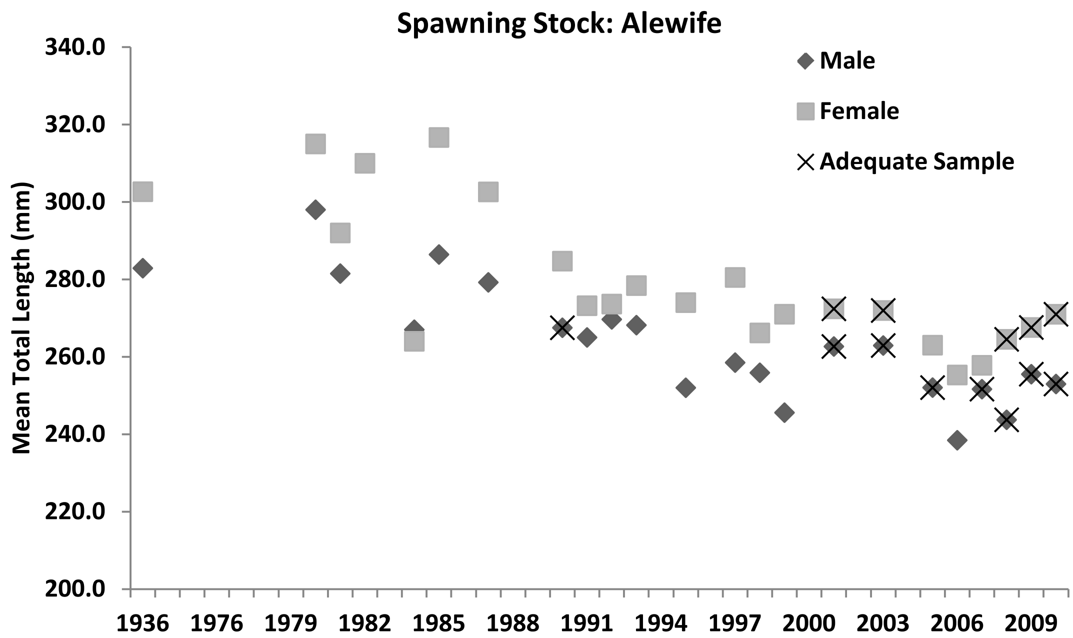


Figure 10.12 Mean total length of adult (>170mm) alewife collected in electrofishing, beach seine, and herring seine gears in the Hudson River Estuary.

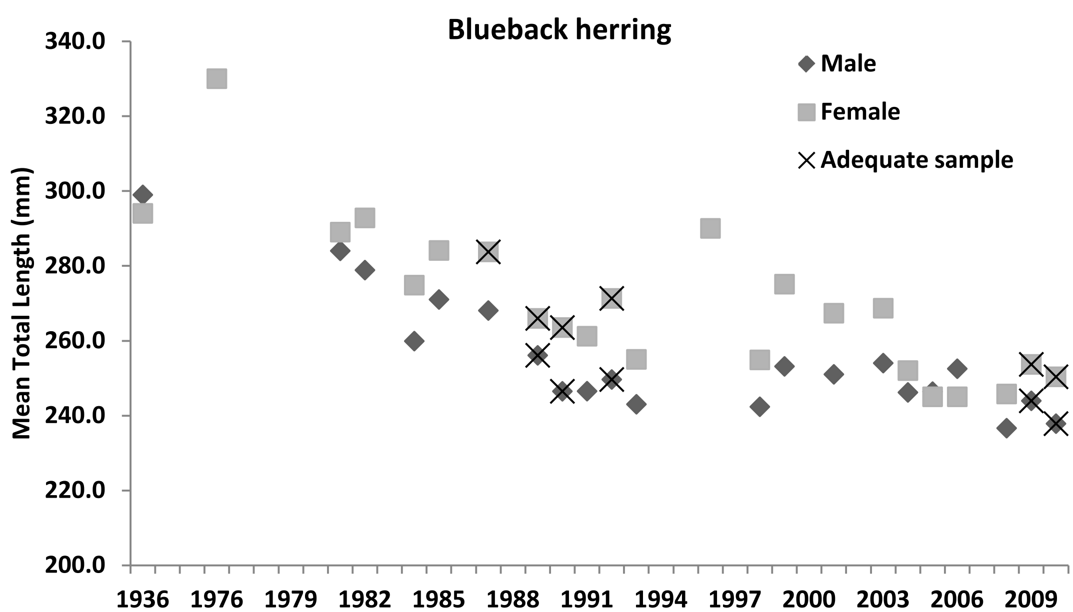


Figure 10.13 Mean total length of adult (>170mm) blueback herring collected in electrofishing, beach seine, and herring seine gears in the Hudson River Estuary.

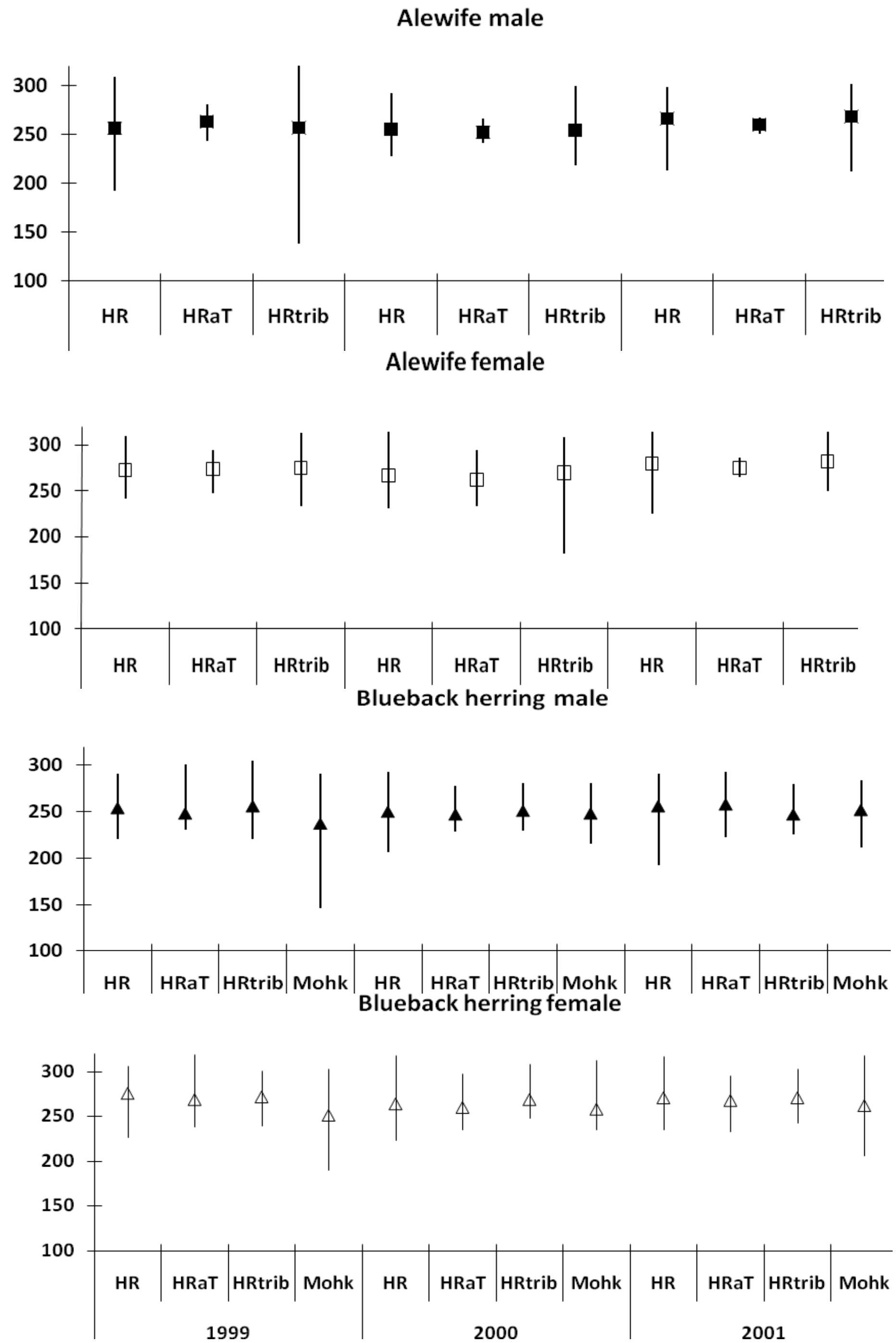


Figure 10.14 Mean total length of river herring (with min-max lines) collected during the Normandeau river wide survey, 1999-2001. HR = Hudson River, HRaT = Hudson River above Troy, Hrtrib = Hudson Estuary tributaries and Mohk = Mohawk River.

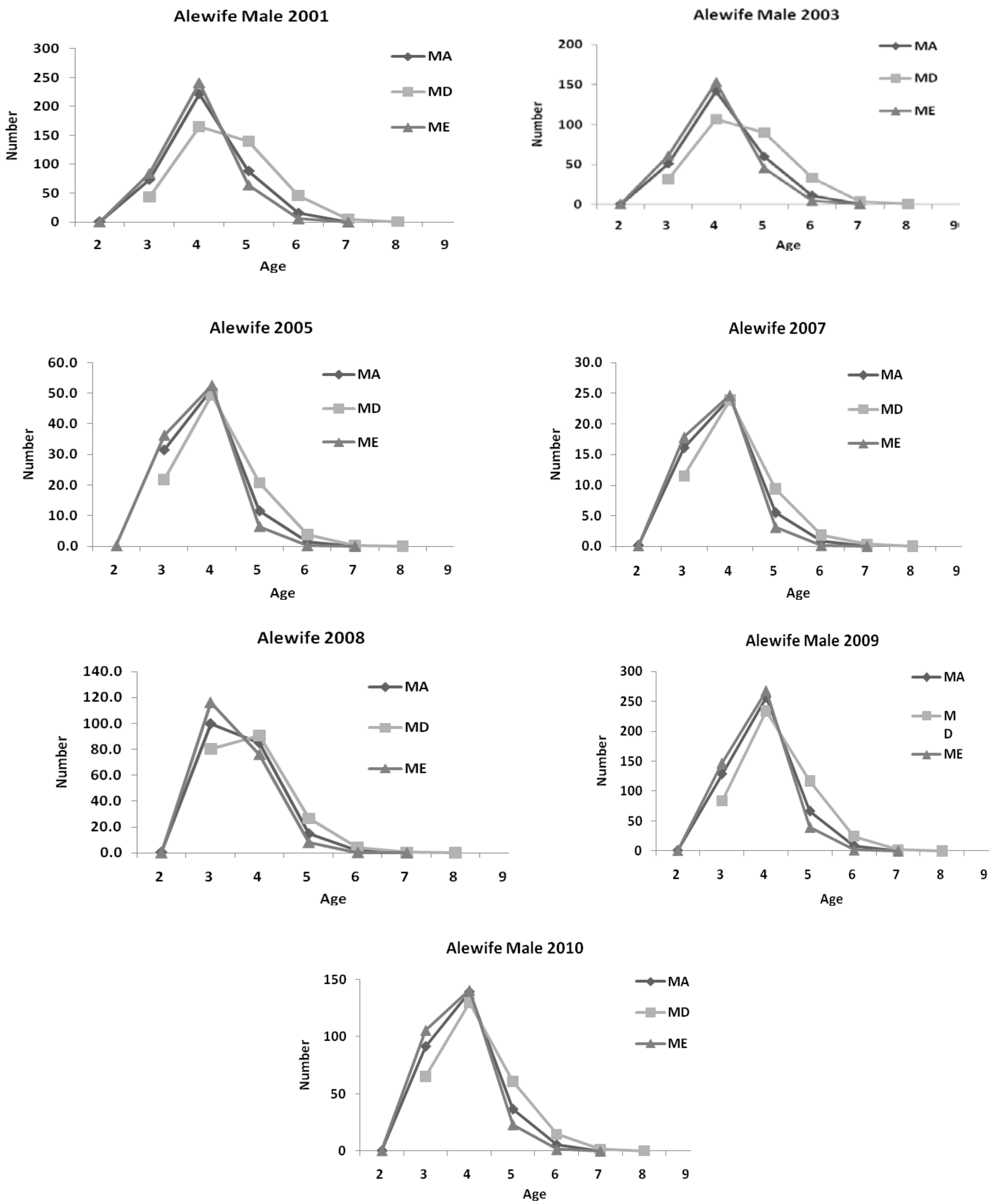


Figure 10.15 Age structure of Hudson River spawning alewife estimated from length age keys from ME, MA and MD.

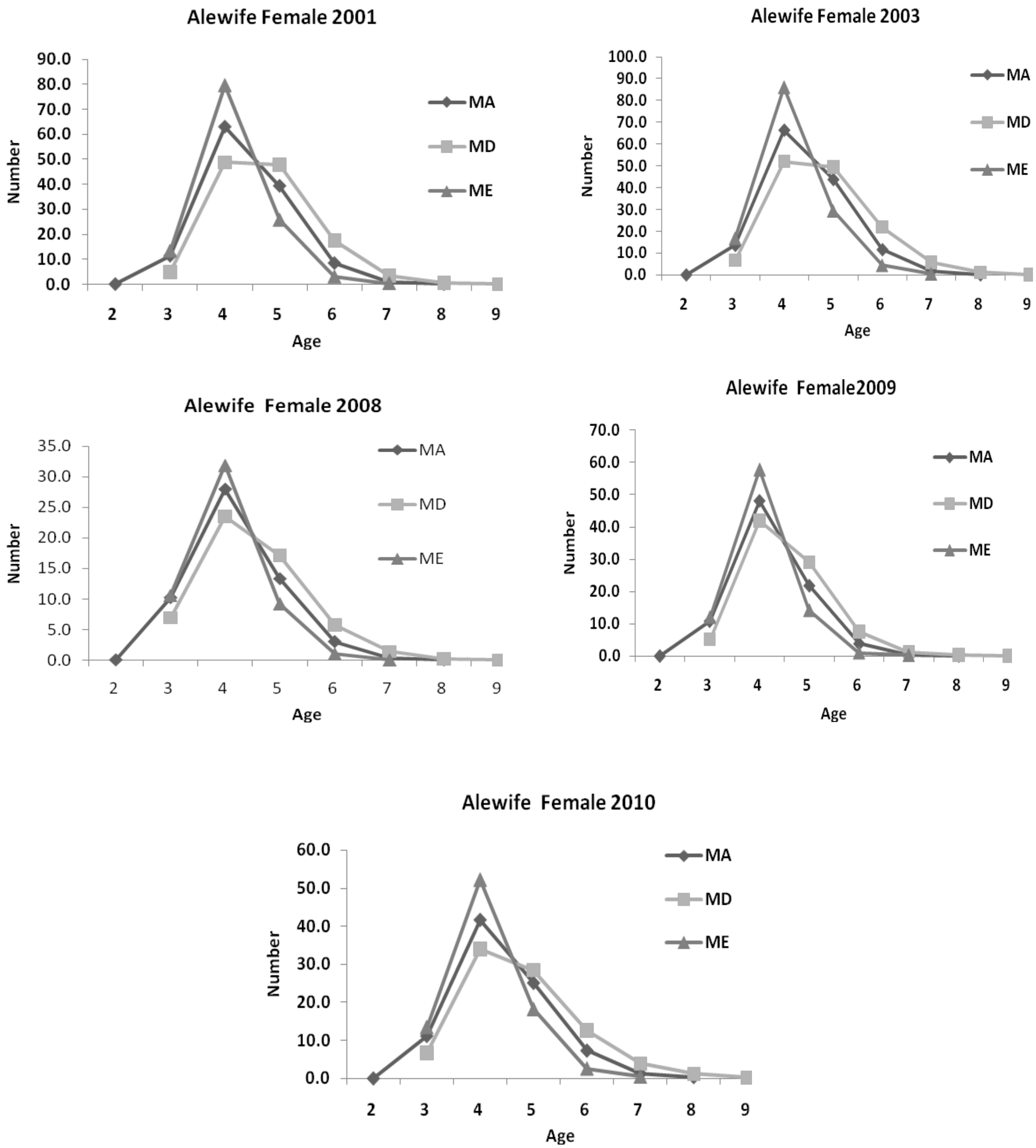


Figure 10.15 Continued.

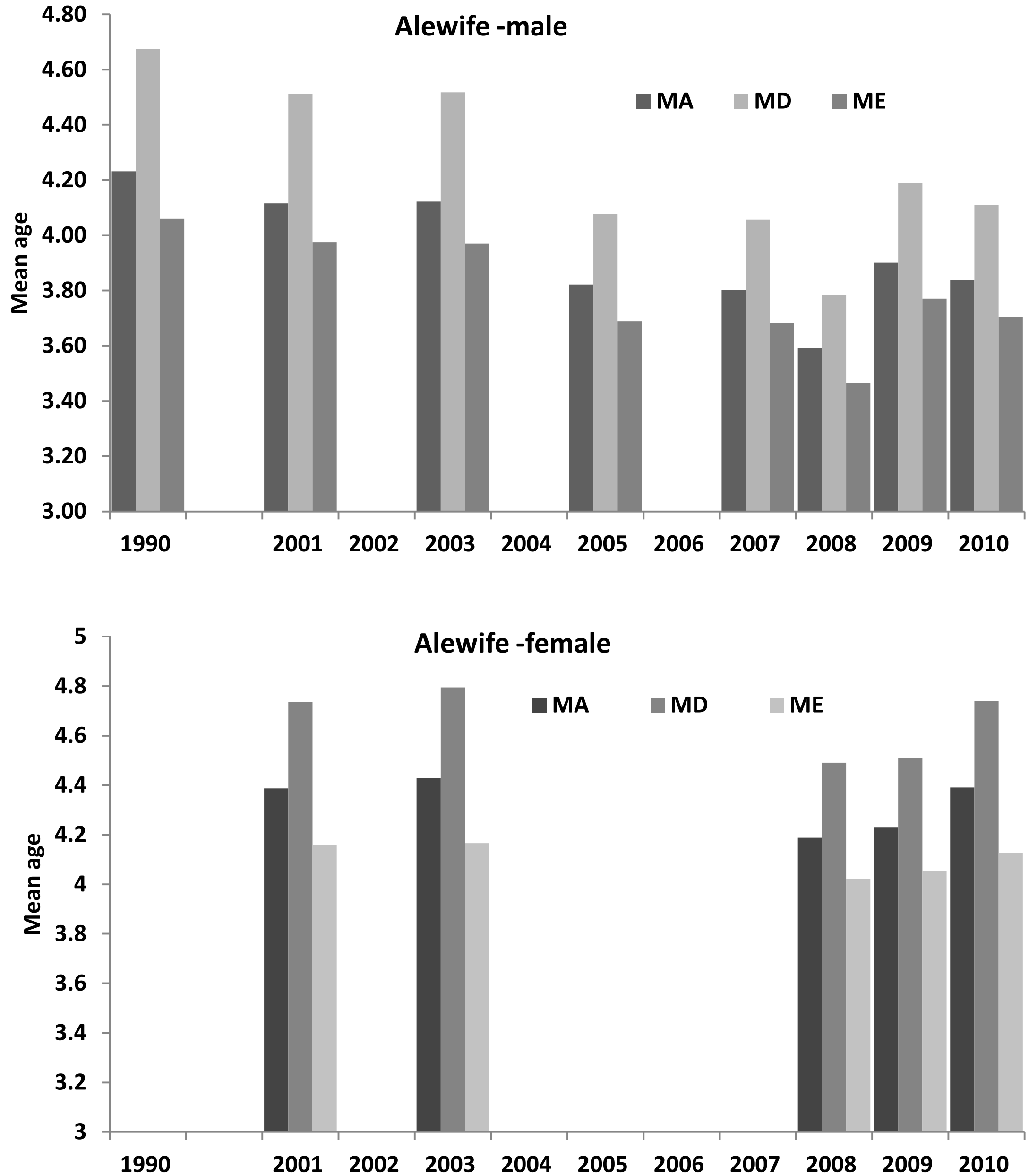


Figure 10.16 Mean age of Hudson River spawning alewife estimated from length age keys from ME, MA and MD.

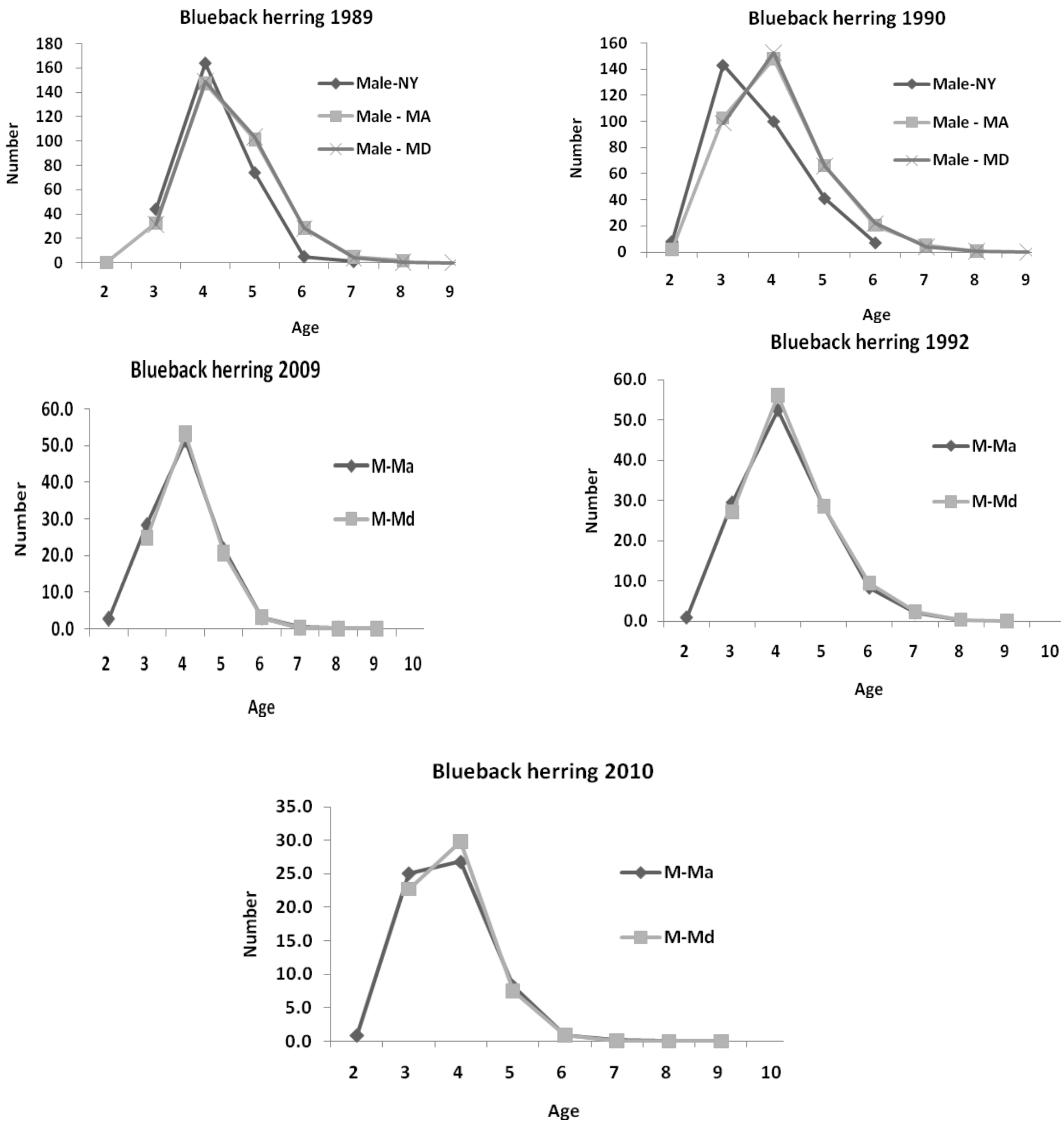


Figure 10.17 Age structure of Hudson River spawning blueback herring estimated from length age keys from ME, MA and MD.

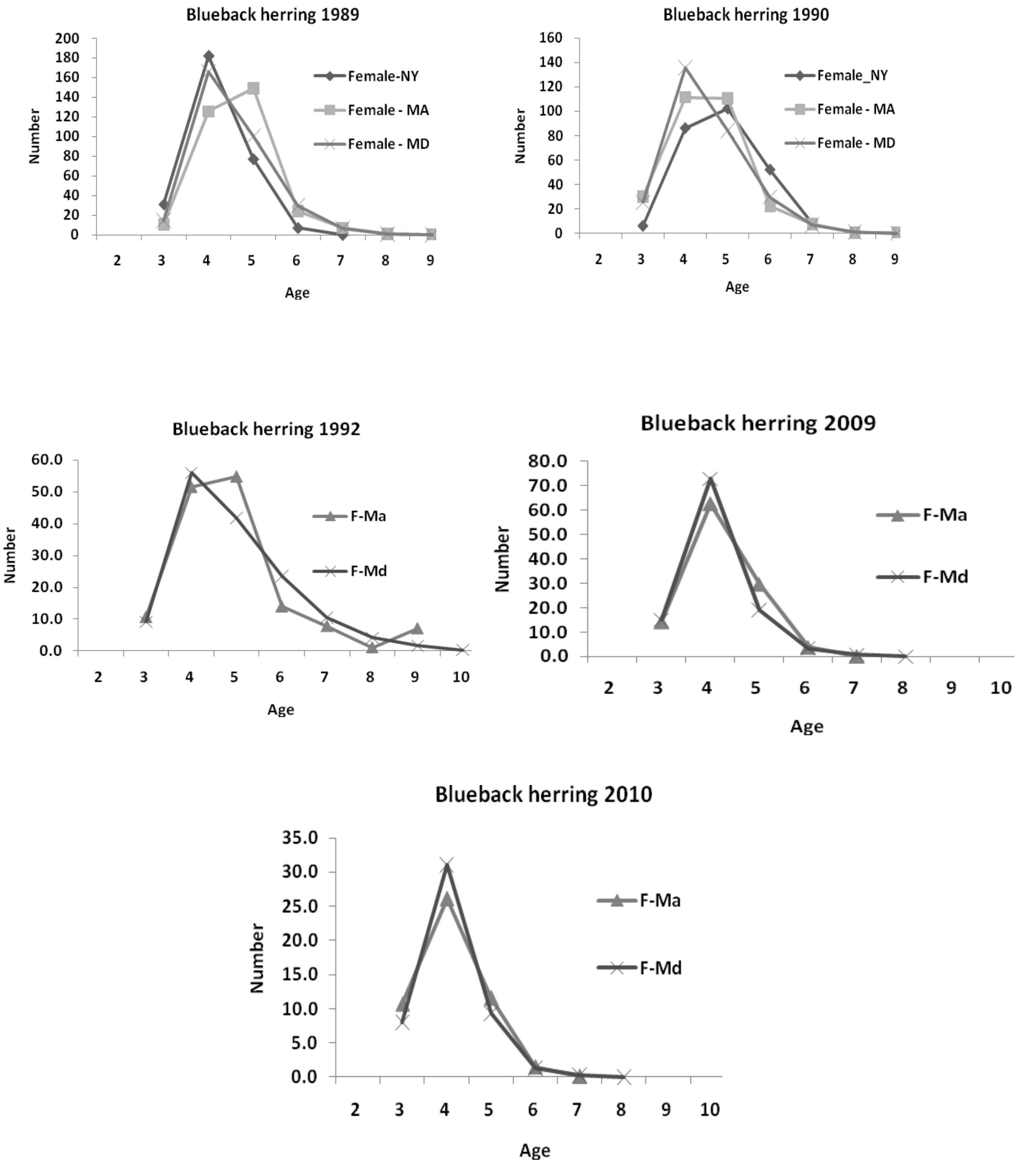
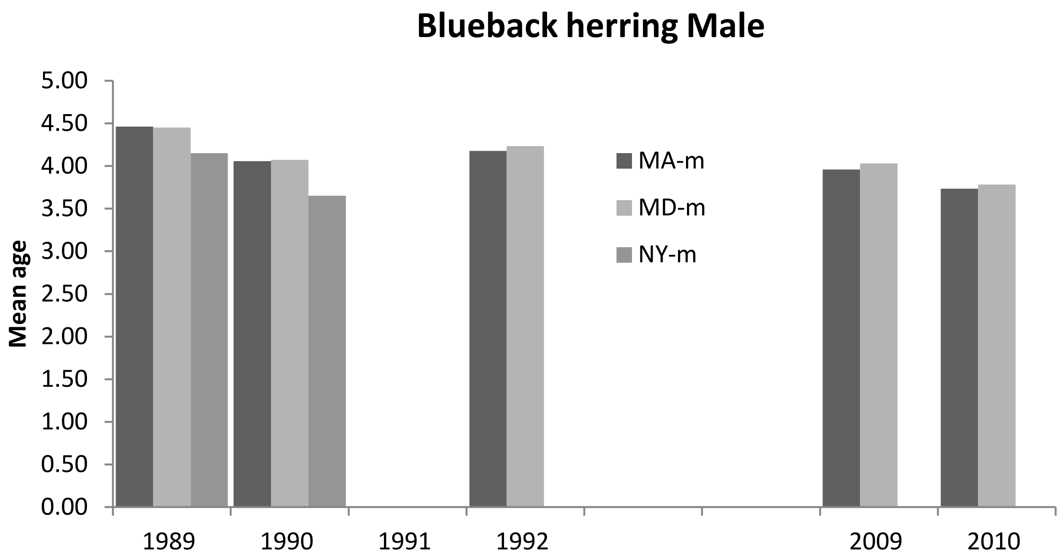


Figure 10.17. Continued



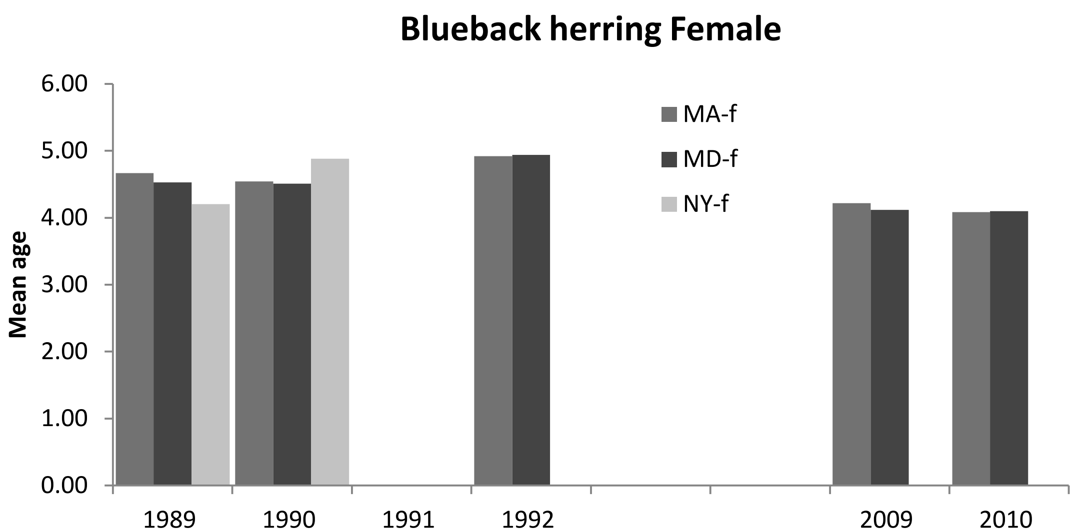


Figure 10.18 Mean age of Hudson River spawning blueback herring estimated from length age keys from ME, MA and MD.

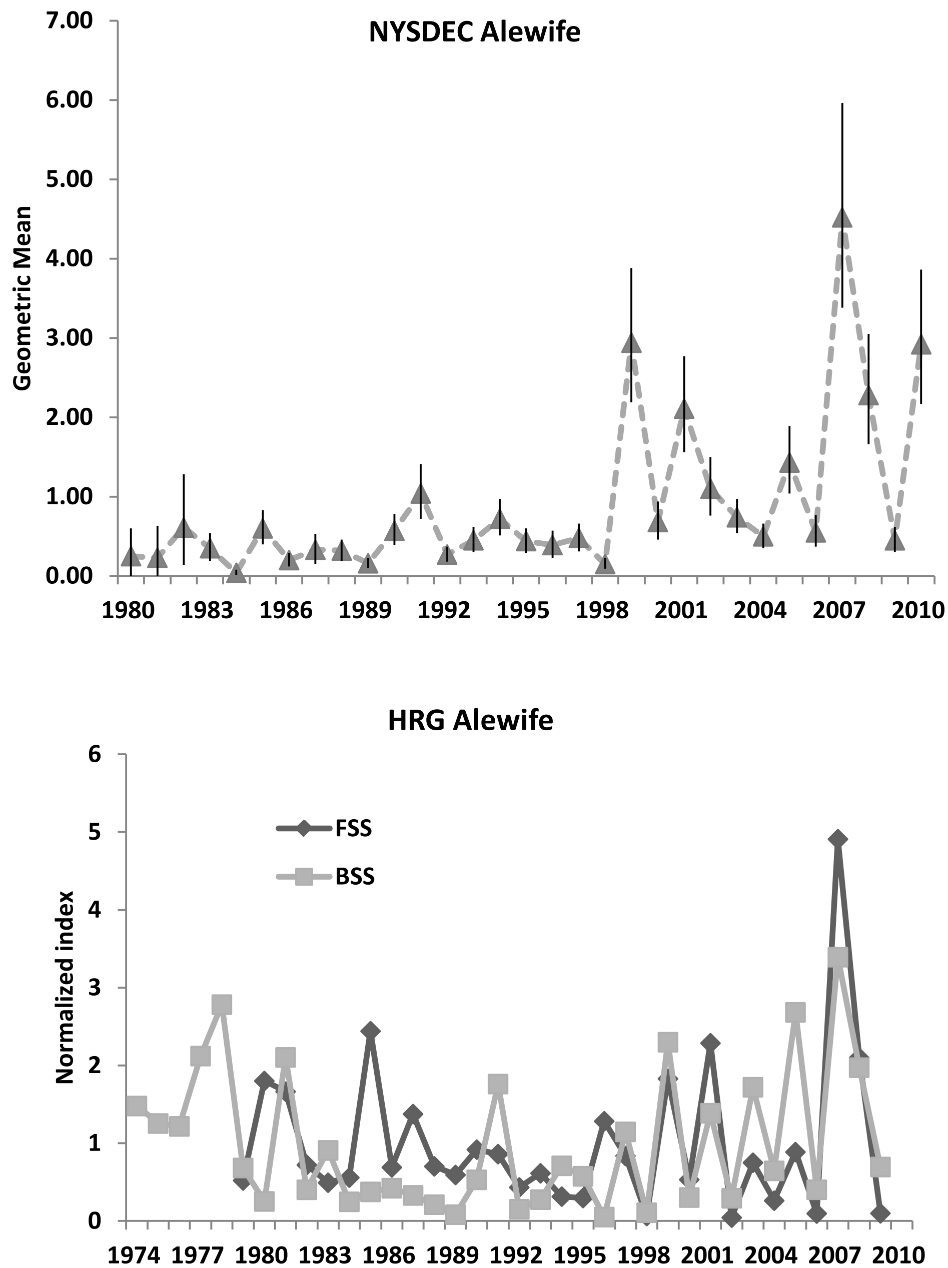
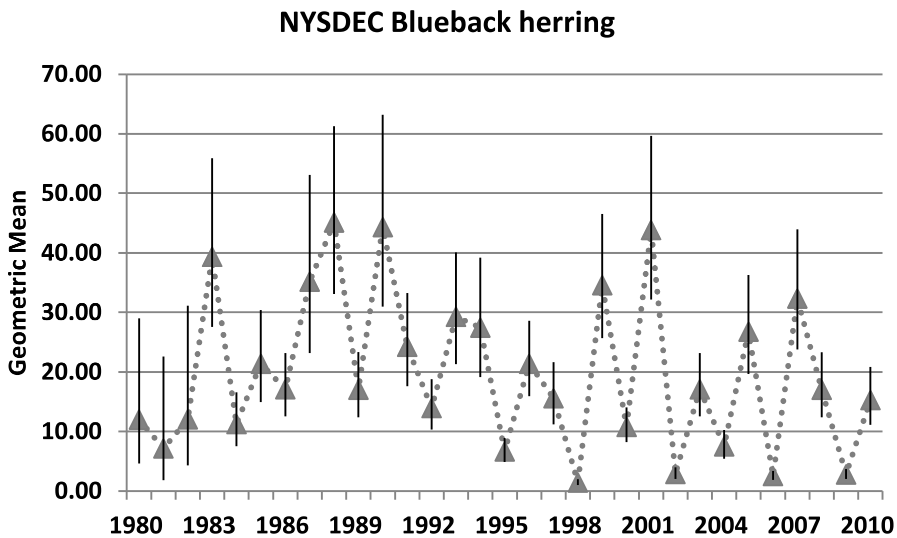


Figure 10.19 NYSDEC young of the year indices for alewife collected in the Hudson River Estuary (top). FSS and BSS are Hudson River Generating company survey indices (bottom); 2010 data not yet available.



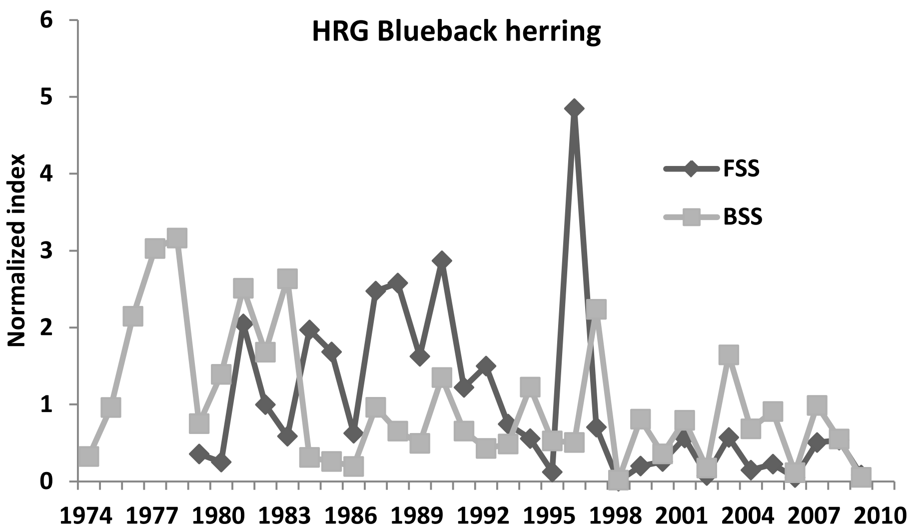
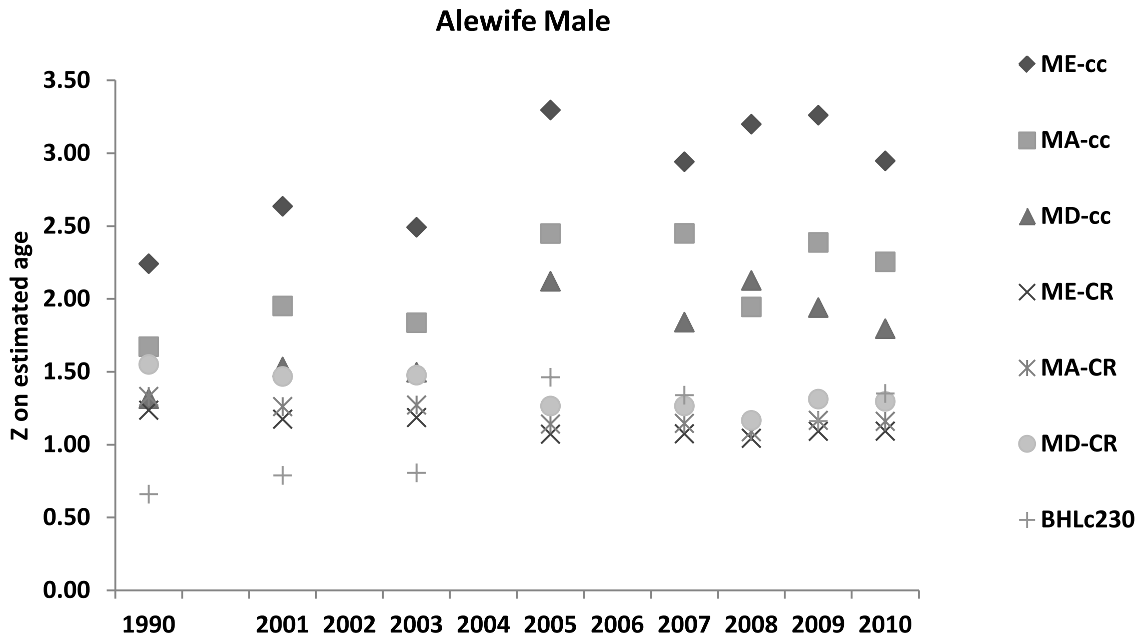


Figure 10.20 NYSDEC young of the year indices for blueback herring collected in the Hudson River Estuary (top). FSS and BSS are Hudson River Generating company survey indices(bottom); 2010 not yet available.



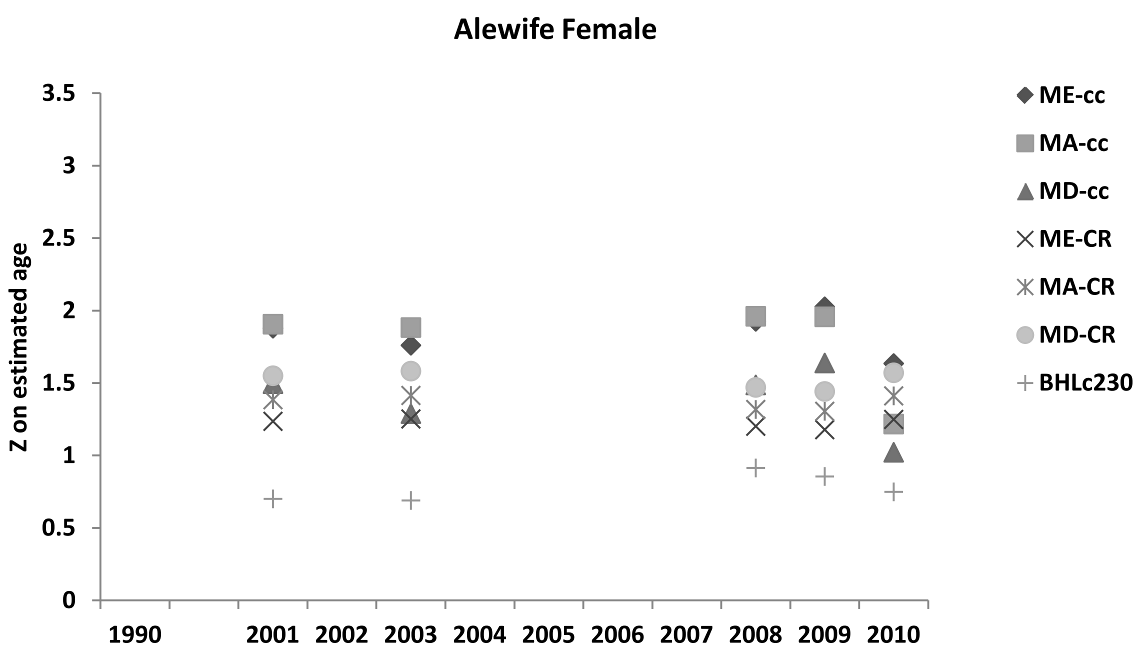
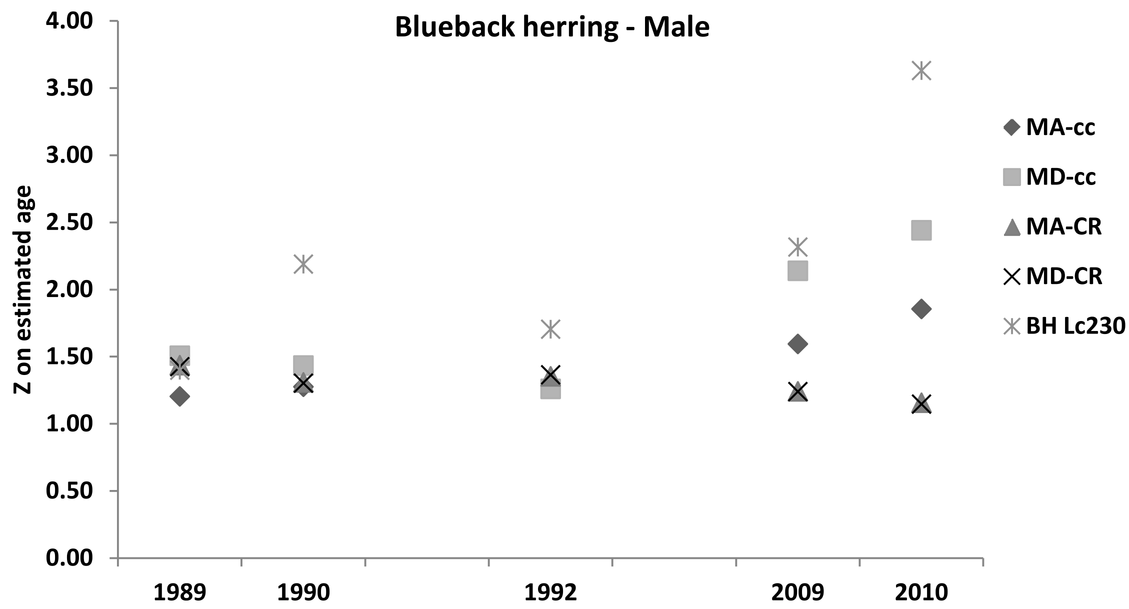


Figure 10.21 Total mortality of spawning alewife in the Hudson River Estuary based on age estimated from length-age keys from ME, MA and MD data; estimated calculated using catch-curve (CC), Chapman-Robson and Beverton-Holt length based methods.



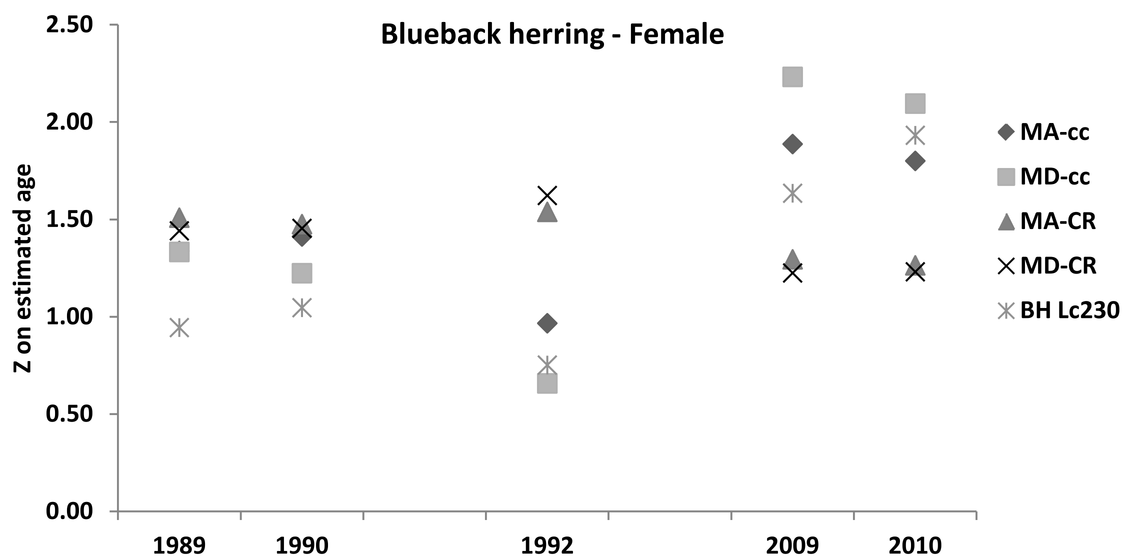
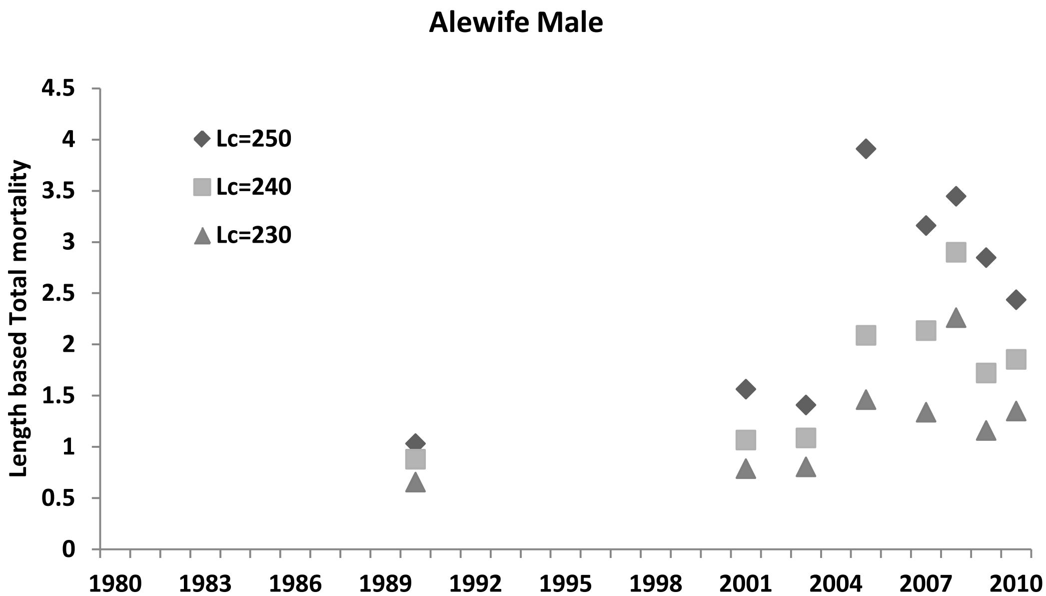


Figure 10.22 Total mortality of spawning blueback herring in the Hudson River Estuary based on age estimated from length-age keys from ME, MA and MD data; estimated calculated using catch-curve (CC), Chapman-Robson and Beverton-Holt length based methods.



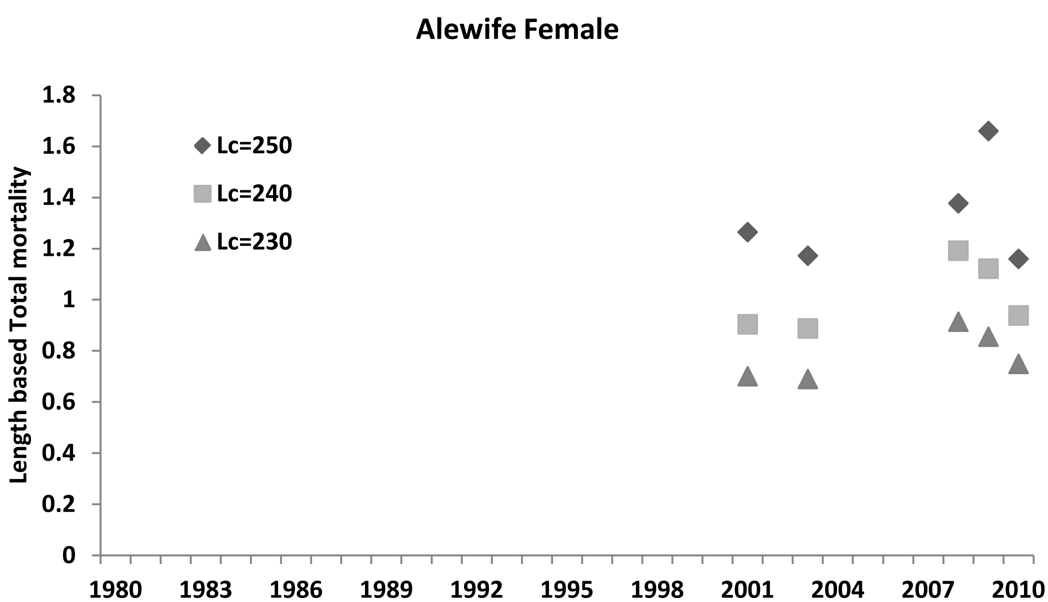
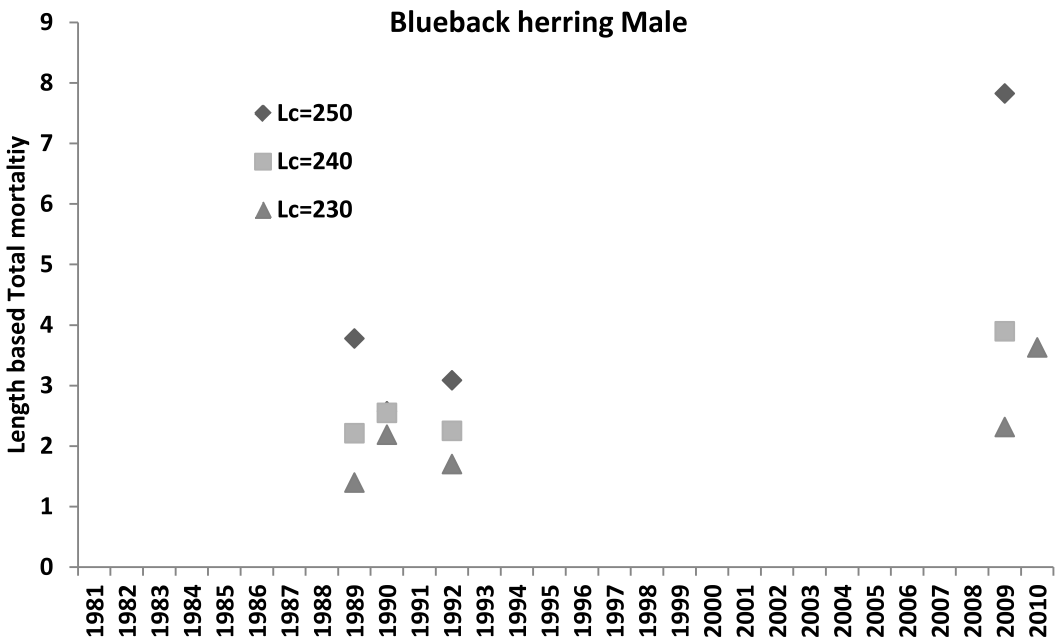


Figure 10.23 Beverton-Holt length based total mortality estimates for alewife collected in the Hudson River Estuary; data points of adequate sample size.



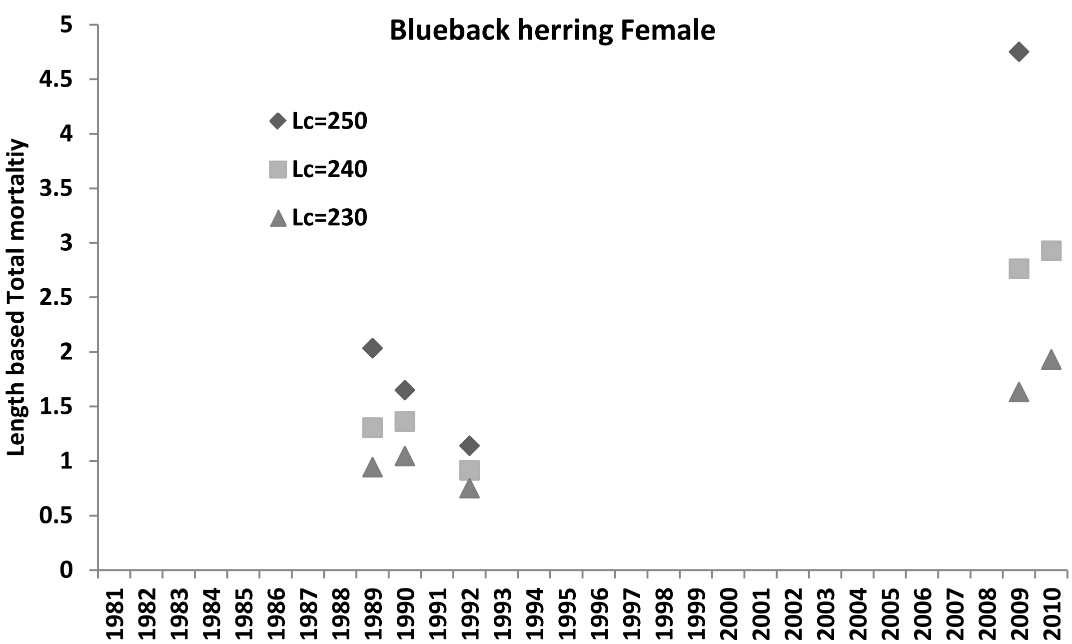


Figure 10.24 Beverton-Holt length based total mortality estimates for blueback herring collected in the Hudson River Estuary. Data points of adequate sample size.

Appendix Table.A. New York rivers, streams and water bodies identified to have, or are likely to have, anadromous river herring runs. This list may not be complete.

Hudson River						Bronx and Westchester Counties		Long Island			
River mile	County	Tributary	River mile	County	Tributary	County	Stream	Shore	Stream/pond	Shore	Stream/pond
Above Troy Dam		Mohawk River	75	Dutchess	Falkill	Bronx	Bronx River	South	Beaver Dam Creek	East End	Georgica Pond
150	Renssalaer	Poesten Kill	69	Ulster	Lattintown Creek	Bronx	Hutchinson River	South	Browns River	East End	Halsey's-Neck Pond
149.5	Renssalaer	Wynants Kill	69	Ulster	South Lattintown	Westchester	Beaver Swamp Brook	South	Carlls River	East End	Hog Creek
144	Renssalaer	Mill Creek	67	Dutchess	Hunters Brook	Westchester	Blind Brook	South	Carmans River	East End	Hook Pond
142	Albany	Normans Kill	67	Dutchess	Wappingers Creek	Westchester	Byrum River	South	Champlin Creek	East End	Lake Montauk
137	Albany	Vloman Kill	66	Orange	Roseton Brook	Westchester	East Creek	South	Connetquot R.- Rattlesnake Brook	East End	Ligonee Brook
137	Renssalaer	Papscanee	62	Orange	Quassaick Creek	Westchester	Mamaroneck River	South	Connetquot R.- West Brook	East End	Mill Pond - Mecox Bay Ext.
136	Renssalaer	Vlockie Kill	59	Dutchess	Fishkill Creek	Westchester	New Rochelle Creek	South	Connetquot River- Main stem	East End	Peconic River
135	Renssalaer	Schodack	58	Dutchess	Malzingah Brook (Gordon's Brook)	Westchester	Otter Creek	South	Forge River	East End	Sagaponack Pond - Jeremy's Hole
132	Albany	Coeymans	57	Orange	Moodna Creek	Westchester	Premium River	South	Massapequa Creek	East End	Scoy Pond
131	Albany	Hannacroix	57	Dutchess	Wades Brook			South	Mud Creek	East End	Silver Lake/Moore's Drain
128	Columbia	Mill Creek	55	Putnam	Breakneck Brook			South	Patchogue River	East End	Stepping Stones Pond
126	Greene	Coxsackie	53	Putnam	Foundry Brook			South	Penataquit Creek		
121	Columbia	Stockport Creek	53	Orange	Crows Nest brook			South	Pipes Creek		
118	Greene	Murderers Creek	52	Putnam	Phillipse Brook			South	Swan River		
112	Greene	Catskill Creek	52	Putnam	Arden Brook			North	Beaver Brook		
110	Columbia	Roeliff Jansen Kill	52	Putnam	Indian Brook			North	Cold Spring Brook		
105	Columbia	Cheviot Creek	48	Putnam	Copper Mine Brook			North	Fresh Pond/Baiting Hollow		
101	Ulster	Esopus Creek	46	Orange	Popolopen Creek			North	Mill River, Oyster Bay (Site)		
100	Dutchess	Stony Creek	44	Westchester	Annsville Creek			North	Nissequogue River		
98	Columbia	South Bay Creek	43	Westchester	Dickey Brook			North	Setauket Mill pond		
98	Dutchess	Saw Kill	39	Rockland	Cedar Pond Brook			North	Stony Hollow Run, Ctrpt.		
91	Ulster	Rondout Creek	38	Westchester	Furnace Brook			North	Sunken Meadow Creek		
87	Dutchess	Fallsburg Creek	38	Rockland	Minisceongo			North	Wading River		
87	Dutchess	Landsman Kill	34	Westchester	Croton River			East End	Alewife Brook		
84	Dutchess	Indian Kill	33	Westchester	Sing-Sing			East End	Alewife Creek/Big Fresh Pond		
84	Ulster	Black Creek	28	Westchester	Pocantico River			East End	Big Reed Pond		
81	Dutchess	Crum Elbow	25	Westchester	Wicker's Creek			East End	Ely Pond		
78	Dutchess	Maritje Kill	24	Rockland	Sparkill Creek			East End	Fort Pond		
76	Ulster	Twaalfskill	18	Westchester	Saw Mill			East End	Gardiner Bay Creeks		

Appendix Table B. Summary of fishery regulations for alewife and blueback herring in New York State.

Fishery / Area
Commercial Harvest:
Inland waters
Hudson River Estuary: G. Washington Bridge north to Troy Dam (River kilometer 19-245)
- season: 15 March through 15 June
- 36 hour escapement period (Friday 6 am to Saturday 6pm, prevailing time)
- net size restriction: limit of 600 ft, mesh size restriction: mesh <3.5 inch stretch mesh
- net deployment restrictions (distance between fishing gear > 1500 ft)
- area restrictions (drifted gears allowed in certain portions of the river)
Long Island: No restrictions, except for some towns which have restricted fishing within their township
Marine Waters: Hudson River - G. Washington Bridge south; and waters including NY Harbor and around Long Island
- No limits or season.
Delaware River: NY portion, north of Port Jervis
- no commercial fishery exists in this portion; no rules prohibit it
Recreational Harvest:
- No daily limit
- No season
- Harvest can by by hook and line, and some net gears: dip nets (14inches round), scoop nets (13 x 13 inches square), cast net (maximum of 10 feet in diameter) and seine and scap / lift nets 36 square feet or less. A New York Inland recreational fishing license is required, but not in the main-stem Hudson River.

11. STATUS OF RIVER HERRING IN NEW JERSEY

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11.1. INTRODUCTION

In this report, river herring refers collectively to alewife (*Alosa pseudoharengus*) and blueback herring (*Alosa aestivalis*). The river herring data presented within this report focuses on the coastal waters off of New Jersey. Data on river herring occurring within the Delaware River Drainage Basin (Basin) can be found in Section 12. Coastal areas are monitored through New Jersey's Stock Assessment Trawl Survey and the sampling area includes the near shore waters from the entrance of New York Harbor south, to the entrance of the Delaware Bay (Figure 11.1). The Raritan River fish ladder is located at the Island Farm weir just downriver of the Millstone-Raritan river confluence.

11.2. MANAGEMENT UNIT DEFINITION

New Jersey Division of Fish and Wildlife manages river herring populations occurring within New Jersey's sections of the Basin and the coastal waters from Cape May Point to Sandy Hook including Raritan Bay and River.

11.3. REGULATORY HISTORY

11.3.1. Commercial Fishery

Historically, no specific regulations have been adopted to reduce or restrict commercial landings of river herring in New Jersey, however there have been regulations which have limited commercial fishing effort and have a direct impact on catch. New Jersey adopted general regulations that apply to the commercial fishery such as limited entry, limitations on the amount of gear, and gear restrictions in defined areas. Note these restrictions apply to all New Jersey waters and not just the coastal jurisdiction, unless otherwise noted. These restrictions include but are not limited to:

1. From November 1 to April 30, only haul seines with a mesh size ≥ 2 ¾ inch stretch and with a maximum length of 420 feet can be used in the Delaware River. This is currently limited to one commercial fishery based in Lambertville and rarely harvests river herring,

2. From February 1 through December 15, gill nets may be used in Delaware Bay and River. From February 12 through May 15, the maximum net length allowed is 2400 feet; from May 16 through December 15, the maximum net length is 1200 feet,

3. Gill net small mesh exemption permit (GNSMEP) allows fishers to use gill nets between 2.75 inch stretched mesh to 3.25 inch stretched mesh within two nautical miles of the mean high water line between sunrise and sunset. Holders of these permits are required to report all landings and any weakfish discards.

4. Pound nets are allowed all year in Ocean waters and Sandy Hook/Raritan Bay. In Delaware Bay, pound nets are allowed only during February 15 to May 15

As of January 1, 2012 landings of river herring in New Jersey is prohibited. These regulations are in compliance with the Atlantic States Marine Fisheries Commission Amendment 2 to the Fisheries Management Plan for Shad and River herring.

11.3.2. Recreational Fishery

Historically, the recreational fishery for river herring was very small with few participants and low retention rates. Those herring that were landed were typically frozen for bait, pickled, harvested for their roe, and other traditional uses. In the freshwater areas of the state, the current limit is 10 fish in aggregate of river herring, while the marine section is 35 fish. Recreational gear includes hook and line, dip net, bait seine, cast net. No bait net license is required for the taking of bait fish such as river herring for personal use with the following gear:

1. Dip nets 24 inches or less in diameter,
2. Bait seines 50 feet long or less,
3. Cast nets 20 feet in diameter or less, and
4. Lift or umbrella nets four feet square or less

As of January 1, 2012 the recreational fishery will be closed.

11.4. ASSESSMENT HISTORY

No stock assessments have been completed on river herring populations in New Jersey's coastal rivers and streams.

11.5. STOCK SPECIFIC LIFE HISTORY

Adult alewife and blueback herring will typical enter New Jersey streams to spawn beginning in early February. Peak spawning activity occurs during mid-April through May. Post-spawned adults will return to the ocean by mid-June. Larvae will hatch and juvenile will maintain freshwater residence through mid-November, although juvenile emigration can occur as early as July. Mature adults will return to their natal streams to spawn.

11.6. HABITAT DESCRIPTION

Many of New Jersey's rivers and streams contained spawning runs of river herring until pollution, overfishing and dams restricted the population and destroyed spawning habitat. It is estimated from 1953 to 1973, 61,678 acres of coastal wetlands and uncounted acreage of adjacent transitional wetlands were lost to filling and diking in New Jersey (Ferrigno et al 1973). Field investigations during the early to mid-1970s confirmed 132 river herring spawning runs (108 alewife and 24 blueback) in rivers and streams that were continuous with the marine environment (Zich 1977). The majority of these runs were river herring. Zich concluded that nine herring runs had already become extinct.

Also during these field investigations, 83 constructed barriers were found on streams where herring runs were reported or confirmed. These barriers were assessed to be blocking or limiting fish passage and therefore reducing spawning habitat. There is no current estimate as to whether or not this number has changed significantly since that time. Recent efforts have been undertaken to restore river herring runs in some of these systems by removing dams, installing fish ladders and/or trap and transport.

11.7. RESTORATION PROGRAMS

Restoration programs for river herring in New Jersey have been limited to the installation of fish ladders and occasional minor trap and transport programs or dam removal. The total amount of freshwater habitat opened up through these efforts has not been calculated. The only usable data available is from PSEG and represents fish ladder monitoring for both Delaware and New Jersey (PSEG 2009).

11.8. AGE

No age data has been reported for New Jersey. Otoliths have been collected during the January and April Ocean Stock Assessment trawls since 2009. Processing and aging of these samples will be completed as funding becomes available.

11.9. FISHERY DESCRIPTION

11.9.1. Commercial Fishery

New Jersey river herring landing estimates were obtained from two sources (Table 11.1; Figure 11.2). The NMFS estimates (1950 to 2009) are for the entire state, while mandatory logbooks of the GNSMEP (2000 to 2009) are from Delaware Bay. The average reported NMFS landings for the time period is estimated at 8,180 pounds. There are no estimates of underreporting, however it is assumed that the current data for river herring is underreported since some landings may be categorized as bait.

11.9.2. Recreational Fishery

Recreational surveys within the coastal jurisdictions have not been conducted.

11.9.3. Characterization of Other Losses

There are many potential unknown sources of mortality from power plant intakes, recreational harvest, commercial discards and landings categorized as "bait". Many of these could be significant according to some data points. The increased popularity of herring used as bait for striped bass fishing is an additional source of unknown loss for coastal stocks.

11.10. FISHERY-INDEPENDENT SURVEYS

11.10.1. Coastal waters

Ocean Trawl Survey

The New Jersey Ocean Trawl Survey is a multispecies survey that started in August 1988 and samples the near shore waters from the entrance of New York Harbor south, to the entrance of the Delaware Bay five times a year (January, April, June, August and October). There are 15 strata with five strata assigned to three different depth regimes; inshore (3 to 5 fathoms), mid-shore (5 to 10 fathoms), and off-shore (10 to 15 fathoms). Station allocation and location is random and stratified by strata size (Figure 11.1).

The survey net is a two-seam trawl with forward netting of 4.7 inch stretch mesh and rear netting of 3.1 inches stretch mesh. The codend is 3.0 inches stretch mesh and is lined with a 0.25 inch bar mesh liner. Each trawl is 20 minutes long and at the end of each tow, the total weight of each species is measured in kg and the length of all individuals, or a representative sample by weight for large catches, is measured to the nearest cm. A series of water quality parameters, such as surface and bottom salinity, temperature and dissolved oxygen, are also recorded at the start of each tow. New Jersey began collecting otoliths and other biological data in 2009 to develop age at length keys for both species. Data was collected in 2010 also but no samples for either year have been processed at this time.

Raritan River Fish Passage

The Raritan River, which empties into Raritan/Sandy Hook Bay, historically supported a spawning run of American shad. In the early 1980s adult male and gravid female Delaware River American shad were stocked there in an attempt to reestablish a spawning run. A dam constructed at the confluence of the Millstone and Raritan rivers was equipped with a fish ladder that included an underwater viewing room. Data is available for 1996 to 2005 (except for 2000 and 2004). A CPUE was developed as the number of fish counted per day. Confidence that all herring are counted is somewhat low.

11.11. ASSESSMENT APPROACHES AND RESULTS

The purpose of this report is to assess the stock status of the New Jersey's coastal populations of blueback herring and alewife. It is obvious from historical data and anecdotal information that river herring populations statewide were much larger in the past and have declined drastically since the robust numbers of the late 1800s. The only data available for assessment is data from New Jersey's Ocean Trawl Survey and a fish ladder index from the Raritan River.

11.12. Trends in Spawning Stock Size

The trawl index for blueback herring showed a declining trend from 1993 to 2004 but has shown an increasing trend ever since. This included the highest index of the time series in 20012. The alewife index has varied without much of a trend since the beginning, although there has been a slight increase since 2000.

The majority of river herring are captured during the January and April trawls so only those months are used for the geometric mean (Table 11.2; Figure 11.3). The blueback index declined from 1993 through 2004 but has increased rapidly in recent years, with two of the top three values in 2008 and 2009. The alewife index varied with an increasing trend until 1998 before declining rapidly through 2002 (Table 11.2; Figure 11.3). The index has shown a slight increasing trend since that time. Length frequencies for blueback herring and alewives, for the entire time series, are found in Figure 11.4.

The Raritan fish ladder data is a very short term data set that was discontinued in 2005. Regardless, the data showed a decreasing trend from 1997 to 2005 (Table 11.3; Figure 11.5).

11.13. BENCHMARKS

No benchmarks were developed for the coastal waters of New Jersey.

11.14. CONCLUSIONS AND RECOMMENDATIONS

Data for stock assessment of New Jersey's coastal rivers and streams is virtually non-existent. Additional data for New Jersey's portion of the Delaware Basin can be found in section 12. There are only two sources of river herring data from New Jersey's coastal waters, only one of which is currently ongoing. The Ocean Trawl survey, which collects fishery independent data of mixed coastal stocks, showed an increase in blueback herring in recent years and a slight increasing trend for alewife since 2002. In contrast, the short data set from the Raritan fish ladder showed an overall decreasing trend. With so little data available, it is not possible to determine an accurate state of river herring stocks in New Jersey's coastal waters. It would be beneficial to undertake a more rigorous investigation of the population dynamics of these species within and outside the New Jersey coast.

For the New Jersey coast, this would include:

- Additional information on commercial and recreational landings
- Improved assessment of river herring adults at all fish ladder installations
- Improved assessment of river herring production in targeted tributaries
- Predator-prey relationships especially with striped bass, bluefish and white perch for yoy and striped bass, weakfish, bluefish, spiny dogfish for adults
- Habitat evaluations
- Development of age-length keys from samples collected during the Ocean Trawl Survey
- Revisit Raritan Bay fish ladder survey data

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Table 11.1 New Jersey commercial river herring (alewife and blueback herring) landings, in pounds: 1950 – 2009. NMFS landings are statewide; Logs are from the Delaware Basin.

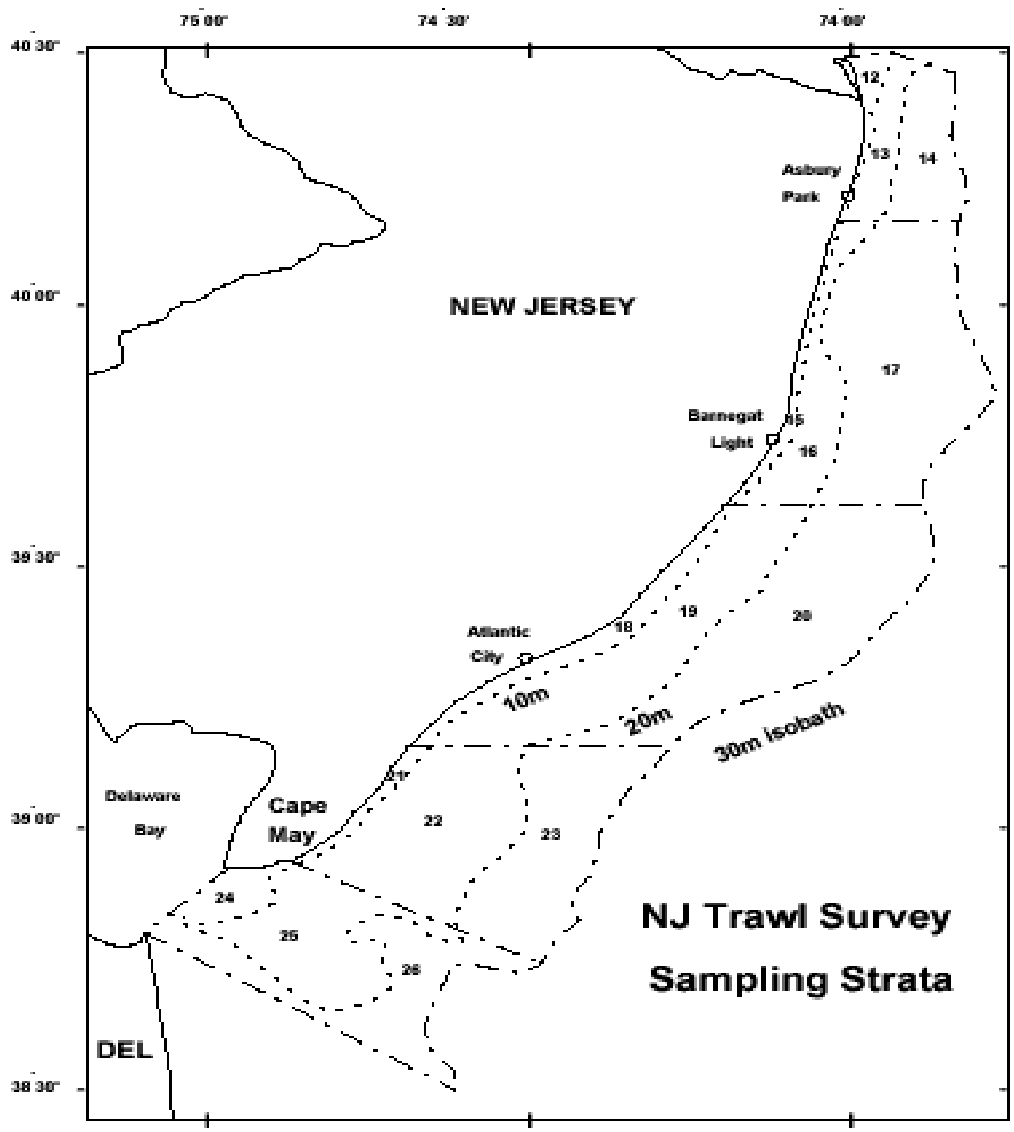
Year	NMFS	Logs		Year	NMFS	Logs
1950	29,000	-		1981	13,800	-
1951	7,200	-		1982	13,600	-
1952	600	-		1983	2,200	-
1953	8,600	-		1984	3,100	-
1954	0	-		1985	4,800	-
1955	22,900	-		1986	4,200	-
1956	22,300	-		1987	5,200	-
1957	8,100	-		1988	700	-
1958	1,400	-		1989	800	-
1959	2,200	-		1990	42,494	-
1960	3,000	-		1991	9,994	-
1961	16,500	-		1992	3,069	-
1962	20,300	-		1993	2,659	-
1963	3,400	-		1994	328	-
1964	14,200	-		1995	795	-
1965	21,500	-		1996	4,449	-
1966	12,400	-		1997	4,515	9,229
1967	9,000	-		1998	7,371	-
1968	8,400	-		1999	1,377	3,885
1969	5,100	-		2000	0	5,335
1970	7,500	-		2001	1,034	2,881
1971	9,500	-		2002	3,366	1,303
1972	14,700	-		2003	228	3,439
1973	7,000	-		2004	2,548	4,583
1974	10,600	-		2005	1,079	2,964
1975	9,300	-		2006	469	2,866
1976	11,300	-		2007	0	223
1977	10,600	-		2008	631	1,890
1978	2,400	-		2009	0	489
1979	6,600	-		2010	N/A	1,004
1980	18,600	-		AVG	8,180	3,084

Table 11.2 Ocean Trawl Survey river herring geometric mean per tow: 1989-2010

Year	Blueback	Alewife
1989	5.10	3.01
1990	3.68	2.57
1991	3.33	5.01
1992	4.60	2.85
1993	6.57	7.03
1994	4.72	2.82
1995	5.51	5.01
1996	4.71	8.23
1997	3.85	3.97
1998	2.99	30.08
1999	4.01	11.85
2000	4.23	1.76
2001	4.64	1.79
2002	2.15	2.39
2003	2.21	4.69
2004	1.81	4.67
2005	3.24	3.92
2006	4.48	2.44
2007	3.33	4.63
2008	8.77	5.71
2009	6.21	4.89
2010		
mean	**4.29**	**5.68**

Table 11.3 Raritan River Island Farm Weir fish ladder viewing cpue: 1996-2005

Year	CPUE
1996	0.00
1997	1.70
1998	0.16
1999	0.55
2000	N/A
2001	0.82
2002	0.29
2003	0.15
2004	N/A
2005	0.00



** Strata correspond to those of the National Marine Fisheries Service's spring and fall groundfish surveys*

Figure 11.1 New Jersey Ocean Trawl Survey area: 2010

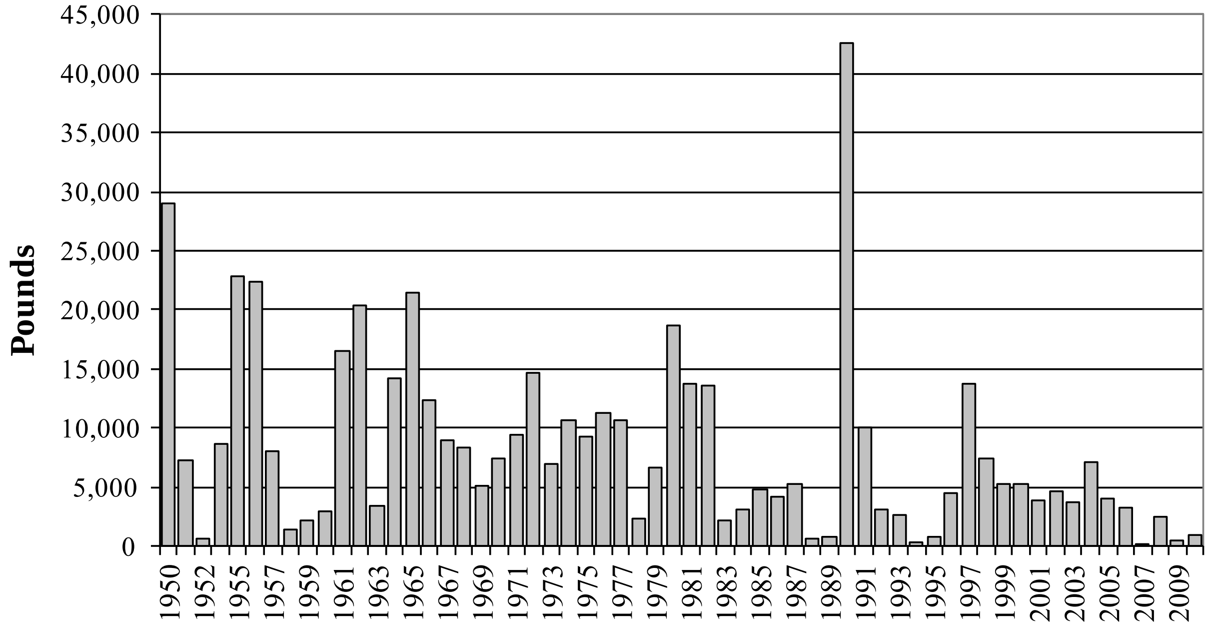


Figure 11.2 New Jersey Reported Commercial Landings 1950-2010

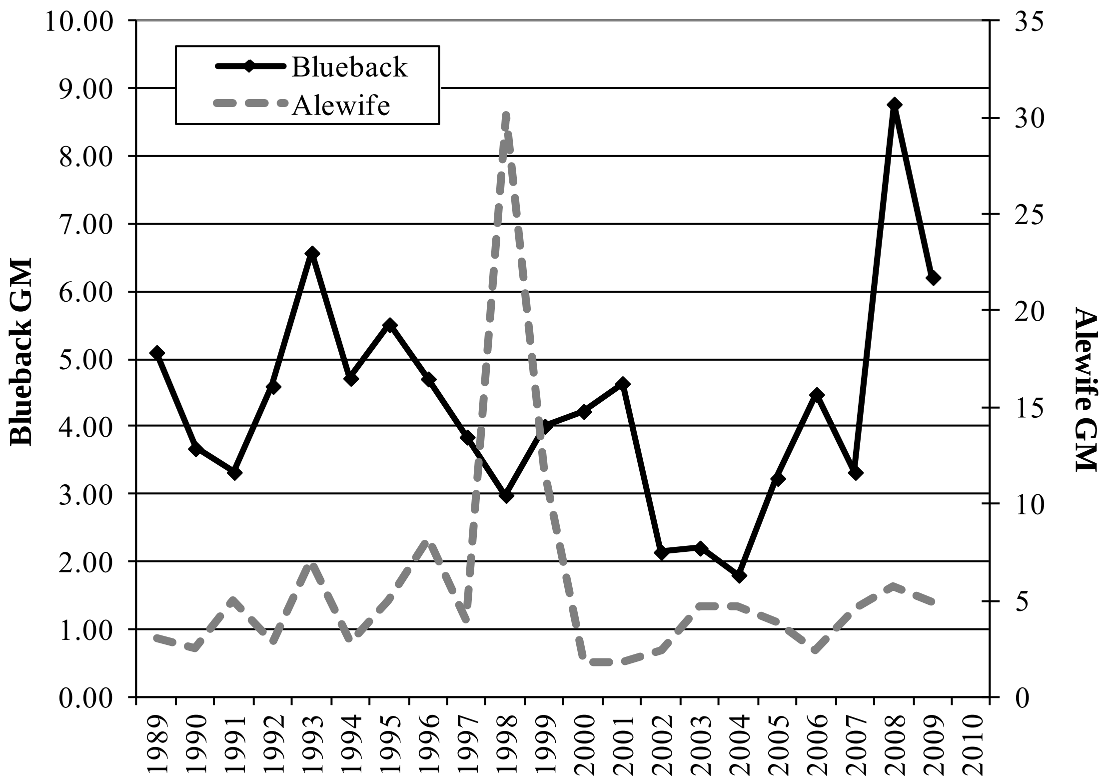


Figure 11.3 Ocean Trawl Survey river herring geometric mean per tow: 1989-2010

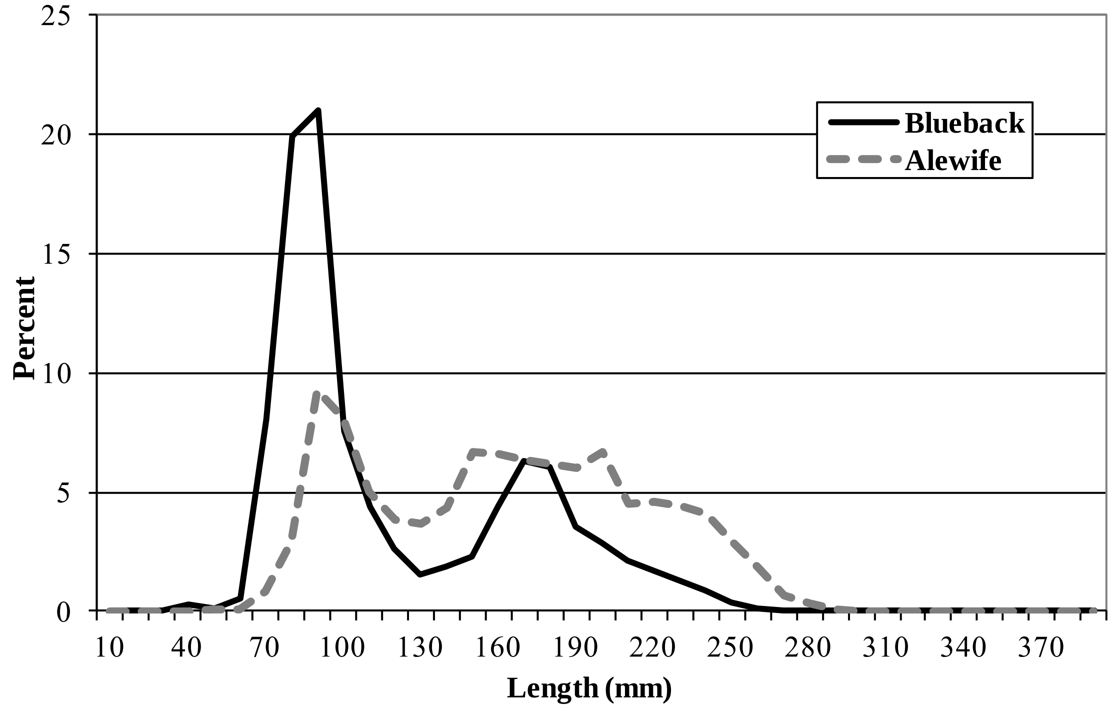


Figure 11.4 Ocean Trawl Survey percent length frequencies: 1989-2009

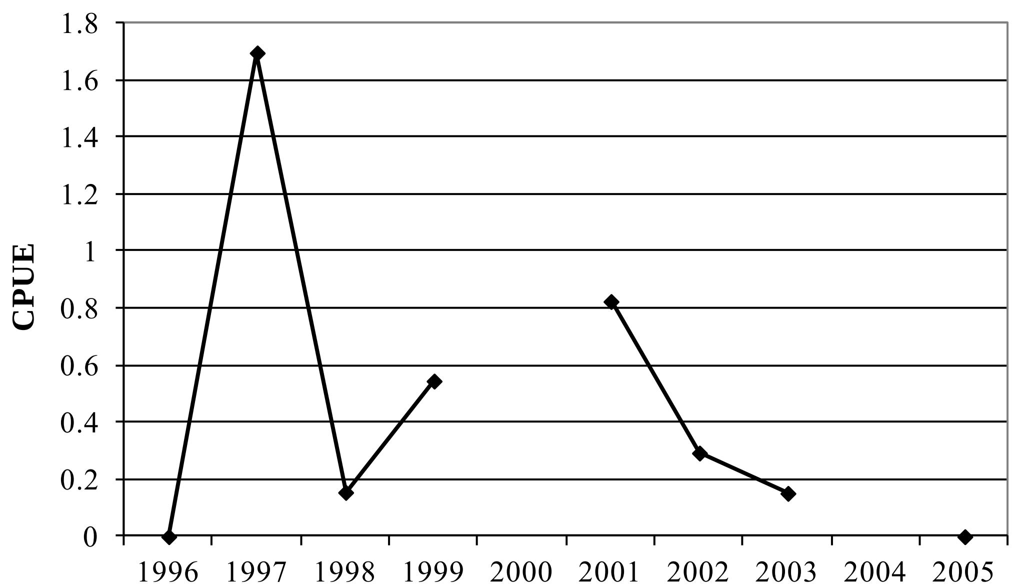


Figure 11.5 Raritan River Island Farm Weir fish ladder viewing CPUE (1996-2005).

12. Status of River Herring in Delaware River and Bay

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12.1. INTRODUCTION

River herring populations in the state of Delaware, Pennsylvania and New Jersey consist of two species, alewife and the blueback herring. Both species occur throughout the Delaware River and Bay (Basin).

During the early 1900s the volume of herring in the Delaware River was so great that they often flipped onto the creek banks of the river each spring. The decline of river herring in the Basin began in the 1940's due to heavy organic loads around Philadelphia, Pennsylvania which caused severe declines in dissolved oxygen (DO). The ensuing "DO blocks" made parts of the lower Delaware River uninhabitable for fish during the warmer months of the year **(**Sykes and Lehman 1957). The contamination continued to worsen to such a degree that by 1951 it was advised that no one should go into the water. During the 1940s, commercial herring fisheries were mainly limited to the lower reaches of the River and Bay below Pennsylvania. By 1950, the urban reach of the Delaware River was one of the most polluted stretches of river in the world.

A remnant of the herring runs in the upper Basin survived by migrating upstream early in the season, when water temperatures were low and flows were high, before low DO ensued. These fish, because of their early arrival, migrated farther up the Delaware to spawn. Runs in the lower Basin survived by spawning below the DO block. Out-migrating juveniles survived by moving downriver late in the season during high flows and low temperatures, thus avoiding the low oxygen waters present around Philadelphia earlier in the fall. Pollution continued to be a major factor until passage of the Federal Clean Water Act in 1972. This Act was instrumental in the elimination of the pollution block in the region around Philadelphia.

12.2. MANAGEMENT UNIT DEFINITION

The Delaware River Drainage Basin consists of the Delaware River, including the East and West branches above Hancock, New York, and its tributaries to the mouth of Delaware Bay, encompassing some 13,539 square miles and 216 tributaries. The Basin includes the states of Delaware, New Jersey, New York, and Pennsylvania. Management authority lies with the New York Department of Environmental Conservation (NYDEC), Pennsylvania Fish and Boat Commission (PFBC), New Jersey

Division of Fish and Wildlife (NJFFW) and Delaware Division of Fish and Wildlife (DFW)

The main-stem of the Delaware River is the longest un-dammed river east of the Mississippi and stretches for 330 miles. There are individual runs of river herring in nearly all of Delaware Basin's larger streams and rivers to at least river-mile 155. The Delaware River north of Port Jervis, NY is a shared water body between the states of New York and Pennsylvania. River herring have not been documented to occur in this section of the Delaware River and will not be discussed in this chapter.

12.3. REGULATORY HISTORY

12.3.1. Commercial Fishery

No specific regulations have been adopted to reduce or restrict commercial landings of river herring, however there are regulations that apply to the commercial fishery that limited commercial fishing effort and have a direct impact on catch and effort. Within the Delaware Bay, unless otherwise noted, these restrictions include a limited entry license system, limitations on the amount of gear allowed to be fished, and season and area closures. As of January 1, 2012 landings of river herring in systems without an approved sustainable fisheries management plan are prohibited. These regulations are in compliance with the Atlantic States Marine Fisheries Commission Amendment 2 to the Fisheries Management Plan for Shad and River herring.

Within Delaware's waters of the Basin, DFW restrictions historically included:

1. Drift nets are prohibited from Saturday through 1600 hours Sunday.
2. No fixed gill nets from January 1 through May 31, and not more than 200 feet of net from June through September in the Delaware River.
3. No fixed gill nets from May 10 through September 30 in Delaware Bay.
4. The use of any type of net within 300 feet of any dam is prohibited on any tributary.
5. The striped bass spawning grounds which include the Nanticoke, Delaware River and C&D Canal are closed to all gill nets from April 1 to May 31.

Within New Jersey's waters of the Basin, NJDFW restrictions historically included:

1. From November 1 to April 30, only haul seines with a mesh size ≥ 2 ¾ inch stretch and with a maximum length of 420 feet can be used in the Delaware River. This is currently limited to one commercial fishery based in Lambertville and rarely harvests river herring,
2. From February 1 through December 15, gill nets may be used in Delaware Bay and River. From February 12 through May 15, the maximum net length allowed is 2400 feet; from May 16 through December 15, the maximum net length is 1200 feet,
3. Gill net small mesh exemption permit (GNSMEP) allows fishers to use gill nets between 2.75 inch stretched mesh to 3.25 inch stretched mesh within two nautical miles of the mean high water line between sunrise and sunset. Holders of these permits are required to report all landings and any weakfish discards.
4. Pound nets are allowed all year in Ocean waters and Sandy Hook/Raritan Bay. In Delaware Bay, pound nets are allowed only during February 15 to May 15

A robust commercial river herring fishery existed near Philadelphia in the late 1800's and early 1900's. This fishery was eliminated by the "DO block" in the mid 1900's. No commercial fishery has existed for river herring within New York's shared portion of the Delaware River. As of January 1, 2012 landings are prohibited within the Delaware and New Jersey portions of the Basin.

12.3.2. Recreational Fishery

Historically, the recreational fishery for river herring was very small with few participants and low retention rates. Those herring that were landed were typically frozen for bait, pickled, kept for their roe or other traditional uses. As of January 1, 2012 the recreational fishery in Delaware, New Jersey and Pennsylvania waters were closed.

Delaware

In the Delaware portion of the Basin, the recreational fishery took place at the various low-head dams that form mill ponds on the majority of Delaware's tidal rivers where herring concentrated during the spring spawning season. Some recreational fishermen used hook and line, but most herring were landed using lift nets (umbrella nets) or dip nets at the peak of the run. Prior to 2005, no recreational limit for river herring existed in the State of Delaware. The catch and effort for river herring has increased as striped bass stocks rebounded and the popularity of using live river herring for bait escalated. In an effort to prevent over exploitation of these small herring runs, a 25 fish per day limit was adopted in 2005. The popularity of this fishery continued to increase and consequently a 10 fish per day possession limit was adopted in spring of 2008 to help conserve remaining spawning stocks and to prevent stock-piling fish in net pens or live cars. In addition, during 2008, Delaware's General Assembly approved legislation that prohibits the use of any net by any fisherman within 300 feet of any dam on any tidal tributary. The 10 fish possession limit and the prohibited use of any net immediately below any dam greatly reduced both catch and effort by forcing recreational fishermen to use only hook and line and to limit landings to the possession limit.

New Jersey

In the freshwater areas of New Jersey, the limit was historically 10 fish per angler per day, while the marine section was 35 fish. Recreational gear included hook and line, dip net, bait seine, cast net. No bait net license was required for the taking of bait fish such as river herring for personal use with the following gear:

1. Dip nets 24 inches or less in diameter,
2. Bait seines 50 feet long or less,
3. Cast nets 20 feet in diameter or less, and
4. Lift or umbrella nets four feet square or less

Pennsylvania

Historically, the sport fishery for river herring in Pennsylvania was almost exclusively a bait fishery which was limited to hook and line fishing, open year-round, with no minimum length limit. Since the mid-1980's, the daily creel limit for river herring in the Delaware River and Estuary was a total of 35 fish. Beginning in 2010, the Pennsylvania Fish and Boat Commission adopted regulations in coordination with New Jersey and later coordinated with New York reducing the daily creel limit from the historic limit to a limit of 10 river herring from the confluence of the East and West Branches downriver to the Commodore Barry Bridge. The remaining 2.9 river miles below the Commodore Barry Bridge remained at the historic daily limit of 35 herring, in cooperation with New Jersey's Marine Council. Sale of sport caught alosines in Pennsylvania is prohibited.

12.4. ASSESSMENT HISTORY

There has been no prior assessment of the river herring stocks of the Delaware River Basin. The

Delaware River was not included in the 1990 ASMFC coastwide stock assessments of river herring from selected Atlantic coast rivers (ASMFC 1990).

12.5. STOCK SPECIFIC LIFE HISTORY

Adult alewife and blueback herring will typically enter the Basin to spawn beginning in early February. Peak activity for alewife occurs during April and the beginning of May, while for blueback herring peak activity occurs during April and through the end of May. The adults emigrate downstream soon after spawning although a minority remains in the ponds through the summer. Larvae will hatch and juvenile will maintain freshwater residence through November, although juvenile emigration can occur as early as the water temperatures decline through the fall. Once mature, adults will return to their natal streams to spawn.

12.6. HABITAT DESCRIPTION

Many of the Basin tributaries contained spawning runs of river herring until pollution, overfishing and dams restricted the population and destroyed spawning habitat.

On the Delaware side of the Basin all of the major tributaries contained spawning runs of river herring as recently as 1990. At that time, there were 13 tidal streams that had either confirmed runs from a variety of adult and juvenile monitoring activities, or the collection of eggs and early life stages during the spring spawning season. All of the tidal streams have reduced amounts of available spawning habitat due to the construction of low-head dams that formed mill ponds dating to the 1800's or earlier 1900's. No new dams have been constructed since the 1960's that interfere with river herring spawning. Although all of Delaware's tidal rivers have been dammed to some extent, there was some suitable spawning and nursery habitat available in each system to sustain at least a remnant stock. All of the tidal streams are relatively short in length. This results in a fairly steep salinity gradient, especially in those rivers that terminate in the lower Bay where the ambient salinity is high. Subsequently, all spawning is usually restricted to the short distance of freshwater near the dam and immediately downstream. In northern Delaware, where springtime salinities in the adjacent Delaware River are very low, the spawning areas are more dispersed, and eggs and larvae are found throughout much of each system. The Christina River is the longest and is approximately 15 miles from the Bay to the first dam. Young of the year river herring use these tributaries for nursery habitat from spring through early fall and then migrate to the mainstem Delaware River and Bay. Those adults (typically blueback herring) that use the ladders generally do so during the peak of the run and all spawning occurs in the impoundment; no movement into upstream tributary streams has been documented. The adults emigrate downstream soon after spawning although a minority remains in the ponds through the summer. The juvenile year class generally congregates in the deeper waters near the dam in October and leave as the water temperatures decline through the fall.

On the New Jersey side of the Basin, it is estimated from 1953 to 1973, 61,678 acres of coastal wetlands and uncounted acreage of adjacent transitional wetlands were lost to filling and diking (Ferrigno et al 1973). Field investigations during the early to mid-1970s confirmed 132 river herring spawning runs (108 alewife and 24 blueback) in rivers and streams that were contiguous with the marine environment (Zich 1977). Zich concluded that nine herring runs had already become extinct. Also during these field investigations, 83 constructed barriers were found on streams where herring runs were reported or confirmed. These barriers were assessed to be blocking or limiting fish passage and therefore reducing spawning habitat. There is no current estimate as to whether or not this number has changed significantly since that time. Recent efforts have been undertaken to restore river herring runs in some of these systems by removing dams, installing fish ladders and/or trap and transport.

12.7. RESTORATION PROGRAMS

Efforts in Delaware and New Jersey have been undertaken to restore river herring runs in some of these systems by installing fish ladders. Twelve tidal streams located within the Delaware River/Bay watershed have fish ladders installed (eight in Delaware and four in New Jersey) at the first upstream dam to allow for river herring passage into the non-tidal impoundments above the dams. The fish ladders are all of Alaskan Steeppass design and are operated to allow for increased spawning and nursery habitat. All of the ladders have been monitored at some level to determine passage rates and develop species use following construction. All fish using the ladder were trapped in a fish ladder exit trap, identified, counted and released. Only target species were released into the impoundment. A target passage rate of 5 adults per surface acre was established for all ladders as a threshold for successful river herring passage. Once the target rate was achieved, annual monitoring was suspended. Annual monitoring has continued at those ladders that have not met the 5 fish per surface acre target. Some engineering modifications to the entrance to the ladders have been done to enhance passage. Monitoring at the ladders was discontinued at those sites that achieved their target for two consecutive years to avoid potentially impacting spawning behavior. Monitoring resumes at these sites every third year to determine trends in abundance and continued use. A supplemental stocking program for river herring was initiated in some impoundments as part of their restoration efforts (Table 12.5). This stocking element was dependent on the availability of adult river herring in hopes of increasing spawning run size in subsequent years. No stocking occurred during 2005 through 2009 due to the limited availability of adult herring for trap and transfer.

Within Pennsylvania, restoration efforts have also focused on dam removal and installation of fish passage. Fishways have been constructed in the Schuylkill River at Fairmount Dam (rebuilt in 2008), Flat Rock Dam (2007), Norristown Dam (2007), and Black Rock Dam (2009), which, along with dam removals have opened up 100 river miles to migratory fish. Fishways have been built on the Lehigh River at Easton Dam (rebuilt in 2001), Chain Dam (rebuilt in 2001), and Hamilton Street Dam (1983), opening up 24 river miles to migratory fish. Dam removals have occurred in Ridley Creek (2 dams), Chester Creek (2 dams), Neshaminy Creek (2 dams), Darby Creek (4 dams, 10.5 miles opened), and Pennypack Creek (7 dams, 22 miles opened).

12.8. AGE

No age data has been reported from the Delaware Basin.

12.9. FISHERY DESCRIPTION

Fisheries data, with some exceptions, is reported and compiled by state. There is no commercial fishery within Pennsylvania.

12.9.1. Commercial Fishery

Delaware

Delaware's commercial landings were determined annually from mandatory commercial catch reports under the provisions enacted by the Delaware General Assembly in 1984 (Greco et al. 2007). 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. The reported commercial gill net landings and the kilograms of fish landed per meter of gill net for Delaware's portion of the Delaware Estuary are found in Table 12.1 and Figure 12.3. The effort data reflects days that fishermen actually landed river herring and does not account for days when the species was not landed.

The commercial fishery for river herring is relatively small but highly variable in Delaware, ranging from

500 lbs to 36,000 lbs annually since 1985. Commercial landings occur from February through May with peak landings in March and April. Landings occur from all of the broader regional areas of Delaware but the Nanticoke River has traditionally yielded the majority of landings and it also has the largest herring runs of any of the tidal streams in the state (see Section 13 for more information on the fishery in the Nanticoke River). Both species are represented in the catch but the majority is probably blueback herring based on observations of relative abundance and temporal distributions within state waters.

Adult river herring in Delaware have not been sampled for any biological characteristics such as size, sex, and age structure or species composition. In the past there has been concern over the misidentification of river herring by commercial watermen in the Delaware Estuary. Analysis of past data has resulted in a cutoff date of June 1 for reported herring landings. Landings were reported monthly until 1989, after which they were reported on a daily basis. The commercial fishery for river herring is relatively small in Delaware, contributing only an estimated $248 of dockside cash value to Delaware's total estimated dockside value of $0.9 million for all species combined in 2010.

New Jersey

New Jersey river herring landing estimates were obtained from two sources (Table 12.5 and 12.8). The NMFS estimates (1950 to 2010) are for the entire state, while mandatory logbooks of the GNSMEP (2000 to 2010) are from Delaware Bay. The average reported NMFS landings for the time period is estimated at 8,180 pounds. There are no estimates of underreporting, however it is assumed that the current data for river herring is underreported since some landings may be categorized as bait.

The GNSMEP is primarily directed towards white perch and other species with river herring being a harvestable bycatch. The gear is not standardized and therefore the data should only be used for potential trends and not absolute numbers. Harvest was only categorized as herring and could include some Atlantic herring landings. A CPUE developed for this data shows a declining trend since 2000 (Table 12.1 and 12.8).

12.9.2. Recreational Fishery

Delaware

There are over 500 'recreational' gill net permits issued to Delaware fishermen. The permit stipulates that a fisherman is entitled to set up to 200 feet of anchored or fixed gill net with a minimum mesh size of 3.25 inches. Many commercial crabbers hold these permits which allow them to catch bait, primarily Atlantic menhaden. River herring were also reported as discards from this fishery but were highly variable ranging from 6 fish per year to over 1,000. All recreational gill net fishermen abided by the same seasons, size and creel limits for foodfish that applied to recreational anglers except the harvest of certain species (such as striped bass) was not allowed. From 1996 through 2003 annual total harvest estimates ranged from 4,400 fish in 1996 to 297 in 2002 (Table 12.2). The number of river herring harvested per trip declined steadily from 1998 through 2004 (Table 12.2).

New Jersey

The only survey of the recreational fishery for river herring within the Delaware Basin was an access point survey in conjunction with an aerial effort survey conducted by Versar, Inc. during 2002 (Volstad et al 2003). The study area included all tidal and non-tidal waters from the Delaware Memorial Bridge to Downsville, NY.

A total of 7,553 river herring were estimated to be caught and 4,916 were harvested by recreational anglers in the Delaware River for 2002. Angler catch rate was estimated 0.0189 per angler hour and the harvest rate was estimated at 0.0123 per angler hour.

12.9.3. Subsistence Fishing

There is no known subsistence fishery for river herring within the Basin.

12.9.4. Characterization of Other Losses

There are many potential unknown sources of mortality from power plant intakes, commercial discards, and landings categorized as "bait". Many of these could be significant. The increased popularity of herring used as bait for striped bass fishing is an additional source of unknown loss within the Basin.

12.10. FISHERY-INDEPENDENT SURVEYS

12.10.1. Spawning Stock Surveys

The Delaware Estuary is monitored annually by DFW to document the relative abundance and distribution of a number of important finfish species. A 30-foot bottom trawl was used to sample nine fixed stations in the Delaware Bay from March through December (Michels and Greco 2010). Tow duration was 20 minutes with a minimum tow time of 10 minutes required for the data to be considered valid. A global positioning system (GPS) was used to determine exact vessel position at the start and conclusion of each tow. Odometer readings from the GPS unit were used to determine distance towed (nautical miles). Adult densities were calculated for blueback herring and alewife by dividing the number of individuals for a species by the distance towed (N/NM) at each station sampled, then calculating arithmetic means and standard errors in the typical fashion.

Length frequencies have been determined for blueback herring (Figure 12.9) and alewife (Figure 12.10) resulting from collections during the adult finfish surveys conducted on the Delaware Bay. Species represented by less than 50 individuals were measured for fork length to the nearest half-centimeter. Species with more than fifty individuals were randomly sub-sampled (50 measurements) for length with the remainder being enumerated.

One of the area utilities Public Service Electric and Gas (PSEG) constructed and maintained fish ladders on Delaware River Estuary tributaries for spawning run restoration of alewife and blueback herring (Table 12.3). Alaska Steeppass fish ladders have been installed at twelve sites: Sunset Lake, Stewart Lake, Newton Lake, and Cooper River Lake in New Jersey, and Noxontown Pond, Silver Lake (Dover), Silver Lake (Milford), McGinnis Pond, Coursey Pond, McColley Pond, Garrisons Lake and Moores Lake in Delaware. Adult passage monitoring typically occurred from March to early June. Sampling was performed using a fish ladder exit trap net. Sites were not sampled every year. Sampling was stopped when a fish ladder consistently passed adult herring, to avoid potentially impacting spawning behavior.

12.10.2. Juvenile Surveys

The Delaware Estuary is monitored annually by DFW to document the relative abundance and distribution of a number of important juvenile finfish species encountered during 16-foot sampling in the Delaware Bay and River from April through October at 39 fixed stations. Tow duration was 10 minutes for the 16-foot trawl survey. A global positioning system (GPS) was used to determine exact vessel position at the start and conclusion of each tow. Odometer readings from the GPS unit were used to determine distance towed (nautical miles). JAIs were determined for yoy and age 1 blueback herring and alewife resulting from collections during juvenile finfish surveys. Fish densities were calculated by dividing the number of individuals for a species by the distance towed (No/NM) at each station sampled, then calculating arithmetic means and standard errors. Length frequencies have been determined for blueback herring and alewife resulting from collections during juvenile finfish surveys conducted on the Delaware River and Delaware Bay. A representative subsample of 30 juvenile specimens per species was measured for fork length to the nearest millimeter; the remainder was enumerated.

The reproductive success of YOY river herring was assessed, prior to assumed out-migration, in Delaware ponds using a boat-mounted pulsed-DC electrofisher by DFW staff during 1995-96 and 2000 to the present (Jacobini 2010). Fall samples were obtained to determine spawning success and recruitment and relative abundance between impoundments. Most of these impoundments are small, averaging less than 64 acres, and the entire pond can be surveyed relatively quickly. Young river herring are either counted individually or size of the schools estimated. Subsamples are taken to determine species composition and size ranges. The CPUE was calculated using the total river herring observed which included estimates of larger schools. Estimates of total production are not determined. Careful analysis of the juvenile electrofishing data is warranted since not all impoundments were equally sampled throughout the time period.

PSEG also conducted electrofishing twice a month from September through November to gauge juvenile river herring presence and relative abundance at the impoundments discussed earlier in this document (Table 12.6). Fish were counted each time the foot switch was pressed. The count of small numbers of fish was an exact count. Estimates of larger numbers of fish were made in 10, 25, 50, 100, 150, and 200 fish increments. Sampling frequency and locations varied. Additionally, when herring were encountered in considerable numbers, electroshocking was briefly interrupted to limit the stress on the fish. The survey was discontinued in 2005.

New Jersey has conducted a juvenile abundance survey for striped bass in the Delaware River from Trenton to Artificial Island since 1980. The program utilizes a 100-foot bagless beach seine during the months of August, September, and October at representative stations. A juvenile abundance index (JAI) is calculated for alewife and blueback herring using a geometric mean. Since river herring are not collected at all stations, those farthest downriver stations (below the Delaware Memorial Bridges) have been removed from analysis to give a more accurate picture of juvenile production in the lower Delaware River. Length frequencies of juvenile blueback herring and alewife have been determined from collections since 2002 (Table 12.9). A representative subsample of 30 juvenile specimens per species was measured for fork length to the nearest half centimeter; the remainder was enumerated. No trends were discernible from this short time series of data.

12.11. ASSESSMENT APPROACHES AND RESULTS

The purpose of this report is to document and update the stock status of river herring in the Delaware River and Estuary. It is obvious from historical data and anecdotal information that river herring populations were much larger in the past and have declined drastically since the late 1800s.

12.11.1. Spawning Stock Abundance

Adult river herring commercial landings are typically the result of bycatch from other fisheries like the white perch fishery. Overall landings data in both New Jersey and Delaware show that landings have declined in recent years. The best indicator of the commercial fishery seems to be the CPUE from mandatory commercial catch reports. In Delaware, the commercial CPUE for the Delaware Estuary has been in decline since the mid-1990's and the lowest CPUE in the time series for the Delaware River occurred in 2010. The New Jersey commercial CPUE, except for 2000, has decreased since 1997. The recreational gill net CPUE for Delaware peaked in 1998 with no data between 2004- 2006, then a slight incline with data collected in 2007. The declines seen in the commercial and recreational data could be a result of declining stocks, declining effort, or regulatory changes.

Adult data from Delaware's finfish trawl survey show the greatest recent increase in alewife abundance occurred from 1996-1998. After 1998 alewife relative abundance decreased and has remained at substantially depressed levels since 2002. Blueback herring varied without trend throughout the 1990's prior to good year classes in 1999 and 2000. Blueback herring abundance has trended downward from 2001-2003 and has remained at depressed levels without trend since 2003.

The aggregate PSEG fish ladder passage CPUE (#/Hr) has trended downward since 1996 in Delaware and New Jersey ponds. This index has declined throughout the time series from the highest value of 0.5 in 1996 to the lowest value of 0.01 in 2010 (PSEG 2009). Blueback herring have been the primary users of the fish ladders and river herring runs in the Basin are dominated by blueback herring overall. Alewife use of the ladders increases slightly in the northern part of the Basin. These numbers need to be considered with certain caveats however. For blueback herring, ladders that had high usage are no longer sampled every year. Likewise, newer ladders have yet to see any significant usage but are monitored 24 hours per day. The increase in alewife usage comes mainly from the Sunset Lake (NJ) fish ladder where restoration seems to be going well for alewife while all other fish ladders have yet to see the same results.

12.11.2. Juvenile Abundance

The annual abundance (geometric mean catch per tow) from 16-foot otter trawl sampling for YOY alewife in the Delaware River and Bay varied without trend throughout the time series with peak years in 1996, 2000, 2003 and 2007. The Age 1 alewife index declined since the highest value was reached in 1997. The YOY index for blueback herring increased slightly from 1990 through 2003, but substantial declines were noted since then. The age 1 blueback herring index has varied substantially since 1991 with no discernible trend. It is unknown if these changes in the trawl index are actual trends or more a function of gear inefficiency. A bottom trawl is not the most efficient gear for capturing alosines, and can result in low sample numbers. Environmental conditions may have also played a factor in the number of river herring captured.

The PSEG electrofishing survey for YOY alewife fluctuates wildly but shows an increasing trend. The blueback herring index shows an increasing trend from 1996 to 2001 before declining through 2005 when sampling was discontinued (PSEG 2009).

Overall CPUE (catch per minute) of YOY river herring collected during electrofishing efforts throughout seven Delaware impoundments by DFW staff exhibited the highest values in 1999, 2004 and 2007. However, the overall CPUE is often driven by a single pond's catch and does not represent an overall trend in use or reproductive success. For example the 1999 and 2004 CPUE were driven by high numbers sampled primarily in one pond (Wagamon's Pond). The 2007 value was driven by a high number of river herring caught in McColley Pond as well.

Juvenile production was very low for both species in the early years of the NJDFW striped bass survey (Table 12.9). Since that time, the blueback herring index was varied with a fairly steady increase in blueback herring production from 1980 through the first real high year class in 1993. From 1993 through 2001, the survey included two additional large year classes (1996 and 2001) with some production years below average. Since 2001 the production of blueback herring has decreased with five straight years of below average recruitment. Abundance of YOY alewife has fluctuated without trend with years of high abundance (1988, 1996, 2001 and 2005) mixed with years of low abundance (1992, 1998, 2002, and 2006). More recent alewife trends are similar to blueback herring, although 2007 was considered a good year. It should be noted that environmental conditions in 2002 (drought) and 2006 (floods) were not conducive for good spawning or survival of either species.

12.12. BENCHMARKS

No benchmarks were developed at this time for river herring fisheries in the Basin.

12.13. CONCLUSIONS AND RECOMMENDATIONS

The data is presented here is a stock status report update of the original stock status report of 2008, and is not intended as a full assessment of river herring within the Delaware River Basin. Additional assessment techniques and data should be used in attempt to determine why these stocks have declined in recent years. This would include comparisons to data from other east coast river systems, predation, fishing mortality estimates if available, and offshore harvest and discards.

Overall river herring landings in the Delaware Basin have declined since 1992. Although fish passage may have been considered fair to good in some years, reproduction in these freshwater impoundments has been poor overall. The installation of fish ladders in Delaware ponds have resulted in little success and it appears that to date this effort has been ineffective in restoring river herring populations. However, alewives in New Jersey have increased in recent years due to an increase in passage at the Sunset lake fish ladder.

The overall assessment of data from these stocks indicates stocks have declined. The reason for this is unknown. There are no estimates of mortality for the Delaware Basin stocks of river herring so it is not possible to determine the cause or causes of this decline. It would be beneficial to undertake a more rigorous investigation of the population dynamics of these species within and outside the Delaware River basin.

For the Delaware River basin states this would include:

- Improved assessment of river herring adults at all fish ladder installations such as tagging studies below the ladders to estimate population numbers and ladder passage rates
- Improved assessment of river herring production in targeted tributaries within the basin
- Predator-prey relationships especially with striped bass, bluefish and white perch for yoy and striped bass, weakfish, bluefish, spiny dogfish for adults
- Habitat evaluations

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Table 12.1 Delaware Estuary Gill Net Landings and CPUE (Source: DFW).

Year	Kgs Landed	CPUE (kgs/ net meter)
1985	2158	0.044
1986	643	0.015
1987	496	0.010
1988	1263	0.009
1989	1560	0.112
1990	746	0.046
1991	3305	0.070
1992	307	0.018
1993	2568	0.102
1994	170	0.043
1995	110	0.019
1996	679	0.071
1997	44	0.014
1998	181	0.017
1999	128	0.042
2000	223	0.028
2001	562	0.053
2002	38	0.012
2003	196	0.029
2004	231	0.023
2005	8	0.003
2006	579	0.016
2007	85	0.005
2008	886	0.064
2009*	**confidential**	
2010*	**confidential**	

Table 12.2 Recreational fishery for river herring in Delaware, 1996 – 2003, and 2007 (Source DE DFW).

Year	Harvested N	Released Alive N	Total N	# of Fishers	Effort Trips	Net Yard Days	Catch per Trip	Harvest per Trip
1996	4399	.	4399	391	3,808	196,381	1.16	1.16
1997	2247	.	2247	274	2,291	111,659	0.98	0.98
1998	2835	.	2835	269	1,161	55,453	2.44	2.44
1999	460	14	474	27	948	49,342	0.50	0.49
2000	1134	6	1140	197	1,560	84,396	0.73	0.73
2001	502	1028	1530	198	1,686	82,301	0.91	0.30
2002	297	48	345	179	1,615	83,022	0.21	0.18
2003	370	43	413	173	1,390	65,779	0.30	0.27
2004	No Data	.	.	.	.	.	.	.
2005	No Data	.	.	.	.	.	.	.
2006	No Data	.	.	.	.	.	.	.
2007	341	495	836	144	878	43,096	0.95	0.39

Table 12.3 Fish ladder information from PSEG

	Ladder Date	Size (acres)	Length (miles)	Perimeter (miles)	Lake Watershed (acres)
New Jersey					
Cooper River Lake	1998	190	4.53	9.57	23,680
Newtown Lake	2004	41	2.87	6.03	2,332
Stewart Lake	2004	38	1.17	4.39	2,897
Sunset Lake	1997	94	0.67	2.1	29,248
Delaware					
Coursey Pond	1997	58	0.72	2.48	14,579
Garrison Lake	1999	86	0.76	2.19	10,752
McColley Pond	1996	49	1.14	3.34	6,080
McGuiness Pond	1996	31	0.76	2.16	7,040
Moores Lake	1999	27	0.76	1.87	11,776
Noxontown Pond	2004	162	1.99	7.03	6,110
Silver Lake (Dover)	1996	171	1.71	4.52	20,480
Silver Lake (Milford)	2004	27	0.49	1.56	17,326

Table 12.4 PSEG river herring fish passage CPUE for Delaware and New Jersey Ponds. Source: NJ DFW.

Year	Effort	BB	AW
1996	239	0.490	0.013
1997	593	0.312	0.002
1998	3501	0.196	0.006
1999	7384	0.176	0.031
2000	12242	0.118	0.007
2001	14684	0.134	0.006
2002	14552	0.181	0.019
2003	14928	0.059	0.013
2004	17679	0.065	0.054
2005	16053	0.022	0.002
2006	12232	0.016	0.002
2007	13103	0.008	0.025
2008	17987	0.138	0.010
2009	19942	0.010	0.028
2010	13165	0.010	0.060

Table 12.5 PSEG river herring stocking for Delaware and NJ Ponds (1996-2004). Source: NJ DFW.

Bluebacks										
Impoundment	1996	1997	1998	1999	2000	2001	2002	2003	2004	Total
Cooper River Lake (NJ)	N/A	N/A	766	1,069	964	1,071	840	197	0	4,907
Coursey Pond	N/A	0	156	0	0	0	0	0	0	156
Garrisons Lake	N/A	N/A	N/A	318	48	473	432	0	17	1,288
McColley Pond	8	0	7	11	0	0	0	0	0	26
McGinnis Pond	32	0	211	166	0	241	0	22	11	683
Moore's Lake	N/A	N/A	N/A	271	70	0	0	0	0	341
Newton Lake (NJ)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Noxontown Pond	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	23	23
Silver Lake (Dover)	84	0	713	687	419	993	865	201	0	3,962
Silver Lake (Milford)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Stewart Lake (NJ)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sunset Lake (NJ)	N/A	50	1,045	892	430	1,337	756	969	126	5,605
Alewife										
Impoundment	1996	1997	1998	1999	2000	2001	2002	2003	2004	Total
Cooper River Lake (NJ)	N/A	N/A	0	0	0	0	0	0	0	0
Coursey Pond	0	0	0	0	0	0	0	0	0	0
Garrisons Lake	N/A	N/A	N/A	0	0	0	0	0	0	0
McColley Pond	0	0	0	0	0	0	0	0	0	0
McGinnis Pond	0	0	0	5	0	0	0	0	0	5
Moore's Lake	N/A	N/A	N/A	0	0	0	0	0	0	0
Newton Lake (NJ)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Noxontown Pond	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0
Silver Lake (Dover)	0	0	0	0	0	0	0	0	0	0
Silver Lake (Milford)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Stewart Lake (NJ)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sunset Lake (NJ)	N/A	0	0	3	71	0	254	0	0	328

Table 12.6 PSEG river herring electrofishing CPUE for Delaware and New Jersey Ponds. Source: NJ DFW.

Year	Effort	Blueback	Alewife
1996	707.4	0.062	0.000
1997	470.8	0.520	0.002
1998	618.6	4.470	0.000
1999	493.6	26.244	0.063
2000	433.1	12.136	0.028
2001	499.5	49.215	0.212
2002	434.9	8.533	0.000
2003	433.9	15.266	0.364
2004	720	5.819	0.013
2005	720	6.639	0.554

Table 12.7 New Jersey commercial river herring (alewife and blueback herring) landings, in pounds (1950 – 2010). NMFS landings are statewide; Logs are from the Delaware Basin. Source: NJ DFW.

Year	NMFS	Logs		Year	NMFS	Logs
1950	29,000	-		1981	13,800	-
1951	7,200	-		1982	13,600	-
1952	600	-		1983	2,200	-
1953	8,600	-		1984	3,100	-
1954	0	-		1985	4,800	-
1955	22,900	-		1986	4,200	-
1956	22,300	-		1987	5,200	-
1957	8,100	-		1988	700	-
1958	1,400	-		1989	800	-
1959	2,200	-		1990	42,494	-
1960	3,000	-		1991	9,994	-
1961	16,500	-		1992	3,069	-
1962	20,300	-		1993	2,659	-
1963	3,400	-		1994	328	-
1964	14,200	-		1995	795	-
1965	21,500	-		1996	4,449	-
1966	12,400	-		1997	4,515	9,229
1967	9,000	-		1998	7,371	-
1968	8,400	-		1999	1,377	3,885
1969	5,100	-		2000	0	5,335
1970	7,500	-		2001	1,034	2,881
1971	9,500	-		2002	3,366	1,303
1972	14,700	-		2003	228	3,439
1973	7,000	-		2004	2,548	4,583
1974	10,600	-		2005	1,079	2,964
1975	9,300	-		2006	469	2,866
1976	11,300	-		2007	0	223
1977	10,600	-		2008	631	1,890
1978	2,400	-		2009	0	489
1979	6,600	-		2010	N/A	1,004
1980	18,600	-		AVG	8,180	3,084

Table 12.8 New Jersey Commercial CPUE for Delaware Bay (1997-2010). Source: NJ DFW.

Year	Hr*Ft/100	Lbs	CPUE
1997	15,248	9,221	0.60
1998	8,100	2,430	0.30
1999	22,608	3,880	0.17
2000	6,846	5,410	0.79
2001	12,696	1,900	0.15
2002	17,872	552	0.03
2003	12,160	2,127	0.17
2004	43,348	3,192	0.07
2005	40,176	2,402	0.06
2006	45,288	2,793	0.06
2007	-	-	-
2008	49,176	1,551	0.03
2009	29,808	177	0.01
2010	26,688	409	0.02

Table 12.9 Delaware River index of relative abundance, geometric mean, for juvenile river herring collected during New Jersey's striped bass young of year survey (1980-2010). Source: NJ DFW.

YEAR	Alewife	Rank	Blueback	Rank
1980	0.00	27	30.30	2
1981	0.00	27	0.26	30
1982	0.10	20	3.19	23
1983	0.28	11	46.15	1
1984	0.00	27	16.99	8
1985	0.06	22	7.17	16
1986	0.52	6	18.13	6
1987	0.23	14	10.72	10
1988	3.17	1	9.03	13
1989	0.18	16	17.90	7
1990	0.26	12	4.63	19
1991	0.47	7	9.84	11
1992	0.03	24	6.91	17
1993	0.35	9	19.78	5
1994	0.19	15	2.38	25
1995	0.11	19	1.84	26
1996	1.96	2	24.97	4
1997	0.15	17	2.61	24
1998	0.03	25	4.36	20
1999	0.41	8	5.34	18
2000	0.14	18	12.33	9
2001	0.83	4	26.33	3
2002	0.00	27	0.62	29
2003	0.30	10	7.50	15
2004	0.24	13	8.15	14
2005	0.95	3	9.79	12
2006	0.00	27	0.15	31
2007	0.52	5	4.29	21
2008	0.01	26	1.37	27
2009	0.06	21	3.55	22
2010	0.04	23	1.26	28
1980-2010	**0.37**		**10.25**	
2001-2010	**0.30**		**6.30**	
2006-2010	**0.13**		**2.12**	

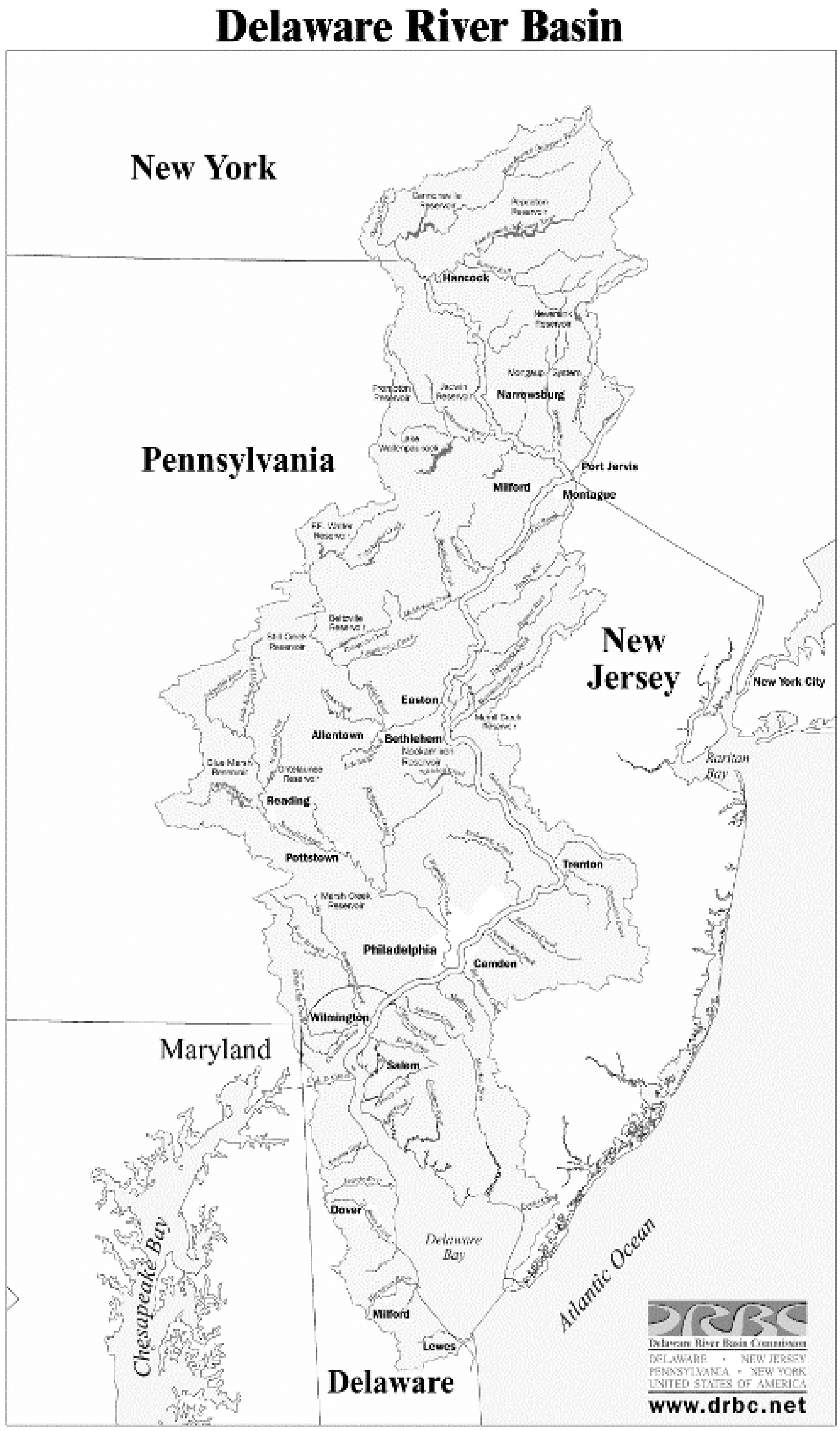

Figure 12.1 Map of the Delaware River/Bay Watershed.

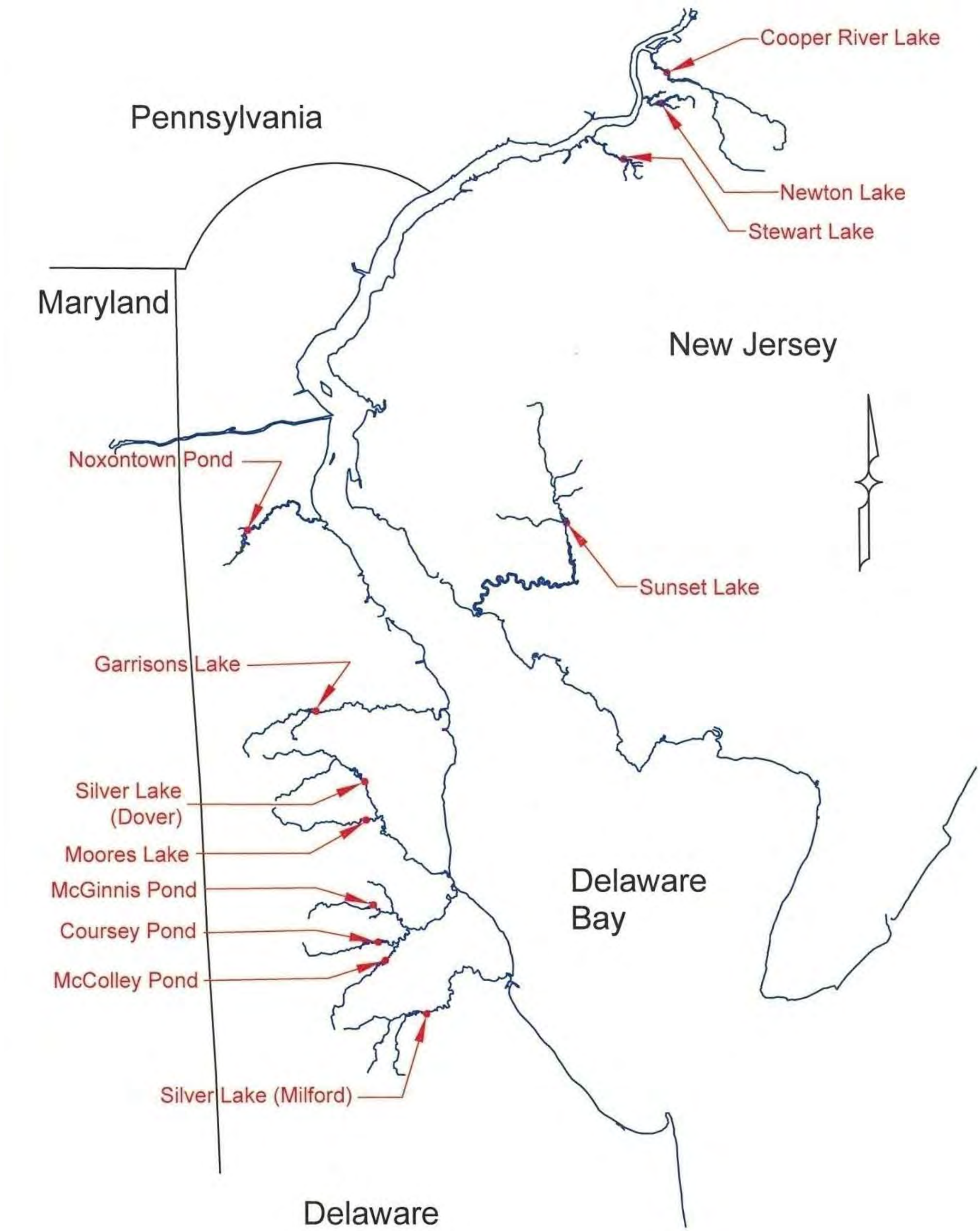

Figure 12.2 Locations of PSEG fish ladders within the Delaware River Basin (2009).

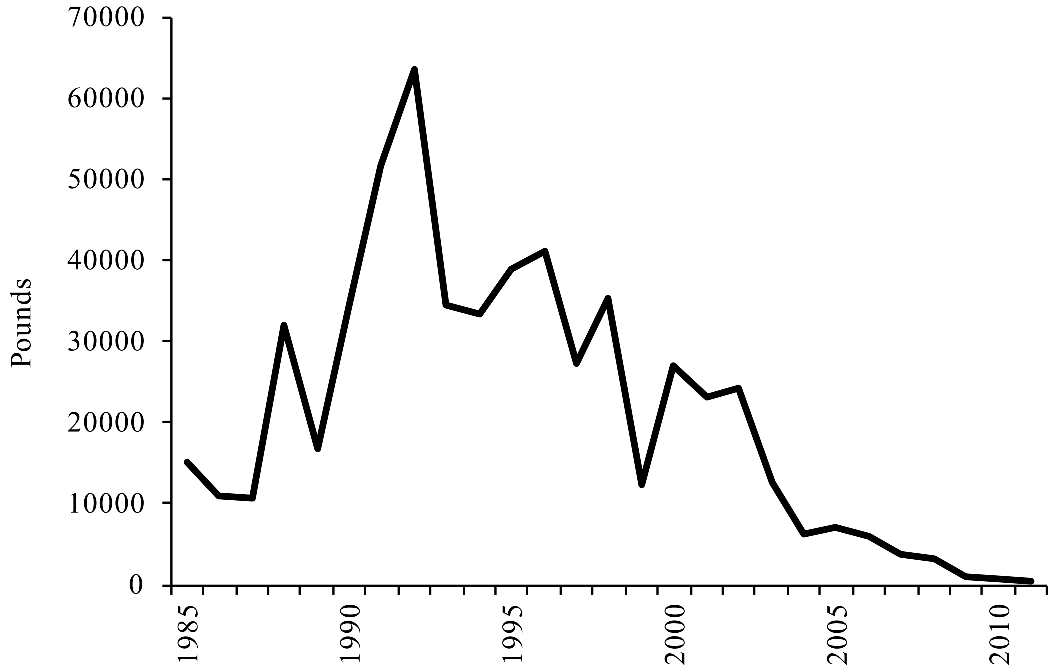

Figure 12.3 The reported **statewide** river herring commercial landings for Delaware, all gears combined. Source: DE DFW

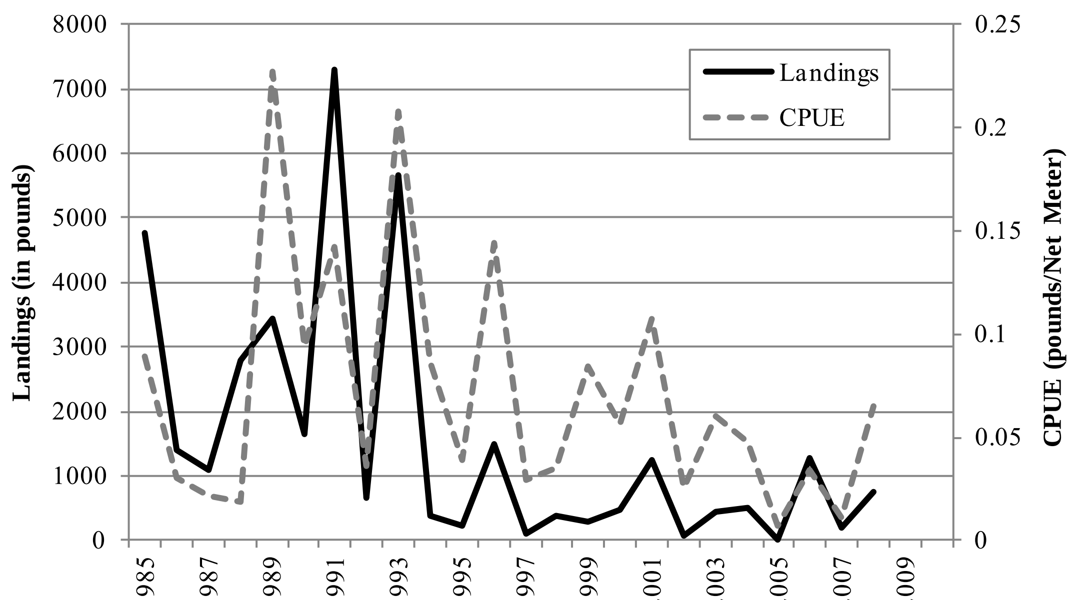

Figure 12.4 The reported commercial gill net landings and the pounds of fish landed per meter of gill net for Delaware's portion of the **Delaware Estuary**. *** Data from 2009 and 2010 are confidential.** Source: DE DFW

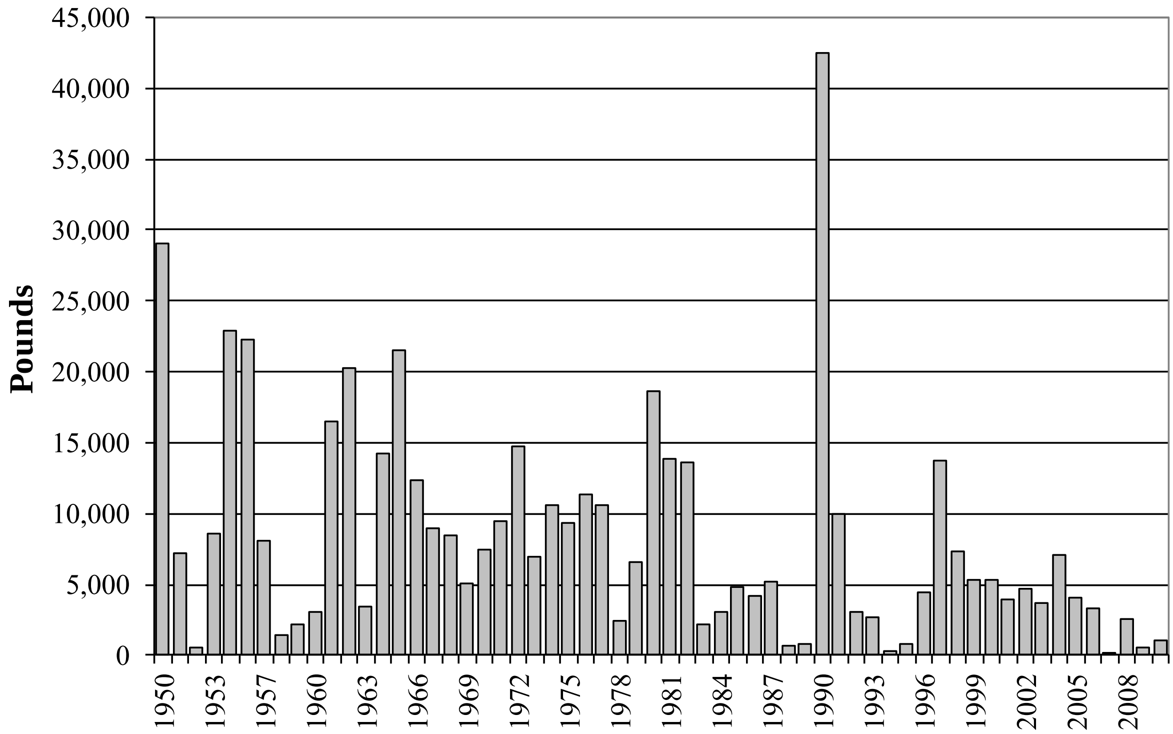

Figure 12.5 New Jersey Reported Commercial Landings (1950-2010). Source: NJ DFW

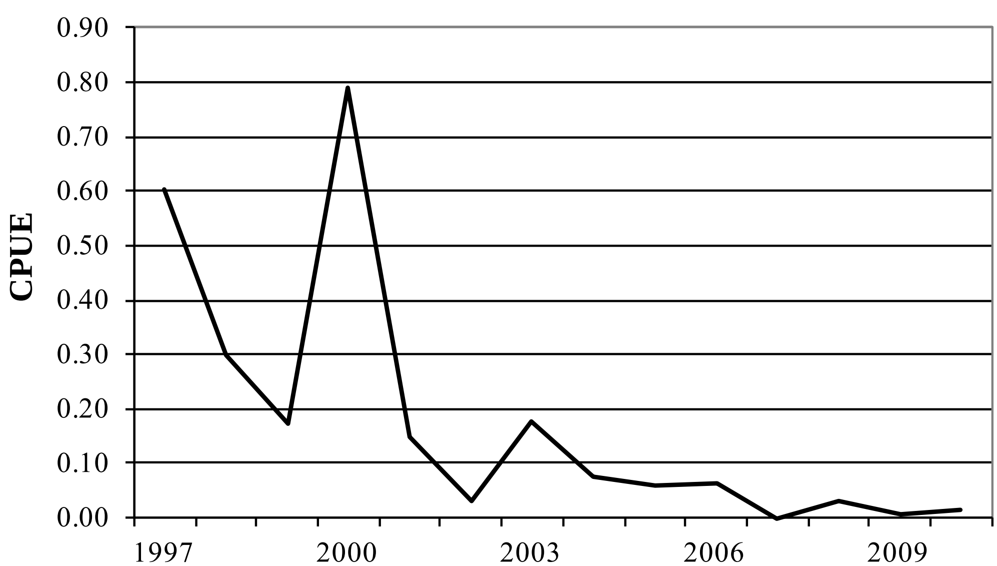

Figure 12.6 New Jersey Commercial CPUE for lower Delaware Bay (1997-2010). Harvest is bycatch in small mesh weakfish/perch fisheries during February to May. Source: NJ DFW

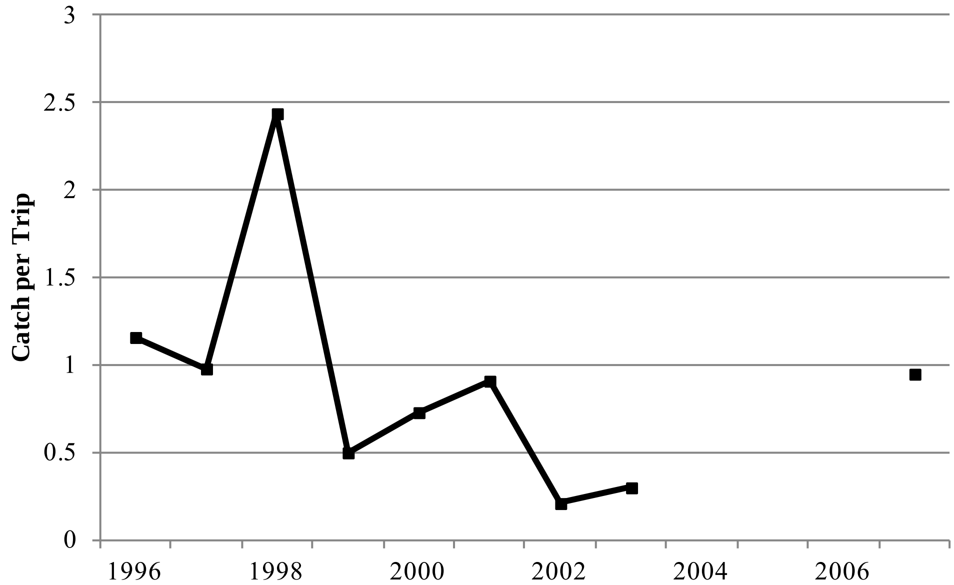

Figure 12.7 The recreational gill net fishery annual catch per trip for river herring in Delaware (1996 – 2003 and 2007). Source: DE DFW

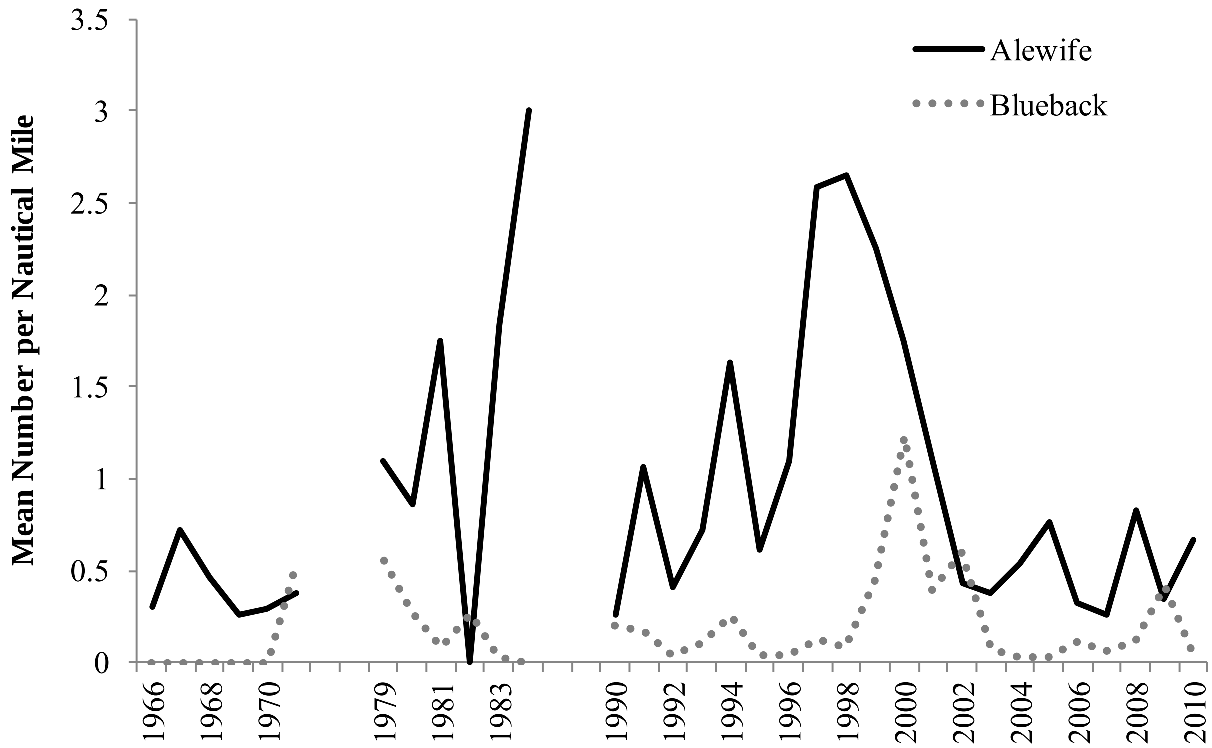

Figure 12.8 Adult River Herring indices for the Delaware Bay 30 foot trawl: 1966 – 2010. There is no data for 1972-1978 and 1985-1989. Source: DE DFW.

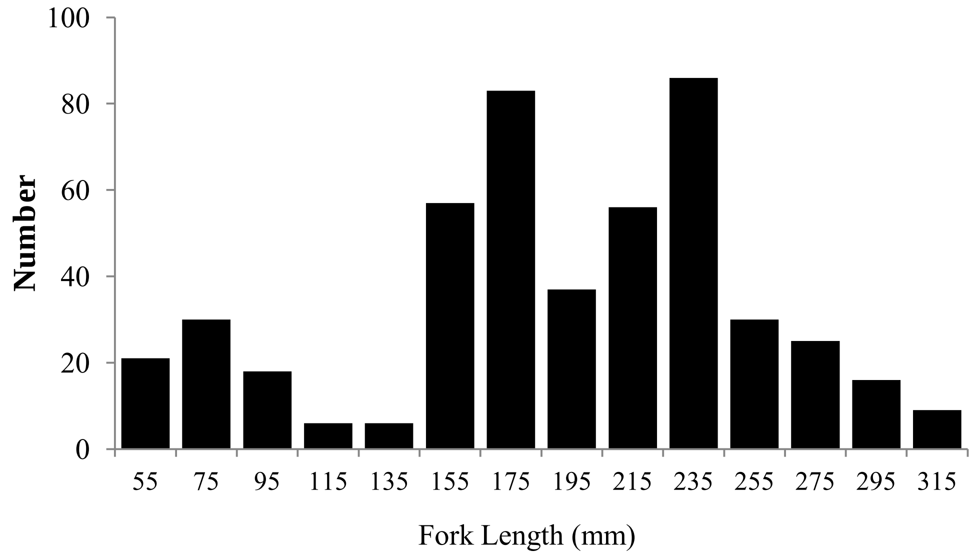

Figure 12.9 Adult Blueback Herring length frequencies for the Delaware River/Bay 30 foot trawl: 1966 – 2007. There was no data for 1972-1978 and 1985-1989. Source: DE DFW.

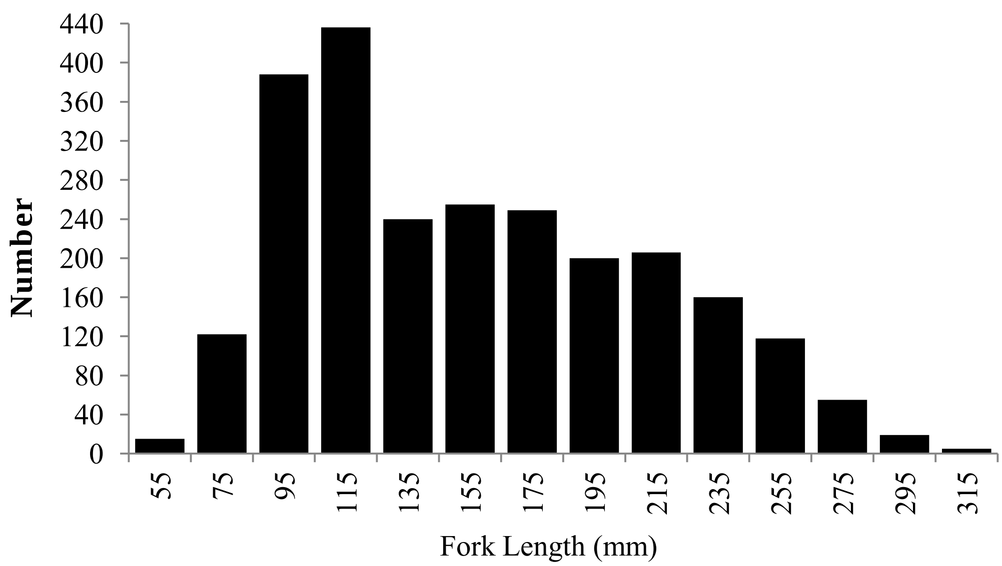

Figure 12.10 Adult Alewife length frequencies for the Delaware River/Bay 30 foot trawl: 1966 – 2007. There was no data for 1972-1978 and 1985-1989. Source: DE DFW.

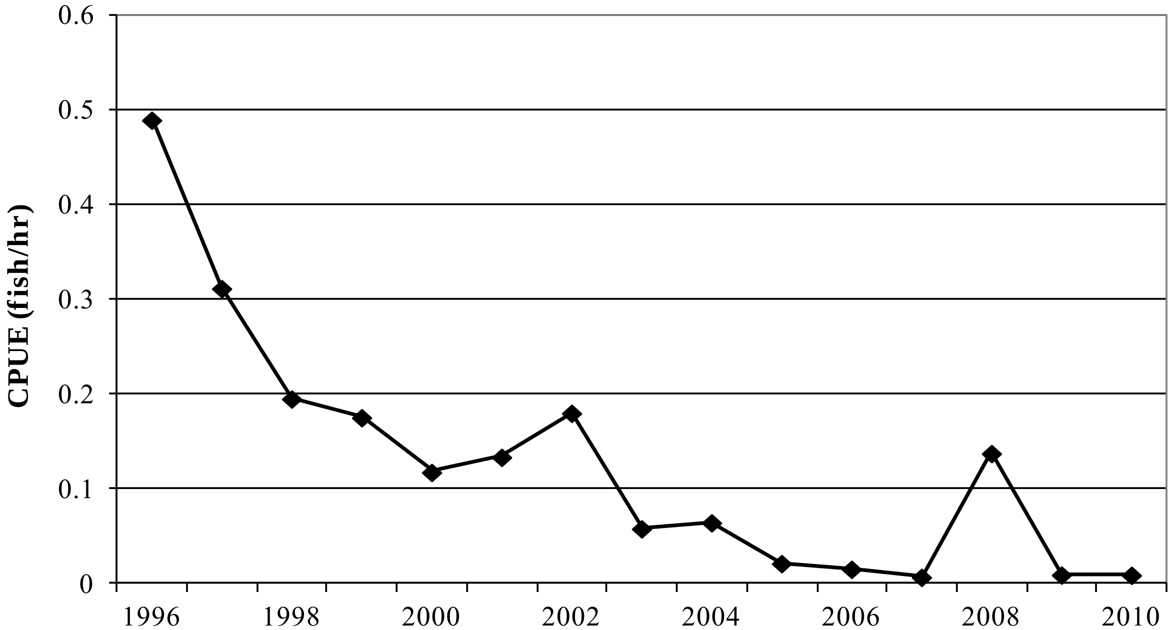

Figure 12.11 PSEG blueback herring fish passage CPUE (fish per hour) for Delaware and New Jersey Ponds. Source: NJ DFW.

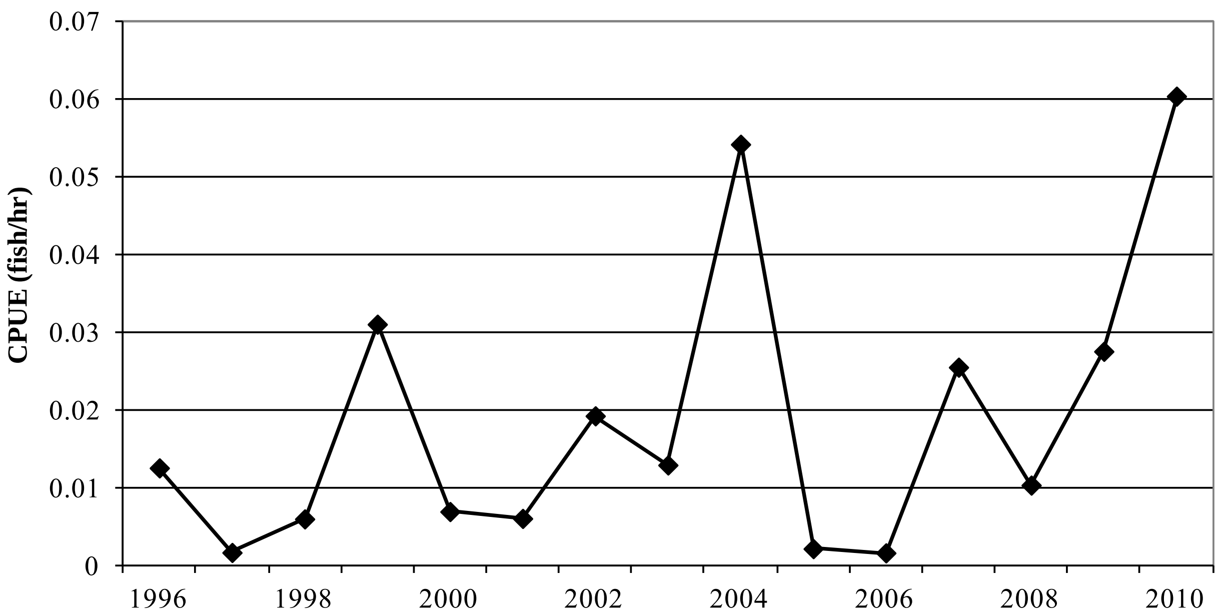

Figure 12.12 PSEG alewife fish passage CPUE (fish per hour) for Delaware and New Jersey Ponds. Source: DE DFW.

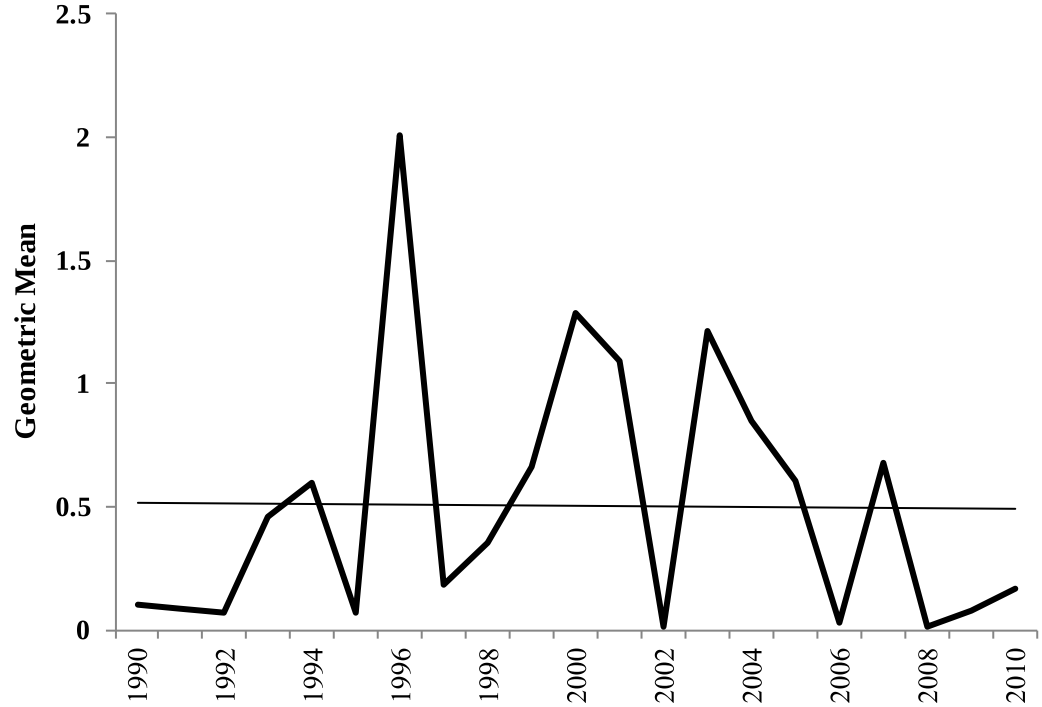

Figure 12.13. Annual YOY alewife relative abundance index (geometric mean catch per tow) and trend from the 16 foot otter trawl survey in the Delaware Estuary. Source: DE DFW.

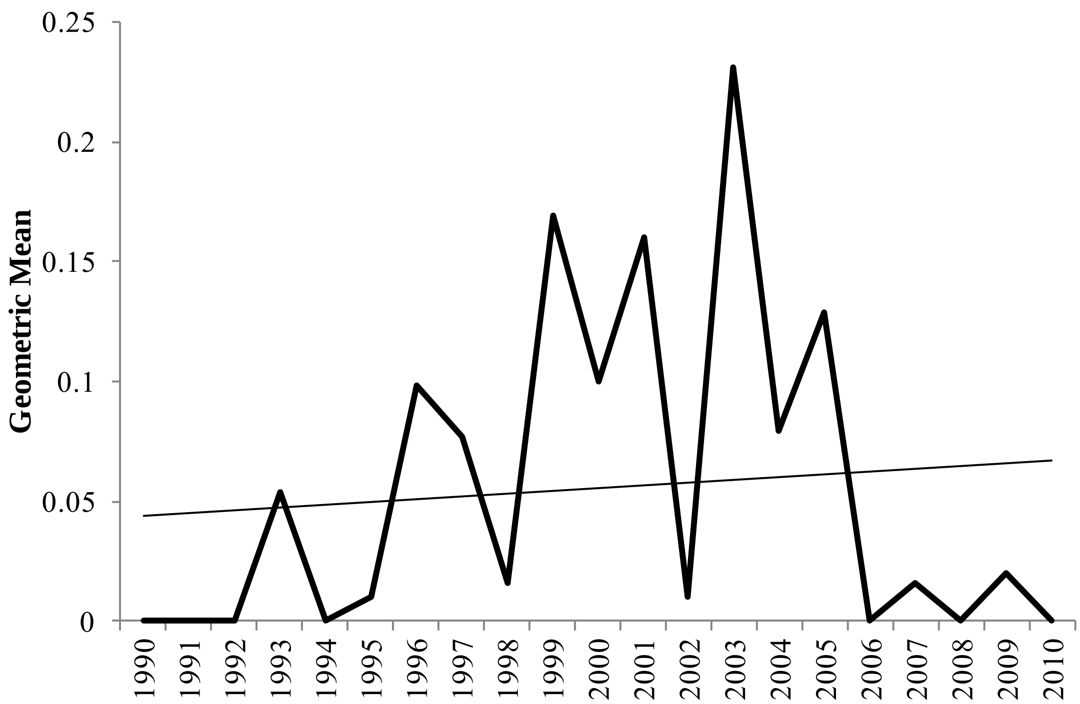

Figure 12.14 Annual YOY blueback herring relative abundance index (geometric mean catch per tow) and trend from the 16 foot otter trawl survey in the Delaware Estuary. Source: DE DFW.

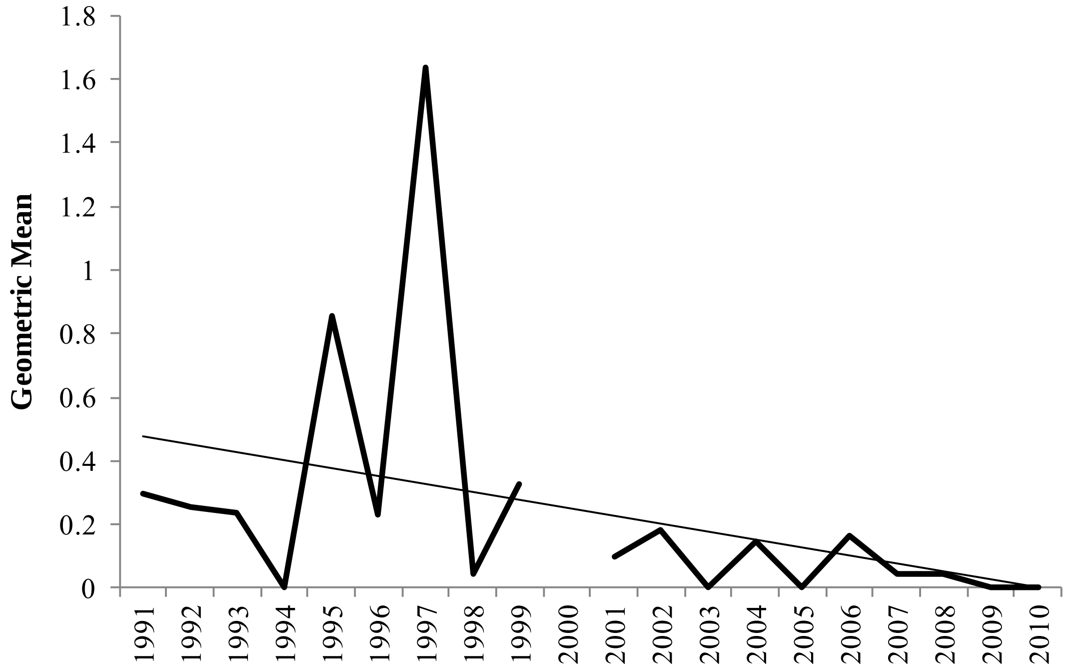

Figure 12.15 Annual Age 1 alewife relative abundance index (geometric mean catch per tow) from the 16-foot otter trawl survey in the Delaware Estuary. The 2000 age 1 annual abundance estimate was not available due to sampling missed in April of that year. Source: DE DFW.

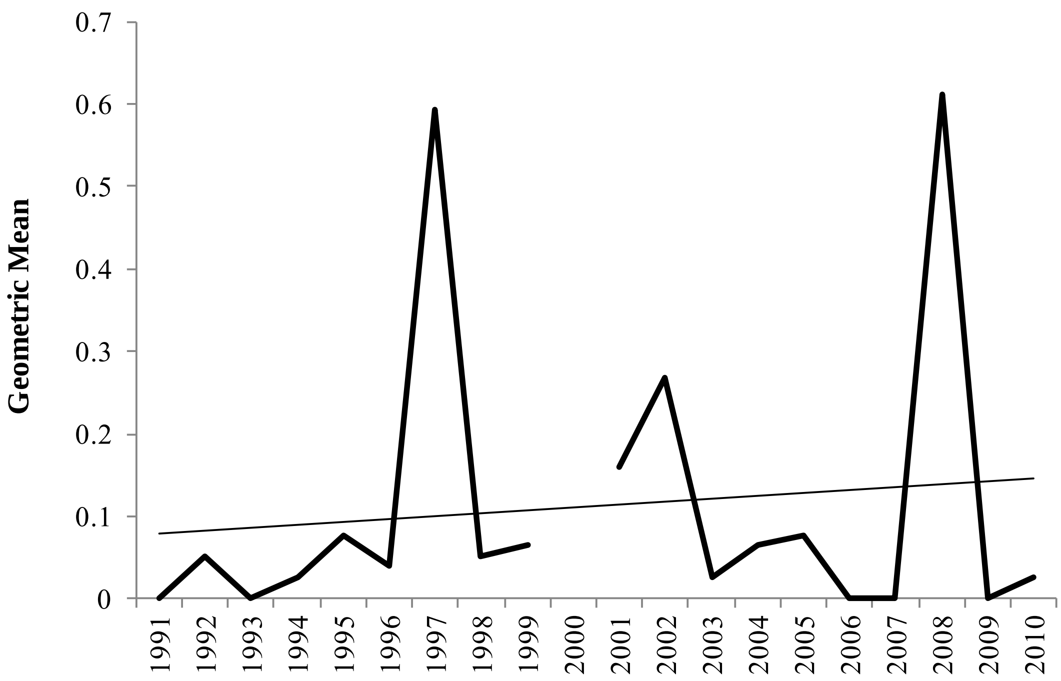

Figure 12.16 Annual age 1 blueback herring relative abundance indices (geometric mean catch per tow) from the 16 foot otter trawl survey in the Delaware Estuary. The 2000 age 1 annual abundance estimate was not available due to sampling missed in April of that year. Source: DE DFW.

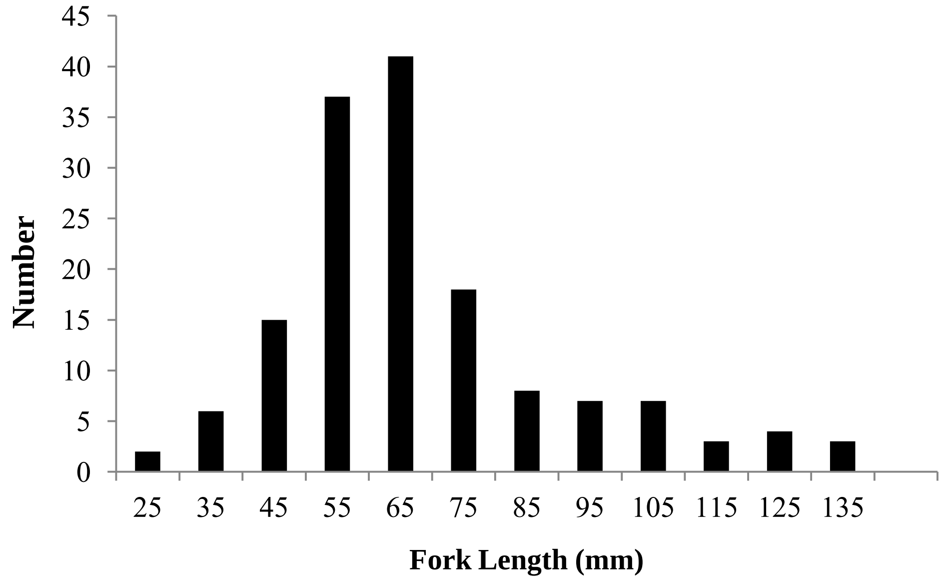

Figure 12.17 Delaware River length frequencies for YOY blueback herring collected during Delaware's 16 foot otter trawl survey in the Delaware Estuary. Source: DE DFW.

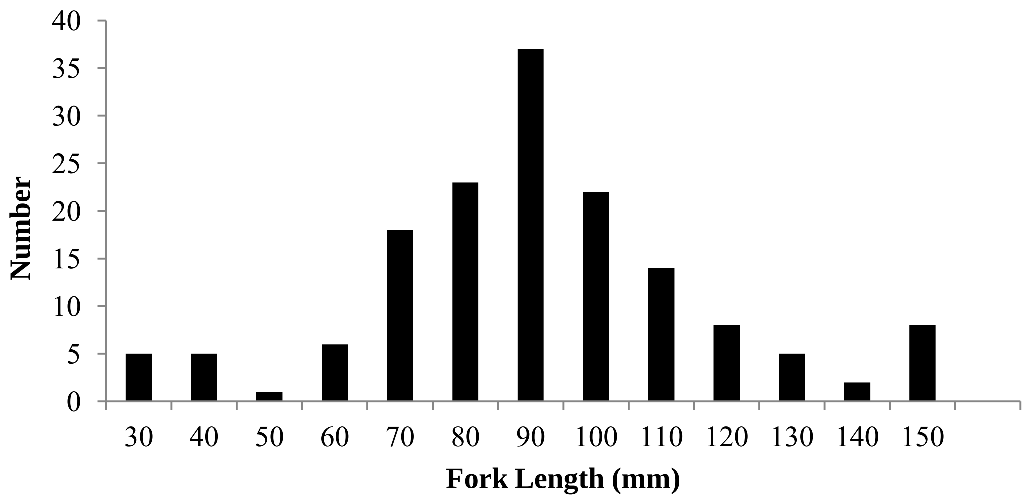

Figure 12.18 Delaware River length frequencies for Age 1 blueback herring collected during Delaware's 16 foot trawl survey in the Delaware Estuary. Source: DE DFW.

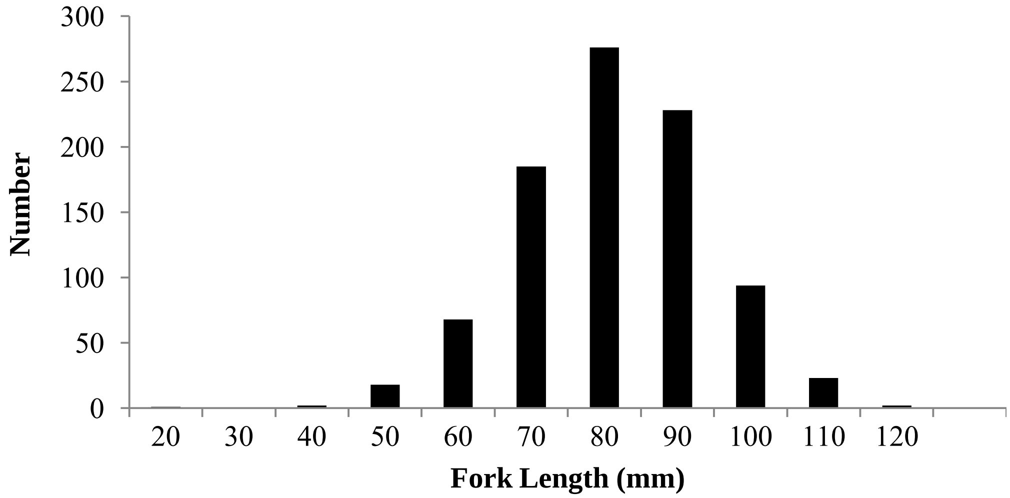

Figure 12.19 Delaware River length frequencies for YOY alewife collected during Delaware's 16 foot trawl survey in the Delaware Estuary. Source: DE DFW.

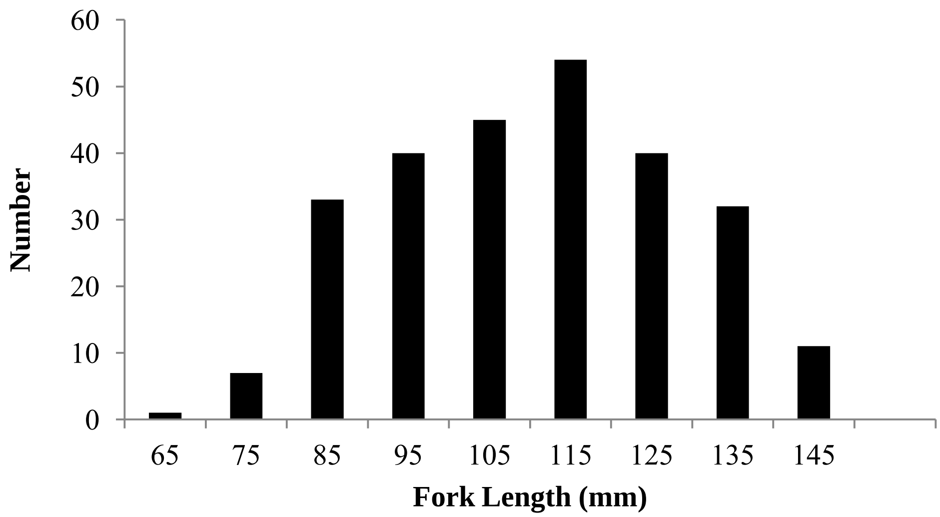

Figure 12.20 Delaware River length frequencies for Age 1 alewife collected during Delaware's 16 foot trawl survey in the Delaware Estuary. Source: DE DFW.

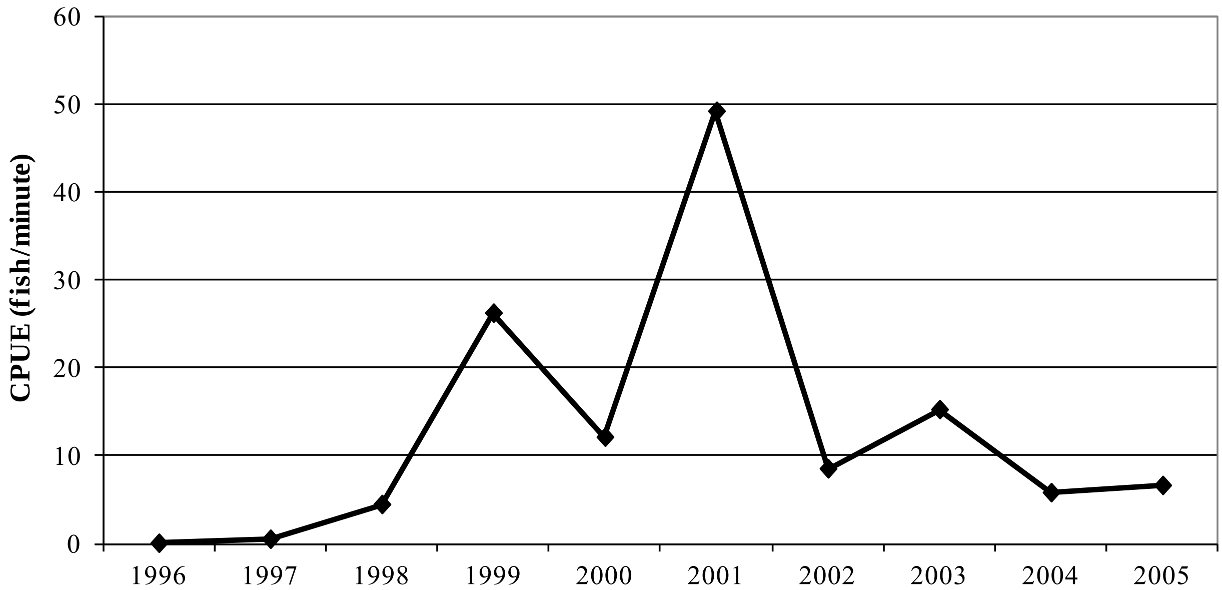

Figure 12.21 PSEG blueback herring electrofishing CPUE for Delaware and New Jersey Ponds (1996 – 2005). Source: NJ DFW.

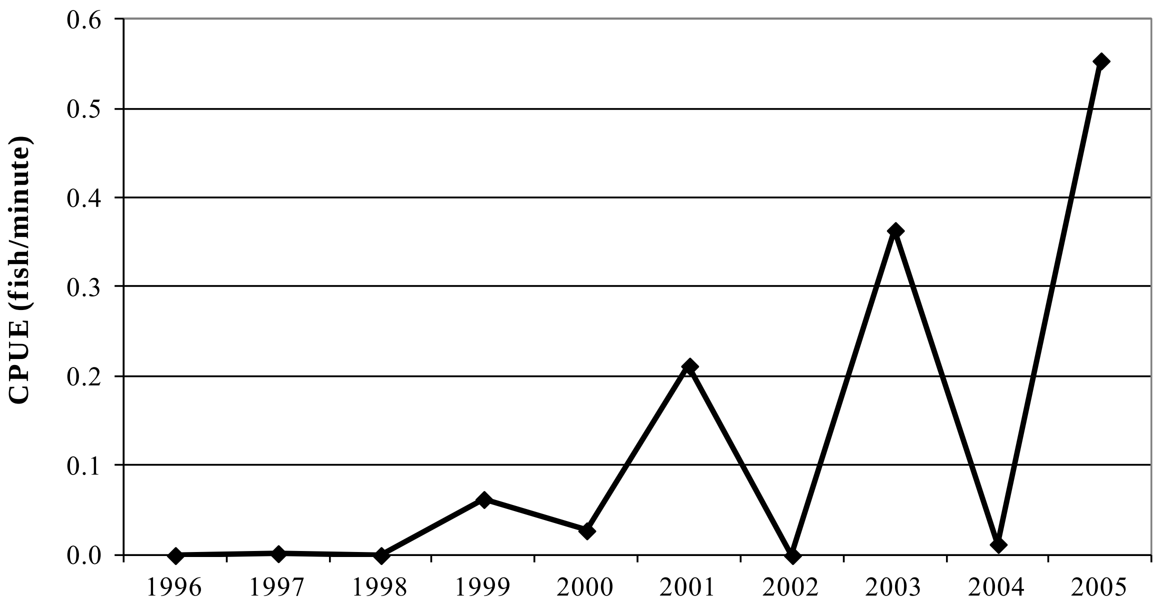

Figure 12.22 PSEG alewife electrofishing CPUE for Delaware and New Jersey Ponds (1996 – 2005). Source: NJ DFW.

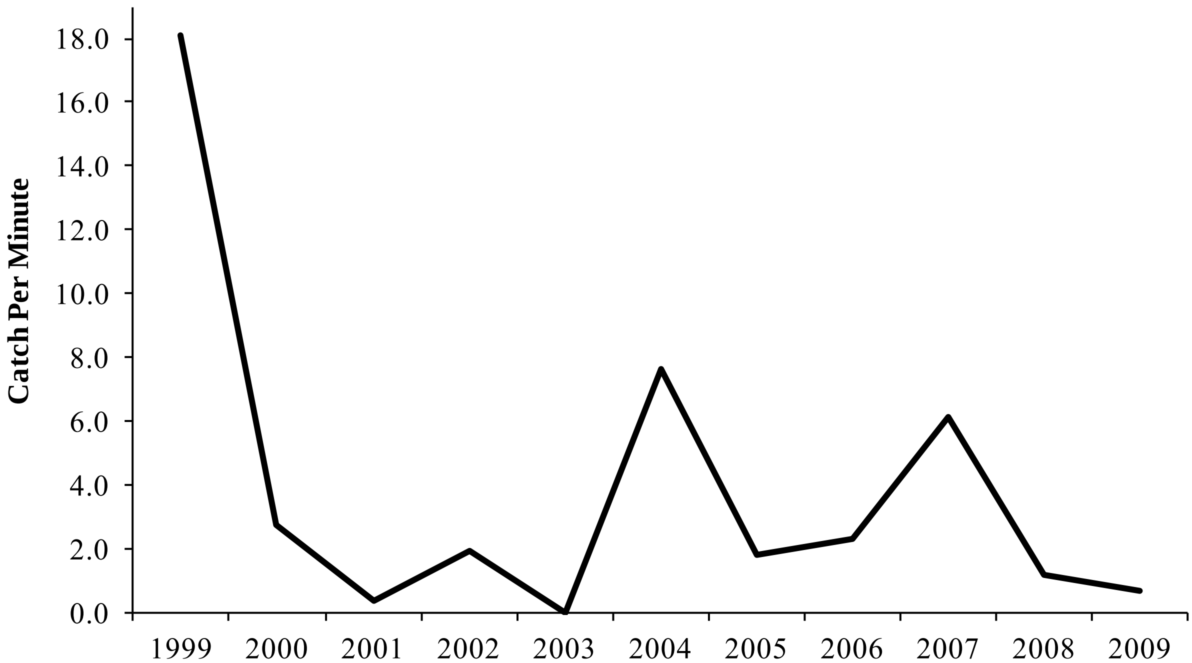

Figure 12.23 Overall CPUE (catch per minute) of YOY river herring collected during electrofishing at seven Delaware impoundments equipped with Alaskan Steeppass fish ladders, 1999-2009. Each pond was not sampled annually. These values reflect an aggregate CPUE calculated from those ponds sampled during that specific year. Source: DE DFW.

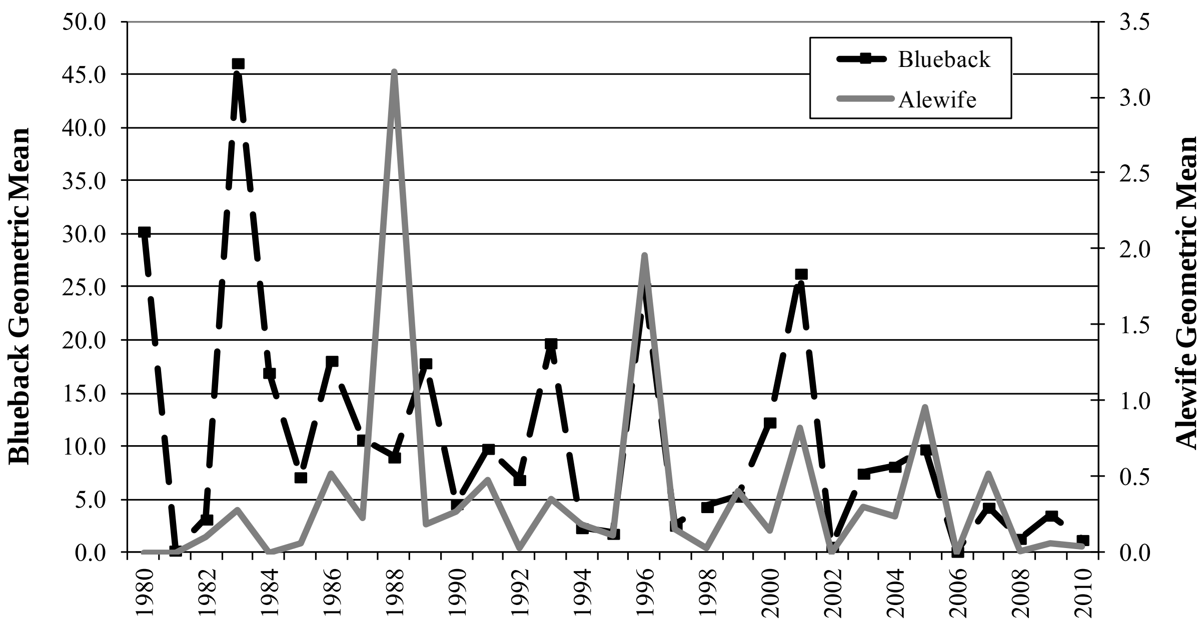

Figure 12.24 Delaware River index of relative abundance, geometric mean, for juvenile river herring collected during New Jersey's striped bass young of year survey (1980-2010). Source: NJ DFW.

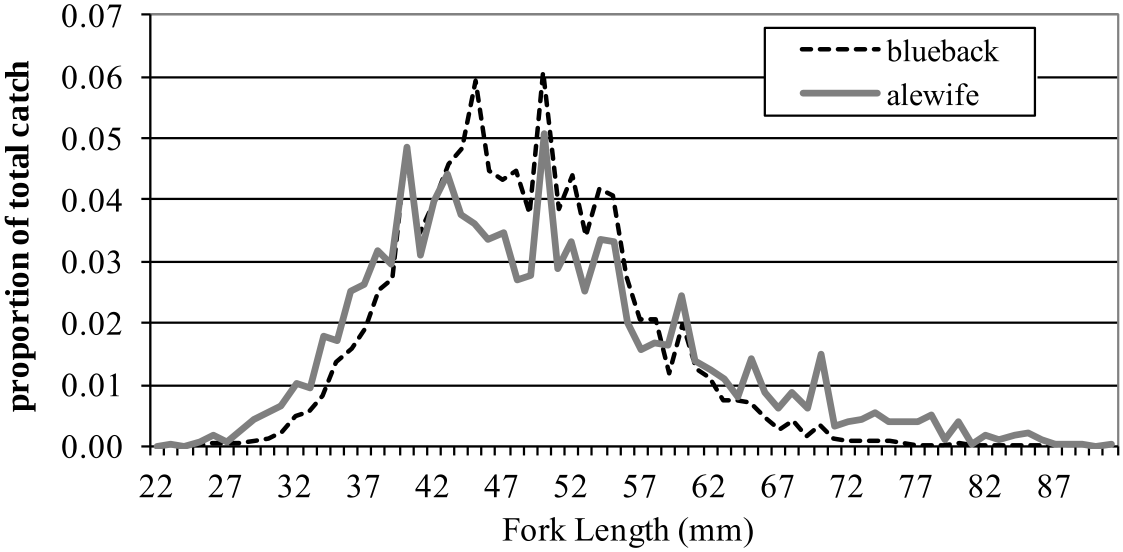

Figure 12.25 Delaware River juvenile river herring (alewife and blueback herring) length frequency (proportion at length) collected during New Jersey's striped bass young of year survey (2000-2010). Source: NJ DFW.

13. Status of River Herring in Maryland and the Upper Chesapeake Bay

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13.1. INTRODUCTION

Alewife and blueback herring are synonymous with the term river herring. Both species historically occur in significant numbers in the Chesapeake Bay with pre-spawn alewife herring appearing in the tributaries during late February followed by blueback herring in April. Evidence suggests that Native Americans depended partially on fish for food and caught shad and herring in large quantities long before European colonists arrived in North America (Meehan, 1897; Gay, 1892). Herring were likely caught for subsistence since colonial days, Radoff (1971) noted that herring were first exported from Maryland in 1753 but the fishery was more local and seasonal because salt was limited.

Documented landings from Maryland's portion of the Chesapeake Bay and tributaries date back to the 1800's. This serves as one of the best sources of data for river herring in the Upper Chesapeake Bay. Commercial landings are also available from Delaware's portion of the Nanticoke Rive. The fishery in this area was an important local resource for commercial fishermen in the past. The commercial and recreational fisheries in the Upper Chesapeake Bay were closed in 2012.

13.2. MANAGEMENT UNIT DEFINITION

In general, since most river herring in the Chesapeake Bay will return to their natal rivers to spawn, each river is considered a separate stock. The Maryland portion of the Chesapeake Bay begins at the Virginia line, at the mouth of the Pecomoke River, and continues north, ending at the Susquehanna Flats. There are a few minor tributaries of the Bay on Marylans'd western shore that have small runs as well.The two major Chesapeake Bay tributaries in the Upper Chesapeake are the Susquehanna and Nanticoke Rivers. The Susquehanna River watershed is located in Maryland, Pennsylvania and New York; however the New York portion will not be discussed in this report because river herring cannot access this portion. The Nanticoke River watershed originates in southwest Delaware and flows through Maryland before emptying into the Chesapeake Bay along Maryland's eastern shore. In addition, the mainstem of the Nanticoke

River, herring runs primarily occur in two main tributaries to the Nanticoke River in Delaware, Deep Creek and Broad Creek.

While distinct geographic areas divide the Chesapeake Bay into two or three zones, the divisions were not consistent in the literature. The Upper Chesapeake Bay area designated for this assessment is defined as the area from the Susquehanna River to the Nanticoke River and analyzes data from Maryland, Pennsylvania and Delaware. The management authorities in the Upper Chesapeake Bay include the Maryland Department of Natural Resources (MD DNR), the Delaware Division of Fish and Wildlife (DFW) and the Pennsylvania Fish and Boat Commission (PFBC).

13.3. REGULATORY HISTORY

Since the Upper Chesapeake Bay is under the jurisdiction of four separate states, there have been differing regulations pertaining to river herring within the Bay. As of January 1, 2012 landings of river herring in systems without an approved sustainable fisheries management plan are prohibited. These regulations are in compliance with the Atlantic States Marine Fisheries Commission Amendment 2 to the Fisheries Management Plan for Shad and River herring (2009). Regulations below may apply state-wide unless otherwise noted.

13.3.1. Commercial

Maryland

Maryland's commercial river herring fishery historically has been seasonally restricted, closed from June 5th to Jan 1st of the next year. Since migrations occur in the spring, this law has little, if any, management consequences. Up until 2005, it was primarily a directed fishery using drift gill nets with meshes ranging from 3 ⅛ to 3 ¼ inches. A limited pound and fyke net bycatch fishery also exists. After 2005, the directed fishery reported few fish and little effort, and many commercial gill netters no longer targeted river herring. A directed commercial river herring fishery has developed since 2006 in a select Chesapeake Bay tributary (based on landing records) and is the result of new spring regulations allowing river herring as live bait to target striped bass in the upper Chesapeake Bay. There were also no state limits on total river herring catch or the amount of gear utilized and individual rivers may have distinct gill net area restrictions. As of January 1, 2012 possession of river herring is prohibited in Maryland.

Delaware

No specific regulations were ever adopted to reduce or restrict commercial landings of river herring, however there are regulations that applied to the commercial fishery that limited commercial fishing effort and have a direct impact on catch and effort. In Delaware, these restrictions include a limited entry license system, limitations on the amount of gear allowed to be fished, and season and area closures. Examples include:

1. Drift nets are prohibited from Saturday through 1600 hours Sunday.
2. No fixed gill nets from January 1 through May 31, and not more than 200 feet of net from June through September in the Delaware River.
3. No fixed gill nets from May 10 through September 30 in Delaware Bay.

4. The use of any type of net within 300 feet of any dam is prohibited on any tributary.
5. The striped bass spawning grounds which include the Nanticoke , Delaware River and C&D Canal are closed to all gill nets from April 1 to May 31

Additionally, since 1985, 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. Those herring that were landed were typically frozen for bait, pickled, kept for their roe and other traditional uses. As of January 1, 2012 possession of river herring are prohibited in Delaware.

Pennsylvania

Harvest of river herring is prohibited in Pennsylvania waters of the Susquehanna River.

13.3.2. Recreational

Maryland

Maryland's recreational river herring fishery historically was seasonally restricted, closed from June 5th to Jan 1st of the next year. There were no size or creel limits on river herring. Maryland has no recreational landings data. Limited data indicated that catches were minimal but there may be small incidental catches of river herring used for striped bass bait that are not documented. Historically, anglers used dip nets to catch river herring and very few herring were caught by hook and line, usually when fishing for other species. Dip nets may not be used within 50 yards of the mouth of any river or tributary or the base of a dam and may not be used in any waters of the state stocked with trout. In non-tidal waters an individual can only use hook and line to take herring. Dip nets may not be used in the Susquehanna River upstream of Deer Creek. Nets, other than a landing net, cannot be used in Deer Creek. As of January 1, 2012 the recreational fishery was closed.

Delaware

The recreational fishery in Delaware often occurred at the various low-head dams that form mill ponds on the many of Delaware's tidal rivers where herring concentrated during the spring spawning season. Recreational fishermen used hook and line and t lift nets (umbrella nets) or dip nets during the peak of the run to catch herring. Prior to 2005, no recreational limit for river herring existed in the State of Delaware. Anecdotal reports indicated the catch and effort for river herring has increasing as striped bass stocks rebounded and the popularity of using live river herring for bait escalated. In an effort to prevent over exploitation of these small herring runs, a 25-fish limit was adopted in 2005. The popularity of this fishery continued to increase and consequently a 10-fish possession limit was adopted in spring of 2008 to help conserve remaining spawning stocks and to prevent "stock-piling" in net pens or live cars. In addition during 2008, Delaware's General Assembly approved legislation that prohibits the use of any net by any fisherman within 300 feet of any dam on any tidal tributary. The 10-fish possession limit and the prohibited use of any net immediately below any dam greatly reduce both catch and effort by forcing recreational fishermen to use only hook and line and to limit landings to the possession limit. As of January 1, 2012 the recreational fishery was closed.

Pennsylvania

There has been no sport fishery for river herring in Pennsylvania waters of the Susquehanna River since the 1920's when the Conowingo Dam was built. As of January 1, 2012 the recreational fishery was closed.

13.4. ASSESSMENT HISTORY

River herring assessments in Maryland waters have been conducted sporadically during the last fifty years, and were generally regionally specific. The most comprehensive collection of data by Mowrer et al (1984) summarized river-specific data and stock status of river herring. This study concluded that:

- Commercial landings had declined since the 1930's and was due to exploitation
- Recreational river herring fishery in the 1980s was less than 1% of the reported commercial landings
- Stock levels were at historically low levels

Mowrer et al (1984) also provided a 1980 population estimate of 57,628 blueback herring in the Susquehanna River. In the Choptank River, a tributary of the Chesapeake Bay on the Delmarva Peninsula, he estimated river herring (species combined) abundance of 570,543 in 1972 and 305,794 in 1973.

The Nanticoke River was included in the 1990 ASMFC coastwide stock assessments of river herring from selected Atlantic coast rivers (ASMFC 1990). Nanticoke River alewife were not overfished ($u < u_{msy}$) but have experienced a stock decline in recent years. The current or historical u values for Nanticoke alewife were within 75% of the u_{msy} levels, and therefore were considered by our criteria to be fully exploited. Abundance from these river herring stocks has exhibited a significant decline in recent years. The Nanticoke River blueback herring were considered to be partially exploited, since the current and historical fishing rates for these stocks were less than 75% of the river-specific u_{msy} levels.

Of the 15 river herring stocks examined in this assessment, nine stocks were judged by our criteria to be either overfished ($u > u_{msy}$) or severely depleted. These overfished stocks were confined to the northern and mid-southern end of the geographic range for river herring and included the Nanticoke stock of alewife. There are substantial weir fisheries on the river herring stocks within the north and south, whereas river herring from mid-southern rivers, such as the Nanticoke, are harvested primarily by pound nets that are set in or just outside these river systems (ASMFC 1985).

13.5. STOCK-SPECIFIC LIFE HISTORY

Alewife (*Alosa pseudoharengus*) and blueback herring (*Alosa aestivalis*) are anadromous clupeids and members of the herring family which include the two shad species. These two species collectively known as river herring, mature between two and five years of age in the

Chesapeake Bay, and peak catch-at-age is from four to six years. Some fish may return to spawn for four consecutive years (repeat spawning; Sadzinski and Jazynski. 2007). Hatching occurs one week after fertilization. Young-of-the-year begin leaving the Chesapeake Bay in late fall. Juveniles remain in the ocean until sexual maturity, most returning to their natal rivers to spawn. There appears to be annual overwintering of both species of herring in the Chesapeake (Duvol 1972 and Carter 1969).

13.5.1. Growth

Dovel (1971) estimated young-of-the-year growth rates for blueback herring at six months old to be 65.0 mm total length (TL) with an estimated hatching date of 15 April. One-year old TL was estimated to be 80.0 mm. Preliminary review of the literature has not revealed adult river herring growth studies in the Chesapeake Bay.

Mowrer et. al 1980 also estimated young-of-the-year growth from beach seine samples and noted the larger size of alewife as compared to blueback herring; however both species were comparable in length by September. Their growth curves quickly flattened, indicating outward migration of larger fish.

13.5.2. Maturity Schedule

Using Speir and Mowrer’s (1987) maturity schedule calculation, 84% of male alewife and 100% of male blueback herring were mature by age 4 in 2010. The percentages of female alewife and blueback herring mature by age 4 in 2010 were 66% and 93%, respectively.

13.5.3. Natural Reproduction

Dovel (1971) collected egg and larval fish throughout the Chesapeake Bay in the late 1960’s and early 1970’s and noted significant numbers of Alosa species in his samples, including river herring.

O’Dell et al (1984) surveyed anadromous fish species in Maryland streams from 1979-1982. They concluded that river herring successfully spawned in each major river system through the capture of pre-spawned adults and later by fertilized eggs or larval fish. Natural reproduction of river herring did occur in all major tributaries and likely still occurs in every major river system.

13.6. HABITAT DESCRIPTIONS

Carter et. al (1980) surveyed more than 700 streams in Maryland from 1970 to 1980 and documented anadromous species in 323 of these streams. The report defines spawning and nursery areas by river system and is species specific. Natural or man-made barriers to migration were also noted. Based on his data and juvenile indices, river herring were a prolific species in Maryland tributaries and spawning and nursery habitat was not limiting.

The first major hydroelectric plant on the Susquehanna River was constructed at York Haven, PA (river km 90) in 1904. In 1910, Holtwood Dam (river km 39) was built with two fishways that were later shown to be ineffective. Commercial fishing continued below Holtwood until 1924 (Kotkas and Robbins 1977) but soon disappeared because of the absence of American shad.

Conowingo Dam (river km 16) was constructed in 1928 and Safe Harbor Dam (river km 52) was completed in 1931. These dams permanently cut off river herring from their historical spawning areas in the Susquehanna River until 1972 when the Conowingo Dam was retrofitted with a fish elevator and fish were trucked above the upper most mainstream dam.

The Nanticoke River is a major tributary of the Chesapeake Bay. It begins in Delaware and flows 64 miles, including 37 miles through Maryland, before emptying into the Bay. It is a free-flowing river originating near Greenwood, Delaware. Delaware Division of Fish and Wildlife staff reported river herring caught by recreational anglers as far upstream as Bridgeville, Delaware. River herring spawn within two primary tributaries that flow into the Nanticoke River within Delaware boundaries as well. Deep Creek begins at the dam below Concord Pond and flows into the Nanticoke proper at Seaford, DE. Broad Creek extends from the dam below Records Pond in Laurel, DE and flows into the mainstem of the Nanticoke just upstream of the Maryland state line. Although the dams on Deep Creek and Broad Creek inhibit upstream passage, there is sufficient spawning habitat below the structures to maintain a stable run. Smaller tributaries, many of which are tidal freshwater, also contribute to the total amount of spawning and rearing habitat available. These tributaries include Marshyhope Creek and Barren Creek on the Maryland side.

13.7. RESTORATION PROGRAMS

There are no dedicated restoration programs for river herring in the Upper Chesapeake Bay. There has been some experimental stocking in select rivers, but numbers of larval fish stocked (less than 500,000) were likely not significant enough to impact the stock and stocking was not consistent over time. Stocking was primarily done as mitigation for construction projects and to evaluate fish passage effectiveness. No evaluation of stocked fish survival or how the stocking contributed to populations was conducted. Adult river herring were captured from the west fish lift at Conowingo Dam, transported upstream and stocked in Pennsylvania waters during 1990 to 2001 (Table 13.1).

As part of the Chesapeake 2000 Agreement, several fish passage commitments were developed that are important for anadromous fish, especially shad and river herring. The commitments include: 1) identify the final initiatives necessary to achieve the existing goal of restoring fish passage to more than 1,357 miles of currently blocked river habitat and establish a monitoring program to assess outcomes; 2) set a new goal with implementation schedules for additional migratory and resident fish passages; 3) determine tributary-specific target population sizes; and, 4) revise fish management plans. The fish passage goal was met at the end of 2004 with approximately 1,400 miles of habitat reopened for anadromous fish. A new goal was established and began in 2005. An ecosystem-based management plan for alosines is under development and will include population and habitat strategies.

On the Susquehanna River, the Policy Committee of the Susquehanna River Anadromous Fish Restoration Cooperative (SRAFRC) approved an "Alosine Management and Restoration Plan for the Susquehanna River Basin" in 2010. The restoration goal is:

> *"By 2025, produce self-sustaining annual populations of 2 million American shad and 5 million river herring, reproducing in the free-flowing Susquehanna River*

above York Haven Dam, and in suitable tributaries, and provide 500,000 angling days annually throughout the Basin for these species."

13.7.1. Upstream Fish Passage Efficiency

Fishway counts at the four dams along the Susquehanna River (from south to north: Congowingo (MD), Holtwood (PA), Safe Harbor (PA) and York Haven (PA)) are provided Figure 13.1 and in Tables 13.2 and 13.3. River herring passage was episodic prior to 2002 and has plummeted since then. Few river herring have passed upstream of Holtwood Dam except in 2000 and 2001 when river herring were transported to the Conestoga River, a tributary of the Susquehanna River. Apparently, the transported river herring left the Conestoga River and moved up the mainstem Susquehanna River all the way to the Safe Harbor Dam. In 2001, transports to the Conestoga River included 2,983 blueback herring in 2000 and 4,200 blueback herring and 1,820 alewives. Other reports of alewife upstream of Holtwood Dam are largely attributed to movement of individuals from landlocked populations in several lakes in the drainage. Smaller fish ladders have been installed on a number of dams allowing river herring to pass but fish counts and efficiency have not been assessed for any of these structures.

13.8. AGE

MD DNR has collected scale samples from river herring through fishery dependent sampling in the Nanticoke River since 1984. Scales were removed below the insertion of the dorsal fin. A minimum of four scales per fish were cleaned, mounted between two glass slides and read for age and spawning history using a Bell and Howell MT-609 microfiche reader. The scale edge was counted as a year-mark since it was assumed that each fish had completed a full year's growth at the time of capture. Annuli were identified using Cating's (1953) method and the same two readers have aged river herring in Maryland since 1984. The number of repeat spawning marks, defined as the freshwater spawning mark on the scale was recorded for each fish.

13.9. FISHERY DESCRIPTIONS

13.9.1. Commercial Fisheries

In the last eight years, river herring populations have significantly decreased and therefore most commercial fishermen are no longer targeting river herring but catch them as bycatch while targeting white perch.

Maryland

Evidence suggests that Native Americans depended partially on fish for food and caught shad and herring in large quantities long before European colonists arrived in North America (Meehan, 1897; Gay, 1892). The earliest commercial fisheries were initiated in the late 1800s and with the introduction of the pound net into Maryland waters, herring catches likely peaked. During the 20th century, pound and fyke nets were extensively used to catch river herring. After the 1980's the fishery was in decline and it evolved more into a bycatch fishery. In addition, commercial fishermen could target river herring on their spawning grounds using small mesh gill nets.

Commercial Landings and Catch Rates

Commercial landings data became mandatory in Maryland in 1985. From 1929 – 1975 Maryland statewide landings ranged from one to eight million pounds. Landings exhibited a cyclical pattern with an overall downward trend. Landings declined precipitously after 1975 and have remained low (Figure 13.2). The commercial river herring landings for the Nanticoke River have significantly decreased since 1989 (Figure 13.3).

Relative abundance, measured as annual CPUE for alewife and blueback herring collected from pound and fyke nets in the Nanticoke River, was calculated as the geometric mean (based on a $\log_e$-transformation; Sokal and Rohlf 1981) of fish caught per net day. Nanticoke River pound net CPUEs and commercial landings of alewife and blueback herring (species combined) were analyzed for trends using linear regression.

The combined geometric mean CPUE for alewife and blueback herring have shown no trend overtime (1989-2010; r^2=0.15 P=0.08, Figure 13.3). Alewife geometric mean CPUE has varied without trend (1989-2010, Figure 13.4), while blueback herring geometric mean CPUE has significantly decreased (1989-2010, Figure 13.5).

Commercial Sampling

Alewife and blueback herring in Maryland's portion of the Nanticoke River were collected from commercial pound nets and fyke nets, and the number of nets and locations were fished at the discretion of the commercial watermen. These nets were generally sampled at least once per week from early March to late April. Fish were sorted according to species and transferred to the survey boat for processing.

A minimum of ten alewife and ten blueback herring selected at random from unculled commercial catches were counted, sexed, fork length measured and scales removed for age analysis. The total number of herring harvested was estimated by multiplying the number of bushels harvested by the number of fish per bushel from sampled nets on that particular day or by direct counts.

Delaware

Commercial Landings and Catch Rates

Since 1985, Delaware's commercial landings were determined annually from mandatory commercial catch reports. Landings occur from all of the broader regional areas of Delaware but the upper Nanticoke River has traditionally yielded the majority of landings and it also has the largest herring runs of any of the tidal streams in the state. In 2010, 84% of river herring landings reported in Delaware came from the Nanticoke. Commercial landings occurred from January through May with peak landings occurring in March. Both species are represented in the catch but the majority is probably blueback herring based on observations of relative abundance and temporal distributions within state waters. Additional sampling is not performed.

In Delaware's portion of the Nanticoke River the CPUE has been in decline since the mid 1990's and the lowest CPUE in the time series occurred in 2010 (Table 13.4). The effort data reflects days that fishermen actually landed river herring and does not account for days when the species was not landed.

13.9.2. Recreational Fisheries

Maryland

MD DNR has conducted a roving creel survey below Conowingo Dam on the Susquehanna River since 2001. In general, few anglers (less than one percent) target river herring in the spring because most anglers are targeting American or hickory shad and walleye. In most river systems, river herring are not targeted and are caught as bycatch.

Delaware

There are over 500 'recreational' gill net permits issued to Delaware fishermen statewide. Mostly commercial crabbers hold these permits which allow them to catch bait, primarily Atlantic menhaden. River herring were also reported as discards from this fishery but were highly variable ranging from 6 fish per year to over 1,000. From 1996 through 2003 annual total harvest estimates ranged from 4,400 fish in 1996 to 297 in 2002 (Table 13.5).

13.9.3. Subsistence Fisheries

Herring were likely caught for subsistence since colonial days Radoff (1971) noted that herring were first exported from Maryland in 1753 but the fishery was more local and seasonal because salt was limited. No additional information on subsistence fishing is available.

13.9.4. Bycatch losses

Bycatch losses were typically minimal because the commercial fisheries (typically white perch) were allowed to harvest and land river herring. As of January 1, 2012 no landings of river herring will be allowed in Maryland or Delaware.

13.9.5. Other losses

Herring are used as bait in eel and crab pots in Maryland. Some of the herring used as bait are females that have had their roe removed for market.

13.10. FISHERY-INDEPENDENT SURVEYS

13.10.1. Adult catch data

The only source of fishery-independent data for river herring comes from the fish lifts at Conowingo Dam in the Susquehanna River. There are two lifts (west and east) operating at the lowest dam on the Susquehanna River. The lifts are operated to give priority to American shad passage and may exclude other species, including river herring. The two fish lifts are operated each spring during mid April, which may eliminate alewife herring because their peak spawning period is likely prior to the opening of the lifts.

The west fish lift at Conowingo Dam has been used to monitor adult abundance since 1972. This lift operates in the traditional manner except that fish collected are dumped into a large steel trough where the catch is hand sorted by biologists. Target species are enumerated, sampled and then released back into the Conowingo Dam tailrace, used for tank-spawning, or transported upstream, as dictated by restoration plan requirements.

The Conowingo east fish lift is constructed with a viewing window where a trained biologist counts all fish species as they exit the fishway and enter the upstream reservoir. This lift has been operating since 1991 but prior to 1997, fish were manually trucked upriver. It is also worth noting that flows have been increased since the late 1990's to maximize American shad catches in the east lift, which may decrease river herring catches.

13.10.2. Juvenile Catch Data

Maryland's river herring juvenile indices are derived annually from seine sampling at 22 fixed stations within the Chesapeake Bay. A 30.5-m x 1.24-m bagless beach seine of untreated 6.4-mm bar mesh was set by hand. One end was held on shore. The other was fully stretched perpendicular from the beach and swept with the current (Durell et. al 2007).

Stations have been sampled continuously since 1954, with changes in some station locations (see http://www.dnr.state.md.us/fisheries/juvindex/sitemap.jpg). They are divided among four of the major spawning and nursery areas: seven each in the Potomac River and Head of Bay areas and four each in the Nanticoke and Choptank Rivers. Sampling is monthly, with rounds occurring during July, August, and September.

Replicate seine hauls, a minimum of thirty minutes apart, are taken at each site on each sample round. This produces a total of 132 samples from which bay-wide means are calculated. In 1962, stations were standardized and a second sample round was added for a total of 88 samples. A third sample round, added in 1966, increased sample size to 132. Auxiliary stations have been sampled on an inconsistent basis and are not included in survey indices.

A 150' haul seine is used to generate juvenile indices of abundance for the upper Nanticoke River stock in Delaware (Stangl, 2010). Haul seine sampling was initiated in 1999 and continued annually to assess reproduction and recruitment of all alosines. Sampling in 2010 was conducted at four locations using a haul seine from July-October. Samples were obtained once every two weeks at ebb or low slack tide. The geometric mean was calculated using the number taken per haul and utilized as an index of relative abundance for each species. Alosine samples with more than 90 individuals per species were randomly sub-sampled for lengths (Figures 13.6 and 13.7) with the remainder being enumerated.

13.11. ASSESSMENT APPROACHS AND RESULTS

13.11.1. Spawning Stock Abundance

As was described in Section 13.9, commercial landings in the Upper Chesapeake Bay have declined. Alewife geometric mean CPUEs for the lower Nanticoke River have varied without trend, while those for blueback herring have significantly decreased River herring lift catches at the Conowingo Dam (Figure 13.1) were erratic for the time series. Flows have been increased in recent years to encourage American shad to use the lift. Although high flow preclude river herring usage of the lifts this may not explain the wide range of annual values.

13.11.2. Juvenile Abundance

Haul seine sampling conducted by MD DNR since 1959 in the lower Nanticoke has fluctuated without much trend for both alewife and blueback herring (Figure 13.8 and 13.9). The highest index value in a decade was recorded for blueback herring in 2011 (0.98) although this was still below the series average (1.16).

Haul seine sampling conducted in the Upper Nanticoke River by DFW has seen no long-term trend from 1999-2010 in juvenile blueback herring relative abundance. However, juvenile blueback herring relative abundance increased to the third highest value in 2009 and to the highest value in the 12-year time series in 2010 (Table 13.6, Figure 13.10). Anecdotal information from Delaware electrofishing surveys indicated the majority of river herring in the upper Nanticoke system consisted of blueback herring. As a result, alewife relative abundance has been calculated from small sample sizes. Alewife relative abundance has trended down since 1999 but the 2010 alewife geometric mean CPUE increased to the highest index value over the past eight years (Figure 13.11).

Baywide juvenile alewife and blueback herring indices are presented in Figure 13.12 and 13.13, respectively.

13.11.3. Trends in Mean Age and Length at Age

The river herring data for Maryland is based on the commercial fishery in the lower Nanticoke River. Sample bias is likely minimum because of the very small mesh sizes used in both the pound and fyke nets (1.5 inch stretched mesh). Therefore, changes in mean age and length of fish over time is likely due to population changes, especially since the same gear and mesh sizes have been used during our sampling efforts.

Data from MD DNR indicated that in the recent years, older fish are no longer present and mean length-at-age is decreasing for both sexes (Table 13.7). Age four and five fish were most prevalent in the samples but river herring were generally not fully recruited to the spawning population until age five. Number of alewife and blueback herring sampled by sex and age class from Maryland's commercial fishery in the lower Nanticoke River is presented in Tables 13.8 and 13.9 respectively. Mean length-at-age for alewife and blueback herring sampled from the Nanticoke River is presented in Tables 13.10 and 13.11 respectively.

13.11.4. Trends in Repeat Spawning

The arcsine-transformed proportion of alewife repeat spawners (sexes combined) from Maryland's commercial fishery in the lower Nanticoke River indicated no trend (1989-2010; $r^2<0.01$ $P=0.95$), while blueback herring repeat spawning showed a decreasing trend (1989-2010; $r^2=0.56$, $P<0.01$; Figure 13.14).

13.11.5. Trends in Z-estimates

Total instantaneous mortalities (Z) were estimated from Maryland's commercial fishery in the lower Nanticoke River by the $\log_e$-transformed spawning group frequency plotted against the corresponding number of times spawned, assuming that consecutive spawning occurred. Mortality rates based on repeat spawning marks for alewife and blueback herring by sex is presented in Figures 13.15 and 13.16, respectively.

13.12. BENCHMARKS

No benchmarks have been developed for Maryland at this time.

13.13. CONCLUSIONS AND RECOMMENDATIONS

Commercial landings in Maryland and Delaware have shown a decline. The declines seen in the commercial and recreational data could be a result of declining stocks, declining effort, or regulatory changes. Possession of all river herring were prohibited in Maryland and Delaware beginning January 1, 2012. This regulatory change will help protect the remaining spawning populations and aid in reversing the declining trend in river herring abundance.

Maryland's best estimate of adult relative abundance comes from the Nanticoke River and shows that both alewife and blueback herring populations have remained low for the time series, and blueback herring continue to decline. Data from the Conowingo Dam fish lifts on the Susquehanna River are highly influenced by flow and likely do not reflect the abundance of river herring in the system Juvenile alewife abundance shows a decreasing trend in the upper Nanticoke, but higher values were seen during sampling efforts in 2010 in both the upper and lower portions of the river. Blueback herring juvenile relative abundance increased to the third highest value in 2009 and to the highest value in 2010 during the 12-year time series.

In general, ages four and five were the most prevalent fish in the samples, but river herring were generally not fully recruited to the spawning population until age five, as shown with the freshwater spawning mark not present on all five year-old fish. Mean length-at-age of adult river herring captured from the Nanticoke River exhibited decreasing trend for the time series.

MD DNR is exploring the use of cull panels or other gear modification methods in fyke and pound nets during the spring river herring run to reduce bycatch within the state. Collection of data by MD DNR from commercial fishermen on the Nanticoke River may be effected by the both the regulatory change and any bycatch reduction devices employed by cooperating fishermen. This could lead to the loss of Maryland's best source of biological river herring data. MD DNR will attempt to maintain the Nanticoke River sampling to evaluate the effect of the regulation change. MD DNR also recommends there be a reduction in the ocean bycatch of river herring.

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Table 13.1. River herring transported from the Conowingo Dam fish lifts to upstream areas in the Susquehanna River.

	Blueback herring	Alewife
1990	1,027	7
1991	2,605	1,396
1992	12,435	233
1993	1,130	203
1994	286	58
1995	17,935	3,120
1996	410	0
1997	27,783	1
1998	4,755	0
1999	2,204	0
2000	4,783	2,026
2001	5,049	1,820
2002	0	0
2003	0	0
2004	0	0
2005	0	0
2006	0	0
2007	0	0
2008	0	0
2009	0	0
2010	0	0
Total	80,402	8,864

Table 13.2. Blueback herring passage at Susquehanna River Dams.

Year	Conowingo (rm 10.0)	Holtwood (rm 24.6)	Safe Harbor (rm 32.2)	York Haven (rm 56.1)
1997	242,815	1,042	534	no fishway
1998	700	62	20	no fishway
1999	130,625	73	30	no fishway
2000	14,963	27	21	0
2001	284,921	1,300	378	4
2002	2,037	13	0	0
2003	530	3	0	0
2004	101	0	0	0
2005	4	0	0	0
2006	0	0	0	0
2007	460	0	0	0
2008	1	0	0	0
2009	0	0	0	0
2010	4	0	0	0
Total	677,161	2,520	983	4

Table 13.3. Alewife passage at Susquehanna River Dams.

Year	Conowingo (rm 10.0)	Holtwood (rm 24.6)	Safe Harbor (rm 32.2)	York Haven (rm 56.1)
1997	63	0	1	no fishway
1998	6	0	0	no fishway
1999	14	1	1	no fishway
2000	2	0	685	2
2001	7,458	431	345	0
2002	74	0	1	1
2003	21	2	0	0
2004	89	0	1	0
2005	0	0	0	0
2006	0	0	0	0
2007	429	0	0	0
2008	1	0	0	0
2009	0	1	0	0
2010	1	0	0	2
Total	8,158	435	1,034	5

Table 13.4 Nanticoke River Gill Net Landings and CPUE

Year	Kgs Landed	CPUE (kgs/ net meter)
1985	1271	0.165
1986	1862	0.162
1987	1759	0.163
1988	5901	0.175
1989	1706	0.097
1990	6818	0.315
1991	6824	0.458
1992	13495	0.410
1993	4541	0.211
1994	6950	0.547
1995	8056	0.800
1996	8378	0.810
1997	5445	0.282
1998	7627	0.397
1999	2490	0.089
2000	5188	0.133
2001*	confidential	
2002*	confidential	
2003*	confidential	
2004*	confidential	
2005*	confidential	
2006*	confidential	
2007*	confidential	
2008*	confidential	
2009*	confidential	
2010*	confidential	

Table 13.5 Recreational fishery for river herring in Delaware (statewide).

					Effort		Catch	Harvest
	Harvested	Released Alive	Total	# of		Net Yard	per	per
Year	N	N	N	Fishers	Trips	Days	Trip	Trip
1996	4399	.	4399	391	3,808	196,381	1.16	1.16
1997	2247	.	2247	274	2,291	111,659	0.98	0.98
1998	2835	.	2835	269	1,161	55,453	2.44	2.44
1999	460	14	474	27	948	49,342	0.50	0.49
2000	1134	6	1140	197	1,560	84,396	0.73	0.73
2001	502	1028	1530	198	1,686	82,301	0.91	0.30
2002	297	48	345	179	1,615	83,022	0.21	0.18
2003	370	43	413	173	1,390	65,779	0.30	0.27
2004	No Data	.	.	.	.	.	.	.
2005	No Data	.	.	.	.	.	.	.
2006	No Data	.	.	.	.	.	.	.
2007	341	495	836	144	878	43,096	0.95	0.39

Table 13.6 The geometric mean (GM), 95% confidence limits (CI), CPUE (fish/haul) and standard error (SE) for alewife and blueback herring caught with a haul seine on the upper Nanticoke River from 1999 to 2010.

	Blueback herring				Alewife			
YEAR	GM	95% CI	CPUE	SE	GM	95% CI	CPUE	SE
1999	6.7	0.9, 30.4	42.0	22.9	0.9	0.1, 2.3	1.8	0.9
2000	8.2	3.3, 18.7	30.0	8.2	0.8	0.2, 1.8	2.9	1.8
2001	8.3	2.8, 21.9	116.0	51.4	1.3	0.4, 3.0	10.0	5.1
2002	2.0	0.5, 4.9	31.0	19.0	0.7	0.2, 1.4	2.1	1.0
2003	5.2	2.1, 11.3	39.0	19.2	0.2	-0.1, 0.5	1.0	0.9
2004	10.6	3.8, 26.9	173.0	83.2	0.1	-0.1, 0.2	0.1	0.1
2005	1.9	0.6 , 4.2	34.0	19.0	0.3	0.1 , 0.7	0.9	0.5
2006	3.3	1.1 , 7.8	38.0	20.0	0.1	-0.04, 0.3	0.2	0.2
2007	6.7	2.5,15.9	71.1	29.3	0.2	-0.08,0.6	1.6	1.5
2008	0.6	0.1 , 1.3	2.8	1.5	0.07	-0.07 , 0.2	0.3	0.3
2009	10.3	4.0 , 24.8	125.7	74.8	0.1	-0.02 , 0.2	0.19	0.1
2010	10.7	3.7 , 28.0	78.2	26.8	0.6	0.2 , 1.0	1	0.3

Table 13.7. Regression statistics based on length-at-age data for adult alewife and blueback herring sampled from the Nanticoke River pound and fyke nets, 1989-2010.

Alewife								
	Male				Female			
Age	**N**	**Slope**	**r^2**	**P**	**N**	**Slope**	**r^2**	**P**
3	373	-0.099	0.002	0.353	112	-0.216	0.0122	0.247
4	1348	-0.378	0.0474	<0.001	1213	-0.374	0.0484	<0.001
5	1101	-0.377	0.0432	<0.001	1642	-0.350	0.0485	<0.001
6	454	-0.454	0.0642	<0.001	1023	-0.352	0.0478	<0.001
7	70	-0.937	0.178	<0.001	333	-0.492	0.104	<0.001
8	6	-1.183	0.117	0.506	94	-0.594	0.0837	0.005
9					12	-0.625	0.0680	0.413

Blueback herring								
	Male				Female			
Age	**N**	**Slope**	**r^2**	**P**	**N**	**Slope**	**r^2**	**P**
3	194	-0.213	0.0233	0.034	50	-0.314	0.0627	0.079
4	845	-0.231	0.0197	<0.001	732	-0.220	0.0180	<0.001
5	934	-0.181	0.0085	0.005	904	-0.256	0.0202	<0.001
6	648	-0.526	0.0436	<0.001	685	-0.447	0.0309	<0.001
7	281	-0.602	0.030	0.004	337	-0.371	0.0241	0.004
8	90	-0.259	0.0025	0.641	111	-0.430	0.0198	0.141
9	21	-4.561	0.258	0.019	33	-0.005	<0.001	0.996
10					5	+1.667	0.357	0.287

Table 13.8. Annual catch-by-age and sex for alewife herring sampled from the Nanticoke River, 1989-2010.

Males

Year	Catch-by-Age									
	2	3	4	5	6	7	8	9	10	11
1989		14	76	79	20	3				
1990		53	94	142	75	12	1			
1991		18	249	123	54	12	1			
1992		29	99	135	27	6				
1993		15	73	93	48	7	1			
1994		29	77	94	31	7				
1995		8	18	10	6	2				
1996	1	62	81	40	11	1				
1997		18	53	32	5	0	1			
1998		9	52	27	11	2				
1999		21	36	53	39	5				
2000		13	72	19	1					
2001		16	48	40	2					
2002		5	42	48	26	4				
2003		5	19	24	16	1				
2004		12	37	22	11	3				
2005		6	39	19	5	1				
2006		4	13	22	11					
2007		13	49	19	7					
2008		5	24	26	10	1				
2009		5	33	15	5					
2010		2	14	4	5					

Table 13. 8 Continued

Females

Year	Catch-by-Age									
	2	3	4	5	6	7	8	9	10	11
1989		6	85	87	50	13	2			
1990		12	78	141	93	26	21	1		
1991		8	158	102	77	35	7	6		
1992		13	116	244	70	30	7	2		
1993		1	78	151	129	30	11			
1994		8	75	135	90	34	3			
1995		4	23	12	15	11				
1996		25	61	68	28	19	7	1		
1997		6	67	48	19	3	4			
1998		2	69	65	28	5	0	1		
1999		7	31	75	48	1	1			
2000		2	62	30	23	6				
2001		1	38	62	24	7	1			
2002		1	21	54	75	19	2			
2003		2	13	35	43	10				
2004		0	26	40	31	15	6			
2005		0	28	24	27	17	3			
2006		2	15	56	24	4	4			
2007		2	38	40	35	12	3			
2008		2	26	56	17	13	2	1		
2009		4	50	61	33	10				
2010		0	5	19	16	4				

Table 13.9. Annual catch-by-age and sex for blueback herring sampled from the Nanticoke River, 1989-2010.

Males

Year	Catch-by-Age								
	2	3	4	5	6	7	8	9	10
1989		10	110	122	76	15	6	1	
1990		15	69	131	110	79	29	11	
1991		11	101	82	101	54	19	2	1
1992		10	43	54	49	36	14	4	
1993		5	39	74	73	40	15	3	
1994		24	91	102	41	9			
1995		2	13	11	10	4			
1996	1	13	67	63	12	1	2		
1997		10	18	53	82	11	2		
1998		7	22	23	22	15			
1999		7	14	20	14	3			
2000		8	59	31	10	5			
2001		7	23	17	4				
2002		8	24	25	7				
2003		2	17	27	12				
2004		16	29	19	4	1			
2005		3	3	2	0				
2006		1	6	15	3	1			
2007		11	17	7	1				
2008		5	19	11					
2009		9	17	5					
2010		2	8	0	1				

Table 13.9 Continued

Females

Year	Catch-by-Age								
	2	3	4	5	6	7	8	9	10
1989		3	112	126	76	37	6	1	
1990		0	43	78	75	64	18	5	4
1991		6	76	68	106	54	24	14	
1992		2	34	44	50	31	20	5	
1993		1	29	90	72	43	18	6	1
1994		3	42	70	46	19	4	1	
1995		3	11	7	5	1	3		
1996		2	57	63	24	3	3		
1997		3	33	50	67	14	3	1	
1998		0	38	39	41	22	3		
1999		1	9	36	14	5			
2000		4	41	20	11	7	2		
2001		1	24	20	7	2			
2002		1	27	41	15	1			
2003		1	22	26	15	5	1		
2004		0	20	25	8	9	1		
2005		1	6	1	2				
2006		1	13	22	6				
2007		8	13	11	4	2			
2008		3	23	14	3	3	1		
2009		5	20	8	1	1			
2010		0	7	6	2				

Table 13.10. Mean length-at-age by sex for alewife herring sampled from the Nanticoke River, 1989-2010.

Males

Year	Age									
	2	3	4	5	6	7	8	9	10	11
1989		230	236	243	256	261				
1990		221	231	244	250	263	264			
1991		224	234	240	251	260	243			
1992		216	228	238	247	254				
1993		208	225	239	246	248	246			
1994		207	219	231	239	246				
1995		214	226	238	246	251	244			
1996	212	219	228	238	242	263				
1997		213	228	233	240		252			
1998		217	225	238	243	254				
1999		211	222	233	238	244				
2000		220	228	238	258					
2001		225	234	240	247					
2002		225	233	241	244	248				
2003		228	239	245	251					
2004		228	242	251	250					
2005		214	226	236	252	252				
2006		219	223	235	242					
2007		219	227	235	248					
2008		216	217	229	235	278				
2009		221	224	231	241					
2010		221	224	232	248					

Table 13.10 Continued.

Females

Year	Age									
	2	3	4	5	6	7	8	9	10	11
1989		229	244	253	267	277	286			
1990		225	238	253	261	274	283	286		
1991		227	243	251	263	270	273	286		
1992		223	240	248	256	265	276	279		
1993		225	233	247	256	265	277			
1994		219	228	243	254	258	270			
1995		221	235	252	263	268	274		280	
1996		219	231	250	257	267	268	260		
1997		228	234	242	253	267	271			
1998		224	235	245	255	264		277		
1999		220	229	242	250	260	272			
2000		237	237	250	257	270				
2001		239	243	249	256	266	270			
2002		226	238	248	255	260	263			
2003		240	239	250	260	263				
2004		235	249	259	262	270				
2005			233	243	257	267	272			
2006		228	240	247	256	264	277			
2007		220	236	247	256	265	269			
2008		217	231	238	248	256	276	279		
2009		215	231	242	252	261				
2010			234	245	257	251				

Table 13.11. Mean length-at-age by sex for blueback herring sampled from the Nanticoke River, 1989-2010.

Males

Year	Age								
	2	3	4	5	6	7	8	9	10
1989		218	227	234	245	259	262	279	
1990		218	232	239	249	258	263	270	
1991		217	229	237	247	258	260	273	
1992		212	224	235	245	251	260	256	
1993		205	224	237	247	256	262	261	
1994		213	223	238	250	256			
1995		220	226	233	247	256			
1996	205	219	230	240	244	270	261		
1997		212	225	238	241	247	257		
1998		212	225	233	245	253			
1999		200	222	232	239	251			
2000		219	225	235	246	249			
2001		218	231	235	250				
2002		217	229	234	243				
2003	215	230	240	238					
2004	216	231	234	245	250				
2005		222	226	238					
2006		209	224	235	236	270			
2007		207	221	227	266				
2008		206	216	220					
2009		214	219	231					
2010		219	227		228				

Table 13.11 Continued.

Females

Year	Age								
	2	3	4	5	6	7	8	9	10
1989		227	236	244	257	271	279	297	
1990			241	252	262	271	281	286	291
1991		228	238	251	260	264	273	285	
1992		230	230	250	260	264	272	281	
1993		220	236	246	259	269	277	290	296
1994		215	226	245	260	272	282	277	
1995		228	235	248	260	264	270		
1996		218	238	249	257	275	278		
1997		226	242	247	254	268	276	290	
1998			233	246	257	265	281		
1999		219	236	244	253	273			
2000		227	231	243	260	269	275		
2001		219	242	248	260	273			
2002		220	235	246	257	260			
2003	224	235	248	252	264	283			
2004		236	245	254	262	262			
2005		241	236	248	264				
2006		204	235	242	246				
2007		217	221	246	247	266			
2008		213	227	234	252	251	261		
2009		227	232	242	260	278			
2010			243	238	247				

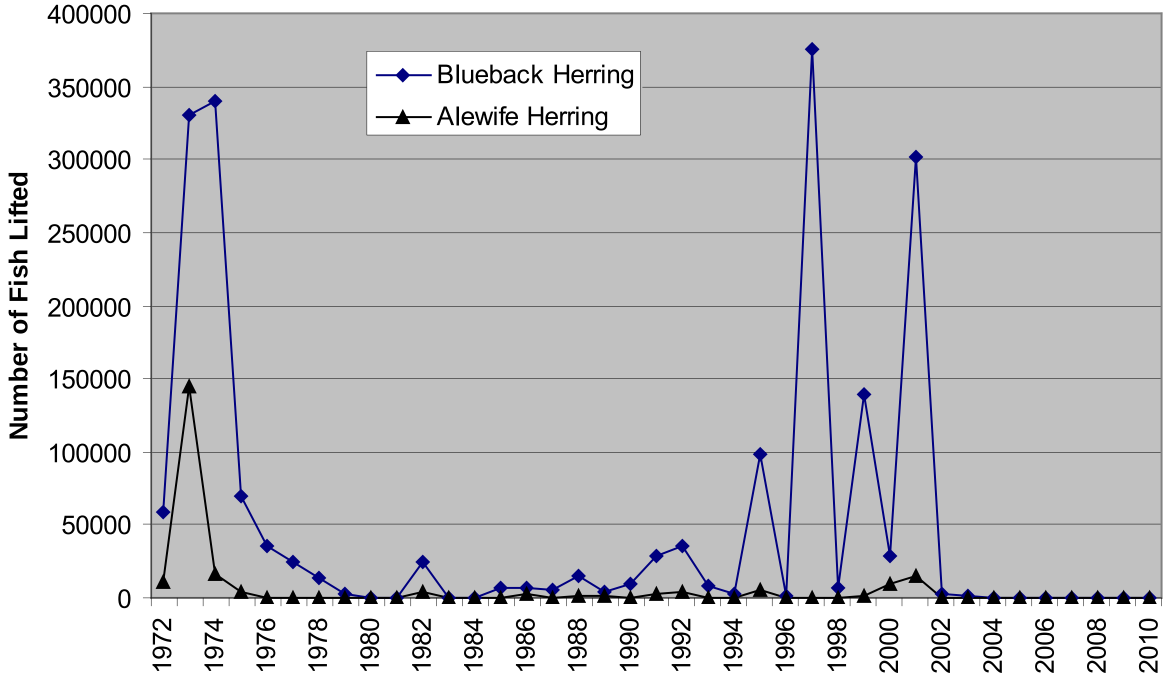

Figure 13.1. Annual combined east and west lift spring catches of adult alewife and blueback herring from Conowingo Dam on the Susquehanna River, 1972-2010.

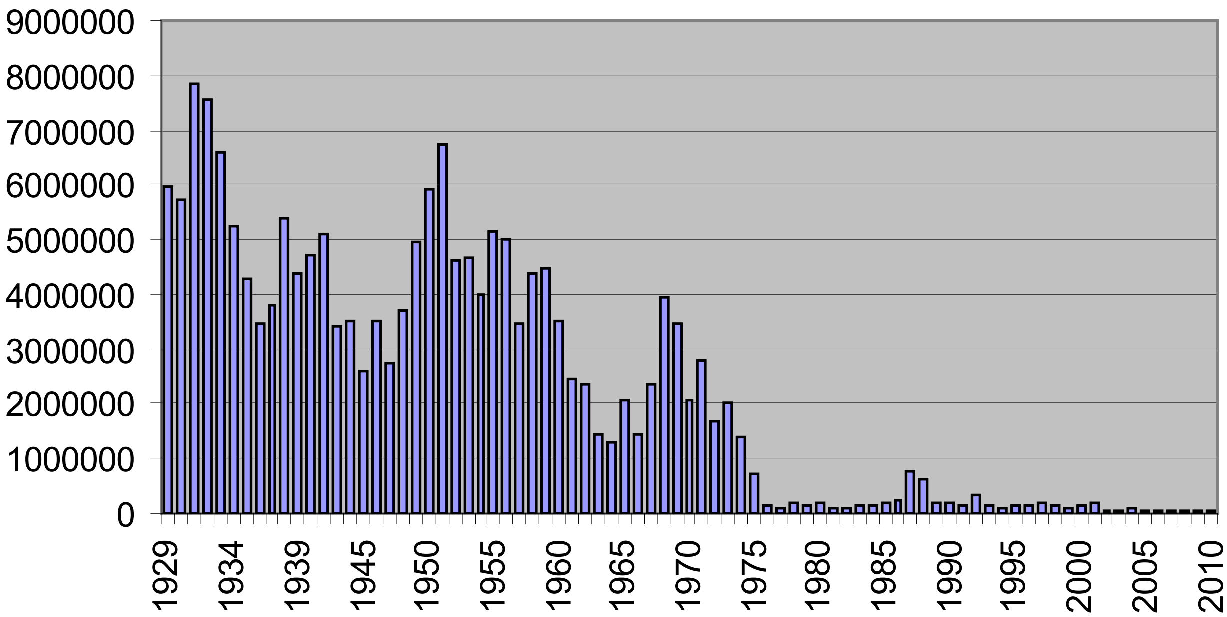

Figure 13.2 Commercial river herring landings from Maryland waters, 1929-2010.

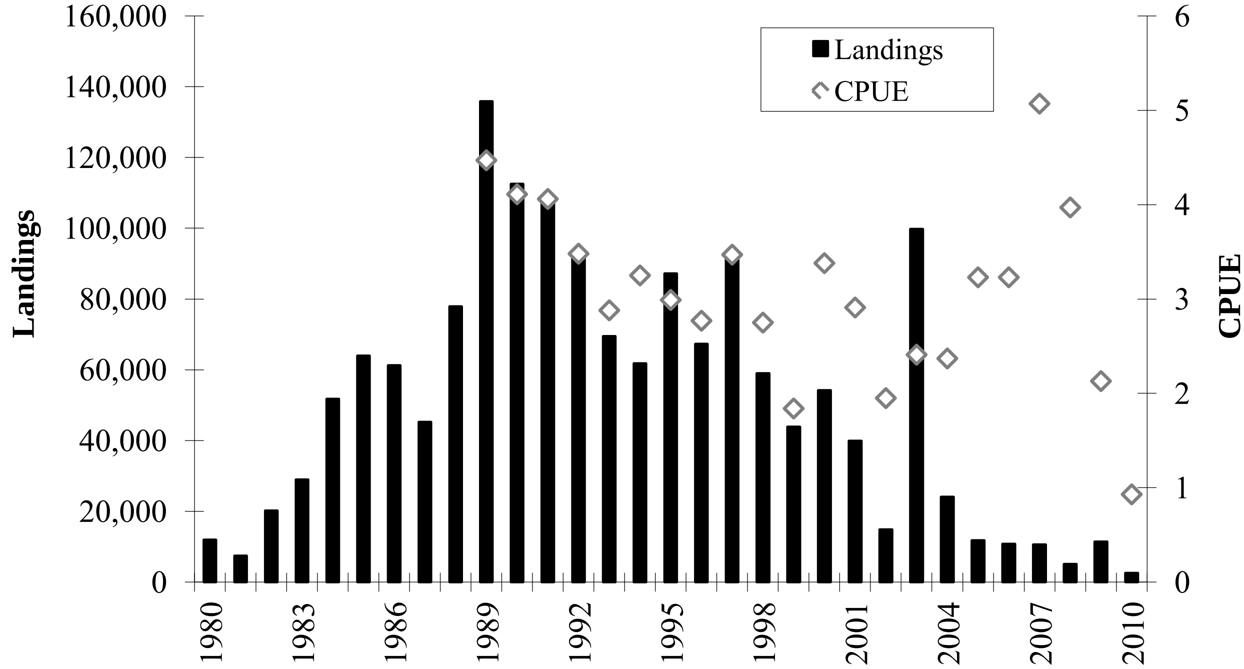

Figure 13.3. Geometric mean CPUE (alewife and blueback herring combined, 1989-2010), and the total commercial river herring landings in pounds, 1980-2010 from the Nanticoke River.

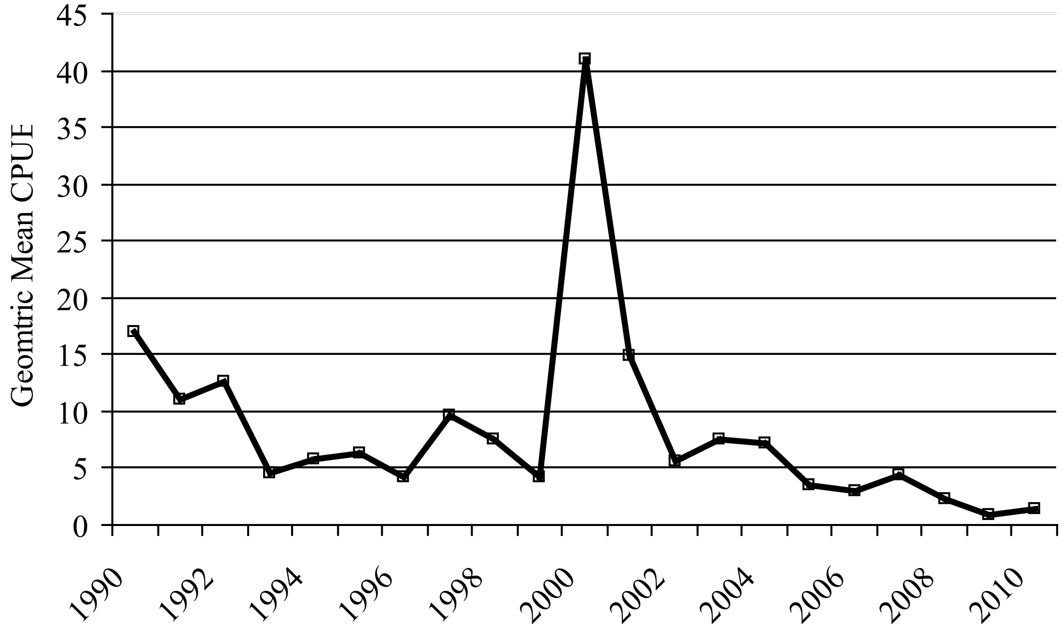

Figure 13.4 Geometric mean CPUEs of adult alewife herring from the Nanticoke River fyke nets, 1989-2010.

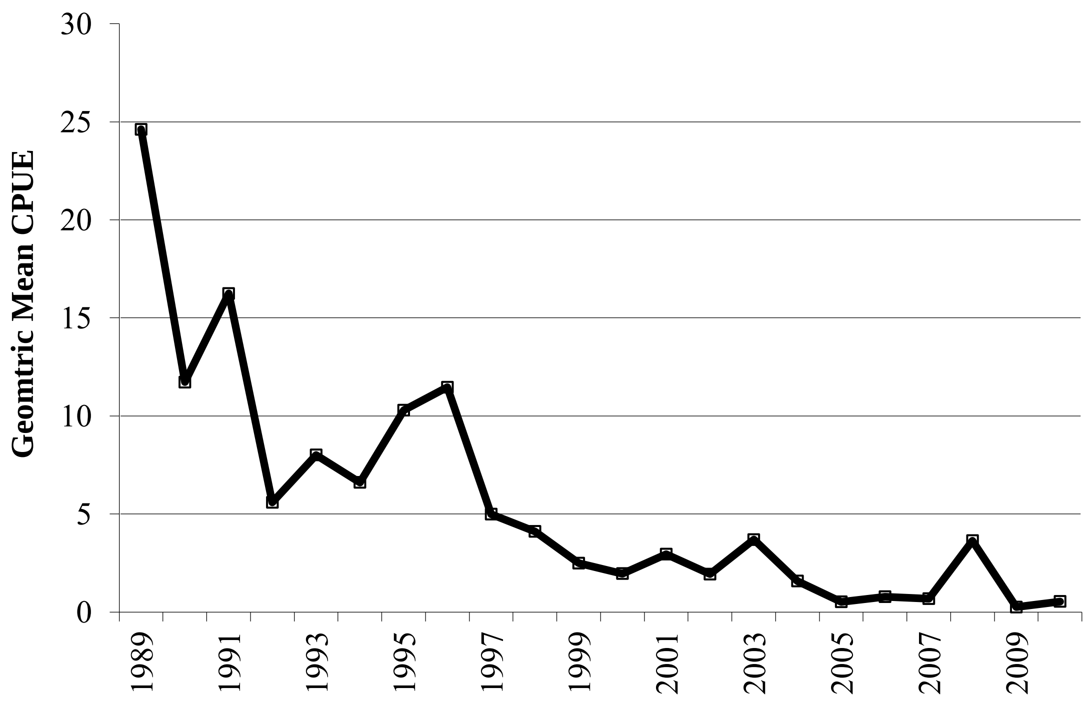

Figure 13.5 Geometric mean CPUEs of blueback herring from the Nanticoke River fyke nets, 1989-2010.

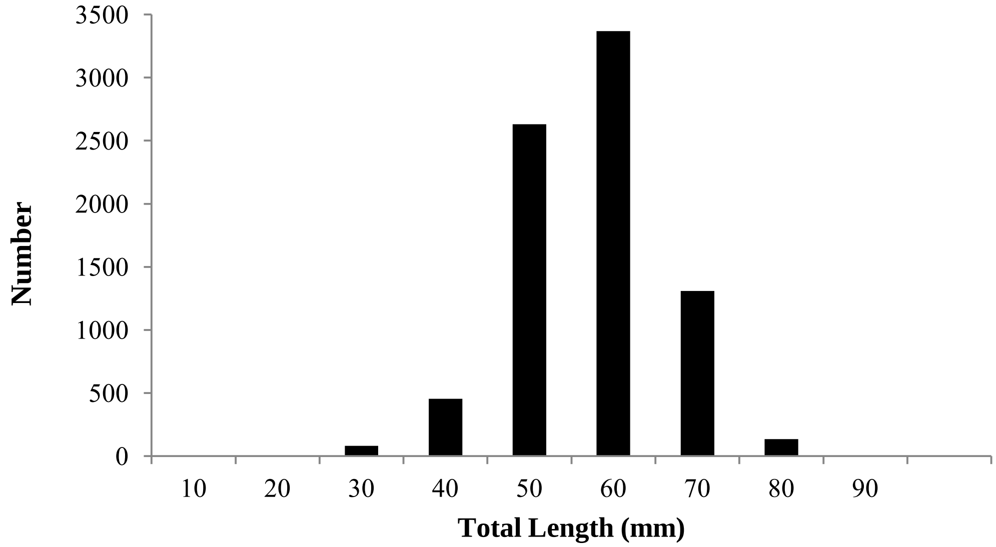

Figure 13.6 Length frequency of YOY blueback herring from the haul seine survey on the Nanticoke River in Delaware 1999-2010.

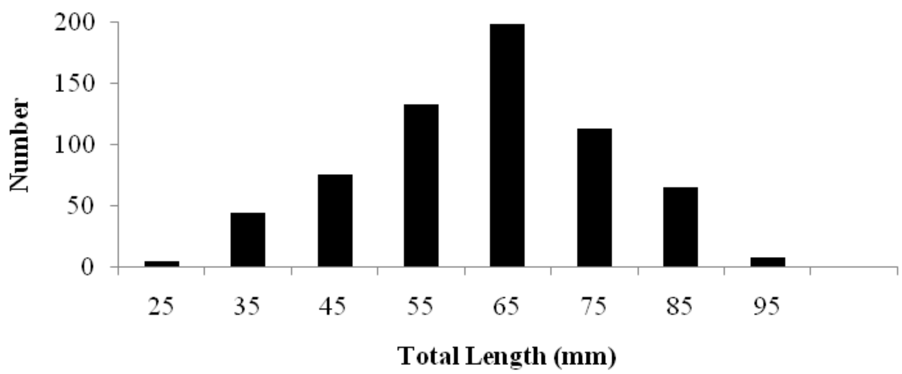

Figure 13.7 Length frequency of YOY alewife from the haul seine survey on the Nanticoke River in Delaware 1999-2010.

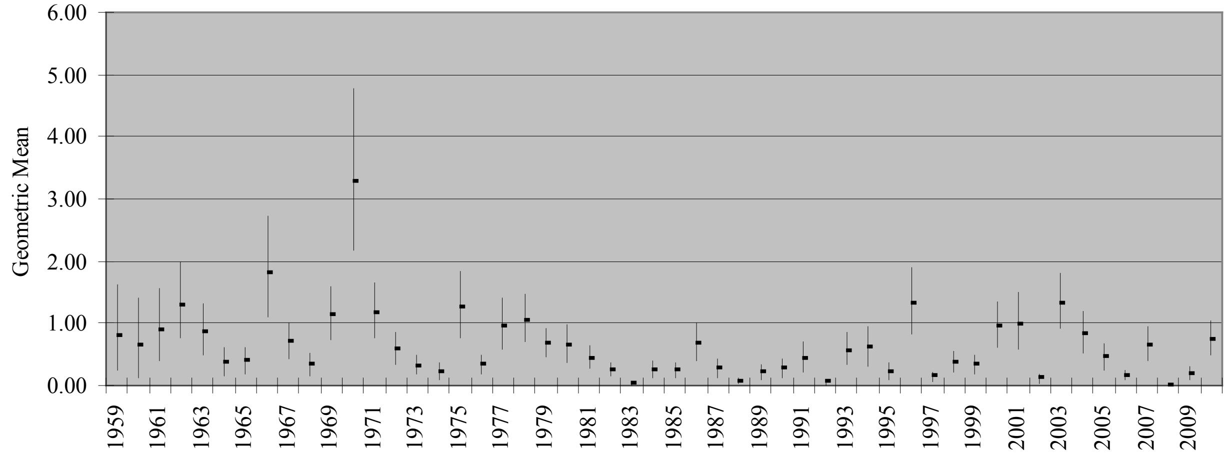

Figure 13.8 Baywide juvenile alewife herring geometric mean CPUEs with 95% confidence intervals, 1959-2010.

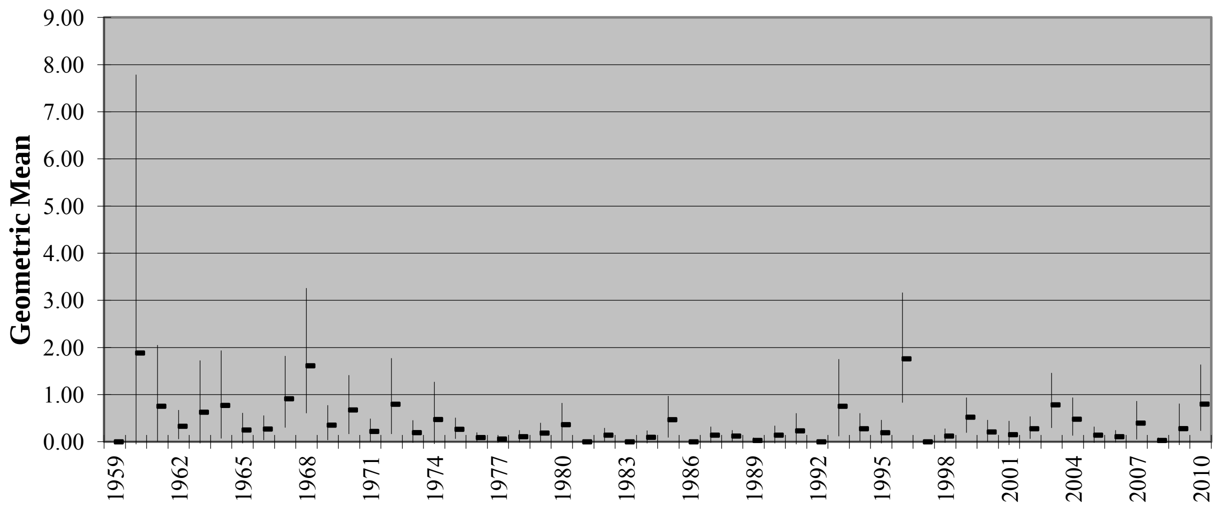

Figure 13.9 Nanticoke River juvenile alewife herring geometric mean CPUEs with 95% confidence intervals, 1959-2010.

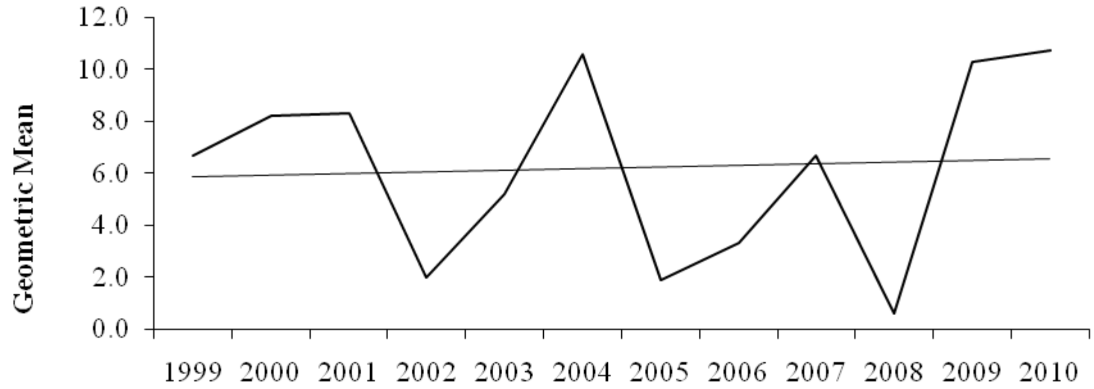

Figure 13.10 The geometric mean for juvenile blueback herring caught with the haul seine from the Nanticoke River and Broad Creek from 1999 through 2010.

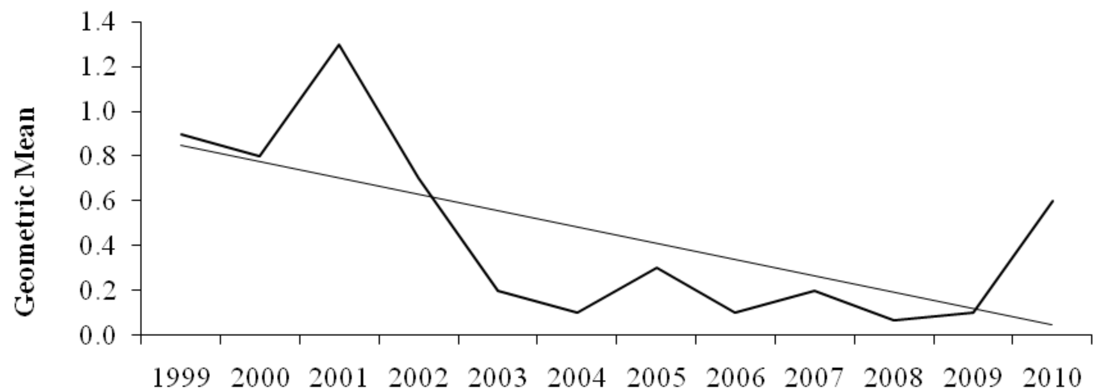

Figure 13.11 The geometric mean for juvenile alewife caught with the haul seine from the Nanticoke River and Broad Creek from 1999 through 2010.

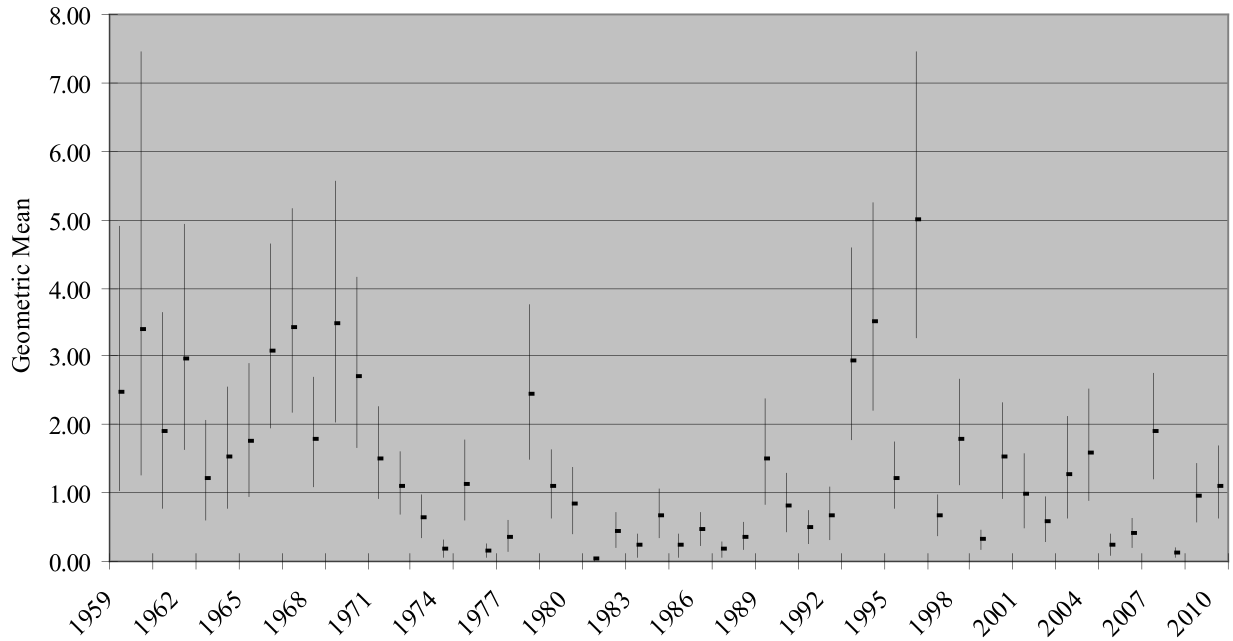

Figure 13.12 Baywide juvenile blueback herring geometric mean CPUEs with 95% confidence intervals, 1959-2010.

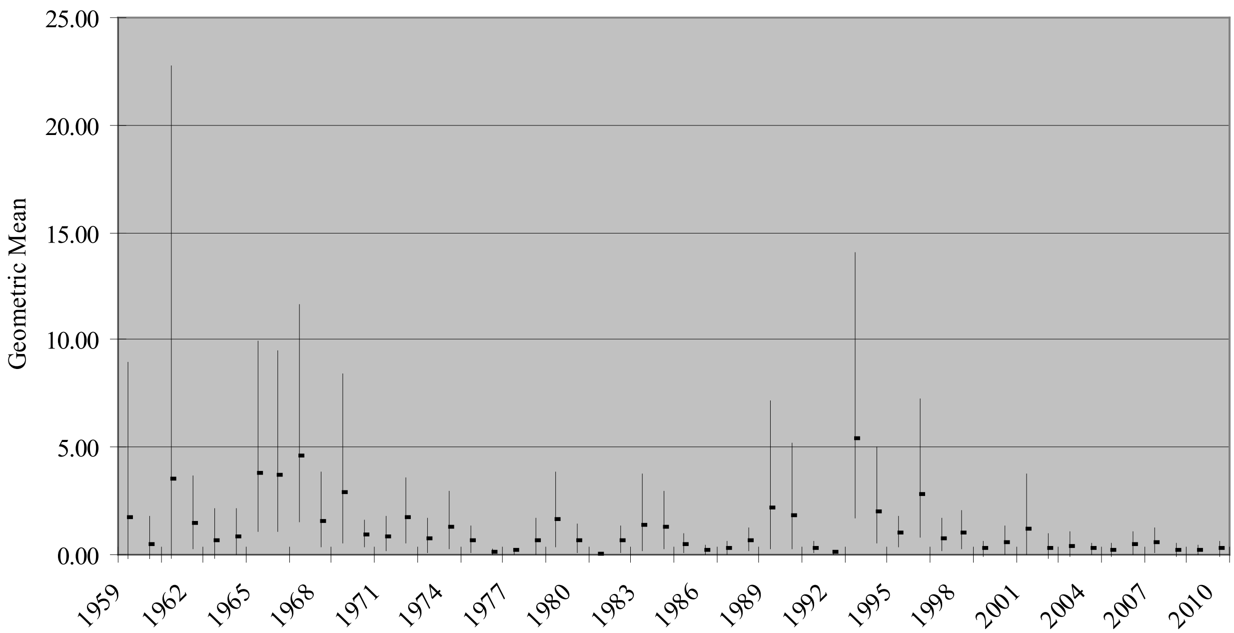

Figure 13.13 Nanticoke River juvenile blueback herring geometric mean CPUEs with 95% confidence intervals, 1959-2010.

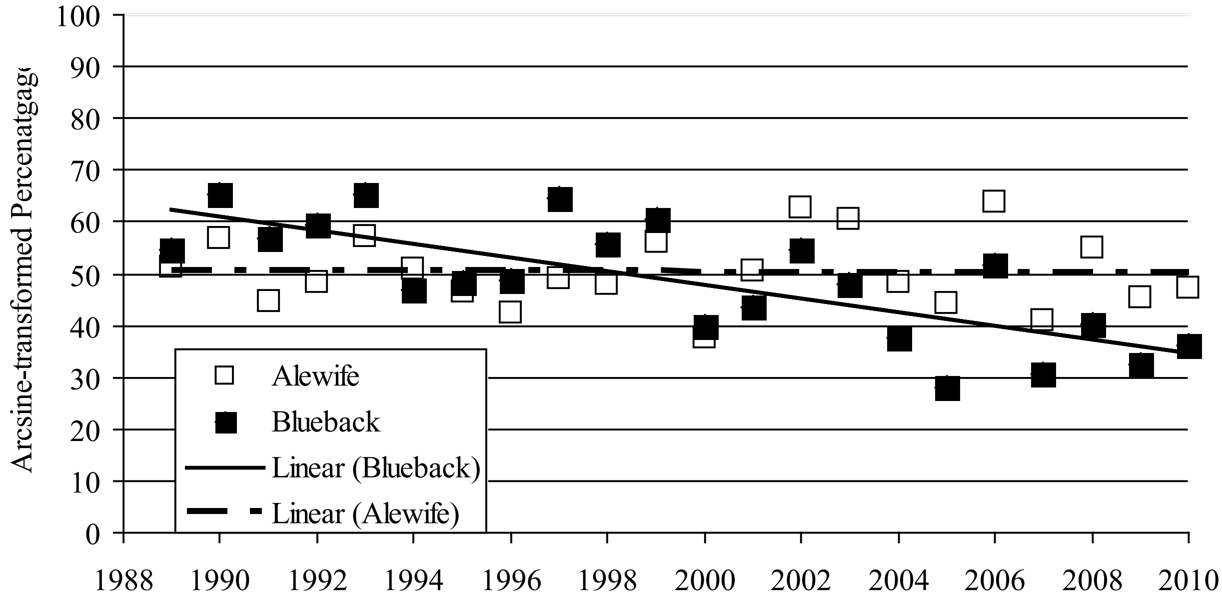

Figure 13.14 Trends in the arcsine-transformed percentage of repeat spawning alewife and blueback herring (sexes combined) from the Nanticoke River, 1989-2010.

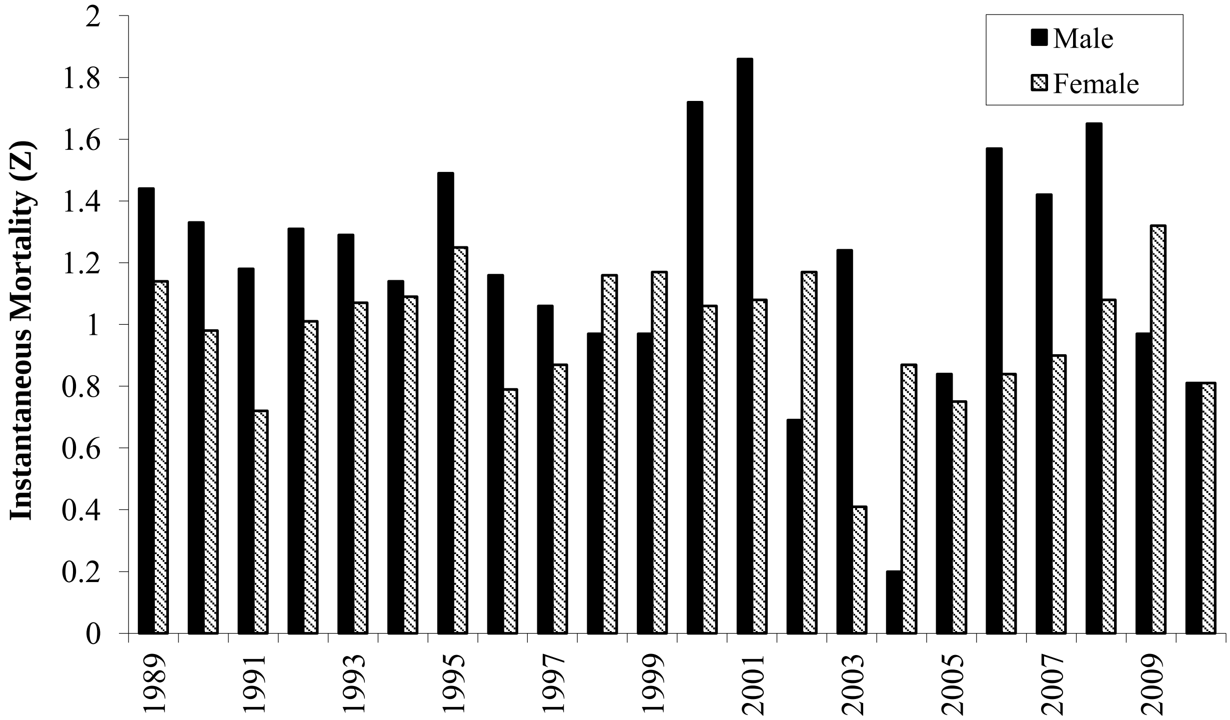

Figure 13.15 Alewife mortality rates for male and females from the Nanticoke River, 1989-2010.

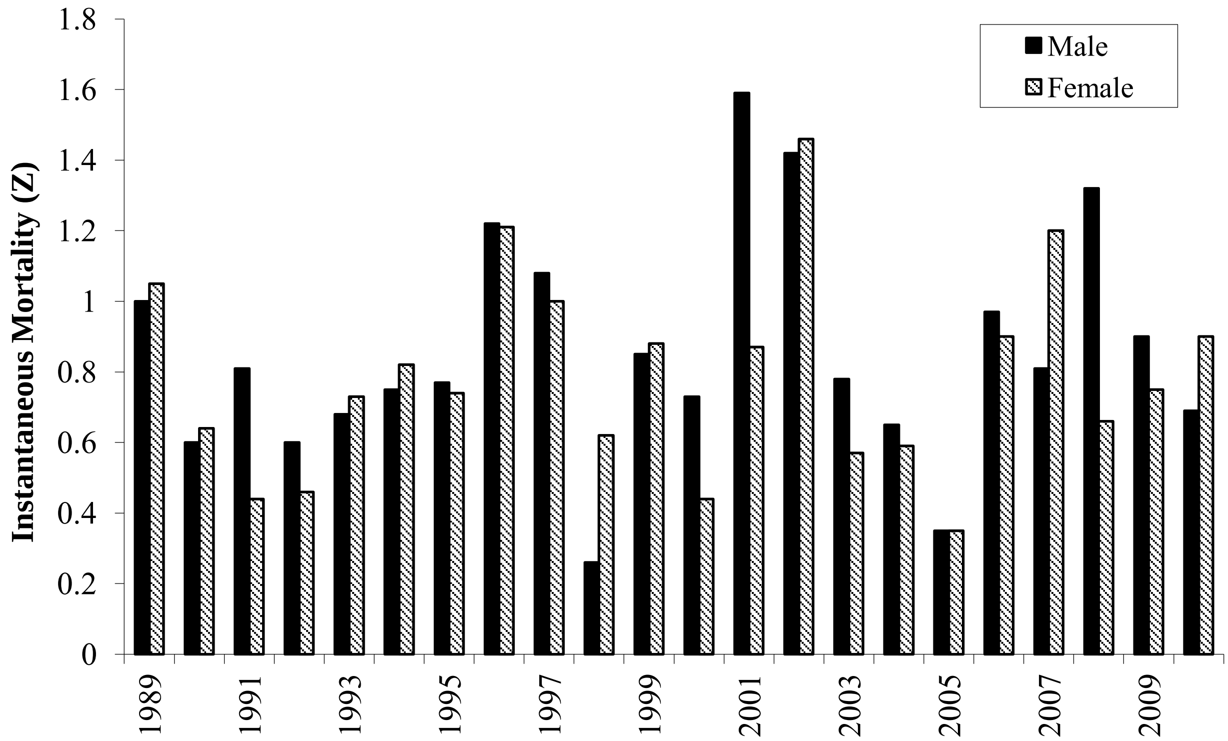

Figure 13.16 Blueback herring mortality rates for male and females from the Nanticoke River, 1989-2010.

Appendix 13.1: Development of a statistical catch-at-age model for the Nanticoke River MD

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Atlantic States Marine Fisheries Commission

1 Model Structure

The model structure was based on the cohort dynamics described in Gibson and Myers (2003). The model tracks abundance at year (*y*), age (*a*), and repeat spawner class (*r*) and fits against observed proportion at age and repeat spawner class, total catch, and a fishery-dependent CPUE index. The model was implemented in ADMB.

Alewife and blueback herring first return to the Nanticoke River at age-3, although the majority of individuals do not mature until age-4, based on repeat spawner marks on their scales. Without data on the at-sea portion of the river herring life cycle, the model treats age-3 as the first age class.

Age-3 recruits (R_y) are estimated by the model directly each year. The total number of age-3 recruits is broken down into numbers at spawning class 1 (immature fish) and spawning class 2 (virgin spawners) based on the proportion of fish that mature at age-3. The proportion of fish that mature at each age ($p_{mat}(a)$) was estimated from the repeat spawner data pooled across years and sexes. The number of age-3 fish in the higher repeat spawner classes is set to zero, as it is assumed no fish mature before age-3.

Immature recruits:

$$NAA_{y,1,1} = R_y \cdot \left(1 - p_{mat}(1)\right)$$

Virgin recruits:

$$NAA_{y,1,2} = R_y \cdot p_{mat}(1)$$

Recruitment of age-3 river herring is modeled as a log-normal deviation from average recruitment.

The model also estimates the initial age and repeat spawning structure of the population.

Abundance of ages-4+ from year *y*+1 forward are calculated as:

Immature fish:

$$NAA_{y,a,1} = NAA_{y-1,a-1,1} \cdot e^{-M} \cdot (1 - p_{mat}(a))$$

Virgin fish:

$$NAA_{y,a,2} = NAA_{y-1,a-1,1} \cdot e^{-M} \cdot p_{mat}(a)$$

Mature fish that have previously spawned ($r \geq 3$):

$$NAA_{y,a,r} = NAA_{y-1,a-1,r-1} \cdot e^{-M-F_{y-1}}$$

The oldest age (A) and highest repeat spawner class (RPS) are treated as a plus group:

$$NAA_{y,A,RPS} = NAA_{y-1,A-1,RPS-1} \cdot e^{-M-F_{y-1}} + NAA_{y-1,A,RPS} \cdot e^{-M-F_{y-1}}$$

The model estimates an annual fishing mortality rate, F_y, and all mature fish are assumed to be equally vulnerable to the fishery, which is primarily prosecuted with fyke and pound nets. Catch is calculated for each age and repeat spawner class by year:

$$\hat{C}_{y,a,r} = NAA_{y,a,r} \cdot (1 - e^{-F_y}) \cdot \frac{F_y}{Z_{y,a,r}}$$

Total catch is summed across age and repeat spawner class to obtain predicted annual total catch, and the catch at age and repeat spawner class is divided by total annual catch to obtain the predicted proportion of catch at age and repeat spawner class:

$$\hat{P}_{y,a,r} = \frac{\hat{C}_{y,a,r}}{\sum_a \sum_r \hat{C}_{y,a,r}}$$

To tune the model, a fishery dependent CPUE (fish per net-day) from the fyke net fishery was used. Catchability was estimated by the model on a log scale, and the predicted index was calculated as the catchability times the abundance of mature fish:

$$\hat{I}_y = q \cdot N_{total,mature}$$

Lognormal errors were assumed for the total catch data and the index data:

$$-\ln(L) = \ln(\sigma) + 0.5 \cdot n_{years} \cdot \sum_y \frac{(\ln(obs) - \ln(pred))^2}{\sigma^2}$$

Multinomial errors were assumed for the proportion at age and repeat spawn class:

$$-\ln(L) = -ESS\sum_{a}\sum_{r} obs \cdot \ln{(pred)}$$

Effective sample size was the annual number of sampling trips over which the biological samples were obtained. ADMB's delta-method was used to estimate standard deviation for parameters of interest.

2 Data Used

Total catch of river herring in Maryland is not reported by species. Since the runs of alewife and blueback herring peak at different times, the species composition of the fisheries dependent sampling by month was multiplied by the reported landings by month to obtain landings by species by month, and then summed across month to obtain total annual landings by species (Figure 13.1.1). For month and year combinations with low sample size, the average species composition across years for that month was used.

Proportion of catch at age and repeat spawner class was obtained from the same biological sampling of the fishery. See the Maryland Report (Chapter 13) for more details on the sampling protocols. Age 7 was the final age in the model, and 4 was the maximum number of repeat spawner classes, plus an additional class to represent immature fish which was not included in the likelihood function.

A fishery-dependent CPUE of the geometric mean of fish per net-day from the fyke net fishery was used as a tuning index; see the Maryland Report (Chapter 13) for more details. The index was assigned a higher CV than the total catch estimates, to reflect the fact that the index was more variable over time and less precise than the catch, which are assumed to be well-reported over the time period of the model.

M was assumed to be age constant for ages-3+ and set at 0.35 for both species, based on the maximum observed ages for alewife and blueback herring.

3 Reference Points

A spawner-recruit curve was not calculated for this model, as the short time series without a lot of contrast in stock size would not be informative. In addition, the number of age-3 recruits is also a function of at-sea mortality, and if that is not in equilibrium, it may bias the underlying relationship. Instead, SPR benchmarks were calculated externally from the model using the YPR program (v. 2.7.2) in the NFT toolbox.

Given the at-sea fisheries that act on immature fish and the concerns about increasing predation on juveniles as well as adults, a constant vulnerability function was assumed, which results in a lower $F_{20\%SPR}$ than would be calculated for a fishery that operated solely on mature adults.

4 Results and Conclusions

The spawning stock and total age-3+ abundance of both alewife and blueback herring were at low levels (Figure 13.1.2, Figure 13.1.3). Exploitation rates have increased in recent years for alewife and are now above the $F_{\%SPR}$ benchmarks (Figure 13.1.8); the estimates from this period also have higher error associated with them.

Blueback herring showed a peak in exploitation rates in 2004 and 2005, although again, they were not well estimated by the model. Otherwise, fishing mortality has varied near or below the SPR benchmarks (Figure 13.1.9).

Recruitment residuals for both species were negative in recent years (Figure 13.1.4, 5), indicating recruitment of age-3 fish has been below average. Since there has not been a trend in YOY indices in the same time-period, it suggests that at-sea mortality may be playing a role in driving recruitment of mature adults to the fishery.

For both species F showed a stronger retrospective effect than SSB; as more years of data were added, the overall trend did not change much for either parameter, but peaks appeared in different years for F (Figure 13.1.13, Figure 13.1.14).

More work needs to be done to quantify losses at-sea, both natural and anthropogenic. Genetic work can help identify Nanticoke river herring in the ocean incidental catch, and including that time stream of data would improve estimates of fishing mortality by fleet.

Additionally, increasing M across the board changed estimates as expected, resulting in higher abundance and lower F. Attempting to estimate M made the model unstable. As Maryland is closing their river herring fisheries, but planning to maintain sampling of incidentally caught fish, future years of data may help address questions on non-directed sources of mortality for this stock.

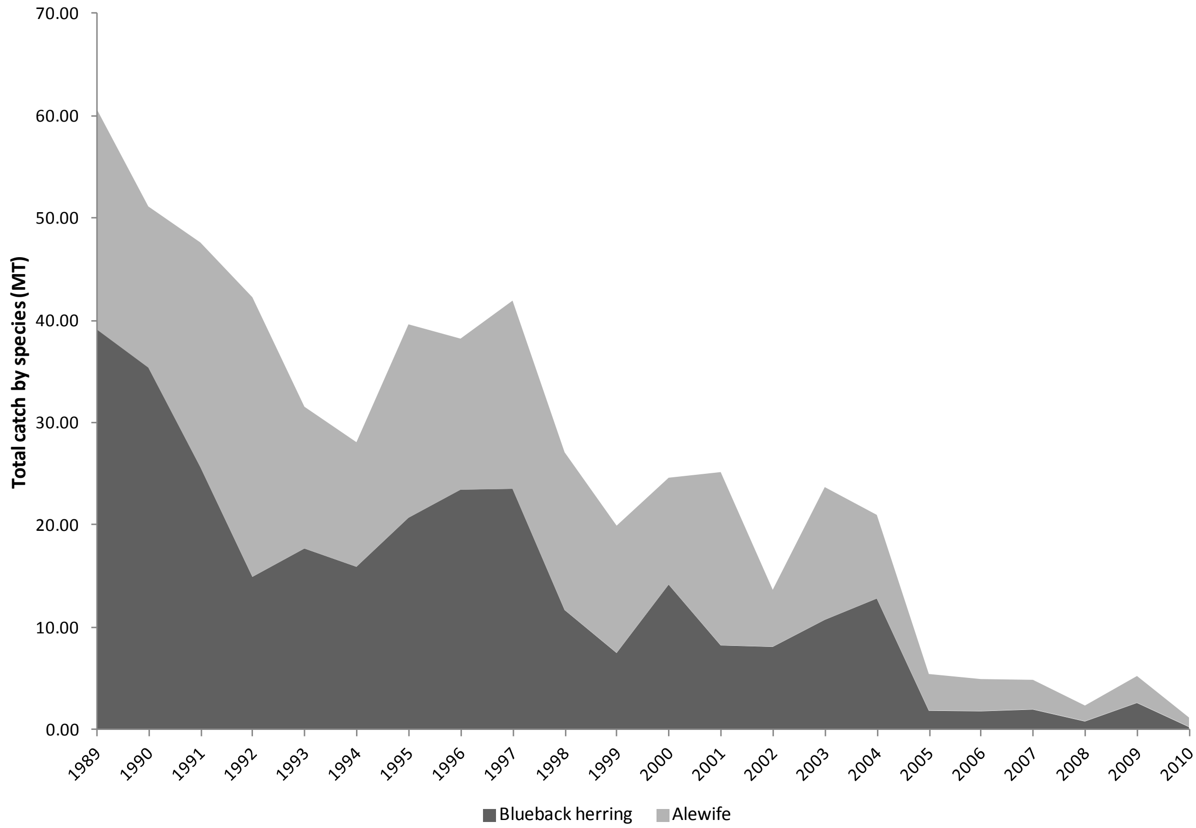


Figure 13.1.1 Total catch of river herring in metric tons from the Nanticoke River by species.

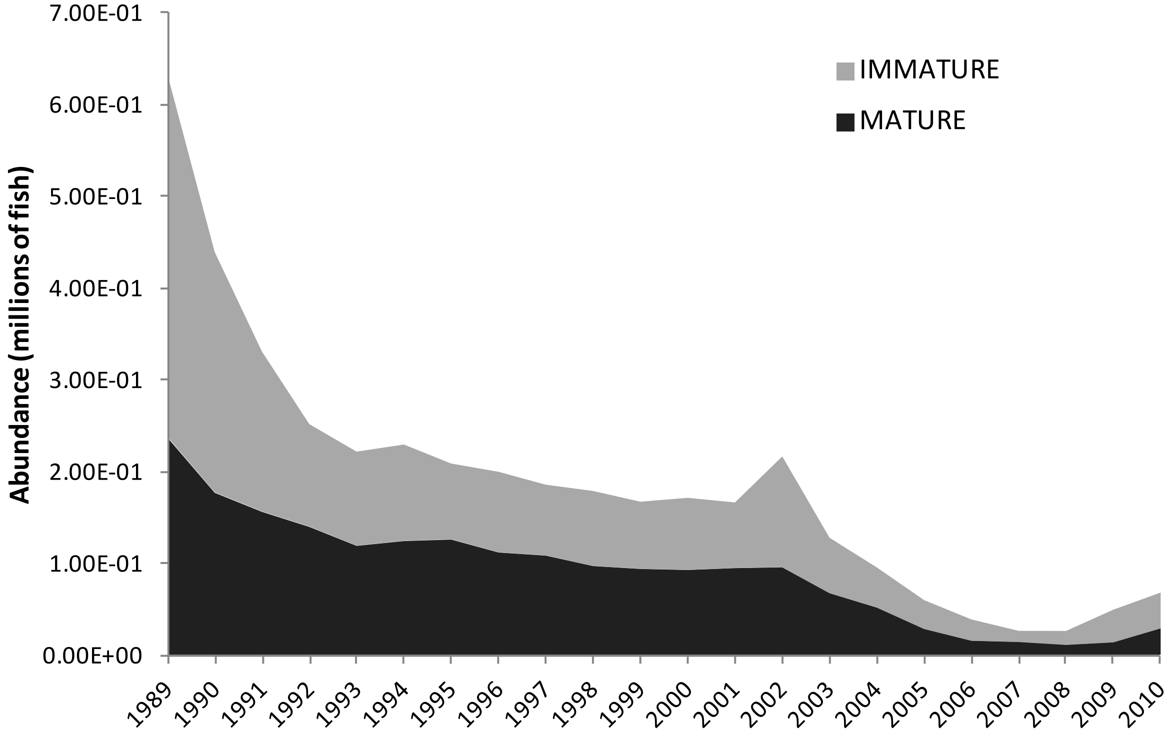


Figure 13.1.2: Total age-3+ abundance of alewife in millions of fish.

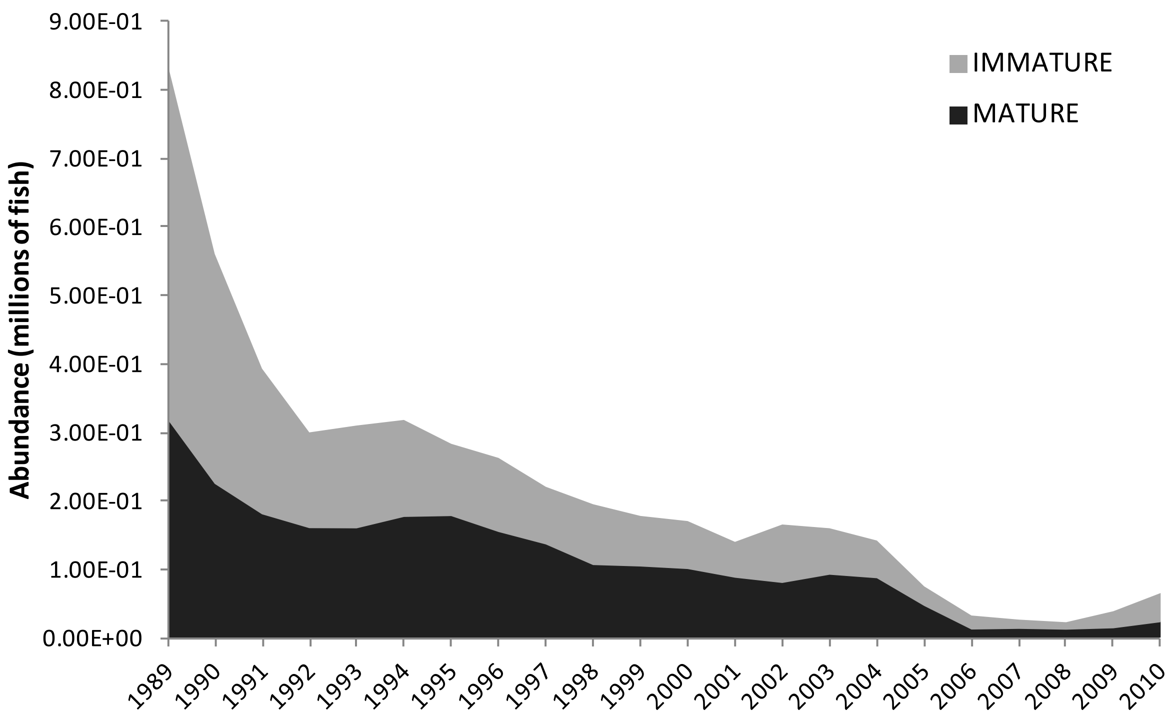


Figure 13.1.3 Total abundance of age-3+ blueback herring in millions of fish.

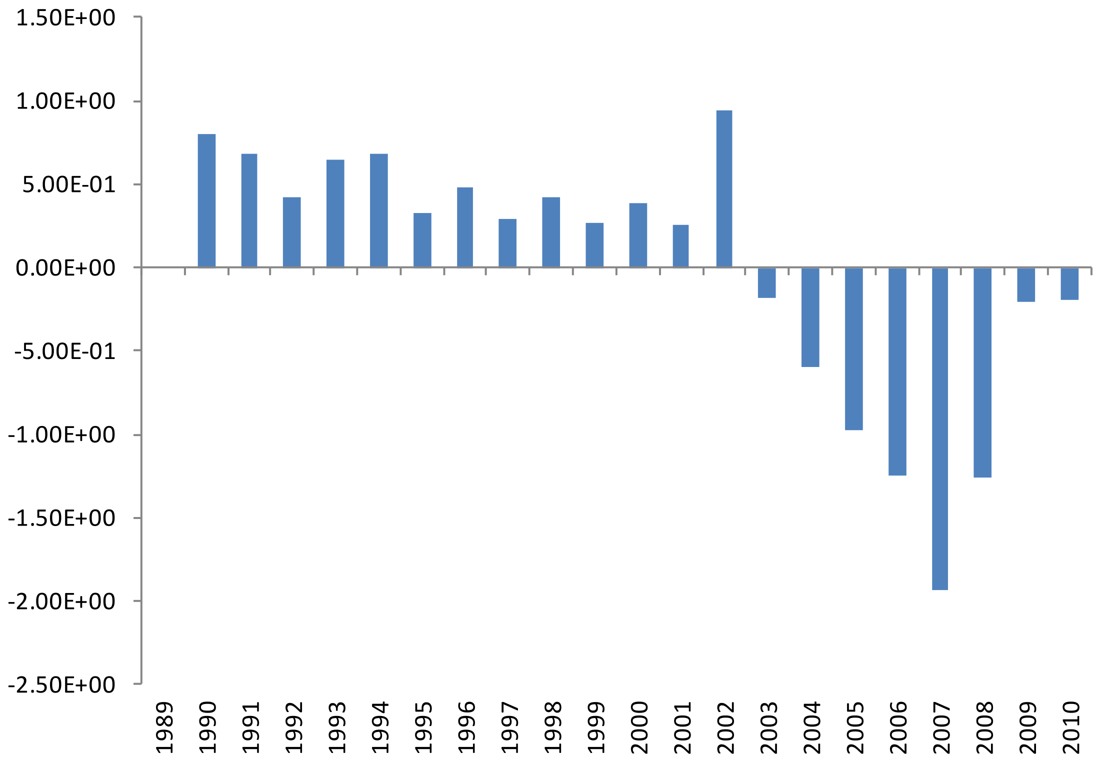


Figure 13.1.4 Recruitment deviations (log-scale) for alewife.

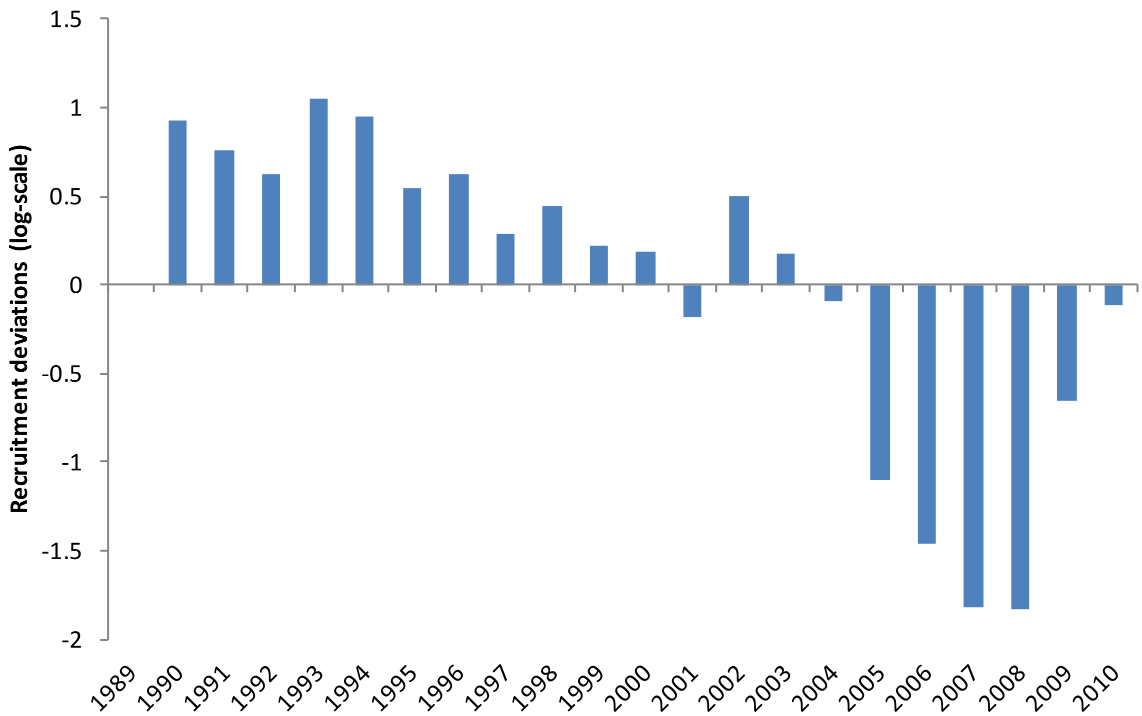
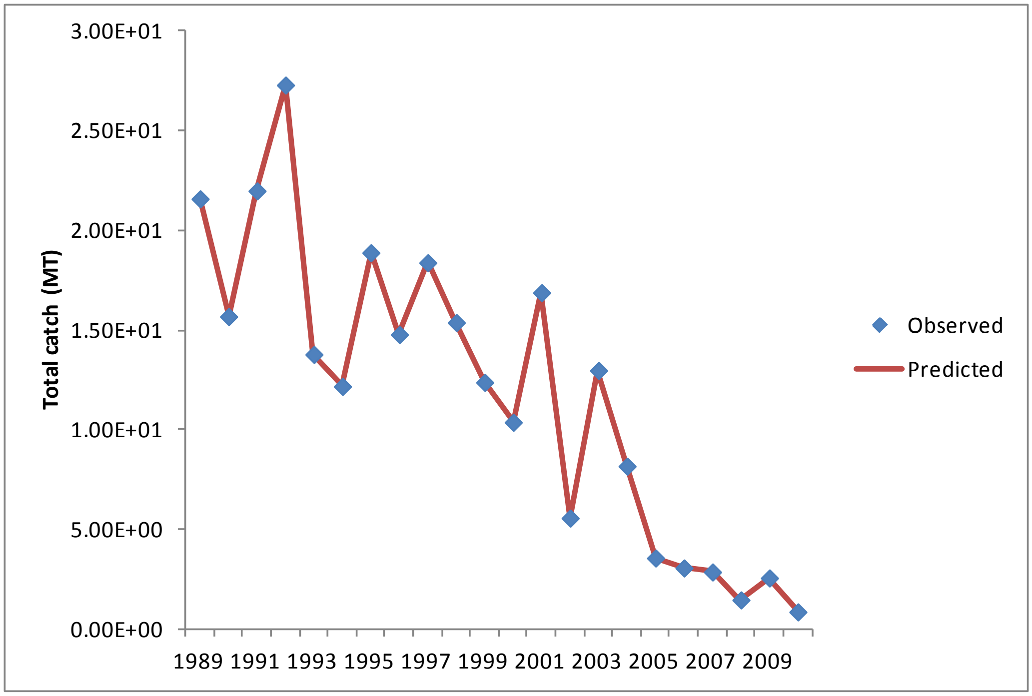


Figure 13.1.5 Recruitment deviations (log-scale) for blueback herring.



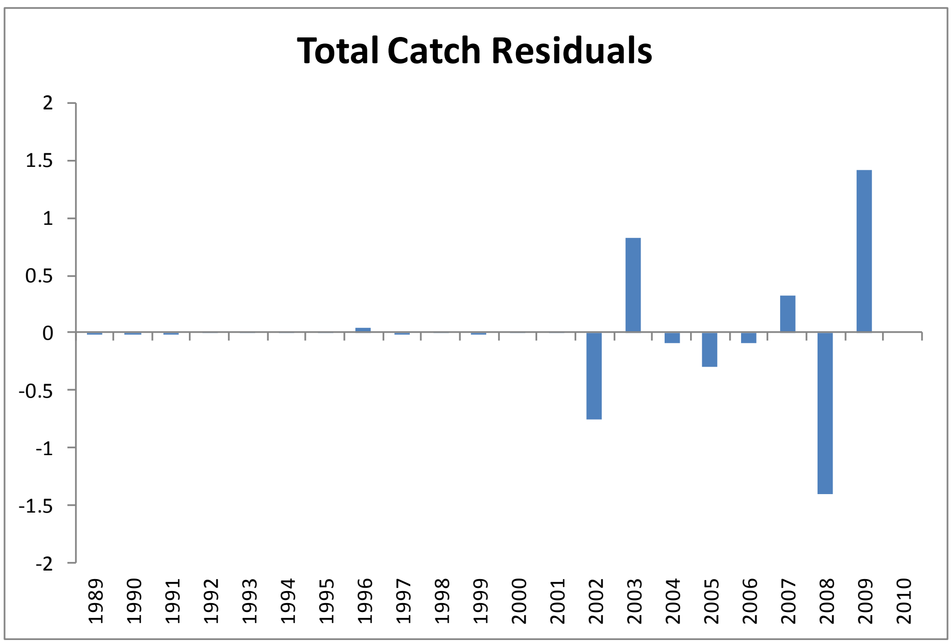


Figure 13.1.6 Observed and predicted total catch (top) and standardized total catch residuals for alewife.

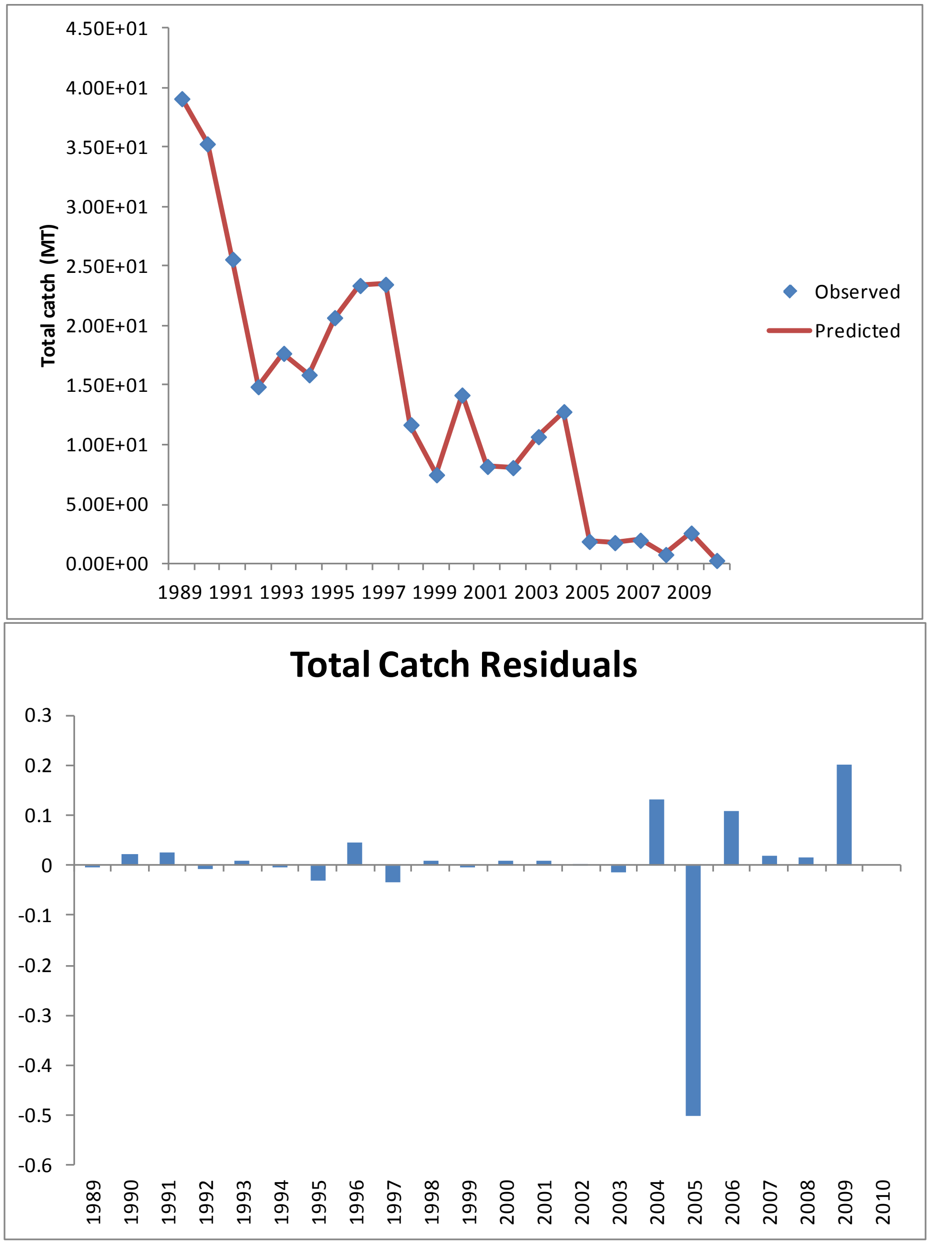


Figure 13.1.7 Observed and predicted total catch (top) and standardized total catch residuals (bottom) for blueback herring

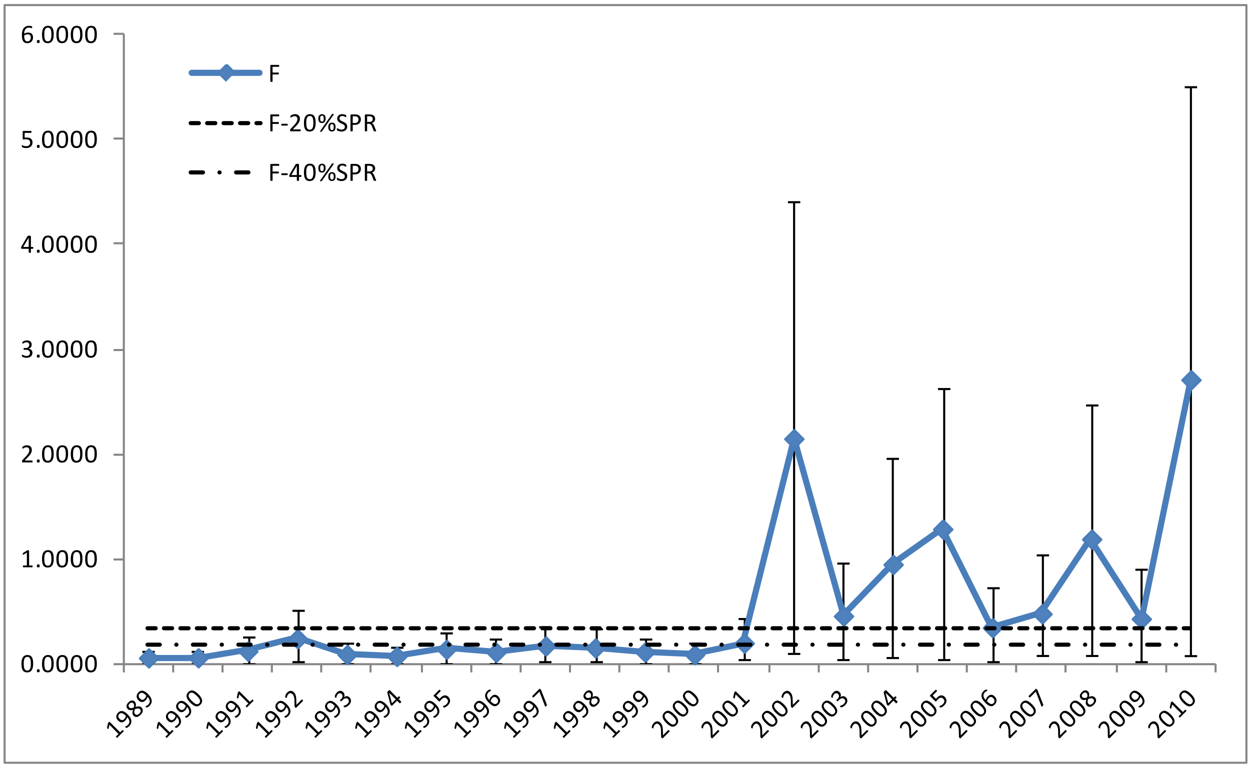


Figure 13.1.8: Predicted F for alewife herring with $F_{20\%SPR}$ and $F_{40\%SPR}$.

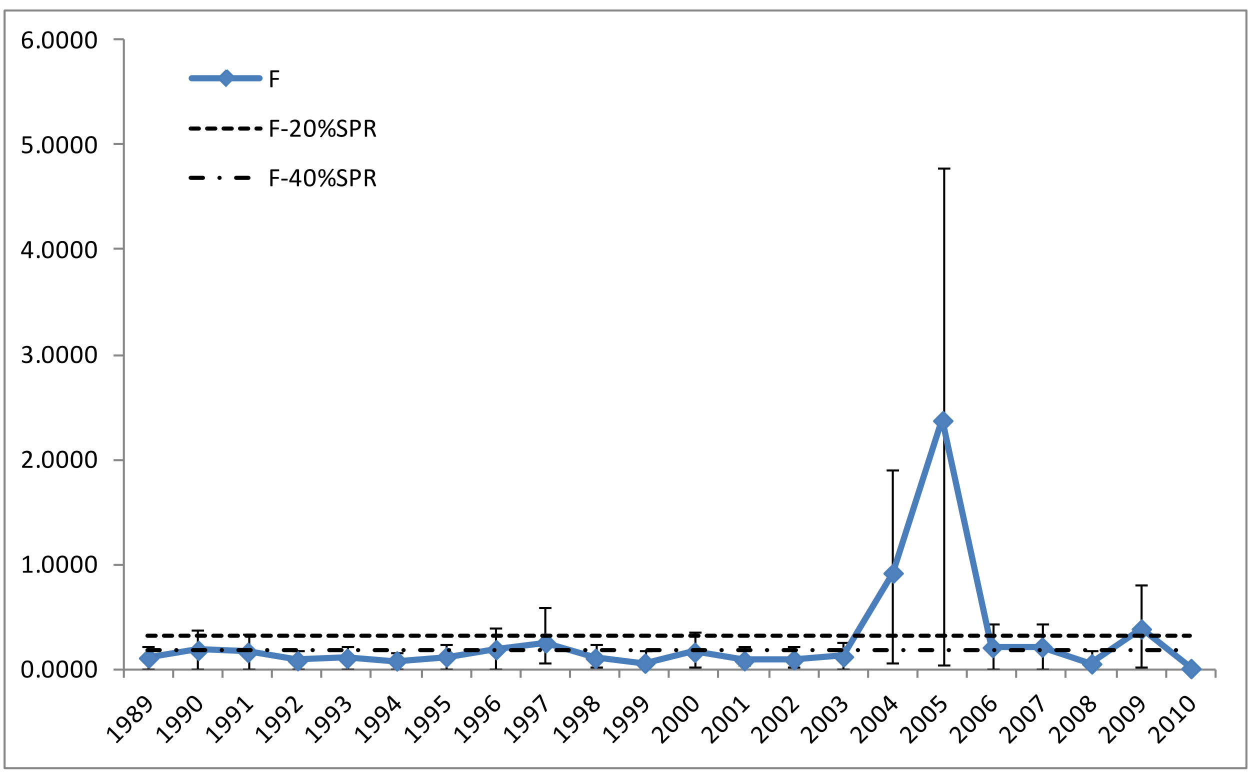
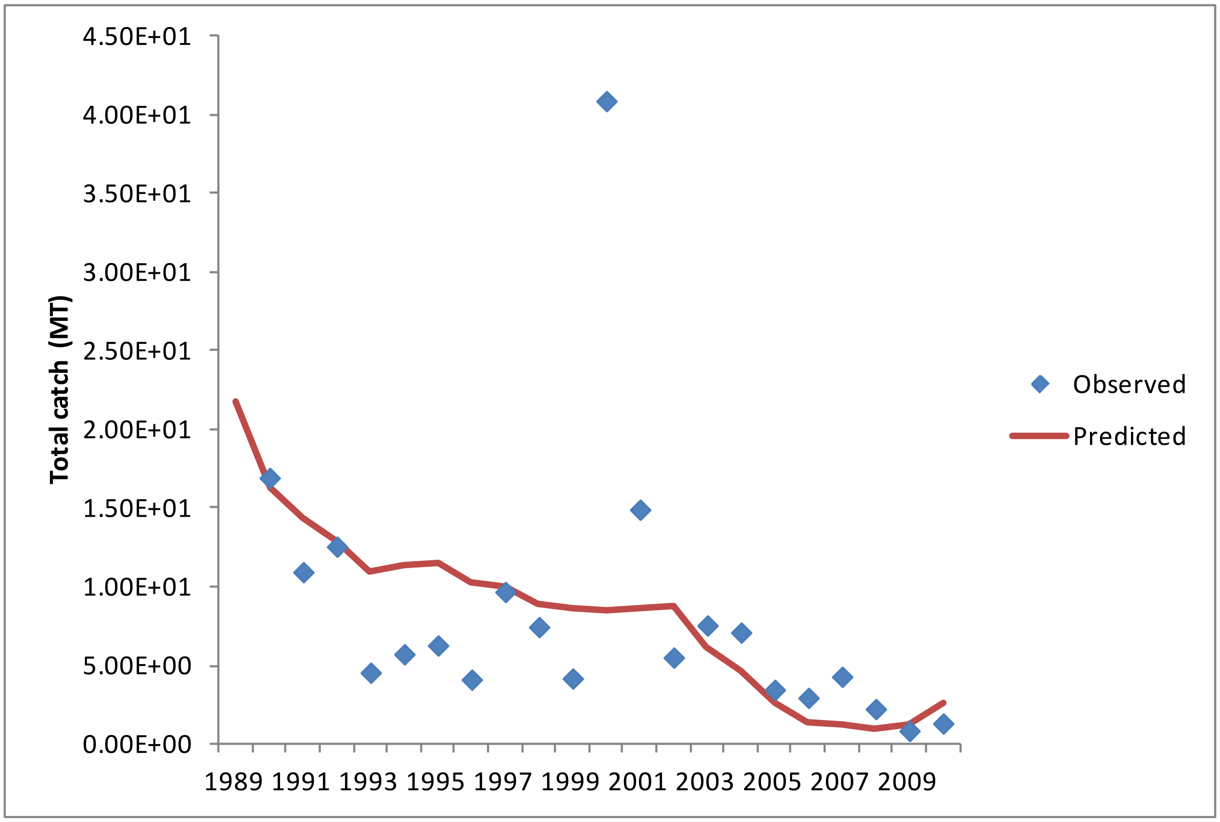


Figure 13.1.9 Predicted F for blueback herring with $F_{20\%SPR}$ and $F_{40\%SPR}$.



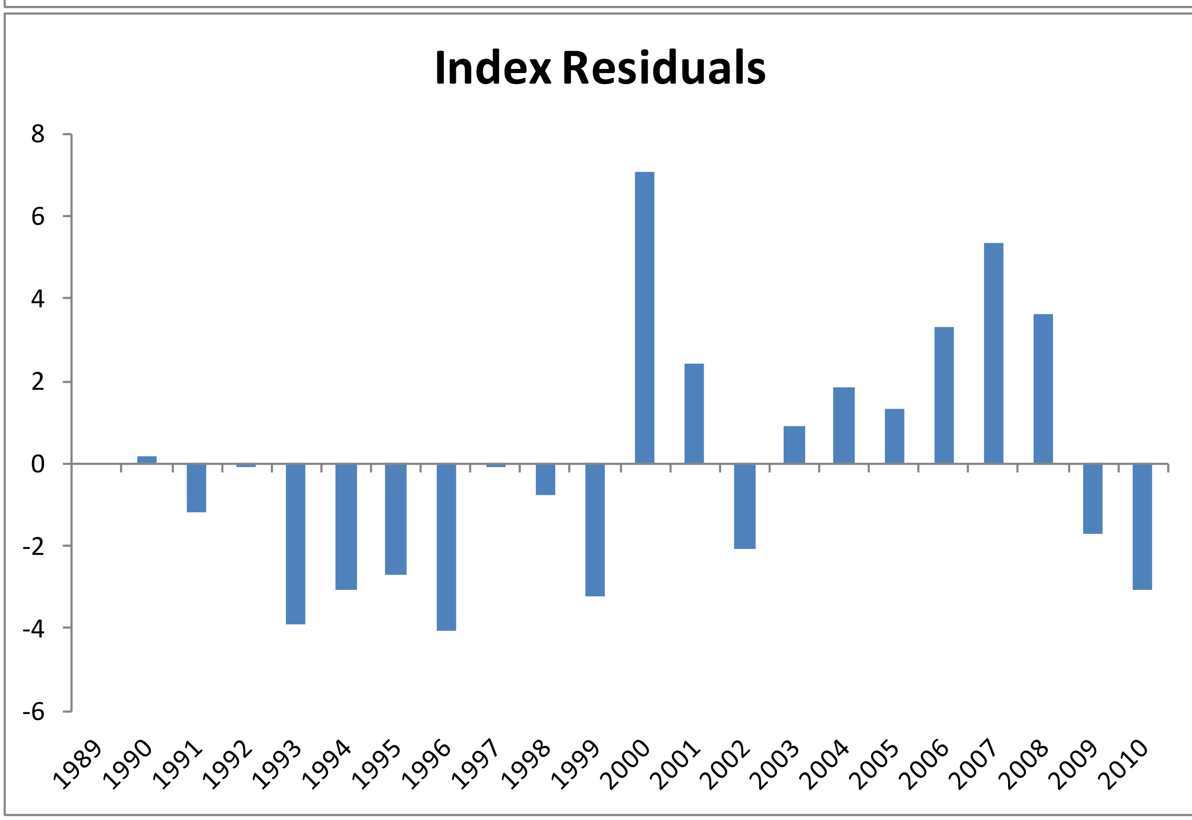
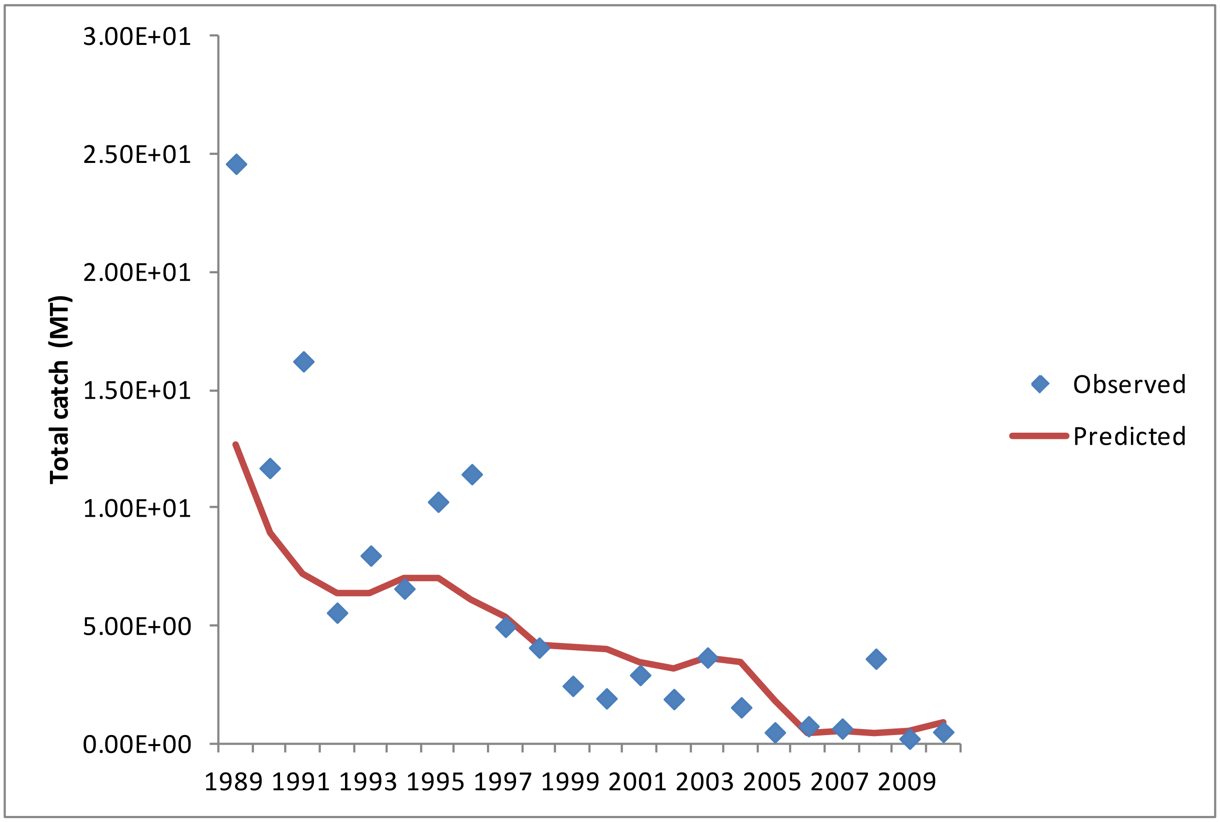


Figure 13.1.10 Fits to the fishery dependent index for alewife.



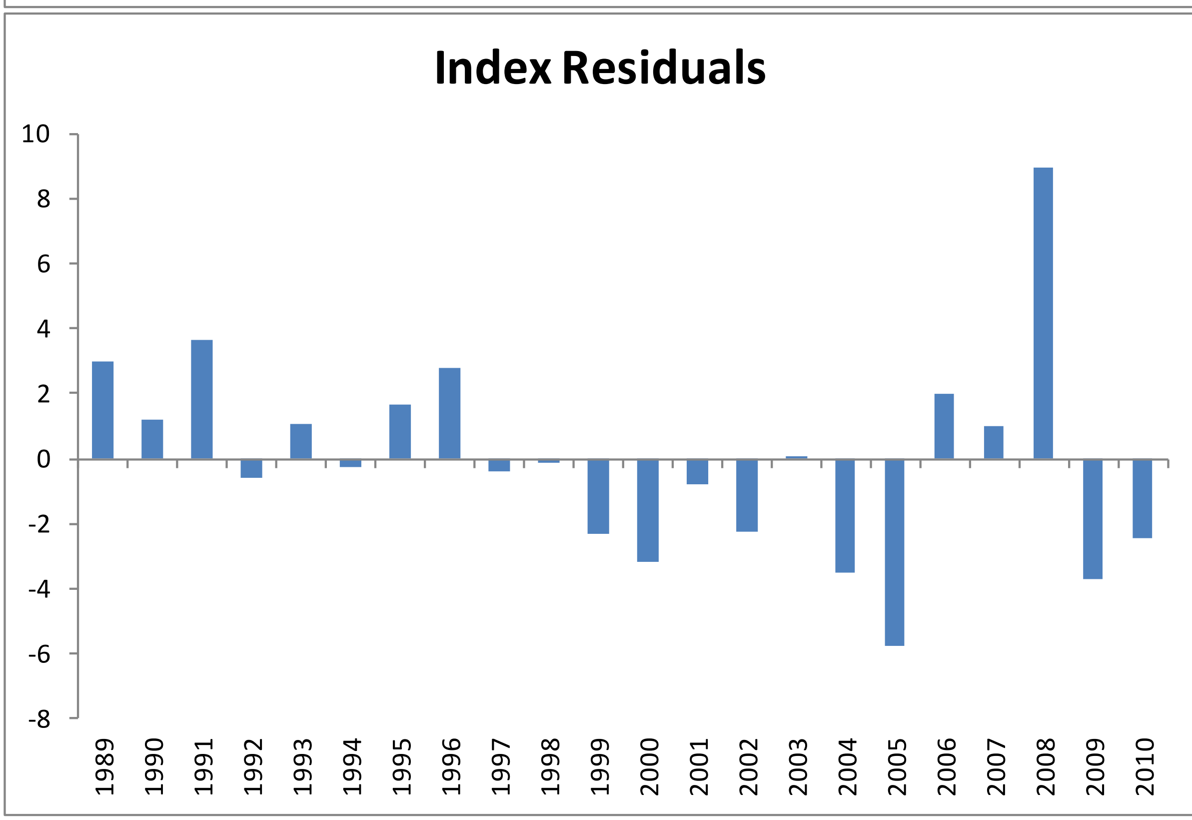


Figure 13.1.11 Fits to the fishery dependent index for blueback herring.

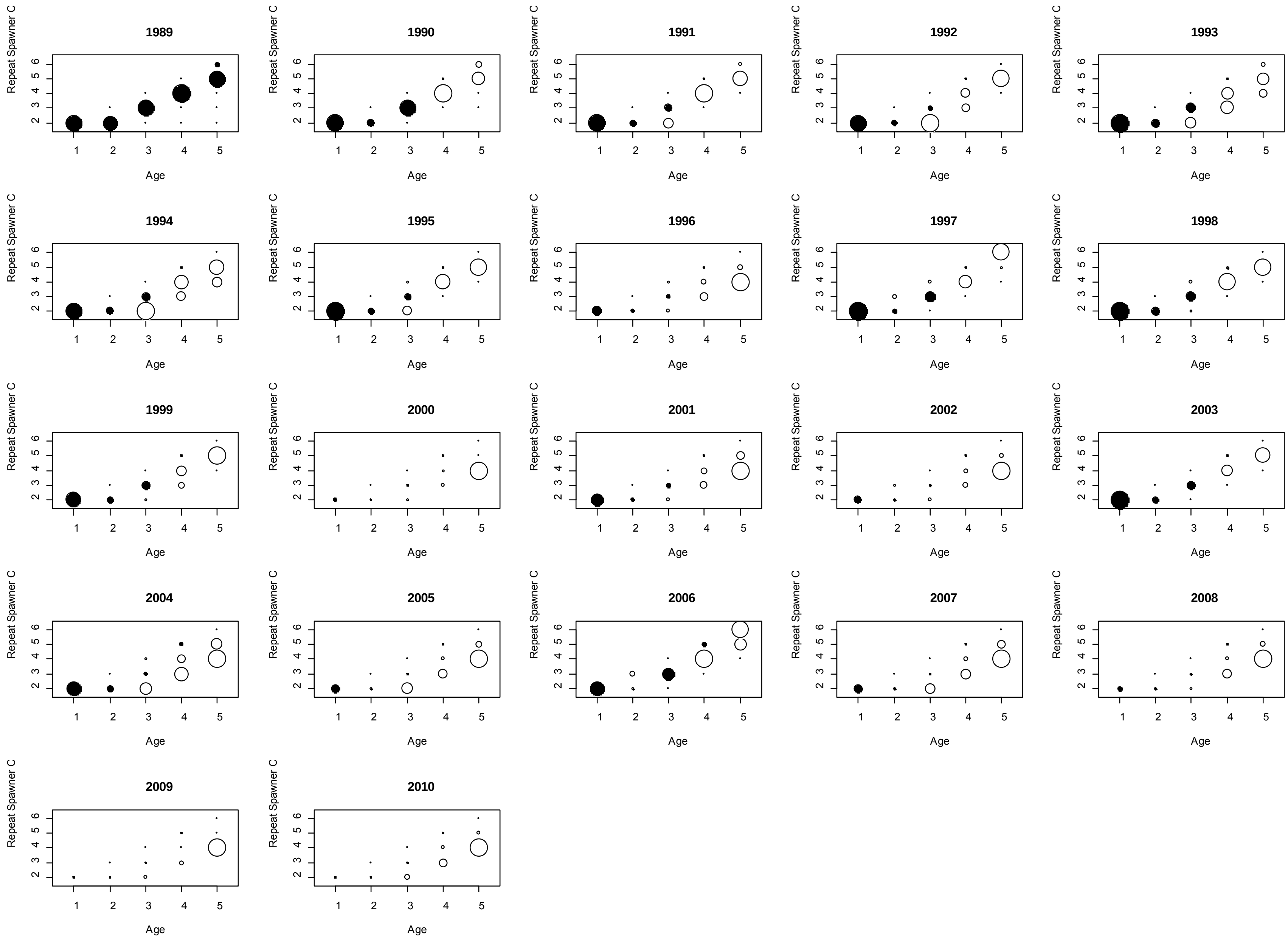


Figure 13.1.12 Residuals for proportion at age and repeat spawner class for alewife (filled = positive, empty=negative).

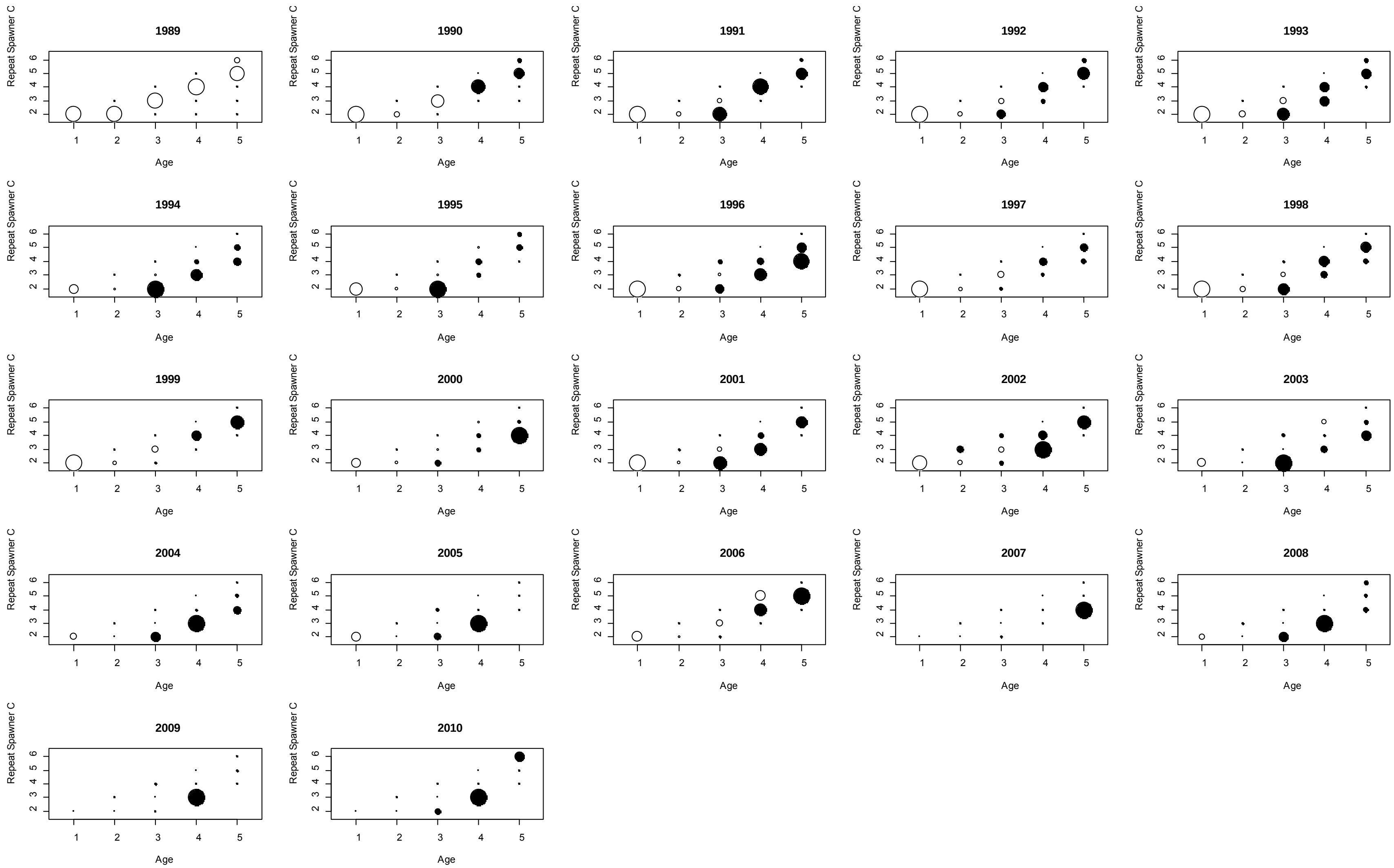


Figure 13.1.13 Residuals for proportion at age and repeat spawner class for blueback herring (filled = positive, empty=negative).

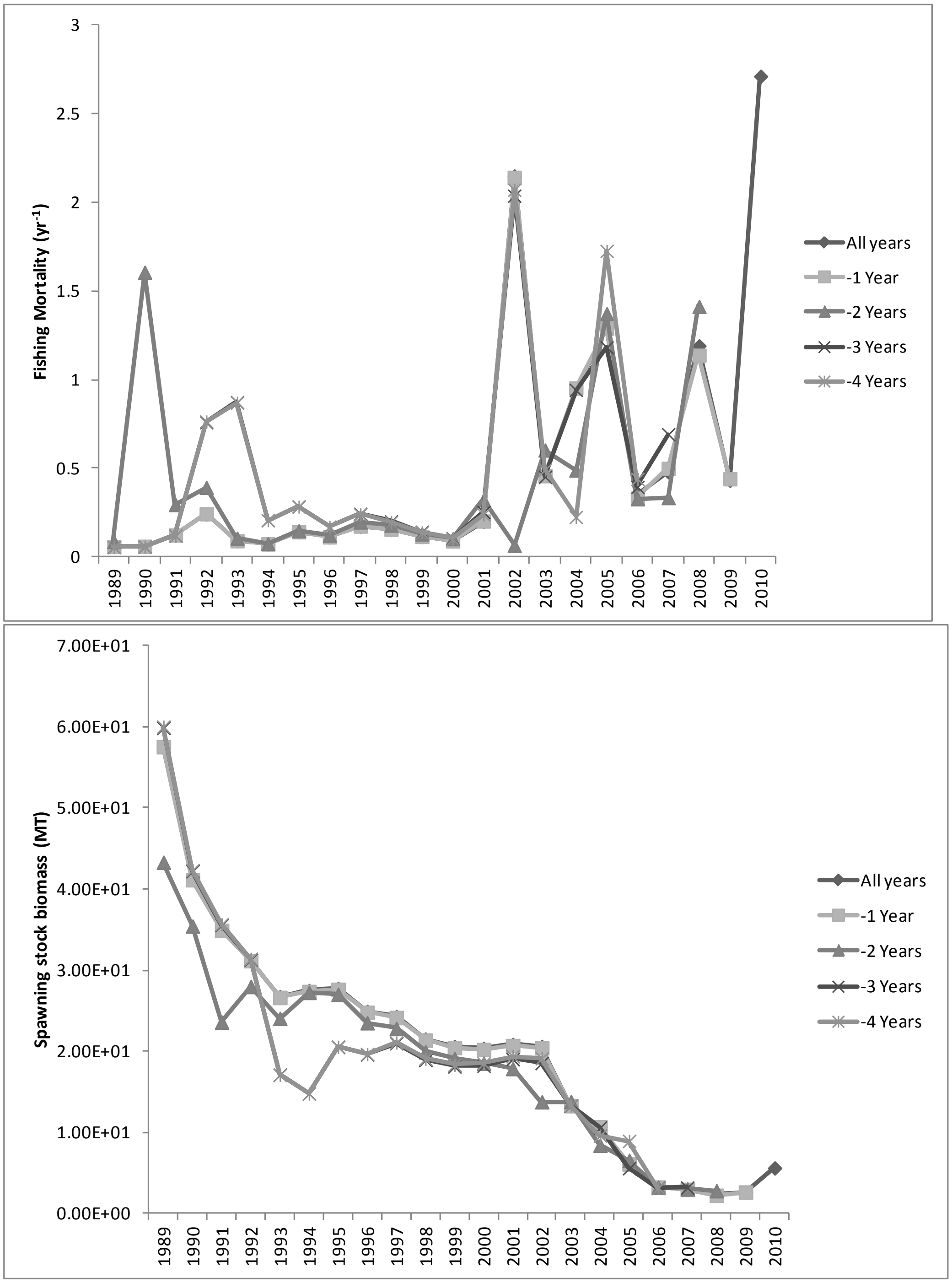
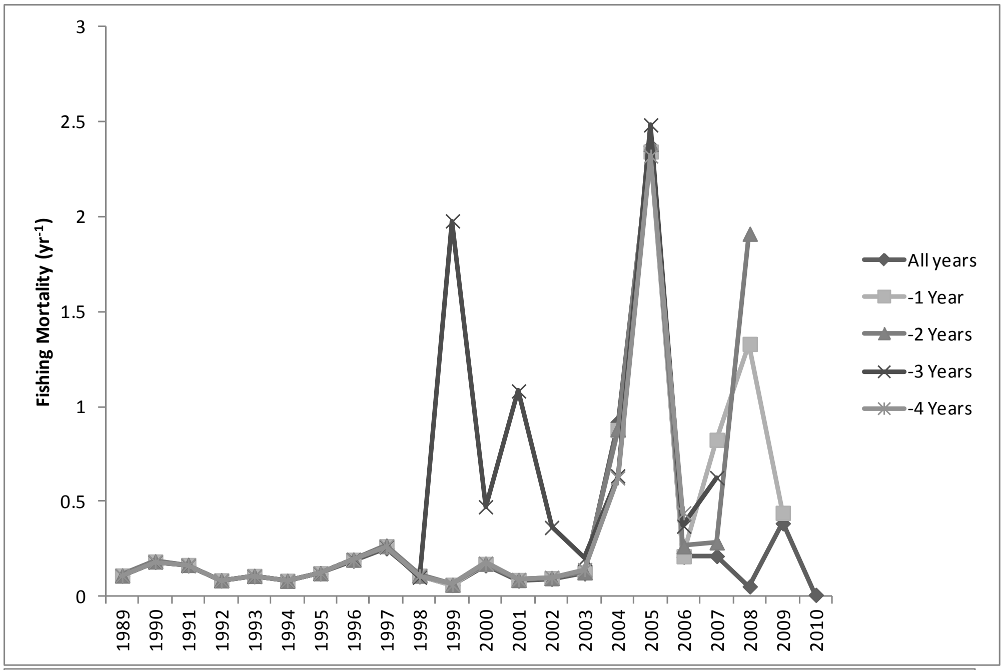


Figure 13.1.14 Retrospective analysis for alewife for fishing mortality (top) and spawning stock biomass (bottom).



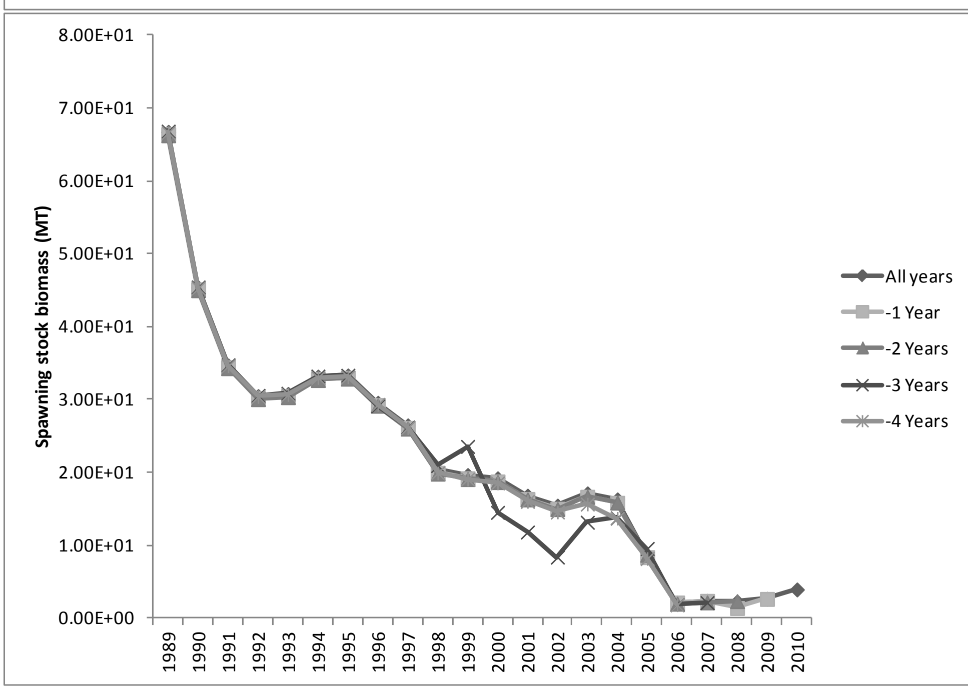


Figure 13.1.15 Retrospective analysis for blueback herring for fishing mortality (top) and spawning stock biomass (bottom).

Model Code

```
DATA_SECTION
//FIRST CALENDAR YEAR OF MODEL
  init_int start_year;

//TOTAL NUMBER OF YEARS
  init_int n_years;

//TOTAL NUMBER OF AGES
  init_int n_ages;

//NUMBER OF REPEAT SPAWNER CLASSES
  init_int n_rps;

//PROBABLITY OF MATURING AT AGE
  init_vector pMat(1,n_ages);

//NATURAL MORTALITY FOR IMMATURE FISH
  init_vector M_i(1,n_ages);

//NATURAL MORTALITY FOR MATURE FISH
  init_vector M_m(1,n_ages);

//WEIGHT-AT-AGE
  init_vector weight(1,n_ages);

//PROPORTION OF FEMALES IN SPAWNING STOCK
//  init_vector p_females(1,n_years);


//IN-RIVER CATCH + CV
  init_vector obs_catch(1,n_years);
  init_vector catch_cv(1,n_years);

//CPUE INDEX + CV
  init_vector obs_index(1,n_years);
  init_vector index_cv(1,n_years);

//CATCH AT AGE & REPEAT SPAWNER CLASS + ESS
  init_3darray obs_paa(1,n_years,1,n_ages,2,n_rps);
  init_vector caa_ess(1,n_years);

//LIKELIHOOD WEIGHTS
  init_vector lambda(1,4);

//TEST EOF
  init_int eof;

//INDEXING VARIABLES (YEAR, AGE, RPS CLASS)
```

```
  int y;
  int a;
  int r;
  int i;

  !!cout << "TEST EOF: " << eof << endl;

PARAMETER_SECTION

//INITIAL NUMBERS-AT-AGE-AND-RPS-CLASS (LOG SPACE)
  init_bounded_vector ln_NAA_init(1,20,-5.0,30.0,1);

//AGE-3 RECRUITMENT + RECRUITMENT DEVIATIONS (LOG SPACE)
 init_bounded_number ln_R0(10,25,1);
 init_bounded_vector ln_recdev(2,n_years,-7.5,7.5,2);

//IN-RIVER F
 init_bounded_vector F_river(1,n_years,0.0,3.0,1);
 sdreport_vector SSB_sd(1,n_years);

//CPUE CATCHABILITY
  init_bounded_number ln_q(-25.0,1,2);

//POPULATION ARRAYS
 3darray Z(1,n_years,1,n_ages,1,n_rps);
 3darray NAA(1,n_years,1,n_ages,1,n_rps);
 matrix N_total(1,n_years,1,2);
 vector SSB(1,n_years);
 3darray pred_caa(1,n_years,1,n_ages,2,n_rps);
 3darray pred_paa(1,n_years,1,n_ages,2,n_rps);
 vector pred_catch_N(1,n_years);
 vector pred_catch_W(1,n_years);
 vector pred_index(1,n_years);
 vector index_resid(1,n_years);
 3darray paa_resid(1,n_years,1,n_ages,2,n_rps);
 3darray paa_rss(1,n_years,1,n_ages,2,n_rps);
 vector catch_resid(1,n_years);

// vector pred_yoy(1,n_years);

//LIKELIHOOD COMPONENTS
 matrix sigma(1,n_years,1,2);
 number LL_catch;
 number LL_paa;
 number LL_index
//  number LL_pvirgin
 number LL_recdev;
 number AIC;


 objective_function_value f;
```

```
PROCEDURE_SECTION

 calc_popn_size();
//   cout << "Pop size done." << endl;
 calc_pred_values();
//  cout << "Pred values done." << endl;
 evaluate_the_objective_function();
//  cout << "Obj function evaluated." << endl;

FUNCTION calc_popn_size

//CALCULATE Z
//  Z_devs = 0.0;
 for(y=1;y<=n_years;y++){
        for(a=1; a<=n_ages; a++){
                Z(y,a,1) = M_i(a);
                for(r=2; r<=n_rps; r++){
                        Z(y,a,r) = M_m(a) + F_river(y);
                }
        }
 }

//YEAR-1 POPULATION SIZE ESTIMATED BY MODEL

 for(a=1; a<=n_ages; a++){
        i=1;
        for(r=1; r<=n_rps; r++){
                if(r<=a+1){
                        NAA(1,a,r) = mfexp(ln_NAA_init(i));
                        i++;
                }
                else {
                        NAA(1,a,r) = 0.0;
                }
        }
 }

//AGE-3 RECRUITS ESTIMATED BY MODEL

  for(y=2; y<=n_years; y++){
        NAA(y,1,1) = mfexp(ln_R0 +ln_recdev(y)) * (1.0 - pMat(1));
        NAA(y,1,2) = mfexp(ln_R0 +ln_recdev(y)) * pMat(1);
        for(r=3; r<=n_rps; r++){
                NAA(y,1,r) = 0.0;
        }
  }

//PROJECT POPULATION FORWARD

  for(y=2; y<=n_years; y++){
```

```
		for(a=2; a<=n_ages; a++){
			NAA(y,a,1) = NAA(y-1, a-1, 1) * mfexp(-1.0*Z(y-1, a-1, 1)) * (1.0 - pMat(a));
			NAA(y,a,2) = NAA(y-1, a-1, 1) * mfexp(-1.0*Z(y-1, a-1, 1)) * pMat(a);
			for(r=3; r<n_rps; r++){
				NAA(y,a,r) = NAA(y-1,a-1,r-1) * mfexp(-1.0*Z(y-1,a-1,r-1));
			}
		}
		NAA(y,n_ages,n_rps) = NAA(y-1,n_ages-1,n_rps-1)*mfexp(-1.0*Z(y-1,n_ages-1,n_rps-1)) +
NAA(y-1,n_ages,n_rps) * mfexp(-1.0*Z(y-1,n_ages,n_rps));
  }

//CALCULATE ABUNDANCE AND SSB

  N_total = 0.0;
  SSB = 0.0;
  for(y=1; y<=n_years; y++){
		for(a=1; a<=n_ages; a++){
			N_total(y,1) += NAA(y,a,1);
			for(r=2; r<=n_rps; r++){
				N_total(y,2) += NAA(y,a,r);
				SSB(y) += NAA(y,a,r)*weight(a) / 1000;
			}
		}
  }
  if(sd_phase()){
		SSB_sd = SSB;
  }

FUNCTION calc_pred_values

//   pred_caa = 0.0;
//   pred_paa = 0.0;
  pred_catch_N = 0.0;
  pred_catch_W = 0.0;

  for(y=1; y<=n_years; y++){
			for(a=1; a<=n_ages; a++){
				for(r=2; r<=n_rps; r++){
					pred_caa(y,a,r) = NAA(y,a,r) * F_river(y) * mfexp(1.0-F_river(y)) /
Z(y,a,r);
					pred_catch_N(y) += pred_caa(y,a,r);
					pred_catch_W(y) += pred_caa(y,a,r) * weight(a) / 1000;
				}
			}
			pred_paa(y) = pred_caa(y) / pred_catch_N(y);
  }

  for(y=1; y<=n_years; y++){
		pred_index(y) = mfexp(ln_q) * N_total(y,2);
  }
```

```
FUNCTION evaluate_the_objective_function

  for(y=1; y<=n_years; y++){
        sigma(y,1) = log(square(catch_cv(y)) + 1.0);
        sigma(y,2) = log(square(index_cv(y)) + 1.0);
  }

  LL_catch = 0.0;
  for(y=1; y<=n_years; y++){
        catch_resid(y) = (log(obs_catch(y)+1e-5) - log(pred_catch_W(y)+1e-5)) / sigma(y,1);
        LL_catch += log(sigma(y,1)) + 0.5 * square(catch_resid(y)) * 0.5;
  }

  LL_index = 0.0;
  for(y=1; y<=n_years; y++) {
         if(obs_index(y) > -1) {
                index_resid(y) = (log(obs_index(y) + 1e-5) - log(pred_index(y)+1e-5)) / sigma(y,2);
                LL_index += log(sigma(y,2)) + 0.5 * square(index_resid(y)) * 0.5;
               }
  }
  LL_paa = 0.0;
  for(y=1; y<=n_years; y++){
               for(a=1; a<=n_ages; a++){
                      for(r=2; r<=n_rps; r++){
                             paa_rss(y,a,r) = (obs_paa(y,a,r)+1e-5) * log(pred_paa(y,a,r)+1e-5);
                             if(pred_paa(y,a,r) > 0.0) {
                                    paa_resid(y,a,r) = (obs_paa(y,a,r) - pred_paa(y,a,r)) /
sqrt((pred_paa(y,a,r)*(1.0-pred_paa(y,a,r))/mean(caa_ess)));
                             }
                             LL_paa += -1.0 * caa_ess(y) * paa_rss(y,a,r);
                      }
               }
        }

  LL_recdev = norm2(ln_recdev);

  f = lambda(1)*LL_catch + lambda(2)*LL_paa + lambda(3)*LL_recdev + lambda(4)*LL_index;

  AIC = 2.0*(n_ages * n_rps + 2.0*n_years + 1) - 2.0 * log(f);

REPORT_SECTION
  char sdate[9];
  char stime[9];
  _strdate( sdate );
  _strtime( stime );
  report << "NANTICOKE RIVER HERRING MODEL WITH NO OCEAN FISHING MORTALITY" <<
endl;
  report << "Last Run:    " << sdate << "  " << stime << endl;
  report << "  " << endl;
  report << "-----------------------------------------------------------------" << endl;
  report << "LIKELIHOOD RESULTS" << endl;
```

```
  report << "------------------------------------------------------------------" << endl;
  report << "OBJECTIVE FUNCTION  : " << setw(12) << setprecision(5) << f << endl;
  report << "AIC   : " << setw(12) << setprecision(5) << AIC << endl;
  report << "  Likelihood Components: " << endl;
  report << "    Catch            : " << setw(12) << setprecision(5) << LL_catch    << endl;
  report << "    CAA              : " << setw(12) << setprecision(5) << LL_paa   << endl;
//   report << "    Indices          : " << setw(12) << setprecision(5) << LL_index    << endl;
  //report << "    m natural mort. : " << setw(12) << setprecision(5) << m_lklhd  << endl;
//   report << "    Recruitment devs  : " << setw(12) << setprecision(5) << LL_recdev  << endl;
  report << "    Recruitment Deviations: " << setw(12) << setprecision(5) << LL_recdev  << endl;
  //report << "    q catchability  : " << setw(12) << setprecision(5) << q_lklhd  << endl;
  report << "              " << endl; report << "              " << endl;

  report << "------------------------------------------------------------------" << endl;
  report << "PARAMETER ESTIMATES" << endl;
  report << "------------------------------------------------------------------" << endl;
  report << "   Average recruitment (R0)      : " << setw(12) << setprecision(5) << exp(ln_R0)   << endl;
//   report << "   Probability of maturing at age: " << setw(12) << setprecision(5) << pmat   << endl;
// //   report << "   SSB Ratio              : " << setw(12) << setprecision(5) << SSB_ratio   << endl;
//   //report << "   Steepness (h)         : " << setw(12) << setprecision(5) << h  << endl;
//   report << "              " << endl; report << "              " << endl;
//
  report << "------------------------------------------------------------------" << endl;
  report << "ABUNDANCE ESTIMATES OF FISH by maturity (MILLIONS OF FISH)" << endl;
  report << "Year" << " ";
//   report.setf(ios::fixed, ios::floatfield);
//   for ( a=1; a<n_ages; a++) report << setw(8) << setprecision(0) << a << "     ";
//   report << setw(8) << setprecision(0) << n_ages << endl;
  report << "IMMATURE                                               MATURE
                                          "  << endl;
  report << "------------------------------------------------------------------" << endl;
  for (y=1; y<=n_years; y++) {
    report.setf(ios::fixed, ios::floatfield);
    report << setw(4) << setprecision(0) << start_year + y - 1 << "  ";
    report.setf(ios::scientific, ios::floatfield);
    report << setw(12) << setprecision(4) << N_total(y,1) / 1e6 << " ";
    report << setw(12) << setprecision(4) << N_total(y,2) / 1e6 << endl;
  }
  report << "              " << endl; report << "              " << endl;

    report << "-------------------------------------------------------------------------" << endl;
  report << "TOTAL CATCH ESTIMATES - RIVER" << endl;
  report << "Year" << "    Observed" << "    Predicted" << "    F_river" << endl;
  report << "-------------------------------------------------------------------------" << endl;
    report.setf(ios::fixed, ios::floatfield);
      for (y=1; y<=n_years; y++) {
        report.setf(ios::fixed, ios::floatfield);
        report << setw(4) << setprecision(0) << start_year + y - 1 << "  ";
        report.setf(ios::scientific, ios::floatfield);
        report << setw(12) << setprecision(4) << obs_catch(y);
        report << setw(12) << setprecision(4) << pred_catch_W(y);
```

```
      report << setw(12) << setprecision(4) << F_river(y)  << endl;
    }
    report << endl;
  report << "               " << endl; report << "               " << endl;

    report << "--------------------------------------------------------------------------" << endl;
  report << "INDEX ESTIMATES - RIVER" << endl;
  report << "Year" << "    Observed" << "    Predicted" << endl;
  report << "--------------------------------------------------------------------------" << endl;
   report.setf(ios::fixed, ios::floatfield);
    for (y=1; y<=n_years; y++) {
      report.setf(ios::fixed, ios::floatfield);
      report << setw(4) << setprecision(0) << start_year + y - 1 << "  ";
      report.setf(ios::scientific, ios::floatfield);
      report << setw(12) << setprecision(4) << obs_index(y);
      report << setw(12) << setprecision(4) << pred_index(y) << endl;
    }
    report << endl;
  report << "               " << endl; report << "               " << endl;

  report << "-----------------------------------------------------------------" << endl;
  report << "SPAWNING STOCK BIOMASS ESTIMATES" << endl;
  report << "Year" << " " << endl;
  report.setf(ios::fixed, ios::floatfield);
  report << "-----------------------------------------------------------------" << endl;
  for (y=1; y<=n_years; y++) {
   report.setf(ios::fixed, ios::floatfield);
   report << setw(4) << setprecision(0) << start_year + y - 1 << "  ";
   report.setf(ios::scientific, ios::floatfield);
   report << setw(12) << setprecision(4) << SSB(y)  << " " << ln_recdev(y) << endl;
  }
  report << "               " << endl; report << "               " << endl;

   report << "--------------------------------------------------------------------------" << endl;
  report << "TOTAL CATCH + INDEX RESIDUALS" << endl;
  report << "--------------------------------------------------------------------------" << endl;
   report.setf(ios::fixed, ios::floatfield);
    for (y=1; y<=n_years; y++) {
      report.setf(ios::fixed, ios::floatfield);
      report << setw(4) << setprecision(0) << start_year + y - 1 << "  ";
      report.setf(ios::scientific, ios::floatfield);
      report << setw(12) << setprecision(4) << catch_resid(y) << " " << index_resid(y) << endl;
    }
    report << endl;
  report << "               " << endl; report << "               " << endl;

   report << "-----------------------------------------------------------------" << endl;
  report << "PROPORTION AT AGE AND RPS CLASS RESIDUALS" << endl;
  report << "Year" << " ";
  report.setf(ios::fixed, ios::floatfield);
  for ( r=2; r<n_rps; r++) report << setw(8) << setprecision(0) << r << "     ";
```

```
 report << setw(8) << setprecision(0) << n_rps << endl;
 report << "------------------------------------------------------------------" << endl;
 for (y=1; y<=n_years; y++) {
   for (a=1; a<=n_ages; a++) {
		for(r=2; r<=n_rps; r++)	{
			report.setf(ios::fixed, ios::floatfield);
			report << setw(4) << setprecision(0) << start_year + y - 1 << " " << a << " " << r << " ";
			report.setf(ios::scientific, ios::floatfield);
				report << setw(12) << setprecision(4) << paa_resid(y,a,r) << endl;
				}
			}
 }
//		ofstream caa_res_out("caa_resid.csv", ios::app);
//   {
//     for (y=1; y<=n_years; y++) {
//        for (a=1; a<=n_ages; a++) {
//			for(r=2; r<=n_rps; r++)	{
//				caa_res_out << start_year + y - 1 << " " << a << " " << r << " " << paa_resid(y,a,r)
<< endl;
//				}
//			}
//        }

//   }
//   caa_res_out.close();
//  }
//
```

14. Status of River Herring in the Potomac River

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Executive Summary

The following report will give a brief overview of the work done by the District Department of the Environment (DDOE) and the Potomac River Fisheries Commission (PRFC) as it relates to river herring management and monitoring. PRFC monitors commercial landings of river herring in the Potomac River. Landings reached a high of over 11 million pounds in 1962 but have declined continuously since then. As of 2010 landings of river herring were prohibited, with the exception of a limited pound net bycatch of 50 pounds per fishermen per day. The adult stock of river herring in the Potomac River, based on the landing data, is at an extremely low level. Surveys conducted by DDOE include fisheries independent electrofishing for adults and seining and push net sampling for juveniles. Additionally, Maryland Department of Natural Resources (MD DNR) also conducts a juvenile survey in the Potomac River. There has been a drastic decline in CPUE of alewife and blueback herring in the DDOE adult electrofishing survey from the late 1990s to early 2000s. However, size structure trends from the electrofishing survey have remained relatively stable from 2005-2010. The YOY indices have fluctuated widely without trend. The population of blueback herring appears to be more abundant in the Potomac River than alewife herring.

14.1. INTRODUCTION

River herring (alewife, *Alosa psuedoharengus,* and blueback herring, *Alosa aestivalus*) are important anadromous species that frequent the waters of the Potomac River. There was a significant abundance of herring caught in the Potomac River from the colonial period through the 19th century. Historically, the primary gear for commercially harvesting river herring in the Potomac River was the haul seine. Harvest was estimated in number of fish, since river herring were sold by count and not by the pound. Tilp (1978) provided an estimate of the 1832 shad and river herring harvest (in *Gazetteer of Virginia,*1835): "The lowest prices at which these fish sell when just taken are 25 cents per thousand for herrings. Herrings are sometimes taken so plentifully that they are given away or hauled on the land as manure for want of purchasers. [The] number of herrings taken [in a good season (six weeks) is] 750,000,000". Another estimate by Baird (1886) on the amount of herring from one single haul seine catch in 1832 was "from 100,000 to 300,000." Massmann (1961) analyzed the original fishing record books of George Chapman, a haul seine fisherman in the Potomac River during the period 1814 – 1824 and estimated the annual herring catch ranged from 343,341 to 1,068,932 fish in a single season. The large haul seine fisheries of the 18th and 19th centuries are now gone and replaced today by much smaller, shorter seines (2,400 ft. maximum).

Sexually mature river herring return each spring to spawn in the Potomac River. Locally and historically, the "herring run" is an anticipated fishing event as eager anglers, birds, and other opportunists take advantage of these nutrient rich visitors. Adult herring are normally present in the Potomac River for about three months each year from March through May. In addition to the annual run of adult river herring, the juveniles that were spawned use the region as a nursery to grow and develop. Each year clouds of juvenile river herring consume tiny plankton during the summer months before migrating out of our region by autumn.

River herring are monitored by DDOE and the PRFC each year to assess the status of the local populations and determine how that may affect the overall coastal stock. Because of the two distinct life stages (adult and juvenile) that are represented in the Potomac River, sampling efforts are designed to target each group specifically. Data is analyzed annually and compared by year to determine significant trends in population structure and size.

14.2. DEFINITION OF MANAGEMENT UNITS

The low water mark of the southern shore Potomac River, exclusive of the tributaries, is the boundary line between the states of Maryland and Virginia, with Maryland being the owner of the river (Figure 14.1). Maryland and Virginia first entered into a compact in 1785 (before the adoption of the U.S. Constitution) to regulate, among other things, the fisheries of the Potomac. After the adoption of the U.S. Constitution and the formation of a Federal Government, Maryland ceded the area, including that part of the Potomac River, which is now the District of Columbia.

There are five fishery management authorities on the Potomac River. The Potomac River Fisheries Commission (PRFC) is the Maryland-Virginia bi-state Commission with fisheries management authority for the main stem, exclusive of the tributaries on either side, from the Chesapeake Bay to the southern Maryland – District of Columbia boundary line; the District Department of the Environment (DDOE) with authority for the Potomac River to the Virginia shore and other waters within D.C.; the Maryland Department of Natural Resources (MDDNR) with authority for the tributaries of the Potomac on the Maryland side of the river and the fluvial portion of the river upstream of D.C.; the Virginia Marine Resources Commission (VMRC) with authority for commercial fisheries in all tidal Virginia tributaries and for recreational fisheries in the saltwater portions of the tidal Virginia tributaries below the Route 301 Bridge; and the Virginia Department of Game and Inland Fisheries (VDGIF) with authority for recreational fisheries in the freshwater portions on the Virginia tributaries. Additionally the federal government controls much of the shoreline, and therefore access, of the Potomac through several military bases and National Park Service lands.

14.3. REGULATORY HISTORY

During colonial times, the fisheries in the Potomac were essentially unregulated. In 1785 Maryland and Virginia adopted a compact to regulate the fisheries by requiring all fishery laws for the Potomac River to be enacted jointly by the legislatures of both states. In 1963 the PRFC was created and charged with the establishment and maintenance of a program to conserve and improve fishery resources. While PRFC has never had any specific regulations regarding river herring, there have been prohibitions against certain gears such as purse nets, trawls, trammel nets, troll nets, or drag nets have been in place which has limited commercial harvest of river herring such that river herring harvest in the Potomac is almost exclusively taken by pound nets. The District of Columbia does not allow commercial harvest of river herring from their portion of the Potomac River.

The pound net fishery shifted from a shad and herring fishery in the 1960’s and early 1970’s, when those species began declining, to primarily a menhaden fishery in the late 1970’s and early 1980’s. The deep water in-line pound nets were replaced by shallow water singly-set pound nets, and as a result shad and river herring became by-catch species in pound nets. The PRFC now has no directed commercial or recreational fisheries for river herring. The PRFC adopted a commercial fishery moratorium for river herring in 2010, with a minimal bycatch provision of 50 pounds per licensee per day for pound nets. A pound net bycatch provision was put in place to enable monitoring of river herring runs. This fishery dependant data will be used to help assess the progress of river herring restoration in the Potomac River. This approach is similar to the shad pound net bycatch provision in place since 1981. For American shad, PRFC has been able to utilize the CPUE of catch plus discards to track the increasing level of shad in the Potomac. When the fishermen complete their daily harvest reports, any shad that have been discarded (released) are recorded on their reports. Prior to 2010, no river herring were reported as discarded because it was an open fishery and the fishermen kept their entire catch. The fishermen are now adding data for the discard/release of river herring, and in 2010 there were 820 pounds of river herring that were reported as discarded.

The PRFC adopted the mandatory use of fish cull panels in all pound nets in the Potomac River, effective January 1, 2011. Fish cull panels are specially designed and manufactured bycatch reduction devices that have been tested and used (prior to 2011) voluntarily in Potomac River pound nets. They were effective in the safe release of sublegal flounder, weakfish, spot, croaker and bluefish when installed in the bottom corners of the sides of the pound nets. The new regulation requires that four panels be installed in the bottom corners of the upriver and downriver sides of the net, and two additional panels be installed closer to the surface for the purpose of releasing river herring. It is expected that this new conservation measure will greatly reduce the bycatch of small fish in pound nets.

The Potomac River recreational fishery for river herring under the jurisdiction of PRFC was closed in 2010 in the mainstem of the river below the District of Columbia. Recreational anglers have historically been permitted to harvest river herring within the District of Columbia's portion of the Potomac River by way of hook and line fishing, dip netting, and snagging, with no size or creel limit. However, beginning January 1, 2012 recreational harvest of river herring will be prohibited within the District's waters.

The PRFC regulates and records the harvest of only the main stem of the river, while the tributaries on either side are under Maryland and Virginia jurisdiction. Harvest records for alewife and blueback herring have been historically combined as river herring.

14.4. ASSESSMENT HISTORY

A "severe reduction in catch" in the river herring fishery occurred from 1967-1974. Hoagman, *et al.* (1975), concluded that the decline in river herring catch, on a catch per unit effort basis, represented true reduction in stock size. Year class strength of juvenile alosine fishes was assessed in 1975 (Merriner, J.V.) and found that juvenile abundance had been depressed since 1970 and short-term forecasts for the fishery do not point toward higher landings.

A stock assessment on selected river herring stock was conducted in 1990 by ASMFC (ASMFC, 1990). This assessment included both alewife and blueback herring populations in the Potomac River. Stock-recruitment (S-R) analyses were originally planned for the Potomac River but the river herring S-R data were considered to be unreliable because recruitment estimates were either missing for certain years, were of unacceptably short duration (<15 years), or yielded imprecise and implausible S-R parameters.

The 1990 assessment found that Potomac River alewife populations were or were being overfished ($u > u_{msy}$ or u_{coll}) to the extent that recruitment failure was apparent in the late 1980's. The Potomac River blueback herring stocks were not overfished ($u < u_{msy}$) but were experiencing a stock decline. The 1990 or historical u values for Potomac River blueback herring were within 75% of the u_{msy} levels, and therefore were considered by our criteria to be fully exploited. The time series of alewife and blueback herring abundance exhibited a pronounced downward trend during the 1980's which was consistent with excessive fishing mortality.

The assessment also concluded that the highest fishing mortality rates ($u>0.60$) on river herring occurred mainly near the northern (St. John and Damariscotta Rivers) and southern (Potomac, Rappahannock, Chowan Rivers) end of the distribution, where there were directed riverine fisheries. In order to rebuild the spawning population and stabilize recruitment in these river herring stocks, additional conservation measures were recommended to be imposed to reduce the fishing mortality rates below the u_{msy} levels.

The results strongly suggested that heavy fishing pressure by the states of Maine, Virginia and North Carolina was primarily responsible for the continued decline of river herring stocks in the Damariscotta, Potomac, Rappahannock and Chowan Rivers.

14.5. STOCK-SPECIFIC LIFE HISTORY

Alewife and blueback herring are anadromous clupeids. Adult river herring usually appear in the Potomac River waters in March, and they can be observed spawning through May. Locally and historically, the "herring run" is an anticipated fishing event as eager anglers, birds, and other opportunists take advantage of these nutrient rich visitors. Hatching occurs one week after fertilization. In addition to the annual run of adult river herring, the juveniles that were spawned use this region as a nursery to grow and develop. Each year clouds of juvenile river herring consume tiny plankton during the summer months before migrating out of our region by autumn. There appears to be overwintering annually of both species of herring in the Chesapeake (Duvol 1972 and Carter 1969). Juveniles remain in the ocean until sexually mature, most returning to their natal rivers.

14.6. HABITAT DESCRIPTION

The Potomac River is a major tributary of the Chesapeake Bay, the area of its watershed ranking fourth on the East Coast (Figure 14.1). The estuary extends 113 miles from its mouth to the head of tide. On the outskirts of the District of Columbia at Little Falls, a low head dam for water withdrawal has a fish passage facility that allows river herring to extend their spawning range an additional 10 to 12 miles upstream to Great Falls, a natural barrier to all anadromous species. Alosine fishes (American shad, hickory shad, alewife, and blueback herring) utilize that reach of the Potomac extending from Ragged Point to the fall line near Washington, D.C. (Warinner et al., 1970; Lippson and Moran, 1974). The primary spawning grounds of alosine fishes include mainstream and tributaries from Mathias Point to the fall line. River herring (alewife and blueback) also utilize the freshwater portions of downriver tributary streams in Maryland and Virginia between river mile 60 and 30 as spawning sites (Davis, et al., 1970; O'Dell, personal communication).

Within the District of Columbia, spawning herring are typically found congregating adjacent to man-made sea walls and rip rap barriers which account for much of the shoreline habitat. They can also be found "staging" in deeper holes and pools prior to significant rain events which trigger upstream migration and subsequent spawning. The larvae and juveniles spread throughout the tidal freshwater portion of the estuary (Warinner et al., 1970) and remain there until water temperatures drop in the fall; at that time they proceed seaward. Juvenile river herring tend to remain in clusters or schools moving along various types of shoreline cover, submerged aquatic vegetation beds, and open water. There has been no significant loss of habitat over the past twenty years while potential habitat has been made available in Rock Creek. In 2007, DDOE installed a fish ladder at Pierce Mill in Rock Creek in conjunction with the removal of all of the remaining man-made obstructions to fish passage. These habitat improvements were designed to expand potential spawning habitat for river herring and other anadromous species. Electrofishing efforts in Rock Creek have been expanded to include this additional habitat but have so far failed to confirm the utilization of the fish ladder by river herring.

14.7. RESTORATION

DDOE and PRFC currently have no restoration programs for river herring.

14.8. AGE

DDOE and PRFC currently have no age data for river herring.

14.9. FISHERY DESCRIPTIONS

14.9.1. Commercial Permits

In 1964, the first year that the PRFC collected harvest data, there were 138 pound nets licensed. Pound net licenses have fluctuated from a high of 181 in 1969 to a low of 69 in 1974. The pound net fishery shifted from a shad and river herring fishery in the 1960's and early 1970's, when those species began declining, to primarily a menhaden fishery in the late 1970's and early 1980's with shad and river herring as bycatch species. After Maryland and Virginia established limited entry fisheries in the 1990's, the PRFC responded to industry's request and capped the Potomac River pound net fishery at 100 licenses in 1995. The 100 pound net licenses are held by 23 fishermen in 2010. The PRFC only requires that one net be set by each fisherman annually; consequently the number of pound nets being fished in the Potomac is at a very low level.

14.9.2. Commercial Landings

The PRFC regulates all the commercial harvest of river herring in the Potomac River. Since the mid-1960's, the river herring harvest has declined from just over 11 million pounds to the current low level (Table 14.1; Figure 14.2). From 1966 to 1976 there was a dramatic and consistent decline. From 1976 through 1987 harvest was relatively stable, but at very low levels. After 1988 the fishery has been all but non-existent. CPUE data (pounds/pound net days fished, i.e. – pounds per one pound net fished one time) shows similar trends to the harvest data (Figures 14.3 and 14.4).

In 2009, the commercial harvest of river herring amounted to 8,925 pounds which were caught by ten commercial pound net fishermen during March, April and May. Pound net effort included 159 pound net fishing days; consequently pound net CPUE was 56.1 pounds/pound net days fished.

With the moratorium in place in 2010, preliminary data for the bycatch allowance resulted in a commercial pound net harvest of 898 pounds (Table 14.1) caught by five pound net fishermen. Landings were reported during April, May and June; however 99 percent of the harvest was during April. The pound net effort level was 43 pound net fishing days and the CPUE was 20.9 pounds/pound net days fished. Approximately 820 pounds of river herring were reported as discards. When catch (898 pounds) and discards (820 pounds) are combined the CPUE increases to 40.0 pounds/pound net days fished. In total, pound nets landed 1,007,351 pounds of finfish (all species combined) in April, May and June 2010 from the Potomac River. Therefore river herring bycatch landings represented 0.09 percent of the total April, May and June pound net landings.

14.9.3. Recreational Fishery

There is no information on the recreational fishery occurring in the Potomac River below the District and in the tributaries of Maryland and Virginia. Within the District, recreational fishing may have occurred, but it is believed to have been minimal. As of January 1, 2010 recreational landings were prohibited in the mainstem of the Potomac River under the jurisdiction of PRFC. As of January 1, 2012 recreational landings are prohibited in the Potomac River water's under the jurisdiction of the DDOE.

14.10. FISHERY INDEPENDENT SURVEYS

The DDOE Fisheries Research Branch conducts three main surveys in which river herring are regularly encountered. These surveys include boat electrofishing, seining, and push net. Additionally, MD DNR conducts a juvenile survey in the Potomac River.

14.10.1. Spawning Stock Survey

A standardized electrofishing survey is conducted throughout the District of Columbia's waters from March–November. This survey is conducted on a monthly basis at eight standard sites located throughout the District's jurisdiction. Four alternate sites were added in 1995; alternate sites are only visited every other month during May–November. Transects are run at each site for 600 seconds with 2 repetitions conducted at each site. This survey targets all species of fish located in the District and allows biologist to track population trends of both resident and anadromous fish species. In the spring, typically from April – June, adult river herring appear in this survey. The data collected from the herring include species identification, length, and sex of each river herring netted. For large samples, data from 50 fish are recorded and the remaining fish are counted. The DDOE uses this survey to monitor trends in run sizes and the size structure of adults. CPUE is calculated by number of fish captured per hours of shock time; because the survey is conducted March – November only the data collected from March – June is used for the calculation of the adult herring CPUE.

MD DNR has conducted a spring striped bass spawning stock survey since 1990 in which adult river herring are encountered. The survey occurs above the Rt. 301 Bridge, approximately 45 miles upstream from the mouth of the Potomac River. Samples are collected using a drift gill net from late-March through mid-May, six days per week as weather permits.

14.10.2. Juvenile Surveys

A beach seining survey was initiated by DDOE in 1990. During June through October, a single haul is made at each of six fixed locations. Prior to 2010, sampling sites were visited once a month; as of 2010, the frequency of visits to the sites was increased to twice a month. This survey targets all YOY finfish occurring within the District of Columbia. The data that are recorded includes species and length. For large samples, data from 50 fish are recorded and the remaining fish are counted. Juvenile river herring show up in this survey typically from June – October.

The push net survey is conducted in the District of Columbia's Potomac River waters from July to September. This survey has been in effect from 2005 – present. The push net consists of a 4'x 3' frame with a 1/8" mesh bag attached. The frame pivots out over the bow of the boat and the net is then allowed to skim just below the surface of the water. A total of six fixed transects are run. The boat is kept at a constant speed of five mph for 10 min. Each site is sampled once a week for 11 consecutive weeks. This survey is designed to capture YOY alosine species. When samples are examined all fish are identified to species and counted; lengths are taken from a subset of 50 individuals. A previous push net juvenile survey was conducted by the Interstate Commission on the Potomac River Basin (ICPRB) and U.S. Fish and Wildlife Service (USFWS) from 1997 to 2002 (Figure 14.5). This survey was generally upstream of the area of the river sampled by the MD DNR YOY survey (described below). The purpose of the USFWS survey was to capture juvenile American shad to determine proportion of hatchery fish. Identification of river herring to species was not done by technicians all of the time, but blueback herring were encountered. Data from 1997 is not considered reliable because the sampling protocol and sites had not been standardized. Additionally data from 2002 was not processed. Funding for the ICPRB/USFWS survey ended in 2002.

MD DNR has been annually sampling for juvenile and YOY river herring within the Chesapeake Bay since 1959. Seine sampling occurs at 22 fixed stations using a 30.5 x 1.24 meter bagless beach seine of untreated 6.4 mm bar mesh which is set by hand. One end is held on shore while the other is fully stretched perpendicular from the beach and swept with the current (Durell et. al 2007). Stations have been sampled continuously since 1954, with changes in some station locations. (For more information see http://www.dnr.state.md.us/fisheries/juvindex/sitemap.jpg.) The sampling is divided among four of the major spawning and nursery areas: seven each in the Potomac River and Head of Bay areas and four each in the Nanticoke and Choptank Rivers. Sampling is monthly, with rounds occurring during July, August, and September. Replicate seine hauls, a minimum of thirty minutes apart, are taken at each site on each sample round. This produces a total of 132 samples from which bay-wide means are calculated. In 1962, stations were standardized and a second sample round was added for a total of 88 samples. A third sample round, added in 1966, increased sample size to 132. Auxiliary stations have been sampled on an inconsistent basis and are not included in survey indices. The river herring juvenile indices for the Potomac River are derived from the MD DNR juvenile survey.

14.11. ASSESSMENT APPROACHES AND RESULTS

There is very little data available to conduct an assessment of the population of river herring in the Potomac River.

14.11.1. Trends in Spawning Stock

Trends in spawning stock can be observed in data collected from the electrofishing survey in which a CPUE is generated. CPUE (fish captured per hour of shock time) indices derived from this survey show a drastic decline for both alewife and blueback herring from the late 1990s to early 2000s (Figure 14.6).

The MD DNR striped bass spawning stock survey encounters adult river herring. CPUE (number of fish caught per 1000 square yards of drift gill net per hour) for alewife has been low, but stable, with peaks occurring from 2002 – 2004 (Figure 14.7). CPUE for blueback herring have been at a similar level as for alewife, but has been slightly declining over the course of the time series (Figure 14.8).

14.11.2. Trends in Length

The electrofishing survey provides data to observe trends in size structure of adult river herring. Size structure trends have remained relatively stable from 2005 – 2010 (data prior to 2005 is unavailable) (Table 14.2;Figure 14.9). During this time period average annual adult alewife lengths were between 259 and 270 mm for males and 283 to 290 for females. For blueback herring, average annual adult lengths were between 239 and 251mm for males and 258 and 270 mm for females.

14.11.3. Trends in Juvenile Abundance

The beach seining and push net surveys conducted by DDOE provide relative abundance data for juvenile river herring. Due to the differences in survey design and species identification it is difficult to draw trends between the USFWS/ICPRF and DDOE push net surveys. Geometric means (average number of fish per haul) derived from the beach seining survey show a dramatic decline in alewife numbers from the early 1990's until present day (Figure 14.10). By comparison geometric means derived for blueback herring appear to have followed a cyclical pattern since 1994. The push net survey show similar trends for both alewife and blueback. Since 2005, when the push net survey was started, the geometric means seem to follow a cyclical pattern (Figure 14.11).

The MD DNR juvenile and YOY river herring survey catches blueback herring in higher proportions. The YOY average geometric mean CPUE (catch per haul) for blueback herring is 1.41, while for alewife it is 0.50 (Figures 14.12 and 14.13 . There are no apparent trends in the YOY indices.

14.11.4. Trends in Sex

In the DDOE electrofishing survey male alewives have consistently occurred more frequently than females, while there is no apparent trend for blueback herring (Figure 14.14).

14.11.5. Trends in Age

No data is available for trends in age.

14.11.6. Trends in Repeat Spawning

No data is available for trends in proportion of repeat spawners.

14.11.7. Trends in Mortality

No data is available for trends in total instantaneous mortality.

14.12. BENCHMARKS

There are no benchmarks established for river herring fisheries in the Potomac River.

14.13. CONCLUSIONS

The adult stock of river herring in the Potomac River, based on the landing data, is at an extremely low level. Harvest has been on a declining trend since the 1960's. The pound net CPUE is also low, but relatively stable. The CPUE tracks harvest and is a reliable proxy for harvest, even at low levels. The PRFC will continue to use the combined catch plus discards for a CPUE (c+d) to monitor the stock.

The YOY indices have fluctuated widely without trend. The 2010 MD DNR YOY survey geometric mean CPUE for alewife was 0.47, which was very close to the average, indicating that spawning is occurring and for blueback herring was 1.41 which exceeded the average. The population of blueback herring appears to be more abundant in the Potomac River than alewife herring.

PRFC and DDOE recognize that invasive species such as blue catfish potentially pose a threat to the river herring populations within the Potomac River. There has been increased concern expressed by fishermen over the expanding range of blue catfish. DDOE is currently establishing sampling protocol to investigate blue catfish populations and diet within the waters of the District of Columbia. ASMFC has also passed a resolution to develop and implement "a strategy to minimize the population of non-native invasive catfish species throughout the Chesapeake Bay watershed."

The PRFC and DDOE will continue to use the bycatch landings data, CPUE, and YOY indices to track relative health of the river herring stock. PRFC and DDOE will continue to communicate with the other management authorities on the Potomac River for additional data that may become available for the assessment of river herring.

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Table 14.1 Commercial Landings of River Herring in the Potomac River. A moratorium on the harvest of river herring was enacted in 2010, except for the limited pound net bycatch of 50 lbs per day. Source: PRFC.

Year	Landings	Year	Landings
1960	5,788,600	1985	261,675
1961	6,234,900	1986	1,198,669
1962	11,013,600	1987	1,164,854
1963	8,037,800	1988	182,656
1964	8,162,444	1989	97,047
1965	9,959,891	1990	49,734
1966	11,127,487	1991	365,966
1967	8,580,234	1992	162,885
1968	7,477,581	1993	144,752
1969	3,433,438	1994	80,258
1970	6,184,858	1995	113,504
1971	5,858,125	1996	80,447
1972	5,720,951	1997	59,949
1973	2,005,057	1998	18,501
1974	3,529,221	1999	26,656
1975	5,758,824	2000	33,370
1976	1,308,222	2001	35,723
1977	473,531	2002	55,086
1978	1,467,743	2003	20,132
1979	997,360	2004	19,739
1980	1,686,203	2005	8,507
1981	84,143	2006	6,819
1982	493,039	2007	6,011
1983	1,728,810	2008	5,476
1984	899,275	2009	8,925
		2010	898*

Table 14.2 Adult alewife and blueback herring length frequency caught by electrofishing by year in Potomac River. Source: DDOE.

	Alewife - male								Alewife - female							
Bin	2003	2004	2005	2006	2007	2008	2009	2010	2003	2004	2005	2006	2007	2008	2009	2010
230-239						1		9								
240-249				2	6	1	3	19								1
250-259			4	2	11	5	4	20				1	1	1		2
260-269			12	5	13	5	10	14			1		4	2		6
270-279			9	17	24	2	13	11			3	2	4		1	8
280-289			7	22	9	3	15	6			2	3	6	2	2	8
290-299			9	8	2	2	2	6			2	3	3	1	5	7
300-309			3	2			1				12	2	6		1	3
310-319							1				3	5	2		6	
320-329														1		1
> 330																
Total	0	0	44	58	65	19	49	85	0	0	23	16	26	7	15	36

	Blueback herring - male								Blueback herring - female							
Bin	2003	2004	2005	2006	2007	2008	2009	2010	2003	2004	2005	2006	2007	2008	2009	2010
210-219				1												
220-229				5	3	1										
230-239				25	24	3	3	10								
240-249				18	49	9	14	22					2		3	2
250-259			1	18	51	22	26	22			1		6	4	7	3
260-269				18	27	19	22	11			1		15	21	20	1
270-279				4	8	12	4	6					8	34	25	4
280-289				2	1	6	1				1	1	5	11	14	2
290-299						1							4	3	9	
300-309														4	1	
> 310																
Total	0	0	1	91	163	73	70	71	0	0	3	1	40	77	79	12

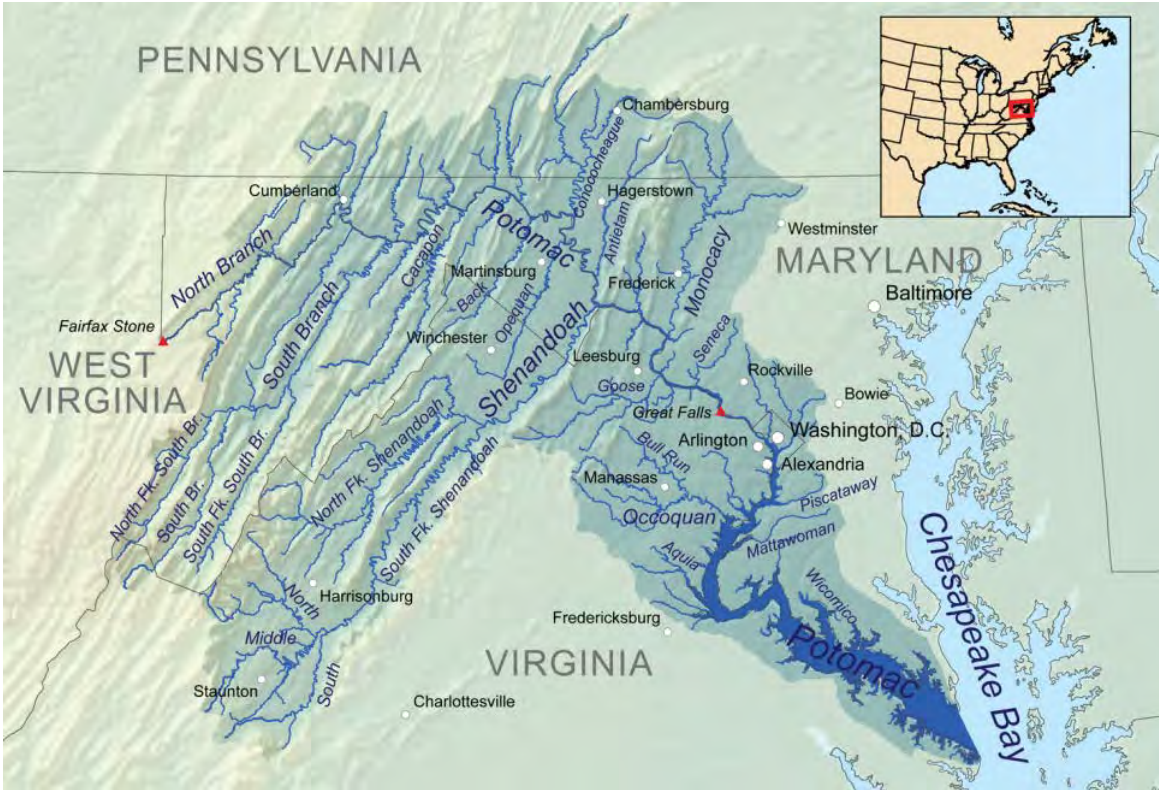


Figure 14.1 The Potomac River Basin.

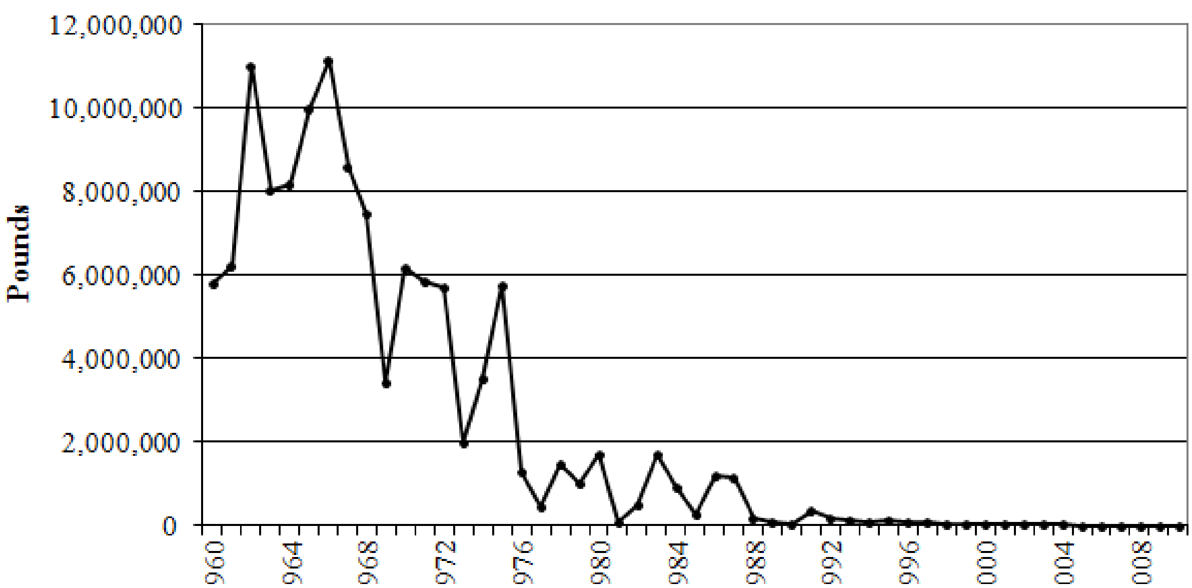


Figure 14.2 River Herring Harvested (pounds) in the Potomac River from 1960 – 2010. Source: PRFC

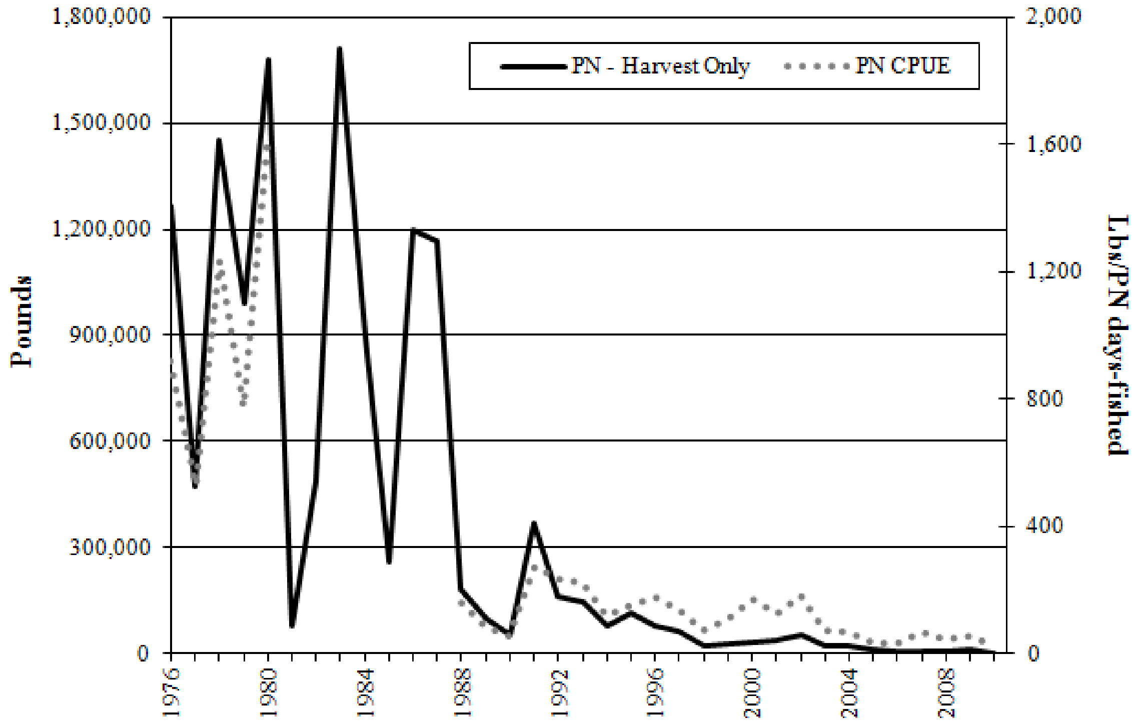


Figure 14.3 River herring pound net harvest (not including discards) and CPUE in the Potomac River (1976 – 2010). Source: PRFC

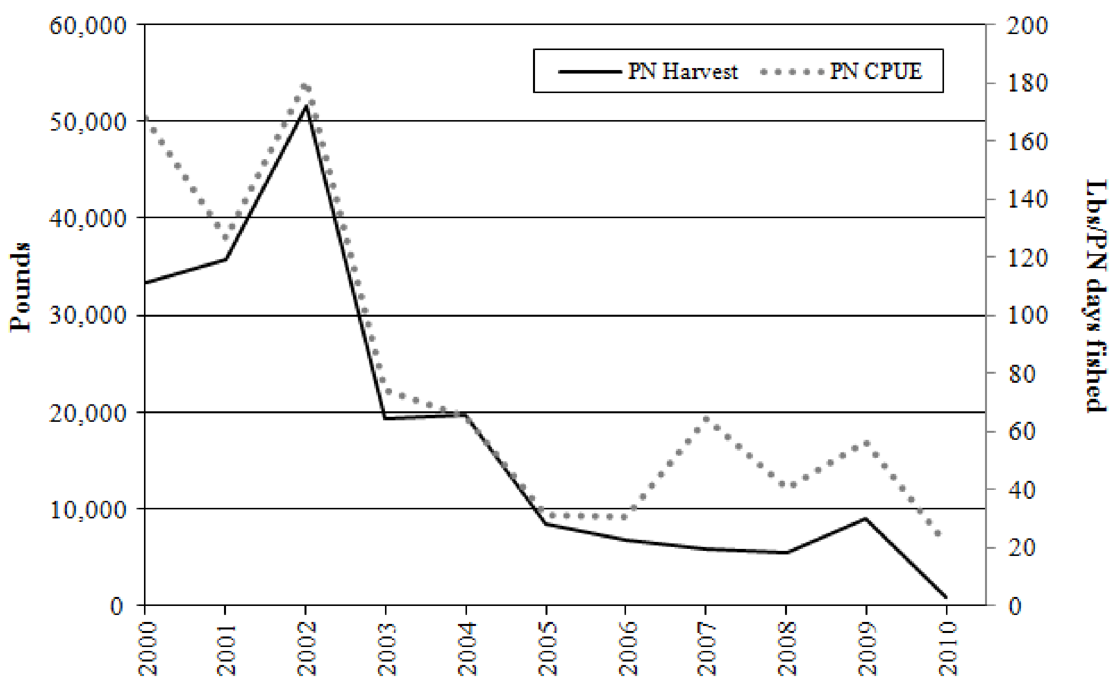


Figure 14.4 River herring pound net harvest and CPUE in the Potomac River (2000 – 2010). After 2009, harvest includes discards. Source: PRFC

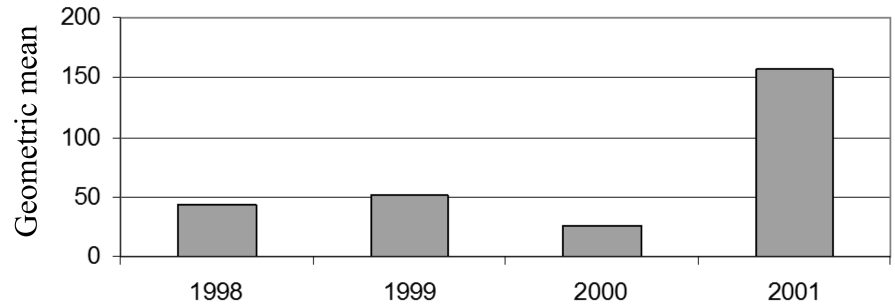


Figure 14.5 USFWS river herring juvenile index for the upper Potomac River. Source: PRFC.

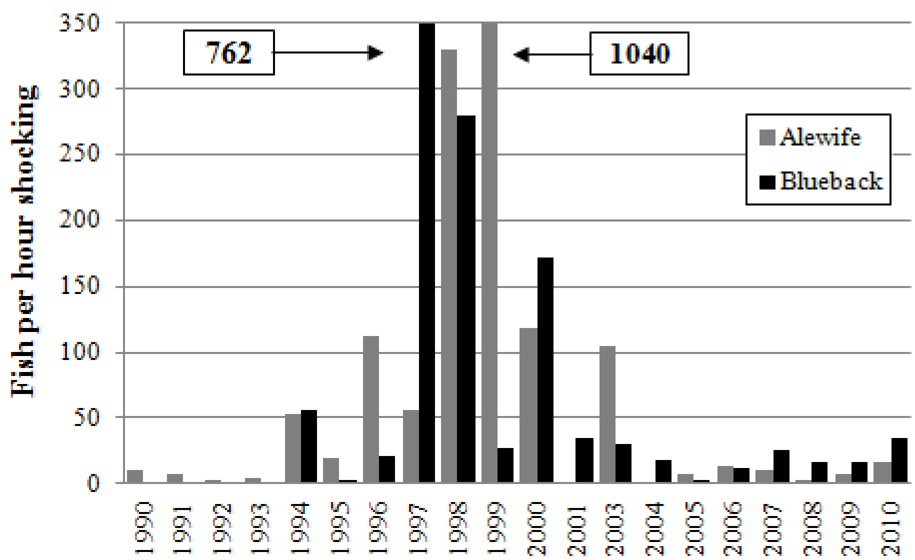


Figure 14.6 CPUE (fish per hour of shocking) of adult alewife and blueback herring during boat electrofishing survey in the Potomac River, 1990-2010. Source: DDOE.

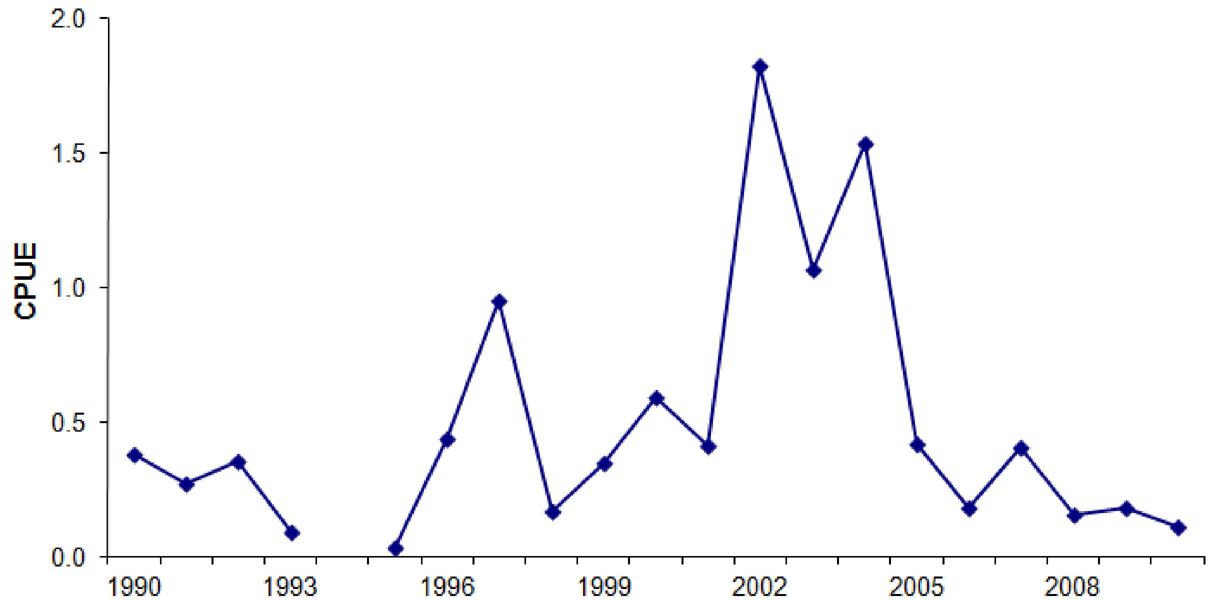


Figure 14.7 Effort corrected catch of alewife on the Potomac River during the MD DNR striped bass spawning stock survey. CPUE is standardized as the number of fish caught per 1000 square yards of drift gill net per hour. Source; MD DNR.

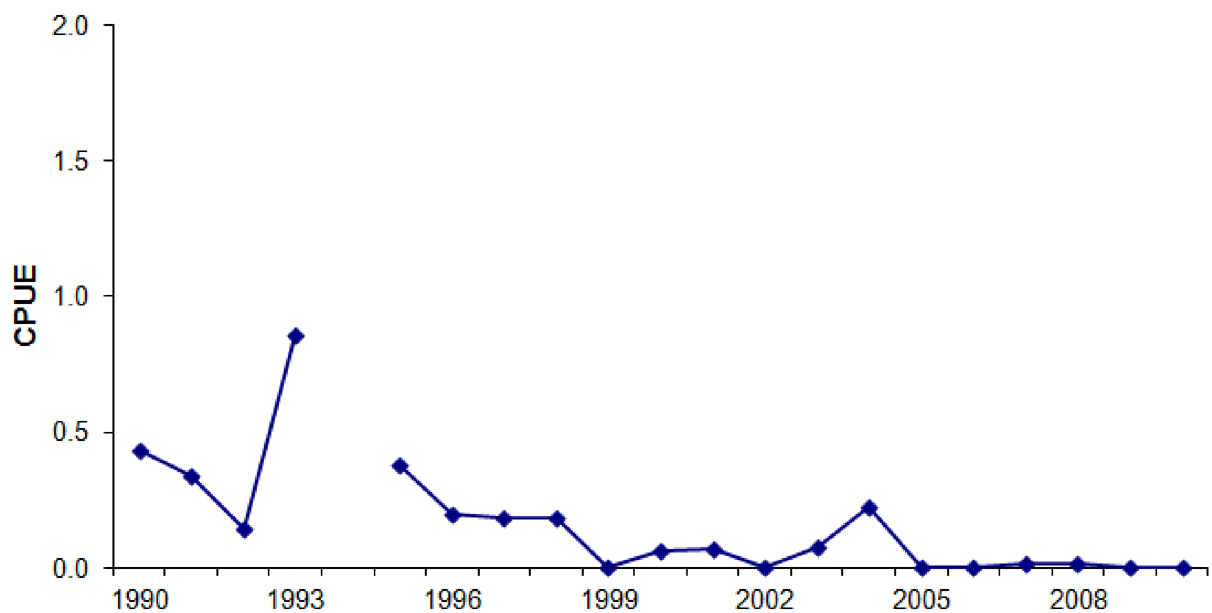


Figure 14.8 Effort corrected catch of blueback herring on the Potomac River during the MD DNR striped bass spawning stock survey. The CPUE is standardized as the number of fish caught per 1000 square yards of drift gill net per hour. Source: MD DNR.

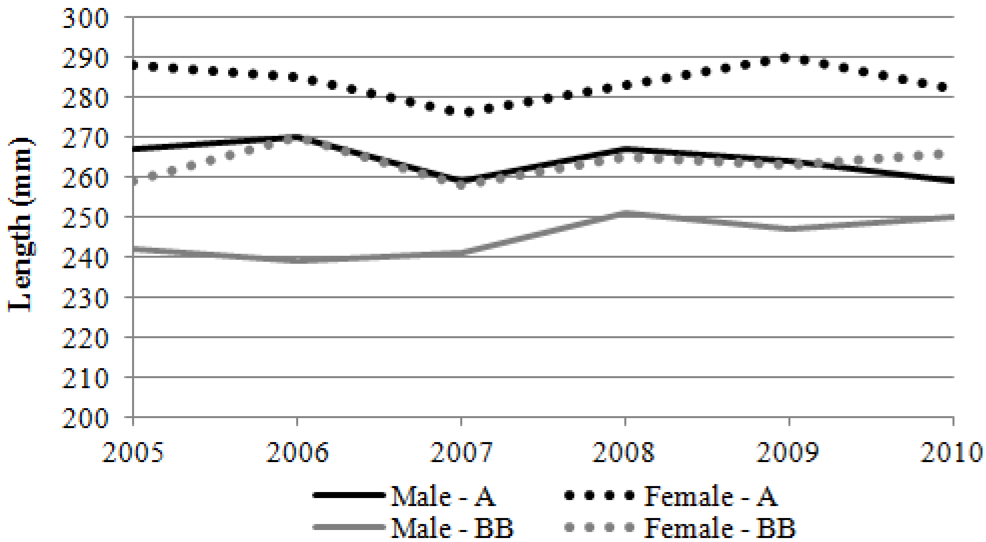


Figure 14.9 Size structure of male and female adult alewife (A) and blueback herring (BB) caught during boat electrofishing survey, 2005-2010. Source: DDOE.

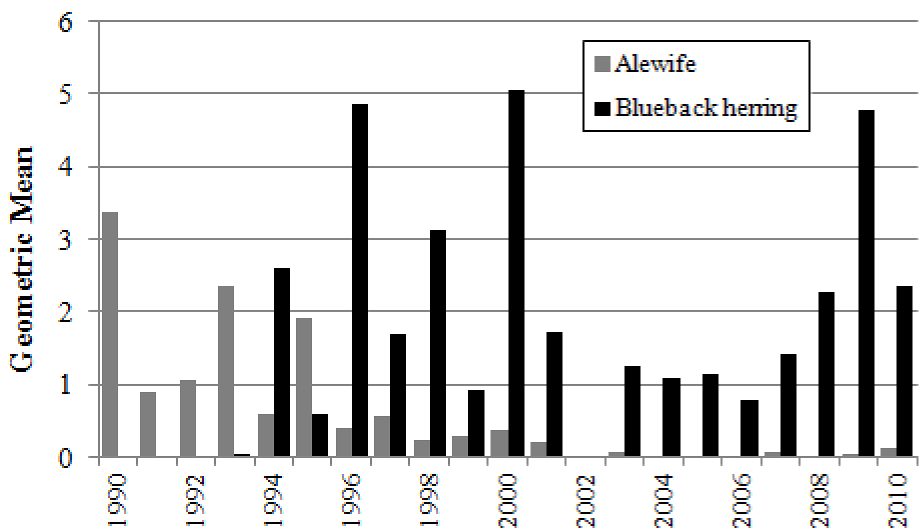


Figure 14.10 Geometric mean (average number of fish per haul) of YOY alewife and blueback herring caught during 100ft beach seining survey, 1990-2010 (no data available for 2002). Source: DDOE.

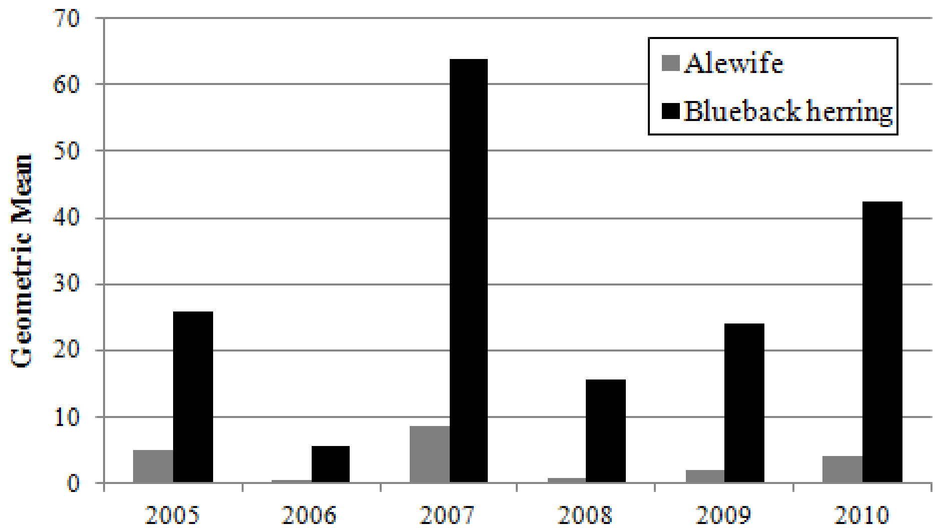


Figure 14.11 Geometric mean (average number of fish per haul) of YOY alewife and blueback herring caught during 10 minute push net survey, 2005-2010. Source: DDOE.

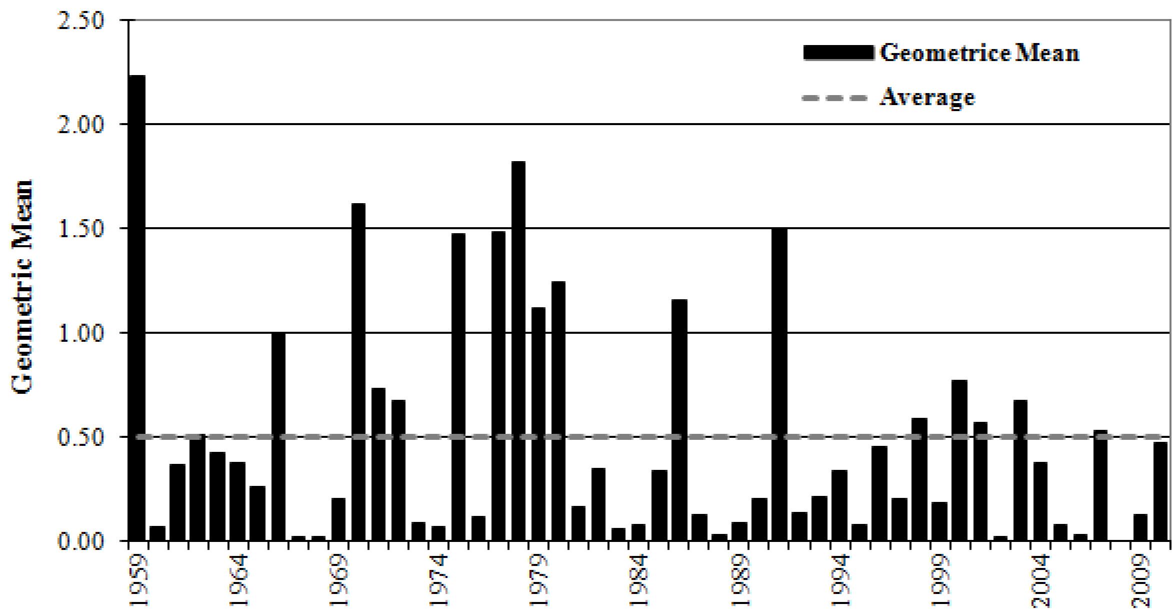


Figure 14.12 Juvenile alewife geometric mean (catch per haul) in the Potomac River (1959 – 2010). Source: MD DNR.

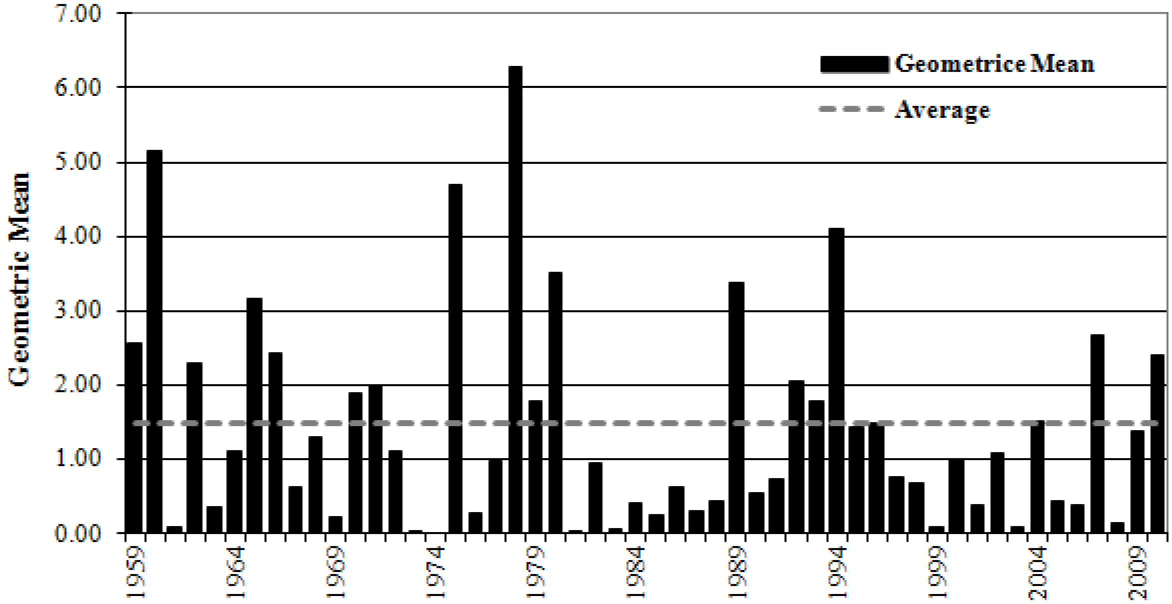
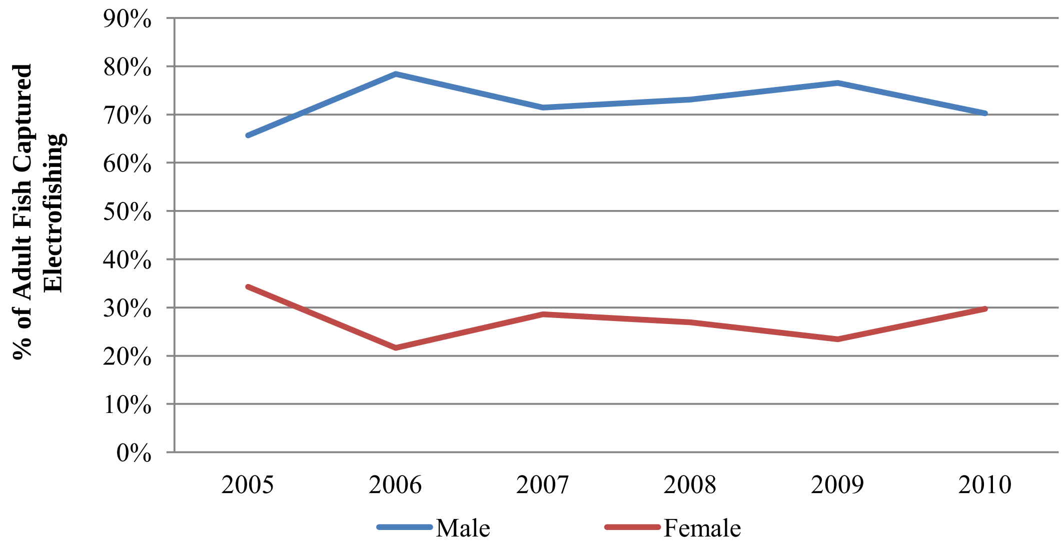


Figure 14.13 Juvenile blueback herring geometric mean (catch per haul) in the Potomac River (1959 – 2010). Source: MD DNR



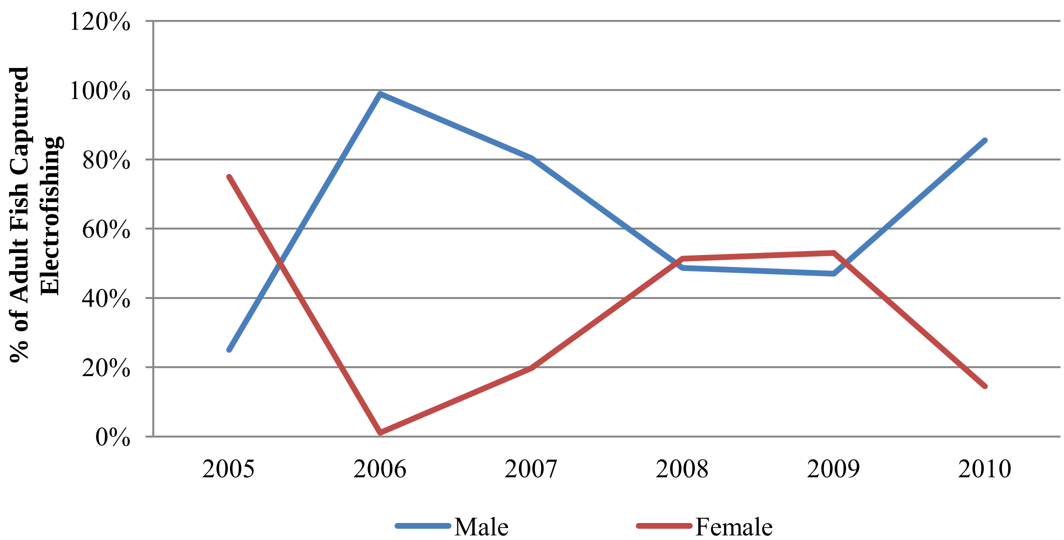


Figure 14.14 Adult alewife (top) and blueback herring (bottom) trends in sex from electrofishing survey from 2005 – 2010. Source: DDOE.

15 Status of River Herring in Virginia

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Executive Summary

River herring have been exploited by fisheries for a long time in Virginia and currently occur in all of Virginia's major rivers (Figure 15.1). Since 1994, the majority of commercial harvest of river herring from Virginia waters has been attributed to the main stem of the Chesapeake Bay, averaging over 35 thousand kilograms (alewives and blueback herring combined) a year from 1994 through 2010. Gill nets were responsible for nearly 82% of the commercial harvest of river herring from the Chesapeake Bay during this time period. The gill net harvests are likely composed of mixed spawning runs of river herring migrating to Virginia and Maryland systems. Fisheries-independent sampling of juvenile abundance depicts considerable annual variability and show little trend over the available time series. However, there are no data on juvenile abundance during the 1950s to 1970s when landings were higher and spawning runs were presumably stronger. The available data reported here are insufficient to quantitatively assess the current status of alewives and blueback herring in the James, York, and Rappahannock rivers.

The collapse of Virginia's commercial river herring fishery in the late 1970s reflects the same trend that has been observed for river herring landings along the U.S. east coast (Schmidt et al. 2003). This pattern has also been reported for Virginia's stocks of American shad during the same time period (ASMFC 2007). In the case of American shad, the VMRC imposed a ban on fishing in the Chesapeake Bay and its tributaries in 1994 in response to declining harvest. The 2007 shad stock assessment has confirmed that the 1994 ban on fishing was an appropriate action that has led to some recovery in the York River system (ASMFC 2007).In response to the collapse of the river herring fishery over the last four decades and in order to comply with ASMFC Amendment 2 to for Shad and River Herring (ASMFC 2009) VMRC voted to implement a ban on the possession of alewives and blueback herring in state waters effective January 1, 2012.

15.1 INTRODUCTION

Assessment of alewife and blueback herring stocks is performed on a river-specific basis; each natal river is considered a unit stock. In Virginia, the majority of data available for river herring come from the James, York, and Rappahannock rivers (an assessment of river herring occurring in the Potomac River can be found elsewhere in this report). The stocks occurring in these river systems are the focus of this chapter.

15.2 DESCRIPTION OF MANAGEMENT UNIT(S)

Virginia's Department of Game and Inland Fisheries (VDGIF) is responsible for the management of fishery resources in the state's inland waters. The Virginia Marine Resources Commission (VMRC) oversees the management of resources in the state's marine waters.

15.3 REGULATORY HISTORY

The conservation and management of Virginia's river herring stocks dates back to colonial times. Loesch and Atran (1994) provide a brief historical overview of *Alosa* fisheries management in Virginia.

As of January 1, 2008, possession of alewives and blueback herring is prohibited on rivers draining into North Carolina (4 VAC 15-320-25). Those rivers include the Meherrin River, Nottoway River, Blackwater River (Chowan Drainage), North Landing and Northwest rivers, and their tributaries plus Back Bay. On June 28, 2011, the VMRC voted to implement a ban on the possession of alewives and blueback herring in state waters. The ban will become effective as of January 1, 2012. The ban was enacted due to the collapse of the fishery over the last four decades and in order to comply with Amendment 2 to the Interstate Fishery Management Plan for Shad and River Herring (ASMFC 2009).

In evaluating Virginia's fisheries for river herring, it is important to note that the ocean fishery is a mixed-stock fishery, comprising river herring from different river systems. As such, river herring landed in Virginia have not necessarily originated in Virginia waters. The proportion of river herring from Virginia harvested from anywhere along the coast is currently unknown.

15.4 ASSESSMENT HISTORY

During 1966 through 1988, the Virginia Institute of Marine Science (VIMS) collected biological samples from Virginia's inshore alosine fishery as part of their annual assessment of the structure of adult alosine populations in the fishery. See sections 1.3.1.1–1.3.1.4, this report, for updated analyses of these data.

Tsimenides (1970) estimated total mortality of alewives using scales sampled from pound nets in the Rappahannock River during 1965 through 1969. The estimate of annual discrete total mortality rate (A) for male alewives was 0.594 and for females the estimate was 0.556. The male estimate of discrete total mortality (A = 0.594) corresponds to an instantaneous total mortality rate (Z) of 0.901. The estimate of discrete total mortality for female alewives (A = 0.556) corresponds to Z equal to 0.812.

A formal assessment of the alewife and blueback herring stocks occurring in the Rappahannock River was performed in 1990 as part of an assessment of multiple river herring stocks along the Atlantic Coast (Crecco and Gibson 1990). Stock status was assessed by comparing the annual discrete fishing mortality rate (u) at the time of the assessment to the river- and stock-specific annual discrete fishing mortality rate that produces maximum sustainable yield (u_{MSY}). The instantaneous natural mortality rate (M) was assumed equal to 1.0 based on a maximum age of 9 years. This value was assumed for all river herring stocks along the coast and was assumed constant for all adult age groups (ages 3–8). That instantaneous value of M (M = 1.0) corresponds to a discrete natural mortality rate (m) of 0.63. Estimated u was 0.37 for alewives and 0.42 for blueback herring based on data collected from 1980 through 1985. The estimated value of u_{MSY} was 0.62 for alewives and 0.67 for blueback herring. Both the alewife and blueback herring stocks were considered partially exploited because the estimate u for each stock was less than 75% of the respective u_{MSY}. The stock condition of the Rappahannock River alewife stock was defined as severely depleted due to a substantial decline in recruitment.

15.5 STOCK SPECIFIC LIFE HISTORY

River herring (alewife, *Alosa pseudoharengus* and blueback herring, *A. aestivalis*) are anadromous, highly migratory, schooling, pelagic fishes that spend most of the annual cycle at sea but enter Virginia's rivers and streams to spawn during late winter and spring. Alewives migrate earlier than other alosine fishes (blueback herring, American shad, hickory shad) and spawn at lower temperatures (Schmidt et al. 2003), thereby being the first anadromous species available for harvest each year in Virginia. The flesh of river herring is consumed usually as a smoked, salted, or fresh product. The ripe ovaries (roes) of females are highly prized. The annual spring spawning run of river herring and American shad is an important cultural and culinary event in Virginia and their traditional fisheries have cultural significance. In addition to human consumption, river herring are the prey of striped bass, blue catfish, longnose gar, and other predators encountered along the migratory route. A comprehensive review of river herring biology and their ecological services is presented by Munroe (2002).

The species are distinct and can be distinguished by cutting the abdomen and examining the pigmentation of the peritoneum—the membrane that lines the abdominal cavity. In alewives, the peritoneum is pale or white; in blueback herring, the peritoneum is sooty dark or black. This dissection is not a routine procedure in most commercial fisheries. When fresh specimens of both species are in hand, the alewife has a much larger eye and is deeper bodied than the blueback herring. Despite these clear differences, the species are often misidentified and mixed in fishery statistics. To further complicate assessments of abundance and stock status, river herrings can be confused with young American shad, hickory shad, Atlantic menhaden, Atlantic herring, and other similar species. Scientists suspect that these species are often misidentified and mixed in reports of harvest and landings.

15.6 HABITAT DESCRIPTION

In Virginia, river herring are found in the Chesapeake Bay and its major tributaries, including the Potomac, Rappahannock, York, and James rivers, as well as smaller tributaries and other coastal habitats (e.g., along the Delmarva peninsula). Additionally, both alewife and/or blueback herring are found in certain rivers in Virginia that drain to North Carolina, including the Meherrin River, Nottoway River, Blackwater River (Chowan Drainage), North Landing and Northwest rivers, and their tributaries plus Back Bay. Both species have been introduced into landlocked reservoirs in Virginia; a reproducing population of blueback herring occurs in Kerr Reservoir, and reproducing populations of alewife are found in at least Smith Mountain Lake, Leesville Reservoir, Claytor Lake, and Bluestone Reservoir (Desfosse et al., 1994). The Potomac Rivers and those of North Carolina are described elsewhere in this assessment; here we focus on the major western tributaries of the Chesapeake Bay.

15.6.1 James River

The James River forms at the junction of Cowpasture and Jackson rivers (rkm 580), and its drainage is the largest watershed in Virginia, totaling 26,164 km^2 (Jenkins and Burkhead, 1994). Average annual spring discharge on the James River is 294.2 m^3/s (Tuckey 2009). Prior to damming, which began in the colonial period, shad and river herring were reported to reach these headwaters and far into the major tributaries of the James River (Loesch and Atran, 1994). The two primary tributaries of the James River below the fall line at Richmond are the Appomattox River, which joins at the city of Hopewell (rkm 112), and the Chickahominy River, which joins at rkm 65. The extent of salt water is variable, but brackish conditions are observed as far up as the mouth of the Chickahominy River on a seasonal basis. Tidal water reaches Boshers Dam in Richmond (rkm 182). Numerous dams on the James River and its tributaries have historically blocked migration of fishes. Between 1989 and 1993 three dams below the fall line were breached or notched, extending available habitat to the base of Boshers Dam. A fish passage was installed in Boshers Dam in 1999, reopening 221 km of the upper James River and 322 km of its tributaries to river herring and other anadromous fishes; the next dam of the mainstem is at Lynchburg, VA (Weaver et al., 2003). The first existing dam on the Appomattox River is at rkm 17; and that on the Chickahominy is Walkers Dam at rkm 35 (with a fish passage rebuilt in 1989). A number of additional dam removal and fishway construction projects have occurred on several smaller creeks and streams in the James River drainage as well (http://www.dgif.virginia.gov/fishing/fish-passage/).

15.6.2 York River System

The York River system includes the Mattaponi and Pamunkey rivers, which merge at West Point, VA, to form the York River (53 rkm). This is the smallest of the three western tributary systems, with a watershed of 6,892 km^2 (Jenkins and Burkhead, 1994); the Pamunkey drainage is larger and has greater average spring discharge than that of the Mattaponi (3,768 km^2 and 47.5 m^3/s vs. 2,274 km^2; 27.2 m^3/s, Bilcovic 2000). Tidal propogation extends to approximately 67 rkm in the Mattaponi and 97 rkm in the Pamunkey (i.e., approximately 120 km and 150 km, respectively, from the mouth of the York River; Lin and Kuo, 2001). The extent of the salt intrusion varies by season, but moderate salinity values (>2 ppt) are often observed in lower portions of these rivers. The Mattaponi, Pamunkey, and York rivers are all undammed.

15.6.3 Rappahannock River

The Rappahannock River, which is approximately 195 km in length (172 km is tidal; 118 is salt water), has its headwaters in the piedmont and is fed by the Rapidan River. The Rappahannock watershed encompasses a total of 7,032 km^2 (Jenkins and Burkhead, 1994), and the average annual discharge at the fall line is 45 m^3/s (O'Connell and Angermeier 1997). The Rappahannock River was dammed until 2004, when the Embrey Dam, built in 1855 at Fredericksburg (rkm 250), was breached. Removal of the dam opened 170 km of potential habitat for migratory fishes, such as river herring. The Embrey Dam was the last remaining dam on the Rappahannock. A fish passage was installed on the Orange Dam on the Rapidan River (http://www.dgif.virginia.gov/fishing/fish-passage/). An estimated 125 tributaries of the Rappahannock River are potentially used by alosines (O'Connell and Angermeier 1997).

15.7 RESTORATION PROGRAMS

Since 2005, Virginia Commonwealth University (VCU) and USFWS's Harrison Lake National Fish Hatchery have conducted a river herring restoration program focused on Kimages Creek, a small tributary of the James River (VCU Rice Center, Charles City County, VA). Historically, Kimages Creek supported a river herring run but was impounded at the mouth in 1928. Remnants of the run persisted below the dam into the 1970s. VCU collected broodstock from several locations, including Herring Creek, Wards Creek, and the James River, and USFWS staff at Harriosn Lake National Fish Hatchery reared and OTC-marked the larvae, which were stocked into Kimages Creek. An informal target of 1M larvae (mostly blueback herring but some alewife) annually up to Spring, 2011. From 2008 through 2011 limited monitoring for returning adults has recovered approximately 10 OTC-marked, reproductive adults in Kimages Creek. However, there are no funds to formally continue any dedicated restoration at this time. In December 2010, VCU, The Nature Conservancy and American Rivers re-established fish passage into a restored tidal Kimages Creek by removing 200 feet of the earthen dam at the Rice Center.

The Virginia Department of Game and Inland Fisheries (VDGIF) has been working to restore access to two major river systems (the James and Rappahannock rivers), and their tributaries as part of a restoration effort for all anadromous species. Most of these projects have taken place over the past two decades and are described in section 15.6 of this report.

15.8 AGE

Fisheries dependent sampling for scales was conducted from 1966 through 1978, and for otoliths from 1975 through 1988. In this assessment, data from the following reports were used: Davis et al. 1970, 1971, 1972; Hoagman et al. 1973, 1974; Hoagman and Kriete 1975; Loesch and Kriete 1976, 1980–1984; Johnson et al. 1978; Loesch et al. 1977, 1981, 1985, 1986; Blumberg and Loesch 1988, 1989.

15.9 FISHERIES DESCRIPTIONS

Since 2003, commercial fishing for river herring in Virginia takes place primarily in marine and estuarine waters. The major gears are gill nets and pound nets, with some ancillary use of haul seines, fyke nets, and other gears. The other category includes common dip nets, hand lines, and pots, based on VMRC reporting records. Recreational anglers fish for river herring primarily in upstream areas using hook and line, recreational gill nets, and dip nets. A brief history of Virgnia's *Alosa* fisheries can be found in Loesch and Atran (1994).

15.9.1 Fisheries-Dependent

15.9.1.1 **Commercial Fisheries Reporting**

The VMRC's commercial fisheries records include information on both commercial harvest (fish caught and kept from an area) and landings (fish offloaded at a dock) of marine species in Virginia. The VMRC began collecting voluntary reports (monthly) of commercial landings from seafood buyers in 1973. A mandatory harvester reporting system was initiated in 1993 and collects trip-level data on harvest and landings within Virginia waters. Data collected from the mandatory reporting program are considered reliable starting in 1994, the year after the pilot year of program. The Potomac River Fisheries Commission (PRFC) has provided information on fish caught in their jurisdiction and landed in Virginia since 1973. Records of fish harvested from federal waters and landed in Virginia have been provided by the NMFS and its predecessors since 1929 (NMFS, Fisheries Statistics Division, Silver Spring, MD, pers. comm.).

Estimates of commercial landings for river herring prior to the start of the mandatory harvester reporting program should be interpreted with care. A significant portion of the river herring catch has been used for oil, meal, and crab bait (Joseph and Davis 1965). Prior to 1993, most of that catch was not recorded since data collection programs primarily considered food fish. The mandatory harvester program does, however, allow the reporting of landings as "bait" with no identification to species. As such, some true river landings may be reported as bait and therefore not classified as river herring in the data (VMRC, Fisheries Management Division, pers. comm.). Another issue is that the river herring species were not differentiated in the landings records prior to VMRC's mandatory harvester reporting program—historic landings recorded as alewives include both alewives and river herring (e.g., U.S. Bureau of Fisheries 1941). Data obtained from the VMRC's mandatory reporting program suggest alewives continue to make up the majority (~98%) of Virginia's commercial river herring landings. However, available biological samples from the commercial fisheries suggest the proportion of alewives in the commercial landings is not that excessive or, at least, did not dominate the landings to that degree in the past (see section 1.2.1.3, this report). It is likely that at least a portion of the blueback herring landings continue to be reported as alewives. There is also concern that some commercial landings reported as alewives are, in fact, Atlantic menhaden (VMRC, Fisheries Management Division, pers. comm.). This may be reflected in river herring landings being reported in all months of the year and in gill nets that are harvesting larger fish, like striped bass, which has an eighteen inch minimum size.

Annual commercial landings were available for intermittent years from 1880 through 1925 and were available for all years beginning in 1929 (Table 15.1). Available historical commercial landings data for river herring in Virginia depict an active and productive fishery in the period 1950–1970 with total landings exceeding 14 million kilograms in some years (Figure 15.2). The time series of commercial landings suggest several periods of declining landings (during the 1930s; during the mid-1950s to early 1960s) followed by periods of increased landings. A steep decline in Virginia's landings in the late 1970s was followed by an apparent collapse of the fishery.

Since 1994 (VMRC mandatory harvester reporting), commercial harvest of river herring from Virginia waters ranged from 9.5 thousand kilograms to 118 thousand kilograms from 1994 through 2010 (Figure 15.3). Most of the commercial harvest since 1994 (55%) has been reported from the main stem of the Chesapeake Bay (Figure 15.4). The James (8.43%), York (16.7%), and Rappahannock (10.4%) rivers combined account for about 35% of the commercial harvest. The majority of Virginia's commercial river herring harvest has been taken by gill nets (Figure 15.5).

Annual commercial fishery harvest rates for alewives were calculated for 1994 to 2010 for selected Virginia water bodies. Harvest rates were calculated for gill nets—the major commercial gear for the time period. Annual harvest rates were computed as ratio estimators by dividing commercial harvest (kilograms) by the number of fishing trips for each water body (Pollock et al. 1994). Only fishing trips with positive harvest of alewives were included in the calculations; information on unsuccessful trips were not available. Annual harvest rates have been variable in the James, York, and Rappahannock rivers (Figure 15.6). Harvest rates in the James River have been variable over the time series. Gill-net harvest rates in the York River were relatively low through 2002 and have been variable, but generally increasing, over the rest of the time series. In the Rappahannock River, a three-year period of relatively higher rates occurred from 2002 to 2004. A small peak occurred in 2000, and there is evidence of another peak in 2010, but there is no obvious trend in harvest rates over time in the Rappahannock.

15.9.1.2 **Voluntary Logbooks from an Individual**

The VIMS obtained voluntary logbooks of one commercial river herring fisherman. The fisherman and his father fish the upper Rappahannock River above Port Royal, Virginia with drift gill nets and have been recording their annual catches of river herring from 1995 through 2008. It was not possible to estimate precise catch rates from these records since the logbooks do not indicate the number of nets fished each day or the catch associated with each net. In addition, mesh sizes, lengths of nets, and the daily number of sets may have changed during the time period. The logbooks show that the total catch of river herring has been generally proportional to the number of days fished each year (Figure 15.7). The highest levels of catch and effort occurred from 1999 through 2002. In this period, the fisherman landed from nearly 4,000 to almost 6,000 fish each year from the Rappahannock River. Since 2002, catches have declined considerably. The fisherman reported to VIMS scientists that he has reduced effort in recent years because fewer river herring have been available.

15.9.1.3 **Biological Sampling**

15.9.1.3.1 **VMRC Biological Sampling Program**

The VMRC Biological Sampling Program was initiated in 1989 to collect fisheries-dependent biological information to support assessment and management activity within the state and coast-wide. There are currently twenty-one species targeted for sampling in the program; non-target species, such as alewives and blueback herring, are sampled based on availability and staff time. When river herring are available for sampling, samples are identified to species, measured for total length (TL), and individual weights are taken for most samples. The fork length and sex of most samples is also recorded. River herring have been available for sampling from Virginia’s commercial fishery in all years since the program’s inception, except for 2009 and 2010. The samples were considered insufficient for characterizing the species composition of the commercial landings (J. Cimino, VMRC, pers. comm.).

The lengths of male alewives sampled from Virginia’s commercial landings between 1989 and 2008 ranged between 210 and 390 mm TL and demonstrate a mode at 270 mm TL (Figure 15.8). Female alewives sampled from the commercial fishery exhibited a mode at 290 mm TL and ranged between 150 and 390 mm TL. Similar to the alewife samples, the female blueback herrings sampled from the commercial landings tended to be larger than the males (Figure 15.9). Male blueback herring ranged between 210 and 380 mm TL while females ranged between 180 and 350 mm TL. Male and female blueback herring demonstrated modes at 250 mm TL and 270 mm TL, respectively.

The average length of alewives sampled from Virginia’s commercial fishery ranged from 258 to 297 mm TL per year between 1989 and 20081 (Figure 15.10). The annual average length of blueback herring samples ranged between 252 and 284 mm TL. The average annual length of both species shows an overall declining trend over the time series. The average individual weight of alewife commercial samples ranged between 161 and 276 g per year and blueback herring samples ranged between 121 and 219 g per year in individual weight (Figure 15.11). Like average length, the average individual weight of both alewives and blueback herring demonstrate a decrease over time.

15.9.1.3.2 **VIMS Assessment of Virginia’s Inshore Alosine Fishery (Historic Samples)**

The VIMS collected biological samples from Virginia's commercial fishery from 1966 to 1988 as part of their annual assessment of the structure of adult alosine populations in Virginia's inshore alosine fishery. Adult alosines were randomly sampled from the commercial fishery—primarily pound nets—over the duration of the spring spawning run. The majority of samples were collected from the James, York, Rappahannock, and Potomac rivers. The Potomac River samples are not included in this report. Individual samples were identified to species, measured for fork length (FL), weighed, and sexed. Structures were also removed and processed for ageing. Scales were collected during 1966 through 1978, and otoliths were collected during 1975 through 1988. In this assessment, data from the following reports were used: Davis et al. 1970, 1971, 1972; Hoagman et al. 1973, 1974; Hoagman and Kriete 1975; Loesch and Kriete 1976, 1980–1984; Johnson et al. 1978; Loesch et al. 1977, 1981, 1985, 1986; Blumberg and Loesch 1988, 1989. Refer to one of the cited reports for a more detailed description of this monitoring program. Also note that most of those data were not available in raw form.

The numbers of each species sampled were summarized by year to evaluate the species composition of Virginia's commercial river herring landings (see also section 15.9.1, this report). During the earliest years of the program (1967–1972), alewives composed the majority of the commercial landings, except in 1971 when nearly equal quantities of alewives and blueback herring were sampled (Table 15.2). The proportion of blueback herring sampled exceeded that of alewives beginning in 1973 and gradually increased through 1981; in 1981, 92% of the commercial samples were identified as blueback herring. The proportion of blueback herring then decreased but remained higher than that of alewives through 1988, the last year of the monitoring program.

The ages of alewives sampled from commercial harvest in the James River ranged from 3 to 9 years (Figure 15.12). Alewives age 4 and 5 dominated the James River commercial samples. In the Rappahannock River, alewives ranged in age from 2 to 9 in the commercial harvest (Figure 15.13). The age-frequency distributions demonstrate that the 1963, 1966, 1981, and 1982 year-classes of alewives were relatively strong in the Rappahannock River. Where both scale and otoliths ages were available, the pattern in the proportion of alewives at age is similar between the two structures, and there is no evidence of consistent over- or under-ageing by either structure. Alewives collected from the York River commercial fishery harvest ranged in age from 3 to 13 years and the majority of samples were 4- and 5-years-old (Figure 15.14). The York River age compositions suggest the 1982 year-class of resident alewives was relatively strong.

Blueback herring sampled from the James River commercial harvest were primarily age 4 and 5 in most years and ranged in age from 3 to 9 years (Figure 15.15). Blueback herring age 3 to 13 were observed in the commercial harvest samples from the Rappahannock River (Figure 15.16). The age-frequency distributions show that the 1966, 1970, 1971, 1975, 1978, and 1979 year-classes of blueback herring in the Rappahannock River were relatively strong. As with the alewife samples from the Rappahannock River, the age compositions of blueback herring based on scales were similar to those based on otoliths, and there is no evidence of consistent over- or under-ageing by either structure. The blueback herring samples from the Rappahannock River commercial harvest were dominated by 4- and 5-year-old fish from 1966 to 1975 and show increasing dominance of 5- and 6-year-olds from 1976 through 1988. In the York River, blueback herring ranged in age from 3 to 13 in the commercial harvest (Figure 15.17). The majority of blueback herring sampled from the York River commercial harvest were 4- to 6-years-old. The 1975, 1978, 1981 year-classes of blueback herring in the York River appeared to be relatively strong.

The spawning frequency data show that male and female alewives sampled from commercial harvest in the James River spawned as many as six times (Figure 15.18). In three of the four years for which data were available, the majority of male alewives sampled from the James River had spawned at least once while the majority of female alewives sampled had not yet spawned. The limited data available characterizing spawning frequencies at age suggest most of the alewives in the James River that have spawned once are 5- or 6-years-old (Table 15.3). In the York River, male alewives spawned as many as five times, and females experienced as many as six spawning events (Figure 15.19). First-time spawners were 4- to 6-years-old (Table 15.3). The blueback herring spawning frequency data collected from the James River commercial harvest show that males spawned as many as six times, and females spawned as many as five times (Figure 15.20). In all years for which data were available, the majority of female blueback herring collected from the James River were virgin spawners. Most of the blueback herring sampled from the James River that spawned once were age 6 (Table 15.4). Both male and female blueback herring spawned as many as six times based on samples collected from commercial harvest in the York River (Figure 15.21). Similar to the James River, the majority of first-time spawners in the York River were 6-years-old (Table 15.4).

15.9.1.4 **Recreational Fisheries Monitoring**

The NMFS Marine Recreational Fishery Statistics Survey (MRFSS) is the primary source of marine recreational fisheries statistics for Virginia. The MRFSS program utilizes telephone surveys, angler-intercept surveys, and at-sea headboat sampling (begun in 2005) to estimate recreational fisheries statistics. The MRFSS raw data files demonstrate that alewives and blueback herring were rarely encountered during surveys of Virginia's recreational anglers. During 1981 through 2010, a total of 206 alewives and 51 blueback herring were encountered in the angler-intercept survey in Virginia. Additionally, one blueback herring was encountered during the MRFSS at-sea headboat survey. These observations occurred in only six years over the available survey time series (1981–2010); recreational statistics of alewives and blueback herring could only be derived for those years where samples were recorded. The limited availability of samples resulted in low precision (high proportional standard error) of the estimates that could be computed. As such, the MRFSS estimates of Virginia's recreational alewife and blueback herring catches are not considered reliable or representative and so are not presented here.

Estimates of recreational catch and effort from non-marine waters are not available, though river herring is a popular recreational species in Virginia's inland waters.

15.10 FISHERIES INDEPENDENT SURVEYS

15.10.1 VDGIF Electrofishing Surveys, 1994–present

The VDGIF has conducted electrofishing surveys for American shad and river herring in the Rappahannock River near Route 1 and in the James River near the Manchester Bridge in downtown Richmond. Sampling is conducted weekly at both locations. The total number of each species collected and the sex of each individual in a sample is recorded. Individual weights and total lengths are collected from a subsample per sampling date at each station.

The Route 1 sampling station starts at the very head of tide (the tidal/non-tidal interface) approximately 1.5 miles downstream of the Embrey Dam and extends downstream several hundred meters (900 seconds of boat electrofishing effort). This area was essentially unchanged by the dam removal in 2004 and represents the most consistently sampled site by the VDGIF over the last eight years on the river. Alewives are observed at the Rappahannock stations in March and April of each year. Blueback herring can be found in April through early June; the two species usually co-occur in April only.

Three of the four stations (Manchester 1, 2, and 4) in the James River start at the very head of tide just downstream of the last riffle/rapids and extend downstream to the 14th Street Bridge (300–500 seconds of electrofishing effort each). The Manchester 5 sampling station starts at Interstate 95 and extends downstream along the bank (500 seconds of electrofishing effort). Alewives appear in March and April at the Manchester Bridge sampling sites on the James River. Blueback herring occur at this site in April, May, and early June.

Annual cumulative catch rates were computed for the Rappahannock River (Route 1 sampling station) for 2000 to 2010 and for the James River (Manchester stations 1, 2, 4, and 5 combined) for 2002 to 2010. The years used represent the most consistent, continuous time series for each location. Catch rates were calculated as the average number of fish collected per minute of electrofishing. In the Rappahannock River, peak catch rates of blueback herring occurred in 2001 (Figure 15.22). In some years, blueback herring were not collected in the survey. Peak catch rates of alewives occurred in 2004 and 2005. In the James River, blueback herring have dominated the catch (Figure 15.23). The 2010 catch rate for blueback herring in the James River was the highest in the time series. The catch rates show a low relative abundance of alewives in the James River relative to the Rappahannock (Figures 15.22 and 15.23).

15.10.2 VIMS Experimental Anchor Gill-Net Survey, 1991–present

The VIMS performs an annual striped bass spawning stock survey in the James and Rappahannock rivers using multi-mesh anchored gill nets. Adult river herring are encountered in the Rappahannock River, but river herring are rarely observed in the James River samples. The gear is set twice a week from late March through early May, and soak time is twenty-four hours for each set. Although the peak of the blueback herring run takes place during the duration of the survey, a significant portion of the alewife migration occurs before late March and may be missed.

Indices of relative abundance based on observations from the Rappahannock River were calculated as the arithmetic average number of fish per day for alewives and blueback herring. The index for alewives has maintained relatively low levels with no obvious trend over the time series (Figure 15.24). The blueback herring index declined from the beginning of the time series through 1994 and increased to the time series peak in 1995. The index then decreased and has remained at relatively low levels through the present.

15.10.3 VIMS Juvenile Fish and Blue Crab Trawl Survey, 1979–present

The VIMS Juvenile Fish and Blue Crab Trawl Survey monitors the distribution and abundance of important finfish and invertebrate species occurring in the Chesapeake Bay. The survey sites and sampling frequency have not been consistent throughout the history of the survey (Tuckey and Fabrizio 2010). The survey currently employs a mixed design, incorporating both stratified random sites and fixed (historical mid-channel) sites. The stratification system is based on depth and latitudinal regions in the bay (random stations), or depth and longitudinal regions in the tributaries (random and fixed stations).

Annual juvenile abundance indices (JAIs) for young-of-year alewives and blueback herring were computed as random stratified geometric average number of fish per standard tow. The indices series start in 1996 because that is the year when random stations were added to the survey. The JAIs for both species were calculated based on data collected in December through March and fish less than or equal to 110 mm. Indices were calculated for the James, York, and Rappahannock rivers separately. The relative abundance of juvenile alewives was variable without trend for each river (Figure 15.25). Similar to the alewife JAIs, the JAIs for blueback herring varied without trend for each of the three rivers (Figure 15.26). Variability about the annual JAIs values is fairly high for both species, especially for the Rappahannock River (Figures 15.25 and 15.26).

15.10.4 VIMS Juvenile Striped Bass Seine Survey, 1967–present (gap 1974–1979)

The VIMS Juvenile Striped Bass Seine Survey tracks trends in the annual year-class strength of striped bass in the spawning and nursery areas of the lower Chesapeake Bay. JAIs for alewives and blueback herring were calculated as the geometric average number of fish per seine set for the James, York, and Rappahannock rivers separately. The indices series start in 1989 because the number of sites sampled (~109) became consistent in that year. The JAIs for both species were calculated based on data collected in July through September using only data from sites where each species can be expected to be captured. All sampling sites are fixed in location. The JAI for alewife (Figure 15.27) has been consistently lower than the blueback herring JAI (Figure 15.28) in all three rivers. There are no obvious trends in the JAI time series for either of the species, and variability about the annual estimates has been fairly high (Figures 15.27 and 15.28).

15.10.5 VIMS Juvenile Shad-River Herring Push-Net Survey, 1979–2002 (gap 1988–1990)

The VIMS Push-Net Survey, initiated in 1979, was an evening push-net survey of the York River system that targeted American shad. The survey was discontinued in 2002. Sampling in the Mattaponi and Pamunkey rivers was typically conducted from mid-May through August or until the catch of American shad was zero. The survey was temporarily halted following the 1987 sampling year. Sampling resumed again in 1991, though there were changes to the sampling design and methodology. Wilhite et al. (2003) examined the sampling strategies employed in this survey and concluded that data collected before and after the interruption in sampling (1979–1987; 1991–2002) should be considered separate data series and not compared since the collection methods differed substantially in each period. The survey data were used to calculate JAIs for alewives and blueback herring as the geometric average number of fish per standard set. Juvenile indices were calculated for both the Mattaponi and Pamunkey rivers. The majority of alewives and blueback herring caught in the survey were between 27 and 70 millimeters in length. The JAI values for alewives have been lower than that for blueback herring in both tributaries throughout the time series (Table 15.5); however, catchability of alewives and blueback herring by the push net may differ, accounting for these patterns (Loesch et al. 1982).

15.10.6 VIMS American Shad Monitoring Program, 1998–present

Few alewife or river herring are encountered in the VIMS American Shad Monitoring Program in the Rappahannock, York, and James rivers (<60 individuals of both species in all rivers combined over the history of the program) due to specificity of the gear used for the larger species, American shad (this program mimics the historical commercial American shad fishery, which targeted female American shad). Therefore, no trends or inference on alewife and river herring can be drawn from these data, and they are not included in the assessment.

15.11 ASSESSMENT APPROACHES AND RESULTS

15.11.1 Trends in Relative Abundance

The indices of relative abundance for adult and juvenile river herring were tested for overall temporal trends and were compared to evaluate whether there was consistency in temporal trends among the indices. Only indices derived from the fishery-independent surveys were considered because the fishery-dependent harvest rate indices have not been corrected for changes in efficiency over time, only include records of positive tows, and would reflect trends in fished areas only. Indices derived from the VIMS Push-Net Survey were not included in the analyses because that survey was discontinued in 2002.

The Mann-Kendall test was applied to quantitatively evaluate the overall trend in relative abundance of alewives and blueback herring, by species, life stage, river, and survey. The Mann-Kendall test is a non-parametric test for monotonic trend in time-ordered data and allows for both missing observations and ties (Gilbert 1987). Trends were considered statistically significant at $\alpha = 0.05$. Spearman's rank-order correlation coefficient, ρ, was calculated to measure the degree of linear association between indices. Spearman's rank-order correlation is a non-parametric test for determining if there is an association between two variables. Indices were considered significantly correlated at $\alpha = 0.05$. Comparisons were made by species and life stage.

The temporal trend of eighteen fishery-independent survey indices was evaluated using the Mann-Kendall test. Statistically significant trends were detected in two indices (Table 15.6). The indices of relative abundance of adult alewives and adult blueback herring in the Rappahannock River derived from the VIMS Experimental Anchor Gill-Net Survey (Figure 15.24) were found to have significantly decreasing trends over the time series (alewives: $S = -74$, $P = 0.0176$; blueback herring: $S = -141$, $P = 5.50\text{E-}06$). Statistically significant trends were not found in any of the other indices evaluated.

There were no statistically significant correlations detected among the adult indices of relative abundance for either species (Table 15.7). The indices of alewife juvenile abundance in the York River derived from the VIMS Juvenile Striped Bass Seine Survey and the VIMS Juvenile Fish and Blue Crab Trawl Survey were found to be significantly and positively correlated ($\rho = 0.665$, $P = 0.00680$). Indices of blueback herring juvenile abundance derived from the VIMS Juvenile Striped Bass Seine Survey were significantly and positively correlated between the James and Rappahannock rivers ($\rho = 0.712$, $P = 0.000200$), James and York rivers (ρ = 0.478, P = 0.0246), and York and Rappahannock (ρ = 0.560, P = 0.00670; Table 15.8).

15.11.2 Temporal Trends in Size

Size data available from the VIMS inshore alosine fishery sampling were compared to data available from the VMRC's Biological Sampling Program to evaluate trends in average size over time. The historic VIMS sampling program measured lengths in terms of fork lengths; length data from the VMRC were converted to fork lengths for consistency. Size data from the historical VIMS report were only available in summarized form and were typically reported as annual averages for the major tributaries of the Chesapeake Bay. Additionally, the historical VIMS data were primarily collected from commercial pound nets. Pound net samples collected by the VMRC were examined and it was found that only samples collected from the Rappahannock River could provide enough years to include in the evaluation. Note that the comparison may be confounded by the fact that the VIMS sampling only occurred during the spring spawning run and the VMRC sampling can occur anytime during the year when landings are available for sampling.

The Mann-Kendall test was performed to quantitatively evaluate the time-series trend in average length and weight for alewives and blueback herring, by sex. Trends were considered statistically significant at α = 0.05.

The average length of male alewives ranged from 125 to 228 mm FL per year and the average lengths of females ranged from 160 to 294 mm FL per year (Figure 15.29). The average weight of male alewives ranged between 224 and 250 g per year while the average weight of females ranged between 236 and 265 g per year (Figure 15.30). The Mann-Kendall test detected statistically significant decreasing trends over time for the average length and weight of both male and female alewives sampled from the Rappahannock River commercial pound net fishery (Table 15.9).

There were only three years (2004, 2007, and 2008) during the recent time period in which blueback herring were available for sampling from commercial pound nets in the Rappahannock River. Despite the limited data from recent years, the annual average lengths of male and female blueback herring show evidence of an overall declining trend over time (Figure 15.31). The Mann-Kendall test found the declining trend in average length of male and female blueback herring to be statistically significant (Table 15.9). The average weight of male blueback herring ranged from 213 to 251 g per year and the average weight of females ranged from 231 to 259 g per year (Figure 15.32). No significant trends were detected in the average weight of blueback herring over time (Table 15.9).

15.11.3 Sex Ratio

Sex ratios for river herring were calculated using the data available from the VIMS sampling of Virginia's inshore alosine fishery. Samples collected by the VMRC's Biological Sampling Program were considered insufficient for calculating sex ratios (J. Cimino, VMRC, pers. comm.) and would not be comparable to the VIMS historical data because the VMRC sampling can occur throughout the year while the VIMS only sampled during the spring spawning run.

Sex ratios were computed for each species by year for the James, York, and Rappahannock rivers. The χ^2 goodness-of-fit test with Yate's correction for continuity was applied to test whether the observed sex ratios departed from a 1:1 (male: female) ratio (Zar 1999).

The sex ratio (male: female) for alewives sampled from the James River ranged from 1.1 (52% male) to 3.9 (79% male) between 1967 and 1980 (Table 15.10). Male alewives were encountered more frequently than females in all the years data were available from the James River (1967–1980). The χ^2 goodness-of-fit indicated that most of the sex ratios for alewives sampled from the James River significantly deviated from a 1:1 ratio (P < 0.05), in favor of males. In the York River, the sex ratio of alewives ranged from 0.53 (35% male) to 1.6 (62% male) and demonstrated an overall decrease over the time series (1967–1988). In most years, the sex ratios of alewives collected from the commercial fishery in the York River were not statistically different from a 1:1 ratio ($P \geq 0.05$). Male alewives dominated the Rappahannock River samples in most years of the available time series. Sex ratios of alewives in the Rappahannock River ranged between 0.55 (35% male) and 1.8 (65% male).

The proportion of male blueback herring sampled from the James River fishery was found to be significantly larger ($P < 0.05$) than the proportion of females sampled in all but one of the years samples were available (Table 15.11). The sex ratio of James River blueback herring ranged from 1.2 (54% male) to 5.1 (84% male) between 1967 and 1980. Blueback herring collected from the York River exhibited sex ratios ranging from 0.58 (37% male) to 1.7 (63% male). In the Rappahannock River, blueback herring sex ratios ranged between 0.73 (42% male) and 2.0 (67% male) and were dominated by males in most years.

15.11.4 Spawning Frequency

Data characterizing the spawning frequency of river herring were available for a limited number of years from the James (1967–1970) and York (1967, 1969–1970) rivers. The data were collected by the VIMS inshore alosine fishery sampling program. Repeat spawner rates were calculated by dividing the number of sampled fish with one or more spawning marks by the total number of fish sampled and multiplying the resulting quotient by 100. Rates were calculated by species, sex, and year for each river.

The percentage of male alewives that previously spawned at least one time was nearly 50% or greater for samples collected from the James River commercial fishery (Table 15.12). Repeat spawning rates of female alewives sampled from the James River ranged between 42% and 83%. Alewives in the commercial fishery samples from the York River exhibited repeat spawning rates ranging from 46% to 70%. Female alewives sampled from the York River exceeded 50% in all three of the years for which data were available.

Repeat spawning rates for blueback herring sampled from commercial harvest in the James River ranged from 36% to 82% (Table 15.13). The proportion of females in the James River that previously spawned ranged between 33% and 73% among the years when data were available. In the York River, repeat spawner rates were 60% or greater for male blueback herring sampled from the fishery. Female blueback herring repeat spawner rates in the York River ranged from 50 to 72%.

15.11.5 Mortality

Age data collected from Virginia's inshore alosine fishery by the VIMS were used to derive catch curves in order to estimate instantaneous total mortality rates (Z). The age data obtained from the historical VIMS reports were sometimes presented in terms of proportion at age without additional information on sample size. This prevents the calculation of standard error for Z estimates so catch curves were not calculated for years when sample size information was not available. Additionally, the available data were insufficient to calculate longitudinal catch curves. Though longitudinal catch curves are generally preferred, age composition data were not available for a sufficient number of consecutive years to follow cohorts through time. Instead, cross-sectional catch curves, which are based on the estimated abundance of successive age classes within a particular year, were computed for each species by water body, ageing structure, and year based on availability of data. The data used were collected during the mid-1970s through the late 1980s.

Catch curves were computed using the method of Robson and Chapman (1961). Both alewives and blueback herring were considered fully recruited to the gear at age 4 years. Catch curves were only applied to age compositions that had samples for the assumed age at full recruitment and at least three older ages.

Estimates of annual Zs for alewives ranged from a low of 0.44 to a high of 1.8 among all computed estimates (Table 15.14). Annual Zs were highest in the Rappahannock River for most years. Alewife samples from the James River yielded the lowest estimates of Z. Blueback herring total mortality estimates ranged between 0.32 and 2.0 (Table 15.15). Estimates of blueback herring Zs were generally similar among the three rivers.

15.12 BENCHMARKS

The available data for alewives and blueback herring in the James, York, and Rappahannock rivers were considered insufficient to perform a reliable assessment of the status of these stocks. The data were also considered inadequate for developing benchmarks.

15.13 CONCLUSIONS AND RECOMMENDATIONS

15.13.1 Management Actions and Outcomes

On June 28, 2011, the VMRC voted to implement a ban on the possession of alewives and blueback herring in state waters. The ban will become effective as of January 1, 2012. The ban was enacted due to the collapse of the fishery over the last four decades and in order to comply with Amendment 2 to the Interstate Fishery Management Plan for Shad and River Herring (ASMFC 2009). The outcome of the moratorium means the loss of harvest information. Additionally, as in the case of American shad in Virginia, a ban on possession of river herrings will not reduce removals by pound nets and some other gears, rendering discards of river herring as unreported.

It would be prudent to initiate an observer program for pound nets in the Chesapeake Bay to obtain information on patterns of species-specific exploitation (catch rates, temporal and spatial trends in catch). This program also would provide materials for biological characterization of the catch and could produce more reliable information of relative abundance of each species.

15.13.2 Research Recommendations

- Develop and implement program for sampling commercial landings classified as "bait" in order to evaluate the relative importance of river herring (and other species) in the bait landings
- Collect structures for determining age and spawning frequency from fisheries-independent monitoring programs
- Develop fisheries-independent survey for the spawning stock of river herring
- Estimate magnitude of by-catch and discards in state and ocean waters; estimate associated mortality
- Initiate an observer program for pound nets in the Chesapeake Bay to obtain information on patterns of species-specific exploitation
- Develop studies to estimate stock-specific (river-specific) estimates of natural mortality
- Develop studies to estimate contribution of Virginia stocks to ocean fisheries by-catch
- Develop a fish passage facility monitoring plan to estimate stock size at, and upstream of, dams with fishways and to track population trends
- Use existing creel surveys in rivers to estimate incidental catch of river herring by recreational anglers

15.13.3 Summary

The available data reported here are insufficient to quantitatively assess the current status of alewives and blueback herring in the James, York, and Rappahannock rivers. The most recent comprehensive assessment of river herring stocks examined long-term datasets from large rivers along the U.S. east coast (including the Hudson, Connecticut, Delaware, and Chowan rivers) and concluded that both river herring species in these systems showed signs of overexploitation including reductions in average age, decreases in the percent of repeat spawning, declines in recruitment, and decreases in adult abundance (Schmidt et al. 2003). With the exception of the juvenile abundance surveys, such long-term data are not currently available for Virginia. The analysis of sex ratios and spawning frequency and estimation of mortality rates were based on historical data and not informative about the status of the population in recent years.

Based on the results of fishery-independent sampling that depicts the presence of both species of river herring, there is strong evidence that commercial harvest data since 1994 are not an accurate depiction of the species composition of the catch in Virginia. Schmidt et al. (2003) emphasized that alewife and blueback herring should be managed separately. The species are likely misidentified in Virginia reported harvest and landings and this fact significantly diminishes our understanding of their exploitation.

River herring have been exploited by fisheries for a long time in Virginia. Since 1994, the majority of commercial harvest of river herring from Virginia waters has been attributed to the main stem of the Chesapeake Bay, averaging over 35 thousand kilograms (alewives and blueback herring combined) a year from 1994 through 2010. Gill nets were responsible for nearly 82% of the commercial harvest of river herring from the Chesapeake Bay during this time period. The gill net harvests are likely composed of mixed spawning runs of river herring migrating to Virginia and Maryland systems.

Interviews with one fisherman and examination of his voluntary logbook data suggest that the strength of the spawning run of river herring has declined in the Rappahannock River since 1995. This observation is supported by the VIMS multi-mesh anchored gill-net survey—the longest available fisheries-independent time series of adult river herring occurring in the Rappahannock River (1991–2010)—and the commercial harvest rate estimates of gill nets in the river.

Fisheries-independent sampling and commercial harvest reveal that river herring occur in all of Virginia's major rivers. Abundance indices of juveniles depict considerable annual variability and show little trend over the available time series. However, there are no data on juvenile abundance during the 1950s to 1970s when landings were higher and spawning runs were presumably stronger. Additionally, the results of the correlation analyses suggest little consistency among the fishery-independent survey indices of relative abundance.

The collapse of Virginia's commercial river herring fishery in the late 1970s (Figure 15.2) reflects the same trend that has been observed for river herring landings along the U.S. east coast (Schmidt et al. 2003). This pattern has also been reported for Virginia's stocks of American shad during the same time period (ASMFC 2007). In the case of American shad, the VMRC imposed a ban on fishing in the Chesapeake Bay and its tributaries in 1994 in response to declining harvest (4 VAC 20-530 et seq.). At the time, fisheries-independent data were insufficient to assess the stocks and there were no existing monitoring programs to evaluate stock status. Subsequent research and the recent ASMFC stock assessment have confirmed that the 1994 ban on fishing was an appropriate action that has led to some recovery in the York River system (ASMFC 2007).

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Table 15.1 Annual commercial landings (kilograms) of river herring in Virginia, 1880–2010. Note that estimates are not available for all years prior to 1929.

Year	Commercial Landings (kilograms)
1880	3,141,127
1887	1,996,713
1888	2,927,031
1890	4,827,129
1891	4,995,412
1896	5,532,919
1897	6,209,679
1901	6,311,283
1904	6,624,262
1908	17,184,345
1909	12,599,887
1915	7,281,971
1920	7,559,116
1921	8,542,958
1925	8,123,838
1929	5,701,681
1930	6,979,433
1931	7,819,510
1932	6,283,384
1933	8,698,743
1934	2,651,791
1935	4,977,767
1936	3,941,128
1937	6,833,051
1938	8,024,497
1939	6,727,137
1940	5,186,057
1941	5,420,882
1942	4,199,312
1944	8,092,450
1945	6,631,111
1946	5,455,944
1947	10,057,593
1948	8,783,634
1949	9,980,346
1950	13,018,870
1951	14,788,924
1952	13,082,056
1953	10,875,329
1954	12,668,879
1955	9,907,635
1956	10,027,338
1957	8,508,303
1958	8,328,544
1959	7,913,825
1960	7,014,351
1961	7,042,383
1962	11,092,056
1963	11,832,137
1964	12,083,699
1965	16,420,178
1966	12,943,166
1967	12,749,300
1968	14,659,831
1969	13,809,935
1970	8,638,847
1971	4,657,531
1972	4,740,403
1973	4,204,317
1974	6,051,813
1975	5,152,585
1976	1,922,171
1977	630,527
1978	965,278
1979	766,000
1980	537,138
1981	235,650
1982	593,023
1983	833,550
1984	570,220
1985	195,956
1986	343,824
1987	355,052
1988	324,152
1989	296,023
1990	227,311
1991	319,583
1992	483,977
1993	160,032
1994	81,063
1995	109,040
1996	64,405
1997	64,929
1998	21,792
1999	23,353
2000	17,671
2001	28,574
2002	120,517
2003	103,416
2004	101,798
2005	44,053
2006	23,695
2007	47,884
2008	72,854
2009	88,835
2010	78,264

Table 15.2 Species composition (%) of river herring sampled from commercial harvest in the James, York, and Rappahannock rivers, 1967–1988.

Year	n	Alewife	Blueback Herring
1967	1,419	56.1	43.9
1968	718	55.7	44.3
1969	1,090	60.2	39.8
1970	978	80.0	20.0
1971	875	49.1	50.9
1972	736	60.0	40.0
1973	865	38.5	61.5
1974	2,498	42.4	57.6
1975	4,846	38.7	61.3
1976	4,110	44.2	55.8
1977	4,860	34.0	66.0
1978	3,066	25.3	74.7
1979	2,113	22.2	77.8
1980	2,050	22.8	77.2
1981	2,168	8.03	92.0
1982	1,703	13.4	86.6
1983	2,327	42.2	57.8
1984	2,098	30.9	69.1
1985	2,452	44.5	55.5
1986	1,911	26.5	73.5
1987	1,283	36.9	63.1
1988	1,159	37.0	63.0

Table 15.3 Percent at age by number of spawning marks for alewives sampled from Virginia's commercial harvest. (Source: Loesch et al. 1977)

Water Body	Year	n	Number Spawn Marks	Percent at Age							
				4	5	6	7	8	9	10	11
James	1977	43	**0**	9.30	83.7	6.98					
	1977	25	**1**		36.0	64.0					
	1977	5	**2**			40.0	60.0				
	1977	2	**3**				100				
York	1977	106	**0**	17.0	74.5	8.49					
	1977	41	**1**	2.44	36.6	58.5	2.44				
	1977	5	**2**			60.0	40.0				
Rappahannock	1977	305	**0**	4.92	54.8	38.4	1.97				
	1977	194	**1**		29.4	66.0	4.64				
	1977	20	**2**			50.0	50.0				
	1977	3	**3**				66.7	33.3			
	1977	2	**4**						100		

Table 15.4 Percent at age by number of spawning marks for blueback herring sampled from Virginia's commercial harvest. (Source: 1965-1966 data—Davis et al. 1970; 1977 data—Loesch et al. 1977)

Water Body	Year	n	Number Spawn Marks	Percent at Age							
				4	5	6	7	8	9	10	11
James	1977	138	**0**	3.62	55.8	39.1	0.725	0.725			
	1977	92	**1**	2.17	15.2	82.6					
	1977	21	**2**		4.76	52.4	42.9				
	1977	7	**3**				85.7	14.3			
	1977	1	**4**					100			
	1977	1	**5**		100						
York	1977	129	**0**	0.775	52.7	44.2	2.33				
	1977	89	**1**		10.1	83.1	6.74				
	1977	29	**2**			72.4	27.6				
	1977	9	**3**				100				
Rappahannock	1965–1966	162	**0**	23.5	48.1	25.3	3.09				
	1965–1966	98	**1**		8.16	66.3	24.5	1.02			
	1965–1966	40	**2**			22.5	65.0	10.0	2.50		
	1965–1966	17	**3**				29.4	47.1	17.6	5.88	
	1965–1966	2	**4**					50.0	50.0		
	1965–1966	1	**5**								100
	1977	240	**0**	3.75	56.7	38.3	1.25				
	1977	202	**1**	1.49	32.7	65.3	0.495				
	1977	34	**2**		2.94	67.6	29.4				
	1977	6	**3**				100				

Table 15.5 Annual JAIs (geometric average number per set) of alewives and blueback herring collected from the Mattaponi and Pamunkey rivers by the VIMS Push-Net Survey, 1979–2002. The push-net survey was not conducted in 1988, 1989, and 1990.

Year	Mattaponi River		Pamunkey River	
	Alewife	Blueback Herring	Alewife	Blueback Herring
1979	0.6	9.7	1.3	31.7
1980	0.6	2.1	0.6	32.7
1981	1.1	0.6	1.2	5
1982	11	40.2	5.2	124.2
1983	1.5	2.3	1.3	28.7
1984	7	8.7	0.4	13.9
1985	7.2	27.6	3.1	25
1986	2.6	2.6	2.7	19.4
1987	0.3	2	0.4	52.2
1988				
1989				
1990				
1991	0.1	2.1	0.1	5
1992	0	0.04	0	0.01
1993	0.1	2.2	0.03	0.8
1994	2.3	10.8	1.5	33.7
1995	0.02	0.1	0.01	2
1996	4	12.8	2.1	28.5
1997	1.9	6.5	0.1	9.8
1998	1.06	21.05	0.12	5.7
1999	0.63	7.93	no data[1]	no data[1]
2000	1.27	5.37	0.34	9.24
2001	2.23	5.39	0.66	5.39
2002	3.32	5.36	0.41	2.14

[1] Data collected from the Pamunkey River by the VIMS push-net survey in 1999 are missing or not available.

Table 15.6 Results of the Mann-Kendall test for temporal trends in relative abundance of alewives and blueback herring sampled from fishery-independent surveys. The number of years for which data were available is represented by n, *S* is the Mann-Kendall test statistic, and *P* is the two-tailed probability. Trend indicates the direction of the trend if a statistically significant temporal trend was detected ($\alpha = 0.05$); NS = not significant.

Species	**Life Stage**	**River**	**Survey**	**n**	***S***	***P***	**Trend**
Alewife	Adult	James	Electrofishing	9	3	0.831	NS
		Rappahannock	Electrofishing	11	1	1.00	NS
		Rappahannock	Gill Net	20	-74	0.0176	↓
	Juvenile	James	Seine	22	62	0.0580	NS
		James	Trawl	15	15	0.488	NS
		York	Seine	22	8	0.828	NS
		York	Trawl	15	7	0.767	NS
		Rappahannock	Seine	22	-3	0.955	NS
		Rappahannock	Trawl	15	-31	0.138	NS
Blueback Herring	Adult	James	Electrofishing	9	-2	0.919	NS
		Rappahannock	Electrofishing	11	-4	0.813	NS
		Rappahannock	Gill Net	20	-141	5.50E-06	↓
	Juvenile	James	Seine	22	-46	0.203	NS
		James	Trawl	15	-1	1.00	NS
		York	Seine	22	8	0.835	NS
		York	Trawl	15	1	1.00	NS
		Rappahannock	Seine	22	-34	0.352	NS
		Rappahannock	Trawl	15	25	0.235	NS

Table 15.7 Spearman's rank-order correlation between indices of adult relative abundance for (A) alewives and (B) blueback herring. *P*-values are shown in parentheses. Values of ρ that are statistically significant are formatted in **bold** font.

(A) Alewife

	James—Electrofishing	**Rappahannock—Electrofishing**
Rappahannock—Electrofishing)	0.136 (0.728)	
Rappahannock—Gill Net	-0.272 (0.478)	-0.0228 (0.947)

(B) Blueback Herring

	James—Electrofishing	**Rappahannock—Electrofishing**
Rappahannock—Electrofishing)	0.176 (0.651)	
Rappahannock—Gill Net	0.109 (0.781)	0.290 (0.388)

Table 15.8 Spearman's rank-order correlation between indices of juvenile relative abundance for (A) alewives and (B) blueback herring. *P*-values are shown in parentheses. Values of ρ that are statistically significant are formatted in **bold** font.

(A) Alewife

	James—Seine	**James—Trawl**	**Rappahannock—Seine**	**Rappahannock—Trawl**	**York—Seine**
James—Trawl	0.336 (0.221)				
Rappahannock—Seine	0.135 (0.548)	0.267 (0.336)			
Rappahannock—Trawl	0.143 (0.610)	-0.329 (0.232)	0.210 (0.453)		
York—Seine	0.106 (0.638)	-0.0302 (0.915)	0.533 (0.107)	0.299 (0.280)	
York—Trawl	0.198 (0.479)	0.111 (0.694)	-0.124 (0.660)	0.161 (0.567)	**0.665 (0.00680)**

(B) Blueback Herring

	James—Seine	**James—Trawl**	**Rappahannock—Seine**	**Rappahannock—Trawl**	**York—Seine**
James—Trawl	0.397 (0.143)				
Rappahannock—Seine	**0.712 (0.000200)**	0.445 (0.0965)			
Rappahannock—Trawl	-0.0232 (0.934)	0.0571 (0.840)	-0.261 (0.348)		
York—Seine	**0.478 (0.0246)**	0.457 (0.0865)	**0.560 (0.00670)**	-0.127 (0.651)	
York—Trawl	-0.107 (0.704)	0.339 (0.216)	0.141 (0.616)	0.368 (0.177)	-0.0572 (0.840)

Table 15.9 Results of the Mann-Kendall test for temporal trends in sex-specific average length and weight of alewives and blueback herring sampled from commercial pound nets in the Rappahannock River. The number of years for which data were available is represented by n, *S* is the Mann-Kendall test statistic, and *P* is the two-tailed probability. Trend indicates the direction of the trend if a statistically significant temporal trend was detected ($\alpha = 0.05$); NS = not significant.

Species	**Data**	**Sex**	**n**	***S***	***P***	**Trend**
Alewife	Length	Male	26	-90	0.0497	↓
		Female	26	-127	0.00548	↓
	Weight	Male	29	-154	0.00409	↓
		Female	29	-137	0.0107	↓
Blueback Herring	Length	Male	23	-99	0.00965	↓
		Female	23	-108	0.00470	↓
	Weight	Male	23	-65	0.0908	NS
		Female	25	-69	0.112	NS

Table 15.10 Calculated sex ratios (male: female), sample sizes (n), $\chi 2$ values (Yate's corrected), and probabilities (*P*) that the sex ratio for alewives is 1:1 based on historical sampling of the commercial fishery. Statistically significant sex ratios are formatted in bold.

Water Body	Year	n	Sex Ratio	χ^2	*P*
James	1967	372	**3.2**	102	< 0.001
	1968	400	1.1	0.723	0.395
	1969	344	1.2	3.56	0.0592
	1970	367	**3.4**	107	< 0.001
	1974	551	**3.9**	191	< 0.001
	1975	459	**3.1**	119	< 0.001
	1977	189	**2.4**	30.6	< 0.001
	1978	148	**1.9**	13.7	< 0.001
	1979	112	**2.0**	12.2	< 0.001
	1980	151	**1.5**	5.96	0.0146
York	1967	424	**1.6**	23.1	< 0.001
	1969	312	0.82	2.70	0.101
	1970	415	**0.80**	5.10	0.0239
	1974	139	**1.6**	6.47	0.0109
	1975	211	1.2	1.54	0.215
	1976	280	0.84	1.89	0.169
	1977	291	1.2	3.09	0.0786
	1978	203	1.3	3.33	0.0680
	1979	48	0.78	0.521	0.470
	1980	114	0.87	0.430	0.512
	1981	89	**0.59**	5.44	0.0197
	1982	78	0.95	0.0128	0.910
	1983	84	0.68	2.68	0.102
	1984	82	0.64	3.52	0.0605
	1985	352	1.0	0.0256	0.873
	1986	76	0.90	0.118	0.731
	1987	83	0.80	0.771	0.380
	1988	188	**0.53**	17.3	< 0.001
Rappahannock	1974	369	**1.2**	3.91	0.0479
	1975	1,206	1.0	0.000829	0.977
	1976	1,537	**1.2**	7.87	0.00502
	1977	1,171	**1.4**	34.8	< 0.001
	1978	425	**1.3**	7.92	0.00490
	1979	309	0.94	0.207	0.649
	1980	202	1.1	0.401	0.527
	1981	85	**0.55**	6.78	0.00924
	1982	151	**1.8**	12.8	< 0.001
	1983	897	**0.86**	4.86	0.0275
	1984	567	1.0	0.0635	0.801
	1985	738	**1.2**	8.03	0.00459
	1986	431	0.99	0.00928	0.923
	1987	390	0.96	0.126	0.723
	1988	241	0.79	3.25	0.0713

Table 15.11 Calculated sex ratios (male: female), sample sizes (n), χ2 values (Yate's corrected), and probabilities (*P*) that the sex ratio for blueback herring is 1:1 based on historical sampling of the commercial fishery. Statistically significant sex ratios are formatted in bold.

Water Body	Year	n	Sex Ratio	χ^2	*P*
James	1967	291	**2.4**	49.5	< 0.001
	1968	318	**2.2**	46.0	< 0.001
	1969	241	**2.3**	35.1	< 0.001
	1970	177	**5.1**	78.7	< 0.001
	1974	224	1.2	1.61	0.204
	1975	682	**1.9**	61.6	< 0.001
	1977	586	**1.7**	36.9	< 0.001
	1978	223	**1.5**	9.49	0.00207
	1979	245	**1.3**	4.18	0.0409
	1980	247	**1.8**	21.0	< 0.001
York	1967	332	**1.3**	5.06	0.0244
	1969	193	**1.4**	4.66	0.0308
	1970	19	0.90	0	1.00
	1974	171	0.99	0	1.00
	1975	546	**1.6**	28.6	< 0.001
	1976	206	0.82	1.75	0.186
	1977	777	**1.3**	15.6	< 0.001
	1978	726	1.1	2.10	0.148
	1979	436	1.1	0.828	0.363
	1980	577	1.1	1.56	0.212
	1981	1,205	0.93	1.46	0.226
	1982	708	**1.7**	47.3	< 0.001
	1983	826	0.93	1.02	0.313
	1984	827	**0.58**	58.5	< 0.001
	1985	680	1.1	0.649	0.421
	1986	881	**0.78**	13.2	< 0.001
	1987	515	1.1	0.280	0.597
	1988	402	0.86	2.09	0.148
Rappahannock	1974	489	**1.9**	47.2	< 0.001
	1975	1,300	**1.2**	13.6	< 0.001
	1976	2,087	**1.5**	90.3	< 0.001
	1977	1,846	**1.3**	25.0	< 0.001
	1978	1,341	**0.84**	10.4	0.00127
	1979	963	**1.5**	35.2	< 0.001
	1981	789	**0.83**	6.57	0.0104
	1980	759	0.94	0.638	0.425
	1982	766	**2.0**	84.9	< 0.001
	1983	520	1.1	2.09	0.148
	1984	622	1.1	1.75	0.186
	1985	682	**1.3**	13.8	< 0.001
	1986	523	**1.3**	7.35	0.00671
	1987	295	1.1	0.488	0.485
	1988	328	**0.73**	7.93	0.00486

Table 15.12 Estimated rates of repeat spawning for male and female alewives sampled from the commercial fishery in the James and York rivers.

Water Body	Year	Males			Females		
		Total	Repeats	% Repeats	Total	Repeats	% Repeats
James	1967	284	185	65.1	88	46	52.3
	1968	209	145	69.4	191	127	66.5
	1969	190	134	70.5	154	128	83.1
	1970	283	141	49.8	84	35	41.7
York	1967	262	134	51.1	162	92	56.8
	1969	141	98	69.5	171	135	78.9
	1970	184	84	45.7	231	123	53.2

Table 15.13 Estimated rates of repeat spawning for male and female blueback herring sampled from the commercial fishery in the James and York rivers.

Water Body	Year	Males			Females		
		Total	Repeats	% Repeats	Total	Repeats	% Repeats
James	1967	206	115	55.8	85	28	32.9
	1968	220	130	59.1	98	36	36.7
	1969	167	137	82.0	74	54	73.0
	1970	148	53	35.8	29	12	41.4
York	1967	187	117	62.6	145	84	57.9
	1969	112	79	70.5	81	58	71.6
	1970	9	6	66.7	10	5	50.0

Table 15.14 Catch curve estimates of instantaneous total mortality (*Z*) for alewives sampled from commercial harvest in the James, York, and Rappahannock rivers.

Water Body	Structure	Year	*Z*	SE[*Z*]
James	Scale	1974	0.846	0.0373
		1975	1.38	0.0748
		1978	0.502	0.0492
	Otolith	1979	1.04	0.162
		1980	0.894	0.0896
York	Scale	1974	1.18	0.107
		1975	1.26	0.102
		1978	0.539	0.0593
	Otolith	1979	1.23	0.246
		1980	0.934	0.105
		1981	0.804	0.109
		1982	1.16	0.147
		1983	0.834	0.101
		1984	0.728	0.0956
		1985	0.791	0.0624
		1986	0.437	0.0531
		1987	0.488	0.0661
		1988	0.527	0.0561
Rappahannock	Scale	1974	1.02	0.0558
		1975	1.83	0.0718
		1978	0.487	0.0291
	Otolith	1979	1.04	0.0917
		1980	1.05	0.0892
		1981	1.09	0.152
		1982	1.42	0.132
		1983	1.02	0.0506
		1984	0.970	0.0612
		1985	0.799	0.0460
		1987	0.511	0.0364
		1988	0.507	0.0461

Table 15.15 Catch curve estimates of instantaneous total mortality (*Z*) for blueback herring sampled from commercial harvest in the James, York, and Rappahannock rivers.

Water Body	Structure	Year	*Z*	SE[*Z*]
James	Scale	1974	0.758	0.0546
		1975	1.60	0.0845
		1978	0.355	0.0326
	Otolith	1979	0.768	0.0745
		1980	0.677	0.0631
York	Scale	1974	2.04	0.187
		1975	1.31	0.0774
		1978	0.441	0.0224
	Otolith	1979	0.958	0.0698
		1980	0.849	0.0650
		1981	0.674	0.0374
		1982	0.777	0.0465
		1983	0.481	0.0236
		1984	0.448	0.0286
		1985	0.419	0.0210
		1987	0.324	0.0280
		1988	0.428	0.0376
Rappahannock	Scale	1974	0.767	0.0360
		1975	1.95	0.0816
		1978	0.410	0.0137
	Otolith	1979	1.00	0.0536
		1980	0.667	0.0383
		1981	0.775	0.0410
		1982	0.888	0.0538
		1983	0.886	0.0607
		1984	0.681	0.0452
		1985	0.445	0.0256
		1986	0.420	0.0289
		1987	0.459	0.0381
		1988	0.461	0.0438

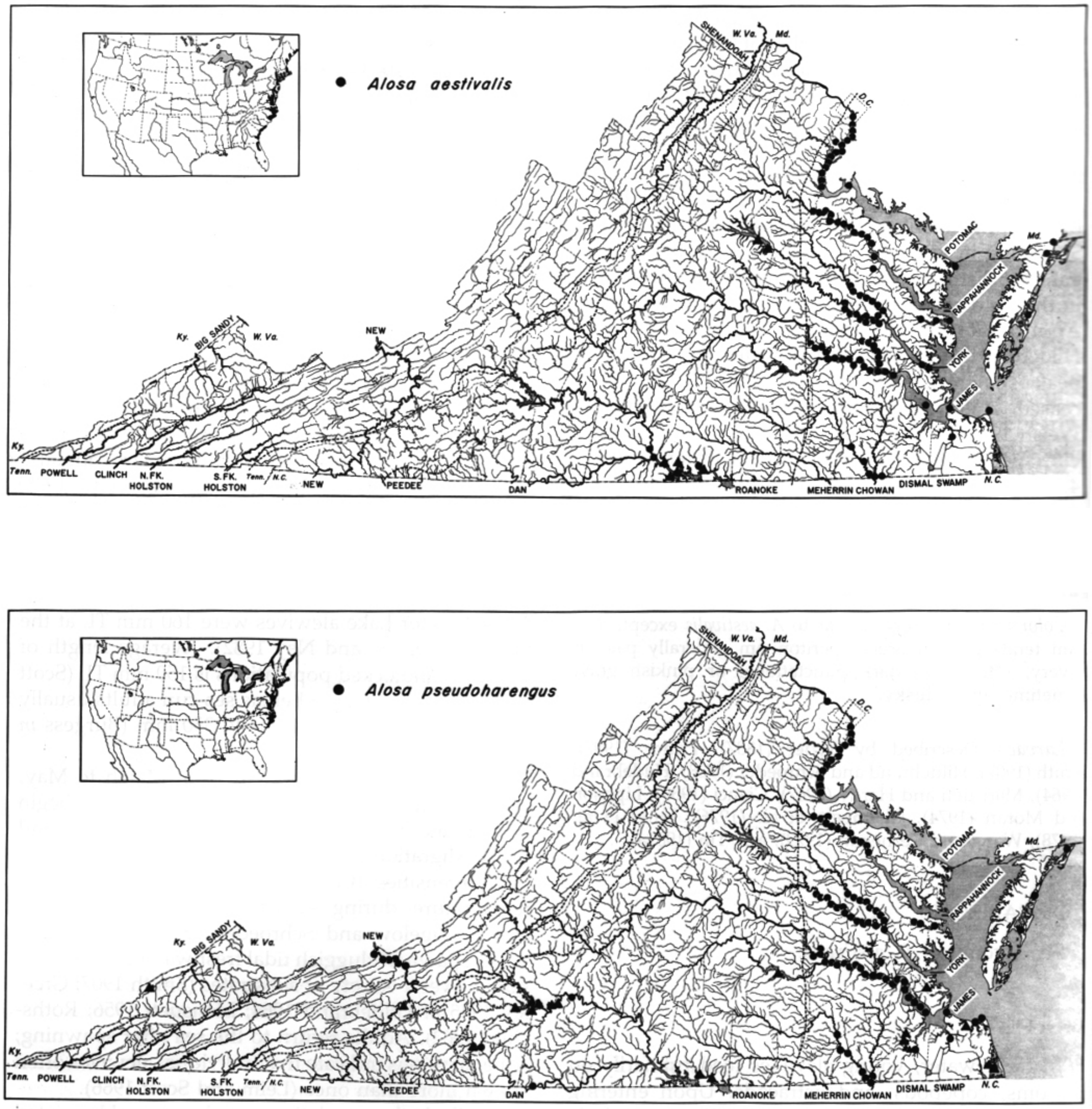

Figure 15.1 Distribution of blueback herring (top) and alewife (bottom) in Virginia. From Lee et al. 1980.

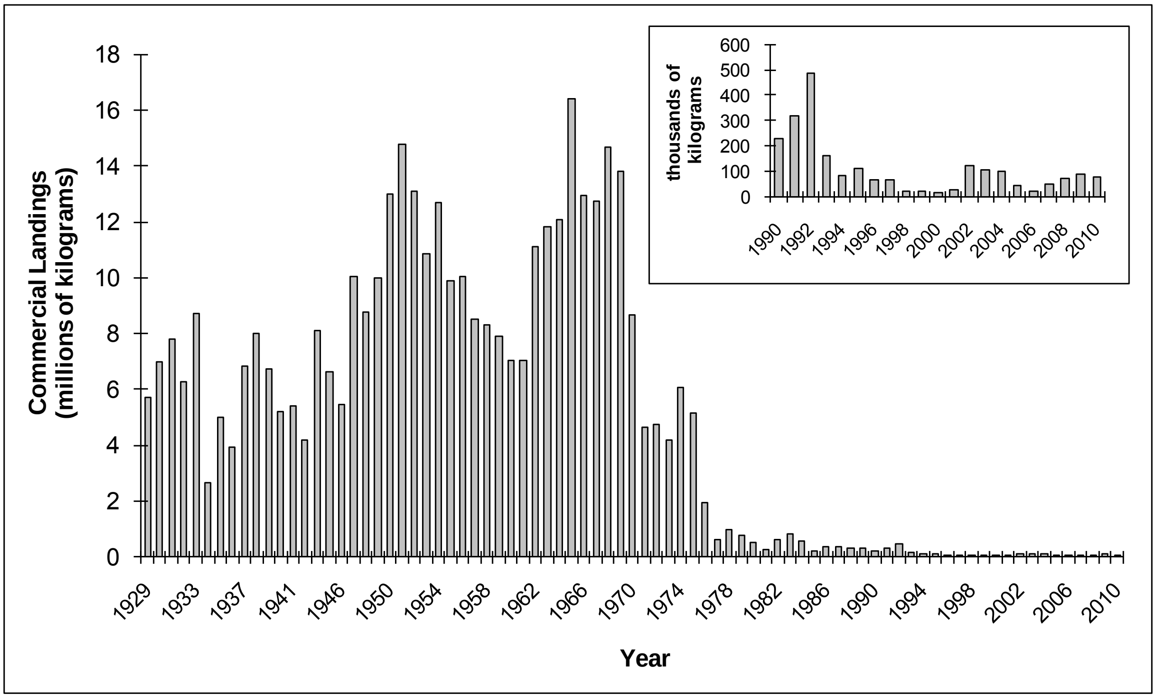

Figure 15.2 Annual commercial landings (millions of kilograms) of river herring in Virginia, 1929–2010. Inset depicts annual commercial landings (thousands of kilograms) during 1990 through 2010.

Figure 15.3 Annual commercial harvest (kilograms) of river herring from Virginia waters, 1994–2010.

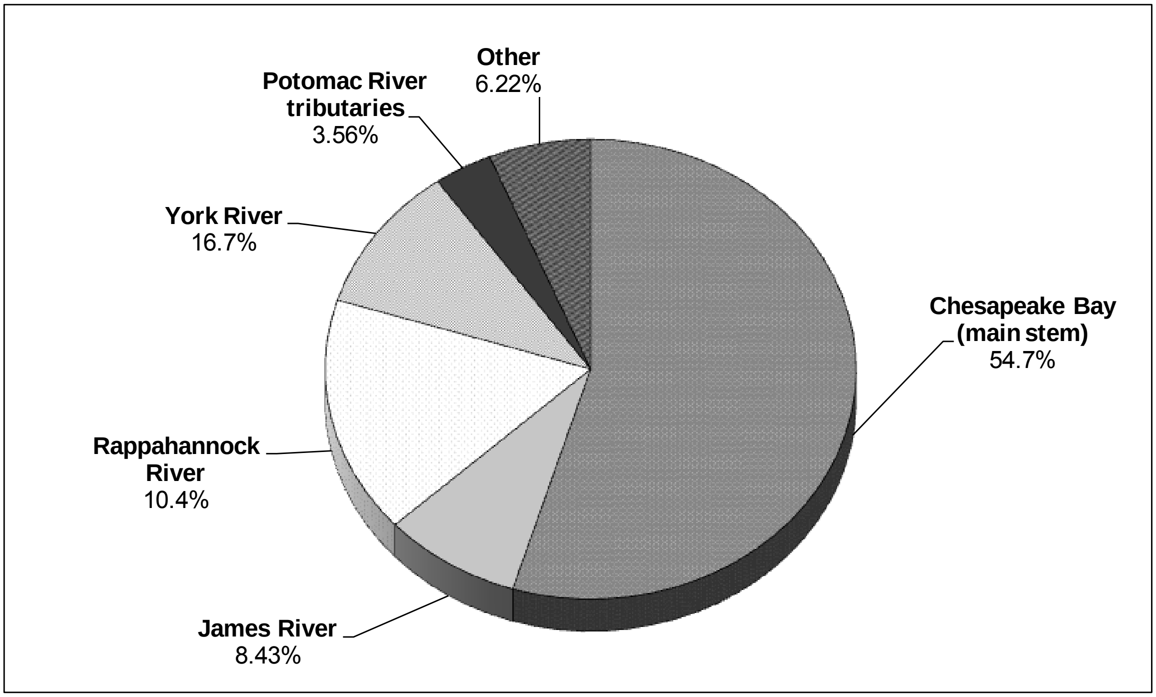

Figure 15.4 Commercial harvest (% of total kilograms) of river herring from Virginia waters, by harvest area, based on 1994–2010 average.

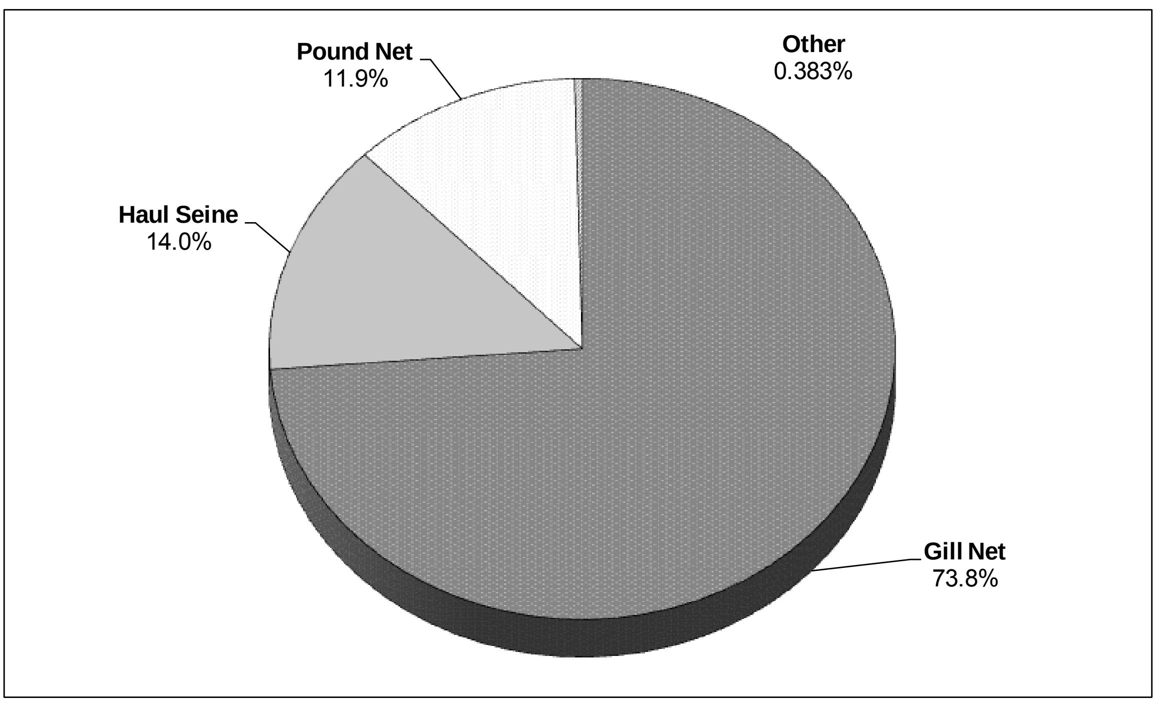

Figure 15.5 Commercial harvest (% of total kilograms) of river herring from Virginia waters, by major gear, based on 1994–2010 average.

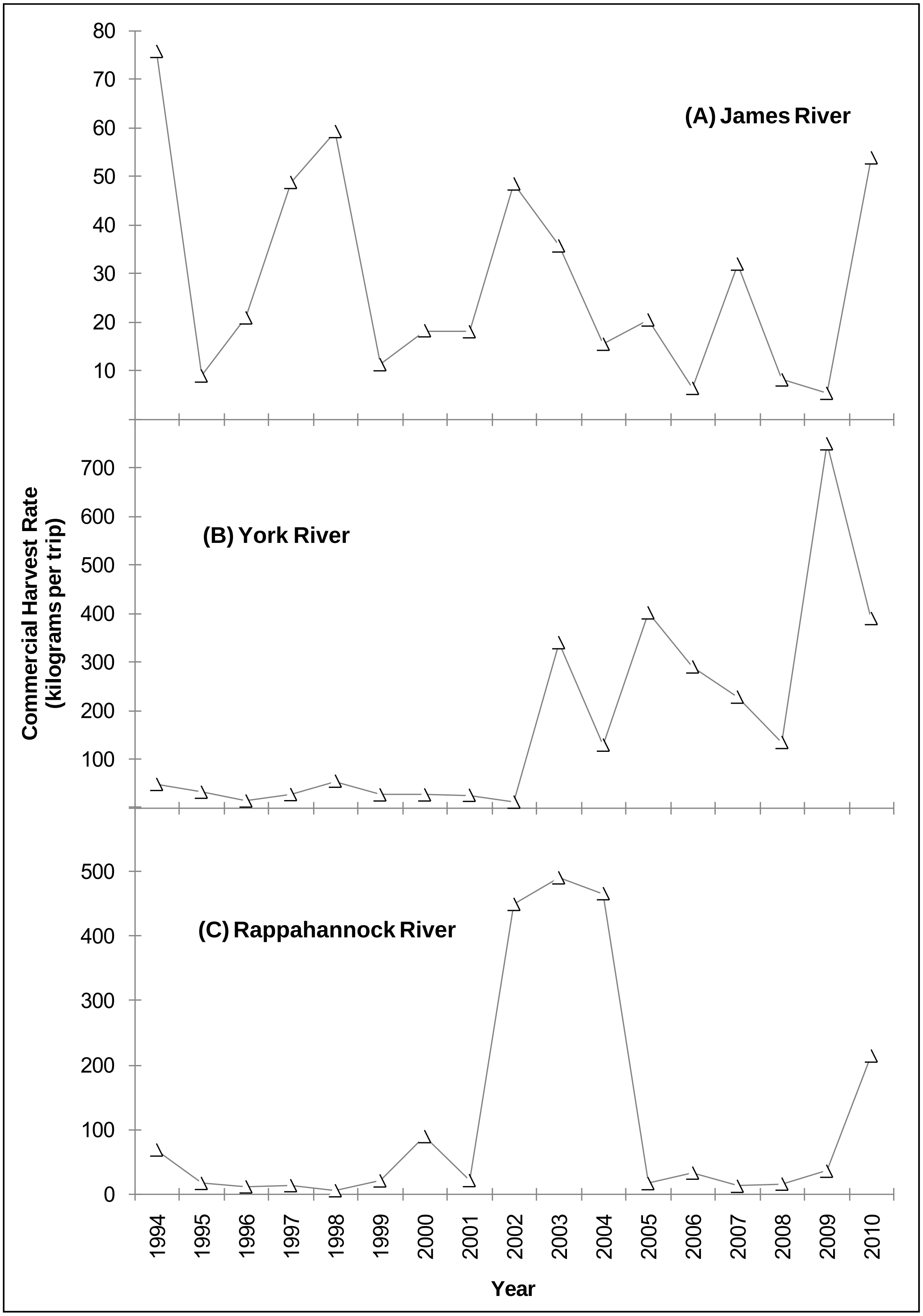

Figure 15.6 Annual commercial harvest rates (kilograms per trip) for alewives harvested by gill nets from the (A) James, (B) York, and (C) Rappahannock rivers, 1994–2010.

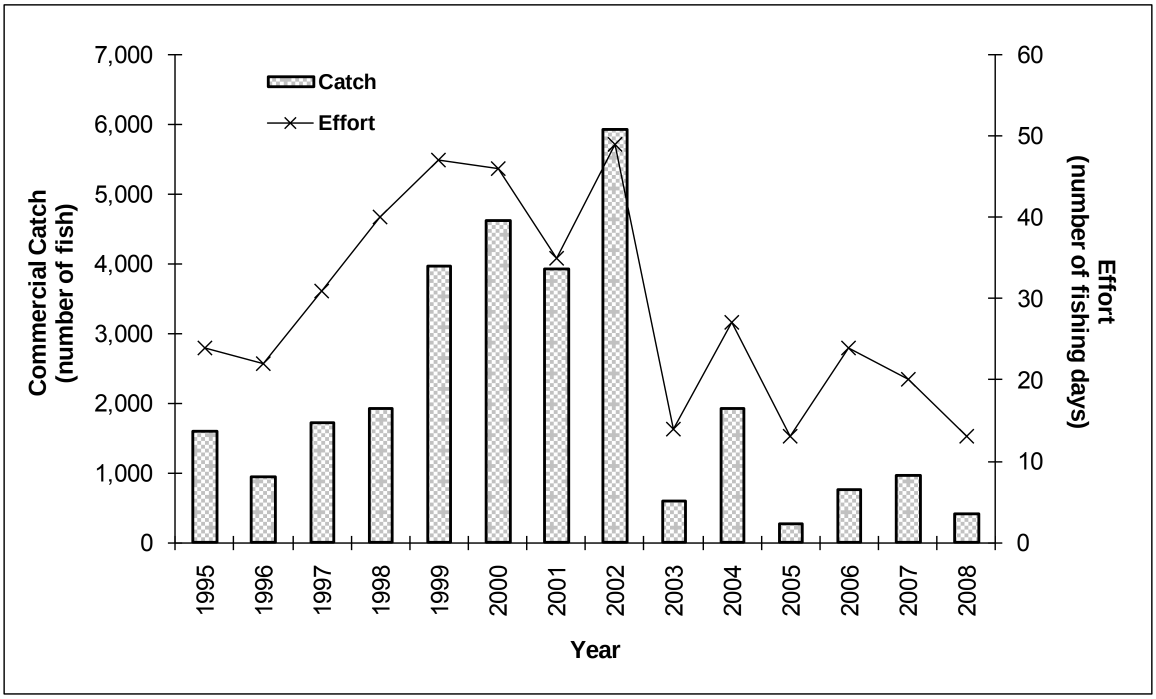

Figure 15.7 Annual commercial catch (number of fish) of river herring and effort (number of fishing days) in the upper Rappahannock River recorded in commercial logbooks, 1995–2008.

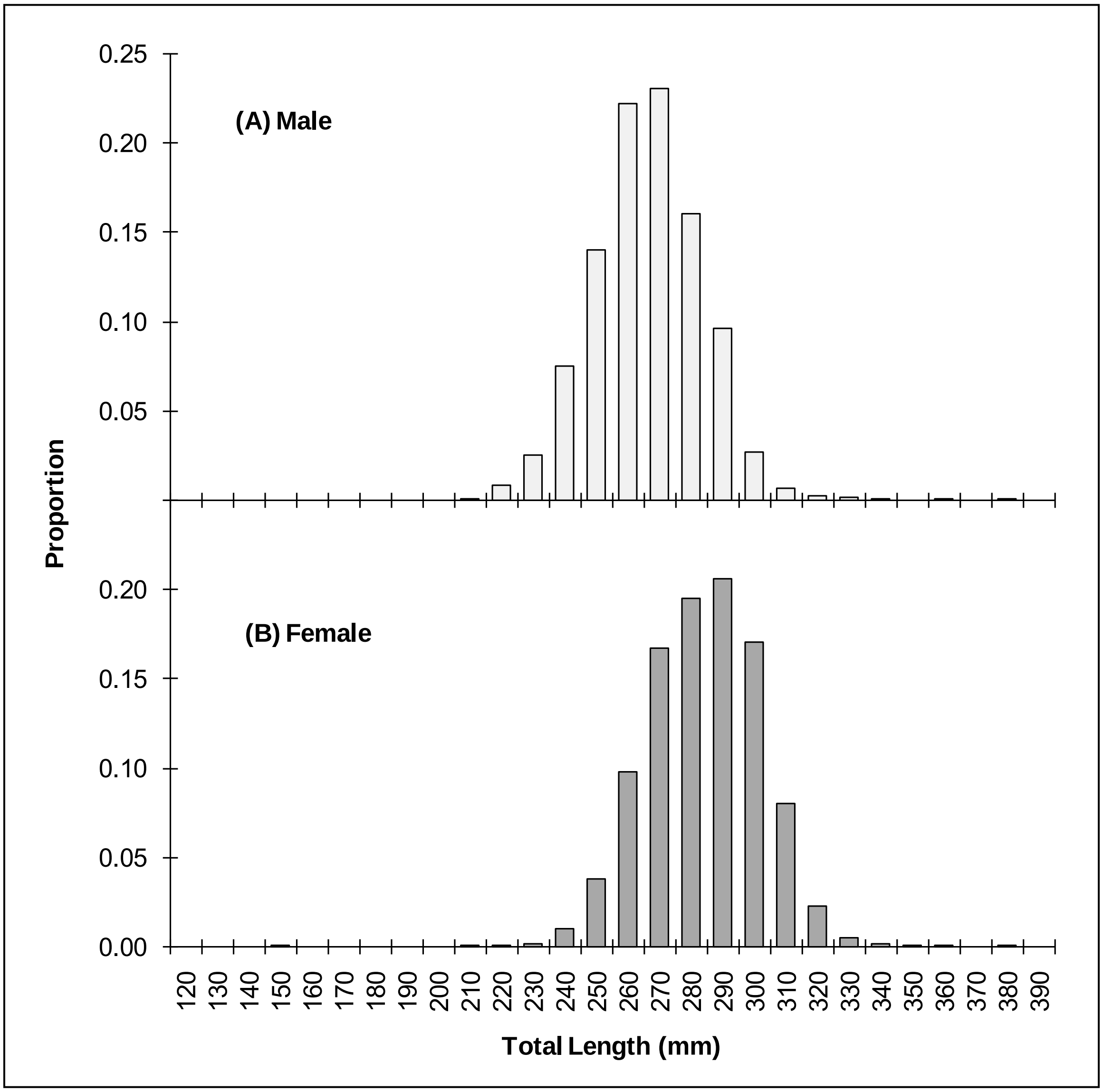

Figure 15.8 Proportion of commercial fishery samples at total length for (A) male and (B) female alewives pooled over gears, water bodies, and years, 1989–2008. Note that no river herring were sampled from the commercial fishery in 2009 and 2010.

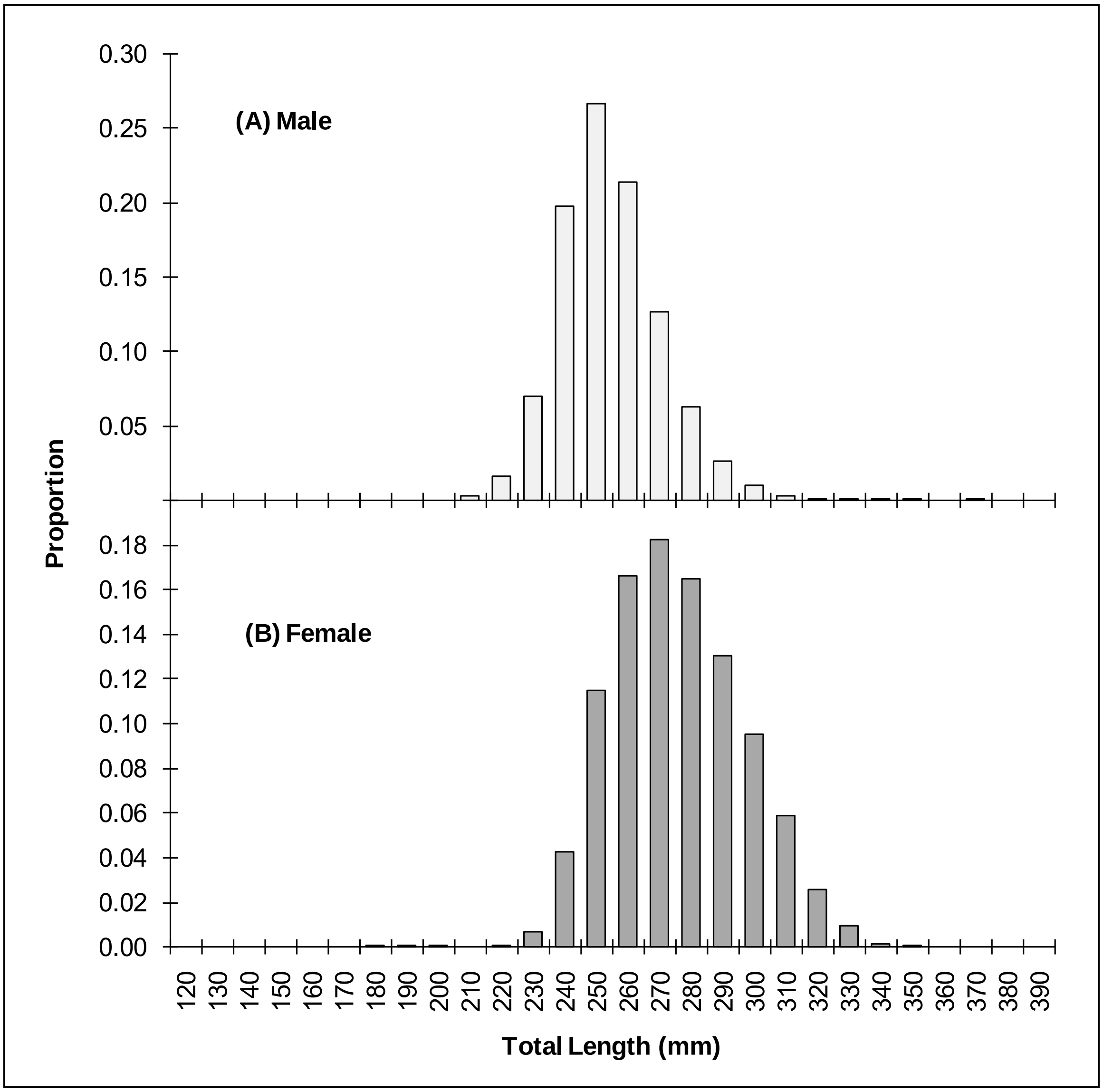

Figure 15.9 Proportion of commercial fishery samples at total length for (A) male and (B) female blueback herring pooled over gears, water bodies, and years, 1989–2008. Note that no river herring were sampled from the commercial fishery in 2009 and 2010.

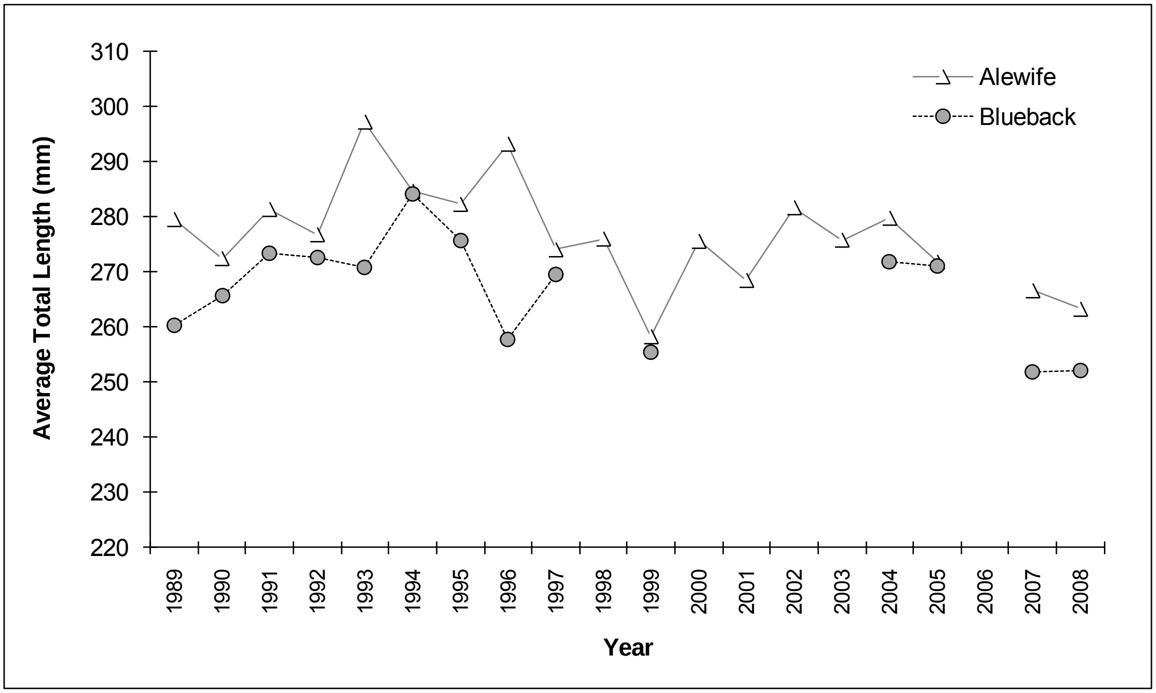

Figure 15.10 Average total length (mm) of alewives and blueback herring sampled from Virginia's commercial landings, 1989–2008. Note that no river herring were sampled from the commercial fishery in 2009 and 2010.

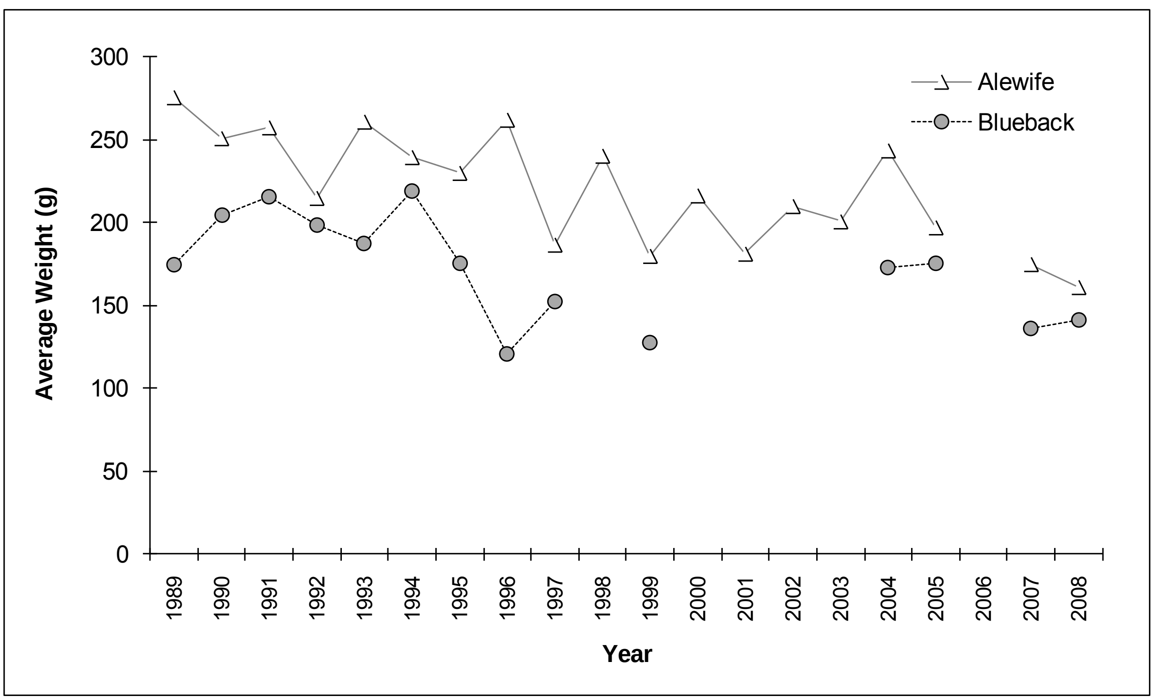

Figure 15.11 Average weight (g) of alewives and blueback herring sampled from Virginia's commercial landings, 1989–2008. Note that no river herring were sampled from the commercial fishery in 2009 and 2010.

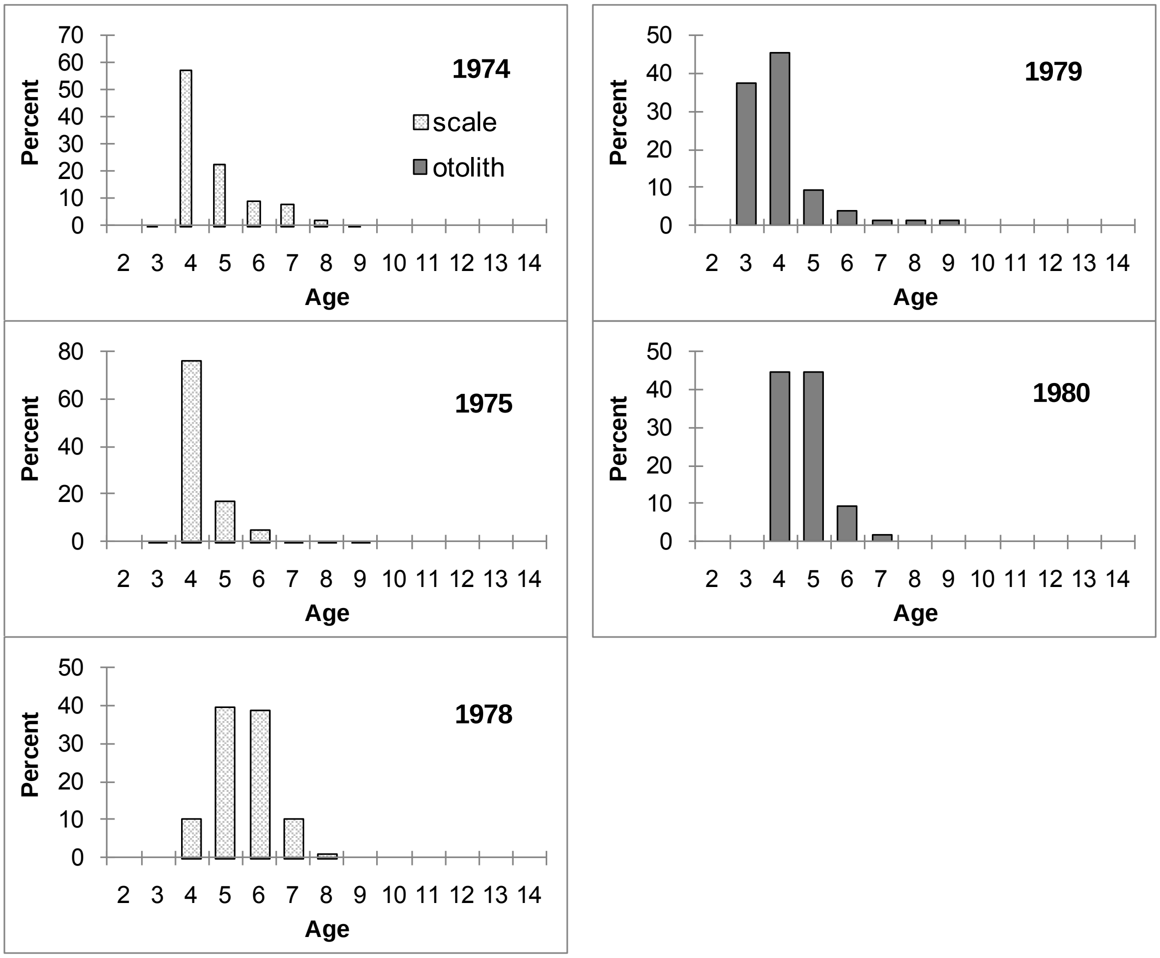

Figure 15.12 Percent at age for alewives sampled from commercial harvest in the James River, 1974–1980.

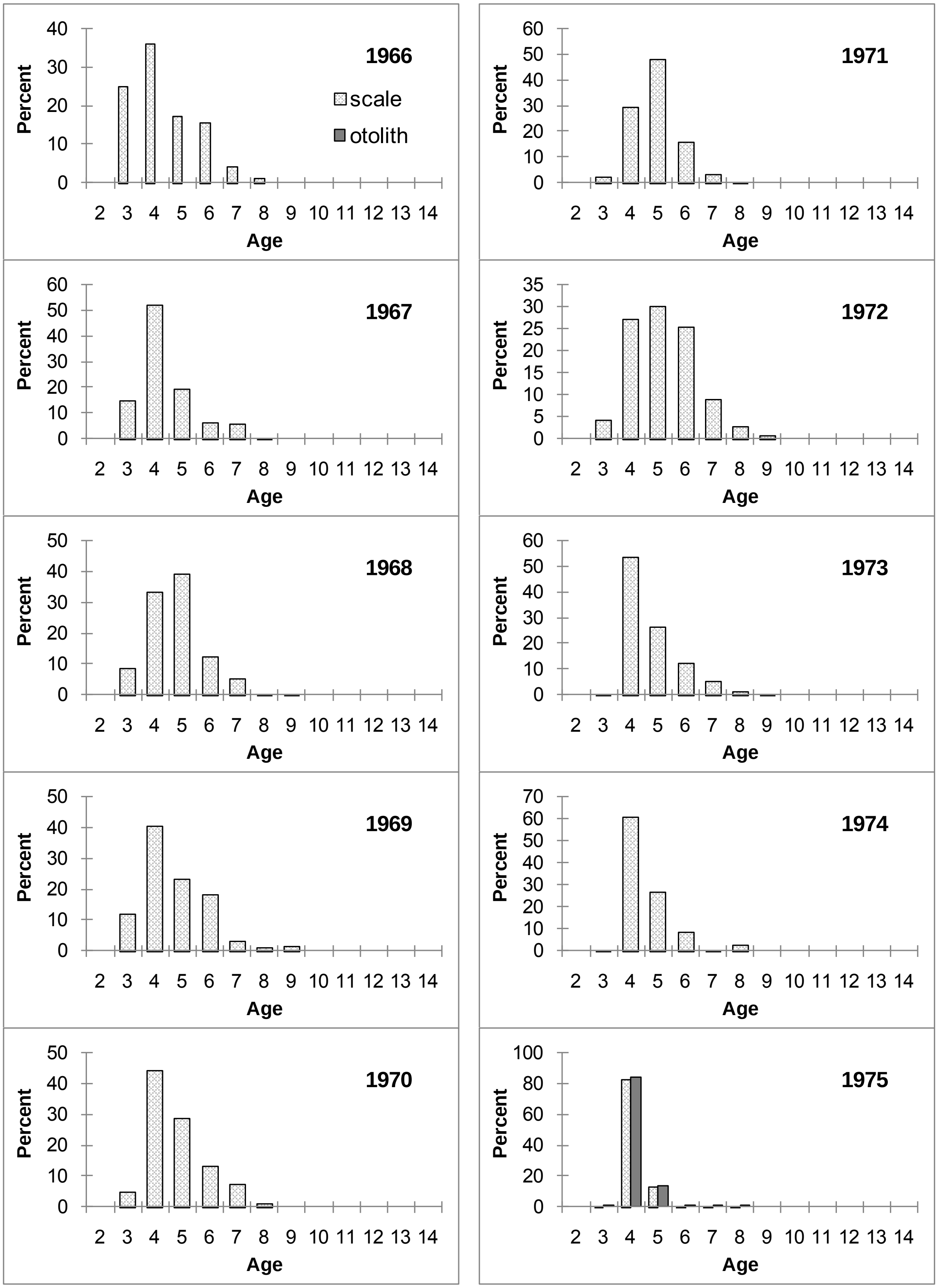

Figure 15.13 Percent at age for alewives sampled from commercial harvest in the Rappahannock River, 1966–1988.

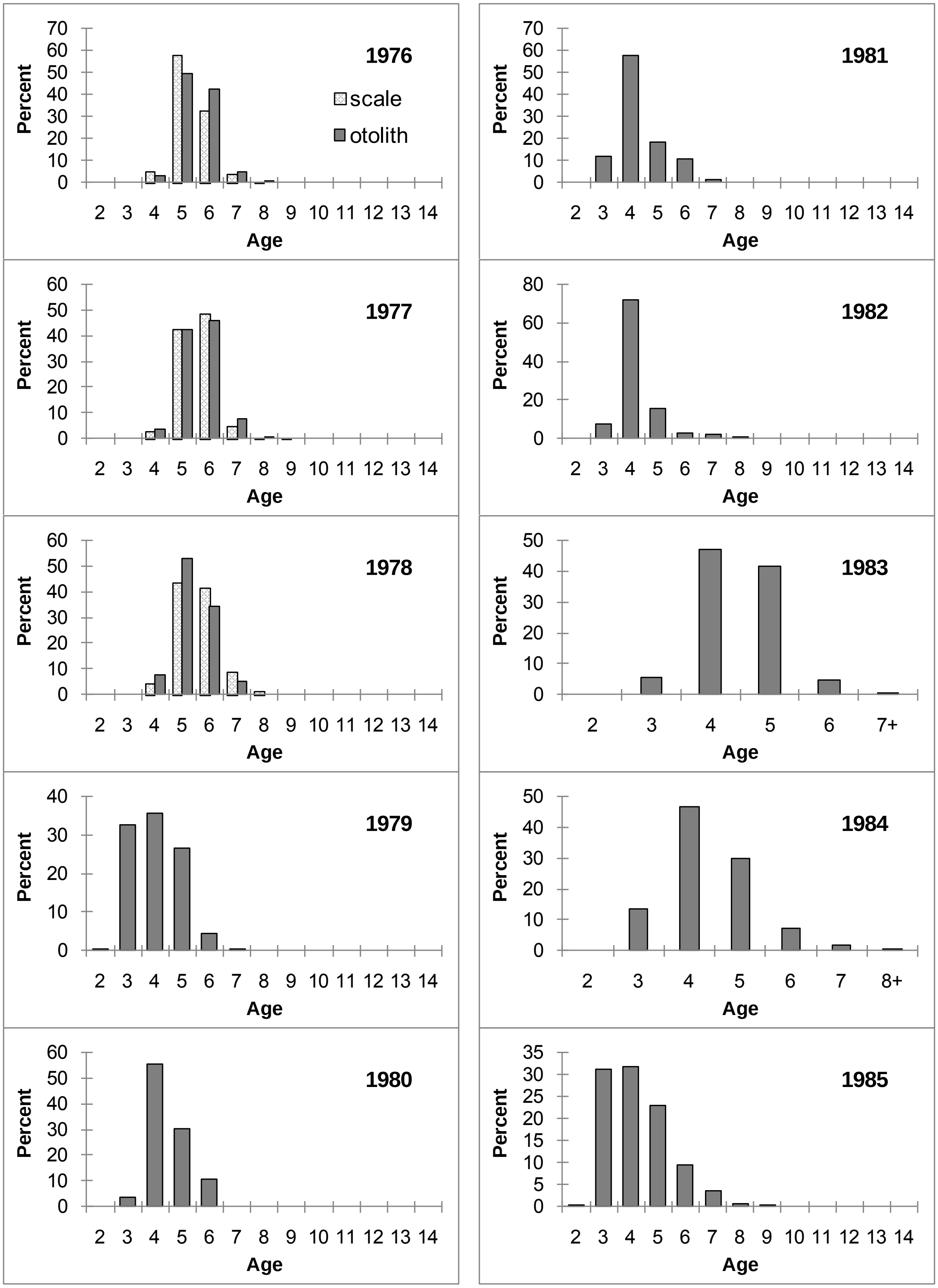

Figure 15.13. Continued.

Figure 15.13. Continued.

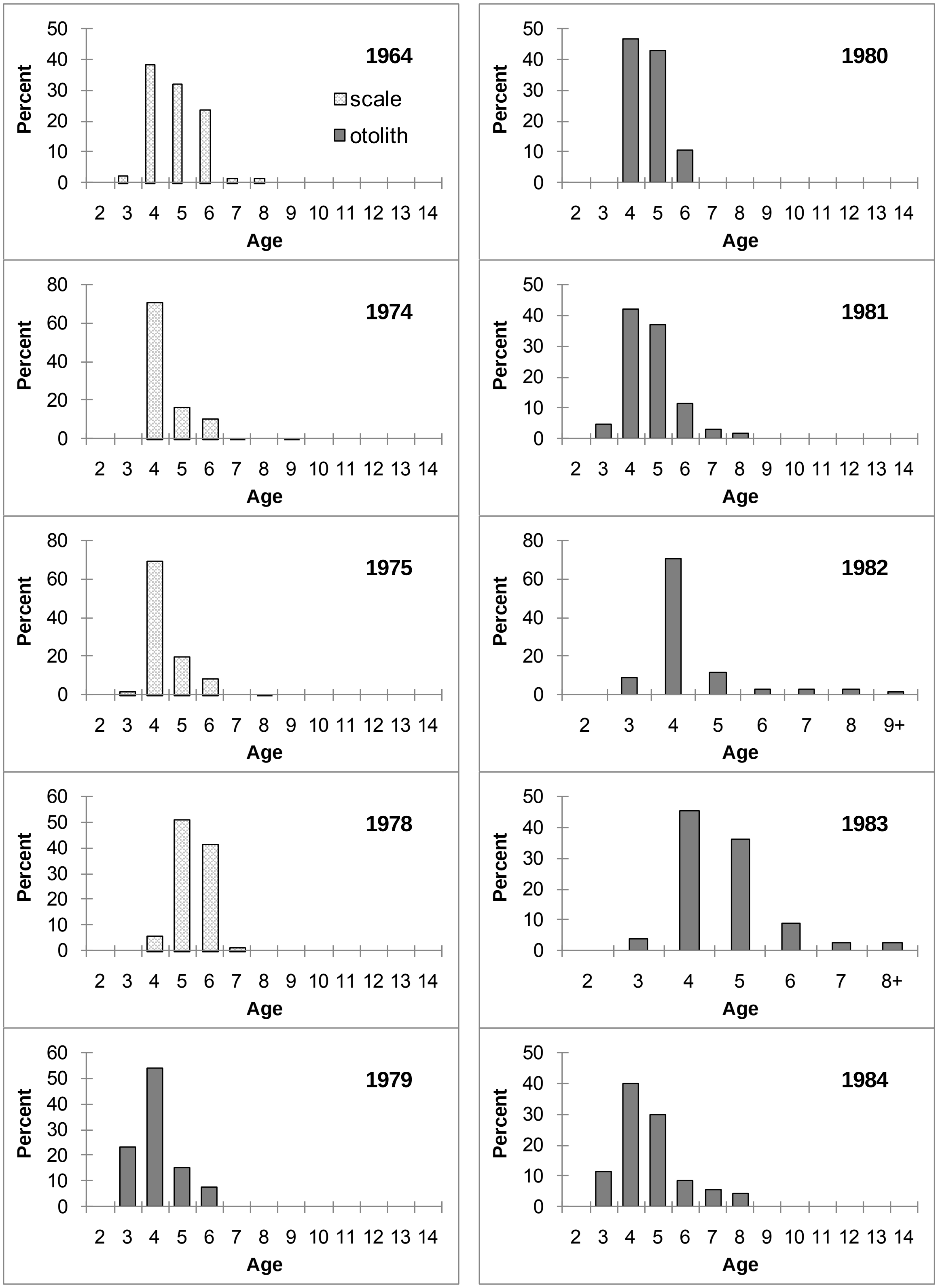

Figure 15.14 Percent at age for alewives sampled from commercial harvest in the York River, 1964–1988.

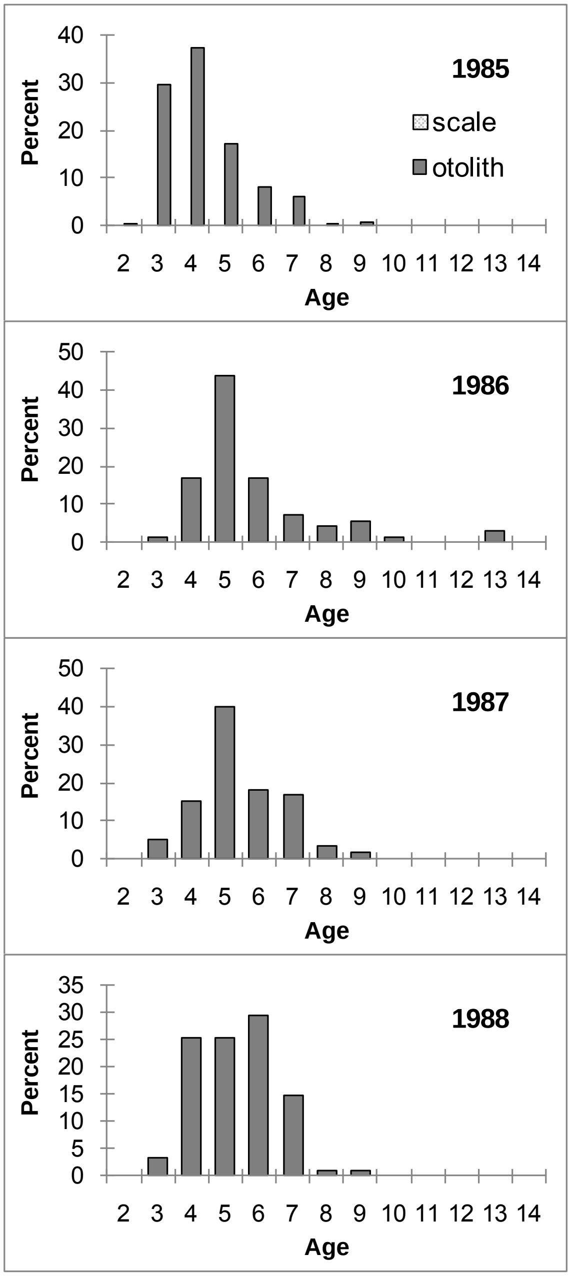

Figure 15.14. Continued.

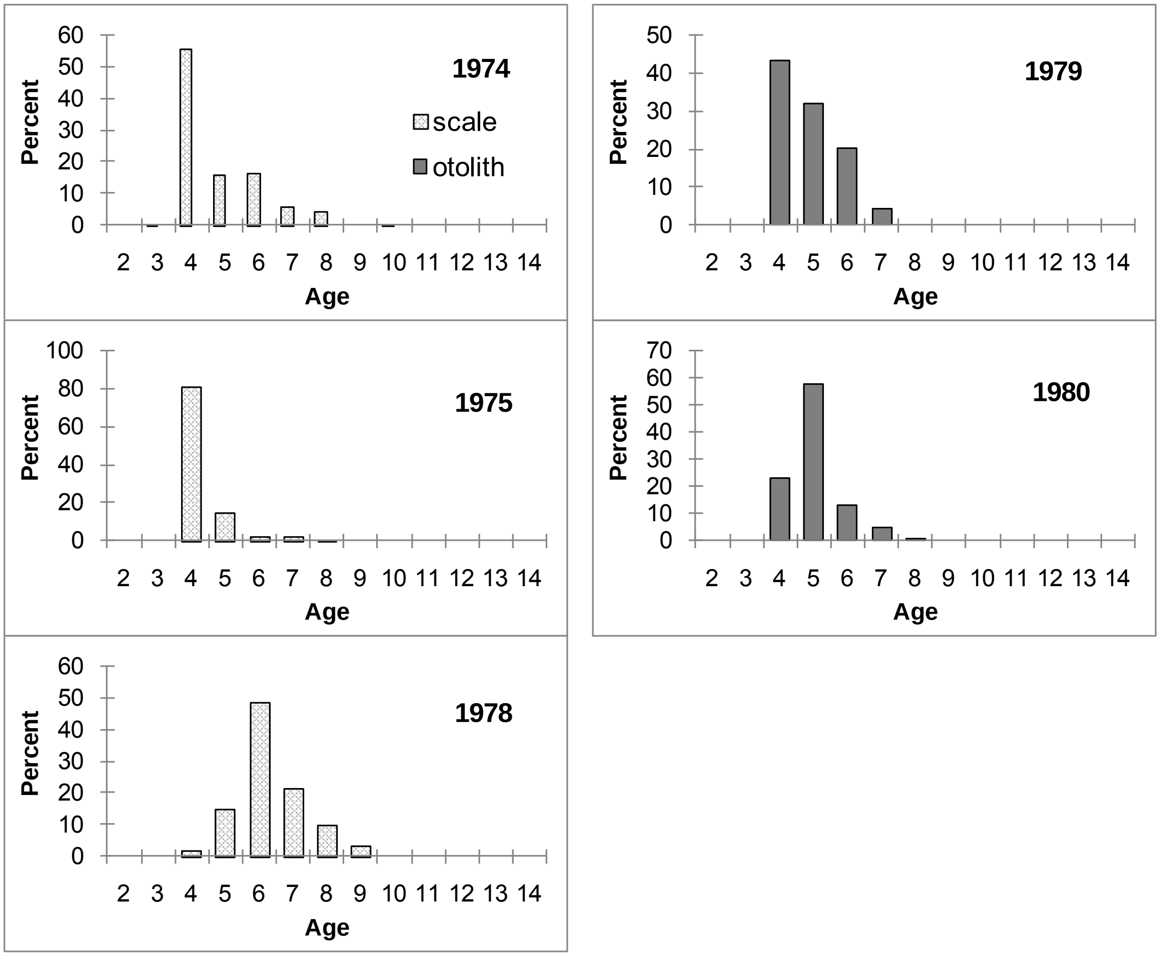

Figure 15.15 Percent at age for blueback herring sampled from commercial harvest in the James River, 1974–1980.

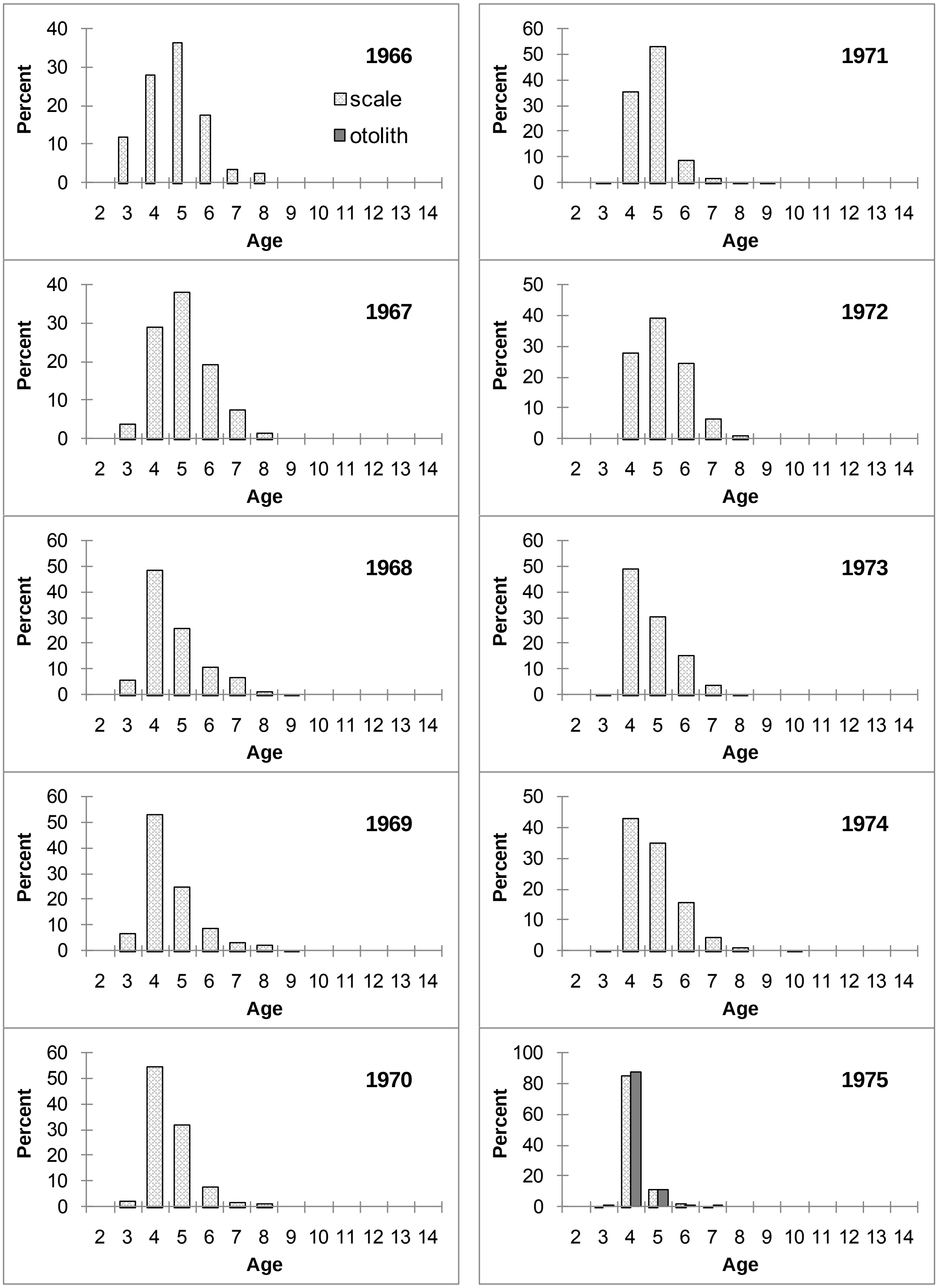

Figure 15.16 Percent at age for blueback herring sampled from commercial harvest in the Rappahannock River, 1966–1988.

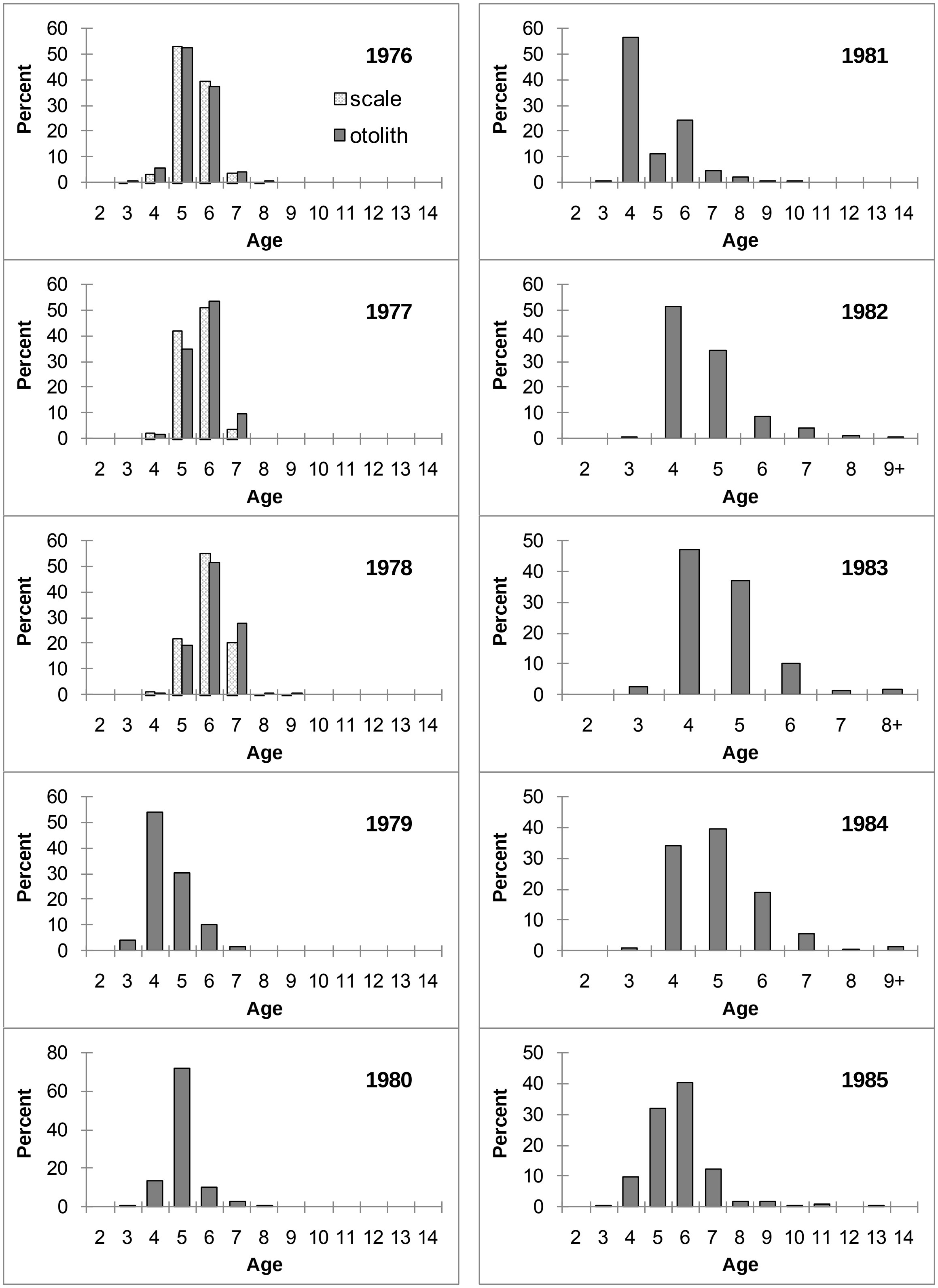

Figure 15.16. Continued.

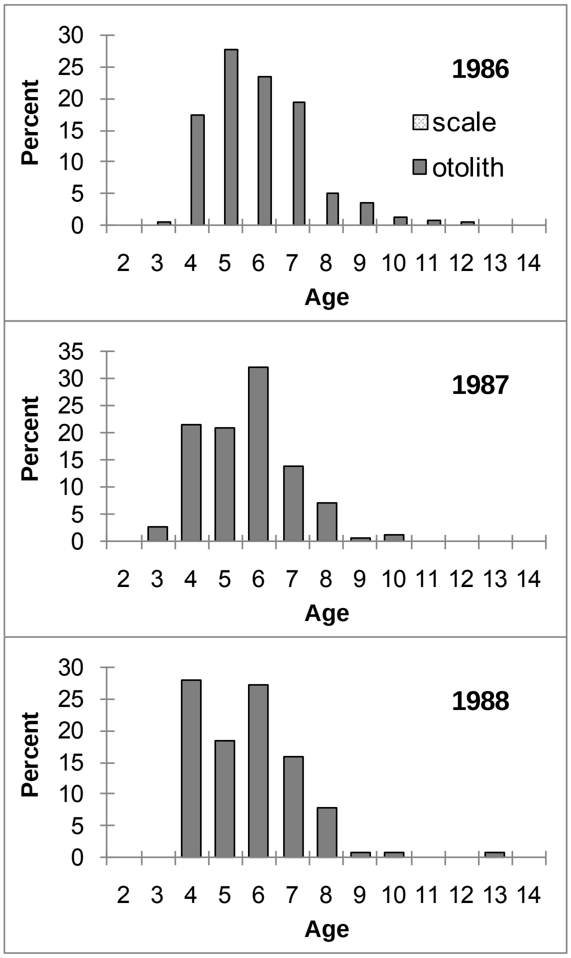

Figure 15.17 Percent at age for blueback herring sampled from commercial harvest in the York River, 1974–1988.

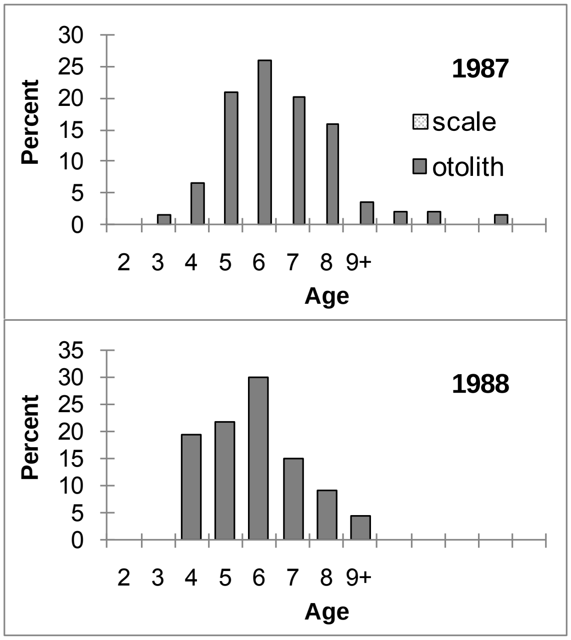

Figure 15.17. Continued.

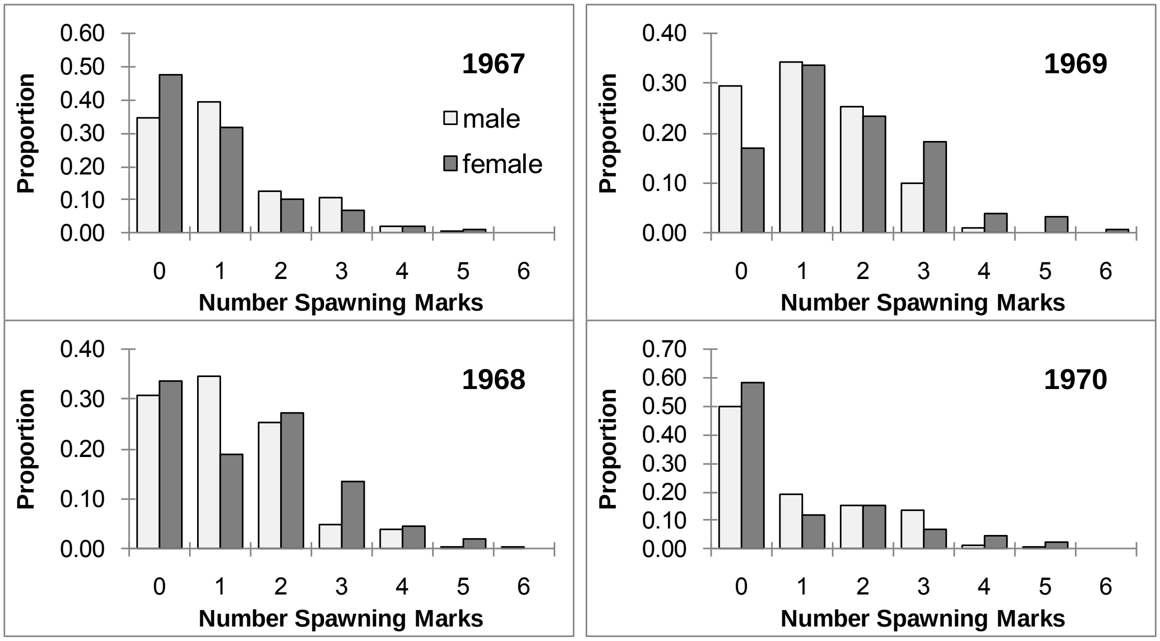

Figure 15.18 Spawning frequency of alewives sampled from commercial harvest in the James River, 1967–1970.

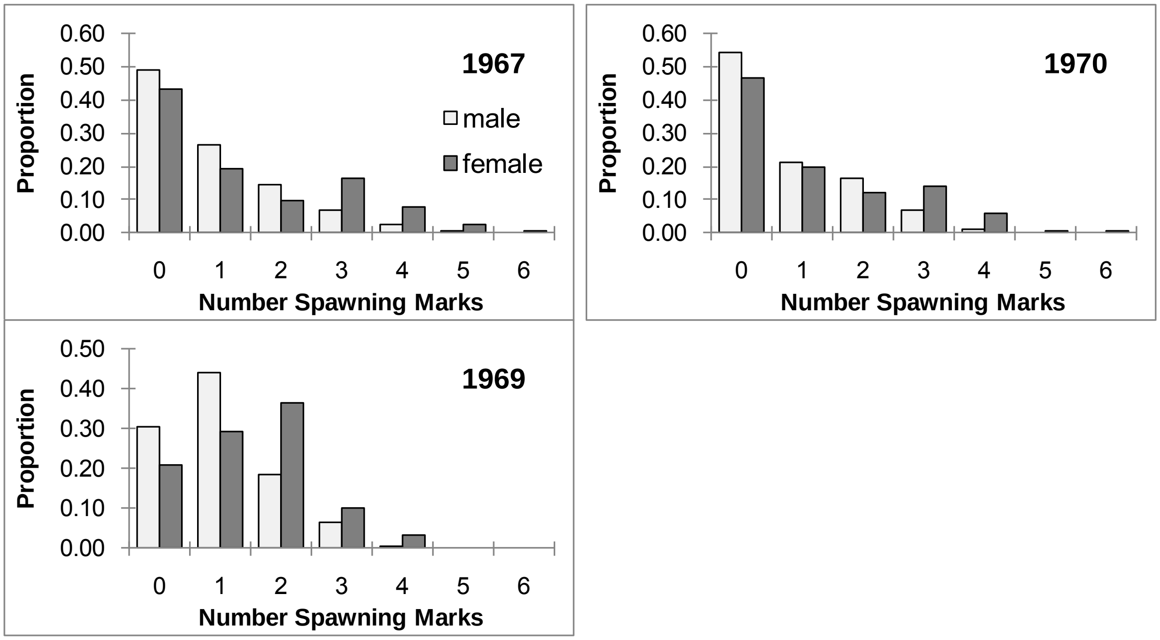

Figure 15.19 Spawning frequency of alewives sampled from commercial harvest in the York River, 1967–1970.

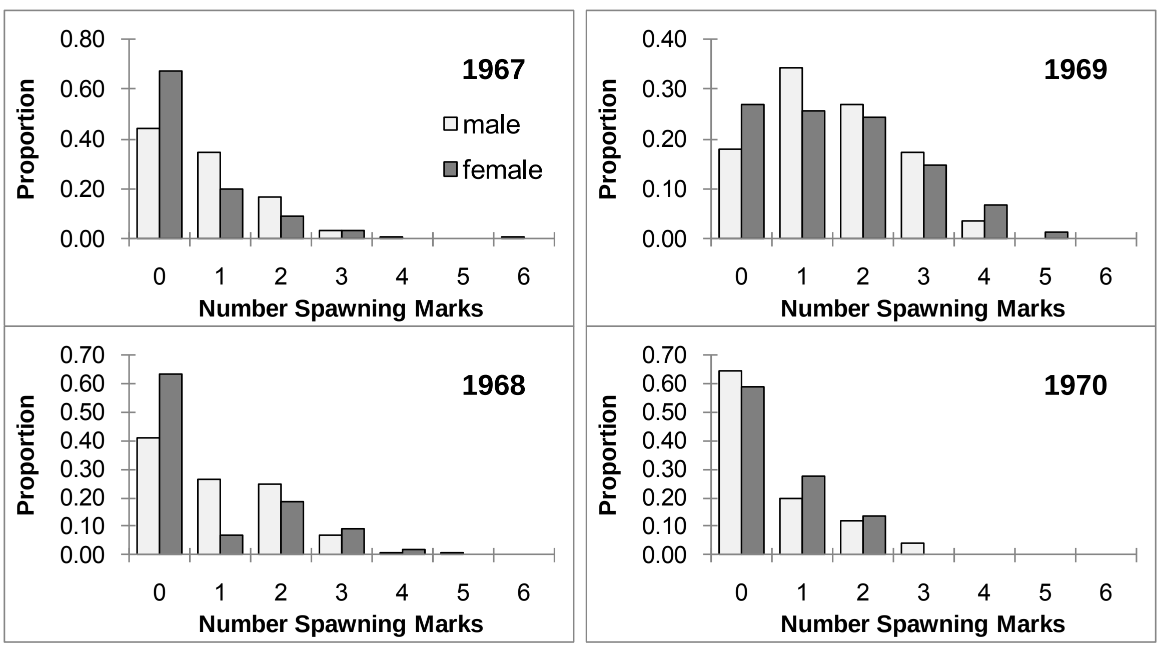

Figure 15.20 Spawning frequency of blueback herring sampled from commercial harvest in the James River, 1967–1970.

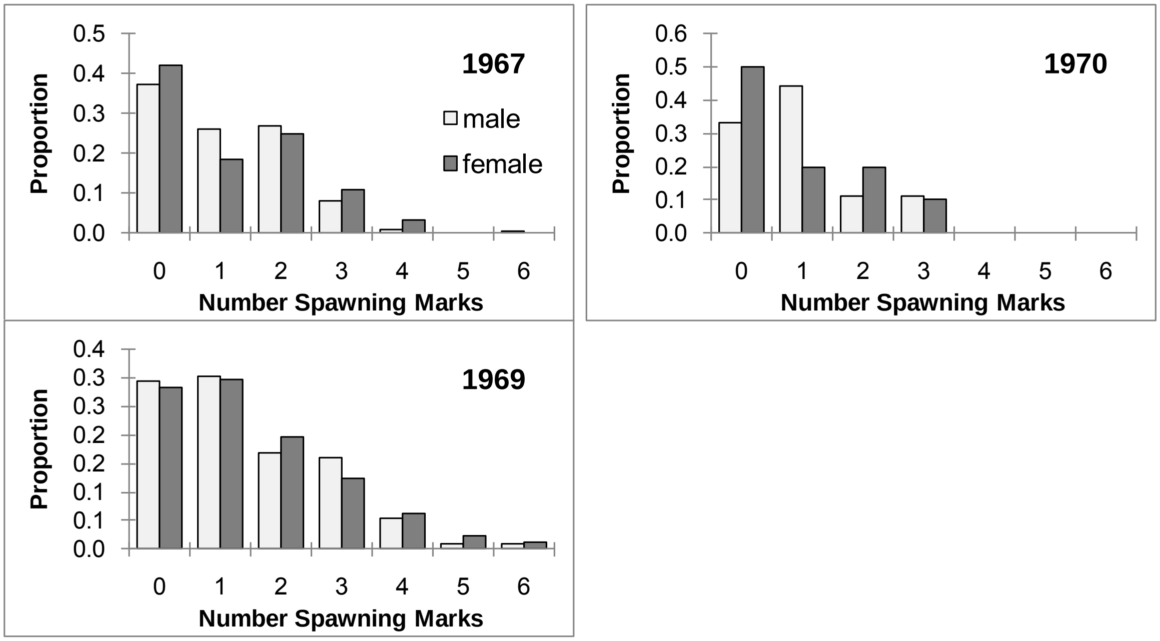

Figure 15.21 Spawning frequency of blueback herring sampled from commercial harvest in the York River, 1967–1970.

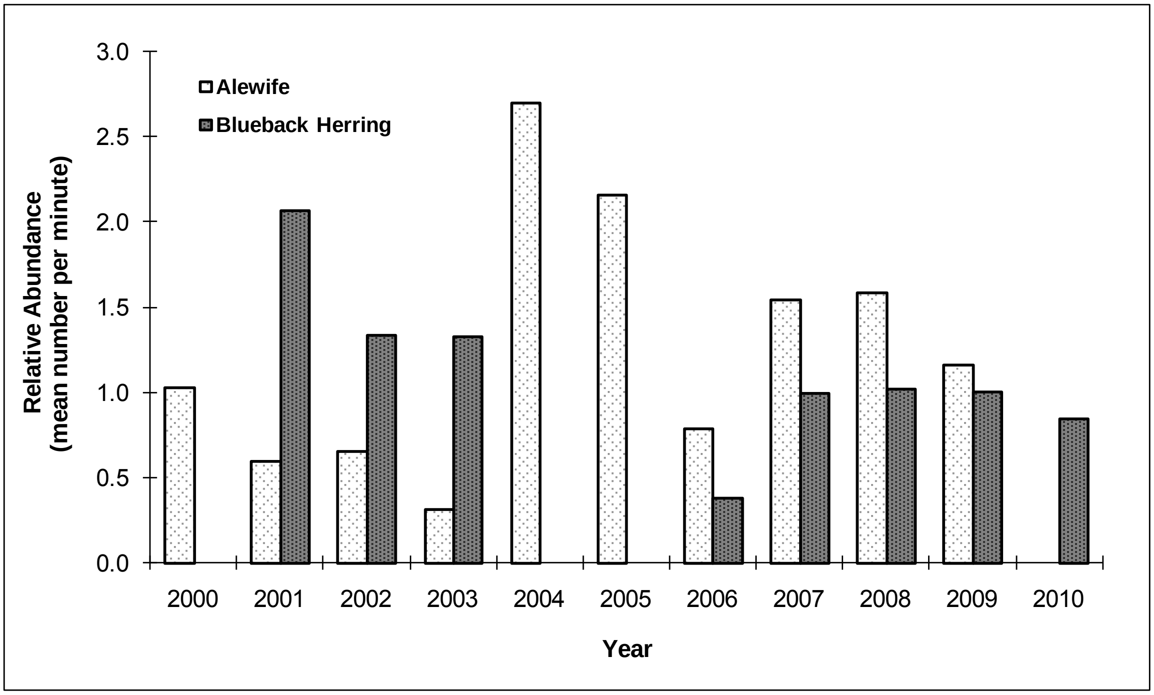

Figure 15.22 Catch rates (arithmetic average number of fish per minute) of alewives and blueback herring collected by the VDGIF's electrofishing survey of the Rappahannock River (Route 1 station), 2000–2010.

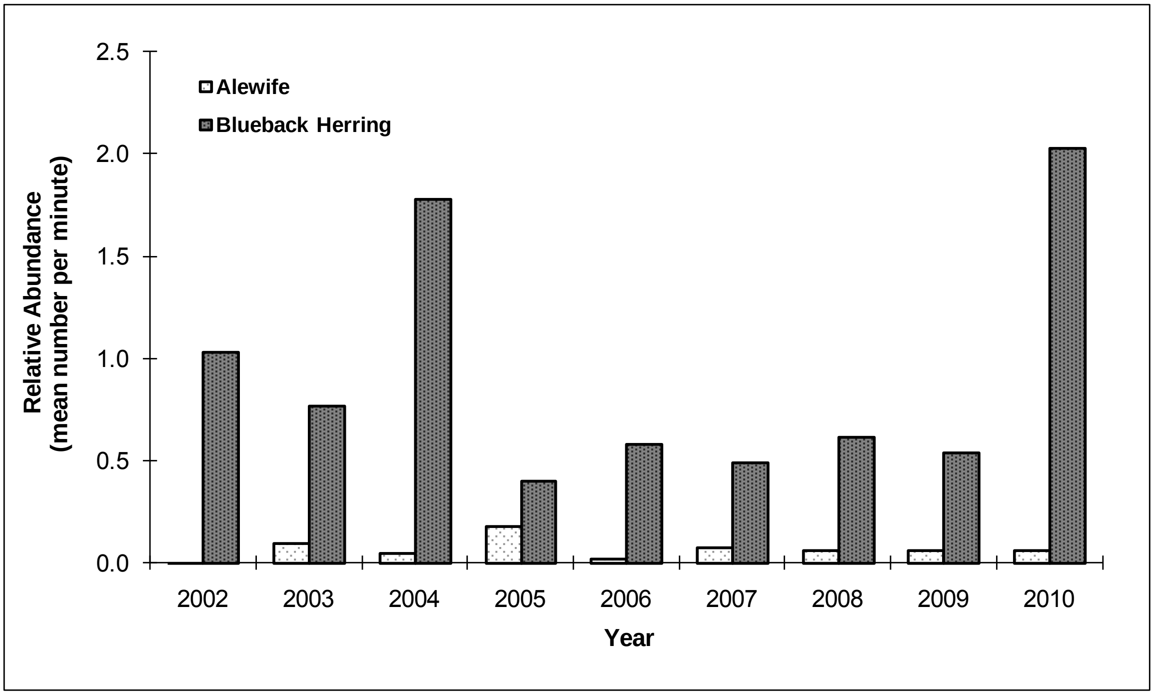

Figure 15.23 Catch rates (arithmetic average number of fish per minute) of alewives and blueback herring collected by the VDGIF's electrofishing survey of the James River (Manchester stations 1, 2, 4, and 5 combined), 2002–2010.

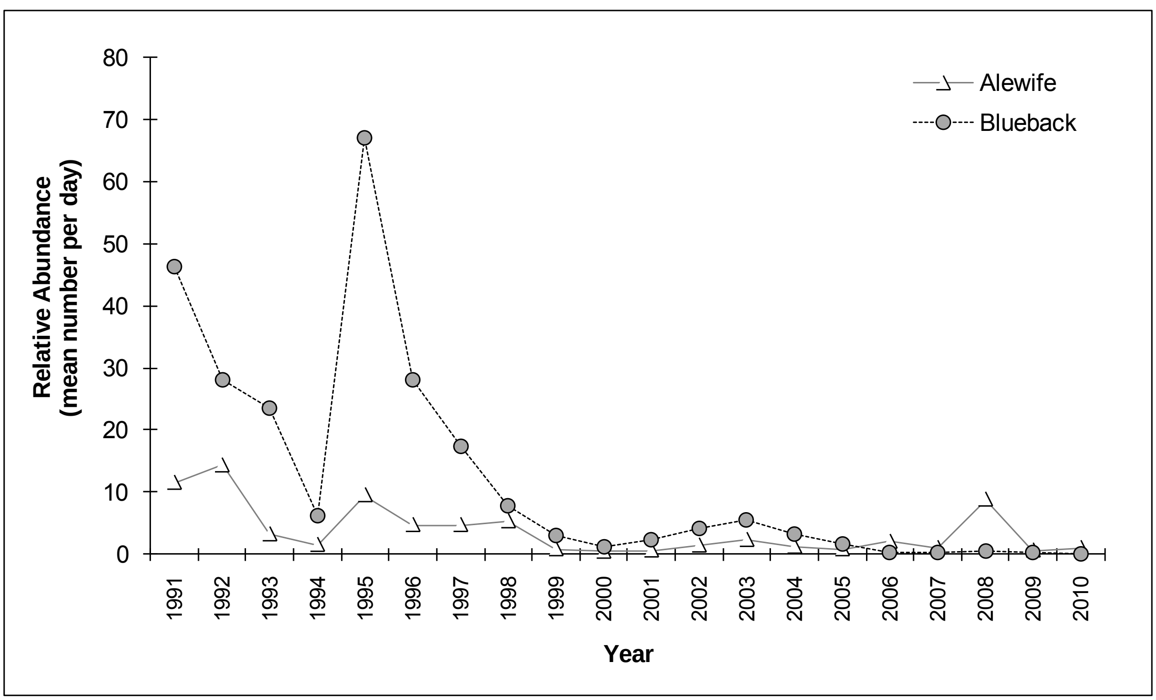

Figure 15.24 Annual relative abundance (average number per day) of adult river herring collected from the Rappahannock River by the VIMS Experimental Anchor Gill-Net Survey, 1991–2010.

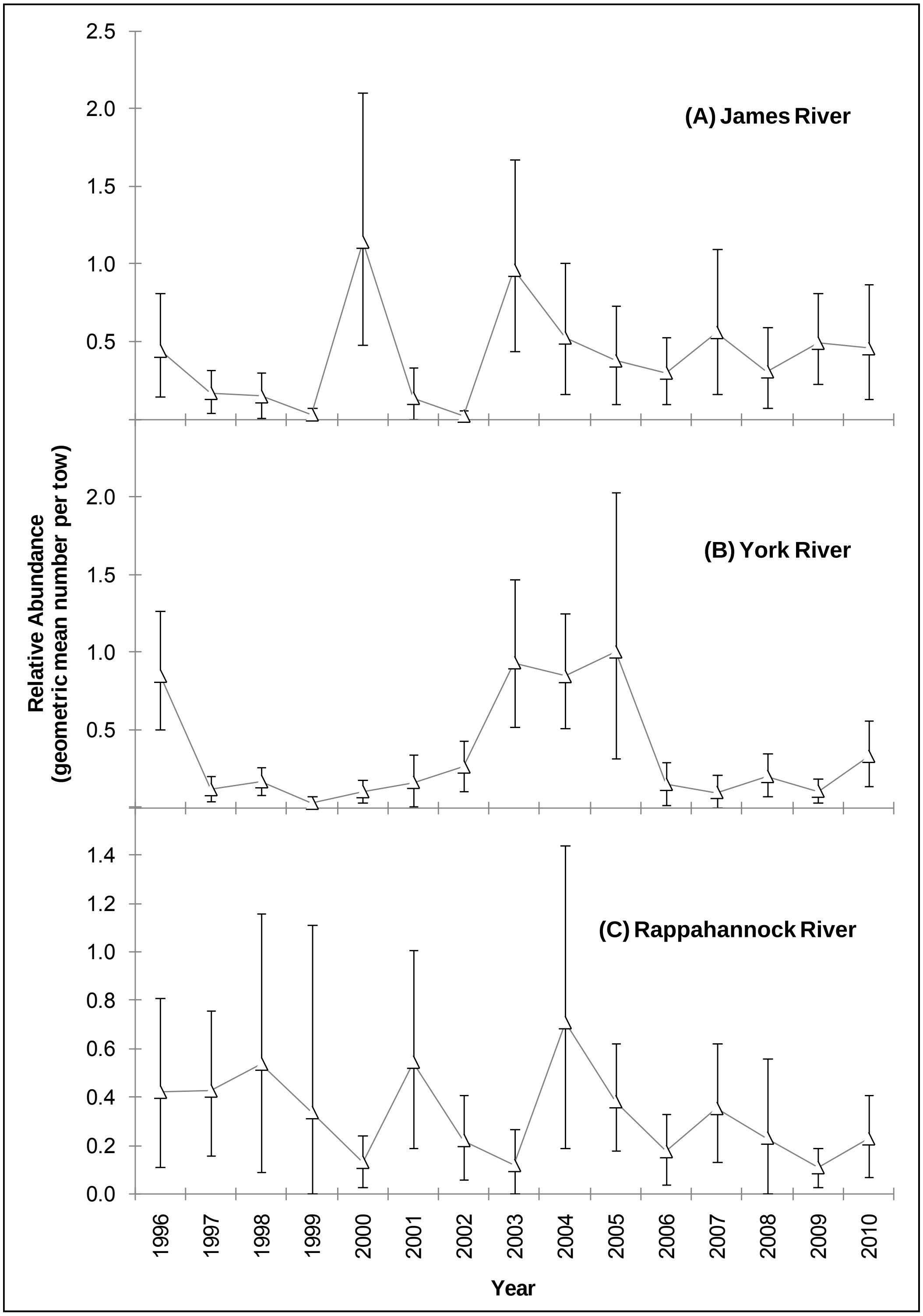

Figure 15.25 Annual JAIs (geometric average number per standard tow) for alewives collected from the (A) James, (B) York, and (C) Rappahannock rivers by the VIMS Juvenile Fish and Blue Crab Trawl Survey, 1996–2010. Error bars represent the 95% confidence intervals.

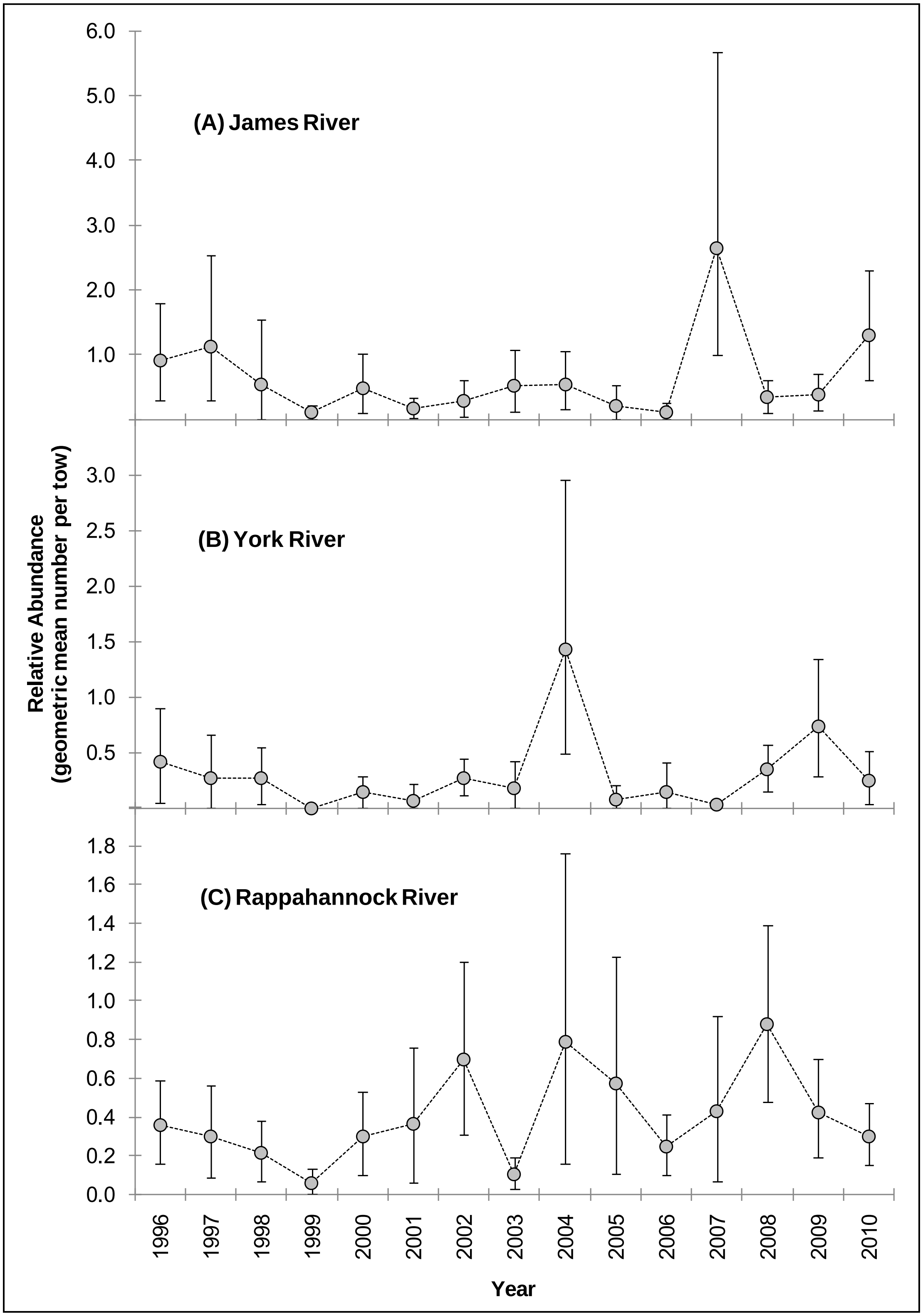

Figure 15.26 Annual JAIs (geometric average number per standard tow) for blueback herring collected from the (A) James, (B) York, and (C) Rappahannock rivers by the VIMS Juvenile Fish and Blue Crab Trawl Survey, 1996–2010. Error bars represent the 95% confidence intervals.

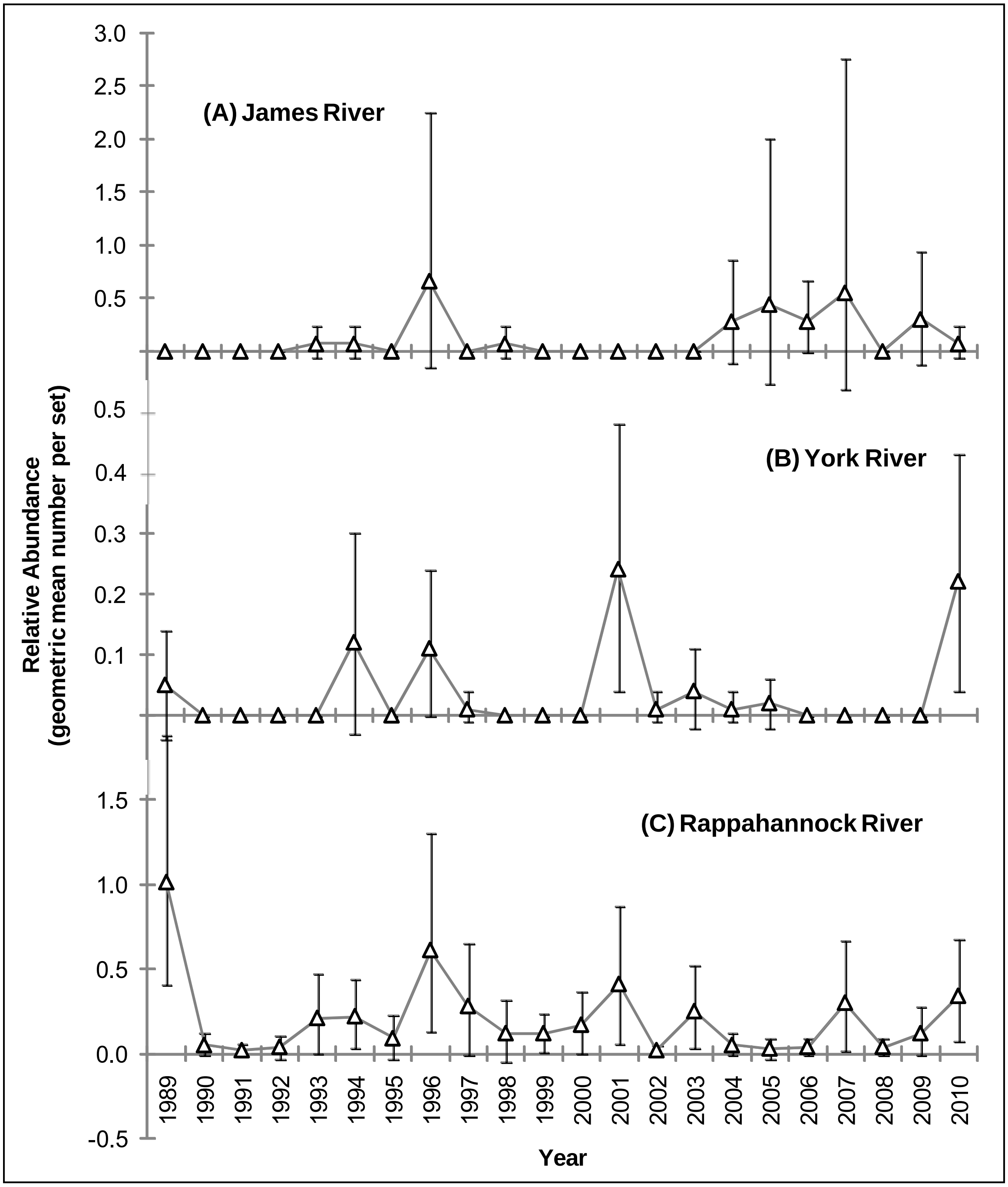

Figure 15.27 Annual JAIs (geometric average number per seine set) for alewives collected from the (A) James, (B) York, and (C) Rappahannock rivers by the VIMS Juvenile Striped Bass Seine Survey, 1989–2010. Error bars represent the 95% confidence intervals.

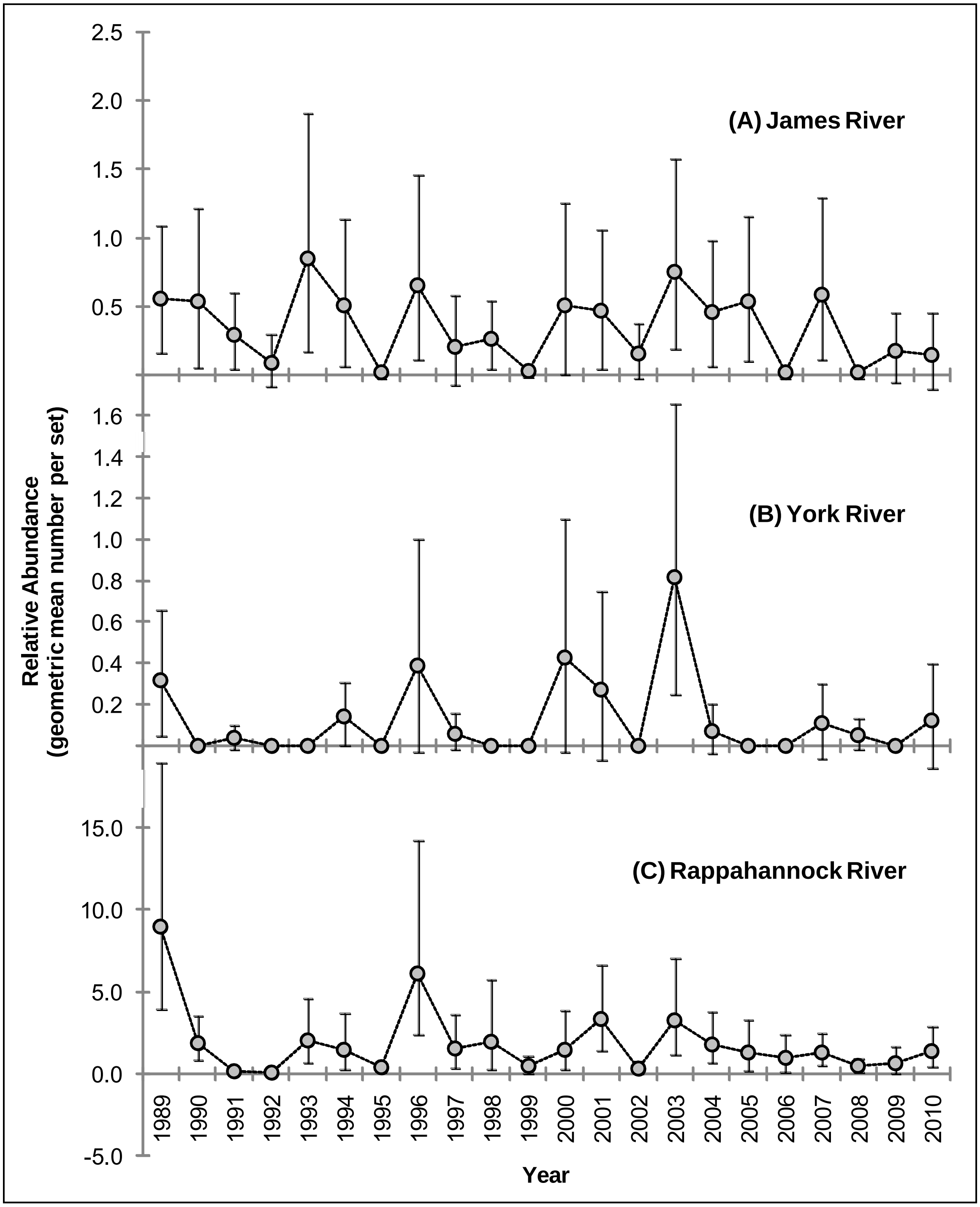

Figure 15.28 Annual JAIs (geometric average number per seine set) for blueback herring collected from the (A) James, (B) York, and (C) Rappahannock rivers by the VIMS Juvenile Striped Bass Seine Survey, 1989–2010. Error bars represent the 95% confidence intervals.

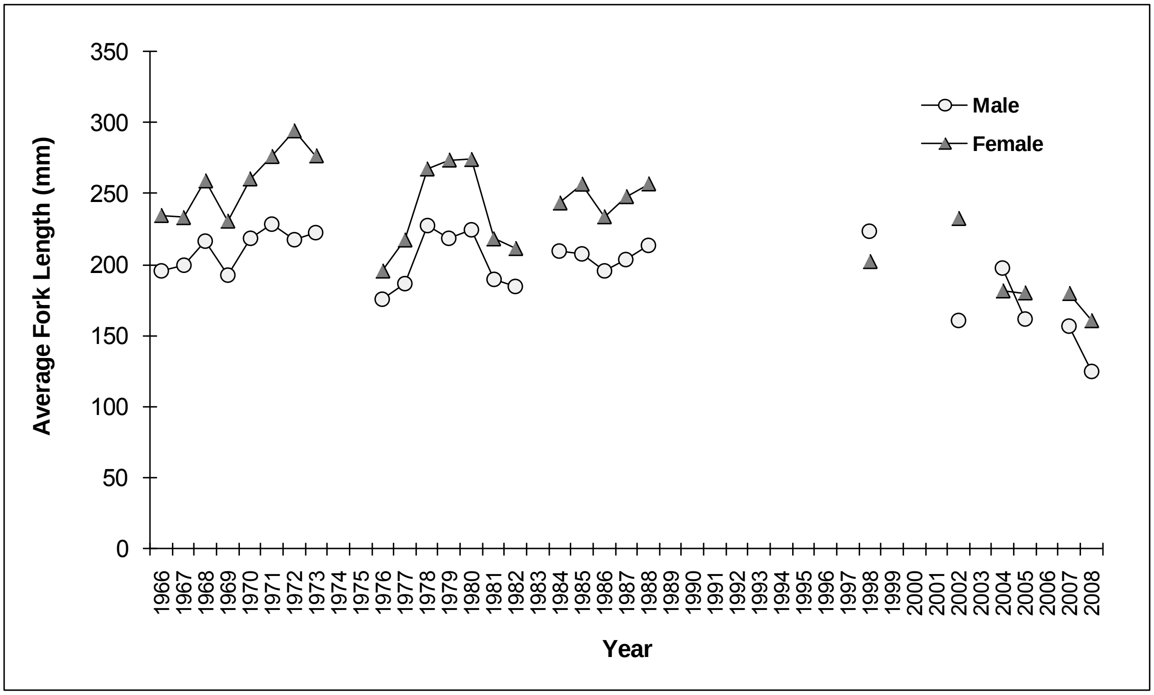

Figure 15.29 Average fork length (mm) of alewives sampled from commercial pound net harvest in the Rappahannock River, by sex, 1966–2008. Note that no river herring were sampled from the commercial fishery in 2009 and 2010.

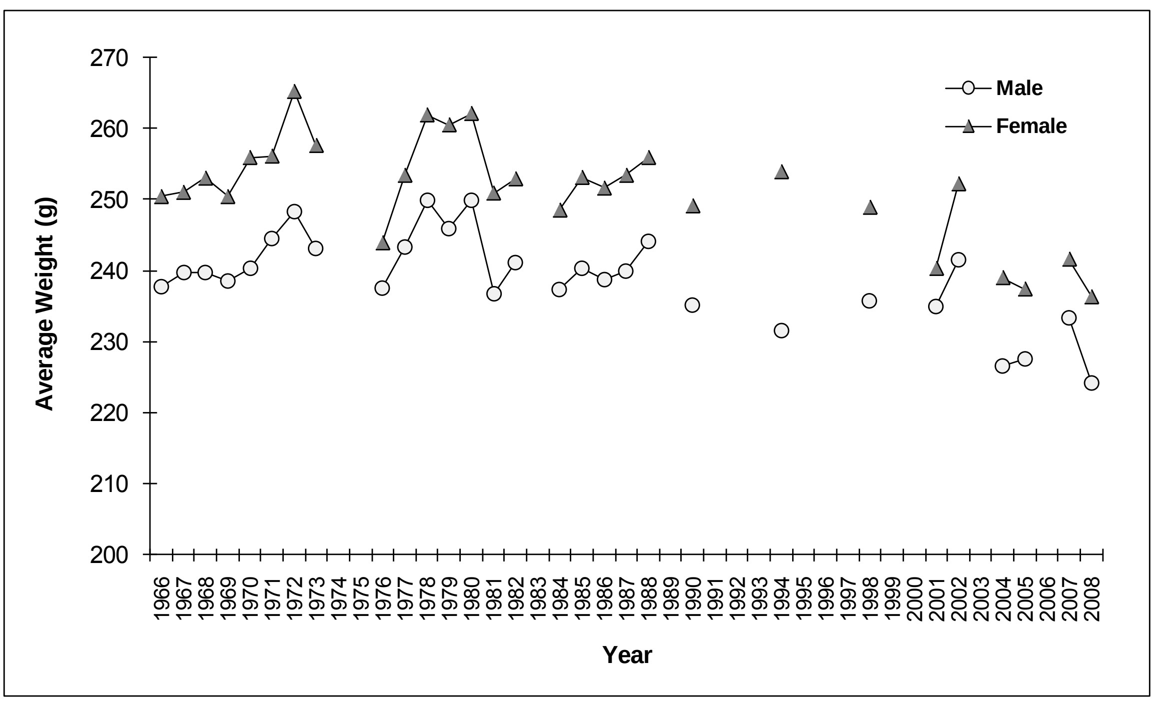

Figure 15.30 Average weight (g) of alewives sampled from commercial pound net harvest in the Rappahannock River, by sex, 1966–2008. Note that no river herring were sampled from the commercial fishery in 2009 and 2010.

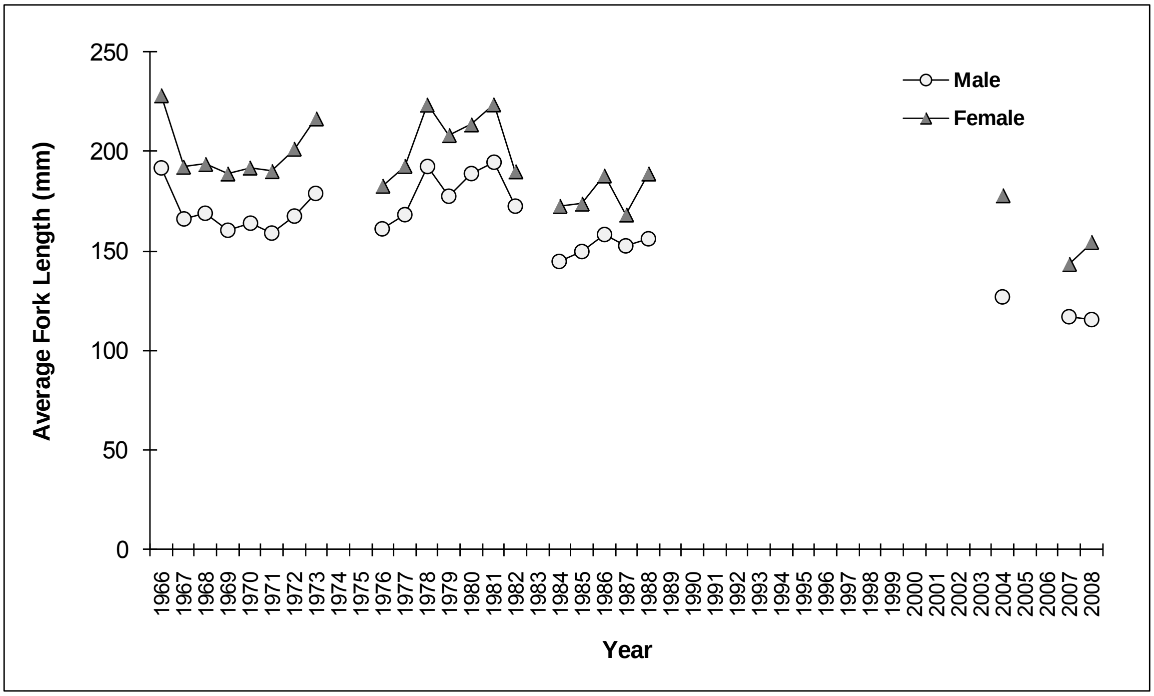

Figure 15.31 Average fork length (mm) of blueback herring sampled from commercial pound net harvest in the Rappahannock River, by sex, 1966–2008. Note that no river herring were sampled from the commercial fishery in 2009 and 2010.

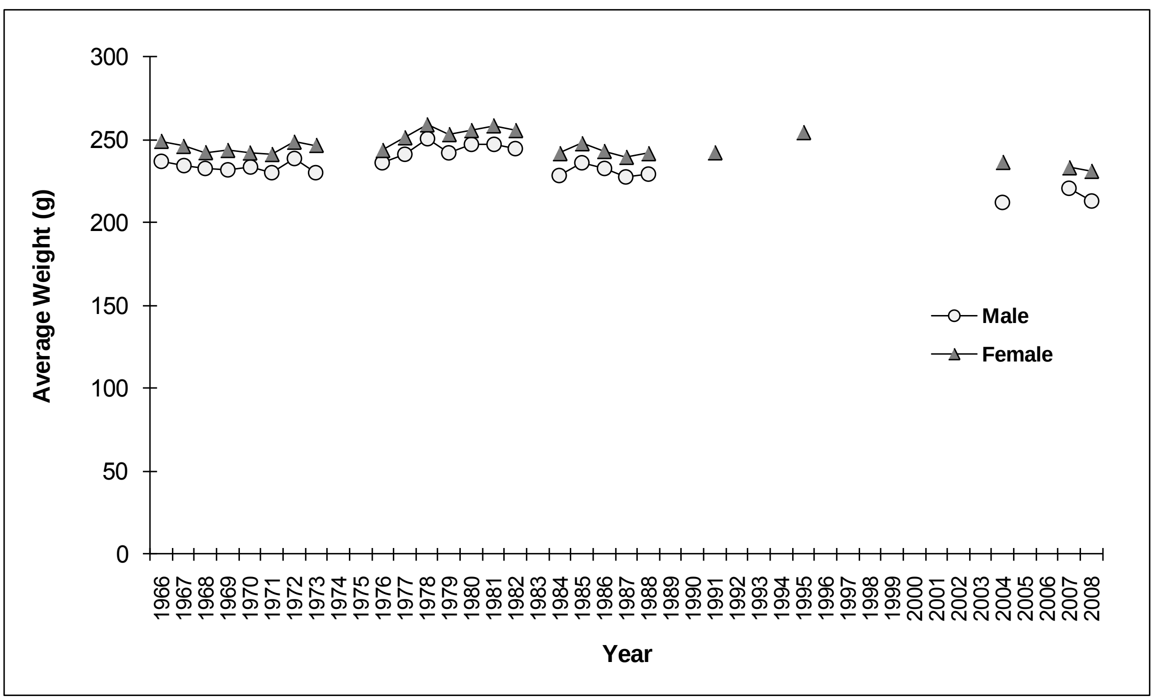

Figure 15.32 Average weight (g) of blueback herring sampled from commercial pound net harvest in the Rappahannock River, by sex, 1966–2008. Note that no river herring were sampled from the commercial fishery in 2009 and 2010.

16. Status of River Herring Stocks in North Carolina Rivers

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Executive Summary
River herring fisheries in North Carolina's coastal sounds and rivers were once among the largest freshwater fisheries in the world. Significant declines in commercial landings and overall stock abundance began in the mid to late 1980s and continues on an overall declining trend. In 2007 the NC Marine Fisheries Commission adopted the NC River Herring Fishery Management Plan (NCRHFMP) that implemented a no harvest provision for commercial and recreational river herring fisheries in the Coastal and Joint waters of the state.

A forward- projecting age structured statistical catch -at -age (SCA) model for Chowan River blueback herring (*Alosa aestivalis)* was applied to the total in-river catches, age compositions, length compositions, and a fisheries independent young-of-year (YOY) index to estimate age-3 abundance and mortality rates. The assessment time period was 1972-2009. Exploitation rates for blueback herring in the Chowan River before the 2007 moratorium ranged as low as 0.14 in 1979 to as high as 0.87 in 1986. Exploitation averaged about 0.28 prior to 1985, increased to an average of 0.70 during 1985–1988, and averaged about 0.40 between 1989 and 2006. Since the moratorium, exploitation rates have been close to zero. Fishing mortality averaged about 0.34 prior to 1985, increased to an average of 1.3 during 1985–1988, and averaged about 0.56 between 1989 and 2006. Since the moratorium, fishing mortality has been close to zero. Blueback herring total abundance (3+) declined steadily from 133 million fish in 1979 to 55 million fish in 1980. Total abundance increased through 1983 to 103 million fish and then declined precipitously to its lowest value of 1.1 million fish in 2002. Since 2002 total abundance has averaged 1.9 million fish. Age- 3 abundance peaked at 81 million fish in 1975, and has declined precipitously since 1983 to 0.62 million fish in 2001. Since 2002, total abundance of age-3 fish has averaged 1.0 million fish. Female SSB fluctuated but declined steadily from the peak of 5.2 million kilograms in 1972 to a low of 0.14 million kilograms in 1986. Female SSB increased slightly to 0.46 million through 1990, but then it declined slowly to its lowest level of 15,000 kilograms in 2003. Since 2004, female SSB has averaged about 81,000 kilograms.
From the spawner-recruit data and production model, F_{MED} was estimated to be 0.59. The fishing mortality rate that produces maximum sustainable yield, F_{MSY}, was 0.39 and corresponding spawning stock bass, SSB_{MSY}, was 1,955,333 kilograms. SSB_{MSY} was higher than the 20% of the equilibrium spawner biomass, $SSB_{20\%}$ (1,195,873 kilograms). Current female spawning stock biomass is only 5% of SSB_{MSY}. The fishing mortality rate that drives the population to extinction, F_{COL}, was 0.91. The estimates of F_{MSY} and F_{COL} are considerably lower than those estimated for alewife ($F_{MSY} > 1.0$; $F_{COL} > 1.82$) in three Canadian rivers by Gibson and Myers (2003b). When comparing fishing mortality rate estimates to the derived reference points the fishing mortality exceeded all reference points several times over the time series, particularly after 1985.

Excessive exploitation and poor recruitment have lead to depletion of the Chowan River blueback herring stock. Despite a fishing pressure that is almost negligibly low since implementation of the 2007 no-

harvest provision, the stock remains overfished as the spawning stock biomass remains less than 5% of the amount necessary to replace itself in the complete absence of fishing.

16.1. INTRODUCTION

Historically, river herring (blueback herring *Alosa aestivalis and* alewife *Alosa pseudoharengus)* supported commercial and recreational fisheries in most of North Carolina's coastal rivers. The major concentrations of river herring historically and currently are found in the Albemarle Sound and its tributaries (Figure 16.1). Due to overfishing, habitat loss and water quality degradation, river herring landings in North Carolina began to decline in the mid to late 1980's. The 2005 North Carolina River Herring Stock Assessment indicated that river herring were overfished and that overfishing was occurring (Grist 2005). In 2006 the NC Wildlife Resources Commission (NCWRC) adopted a rule that prohibits possession of river herring six inches and greater in all inland waters of the state. In 2007 the NC Marine Fisheries Commission (NCMFC) adopted Amendment 1 to the NC River Herring Fishery Management Plan (NCRHFMP), which prohibited commercial and recreational harvest in all coastal and joint waters of the state and set aside a 7,500 pound annual research harvest with area, season and gear restrictions. A maximum 4,000 pounds (of the 7,500 pounds) are allocated for commercial harvest and data collection in a limited fishery with quota, time and area restrictions. This fishery was approved by the ASMFC Shad & River Herring Management Board in 2011. The NCRHFMP also identified stock recovery indicators which are currently being monitored by the NC Division of Marine Fisheries (NCDMF). Revision of the 2007 NCRHFMP will begin in July of 2012. River herring data available from 2007-2011 will be analyzed and presented in the update of the 2007 FMP.

Although the 2007 NCRHFMP was a statewide plan, river herring data from systems outside of the Albemarle Sound area are not available. The NCDMF has conducted spawning and nursery area surveys and some age composition work for most of the coastal streams outside the Albemarle Sound area, but this work ended 15 – 23 years ago, varying with area, as federal aid funds were decreased. Current data, other than landings data, simply do not exist for river herring outside the Albemarle Sound area. Data from the Albemarle Sound and particularly Chowan River were used to determine the 2005 stock status of alewife and blueback herring in NC. Blueback herring was selected as the indicator species for the 2005 NC River Herring Stock Assessment and the overall development of the NCRHFMP. One of the key research recommendations in the 2007 NCRHFMP was to expand data collection programs to other river systems in the state. Currently, no expansion of those data collection programs has occurred.

16.2. DESCRIPTION OF MANAGEMENT UNIT

The management of river herring in North Carolina is conducted in joint and coastal waters by the NCDMF and in inland waters by the NCWRC. The management units established in the 2000 Albemarle Sound River Herring Fishery Management Plan (ASFHRMP) include the two species of river herring (blueback and alewife) and their fisheries throughout coastal North Carolina.

The management areas are defined as follows:

The Albemarle Sound River Herring Management Area (ASRHMA)- Albemarle Sound and all its Coastal, Joint and Inland water tributaries; Currituck Sound; Roanoke and Croatan sounds and all their Coastal, Joint and Inland water tributaries, including Oregon Inlet, north of a line from Roanoke Marshes Point 35° 48.3693' N -75° 43.7232' W across to the north point of Eagles Nest Bay 35° 44.1710' N - 75° 31.0520' W.

The Chowan River Herring Management Area (CRHMA)- Northwest of a line from Black Walnut Point 35° 59.9267’ N - 76° 41.0313’ W to Reedy Point 36°02.2140’ N - 76° 39.3240’ W, to the North Carolina/Virginia state line; including the Meherrin River.

16.3. REGULATORY HISTORY

From 1915-1965 various regulations including season and area closures as well as gear restrictions were implemented in the N.C. river herring fisheries. Beginning in 1995 various restrictions including season closures and total allowable catch limits were implemented.

The two management areas (ASRHMA and CRHMA) were established in the 2000 ASRHFMP and defined in North Carolina Fisheries Rules for Coastal Waters 2003 rule 15A NCAC 3J. 0209. An annual quota, or total allowable catch (TAC) of 300,000 pounds was established in 2000 for the ASRHMA and was allocated as follows: 200,000 pounds to the pound net fishery for the CRHMA; 67,000 pounds to the ASRHMA gill net fishery; 33,000 pounds to be allocated at the discretion of the NCDMF Director (15A NCAC 3M.0513). The same rule also granted the Director proclamation authority as it applies to blueback herring, alewife, American and hickory shad fisheries, and also established a 25 fish per person per day (blueback herring and alewife combined) recreational creel limit.

The commercial TAC was further reduced in 2006 for the ASRHMA with 65,000 pounds allocated to CRHMA pound net fishery; 35,000 pounds to the ASRHMA gill net fishery; 5,000 pounds to be allocated at the NCDMF Director discretion.

Rule 15A NCAC 3O.0503 outlines the requirements for the Albemarle Sound Management Area River Herring Dealer Permit. To purchase river herring a dealer must obtain an Albemarle Sound Management Area River Herring Dealer Permit. The permit conditions require the dealer to report landings daily to the NCDMF, and allow biological sampling of catches by NCDMF personnel.

The NCMFC through the development and approval of Amendment 1 to the NCRHFMP approved a no harvest provision for river herring, commercial and recreational, in waters under their jurisdiction in 2007. The NCMFC approved a 7,500 pound limited research set aside to be allocated at the NCDMF Director’s discretion to collect data necessary for stock analysis, and to provide availability of local product for local festivals. To implement the harvest of this discretionary amount, a Discretionary Herring Fishing Permit (DHFP) was created. Individuals interested in participating had to meet the following requirements: (1) obtain a DHFP, (2) harvest only from the Joint Fishing Waters of Chowan River during the harvest period, (3) must hold a valid North Carolina Standard Commercial Fishing License (SCFL) or a Retired SCFL, and (4) participate in statistical information and data collection programs. If harvested river herring were sold they had to be sold to a licensed and permitted River Herring Dealer. The Director allocated a maximum of 4,000 lbs of the 7,500 lb set aside for harvest in the limited fishery. Each permit holder was allocated 125-250 lbs for the four day season during Easter weekend from 2007-2010. This limited fishery has also met the requirements of Amendment 2 to the ASMFC Shad & River Herring Fisheries Management Plan and was approved by the ASMFC Shad & River Herring Management Board in 2011.

Anadromous Fish Spawning Areas (AFSA) have been adopted by NCWRC and NCMFC into NC rule 15NCAC 03R.0115 through the implementation of Amendment 1 of the NCRHFMP. These areas are designated using spawning area surveys conducted in North Carolina as well as current and future surveys that will continue to re-evaluate spawning habitat.

The NCWRC has authority over the Inland Waters of the state. Since July 1, 2006 harvest of river herring, greater than 6 inches has been prohibited in the inland waters of North Carolina's coastal systems.

16.4. ASSESSMENTS HISTORY

In 2005, an updated stock assessment was conducted examining both blueback herring and alewife in NC. Although blueback herring and alewife are landed in other areas of the Albemarle Sound by a variety of gears, the largest fishery, both in the present and historically, is that of the Chowan River pound nets. Catch-at-age data from the Chowan River pound net fishery were used to estimate exploitation rates and abundance from 1972 to 2003. Cohort and annual catch curves provided initial estimates of mortality, while a spreadsheet- based catch at age model incorporating a multinomial error distribution provided estimates of annual recruitment, abundance at age, and fishing mortality. Bootstrapping and log-likelihood profiling were used to evaluate the precision of model estimates. Estimated fishing mortality for 1972 to 1994 is 0.90 for blueback herring and, except for 1995 and 1997, fishing mortality has ranged from a low of 0.98 in 1998 to a high of 1.91 in 2003, with a corresponding exploitation ranging from 63% to 85%. Estimated fishing mortality for 1972 to 1994 is 0.98 for alewife and, except for 1995 and 1997, fishing mortality has ranged from a low of 1.01 in 1998 to a high of 1.86 in 2002, with corresponding exploitations ranging from 64% to 85%. Chowan River blueback herring recruitment averaged 28.9 million age-3 fish per year between 1972 and 1985. However, since 1986 it has only averaged around 3.6 million fish, and in the last five-years, only 552,000 fish. Chowan River alewife recruitment averaged 7.5 million age-3 fish a year between 1972 and 1986. However, since 1987 it has only averaged around 587,000 fish and in the last five-years, only 317,000 fish.

Blueback herring declines in recruitment through the 1990's dramatically reduced SSB to a record low of 89,678 pounds in 2003. Similarly, alewife spawning stock biomass declined rapidly during the early 1990's. From 1994 to 1999, alewife SSB averaged 22,953 pounds, with a record low of 10,862 pounds in 1995. Excessive exploitation combined with poor recruitment has significantly reduced abundance of both river herring species over the last 20 years and has led too much lower catches than were supported historically. Utilizing blueback herring as an indicator species, a Beverton-Holt stock-recruitment model and a stochastic recruitment model were fit and estimated model parameters were used to project population conditions under various management strategies (Grist 2005).

The 2010 Chowan River blueback herring stock assessment report results can be found in section 16.11 of this document.

16.5. STOCK SPECIFIC LIFE HISTORY

The alewife and the blueback herring, collectively known as river herring, are anadromous members of the family Clupeidae (herrings and shads). "Anadromous" means they migrate from the ocean, enter coastal bays and sounds through inlets, and ascend into freshwater rivers and streams to spawn, traveling further upstream in wet years and remaining downstream in dry years. Surviving adults then return to the ocean after spawning. The young-of-the-year fish use rivers and estuaries as nursery grounds as they migrate downstream after hatching. After the juveniles leave the rivers and estuaries in the fall or early winter, they complete their development in the Atlantic Ocean, over the continental shelf off New England (Loesch 1987; Jenkins and Burkhead 1993). The two species occur geographically together from New Brunswick and Nova Scotia in Canada south to the northern coastal area of South Carolina. Blueback herring occur further south, to northern Florida. There are important life history differences between the two species (Loesch 1987). Alewives select slower-flowing areas for spawning, with blueback herring reported to select faster-flowing sites in areas where both species occur. In areas where both species occur, alewives generally spawn earlier. While fish are believed to return to the streams of their birth for spawning, both species readily colonize new streams or ponds and will reoccupy systems from which they have been extirpated (Loesch 1987). Both juveniles and adults respond negatively to light, in both riverine and offshore habitats, with alewives remaining deeper in the water column in both habitats (Klauda et al. 1991). Both species are important prey during all life stages for many other species of commercial and recreational importance. Both species have also been widely stocked in inland freshwater lakes and reservoirs where they live and reproduce entirely in freshwater and serve as prey for freshwater game fish.

In the collective population of river herring, the percentage of alewife and blueback herring present in major Albemarle Sound tributaries has varied based on sampling of the commercial catch (Johnson et al. 1981). For example, percent composition of alewife ranged from 4 % in 1977 to 49 % in 1979, with alewife dominating the early catches in each year. From 1989 through 1992, the percentage of alewife ranged from 14.2 to 31.2% (Winslow and Rawls 1992). The same pattern of early dominance by alewife, with subsequent later dominance by blueback herring, is evident in weekly species composition samples taken during the 1980-92 spawning runs on the Chowan and Scuppernong rivers (Winslow et al. 1983; Winslow and Rawls 1992). The fraction of alewife in the commercial catch for those years ranged from 27 to 37%.

16.6. HABITAT DESCRIPTION

River herring have historically been found in all N.C. coastal rivers and streams. The main populations of river herring are found in the Albemarle Sound and its tributaries, with smaller runs historically in the Tar, Pamlico, Neuse and Cape Fear River systems.

The Albemarle Sound system includes Albemarle, Croatan, Roanoke and Currituck Sounds and all of their tributaries. The Albemarle Sound, located in the northeastern portion of North Carolina, is a shallow estuary extending 55 miles in an east-west direction averaging 7 miles wide and 13-20 ft deep. Ten rivers drain into the Albemarle Sound which joins Pamlico Sound through Croatan and Roanoke Sounds and empties into the Atlantic Ocean via Oregon Inlet. The majority of tributaries that empty into the sound originate in extensive coastal swamps.

The Chowan River flows approximately 50 miles and is formed with the merging of Virginia's Blackwater and Nottoway rivers. It is a major tributary to the Albemarle Sound and it is the primary spawning area for river herring in North Carolina. The Chowan River empties into western Albemarle Sound. This area as well as most of the Albemarle Sound and all of its tributaries serves as a major anadromous fishery nursery area for river herring.

Anadromous spawning area surveys conducted by the NCDMF demonstrated that river herring use a wide range of habitat types for spawning, such as small, densely vegetated streams; fresh and brackish marshes; hardwood swamps; and flooded low-lying areas adjacent to both mainstem rivers and tributaries. In North Carolina, anadromous fish spawning areas are designated in NCMFC rule 15A NCAC 03R.0115 and NCWRC rule 15A NCAC 10C .0603 and include areas in most river systems.

River herring spawn in the upper reaches of North Carolinas coastal rivers and streams in the early spring. The juveniles spend most of their first year in the nearshore waters of the coastal rivers and sounds and emigrate to the ocean when water temperatures begin to cool in the fall.

16.7. RESTORATION PROGRAMS

The 2007 NCRHFMP identified various restoration targets for the river herring stocks. The 2007 NCRHFMP utilized the Chowan River blueback herring stock as the indicator species to establish stock recovery indicators. The plan identified stock recovery indicators that would be used to evaluate and determine recovery status of the river herring stock. The stock recovery indicators for the 2007 NCRHFMP are as follows:

Juvenile abundance – The restoration target for juvenile abundance of blueback herring is to achieve a three year moving average catch per unit of effort of at least 60.

Percent Repeat Spawners – The Chowan River blueback herring spawning stock should contain at least 10% repeat spawners (percent of the spawning stock that have spawned more than once).

Spawning Stock Biomass (SSB) – The restoration target to restore Chowan River blueback herring SSB to a minimum stock size threshold (MMST) of 4 million pounds.

Recruitment – Recruitment of age three blueback herring should be restored to a three-year moving average of at least 8 million fish.

In addition to the above stock recovery indicators the 2007 NCRHFMP recommended a variety of research needs and management options that address various issues such as habitat availability and degradation, predation, bycatch, critical habitat and water quality and that would contribute to the recovery of river herring stocks in North Carolina. A full description of these recommendations can be found in the 2007 NCRHFMP.

16.8. AGE

Age samples of the blueback herring and alewife catch from the Chowan River commercial pound net fishery are available from fish house sampling conducted from 1972-2006. The target sampling frequency is to collect unculled samples of at least 30 fish weekly, from at least 3 area commercial fishhouses during the fishing season.

Following the closure of the commercial river herring fisheries in N.C. a commercial pound net survey was implemented to collect aging samples of river herring from the Chowan River. Depending on the year 3- 4 commercial fishermen were contracted to fish commercial pound net sets in the Chowan River, NC during the traditional river herring commercial harvest season. All fishermen were required to obtain a weekly unculled adult sub-sample of approximately 20 pounds of river herring from their contracted pound nets. In 2009 sampling was expanded to include a visual estimate of the total daily catch of river herring in pounds from all of the pound nets set regardless of whether it was a designated contracted net or not. Adult samples were sorted to species and all individuals of each alosine species present were measured (mm, FL,TL), weighed (kg), sexed, spawning maturity was determined, and an ageing sample was taken. A complete analysis of the Chowan River Pound Net Survey data will be included in the update of the 2007 NC River Herring FMP which will begin in July 2012.

Scale samples collected for ageing were mounted between two microscope slides and read under an Eyecom 3000 microfiche reader and aged by methods similar to that in Street et al. (1975). Stratified sub-sampling, based on techniques developed by Ketchen (1950), was used to compile individuals for ageing. Samples were sorted by species, and sex, then placed in 10 mm size groups. If 15 or less samples were present in a size group, all of the samples were aged. If more than 15 samples were present in a size group, half of the fish in the group were aged. Proportions within each sex and size group were calculated and expanded to the remaining sample.

16.9. FISHERY DESCRIPTIONS

Since 2007 the commercial and recreational harvest of river herring is prohibited in all coastal and joint waters of the state. There is a 7,500 pound research set-aside harvest, with 4,000 pounds allocated to be taken over a four day period with area and gear restrictions (see section 13.3 for a complete description).

The possession of river herring greater than 6 inches in the inland waters of North Carolina has been prohibited since 2006.

16.9.1. Commercial Fishery

Commercial Landings

River herring have been subjected to intensive exploitation since colonial times along the Atlantic coast. The Albemarle Sound area has always been the center of the North Carolina fishery. In North Carolina, river herring were among the first fish to be exploited commercially because their oily flesh allowed them to be salt-preserved, without ice or refrigeration.

NCDMF has monitored commercial landings of river herring since 1972. Prior to 1994, commercial landings in North Carolina were acquired via a NCDMF and National Marine Fisheries Service (NMFS) Cooperative statistics program on a monthly basis from licensed seafood dealers; however, reporting at the time was not mandatory. In 1994 NCDMF implemented a mandatory commercial harvest data collection system known as the Trip Ticket Program (TTP). The Trip Ticket Program is a dealer-based reporting program that obtains a trip-level census of commercial landings in North Carolina.

The annual commercial harvest of river herring for the Albemarle Sound as well as other areas of the state is presented in Table 16.1. As mentioned previously, the Chowan River is the historical mainstay of the North Carolina river herring fishery and continued to serve in that capacity until the close of the commercial fishery statewide in 2007.

The use of pound nets revolutionized fishing in North Carolina, especially in the Albemarle Sound (Taylor 1992). Chestnut and Davis (1975) reported that 2,767 pound nets were set in North Carolina in 1927. Since the 1960s, the majority of the river herring pound nets have been set in the rivers, and the leads seldom exceeded 200 yards in length (Walburg and Nichols 1967). The Chowan River has been the center of the river herring pound net fishery, and from the late 1970s to the late 1980s the number of river herring pound nets ranged from 421 to 615 nets annually, with the amount of pound nets declining from 348 in 1989 to 175 in 1994.

Gill nets, anchor and drift, have historically been utilized in the river herring fishery. The amount of gill net effort in the fishery prior to 1994 is unknown. During the 1970s, the gill net harvest of river herring accounted for approximately 15% of the total Albemarle Sound area harvest. However, from 1987 to 1994, the proportion of gill net landings increased to 24-40% of the total river herring harvest from the Albemarle Sound area. This increase may have been due to a directed fishery for roe fish. In 1986, approximately 6 million pounds were harvested in pound nets and 900,000 pounds from gill nets. During 1988, pound nets landed 2.3 million pounds and gill nets 1.5 million pounds. In contrast, 1994 totals of 425,000 pounds from pound nets and 175,000 pounds from gill nets was harvested.

Several other types of commercial gears have been used in the river herring fishery: fyke nets, fish wheels and dip nets. These gears have contributed very little to the total harvest in the Albemarle area. From 1915 through 1965, various regulations were enacted for the Albemarle Sound river herring fishery (seasons, area closures, gear restrictions).

The Albemarle Sound area accounted for 66-100% of the state’s river herring harvest from 1889 to 1994. Between 1962 and 1994, the Chowan River pound net fishery contributed 43-97% of the state’s total river herring landings. From 1950 to 1994, North Carolina accounted for 13.6-84.5% of the river herring landings of the Atlantic coast states.

Since the late 1800s, the areas fished and gears used to harvest river herring have remained essentially unchanged. The extent of the river herring fisheries in both the amount of gear and harvest, however, has declined significantly. The fisheries in the Albemarle Sound area are now pursued as multi-species fisheries, which are not totally dependent on river herring.

During 1995-1998, North Carolina accounted for 29-52% of the total river herring landings from the Atlantic coast. From 1999-2004, the State contributed 9-33% of the Atlantic coast river herring harvest. Landings from the Albemarle Sound area accounted for 91.6-99.8% of the state's total river herring landings during 1995-2004. The Chowan River pound net fishery contributed 60.3-76.5% of North Carolina's annual river herring harvest during 1995-1999.

Since 2000, the Chowan River pound net fishery contributed 41-66% of the state's total river herring harvest. Since 1988, regulations enacted for striped bass conservation (gill net mesh size restrictions, yardage restrictions, area closures) have impacted river herring harvest in the Albemarle Sound area. Even with these regulations, the river herring gill net fishery has accounted for a greater proportion of the overall harvest from 1995 - 1999 (21.2-38.1%). Since the 67,000 pound TAC was implemented in 2000, gill nets have accounted for 24.4-39.5% of the annual river herring landings in the Albemarle area.

Currently, the commercial harvest is restricted to a 7,500 pound research set aside, with a 4,000 pound maximum allocation to be harvested over a four day period during the Easter holiday weekend in the Chowan River. Participation is limited to permitted fishermen. Landings for the research set aside season have ranged from 643 pounds in 2009 to 1,765 pounds in 2010 (Table 16.2). The number of permits issued to participate in the fishery has ranged from 30 in 2010 to 13 in 2008.

Commercial Catch Rates

Catch per unit effort (CPUE) for the Chowan river pound net fishery has been calculated since 1977 (Table 16.3; Figure 16.2). Catch effort was calculated by dividing the total weight (kg) by the total effort in pound net weeks (calculated as the number of pound nets fished each week summed over the entire season). Weeks were considered Sunday to Saturday and begin the first full week in January. Pound net effort was determined by an aerial survey, conducted with the assistance of the NCDMF marine patrol as well as pound net permit application data.

While the maximum number of pound nets set in any given week decreased drastically from a high of 624 in 1977 to only 36 in 2004, the total weeks fished has differed little over the years with the exception of 1997 when nets were only set for 5 weeks. Therefore, the overall decrease in total effort is due more to fewer nets set than to a reduction in the length of the fishing season. Since 2001, the number of weeks fished has increased slightly as a result of the TAC not being met, and the season remaining open longer, or nets being set earlier in the fishing season. Effort has decreased considerably since the implementation of a harvest quota in 1995 and has varied without trend since that time.

Catch per unit effort for blueback herring and alewife from the Chowan River commercial pound net fishery declined considerably since the mid 1980s. Blueback herring CPUE increased slightly during the 1995-2005 seasons, but declined significantly in 2000. Alewife CPUE decreased considerably in 1993-1999, with slight increases in 2001. Both CPUE's remained well below the historical levels until the close of the fishery in 2006.

Repeat Spawners

The NCDMF has monitored repeat spawning for the Chowan River blueback herring and alewife since 1972 (Table 16.4). Percent repeat spawners for blueback herring from the Chowan River spawning stock is one of the stock recovery indicators identified in the 2007 NCRHFMP. The Chowan River blueback herring spawning stock should contain at least 10% repeat spawners (percent of the spawning stock that have spawned more than once). The percent of blueback herring repeat spawners in the pound net harvest averaged 14.8% during 1972-1982. From 1983 through 1989, the percentage of repeat spawners declined significantly, ranging from 0.6% to 6.1%. During the 1990s, blueback herring spawning repetition remained low, ranging from 1.2% (1994) to 4.7% (1993). During 2000 through 2003, a slight increase in the percentage was observed but declined again in 2004 (2.9%). Percentages increased again in 2007 and 2008 but declined again in 2009 and remain well below the historical average.

The percentage of alewife repeat spawners has also decreased since the 1970s, with a mean of 9.4% from 1972 through 1981. From 1988-1999, no or very small samples of alewife were obtained from the Chowan River pound net fishery, due to scarcity in the harvest. During 2001-2004, alewife samples were obtained from the pound net fishery and an increase in the percentage of repeat spawners was observed. Percent repeat spawners averaged 9.1 from 2004-2009.

Age Composition/Mean Size at Age

The age structure of blueback herring taken in the Chowan River pound net fishery has been characterized since 1972. From the 1970s to the early 1990s, sampling was conducted at up to six fish houses on a weekly basis. From 2000 through 2006, samples were obtained weekly from up to three fish houses until the season closed in 2006. Throughout the years, unculled pound net samples of at least 30 individuals each of blueback herring and alewife were obtained at least weekly during the spring. Size, age and sex composition of the harvest was determined from these samples. Samples of up to 30 fish from each fishhouse were obtained, up to three times per week during the season, and after the season, into the second week of May. Samples in 2007 were obtained from Chowan River pound nets during the research set aside season. Samples since 2008 have been collected from the Chowan River Pound Net Survey.

The aged pound net samples have been dominated by fish ages 4-6 throughout the entire time period (Appendix Table 16.3.) From 1972-1981, seven year olds comprise 4.1 % of the aged sample annually. In recent years, age seven fish comprise less than 1% of the aged sample.

Data from pound net samples for both blueback herring and alewife shows a decline in mean length at age since 1972 (Figures 16.3 and 16.4).

16.9.2. Recreational Fishery

Historically, river herring have been taken for personal consumption in every major North Carolina coastal river system. An analysis of river herring harvest by Baker (1968) indicated the majority of herring harvested by special device licensees in 1967-1968 occurred in the Chowan and Roanoke River basins. River herring were also harvested in other river basins, but American shad and hickory shad (*Alosa mediocris*) were of more importance to fishermen in those areas. Coastwide, Baker (1968) estimated that special device licensees harvested 2.9 million pounds of river herring some of which were sold. The recreational component of this total, however, is unknown. Although these fish were taken by fishermen licensed by NCWRC at that time, changes in designations of Coastal/Joint/Inland Waters, changes in jurisdictional responsibilities between NCDMF and NCWRC, and the unknown proportion of these fish which were harvested with the intent of sale precludes an estimate of the historical level of river herring harvest for personal consumption. The recreational fishery for river herring closed in 2007. It is now illegal to possess recreationally caught river herring in the coastal and joint waters of the state. It is also illegal to possess river herring greater than 6 inches from the inland waters of the state.

For the years leading up to the 2007 harvest closure, the extent of river herring harvest for personal consumption in coastal North Carolina is unknown. According to NCWRC Enforcement Officers who patrollled the inland waters of the Cape Fear, Neuse, and Tar-Pamlico river basins at that time, very few (usually none) special device licensees specifically targeting river herring were encountered in these areas, principally due to the low numbers or absence of these species. Special device licensees targeting river herring are still encountered in small tributaries of the Roanoke and Chowan rivers during the spring months of years prior to the closure, and an active recreational herring fishery persisted in tributaries to the Meherrin River. Recreational river herring fishermen are still found at small bridge crossings over tributaries to other Albemarle Sound river systems such as the Pasquotank, Perquimans, Yeopim and Scuppernong rivers. Low effort directed at river herring harvest in these areas is likely indicative of low river herring abundance.

A recreational drift net river herring fishery existed on the Roanoke River for many years. This fishery has never been fully assessed by NCDMF or NCWRC. The NCDMF initiated a pilot drift net creel survey in 1999 to characterize this fishery for development of future monitoring strategies and to provide managers with weekly reports of recreational drift net activity (participation, catch rates, species composition, net sizes, etc). Sampling was conducted in the lower river area including Williamston, Jamesville, and Plymouth. Interviews were conducted three days per week, for a total of 21 sampling days in 1999. Catches of river herring ranged from 20 to 300 fish per vessel with a mean of 106. Drift duration ranged from 1 to 5 hours with a mean of 2.2 hours. A total of 2,764 river herring were observed in the survey. Because there was no estimate of total effort, total catch cannot be estimated.

The recreational fishery for river herring closed in 2007. It is illegal to possess recreationally caught river herring in the coastal and joint waters of the state. It is also illegal to possess river herring greater than 6 inches from the inland waters of the state.

16.10. FISHERIES INDEPENDENT SURVEYS

16.10.1.Juvenile abundance

The NCDMF began nursery area sampling for juvenile blueback herring and alewife in the Albemarle Sound area in 1972, with eleven core stations being established and sampled throughout the time period (Figure 16.5). This survey was designed to index annual relative abundance of juvenile blueback herring and alewife. Thirty-four stations were established in the western Albemarle Sound area and sampled with trawls and seines. The Carolina wing trawl was adopted as the standard trawl in place of the Cobb trawls in June 1974 (Johnson et al. 1977), and the seines continued. The 34 stations (23 trawls and 11 seines) were sampled monthly during June-October. During September, an additional 43 stations (28 trawls and 15 seines) were sampled throughout the Albemarle Sound area to determine distribution and nursery areas of anadromous species.

Seine stations were sampled with a 60 ft bag seine with ¼ inch mesh bag, with a single haul considered one catch-per-unit-of-effort (CPUE). The Carolina wing trawl had a headrope length of 26 ft, containing webbing which ranged from 4 inch stretched mesh in the wings to 1/8 inch mesh tail bag. The trawl was pulled for 10 minutes, and was considered one CPUE. Samples were sorted to species, and up to 30 individuals of each alosine species present were measured to the nearest millimeter fork length (mm, FL), and all others were counted.

Based on catch consistency the seine proved to be the best sampling gear for blueback herring, and the wing trawl was the best for alewife. Due to a further reduction in federal aid funds, trawl sampling was dropped at the end of June 1984. Sampling with seines at the 11 cores stations has continued during June-

October each year from 1972-2011. During September, an additional 13 seine stations are sampled throughout the Albemarle Sound area to determine distribution and migration.

Juvenile abundance indices (JAI) are established for alewife and blueback herring using data from the 11 core stations sampled once per month, June-October, 1972-2010 (Figures 16.6 and 16.7). The JAI for blueback herring and alewife fluctuated over the years in the Albemarle Sound area. The highest CPUE recorded for blueback herring was in 1973 (362.9 fish/seine); the lowest was in 1994 (0 fish/seine), part of a very low CPUE trend during 1986-2005. The thirty-nine year average CPUE for blueback herring is 50.6, dropping from 70.4 long-term average as reported in the 2000 River Herring FMP. The stock recovery indicator for juvenile abundance of blueback herring is to achieve a three year moving average catch per unit of effort of at least 60. The current 3 year average based on the 2008-2010 data is 1.39.

The average CPUE for alewife during the 1972-2010 period is 2.0 fish/seine compared to the 2.5 fish/seine reported in 2000. Alewife JAI increased slightly in 2003 and dropped again in 2006. However, numbers increased dramatically in 2010 with a JAI of 4.13.

16.10.1.1. Independent Gill Net Survey

Since 1990, NCDMF has been conducting an independent gill net survey (IGNS) throughout the Albemarle Sound area (Figure 16.8). The survey was designed for striped bass data collection. However, river herring are captured during the survey and size, age, and sex data are collected. Gill nets are set in sizes from 2.5 through 7.0 inch stretched mesh (ISM), in half-inch increments and 8.0, and 10.0 ISM are utilized.

River herring CPUE has been calculated from the IGNS throughout the Albemarle Sound area since 1991. Blueback herring and alewife CPUE from the 2.5 ISM and 3.0 ISM (combined) January-May, 1991-2010 are shown in Figure 16.9. The CPUE of blueback herring has continued a general decline since 2000. Alewife CPUE has been low for most of the time series with a general increase since 2005. CPUE has been steady from 2008-2010.

16.11. ASSESSMENT APROACHES AND RESULTS

16.11.1. Statistical catch-at-age model for the Chowan River

A forward-projecting age-structured statistical catch-at-age (SCA) model for the Chowan River blueback herring stock was applied to total in-river catches, age compositions, length compositions, and a fisheries-independent young-of-year (YOY) index to estimate age-3 abundance and mortality rates. The assessment time period was 1972 to 2009.

16.11.1.1. Model Structure

The population model is aged-based and projects the population numbers-at-age by sex s forward through time given model estimates of age-3 numbers and mortality rates, assumed known values of natural mortality for immature and mature fish by age, and proportion mature-at-age. The population numbers-at-age ($N_{s,d,y,a}$) matrix has dimensions s x d x y x A-2, where s is number of sexes, d is the number of maturity phases, y is the number of years, and A is the oldest age group (age 8+). There were six year-classes in the model, representing ages 3 through 8+.

The cohort dynamics of the model is a hybrid of the Margaree River model in Gibson and Myers (2003a). The model incorporates the immature and mature phases by sex and assumes the year begins at the start of spawning. Mature individuals of each age move into the Chowan River where they are intercepted and

removed for harvest. The model assumes harvest occurs before the fish reach the spawning grounds. Biological samples for sex, and age and repeat-spawning data are collected from fishery landings. The model allows different natural mortality values for each year, age, sex, and maturity phase.
Given the above dynamics, population numbers-at-age by sex and maturity phases are calculated through time by using the cohort survival models shown in Figure 16.10. The number of age-3 bluebacks at the beginning of spawning season (R_y) are directly estimated in the model, and these estimates are partitioned into sex- (1=female; 2=male) and maturity phase- (1=immature; 2=mature) specific estimates of age-3 abundance using sex ratio and mature proportions-at-age (derived outside of the model):

Female

Immature: $$\hat{N}_{1,1,y,3} = \hat{R}_y \cdot f \cdot (1 - p_{1,y,3})$$

Mature: $$\hat{N}_{1,2,y,3} = \hat{R}_y \cdot f \cdot p_{1,y,3}$$

Male

Immature: $$\hat{N}_{2,1,y,3} = \hat{R}_y \cdot (1 - f) \cdot (1 - p_{2,y,3})$$

Mature: $$\hat{N}_{2,2,y,3} = \hat{R}_y \cdot (1 - f) \cdot p_{2,y,3}$$

where f is the female sex ratio (proportion) and p is the proportion mature by sex s, year y, and age a. Recruitment of age-3 bluebacks (R_y) is modeled as a log-normal deviation from average recruitment:

$$\hat{R}_y = \hat{\overline{R}} \cdot \exp^{\hat{e}_y}$$

where $\overline{R}$ is the average recruitment parameter and e_y are independent and identically distributed normal random errors with mean zero and constant variance and are constrained to sum to zero over all years. This formulation differs from the original Gibson and Meyers model, which linked recruitment via a Beverton-Holt equation to log-normal deviations.

The initial population abundance-at-age for ages 4 to 8+ in 1972 for each sex and maturity phase is calculated by assuming a static stock:

Immature: $$\hat{N}_{s,1,1972,a} = \hat{N}_{s,1,1972,a-1} \cdot \exp^{-M_{s,1,1972,a-1}} \cdot (1 - p_{s,1972,a})$$

Mature: $$\hat{N}_{s,2,1972,a} = \hat{N}_{s,2,1972,a-1} \cdot (1 - \hat{u}_{1972}) \cdot \exp^{-M_{s,2,1972,a-1}} + \hat{N}_{s,1,1972,a-1} \cdot \exp^{-M_{s,1,1972,a-1}} \cdot p_{s,1972,a}$$

where M is the sex-, maturity phase-, year-, and age-specific instantaneous natural mortality rate, and u is the year-specific exploitation rate. Population abundance-at-age for ages 4 through 7 in the remaining years is calculated by:

Immature: $$\hat{N}_{s,1,y,a} = \hat{N}_{s,1,y-1,a-1} \cdot \exp^{-M_{s,1,y-1,a-1}} \cdot (1 - p_{s,y,a})$$

Mature: $$\hat{N}_{s,2,y,a} = \hat{N}_{s,2,y-1,a-1} \cdot (1 - \hat{u}_{y-1}) \cdot \exp^{-M_{s,2,y-1,a-1}} + \hat{N}_{s,1,y-1,a-1} \cdot \exp^{-M_{s,1,y-1,a-1}} \cdot p_{s,y,a}$$

The population abundance of the plus group (8+) is calculated as:

Mature: $$\hat{N}_{s,2,y,8+} = \hat{N}_{s,2,y-1,a-1} \cdot (1-\hat{u}_{y-1}) \cdot \exp^{-M_{s,2,y-1,a-1}} + \hat{N}_{s,1,y-1,a-1} \cdot \exp^{-M_{s,1,y-1,a-1}} \cdot p_{s,y,a} + \hat{N}_{s,2,y-1,8+} \cdot (1-\hat{u}_{y-1}) \cdot \exp^{-M_{s,2,y-1,8+}}$$

Exploitation rates for each year (u_y) are estimated as individual parameters in the model.

Input values for age- and sex-specific M were calculated using the Lorenzen (1996) equation that relates body weight (in grams) to natural mortality. The grand mean of average weight-at-age of blueback herring from the pound net fishery during 1972 through 1980 was used to derive M. Natural mortality rate was assumed constant with time and among maturity phases for the base model runs. The M estimates for each sex and age were:

	Age					
	3	4	5	6	7	8
Female	0.71	0.66	0.64	0.62	0.60	0.59
Male	0.72	0.70	0.67	0.64	0.62	0.61

The annual proportions of fish mature at each age and sex were calculated from repeat-spawner frequency data provided by the NCDMF. When data were missing in some years and ages, averaged values from surrounding cells were used to fill in missing data (Appendix Table 16.1).

Total removals of blueback herring are one set of data from which age-3 abundances and exploitation rates are estimated. Total catch in numbers was provided by NCDMF (Appendix Table 16.2). Total catch for 2007 to 2009 was estimated by using pound net catch proportions provided in 2008, average blueback landings to alewife landings ratio from years prior to 2007, and annual mean weight by species. Given estimates of annual numbers of mature for fish at each sex and age, predicted removals-at-age is computed by:

$$\hat{C}_{y,s,a} = \hat{N}_{y,s,m,a}\hat{u}_y$$

where $C_{y,s,a}$ is the predicted in-river removals of sex (*s*) of age (*a*) during year (*y*). All predictions are stored in an array of dimensions *s* x *y* x *A-2*. Predicted catch-at-age data are then compared to the observed total catch and observed proportions of catch numbers-at-age data (sample numbers at age are provided in Appendix Table 16.3) through the equations:

Predicted Total Catch: $$\hat{C}_y = \sum_s \sum_a \hat{C}_{y,s,a}$$

Predicted Proportions of Catch Numbers-At-Age: $$\hat{P}_{y,s,a} = \frac{\hat{C}_{y,s,a}}{\sum_a \hat{C}_{y,s,a}}$$

The North Carolina YOY seine survey index for blueback herring was incorporated into the model by linking it to the recruitment estimates:

$$\hat{I}_y = \hat{q} \cdot \hat{R}_{y+3}$$

where $\hat{I}_y$ is the predicted index of survey in year *y*, and *q* is the catchability coefficient. Based on the lagged year comparison, YOY indices from 1972 to 2006 (Appendix Table 16.4) were used to tune recruitment estimates for 1975 to 2009.

Female spawning stock biomass (SSB) in year y was calculated as:

$$SSB_y = \sum_a \hat{N}_{1,2,y,a} \cdot (1-\hat{u}_y) \cdot w_{1,2,y,a}$$

where $w_{1,2,y,a}$ is the mean weight-at-age for mature females in year y and age a. Calculated mean weights-at-age are provided in Appendix Table 16.5.

Fishing mortality rates were calculated from the estimated exploitation rates assuming a Type I fishery:

$$\hat{F}_y = -\log_e(1-\hat{u}_y)$$

Standard errors of fishing mortality rates were derived using the delta method provided in AD Model Builder.

Lognormal errors were assumed for the total catch data and YOY index. The concentrated likelihood was weighted for variation in each observation. The generalized concentrated negative log-likelihood ($-L_l$; Parma 2002; Deriso et al. 2007) is:

$$-L_l = 0.5 * \sum_i n_i * \ln\left(\frac{\sum_i RSS_i}{\sum_i n_i}\right)$$

where n_i is the total number of observations and RSS_i is the weighted residual sum-of-squares from dataset i. Equations for the weighted residual sum-of-squares of total removals (C) and escapement numbers (E) are:

$$RSS_C = \lambda_C \sum_y \left(\frac{\log_e(C_y + 1e^{-5}) - \log_e(\hat{C}_y + 1e^{-5})}{CV_y}\right)^2$$

$$RSS_I = \lambda_E \sum_y \left(\frac{\log_e(I_y + 1e^{-5}) - \log_e(\hat{I}_y + 1e5)}{CV_y}\right)^2$$

where CV_y is the coefficient of variation for the observed catch or index estimate in year y, and λ_C and λ_E are the relative weights (Parma 2002; Deriso et al. 2007). The CVs for the YOY index were high; therefore, the lambda value for total catch was set to 10 to force the model to fit the pattern in total catch since the catch values are likely more accurate.

For catch age composition data, a multinomial error distribution is assumed and the negative log-likelihood is calculated using the general equation:

$$-L_p = \lambda_p \sum_y \sum_s -n_{y,s} \sum_a (P_{y,s,a} + 1e^{-5}) \cdot \ln(\hat{P}_{y,s,a} + 1e^{-5})$$

where $n_{y.s}$ is the effective number of fish of sex s aged in year y, and $P_{y,s,a}$ is the observed proportions of catch-at-age.

Effective sample size is estimated using the iterative procedures of McAllister and Ianelli (1997). In essence, the average effective sample size for catch age (or length) composition data of each sex is calculated using the following formula:

$$\hat{\bar{n}}_s = \frac{\sum_y \hat{n}_{y,s}}{d_{y,s}}$$

and $\hat{n}_y$ is defined as:

$$\hat{n}_{y,s} = \frac{\sum_a \hat{P}_{y,s,a}(1-\hat{P}_{y,s,a})}{\sum_a (P_{y,s,a} - \hat{P}_{y,s,a})^2}$$

where $\hat{P}_{y,s,a}$ is the predicted proportion-at-age *a* (or *l* for length data) in year *y* from the escapement numbers, $P_{y,s,a}$ is the observed proportion-at-age, and d_y is the number of years of data for escapement series. The average effective sample size is applied, re-calculated, and re-substituted until the average effective sample size stabilizes under equal weighting of all likelihood components.

The total log-likelihood of the model is:

$$f = -L_l - L_p$$

The total log-likelihood was estimated by the auto-differentiation routine in AD Model Builder to search for the "best" age-3 abundance estimates that minimize the total log-likelihood. AD Model Builder allows the minimization process to occur in phases. During each phase, a subset of parameters is held fixed and minimization is done over another subset of parameters until eventually all parameters have been included. In this model, the following parameters were solved over two phases:

Phase	
1	average recruitment (log scale) and exploitation rates
2	catchability coefficient(s) (log scale)
3	recruitment deviations

Model fit for all components was checked by using standardized residual plots and root mean square errors. Standardized residuals (*r*) for lognormal (total catch and YOY index) were calculated as:

Total Catch:

$$r_{C,y} = \frac{\log_e(C_y + 1e^{-5}) - \log_e(\hat{C}_y + 1e^{-5})}{\sqrt{\log_e(CV_y^2 + 1)}}$$

YOY Index:

$$r_{I,y} = \frac{\log_e(I_y + 1e^{-5}) - \log_e(\hat{I}_y + 1e^{-5})}{\sqrt{\log_e(CV_y^2 + 1)}}$$

The root mean square error for total catch and the YOY index was calculated as:

YOY Index

$$RMSE_C = \sqrt{\frac{\sum_y r_{C,y}^2}{n}}$$

Total Catch

$$RMSE_I = \sqrt{\frac{\sum_y r_{I,y}^2}{n}}$$

where n is the total for Total Catch or YOY index values.
For catch age composition data, standardized residuals were derived as:

$$r_{y,s,a} = \frac{P_{y,s,a} - \hat{P}_{y,s,a}}{\sqrt{\frac{\hat{P}_{y,s,a}(1-\hat{P}_{y,s,a})}{\hat{n}_s}}}$$

where n_s is the average effective sample size for sex s and type of data.

16.11.1.2. Reference Point Derivation

Reference points for management were derived using three analytical approaches. First, yield-per-recruit (YPR) analyses were conducted to derive $F_{0.10}$ (F where slope between two adjacent YPR values is 10% of the slope at the origin) and F_{MAX} (F at maximum yield) reference values. Second, spawning biomass-per-recruit (SPR) analysis was conducted to derive the $F_{40\%}$ and $F_{20\%}$ reference points (fishing mortality rates that reduce the spawning biomass to 40% and 20% of the maximum unfished biomass, respectively). Third, recruitment and spawning stock biomass estimates in conjunction with SPR and YPR (production model method in Gibson and Myers 2003b) were used to derive values for F_{MED} (level of fishing mortality where recruitment has been sufficient to balance losses to fishing mortality in half the observed years), F_{COL} (the fishing mortality that drives the population to extinction), F_{MSY} (the fishing rates that produces maximum sustainable yield), SSB_{MSY} (the spawning stock biomass at MSY), and $\text{SSB}_{20\%}$ (minimum threshold population size).

The YPR and SPR analyses follow the model adapted by Gibson and Myers (2003c) for alewife. For a given F, YPR is calculated as:

$$YPR_F = \sum_{a=3}^{\max a} SS_a w_a (1 - e^{-F})$$

where SS_a is given by:

$$SS_3 = p_3$$
$$SS_4 = SS_3 e^{-M_{m,3}-F} + (1-p_3)e^{-M_{i,3}} p_4$$
$$SS_5 = SS_4 e^{-M_{m,4}-F} + (1-p_3)(1-p_4)e^{-M_{i,3}-M_{i,4}} p_5$$
$$SS_6 = SS_5 e^{-M_{m,5}-F} + (1-p_3)(1-p_4)(1-p_5)e^{-M_{i,3}-M_{i,4}-M_{i,5}} p_6$$
$$SS_7 = SS_6 e^{-M_{m,6}-F} + (1-p_3)(1-p_4)(1-p_5)(1-p_6)e^{-M_{i,3}-M_{i,4}-M_{i,5}-M_{i,6}} p_7$$
$$SS_8 = SS_7 e^{-M_{m,7}-F} + (1-p_3)(1-p_4)(1-p_5)(1-p_6)(1-p_7)e^{-M_{i,3}-M_{i,4}-M_{i,5}-M_{i,6}-M_{i,7}} p_8$$

Where a is the age of the fish, p_a is the proportion mature at that age, $M_{m,a}$ and $M_{i,a}$ are the instantaneous natural mortality rates for mature and immature fish of age a, and w_a is the female weight at age.

Since a plus group was used in the model, one additional SS_a was calculated to match the maximum observed age (9) for female blueback:

$$SS_9 = SS_8 e^{-M_{m,8}-F} + (1-p_3)(1-p_4)(1-p_5)(1-p_6)(1-p_7)(1-p_8)e^{-M_{i,3}-M_{i,4}-M_{i,5}-M_{i,6}-M_{i,7}-M_{i,8}} p_8$$

Similarly, SPR is calculated as:

$$SPR_F = \sum_{a=3}^{\max a} SS_a w_a e^{-F}$$

YPR and SPR were calculated for a set of Fs that ranged from 0 to 5 with an increment of 0.01. F_{MAX} was found by selecting the fishing mortality where YPR_F takes its largest value, and $F_{0.10}$ was found by selecting the fishing mortality where the marginal gain in yield was 10% that at F = 0. The $SPR_{x\%}$ reference points were found by selecting the fishing mortality rate where SPR_F was x% that of $SPR_{F=0}$. Data from 1976 were used to calculate SPR and YPR values to develop historical estimates of population quantities before the decline in abundance and changes in age structure.

F_{MED} was calculated by finding the fishing mortality rate that produced a SPR replacement line with a slope that equals the median survival ratio (median of R_y/SSB_{y-3}) from the spawner-recruitment (S-R) biomass estimates. The remaining quantities were produced using a production model based on the Beverton-Holt spawner-recruit model. A Beverton-Holt spawner-recruit model was fit externally to the age-3 recruitment numbers (R_y) and corresponding spawning stocking biomass (SSB_{y-3}). The model is:

$$R_y = \frac{aSSB_{y-3}}{1 + (aSSB_{y-3} / R_0)} e^{\epsilon}$$

Here, a is the slope at the origin of the spawner-recruit relationship (the maximum rate at which spawners can produce recruits at low population sizes) and R_0 is the asymptotic recruitment level which is the carrying capacity expressed as the number of fish that survive to age-3 (Gibson and Myers 2003b, 2003c). The linearized form of the model:

$$\log_e(R_y) = \log_e(a) + \log_e(SSB_{y-3}) - \log_e(1 + aSSB_{y-3}/R_0) + \varepsilon$$

was fitted to the spawner-recruitment data using non-linear least-squares regression. Only estimates of recruitment from 1978–2005 and SSB from 1975–2002 were used to estimate the S-R relationship to eliminate the influence and possible bias of the static stock abundance estimates during the first year (1972) and the retrospective bias near the terminal (see below). For a given level of F, the equilibrium spawning biomass (SSB*) is calculated using the relationship:

$$SSB^* = \frac{(\hat{a}SPR_F - 1)\hat{R}_0}{\hat{a}}$$

The corresponding equilibrium number of recruits (R*) is found by substituting SSB* in the spawner-recruit model:

$$R^* = \frac{\hat{a}SSB^*}{1 + (\hat{a}SSB^* / \hat{R}_0)}$$

The equilibrium catch (C*) is R* multiplied by the yield-per-recruit for the given value of F:

$$C^* = R^* \cdot YPR_F$$

F_{MSY} is found by finding the fishing mortality rate that produces the maximum C*, and SSB_{MSY} is the value of SSB* corresponding to this fishing mortality rate. F_{COL} is the value of F where $1/SPR_{F=0} = a$. The minimum threshold population size ($SSB_{20\%}$) was calculated as 20% of the equilibrium spawner abundance in the absence of fishing:

$$SSB_{20\%} = 0.2\frac{(\hat{a}SPR_{F=0} - 1)\hat{R}_0}{\hat{a}}$$

16.11.1.3. Base Model Results

The female sex ratio (f) used in the base model run was 0.5. Initial CVs used for the total catch were 0.30, and for the YOY index, the CVs estimated for the arithmetic mean were used as a proxy since the standard error for the geometric mean was not provided. As noted above, a lambda for the total catch was set of 10 to force the model match the total catch patterns. The root mean square error (RMSE) for the YOY index was 1.96. Based on examination of estimated effective sample sizes, a constant effective sample size for female and male catch age composition was set at 35.

Resulting contributions to total likelihood are listed in Table 16.5. The converged total likelihood was 3,567.7. A total of 78 parameters were estimated in the model. The resulting estimates of recruitment, exploitation rates, and catchability coefficients are given in Table 16.6. The model fit the observed total catch YOY index (Figure 16.11), as well as catch age composition of each sex fairly well (Figures 16.12 and 16.13). Based on coefficients of variation, most parameter estimates, except those near the terminal year, were precise (<0.20; Table 16.6).

16.11.1.4. Exploitation and Fishing Mortality Rates

Exploitation rates for blueback herring in the Chowan River before the 2007 moratorium ranged as low as 0.14 in 1979 to as high as 0.87 in 1986 (Table 16.6; Figure 16.14). Exploitation averaged about 0.28 prior to 1985, increased to an average of 0.70 during 1985–1988, and averaged about 0.40 between 1989 and 2006. Since the moratorium, exploitation rates have been close to zero. Corresponding fishing mortality rates are listed in Table 16.7 and are plotted in Figure 16.14. Fishing mortality averaged about 0.34 prior to 1985, increased to an average of 1.3 during 1985–1988, and averaged about 0.56 between 1989 and 2006. Since the moratorium, fishing mortality has been close to zero.

16.11.1.5. Population Abundance

The abundance estimates of the Chowan River blueback herring stock by sex, maturity phase, year, and age are given in Table 16.8, and total abundance by maturity state and year is given in Table 16.9. Blueback herring total abundance (3+) declined steadily from 134 million fish in 1976 to 55 million fish in 1980 (Table 16.9; Figure 16.14). Total abundance increased through 1983 to 103 million fish but then declined precipitously to its lowest value of 1.1 million fish in 2002 (Figure 16.15). Since 2003, total abundance has averaged 1.9 million fish. Age-3 abundance peaked at 81 million fish in 1975, , and declined precipitously since 1983 to .62 million fish in 2001. Since 2002, total abundance of age-3 fish has averaged 1.0 million fish.

16.11.1.6. Spawning Stock Biomass

Estimates of female spawning stock biomass for blueback herring are provided in Table 16.10. Female SSB fluctuated but declined steadily from the peak of 5.2 million kilograms in 1972 to a low of 0.14 million kilograms in 1986 (Figure 16.14). Female SSB increased slightly to 0.46 million through 1990, but then it declined slowly to its lowest level of 15,000 kilograms in 2003. Since 2004, female SSB has averaged about 61,000 kilograms.

16.11.1.7. Retrospective Analysis

Small to moderate retrospective bias was evident in estimates of age-3 abundance, exploitation rate, female SSB, and total population abundance (Figure 16.16). For age-3 abundance and total population abundance, the terminal year estimate was consistently under-estimated. For exploitation rates and female SSB, the retrospective patterns were over- and under-estimation of the value, respectively.

16.12. BENCHMARKS

The fit of the Beverton-Holt stock-recruitment equation to the age-3 abundance and female SSB is shown in Figure 16.17. A plot of the residuals indicated reasonable model fit (Figure 16.17). The estimates of a and R_0 are 22.529 (SE = 4.698) and 39,930,375 fish (SE = 17,869,407), respectively. The estimate of a was precise (CV=0.21), but the estimate of R_0 was only moderately precise (CV=0.45). Reference points generated from YPR, SPR, and the production model are shown in Table 16.11. For YPR analysis, the fishing mortality rate that maximized the yield-per-recruit, F_{max}, was greater than 5, and $F_{0.1}$ was 1.03 (Figure 16.18). The fishing mortality that reduced the female spawning biomass to 40% and 20% of the level without fishing was 0.53 and 1.01, respectively.

From the spawner-recruit data and production model, F_{MED} was estimated to be 0.59. The fishing mortality rate that produces maximum sustainable yield, F_{MSY}, was 0.39 and corresponding spawning stock bass, SSB_{MSY}, was 1,955,333 kilograms. SSB_{MSY} was higher than the 20% of the equilibrium spawner biomass, $SSB_{20\%}$ (1,195,873 kilograms). Current female spawning stock biomass is only 5% of SSB_{MSY}. The fishing mortality rate that drives the population to extinction, F_{COL}, was 0.91. The relationships between the reference points from the production model are shown with the S-R data in Figure 16.19. The estimates of F_{MSY} and F_{COL} are considerably lower than those estimated for alewife ($F_{\mathrm{MSY}} > 1.0$; $F_{\mathrm{COL}} > 1.82$) in three Canadian rivers by Gibson and Myers (2003b). Fishing mortality rate estimates are compared to the derived reference points in Figure 16.20 and show that fishing mortality exceeded all reference points several times over the time series, particularly after 1985.

16.12.1.Sensitivity Analyses

Sensitivity analyses were conducted to determine the influence of assumed-known input values on the resulting estimates of age-3 abundance, exploitation rates, female SSB, and total population abundance. The sensitivity of the base model to the female sex ratio, proportion mature-at-age, and natural mortality rate inputs were examined. The following changes in input parameters were made:

Female sex ratio:	±20% change
Sex-specific proportions-at-age:	Used average for entire time series
Natural mortality:	±20% change in all age-specific values;
	Linear increase of mature fish base rates to 20% over time from 1990 to 2009

In addition, changes to the total catch were made to determine potential effects of missing recreational catch and by-catch. In this scenario, total catch was increased by 10% and 30% from 1990 to 2006. The time period of increase for this exercise and the linear increase in natural mortality was selected to mirror the increasing striped bass harvest and potential interest in river herring as bait to catch striped bass. Changing the female sex ratio by ± 20% had little impact (< ± 4%) on the estimates of age-3 abundance, exploitation rates, and total population abundance (). The ± 20% change had about an equivalent impact (± 20% change) on the female SSB estimates (Figure 16.20).

Use of the time-series average proportion mature-at-age for each sex had a profound effect on the model output. In a few years, estimates of age-3 abundance, exploitation rates, female SSB, and total population abundance changed by as much as 100% (Figure 16.21). These changes were the result of the worsening agreement between predicted and observed catch age composition.

Increases in the sex- and age-specific natural mortality rates by 20% had large impacts (changes up to ± 20%) on the estimates of age-3 abundance, female SSB, exploitation rates, and total population abundance (Figure 16.22). Decreasing the sex- and age-specific natural mortality rates by 20% had only a moderate impact (some changes up to ± 50%) on the estimates of age-3 abundance, exploitation rates, female SSB, and total population abundance (Figure 16.22).

Linear increases in the sex- and age-specific natural mortality rates of the mature male and female bluebacks from 0% in 1990 to 20% in 2009 had moderate impacts (< ± 40% change) on the estimates of age-3 abundance, exploitation rates, female SSB, and total population abundance (Figure 16.23).

Increases in total catch by 10% and 30% from 1990 to 2006 produced larger estimates of age-3 abundance, female SSB, and total population abundance, and smaller estimates of exploitation rates (Figure 16.24).

16.12.1.1. Alternate Natural Mortality Rates

The impact of alternate estimates of age- and sex-specific natural on model results was evaluated. The Lorenzen (1996) values derived earlier were scaled such that cumulative survival from age 1 to maximum age (9 females; 8 males) was equal to 1.5%. This cumulative survival value comes from the method of Hoenig (1983) as described in Hewitt and Hoenig (2005). The resulting values were:

			Age			
	3	4	5	6	7	8
Female:	0.50	0.47	0.45	0.44	0.42	0.41
Male:	0.55	0.52	0.50	0.48	0.46	0.45

Lower natural mortality rates produced lower estimates of age-3 number, spawning stock biomass, and total population size but higher estimates of exploitation rates (Figure 16.25).

16.13. CONCLUSIONS AND RECOMMENDATIONS

The previous NCRHFMP (NCDMF 2007) concluded that the ASMA river herring stock was undergoing overfishing and was overfished, despite the low TAC. No model used in the assessment (Grist, 2005) was estimated to rebuild the stock within the legal time frame of 10 years. Based on these results, the 2007 FMP recommended a no harvest provision, coupled with various gear restrictions The 2007 NCRHFMP identified four stock recovery indicators for the Chowan River blueback herring stock: a three-year running average juvenile abundance index of greater than 60 fish per haul, a spawning population comprised of greater than 10% repeat spawners, a spawning stock biomass of greater than 4 million pounds (1.8 million kg) and a three-year running average of greater than 8 million age three fish.

The factors leading to this recommendation remain largely unchanged since 2007, despite a fishing pressure that is almost negligibly low. Therefore, although the stock is not currently experiencing overfishing, it remains overfished since the spawning stock biomass remains less than 5% of the amount necessary to replace itself in the complete absence of fishing (Figure 16.10).

Estimates of fishing mortality are well below all estimated thresholds for the final three years (Table 16.7, Figure 16.11). The forward-projecting statistical catch-at-age model estimates juvenile abundance as well below the target of 60 fish per haul (Figure 16.26), with no increasing pattern evident. After an abrupt increase to 8.8% in 2007, the percentage of repeat spawners declined to below its average for the previous decade (Figure 16.4). A Mann-Kendall trend analysis shows that the spawning stock biomass has increased significantly (p=0.002) during the past decade, but remains at approximately 5% of the target of 1.8 million kg (Table 16.10, Figure 16.5). The recruitment target continues at less than 1million fish, well below the 8-million fish target, with no increasing pattern evident.

While current research programs are recommended to continue, assessing progress towards recovery goals would be improved with additional research and surveys. Many recommendations made in the previous assessment (Grist, 2005) and the 2007 NCRHFMP are echoed here. A complete assessment of all river herring spawning and nursery areas in NC are identified in the 2007 NCRHFMP as needed research. In addition, the NCRHFMP identified four stock recovery indicators as restoration targets. Data collected through a Chowan River Pound Net Survey and a juvenile abundance survey to monitor these indicators are essential in determining stock status of Chowan River blueback herring.

Although the Chowan River is the dominant system for river herring in North Carolina, the 2007 NCRHFMP identified a research need to expand data collection to all areas of the Albemarle Sound as well as other systems in the state.

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Table 16.1 Commercial landings of river herring in North Carolina, 1972-2006.

Year	Atlantic Ocean	Albemarle Sound Area (excluding Chowan River)	Chowan River	Other Areas	Lb
1972	--	643,026	10,594,117	0	11,237,143
1973	--	573,931	7,350,578	1,389	7,925,898
1974	--	467,992	5,736,905	4,645	6,209,542
1975	2,338	917,723	5,031,756	250	5,952,067
1976	--	666,584	5,734,776	0	6,401,360
1977	--	1,102,125	7,418,218	3,470	8,523,813
1978	--	954,939	5,615,113	37,101	6,607,153
1979	19,388	796,099	4,303,663	0	5,119,150
1980	*	796,237	5,382,954	39,332	6,218,523
1981	143,232	1,245,401	3,314,447	50,643	4,753,723
1982	7,679	1,872,156	7,459,968	97,900	9,437,703
1983	--	1,453,033	4,405,915	9,384	5,868,332
1984	9,497	1,931,492	4,561,503	13,617	6,516,109
1985	*	2,665,334	8,871,391	11,553	11,548,278
1986	40,270	999,093	5,767,874	7,086	6,814,323
1987	19,279	838,689	2,334,719	2,288	3,194,975
1988	19,517	1,570,788	2,259,888	341,018	4,191,211
1989	--	581,486	908,145	1,446	1,491,077
1990	11,073	433,891	710,849	1,812	1,157,625
1991	--	372,843	1,202,535	0	1,575,378
1992	110,794	476,649	1,135,340	395	1,723,178
1993	--	115,072	801,115	*	916,235
1994	38,834	211,372	390,852	3,251	644,309
1995**	19,174	150,082	280,681	4,049	453,984
1996**	*	123,725	404,884	894	529,503
1997**	5,568	126,453	201,929	861	334,809
1998**	--	143,424	377,312	1,197	521,930
1999**	--	110,657	332,464	373	443,494
2000**	599	140,696	182,658	8,378	332,336
2001**	*	89,767	201,717	15,277	306,761
2002**	*	75,736	92,979	6,145	174,860
2003**	*	98,440	84,591	16,685	199,716
2004**	*	107,430	77,177	3,934	188,542
2005**	--	92,688	157,088	245	250,021
2006**	--	40,590	67,404	1,249	109,243

**Denotes confidential data*
***Season or TAC in ASMA*

Table 16.2 Commercial landings and value of research set-aside river herring harvest in North Carolina, 2007-2010.

Year	# of Permits Issued	Quota (lbs/permit/period)	Harvest (lbs)
2007	15	200	1,103
2008	13	250	1,292
2009	27	125	643
2010	30	125	1,765
Average	21	175	1,201
Total	85		4,803

Table 16.3 Catch-per-unit effort of blueback herring and alewife in the commercial pound net fishery, Chowan River, NC.

Year	Total PN fished	Weeks fished	Effort in PN weeks	PN BB Catch	BB CPUE	PN ALE.Catch	ALE. CPUE
1977	624	9	4,854	7,001,059	1,442	291,711	60
1978	383	10	3,645	4,050,767	1,111	1,209,970	332
1979	502	12	4,996	2,118,907	424	2,035,813	407
1980	500	9	3,090	3,388,983	1,096	1,824,837	590
1981	525	10	4,120	2,041,319	495	1,198,870	291
1982	480	11	4,461	5,388,115	1,207	1,992,865	446
1983	486	12	4,895	2,380,261	486	1,947,488	398
1984	480	12	5,040	3,196,416	634	1,305,578	259
1985	421	12	3,708	6,845,568	1,846	1,930,802	520
1986	451	12	4,241	4,244,280	1,000	1,340,299	316
1987	501	11	4,969	1,353,601	272	980,194	197
1988	506	12	4,689	1,430,114	305	804,440	171
1989	348	9	3,063	626,222	204	281,347	92
1990	360	11	3,077	610,931	198	99,455	32
1991	226	11	2,037	720,218	353	294,174	144
1992	180	12	1,669	806,091	483	329,249	197
1993	197	11	1,729	640,092	370	160,023	92
1994	175	8	1,173	377,728	322	7,709	6
1995	73	8	484	263,163	543	5,371	11
1996	95	10	555	394,491	711	3,985	7
1997	102	5	461	190,071	412	1,920	4
1998	75	11	463	361,285	780	7,373	16
1999	68	8	471	318,495	676	6,500	14
2000	51	9	445	146,126	328	36,532	82
2001	63	7	385	136,998	356	64,470	167
2002	62	12	648	47,235	73	38,648	60
2003	50	10	419	45,326	108	35,614	85
2004	36	12	376	29,595	79	42,589	113
2005	41	15	447	148,552	332	7,424	16
2006	39	13	355	45,578	128	20,224	57

Table 16.4 Percentage of blueback herring and alewife repeat spawners (spawned more than once) from the Chowan River pound net fishery, 1972-2009.

Year	Percent BB	Percent Alewife
1972	21.1	15.9
1973	18.3	13.2
1974	16.4	4.6
1975	3.9	9.3
1976	5.3	14.4
1977	7.3	4.1
1978	7.1	4.9
1979	20.1	3.3
1980	24.6	13.7
1981	16.2	9.7
1982	13.9	0.5
1983	1.6	2.5
1984	1.3	10.2
1985	3.3	0.0
1986	6.1	0.0
1987	3.3	0.7
1988	2.0	2.5
1989	0.6	0.0
1990	2.5	No Samples
1991	4.2	5.7
1992	3.7	12.5
1993	4.7	No Samples
1994	1.2	No Samples
1995	1.6	No Samples
1996	2.8	No Samples
1997	2.7	No Samples
1998	2.7	No Samples
1999	2.6	No Samples
2000	6.0	1.1
2001	3.1	5.0
2002	4.7	14.8
2003	5.9	5.4
2004	2.9	10.4
2005	2.1	12.6
2006	0.0	3.1
2007^	7.7	10.0
2008*	5.8	8.0
2009*	1.7	10.5

^ Based on research set aside data
*Based on samples obtained from contracted pound net sets

Table 16.5 Likelihood components with respective contributions in base model run.

Likelihood Components

	Weight	RSS
YOY Index	1	104.056
Total Catch	10	14.4095
Catch Age Comps	1	3549.76
Total Likelihood		3567.68
Number of Estimates		78
AIC		7291.37

Catch RMSE	0.199002
Index RMSE	1.95584

Table 16.6 Parameter estimates and associated standard deviations of base model configuration.

Year	Age-3 Numbers	SD	CV
1972	64,476,000	5.93E+06	0.09
1973	39,926,000	6.55E+06	0.16
1974	68,271,400	1.00E+07	0.15
1975	81,223,300	1.01E+07	0.12
1976	74,589,600	9.53E+06	0.13
1977	55,735,400	7.67E+06	0.14
1978	33,063,000	5.01E+06	0.15
1979	26,287,600	4.46E+06	0.17
1980	26,402,600	4.64E+06	0.18
1981	44,989,000	6.12E+06	0.14
1982	55,936,600	7.12E+06	0.13
1983	66,017,800	7.00E+06	0.11
1984	25,929,900	3.66E+06	0.14
1985	12,777,100	1.91E+06	0.15
1986	9,536,740	1.30E+06	0.14
1987	9,844,720	1.19E+06	0.12
1988	6,089,410	9.18E+05	0.15
1989	6,987,980	9.84E+05	0.14
1990	8,391,700	9.66E+05	0.12
1991	8,479,400	8.71E+05	0.10
1992	2,375,930	4.21E+05	0.18
1993	4,934,790	5.93E+05	0.12
1994	3,443,090	4.58E+05	0.13
1995	2,497,120	3.87E+05	0.15
1996	3,856,640	4.66E+05	0.12
1997	3,344,890	3.69E+05	0.11
1998	1,721,320	2.22E+05	0.13
1999	1,217,790	1.52E+05	0.13
2000	1,019,300	1.44E+05	0.14
2001	623,960	1.22E+05	0.20
2002	631,886	1.47E+05	0.23
2003	708,111	1.74E+05	0.25
2004	1,231,180	2.93E+05	0.24
2005	1,308,180	4.39E+05	0.34
2006	879,986	3.70E+05	0.42
2007	1,487,230	6.40E+05	0.43
2008	1,649,470	7.40E+05	0.45
2009	504,497	437682	0.87

Year	u	SD	CV
1972	0.263	0.031	0.12
1973	0.330	0.047	0.14
1974	0.383	0.059	0.15
1975	0.160	0.026	0.16
1976	0.224	0.032	0.14
1977	0.487	0.066	0.13
1978	0.252	0.037	0.15
1979	0.140	0.022	0.16
1980	0.320	0.048	0.15
1981	0.285	0.050	0.17
1982	0.455	0.061	0.13
1983	0.160	0.023	0.14
1984	0.206	0.025	0.12
1985	0.674	0.048	0.07
1986	0.872	0.040	0.05
1987	0.610	0.070	0.11
1988	0.644	0.065	0.10
1989	0.392	0.058	0.15
1990	0.224	0.031	0.14
1991	0.336	0.039	0.12
1992	0.413	0.044	0.11
1993	0.657	0.067	0.10
1994	0.434	0.052	0.12
1995	0.360	0.049	0.14
1996	0.514	0.061	0.12
1997	0.169	0.023	0.13
1998	0.479	0.048	0.10
1999	0.681	0.053	0.08
2000	0.513	0.054	0.10
2001	0.604	0.068	0.11
2002	0.333	0.063	0.19
2003	0.371	0.082	0.22
2004	0.156	0.040	0.26
2005	0.475	0.132	0.28
2006	0.182	0.070	0.39
2007	0.001	0.001	0.44
2008	0.002	0.001	0.44
2009	0.001	0.000	0.44

q	Estimate	SD	CV
1	2.44E-07	3.10E-08	0.13

Table 16.7 Derived fishing mortality values for Chowan River blueback herring.

Mature Fish			
Year	F	SD	CV
1972	0.305	0.042	0.14
1973	0.401	0.070	0.18
1974	0.483	0.096	0.20
1975	0.175	0.031	0.18
1976	0.254	0.041	0.16
1977	0.667	0.128	0.19
1978	0.291	0.049	0.17
1979	0.151	0.026	0.17
1980	0.386	0.071	0.18
1981	0.336	0.069	0.21
1982	0.607	0.113	0.19
1983	0.175	0.028	0.16
1984	0.230	0.032	0.14
1985	1.120	0.146	0.13
1986	2.053	0.309	0.15
1987	0.941	0.179	0.19
1988	1.033	0.182	0.18
1989	0.497	0.095	0.19
1990	0.254	0.040	0.16
1991	0.410	0.059	0.14
1992	0.532	0.075	0.14
1993	1.071	0.196	0.18
1994	0.570	0.092	0.16
1995	0.446	0.076	0.17
1996	0.722	0.126	0.17
1997	0.185	0.027	0.15
1998	0.652	0.092	0.14
1999	1.143	0.166	0.15
2000	0.720	0.111	0.15
2001	0.926	0.173	0.19
2002	0.406	0.095	0.23
2003	0.464	0.131	0.28
2004	0.170	0.047	0.28
2005	0.644	0.251	0.39
2006	0.201	0.086	0.43
2007	0.001	0.001	0.44
2008	0.002	0.001	0.44
2009	0.001	0.000	0.44

Table 16.8 Estimates of population abundance by sex, maturity state, year, and age.

		Female Immature Age					
Year	Total	3	4	5	6	7	8+
1972	19,766,980	18,053,300	1,695,280	18,400	0	0	0
1973	22,826,950	19,723,500	3,071,030	32,420	0	0	0
1974	36,466,683	34,135,700	2,269,080	61,903	0	0	0
1975	40,976,900	39,718,200	1,258,700	0	0	0	0
1976	41,618,960	36,698,100	4,920,860	0	0	0	0
1977	40,136,304	27,867,700	12,250,800	17,804	0	0	0
1978	22,937,488	16,366,200	6,507,970	63,318	0	0	0
1979	14,481,139	12,539,200	1,915,030	26,909	0	0	0
1980	16,639,840	13,082,500	3,507,780	49,489	71	0	0
1981	27,717,575	22,494,500	4,978,320	244,755	0	0	0
1982	31,515,120	27,688,600	3,826,520	0	0	0	0
1983	35,547,740	32,348,700	3,199,040	0	0	0	0
1984	17,446,080	12,420,400	5,025,680	0	0	0	0
1985	11,243,150	6,388,540	4,854,610	0	0	0	0
1986	6,953,091	4,768,370	2,129,520	55,201	0	0	0
1987	5,505,510	4,681,160	811,142	13,208	0	0	0
1988	3,578,650	3,044,710	533,940	0	0	0	0
1989	3,692,056	3,413,630	278,426	0	0	0	0
1990	3,545,486	3,394,440	151,046	0	0	0	0
1991	3,794,990	3,561,350	233,640	0	0	0	0
1992	1,629,206	1,121,440	507,766	0	0	0	0
1993	2,716,618	2,408,180	302,139	6,299	0	0	0
1994	2,124,655	1,666,460	458,195	0	0	0	0
1995	1,507,889	1,223,590	284,299	0	0	0	0
1996	2,352,359	1,928,320	421,100	2,939	0	0	0
1997	1,956,022	1,628,960	324,233	2,829	0	0	0
1998	1,231,369	860,660	369,201	1,508	0	0	0
1999	818,688	608,895	209,030	763	0	0	0
2000	627,019	509,648	113,158	4,213	0	0	0
2001	459,551	310,732	148,585	234	0	0	0
2002	422,118	315,943	106,175	0	0	0	0
2003	482,443	354,056	127,838	549	0	0	0
2004	653,796	589,738	64,058	0	0	0	0
2005	622,532	588,029	34,503	0	0	0	0
2006	481,913	439,993	41,920	0	0	0	0
2007	739,596	649,174	90,422	0	0	0	0
2008	930,308	824735	104685	888	0	0	0
2009	364,159	252248	111911	0	0	0	0

		Female Mature Age					
Year	Total	3	4	5	6	7	8+
1972	35,432,718	14,184,700	12,321,100	5,551,980	2,167,660	859,551	347,727
1973	20,239,939	239,556	10,945,400	5,537,960	2,167,660	859,551	489,812
1974	16,070,182	0	7,506,700	5,312,950	1,972,190	780,719	497,623
1975	22,836,069	893,457	15,523,900	3,567,450	1,761,740	654,814	434,708
1976	25,837,012	596,716	14,975,100	7,386,400	1,579,190	795,616	503,990
1977	18,782,957	0	6,019,150	8,528,720	3,020,840	658,895	555,352
1978	18,716,349	165,315	7,193,020	7,864,480	2,316,440	833,659	343,435
1979	17,462,720	604,614	6,192,070	6,116,250	3,133,750	931,644	484,392
1980	11,632,484	118,812	2,912,680	3,692,730	2,787,770	1,449,830	670,662
1981	7,249,182	0	1,493,340	2,591,950	1,350,180	1,019,830	793,882
1982	12,976,973	279,683	7,232,780	3,124,750	1,105,970	519,168	714,622
1983	16,756,929	660,178	10,488,800	4,014,790	897,839	324,200	371,122
1984	20,406,776	544,528	11,150,900	6,205,860	1,777,730	405,589	322,169
1985	12,318,412	0	1,464,490	7,175,990	2,599,530	759,704	318,698
1986	5,597,709	0	1,011,370	2,700,990	1,235,120	456,467	193,762
1987	3,272,027	241,196	1,533,200	1,154,530	211,892	85,273	45,936
1988	2,859,557	0	1,813,810	728,507	244,552	44,486	28,202
1989	2,106,438	80,362	1,218,490	609,729	136,762	46,837	14,258
1990	3,140,580	801,407	1,551,280	527,073	195,610	44,762	20,448
1991	3,444,351	678,352	1,740,870	700,051	215,598	81,630	27,850
1992	2,611,186	66,526	1,464,550	718,076	245,051	76,994	39,989
1993	1,366,106	59,218	268,422	700,779	222,412	77,434	37,842
1994	1,187,267	55,090	735,749	203,708	129,962	41,005	21,754
1995	1,146,990	24,971	550,322	451,870	60,744	39,537	19,546
1996	708,541	0	188,327	326,015	152,470	20,911	20,818
1997	1,065,453	43,484	623,816	262,093	85,044	39,838	11,179
1998	1,060,979	0	449,429	433,928	116,304	38,007	23,311
1999	695,265	0	214,108	311,029	119,953	32,583	17,592
2000	407,346	0	186,202	139,095	52,675	20,567	8,808
2001	267,861	1,248	101,980	105,075	37,905	13,786	7,867
2002	179,367	0	46,838	97,669	22,063	8,075	4,723
2003	144,896	0	27,494	70,464	34,328	7,911	4,699
2004	250,528	25,855	110,012	75,012	23,662	11,617	4,370
2005	464,866	66,063	266,165	81,092	33,379	10,742	7,424
2006	391,462	0	264,239	90,080	22,456	9,430	5,257
2007	409,065	94,439	125,898	133,378	38,852	9,881	6,617
2008	471,848	0	260842	110826	70231	20871	9078
2009	595,218	0	293565	188682	58801	37713	16457

Table 16.8. Continued.

Male Immature Age							
Year	Total	3	4	5	6	7	8+
1972	19,927,002	18,730,300	1,194,330	2,372	0	0	0
1973	19,054,260	17,787,000	1,267,260	0	0	0	0
1974	34,378,862	33,487,100	891,762	0	0	0	0
1975	39,554,890	37,403,300	2,151,590	0	0	0	0
1976	37,082,090	34,460,400	2,621,690	0	0	0	0
1977	38,703,500	27,867,700	10,835,800	0	0	0	0
1978	20,635,714	15,490,000	5,059,620	86,094	0	0	0
1979	13,122,458	12,315,700	806,758	0	0	0	0
1980	15,124,954	12,897,700	2,218,040	9,214	0	0	0
1981	26,030,584	22,292,100	3,697,730	40,754	0	0	0
1982	28,543,270	25,982,500	2,560,770	0	0	0	0
1983	30,708,020	29,278,900	1,429,120	0	0	0	0
1984	13,687,760	10,851,700	2,836,060	0	0	0	0
1985	9,007,560	6,139,390	2,868,170	0	0	0	0
1986	5,419,508	4,549,030	857,659	12,819	0	0	0
1987	4,852,357	4,577,790	274,567	0	0	0	0
1988	2,421,304	2,298,750	122,554	0	0	0	0
1989	2,785,455	2,718,320	67,135	0	0	0	0
1990	2,272,787	2,248,970	23,817	0	0	0	0
1991	2,792,311	2,713,410	78,818	83	0	0	0
1992	1,115,190	1,072,730	42,264	196	0	0	0
1993	2,478,836	2,351,430	127,406	0	0	0	0
1994	1,246,731	1,158,600	88,131	0	0	0	0
1995	1,318,864	1,199,870	118,994	0	0	0	0
1996	1,612,167	1,561,940	50,227	0	0	0	0
1997	1,084,963	1,021,860	63,103	0	0	0	0
1998	872,435	771,151	100,971	313	0	0	0
1999	662,164	573,579	88,585	0	0	0	0
2000	509,932	497,927	12,005	0	0	0	0
2001	328,695	305,428	23,267	0	0	0	0
2002	318,804	308,992	9,812	0	0	0	0
2003	337,127	327,501	9,626	0	0	0	0
2004	437,109	431,530	5,579	0	0	0	0
2005	513,553	510,192	3,361	0	0	0	0
2006	381,088	365,194	15,894	0	0	0	0
2007	576,006	569,607	6,399	0	0	0	0
2008	835,872	757,931	77,909	32	0	0	0
2009	363,494	245,438	118,056	0	0	0	0

Male Mature Age							
Year	Total	3	4	5	6	7	8+
1972	34,607,460	13,507,700	12,769,200	5,264,860	1,987,090	772,348	306,262
1973	23,327,864	2,175,970	12,696,300	5,267,230	1,987,090	772,348	428,926
1974	16,914,643	648,578	8,475,260	4,850,520	1,804,560	701,513	434,212
1975	23,089,760	3,208,320	14,343,200	3,040,470	1,531,940	587,293	378,537
1976	29,200,015	2,834,400	16,895,500	7,047,940	1,306,140	678,140	437,895
1977	18,616,152	0	7,007,950	7,809,310	2,797,230	534,176	467,486
1978	19,711,018	1,041,480	8,505,050	7,080,080	2,050,020	756,664	277,724
1979	17,588,286	828,059	7,112,050	5,670,170	2,752,700	808,166	417,141
1980	12,168,268	303,630	4,123,310	3,428,820	2,495,360	1,248,320	568,828
1981	8,095,685	202,451	2,680,750	2,453,070	1,197,840	894,753	666,821
1982	15,106,506	1,985,750	8,360,380	2,787,780	918,099	451,469	603,028
1983	20,360,589	3,730,010	11,744,600	3,533,950	777,343	263,799	310,887
1984	22,784,463	2,113,290	12,940,100	5,607,290	1,518,560	344,203	261,020
1985	13,168,564	249,153	3,231,070	6,513,100	2,279,380	636,101	259,760
1986	5,962,838	219,345	2,170,290	1,935,210	1,087,900	392,325	157,768
1987	3,107,525	344,565	1,953,380	564,219	133,651	73,622	38,088
1988	3,595,738	745,953	2,171,150	514,920	112,678	27,504	23,533
1989	2,526,217	775,666	1,181,060	444,710	93,808	21,153	9,820
1990	4,044,813	1,946,870	1,529,050	390,175	138,453	30,095	10,170
1991	4,106,436	1,526,290	1,751,010	600,773	154,883	56,634	16,846
1992	2,787,751	115,232	1,771,690	616,185	204,126	54,216	26,301
1993	1,355,510	115,968	427,696	537,782	185,313	63,225	25,526
1994	1,918,994	562,946	1,075,780	136,057	94,313	33,489	16,410
1995	1,077,211	48,694	599,918	345,873	39,372	28,123	15,230
1996	1,306,604	366,381	548,978	249,727	113,256	13,285	14,977
1997	1,690,221	650,581	783,793	157,351	62,067	29,006	7,424
1998	1,213,783	89,509	659,505	354,375	66,892	27,189	16,314
1999	690,674	35,316	309,464	220,696	94,596	18,369	12,233
2000	434,517	11,722	272,665	92,970	35,994	15,898	5,268
2001	338,199	6,552	221,876	71,838	23,146	9,234	5,554
2002	224,806	6,951	140,119	55,185	14,557	4,833	3,162
2003	247,656	26,554	143,032	51,253	18,823	5,116	2,878
2004	420,944	184,062	161,964	49,461	16,498	6,244	2,715
2005	529,619	143,900	282,295	70,645	21,359	7,341	4,079
2006	447,455	74,799	269,229	75,289	18,985	5,915	3,238
2007	536,140	174,005	201,141	117,251	31,513	8,188	4,042
2008	536,720	66,804	283,927	102,890	59,914	16,593	6,592
2009	566,160	6,811	283,327	179,430	52,571	31,536	12,486

Table 16.9 Total population abundance (number of fish 3+) estimate for the Chowan River blueback herring stock by maturity state.

Year	Immature	Mature	Total
1972	39,693,983	70,040,178	109,734,161
1973	41,881,210	43,567,803	85,449,013
1974	70,845,545	32,984,825	103,830,370
1975	80,531,790	45,925,829	126,457,619
1976	78,701,050	55,037,027	133,738,077
1977	78,839,804	37,399,109	116,238,913
1978	43,573,203	38,427,367	82,000,570
1979	27,603,597	35,051,006	62,654,603
1980	31,764,795	23,800,752	55,565,547
1981	53,748,159	15,344,867	69,093,026
1982	60,058,390	28,083,479	88,141,869
1983	66,255,760	37,117,518	103,373,278
1984	31,133,840	43,191,239	74,325,079
1985	20,250,710	25,486,976	45,737,686
1986	12,372,598	11,560,547	23,933,145
1987	10,357,867	6,379,552	16,737,419
1988	5,999,954	6,455,295	12,455,249
1989	6,477,511	4,632,655	11,110,166
1990	5,818,273	7,185,392	13,003,665
1991	6,587,301	7,550,787	14,138,087
1992	2,744,396	5,398,937	8,143,332
1993	5,195,454	2,721,616	7,917,069
1994	3,371,386	3,106,261	6,477,647
1995	2,826,753	2,224,201	5,050,954
1996	3,964,526	2,015,144	5,979,670
1997	3,040,986	2,755,674	5,796,659
1998	2,103,805	2,274,762	4,378,567
1999	1,480,852	1,385,939	2,866,791
2000	1,136,952	841,863	1,978,815
2001	788,246	606,060	1,394,307
2002	740,922	404,173	1,145,095
2003	819,570	392,552	1,212,121
2004	1,090,905	671,472	1,762,377
2005	1,136,085	994,486	2,130,570
2006	863,000	838,917	1,701,917
2007	1,315,602	945,206	2,260,808
2008	1,766,180	1,008,568	2,774,748
2009	727,653	1,161,378	1,889,031

Table 16.10 Estimates of female spawning stock biomass (kilograms) for the Chowan River blueback herring stock

		Female SSB (kg)					
		Age					
Year	Total	3	4	5	6	7	8+
1972	5225143	1944810	1861860	855338	354721	133056	75358
1973	2768179	23417	1370370	778638	343958	155382	96415
1974	2063930	0	866408	688631	288489	130104	90298
1975	3781748	109509	2437070	628930	350521	148425	107293
1976	4014457	67572	2171980	1203080	290286	166614	114925
1977	2038547	0	577430	918810	367282	91265	83760
1978	2912659	18045	1005640	1234750	410451	168284	75489
1979	3153966	75918	995848	1104640	638746	216336	122478
1980	1759074	11796	370384	527332	449287	266194	134081
1981	1241358	0	213485	420563	248030	192447	166833
1982	1483053	19813	756725	379710	146448	76384	103973
1983	2812416	74842	1620670	748456	196030	72690	99728
1984	2948732	57533	1497060	916973	314928	86995	75244
1985	761371	0	80311	416944	176496	57036	30585
1986	144928	0	21028	68290	34240	14060	7311
1987	226036	11955	97534	85160	17697	8420	5271
1988	170264	0	98155	46945	18806	3405	2952
1989	238725	6845	123806	78275	19554	7694	2550
1990	457807	101336	229851	75642	37633	8681	4664
1991	400196	60794	181443	100847	34064	17612	5436
1992	272198	5471	138505	78877	30228	12211	6906
1993	79332	2030	13799	40589	13263	5838	3813
1994	98670	3738	53258	16243	17639	4174	3617
1995	121908	1918	54232	46844	7774	7464	3677
1996	69715	0	17197	30719	16440	2387	2973
1997	173968	3974	84992	53782	17734	10756	2730
1998	91596	0	34406	37061	11750	4810	3569
1999	38579	0	10714	17547	6614	2056	1648
2000	33737	0	13679	11911	4715	2171	1260
2001	20160	59	6300	7947	3452	1485	916
2002	22390	0	4870	12174	3235	1184	926
2003	15460	0	2145	7491	4060	896	869
2004	32303	2618	12998	9495	3794	2314	1084
2005	36781	4163	19570	7240	3331	1331	1146
2006	51024	0	32421	11789	3729	1820	1264
2007	73233	12920	22127	25573	8342	2329	1943
2008	75164	0	35932	17700	13951	4917	2664
2009	95432	0	39899	30169	11635	8894	4835

Table 16.11 Reference points derived from YPR, SPR and production model methods

	Basis	Estimate
Yield Per Recruit	F0.1	1.03
	Fmax	5
Spawner Per Recruit	F40%	0.51
	F20%	1.01
Production Model	Fmed	0.59
	Fcol	0.91
	Fmsy	0.39
	SSBmsy	1955333
	SSB20%	1195873

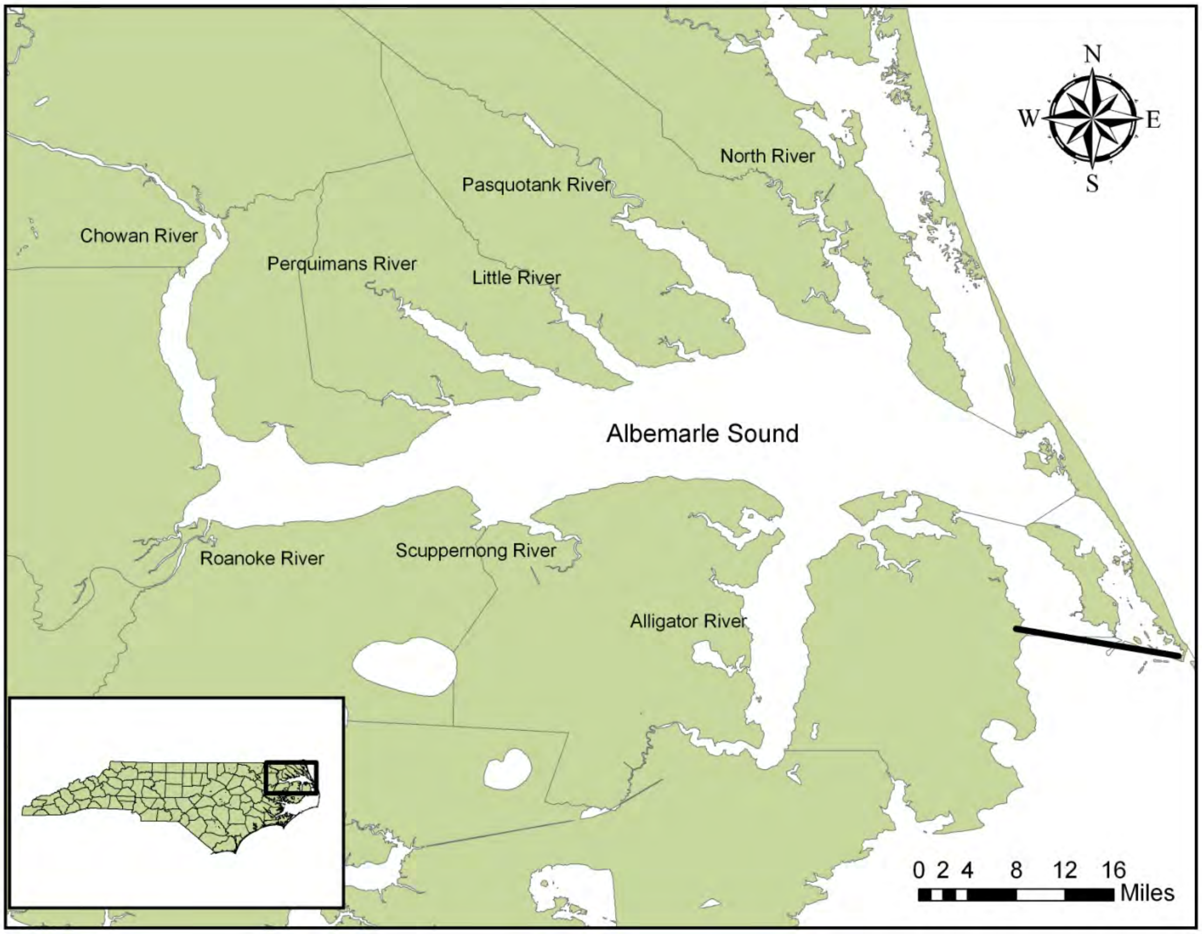


Figure 16.1 Albemarle Sound and tributaries, NC.

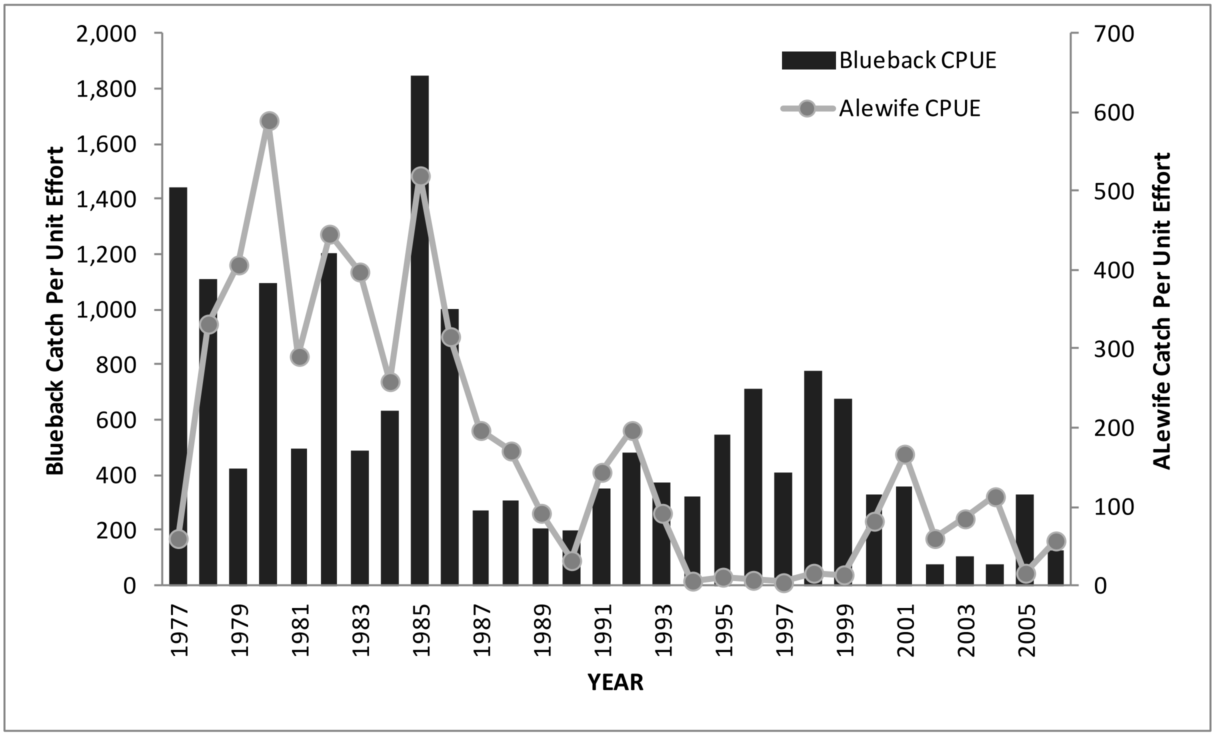
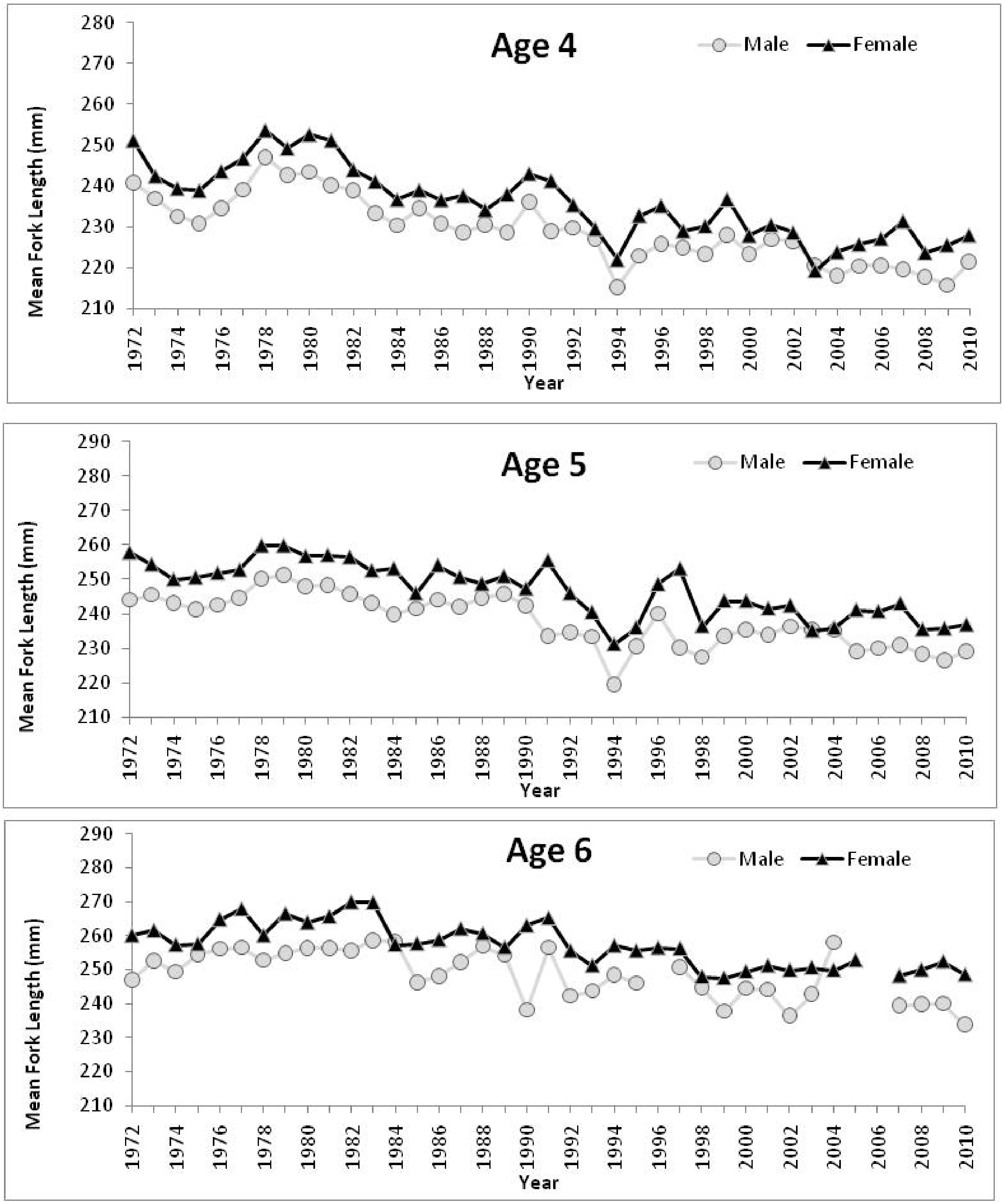
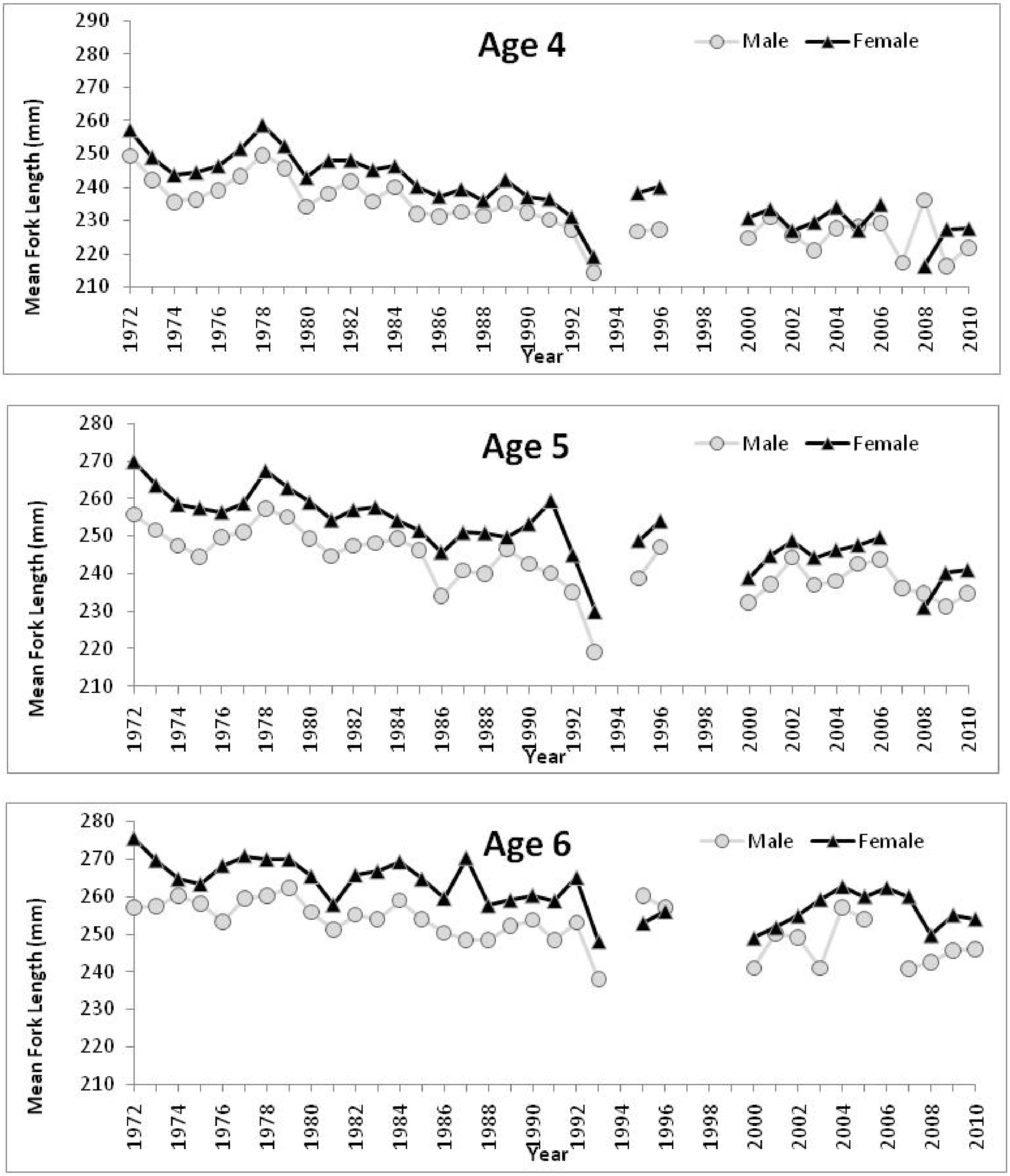


Figure 16.2 Catch per unit effort for blueback herring and alewife from the Chowan River commercial pound net fishery 1977-2006.



**2007 results based on samples collected from the research set aside harvest, April 4-7*
***2008-2010 results based on samples obtained from contracted pound net sets*

Figure 16.3 Mean length at age of blueback herring from the Chowan River pound net fishery, NC, 1972-2010.



**2007 results based on samples collected from the research set aside harvest, April 4-7*
***2008-2010 results based on samples obtained from contracted pound net sets*

Figure 16.4 Mean length at age of alewife from the Chowan River pound net fishery, NC, 1972-2010.

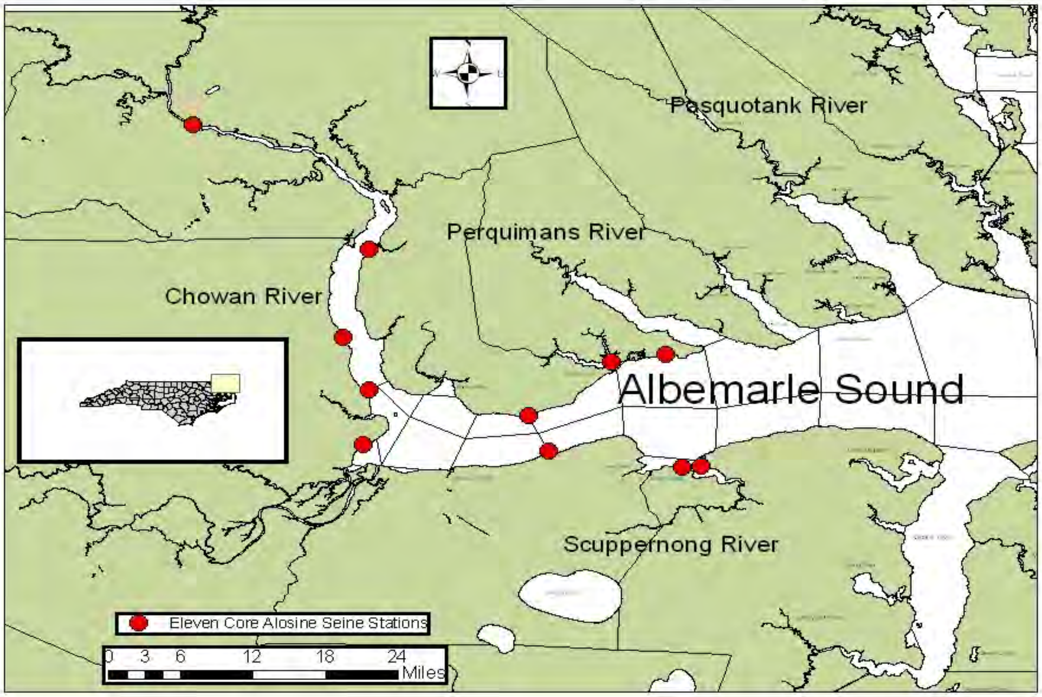


Figure 16.5 Alosine nursery area sampling sites in the Albemarle Sound area, NC 1972-2010.

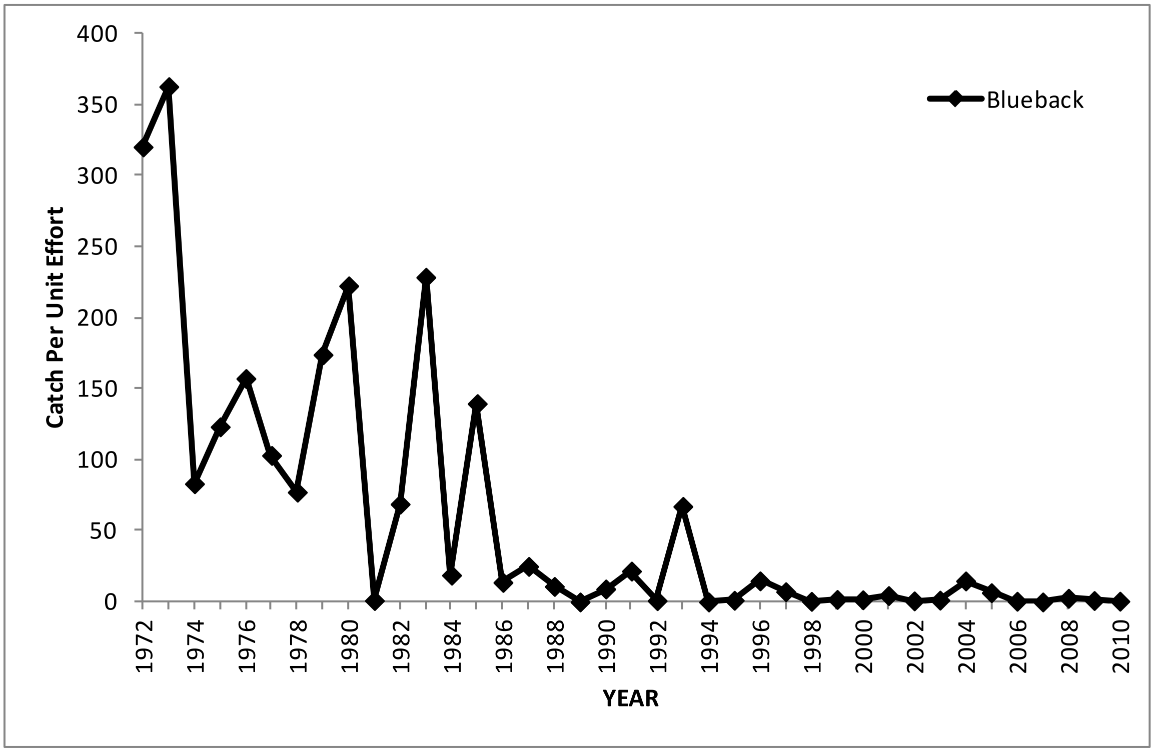


Figure 16.6 Juvenile blueback herring catch per unit effort from core seine stations, Albemarle Sound area, NC, 1972-2010.

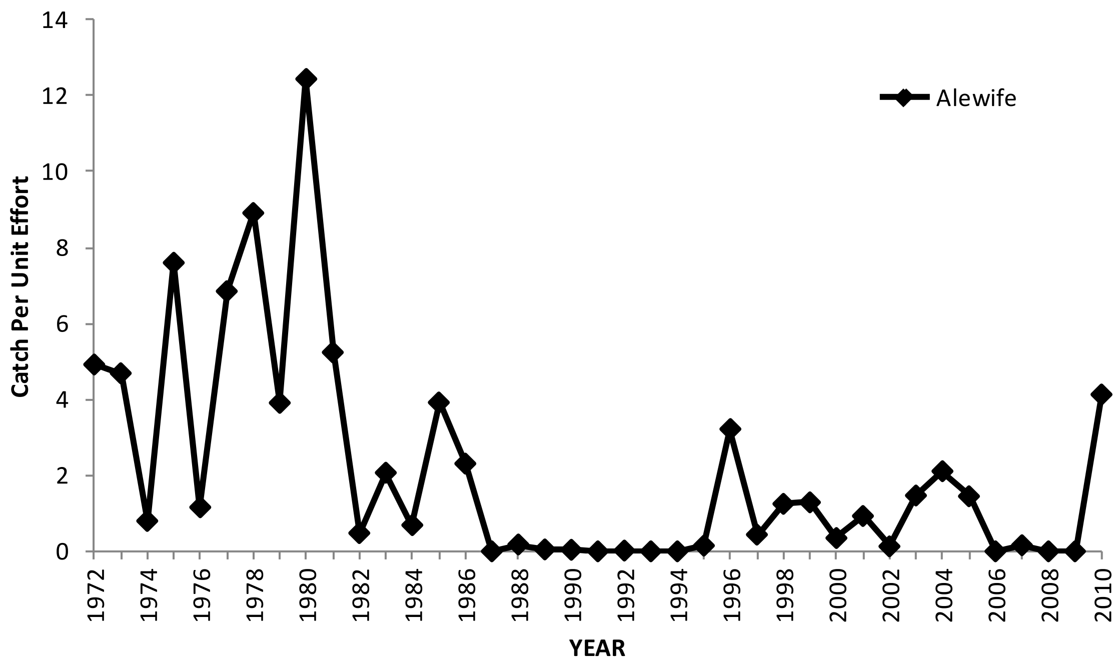


Figure 16.7 Juvenile alewife catch per unit effort from core seine stations, Albemarle Sound area, NC, 1972-2010.

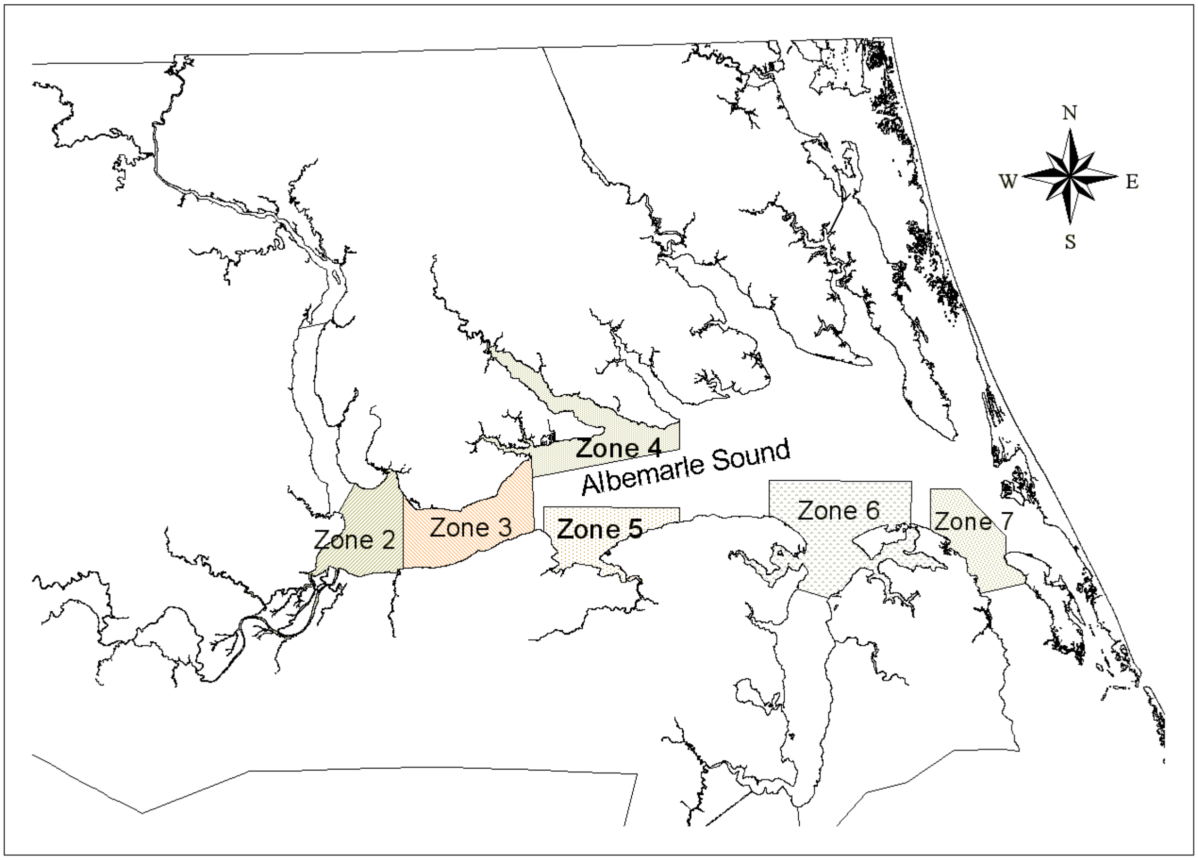


Figure 16.8 Location of sample zones for NCDMF independent gill net survey, Albemarle Sound area, 1990 – 2010.

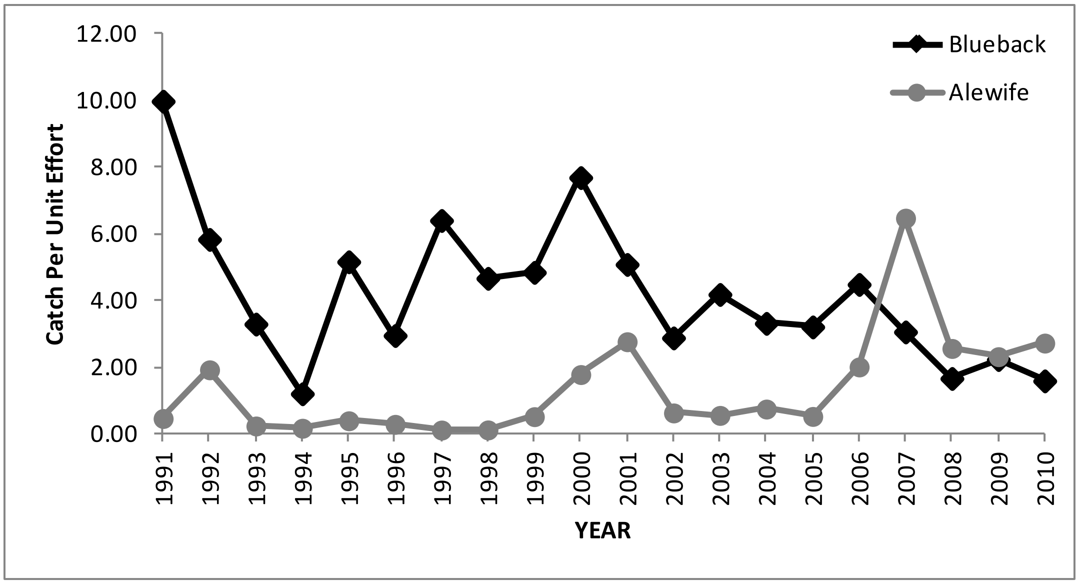


Figure 16.9 Catch per unit effort for alewife and blueback herring from the Albemarle Sound Independent Gill Net Survey, 2.5 and 3.0 ISM gill net, January-May, 1991-2010.

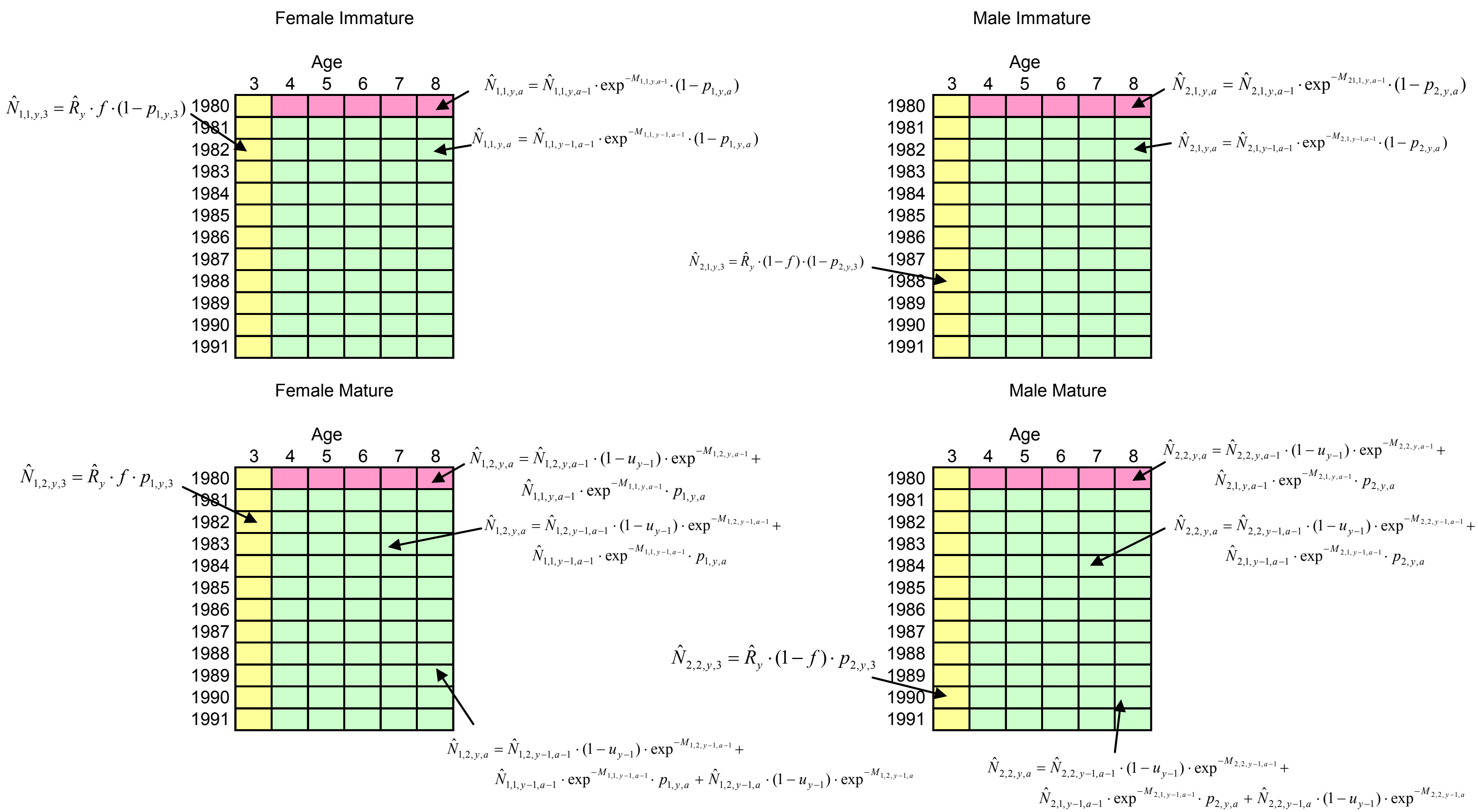


Figure 16.10 Diagram of blueback herring cohort population dynamics .

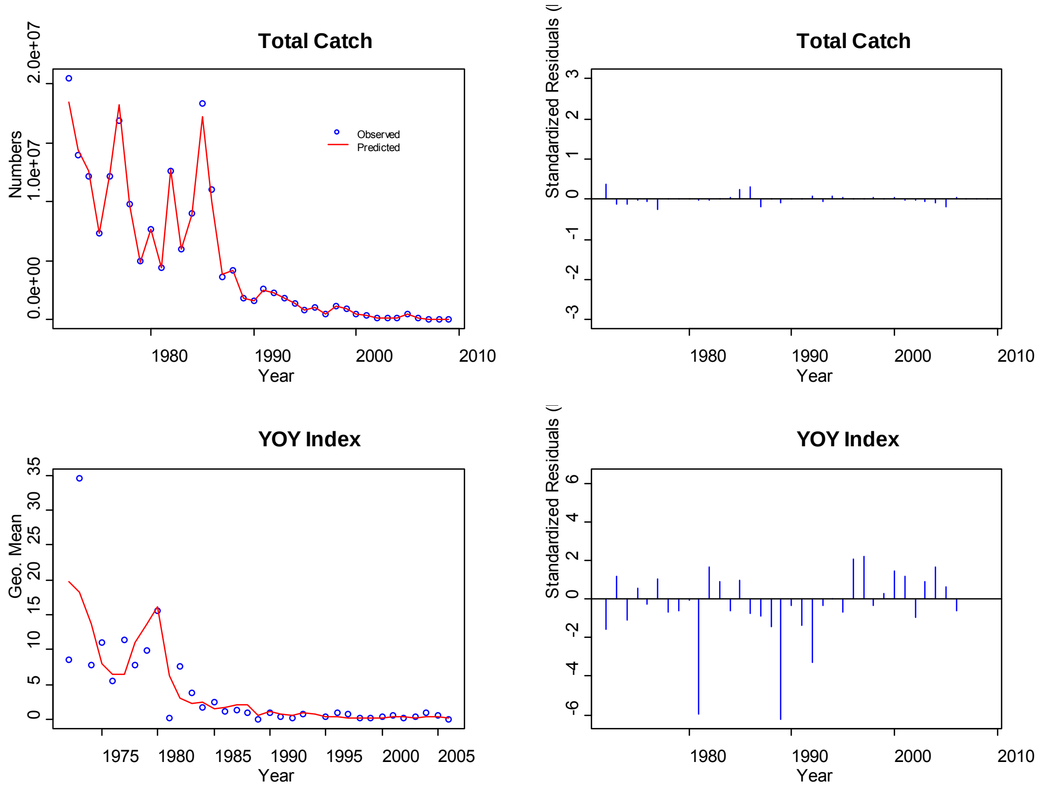


Figure 16.11 Comparison of total catch and YOY index observed and predicted values and standardized residuals for Chowan River blueback herring.

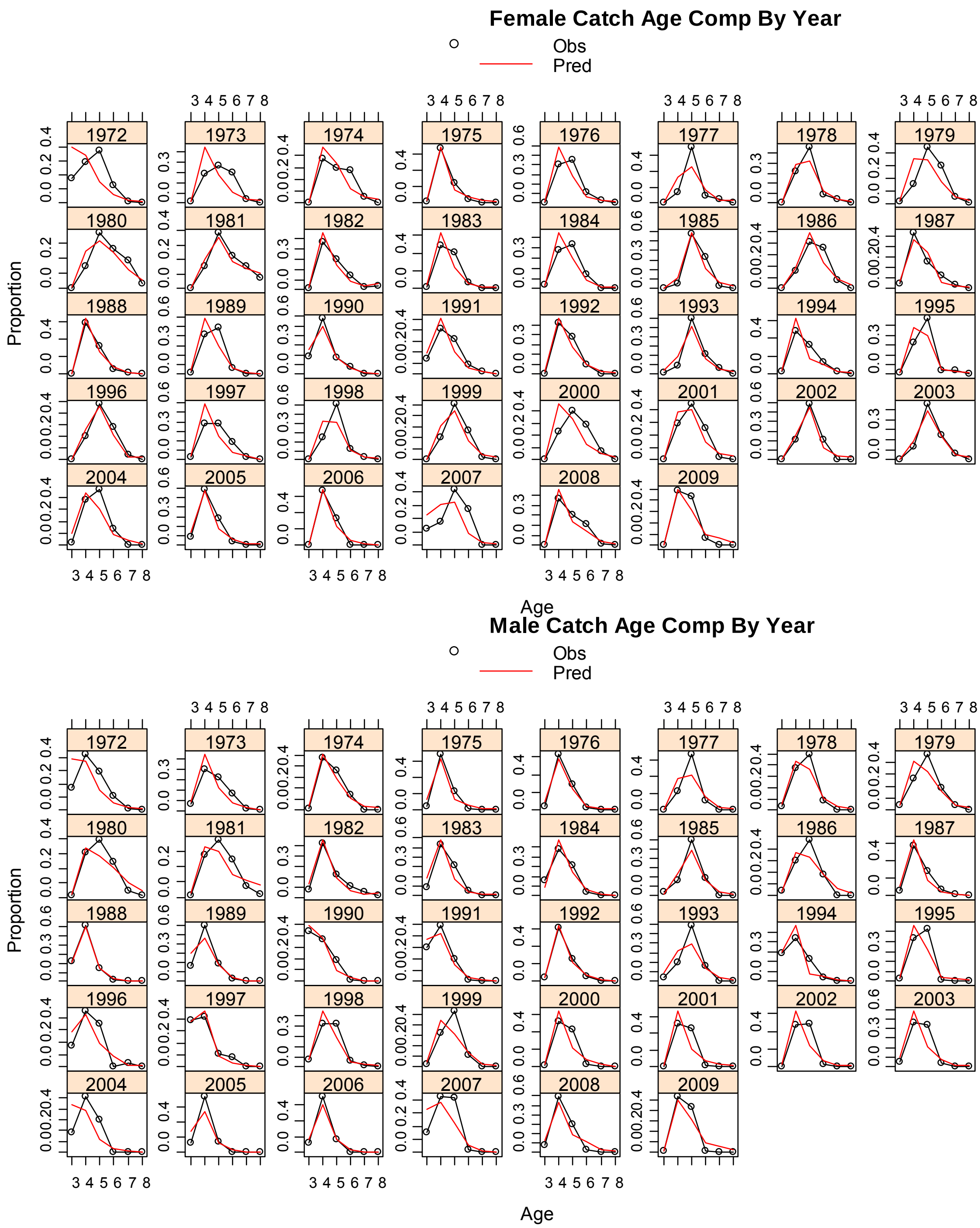


Figure 16.12 Observed and predicted catch age composition (proportions) for Chowan River blueback herring by sex, age, and year.

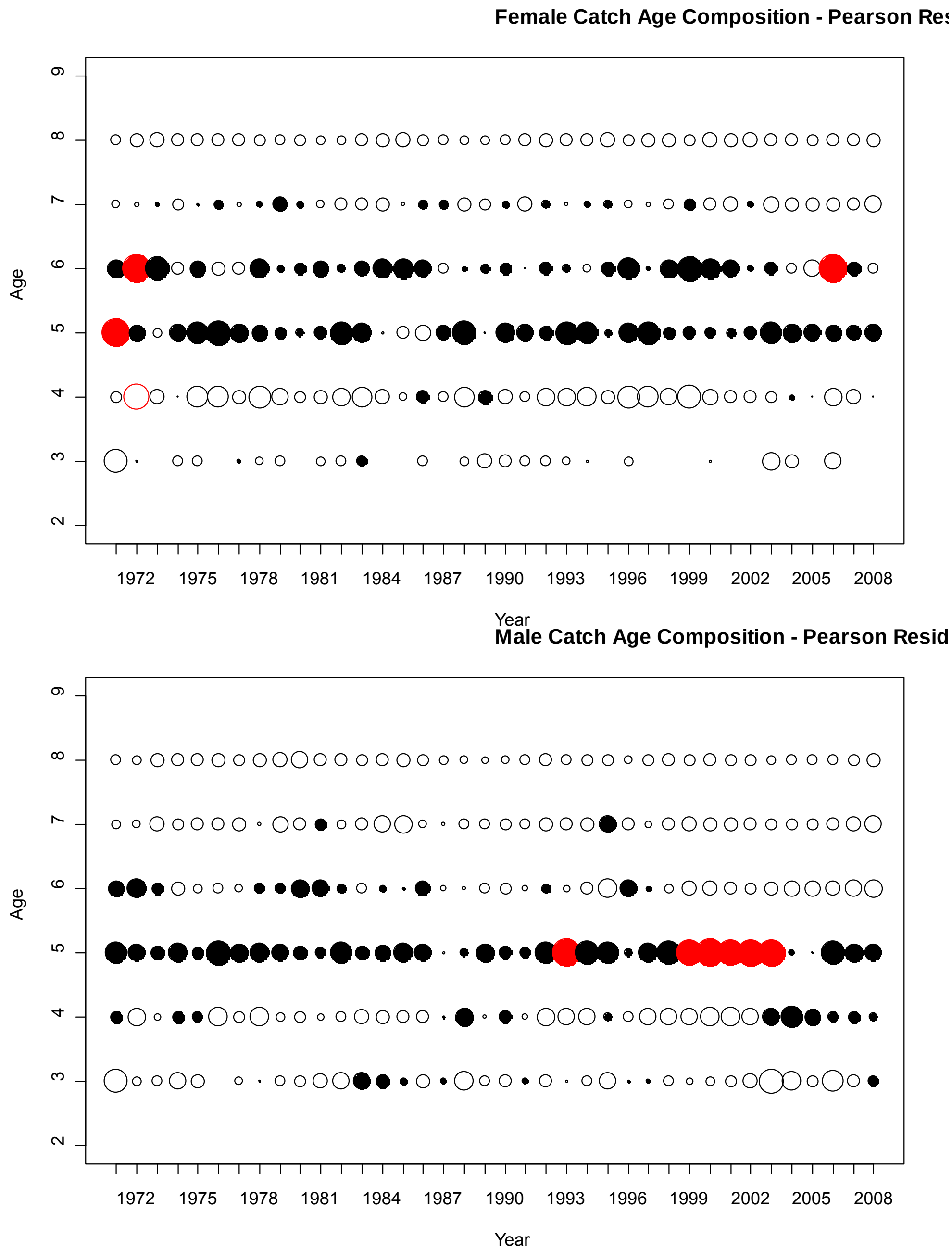


Figure 16.13 Bubble plots of standardized residuals of catch age composition by sex, year, age.

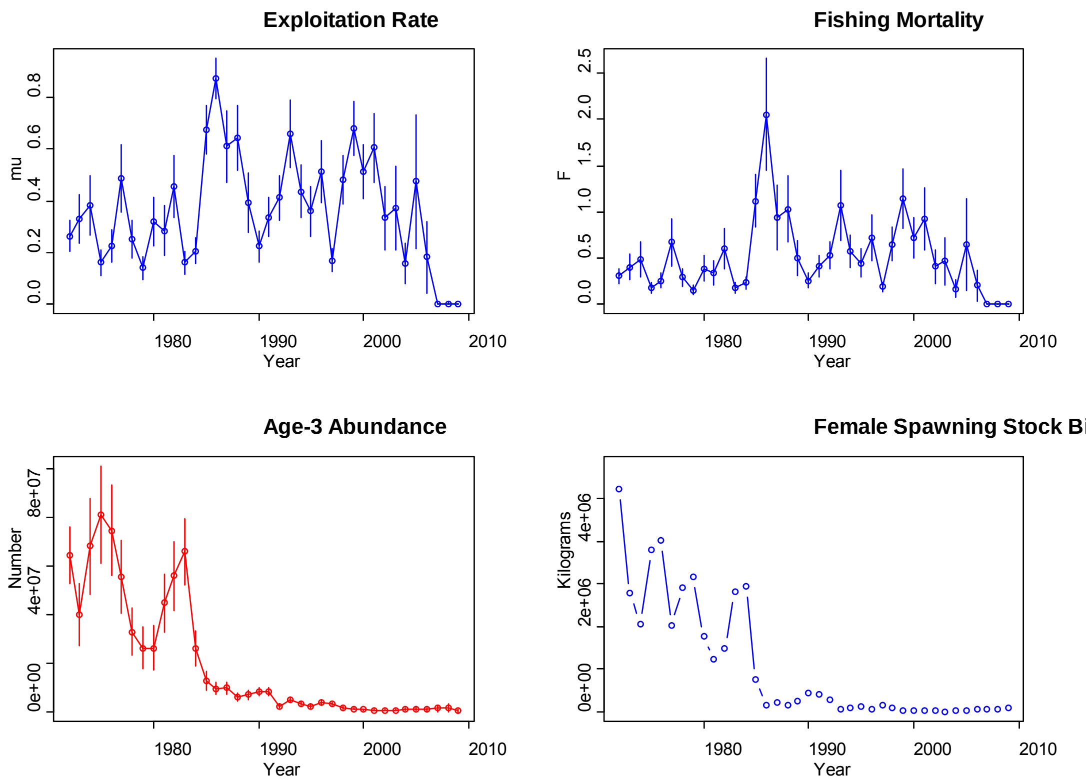


Figure 16.14 Estimates of exploitation rates, derived fishing mortality rates, recruitment (age-3 numbers), and estimates of female spawning stock biomass (in kilograms) for Chowan River blueback herring. Vertical lines, where present, represent 95% confidence intervals.

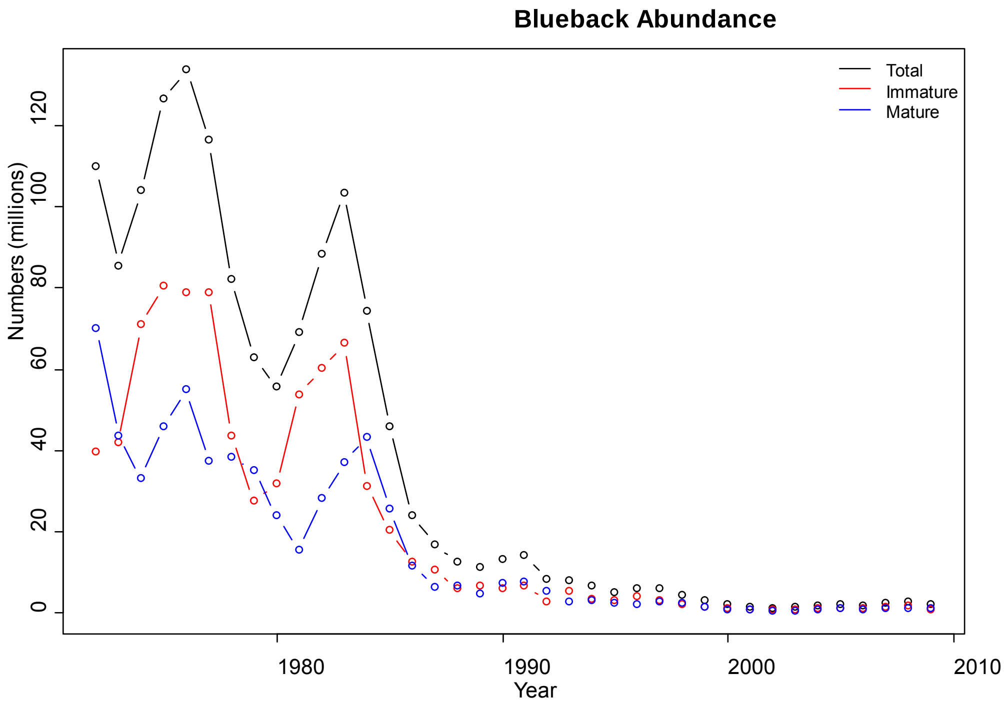


Figure 16.15 Population abundance (3+) estimates of the Chowan River blueback stock. Abundances are shown for immature and mature fish (sexes combined) and the total population.

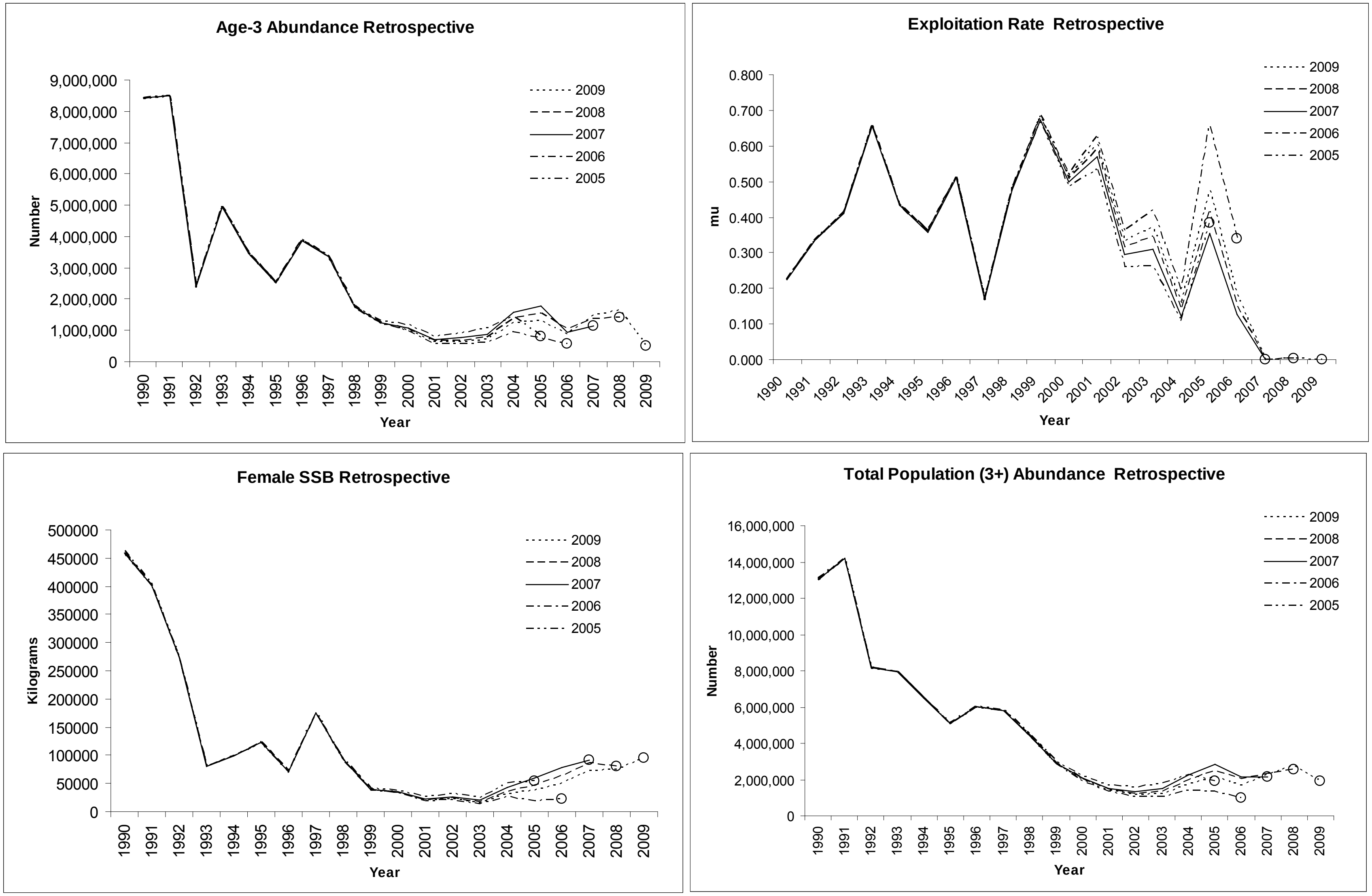


Figure 16.16 Retrospective analyses for age-3 abundance, exploitation rate, female spawning stock biomass, and total population abundance.

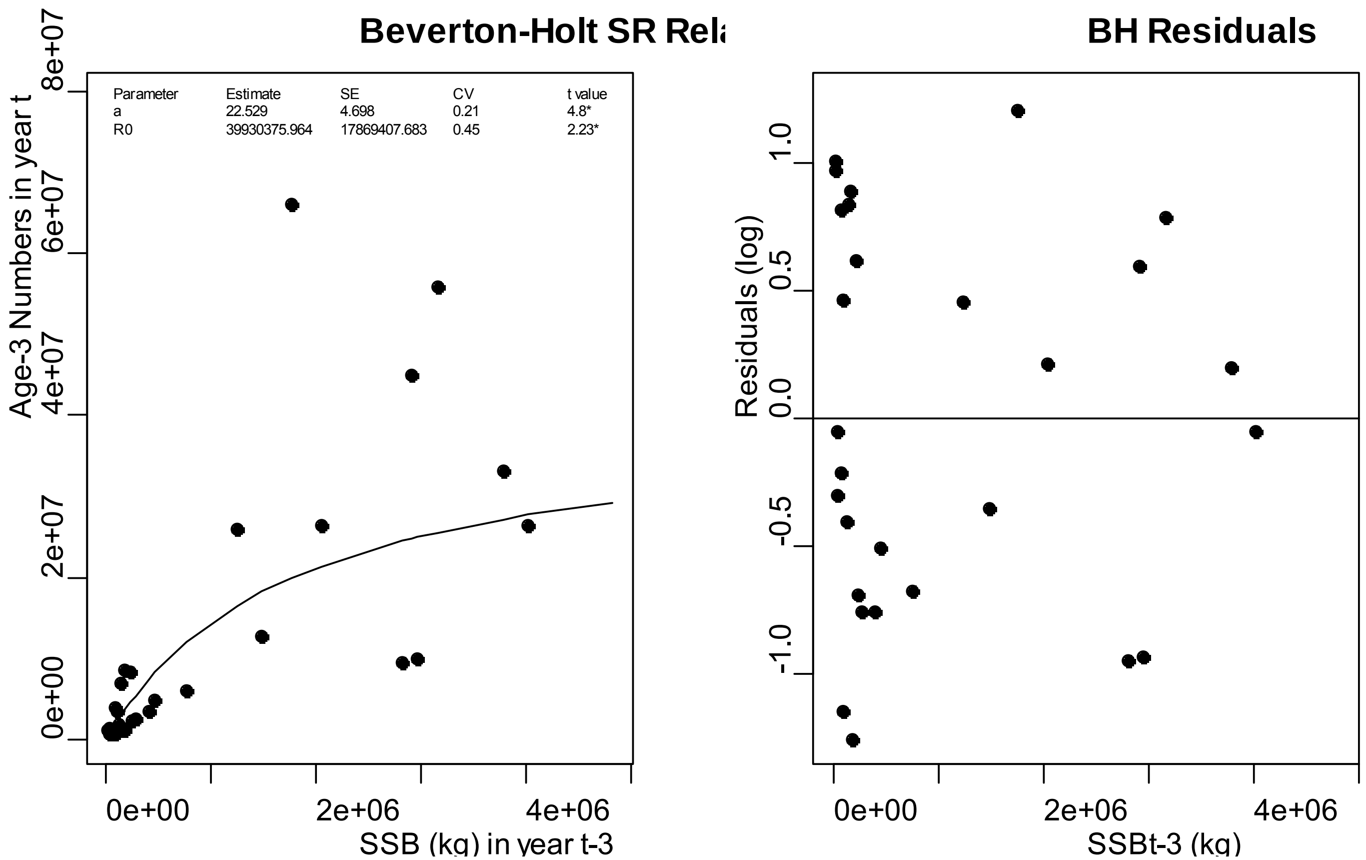


Figure 16.17 Fit of the Beverton-Holt stock-recruitment relationship to the age-3 abundance and female spawning stock biomass. Estimates of parameters *a* and R_0 from the Beverton-Holt equation are provided in the first graph, and residuals for the model fit are shown in the second graph.

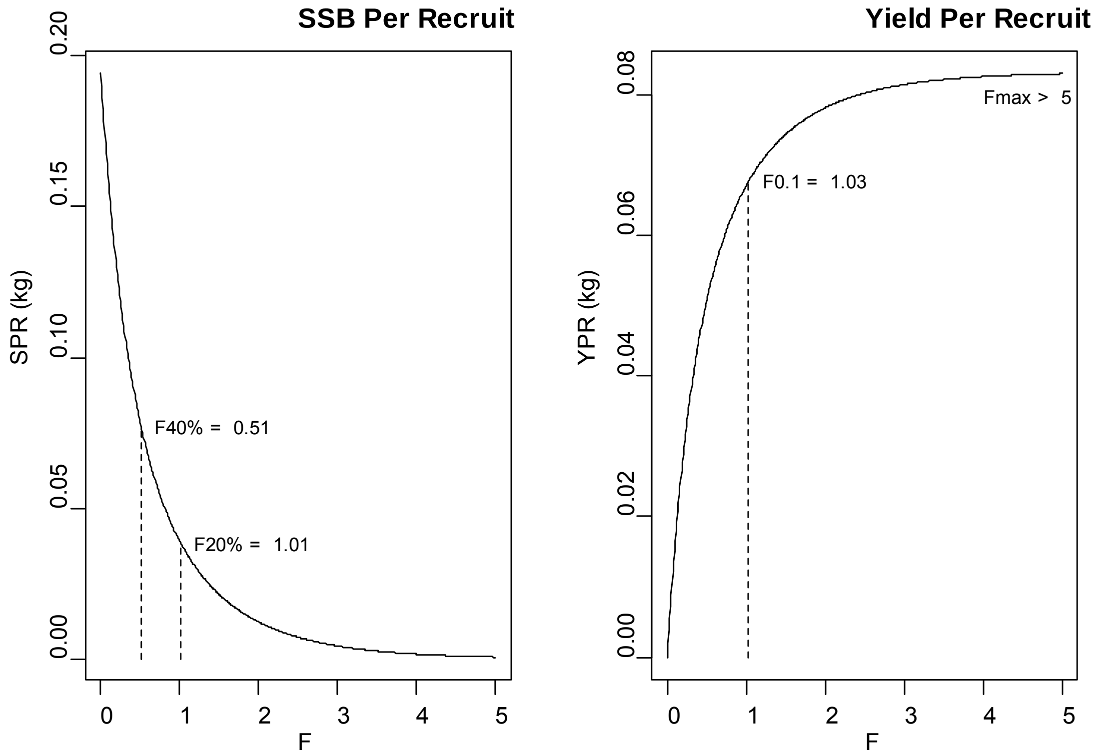


Figure 16.18 Results of spawning biomass per recruit and yield-per-recruit and analyses for the Chowan River blueback herring stock.

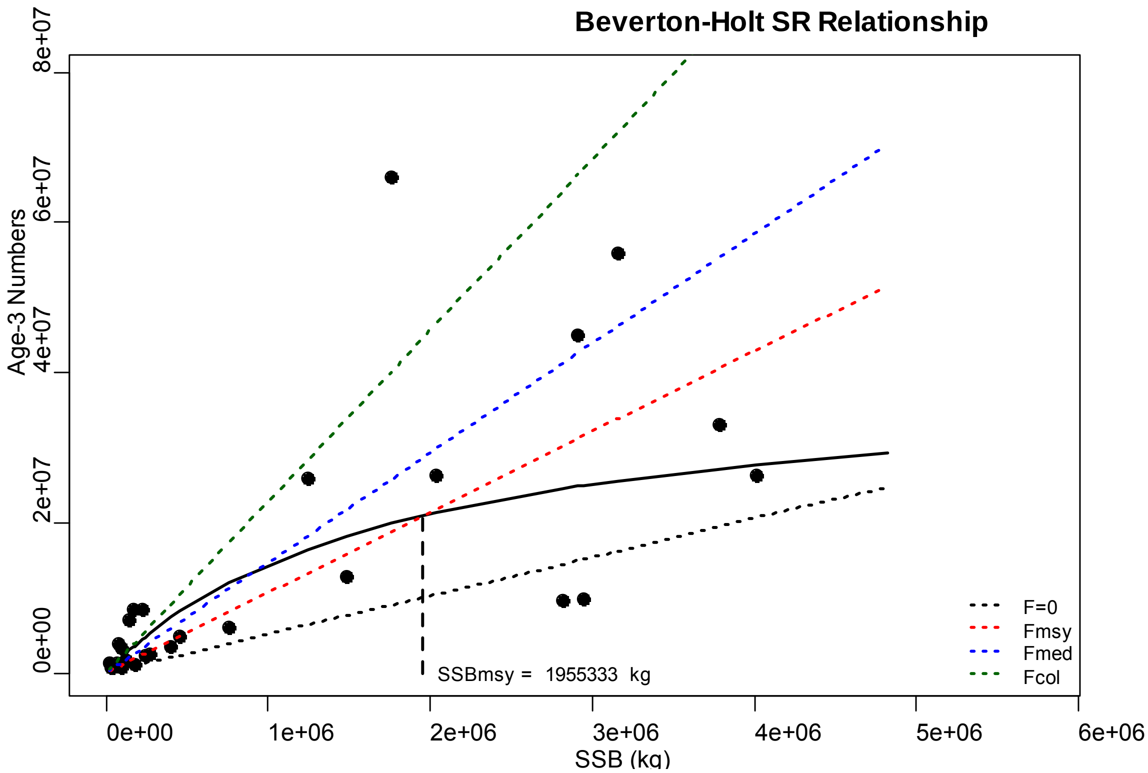


Figure 16.19 Beverton-Holt spawner-recruit model and production model reference points (see text) for the Chowan River blueback herring stock. Also shown is the replacement line in absence of fishing mortality (F=0).

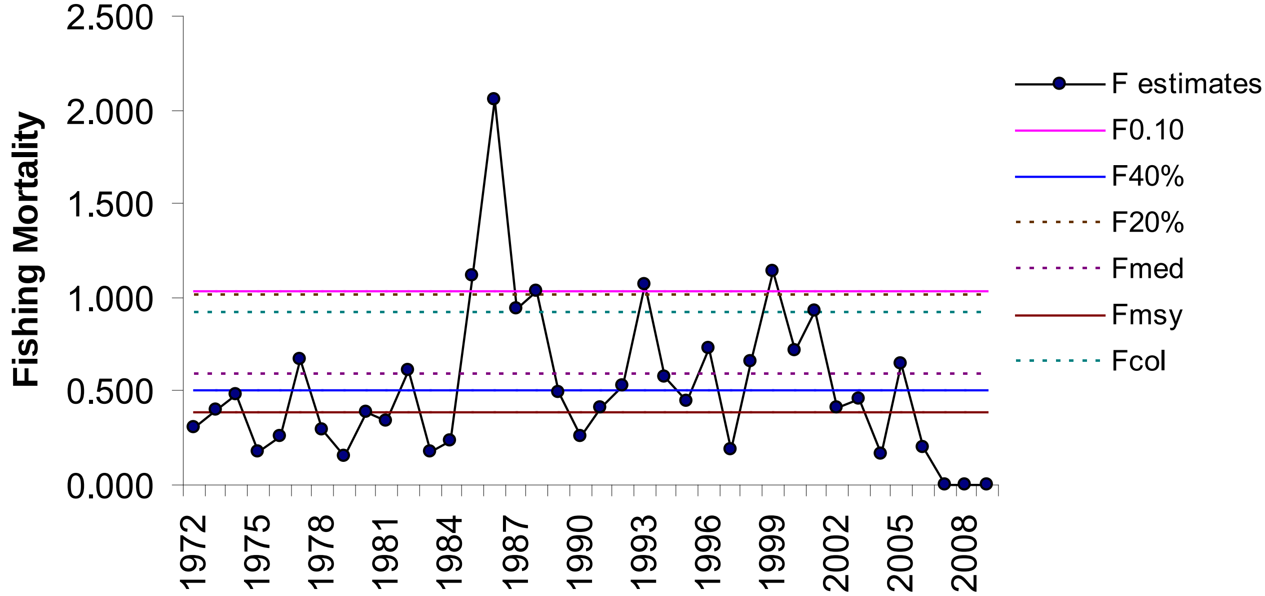


Figure 16.20 Comparison of fishing mortality rates to reference points.

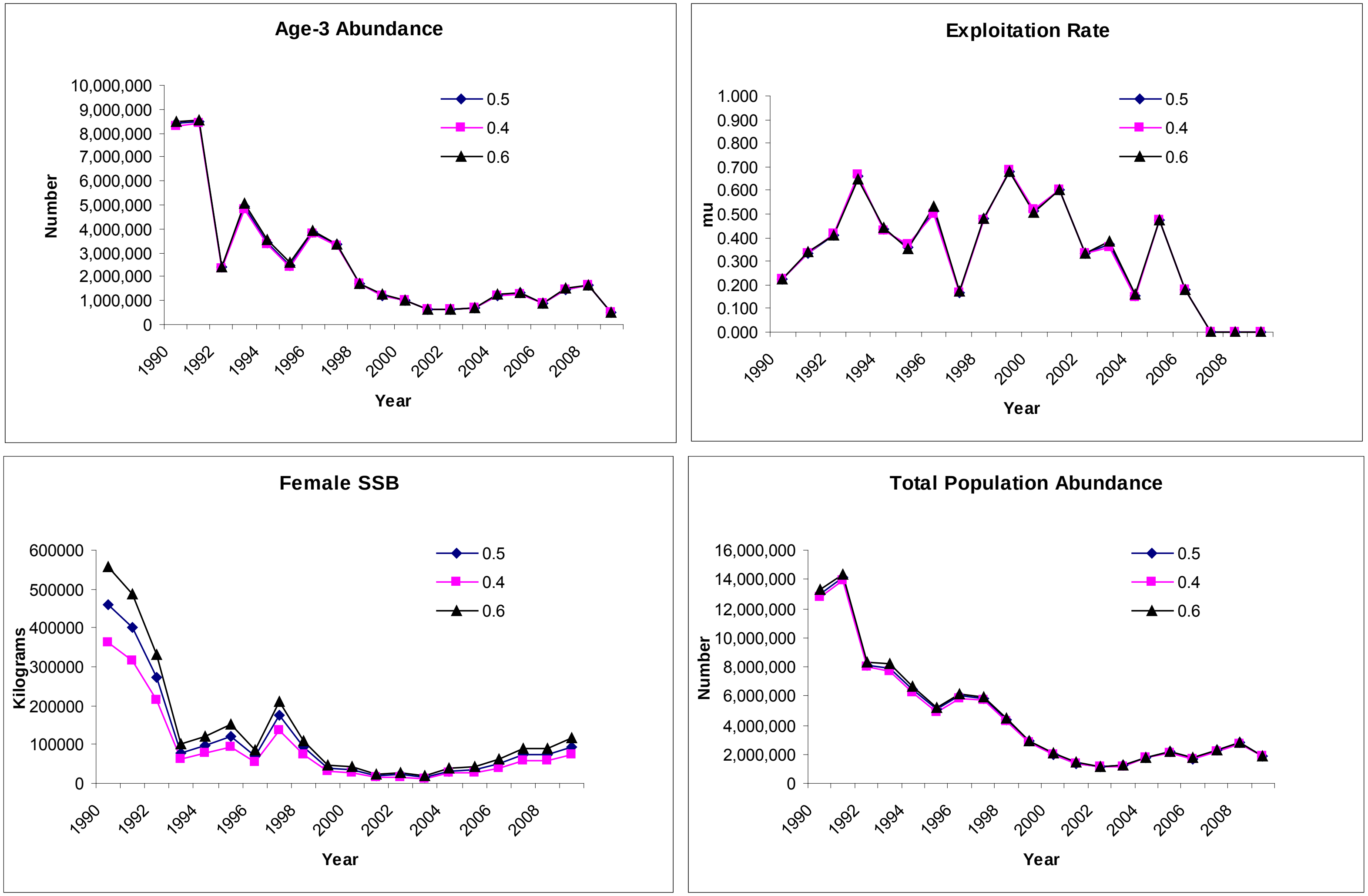


Figure 16.21 Results of sensitivity analysis of input female sex ratio. Base model ratio =0.5.

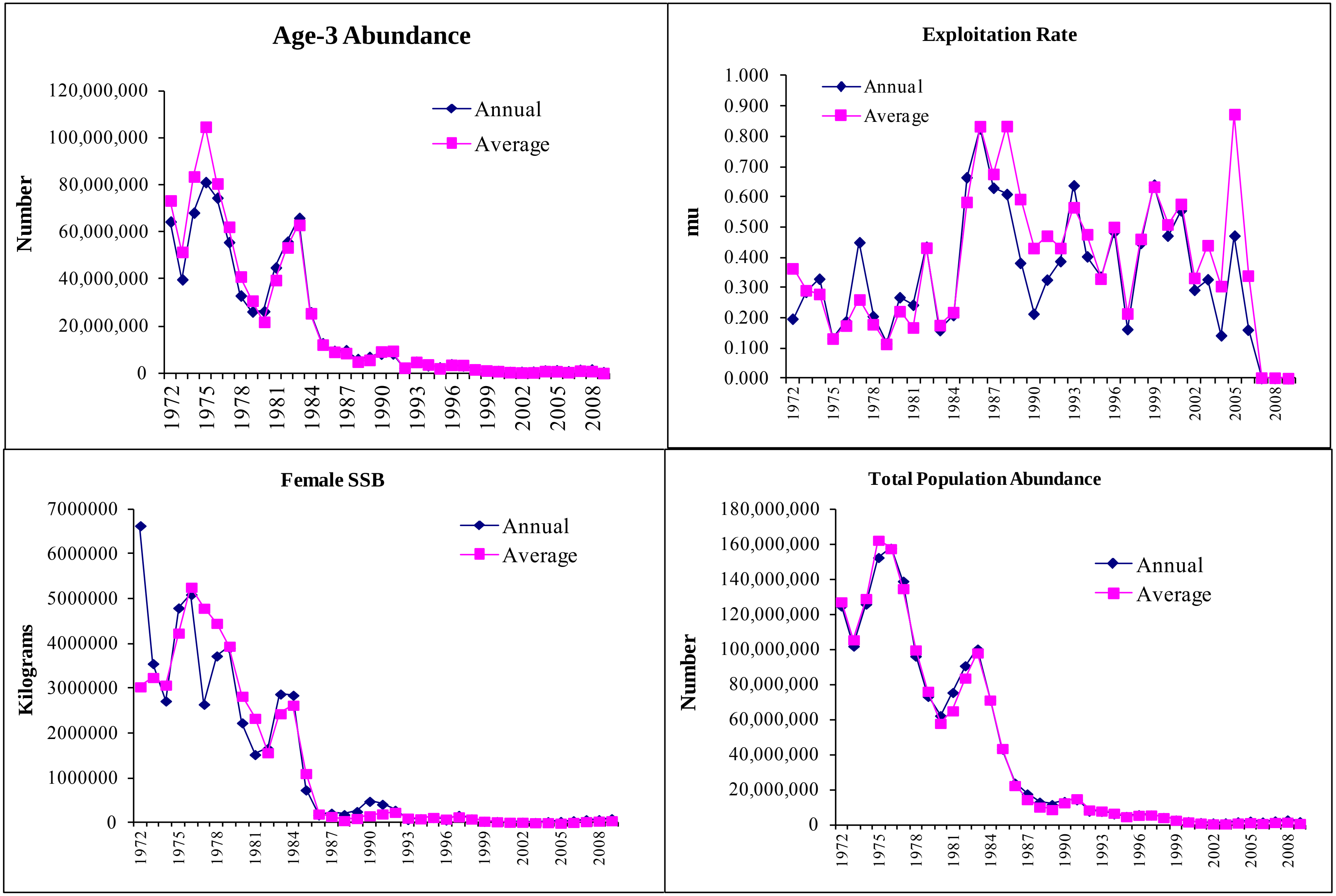


Figure 16.22 Results of sensitivity analysis of proportion mature-at age using annual estimates (base model) or time series averages.

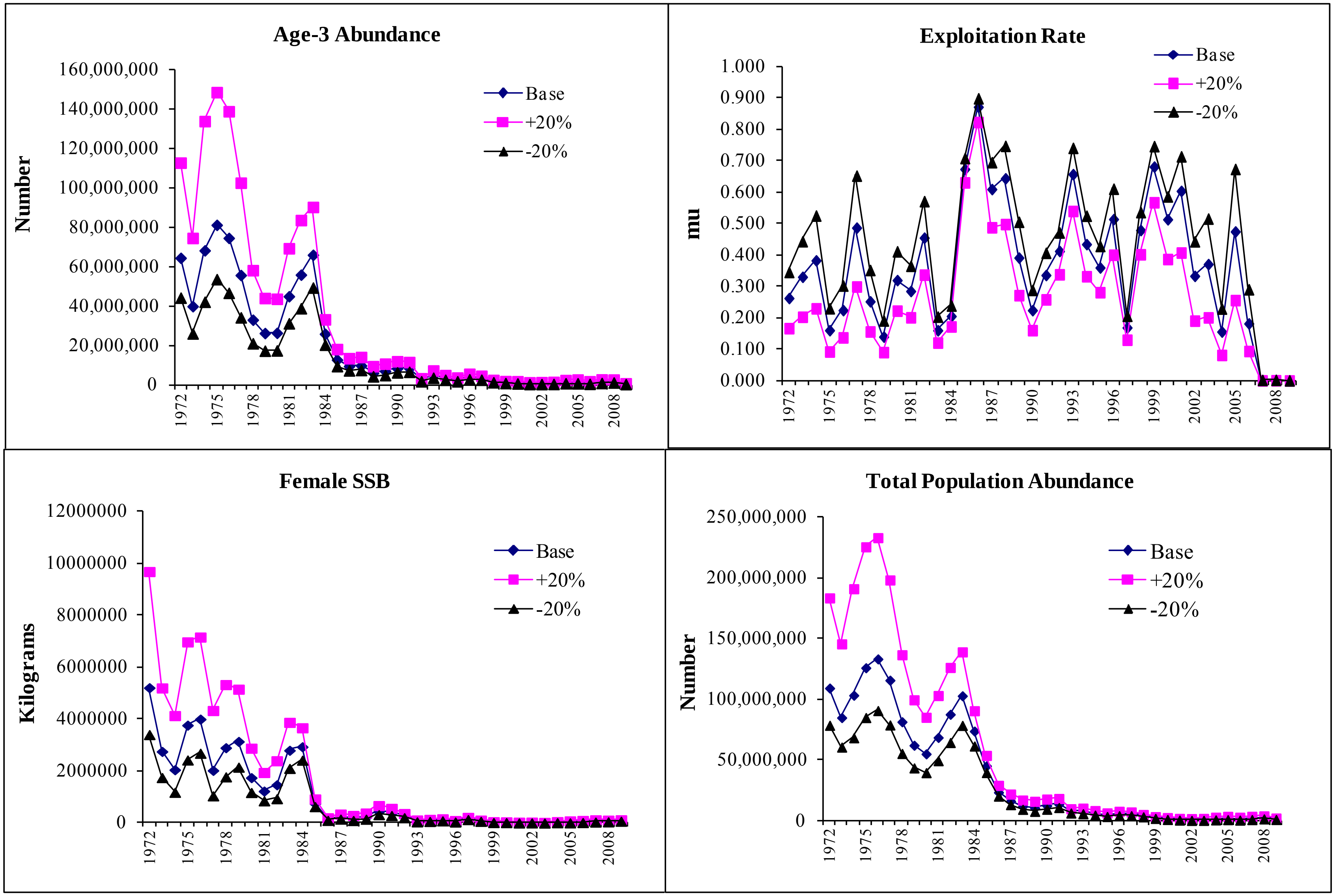


Figure 16.23 Results of sensitivity analysis of changing input sex- and age-specific natural mortality rates by ±20%.

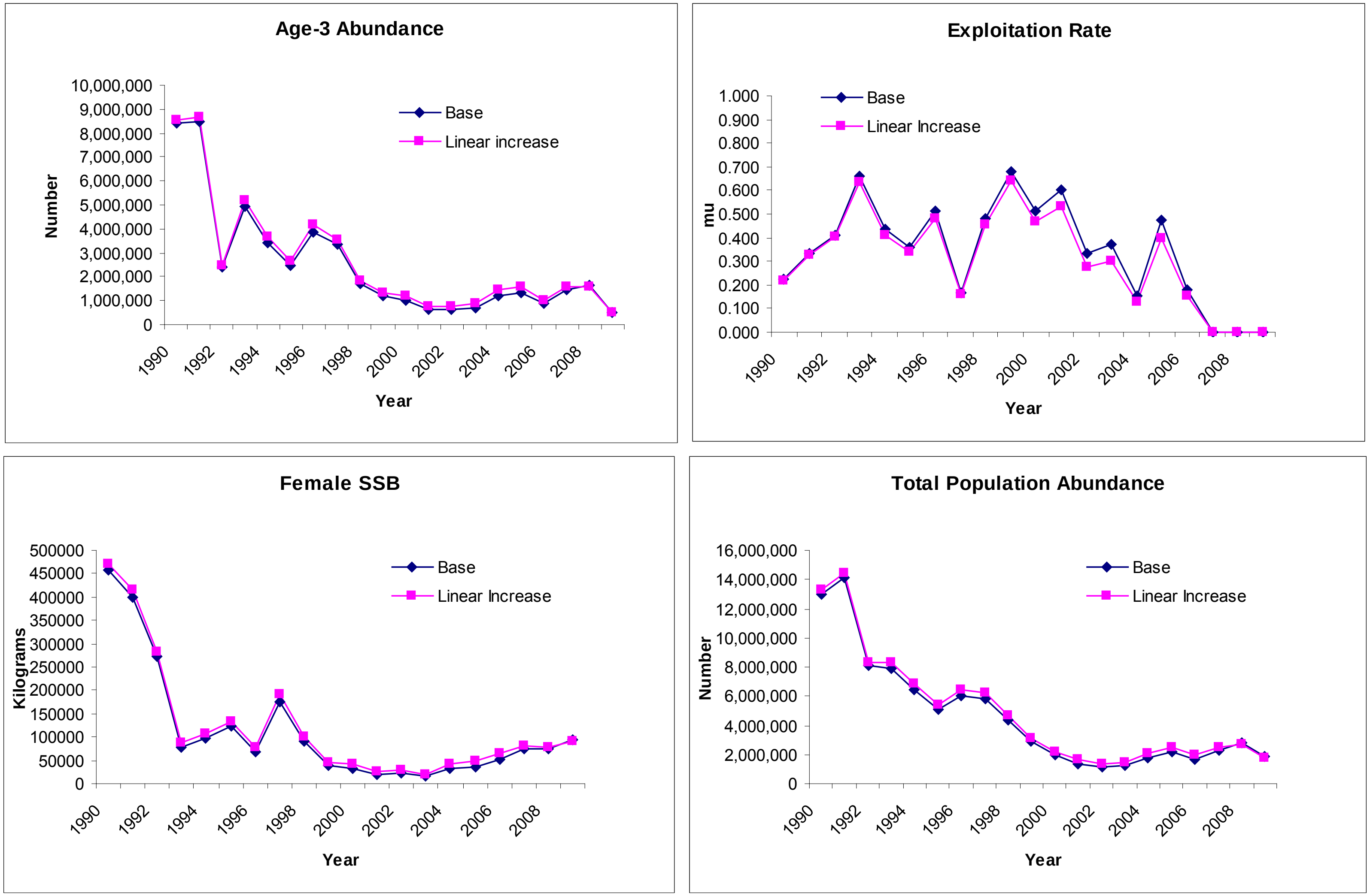


Figure 16.24 Results of sensitivity analysis of input sex- and age-specific natural mortality rates for mature fish (linear increase to 20% of base from 1990-2009).

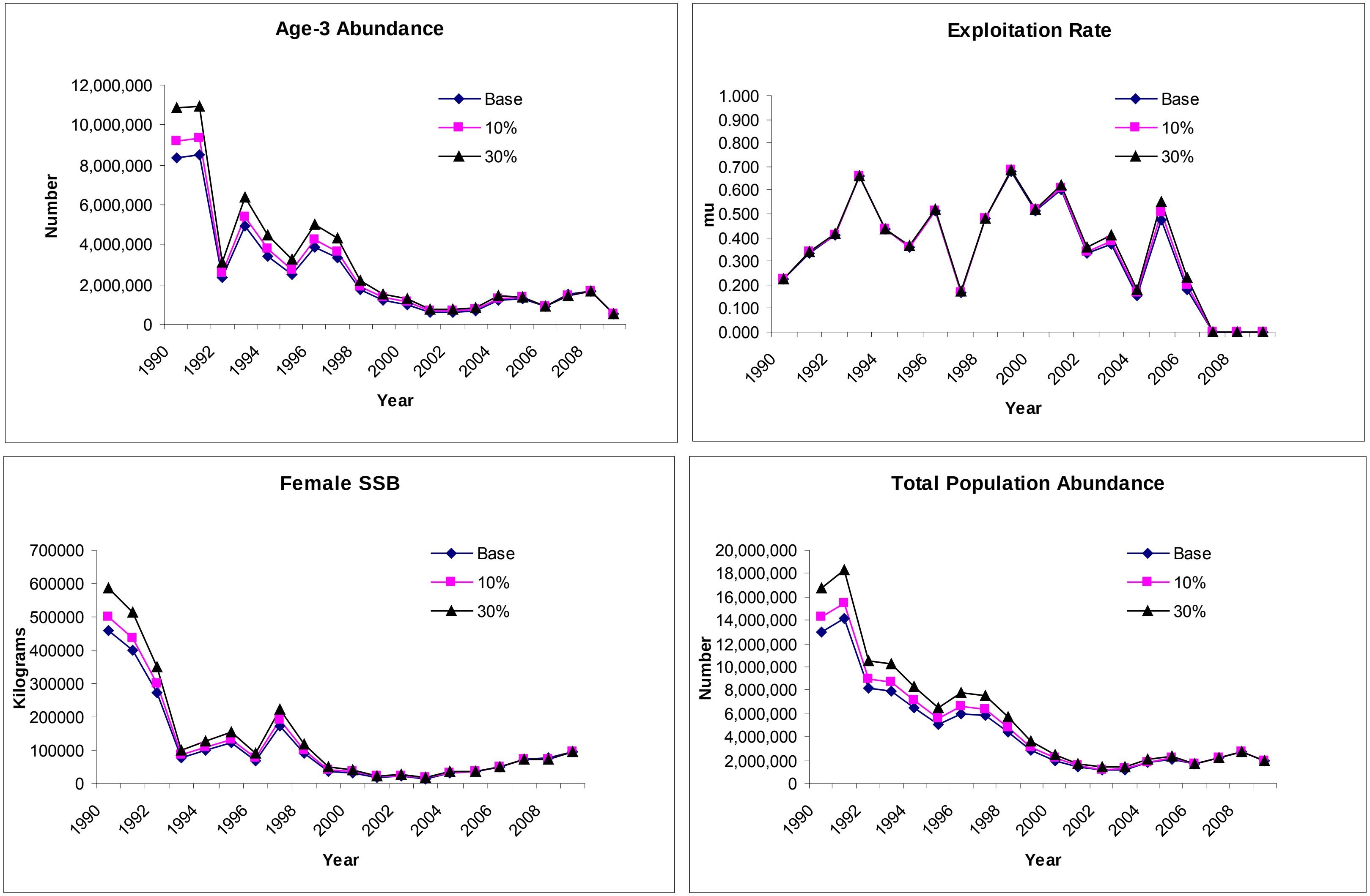


Figure 16.25 Results of sensitivity analysis of total catch. Total catch from 1990-2006 was increased by 10% and 30%.

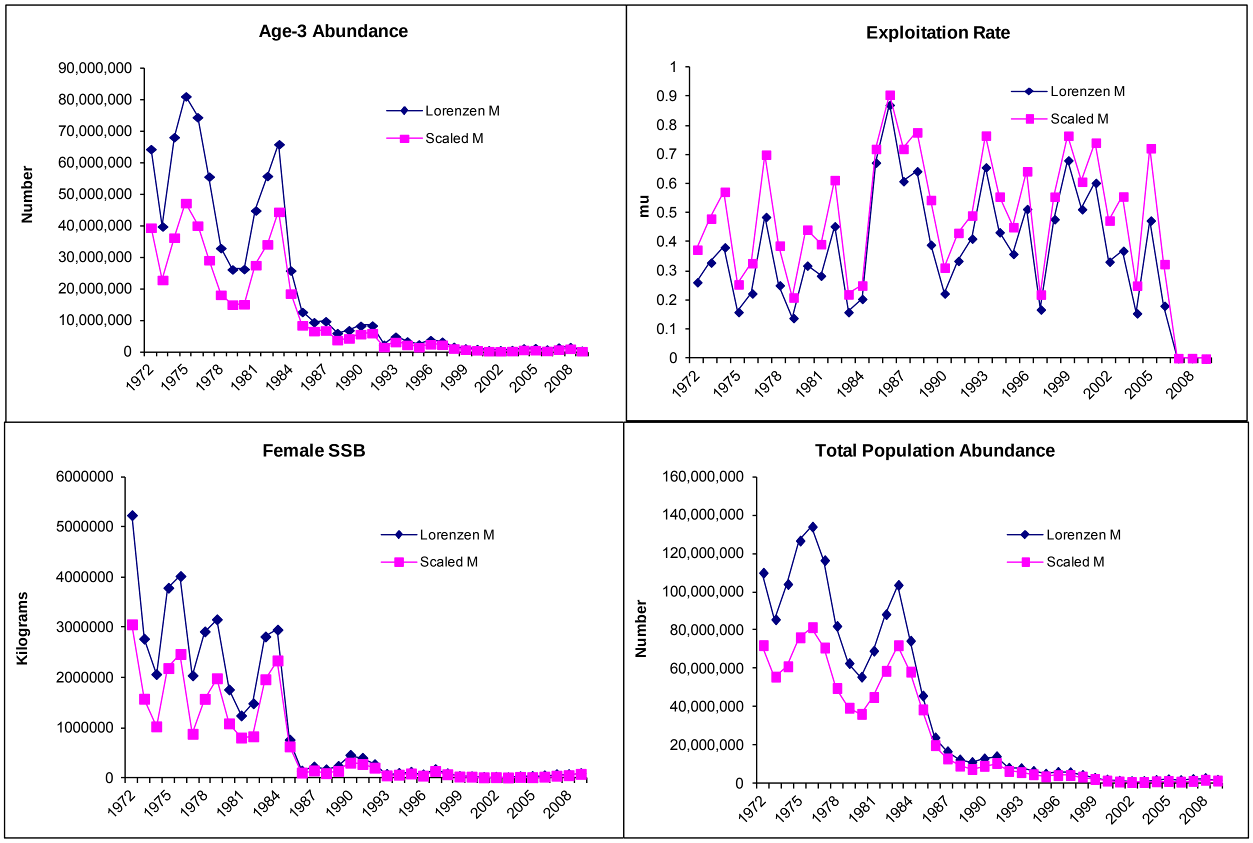


Figure 16.26 Comparison of Age-3, exploitation rates, spawning stock biomass, and total population estimates resulting from use of age-specific Lorenzen (1996) natural mortality estimates and Lorenzen (1996) values scaled to Hoenig (1983) estimate of natural mortality

Appendix Table 16.1. Estimates of proportion mature-at-age for female and male blueback herring in the Chowan river by year.

Female

Year	3	4	5	6	7	8
1972	0.440	0.809	0.979	1.000	1.000	1.000
1973	0.012	0.654	0.963	1.000	1.000	1.000
1974	0.000	0.766	0.961	1.000	1.000	1.000
1975	0.022	0.925	1.000	1.000	1.000	1.000
1976	0.016	0.748	1.000	1.000	1.000	1.000
1977	0.000	0.321	0.993	1.000	1.000	1.000
1978	0.010	0.525	0.990	1.000	1.000	1.000
1979	0.046	0.762	0.992	1.000	1.000	1.000
1980	0.009	0.431	0.950	0.995	1.000	1.000
1981	0.000	0.226	0.865	1.000	1.000	1.000
1982	0.010	0.654	1.000	1.000	1.000	1.000
1983	0.020	0.765	1.000	1.000	1.000	1.000
1984	0.042	0.684	1.000	1.000	1.000	1.000
1985	0.000	0.205	1.000	1.000	1.000	1.000
1986	0.000	0.322	0.978	1.000	1.000	1.000
1987	0.049	0.654	0.988	1.000	1.000	1.000
1988	0.000	0.768	1.000	1.000	1.000	1.000
1989	0.023	0.814	1.000	1.000	1.000	1.000
1990	0.191	0.910	1.000	1.000	1.000	1.000
1991	0.160	0.860	1.000	1.000	1.000	1.000
1992	0.056	0.710	1.000	1.000	1.000	1.000
1993	0.024	0.452	0.976	1.000	1.000	1.000
1994	0.032	0.613	1.000	1.000	1.000	1.000
1995	0.020	0.653	1.000	1.000	1.000	1.000
1996	0.000	0.300	0.980	1.000	1.000	1.000
1997	0.026	0.658	0.987	1.000	1.000	1.000
1998	0.000	0.539	0.991	1.000	1.000	1.000
1999	0.000	0.506	0.996	1.000	1.000	1.000
2000	0.000	0.622	0.961	1.000	1.000	1.000
2001	0.004	0.407	0.996	1.000	1.000	1.000
2002	0.000	0.305	1.000	1.000	1.000	1.000
2003	0.000	0.177	0.990	1.000	1.000	1.000
2004	0.042	0.632	1.000	1.000	1.000	1.000
2005	0.101	0.881	1.000	1.000	1.000	1.000
2006	0.000	0.855	1.000	1.000	1.000	1.000
2007	0.127	0.582	1.000	1.000	1.000	1.000
2008	0.000	0.672	0.981	1.000	1.000	1.000
2009	0.000	0.724	1.000	1.000	1.000	1.000

Male

Year	3	4	5	6	7	8
1972	0.419	0.869	0.996	1.000	1.000	1.000
1973	0.109	0.861	1.000	1.000	1.000	1.000
1974	0.019	0.897	1.000	1.000	1.000	1.000
1975	0.079	0.868	1.000	1.000	1.000	1.000
1976	0.076	0.856	1.000	1.000	1.000	1.000
1977	0.000	0.354	1.000	1.000	1.000	1.000
1978	0.063	0.627	0.984	1.000	1.000	1.000
1979	0.063	0.893	1.000	1.000	1.000	1.000
1980	0.023	0.630	0.977	1.000	1.000	1.000
1981	0.009	0.411	0.963	1.000	1.000	1.000
1982	0.071	0.764	1.000	1.000	1.000	1.000
1983	0.113	0.887	1.000	1.000	1.000	1.000
1984	0.163	0.801	1.000	1.000	1.000	1.000
1985	0.039	0.457	1.000	1.000	1.000	1.000
1986	0.046	0.713	0.991	1.000	1.000	1.000
1987	0.070	0.876	1.000	1.000	1.000	1.000
1988	0.245	0.945	1.000	1.000	1.000	1.000
1989	0.222	0.940	1.000	1.000	1.000	1.000
1990	0.464	0.982	1.000	1.000	1.000	1.000
1991	0.360	0.928	0.993	1.000	1.000	1.000
1992	0.097	0.968	0.995	1.000	1.000	1.000
1993	0.047	0.756	1.000	1.000	1.000	1.000
1994	0.327	0.923	1.000	1.000	1.000	1.000
1995	0.039	0.789	1.000	1.000	1.000	1.000
1996	0.190	0.914	1.000	1.000	1.000	1.000
1997	0.389	0.917	1.000	1.000	1.000	1.000
1998	0.104	0.797	0.990	1.000	1.000	1.000
1999	0.058	0.764	1.000	1.000	1.000	1.000
2000	0.023	0.957	1.000	1.000	1.000	1.000
2001	0.021	0.904	1.000	1.000	1.000	1.000
2002	0.022	0.934	1.000	1.000	1.000	1.000
2003	0.075	0.936	1.000	1.000	1.000	1.000
2004	0.299	0.965	1.000	1.000	1.000	1.000
2005	0.220	0.984	1.000	1.000	1.000	1.000
2006	0.170	0.936	1.000	1.000	1.000	1.000
2007	0.234	0.964	1.000	1.000	1.000	1.000
2008	0.081	0.719	0.990	1.000	1.000	1.000
2009	0.027	0.680	1.000	1.000	1.000	1.000

Appendix Table 16.2. Estimates of total catch (in numbers) of pound nets for blueback herring in the Chowan River used in the base model run.

Year	Numbers
1972	20,443,867
1973	13,918,880
1974	12,141,597
1975	7,286,423
1976	12,121,822
1977	16,831,692
1978	9,762,107
1979	4,921,229
1980	7,617,940
1981	4,360,204
1982	12,658,422
1983	5,955,402
1984	9,023,870
1985	18,364,344
1986	10,997,451
1987	3,664,782
1988	4,162,095
1989	1,772,115
1990	1,612,157
1991	2,545,614
1992	2,281,605
1993	1,763,114
1994	1,380,804
1995	814,048
1996	1,043,026
1997	468,830
1998	1,105,760
1999	948,791
2000	436,067
2001	363,260
2002	133,659
2003	143,201
2004	102,534
2005	447,376
2006	153,862
2007	1,325
2008	1,808
2009	763

Appendix Table 16.3. Number of Chowan River blueback samples from pound nets aged by sex, year, and age.

Female

Year	3	4	5	6	7	8
1972	25	42	54	18	2	0
1973	1	23	30	24	3	0
1974	0	29	23	21	4	0
1975	2	63	23	4	1	0
1976	1	49	55	14	4	0
1977	0	20	98	14	7	1
1978	1	31	55	8	4	0
1979	3	21	58	39	8	1
1980	0	32	80	57	41	8
1981	0	50	122	73	50	23
1982	1	49	31	15	3	4
1983	2	50	42	7	0	1
1984	4	36	42	13	0	0
1985	0	5	48	28	2	0
1986	0	14	37	32	7	0
1987	4	43	21	10	3	0
1988	0	48	27	5	2	0
1989	1	18	21	3	0	0
1990	16	51	15	7	0	0
1991	14	42	32	9	3	0
1992	1	55	41	10	0	0
1993	1	4	25	9	3	0
1994	1	15	10	4	1	0
1995	1	16	28	2	2	0
1996	0	10	24	14	2	0
1997	2	29	29	14	2	0
1998	0	131	321	60	17	0
1999	0	50	125	67	7	0
2000	0	58	102	74	19	1
2001	1	72	111	64	5	0
2002	0	29	82	29	1	0
2003	0	13	53	24	6	0
2004	2	36	44	13	0	0
2005	15	98	47	8	0	0
2006	0	37	18	0	0	0
2007	7	10	23	15	0	0
2008	0	148	98	66	5	0
2009	0	105	93	15	1	0

Male

Year	3	4	5	6	7	8
1972	46	112	78	28	3	0
1973	16	93	76	38	5	2
1974	3	74	55	22	1	0
1975	6	77	27	3	1	0
1976	12	147	69	7	1	0
1977	0	39	115	20	1	0
1978	5	47	62	11	1	0
1979	12	66	116	48	11	0
1980	2	66	85	53	9	2
1981	3	97	131	87	25	7
1982	10	74	31	16	7	2
1983	19	108	65	11	1	0
1984	23	68	44	6	0	0
1985	5	22	76	24	0	0
1986	5	32	51	20	0	0
1987	8	73	36	10	2	0
1988	36	99	23	4	1	0
1989	20	70	23	4	0	0
1990	48	41	20	2	0	0
1991	42	68	27	2	0	0
1992	9	116	49	12	1	0
1993	4	17	50	14	1	0
1994	15	23	12	2	0	0
1995	2	33	40	1	0	0
1996	10	26	20	0	2	0
1997	14	15	4	3	0	0
1998	30	163	163	23	6	0
1999	9	101	167	35	1	0
2000	15	383	316	24	1	0
2001	3	170	155	7	0	0
2002	2	86	87	6	0	0
2003	9	80	76	8	0	0
2004	27	73	43	1	0	0
2005	16	89	18	0	0	0
2006	12	66	16	0	0	0
2007	25	70	69	3	0	0
2008	49	358	181	20	0	0
2009	7	174	142	5	0	0

Appendix Table 16.4. Young-of-the-year blueback herring seine index by year. -1 = not used. The 1994 value was not used because the model could not reconcile zero YOY fish.

Year	Geo Mean
1972	8.63
1973	34.52
1974	7.70
1975	11.08
1976	5.52
1977	11.32
1978	7.76
1979	9.90
1980	15.57
1981	0.25
1982	7.58
1983	3.80
1984	1.75
1985	2.47
1986	1.16
1987	1.25
1988	0.95
1989	0.02
1990	0.99
1991	0.40
1992	0.10
1993	0.79
1994	-1.00
1995	0.29
1996	0.90
1997	0.81
1998	0.13
1999	0.18
2000	0.38
2001	0.58
2002	0.19
2003	0.36
2004	0.90
2005	0.56
2006	0.09
2007	0.06
2008	0.17
2009	0.10

Appendix Table 16.5. Female weights-at-age (kg). Color indicates that values were estimated from observed values from other years.

Year	3	4	5	6	7	8
1972	0.19	0.20	0.21	0.22	0.21	0.29
1973	0.15	0.19	0.21	0.24	0.27	0.29
1974	0.15	0.19	0.21	0.24	0.27	0.29
1975	0.15	0.19	0.21	0.24	0.27	0.29
1976	0.15	0.19	0.21	0.24	0.27	0.29
1977	0.15	0.19	0.21	0.24	0.27	0.29
1978	0.15	0.19	0.21	0.24	0.27	0.29
1979	0.15	0.19	0.21	0.24	0.27	0.29
1980	0.15	0.19	0.21	0.24	0.27	0.29
1981	0.15	0.20	0.23	0.26	0.26	0.29
1982	0.13	0.19	0.22	0.24	0.27	0.27
1983	0.14	0.18	0.22	0.26	0.27	0.32
1984	0.13	0.17	0.19	0.22	0.27	0.29
1985	0.13	0.17	0.18	0.21	0.23	0.29
1986	0.13	0.16	0.20	0.22	0.24	0.29
1987	0.13	0.16	0.19	0.21	0.25	0.29
1988	0.13	0.15	0.18	0.22	0.22	0.29
1989	0.14	0.17	0.21	0.24	0.27	0.29
1990	0.16	0.19	0.18	0.25	0.25	0.29
1991	0.13	0.16	0.22	0.24	0.33	0.29
1992	0.14	0.16	0.19	0.21	0.27	0.29
1993	0.10	0.15	0.17	0.17	0.22	0.29
1994	0.12	0.13	0.14	0.24	0.18	0.29
1995	0.12	0.15	0.16	0.20	0.30	0.29
1996	0.13	0.19	0.19	0.22	0.24	0.29
1997	0.11	0.16	0.25	0.25	0.33	0.29
1998	0.12	0.15	0.16	0.19	0.24	0.29
1999	0.13	0.16	0.18	0.17	0.20	0.29
2000	0.13	0.15	0.18	0.18	0.22	0.29
2001	0.12	0.16	0.19	0.23	0.27	0.29
2002	0.13	0.16	0.19	0.22	0.22	0.29
2003	0.13	0.12	0.17	0.19	0.18	0.29
2004	0.12	0.14	0.15	0.19	0.24	0.29
2005	0.12	0.14	0.17	0.19	0.24	0.29
2006	0.13	0.15	0.16	0.20	0.24	0.29
2007	0.14	0.18	0.19	0.22	0.24	0.29
2008	0.13	0.14	0.16	0.20	0.24	0.29
2009	0.13	0.14	0.16	0.20	0.24	0.29

17. Status of South Carolina Herring Stocks

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Executive Summary

Historically, river herring (blueback herring, *Alosa aestivalis,* and alewife, *Alosa pseudoharengus*) occurred in most of South Carolina's major rivers. In recent years, there has been no evidence of alewife in South Carolina and we believe that North Carolina has become the southernmost extent of their range. All available data show that river herring landings have declined from historic levels in South Carolina. Abundance of blueback herring in the Santee and Cooper Rivers has varied widely between rivers and among years. Changes in abundance appear to have resulted from a combination of habitat alteration from flow regulation and drought, and from fishing. Abundance of blueback herring in the Cooper River was reduced in the early 1970s from apparent over fishing and following the rediversion of water from the Cooper back to the Santee River and has remained low since the mid-1980s. Blueback herring abundance in the Santee River increased following rediversion and remained at relatively high levels through the 1990s, but has since declined abruptly after several years of drought. It is unlikely that fishing has affected stock abundance or age structure and we do not know if current abundance indices (CPUE, minimum population size) reflect low stock level resulting from poor recruitment following the drought or are just low index values caused by decreased effectiveness of fishing and passage. Commercial harvest regulations should not be relaxed for the Santee-Cooper system. Harvest in the Cooper River and Rediversion Canal recreational fisheries appear to be minor since herring are not target species. However, we advise continuing the creel survey to monitor this fishery. As of January 1, 2012 the Santee-Cooper and Pee Dee Rivers are the only systems in South Carolina with an approved commercial and recreational sustainable fishing plan, as required under Amendment 2 to the ASMFC Shad & River Herring FMP.

17.1. INTRODUCTION

Historically, river herring (blueback herring, *Alosa aestivalis,* and alewife, *Alosa pseudoharengus*) occurred in most of South Carolina's major rivers (Figure 17.1). In recent years, there has been no evidence of alewife in South Carolina and we believe that North Carolina has become the southernmost extent of their range. Commercial fisheries for blueback herring in South Carolina occur to a limited extent in open rivers such as Winyah Bay tributaries, but most fishing activity occurs in hydro-electric tailraces of the Santee-Cooper River system. Recreational fisheries for blueback herring exist, but only as a bycatch to the American shad fishery. Data are available to assess trends in fishery and stock status of blueback herring for the following river systems and life stages in South Carolina: Cooper River, Santee River, and the Rediversion Canal for adult herring and Winyah Bay, Waccamaw River, Santee River, Cooper River, Edisto River, and Combahee River for juveniles.

17.2. MANAGEMENT UNIT

Management of blueback herring in South Carolina is shared between the Marine Resources and Freshwater Divisions of the Department of Natural Resources (SCDNR). Management units are defined by stock and the complex of river(s) utilized. Management units include all rivers and tributaries within each area complex: Winyah Bay (Sampit, Lynches, Pee Dee, Bull Creek, Black, and Waccamaw Rivers), the Santee-Cooper Rivers complex, the Savannah River and the ACE Basin (Ashepoo-Combahee-Edisto Rivers). Detailed descriptions of these units are in Section 17.6.

17.3. REGULATORY HISTORY

The SCDNR manages commercial herring fisheries using a combination of seasons, gear restrictions, and catch limits. In 1964, commercial blueback herring fishing in Cooper River was restricted to daylight hours with a dip net not more than three feet in diameter and a limit of 100 lb (45.4 kg) per man per day. By 1969, regulations had been liberalized to allow nets with six foot diameters, fishing until ten o'clock p.m., and no limit on the harvest. Between 1966 and 1969, herring were abundant and the fishery expanded. Fishing success declined in the early 1970s and a limit of 45.4 kg of herring per man day was reimposed in 1975. Today, the commercial fishery for blueback herring has a 10 bushel daily limit (227 kg) per boat in the Cooper and Santee Rivers and the Santee-Cooper Rediversion Canal and a 250 lb (113.4 kg) per boat limit in the Santee-Cooper lakes. Seasons generally span the spawning season. All licensed fishermen have been required to report their daily catch and effort to the SCDNR since 1998. Current regulations are summarized in Appendix 13.1.

The recreational fishery has a 1 bushel (22.7 kg) fish aggregate daily creel for blueback herring in all rivers; however very few recreational anglers target blueback herring.

17.4. ASSESSMENT HISTORY

The first ASMFC assessment of the coast-wide river herring stocks occurred in 1990 (ASMFC 1990). South Carolina stocks were not included in this analysis.

17.5. STOCK SPECIFIC LIFE HISTORY

Blueback herring of South Carolina spawn in the spring in freshwater portions of coastal rivers and streams. The best life history information comes from of studies of blueback herring in the Santee-Cooper system in the central part of the state (Figure 17.2) prior to rediversion of Cooper River flows to the Santee River. Spawning in these systems occurred in Lakes Moultrie and Marian and below the Pinopolis Dam on the Cooper River and the Wilson Dam on the Santee River (Bulak and Curtis 1977). Spawning was concentrated between the Pinopolis Dam (km 143) and km 77 in the Cooper River and around km 60 on the Santee River. Limited spawning also occurred in the tributaries of the Santee and Cooper Rivers and in rice fields adjacent to the Cooper River. Use of these rice fields may have declined since rediversion and the resulting decline of Cooper River flows. Prior to rediversion, blueback herring spawned from March through early May in the Cooper River and February to April in the Santee River. Bulak and Curtis (1977) observed spawning in the Santee River at water temperatures of 12 to 20^{o}C. River spawning below the Pinopolis and Wilson Dams was often disrupted by changes in dam discharge (Meador et al. 1984). Since rediversion, blueback herring have expanded spawning in the Santee River to the rediversion canal and spawning times in the two rivers have become more closely synchronized (Cooke and Leach 2000). Mature fish leave the spawning reaches shortly after spawning. Once in the ocean, blueback herring from the Santee River migrate widely along the Atlantic Coast. Tag returns from fish tagged in spring in the Santee River have been recaptured from as far north as the Bay of Fundy (Christie and Cooke 1987)

Meristic and enzyme studies by Christie and Cooke (1985) indicated that separate stocks of blueback herring were present in the Cooper and Santee Rivers prior to rediversion. However, the authors found evidence of straying between these two rivers and of fish from other South Carolina coastal rivers. It is likely that stocks in the Santee and Cooper rivers have mixed to a greater degree since completion of the rediversion project in 1985 and subsequent flow changes.

Young blueback herring are important forage in Lakes Moultrie and Marian (Bulak and Curtis 1978). Downriver movement of each year's juveniles starts in June and may continue through the following June (Cooke and Coale 1996). Downriver movement of adults that spawn above the dams and of young produced above the dams occurs through power turbines at all three dams, spillage over the Wilson Dam, or through the navigation locks at the Pinopolis Dam. In drought years, downriver passage declines as dam discharge declines.

Blueback herring in the Santee River are iteroparous and have been observed to spawn up to four times over their lifetime (Christie and Barwick 1984). Percent of repeat spawn has been observed as high as 31% for males and 33% for females. Male and female blueback herring can begin spawning as early as age two (Table 17.1). However, full maturity of both sexes does not occur until age six. Males generally mature at a faster rate than females.

17.6. HABITAT DESCRIPTION

Blueback herring are present in tributaries of Winyah Bay, the Santee-Cooper system, and the Savannah River. Abundance is highest in the Winyah Bay tributaries and the Santee-Cooper system. Blueback herring are at low abundance or absent from the Edisto, Ashepoo, and Combahee Rivers (Figure 17.1).

17.6.1. Winyah Bay System

Winyah Bay extends nearly 24 km inland and has six major tributaries that have spawning runs of anadromous fish (Sampit, Lynches, Pee Dee, Bull Creek, Black, and Waccamaw). The Sampit is a small, tidal river that is navigable to about km 64. The mouth of the Black River is near the junction of the Great Pee Dee River and upper Winyah Bay and it has approximately 40 km of navigable waters. The Pee Dee River estends well into North Carolina and it is dammed at Blewett Falls, North Carolina (320 km inland) (Post *et al*. 2004).The Little Pee Dee is the largest tributary of the Pee Dee River and it extends about 96 km to the North Carolina state line. Bull Creek and Lynches River are both tributaries of the Pee Dee River. The Lynches River is navigable for over 113 km from its confluence with the Pee Dee. Bull Creek extends 24 km and borders the Waccamaw River to the south and the Great Pee Dee to the north.

17.6.2. Santee-Cooper System

The Santee River, formed by the Wateree and Congaree Rivers, was historically one of the longest river systems on the Atlantic coast. At one time, it supported spawning runs of anadromous fish to Great Falls (km 438) on the Wateree River and up to river km 602 on the Congaree River (Walburg and Nichols 1967). In 1938, the South Carolina Public Service Authority (SCPSA) initiated a large diversion project to move water from the Santee River to the Cooper River. The project included the construction of the Wilson Dam for flood control on Santee River at km 143, which created Lake Marion and the construction of Pinopolis Dam at km 77 on the Cooper River, which is a hydroelectric facility with a navigation lock (Figure 17.2). Pinopolis Dam formed Lake Moultrie (Cooke and Leach 2003). Flows were diverted from Lake Marion on the Santee River to Lake Moultrie on the Cooper River and mean annual flows in the Santee River declined from 525 m^3/s to 63 m^3/s. When not in flood, the Santee River is a shallow, slow moving, meandering river that flows through hardwood swamps (Bulak and Curtis 1977). Discharge from the Pinnopolis Dam flows 29 km through a discharge canal to its confluence with the East Branch of the Cooper River. The Cooper River downriver of the confluence receives drainage from several swamps and tributaries and is adjacent to many abandoned rice fields.

Increased flows from the Santee-Cooper Diversion Project to the Cooper River led to shoaling in Charleston Harbor, due to increased sediment loads. Consequently, starting in 1985, water was rediverted through a 15 km Rediversion Canal from Lake Moultrie to the Santee River below Lake Marion. The St. Stephen Dam was constructed 7 km up the Rediversion Canal to control flow and to provide hydro power. The Rediversion Canal diverted 75 percent of the Cooper River flow to the Santee River and increased the mean annual flow in the Santee River from 63 m^3 /s to 295 m^3 /s (Cooke and Leach 2003a). However, SCPSA has set a mean weekly discharge of 127 m^3 /s from the Pinopolis Dam on the Cooper River and when inflow to Lake Moultrie declines below that threshold flow to the Rediversion Canal declines. Discharge from the Wilson Dam on the Santee above the confluence with the Rediversion Canal was set at a continuous release of 14.6 m^3 /s. The result of this water management regime is that flow to the Santee River is greater from the Rediversion Canal than from Wilson Dam except on low flow years when flow through the Rediversion Canal is reduced. Data suggested that large numbers of blueback herring which utilized the Cooper River before rediversion, switched to Santee River after rediversion (Cooke and Coale 1996).

17.6.3. ACE Basin (Edisto River, Combahee River, and Ashepoo River)

The lower portions of these systems comprise the ACE (Ashepoo-Combahee-Edisto) Basin National Estuarine Research Reserve (Figure 17.1). The Edisto River drains approximately 4,800 km^2 within the South Carolina Coastal Plain. This river is approximately 320 km long and has no dams. At approximately km 180, the North and South Forks merge forming the Edisto River proper. Anadromous fish can reach at least 161 km in the North Edisto and at least 193 km in the South Edisto on their spawning migration (Walburg and Nichols 1967). The lower 75 km of this system is tidally influenced and the lower 50 km drains substantial areas of fresh, brackish and salt marsh. The Edisto, Combahee and Ashepoo Rivers are connected for 20 km before entering the Atlantic Ocean through St. Helena Sound. The Combahee River is a black-water river about 72 km long. The Salkehatchie and Little Salkehatchie are major tributaries. There are no impoundments on the Combahee River and anadromous fish reach could reach river km 137 near Walker, South Carolina (Walburg and Nichols 1967). The Ashepoo River is the smallest of the ACE Basin Rivers and it has no obstructions to anadromous fish migration.

Increased timber harvest in the 1980s may have affected the river herring population in the ACE Basin by increasing siltation of river spawning habitat (Chris Thomason, SCDNR, personal communication).

17.6.4. Savannah River

The Savannah River is approximately 560 km long (Figure 17.1). The first barrier to upstream migration is the New Savannah Bluff Lock and Dam (NSBLD) located at Augusta, Georgia (approximately km 301). The lock at NSBLD is designed for navigation and does not provide effective fish passage. However, fish can use the navigation lock and during high flow periods, the river rises above the NSBLD allowing some fish passage. There are 43 km between NSBLD and the next dam which is the J. Strom Thurmond Dam (Billy McCord, SCDNR, personal communication). Water quality may be a problem in the Savannah since the dissolved oxygen in the lower Savannah can fall below 1.0 ppm (Billy McCord, SCDNR, personal communication).

17.7. RESTORATION PROGRAMS

17.7.1. Restoration Objectives

The U.S. Fish and Wildlife Service, the National Marine Fisheries Service (NMFS) and SCDNR developed a fish restoration plan for the Santee-Cooper River basin with proposed restoration targets

(Anonymous 2001). River-specific goals were not established for other systems in South Carolina.

17.7.2. Hatchery Evaluations

Larval or adult river herring are not stocked in South Carolina Rivers.

17.7.3. Fish Passage Efficiency

17.7.3.1. Santee-Cooper System

Pinopolis Dam (Cooper River)

Upriver passage at the Pinopolis Dam occurs through a tailrace canal and navigation lock. Fish passage through the lock is measured by hydro-acoustic methods that estimate annual passage of fish biomass. However, fish species is generally not known and double counting may occur as fish congregate over the hydro-acoustic array. Therefore, we did not consider annual estimates of passage biomass to be good indicators of blueback herring abundance in this system. Downriver passage may occur through the navigation lock.

St. Stephen Dam (Rediversion Canal)

The St. Stephen fish lock is located approximately mid-way on the Santee-Cooper Rediversion Canal at river kilometer 92 (Figure 17.2). Migratory fish are attracted into the entrance of the fish lock by an attraction flow. Fish are forced into the lock chamber and the chamber is then flooded to head level. A brail basket prompts the fish to swim 15 -20 m up in the water column and releases the fish into the exit channel. There they pass viewing windows before continuing on to the upper Rediversion Canal and Santee-Cooper system. Generally, fish lock operations occur on the hour during daylight periods. Operations occur every 30 minutes when warranted by increased fish densities.

Passage efficiency at the St. Stephen Dam is unknown and likely varies among years. Poor passage efficiency was demonstrated by Cooke and Chappelear (1992), Cooke and Coale (1997), Cooke and Leach (2000), and Cooke and Leach (2002). Initially, high or intermittent discharges from the St. Stephen Dam on the Rediversion Canal prevented fish from entering the lock. In the 1990s, the SCPSA implemented a flow agreement to improve the fish-lift function, and a series of modifications were completed from 1995 through 2000 that may have increased the efficiency of the fish-lift. Annual variation in attraction flow, turbine discharge and water temperature in addition to fish abundance in the Rediversion Canal alter annual passage numbers of blueback herring at this facility.

The number of blueback herring that enters the Rediversion Canal from the Santee River varies among years depending on the relative flows in the Rediversion Canal and the Santee River above the canal. In moderate to high flow years, discharge of water from the St. Stephen Dam attracts fish into the Rediversion Canal. However, in low flow years when limited water is released from the St Stephens Dam, fish may bypass the Rediversion Canal and use the Santee River proper.

Fish moving downriver through the Rediversion Canal go through the turbines at the St. Stephens Dam. There have been no directed studies to determine turbine mortality on blueback herring at this facility, but it is believed that turbine strike mortality is minimal, with anecdotal information indicating that passage is more problematic for larger fish. Blueback herring appear to be more affected by pressure differential than by turbine strikes during their downstream migration at this facility (William McCord, SCDNR, pers. comm.).Above Lake Marion, several impediments to migration exist on Santee River tributaries. On the Wateree River, the Wateree Dam is the first obstruction to fish passage.

17.7.3.2. Wilson Dam

There are no fish passage facilities on the Wilson Dam on the Santee River although downriver passage may occur over the spillway.

17.7.3.3. Savannah River

New Savannah Bluff Lock and Dam are located at rkm 301 of the Savannah River. The dam was constructed in the 1930s as a commercial navigation lock. Currently, fish passage is possible by one of two methods: (1) fish pass freely at river flows greater than 453 m^3/s when water levels above and below the dam are roughly equal and (2) through the navigation lock, which is operated 30 to 50 times a year between March 15 and June 15 to facilitate fish passage. In dry years (i.e., when river flows do not reach 453 m^3/s), lock operation is the only source of fish passage. Mortality may occur in this lock when fish are held for long periods of time before release. There are no measures of efficacy for either method (Boltin 1999).

17.8. AGE

Scale samples were used to age blueback herring using methods of Cating (1953) and Marcy (1969). Scales were taken from the left side of each herring in the area below the dorsal fin and above the lateral line. Samples were cleaned in 2% potassium hydroxide and read under a microfiche reader at a magnification of 26 x. Scale ageing was done by two independent researchers and results were not accepted until concurrence was achieved on 75 % of the age estimates for a given days sample. From 1979 to 1985, a single group of readers read scale samples. Maximum age that South Carolina herring stocks can attain is unknown.

17.9. FISHERY DESCRIPTION

17.9.1. Overview

Several commercial herring fisheries occur within South Carolina. Most of the herring landed in the State over the past several decades have been taken in cast and drop net fisheries immediately below Pinopolis Dam on the Cooper River and below St. Stephen Dam on the Santee Rediversion Canal. Landings were typically greater in the Cooper River prior to the completion of the canal in 1986 because flow was greater in the Cooper River. The fishery gradually shifted to the Rediversion Canal once the canal was completed. Exceptions occur during low flow or drought years when the hydroelectric facility at St. Stephens dam does not pass water, thus reducing the attraction flow needed for herring. In such years, herring tend to stay in the main channel of the Santee River, bypassing the Rediversion Canal and continuing to the Santee Dam. During those years, the fishery shifts to the Santee River below the Wilson Dam. A small fishery continues below the Pinopolis Dam on the Cooper River.

A haul seine fishery operated below Wilson Dam on the Santee River prior to completion of the Santee-Cooper Rediversion Project in 1985. However, increased water levels and flows have largely prevented the operation of this fishery since rediversion. A recreational bow net fishery also occurred below the Wilson Dam on the Santee River prior to 1985, but only a small percent of the landings occurred in this gear. Fisheries in the Santee-Cooper system target pre-spawning adult blueback herring. Catch from these fisheries is sold for both bait and for human consumption, particularly the roe.

A limited, more traditional gill-net fishery occurs in rivers of the Winyah Bay watershed. Take in these fisheries is presumed to be largely adult blueback herring and most landings are consumed locally by fishers or sold as bait.

Blueback herring are also caught in commercial fisheries of several South Carolina reservoirs. Cast and drop nets are the legal gears for these bait fisheries. Catches within the Santee-Cooper Lakes where passage is provided for adult blueback herring, hickory, and American shad may include a mixture of adults and juveniles of these and other clupeids such as threadfin shad and gizzard shad. The Savannah River impoundments are not equipped with fish passage devices, but blueback herring populations are land-locked within these reservoirs as a result of forage-fish stockings taken from the Santee-Cooper Lakes. Catches in the Savannah River reservoirs are also likely a mixed bag, but would not include American or hickory shad. “Shad” and “herring” landed in above-dam areas are generally sold (or used personally) as live, or fresh dead, bait for striped bass, hybrid striped bass, or catfishes.

Hook & line and cast nets are the only legal recreational gears for herring in South Carolina. Currently, most of the recreational take occurs as bycatch to the American shad fishery in the Cooper, Santee (including the Rediversion Canal), and Savannah Rivers. Since most fishermen target American shad, herring are usually released. There is also some undetermined amount of directed effort for herring by fishermen using weighted treble hooks for "snatching" below dams where the fish are concentrated.

17.9.2. Fishery Data

Reported commercial landings data of river herring in South Carolina are available from the National Marine Fisheries Service and the state. Landings reported to the NMFS prior to 1979 were collected from major wholesale outlets located near the coast and probably did not account for inland landings which were generally not sold at these outlets. NMFS data collected since 1979 usually include inland landings. In 1998, the state of South Carolina instituted mandatory reporting of commercial catch and effort. However, questions regarding the integrity of the reports, accuracy of effort data, irregular or infrequent fishing by license holders, and year-to-year variability in river-wide records have hindered successful development of total catch and effort statistics by river from these data. The SCDNR is working to improve the scope and reliability of licensee data. The wholesale dealer reporting system utilized by the NMFS may not include herring landings because herring sold as bait to licensed bait dealers may not be reported.

In 1969, the South Carolina Department of Natural Resources instituted a commercial creel survey to estimate catch and effort in the fisheries in the Santee Cooper system. Surveys occur at landings used to off-load and transport catch. The majority of herring harvested from the Cooper River (1969-1989) were landed at two locations between the hours of six p.m. and ten p.m. daily. Creel clerks stationed at these locations interviewed individual fishermen as the catch was unloaded. The time, date, type of gear used, catch, and number of fishermen aboard were recorded as each boat landed. The survey was expanded to the major landing below the St. Stephens Dam on the Rediversion Canal starting in 1990 as fish abundance declined in the Cooper River and increased in the Santee River and the Rediversion Canal. During low flow years, herring and the fishery move to the Santee River below the Wilson Dam. Surveys have been infrequent at that location. Weight of harvest was estimated from the number of bushels of herring landed and a mean bushel weight of 25.4 kg (Cooke 1998). Numbers of adult blueback herring landed were estimated by dividing kg landed by the mean weight of an adult herring (0.14 kg). Although some landings are occasionally missed during the creel survey, the survey produces the most reliable estimates of catch and effort available for South Carolina waters. Landings were not estimated for reservoir fisheries with landings of mixed species and size composition.

SCDNR has conducted an annual recreational creel survey since 2001 to estimate exploitation and catch-per-effort in the recreational fishery of the Santee Cooper system. These data consist of access point creel surveys (at end of a party’s fishing day) for at least 2 h/d, 4 d/week along with effort estimates made by counting boats below the Pinopolis Dam, the Wilson Dam, or the Rediversion Canal at approximately 1400h each day of survey. Previous data demonstrated that a 1400h boat count measures maximum daily fishing pressure. This does not account for angler turnover, particularly of anglers that fish in the morning only. Also, while the majority of the season is surveyed, some fishing activity occurs prior to and after the study period, so results presented here are underestimated.

SCDNR also conducted sportfishing creel surveys on the Cooper and Santee Rivers in 1981 - 1982 and 1991 - 1993 to evaluate the impact of the Rediversion Canal on these recreational fisheries (Cook and Chappelear 1994). These surveys examined the total recreational fisheries on each river, but did not provide data on catch of blueback herring. Thus, the surveys could only be used to indicate change in the size of the fishery.

Recreational creel surveys were conducted on the Savannah River in the late 1990s by the Georgia Department of Natural Resources in 1997 and SCDNR in1998 and 1999. Estimates of catch from these surveys varied from year to year largely due to dramatically different flow conditions. Catch estimates from each of these creel surveys were provided in Boltin (1999).

17.9.3. Fishery Dependent Data - Commercial

Reported Landings

Over 1,000,000 kg of river herring were reported from South Carolina commercial fisheries in 1969 (Table 17.2, Figure 17.3). Landings declined precipitously soon after. They rebounded to a high of approximately 260,000 kg in the early 1980s and again in the 1990s. They have fluctuated at less than 70,000 kg since 2001. The bulk of the reported landings since 1989 have come from the Santee-Cooper system (Table 17.3). Reported landings for the Pee Dee River of the Winyah Bay system have remained at less than 500 kg per year since mandatory reporting was initiated in 1989 (Table 17.4).

Annual variation in reported landings since the early 1970s may have been influenced by changes in allowable catch over the years. Landings in the Santee Cooper system were also affected by changes in discharge from the three dams and concurrent changes in fish migration and gear effectiveness.

Estimated Effort, Harvest, and Catch Rates

Annual estimates of catch in kg, effort in man days, and kg catch/man day (CPUE) are available since 1969 from surveys of the Santee-Cooper fishery (Table 17.5, Figure 17.4). Estimates of all three parameters have fluctuated widely over the time series. Highest estimates of landings and CPUE occurred early in the time series in the Cooper River. Estimates of effort, landings, and CPUE in the Cooper River declined dramatically soon after to a low that lasted through the late 1970s. Estimates climbed again through the early 1980s and then declined as the Rediversion Canal was completed and flows shifted to the Rediversion Canal and the Santee River. Estimates of effort, landings, and CPUE then increased in the Rediversion Canal and the Santee River. Effort and fishing success began to decline again in the late 1990s and have stayed at low levels since.

Many factors likely affected effort and landings. To evaluate potential causes of change, we separated data from the Cooper River into two times series (1969 - 1974 and 1975 – 2008) and subset data for the Santee River to those from 1975 – 2008. We then normalized the estimates by dividing annual values by the series mean (Figure 17.5). Sub setting the Cooper River data reduced the influence of the relatively large estimates obtained early in the time series on the rest of the data. Normalizing the time series placed all of the parameters on a comparable scale. Effort and landings were highly correlated in both the Cooper River fisheries (1969-1974, r^2=0.90; 1975-2008, r^2=0.85) and the Santee River fisheries (1990-2008, r^2=0.94) (Figure 17.6). Apparently, effort played an important role in dictating landings. However, CPUE was also related to effort (Figure 17.5). If we assume that CPUE was a measure of relative stock abundance, then we can speculate that changes in stock abundance and related fishing success led to changes in effort and then in landings.

The variation in CPUE among years suggests that several cycles in blueback herring abundance occurred in the Santee Cooper System (Figure 17.4 and Figure 17.5). The dramatic CPUE decline in the first six years of the Cooper River time series may have been caused by overfishing. Following the imposition of harvest restrictions in 1975, CPUE bottomed out and remained at low levels for four years before rebounding through the early 1980s. Cooper River CPUE declined again following completion of the Rediversion Canal in 1985 and it has remained at relatively low levels since 1987. It is likely that reduced flows in the Cooper River led to degradation of spawning and nursery habitat in the river below the Pinopolis Dam and reduced access to flooded rice fields that had been previously used for spawning.

CPUE in the Santee River fishery increased rapidly following increased flows from rediversion. CPUE leveled off in the mid to late 1990s and then declined abruptly following a severe drought that lasted from 1999 through mid 2002. Santee River CPUE has fluctuated without trend since that time. The initial CPUE increase in the Santee River fishery likely resulted from a combination of herring from the Cooper River stock that began to migrate into the Santee River as flow increased and improved production from improved spawning and nursery habitat. Stock increase was enhanced by regulations that prevented harvest from the Rediversion Canal from 1985 through 1989. We do not know if reduced CPUE since the drought resulted from declining stock levels or from low fishing success caused by low water levels. Fishing did not occur, or was severely limited in 2001, and harvest estimates were not made. If the drought reduced or eliminated several year classes of fish, it may take some time for the stock to rebound to levels of the mid 1990s.

It is interesting to note that the CPUE of the Cooper River fishery during the peak years of 1979 through 1986 (135.2) exceeded estimates obtained for the Santee River fishery during its peak years of 1992 through 2001 (102.9). Highest CPUE on the Cooper River since 1975 was 163.3 in 1983 just before rediversion. Highest CPUE on the Santee-Cooper Rediversion Canal was 137.2 in 1998 some 13 years after rediversion. It is not yet known if habitat in the Santee system will support greater numbers of blueback herring than did the Cooper River prior to diversion. The highest CPUE of the time series (607.5) occurred in the Cooper River in 1969.

CPUE in the Santee-Cooper commercial fisheries may have been affected by changes in harvest regulations. However, affects must have been minor because in many cases the low estimates of catch per man day were well below the minimum daily catch at the time. For example, the fishery went from one with no take limits in the early 1970s to one with a daily maximum take limit of 45.4 kg (100 lbs) per person in 1975. CPUE dropped from a high of 608 kg per fisherman day in 1969 to 55 kg in 1974 a then dropped to and remained at less than 35 kg through 1978. If the daily cap had been the cause of decline, then one would expect the CPUE to drop to and remain at the cap as soon as it was imposed. Since this did not occur, it is more likely that much of the change in CPUE was caused by concomitant changes in herring abundance.

Bycatch

River herring occur as bycatch in fisheries along the Atlantic coast from North Carolina up to the Gulf of Maine. Since blueback herring from South Carolina migrate through this reach of ocean, it is likely that South Carolina fish are included. River herring bycatch in the Atlantic herring and mackerel fishery in the New York Bight and Gulf of Maine is currently being estimated. Preliminary results suggest that bycatch of river herring in the Atlantic herring fishery can be equal to, or exceed the total of all in-river landings (ASMFC 2008).

Size and Age Distribution

Mean fork length of blueback herring taken in the commercial fisheries in the Santee Rediversion Canal varied widely among years (Table 17.6, Figure 17.7). Mean length of males showed a slight declining trend over the time series, while mean length of females showed a slight increasing trend. Mean length of females has exceeded that of males since 2001. Mean lengths of both sexes have declined since 2003. Blueback herring in the commercial catch tended to be smaller than those that survived the fishery and were lifted over the St Stevens Dam. That and the wide interannual fluctuations in lengths of fish from the commercial fishery relative to those in the fish lift suggest gear selectivity and a change in fishing gear in 2001 (Figure 17.6). Data are not available on age distribution of blueback herring in the fishery.

17.9.4. Fishery Dependent Data - Recreational

Catch per unit effort of blueback herring in the recreational fishery varied without trend from 2003 through 2007 (Table 17.7).

17.10. FISHERY INDEPENDENT SURVEYS

A variety of sampling efforts have been conducted to assess the condition of blueback herring stocks in South Carolina. Annual passage counts at the St. Stephen Dam on the Santee-Cooper Rediversion Canal and the Pinopolis Dam on the Cooper River provide the longest times series of data. Periodic electrofishing and gill net sampling occurred in the Santee River below the Wilson Dam and population estimates were obtained for several years at that location. In addition, annual electrofishing for juvenile herring has been conducted in Winyah Bay and the Santee, Cooper, Edisto, and Combahee Rivers. Ichthyoplankton surveys were made for several years on the Santee and Cooper Rivers. The following summarizes results of the more useful surveys.

17.11. ASSESSMENT APPROACHES AND RESULTS

17.11.1. Adult Surveys

Santee River Population Estimates

Mark recapture population estimates of blueback herring were conducted in the Santee River from 1977 through 1990. During the first two years, researchers attempted to tag immigrating fish in the lower river and recapture the tagged fish upriver of the tagging sites. Researchers used seines, fyke nets, pound nets, and electrofishing to capture fish, but failed to obtain adequate numbers of fish for valid population estimates (Christie and Cooke 1987). Moreover, fish tagged in the lower reaches of the river often moved downriver and out of the system (Christie and Cooke 1986). Starting in 1979, fish for tagging were collected by electrofishing below the Wilson Dam. Additional fish for tagging were obtained from the Cooper River and once the rediversion system was in place, from the Rediversion Canal. Number of marked fish was decremented by 10% to account for handling mortality and tag loss for fish caught by electrofishing and by 20% for fish caught in the St. Stephen's fish lift. Results were further discounted by estimates of the number of tagged fish that went upstream through the St. Stephen's fish lift rather than spawning below the dam and then emigrating downriver. Recaptures were obtained by gill netting downriver of the tagging site in the Santee River. To insure that only the tagged population was included in the recapture effort, only fish moving downriver (from the upriver side of the net) were counted in recapture collections. Valid recaptures were those captured between three days after tagging began through 10 days after tagging ended.

Estimates were calculated by Chapman's non-stratified modification of the Peterson formula (Ricker 1975):

$$N = ((M+1)*(C+1)/(R+1))-1$$

Where:

M = number of marked herring tagged and released decremented by the appropriate factor for handling mortality, tag loss, and upriver passage
C = number of herring captured at the recapture site
R = number of tagged herring that were recaptured.

Standard error was calculated as:

$$SE = \sqrt{(N-M)*(N-C)/M*C*(N-1)}$$

The coefficient of variation (CV) was calculated as SE/N.

Resulting population estimates varied substantially among years and had wide confidence limits (Table 17.8). Estimates declined from 1980 to 1982, then increased through 1990 with the exception of a one-year decline in 1987 one year after completion of the Rediversion Canal (Figure 17.8) The increase in Santee River population estimates after completion of the canal occurred concurrently with the decline in CPUE in the commercial fishery on the Cooper River (Figure 17.4, Figure 17.8). It is interesting to note that estimates began to increase in the Santee River in 1984 which was the second year of a harvest ban in the Santee Fishery, but one year before the rediversion was completed. The population estimates did not correlate with passage numbers at the St. Stephen Fish Lift in 1986-1990 ($r^2 = 0.0$).

St. Stephen Fish Lift Counts- Santee-Cooper Rediversion Canal

Fish released upriver of the St. Stephen Dam are counted as they pass through the exit channel of the fish lift. Numbers were interpreted from hydro-acoustic sampling in 1986 and1987, real-time observer counts in 1988-1994, and from time-lapse video recording from 1994 through 2007. Passage counts varied widely among years and did not appear to be affected by changes in counting methodology (Table 17.9 and Figure 17.9). With the exception of 1996 and 2001 annual counts were below 700,000 animals. Lowest counts occurred in 2004 with 35,545 animals and in 2007 with 49,343 animals.

Peaks in passage occurred in 1992, 1996, and 2001 and are of interest. Cooke and Leach (2000) suggested that these peaks reflected the cycling of strong year classes through the population. They developed a predictive model for passage numbers that indicated high passage numbers were expected in 2000 and 2004. Cooke and Leach (2001) explained the lower than expected passage in 2000 and the higher than expected passage in 2001 as a result of differences in spring flows and turbine operation at the St Stephens Dam. They hypothesized that four year old fish were not able to enter the fish lift entrance in 2000 and they returned again in 2001 as five year olds. Unfortunately, no significant increase in mean length of lifted fish occurred in 2001 that would have supported this hypothesis. The relationship broke down completely with the lack of any strong passage since 2001.

Since efficiency of the lift operation is poorly known and probably varied among years with changes in operational characteristics and river flow, we did not consider passage numbers to be good indices of numbers of blueback herring in the Santee-Cooper system. We normalized annual number lifted at the St. Stephens Dam and CPUE from the Rediversion Canal fishery by dividing each value by the series mean. A comparison of the two time series indicated little, if any relationship among years (Figure 17.10). However, number lifted did constitute a minimum number of fish that survived the canal commercial fishery below the dam. Therefore, we added annual number lifted to annual harvest in numbers for estimates of annual minimum population size in the Rediversion Canal (Table 17.9). Annual results were a small fraction of estimated annual population size for the overlapping years of 1986 – 1990 suggesting that a very small fraction of blueback herring in the Santee River are caught or are lifted over the St. Stephens Dam.

Santee River System Abundance Trends

A comparison of population estimates, minimum population size, and CPUE in the Rediversion Canal indicated a very general trend of abundance increase through the 1980s, a plateau during the 1990s, and a decline in the 2000s (Figure 17.11). Since it is not clear if reduced recruitment or reduced fishing and dam passage efficiency are involved, monitoring of lift numbers and fishery catch rates should continue. It would also be wise to conduct several years of Santee River/Rediversion Canal population estimates to verify trends apparent in other abundance data. Cooke and Leach (2003b) argue convincingly that changes in the flow regimes of the Cooper and Santee Rivers were responsible for the demise of the Cooper River fish and the resurgence of the Santee River stock.

Navigation Lock at the Pinopolis Dam on the Cooper River

We did not consider estimates of fish biomass passed through the lock to be reliable indices of annual run size. Not only was the fish species composition of the estimates poorly known, but double counting of passed fish was a factor in some years of operation. However, estimated biomass of fish has declined since rediversion was completed (Cooke and Leach 2000).

17.11.2. Size and Age Distribution

Mean size (fork length-mm) of blueback herring in the St. Stephen's Fish Lift on the Rediversion Canal declined between 1991 and 2007 (Table 17.10 and Figure 17.7). The decline was most pronounced in the last four years and mean lengths of both males and females are now well below long term averages. Mean lengths of females generally exceeded those of males. The fact that lengths of blueback herring from the fishery below the St. Stephens Dam also declined during this time period is a cause for concern (Table 17.6, Figure 17.7). Decreased length could result from declining recruitment to the fished population or from increased mortality. The situation should be closely monitored in the future.

Data on annual age composition of blueback herring were obtained prior to rediversion from fishery independent sampling in the Cooper River in 1975-1982 (Table 17.11) and by fishery independent gill net sampling in the Santee River in1975-1982 (Tables 17.12 and 17.13). Mean age of blueback herring in both rivers increased prior to rediversion as the age structure broadened to include older fish (Figure 17.12). This increase was most dramatic in the Cooper River where the increase encompassed a time period prior to and during rapid population increase. Such a change in age structure often accompanies declining rates fishing mortality which could also explain the population growth. Mean age of females generally exceeded that of males in the Santee River data (Tables 17.12 and 17.13; Figure 17.12). Current age data are needed for both populations. This is especially important for the Santee River population where fish size has been decreasing.

Data on frequency of repeat spawning were obtained for blueback herring of the Santee River prior to rediversion. Percent of males and females that spawned more than once varied without trend (Tables 17.14 and 17.15). Since high variation in frequency of repeat spawning often occurred between years, it likely reflected recruitment variation rather than changes in mortality. Percent of repeat spawn ranged from 0.0% to 31.6 % in males and from 18.4 to 40.0 % in females.

17.11.3. Growth

Mean fork length at age was available for blueback herring of the Cooper River (sexes combined) and the Santee River (by sex). Mean length at age varied without trend among years for herring of both stocks. However interannual variation was greater for Cooper River herring (Table 17.16, Figure 17.13) than for herring of the Santee River (Table 17.17, Figures 17.14 and 17.15). We calculated Von Bertalanffy curves for mean fork length at age (sexes combined) in Cooper River blueback herring (Figure 17.16) and for Santee River herring by sex (Figure 17.16). Since growth curves are often influenced by lengths of age one and younger fish, we converted length at date data from young emigrating blueback herring to length at age using an assumed hatch date of March (Table 17.18). Data on length of young blueback herring from the Cooper River came from the forebay of the Pinopolis Dam (Cooke and Coale 1996). Data for blueback herring of the Santee River came from the Wilson Dam tailrace. Von Bertalanffy parameters suggested very similar growth curves for males and females in the Santee system and a slightly larger maximum length for Cooper River herring (Table 17.19).

17.11.4. Mortality Estimates

We calculated total instantaneous mortality (Z) using catch curves of number at age within collection year (Ricker 1975). We confined estimates to ages from the Cooper River because collections were made by a variety of gears. We did not use age date from the Santee River because Santee fish were collected with a single mesh gill net and size/age selectivity was expected. We estimated Z as the negative slope of the linear regression of log e number at age on log e age. Results ranged from Z = 0.23 in 1977 to Z = 2.15 in 1975 (Table 17.20). The extreme interannual fluctuation in Z estimates suggested a strong influence of recruitment variation on analyses. No trend in Z among years was apparent.

We evaluated potential rates of exploitation (u) in the Santee River stock after rediversion by dividing annual harvest by annual minimum population size.We considered resulting estimates of u to be maximum values because the denominator was the smallest possible estimate of abundance for this stock. Exploitation rates were very low ($u \leq 0.18$, Table 17.21) and no trend was apparent among years. By comparison, u_{msy} for blueback herring of the Chowan River, North Carolina was $u_{msy} = 0.67$, while that for herring of the Connecticut River, Connecticut and St. John River, New Brusnwick were $u_{msy} = 0.75$ (ASMFC 1990). A recent estimate of u_{30} for NY herring stocks was $u_{30} = 0.35$. Our analysis suggests that rates of mortality imposed by the commercial fishery in the Rediversion Canal were low relative to available benchmarks for the species and are sustainable.

Although fishing rates may not be an issue in Santee River blueback herring stock, the picture for fish passage is not as clear. We do not know if fish lifted over the St. Stephens Dam emigrate after spawning or if they do, whether they survive emigration through the turbines. It is also not clear if a significant number of juveniles produced above the dams in the Santee Cooper Lake system successfully emigrate to the ocean. If adults lifted over the dam do not survive, and if few lake-produced progeny survive emigration to the ocean, then high lift numbers may be harmful to the main river population. Santee River blueback herring were iteroparous prior to construction of dams and it is likely that iteroparourity is necessary for the maintenance of resilient populations. If a high percentage of adults are lifted over the St. Stephens Dam and they do not survive to spawn again, then the population suffers high mortality that erodes age structure and reduces incidence of repeat spawning. Such changes are similar to those caused by excessive fishing mortality. Evaluation of recent change in age structure, incidence of repeat spawning, and rates of total mortality will require collection and analyses of three or more years of age and repeat spawn data from the current population.

17.11.5. Young-of-the-Year Surveys

Limited juvenile abundance data for blueback herring in South Carolina have been obtained by electrofishing (Table 17.22). Collections were made in Winyah Bay in 2001-2007, the Santee River in 2001-2003, the Cooper River in2001-2007, the Edisto River in 2001-2007, and the Combahee River 2001-2007. Catches of blueback herring in this sampling have been too low to detect annual trends.

17.12. BENCHMARKS

Benchmarks were not developed for any South Carolina river herring stock.

17.13. CONCLUSIONS AND RECOMMENDATIONS

All available data show that river herring landings have declined from historic levels in South Carolina.

Abundance of blueback herring in the Santee and Cooper Rivers has varied widely between rivers and among years. Changes in abundance appear to have resulted from a combination of habitat alteration from flow regulation and drought, and from fishing.

Abundance of blueback herring in the Cooper River was reduced in the early 1970s from apparent over fishing. It rebounded a bit in the early 1980s after imposition of harvest regulations, but declined again following the rediversion of water from the Cooper back to the Santee River in 1985. Abundance has remained low in the Cooper River since that time.

Blueback herring abundance in the Santee River increased following rediversion and remained at relatively high levels through the 1990s. Abundance declined abruptly in the early 2000s after several years of drought. Rates of mortality from commercial harvest of this stock from 1990 through the present have been low and it is unlikely that fishing has affected stock abundance or age structure. We do not know if current abundance indices (CPUE, minimum population size) reflect low stock level resulting from poor recruitment following the drought or are just low index values caused by decreased effectiveness of fishing and passage.

Fish size has declined dramatically in the past few years in the Santee-Cooper Rediversion Canal.

We recommend that age data be obtained from blueback herring of the Santee River, the Santee-Cooper Rediversion Canal, and the Cooper River and that the commercial creel survey of tailrace fisheries in the system be continued. Age and harvest data are important to understanding current stock dynamics and factors affecting recent river herring abundance.

We recommend that estimates be made of bluback herring absolute abundance in the Santee system to verify abundance changes suggested indices. Estimates should be made for three or more contiguous years.

We also recommend that a sample program be developed or existing programs be improved to track annual production of young. Numbers of blueback herring collected in current sample programs for juvenile fish are too low for meaningful evaluations.

Commercial harvest regulations should not be relaxed for the Santee-Cooper system.

Harvest in the Cooper River and Rediversion Canal recreational fisheries appear to be minor since herring are not target species. However, we advise continuing the creel survey to monitor this fishery.

We recommend that bycatch of river herring in near-shore-ocean fisheries should be evaluated, in concert with other states.

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Table 17.1 Maturity at age of blueback herring collected from the Santee River in SC, 1978-1983

Percent Mature		
Age	Males	Females
1	0.0	0.0
2	2.5	0.7
3	21.4	12.6
4	72.2	53.4
5	95.6	89.8
6	99.6	99.6
7	100.0	100.0

Table 17.2 Reported weight (kg) of blueback herring taken in the commercial fishery of SC.

Year	Weight (kg)	Year	Weight (kg)	Year	Weight (kg)	Year	Weight (kg)	Year	Weight (kg)
1969	1111774	1978	15255	1987	61350	1996	160260	2005	135400
1970	145379	1979	65341	1988	48830	1997	112680	2006	395600
1971	629234	1980	169020	1989	37560	1998	152750	2007	137040
1972	448973	1981	117690	1990	31300	1999	127710	2008	29970
1973	164657	1982	175280	1991	33800	2000	146490	2009	145960
1974	40053	1983	146490	1992	88890	2001	92650	2010	126160
1975	8318	1984	180290	1993	127710	2002	-		
1976	11689	1985	111430	1994	100160	2003	93900		
1977	13572	1986	111430	1995	130210	2004	44700		

Table 17.3 Number and weight of blueback herring reported by the commercial fishery in the Cooper and Santee Rivers, SC.

	Cooper River	Santee River		
Year	Kg	Number	Kg	Mean Weight (kg)
1998	0	898050	179610	0.20
1999	0	601900	120380	0.20
2000	0	749056	134830	0.18
2001	580	151813	24290	0.16
2002	0			
2003	900	373214	52250	0.14
2004	3580	64286	9000	0.14
2005	11320	250286	35040	0.14
2006	0	53571	7500	0.14
2007	0	338000	50700	0.15
2008	3000		3600	
2009	0		71600	
2010	0		69600	

Table 17.4 Number and weight (kg) of blueback herring reported by the commercial gill net fishery of the Pee Dee River, SC.

Year	Number	Kg	Mean Weight (kg)
1998	10	2	0.23
1999	73	15	0.20
2000	1777	323	0.18
2001	2375	431	0.18
2002	768	139	0.18
2003	1790	244	0.14
2004	10	1	0.14
2005	1416	193	0.14
2006	140	19	0.14
2007	1779	266	0.15

Table 17.5 Estimated commercial effort, landings (kg), and CPUE of blueback herring in the Santee-Cooper System, SC.

	Cooper River			Santee River below Wilson Dam		Santee River Rediversion Canal			Total		
Years	Fisherman Days	Landings	CPUE	Fisherman Days	Landings	Fisherman Days	Landings	CPUE	Fisherman Days	Landings	CPUE
1969	1830	1111774	607.5						1830	1111774	607.5
1970	737	145379	197.3						737	145379	197.3
1971	1059	629234	594.2						1059	629234	594.2
1972	1215	448973	369.5						1215	448973	369.5
1973	1065	164657	154.6						1065	164657	154.6
1974	724	40053	55.3						724	40053	55.3
1975	399	8318	20.8						399	8318	20.8
1976	391	11689	29.9						391	11689	29.9
1977	468	13572	29.0						468	13572	29.0
1978	449	15255	34.0						449	15255	34.0
1979	566	65341	115.4						566	65341	115.4
1980	1399	177444	126.8		31900				1399	209344	149.6
1981	755	71392	94.6	500	101802				1255	173194	138.0
1982	639	93428	146.2						639	93428	146.2
1983	1608	262618	163.3		a				1608	262618	163.3
1984	1727	251450	145.6		a				1727	251450	145.6
1985	1520	135926	89.4	60	9600		a		1580	145526	92.1
1986	737	66029	89.6	32	35200		a		769	101229	131.6
1987	1369	67988	49.7				a		1369	67988	49.7
1988	515	20133	39.1				a		515	20133	39.1
1989	592	17791	30.1				a		592	17791	30.1
1990	662	17846	27.0			87	1154	13.3	749	19000	25.4
1991	324	7829	24.2			296	8859	29.9	620	16688	26.9
1992	145	7723	53.3			1118	82673	73.9	1263	90395	71.6
1993	145	4170	28.8			1479	162977	110.2	1624	167147	102.9
1994	66	3047	46.2			1407	116125	82.5	1473	119172	80.9
1995	35	472	13.5			1743	186378	106.9	1778	186850	105.1
1996						1854	238781	128.8	1854	238781	128.8
1997						1414	128133	90.6	1414	128133	90.6
1998						1319	180919	137.2	1319	180919	137.2
1999						1052	118164	112.3	1052	118164	112.3
2000						1026	120114	117.1	1026	120114	117.1
2001	55	550	10.0			244	24134	98.9	299	24684	82.6
2002						0	0		0	0	
2003	35	807	23.1			595	46665	78.4	630	47472	75.4
2004	56	3200	57.1			259	8040	31.0	315	11240	35.7
2005						309	10412	33.7	309	10412	33.7
2006						229	6743	29.4	229	6743	29.4
2007						439	50701	115.5	439	50701	115.5
2008	120	3000.051	25.0			89	3600	40.5	209	6600	31.6
2009						402	71600	178.7	402	71600	178.7
2010						470	69600	148.1	470	69600	148.1

a- Fishing prohibited

Table 17.6 Mean fork length (mm) of blueback herring taken in the commercial cast net fishery below the St. Stephens Dam on the Santee - Cooper Rediversion Canal.

Year	Males			Females			Total		
	Number	Mean Fork Length	SD	Number	Mean Fork Length	SD	Number	Mean Fork Length	SD
1995	346	232		248	231				
1996	128	232		122	235				
1997	154	229		73	230				
1998	207	223		263	221				
1999	207	221		193	221				
2000	166	220		215	222				
2001	238	237	10.4	97	248	17.7	335	240	13.9
2002	-	-	-	-	-	-	-	-	-
2003	183	235	10.7	127	246	11.5	310	239	12.3
2004	361	223	13.8	280	239	15.7	641	230	16.7
2005	539	228	8.0	498	238	9.1	1037	233	10.0
2006	310	219	26.6	224	243	30.3	554	230	30.5
2007	333	216	8.7	248	234	11.2	581	224	13.3
2008*									
2009	490	219	10.4	518	233	10.3	1008	226	0.0
2010	295	231	9.02	581	240	10.61	876	329	10.97

**Due to low flows, fishery did not occur in this area*

Table 17.7 Catch per unit effort of blueback herring caught in the American shad recreational fishery on the Santee and Cooper Rivers, SC.

Year	CPUE
2003	0.13
2004	1.15
2005	0.93
2006	1.10
2007	0.85

Table 17.8 Mark recapture population estimates of blueback herring in the Santee River, SC.

Year	N	CV	Confidence Interval	
			Lower	Upper
1980	5,895,796	0.25	3,012,000	8,780,000
1981	4,054,521	0.23	2,236,000	5,873,000
1982	664,151	0.17	400,000	888,000
1983	2,352,005	0.45	297,000	4,407,000
1984	2,625,000	0.24	1,417,000	3,833,000
1985	6,205,353	0.71	0	14,822,650
1986	9,061,064	0.41	1,817,496	16,304,632
1987	3,805,457	0.29	1,657,618	5,953,296
1988	5,507,918	0.50	116,348	10,899,488
1989	5,501,964	0.22	3,153,678	7,850,250
1990	9,353,003	0.22	5,358,472	13,347,534

Table 17.9 Annual number of blueback herring passed at the St. Stevens Fish Lift, caught in the commercial fishery, and minimum population size in the Santee-Cooper Rediversion Canal, SC.

Year	Number Passed	Number Caught	Minimum Population	Breakdown of caught fish kg	lb	#
1986	187,000		187000			
1987	74,000		74000			
1988	232,000		232000			
1989	147,000		147000			
1990	71,000	12540	83540	19000	41800.87	12540.26
1991	400,000	11014	411014	16688	36714.47	11014.34
1992	589,000	59661	648661	90395	198869.5	59660.85
1993	345,000	110317	455317	167147	367723.5	110317.1
1994	298,000	78654	376654	119172	262178.5	78653.56
1995	561,000	123321	684321	186850	411070.2	123321.1
1996	1,452,285	157595	1609880	238781	525318.1	157595.4
1997	176,814	84568	261382	128133	281893.4	84568.03
1998	112,466	119407	231873	180919	398021.8	119406.5
1999	182,798	77988	260786	118164	259960.8	77988.24
2000	695,586	79275	774861	120114	264250.8	79275.24
2001	1,862,015	16291	1878306	24684	54304.8	16291.44
2002	421,459	0	421459	0	0	0
2003	86,909	31332	118241	47472	104438.4	31331.52
2004	35,545	7418	42963	11240	24728	7418.4
2005	175,184	6872	182056	10412	22906.4	6871.92
2006	105,129	4450	109579	6743	14834.6	4450.38
2007*	49,343	33463	82806	50701	111542.2	33462.66
2008*	8,503	4356	12859	6600	14520.24	4356.073
2009	438,746	47256	486002	71600	157520	47256
2010	217,750	45936	263686	69600	153120	45936

Minimum population size = number lifted + number caught in fishery
**Fish lift was not operated normally due to restricted flows (i.e. extreme drought).*

Table 17.10 Mean fork length (mm) of blueback herring from the St. Stephens Dam Fish Lift on the Santee River Rediversion Canal, SC.

	Males			Females			Combined		
Year	Number	Mean Fork Length	SD	Number	Mean Fork Length	SD	Number	Mean Fork Length	SD
1991	166	241		258	255				
1992	345	238		303	252				
1993	181	235		290	247				
1994	75	235		126	251				
1995	180	233		175	252				
1996	257	237		233	248				
1997	140	238		102	253				
1998	251	240		359	256				
1999	200	238		208	245				
2000	250	232		230	245				
2001	227	237	10.1	86	252	15.2	313	241	13.3
2002	119	235	8.7	67	250	17.3	186	240	14.4
2003	122	239	8.7	111	254	10.5	233	246	12.2
2004	8	256	35.2	29	250	12.2	37	251	19.1
2005	52	231	6.8	60	245	8.6	112	238	10.5
2006	34	216	31.2	39	233	16.3	73	225	25.6
2007	42	227	10.5	30	218	9.4	73	223	10.9
2008*									
2009	34	216	31.2	39	233	16.2	73	225	25.6
2010	13	234	9.69	15	248	24.76	28	241	20.2

**Due to low flows, fish were not collected in this area*

Table 17.11 Age composition (no) of blueback herring collected by fishery independent sampling below the Pinopolis Dam on the Cooper River, SC.

Sexes Combined							
Age	1975	1977	1978	1979	1980	1981	1982
2	45	4	3	12		12	
3	103	52	12	33	21	109	10
4	154	152	121	195	30	69	49
5	18	80	25	136	29	227	53
6				3	19	29	11
7						8	2
Mean	3.45	4.07	4.04	4.22	4.46	4.39	4.57
Males							
Age	1975	1977	1978	1979	1980	1981	1982
2				8			
3				15			
4				102			
5				58			
6							
7							
Mean				4.15			
Females							
Age	1975	1977	1978	1979	1980	1981	1982
2				4			
3				18			
4				93			
5				78			
6				3			
7							
Mean				4.30			

Table 17.12 Number at age of blueback herring collected in fishery independent sampling by pound and gill net (GN, PN) and seine (SN) in the lower Santee River, SC.

Sexes Combined				
	GN	PN	SN	GN
Age	1977	1978	1979	1985
1	0	3	0	0
2	0	7	0	0
3	7	18	17	2
4	110	44	17	65
5	15	74	19	245
6	0	6	14	105
7	0	0	5	14
Mean Age	4.1	4.3	4.6	5.1
Males				
	GN	PN	SN	GN
Age	1977	1978	1979	1985
1	0	3	0	0
2	0	6	0	0
3	3	9	17	2
4	54	24	11	48
5	5	35	9	186
6	0	1	5	61
7	0	0	0	5
Mean Age	4.0	4.1	4.0	5.1
Females				
	GN	PN	SN	GN
Age	1977	1978	1979	1985
2	0	1		0
3	4	9		0
4	56	20	6	17
5	10	39	10	59
6	0	5	9	44
7	0	0	5	9
Mean Age	4.1	4.5	5.4	5.3

Table 17.13 Age composition (%) of blueback herring collected in fishery independent sampling by gillnet (GN), seine (SN), pound net (PN) in the lower Santee River, SC.

Males

	GN	PN	SN	GN	GN	GN	GN	GN	GN
Age	1977	1978	1979	1980	1981	1982	1983	1984	1985
1	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.08	0.00	0.00	0.01	0.00	0.00	0.00	0.00
3	0.05	0.12	0.40	0.02	0.06	0.12	0.07	0.03	0.01
4	0.87	0.31	0.26	0.74	0.16	0.43	0.36	0.59	0.16
5	0.08	0.45	0.21	0.23	0.71	0.15	0.44	0.34	0.62
6	0.00	0.01	0.12	0.00	0.06	0.25	0.12	0.04	0.20
7	0.00	0.00	0.00	0.01	0.00	0.05	0.01	0.00	0.02
Mean Age	4.0	4.1	4.0	4.2	4.8	4.7	4.6	4.4	5.1

Females

	GN	PN	Seine	GN	GN	GN	GN	GN	GN
Age	1977	1978	1979	1980	1981	1982	1983	1984	1985
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.06	0.12	0.00	0.01	0.02	0.05	0.02	0.00	0.00
4	0.80	0.27	0.20	0.64	0.14	0.37	0.22	0.37	0.13
5	0.14	0.53	0.33	0.31	0.75	0.15	0.47	0.51	0.46
6	0.00	0.07	0.30	0.03	0.09	0.43	0.29	0.11	0.34
7	0.00	0.00	0.17	0.01	0.00	0.00	0.00	0.01	0.07
Mean Age	4.1	4.5	5.4	4.4	4.9	5.0	5.0	4.8	5.3

Table 17.14 Frequency of repeat spawn of male blueback herring from the Santee River in SC.

	Spawn Marks	Age 2	3	4	5	6	7	Totals	% Virgin	% Repeat
1978										
	0	9	9	23	13			54		
	1			2	19			21		
	2				3	1		4		
	Totals	9	9	25	35	1		79	68.4	31.6
1979										
	0		17	10	8	2		37		
	1							0		
	2							0		
	Totals	0	17	10	8	2		37	100.0	0.0
1980										
	0	1	1	49	12			63		
	1				4	2	1	6		
	2							0		
	Totals	1	1	49	16	2	1	69	91.3	8.7
1981										
	0	2	29	14	24	1		70		
	1			2	25	2		29		
	2				1	1		2		
	Totals	2	29	16	50	4	0	101	69.3	30.7
1982										
	0		15	41	6	3		65		
	1				8	1		9		
	2				1	10	2	11		
	Totals	0	15	41	15	14	2	85	76.5	23.5
1983										
	0		9	34	34	11	1	88		
	1			1	4	1		6		
	2				2		1	2		
	Totals	0	9	35	40	12	2	96	91.7	8.3

Table 17.15 Frequency of repeat spawn of female blueback herring from the Santee River in SC.

	Spawn Marks	Age 2	3	4	5	6	7	Totals	% Virgin	% Repeat
1978										
	0	1	9	19	22	1		52		
	1				15	4		19		
	2				1			1		
	Total	1	9	19	38	5	0	72	72.2	27.8
1979										
	0			6	10	5		21		
	1				4	2		6		
	2						3	0		
	Total	0	0	6	14	7	3	27	77.8	22.2
1980										
	0		1	39	18	9	1	67		
	1			1	3	3	3	7		
	2				1	2		3		
	3						1	77		
	Total	0	0	1	4	5	4	87	77.0	23.0
1981										
	0		6	15	36	5		62		
	1				12	2		14		
	2						1	0		
	Total	0	6	15	48	7	1	76	81.6	18.4
1982										
	0		7	36	10	9	1	62		
	1				2	13	1	15		
	2				2	13	1	15		
	Total	0	7	36	14	35	3	92	67.4	32.6
1983										
	0		5	24	34	12		75		
	1			3	6	11		20		
	2				5			5		
	3				1	2		100		
	Total	0	0	3	12	13	0	125	60.0	40.0

Table 17.16 Mean fork length at age (mm) of blueback herring, sexes combined, collected by fishery independent sampling below the Pinopolis Dam on the Cooper River, SC.

	Age						
Year	1	2	3	4	5	6	7
1975		206	236	261	284		
1976							
1977		234	243	247	254		
1978		220	240	261	289		
1979		198	241	260	277	298	
1980			234	261	266	277	
1981		199	215	222	280	310	319
1982			229	243	254	266	268
All years		242	267	253	309	326	333

Table 17.17 Mean fork length at age (mm) of blueback herring collected by fishery independent gill net sampling below the Wilson Dam on the Santee River, SC.

Year	Age 1	2	3	4	5	6	7
Males							
1980	137	197	227	245	256	270	272
1981	133	192	227	247	258	263	282
1982	134	191	227	246	259	264	269
1983	139	185	220	239	254	263	270
1984	125	182	218	237	248	258	
Mean FL	134	189	224	243	255	264	273
Females							
1980	134	200	232	253	266	278	283
1981	134	198	233	256	270	279	295
1982	136	195	234	255	270	278	284
1983	142	186	221	245	262	273	
1984	123	179	216	238	254	268	274
Mean FL	134	192	227	249	264	275	284

Table 17.18 Mean fork length (mm) at age (yrs) of young blueback herring from the Cooper and Santee Rivers, SC.

Cooper River		Santee River	
Age (yrs)	Length	Age (yrs)	Length
0.67	79.0	0.42	44.6
		0.50	48.0
		0.50	47.4
		0.75	55.3

Table 17.19 Von Bertanlanffy growth parameters based on fork length (mm) of blueback hering collected by fishery independent sampling below the Pinopolis Dam on the Cooper River and the Wilson Dam on the Santee River, SC.

	Cooper River	Santee River	
Parameter	Sexes combined	Male	Female
L-infinity	286.5	267.6	281.0
K	0.630495073	0.6721946	0.610289
t0	0.164542792	0.1417377	0.118728

Table 17.20 Estimates of total instantaneous mortality (Z) for blueback herring of the Cooper River, SC.

	Z	SE
1975	2.15	
1977	0.64	
1978	1.58	
1979	2.09	1.14
1980	0.23	0.16
1981	1.67	0.31
1982	1.64	0.05

Table 17.21 Estimated number of blueback herring harvested from the Santee-Cooper Rediversion Canal, minimum population size, and maximum exploitation rate (u).

Year	Estimated Harvest (No.)	Minimum Population Size	Exploitation Rate (u)
1990	162	71162	0.00
1991	1240	401240	0.00
1992	11574	600574	0.02
1993	22817	367817	0.06
1994	16257	314257	0.05
1995	26093	587093	0.04
1996	33429	1485714	0.02
1997	17939	194753	0.09
1998	25329	137795	0.18
1999	16543	199341	0.08
2000	16816	712402	0.02
2001	3379	1865394	0.00
2002	0	421459	0.00
2003	6533	93442	0.07
2004	1126	36671	0.03
2005	1458	176642	0.01
2006	944	106073	0.01
2007	7098	56441	0.13
2008	504	9007	0.06
2009	22053	460799	0.05
2010	21437	239187	0.09

Table 17.22 Age zero blueback herring collected by electrofishing from several SC rivers.

Year	Winyah Bay	Santee River	Cooper River	Edisto River	Combahee River
2001	0	4	0	0	0
2002	0	84	24	0	0
2003	0	787	0	2	0
2004	11		0	0	0
2005	5		0	1	0
2006	7		26	0	0
2007	1		1	0	1

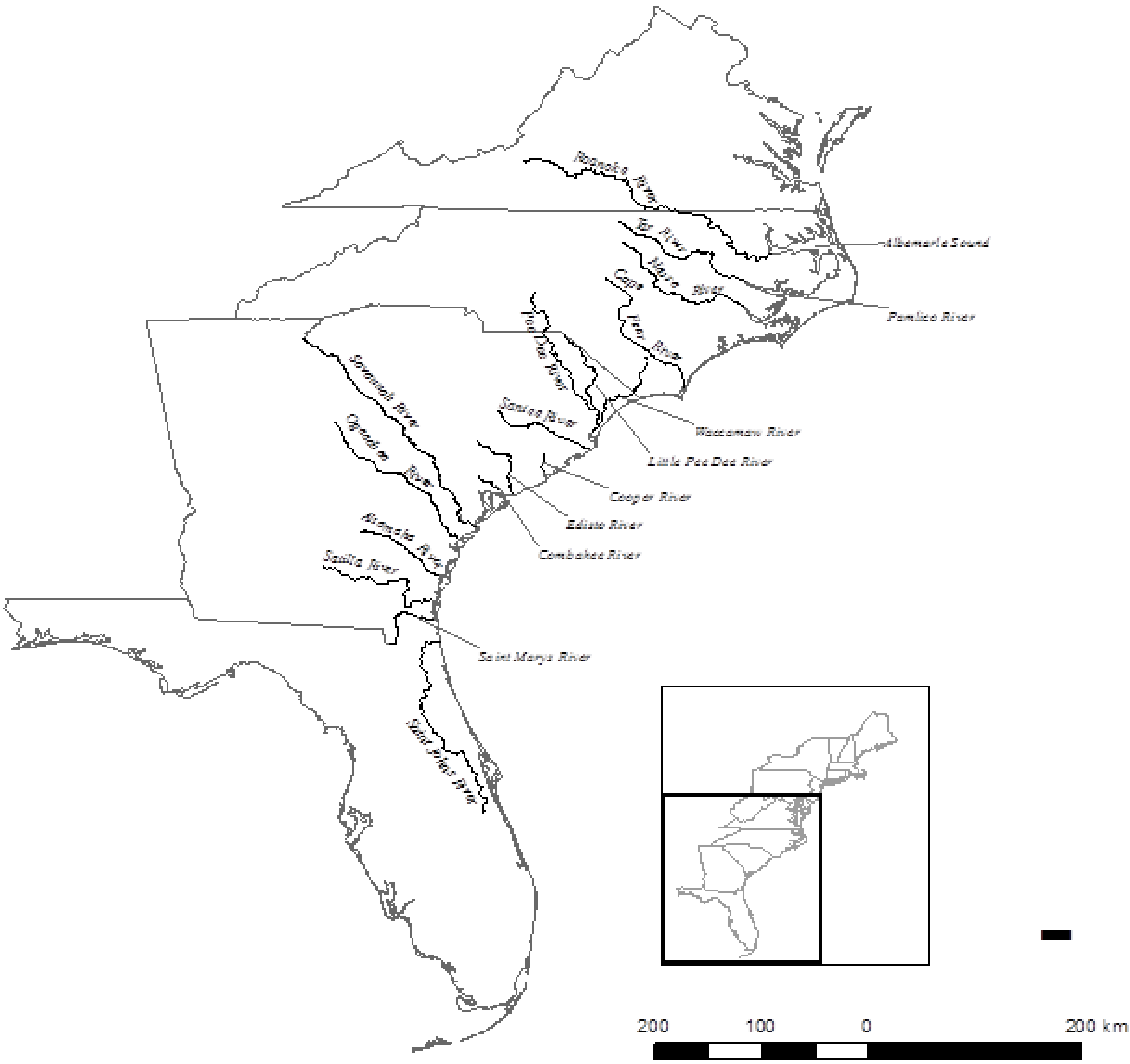


Figure 17.1 South Carolina Rivers

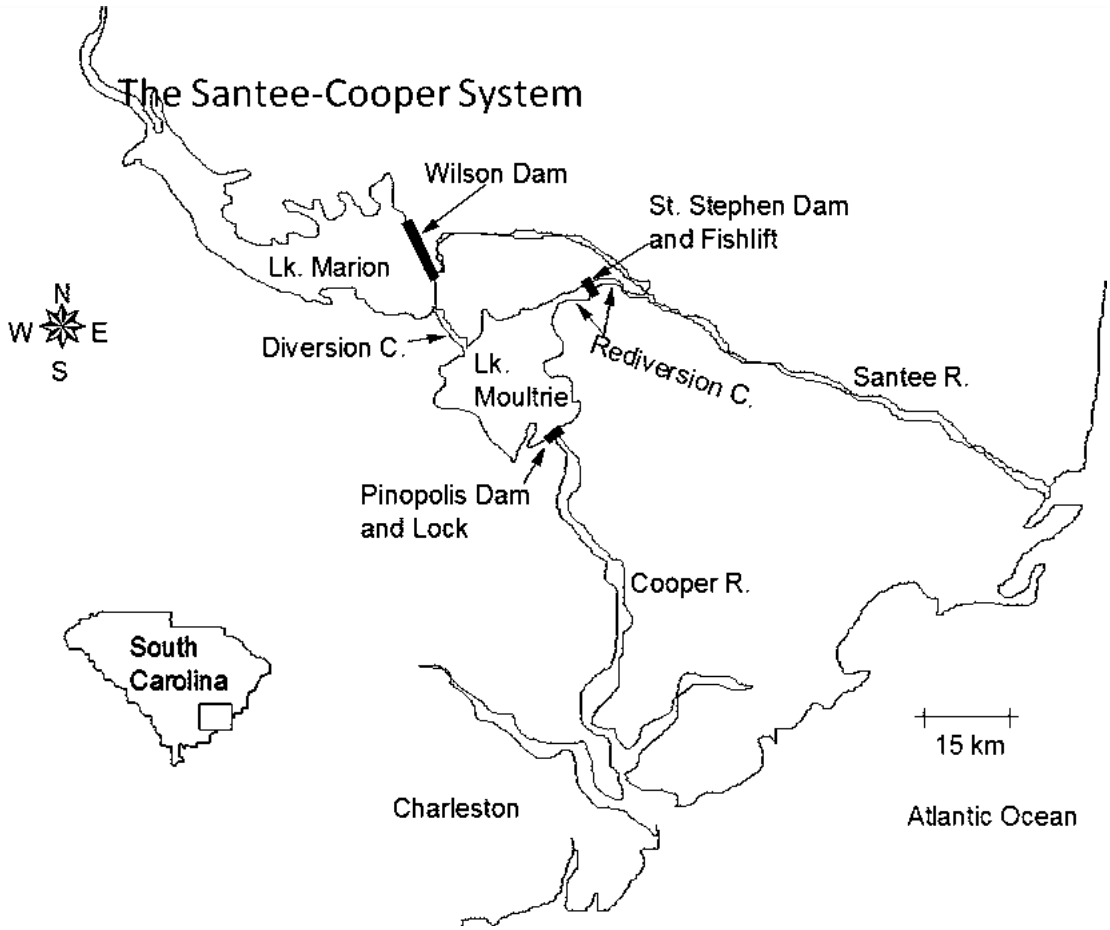


Figure 17.2 Santee-Cooper Rivers complex in South Carolina.

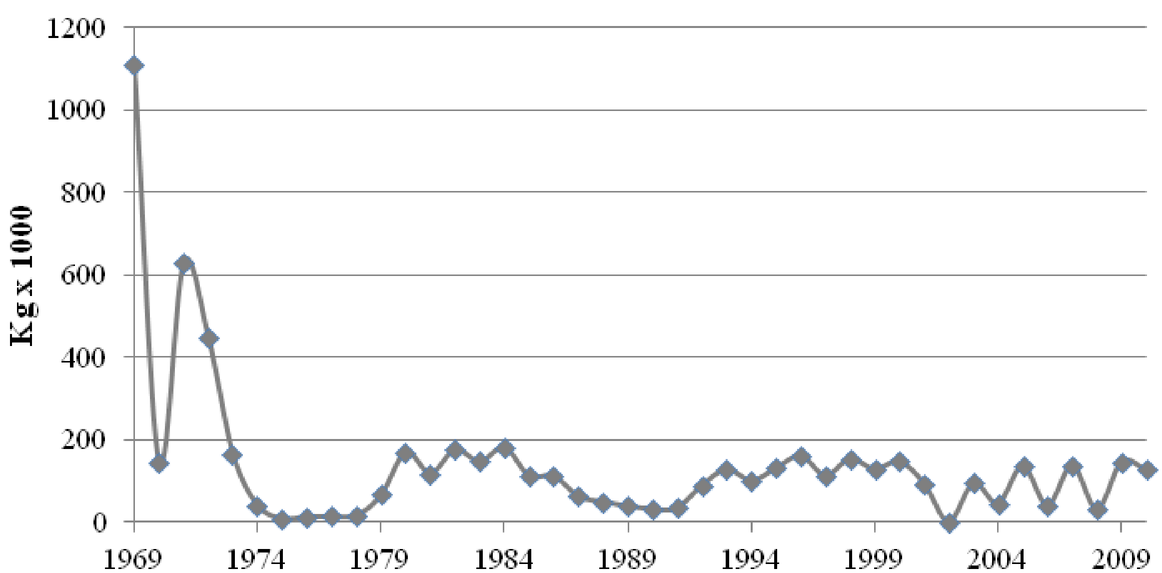
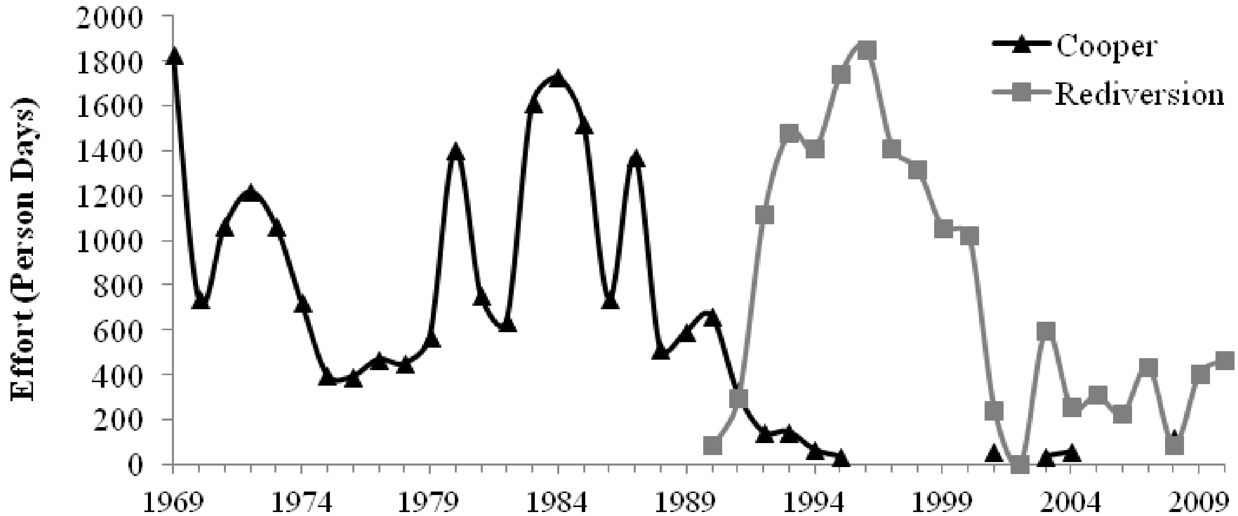


Figure 17.3 Reported landings (kg) of blueback herring taken in the commercial fishery in South Carolina.



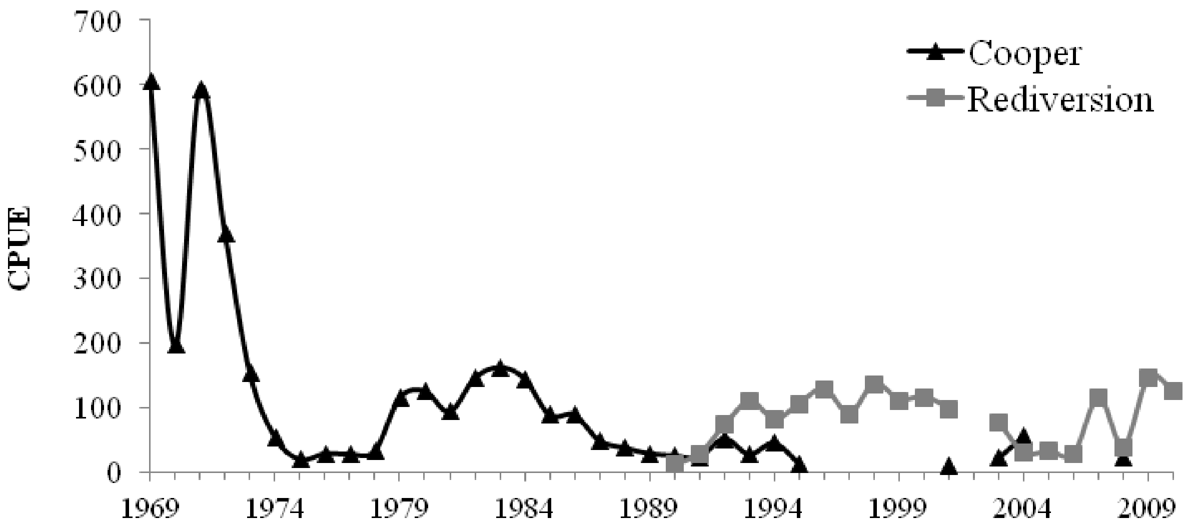


Figure 17.4 Estimated effort (person days, top) and CPUE (bottom) in the commercial fishery for blueback herring in the Cooper River and teh Santee-Cooper Rediversion Canal, SC.

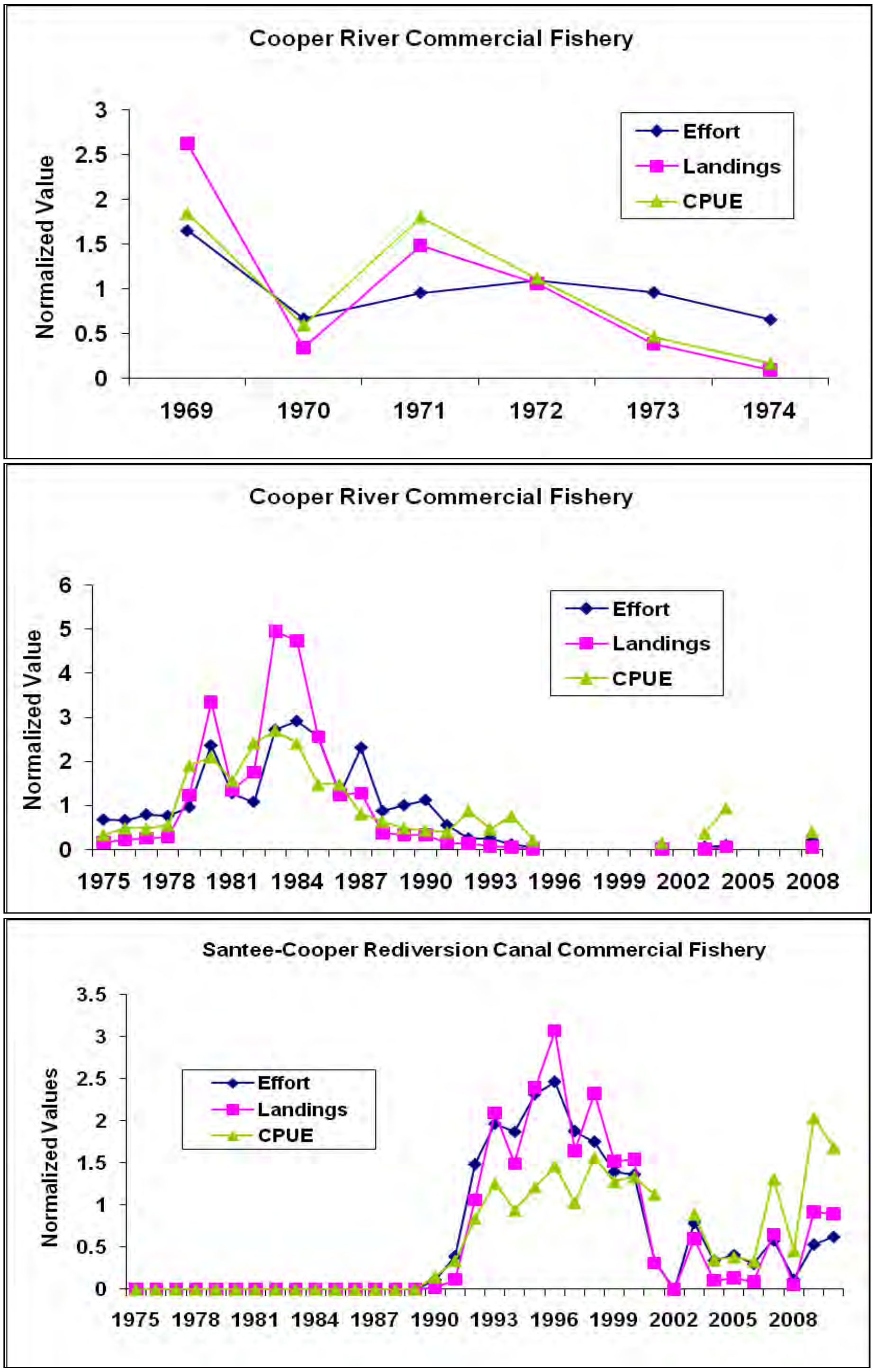


Figure 17.5 Normalized effort (Man days), landings (kg x 1000) and CPUE for the commercial fishery for BBH in the Cooper River and the Santee-Cooper Rediversion Canal, SC. River specific data normalized as ratio of annual data divided by long-term mean.

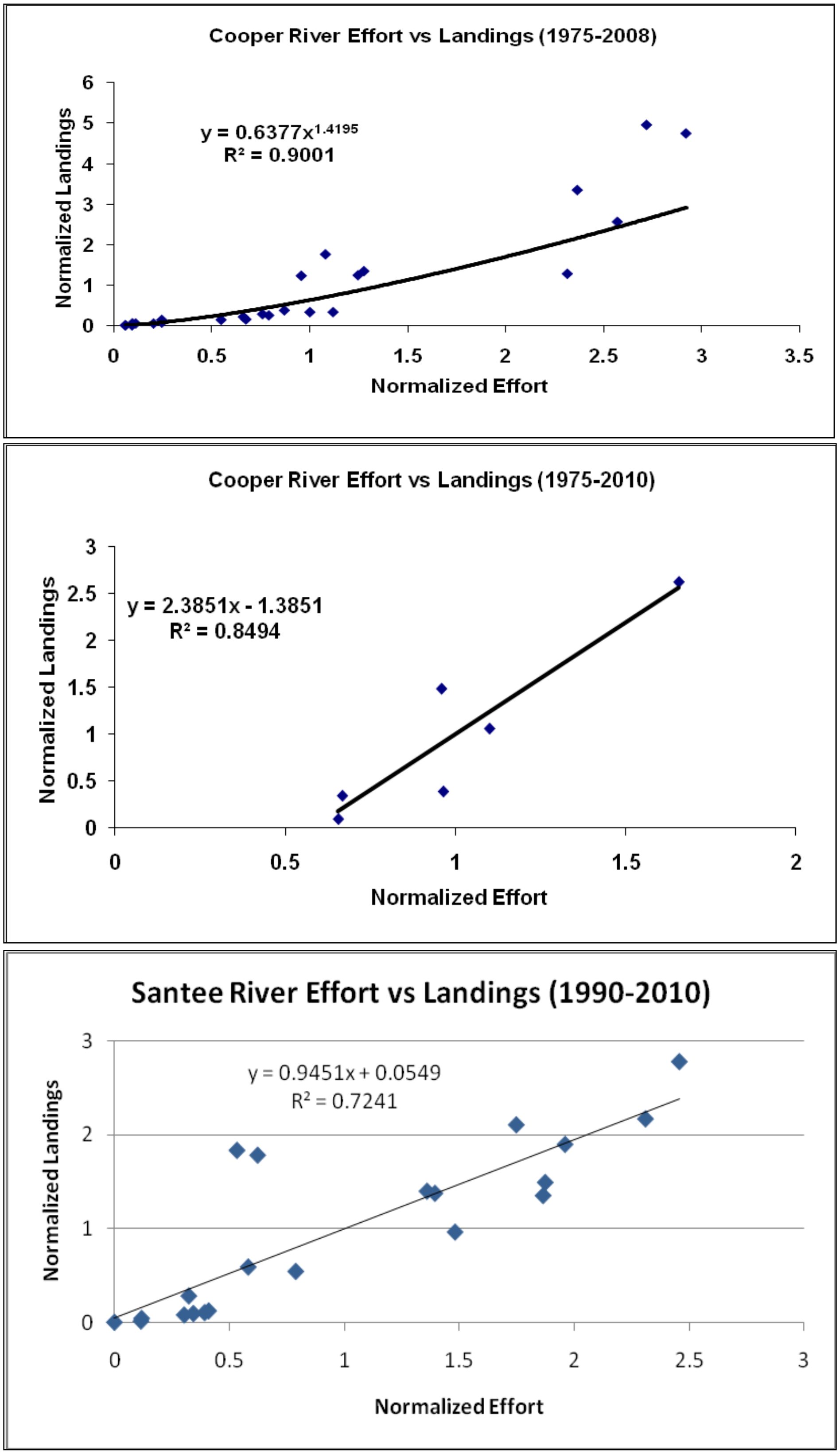


Figure 17.6 Normalized effort vs normalized landings in the commercial fisheries of the Santee and Cooper Rivers, South Carolina.

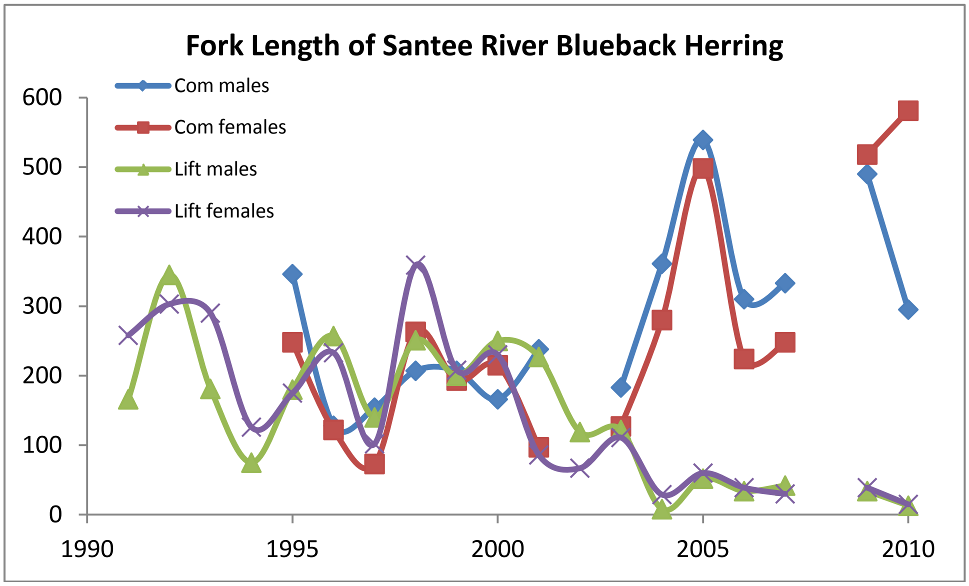


Figure 17.7 Mean fork length (mm) of blueback herring taken in the commercial fishery below the St. Stephens Dam on the Santee-Cooper Rediversion Canal and from the St. Stephens Dam fish lift, South Carolina.

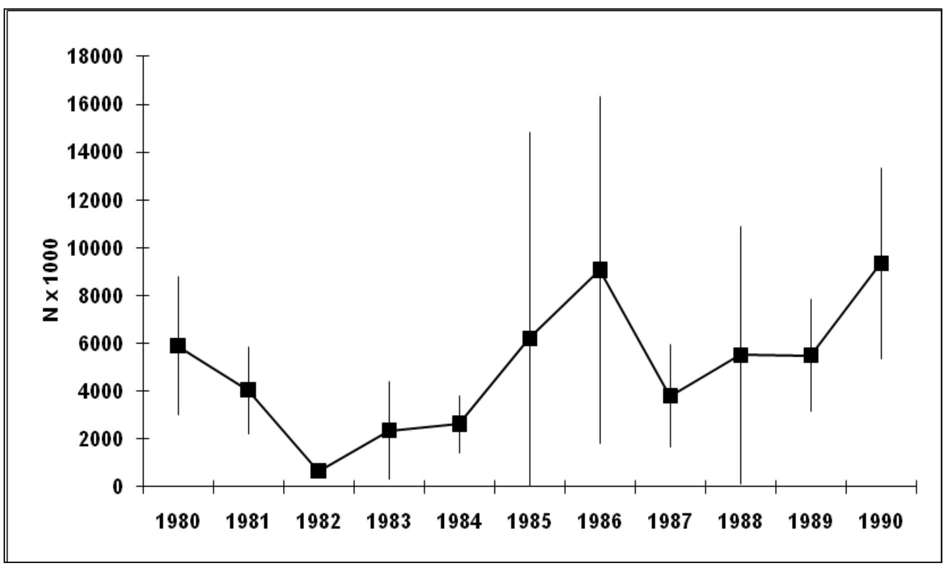


Figure 17.8 Population estimates of blueback herring in the Santee River, SC. Vertical lines denote 95% confidence interval.

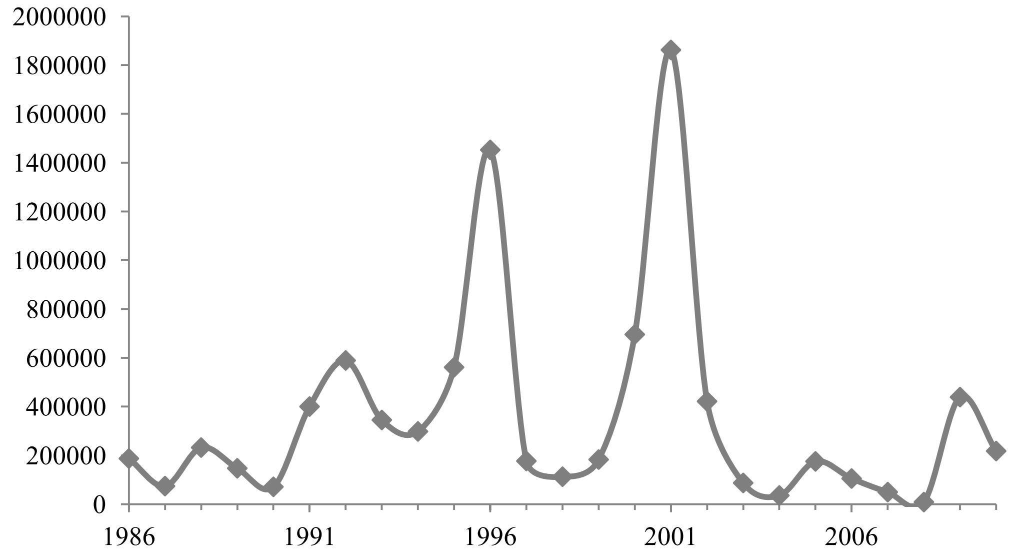


Figure 17.9 Number of blueback herring lifted over the St. Stephens Dam on the Santee-Cooper Rediversion Canal, SC.

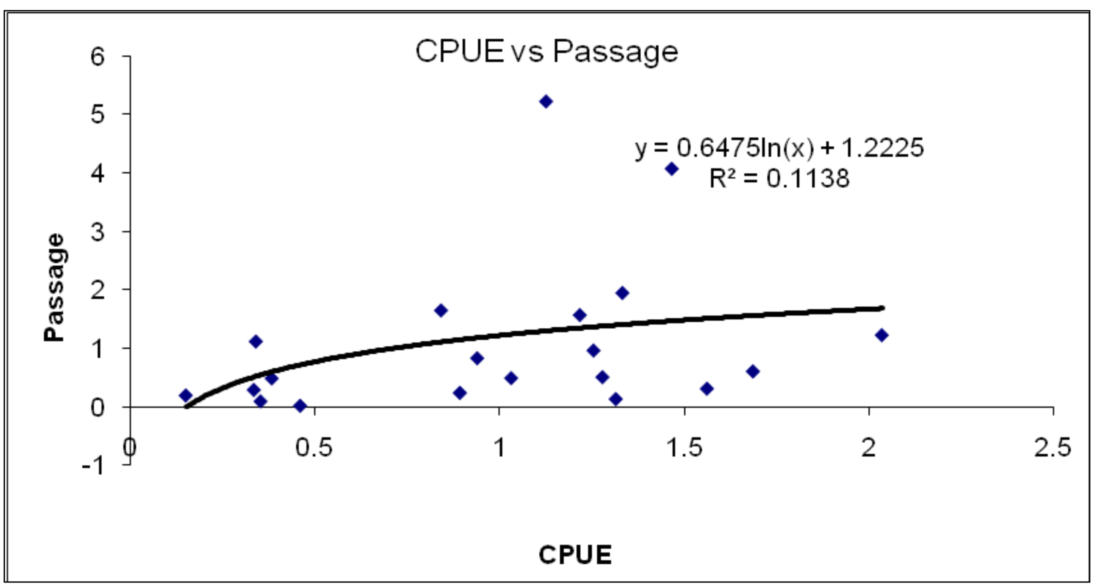


Figure 17.10 Relationship between normalized CPUE of blueback herring in the Santee-Cooper Rediversion Canal commercial fishery and normalized passage numbers in the St. Stephens Dam Fish Lift.

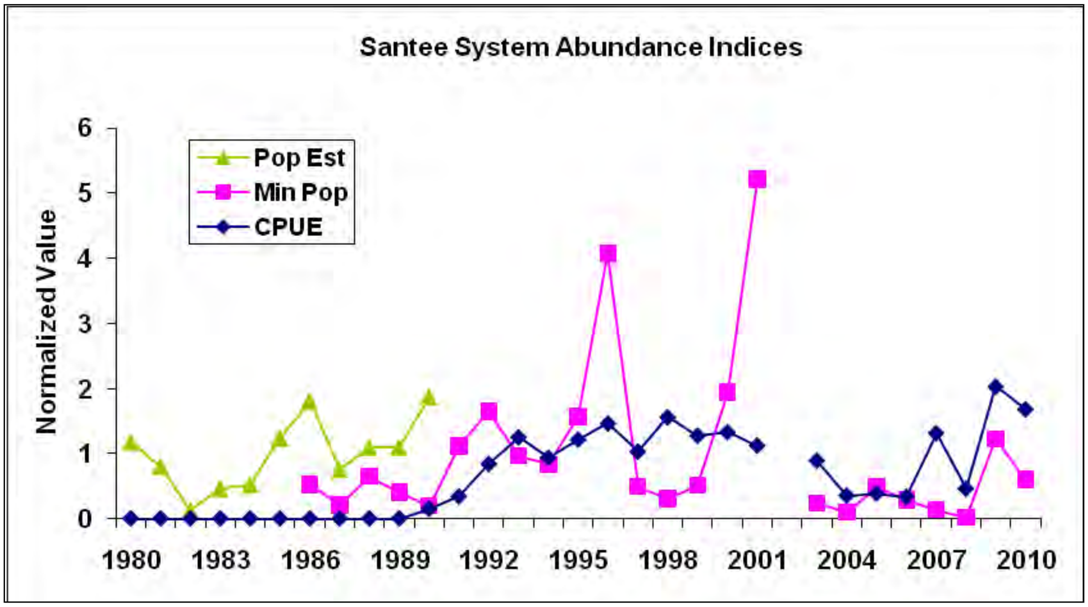
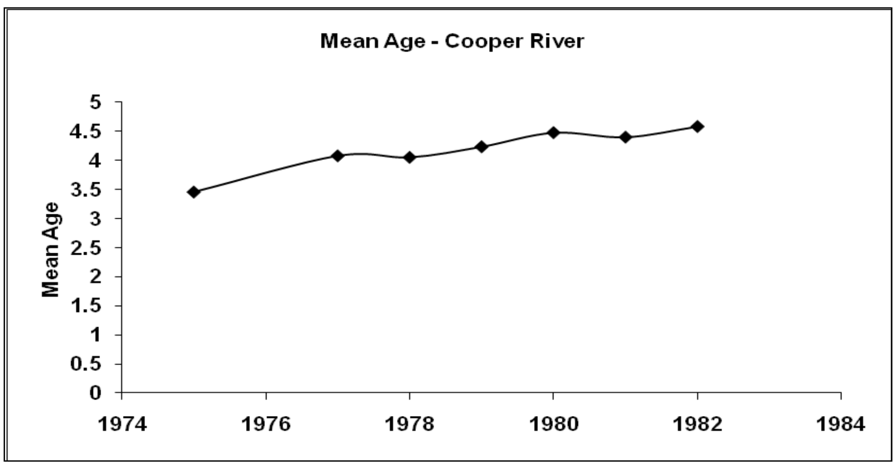


Figure 17.11: Available abundance indices for blueback herring on the Santee River and Santee-Cooper Rediversion Canal, South Carolina. CPUE as kg per man day in the commercial fishery. Passage and population estimates in numbers. All data normalized as annual value / time series mean.



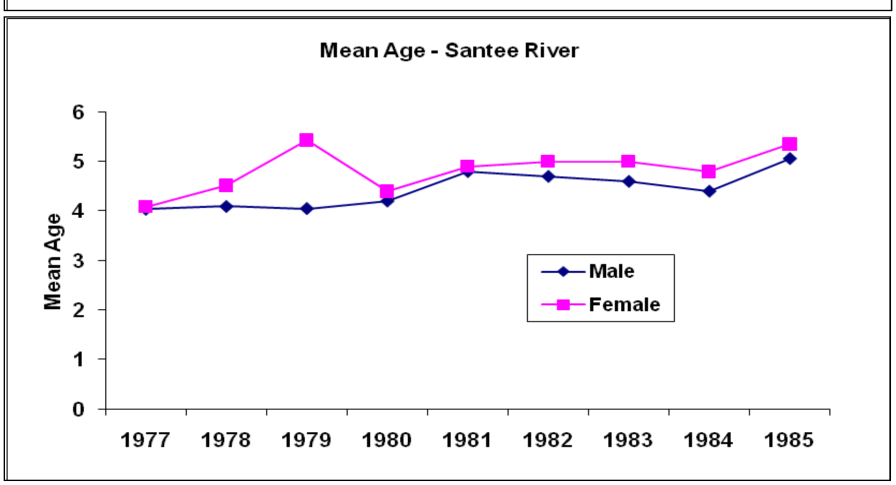
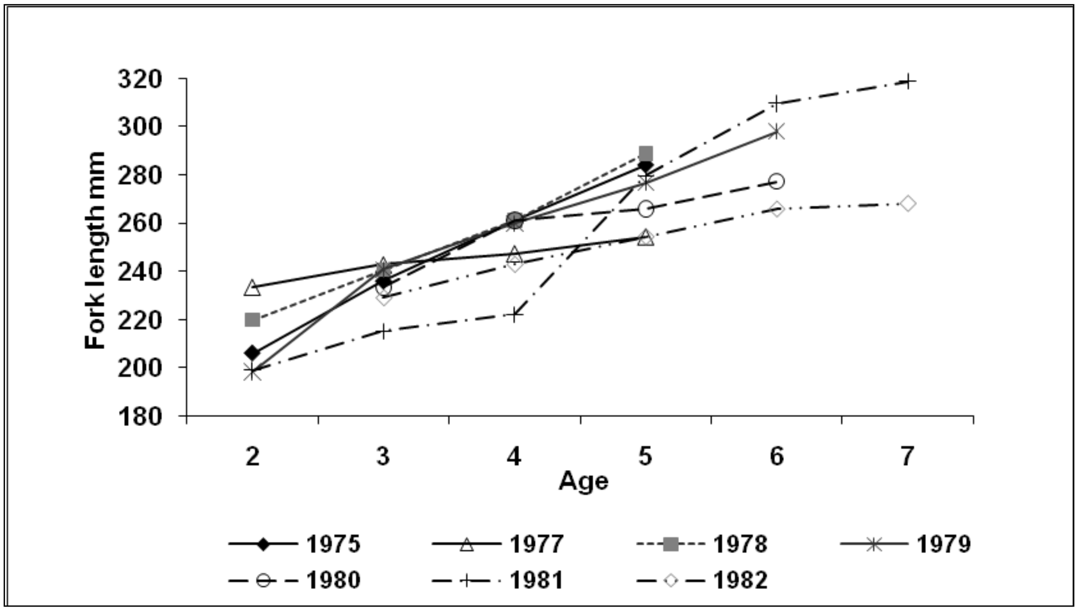


Figure 17.12 Mean age of blueback herring collected from the Santee and Cooper Rivers in SC prior to rediversion in 1985. Cooper River ages for sexes combined.



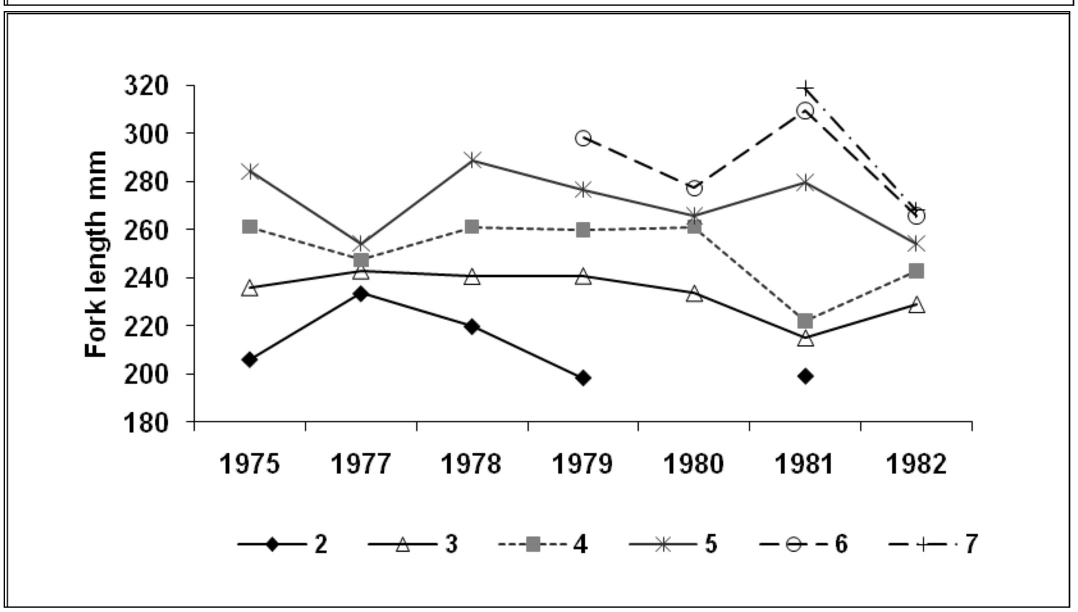


Figure 17.13 Mean fork length (mm) at age of blueback herring collected from the Cooper River in SC. Lengths for sexes were combined.

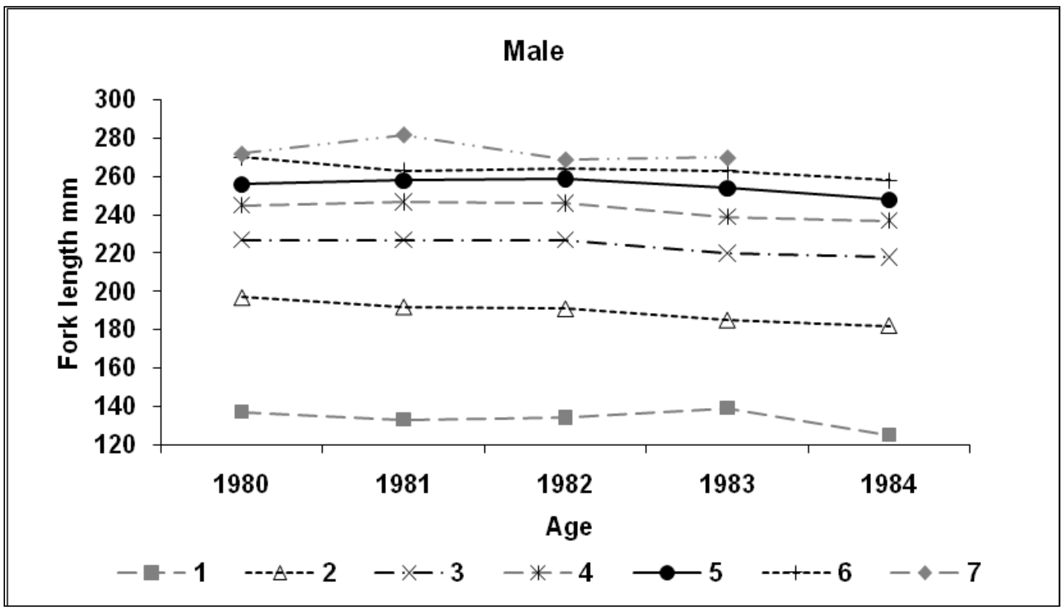


Figure 17.14 Mean fork length (mm) at age of male blueback herring from the Santee River, SC.

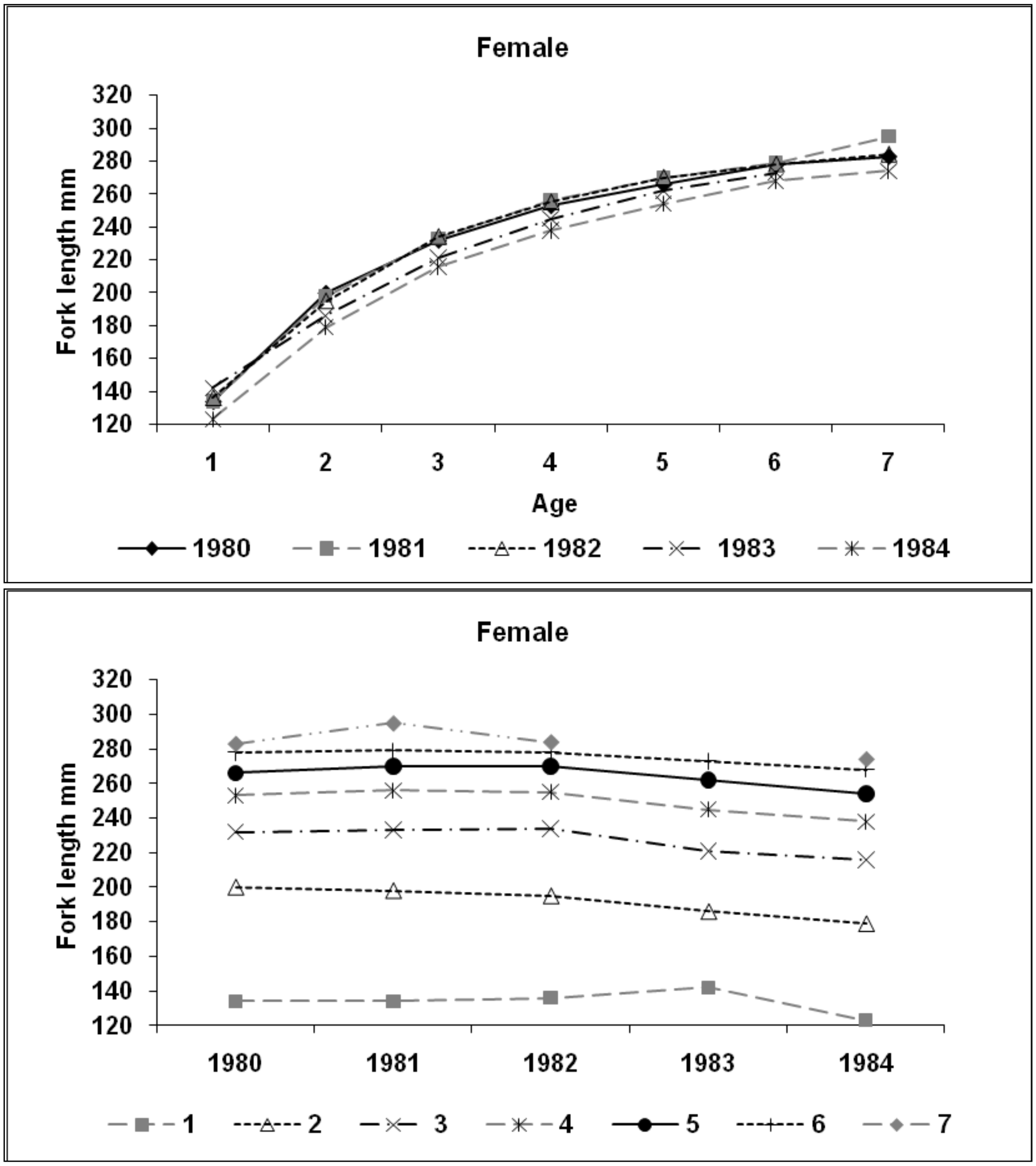


Figure 17.15 Mean fork length (mm) at age of female blueback herring from the Santee River, SC.

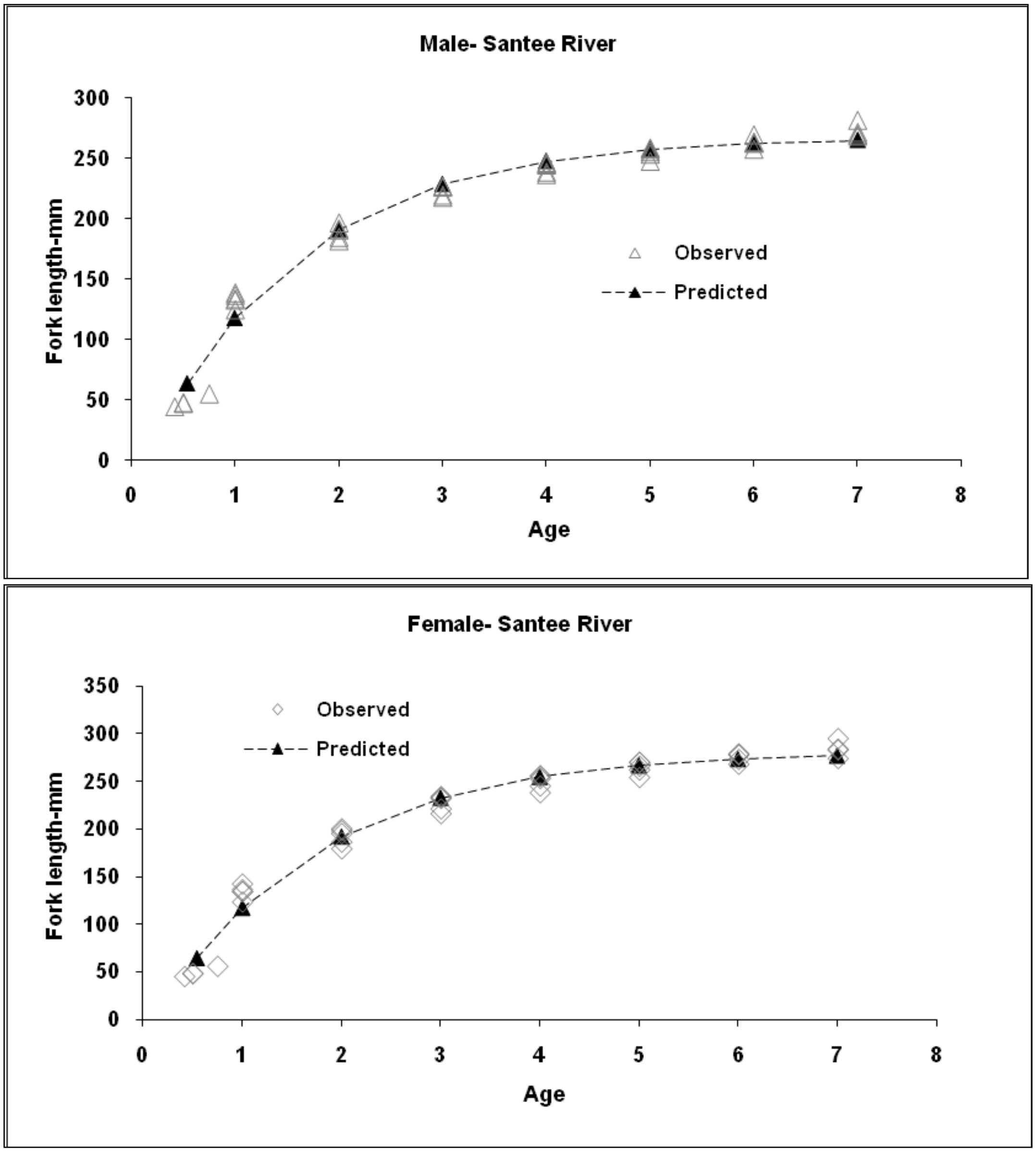


Figure 17.16 Growth curves for blueback herring from the Cooper and Santee Rivers in SC. Cooper River data from 1975-1982, sexes combined. Santee River data from 1980-1984.

Appendix 13.1. Summary of current regulations on take of blueback herring in South Carolina.

General
There is no commercial fishing activity for herring in the Ashley, Edisto, Combahee, Coosawhatchie, and Savannah Rivers or in State territorial Atlantic Ocean waters.

Season
The open season is 15 February - 15 April in the rivers draining into Winyah Bay, the Ashley River, and Charleston Harbor. The open season in the Santee River is 15 February - 1 May. The open commercial season for the Rediversion Canal of Santee River and the Tailrace Canal of Cooper River is 1 March - 1 May of each year. There is no closed season for the commercial take of herring in the Santee-Cooper Lakes with legal gears in open areas.

Harvest Limits
The allowable daily take of herring (including the allowable by-catch)for net fisheries is 10 US bushels per boat in the Tailrace Canal of the Cooper River, 250 lbs per boat in the Santee-Cooper Lakes, and 10 US bushels per boat in the Rediversion Canal. There are no other caps or quotas in effect for commercial herring fisheries in South Carolina.

Gears
Approved commercial gears are anchored (set or stationary) and drift gill-nets in all open riverine waters seaward of dams, with the exceptions of open portions of the Santee and Cooper River where other gears are allowed. Circular drop-nets up to six feet in diameter, lift-nets and cast-nets are the only gears allowed in the upper Tailrace Canal of the Cooper River and in the open portions of the Rediversion Canal of the Santee River. Lift-nets, cast-nets, and hook & line may be used within the Santee-Cooper Lakes and cast-nets and/or hook & line are legal gear in other inland reservoirs. Legal minimum mesh size for gill-nets is 2 1/2" stretched mesh in all State waters open to such gear. The length of any gill-net may not exceed one half of the width of the waterway where it is fished. Gill-nets may not be fished within 200 yards of any previously deployed net. Regulatory changes implemented in 2001 restricted net lengths to a maximum of 200 yards in freshwaters and 300 yards in inland marine waters.

Lift Periods
There is a weekly 84-hour lift period in effect for all waters of the Winyah Bay system during the open gill-netting season. The Ashley River and Charleston Harbor have no weekly lift period during open gill-netting season. The use of nets in the Cooper River Tailrace Canal is allowed only from sunrise until 10:00. Fishing with nets in the Rediversion Canal is allowed from 7:00 PM - 12:00 midnight EST or 8:00 PM – 12:00 PM EDT, with no lift period. Portions of several rivers are closed to commercial gear.

Actual regulations can be found at: http://www.scstatehouse.gov/code/t50c005.htm, under Title 15.

18. Status of River Herring in Georgia and Florida

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Executive Summary

The St. Johns River, Florida harbors the southernmost spawning run of blueback herring *Alosa aestivalis* on the Atlantic coast of the United States. The run is currently not harvested by either commercial or recreational anglers and no harvest has been recorded since the 1960s. Limited landings data and anecdotes suggest that the blueback herring run in the St. Johns River was large in the past. There are no long time series of either fishery dependent or fishery independent data for this stock. Modern abundance indices are not directly comparable to the limited historical data because gears used and sampling methods differ. Available data, though limited in scope, suggest that modern blueback herring abundance is low in the St. Johns River, Florida. Spawning adults are smaller than those collected by researchers in 1972 and 1973. Blueback herring were much more abundant than American shad *Alosa sapidissima* in fishery independent samples in 1972 and 1973 and are now the less abundant in contemporary sampling within the St. Johns River even with shad abundance also historically low.

Due to the limited amount of data on river herring in Georgia, information collected from the state of Georgia has been included with the state of Florida. Inclusion of this data in no way implies that these stocks are genetically similar or should be treated as one management unit. The St. Mary's River on the Georgia/Florida border is known to have historically contained a blueback herring run but no data are available for an assessment of the St. Mary's. Additional populations of blueback herring have been reported in Georgia include the Altamaha and Ogeechee Rivers, as well as the Savannah River on the Georgia/South Carolina Border. For information on river herring in the Savannah River refer to Section 17, Status of River Herring in South Carolina.

18.1. INTRODUCTION

Blueback herring were likely an important fishery in Florida in the 19th and early 20th centuries but catch data are unreliable. Landings of 'alewife' are reported up to a peak around 1 million pounds in the early 20th Century. However, 'alewife' were often the combined landings of blueback herring, hickory shad (*Alosa mediocris*), and menhaden (*Brevoortia* spp.). It is unclear what proportion of these was herring though herring were harvested and salted for market at the time. By the mid-20th Century, herring harvest was limited to bycatch in other fisheries that was sold as crab and catfish bait (Williams et al., 1975). In Georgia, historically the blueback herring fishery was minimal to non-existent, especially when compared to the American and hickory shad fisheries.

In Georgia there is currently no known commercial or recreational fishing for blueback herring while in Florida various gear restrictions have effectively eliminated all commercial harvest of blueback herring and there is no known recreational fishing for them. River herring were largely ignored until the approval of Amendment 1 of the Shad and River Herring Fishery Management Plan in 1999 which required monitoring of American shad stocks. Since the spawning and nursery habitats of the American shad and blueback herring overlap (Williams and Bruger 1972) this allows the collection of data on the relative abundance, size structure, and sex ratio of blueback herring in addition to the targeted sampling for American shad. In Florida, current data are collected using electrofishing for adults and pushed trawls pushed trawls for juveniles and so are not quantitatively comparable to the two years of data provided by Williams et al. 1975 from seine and surface trawl collections. The only inference on historic and modern abundance of blueback herring is derived from the abundance of blueback herring relative to American shad in fishery independent samples. Sampling targeting adult American shad in Georgia has not yielded any data on blueback herring.

18.2. MANAGEMENT UNIT DEFINITION

There is no active management of blueback herring in Georgia or Florida. Blueback herring are known to occur in Florida in the St. Johns and St. Mary's rivers, which would presumptively be two independent management units.

18.3. REGULATORY HISTORY

18.3.1. Georgia

There are no laws regarding the recreational take of river herring in Georgia's rivers. Castnets can be utilized to capture landlocked blueback herring for bait within Georgia reservoirs.

18.3.2. Florida

River herring have not been specifically regulated in the St. Johns River, Florida. Gear restrictions in other fisheries have affected river herring catch. New pound net licenses were no longer issued for the St. Johns River after 1982. Existing pound net licenses were non-transferable (FAC 68A-23.003) and no pound nets are operating on the St. Johns River, Florida. The Florida Constitution was amended by voter referendum to prohibit entanglement nets larger than 500ft^2 in state waters. This net ban became effective on July 1, 1995 (Art. X, Sec. 16).

As of January 1, 1997 hook and line is the only permissible gear for all *Alosa* in Florida (FAC 68B-52.001). Recreational anglers must possess a valid saltwater fishing license in order to retain anadromous species in fresh water.

18.4. ASSESSMENT HISTORY

McBride et al. (2010) described the 2002 – 2005 spawning runs including feeding, reproduction, sex ratio, and size distribution. Overall, McBride el al. (2010) concluded that the stock is persistent, but its status is unknown and the smaller individual sizes evident today suggest that this population is experiencing higher mortality now than a few decades ago.

18.5. STOCK-SPECIFIC LIFE HISTORY

Blueback herring in Florida are iteroparous and spawn in the St. Johns River from January to late March and occasionally early April (Williams et al. 1975, McBride et al. 2010). They spawn in the St. Johns River mature as early as age three for males and age four for females. Males mature slightly earlier with a greater proportion of males than females being age four. The majority of males mature by age five and females by age six. Mature male blueback herring collected from the 1972 and 1973 runs were age three to eight with ages five and six being 83.4% to 77.7% of the population in 1972 and 1973 respectively. Mature female blueback herring collected from the 1972 and 1973 runs were age four to eight and age six was most common (Williams et al. 1975) (Table 18.1).

18.5.1. Fecundity

Fecundity estimates of blueback herring in the Altamaha River Georgia were 120,000 – 400,000 eggs per female with a mean of 244,00 eggs per female (Street 1970).

Fecundity for blueback herring in the St. John's River was reported in Williams et al, 1975. It was estimated that blueback herring contained 151,000 to 349,000 eggs with a mean of 262,024 (N = 24) based off of:

$$F = (110.4198 + 0.7183 * Wt) * 1000$$

F = Fecundity, Wt = total weight

18.6. HABITAT DESCRIPTION

18.6.1. Georgia

The Altamaha is one of the largest rivers within Georgia. The Altamaha River forms at the confluence of the Oconee and Ocmulgee Rivers and flows unobstructed for 137 miles to the Atlantic Ocean (Godwin and Adams, 1969). There is no information available on the use of this habitat by river herring at any life stage.

18.6.2. Florida

Spawning occurs in the St. John's River between river kilometer (rkm) 200 and 375 as well as in some tributaries such as the Wekiva River, Dunn's Creek, and Black Creek, although most spawning appears to occur along the main river (Williams et al., 1975, McBride et al., 2010). The St. Johns River is entirely coastal and drops a total of 9.1 m over its entire 499km length. Most of that drop occurs upstream of river kilometer 314 (McLane 1955). The head of the tide is generally at Lake George (rkm 199). Weak tides can reach as far as the Lake Monroe outlet at river kilometer 266 during low flow. The St. Johns River has a "southern river flow pattern" (Kelly and Gore 2008) in which low flow typically occurs from late winter into early summer and high flows occur in the late summer and early fall corresponding to a summer wet season. The floodplain is rarely inundated during the spawning season. Available habitats along the 175 km of river where spawning has been documented are diverse and include several broad lakes.

The St. Johns River is a large meandering channel averaging three to six meters deep and about 80 meters wide from rkm 200 to 266, between lakes George and Monroe. It is bounded almost entirely by bottomland hardwood floodplain forest and has numerous oxbows and sloughs known as "dead rivers". There are three shallow lakes connected to this stretch; Lake Dexter (1902 acres), Lake Woodruff (2200 acres), Lake Beresford (800 acres). This stretch is at sea level during low flow and is weakly (< 4 cm) affected by lunar tides when flow is below 4000 cubic feet per second. Flow rarely reverses on flood tides but instead slows while the river backs up. Wind events can cause the flow to stop or reverse for a period of days at low flows (Kroening 2004). Substrates are a mix of sand and detritus muck with sand prominent along bluffs and scoured bends and deep muck in backwaters. The littoral zone is generally vegetated and fringed by trees, emergent vegetation such as *Nuphar lutea*, or submerged vegetation such as eelgrass *Vallisneria Americana*. This stretch was altered between 1884 and 1945 for navigation improvement. Numerous bends were cut off by dug channels, thus straightening the channel and creating artificial oxbows. Sandbars were removed to establish a minimum depth of 12 feet between Palatka and Sanford (USACE 2011).

The St. Johns River passes through Lake Monroe (9400 acres) between rkm 266 and 276. Lake Monroe is a round shallow basin averaging two meters in depth. The river braids through seasonally flooded marsh and wet prairie upstream of Lake Monroe between river kilometers 276 and 306. Sand is the dominant substrate in the main river channels with organic detritus dominant in backwater sections. Emergent *Nuphar lutea* fringes much of this stretch of river. The river passes through Lake Harney (6200 acres) between rkm 306 and 314. Lake Harney, like Lake Monroe, is a round shallow basin. Both lakes have sandy bottoms and are usually fringed with submerged vegetation dominated by eelgrass and sometimes hydrilla.

There the river is braided through extensive wet prairie upstream of Lake Harney where the majority of the fall in elevation occurs. Substrate in the channel varies from find sand to peat. There is a weir at rkm 415 but this is upstream of any documented spawning location for blueback herring and the highest density of eggs and larvae and spawning adults collected in previous studies were well downstream of this location in the 30 km reach between Lake Monroa and Lake Harney (Williams et al. 1975, McBride et al. 2010).

Blueback herring have been documented to spawn in both lentic and lotic habitats (Walsh et al. 2005), both which are extensive in the St. Johns River. Spawning may occur in some of the lakes through which the St. Johns River passes but specific habitat selection has not been delineated for this system.

Juveniles reside in the river until late fall or early winter, generally between rkm 125 and 305, with the range gradually shifting downstream to below rkm 125 in the fall or winter. Some blueback herring may over winter far upstream near the spawning grounds in low flow and/or warm years (Williams et al. 1975). The habitat upstream of rkm 200 is described above. Downstream of rkm 200, the St. Johns River is a tidal freshwater estuary that includes 40,000 acre Lake George at the upstream between rkm 182 and 200. Lake George is approximately 18 km long by 10.5 km wide and averages 3 m deep. Below Lake George the tidal freshwater reach varies in width from 0.18 km to 2 km and has an average tide range of 0.33 m.

It is not known what habitat(s) in the St. Johns are most beneficial to blueback herring spawning. New physical habitat alteration is not an imminent threat and most activities on the flood plain center around restoration and protection. As much as 62 percent of the floodplain upstream of Lake Harney was drained for agriculture by the 1970s and much water was diverted out of the basin. Habitats in the primary spawning area, though, remain largely intact. Efforts to restore the upper river floodplain and a natural hydro-period are underway (St. Johns River Water Management District 2007).

New surface water withdrawals of up to 262 million gallons per day (mgd) for consumption are being sought to accommodate a projected population growth in the region from 4.4 million people to 7.3 million people by 2030. The withdrawal may reduce average daily discharge by 7.8 percent with 155 mgd projected to come from three locations along the spawning grounds of blueback herring and other alosines. The effects of this withdrawal on water quality and ecology as well as possible impingement/entrainment are being reviewed (National Research Council 2009). Furthermore, waters in the spawning and nursery habitats are currently considered impaired due to non-attainment of standards for several water quality parameters including nutrient loads, excessive harmful algae, elevated biological oxygen demand, and episodes of depressed dissolved oxygen. Various actions are underway to attempt to mitigate these issues (Florida Department of Environmental Protection FDEP 2005). The trend in water quality during the last two decades has generally been a slow decline with chlorophyll a, total nitrogen, total phosphorous, and total suspended solids increasing in the middle St. Johns River (Keller et al.

2004). High water is commonly associated with dissolved oxygen levels below 5 mg/l but high water typically occurs during September-November upstream of the nursery zone. Downstream sections nearer the river mouth are also subject to summer and fall algae blooms and hypoxia events common in systems with high nutrient loading (Magley and Joyner 2008). It is not known if the downstream water quality is affecting the ability of juveniles to emigrate successfully.

18.7. RESTORATION PROGRAMS

There are no restoration programs in Georgia or Florida.

18.8. AGE

No age date is currently available.

18.9. FISHERIES DESCRIPTIONS

There is no directed fishery (commercial or recreational) in Florida. Gear restrictions preclude there being any fisheries operating where bycatch is likely.

There is no evidence that a directed recreational fishery has ever existed for river herring Georgia's rivers or coastal waters. A 1999 creel survey conducted by the South Carolina Department of Natural Resources at the New Savannah Bluff Lock and Dam documented the only known recreational harvest of blueback herring in Georgia's rivers. This survey was conducted from February 1, 1999 through June 30, 1999 and anglers harvested an estimated total of 95 blueback herring. During this same time period anglers harvested an estimated 3,828 American shad. The extremely low blueback herring harvest numbers seem to indicate that anglers targeting American shad incidentally harvested these fish.

18.10. FISHERIES INDEPENDENT MONITORING

18.10.1. Data Collection Methods

18.10.2. Spawning stock surveys

18.10.3. Seine Survey

In-migrating adult Alosa species were collected in the St. John's River, FL by seine in 1972 and 1973. The seine was a 306m commercial herring seine (6 cm stretched mesh) fished two to three nights per month from January to March at rkm 152. Blueback herring were enumerated and subsampled for biological data, age and fecundity. Juveniles were collected by seine and towed surface trawl throughout the year in 1972 and 1973 (Williams et al. 1975) (Table 18.2).

18.10.4. Electrofishing Survey

Adult Alosa species were collected on the spawning grounds in the St. Johns River by electrofishing beginning in 2001. In 2001 and 2002 sampling was haphazard 10 minute transects. The sampling protocol was standardized beginning in 2003. Standard sampling occurred from January to April in each year. Ten random transects were sampled in two representative river sections lying between rkm 278 and 357. One section is referred to as the "Creel Area". The other section is referred to as "Upstream" and combines two sub-areas. The Creel Area lies between river kilometers 274 and 297 as measured from the river mouth and falls between Lake Monroe and Lake Harney. "Upstream" includes four transects in a six kilometer reach between Lake Harney and Puzzle Lake (rkm 314-320) and six transects in 12 km of river bracketing State Road (SR) 50 near Christmas, Florida (rkm 345-357) (Figure 18.1). In 2009 and 2010, peak-season trips were made to various tributaries in search for spawning locations of Alosa species outside the mainstem of the St. Johns River (Figure 18.2). These locations included spring fed streams, blackwater creeks, and back channels in the braided section of the St. Johns River.

Sampling was conducted using an 18-foot aluminum boat outfitted with a Smith-Root GPP 9.0 electrofisher using two four-dropper Wisconsin rings. Pulsed direct current (60 Hz) was used at 340 or 680 volts depending on water conductivity. Amperage was standardized for effective power transfer and the electricity was cycled 25 seconds on by 5 seconds off. Sampling lasted for 10 minutes of "on pedal" in each transect and targeted open water. The boat path meandered between the center of the channel and the two-foot depth contour or outer edge of vegetation where channel width exceeded 50 meters. The entire navigable channel was covered where channel width was less than 50 m. Electrofishing direction was downstream with boat speed about 1-2 mph faster than ambient current. Two netters were used for all samples in the St. Johns River for catch per unit effort (CPUE) samples.

Fish collected were held live, processed between transects, and then released except when retained for biological sampling. Sex, total length (TL) (mm), and weight (g) were recorded for all *Alosa spp.* collected. From 2003 to 2005 scales and otoliths were retained but aging has not been attempted. River herring are present primarily in February and March so CPUE for the adult index is calculated from sampling conducted in these months.

18.10.5. Juvenile Surveys

18.10.6. Pushnet Survey

A bow mounted pushnet was constructed in 2006 to begin developing a juvenile abundance index for Alosa species in the St. Johns River, Florida. The sample gear consisted of a 5.3 m aluminum boat used to push a modified four panel Cobb trawl mounted on a rigid frame. The net opening was 1.2 m high X 1.5 m wide. The body was 3 m deep and constructed of 19 mm stretched mesh knotless nylon. The cod end was 2 m deep and constructed of 12.7 mm stretched mesh knotless nylon

Pushnet sampling was haphazard in 2006 while the gear was being tested for efficacy in the river. Sampling was expanded to cover the entire nursery zone during the spring, summer, and early fall of 2007 through 2009. The nursery zone was sampled monthly from March to September. Sampling consisted of 48 five-minute tows at randomly selected stations between Warner Point and Lake Harney which corresponds to river kilometers 125 and 305, respectively. The river was stratified into 10 km blocks with 3 samples selected in each block to ensure sample coverage throughout the nursery zone in a sampling month. Sampling occurred on four consecutive nights starting 45 minutes after sunset with 12 stations visited each night along a 40 km river reach. Juveniles appear to be most vulnerable to the gear for the longest period of time between Lake George and Lake Monroe. Therefore, a 40 km reach was selected from rkm 210 to 250 for annual monitoring. In 2010 this stretch was sampled biweekly from the end of March until September. Twelve stations were visited each night with three randomly selected in each 10 km block. The index is calculated as the geometric mean of April through July catches.

Distance pushed through the water was measured using a General Oceanics 2030R mechanical flowmeter mounted between the inner and outer vertical bars of the frame. Tow speed was standardized with the motor at 2000 rpm corresponding to a speed of approximately 2.6 statute miles per hour in still water.

Catch per tow was standardized to the average volume of a five-minute tow in the survey to date using the formula:

$$SC_i = C_i*(686m^3/V_i)$$

where SC_i = standardized catch in the ith tow. C_i = catch of the ith tow. V_i = volume of the ith tow and volume = net aperture area * distance towed.

18.10.7. Seine Survey

In 2010, Georgia Department of Natural Resources initiated juvenile Alosine sampling on the Altamaha, Ogeechee, and Savannah rivers to prepare for the implementation of ASMFC Amendment 3. Juvenile Alosines were sampled utilizing a 50' seine pulled along the edges of sandbars in each of the three rivers.

Given that this survey was recently initiated, the results were not used in this assessment. However, juvenile sampling efforts in these rivers will continue and this information can aide in the refinement of a juvenile Alosine sampling program as well as future assessment work.

18.11. ASSESSMENT APPROACHES AND RESULTS

18.11.1. Relative Abundance

Adult blueback herring were far more abundant in the St. John's River, FL, 9.7 and 7.4 times, than American shad in seine samples in 1972 and 1973 but shad were more numerous in modern electrofishing samples, often by greater than a factor of 10 (Figures 18.3 and 18.4) even though the American shad population is at low abundance (McBride and Holder 2008). However, we do not know whether or not electrofishing is selective for American shad relative to blueback herring or whether by focusing on the primary river channels sampling is missing areas where herring aggregate in this system. Electrofishing in small tributaries and along the littoral zones of larger lakes for other monitoring has not detected blueback herring. To date they are primarily encountered in the main stem of the river when electrofishing for American shad. Electrofishing CPUE has been low and without trend since 2003 (Table 18.3; Figure 18.3).

American shad were more abundant than blueback herring in all years of standard sampling (Figure 18.4). Tributary sampling to date has located mature blueback herring only in the Wekiva River and in Haw Creek at very low densities.

18.11.2. Trends in Juvenile Abundance

Previously, in the St. John's River, FL, Williams et al. 1975 reported 355.3 and 268.3 blueback herring per seine haul during January – March in 1972 and 1973 respectively. Subsequent juvenile sampling in those years yielded 1983 blueback herring in 1972 and 4050 blueback herring in 1973.

During the pushnet survey the average catch rate of juvenile blueback herring was greatest in 2006 during testing of the new gear (Table 18.4). Since then, catches have been lower under the standard protocol with catches of juvenile American shad being similar to or exceeding the catch of blueback herring (Figure 18.5). No trend analysis is feasible on this short time series.

While catch rates are not comparable between the different gears it is apparent that the proportion of each species present has changed. Juvenile herring were six to seven times more abundant that American shad in 1972 and 1973 samples. Juvenile American shad were as or more abundant than juvenile blueback herring in four out of five years of modern (2006-2010) sampling with a pushed trawl. The geographic and temporal coverage was similar between the 1972-73 sampling and modern sampling. There is no reason to believe that the pushed trawl is more selective for American shad relative to herring than the surface trawls and seines used in 1972 and 1973.

18.11.3. Trends in Size

Blueback herring collected from the St. John's River, FL in 1972 and 1973 were larger than those collected in modern sampling (McBride et al. 2010). Although the gears are different and were fishing different sections of the river there isn't reason to believe that either gear was size selective. The reduced mean length of adult blueback herring during 2001-2010 as compared to the runs in 1972 and 1973 could point to a demographic shift. Demographic change has recently been documented for an alewife Alosa pseudoharengus run. A comparison of alewife from 1966-1967 to alewife from 2003-2006 in Bride Brook, Connecticut showed a reduction of mean length, mean age, age of recruitment, and the proportion of repeat spawners in the modern runs (Davis and Schultz 2009). Mean age of the run in Bride Brook declined from 5-7 year to 3-4 years. The mean size of blueback herring spawning in the St. Johns River in 2001-2010 corresponds to age 3-4 fish in the 1972 and 1973 runs during which 2.9% and 17% of males and 0.6% and 9.6%. of females were age 4 in those years. The majority of spawning herring in 1972 and 1973 were older than age 4. Such a shift in demographics can be the result of increased mortality. We have no modern age data so we cannot confirm that the change in size is reflective of reduced growth or age truncation in the St. Johns River population.

Females were larger than males and both males and females were smaller than males and females collected in 1972 and 1973 (McBride et al. 2010; Table 18.5; Figure 18.6).

18.11.4. Trends in Lengths at Age

Length at age is reported in Williams et al. 1975 (Table 18.1).

18.11.5. Potential Sources of Increased Mortality

No fisheries target blueback herring in Florida and Georgia. No fisheries are operating in the rivers that are likely to encounter blueback herring as bycatch. Any additional source of fishing mortality of sub-adults or adults is probably remote to the St. Johns River such as those in the Atlantic mackerel and Atlantic herring fisheries in the northeast (Harrington et al. 2005). The shrimp trawl fishery is the most likely fishery in Georgia waters that may inadvertently capture river herring. However, no reports of herring bycatch have ever been reported.

Dissolved oxygen in the St. Johns River has an inverse relationship to discharge (Kroening 2004). High flow typically occurs during the late summer into fall during the wet season and may be augmented by tropical events (Kelly and Gore 2008). Two notable events have occurred since juvenile monitoring began in 2006; one in 2008 and one in 2009. Tropical Storm Fay dumped one to two+ feet of rain in the St. Johns River basin between August 18 and August 23 2008 which resulted in record high river stages (National Weather Service Melbourne 2009). Dissolved oxygen dropped to 0.5 to 2 mg/l in most of the river reaches and 5 mg/l in the larger lakes. No Alosa were collected in September samples following Fay with sampling having occurred from rkm 125 to 305 in that month. An anomalous rain event inundated the Florida coast in May of 2009. This storm resulted in a one-day total of 20.5 cm of rain at Daytona Beach International Airport and an event total of 52.3 cm. This was an all time record for the month of May and the second highest storm total on record behind an October tropical system. Normal monthly rainfall at this station is 8.3 cm (National Weather Service Melbourne 2010). Runoff from the rain event caused reductions in dissolved oxygen in most river areas between Palatka and Lake Harney with the exception of Lake George (Figures 18.7 and 18.8). . Such episodic events are not taken here to be a change in average conditions that would pose an ongoing threat to river herring in the St. Johns River. These are notable here because they occurred in consecutive years and cover two out of the five years in which juvenile monitoring had occurred and may have had a significant impact on monitoring results. Extreme rainfall events like this could be a threat in the future if the frequency of occurrence of such events increases.

18.12. BENCHMARKS

There are no benchmarks established for Georgia or Florida.

18.13. CONCLUSIONS AND RECOMMENDATIONS

The reduced size of adults might indicate increased mortality remote to the St. Johns. The age structure of the returning adults needs to be determined in order to establish whether the reduced size is a result of a change in growth or age structure of returning adults.

Water quantity and quality are potential threats to both spawning success and juvenile growth and survival to out-migration. As noted in the habitat section, alosines spawn during the dry season in the St. Johns River when water levels are typically low. This may make them particularly sensitive to withdrawals. Data are needed on habitat selection by adults for spawning in order to assess how habitat might be affected by proposed water withdrawals and changes in average stage.

Juvenile monitoring should continue to assess whether any changes in water quality or habitat impact annual juvenile abundance.

There is no blueback herring fishery in Florida therefore there are no possible fishery interventions that would improve the population of blueback herring in the St. Johns River, Florida. The source of at sea mortality needs to be determined and reduced and water quality problems within the St. Johns River should be addressed if blueback herring population of the St. Johns River is to increase.

Neither measure of adult or juvenile abundance is conclusive and it may be a stretch to base the assessment of blueback herring abundance on the relative abundance of blueback herring as compared to the relative abundance of American shad in common samples. However, the low adult relative abundance of blueback herring in electrofishing samples corresponds to what appears to be low relative abundance of juveniles in trawl gear. Blueback herring were the most abundant alosine in the St. Johns River, Florida in past decades (Hale et al. 1985, Moody 1961, Williams et al. 1975). Taken in aggregate these indices do point to low blueback herring abundance relative to historic levels in the St. Johns River.

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Table 18.1 Mean total length (TL) at age as reported in Williams et al. 1975. Lengths here converted from fork lengths (FL) using the equation: TL = 1.1458*FL – 1.2495

	Female		Male	
Age	N	Mean TL	N	Mean TL
3			1	237
4	2	262	6	268
5	45	276	69	269
6	65	289	66	279
7	39	295	12	284
8	3	302		

Table 18.2 Mean catch per seine haul of blueback herring and American shad in 1972 and 1973. N is the number of nights. One to four seine hauls were made during a sampling night but Williams et al. 1975 only reports a mean catch rate for a given night and not the catch in each haul.

	blueback herring			American shad		
Year	N	Mean fish/haul	SE	N	Mean fish/haul	SE
1972	6	355.3	85.0	6	36.8	2.8
1973	6	268.3	36.5	6	71.3	13.7

Table 18.3 Electrofishing CPUE of blueback herring on the spawning ground in the St. Johns River Florida during February and March. Few stations were visited over a short period of the spawning season in 2001 and 2002.

Year	Mean Catch per Sample	SE	Number of Stations
2001	4.63	0.32	16
2002	0.19	0.12	18
2003	0.20	0.06	60
2004	0.58	0.12	105
2005	0.11	0.03	124
2006	0.19	0.05	80
2007	0.11	0.04	81
2008	0.20	0.05	70
2009	0.32	0.07	90
2010	0.53	0.15	51

Table 18.4 Geometric mean catch per two of juvenile blueback herring from April to July in the St. Johns River, Florida between river kilometer 210 and 250.

Year	Number of hauls	Number of fish	Geometric Mean	SD	SE	Zero hauls
2006	22	349	10.04	1.83	0.39	1
2007	46	846	2.95	3.73	0.55	20
2008	48	209	1.41	2.15	0.31	32
2009	48	201	1.13	2.18	0.31	43
2010	96	522	1.23	2.36	0.24	59

Table 18.5 Mean total length (mm) and mean weight (g) of male and female blueback herring collected from the St. Johns River. Mean weight for 1973 and 1972 is estimated by applying the weight/length relationships reported in Williams et al. 1975 to the lengths reported therein.

	Male					Female				
YEAR	N	LENGTH	SD	WEIGHT	SD	N	LENGTH	SD	WEIGHT	SD
1972	743	273.40		161.91		1322	286.80		218.31	
1973	939	266.41		150.93		1044	280.73		204.25	
2001	45	253.00	10.13	132.02	24.96	20	264.35	9.99	156.27	26.90
2002	2	255.00	21.21	135.65	31.18	4	267.25	9.81	157.30	19.62
2003	5	236.40	7.64	106.42	19.60	11	266.09	13.18	154.25	39.35
2004	92	250.35	7.43	126.12	19.54	103	260.85	7.55	141.98	19.08
2005	7	245.29	16.41	119.64	25.20	12	266.00	6.12	137.24	16.98
2006	23	242.96	10.98	106.71	18.36	14	257.29	6.98	135.79	20.58
2007	15	257.87	32.93	144.27	85.40	12	263.42	11.41	151.17	41.73
2008	21	250.57	8.28	130.8571	15.69	14	257.29	8.73	151.29	19.11
2009	42	244.88	7.16	117.1429	16.45	24	258.79	9.31	133.67	17.59
2010	61	250.33	7.05	123.3443	18.44	25	263.24	8.18	159.56	28.48

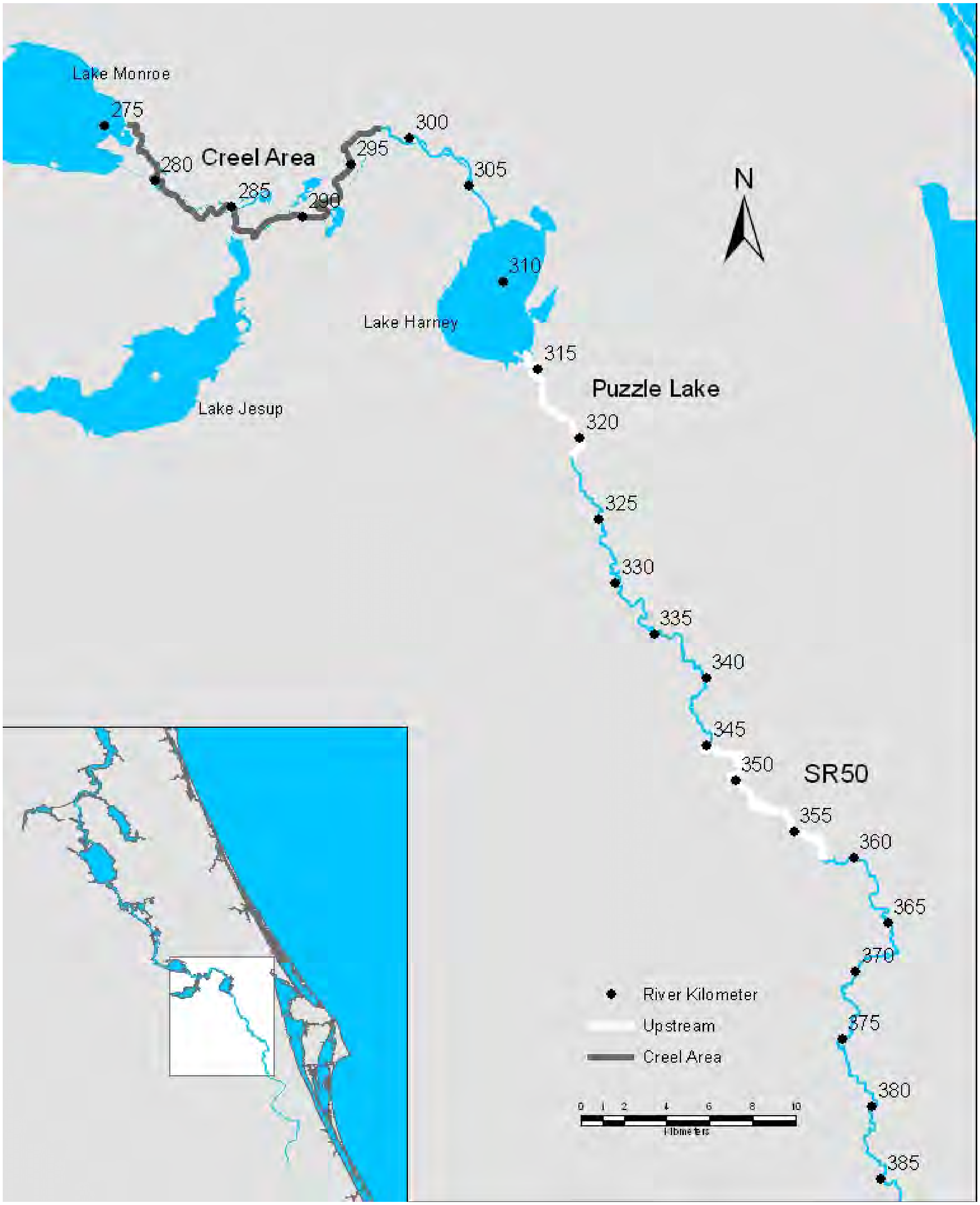

Figure 18.1 Map of areas sampled in the St. Johns River for monitoring of the spawning runs of adult American shad and other Alosa species. Numbers refer to kilometers upstream from the river mouth.

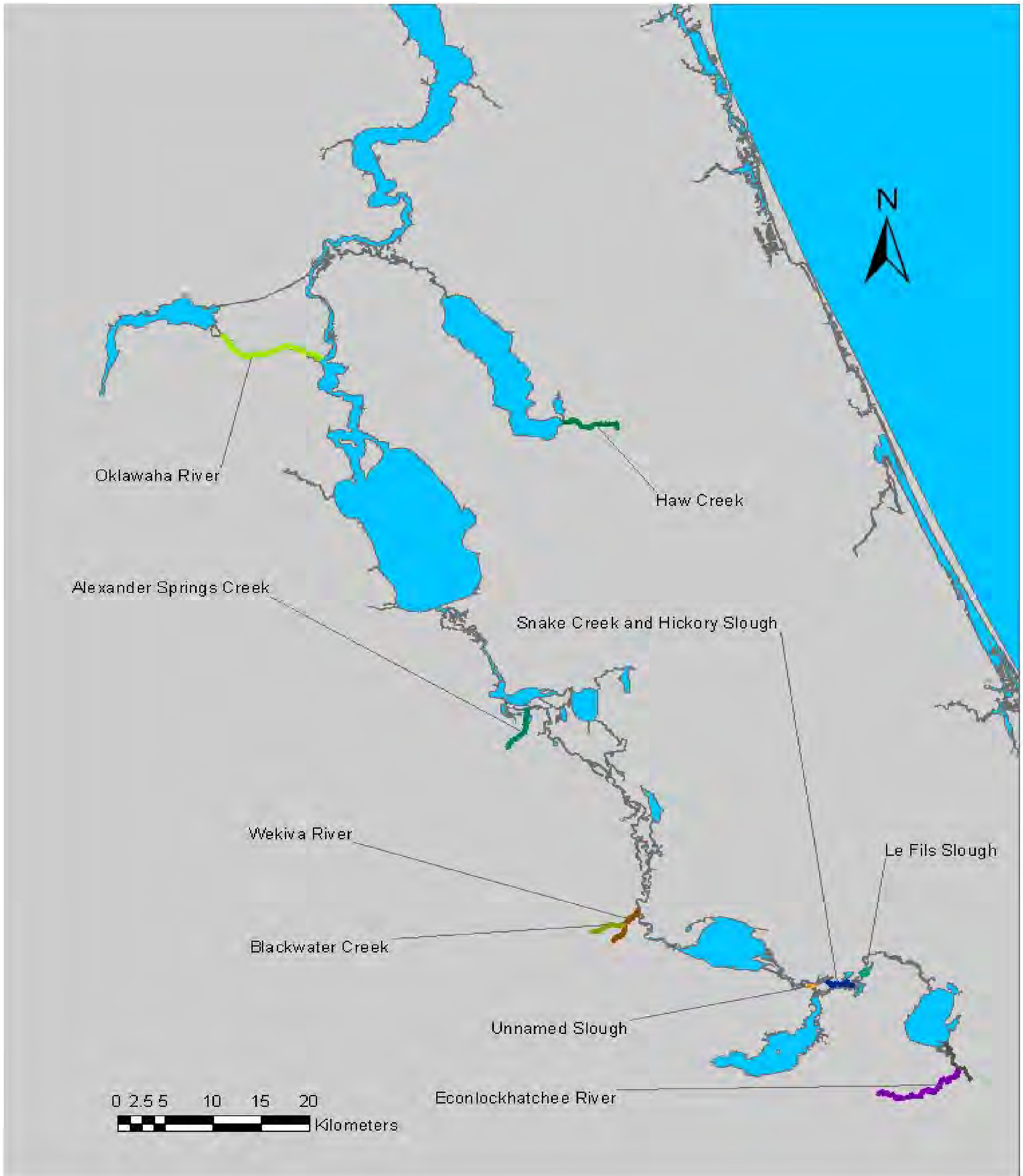

Figure 18.2 Map of targeted tributaries of the St. Johns River for monitoring of the spawning run of adult American shad and other *Alosa* species

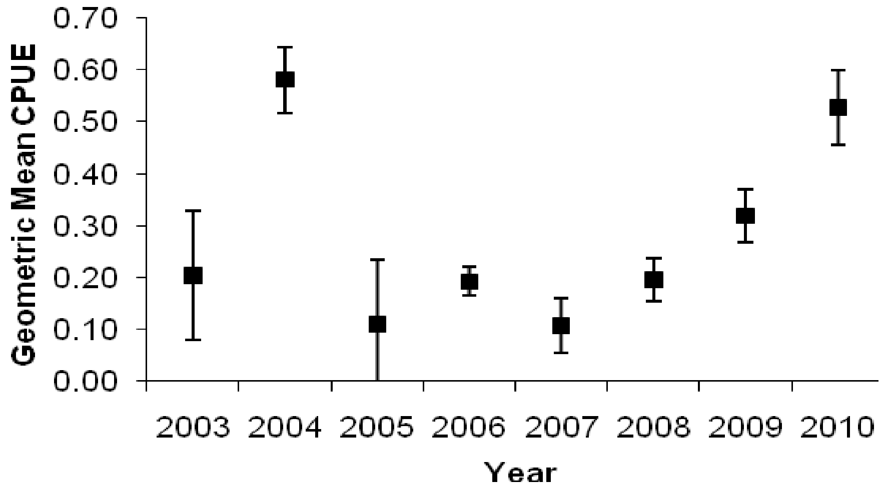

Figure 18.3 Average catch of blueback herring per 10 minute electrofishing transect during February and March in each year

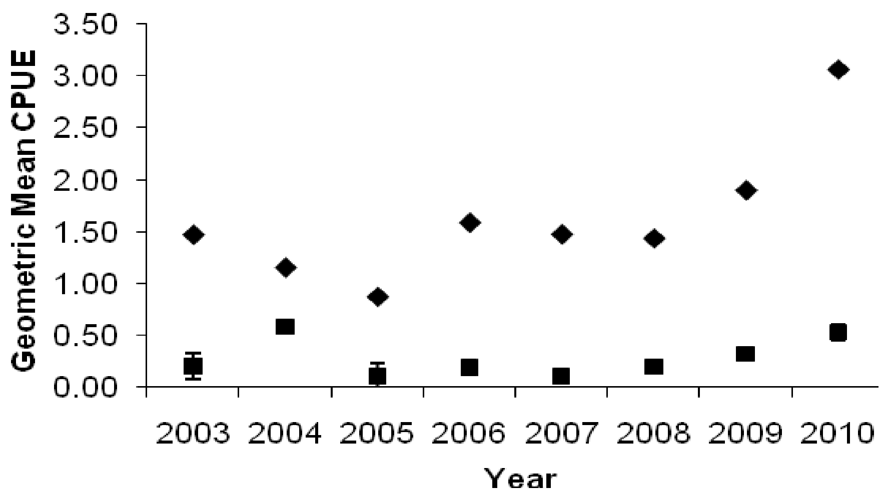

Figure 18.4 Average catch of blueback herring (squares) and American shad (diamonds) per 10 minute electrofishing transect during February and March in each year

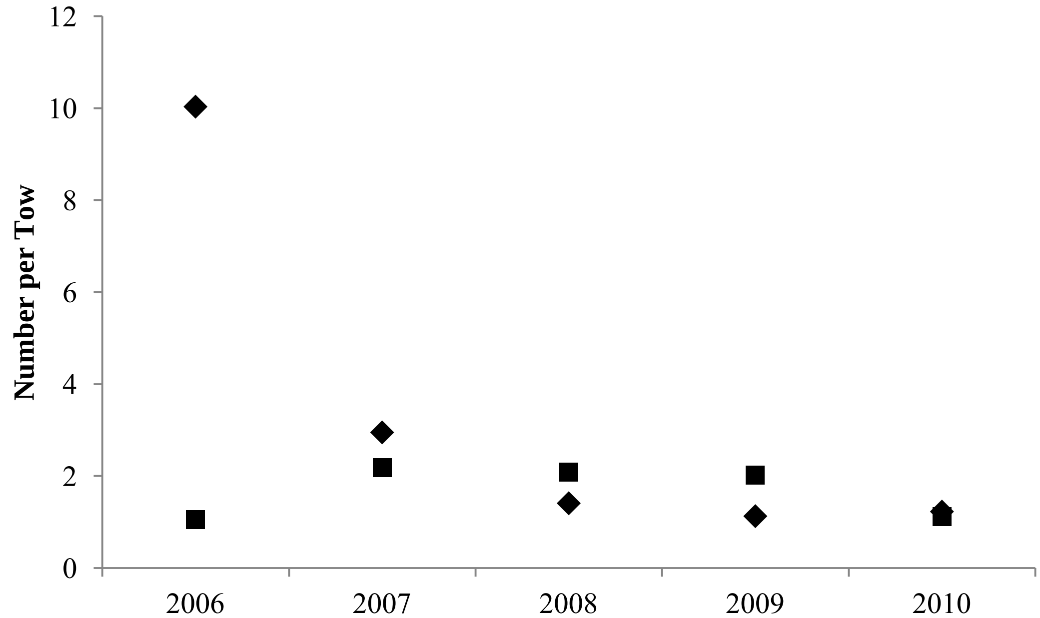

Figure 18.5 Geometric mean catch per 5-minute sample with the push trawl of juvenile blueback herring (diamonds) and American shad (squares) from April to July in each year between river kilometer 210 and 250.

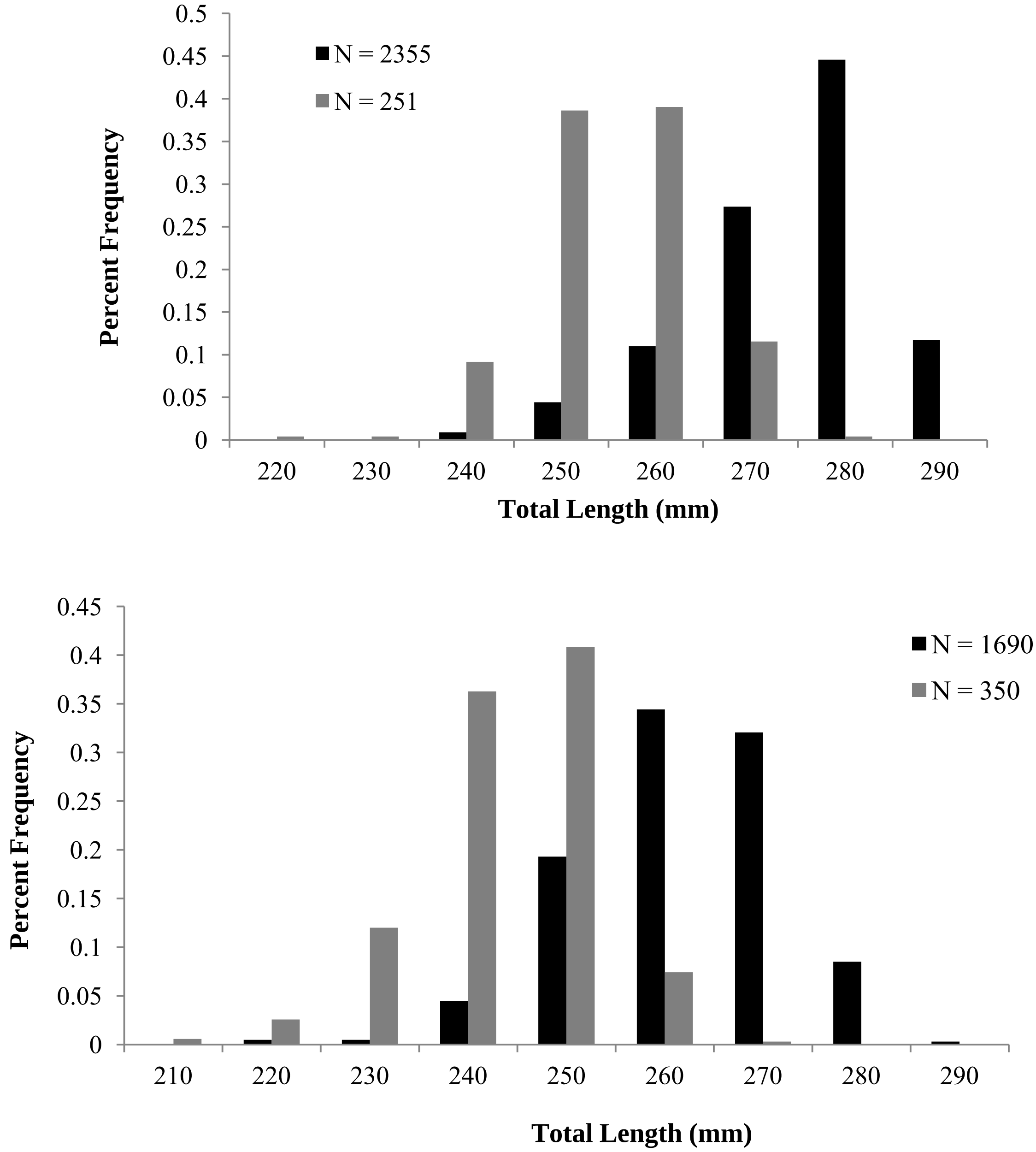

Figure 18.6 Percent length frequency of female (top) and male (bottom) blueback herring collected in 1972-1973 and 2001-2010. Charcoal bars represent 2001-2010. Black bars represent 1972-1973.

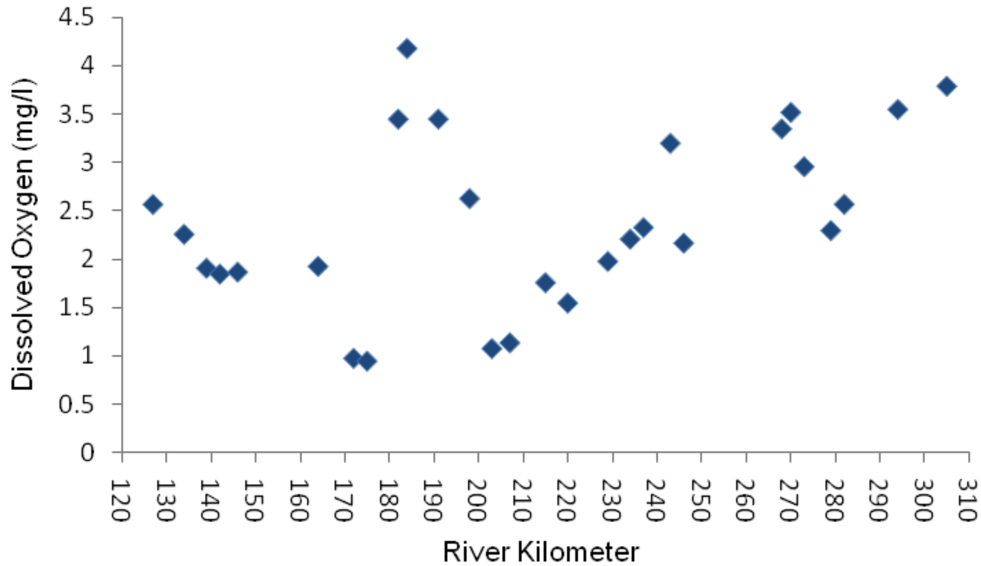

Figure 18.7 Field measurements of dissolved oxygen taken in the main channel of the St. Johns River during the period 15 June 2009 through 18 June 2009. Lake George is located between rkm 180 and 200.

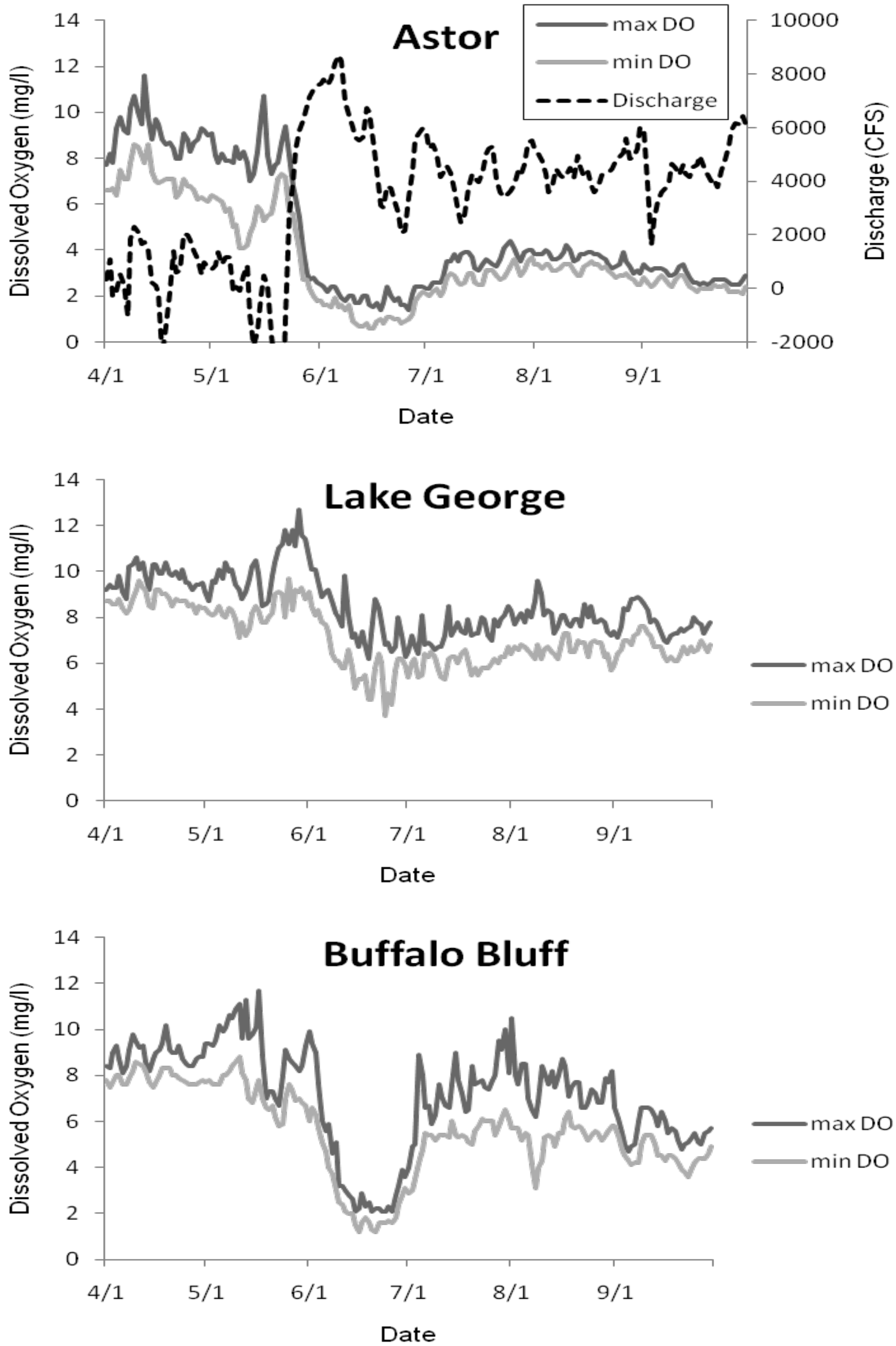

Figure 18.8 Daily minimum and maximum dissolved oxygen measured at US Geological Survey, USGS, gauges [Astor station 02236125, Lake George station 29183008136220, and Buffalo Bluff station 02244040] for 2009. Daily average discharge included for Astor (USGS 2010). Astor station is a non-tidal station at rkm 210. Lake George station is in the center of 40,000 acre Lake George at rkm 190. Buffalo Bluff is on a railroad crossing at rkm 150 in the tidal freshwater portion of the nursery zone.

19. Trends in Alewife and Blueback Herring from the Northeast Fisheries Science Center Bottom Trawl Surveys

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19.1. Objectives

The Northeast Fisheries Science Center (NEFSC) bottom trawl surveys are conducted in both the spring and fall and sample from Maine through North Carolina (Azarovitz et al 1997). These surveys were used to investigate trends in alewife, blueback herring and river herring (combined alewife and blueback herring) relative abundance and biomass, mean length, and growth.

19.2. Methods

Data collected during the NEFSC bottom trawl surveys were used to derive seasonal relative abundance and biomass indices. The surveys follow a stratified random sampling design with strata defined primarily by depth and stations allocated approximately in proportion to stratum area (Azarovitz 1981). Inshore (8-27 m) and offshore strata (27-366 m) have been most consistently sampled by the research vessels *Albatross IV* and *Delaware II* since the fall of 1975 and spring of 1976. Prior to these time periods, either only a portion of the survey area was sampled or a different vessel and gear were used to sample the inshore strata (Azarovitz 1981). Accordingly, seasonal alewife and blueback herring relative abundance indices were derived from these trawl surveys for 1975-2010 in the fall and 1976-2011 in the spring.

Through 2008, standard bottom trawl tows were conducted for 30 minutes at 6.5 km/hour (3.5 knots) with the *Albatross IV* as the primary survey research vessel (Despres-Patanjo et al. 1988). However, vessel, door and net changes did occur during this time, resulting in the need for conversion factors to adjust survey catches for some species. Conversion factors were not available for net and door changes, but a vessel conversion factor for alewife was available to account for years where the RV *Delaware II* was used. A vessel conversion factor of 0.58 was applied to alewife weight-per-tow indices. Alewife number-per-tow indices did not require a conversion factor (Byrne and Forrester 1991).

In 2009, the survey changed primary research vessels from the *Albatross IV* to the *Henry B. Bigelow*. Due to the deeper draft of the *Bigelow*, the two shallowest series of inshore strata (8-18m depths) are no longer sampled. Concurrent with the change in fishing vessel, substantial changes to the characteristics of the sampling protocol and trawl gear were made, including tow speed, net type and tow duration (NEFSC 2007). Calibration experiments, comprising paired standardized tows of the two fishing vessels, were conducted to measure the relative catchability between the two vessel-gear combinations and develop calibration factors to convert *Bigelow* survey catches to *Albatross* equivalents (Miller et al. 2010). Species-specific calibration coefficients were estimated for both catch numbers and weights using the method of Miller et al. (2010) (Table 19.1). The calibration factors were combined across seasons due to low within-season sample sizes from the 2008 calibration studies (less than 30 tows with positive catches by one or both vessels).

Bottom trawl catches of the subject alosid species tend to be higher during the daytime due to diel migration patterns (Loesch et al. 1982; Stone and Jessop 1992). Accordingly, only daytime tows were used to compute relative abundance and biomass indices. In addition, the calibration factors used to convert *Bigelow* catches to *Albatross* equivalents were estimated using only catches from daytime tows.

Daytime tows, defined as those tows between sunrise and sunset, were determined for each survey station based on sampling date, location, and solar zenith angle using the method of Jacobson et al. (2011). Although there is a clear general relationship between solar zenith and time of day, tows carried out at the same time but at different geographic locations may have substantially different irradiance levels that could influence survey catchability (NEFSC 2011). Preliminary analyses (Lisa Hendrickson, NMFS – *unpublished data*) confirmed that river herring catches were generally greater during daylight hours compared to nighttime hours.

Relative abundance and biomass indices

Relative abundance (stratified mean number-per-tow) and biomass (stratified mean kilogram-per-tow) indices, as well as the proportion of positive tows were calculated for alewife and blueback herring using data from NEFSC spring (1976-2011) and autumn (1975-2011) bottom trawl surveys. Survey indices were developed for each species separately as well as for both species combined (i.e., river herring). For both seasons, survey indices were computed for the entire northwest Atlantic coast. For the spring survey, indices were also calculated separately for a northern set and a southern set of survey strata (Figure 19.1). The two strata sets were used to examine whether general trends in run count differences between northern and southern rivers along the U.S. Atlantic coast were apparent in NEFSC survey indices for similar regions. The geographic boundary between the northern and southern NEFSC survey regions reflects the monthly timing of the spring surveys with April as the median month of sampling in the north and March as the median month of sampling in the south. Also, the boundary between northern and southern regions roughly corresponds to the Hudson Canyon. Fall surveys were not split into northern and southern regions because of very limited catches of river herring in southern strata.

To assess trends in relative abundance indices, autoregressive integrated moving average models (ARIMA, Box and Jenkins 1976) were fit to log-transformed stratified mean catches. In years where stratified means equaled zero, a small number (0.01) was added to the stratified mean catch prior to log transformation. By accounting for temporal autocorrelation, the ARIMA approach derives fitted estimates of abundance over the time series where the variance in these fitted estimates is less than the variance of the observed series (Pennington 1986). Helser and Hayes (1995) extended Pennington's (1986) application of ARIMA models to fisheries survey data to infer population status relative to an index-based reference point. This methodology yields a probability that the fitted index value of a particular year is less than the reference point [$P(index_t < reference)$]. Because there is uncertainty in both the reference point as well as the probability of being below the reference point in a particular year, a method suggested by Helser et al. (2002) was employed. This method uses a two-tiered approach when evaluating reference points, incorporating both the probability of being below the reference point and the associated decision confidence level. Through this method, the distributions of both the bootstrapped terminal year index value and the bootstrapped reference point are compared. The confidence level can be thought of as a one-tailed *a*-probability from statistical hypothesis testing. For example, if the $P(index_t < reference) = 0.90$ at an 80% confidence level, there is strong evidence that the index of the year in question is less than the reference point. Helser and Hayes (1995) suggested using the lower quartile (25^{th} percentile) of the fitted abundance index as the reference point in an analysis of Atlantic wolffish (*Anarhichas lupus*) survey data. The use of the lower quartile as a reference point is arbitrary, but provides a reasonable reference point for comparison for data with relatively high and low abundance over a range of years (Helser and Hayes 1995). In this analysis a confidence level of 80% and the 25^{th} percentile reference point were used.

Trends in size structure

Length frequencies were calculated seasonally (spring and fall) for the coastwide population as well as northern and southern regions separately. Trends in mean length (fork length, cm) of alewife and blueback herring were assessed using a non-parametric Mann-Kendall test for a monotonic trend. The test statistic for the Mann-Kendall test (S) is positive if there is an increasing trend and negative if there is a decreasing trend. The Mann-Kendall test was run for both the coastwide and regional indices. Data used in this analysis included lengths from daytime tows only.

Age and Growth

Age data for river herring were available for a limited time period from 1973 – 1987. Length-at-age data from daytime and nighttime tows were combined to increase sample sizes because length distributions between daytime tows and all tows did not substantially differ for either species (Figure 19.2). Non-linear regression was used to fit season-specific von Bertalanffy growth models to both the coastwide and regional data.

19.3. Results

Proportion positive tows

The proportion of tows that caught river herring was greater during the spring compared to fall (Figure 19.3). During spring seasons, there was little trend in coastwide proportions. However, there were different trends between northern and southern regions. In the case of alewife, northern and southern regions tracked fairly consistently until the mid-1990s, at which point the northern region began to slightly increase, while the southern region showed a decreasing trend (Figure 19.3). In contrast, for blueback herring the southern region generally had a higher proportion of positive tows compared to the northern region until the late-1990s. In the 2000s, northern and southern regions exhibited similar proportions of positive tows. Due to differing regional trends between alewife and blueback herring, a consistent temporal trend in the proportion of positive tows was not evident for the combined river herring species group. However, differences between northern and southern regions for the species group were greatest at the beginning and end of the time series. Fall surveys showed little fluctuation in the proportion of positive tows for both each species separately as well as the species combined.

Relative abundance indices

Across all regions, alewife number- and weight-per-tow generally varied without trend until the mid-1990s (Figure 19.4 and Figure 19.5). In the 2000's, coastwide indices for both seasons as well as northern indices during the spring exhibited an increasing trend. The southern region did not exhibit a consistent temporal trend during the spring surveys, though the greatest catches occurred near the beginning of the time series. Trends in blueback herring number- and weight-per-tow were not as pronounced as those for alewife (Figure 19.6 and Figure 19.7), although catches between 1975-1985 and 2005-2011 tended to be greater than catches during the middle portion of the time series. Across both seasons, alewives were typically caught in greater abundances than blueback herring. Consequently, indices for combined river herring followed similar trends as those for alewife (Figure 19.8 and Figure 19.9).

ARIMA model fits to stratified mean number-per-tow indicated similar trends (Figure 19.10 - Figure 19.12). Predicted values from ARIMA models for alewife showed an increasing trend coastwide during both seasons and in the northern region during the spring. These indices exhibited a 0.0 probability that the relative abundance in the final year was below the 25th percentile reference point (Table 19.2). However, the spring survey index for the southern region showed a decreasing trend with a 0.446 probability that the 2011 relative abundance was below the 25th percentile reference point.

Blueback herring and combined river herring also showed similar patterns to alewife, with increasing abundance trends coastwide during the fall and in the northern region during the spring. For the coastwide spring indices, blueback herring appeared to vary without trend, whereas the combined species group reflected the increasing trend of alewife. In the spring, the southern region appeared to decline in the beginning of the time series, but appeared to vary without trend after approximately 1990. For this region and season, the probabilities of being below the 25th percentile reference point in 2011 were 0.162 and 0.250 for blueback herring and the river herring species group, respectively.

Trends in size structure

Modes of length distributions varied through time for both species. Modes in alewife length frequencies ranged from 10 cm to 25 cm and tended to be lower during the 2000s during coastwide spring surveys (Table 19.3) but this temporal pattern was not apparent during coastwide fall surveys (Table 19.4). Modes in alewife length frequencies in the northern region during spring surveys were also lower during the 2000s (Table 19.5) but showed no temporal patterns in the southern region (Table 19.6). Modes in blueback herring length frequencies ranged from 7 to 25 cm and showed no consistent pattern temporally (Table 19.7 - Table 19.10).

Trends in mean length differed by species. Alewife mean length significantly decreased in all seasons and regions (Table 19.11; Figure 19.13). Blueback herring mean length significantly decreased for the coastwide index in the fall. However, blueback herring mean length significantly increased in the southern region in the spring (Table 19.11; Figure 19.14). For the coastwide and northern spring indices, blueback herring mean length did not exhibit a significant monotonic trend.

Age and growth

Von Bertalanffy growth parameters and the associated growth curves for each season- and region-specific model are shown in Table 19.12and Figure 19.15-Figure 19.16. Alewife lengths ranged from 6 to 30 cm and ages ranged from 1 to 14 years. Blueback herring lengths ranged from 6 to 28 cm and ages ranged from 1 to 12 years. Approximate 95% confidence limits were compared to infer differences in growth parameters among regions and seasons. Alewife $L\infty$ and K were not significantly different between seasons in coastwide growth models. During spring surveys, $L\infty$ was slightly greater in the northern region compared to the southern region, but K was greater in the southern than in the northern region. Blueback herring growth parameters did not differ significantly among seasons or regions, potentially due to low sample sizes.

Survey timing

The timing of the NEFSC bottom trawl surveys has changed over the time series included in this analysis (Figure 19.17 and Figure 19.18). Linear regressions between median Julian day of sampling and year indicated significant relationships across both seasons and regions. Median Julian day has significantly decreased with surveys occurring earlier in the year as the time series progressed. This variability in the timing of the trawl surveys may influence the availability of the species to the survey gear. However, across regions and seasons, there was not a consistent significant relationship between median bottom temperature at the time of sampling and year. In the northern region, the relationship between temperature and year was not significant, indicating that the median temperature when the northern region was sampled has not significantly changed even though the survey has occurred progressively earlier. In the southern region, median sampling temperature significantly increased over time in the fall but did not exhibit a significant relationship with year the spring.

19.4. Discussion

Catches of river herring in the NEFSC bottom trawl surveys varied spatially and temporally. Spring and fall survey indices exhibited considerable interannual variability, and in general, were more informative for the spring surveys due to a greater proportion of positive tows. River herring catches generally appeared to increase in northern areas during spring surveys. However in the southern region, river herring catches appear to either decrease or vary without trend. These trends are more evident for alewife than for blueback herring. Differences in relative abundance trends among regions could be a consequence of true regional differences in population trends or a distributional shift of the species. Nye et al. (2009) observed a northward shift in the distribution of alewife, and found that changes in the distribution of multiple species in the NEFSC trawl surveys were correlated with large-scale warming and climactic conditions such as the Atlantic Multidecadal Oscillation.

Coastwide and northern relative abundance indices for alewife and combined river herring were greatest in the last year of the survey time series, when the *RV Bigelow* was used to conduct the survey. However, it is unlikely that this observed increase was due to the change in survey methodology. Relative abundance estimates from 2009-2011 were converted to *Albatross* equivalents using estimated conversion coefficients to account for catchability differences. Furthermore, the observed increase in the fall indices began in 2008, which was before the survey switched research vessels. If the recent increase in river herring relative abundance was highly influenced by the change in survey methodology, we would also expect an increase in the southern region during spring surveys. However, an increase in the southern region for alewife, blueback herring or the combined river herring species group was not observed.

Mean lengths tended to decrease for river herring from the NEFSC bottom trawl surveys, which could be indicative of increasing mortality (Beverton and Holt 1957). However, indications of increasing mortality are contradictory to the observed increasing trends in relative abundance, especially in the northern region during the latter part of the time series. Unfortunately, age data for river herring are not available from the NEFSC bottom trawl survey in recent years to determine how changes in size structure relate to changes in age structure. If age structure has remained the same over the time series, changes in mean length may be due to changes in growth rates as opposed to increasing mortality. Changes in mean length could also be due to changes in the distribution of river herring, as described above, and the NEFSC bottom trawl survey may be sampling different segments of the coastwide river herring population in more recent years compared to earlier years in the time series.

Changes in the timing of the trawl surveys make interpretation of regional trends in relative abundance for anadromous species such as river herring difficult. Changes in relative abundance in northern or southern regions could be an artifact of the timing of sampling rather than true population changes. However, even though the median Julian day for the surveys has changed, the bottom temperature encountered while sampling has largely remained the same. One exception is the median temperature of the southern region in the fall; however, fall regional indices were not examined in this analysis. If river herring migratory behavior is governed by water temperature as it is for Atlantic herring (Maravelias and Reid 1997), observed trends in relative abundance may represent changes in river herring population abundance.

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Table 19.1 Coefficients and associated standard errors used to convert RV *Bigelow* catches of alewife and blueback herring to RV *Albatross IV* equivalents for the 2009-2011 NEFSC bottom trawl surveys.

	Number		Biomass	
Species	**Coefficient**	**SE**	**Coefficient**	**SE**
Alewife	1.05	0.16	0.72	0.11
Blueback herring	0.87	0.17	1.59	0.45

Table 19.2 Summary statistics from ARIMA model fits to river herring stratified mean number-per-tow from NEFSC bottom trawl surveys. $Q_{0.25}$ is the 25th percentile of the fitted values; P(<0.25) is the probability that the final year of the survey is below $Q_{0.25}$ with 80% confidence; r1 - r3 are the first three autocorrelations; θ is the moving average parameter; SE is the standard error of θ; and σ^2_c is the variance of the index.

Species	Region	Season	FinalYear	Q0.25	P(<0.25)	n	r1	r2	r3	θ	SE	σ^2_c
Alewife	Coast	Fall	2010	0.276213	0	36	-0.55	0.18	-0.18	0.78	0.09	0.63
		Spring	2011	1.908339	0	36	-0.26	0.08	0.08	0.46	0.18	0.26
	North	Spring	2011	1.594979	0	36	-0.21	0.05	0.07	0.48	0.18	0.26
	South	Spring	2011	1.451677	0.446	36	-0.28	-0.14	-0.06	0.8	0.16	0.97
Blueback	Coast	Fall	2010	-2.97251	0	36	-0.35	-0.06	0.03	0.67	0.15	1.95
		Spring	2011	0.618258	0.009	36	-0.51	-0.03	0.19	0.75	0.2	0.71
	North	Spring	2011	-0.73406	0	36	-0.5	-0.12	0.27	0.77	0.1	0.95
	South	Spring	2011	1.213535	0.162	36	-0.61	0.19	-0.01	0.82	0.14	1.34
Both	Coast	Fall	2010	0.375722	0	36	-0.49	0.12	-0.15	0.77	0.1	0.62
		Spring	2011	2.238552	0	36	-0.43	-0.01	0.24	0.6	0.17	0.28
	North	Spring	2011	1.723611	0	36	-0.3	0.02	0.13	0.52	0.17	0.27
	South	Spring	2011	2.222637	0.25	36	-0.43	-0.03	0.03	0.8	0.21	0.74

Table 19.3 Length frequency of alewives from the coastwide NEFSC bottom trawl survey during the spring. Only lengths from day tows were included.

Fork Length (cm)	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
3					2																															
4																			1		1															
5					1								1																							
6		2			1				2	3	4		13	6	1							1					2			1	5		1			2
7	1		33	3	1	1			7	5	6	3	18	27	16	5	3	4	16				2		7	6	4		20	9	25	2	4	33	1	37
8	8	2	103	8	26	2	12	4	17	7	5	16	7	22	35	22	4	9	47	5	5	15	11	5	78	7	6	10	60	53	63	6	19	94	4	66
9	36	6	174	52	94	12	85	9	46	16	18	13	20	19	37	47	5	43	58	12	14	29	20	8	225	23	5	32	167	103	141	21	51	247	60	176
10	37	4	161	101	199	37	143	7	63	18	8	11	34	19	32	34	19	86	61	17	23	48	35	18	364	22	9	112	192	270	277	30	70	252	77	293
11	34	14	316	106	217	40	190	17	48	21	24	2	18	7	23	33	27	114	49	14	18	46	71	23	387	33	11	226	165	252	382	26	73	266	95	1367
12	25	6	443	148	439	67	145	17	60	18	16	6	19	10	23	76	20	117	55	19	24	56	103	87	267	85	13	276	93	165	523	20	75	199	58	883
13	33	18	728	111	366	26	149	23	57	14	13	3	19	6	27	67	43	113	119	45	20	65	159	192	111	73	34	187	59	106	656	22	42	142	64	658
14	21	11	543	95	260	20	52	42	31	11	13	5	23	13	23	56	49	129	120	29	29	70	189	185	92	52	28	17	38	94	719	17	29	115	166	212
15	25	6	205	69	191	17	52	50	22	26	21	25	10	25	15	40	20	128	74	29	56	59	152	257	105	59	24	23	57	138	1974	40	68	139	580	190
16	52	6	87	51	173	12	43	113	21	69	27	24	17	33	22	42	17	150	40	34	103	41	185	243	39	69	55	26	69	109	1565	57	118	267	722	272
17	66	9	77	68	284	43	35	158	16	136	24	34	26	37	31	55	12	178	28	26	205	88	167	434	35	80	105	41	77	59	382	69	94	291	675	160
18	54	10	53	229	285	71	101	130	33	129	62	66	20	48	18	55	19	110	38	29	302	103	159	408	74	57	152	60	92	37	121	90	59	117	250	101
19	55	26	70	364	210	153	158	67	39	77	37	99	30	38	16	44	22	89	49	50	159	85	157	171	76	42	74	22	60	35	26	45	34	91	121	186
20	64	26	120	303	144	171	140	39	31	89	38	125	28	34	24	25	134	125	61	92	213	75	125	292	66	35	59	31	66	28	28	51	79	87	140	243
21	64	44	65	136	131	137	74	48	26	57	41	113	31	17	30	18	124	86	47	64	167	200	97	158	50	66	123	40	140	35	29	76	69	94	141	134
22	85	62	57	79	146	118	77	55	13	44	47	106	26	14	17	46	101	42	49	106	178	215	125	281	73	73	111	73	136	53	35	79	67	97	80	89
23	108	80	60	124	155	125	170	43	41	41	52	83	18	10	18	70	105	32	71	115	234	285	210	293	84	61	121	112	44	54	17	76	35	121	56	96
24	146	110	68	161	170	142	140	58	54	21	50	81	26	18	34	162	83	42	40	105	234	333	185	208	107	117	117	92	42	73	11	54	40	155	55	66
25	156	101	91	277	137	180	201	66	96	19	63	88	18	22	44	106	114	35	31	80	190	131	77	112	61	106	132	98	38	46	12	40	26	134	42	65
26	108	168	148	311	204	147	159	69	115	37	67	170	14	31	29	60	48	31	12	43	55	77	45	43	37	56	84	86	55	27	11	31	19	47	22	21
27	102	150	150	286	228	138	103	89	85	35	57	81	15	42	44	20	27	26	8	24	21	17	22	18	8	33	29	56	23	17	3	12	8	21	12	14
28	87	96	81	252	213	116	88	67	49	19	30	33	8	49	41	22	23	8	6	7	9	15	7	13	2	7	4	13	9	9	1	4	3	7	4	4
29	42	53	36	134	80	78	38	43	27	20	11	22	3	16	21	10	11	3	2	2		2	2	3	1	1	4	5	1	1	2			2		
30	18	25	17	53	82	50	30	25	5	7	6	11	1	4	9	4	8	2		1	1	1											1			1
31	9	5	2	32	34	18	8	15	5	2	3		2	1	1	1	2				1															
32	1	1	4	6	7	15	5	7	1		1							1																		
33		2	1	2	1	3	1	1						1																						
34					1	2	3					1	1		1																					
35						1																1														
36			1		2											1					1															
37									1																											
41									1																											
44									1																											
46															1																					
47		1																																		
Sample Size	1437	1044	3894	3561	4484	1942	2402	1262	1013	941	744	1221	466	569	633	1121	1040	1703	1082	948	2263	2058	2305	3452	2349	1163	1306	1638	1703	1774	7008	868	1084	3018	3425	5336

Table 19.4 Length frequency of alewives from the coastwide NEFSC bottom trawl survey during the fall. Only lengths from day tows were included.

Fork Length (cm)	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
4																												2								
5																												1								
7																																1				
8																																1				
10																													2		1			1	9	
11									2						5			1	1					4					2				2		54	8
12									2						49			3	4	7		3		17							2		2	1	271	17
13				2					6						147	3		16	55	12		3	1	41					1		11		1		369	44
14					1		1		2	10				2	148	1		8	64	5		1	2	91				5		19	40		1	5	311	64
15				11		135	9	12	3	6	1			8	123			4	25	2		2	2	131	6	17		19	1	30	186		6	28	326	99
16				6	1	272	48	12	13	36	9		3	9	15	6	23	5	13	10	4	5	10	86	30	50	2	70		43	215	20	25	28	183	73
17				22		100	43	15	41	26	31	2	8	32	26	16	93	36	12	55	2	5	19	162	47	47	4	37	10	47	257	123	24	35	122	65
18		6	2	48	4	19	14	12	27	9	63	16	19	38	47	14	72	88	45	60	29	4	24	263	26	71	26	27	34	74	579	278	12	79	272	132
19		14	1	54	3	7	4	10	12	4	48	12	21	61	70	5	25	84	77	52	81	2	31	216	31	17	50	31	36	44	474	115	15	91	444	242
20		39	5	33	5	17		2	8	2	38	8	17	51	84	11	10	133	108	240	373	3	19	167	13	35	27	25	47	16	430	95	22	97	256	203
21	1	58	11	35	2	13	6	4	3	6	51	13	8	72	69	26	11	29	126	228	419	11	14	101	17	93	21	38	44	22	97	55	35	26	149	121
22	6	41	17	48	11	21	42	1	1	4	80	16	11	47	121	52	8	41	63	195	327	13	25	74	19	185	26	100	35	50	52	80	21	61	62	81
23	38	28	18	58	12	27	95	1	3		94	10	20	34	128	57	5	33	23	86	262	20	22	26	29	331	20	154	33	64	41	93	39	90	18	64
24	68	12	26	47	17	75	68	4	5	1	68	13	17	37	88	31	5	25	14	91	148	15	7	19	12	257	30	249	40	49	51	114	43	84	12	68
25	67	7	21	40	28	81	75	5	11	1	76	28	5	48	44	30	3	10	9	49	64	8	5	15	6	140	55	218	36	16	28	77	34	45	14	38
26	37	5	20	36	48	97	39	3	1	1	42	17	8	22	13	13	9	8	1	12	44	2		6	6	71	33	128	25	8	9	29	11	39	5	23
27	13	2	20	33	30	57	18	5	2		12	7	9	14	6	4	5	4		10	15		4	1	3	3	7	73	15	5	4	4	6	15	3	10
28	9	3	11	26	25	43	45	2	2	3	2	8	6	5	6	3	2	1	1		5					4	2	20	5	1	4	12	1	3	2	5
29	1	1	3	8	15	34	22		3		2	3	1	2	2	3		1	2	1	2						1	4		1	2			1		
30	7		2	6	4	15	8		3	1	2	3	3			1	1	1													1			3		
31	3			2	2	11	2		1				1					1																		
32						1				2		1	1																							
33																										3										
34												1																								
36																										3										
38								1																												
Sample Size	250	216	157	515	208	1025	539	89	151	112	619	158	158	482	1191	276	272	532	643	1115	1775	97	185	1420	245	1327	304	1201	366	489	2484	1097	300	732	2882	1357

Table 19.5 Length frequency of alewives from the NEFSC bottom trawl survey in the northern region during the spring. Only lengths from daytime tows were included.

Fork Length (cm)	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
3					2																															
4																			1		1															
5					1								1																							
6		1			1				1	3	4		13	6	1							1					2			1	5		1			2
7	1		10	3	1	1			7	5	6	3	18	27	16	5	3	2	3				2		7	6	4		20	9	25	2	4	33	1	37
8	7	2	31	8	26	2	1	2	17	7	5	16	5	22	34	22	4	6	29	4	3	5	10	5	78	7	6	10	60	53	59	6	19	94	4	66
9	33	5	65	46	94	8		3	43	16	7	13	20	16	37	47	5	35	54	10	4	4	19	6	225	18	5	32	166	102	119	21	51	247	60	176
10	22	3	99	89	191	11	1	1	56	16	4	11	33	10	31	33	14	63	52	9	9	10	32	14	364	17	9	112	190	266	231	26	70	252	72	293
11	13	14	73	92	213	10	4	1	44	20	13	2	15	4	23	29	25	79	43	10	6	28	64	15	387	23	11	224	163	246	356	22	72	266	81	1367
12	13	6	104	127	435	21	15	2	56	17	8	6	19	7	23	44	20	64	34	15	15	33	96	74	267	35	13	275	91	161	507	16	75	199	45	883
13	25	18	107	100	358	13	24	8	50	12	10	3	19	3	27	46	43	44	30	38	9	40	148	183	110	21	34	187	58	106	645	17	40	142	43	652
14	15	11	110	93	254	4	15	8	29	10	13	5	22	7	23	48	49	52	24	22	16	47	170	181	90	40	28	15	35	93	714	14	25	112	153	183
15	9	6	103	59	186	4	14	4	20	18	21	23	10	17	15	34	20	44	23	25	21	53	137	250	100	51	17	23	54	135	1972	40	39	134	575	165
16	3	5	82	38	152	9	18	14	20	27	24	21	17	25	22	26	15	35	15	27	44	34	174	239	38	65	39	26	62	104	1564	56	63	224	713	246
17	11	7	67	29	161	11	15	4	11	38	17	24	25	25	28	26	12	44	17	21	39	80	129	429	33	75	80	41	53	47	382	67	41	261	674	149
18	13	8	42	70	87	21	13	11	30	19	16	28	20	22	18	23	16	35	26	20	40	98	76	399	70	48	133	58	39	24	119	86	45	111	244	92
19	25	20	46	77	39	36	21	13	36	21	14	45	30	13	15	30	22	30	44	36	29	76	55	167	66	40	73	21	34	12	26	45	31	80	108	149
20	45	19	68	49	20	66	19	15	28	55	21	63	28	18	20	18	128	23	50	64	105	51	62	287	57	34	57	30	46	11	23	49	65	80	112	196
21	51	42	57	38	9	40	18	31	23	46	30	50	31	12	25	10	110	10	44	46	119	156	52	148	38	59	121	33	39	7	20	73	53	82	117	121
22	48	55	48	17	11	17	31	31	7	33	34	36	25	12	13	24	77	12	46	81	133	163	54	260	46	54	109	66	27	7	21	76	54	83	69	68
23	59	73	35	16	7	7	55	14	18	25	30	26	17	8	8	51	81	10	60	86	196	237	90	272	49	34	107	75	16	20	10	69	28	97	53	84
24	45	80	29	17	19	8	58	5	8	9	33	17	20	14	19	145	59	22	36	76	202	300	86	163	84	80	78	51	19	38	7	46	26	123	50	61
25	41	65	48	35	42	17	70	9	10	13	30	24	9	15	29	90	97	19	22	60	170	117	34	86	50	80	94	51	29	18	9	34	24	106	40	58
26	31	83	94	57	110	25	53	10	10	12	42	77	11	18	23	46	30	17	11	36	50	64	17	29	32	45	56	48	30	8	8	24	13	35	22	18
27	25	93	103	56	120	42	59	18	9	15	41	15	13	23	36	12	19	16	6	21	20	13	10	15	7	27	21	40	17	5	1	8	5	20	12	14
28	16	66	63	65	150	42	33	11	5	10	22	8	7	28	36	16	19	4	5	4	8	15		10	2	6	4	10	8	1	1	4	2	5	4	4
29	12	45	34	45	68	35	22	5	1	7	9	5	3	11	18	4	10	1		2		2	2	3	1	1	3	4	1	1	2			1		
30	9	22	16	21	71	25	25	3		4	5	4	1	1	7	2	5	1		1	1	1											1			1
31	1	5	2	12	32	8	8		3	2	2		2		1		2				1															
32	1	1	3		7	10	2		1									1																		
33		2	1	2		3	1							1																						
34					1	2	3								1																					
35																						1														
36			1		2											1					1															
37									1																											
44									1																											
46															1																					
47		1																																		
47		1																																		
Sample Size	574	758	1541	1261	2870	498	598	223	545	460	461	525	434	365	550	832	885	669	675	714	1242	1629	1519	3235	2201	866	1104	1432	1257	1475	6826	801	847	2787	3252	5085

Table 19.6 Length frequency of alewives from the NEFSC bottom trawl survey in the southern region during the spring. Only lengths from daytime tows were included.

Fork Length (cm)	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
6		1							1																											
7			23															2	13																	
8	1		72				11	2					2		1			3	18	1	2	10	1								4					
9	3	1	109	6		4	85	6	3		11			3				8	4	2	10	25	1	2		5			1	1	22					
10	15	1	62	12	8	26	142	6	7	2	4		1	9	1	1	5	23	9	8	14	38	3	4		5			2	4	46	4			5	
11	21		243	14	4	30	186	16	4	1	11		3	3		4	2	35	6	4	12	18	7	8		10		2	2	6	26	4	1		14	
12	12		339	21	4	46	130	15	4	1	8			3		32		53	21	4	9	23	7	13		50		1	2	4	16	4			13	
13	8		621	11	8	13	125	15	7	2	3			3		21		69	89	7	11	25	11	9	1	52			1		11	5	2		21	6
14	6		433	2	6	16	37	34	2	1			1	6		8		77	96	7	13	23	19	4	2	12		2	3	1	5	3	4	3	13	29
15	16		102	10	5	13	38	46	2	8		2		8		6		84	51	4	35	6	15	7	5	8	7		3	3	2		29	5	5	25
16	49	1	5	13	21	3	25	99	1	42	3	3		8		16	2	115	25	7	59	7	11	4	1	4	16		7	5	1	1	55	43	9	26
17	55	2	10	39	123	32	20	154	5	98	7	10	1	12	3	29		134	11	5	166	8	38	5	2	5	25		24	12		2	53	30	1	11
18	41	2	11	159	198	50	88	119	3	110	46	38		26		32	3	75	12	9	262	5	83	9	4	9	19	2	53	13	2	4	14	6	6	9
19	30	6	24	287	171	117	137	54	3	56	23	54		25	1	14		59	5	14	130	9	102	4	10	2	1	1	26	23			3	11	13	37
20	19	7	52	254	124	105	121	24	3	34	17	62		16	4	7	6	102	11	28	108	24	63	5	9	1	2	1	20	17	5	2	14	7	28	47
21	13	2	8	98	122	97	56	17	3	11	11	63		5	5	8	14	76	3	18	48	44	45	10	12	7	2	7	101	28	9	3	16	12	24	13
22	37	7	9	62	135	101	46	24	6	11	13	70	1	2	4	22	24	30	3	25	45	52	71	21	27	19	2	7	109	46	14	3	13	14	11	21
23	49	7	25	108	148	118	115	29	23	16	22	57	1	2	10	19	24	22	11	29	38	48	120	21	35	27	14	37	28	34	7	7	7	24	3	12
24	101	30	39	144	151	134	82	53	46	12	17	64	6	4	15	17	24	20	4	29	32	33	99	45	23	37	39	41	23	35	4	8	14	32	5	5
25	115	36	43	242	95	163	131	57	86	6	33	64	9	7	15	16	17	16	9	20	20	14	43	26	11	26	38	47	9	28	3	6	2	28	2	7
26	77	85	54	254	94	122	106	59	105	25	25	93	3	13	6	14	18	14	1	7	5	13	28	14	5	11	28	38	25	19	3	7	6	12		3
27	77	57	47	230	108	96	44	71	76	20	16	66	2	19	8	8	8	10	2	3	1	4	12	3	1	6	8	16	6	12	2	4	3	1		
28	71	30	18	187	63	74	55	56	44	9	8	25	1	21	5	6	4	4	1	3	1		7	3		1		3	1	8			1	2		
29	30	8	2	89	12	43	16	38	26	13	2	17		5	3	6	1	2	2								1	1						1		
30	9	3	1	32	11	25	5	22	5	3	1	7		3	2	2	3	1																		
31	8			20	2	10		15	2		1			1		1																				
32			1	6		5	3	7			1																									
33					1			1																												
34												1	1																							
35						1																														
41									1																											
Sample Size	863	285	2352	2294	1613	1438	1801	1031	466	481	282	695	31	204	83	289	155	1034	407	234	1021	429	786	217	148	297	202	206	446	299	182	67	237	231	173	251

Table 19.7 Length frequency of blueback herring from the coastwide NEFSC bottom trawl survey during the spring. Only lengths from daytime tows were included.

Fork Length (cm)	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
4						1																														
5														1				1	1																	
6	1		10						1	2	3		1			1		19	8	13			8					3			11		1	1		
7	5	2	35	395	29	9	9	3	30	20	57		11	5	4	19		105	21	20	14	13	35	5				28		9	114		66	4	3	3
8	30	27	63	554	221	62	156	10	59	79	166		24	13	3	43	4	189	76	88	90	86	84	22		7		25	31	30	143		38	16	15	7
9	263	16	164	151	506	310	113	20	82	127	116	1	46	19	2	8	3	195	59	47	80	153	44	19	8	8	1	37	39	41	223	4	64	22	21	6
10	329	7	168	112	326	226	35	32	72	85	18		51	24		14	9	266	31	19	40	63	28	9	10	6	1	15	44	35	319	4	50	28	25	14
11	88		126	95	190	122	26	39	22	43	4	3	29	23		8	27	178	23	20	26	52	23	2	8	7	1	10	27	55	482	8	31	34	16	45
12	44		89	47	129	37	29	28	18	26	3		26	15	2	17	52	110	31	41	20	37	19	29	14	13	2	17	24	50	473	8	14	24	20	31
13	31	2	50	26	73	11	18	7	19	31	1	2	17	5	6	18	67	44	10	29	18	11	9	27	9	29	1	52	24	68	401	12	21	26	39	17
14	27	3	47	47	74	22	4	7	12	44		3	27	3		11	98	44	5	24	26	2	8	22	8	53	3	65	18	58	315	12	15	34	21	120
15	74	6	28	127	123	102	10	2	33	26	15	15	24	11	2	6	114	81	13	57	38	2	16	44	7	21	10	101	12	35	429	7	8	63	31	24
16	142	29	16	321	95	141	23	6	76	35	13	18	27	15	2	12	145	136	15	175	53	6	13	31	2	27	21	33	24	26	226	59	8	127	70	26
17	105	38	13	638	81	92	18	29	169	82	50	60	62	24	8	23	51	98	10	976	75	13	9	27	14	17	29	24	19	47	85	655	6	139	50	26
18	142	68	19	308	60	60	26	77	285	51	36	76	39	23	40	23	12	61	4	411	40	16	11	28	54	17	32	67	46	61	64	1348	7	117	24	16
19	65	60	35	133	27	38	16	66	119	26	18	64	7	5	37	5	1	50	4	56	18	15	9	19	43	19	28	23	35	15	24	183	12	107	58	40
20	32	19	40	100	10	28	11	53	40	13	16	78	7	2	42	1	7	15	12	36	8	20	1	27	27	11	9	21	22	23	38	31	33	135	56	32
21	54	8	36	336	22	70	18	50	32	23	5	41	2	2	12	4	2	6	20	57	8	24	2	19	18	5	17	24	36	6	12	33	22	315	91	38
22	26	12	29	468	27	94	9	27	49	14	4	27	6	4	7	1	4	2	15	54	7	37	1	15	28	13	24	26	23	2	4	32	30	242	71	48
23	32	20	13	425	30	39	9	16	55	21	4	26	3	1	1		19	3	11	40	6	54	1	15	38	17	58	15	21	7	4	38	12	51	45	58
24	18	21	17	264	36	16	15	16	61	38	1	24		2	1	1	24	1	11	15	13	25		13	66	39	33	24	5	5		12	2	27	21	29
25	11	19	20	205	57	12	14	17	42	38	1	16		2		4	17		18	11	7	16		11	61	21	13	10	7	4		6	5	11	6	5
26	5	12	47	169	46	14	8	19	32	27	2	15	1	2		1	19	1	9	10	5	3		10	19	3	2	4	5	2	1	1	1	2	1	
27	2	3	46	134	28	7	13	14	24	12	2	7	3		2	3	14	1	10	2	7			1	3	2		1		1						
28		1	23	45	22	9	4	7	9	7	5	4		1	1		10		1	1		1	1	2	1	1										
29		1	8	51	9		4	4	6	6	4	1	1							1				1												
30	1		2	22		1	1	1	2	4					1						2	1														
31																					1															
32			1					1								1																				
33											1					3																				
34			1									1				1																				
35			1																																	
36			1													3																				
37			1																																	
Sample Size	1527	374	1149	5173	2221	1523	589	551	1349	880	545	482	414	202	173	231	699	1606	418	2203	602	650	322	398	438	336	285	625	462	580	3368	2453	446	1525	684	585

Table 19.8 Length frequency of blueback herring from the coastwide NEFSC bottom trawl survey during the fall. Only lengths from daytime tows were included.

Fork Length (cm)	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
5																						1						1								
6		4																				1														
7		15																				3						2		1						
8		3																				10						9								
9										3												2						1							1	
10																						6						2							74	
11																						26									2				313	
12																				13		17					1		1	1	3		1		170	1
13				4													1			88		1	1							11	1		2	1	34	
14				2		3				2							22			69							3			53	2		2	1	7	
15				4		66											9		1	29							1			47	6			3		
16				4		46													5	46			1				16			7	38			2	4	
17				24		13				1									6	68							10				62	5	6	1	57	8
18				31	1	3		1				1							1	20			2				6			2	146		3	2	125	19
19				33		3						1								1			1			1	8	2			60		2	10	201	32
20				32							2	2							4	6	12		3			1	4		2	1	19	5	3	14	131	36
21				12		1					2								3	17	47		7		4	4	2	6	20	5	9	9	11	16	205	29
22	1		3	7							1	2							1	26	18		5		1	3		42	32	3	12		4	2	39	21
23	1		2	4	1						2		3							12	19		2			17	6	96	26	2	3	3		8	53	9
24	3		6	6	1					1	2	1	3				1			5	6	1	4			12	6	111	23	3	2	7		6	2	1
25	2		15	8						1	1	2	5		1						6		1		3	4	7	78	9			1		4		1
26	3	1	34	1			1				1	2	5		2		2						2			1	3	6	3		1	1				
27	4		29	4	3				2		3	2															1	1		3				1		
28	2		23	1			1		1			1																								
29			5	4					1		1																									
30			2	1																																
31			1	1																																
33				1																																
34																																				
Sample Size	16	23	120	184	6	135	2	1	4	8	15	14	16		3		35		21	400	108	68	29		8	43	74	357	116	139	366	31	34	71	1416	157

Table 19.9 Length frequency of blueback herring from the NEFSC bottom trawl survey in the northern region during the spring. Only lengths from daytime tows were included.

Fork Length (cm)	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
5														1				
6			1							1	3		1			1		
7			3	1	13				7	6	13		4		4	19		2
8			4	8	96		1	3	1	34	1		2	1	3	43		8
9			27	26	267	1	3	2	15	65		1	23	1	2	8	2	9
10	1		41	37	222		3	5	19	72			30	7		13	2	24
11	3		63	41	167	1	9	7	12	39	1	1	14	7		6	1	7
12	6		42	37	125	3	16	14	11	22	1		8	5	1	14	8	9
13	5	2	36	23	72	1	8	2	11	28			7	3	6	15	5	15
14	1		42	30	66		3	2	9	25		1	19	1		7	2	16
15			25	19	86	1	2	1	10	7	2	2	15		2	2		9
16	1	1	11	5	44		2	1	4	7	2		9			1	1	8
17	4		3	17	17			3	1	12	2	3	7				1	5
18	7		2	29	11			3	1	14	1	4	5	2	1		3	7
19	7		4	23	9		1	2	1	13	2	4	3			1	1	5
20	2	2	1	11	3			1	6	3	1	3	1					2
21	3	1	2	2			1		14	1		3	1	2				
22	1	1		4	1		1		10			1						
23	3	1	1	8			1				2							
24			7	9	3		3				1					1		
25	1		9	7	1		2	1								3		
26			23	12	3		1			1		2		1		1		
27		1	20	12	2		3								2	3		1
28			13	11	9	3								1	1			
29			5	6	6		1											
30			1							3					1			
31																		
Sample Size	45	9	386	378	1223	10	61	47	132	353	32	25	149	32	23	138	26	127

Fork Length (cm)	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
5	1																	
6	6	13			8					3			11		1	1		
7	7	20	2	4	34	5				28		9	104		62	4	2	3
8	28	85	17	20	82	18		3		21	21	26	101		27	16	12	7
9	17	40	5	32	42	18	8	3		31	14	27	173	4	63	21	9	6
10	18	14	10	45	27	9	10	2		14	15	8	305	2	45	28	16	14
11	17	10	8	49	23	2	8	4	1	9	13	7	474	7	28	34	13	45
12	22	30	3	36	17	29	14	10	2	16	20	37	468	7	11	24	16	31
13	5	24	7	10	9	26	7	28	1	47	17	65	396	12	19	26	39	17
14	3	14	14	2	8	22	7	52	3	61	17	58	314	12	13	34	21	120
15	6	6	16	2	15	44	6	21	10	97	9	34	428	6	7	59	31	24
16	3	7	7	3	10	30	1	27	19	29	11	10	213	3	7	97	70	26
17	1	7	3	2	7	16	5	8	22	7	5	5	69	14	1	86	48	12
18	1		2		8	11	9	7	19	3	7	7	45	16	2	19	12	
19		1			8	8	13	3	9		5	1	7	6	2	24	30	16
20			1	2		9	10	6	5	3	1		3	2	2	10	24	8
21		2	4	1	1	4	2		6	3				4	4	7	19	9
22	1	1	4	1	1	7	1	1	6	1				6	11	6	8	10
23			3			5	1		9	1	2	1		9	4	3	5	7
24	1		8			8			3	1	1	2		4	1	3	4	
25	9		4			7			1	1		4		3	3	1	1	
26	6		3	1		5						1			1		1	
27	6		4			1						1						
28	1			1		1												
29						1												
30			2															
31			1															
Sample Size	159	274	128	211	300	286	102	175	116	376	158	303	3111	117	314	503	381	355

Table 19.10 Length frequency of alewives from the NEFSC bottom trawl survey in the southern region during the spring. Only lengths from daytime tows were included.

Fork Length (cm)	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
4						1												
5																		1
6	1		9						1	1								19
7	5	2	32	394	16	9	9	3	23	14	44		7	5				103
8	30	27	59	546	125	62	155	7	58	45	165		22	12			4	181
9	263	16	137	125	239	309	110	18	67	62	116		23	18			1	186
10	328	7	127	75	104	226	32	27	53	13	18		21	17		1	7	242
11	85		63	54	23	121	17	32	10	4	3	2	15	16		2	26	171
12	38		47	10	4	34	13	14	7	4	2		18	10	1	3	44	101
13	26		14	3	1	10	10	5	8	3	1	2	10	2		3	62	29
14	26	3	5	17	8	22	1	5	3	19		2	8	2		4	96	28
15	74	6	3	108	37	101	8	1	23	19	13	13	9	11		4	114	72
16	141	28	5	316	51	141	21	5	72	28	11	18	18	15	2	11	144	128
17	101	38	10	621	64	92	18	26	168	70	48	57	55	24	8	23	50	93
18	135	68	17	279	49	60	26	74	284	37	35	72	34	21	39	23	9	54
19	58	60	31	110	18	38	15	64	118	13	16	60	4	5	37	4		45
20	30	17	39	89	7	28	11	52	34	10	15	75	6	2	42	1	7	13
21	51	7	34	334	22	70	17	50	18	22	5	38	1		12	4	2	6
22	25	11	29	464	26	94	8	27	39	14	4	26	6	4	7	1	4	2
23	29	18	12	417	30	39	8	16	55	21	2	26	3	1	1		19	3
24	18	21	10	255	33	16	12	16	61	38		24		2	1		24	1
25	10	18	11	198	56	12	12	16	42	38	1	16		2		1	17	
26	5	11	24	157	43	14	7	19	32	26	2	13	1	1			19	1
27	2	2	26	122	26	7	10	14	24	12	2	7	3				14	
28		1	10	34	13	6	4	7	9	7	5	4					10	
29		1	3	45	3		3	4	6	6	4	1	1					
30	1		1	22		1	1	1	2	1								
32			1					1								1		
33											1					3		
34			1									1				1		
35			1															
36			1													3		
37			1															
Sample Size	1482	362	763	4795	998	1513	528	504	1217	527	513	457	265	170	150	93	673	1479

Fork Length (cm)	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
4																		
5																		
6	2																	
7	14		12	9	1								10		4		1	
8	48	3	73	66	2	4		4		4	10	4	42		11		3	
9	42	7	75	121	2	1		5	1	6	25	14	50		1	1	12	
10	13	5	30	18	1			4	1	1	29	27	14	2	5		9	
11	6	10	18	3				3		1	14	48	8	1	3		3	
12	9	11	17	1	2			3		1	4	13	5	1	3		4	
13	5	5	11	1		1	2	1		5	7	3	5		2			
14	2	10	12				1	1		4	1		1		2			
15	7	51	22		1		1			4	3	1	1	1	1	4		
16	12	168	46	3	3	1	1		2	4	13	16	13	56	1	30		
17	9	969	72	11	2	11	9	9	7	17	14	42	16	641	5	53	2	14
18	3	411	38	16	3	17	45	10	13	64	39	54	19	1332	5	98	12	16
19	4	55	18	15	1	11	30	16	19	23	30	14	17	177	10	83	28	24
20	12	36	7	18	1	18	17	5	4	18	21	23	35	29	31	125	32	24
21	20	55	4	23	1	15	16	5	11	21	36	6	12	29	18	308	72	29
22	14	53	3	36		8	27	12	18	25	23	2	4	26	19	236	63	38
23	11	40	3	54	1	10	37	17	49	14	19	6	4	29	8	48	40	51
24	10	15	5	25		5	66	39	30	23	4	3		8	1	24	17	29
25	9	11	3	16		4	61	21	12	9	7			3	2	10	5	5
26	3	10	2	2		5	19	3	2	4	5	1	1	1		2		
27	4	2	3				3	2		1								
28		1			1	1	1	1										
29		1																
30				1														
32																		
33																		
34																		
35																		
36																		
37																		
Sample Size	259	1929	474	439	22	112	336	161	169	249	304	277	257	2336	132	1022	303	230

Table 19.11 Results of the Mann-Kendall test for a monotonic trend in mean length of river herring from NEFSC spring and fall bottom trawl survey data. Negative *S* statistics indicate a declining trend and positive *S* statistics indicate an increasing trend.

Species	Region	Season	Years of data	Mann-Kendall *S* statistic	p-value
Alewife	Coast	Fall	36	-162	0.03
		Spring	36	-292	<0.01
	North	Spring	36	-228	<0.01
	South	Spring	36	-144	0.05
Blueback	Coast	Fall	36	-203	0.01
		Spring	36	-56	0.45
	North	Spring	36	-71	0.34
	South	Spring	36	184	0.01

Table 19.12 Von Bertalanffy growth parameters for alewife and blueback herring from NEFSC bottom trawl surveys (1973 - 1987). SE and CL are approximate standard errors and 95% confidence limits, respectively.

Species	Region	Season	n	L∞	SE(L∞)	CL(L∞)	K	SE(K)	CL(K)	t_0	SE(t_0)	CL(t_0)
Alewife	Coast	Spring	7,165	29.44	0.10	29.24 - 29.64	0.40	0.01	0.39 - 0.41	-0.22	0.02	-0.26 - -0.19
		Fall	1,203	29.45	0.29	28.88 - 30.01	0.36	0.02	0.33 - 0.39	-1.33	0.09	-1.50 - -1.16
	North	Spring	4,224	30.33	0.16	30.02 - 30.65	0.35	0.01	0.34 - 0.37	-0.30	0.03	-0.35 - -0.25
	South	Spring	2,941	28.26	0.11	28.05 - 28.48	0.49	0.01	0.47 - 0.51	-0.09	0.02	-0.13 - -0.04
Blueback	Coast	Spring	128	27.15	0.47	26.23 - 28.08	0.50	0.04	0.42 - 0.57	0.20	0.07	0.07 - 0.33
		Fall	16	27.73	0.80	26.01 - 29.45	0.35	0.06	0.23 - 0.47	-1.74	0.41	-2.63 - -0.85
	North	Spring	31	28.13	2.05	23.93 - 32.33	0.38	0.08	0.21 - 0.54	-0.03	0.20	-0.43 - 0.38
	South	Spring	85	26.70	0.38	25.96 - 27.45	0.58	0.04	0.50 - 0.67	0.31	0.06	0.19 - 0.42

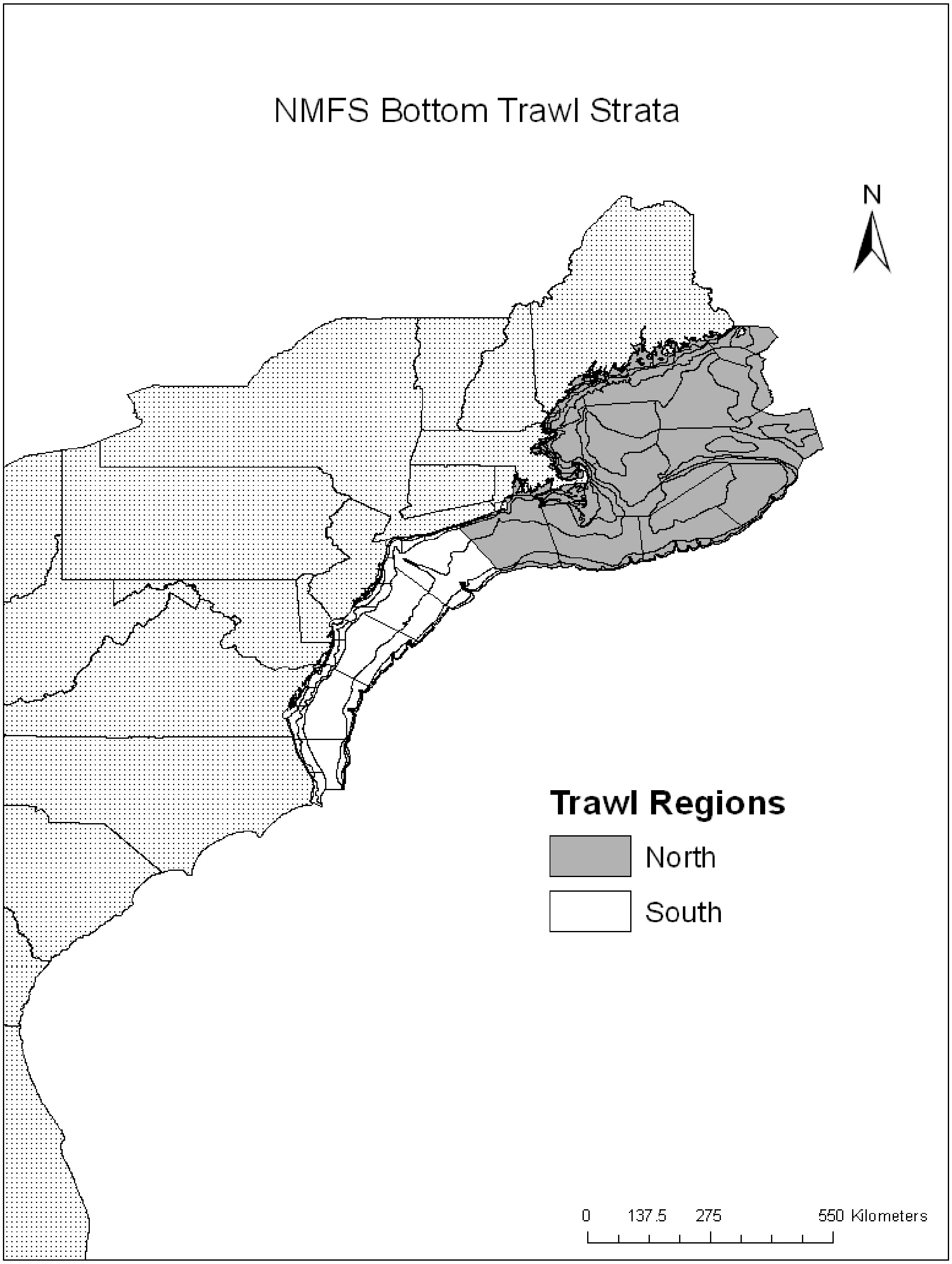

Figure 19.1 NEFSC bottom trawl survey strata comprising the northern and southern regions. The division between regions reflects the median months of sampling in the spring survey: April in the north and March in the south.

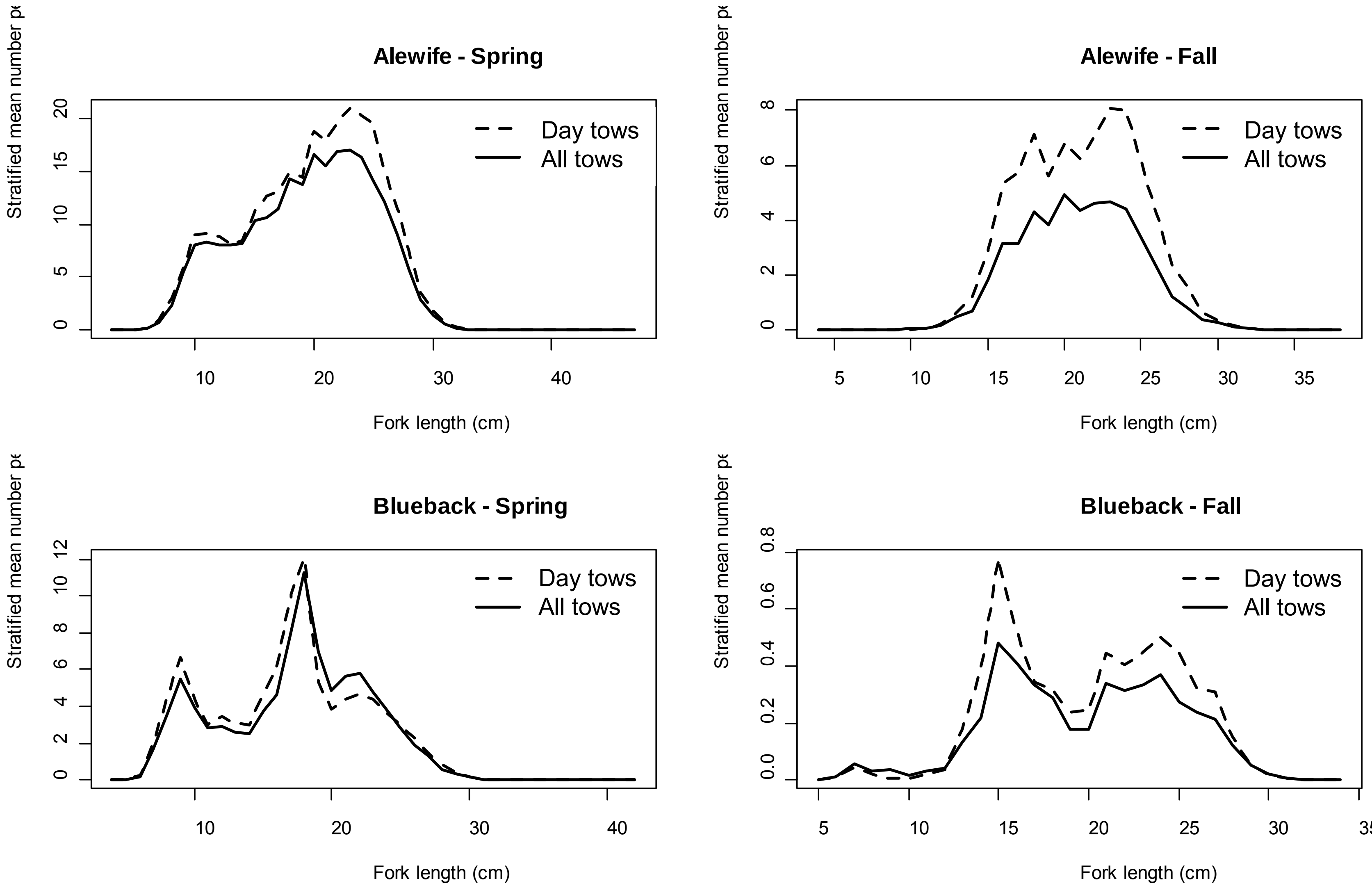

Figure 19.2 Comparison of alewife and blueback herring length distributions from NEFSC bottom trawl day tows and all tows.

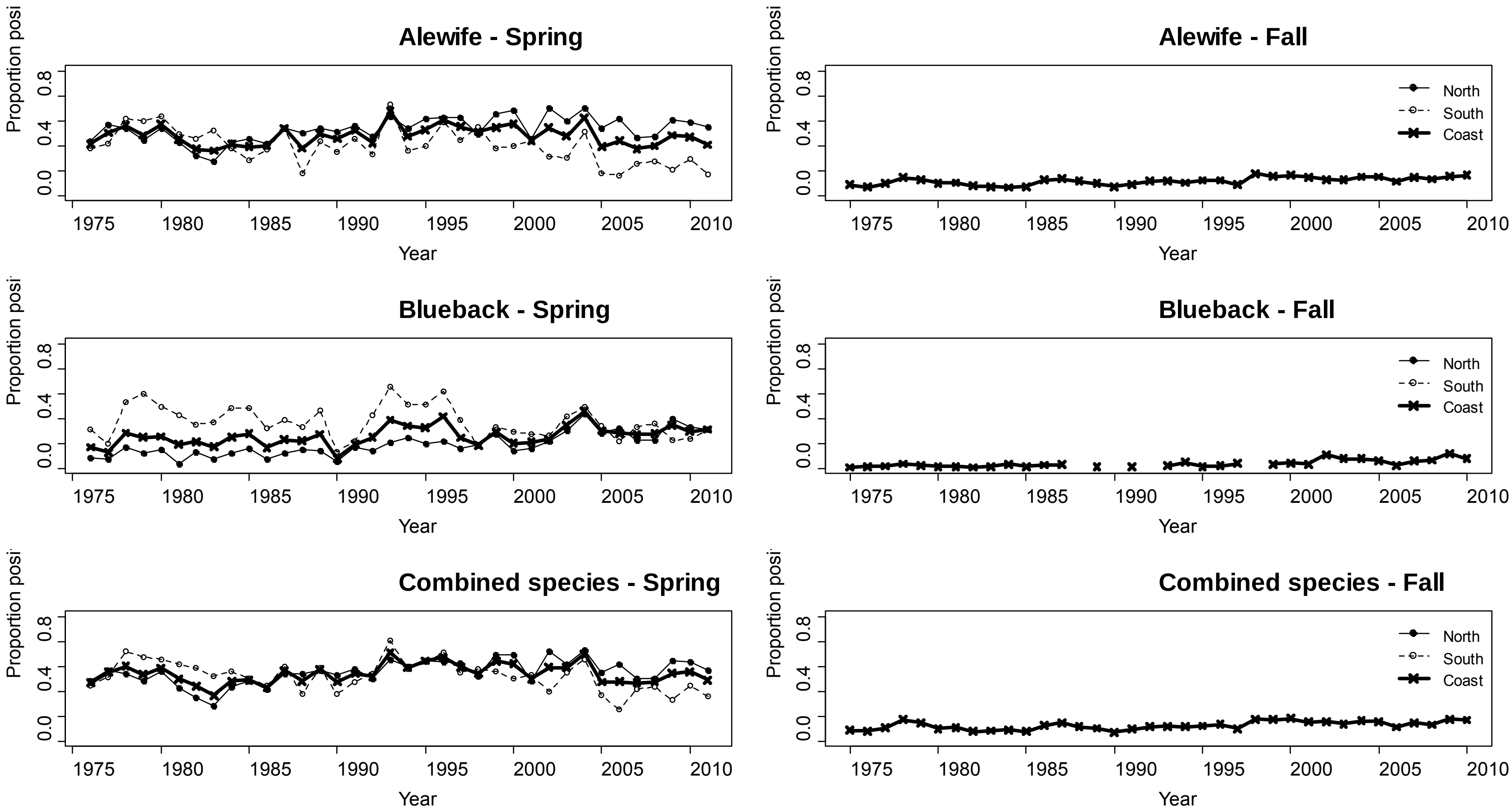

Figure 19.3 Proportions of positive tows for alewife, blueback herring, and combined species from the NEFSC spring (1976-2011) and fall (1975-2011) bottom trawl surveys. Survey strata were not separated into northern and southern regions for the fall survey.

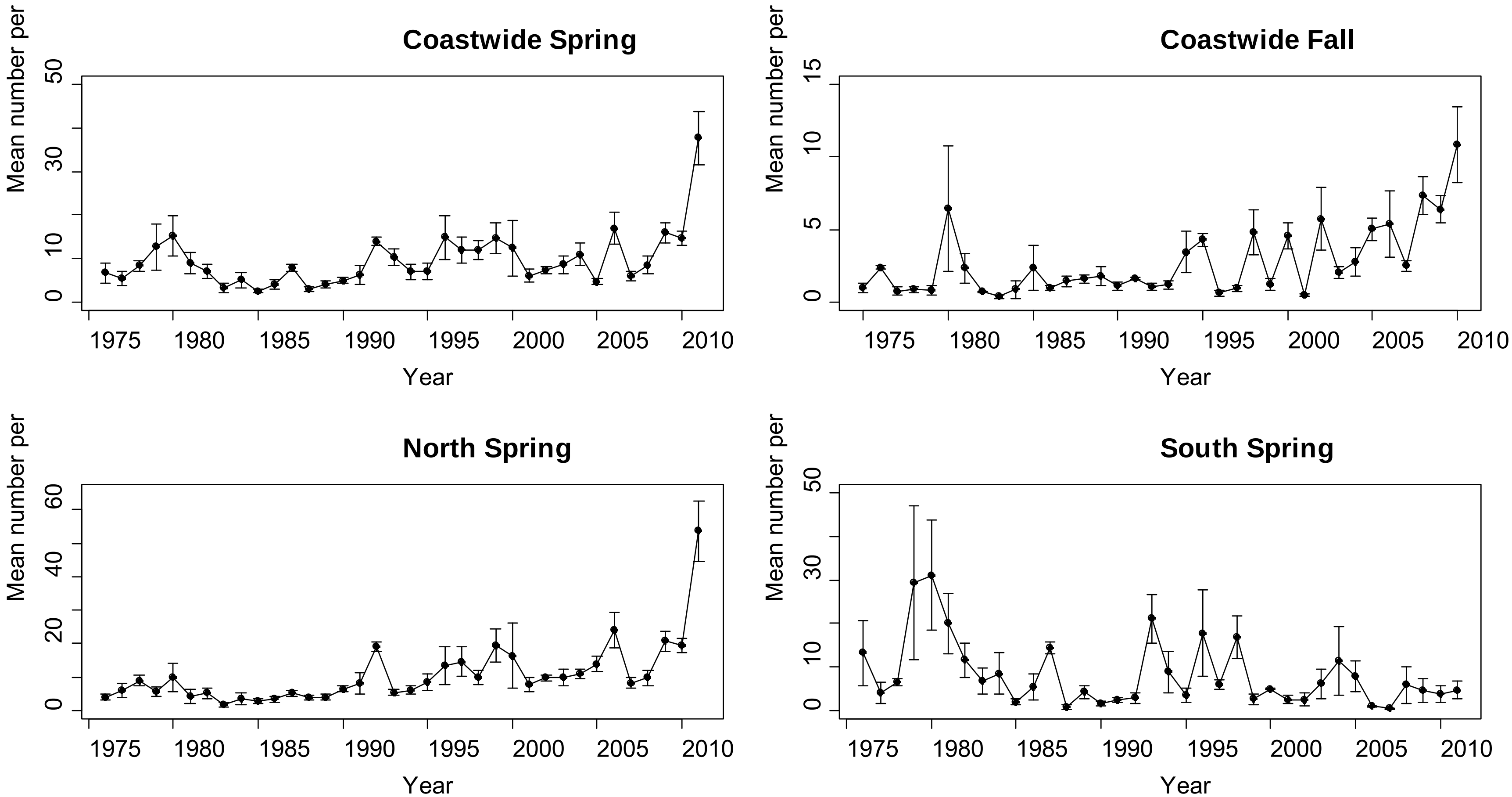

Figure 19.4 Stratified mean number-per-tow of alewife in the NEFSC bottom trawl surveys. Error bars correspond to one standard error.

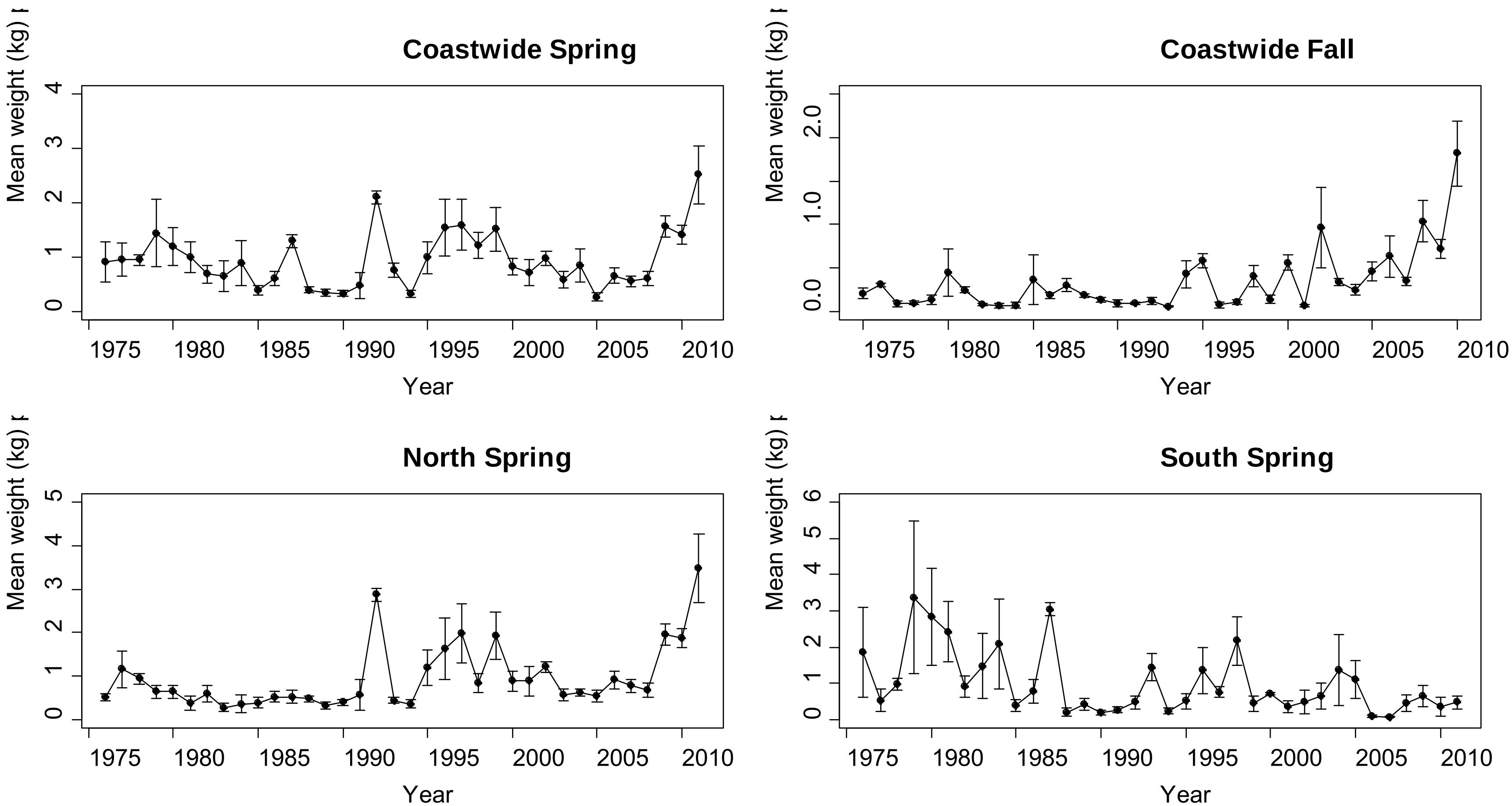

Figure 19.5 Stratified mean weight (kg)-per-tow of alewife in the NEFSC bottom trawl surveys. Error bars correspond to one standard error.

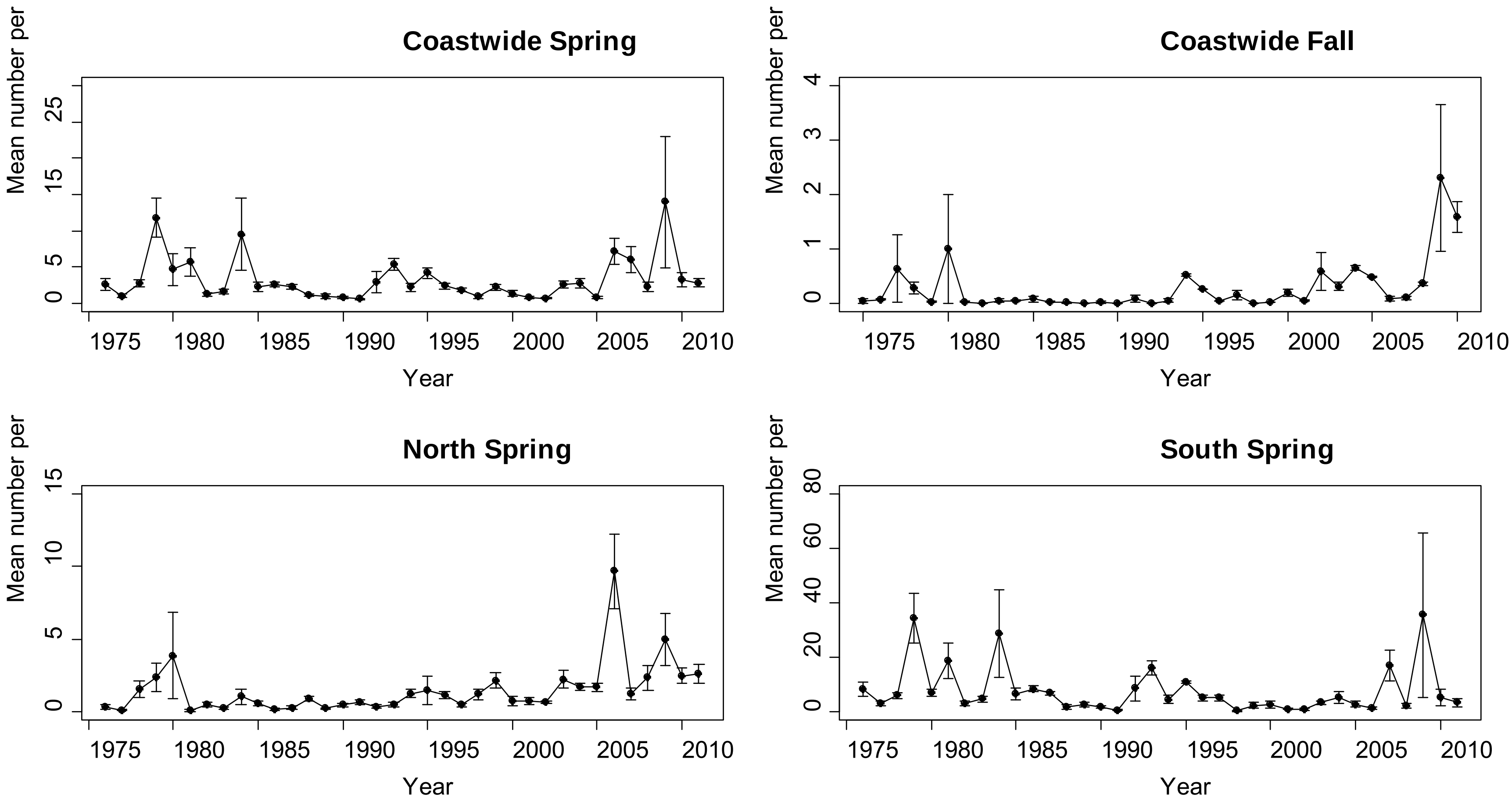

Figure 19.6 Stratified mean number-per-tow of blueback herring in the NEFSC bottom trawl surveys. Error bars correspond to one standard error.

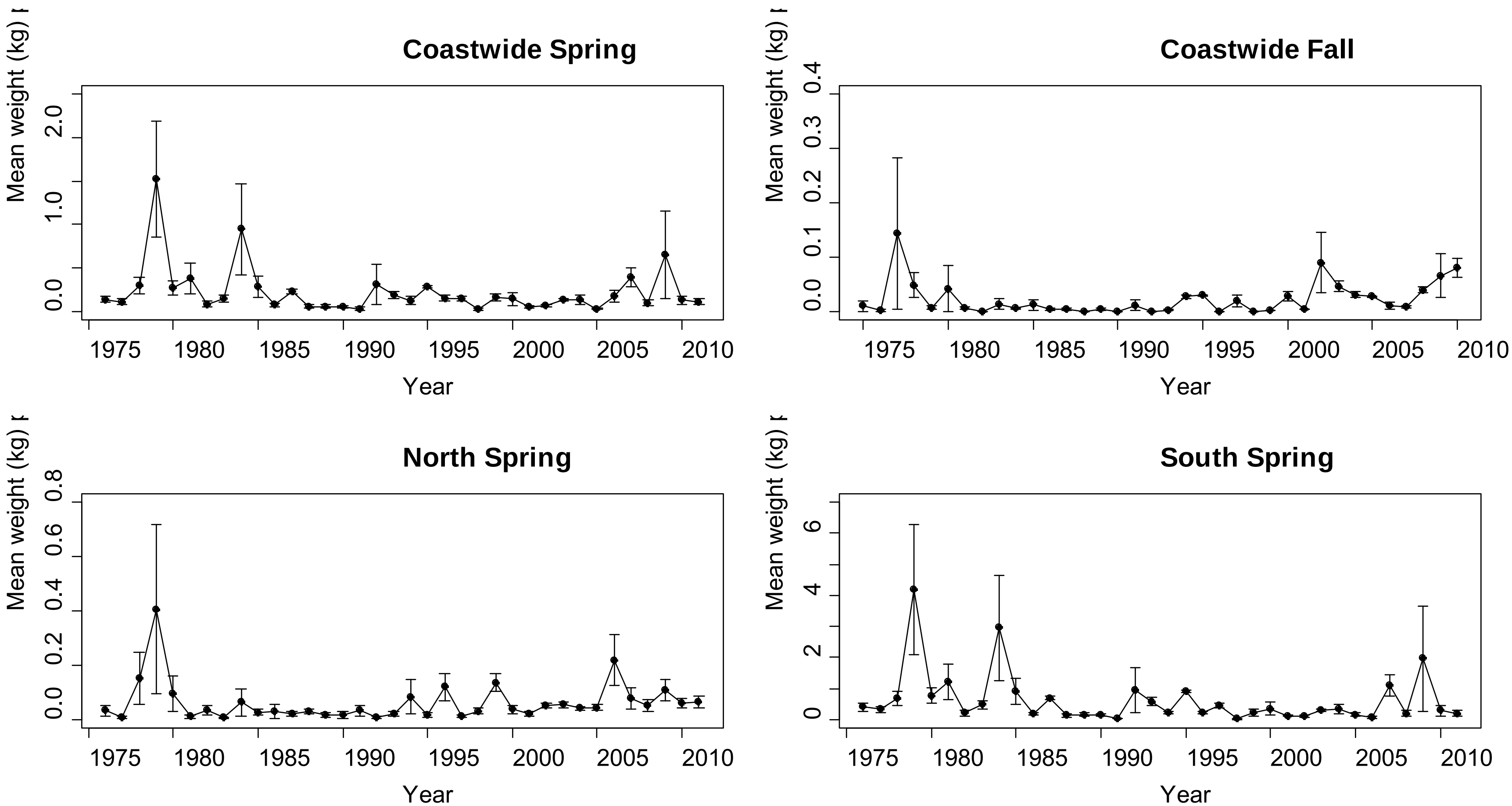

Figure 19.7 Stratified mean weight (kg)-per-tow of blueback herring in the NEFSC bottom trawl surveys. Error bars correspond to one standard error.

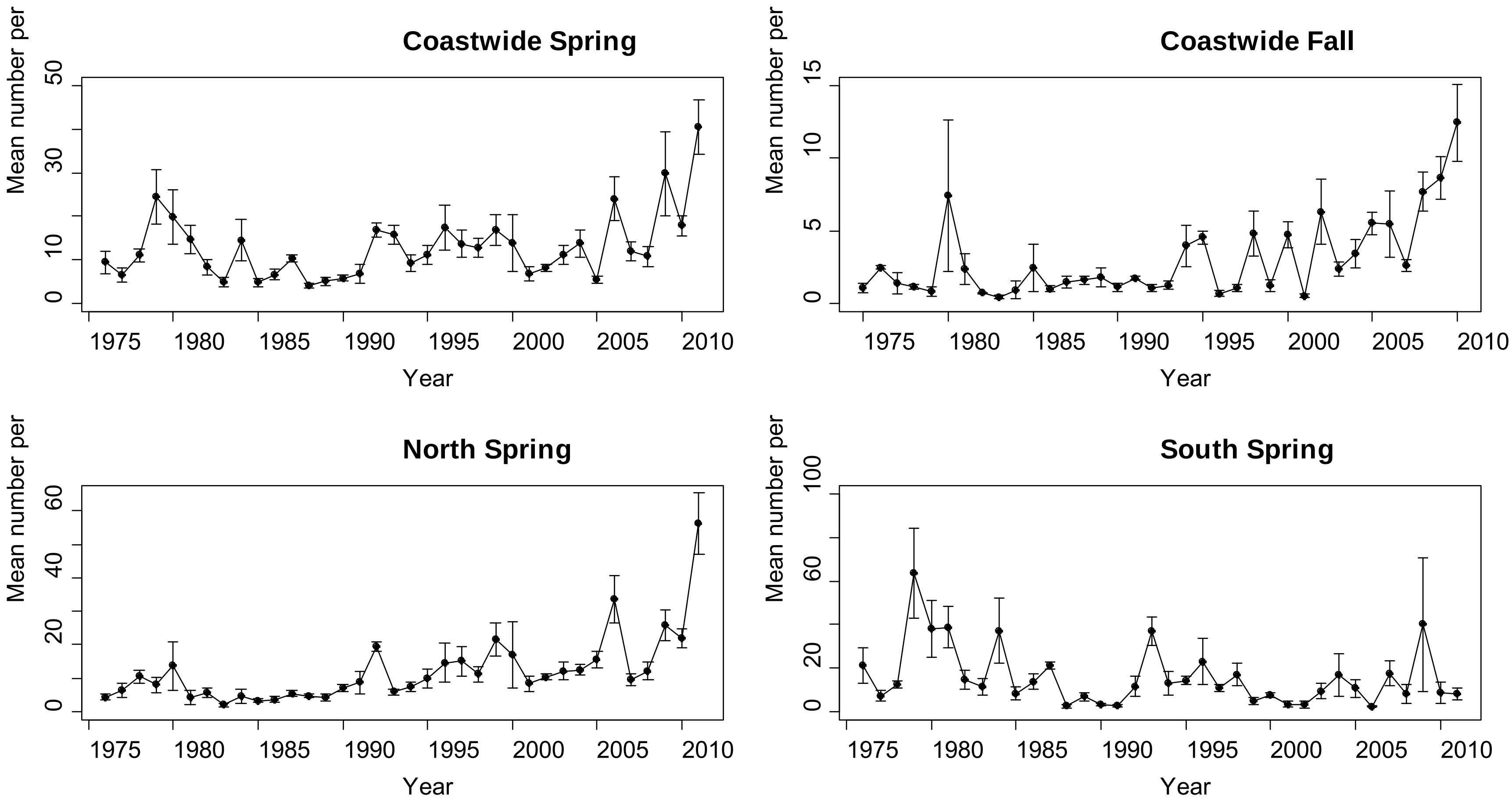

Figure 19.8 Stratified mean number-per-tow of combined river herring in the NEFSC bottom trawl surveys. Error bars correspond to one standard error.

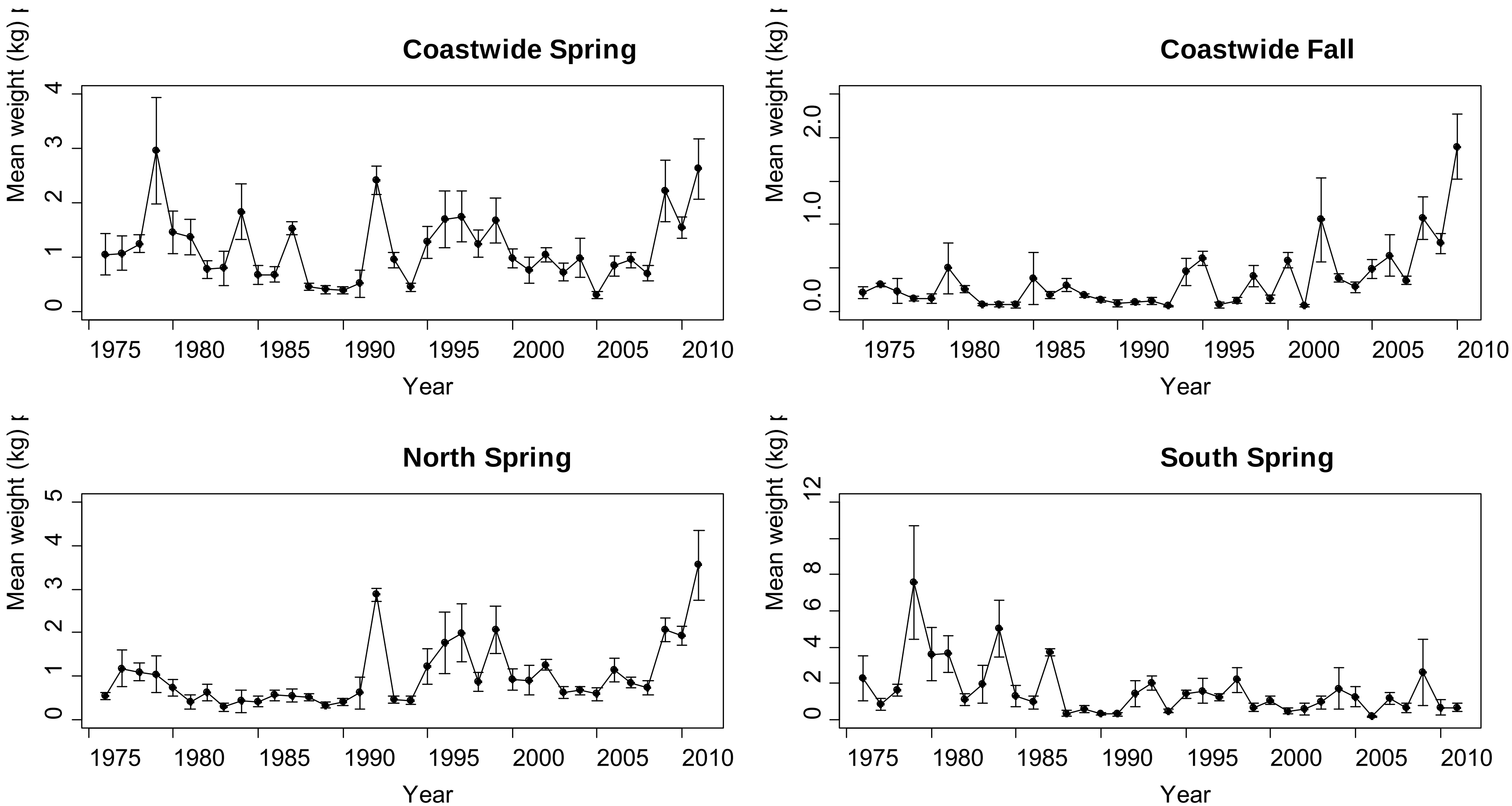

Figure 19.9 Stratified mean weight (kg)-per-tow of combined river herring in the NEFSC bottom trawl surveys. Error bars correspond to one standard error.

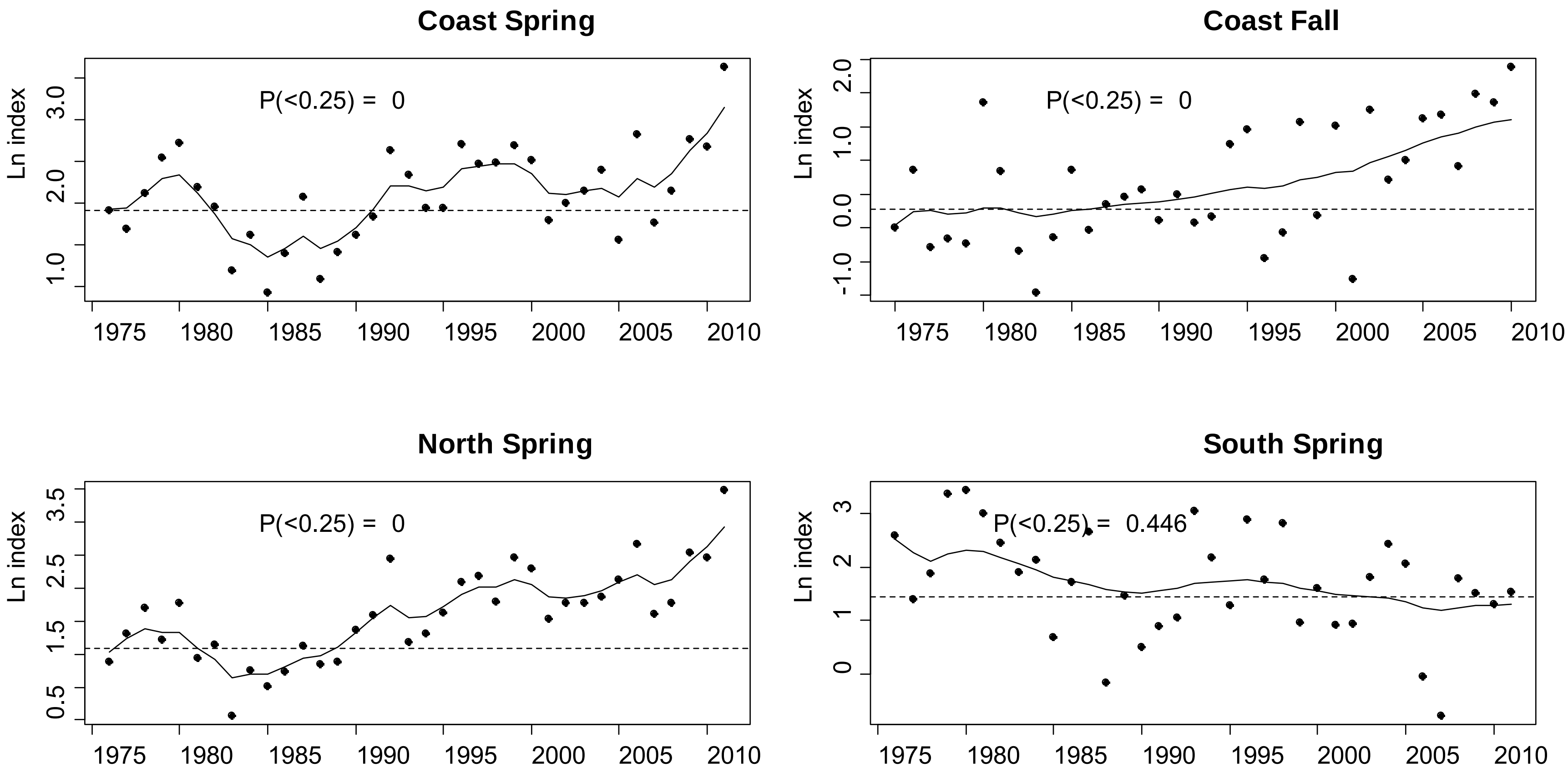

Figure 19.10 Autoregressive integrated moving average (ARIMA) model fits to alewife stratified mean number-per-tow from the NEFSC bottom trawl survey. The dotted horizontal line represents the 25th percentile of the fitted values and the probability represents the probability that the fitted value in the terminal year is less than the 25th percentile index based reference point with 80% confidence.

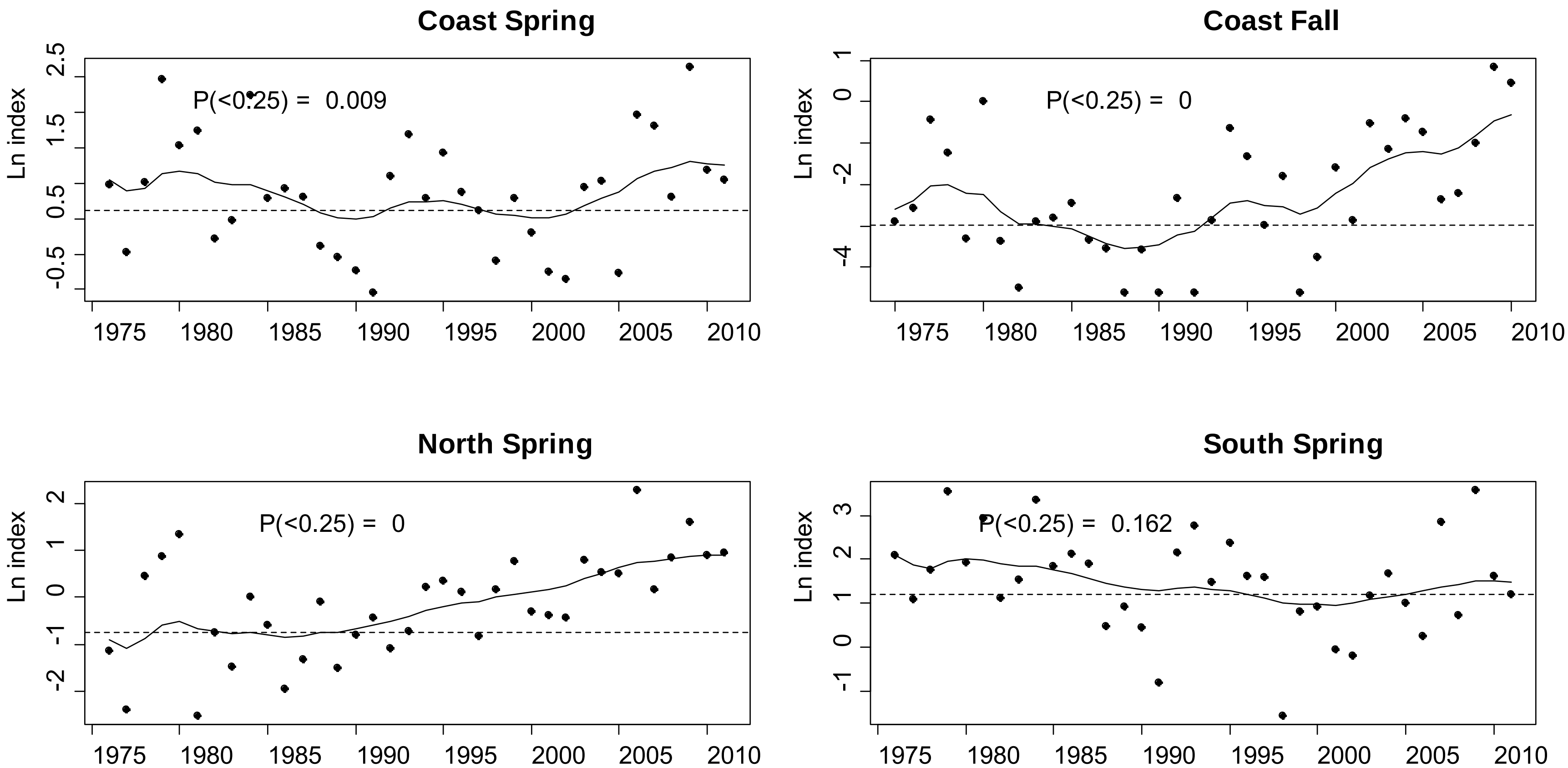

Figure 19.11 Autoregressive integrated moving average (ARIMA) model fits to blueback herring stratified mean number-per-tow from the NEFSC bottom trawl survey. The dotted horizontal line represents the 25th percentile of the fitted values and the probability represents the probability that the fitted value in the terminal year is less than the 25th percentile index based reference point with 80% confidence.

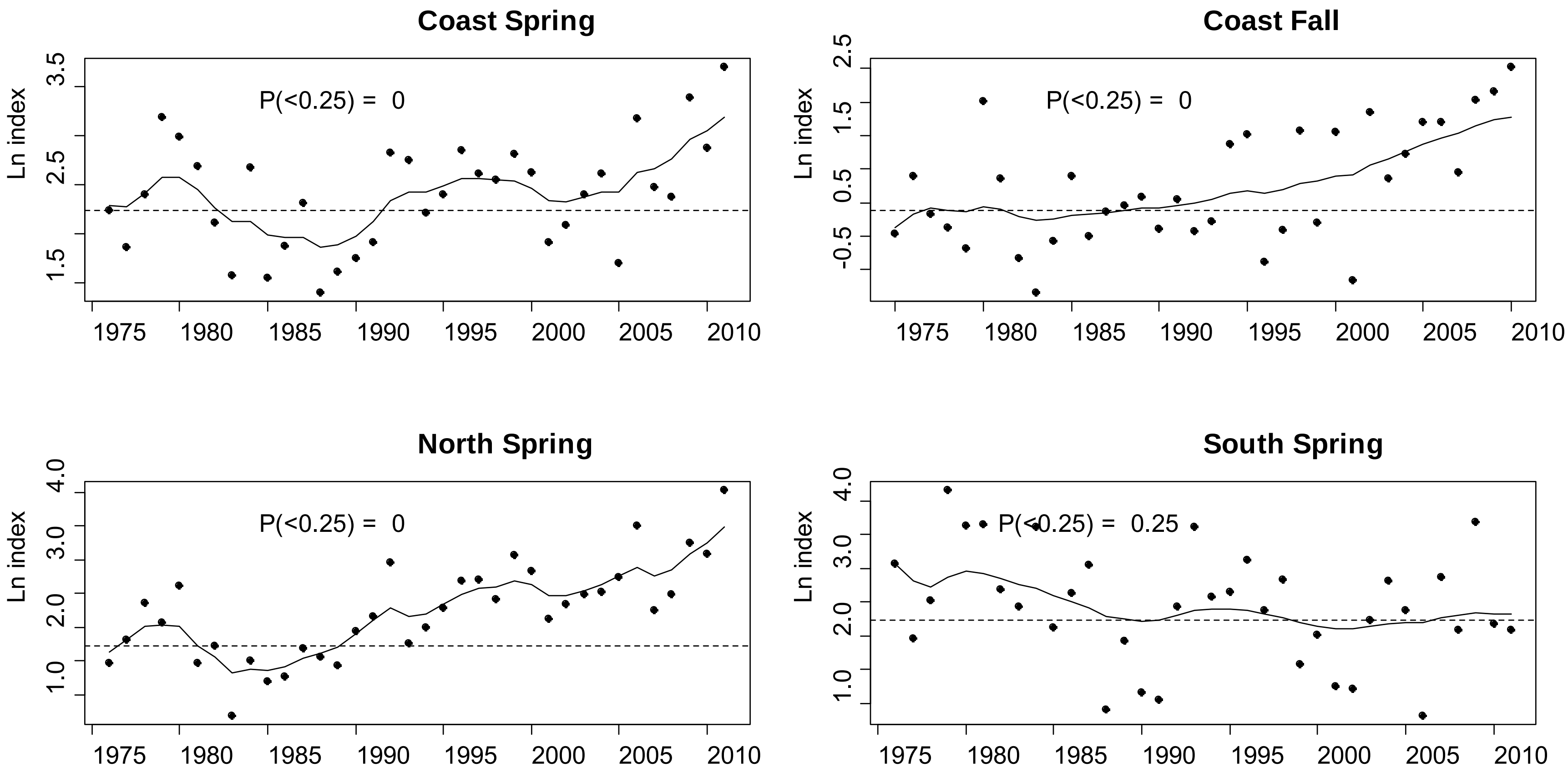

Figure 19.12 Autoregressive integrated moving average (ARIMA) model fits to combined river herring stratified mean number-per-tow from the NEFSC bottom trawl survey. The dotted horizontal line represents the 25th percentile of the fitted values and the probability represents the probability that the fitted value in the terminal year is less than the 25th percentile index based reference point with 80% confidence.

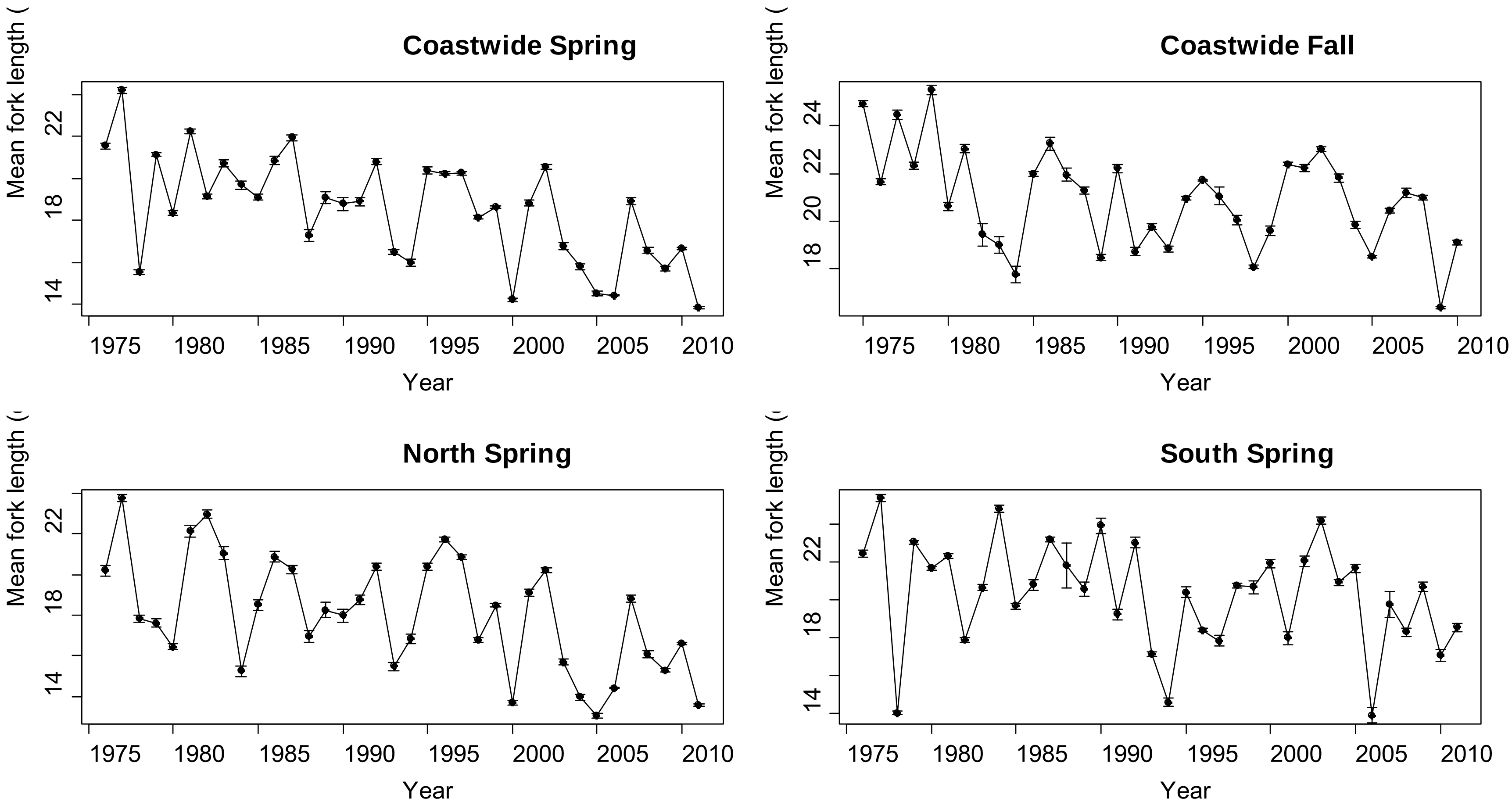

Figure 19.13 Mean length (cm) of alewife from the NEFSC bottom trawl surveys. Error bars correspond to one standard error.

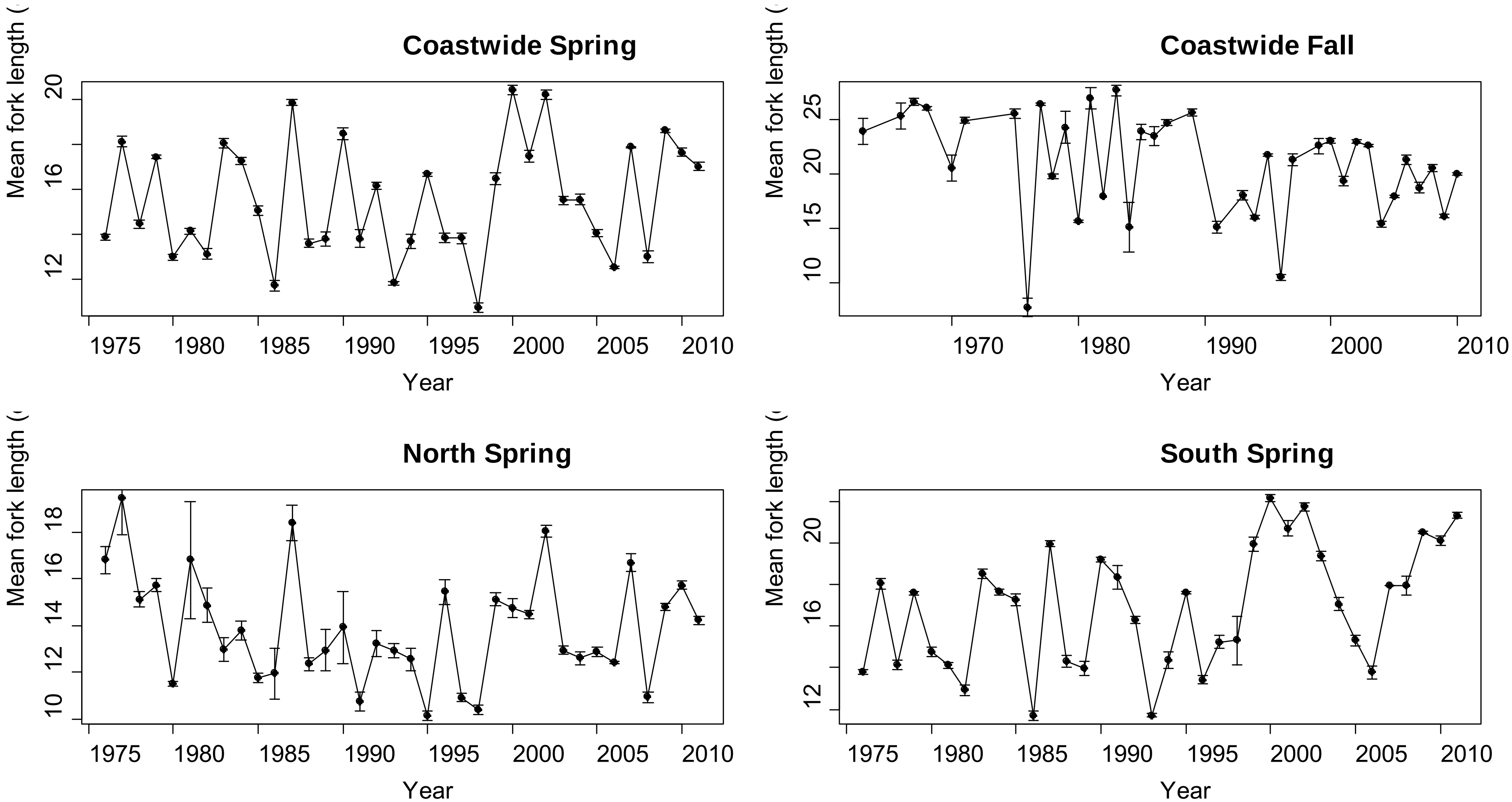

Figure 19.14 Mean length (cm) of blueback herring from the NEFSC bottom trawl surveys. Error bars correspond to standard errors.

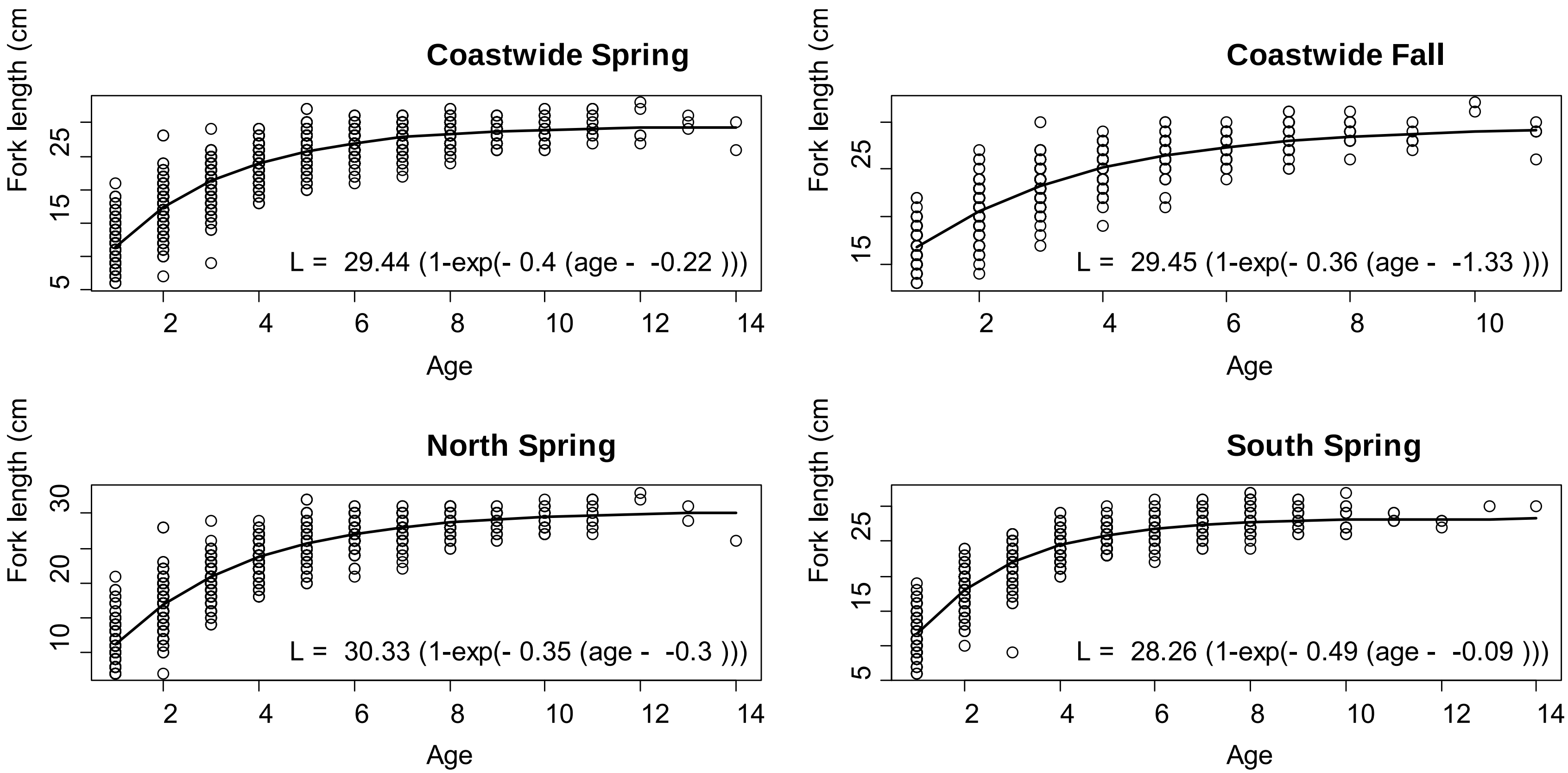

Figure 19.15 Von Bertalanffy growth models fit to alewife length-at-age data from the NEFSC bottom trawl surveys (1973 – 1983).

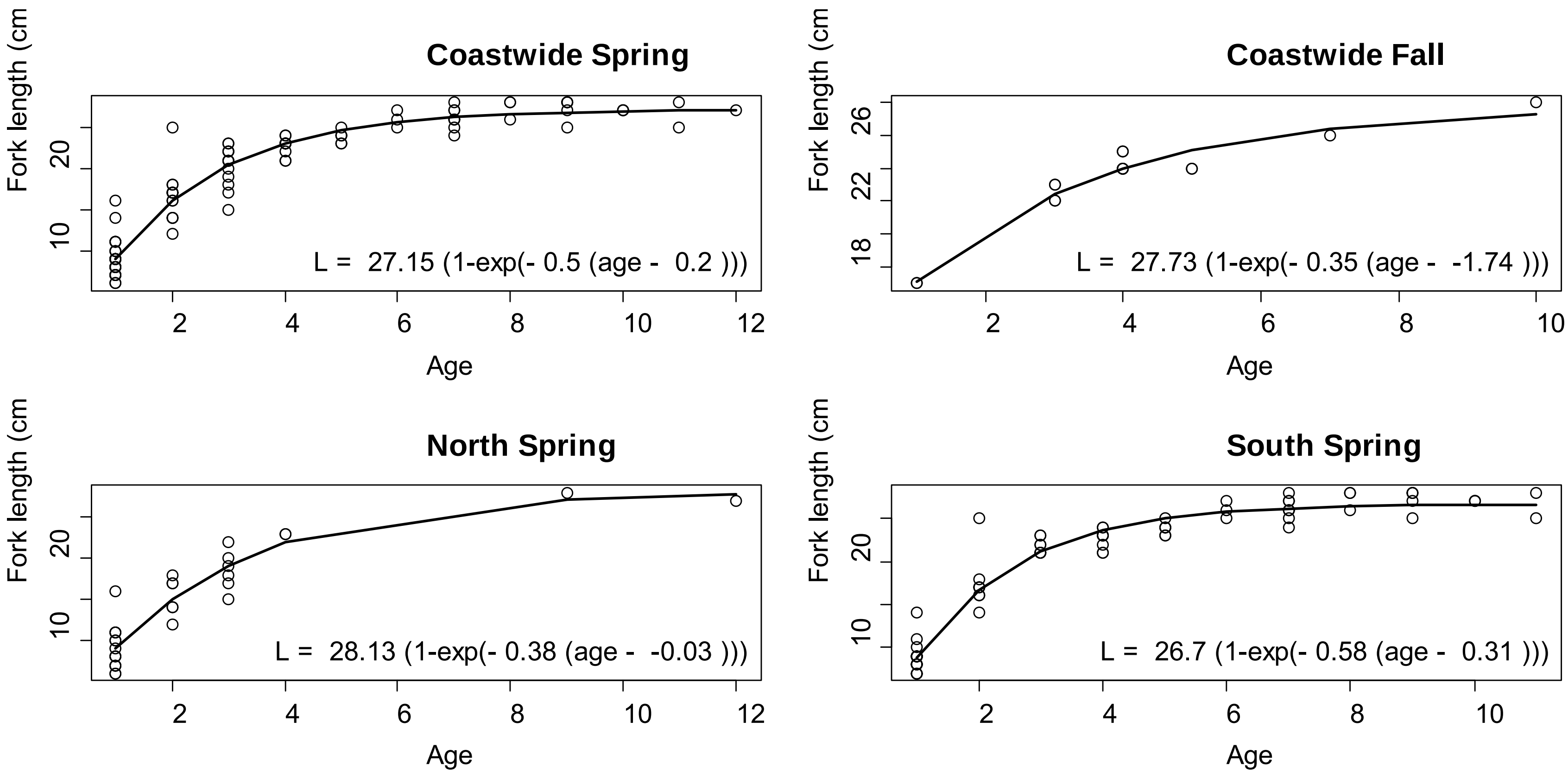

Figure 19.16 Von Bertalanffy growth models fit to blueback herring length-at-age data from the NEFSC bottom trawl surveys (1973 – 1983).

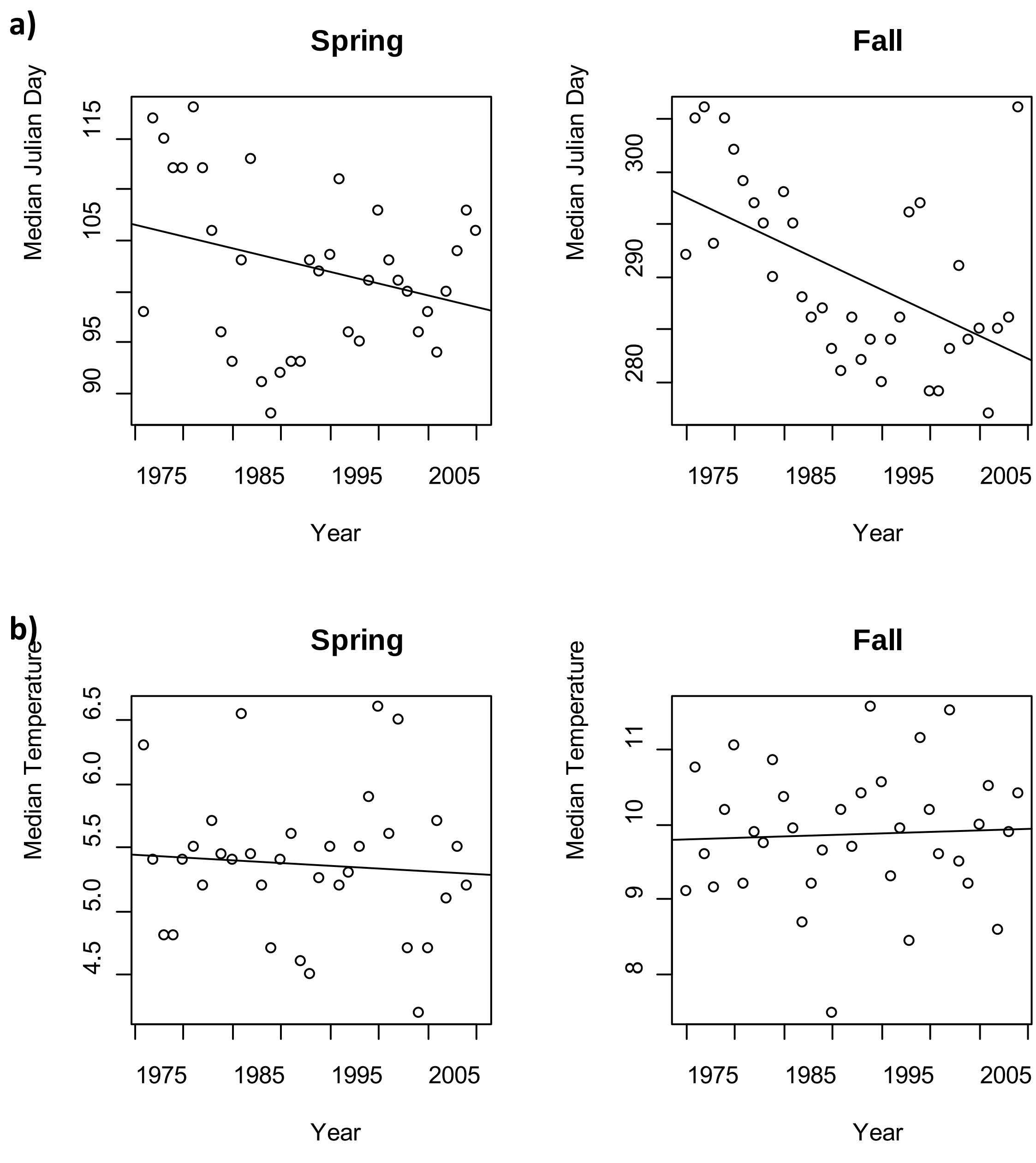

Figure 19.17 Linear regressions of a) median Julian day and b) median bottom temperature with time during NEFSC trawl surveys in the northern region. The lines on the graphs correspond to OLS regression lines. Slopes of the lines for the median Julian day were significantly different from 0 ($p<0.05$). Median temperature regressions were not significant.

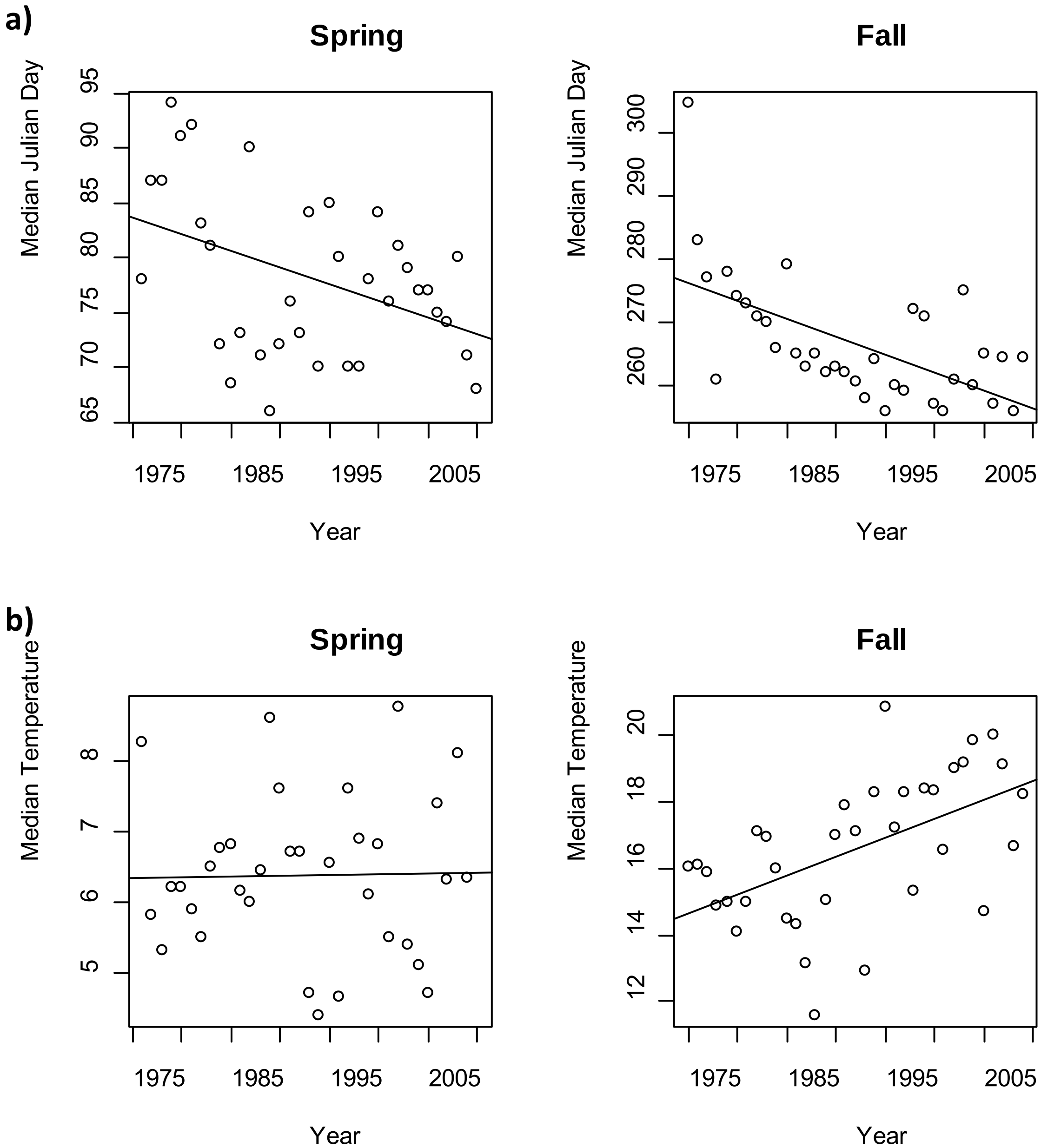

Figure 19.18 Linear regressions of a) median Julian day and b) median bottom temperature with time during NEFSC trawl surveys in the southern region. The lines on the graphs correspond to OLS regression lines. Slopes of the lines for the median Julian day were significantly different from 0 (p<0.05). Median temperature regressions were significant for the fall but not for the spring.